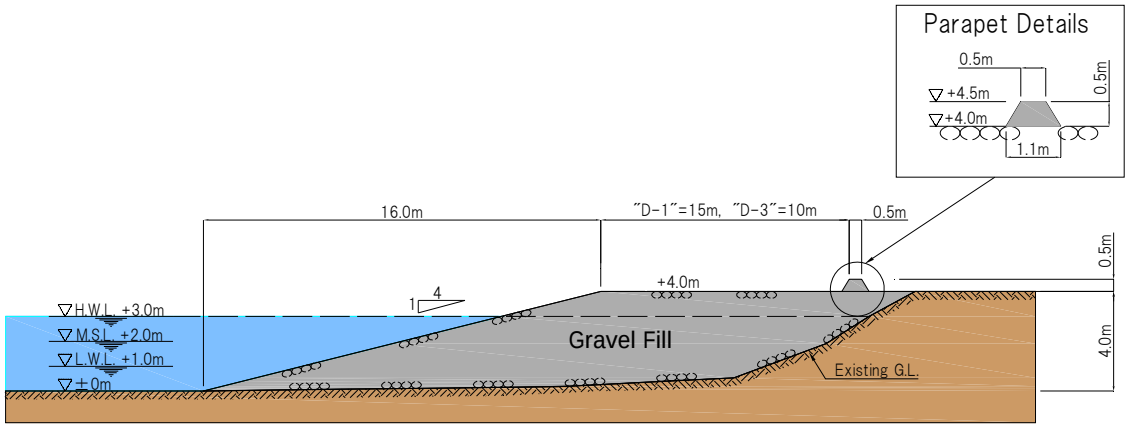
9.5 Construction Plan

9.5.1 Examination of Gravel Beach Nourishment Work

(1) Section of Gravel Beach Nourishment

As examined in previous Section 9.2, typical gravel beach nourishment work is as follows;

- The width of the back shore : 10m in the D-3 area and 15m in the D-3 area
- Crown Height : C.D.L.+4.0m
- Slope gradient: 1 : 4



(Note: Toe G.L. Depth±0.0m, Highest Shore G.L.+4.0m)

Figure 9.30 Typical Section of Proposed Gravel Beach Nourishment Work

For L-C area, due to lack of exploitable gravel volume (▲54,788m3) against required volume, parapet work in stead of beach nourishment work will be planned to elevate the existing storm ridge to prevent overtopping.

(2) Appurtenant Works

a) Parapet

Parapet is installed in order to prevent wave and gravel overtopping at the time of high waves.

Parapet is constructed by Stone masonry using local coral boulders of which the crown height is C.D.L.+4.5m.

The typical section is trapezoidal section for the northern part of L-C area (438m length). For the southern part of L-C area (317m in length), the existing storm ridge is elevated along the side of main road and crown height=C.D.L.+4.5m, which is about +1.0m higher than the existing height.

The typical section of L-D area is the trapezoidal section of which the crown height is C.D.L.+4.5m, about +0.5m higher than the existing storm ridge height.

b) Planting

Planting is implemented to close and consolidate the gravel beach and to protect the washing the coral gravel onto the land. 5 plots including one nursery are organized. The size of a plot is 20 square meters (2m×10m : refer to the attached separate sheet). The plot site is designed for coconut as principal tree at 1.0 m intervals. Around this principal tree "*Cocos"*, *Scaevola taccada"* and *"Pandanus tectorius"* will be planted in the alternate shifts and aligned state. Experimental plot is 2m in the east to west and 10m in the south to north (**Figure 9.20**). Cutting propagation is applied on a trial basis. As it takes several years to be grown and survived as a mature tree, it is necessary to study on technical transfer and implementation system for the planting.

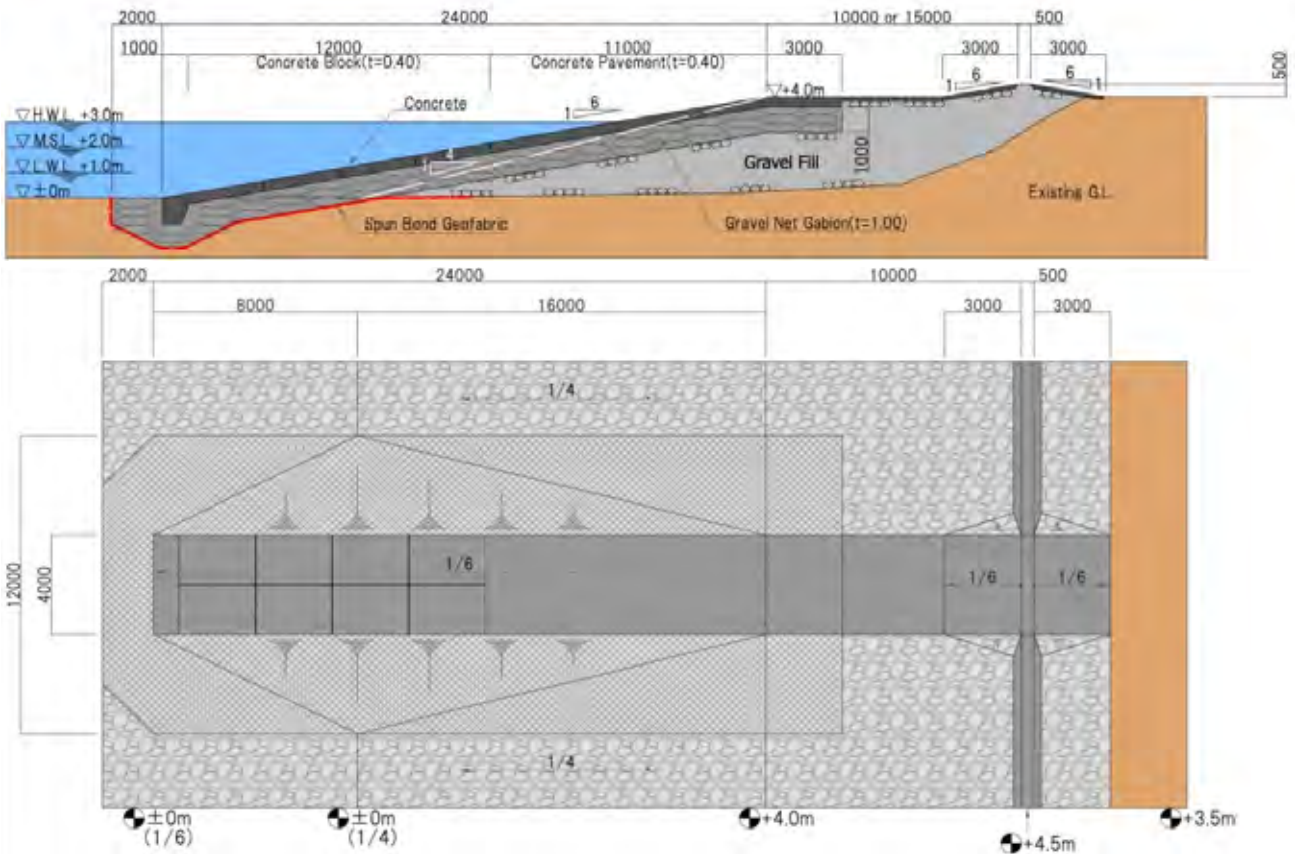
c) Edge Treatment Dike (com fixed boat ramp)

The edge treatment dikes are installed to prevent the gravel from moving along beach line. Two dikes are installed in D-1 area and one dike is installed in D-3 area. This edge treatment dikes can be used as small boat ramps.

It is preferable that the inclination of the edge treatment dikes is same slope of the gravel beach nourishment as 1:4. On the other hand, in general, the slope of boat ramp is set within the range of 1:6 to 1:10 considering boat weight and dimensions.

Edge treatment dike (cum boat ramp) slope is designed as 1:6. Because Tuvaluan people push up wooden heavy boats by manpower, so it is difficult to set the boat ramp slope steeper than 1:6.

In this case, as shown in **Figure 9.31**, difference of the crown height between gravel beach (1:4) and edge treatment dike (1:6) is about 65cm at MS.L.(+2.0m). The central part is constructed with plain concrete blocks (4.0m in width x 40cm in thickness) and the both sides are protected with gravel net gabions.



(Note: Toe G.L. Depth±0.0m, Highest Shore G.L.+4.0m)

Figure 9.31 Typical Section and Plan of Proposed End Treatment Dike (Boat Ramp)

d) Movable Boat Slider

As compensation of the existing small boat ramps (9 nos. in total) owned by local people, 3 places of boat ramps are installed as the edge treatment dike as mentioned in the clause above. For remaining other 6 places, movable boat sliders are provided experimentally.

The boat sliders are made of high density polyethylene resin bars which have the excellent low friction and abrasion resistance and linked with ropes as movable light weight ladder. Assuming the length of a pair to be 5m, weight becomes about 18kg. Two pairs per place are used as a standard.

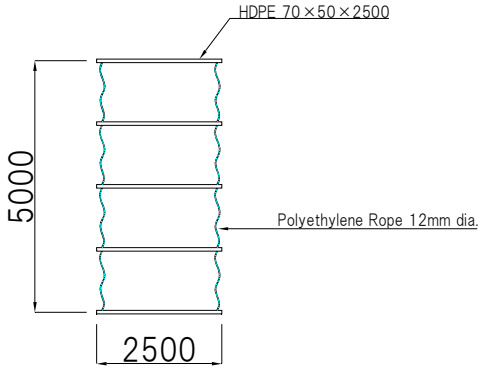


Figure 9.32 Sketch of Movable Boat Slider

9.5.2 Borrow Pit Backfilling Work

(1) Typical Section of Backfill

Bathymetric chart of D-1 area is shown in **Figure 9.33** shows the coastal borrow pits are formed by digging up the beach rock flat area of about 70 to 100m from the shore line toward the lagoon.

When backfilling of the coastal borrow pits is executed, it is necessary to backfill upto the equal height to the peripheral beach flat area and not to deform a local wave and flow.

(2) Use of Dredging Sand

When filling in the coastal borrow pits, basically, gravel is the safest and the most economical material. However in this project, due to lack of exploitable gravel volume (▲54,788m3) against required volume, it is necessary to use dredged sand as much as possible.

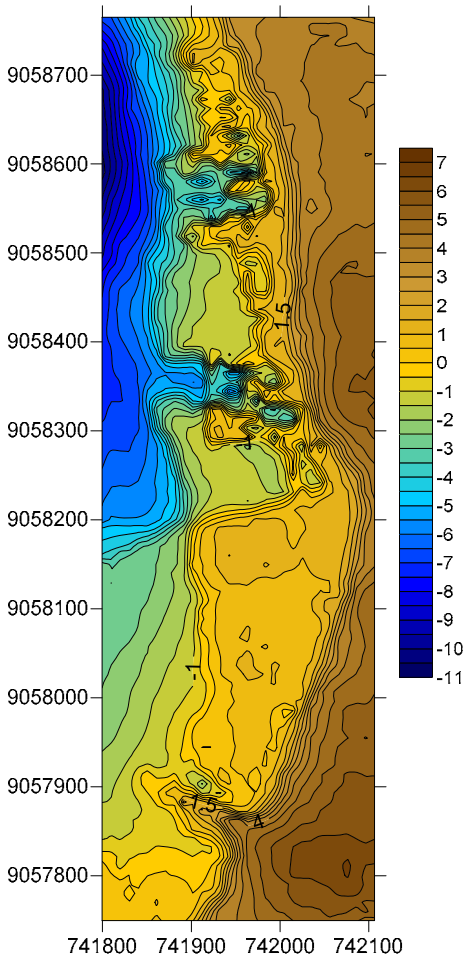


Figure 9.33 Bathymetric Map in D-1 Area (BP-1, BP-2, BP-3)

According to the soil test results of the dredged sand from Funafuti Lagoon, halimeda sand is a predominant sediment around 750m offshore of Vaiaku Wharf and 15m in depth. The halimeda sand, the particle of lime alga origin, is changed into the corpuscle fragilely and like

the crumble silt easily. This seabed soil is classified as Loam to Sandy Loam about the half of which is consisting of 47% of fine-grained fraction. Therefore, when this material is backfilled directly in the coastal borrow pit, the bottom sediment can be disturbed by the breaking wave in the shallow water and is easily flows out offshore by the flow of undertow. It is difficult to estimate what percentage of soil is flowing out and what percentage remains in the borrow pit because it is necessary to clarify complicated strong current in the small borrow pit. Moreover, because it is incontrovertible that the fine-grained fraction diffuses to the peripheral sea area and negatively affects the coral reef.

Therefore, when the dredging sand directly backfilled, it is preferable to confirm the behavior of the current by an experiment before determining the detailed plan of construction.

(3) Filling Method

When the dredged sand is backfilled directly in the coastal borrow pit, some technical problems should be clarified as mentioned above. Thus, a steadier and safer method should be taken for this project.

The following table shows comparative study on different methods using the dredged sand for filling material.

Table 9.15 Comparisons of Filling Work Methods

Method	Direct Backfilling Method	Large sized Sand Bag Method	Soil Cement Method
Outline	・Dredged sand transported to the coastal borrow pit and dump directly into the borrow pits	・Dredged sand is filled in large sized sand bags made of spun bond geofabric to protect flow out of soil particles. The sand bags are filled in-situ underwater.	・After cement is added to the landed dredged sand, and it solidifies to the extent that doesn't collapse easily in the sea like the compound granule in the sea.
Merit	・Shortest work period, the most economical ・No import material	・ Sand can surely be stabilized.	・ Rather economical than Large sized Sand Bag method (depend on cement content)
Demerit	・Risk of soil flow out in the future ・ The influence on the ecosystem by the diffusion of the soil particle is feared. ・ To secure a natural equilibrium slope (slope=1:12), it needs quite large amounts of the soil	・ Very high transportation cost, because sand bag materials should be imported	・It is necessary to verify the hexavalent chromium problem of the cement to be used. ・Long work period
Cost	・The most economical	・The most expensive	・Rather economical than Large sized Sand Bag method (depend on cement content)

As any case of filling method is taken, it is necessary to protect sea side sloping entrance part and top flat surface by natural gravel of approx. 50cm in thickness to avoid erosion.

Figure 9.34and **Figure 9.35** show two different filling methods, i.e. Large sized Sand Bag Method and Soil Cement Method.

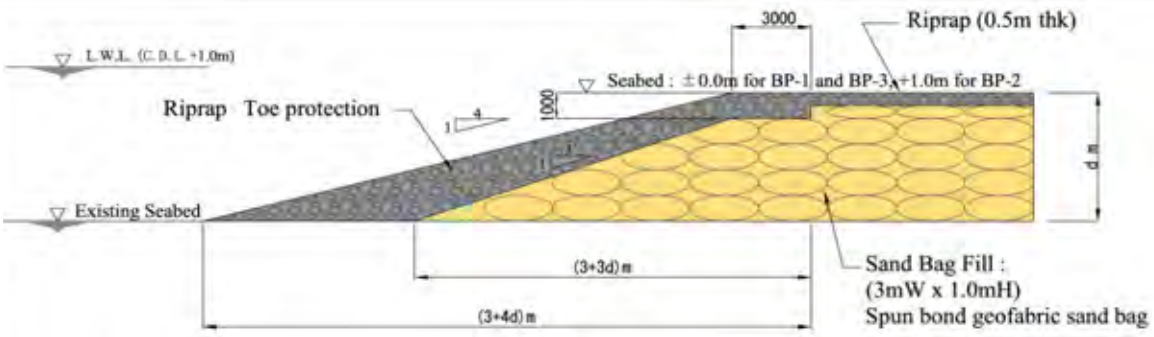


Figure 9.34 Typical Section of Borrow Pit Backfilling Work (Filling: Large Sized Sand Bag Method)

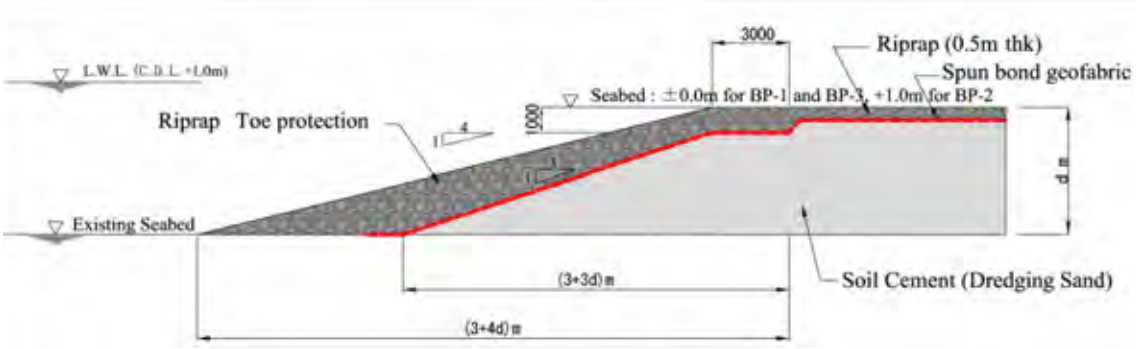


Figure 9.35 Typical Section of Borrow Pit Backfilling Work (Filling: Soil Cement Method)

9.5.3 Material Collection Work

(1) Gravel Material Collection Work from the Existing Runway Area

The consultation meeting with Civil Aviation Department and Public Works Department in Tuvalu was held to explain the outline of the plan, and consult them measures be taken when the gravel collection work is executed at the runway area. In addition, as described in the Section 9.3.2, clause (2)" Gravel Material from the Existing Runway Area", the exploitable gravel material volume was investigated.

As a result, it is deemed that gravel material is possible to be collected in the area shown in **Figure 9.36**. Because the area is close to the existing runway even if it is within the safety area, Civil Aviation Department and Public Works Department pointed out it is necessary to take special care to prevent any structural damage and to apply careful safety management to the existing runway. Especially, around the existing runway area used to be a swamp on the beach

rock low flat area, cracks and voids still remain here and there, and they connect the ocean and inland functioning as an underground water vain, therefore the fine soil particle is possible to be sucked out from the newly backfilled layer with the flow of underground water

In this plan, the offset distance of 10m should be secured from the pavement edge of the existing runway to avoid structural influence and for safety management. For northern end of the runway, the distance of 30m or more should be secured from the shore line on the ocean side.

Moreover, for the countermeasure against the risk of soil sucking out through water vain and hollowing out, it is planned to lay spun bond geofabric which has excellent permeability and soil particle trapping performance.
The area of 200m between (C) and (D) in the following figure, is excluded for a gravel collection site because sandy layer with little exploitable gravel is assumed.

Zone	Area LxBxDepth	Area (m2)	Total Volume (m3)	Gravel Percentage	Gravel Volume (m3)
(A) North End	70m×60m×1.5m	4,200	6,300	85%	5,355
(B)	370m×20m×1.1m	7,400	8,140	85%	6,919
(C)	100m×30m×0.7m	3,000	2,100	80%	1,680
(D)	100m×30m×0.7m	3,000	2,100	80%	1,680
(E)	430m×25m×1.0m	10,750	10,750	85%	9,138
(F) South End	350m×20m×1.0m	7,000	7,000	85%	5,950
	S/Total				**30,722**

Figure 9.36 Gravel Material Collection Site from the Existing Runway Area

The gravel collection work from the eastern side of the safety zone of the runway will be consisting of following works.

1. Excavation and taking out of gravel,
2. Replacing with dredging sand,
3. Leveling and Compaction and
4. Cleaning and withdrawal of equipment

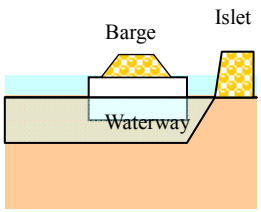
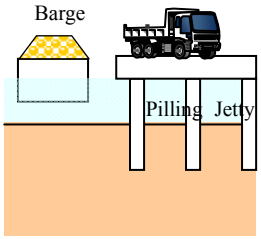
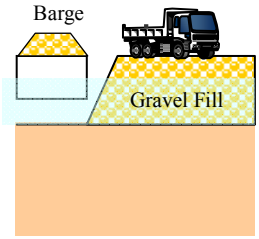
As of September 2010, a twin-propeller airplane (max. 42 people) is regularly operating 2 flights a week (of Tuesday and Thursday) between Suva (Fiji) and Funafuti. Accordingly, the work should complete before every Tuesday and Thursday early morning, thus, the above work cycle should repeated in approximately 2 to 3 days cycles.
Prior to the detailed design and construction, an enough explanation and consultation meetings should be done regarding the contents of the plan, the process, and the safety management with Civil Aviation Department of Tuvalu and Fiji.

(2) Gravel Material Collection Work from the Islets

The work includes; in southeastern islets of Funafuti Atoll (north and south end of the Funamanu Islet and north end of Falefatu Islet) , firstly, an excavator is unloaded from the barge, at high tide from the calm lagoon side. After the excavator lands on the gravel mining site, gravel is gathered by the excavator, it loads into a barge by dump tracks, and the gravel is transported by sea to Fongafale Island by a tugboat and a barge.

Temporary access way (waterway, piled jetty, causeway, etc.) is required to load into the barge. For selection of type of access way, as mentioned on **Table 9.16**, it is necessary to examine carefully influence to the ecosystem, the flow and geographical features in addition the amount of the exploitable gravel volume and cost for the temporary access.
A causeway type is planned that is filled up with the gravel material gathered on each island to secure the depth for barge access on beach flat area in a shallow coast.

Table 9.16 Comparisons of Temporary Access Way

Method	Waterway (Excavated)	Temporary Pilling Jetty	Causeway (Dike)
Sketch			
Influence to the Ecosystem	×	○	△
Influence to the Flow and Geographical Features	×	○	○
Cost	○	×	△
Overall Judgment	×	△	○

(3) Lagoon Sand Dredging

a) Dredging place and bottom sediment

In the lagoon water area of Fongafale Island, a pilot dredging for experimental project had been carried out by SOPAC in the 1990's. This project included dredging lagoon sand and backfilling inland borrow pits, using a small dredging machine.

Figure 9.37 shows the dredged area and the distribution of the bottom sediment which had been conducted under the pilot project by SOPAC.

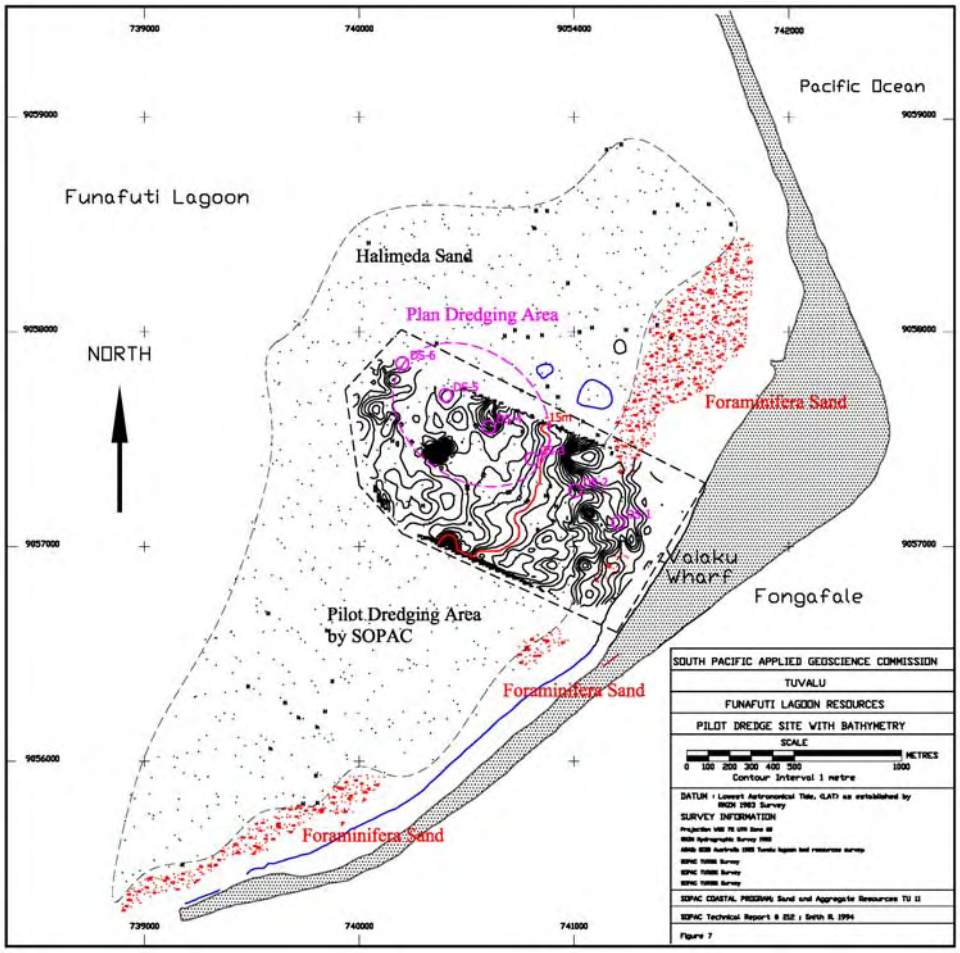


Figure 9.37 Dredged Area and Distribution of Bottom Sediment (Source: SOPAC)

The point is the relation between the bottom sediment and the depth. Most of the lagoon bottom sediment is sand, however the origins of it are roughly sorted into either foraminifera sand or calcareous algae (Halimeda) sand. The foraminifera sand is generally coarse of 1mm in diameter and the particle is rather hard. In contrast, halimeda sand keeps relatively large fragment but it breaks easily by flow and wave and becomes very fine sandy loam.

For distribution area of these sands as shown in the **Figure 9.38**, the foraminifera sand (*area colored in red) is piled up around the shallow water area, on the other hand, halimeda sand is

distributed in deeper area the lime alga origin.

When the dredging is done for this project, it is necessary to dredge from deeper bottom in order to prevent a risk such as coastal current and wave changes due to change of the bathymetric features. However, as noted in the Pilot Dredging Project Report by SOPAC, when dredging is executed in full scale in the future, it is recommend to dredge sea bottom deeper than C.D.L.-15m in consideration of the critical depth of sand movement. In addition, SOPAC advised that the dredging depth is supposed to be maximum C.D.L.-25m, because the deeper the dredging, the higher the cost. In this plan, according to these findings, dredging is planned of sandy loam of halimeda sand deposited between C.D.L.-15m to -25m.

In September, 2010, at the 6 locations shown in **Figure 9.38**, seabed samples were taken for soil test for reconfirmation of SOPAC's study.

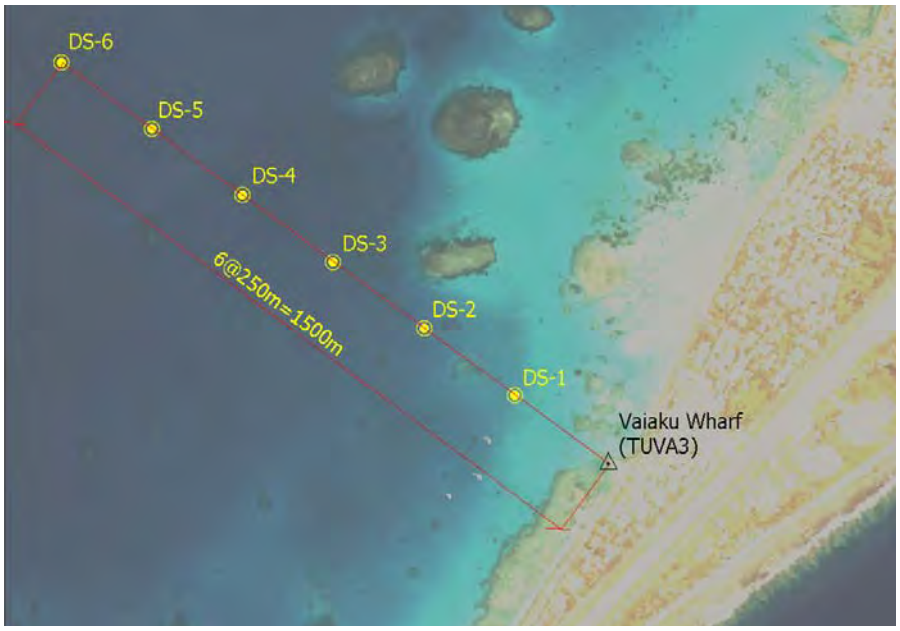


Figure 9.38 Sampling Positions of Dredging Materials

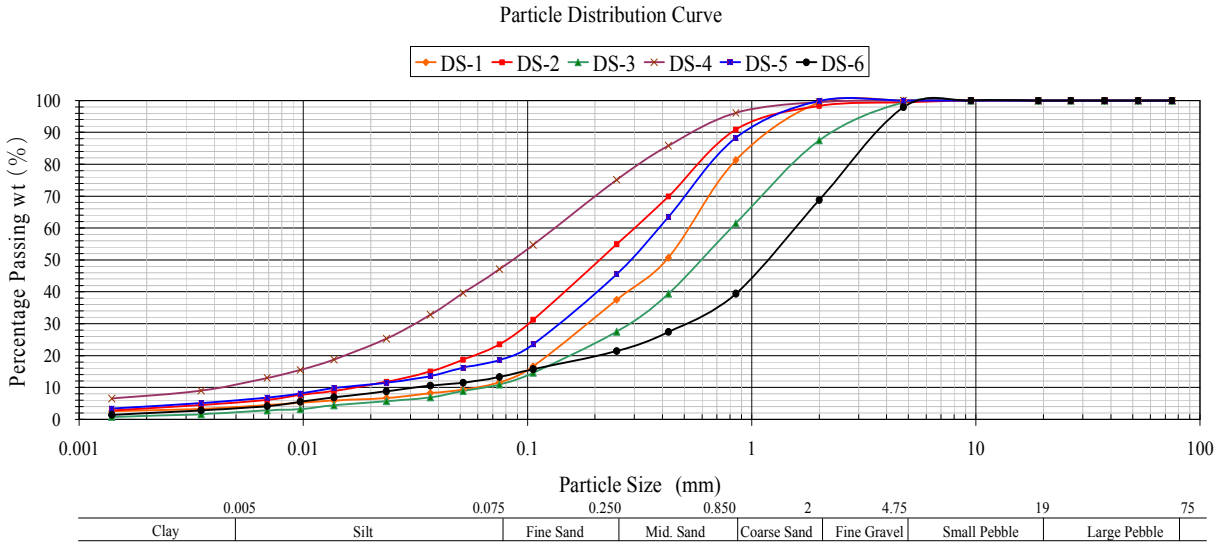
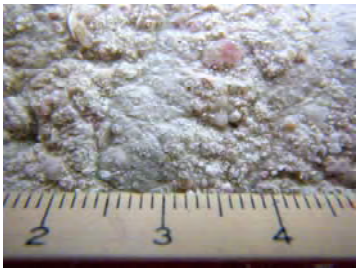


Figure 9.39 Particle Distribution Curves of Dredging Materials

Table 9.17 Particle Distribution Test Results and Classifications of Dredging Materials

Sample ID (Depth below C.D.L.)		**DS-1** (-10.9m)	**DS-2** (-17.9m)	**DS-3** (-17.9m)	**DS-4** (-17.9m)	**DS-5** (-24.1m)	**DS-6** (-24.9m)
Classification (JGS 0051-2009)		S−F Sand with some Fine fraction	SF Sand and Fine fraction	S−FG Sand with some Fine fraction and Gravel	SF Sand and Fine fraction	SF Sand and Fine fraction	SG−F Sand and Gravel with some Fine fraction
2mm Sieve Percentage of Passing Through	%	99.3	98.3	87.5	99.5	99.9	68.8
425μm Sieve Percentage of Passing Through	%	50.7	69.9	39.4	85.8	63.5	27.4
75μm Sieve Percentage of Passing Through	%	11.6	23.5	10.9	47.1	18.6	13.3
Max. Particle Size	mm	4.75	9.50	9.50	4.75	4.75	9.50
D60	mm	0.1325	0.3013	0.8134	0.1325	0.3861	1.6026
D50	mm	0.0860	0.2098	0.6037	0.0860	0.2880	1.2166
D30	mm	0.0316	0.1010	0.2843	0.0316	0.1436	0.5144
D20	mm	0.0153	0.0591	0.1584	0.0153	0.0850	0.2104
D10	mm	0.0043	0.0176	0.0649	0.0043	0.0140	0.0313

Table 9.18 Photographs of Dredging Material Samples

 foraminifera(dominant), medium sand **DS-1 : 250m NW from Vaiaku Wharf (C.D.L.-6.1m)**	 Halimeda(dominant), superfine sand～fine sand **DS-4 : 1000m NW from Vaiaku Wharf (C.D.L.-17.9m)**
 foraminifera(dominant)＋Halimeda, fine sand～medium sand **DS-2 : 500m NW from Vaiaku Wharf (C.D.L.-10.9m)**	 Halimeda(dominant), coarse sand･medium sand **DS-5 : 1250m NW from Vaiaku Wharf (C.D.L.-24.1m)**
 Halimeda(dominant), partially foraminifera, fine sand～medium sand **DS-3 : 750m NW from Vaiaku Wharf (C.D.L.-17.9m)**	 Halimeda(dominant), fragmentary Halimeda＋coarse sand, friable **DS-6 : 1500m NW from Vaiaku Wharf (C.D.L.-24.9m)**

Sample DS-3 to D-6 are taken from seabed C.D.L.-15m to -25m. According to Japanese Geotechnical Society's soil classification system (JGS-0051), D-3 is classified as (S-FG; Sand and Gravel with some Fine fraction), D-6 is classified as (SG-F; Sand with Gravel and some Fine fraction),. These are included some crushed halimeda coarse fragment.
However, DS-4 and DS-5 are classified (SF; Sand and Fine fraction) and are classified "Sandy Loam" in accordance with USDA classification system.

When considering about use of dredging sand as backfill material for this project, DS-3 or D-6 with gravel-mixed soil is suitable. However, the difficulty is expected to dredge such halimeda sand with some gravel fragment and to use for backfilling as soil with remaining of the original particle distribution, because these halimda sand particle becomes DS-4 and DS-5, fine fraction by weak current on sea bottom. Therefore, anyway, it deems dredging soil from DS-4 and DS-5 may be crushed and changed into sandy loam soil and it is necessary to study on the earthwork and dredging method.

b) Dredging Method

This time, it is necessary to dredge very fine sandy soil from the lagoon bottom about -15m to -25m. There are some dredging methods to be adopted for this size of the project, such as glove bucket dredging, sand pump dredging and air lifting dredging system. Therefore, a suitable dredging method is deemed to be an air lifting system, in consideration of operation and maintenance of equipment and cost.

In the SOPAC's project , the air lifting system was adopted from the viewpoint of cost, operation and maintenance. **Table 9.19** shows three comparative dredging systems.

Table 9.19 Comparison of Dredging Systems

Dredging Method	Grove Dredger	Sandy Pump	Air Lifting
Equipment Cost	×	△	○
Transportation Cost	×	△	○
Operating Cost	×	△	○
Efficiency	○	×	△
Maintenance	×	△	○
Overall Judgment	×	△	○

c) Environmental Influence and Prevention Method against Impurity by Dredging

The project includes gravel collection around the safety zone of the existing runway and replacing with dredged sea sand, and backfilling of coastal borrow pits. As for the sea sand, it is planned to dredge sea sand from the lagoon bottom offshore of the Vaiaku Wharf where the pilot dredging had been executed by SOPAC. Dreading materials around this area are consisting of sand and some gravel fragments and/or fine fraction, but these are classified as (SF; Sand and Fine fraction), on the borderline between sand and silt, classified as (SF; Sand and Fine fraction). Therefore, it takes longer time to settle the impurity from dredging, and it diffuses to the larger area. In addition, there exist live coral patches and various livings in the vicinity. It should be planned to take necessary countermeasure to prevent impurity diffusion by such as silt protection fence.

It is expected that the negative impact can be kept in an extremely low level by executing various measures to plan by this project. However, it is necessary to conduct monitoring of the ecosystem around the dredging area, the project site and its surrounding area in order to guarantee not to cause the adverse effect because of the execution of the project.

9.5.4 Outline of the Plan

(1) Countermeasure Works

The project outline is as shown in **Table 9.20**.

Table 9.20 Outline of the Countermeasure Works and Location

Location	Item
L-C area:	- Parapet（438m+317m=approx.755m） *Augment of Existing storm ridge - Backfilling Coastal Borrow Pits (BP-1、BP-2)
D-1 area:	- Gravel Beach Nourishment (approx. 595m) - Parapet（approx. 595m） - Backfilling Coastal Borrow Pits (BP-3-N) *BP-3-S will remain as it is
D-2 area:	- Not included in the project
D-3 area:	- Gravel Beach Nourishment (approx. 367m) - Parapet（approx. 293m）

The project plot plan is shown in **Figure 9.40**.

In order to make allowance for an unexpected case due to the nature with uncertainty and the change of procurement circumstances in advance, the pilot project will be conducted. After this result is grasped through the monitoring, it would be extended to other priority areas for the countermeasures. A pilot project is planned in D-1 area shown in **Figure 9.40**, for the purpose of verification of the gravel behavior of the beach nourishment material, the grasp of water current in borrow pit, the confirmation of opinions from local residents for the countermeasures, and the demonstration experiment for appropriateness of filling materials and work methods.

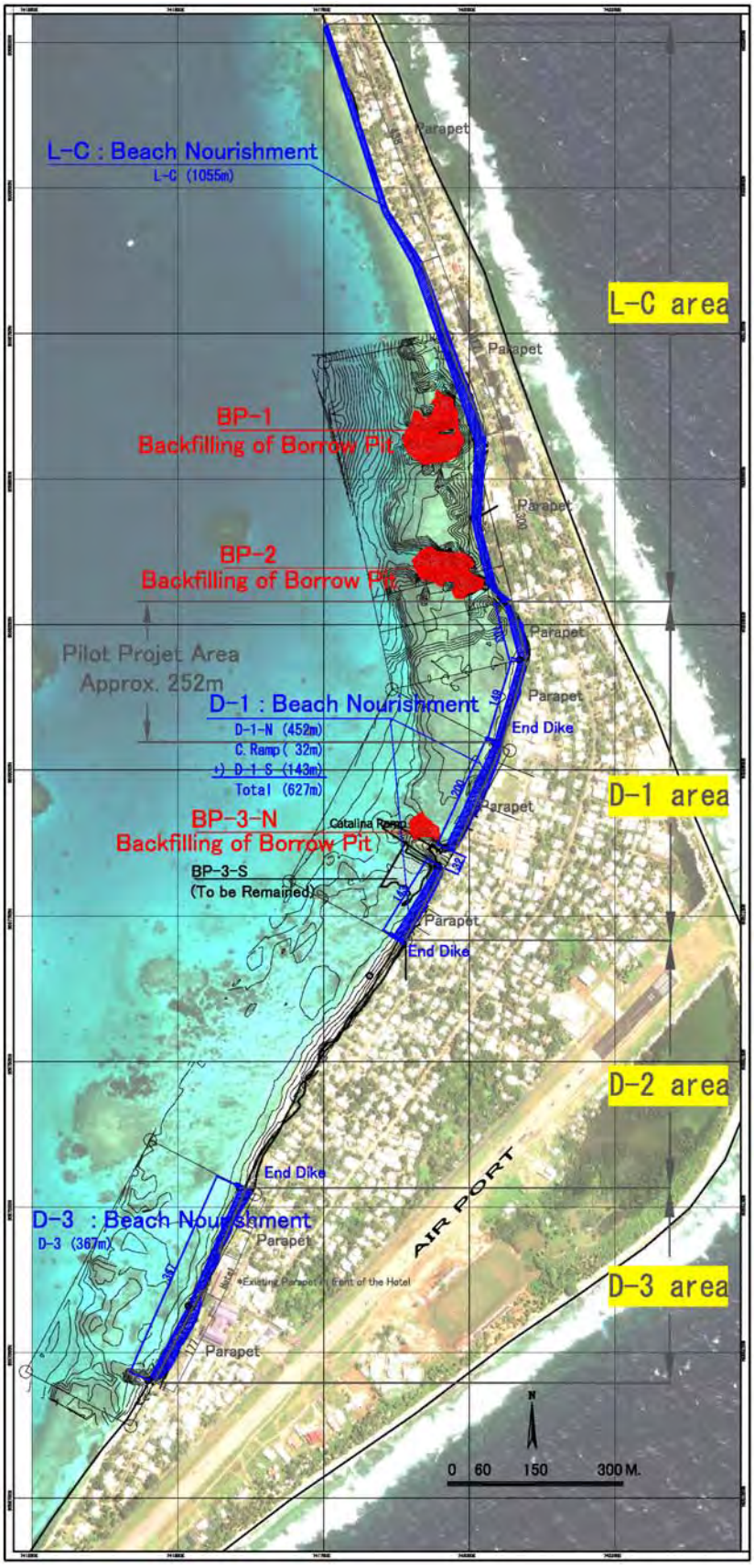


Figure 9.40 Project Plot Plan

(2) Components of the Project

The project consists of following works.

Table 9.21 Components of the Project

	Fongafale Island	Islets
Temporary Work	a) Temporary access for loading and unloading dredging sand Temporary Jetty, causeway	a) Temporary transplant of live coral at temporary causeway area, recovery after gravel collection work
	b) Temporary stock pile yard for dredging sand	b) Temporary causeway for loading gravel materials installation of mooring bitts (on land) / Sinkers (sea)
	c) Temporary access causeway to beach nourishment work site	
	d) Dredging equipment (air compressor, barge, etc.) mooring dock and fuel supply facilities, power supply facilities, installing silt fence	
	from Fongafale Island	from Islets
Material Collection Work	a) Excavation of runway and collection of gravel sorting gravel and sand, washing	a) Gravel collection at sand spit of islets
	b) Lagoon sand dredging, transportation	b) Loading Gravel, transportation and unloading at Fongafale Is.
	Gravel Beach Nourishment	Backfilling of Borrow Pits
Main Work	a) Transportation and spreading of gravel	a) Filling with dredging sang (Filling in Large sized sand bag or Soil cement mix)
	b) Formation and leveling	b) Transportation of gravel to gravel beach nourishment site, gravel filling and leveling
	c) Appurtenant works (edge treatment dike, boat ramp, parapet, etc.)	
	d) Planting	

(3) Earthmoving Plan

The earthmoving plan is shown in **Figure 9.41**.

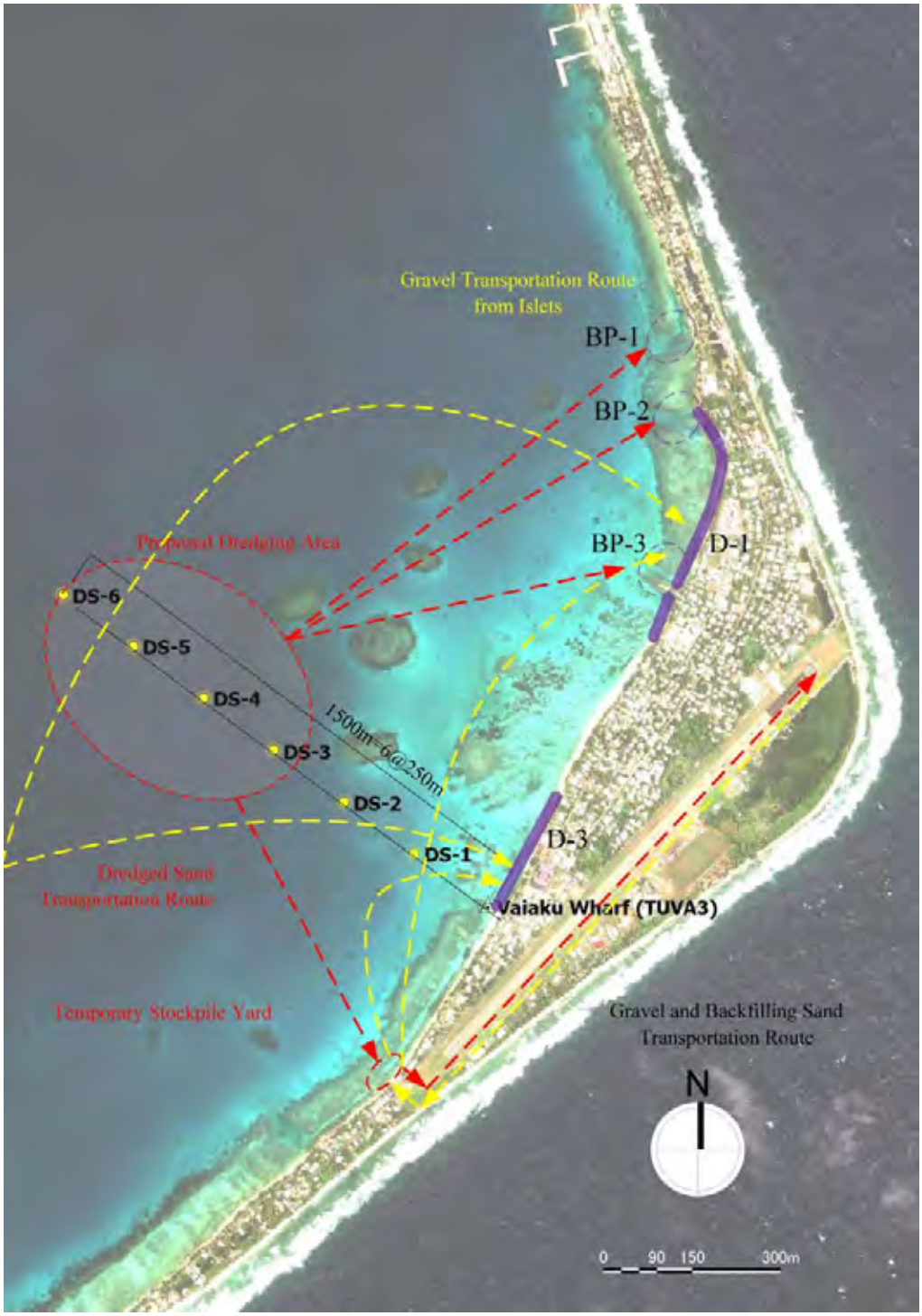


Figure 9.41 Earthmoving Plan

Table 9.21 shows earthwork quantity schedule for "Plan-4".

Table 9.22 shows earthwork quantity schedule for "Plan-3".

Table 9.22 Earthwork Quantity Schedule for "Plan-4"

Item		Required Total Volume (m3)	Required Volume (m3)	Exploitable Volume (m3)	Balance (m3)
A. Countermeasure Works					
A-1 Gravel Beach Nourishment	L-C	36,090	36,090	0	
	D-1	31,018	25,362	5,656	
	D-2	0	0	0	
	D-3	21,173	21,173	0	
	S/Total	**88,281**	**82,625**	**5,656**	
A-2 Parapet	L-C	1,077	1,077	0	
	D-1	357	357	0	
	D-2	0	0	0	
	D-3	176	176	0	
	S/Total	**1,610**	**1,610**	**0**	
A-3 Borrow Pit Backfilling	BP-1	15,505	4,016	11,489	
	BP-2	7,119	2,902	4,217	
	BP-3-N	1,140	709	431	
	S/Total	**23,764**	**7,627**	**16,137**	
A. Countermeasure Works Total		**113,655**	**91,862**	**21,793**	

Item	Location	Exploitable Gravel Volume (m3)	Req'd Sand for Replace (m3)	Exploitable Gravel Volume
B. Exploitable Gravel Resources				
B-1 Islets				
Funamanu Islet	North End	11,110		11,110
Funamanu Islet	South End	11,946		11,946
Falefatou Islet	North End	5,089		5,089
Falefatou Islet	South End	1,461		1,461
Mateika Islet	North End	4,915		4,915
	S/Total	**34,521**		**34,521**
B-2 Runway Area	(A) North End	5,355	5,355	5,355
	(B)	6,919	6,919	6,919
	(C)	1,680	1,680	1,680
	(D)	1,680	1,680	1,680
	(E)	9,138	9,138	9,138
	(F) South End	5,950	5,950	5,950
	S/Total	**30,722**	**30,722**	**30,722**
B. Exploitable Gravel Resources Total		**65,243**	**30,722**	**65,243**

	Required Total Volume (m3)	Exploitable Gravel Volume (m3)	Req'd Sand for Replace (m3)	Exploitable Gravel Volume (m3)	Balance (m3)
Grand Total	**113,655**	**91,862**	**52,515**	**58,867**	**▲ 32,995**

Table 9.23 Earthwork Quantity Schedule for "Plan-3"

Item		Required Total Volume (m3)	Required Volume (m3)		Exploitable Volume (m3)	Balance (m3)
A. Countermeasure Works						
A-1 Gravel Beach Nourishment	L-C	0	0	0		
	D-1	31,018	25,362	5,656		
	D-2	0	0	0		
	D-3	21,173	21,173	0		
	S/Total	**52,191**	**46,535**	**5,656**		
A-2 Parapet	L-C	1,077	1,077	0		
	D-1	357	357	0		
	D-2	0	0	0		
	D-3	176	176	0		
	S/Total	**1,610**	**1,610**	**0**		
A-3 Borrow Pit Backfilling	BP-1	15,505	4,016	11,489		
	BP-2	7,119	2,902	4,217		
	BP-3-N	1,140	709	431		
	S/Total	**23,764**	**7,627**	**16,137**		
A. Countermeasure Works Total		**77,565**	**55,772**	**21,793**		

Item	Location	Exploitable Gravel Volume (m3)	Req'd Sand for Replace (m3)	Exploitable Gravel Volume
B. Exploitable Gravel Resources				
B-1 Islets				
Funamanu Islet	North End	11,110		11,110
Funamanu Islet	South End	11,946		11,946
Falefatou Islet	North End	5,089		5,089
Falefatou Islet	South End	0		1,461
Mateika Islet	North End	0		4,915
	S/Total	**28,145**		**34,521**
B-2 Runway Area	(A) North End	5,355	5,355	5,355
	(B)	6,919	6,919	6,919
	(C)	1,680	1,680	1,680
	(D)	1,680	1,680	1,680
	(E)	9,138	9,138	9,138
	(F) South End	5,950	5,950	5,950
	S/Total	**30,722**	**30,722**	**30,722**
B. Exploitable Gravel Resources Total		**58,867**	**30,722**	**65,243**

	Required Total Volume (m3)	Exploitable Gravel Volume (m3)	Req'd Sand for Replace (m3)	Exploitable Gravel Volume (m3)	Balance (m3)
Grand Total	**77,565**	**55,772**	**52,515**	**58,867**	**△ 3,095**

For Plan-4, even if use of the dredged sand is devised, lack of 32,995m3 gravel should be imported. However for Plan-3, if use of the dredged sand is devised, all necessary gravel and sand materials can be afforded in locally available materials.

(4) Construction Machinery Plan

Construction machinery list to be used for the project is shown in **Table 9.24**.

Table 9.24 Construction Machinery List

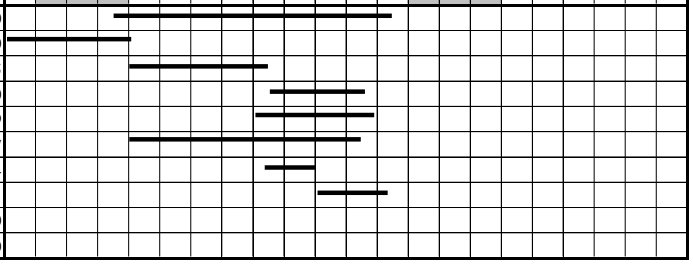
Equipment / Machinery		Q'ty	Unit
1. Work Boats			
Tugboat	For Islet（19t）	1	No.
	For lagoon dredging (19t)	1	No.
Barge	For Islet gravel transportation（700t）	2	Nos.
Barge for Dredging pump	For lagoon dredging (30t）	1	No.
Transportation boat	30PS, 3t	1	No.
Utility boat	Common use with 3t capacity crane	1	No.
2. Vehicles			
Excavator	1.4m3	1	No.
	0.7m3	4	Nos.
Wheel loader	1.0m3	5	Nos.
Dump truck	10t	6	Nos.
3. Others, Temporary equipment and materials			
	Generator	2	Nos.
	Sand Pump	1	No.
	Air Compressor	2	Nos.
	Concrete mixer	1	No.
	Others, (general tools)	1	L.S.
	Temporary Office, lodging	1	L.S.
	Silt Fence	1	L.S.

9.5.5 Work Program

Work programs for each of the proposed projects are shown in **Figure 9.42**.

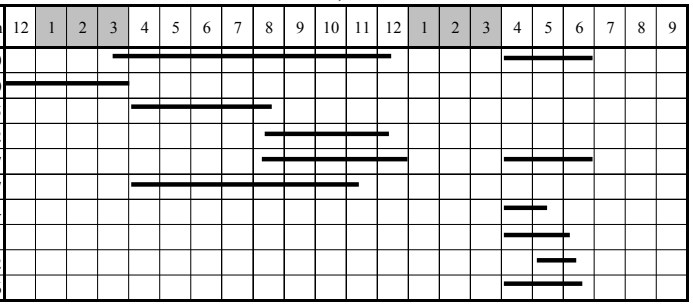
◆Plan-1 Gross Work Period: 11.5 months, Net Work Period: 9.0 months)

Item	Q'ty (m3)	Efficiency (m3/d)	Day	Month
Work in Local				9.0
Procurement, Preparation,Transport				4.0
Gravel Collection (Islets)	28,145	250	113	4.5
Gravel Collection (Runway)	18,923	250	76	3.0
Dredging	24,579	250	98	3.9
Beach Nourishment (Gravel)	46,535	500	93	3.7
Beach Nourishment (Sand)	5,656	160	35	1.4
Parapet	533	10	53	2.1
Borrow Pit (Gravel)	0	250	0	0.0
Borrow Pit (Sand)	0	250	0	0.0



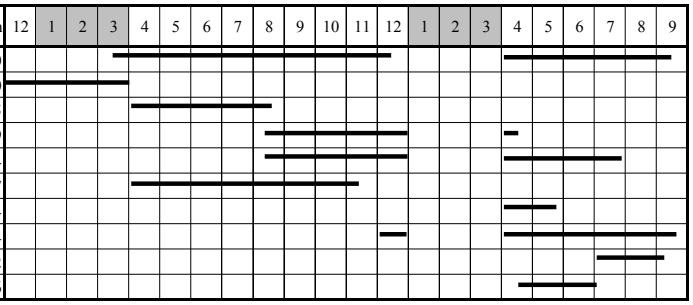
◆Plan-2 Gross Work Period: 19.0 months, Net Work Period: 12.0 months)

Item	Q'ty (m3)	Efficiency (m3/d)	Day	Month
Work in Local				12.0
Procurement, Preparation,Transport				4.0
Gravel Collection (Islets)	28,145	250	113	4.5
Gravel Collection (Runway)	26,550	250	106	4.2
Dredging	48,343	250	193	7.7
Beach Nourishment (Gravel)	46,535	500	93	3.7
Beach Nourishment (Sand)	5,656	160	35	1.4
Parapet	533	10	53	2.1
Borrow Pit (Gravel)	7,627	250	31	1.2
Borrow Pit (Sand)	16,137	250	65	2.6



◆Plan-3 Gross Work Period: 21.5 months, Net Work Period: 15.0 months)

Item	Q'ty (m3)	Efficiency (m3/d)	Day	Month
Work in Local				15.0
Procurement, Preparation,Transport				4.0
Gravel Collection (Islets)	28,145	250	113	4.5
Gravel Collection (Runway)	30,722	250	123	4.9
Dredging	52,515	250	210	8.4
Beach Nourishment (Gravel)	46,535	500	93	3.7
Beach Nourishment (Sand)	5,656	160	35	1.4
Parapet	1,610	10	161	6.4
Borrow Pit (Gravel)	7,627	250	31	1.2
Borrow Pit (Sand)	16,137	250	65	2.6



◆Plan-4 Gross Work Period: 21.5 months, Net Work Period: 15.0 months)

Item	Q'ty (m3)	Efficiency (m3/d)	Day	Month
Work in Local				15.0
Procurement, Preparation,Transport				4.0
Gravel Collection (Islets)	28,145	250	113	4.5
Gravel Collection (Runway)	30,722	250	123	4.9
Dredging	52,515	250	210	8.4
Beach Nourishment (Gravel)	82,625	500	165	6.6
Beach Nourishment (Sand)	5,656	160	35	1.4
Parapet	1,610	10	161	6.4
Borrow Pit (Gravel)	7,627	250	31	1.2
Borrow Pit (Sand)	16,137	250	65	2.6

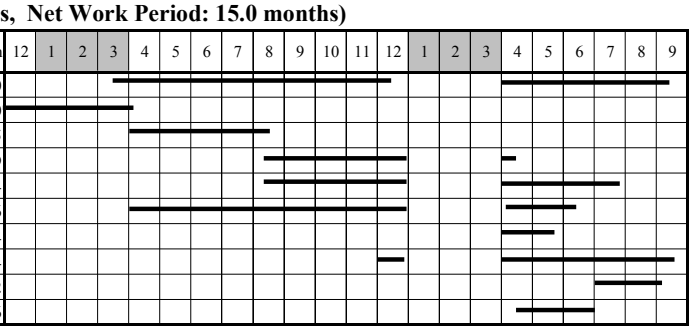


Figure 9.42 Work Program

Note: The lagoon coastal area of Fongafale Island where the westerly wind in the rainy season is superior with high waves season in January, February and March. There is no safe port facilities during high wave. Therefore, for security of work boats it is planned to interrupt the work and to return the work boats to Fiji them restart the work in April.

9.6 Maintenance and Operation Plan

9.6.1 Maintenance Plan

(1) Items necessary for maintenance

Works planned as a priority project are:

1. Gravel nourishment and parapet in central Fongafale,
2. Vegetation planting on nourished berm, and
3. Refilling of coastal borrow pits.

This project aims to recover the traditional coastal landscape of the atoll through these works. The shape of the nourished beach will change somewhat after the works, because even though offshore transport of the gravel will be minimal there will be longshore drift. Particularly when wave action exceeds that of a 10-year return period, it is conceivable that its effectiveness at preventing overtopping will decrease and the beach will erode, with some gravel being transported to non-nourished beaches and some washed up to near the parapet. Therefore, its effect may be reduced if appropriate maintenance is not undertaken, and also if it is used inappropriately there is a possibility that the resulting coast may not fit with the residents living environment.

For maintenance of the coastal protection works it is necessary to:

1. collect the gravel washed up onto land and return it back to the beach,
2. prohibit and policing of removal of sand and gravel from the coastal zone,
3. repair ancillary facilities such as the parapet and end treatment
4. policing of destruction of ancillary facilities such as the parapet and end treatment,
5. prohibit and policing of illegal acts such as dredging and coastal excavation that change the shape of the coast including storm ridge, and construction of seawalls, jetties, and breakwaters,
6. planting and recovery of coastal vegetation,
7. prohibit and policing of illegal cutting down of coastal vegetation, and
8. monitoring survey to grasp effect of works and environmental impact.

(2) Establishment of maintenance organisation

Several of these regulations that need policing to maintain the coastal protection facilities are

being implemented by the Kaupule under Kaupule Law as part of the islet's coastal protection measures. Therefore, it is most suitable to have the Kaupule in charge of maintaining the vegetation and nourishment works of this project. However, there is a lack of manpower and budget for maintenance, and also a lack of awareness regarding maintenance amongst local residents. As such, this is not functioning effectively. With this in mind, it is necessary to form an organization to include residents in monitoring and maintenance to improve and maintain the coastal protection facilities.

Establishment and activities of a "coastal maintenance organisation (tentative name)" for this purpose are outlined in **Table 9.25**. Moreover, this organisation is the proposal of this study, and joint implementation with the abovementioned groups has not yet been coordinated. It is necessary to actively consider the vigorous participation of residents and cooperation from various parties in this coastal maintenance organisation. As for the timing of starting up this organisation, it will be necessary to discuss with the relevant agencies right after the implementation of this project has been decided. Further, the structure of the monitoring survey group mentioned in the table and its activities will be mentioned herein.

Table 9.25 Public Participation for Maintenance of Coastal Protection Structures

	Issue	Contents to be determined	Practice	Subject area
Maintenance of the structure	Maintenance of main coastal structure	* Study on method of maintenance for structure configuration and method of repair * Exclusion method of private usage of the gravels	1) All stakeholders need to understand the necessity of coastal protection structures, and importance of maintenance works of the structure, for their active participation. Likewise, the importance of the organization for maintenance of the structure and the wholesome shoreline. 2) Establishment of "Coastal Structure Maintenance Team (tentative name)" 3) Clarification its mandates in statutory form 4) Formulation of "Coastal Management Plan (tentative name)". a) Study on contents of the plan (i.e. left column) b) Formulation of the "Groups" within "Coastal Structure Maintenance Team" , i.e.: i) Executive group: members from the government, Fale Kauple, Fnafuti Kauple are strongly recommended ii) A group for monitoring survey iii) A group for maintenance of gravels iv) A group for maintenance and improvement of parapet, for living environment v) A group for creation and maintenance of planting vi) A group for improvement of structure from fishery activities point of view vii) A group for incorporating of embarkment/ disembarkment function of the Amatuku ferry's jetty to the structures viii) A group for law ix) A group for accountant c) Clarification of the duties of stakeholder groups, such as womens group, fishermen's group, residents of Alapi, Senala, Vaiaku, and other islanders' groups. d) Frequency of gathering of the groups, reports from each groups, cooperation with other groups, and future activities. e) Payee of administration fee f) Enacting of necessary laws/rules necessary for maintaining the coastal structure	Senala, Alapi, Vaiaku
	Maintenance and modification of parapet	* Study on maintenance plan * Distribution of duties: who make modification plan?/who pays?/who works?)		
	Maintenance of planting	* Maintenance and management plan of the plants (fertilization/trimming/timing of additional fertilization/replanting/Who pays?)		
Utilization	Co-existing with fishery activities along the coast	* Modification for uplifting of fishing boat and cooler box /mooring		
	Co-existing with living environment and the activities along the coast	* Clarification of accepted usage and not accepted usage (i.e. Accepted usage: place hammock, drying fish etc. Not accepted usage: const-ruction of a house/storage, cutting trees, removing gravels/other modification such as lowering parapet, dumping/burning waste and refuse on facilities * Plan on remedies for violators		
Owner-ship	Clarification on owner-ship of reclaimed land	* Clarification of ownership by law * Plan on unlawful occupation	It is necessary to have mutual understanding that the reclaimed area is going to be public land by Funafuti Kauple/Tuvalu and the Government of Tuvalu, and other stakeholders, especially land owners along the shore.	

(3) Ownership of the land to be reclaimed in the Project

The main work to be applied for this Project is beach nourishment, and after implementation of the Project, reclaimed land will be created on the existing foreshore area. According to the "Foreshore and Land Reclamation Ordinance", the ownership of the foreshore and sea-bed vests in the Crown, and land reclaimed shall also vest in the Crown[1]. However, the Ordinance shall not apply to the filling by a landowner of the whole or any portion of the foreshore that borders on his land[2]. On this issue, there is a lawsuit between a landowner and a land leaseholder for the rent for the reclaimed land. The case remains unsolved, however, in case the claim of the landowner were approved, it would be a hindrance to implement the Project. It is a prerequisite for implementation of the Project by international donors, that a statute which clearly defined that the ownership of the land to be reclaimed in the Project shall vest in the Crown and the landowner of the land that borders the reclaimed land shall not have ownership of the reclaimed land, shall be enacted. The ownership of the reclaimed land under the project shall vest in the Crown and the Kaupule is suitable to manage maintenance and appropriate use of them.

9.6.2 Monitoring Plan

(1) Items to be Monitored

The following effects and impacts are expected from implementation of the respective erosion control measures.

Table 9.26 Effects Expected from the Erosion Control Measures and Impact during and after Completion of the Works

Control works	Expected effects	Impact during and after completion of the work
Gravel beach nourishment	Prevention of wave overtopping Prevention of transport of gravel inland Facilitation of transport and sedimentation of sand.	During the works: Water quality (turbidity) and noise. After completion of the works: waves, coastal topography, sediment quality (grain size distribution and grain shapes), condition of biota, scenery, condition of vegetation and use of coastal areas
Planting	Compacting of gravel beaches Improved scenery	
Back-filling	Prevention of wave overtopping Facilitation of transport and sedimentation of sand	

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[1] Foreshore and Land Reclamation Ordinance、Section 3(1) and Section 9 (1)

[2] Foreshore and Land Reclamation Ordinance、Section 11(1)

A plan for the monitoring surveys as described below is required in order to understand the effects and impact of each of the erosion control works.

Table 9.27 Items to be Monitored and Outline of the Surveys

Survey item	Purpose and outline of the survey
Environmental Impact Assessment during the works (water quality, noise and vibration)	(Purpose) To understand the extent of spread of turbidity caused by the installation of gravel and noise created by the works (Outline) Turbidity and noise will be measured at representative points.
Topographic survey	(Purpose) To understand what changes in topography have been caused by the gravel beach nourishment (Outline) Topographic surveys will be conducted along representative lines stretching from roughly 30 m inland to roughly 200 m offshore from the shoreline, and fixed-point photography will be implemented.
Survey of sediment quality	(Purpose) To understand what changes in the condition of sediment quality, including changes in distribution of the gravel, have been caused by the gravel beach nourishment (Outline) Analysis and examination of grain size and composition, and photography with a selection of sediment samples collected at representative points.
Survey of marine organisms	(Purpose) To understand what changes in the state of marine organisms (including coral, algae and benthos) and of the seabed have been caused by the gravel beach nourishment (Outline) Divers will make visual observation of organisms and the condition of the sediment and take and maintain photographic and other records of changes in biota and sediment quality.
Survey of vegetation and scenery	(Purpose) To understand what changes in vegetation and scenery have been caused by the gravel beach nourishment (Outline) Photographic and other records of growth of the planted *Pandanus* and other plants and scenery will be taken at representative points and maintained.
Interview survey of coast users	(Purpose) To understand what impact this project has had on the conventional ways the coastal areas are used (Outline) Interviews will be held with fishery workers and local residents on the impact of this project. (Introduction of a monitoring system: Information will be collected from appointed Informants.)

(2) Monitoring implementation structures

The structures described below are recommended as monitoring structures during the works and after their completion.

Structure to monitor environmental impact during the works

It is considered necessary that the contractors monitor the environmental impact of the works during their implementation and that the Department of Environment of the Government of Tuvalu, the supervising agency for environmental issues, and kaupules (local governments) concerned, confirm the environmental impact of the works by patrolling in and around the project sites when they receive communication or reports from the contractors. The results of the monitoring will be communicated to residents and others concerned at the Liaison and Coordination Committee meetings, and announced over the radio.

Monitoring structure after completion of the works

Sustainable coast management with a long-term perspective requires the introduction of a public-private partnership in the monitoring system after the completion of the works. The organization described below is recommended for the implementation of monitoring after completion of the works. However, public institutions (governmental institutions and kaupules) in Tuvalu have little experience in monitoring these items. Local residents also have little experience in participatory projects and environmental monitoring. Therefore, the establishment of this kind of public-private partnership monitoring structure will require capacity development in monitoring technologies.

Table 9.28 Organizations Implementing Monitoring after Completion of the Works

Survey Item	Monitoring organization
Topographic survey	Department of Lands and Survey (DOLS)
Survey of sediment quality	Kaupules
Survey of marine organisms	Department of Fisheries (DOF)
Survey of vegetation and scenery	Department of Environment (DOE), Kaupules, NGOs and local residents
Interview survey of coast users	DOE, Kaupules and NGOs

Meanwhile, in order to facilitate the sharing of monitoring information related to this project, to strengthen connections between people involved in the project and to implement continuous monitoring, it is recommended that a Liaison and Coordination Committee structured as shown below be established.

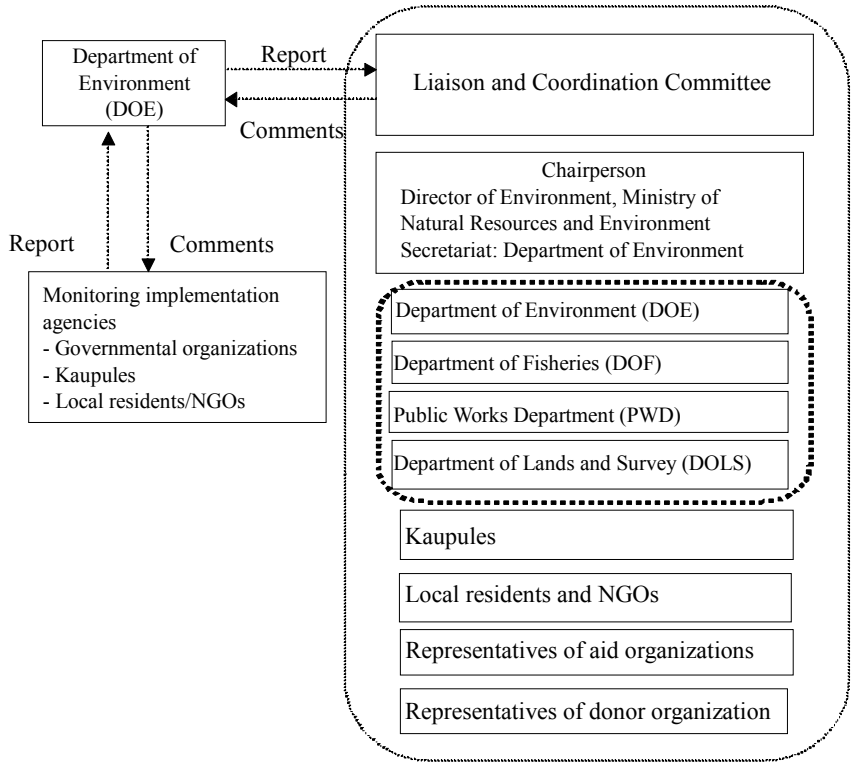


Figure 9.43 Structure of the Liaison and Coordination Committee for Continuous Monitoring

(3) Monitoring Plan

The content and timing of the monitoring survey are given in **Table 9.29** and the position of the survey in **Figure 9.31** and **Figure 9.32**. Also, the project schedule is given in **Table 9.30**. The project schedule is to implement pilot works in the first year, to implement monitoring over the rainy season when high waves are generated in the lagoon, to evaluate the effect/impact of the gravel nourishment, to hold public hearings with residents, and where necessary to reflect these results in the project. The first stage of the monitoring is to be implemented in conjunction with technical transfer by technical experts from Japan and Tuvalu, and the second stage is to be implemented by Tuvaluan technical experts.

Table 9.29 Monitoring Project

Survey item	Survey content		Implementation timing
	First stage (technical transfer)	Second stage (implemented by Tuvalu side)	
Water quality	Survey to grasp extent of turbidity L03IN, L06IN (target	None	Implement at low tide of spring tide during the works (twice monthly)

	points) L042IN, L052IN (nourishment area) Implemented along these four traverse lines at 50, 100 and 150 m offshore. (4 traverse lines × 3 points × 1 m below water surface, half water depth, 1 m above seafloor = 36 locations; see **Figure 9.44**)		
Topographic survey	・Gravel extraction area To grasp topographic changes in surrounding area after gravel extraction ・Nourishment area To grasp movement of gravel and changes to nourished gravel by bathymetric and shoreline survey Implement at 40 m intervals along F/S traverse lines. 54 lines. Approx. 30 m inland from the shoreline and approx. 100 m offshore	・Nourishment area To grasp movement of gravel and changes to nourished gravel by shoreline survey Implement at 40 m intervals along F/S traverse lines. 54 lines. Approx. 30 m inland from the shoreline and approx. 50 m offshore (near C.D.L.0 m)	Implement from April to May after the rainy season
Bottom sediment survey	Measurement and photography of shoreward gravel boundary (distance from base point) 54 traverse lines as in topographic survey	Same as in first stage	Implement from April to May after the rainy season
Marine ecology survey	Grasp distribution, coverage and types of foraminifer, corals, and seaweeds. L02IN, L03IN (target points) L042IN, L052IN (nourishment area) L06IN, L07IN (target	None	Before works: using results of this development study After works: once annually in September or October in conjunction with development study timing

	points) Total: six survey lines (see **Figure 9.44**).		
Vegetation/landscape survey	Photos of vegetation/landscape at fixed points Approx. 10 points	Same as in first stage	Twice annually
Coastal users interview survey	Hold interviews with fishermen and other residents on impact of this project (employ monitor system; decide on monitor in advance and get them to provide information) Approx. 10 people	None	Once annually
Evaluation of impact/effect of nourishment	・Re-run the shoreline change prediction model to find whether the nourished beach has changed according to plan and is effective for disaster prevention, and assess wave runup height. ・Impact assessment on surrounding coast Assess impact/effect of nourishment from survey results, make revised plan if necessary.	None	Once annually
Public hearing	Hold hearings for each group of residents as held during the study, and compile issues that have arisen after the nourishment.	None	Twice after nourishment

Note 1) L042IN and L052IN are survey lines implement in this study, L04IN and L05IN survey lines were moved into the nourishment area.

Note 2) Water quality and marine ecology are affected by global environmental changes, therefore, control surveys were held on lines not expected to be affected by the nourishment as background.

Table 9.30 Project Schedule

Content	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6 on
Works	(Apr.-Dec.) Pilot		(Apr.-Dec.) Main works	(Apr.-Aug.) Main works		
Monitoring (Stage 1)		(April-July)	(April-July)	(April-July)	(April-July)	
Monitoring (Stage 2)						(April-July)

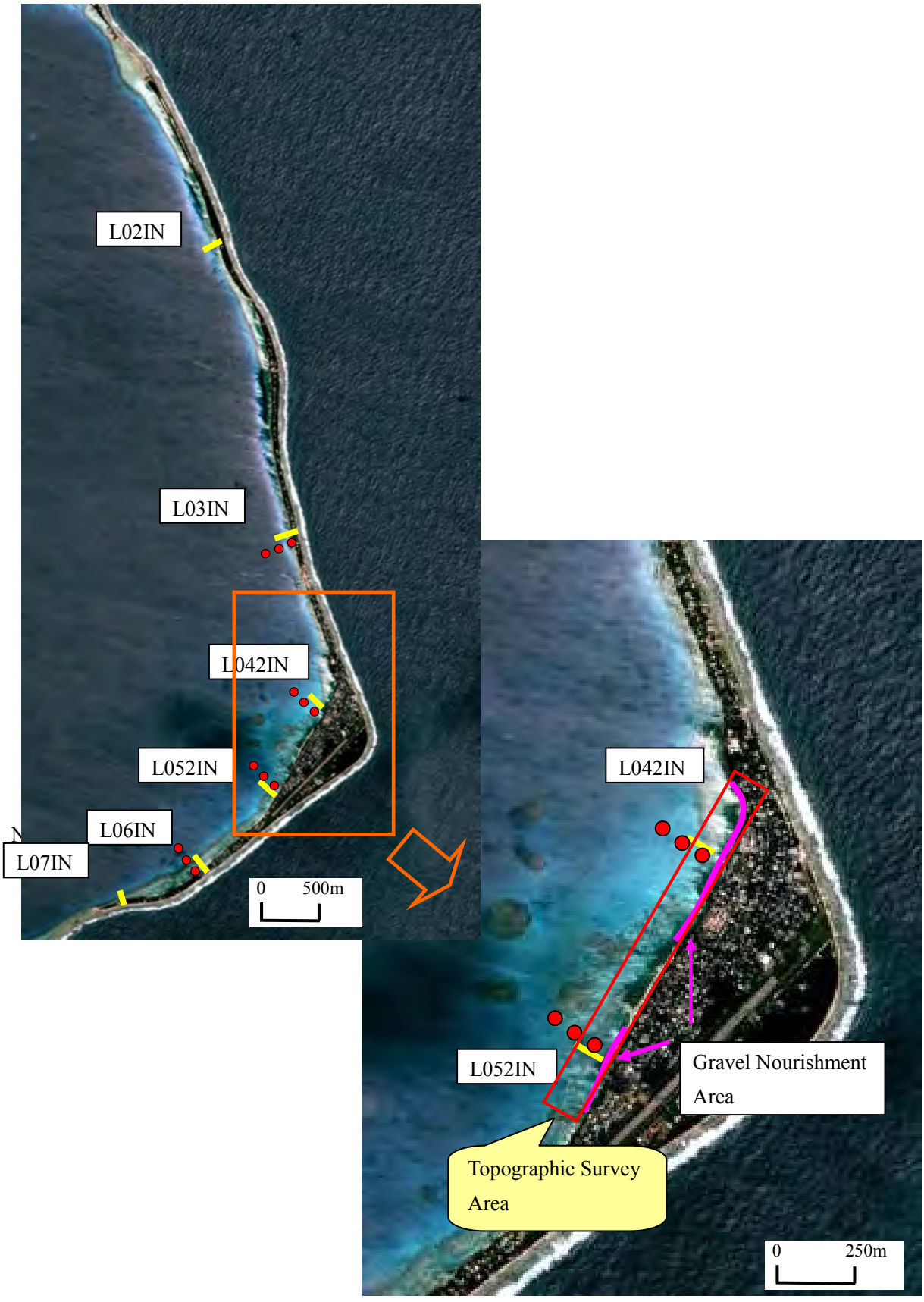


Figure 9.44 Position of Monitoring Survey in Gravel Nourishment Area

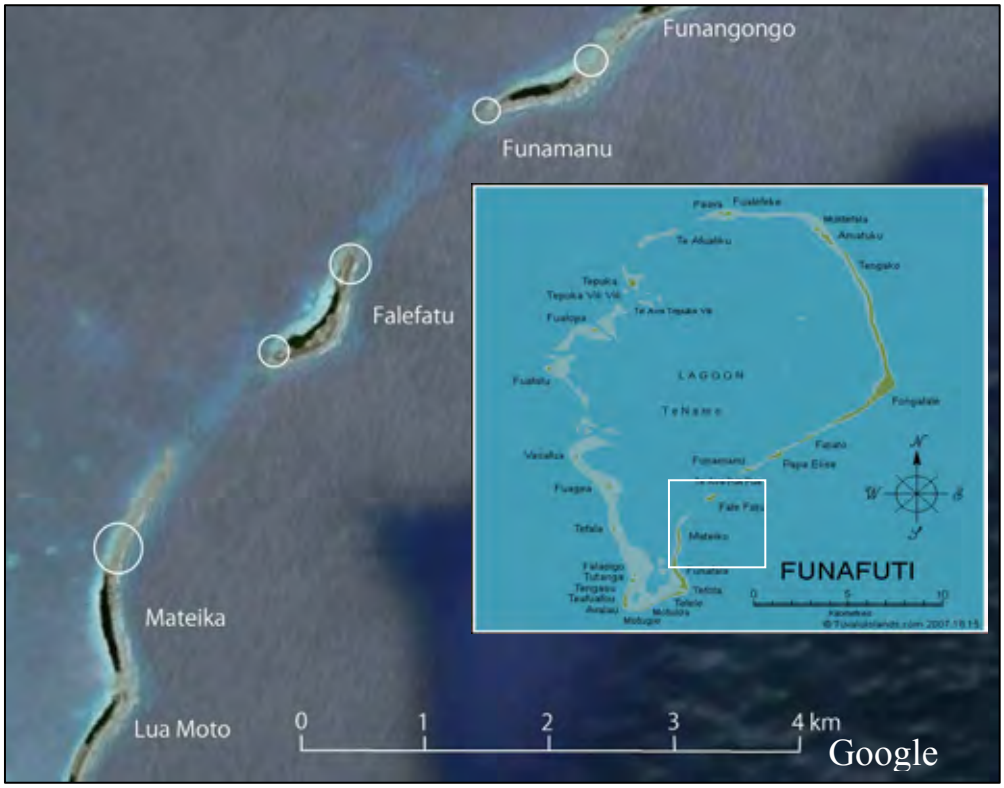


Figure 9.45 Position of Monitoring Survey in Collection Area of Gravel

9.6.3 Management Plan

(1) Soft Component for Coastal Disaster Reduction

Even if the Kaupule is enforcing the bans on illegal mining of the gravels and illegal cutting the plants and trees, they are not effective, because of people's superficial understanding of the adverse effects of the illegal mining and illegal cutting of the plants on the beach protection, and low awareness of the preservation of the beach. Strengthening the enforcement only will not make the bans effective. In addition to the cause and effect analysis, it was found that the residents have extremely limited knowledge about sea level rise; at the same time, there is serious fear of sea level rise. Therefore it is necessary that to hold awareness sessions on sea level rise and vulnerability of the islet against high wave, and after that, soft component as remedies for the real cause of the coastal disaster: high waves during high tide, by initiative of the ocean side residents.

Table 9.31 shows the activities of soft components remedies of coastal disaster for all islanders. In the implementation of these soft components, it is advisable that the concerned parties, being counterpart (C/P) in this study and belonging to Ministry of Natural Resources and Environment (MNRD) in Government of Tuvalu, who have the training on coastal management, such as measures and plans for coastal erosion, protection and rehabilitation in Japan, will lecture them.

Table 9.31 Soft Component Remedies of Coastal Disaster for All Islanders

	Issue	Contents	Practice	Subject Area
Coastal Disaster Prevention	Fear of sea level rise in future	Providing of correct information on sea level rise	Correct information based on coastal engineering, actual causes of danger and remedies shall be provided through radio, seminar, in classroom of schools, gathering of women's meetings etc.	All Fongafale Islet
	High waves during high tide such as when a hurricane approaches	[For Preparation]	* Vulnerable areas should be marked by a zoning map and let the residents know the danger. * To possess danger of islet's vulnerability against high waves by sharing experiences of Hurricane Bebe, or from the residents of Manihiki Islanders. * Conservation measures of storm ridge along the Oceanside (prohibition of excavation, and the recovery). * Preservation of plants just behind shoreline (recognizing the effects, activities that undermine safety of the hinterland residents, plan on plantation of trees, and the implementation	All Fongafale Islet
		[For Emergency Actions]	*Planning and practices of disaster management (planning on series of actions assumed to be required: confirmation of transmission flow of information and order, confirmation on residents who need support, duty of related organization and action plan, confirmation on evacuation route and destination, plan on securing substantial commodities	

(2) The role of the Government of Tuvalu

A substantial financial support for maintenance and management from the Government of Tuvalu may not be expected. The budgets for maintenance of the Government for the recent years were between about 6% and 13% of the operation budget, or about 200 thousand AU$ per year. The value of the Tuvalu Provident Fund have fallen drastically after the Lehman Shock and revenue from the Fund has been hardly expected, so the Government has been compelled to reduce the operation budget, and the increase of allocation to the maintenance cost is deemed difficult. **Table 9.32** shows the summary of total expenditure of the Government by broad class.

Table 9.32 Government Budget: Public Utilities and Industries, Summary of Total Expenditure by Broad Class

(Unit: AU$)

Year	2005	2006	2007	2008	2009
Staff	740,410	751,223	727,509	776,403	923,156
Travel & Communication	48,232	82,417	70,051	58,844	60,700
Maintenace	**118,200**	**138,160**	**135,880**	**264,666**	**201,484**
Purchase of Goods & Services	75,600	97,138	29,718	45,400	704,850
Other Expenses	305,000	305,000	1,333,436	865,015	1,089,949
Total Operating	1,287,442	1,373,938	2,296,594	2,010,327	2,980,139
Total Capital	482,218	11,276,485	1,000	220,000	466,000
TOTAL EXPENDITURE	1,769,650	12,650,423	2,297,594	2,230,327	3,446,139

Source：Tuvalu National Budget 2009,

The budget for maintenance of the Department of Works, of which mandates include maintenance of infrastructures and public utilities, covers maintenance works of the roads, mainly patch works of the damaged pavement, and maintenance of the Government House. Yearly allocated budgets of between 100 thousands AU$ and 200 thousands AU$ may not afford a major maintenance work of the beach.

Table 9.33 Budget of the Dept. of Works for the Last Decade

Year	Road Maintenance	Government House Maintenance	Total PWD	Remarks
2000	$ 28,434.54	$ 192,165.17	$220,599.71	
2001	$ 5,996,583.05	$ 43,004.55	$6,039,587.60	the budget was boosted by the fund for the project of the constructions of new roads
2002				
2003	$ 19,894.45	$ 209,990.49	$229,884.94	
2004	$ 12,125.00	$ 112,456.26	$124,581.26	
2005	$ 9,636.23	$ 56,104.08	$65,740.31	
2006				
2007	$ 13,696.65	$ 226,370.39	$240,067.04	
2008	$ 25,000.00	$ 203,069.00	$228,069.00	
2009	$ 22,000.00	$ 100,000.00	$122,000.00	
2010	$ 22,000.00	$ 170,000.00	$192,000.00	

Source：Department of Works

The Government of Tuvalu is expected, on top of financial supports affordable by them for maintenance and management activities, to enact a statute which clearly defined that the ownership of the land to be reclaimed in the Project shall vest in the Crown and under the management of the Kaupule, as well as, to play the leading role in monitoring after completion of the work.

9.7 Cost Estimation

Necessary project costs for 4 alternative plans are shown in the **Table 9.34**.
Details are shown in **Table 9.35**.

Table 9.34 Project Costs for 4 Alternative Plans

Work Item	Plan-1	Plan-2	Plan-3	Plan-4
Direct Construction Cost				
L-C area				
Gravel Beach Nourishment				○
Parapet			○	○
Borrow Pit Backfilling BP-1		○	○	○
BP-2		○	○	○
L-D area (D-1, D-3)				
Gravel Beach Nourishment	○	○	○	○
Parapet	○	○	○	○
Borrow Pit Backfilling BP-3N		○	○	○
Estimated Cost (Million Yen)	555.3	923.1	994.3	1,424.4

A pilot project is planned for the purpose of confirmation of opinions from local residents, and verification of water current and gravel behavior of the beach nourishment material in the borrow pit and of appropriateness of filling materials and work methods.
When gravel beach nourishment work is executed in D-1 area (approx. 252m), the necessary costs are estimated as follows.

Pilot Project Plan-1 (use runway gravel): approx.153.4 millions Japanese Yen
Pilot Project Plan-2 (use islets gravel): approx. 84.6 millions Japanese Yen
Pilot Project Plan-1 (use import gravel): approx.117.0 millions Japanese Yen

Details for pilot works are shown in the **Table 9.36**.

Table 9.35 Details of Cost Estimations

		●Plan−1			EX.Rate to JPY= 48.9		●Plan−2			EX.Rate to JPY= 48.9		●Plan−3			EX.Rate to JPY= 48.9		●Plan−4			EX.Rate to JPY= 48.9	
	Description	Q'ty	Unit	Unit Rate	Amount (FJ$)	Amount in JPY	Q'ty	Unit	Unit Rate	Amount (FJ$)	Amount in JPY	Q'ty	Unit	Unit Rate	Amount (FJ$)	Amount in JPY	Q'ty	Unit	Unit Rate	Amount (FJ$)	Amount in JPY
A	**Site Establishment, Mobilization & Demobilization**				**311,000**	**15,207,900**				**503,000**	**24,596,700**				**530,000**	**25,917,000**				**530,000**	**25,917,000**
B	**Gravel Excavation and Transportation From Islets**				**2,309,510**	**112,935,039**				**2,309,510**	**112,935,039**				**2,309,510**	**112,935,039**				**2,309,510**	**112,935,039**
1)	Construct Temporary Causeways	27,636.0	m3	15.5	428,358	20,946,706	27,636.0	m3	15.5	428,358	20,946,706	27,636.0	m3	15.5	428,358	20,946,706	27,636.0	m3	15.5	428,358	20,946,706
2)	Excavate / loading Gravel (35000m3)	28,145.0	m3	21.5	605,118	29,590,270	28,145.0	m3	21.5	605,118	29,590,270	28,145.0	m3	21.5	605,118	29,590,270	28,145.0	m3	21.5	605,118	29,590,270
3)	Unload barge at stock pile	28,145.0	m3	8.8	247,676	12,111,356	28,145.0	m3	8.8	247,676	12,111,356	28,145.0	m3	8.8	247,676	12,111,356	28,145.0	m3	8.8	247,676	12,111,356
4)	Remove Causeway after island excavation	27,636.0	m3	15.5	428,358	20,946,706	27,636.0	m3	15.5	428,358	20,946,706	27,636.0	m3	15.5	428,358	20,946,706	27,636.0	m3	15.5	428,358	20,946,706
5)	Temporary Live Coral Remove	3	L.S.	200,000.0	600,000	29,340,000	3	L.S.	200,000.0	600,000	29,340,000	3	L.S.	200,000.0	600,000	29,340,000	3	L.S.	200,000.0	600,000	29,340,000
C	**Dredging**				**1,974,629**	**96,559,358**				**2,870,532**	**140,369,015**				**3,027,816**	**148,060,202**				**3,027,816**	**148,060,202**
1)	Dredging Sand and Barge to Stock yard	24,579.0	m3	16.0	393,264	19,230,610	48,343.0	m3	16.0	773,488	37,823,563	52,515.0	m3	16.0	840,240	41,087,736	52,515.0	m3	16.0	840,240	41,087,736
2)	Unload barge at stock pile	24,579.0	m3	12.2	299,864	14,663,350	48,343.0	m3	12.2	589,785	28,840,487	52,515.0	m3	12.2	640,683	31,329,399	52,515.0	m3	12.2	640,683	31,329,399
3)	Tug and Barge stand by during dredging	24,579.0	m3	9.5	233,501	11,418,199	48,343.0	m3	9.5	459,259	22,457,765	52,515.0	m3	9.5	498,893	24,395,868	52,515.0	m3	9.5	498,893	24,395,868
4)	Dredging Equipment	1	L.S.	1,000,000.0	1,000,000	48,900,000	1	L.S.	1,000,000.0	1,000,000	48,900,000	1	L.S.	1,000,000.0	1,000,000	48,900,000	1	L.S.	1,000,000.0	1,000,000	48,900,000
5)	Special Anchor and mooring during dredging	1	L.S.	48,000.0	48,000	2,347,200	1	L.S.	48,000.0	48,000	2,347,200	1	L.S.	48,000.0	48,000	2,347,200	1	L.S.	48,000.0	48,000	2,347,200
D	**Runway Site Excavation**				**800,444**	**39,141,712**				**1,123,065**	**54,917,879**				**1,299,540**	**63,547,506**				**1,299,540**	**63,547,506**
1)	Excavation and Transport coral gravel	18,923.0	m3	14.6	276,276	13,509,896	26,550.0	m3	14.6	387,630	18,955,107	30,722.0	m3	14.6	448,541	21,933,655	30,722.0	m3	14.6	448,541	21,933,655
2)	Load and Transportation sand fill to Runway	18,923.0	m3	9.5	179,769	8,790,704	26,550.0	m3	9.5	252,225	12,333,803	30,722.0	m3	9.5	291,859	14,271,905	30,722.0	m3	9.5	291,859	14,271,905
3)	Site clean up at runway	18,923.0	m3	2.2	41,631	2,035,756	26,550.0	m3	2.2	58,410	2,856,249	30,722.0	m3	2.2	67,588	3,305,053	30,722.0	m3	2.2	67,588	3,305,053
4)	Geotextile	18,923.0	m2	16.0	302,768	14,805,355	26,550.0	m2	16.0	424,800	20,772,720	30,722.0	m2	16.0	491,552	24,036,893	30,722.0	m2	16.0	491,552	24,036,893
E	**Gravel Beach Fill**				**2,493,971**	**121,955,182**				**2,493,971**	**121,955,182**				**2,493,971**	**121,955,182**				**8,632,880**	**422,147,832**
1)	Gravel Fill	46,535.0	m3	22.6	1,051,691	51,427,690	46,535.0	m3	22.6	1,051,691	51,427,690	46,535.0	m3	22.6	1,051,691	51,427,690	46,535.0	m3	22.6	1,051,691	51,427,690
2)	Sand Fill	5,656.0	m3	21.0	118,776	5,808,146	5,656.0	m3	21.0	118,776	5,808,146	5,656.0	m3	21.0	118,776	5,808,146	5,656.0	m3	21.0	118,776	5,808,146
3)	Sand Bags	5,656.0	m3	234.0	1,323,504	64,719,346	5,656.0	m3	234.0	1,323,504	64,719,346	5,656.0	m3	234.0	1,323,504	64,719,346	5,656.0	m3	234.0	1,323,504	64,719,346
																	36,090.0		170.1	6,138,909	300,192,650
F	**Borrow Pit Fill**				**0**	**0**				**4,287,305**	**209,649,215**				**4,287,305**	**209,649,215**				**4,287,305**	**209,649,215**
1)	Sand Fill	0.0	m3	21.0	0	0	16,137.0	m3	21.0	338,877	16,571,085	16,137.0	m3	21.0	338,877	16,571,085	16,137.0	m3	21.0	338,877	16,571,085
2)	Sand Bag	0.0	m3	234.0	0	0	16,137.0	m3	234.0	3,776,058	184,649,236	16,137.0	m3	234.0	3,776,058	184,649,236	16,137.0	m3	234.0	3,776,058	184,649,236
3)	Gravel Fill	0.0	m3	22.6	0	0	7,627.0	m3	22.6	172,370	8,428,893	7,627.0	m3	22.6	172,370	8,428,893	7,627.0	m3	22.6	172,370	8,428,893
G	**Parapet Work**				**367,770**	**17,983,953**				**367,770**	**17,983,953**				**1,110,900**	**54,323,010**				**1,110,900**	**54,323,010**
1)	Stone Masonry	533.0	m3	690.0	367,770	17,983,953	533.0	m3	690.0	367,770	17,983,953	1,610.0	m3	690.0	1,110,900	54,323,010	1,610.0	m3	690.0	1,110,900	54,323,010
H	**Boat Ramp**	**3.0**	**Nos.**		**261,960**	**12,809,844**	**3.0**	**Nos.**		**261,960**	**12,809,844**	**3.0**	**Nos.**		**261,960**	**12,809,844**	**9.0**	**Nos.**		**785,880**	**38,429,532**
		1箇所当たり			87,320	4,269,948	1箇所当たり			87,320	4,269,948	1箇所当たり			87,320	4,269,948	1箇所当たり			87,320	4,269,948
1)	Gravel Bag	348.0	m3	90.0	31,320	1,531,548	348.0	m3	90.0	31,320	1,531,548	348.0	m3	90.0	31,320	1,531,548	348.0	m3	90.0	31,320	1,531,548
2)	Concrete Block and slab	56.0	m3	1,000.0	56,000	2,738,400	56.0	m3	1,000.0	56,000	2,738,400	56.0	m3	1,000.0	56,000	2,738,400	56.0	m3	1,000.0	56,000	2,738,400
	Sub Total (A to H)				**8,519,284**	**416,592,988**				**14,217,113**	**695,216,826**				**15,321,002**	**749,196,998**				**21,983,831**	**1,075,009,336**
I	**Indirect Cost (A to H)x 20%**	1	L.S.		**1,703,857**	**83,318,607**	1	L.S.		**2,843,423**	**139,043,385**	1	L.S.		**3,064,200**	**149,839,380**	1	L.S.		**4,396,766**	**215,001,857**
	Contractor's Cost Sub Total (A to I)				**10,223,141**	**499,911,595**				**17,060,536**	**834,260,210**				**18,385,202**	**899,036,378**				**26,380,597**	**1,290,011,193**
J	**Engineering Fee (A to I)x 10%**	1	L.S.		**1,022,314**	**49,991,155**	1	L.S.		**1,706,054**	**83,426,041**	1	L.S.		**1,838,520**	**89,903,628**	1	L.S.		**2,638,060**	**129,001,134**
K	**Monitoring (Soft Component)**	1	L.S.		**110,000**	**5,379,000**	1	L.S.		**110,000**	**5,379,000**	1	L.S.		**110,000**	**5,379,000**	1	L.S.		**110,000**	**5,379,000**
	Consutant's Fee Sub Total (I + K)				**1,132,314**	**55,370,155**				**1,816,054**	**88,805,041**				**1,948,520**	**95,282,628**				**2,748,060**	**134,380,134**
	Grand Total				**11,355,455**	**555,281,750**				**18,876,590**	**923,065,251**				**20,333,722**	**994,319,006**				**29,128,657**	**1,424,391,327**

Table 9.36 Details of Cost Estimations for Pilot Works

Description	●Pilot−1: Runway Grav EX.Rate to JPY= 48.9					●Pilot−2: Islets Gravel EX.Rate to JPY= 48.9					●Pilot−3: Import Gravel EX.Rate to JPY= 48.9				
	Q'ty	Unit	Unit Rate	Amount (FJ$)	Amount in JPY	Q'ty	Unit	Unit Rate	Amount (FJ$)	Amount in JPY	Q'ty	Unit	Unit Rate	Amount (FJ$)	Amount in JPY
A Site Establishment, Mobilization & Demobilization				**235,250**	**11,503,725**				**235,250**	**11,503,725**				**186,250**	**9,107,625**
B Gravel Excavation and Transportation From Islets				**0**	**0**				**660,225**	**32,285,003**				**0**	**0**
1) Construct Temporary Causeways		m3	15.5	0	0	7,132.0	m3	15.5	110,546	5,405,699		m3	15.5	0	0
2) Excavate / loading Gravel (35000m3)		m3	21.5	0	0	7,892.2	m3	21.5	169,682	8,297,450		m3	21.5	0	0
3) Unload barge at stock pile		m3	8.8	0	0	7,892.2	m3	8.8	69,451	3,396,154		m3	8.8	0	0
4) Remove Causeway after island excavation		m3	15.5	0	0	7,132.0	m3	15.5	110,546	5,405,699		m3	15.5	0	0
5) Temporary Live Coral Remove		L.S.	200,000.0	0	0	1	L.S.	200,000.0	200,000	9,780,000		L.S.	200,000.0	0	0
C Dredging				**1,345,536**	**65,796,710**				**0**	**0**				**48,000**	**2,347,200**
1) Dredging Sand and Barge to Stock yard	7,892.2	m3	16.0	126,275	6,174,848	0.0	m3	16.0	0	0		m3	16.0	0	0
2) Unload barge at stock pile	7,892.2	m3	12.2	96,285	4,708,337	0.0	m3	12.2	0	0		m3	12.2	0	0
3) Tug and Barge stand by during dredging	7,892.2	m3	9.5	74,976	3,666,326	0.0	m3	9.5	0	0		m3	9.5	0	0
4) Dredging Equipment	1	L.S.	1,000,000.0	1,000,000	48,900,000	0	L.S.	1,000,000.0	0	0		L.S.	1,000,000.0	0	0
5) Special Anchor and mooring during dredging	1	L.S.	48,000.0	48,000	2,347,200	0	L.S.	48,000.0	0	0	1	L.S.	48,000.0	48,000	2,347,200
D Runway Site Excavation				**333,840**	**16,324,776**				**0**	**0**				**0**	**0**
1) Excavation and Transport coral gravel	7,892.2	m3	14.6	115,226	5,634,551	0.0	m3	14.6	0	0		m3	14.6	0	0
2) Load and Transportation sand fill to Runway	7,892.2	m3	9.5	74,976	3,666,326	0.0	m3	9.5	0	0		m3	9.5	0	0
3) Site clean up at runway	7,892.2	m3	2.2	17,363	849,051	0.0	m3	2.2	0	0		m3	2.2	0	0
4) Geotextile	7,892.2	m2	16.0	126,275	6,174,848	0.0	m2	16.0	0	0		m2	16.0	0	0
E Gravel Beach Fill				**174,947**	**8,554,908**				**174,947**	**8,554,908**				**1,316,744**	**64,388,782**
1) Gravel Fill	7,741.0	m3	22.6	174,947	8,554,908	7,741.0	m3	22.6	174,947	8,554,908		m3	22.6	0	0
2) Sand Fill		m3	21.0	0	0		m3	21.0	0	0		m3	21.0	0	0
3) Sand Bags		m3	234.0	0	0		m3	234.0	0	0		m3	234.0	0	0
											7,741.0		170.1	1,316,744	64,388,782
F Borrow Pit Fill				**0**	**0**				**0**	**0**				**0**	**0**
1) Sand Fill	0.0	m3	21.0	0	0	0.0	m3	21.0	0	0	0.0	m3	21.0	0	0
2) Sand Bag	0.0	m3	234.0	0	0	0.0	m3	234.0	0	0	0.0	m3	234.0	0	0
3) Gravel Fill	0.0	m3	22.6	0	0	0.0	m3	22.6	0	0	0.0	m3	22.6	0	0
G Parapet Work				**104,328**	**5,101,639**				**104,328**	**5,101,639**				**104,328**	**5,101,639**
1) Stone Masonry	151.2	m3	690.0	104,328	5,101,639	151.2	m3	690.0	104,328	5,101,639	151.2	m3	690.0	104,328	5,101,639
H Boat Ramp	**3.0**	**Nos.**		**0**	**0**	**3.0**	**Nos.**		**0**	**0**	**3.0**	**Nos.**		**0**	**0**
	1箇所当たり			0	0	1箇所当たり			0	0	1箇所当たり			0	0
1) Gravel Bag		m3	90.0	0	0		m3	90.0	0	0		m3	90.0	0	0
2) Concrete Block and slab		m3	1,000.0	0	0		m3	1,000.0	0	0		m3	1,000.0	0	0
Sub Total (A to H)				**2,193,901**	**107,281,759**				**1,174,750**	**57,445,275**				**1,655,322**	**80,945,246**
I Indirect Cost (A to H)x 20%	1	L.S.		**438,780**	**21,456,342**	1	L.S.		**234,950**	**11,489,055**	1	L.S.		**331,064**	**16,189,030**
Contractor's Cost Sub Total (A to I)				**2,632,681**	**128,738,101**				**1,409,700**	**68,934,330**				**1,986,386**	**97,134,275**
J Engineering Fee (A to I)x 10%	1	L.S.		**394,902**	**19,310,708**	1	L.S.		**211,455**	**10,340,150**	1	L.S.		**297,958**	**14,570,146**
K Monitoring (Soft Component)	1	L.S.		**110,000**	**5,379,000**	1	L.S.		**110,000**	**5,379,000**	1	L.S.		**110,000**	**5,379,000**
Consutant's Fee Sub Total (I + K)				**504,902**	**24,689,708**				**321,455**	**15,719,150**				**407,958**	**19,949,146**
Grand Total				**3,137,583**	**153,427,809**				**1,731,155**	**84,653,480**				**2,394,344**	**117,083,422**

CHAPTER 10 **FINANCIAL & ECONOMIC ANALYSES**

10.1 Policy of the Cost Benefit Analysis

10.1.1 Steps in the Cost-Benefit Analysis of the Project

Steps in the Cost-Benefit Analysis of the Project are as follows.

Step 1: Identify alternative measure(s) for coastal defense

↓

Step 2: Estimate the cost of measure(s) for coastal defense

↓

Step 3: Estimate the benefit of measure(s) for coastal defense

↓

Estimate benefits of measure for coastal defense for a typical natural hazard event

/ Identify natural hazard impacts with and without measure for coastal defense

/ Where possible, identify monetary value of natural hazard impacts with and without measure for coastal defense

/ Calculate monetary value of benefits of measure for coastal defense for typical natural hazard event (impact without measure for coastal defense - impacts with measure for coastal defense)

↓

Estimate annual expected benefits of measure for coastal defense

/ Estimate frequency of future hazard events

/ Calculate annual expected benefits of measure for coastal defense (benefits of typical hazard event x probability of typical hazard event)

↓

Step 4: Discount the estimated costs and benefits

↓

Step 5: Conduct sensitivity analysis

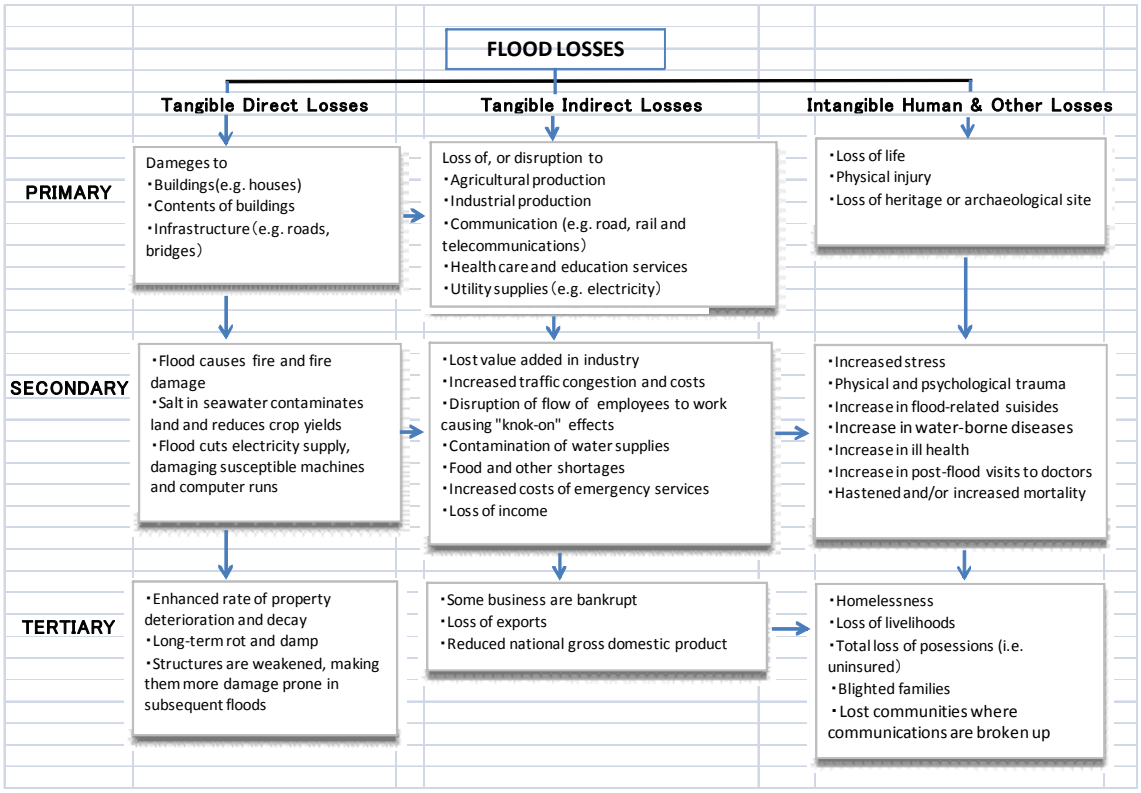
↓

Step 6: Make policy recommendations

10.1.2 Benefits

Flood losses by overtopping waves in the coastal area are not only tangible direct losses of houses and infrastructure such as roads and public utelities, but also tangible indirect losses, as to decreasing of production in agriculture and interception of communication causing these

losses and intangible human and other losses, such as increasing of human loss, injury, and disease. Typical flood losses are categorized as follows.



Source：Conducting Flood Loss Assessments, A tool for Integrated Flood Management, Mar 2007, World Meteorological Organization/ Global Water Partnership

Figure 10.1 Types of Flood Losses

According to the Cost Benefit Analysis Guideline of Projects in Coastal Areas in Japan, the benefits are categorized in the following five items. The benefit means converting the effects into monetary value. According to the Guideline, the effects convertible into monetary value by available knowledge and information shall be calculated, but even if not listed in the Guideline, benefits which can be converted into monetary value are allowed to be included in it. In case it is indispensable to reclaim the land for measure for coastal defense, additional value of the land increased can be calculated as a benefit.

①┌ Benefit of defending from flood water

Benefits for defending property of the hinterland from flood caused by a high sea, waves and tsunami, etc.

② Benefit of defending from erosion

Benefits for defending loss or reduction of loss of the lands and property caused by the coastal erosion.

③ Benefit of defending from wind-blown sand and sea water spray

Benefits for preventing or reduction of losses or damages of crop, damage to properties of the hinterland, and deterioration of local environment (necessity of additional labor).

④ Benefit of coastal environment preservation

Benefits for preserving natural environment such as ecology and water quality and improvements of environment around life of residents by improvement of scenery of the landscape.

⑤ Benefit of good use of the coastal area

Benefits for promoting the coastal area in sea bathing, sports and recreation.

10.1.3 Term of Evaluation

Term of evaluation is basically from starting of the project to the period when the function of the facility will be diminished. According to the Guideline, the evaluation term is determined as the project term plus fifty years (service term) in principle. Although the target year of this project is 2020, the term of evaluation of this project is determined as fifty years because the nourished beach will remain.

10.1.4 Estimate of Amount of Damages

Benefits of measures for coastal defense are calculated based on the following equation.

Benefits of measures for coastal defense
=Benefit of defending from flood water + Benefit of defending from erosion + Benefit of defending from wind-blown sand and sea water spray + Benefit of coastal environment preservation + Benefit of good use of the coastal area + Benefit of Increased land

= Disaster damages to be avoided + Benefits to be created by implementation of the Project

= (Damage without measures for coastal defense – damage with measures for coastal defense) + Benefits created

Budgets for maintenance of the Department of Works covers only maintenance of roads, mainly patch work for damaged roads, and that of Government House. Costs of restoring damages caused by natural hazards such as cyclones and floods, etc. are under the control of Disaster Coordinator of the Office of the Prime Minister. The major duty of Disaster Coordinator is coordinating the aid donor's support after the disaster. As the data on the impacts of previous

natural disasters are inaccurate and incomplete. the value of damages are not possible to be calculated based on the existing record. For estimating the disaster damages and grasping the situation of residents' livelihood, furniture and equipment of their household, transportation equipment, planting and business in their compounds, a Questionnaire Survey for estimating damages caused by flood and overtopping waves was conducted.

Based on the data acquired in the Questionnaire Survey, applying the Economic Survey Manual for Flood Control Project[1] in Japan, monetary values of losses will be estimated. Intangible losses such as human loss, injures and diseases during/after flooding will be estimated applying the guideline[2] of Department of Environment, Food and Rural Affairs, UK.

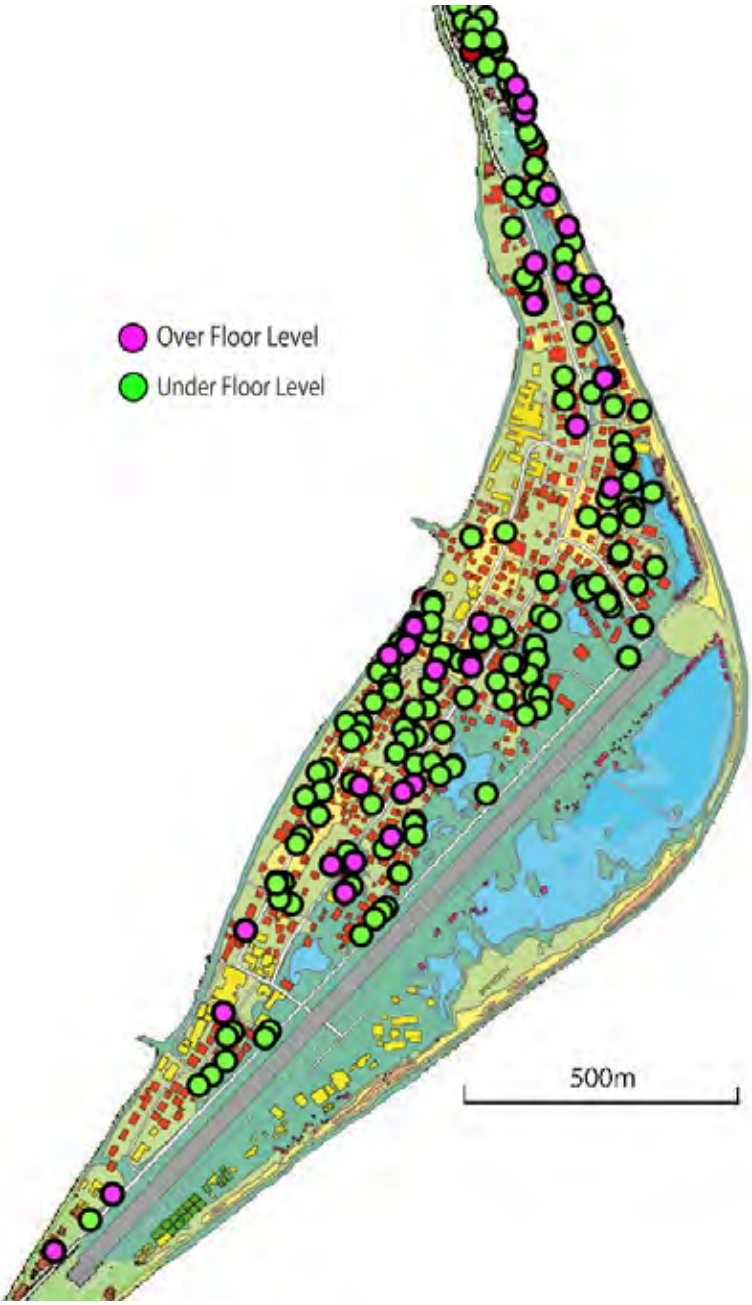
10.2 Situations of the Life and Assets of the Residents in the Target Area

10.2.1 The Questionnaire Survey on Damages Caused by Flood and Overtopping Waves

The following figure illustrates the locations of the flood damaged houses, based on the Questionnaire Survey on the coastal disasters in all of the Fongafale Island, which was conducted in October 2009, prior to the Questionnaire Survey for Cost of restoring damages due to flooding & high waves in the project area.

[1] the Economic Survey Manual for Flood Control Project, April 2005, River Bureau, Ministry of Land Infrastructure and Transport, Japan

[2] Supplementary Note to Operating Authorities, Assessing and Valuing the Risk to Life from Flooding for Use in Appraisal of Risk Management Measures, May 2008, Department of Environment, Food and Rural Affairs.



(Source：Based on Yamono et al., Atoll island vulnerability to flooding and inundation revealed by historical reconstruction: Fongafale Islet, Funafuti Atoll, Tuvalu. Global and Planetary Change 57 (2007))

Figure 10.2 Locations of the Flood Damage Houses

Among these flood damages, houses around and in the eastern area of the Tuvalu road are deemed to be damaged due to flooding from ocean or seepage water from the ground. Flood due to overtopping waves from the lagoon affect the areas of the lagoon side of Senala, Alapi and Vaiaku. The flood damage houses are located between the lagoon and the Fongafale road and also the lagoon and the Tuvalu road in the north side of the hospital. These houses in the damaged area were targeted in the Questionnaire Survey for Cost of restoring damages due to

flooding & high waves. The following figure[3] illustrates the locations of the houses surveyed.

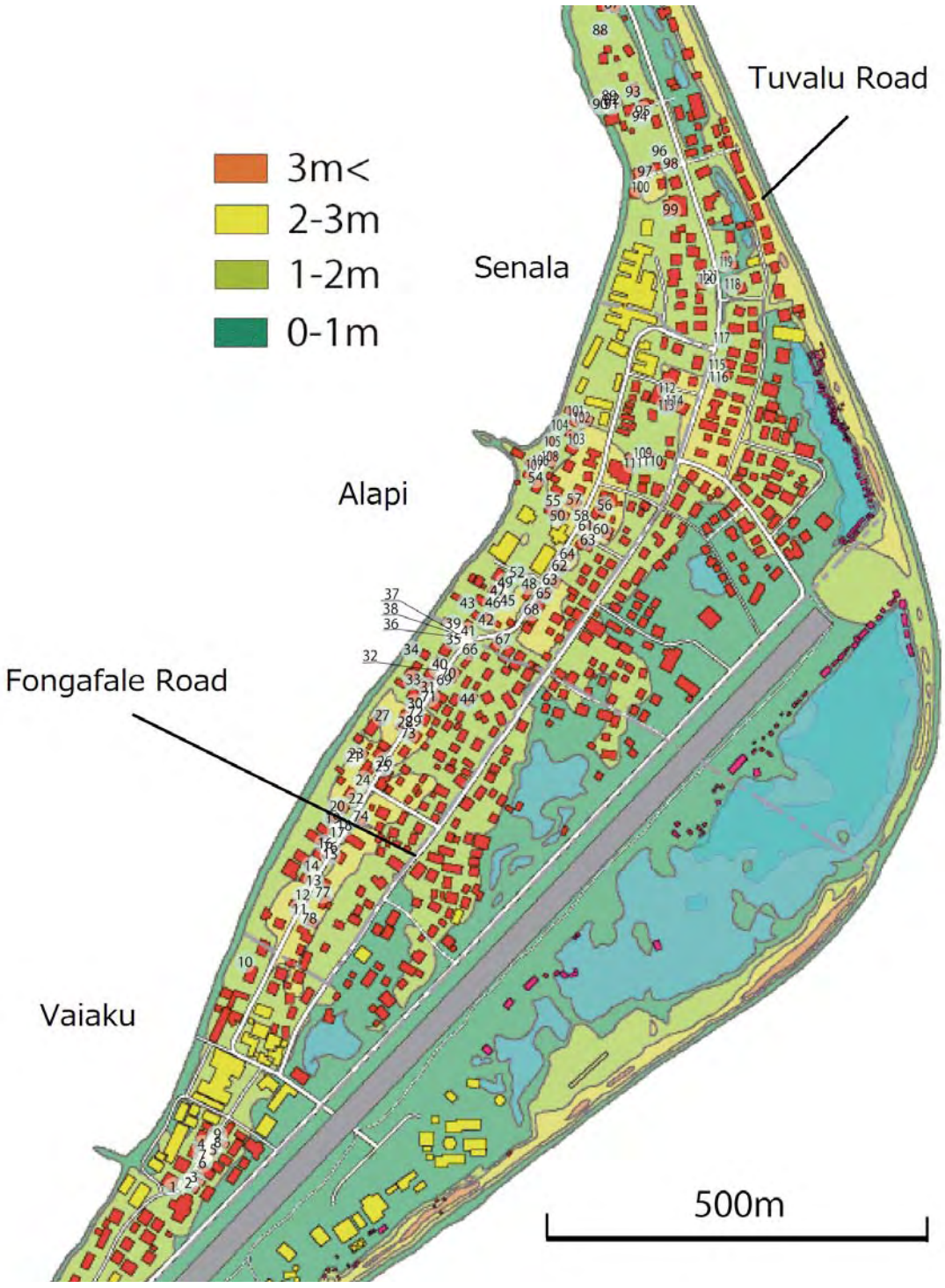


Figure 10.3 Locations of the Houses Surveyed in the Survey for Cost of Restoring Damages

[3] Based on Yamono et al., Atoll island vulnerability to flooding and inundation revealed by historical reconstruction: Fongafale Islet, Funafuti Atoll, Tuvalu. Global and Planetary Change 57 (2007)

The outline and the result of the Questionnaire Survey are summarized as follows.

10.2.2 The Outline of the Questionnaire Survey

The survey was conducted on June 9, 2010, in the manner that surveyors visited house by house in the area of the lagoon side of Senala, Alapi and Vaiaku, asked the content of the questionnaires to the residents and wrote down the answers on the questionnaires sheets, in parallel with acquiring the house positions on GPS, which have been sorted into four areas corresponding to four target areas, C, D-1, D-2 and D-3 areas. Number of answers acquired was 118, meanwhile, as the survey hours were in the daytime of a week day, there were 20% of the houses vacant although those houses had apparently residents living. Considering the above, the numbers of the houses living the residents are estimated at 8 in the C area, 71 in the D-1 area, 44 in the D-2 area and 18 in the D-3 area, totaling 141 in all the area surveyed. The Questionnaires are shown in Section 2 (Data Book) of PART VII in the Supporting report.

(1) Years of residence

Years of residence in their houses are, 20.4% for less than 5 years, 20.4% for 5-10years, and 61.9% for over 10 years, thus those who have been resided in their present house less than 10 years counts about 40%. Most of people have not experience of the impact and damages caused by Hurricane Babe in 1972.

Table 10.1 Rate of Years of Residence in the Surveyed Area

	C	D-1	D-2	D-3	Total Surveyed area
Not more than 5 years	42.9 %	18.6 %	3.8 %	38.5 %	20.4 %
5 to 10 years	14.3 %	16.3%	19.2%	30.8 %	17.7%
More than 10 years	42.9 %	65.1%	76.9 %	30.8 %	61.9%
Total	100 %	100 %	100 %	100 %	100 %

There are more households reside longer years at their present address than the number of household living not so long years, in the D-1 and D-3 areas. Especially in the D-2 area, 76.9 % of the household reside in their houses for more than 10 years, and there are only 3.8 % of the households living at their present address for not more than 5 years. Meanwhile, in the C and D-3 areas, the number of households reside for not more than 5 years constitutes around 40 %.

(2) House

For the main structure of the houses, a 57.5% of the houses is timber, 30.1% is brick, and 12.4% is reinforced concrete. In the D-3 area, timber house constitutes about 85 %. A 50% of the houses in the surveyed area is over 20 years after completion, however 34.9 % of the houses are more than 20 years after completion in the D-1 area. A 8% of houses is 15-20 years and a 17.9% of the houses is

10-15 years, that means three quarters of the houses have passed at least 10 years after completion.

Table 10.2 Structure of the Houses by Area

	C Area	D-1 Area	D-2 Area	D-3 Area	Surveyed area Total
Timber	86.0 %	50.0 %	54.0 %	80.0 %	58.0 %
Brick	14.0 %	32.0 %	37.0 %	13.0 %	30.0 %
Reinforced Concrete	0 %	18.0 %	9.0 %	7.0 %	12.0 %
Total	100 %	100 %	100 %	100 %	100 %

Table 10.3 House Ages after Completion

Ages after completion	C Area	D-1 area	D-2 area	D-3 area	Surveyed area Total
Less than 1 year	0 %	1.6 %	2.9 %	6.7 %	2.7 %
1 to 2 years	0 %	0 %	2.9 %	6.7 %	1.8 %
2 to 3 years	14.3 %	4.8 %	5.9 %	0 %	4.5 %
3 to 5 years	0 %	4.8 %	0 %	6.7 %	3.6 %
5 to 10 years	42.9 %	14.3 %	8.8 %	6.7 %	11.6 %
10 to 15 years	28.6 %	28.6 %	2.9 %	6.7 %	17.9 %
15 to 20 years	0 %	11.1 %	2.9 %	6.7 %	8.0 %
More than 20 years	14.2 %	34.9 %	73.5 %	60.0 %	50.0 %
Total	100 %	100 %	100 %	100 %	100 %

(3) Residents

The median of number of people living in a house is 7 persons, and the average is 7.2 persons, though over 20% of the houses are resided by more than 10 people. There are 18.8% of the houses in which someone suffering from long-term illness resides, and 15.3% of the houses in which someone aged 75 or more are living.

Table 10.4 Rate of Houses in Which Someone Suffering from Long-Term Illness and Someone Aged 75 or More Resides

	C area	D-1 area	D-2 area	D-3 area	Surveyed Area Total
Long-term illness	2.0 %	1.9 %	3.4 %	2.8 %	2.6 %
Aged 75 or more	4.0 %	2.1 %	1.5 %	1.9 %	2.0 %

Following figure shows the houses in which someone suffering from long-term illness and someone aged 75 or more resides.

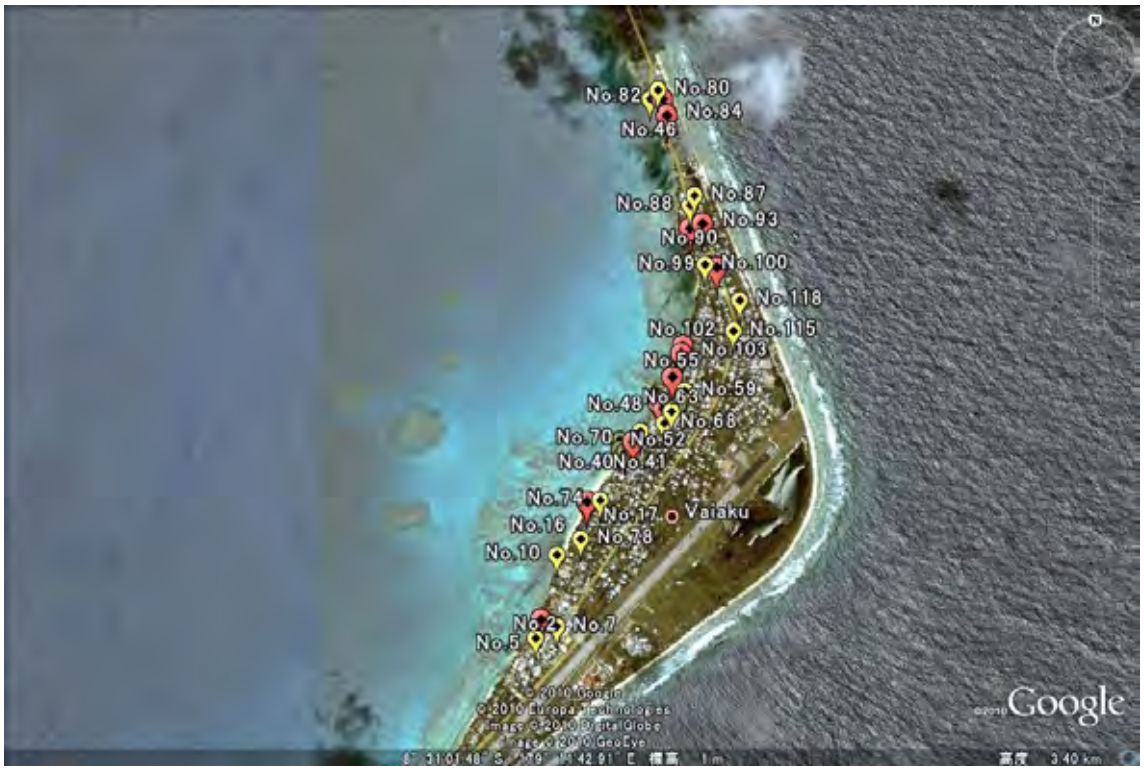


Figure 10.4 Houses in which Someone Suffering from Long-Term Illness and Someone Aged 75 or More Resides

(4) Furniture and Household goods

Possession rates of furniture and household goods in their houses of Chair (234 %), Table (126.8 %), Bed (115.7 %) are over 100 % and followed by Range (gas/kerosene/electric) (85.1 %), Electric fan (74 %), Radio (74 %), Refrigerator (70.6 %), Washing machine (68.9 %), TV (62.1 %), DVD/CD deck (63 %), Fixed telephone (50.2 %), Freezer (46 %), and Sewing machine (46 %). Following tables show the rate of possession in households by each area.

Table 10.5 Rate of Possession of Household Utensils

	Refrigerator	Range	Rice Cooker	Freezer	Electric range
C area	75.0 %	90.0 %	60.0 %	30.0 %	0 %
D-1 area	69.3 %	89.6 %	64.2 %	43.9 %	6.8 %
D-2 area	65.6 %	81.8 %	32.7 %	49.1 %	2.7 %
D-3 area	86.7 %	73.3 %	26.7 %	53.3 %	0 %
Surveyed area Total	70.6 %	85.1 %	49.4 %	46.0 %	4.3 %

	Washing Machine	E. Fan	Mixer	Sowing Machine	Toaster
C area	75.0 %	60.0 %	15.0 %	60.0 %	30.0 %
D-1 area	67.6 %	77.7 %	6.8 %	47.3 %	30.4 %
D-2 area	57.3 %	65.5 %	0 %	38.2 %	13.6 %
D-3 area	100 %	86.7 %	0 %	53.3 %	6.7 %
Surveyed area Total	68.9 %	74.0 %	4.3 %	46.0 %	22.1 %

	E. Jar	Bed	Table	Chair	Arm chair
C area	30.0 %	90.0 %	135.0 %	240.0 %	30.0 %
D-1 area	30.4 %	125.1 %	163.9 %	267.0 %	55.8 %
D-2 area	21.8 %	100.9 %	76.4 %	188.2 %	13.6 %
D-3 area	26.7 %	126.7 %	100.0 %	213.3 %	0 %
Surveyed area Total	27.2 %	115.7 %	126.8 %	234.0 %	34.0 %

	TV	Stereo	DVD/CD Deck	Radio	Fixed Telephone
C area	75.0 %	0 %	90.0 %	105.0 %	45.0 %
D-1 area	60.8 %	0 %	65.9 %	76.1 %	55.8 %
D-2 area	65.5 %	21.8 %	62.7 %	76.4 %	38.2 %
D-3 area	53.3 %	13.3 %	40.0 %	46.7 %	60.0 %
Surveyed area Total	62.1 %	8.5 %	63.0 %	74.0 %	50.2 %

(5) Means of Transportation

As for a means of transportation, possession rate of motorcycle is as high as 132.2 % in the surveyed area. A 70.3% of all houses possess it and 47% of these houses possess more than two. Possession rate of bicycle is 48.3 % of houses, that of car is 11.6 %, truck is 5.9 %, and van is 1.7 %.

Table 10.6 Rate of Possession for Transportation Means

	Bicycle	Motor Cycle	Car	Truck	Van
C area	28.6 %	200.0 %	14.3 %	0 %	0 %
D-1 area	35.6 %	144.1 %	11.9 %	5.1 %	1.7 %
D-2 area	56.8 %	108.1 %	13.5 %	2.7 %	2.7 %
D-3 area	86.7 %	113.3 %	6.7 %	20.0 %	0 %
Surveyed total area	48.3 %	132.2 %	11.9 %	5.9 %	1.7 %

(6) Business

A 38.6% of houses engages business in their premises. Business widely engaged in their

premises are Store (22.7% in all businesses), Motorcycle Repairs (11.4%), Trade (11.4%), followed by Rental business of motorcycles, cars and trucks (total 13.7%), and DVD Hire (4.6%). As most of these businesses are run in a small scale, businesses of which depreciable assets and stocks value less than AU$500 occupy 39.5%. Businesses of which business assets from AU$500 to AU$1,000 occupy 14%, 23.3% of the businesses has assets of between AU$1,000 to AU$5,000 and another 23.3% has assets of between AU$5,000 to AU$10,000. Following table shows rate of engaging business by area and the average value of assets for business.

Table 10.7 Rate of Engaging Business by Area and the Average Value of Assets for Business

Area	C area	D-1 area	D-2 area	D-3 area	Surveyed area Total
Rate of engaging business	25.0 %	39.4 %	29.5 %	55.6 %	37.6 %
Average value of Assets for Business	Au$ 5,656				

(7) Planting vegetables, crops and fruits

In a 32.5% of houses, people are planting and harvesting vegetables, root crops, and fruits in their premises. The rate of planting is the highest in the D-1 area, 39.1 %, and the lowest is that of the D-3 area, 23.0 %. Main crops are banana (60.5% of planting houses), taro (47.4%), cucumber (44.7%), tomato (36.8%), and Chinese cabbage (36.8%).

Table 10.8 Rate of Planting in the Premises by Area

	Rate of Planting in the premises
C area	28.6 %
D-1 area	39.1 %
D-2 area	30.7 %
D-3 area	23.0 %
Surveyed area Total	32.5 %

Table 10.9 Estimated Volume of Major Harvest in a Year by Area

	Banana	Taro	Cucumber	Tomato	Chinese Cabbage
C area	23	48	18	0	12
D-1 area	595	211	196	40	121
D-2 area	48	19	17	22	14
D-3area	54	11	7	2	2
Surveyed area Total	720	289	238	64	149

(Unit : kg)

10.3 Estimate of Direct Losses

10.3.1 Plan for Estimate of Direct Losses

Estimate of the direct losses has been made for the C, D-1 and D-3 areas, in which coastal protection measures against flooding will be implemented. For the D-2 area which is not the target area to be implemented with counter measures, the direct losses have not been counted. Number of houses in the target areas, which may be damaged by flooding due to overtopping waves, is 97.

Economic Survey Manual for Flood Control Project lists up following items susceptible to direct damage.

1. Houses	: Building for residence and for business
2. Household utensils	:Furniture, home appliances, clothes and car, etc.
3. Office depreciable and stock assets	:Machine tools, depreciable assets and stock assets of office equipment
4. Depreciable and stock assets of farmer's and fisher's household	:Production facilities of farm machines, fishing equipment and stock assets
5. Crops	:Crops in the field
6. Infrastructure	:Infrastructures (roads, bridges, and sewages), public utilities (electricity, city water, gas and telephone), farmland and facilities for agriculture such as water way

Rates in the following table will be applied for estimating damage of each assets due to flooding of sea water. The counter measures for the Project will be designed to protect against direct losses by the waves not bigger than the once for ten years return period. Thus damaged losses to be prevented will be those which by a flood of around 10 cm depth and overtopping waves due to the waves not bigger than the once for ten years return period during the high tide, which have been experienced three times a year.

Table 10.10 Loss Rate of Assets due to Flood Damage

Degree of flood hazard / Items		Flood below the floor level	Flood above the floor level				
			Less than 50cm	50-99cm	100-199	200-299	More than 300cm
House		0.045	0.151	0.229	0.480	1.000	1.000
Household utensils		0.021	0.189	0.489	0.889	1.000	1.000
Business	Depreciable assets	0.101	0.278	0.589	1.000	1.000	1.000
	Stock assets	0.056	0.166	0.401	1.000	1.000	1.000
Farmer's and fisher's household	Depreciable assets	0.000	0.187	0.308	0.416	1.000	1.000
	Stock assets	0.000	0.259	0.555	0.859	1.000	1.000

Source: Economic Survey Manual for Flood Control Project : damage rates of the Economic Survey Manual for Flood Control Project are multiplied by damage factor by sea water of the Guideline of Cost Benefit Analysis for Coastal Management, UK

10.3.2 Damages to the Houses

Following table shows the construction costs of the typical house by structure in Fongafale and the estimated service life.

Table 10.11 Construction Cost and Estimated Service Life of House

Main Structure	Construction Cost[4]	Estimated Service Life[5]
Timber	Au$ 40,364	22 years
Brick	Au$ 45,546	38 years
Reinforced Concrete	Au$ 60,728	47 years

Based on the **Table 10.2** Structure of the houses by area, **Table 10.3** House Ages after completion and **Table 10.11** Construction Cost and Estimated Service Life of House, the values of house assets by area are calculated as shown the below table.

Table 10.12 Values of House Assets by Area

	C area	D-1 area	D-3 area	Target areas total
Timber houses sub-total	155,435	538,710	188,112	882,257
Brick houses sub-total	37,829	656,195	64,355	758,378
R.C. houses sub-total	0	544,875	51,846	596,720
Total	193,264	1,739,780	304,312	2,237,355

(Unit : AU$)

[4] Construction area : approx. 67 m^2. Hearing from Funafuti Kaupule and PWD（August 2010）
[5] List of Service Life for House, Income Tax Law, Japan

Losses of the damaged houses by area, which are acquired by the total house assets of each area multiplied by the loss rate for the flood below the floor level, or 0.045, on the Table 9-37 Loss rate of assets due to flood damage are shown on the following table.

Table 10.13 Loss of House Assets by Area（at the First Year）

Area	Loss Value per flood	Annual Loss
C area	8,697	26,091
D-1 area	78,290	234,870
D-3 area	13,964	41,082
Loss of House assets Total	100,681	302,043

（unit：AU$）

Yearly change of the house assets by area for fifty years, which are estimated on the assumption that each house will re-build at the end of their service life, and Yearly change of the loss of house assets by area for fifty years are shown in Section 2 (Data Book) of PART VII in the Supporting report.

10.3.3 Loss of Household Utensils

Values of the household utensils by area, number of each kind house utensils multiplied by the unit price[6] of respective item, are shown below.

Table 10.14 Value of Household Utensils by Area

Area	C area	D-1 area	D-3 area	Total Value of Household
Value of Household Utensils	29,682	259,436	69,258	368,376

(unit：AU$)

Loss of the household utensils by area, the total value of the household utensils of each area multiplied by the loss rate of the household utensils on the Table 9-37 Loss rate of assets caused by flood damage, or 0.021, is shown below.

Table 10.15 Loss of Household Utensils（at the First Year）

Area	Loss of Household Utensils per flood	Annual Loss
C area	623	1,871
D-1 area	5,658	16,974
D-3 area	1,454	4,363
Total loss of Utensils	7,736	23,208

（unit：AU$）

[6] Average prices hearing from the shops in Fongafale. (June, 2010)

The yearly change of the value of the household utensils, on the assumption that the service life of them are six years and at the end of their service life each utensils will be bought a replacement, and the yearly change of the loss of the household utensils by area are shown in Section 2 (Data Book) of PART VII in the Supporting report.

10.3.4 Loss of Business Assets

Loss of business assets by area, which are calculated with Number of houses in each area, Table 9-34 Rate of Engaging Business by Area and the Average Value of Assets for Business and Table 9-37 Loss rate of assets caused by flood damage, are shown in the following table. Loss rate of the business assets are presumed same as that of the stock assets of 0.056, since considering the business scales in the area, the share of the depreciable assets seems very low.

Table 10.16 Loss of Business Assets

Area	Loss of Business Assets per flood	Annual Loss
C area	633	1,900
D-1 area	8,869	26,606
D-3 area	3,167	9,502
Total Loss	12,669	38,008

（unit：AU$）

10.3.5 Loss of Fisher's and Farmer's Assets

Fishers and farmers do not possess the depreciable assets except boats and outboard motors, and also they have hardly any stock assets. Loss of Fisher's and Farmer's assets are not counted up.

10.3.6 Loss of Crops

Rates in the following table is applied for estimating damage of crops, vegetables and fruits caused by flooding of sea water, in accordance with the Economic Survey Manual for Flood Control Project in Japan.

Table 10.17 Damage Rates of Crops by Depth of Flood Level

Item	Flood level												Debris		
Depth of flood	Less than 0.5m				0.5-0.99m				Over 1.0m				Depth of soil and sand piling up from the ground surface		
Duration of Flood (day)	1～2	3～4	5～6	More than 7	1～2	3～4	5～6	More than 7	1～2	3～4	5～6	More than 7	Less than 0.5m	0.5～0.99m	More than 1.0m
Average crops rate	27	42	54	67	35	48	67	74	51	67	81	91	68	81	100

(unit: %)

Source：Economic Survey Manual for Flood Control Project

Based on the volume of harvest in the area, prices of crops, vegetable and fruits in Fongafale[7] and **Table 10.17** Damage rates of crops by depth of flood level, the following loss of crops are worked out, where the depth of flood assumed less than 0.5m, the duration of flood presumed three days and the fruits on the tree are not counted.

Table 10.18 Loss of Crops

Area	Loss of crops per flood	Annual Loss
C area	156	469
D-1 area	957	2,870
D-3 area	58	174
Total Loss of Crops	1,171	3,514

（unit：AU$）

10.3.7 Loss of Infrastructure

The damage value for infrastructures is estimated in the manner that estimated value of private assets damage (total amount of all items) is multiplied by standard rates which are calculated in dividing the damaged value of infrastructures by the damaged value of private assets. Rates applied in Japan in accordance with the Economic Survey Manual for Flood Control Project are shown in the following table.

Table 10.19 Rates of Damages of Infrastructures to Damages of Private Assets

Facilities	Roads	Bridges	Sewages	City facilities	Utilities	Farmland	Facilities for agriculture	Subtotal
Rate of damages	61.6	5.7	0.4	0.2	8.6	29.1	65.8	169.4

（unit：%）

Source: Economic Survey Manual for Flood Control Project

There are roads and utilities in the target areas, but none of bridges, sewages, city facilities, farmland nor facilities for agriculture as the infrastructure. Losses of infrastructure are counted the rates of damages of the roads and utilities to damages of private assets, 61.6% and 8.6% respectively. Following table shows the loss of infrastructure by area.

Table 10.20 Loss of Infrastructure (at the First Year)

Area	Loss of Road	Loss of Utilities	Total Loss of Infrastructure
C area	18,683	2,608	21,272
D-1 area	173,294	24,194	197,488
D-3 area	33,955	4,740	38,695
Total Loss	225,932	31,542	257,475

（unit：Au$）

[7] Hearing from stores in Fongafale (June 2010)

Yearly change of the Loss of Infrastructure is show in Section 2 (Data Book) of PART VII in the Supporting report.

10.4 Estimate of Indirect Losses

Economic Survey Manual for Flood Control Project lists up following items susceptible to indirect damage.

1) Losses of suspension of business
2) Costs of emergency measures in household
3) Costs of emergency measures in business

10.4.1 Losses of Suspension of Business

According to Economic Survey Manual for Flood Control Project, in order to calculate value of losses of suspension of business of each industry, employees of each industry are multiplied by days of suspension of business and by value added per person per day. Then the sum of all industries is calculated. Because of difficulties in calculating value added per person per day in Tuvalu, this item is excluded.

10.4.2 Cost of Emergency Measures in Household

According to Economic Survey Manual for Flood Control Project, in order to calculate the values of labor for cleaning home and add the value of alternative activity in household, value of labor for cleaning home shall be multiplied by number of households.

Number of households x Value of labor for cleaning x Number of cleaning days

Assuming that people younger than 15 years old and older than 70 years old do not engage in cleaning the house after flooding, and that number of days necessary for cleaning up houses are same as the number of days necessary for retrieving gravels from the roads, or 6 days, the cost of emergency measures in household are shown below.

Table 10.21 Cost of Emergency Measures in Household

Area	Cost of Emergency Measures
C area	8 houses×4.5 people×$2×7 hrs×6 days＝$ 3,024
D-1 area	71 houses×4.5 people×$2×7 hrs×6 days＝$ 26,838
D-3 area	18 houses×4.5 people×$2×7 hrs×6 days＝$ 6,804
Total Cost of Emergency Measures in Household	$ 36,666

（unit : Au$）

10.4.3 Cost of Emergency Measures in Business

According to Economic Survey Manual for Flood Control Project, in order to calculate an increase of expenses for alternative activity, a number of offices is multiplied by expenditures for alternative activity corresponding to flood depth. Because of difficulties in calculating expenditures for alternative activity corresponding to flood depth in Tuvalu, this item is excluded.

10.5 Estimate of Human Related Loss

10.5.1 Principle for Estimate of Human Related Loss

The human related losses, such as loss of life, injuries and diseases during and after the flood due to the waves that of smaller than once in ten years return period are estimated. The variables used in estimating the value of the human related losses are;

Flood Hazard (Depth of flood water, Velocity of flood water and Debris factor)
Area Vulnerability (Flood warning, Speed of onset of a flood and Nature of area)
People Vulnerability (Residence rate of aged 75 years or over and Residence rate of suffering from long term illness)

Applying respective variables in each area, loss of life, injuries and diseases are estimated[8] and valued.

10.5.2 Flood Hazard (HR)

The Flood Hazard rating is calculated using the following equation:

$$HR=d \times(v+0.5) +DF$$

Where, HR = (flood) hazard rating;
d= depth of flooding (m);
v= velocity of floodwaters (m/sec); and
DF= debris factor calculated using Table 9-49

Table 10.22 Guidance on Debris Factors for Different Flood Depths, Velocities and Dominant Land Uses

Depths	Pasture/Arable	Woodland	Urban
0 － 0.25m	0	0	0
0.25 － 0.75m	0	0.5	1
d>0.75m and/or v>2	0.5	1	1

Source：DEFRA, Flood Risks to People, Guidance Document

[8] References are made to 'Flood Risks to People, Phase 2, Guidance Document', 'The Flood Risks to People Methodology', DEFRA(Dep. for Environment Food and Rural Affairs, UK), March 2006 and 'Revision to Economic Appraisal on :Appraisal of Human Related Intangible Impacts of Flooding', DEFRA Flood Management Division, July 2004

Critical values of Flood Hazard are shown in **Table 10.23**.

Table 10.23 Hazard to People as Function of Velocity and Depth (HR)

d x (v+0.5)	Degree of Flood Hazard	Description
<0.75	Low	Caution *"Flood zone with shallow flowing water or deep standing water"*
0.75-1.25	Moderate	Dangerous for some (i.e. children) *"Danger: Flood zone with deep or fast flowing water"*
1.25-2.5	Significant	Dangerous for most people *"Danger: flood zone with deep fast flowing water"*
>2.5	Extreme	Dangerous for all *"Extreme danger: flood zone with deep fast flowing water"*

Source : DEFRA op. cit.

Speeds of onset by the flood in the project areas are calculated using the following equation:

$v = \sqrt{(g \times h)}$

Where v: Speed of onset
g = 9.8m/s/s
h: Depth of overtopping (m)

As the average of the depth of overtopping is estimated at 20cm respectively, the average of the speed of onset is calculated at 1.4m/s.
As the velocity of floodwaters and the depth of flooding in the D-1 and the D-3 areas are estimated at 1.4m/s and 10cm respectively, the Flood Hazards of the both areas are calculated as follows.

$HR(C) = d_1 \times (v_1+0.5) + DF_1 = 0.1 \times (1.4+0.5) + 0 = 0.19$
$HR(D\text{-}1) = d_1 \times (v_1+0.5) + DF_1 = 0.1 \times (1.4+0.5) + 0 = 0.19$
$HR(D\text{-}3) = d_3 \times (v_3+0.5) + DF_3 = 0.1 \times (1.4+0.5) + 0 = 0.19$

Thus the degrees of the Flood Hazards of the all target areas are found as "Low".

10.5.3 Area Vulnerability (AV)

The Area Vulnerability is a sum of scores for 'speed of onset', 'nature of area' and 'flood warning'.

Table 10.24 Area Vulnerability (AV)

Parameter	1: Low risk area	2 : Medium risk area	3 : High risk area
Speed of onset	Onset of flooding is very gradual (many hours)	Onset of flooding is gradual (an hour or so)	Rapid flooding
Nature of area	Multi-storey apartments	Typical residential area (2-storey homes); commercial and industrial properties	Bungalows, mobile homes, busy roads, parks, single storey schools, campsites, etc.
Flood warning	Score for flood warning = 3 - (P1 x (P2 + P3)) Where P1 = % of Warning Coverage Target Met P2 = % of Warning Time Target Met P3 = % of Effective Action Target Met		
Area Vulnerability (AV) = sum of scores for 'speed of onset', 'nature of area' and 'flood warning'			

Source : DEFRA op. cit.

The scores for 'speed of onset', 'nature of area' and 'flood warning' and the Area Vulnerability of the areas are shown below.

Table 10.25 Area Vulnerability (AV)

	Speed of onset	Nature of area	Flood warning	Area Vulnerability
C area	2	3	3	8
D-1 area	2	3	3	8
D-3 area	2	3	3	8

10.5.4 People Vulnerability (PV)

(1) Number of injuries

Estimates of the numbers of injuries can be made using the formulae[9]:

$$N(I) = 2 \times N \times X \times Y$$

Where,

N(I) : Numbers of injuries

N : Number of people in the area

X : Rate of People at risk X=（ HR×AV）%

Y : People Vulnerability (% of very old + % of disabled or infirm)

Estimated number of injuries by area calculated with the number of people in the area, Flood Hazard (HR), Area Vulnerability, People Vulnerability are shown below.

[9] The Flood Risks to People Methodology, DEFRA, March 2006

Table 10.26 Estimated Number of Injuries

Area	Number of people in the area	Rate of People at risk			People Vulnerability		Estimated number of injuries
		HR	AV	X (%)	% of very old	% of disabled or infirm	
C area	58	0.19	8	1.521	4.0 %	1.9 %	0.1024 ≒ 0
D-1 area	511	0.19	8	1.521	2.1 %	1.9 %	0.6214 ≒ 1
D-3 area	130	0.19	8	1.521	1.9 %	2.8 %	0.1824 ≒ 0

In the D-1 area, one injury per year by the flood which can be protected by the Project is estimated. There is no injury estimated in the C and D-3 area. Provided that the injury is fracture of a foot and will be substantially recovered, the loss of injury costs Au$4,412[10].

Table 10.27 Loss of Injury

	Loss of Injury per flood	Annual Loss
C area	0	0
D-1 area	4,412	13,236
D-3 area	0	0
Total Loss of Injury	4,412	13,236

(unit: Au$)

(2) Number of fatalities

The number of fatalities is calculated using the following equation[11].

$$N(F) = f(N(Z), HR, AV, PV) = N(ZE) \times 2Y \times 2HR$$

Where:

N(F): Possible number of fatalities

N(Z): Population within the zone at risk of flooding

HR : Flood Hazard

AV: Area Vulnerability

PV: People Vulnerability (Y); Y = % of over 75 years old+% of disabled or infirm

N(ZE): Number of people exposed to risk $N(ZE) = N(Z) \times X$, $X = (HR \times AV)\%$

Population within the area, Flood Hazard (HR), Area Vulnerability (AV), People Vulnerability (PV), and the possible number of fatalities by area are shown below.

[10] Based on'The Criminal Injuries Compensation Scheme (2008)', Criminal Injuries Compensation Authority, UK , in which Values in GBP is converted into AU$ with the exchange rate as of August 2010.

[11] Supplementary Note to Operating Authorities, Assessing and Valuing the Risk to Life from Flooding for Use in Appraisal of Risk Management Measures, DEFRA, May 2008

Table 10.28 Possible Number of Fatalities

Area	Population in the area N(Z)	HR	AV	X =HR × AV (%)	N(ZE)	PV (Y)	Possible number of fatalities N(ZE) × 2Y × 2HR
C area	58	0.19	8	1.52	0.88	6.0 %	0.0396 ≒ 0
D-1 area	511	0.19	8	1.52	7.767	4.0 %	0.2361 ≒ 0
D-3 area	130	0.19	8	1.52	1.976	4.7 %	0.0693 ≒ 0

There is no possible fatalities during flooding due to waves which can be defend by the Project, in all the target areas.

(3) Human related intangible impacts of flooding

Intangible impacts of flooding such as increased stress, health effects and loss of memorabilia can be as important as the direct damage to householders' home and their assets. On top of that, as there is no refuge in the atoll, children and the weak fear overtopping of the waves of 10 years return period which reach as high as C.D.L. 5 m, flooding and increasing the water depth time by time around their own house, which are very much stressful for them and tend to suffer them the post traumatic stress disorder. The results of the DEFRA survey confirmed that flooding caused physical effects in the short time and psychological effects in the short and long terms. Psychological effects included memory of the stress from flooding and damage, and the stress of recovering after an event. DEFRA suggests the following matrix[12] of the Intangible benefits associated with flood defense improvements can be used, in order to determine the difference in annual damages before and after an improvement.

[12] Supplementary Note to Operating Authorities, Revision to Economic Appraisal on : Appraisal of Human Related Intangible Impacts of Flooding, DEFRA, July 2004

Table 10.29 Intangible Benefits Associated with Flood Defense Improvements

Standard of Protection Before – AFP (RP in Years)		Standard of Protection After – AFP (RP in years)							
		0.007 (150)	**0.008 (125)**	**0.010 (100)**	**0.013 (75)**	**0.020 (50)**	**0.033 (30)**	**0.05 (20)**	**0.1 (10)**
1	**(1)**	385	379	353	270	129	44	21	9
0.1	**(10)**	378	371	344	261	120	37	14	0
0.05	**(20)**	364	366	332	249	106	23	0	
0.033	**(30)**	341	334	309	226	83	0		
0.020	**(50)**	256	251	224	141	0			
0.013	**(75)**	115	109	83	0				
0.010	**(100)**	32	26	0					
0.008	**(125**	7	0						

AFP – Annual Flood Probability

RP – Return Period

Annual Benefits=Damages(before)–(Damages (after)

(unit: Au$)

Source: DEFRA op. cit.

Note: Values in GBP have been exchanged into AU$ at the average exchange rate as of August, 2010

The target wave of the Project is of 10 years return period, judging from the above matrix the annual benefit is Au$ 9 per household. The human related intangible loss by area are shown below.

Table 10.30 Human Related Intangible Loss

	Human Related Intangible Loss
C area	72
D-1 area	639
D-3 area	162
Total Human Related Intangible Loss	873

(unit: Au$)

10.6 Benefits to be Created by Implementation of the Project Other than Damages to be Avoided

10.6.1 Benefit of Land to be Created

The Government is the largest leaseholder of lands in Funafuti. The rent of the Government in 2010 is AU$3,000/acre/year, which may be assumed to be benefit of land increased. As a rent is assumed to be a yield of land, though it varies with locality and by individual, in general the expected yields of land in Japan are considered between 1.5% and 2.0% per annual. An international acre is 4,046.856 m². The land area to be reclaimed under the Project will be 14,025 ㎡ in the D-1 area and 6,194 ㎡ in the D-3 area, in total 20,219 ㎡. Benefits of the land increased by area are shown below.

Table 10.31 Benefits of Land Reclaimed

Area	Benefits of Land Reclaimed
C area	0
D-1 area	10,397
D-3 area	4,592
Total Benefits of Land Reclaimed	14,989

(unit: Au$)

10.6.2 Benefit of Good Use of the Coastal Area

The lands to be reclaimed under the Project are in the coastal area of the lagoon side of the centre of the Fongafale Island, and the vacant lots of 10m to 15m wide will be created. The vacant lots can be used for sport and recreation activities for the residents. When sand deposited on the gravel beach, it will be a beautiful atoll sand beach for attracting tourists from overseas. However, these benefits cannot be converted into monetary value due to lack of basic data at this stage.

10.6.3 Benefit of Coastal Environment Preservation

With the reclamation of gravel beach, an ancient landscape of the atoll beach will be back and the scenery of the landscape will be improved, which will ameliorate the environment of the life of residents, though these benefits cannot be converted into monetary value due to lack of basic data at this stage.

10.6.4 Benefit of Preventing from Erosion

In the coastal area of the lagoon side of the Fongafale Island, parts of the land had eroded by wave. With the construction of gravel beach in front of the existing beach, the existing lands will be defended and it will prevent the coastal erosion in diminishing wave energy on the gravel beach, though these benefits cannot be converted into monetary value due to lack of the detailed data.

10.7 Financial Analysis

10.7.1 Net Present Value

Amount of the benefits at the first year are shown below.

Table 10.32 Benefits（First Year）

	C area	D-1 area	D-3 area	Total
Loss of house assets	26,091	234,870	41,082	362,043
Loss of Household Utensils	1,870	16,974	4,363	23,208
Loss of crops	469	2,870	174	3,514
Loss of business assets	1,900	26,606	9,502	38,008
Loss of infrastructure	21,292	197,488	38,695	278,766
Cost of emergency measures in household	3,024	26,838	6,804	39,690
Loss of injuries	0	13,236	0	13,236
Loss of Human related intangible loss	72	639	162	873
Amount of Loss to be decreased	**54,718**	**519,522**	**100,782**	**699,338**
Benefit of Land increased	0	10,397	4,592	14,989
Grand Total of Benefits	**54,718**	**529,919**	**105,374**	**714,327**

（Unit: Au$）

There is disagreement on which rate should be used for the social discount rate. Some studies in the USA recommended using a 3 percent social discount rate with additional sensitivity analysis at rates between 0 percent and 7 percent. The Federal Emergency Agency mandates that a discount rate of 7 percent be used for all cost-benefit analyses of Disaster Risk Management (DRM) projects. It is recommended that the chosen discount rate for cost-benefit analyses of DRM measures in Pacific Island Countries be used on the rate chosen for previous similar studies elsewhere or using a domestic benchmark, such as the real interest rate in the country concerned[13]. In "A preliminary economic analysis of extracting aggregate from the Funafuti Lagoon[14]" by SOPAC 10 percent, 7 percent and 3 percent of the social discount rates are used. The interest rate for saving accounts of the Tuvalu National Bank as of September, 2010, is at 1.5 percent. In this analysis, we use 1.5 percent as the social discount rate, and the rates of 10 percent, 7 percent and 3 percent, are used in the sensibility analysis.

Net Present Value is determined by deducting a present value of the cost from a present value of the benefits. Where the value is a positive number, it means that the present value of the benefits is more than the present value of the cost and that the project is feasible. Net Present Value (NPV) is calculating using the following equation.

Net Present Value (NPV)＝ Present value of total benefits－Present value of total costs

The annual benefits, costs and the cash flows are shown in Section 2 (Data Book) of PART VII

[13] Tool kit for Assessing Costs and Benefits of Disaster Risk Management, USP Solution, USP & SOPAC, April 2005

[14] A preliminary economic analysis of extracting aggregate from the Funafuti Lagoon, SOPAC Project Report 137, SOPAC, March 2009

in the Supporting report. NPVs at 1.5% of the alternative plans for the Project are shown as follows.

Table 10.33 Net Present Value

	NPV at 1.5 %
Plan-1	17,820,194
Plan-2	15,032,475
Plan-3	14,109,739
Plan-4	8,540,302

(unit: Au$)

The largest NPV is that of Plan-1 and the smallest is of Plan-4.

10.7.2 Cost Benefit Ratio (CBR)

The Cost Benefit Ratio is determined by the present total benefit divided by the present total cost. It means a multiple of the benefits to the costs. If this value is more than 100 %, the Project examined has feasibility. Cost Benefit Ratios (at 1.5 %) of the alternative plans for the Project are shown as follows.

Table 10.34 Cost Benefit Ratio

	CBR at 1.5 %
Plan-1	348 %
Plan-2	226 %
Plan-3	210 %
Plan-4	146 %

The largest CBR is that of Plan-1 and the smallest is of Plan-4.

10.7.3 Financial Internal Rate of Return

Internal Rate of Return is the discount rate which make equal the value of the present investment cost to the cash flow of NPV expected for the future. Financial Internal Rate of Returns (FIRR) of the alternative plans for the Project are shown as follows.

Table 10.35 Financial Internal Rate of Return

	FIRR
Plan-1	9.60 %
Plan-2	5.93 %
Plan-3	5.42 %
Plan-4	3.25 %

The largest FIRR is that of Plan-1 and the smallest is of Plan-4.

10.7.4 Sensibility Analysis

(1) Case studies for differences of the discount rates

NPVs of respective alternative plan in the cases of 3%, 7% and 10% of the discount rates are shown in the following table.

Table 10.36 Sensibility Analysis- NPV (Discount Rates)

	Discount rate 3%	Discount rate 7%	Discount rate 10%
Plan-1	11,060,998	2,470,677	－ 279,962
Plan-2	7,739,486	－1,531,760	－ 4,501,122
Plan-3	6,816,750	－2,454,496	－5,423,858
Plan-4	1,247,315	－8,023,933	－10,993,294

CBRs of respective alternative plan in the cases of 3%, 7% and 10% of the discount rates are shown in the following table.

Table 10.37 Sensibility Analysis- CBR (Discount Rates)

	Discount rate 3%	Discount rate 7%	Discount rate 10%
Plan-1	254 %	134 %	96 %
Plan-2	165 %	87 %	62 %
Plan-3	153 %	81 %	58 %
Plan-4	107 %	56 %	40 %

For the Plan-1, in the case of the discount rates at 3 % and 7 %, the benefits will be well over the costs, and in the cases of at 10%, the benefits will be below the costs. However, for the Plan-2, Plan-3 and Plan-4, only in the case of the discount rates at 3 %, the benefits will be over the costs, and in the cases of at 7 % and 10%, the benefits will be below the costs.

(2) Case study for import of materials for gravel beach nourishment and filling up the borrow pits

In the construction plan, gravel necessary for beach nourishment is assumed to be procured from outer islands in the Funafuti Atoll and the safety zone along the runway in Funafuti. Should these materials be unable to be procured locally due to environmental impacts or aviation safety, those materials should be imported. Provided all gravel would be imported from Fiji, the largest NPV at 1.5 % would be Au$ 14,751,454 for the Plan-3, and the smallest NPV would be Au$ 8,964,418 for the Plan-4. As for CBR at 1.5 %, the largest CBR would be 221 % for the Plan-3, and the smallest CBR would be 150 % for the Plan-4. In these cases FIRR are estimated at 4.85 % for the Plan-1, 3.91 % for the Plan-2, 5.83 % for the Plan-3 and 3.47 % for the Plan-4. The following table shows NPVs, CBRs and FIRR s of the respective plan in case gravel be imported.

Table 10.38 Sensibility Analysis (In Case Gravel be Imported)

	Plan-1	Plan-2	Plan-3	Plan-4
NPV (1.5 %)	Au$ 11,599,283	Au$ 10,180,407	Au$ 14,751,454	Au$ 8,964,418
CBR(1.5 %)	186 %	161 %	221 %	150 %
FIRR	4.85 %	3.91 %	5.83 %	3.74 %

In comparison with the case of all material be procured locally, for the Plan-1 and the Plan-2 the cases in which all material be imported would be less financially viable, though for the Plan-3 and the Plan-4 the latter cases would be more financially feasible. However, as the imported aggregate is obliged to be fumigated, it is necessary to have an EIA for the case of dumping it in the lagoon on a massive scale. Furthermore, it should be decided by general consensus over whether it is appropriate to import the aggregate although it could be procured locally.

(3) In case borrow pits were not filled up

In case borrow pits were not to be filled up, the construction cost would be Au$ 7,427,796[15], NPV would be Au$ 17,583,178 at 1.5 %, and CBR would be 339 %, of which FIRR is estimated at 9.279 %.

10.8 Economic Analysis

10.8.1 Standard Conversion Factor (SCF)

The economy of developing countries might lack an adequate market mechanism, or have a distorted one for various reasons, which make the system and information for fair allocation of resources non-existent, which might have been existing when the market were functioning. For this reason, actual market prices are deemed distorted and market prices should be adjusted in the non-distorted Shadow Prices in the economic analysis.

Standard Conversion Factor is calculated for conversion of the domestic market prices into the Shadow Prices.

ADB propose the following simplified formula[16] to estimate the SCF.

$$SCF = \frac{\text{Imports (cif)} + \text{Exports (fob)}}{(\text{Imports} + \text{Imports taxes}) + (\text{Exports} - \text{Exports taxes})}$$

Where, cif = Cost, Insurance and Freight

fob = Free on Board

SCF is estimated at 0.889 as follows.

[15] Based on the average exchange rates from April through October, 2010.

[16] Shadow Exchange Rates for Project Economic Analysis: Toward Improving Practice at the Asian Development Bank, ERD Technical Note No.11, ADB, February 2004

Table 10.39 Standard Conversion Factor (SCF)

	2002	2003	Average
Imports (cif)	20.4	24.0	
Exports(fob)	0.4	0.4	
Imports taxes	2.9	2.7	
Export taxes	0	0	
SCF	**0.8776**	**0.9003**	**0.889**

(Unit: million Au$)

Source: 2006 Tuvalu Economic Report, ADB

10.8.2 Transfer Payment

(1) Import duty

Since the Transfer Payment such as import duties and sales taxes, which do not increase or decrease the availability of real resources to the rest of the economy, however, will affect the distribution of financial costs and benefits to the government, are not economic costs, it should be excluded from the economic analysis. Some rates of the current import duties are given in the following table.

Table 10.40 Tariff of Import Duties

Item	Duty
Gravel	None
Petrol	8%
Diesel	4%
Steel	None
Construction machinery	None
Crane	19%
Vessel	None

Source：Tuvalu Customs Department

(2) Sales Tax

The current rate of sales tax is 5%[17] except for some of the basic daily necessities.

(3) Income tax for individual

The income tax is 30% for amount payable to a resident and 40%[18] for amount paid in respect of work performed in Tuvalu by the non resident.

(4) Income tax for company

The rate of income tax for resident company is 30%, and the rate of income tax for non resident

[17] Tuvalu Sales Tax Act, Schedule

[18] Tuvalu Income Tax Act, Schedule 5

company is 40%[19].

(5) Income tax on value of turnover for supply of fuel by non resident

For supply of petroleum and allied products to or within Tuvalu by non resident or by entity under the control of a non resident, 10% of the value of turnover is imposed as the income tax[20]. As the BP is the only importer of petroleum and allied products, this tax is imposed on all fuel products.

(6) Shadow Wage Rate

According to the statistics of the Government of Tuvalu, the unemployment rate in Funafuti is 8.9% (6.6% for Male, and 12.0% for Female), though, the real unemployment rate deems higher than the official information. A report[21] indicates that the unemployment rate in Funafuti is 49.6%. According to the result of the National Census (2002)[22], 37.34% out of the workforce of the male residents in Funafuti have no work. Therefore, the shadow value for labor is assumed at 75% the local unskilled wage rate[23]. The following table shows population not engaging work in Funafuti.

Table 10.41 Population Not Engaging Work in Funafuti

Funafuti	Male	Female	Total
Resident Tuvaluan	1,994	1,968	3,962
Population over 15 years old	1,269	1,287	2,556
(in which Number of attending secondary school)	38	47	85
Workforce Population	1,231	1,240	2,471
Population engaging in work	771	494	1,265
Employee	731	480	1,211
Employer	17	5	22
Self-employed	23	9	32
Ratio of working population	62.63%	39.84%	51.94%
Ratio of not working population	37.34%	60.16%	48.81%

Source：Tuvalu 2002 Population and Housing Census, Secretariat of the Pacific Community, 2005

[19] Tuvalu Income Tax Act, Schedule 6
[20] Tuvalu Income Tax Act, Schedule 4
[21] A preliminary economic analysis of extracting aggregate from the Funafuti Lagoon, March 2009, SOPAC Project Report 137
[22] Tuvalu 2002, Population and Housing census, Secretary of ther Pacific Community, 2005
[23] Toolkit for Assessing Costs and Benefits of Disaster Risk Management, USP Solutions, USP & SOPAC, April 2005

10.8.3 Result of the Economic Analyses

Based on the above mentioned conditions and assumptions, the economic analyses are examined. Summary of the economic analyses are shown in the following table.

Table 10.42 Summary of Economic Analyses (In Case Gravel be Procured Locally)

	Plan-1	Plan-2	Plan-3	Plan-4
NPV (1.5 %)	Au$ 19,034,353	Au$ 16,896,621	Au$ 16,246,361	Au$ 11,390,156
CBR(1.5 %)	419 %	267 %	251 %	173 %
EIRR	11.60 %	7.25 %	6.77 %	4.28 %

The best EIRR is 11.6 % for the Plan-1. EIRRs for the Plan-2 and Plan-3 are over 6 % and these plans deem feasible, however EIRR for the Plan-4 is below 5 %, which seems rather low for an infrastructure construction project in the developing country.

NPV's in the cases of the discount rates at 3 %, 7 % and 10 % are shown in the following table.

Table 10.43 NPV（Sensibility Analysis-Discount Rate）

Discount rate	3%	7%	10%
Plan 1	Au$ 12,274,858	Au$ 3,683,898	Au$ 932,719
Plan 2	Au$ 9,603,362	Au$ 331,448	－Au$ 2,638,374
Plan 3	Au$ 8,952,103	－Au$ 319,812	－Au$ 3,291,698
Plan 4	Au$ 4,096,898	－Au$ 5,175,017	－Au$ 8,144,838

CBR's in the cases of the discount rates at 3 %, 7 % and 10 % are shown in the following table.

Table 10.44 CBR（Sensibility Analysis-Discount Rate）

Discount rate	3%	7%	10%
Plan 1	305 %	162 %	116 %
Plan 2	195 %	103 %	74 %
Plan 3	183 %	97 %	69 %
Plan 4	126 %	67 %	48 %

Summary of the economic analyses in the case of importation of gravel are shown in the following table.

Table 10.45 Summary of Economic Analyses (In Case Gravel be Imported)

	Plan-1	Plan-2	Plan-3	Plan-4
NPV (1.5 %)	Au$ 18,009,842	Au$ 17,0869,842	Au$ 26,928,918	Au$ 26,928,918
CBR(1.5 %)	357 %	273 %	259 %	163 %
EIRR	9.86 %	7.41 %	6.99 %	3.95 %

In the cases gravel be imported, the best EIRR is 9.86 % for the Plan-1, though it is lower than the EIRR in the case gravel be procured locally.

For the Plan-2 and Plan-3, EIRRs in case of importation of gravel are better than those of local procurement. However, it is necessary to have an EIA for dumping fumigated gravel in the lagoon on a massive scale, and a general consensus over whether it is appropriate to import the aggregate although it could be procured locally.

For the Plan-4, as EIRR in the case of importation of gravel is lower than that of local procurement, it is found not feasible.

CHAPTER 11 ENVIRONMENTAL AND SOCIAL CONSIDERATION

11.1 Tuvaluan Environmental Policies and Laws

11.1.1 Organization for Environmental Impact Assessment

Environmental Impact Assessment becomes mandatory if "Environment Protection (Environmental Impact Assessment) Regulations 2007" (The EIA Guideline) comes in effect; however, it is not yet singed by the Minister for Natural Resources and Environment as of February 2010. The EIA Guideline is pursuant of sections 18 and 39 of the Environment Protection Act 2007, which gives the EIA guideline the binding power of the Law.

Table 11.1 Responsible Organizations for Review of EIA

Ministry of Natural Resources & Environment (MONRE)	Department of Agriculture
	Department of Fisheries Department of Lands & Survey
	Department of Environment*

* Department of Environment will have mandate to supervise EIA process under Minister of MONRE

Environmental Assessment Task Force (EATF) will assist Department of Environment for technical review of the reports in sectoral issues, according to the EIA Guideline. EATF is consisted of following seven (7) members.

- the Permanent Secretary of the Ministry, who shall be Chairperson;
- the Director of Environment (or a representative from the Department)
- the Attorney General (or a representative from the Office of the Attorney General);
- the Director of Health (or a representative from the Department of Health);
- the Director of Planning (or a representative from the Department of Planning),
- the Director of Rural Development (or a representative from the Department of Rural Development), and
- one member appointed by the Director of Environment from the National Environment Council.

11.1.2 Environmental Policies and Laws

Tuvaluan environmental policies and laws can be divided in to respective fields below. Corresponding laws to the project plan shall be sited as the outline of the plan develops, for persuading them.

(1) National Plans for Environmental Concern

- ・Tuvalu's National Adaptation Programme of Action 2007 (NAPA)
- ・Tuvalu National Environmental Management Strategy (NEMS)
- ・Biodiversity Conservation in Tuvalu

・The National Biodiversity Strategy and Action Plan Project (NBSAP)

(2) Legal Framework Supporting Environmental and Social Consideration

[General/EIA]
- Environment Protection Act 2007
- Environment Protection (Environmental Impact Assessment) Regulations 2007

[Coastal and Land]
- Native Lands Ordinance [Cap 22]
- Native Lands (Amendment) Act 2005
- Neglected Lands Ordinance [Cap 23]
- Crown Acquisition of Lands Ordinance [Cap 24]
- Foreshore and Land Reclamation Ordinance [Cap 26]
- Tuvalu Lands Code (L.N. 27/62)

[Marine and Fishery]
- Fisheries (Amendment) Act 1990
- Fisheries (Amendment) Act 1991
- Fisheries Ordinance [Cap 45]
- Marine Pollution Act 1991
- Marine Resources Act 2006
- Marine Zones (Declaration) Act 1983 [Cap 24A]
- Harbours Ordinance [Cap 88]

[Wildlife and Habitat Conservation]
- Wildlife Conservation Act
- Wildlife Conservation Ordinance [Cap 47]
- Conservation Areas Act 1999

[Plants]
- Plants (Amendment) Act 1991
- Plants Ordinance [Cap 39]
- Plants (Prevention of Disease and Citation Pests) Regulations

[Pollution]
- Oil Pollution (Compulsory Insurance) Regulations 1976
- Petroleum (Amendment) Act 1990
- Marine Pollution Act 1991

[Water Supply]
- Water Supply Act
- Water Supply (Delivery of Bulk Supplies) Regulations

11.2 Procedure of Environmental Impact Assessment

The procedure, according to the EIA Guideline, is shown in **Figure 11.1**.

11.2.1 Projects to be the Subject of EIA

Any of the activities listed in "*Schedule 1*: Development Activities" attached to the EIA Guideline shall be subject to the provisions of regulations in the *Regulation 5*. The followings are extracts from *Schedule5*, which may be applicable to an outcome of this Study.

9. Public Works Sector including:

(a) landfills
(b) infrastructure developments
(c) major waste disposal plants including recycling and collection systems
(d) soil erosion, beach erosion and siltation control
(e) hydropower schemes, desalination plants
(f) reservoir development
(g) airport developments
(h) causeways, drainage and disposal systems
(i) dredging
(j) watershed management
(k) seawalls/land reclamation
(l) boat channels
(m) port and harbours
(n) electricity generating stations
(o) marinas (comprising pontoons, jetties, piers, dry storage, moorings) for more than 5 vessels

Almost all public works will be the subject of the provision, except the rehabilitation and maintenance.

11.2.2 Preliminary Environmental Assessment (PEA)

It is necessary to submit PEA with the application form when an outline of the project is formulated, according to the EIA Guideline (**Figure 11.1**). The project will be approved if Department of Environment decides that there would be no significant impact by the project. On the other hand, preparation of an EIA report would be necessary if significant impact is expected. The followings particulars would be of the EIA report. In case of this Study, the Project Proponent (PP) would be the Government of Tuvalu (the Scope of Work).

Preliminary Environment Assessment (PEA) Report shall contain the following particulars.

(a) a brief description of the development proposal;
(b) a brief description of the area to be affected and the nature of the proposed change to the area (including a location map and site plan);
(c) a brief justification for the development proposal;
(d) an assessment of all reasonably foreseeable adverse and positive impacts, including long-term and short-term, primary and secondary consequences;
(e) an indication of possible alternatives to mitigate any identified adverse impacts; and
(f) an indication of measures that the proponent intends to take to mitigate or avoid identified adverse impacts.

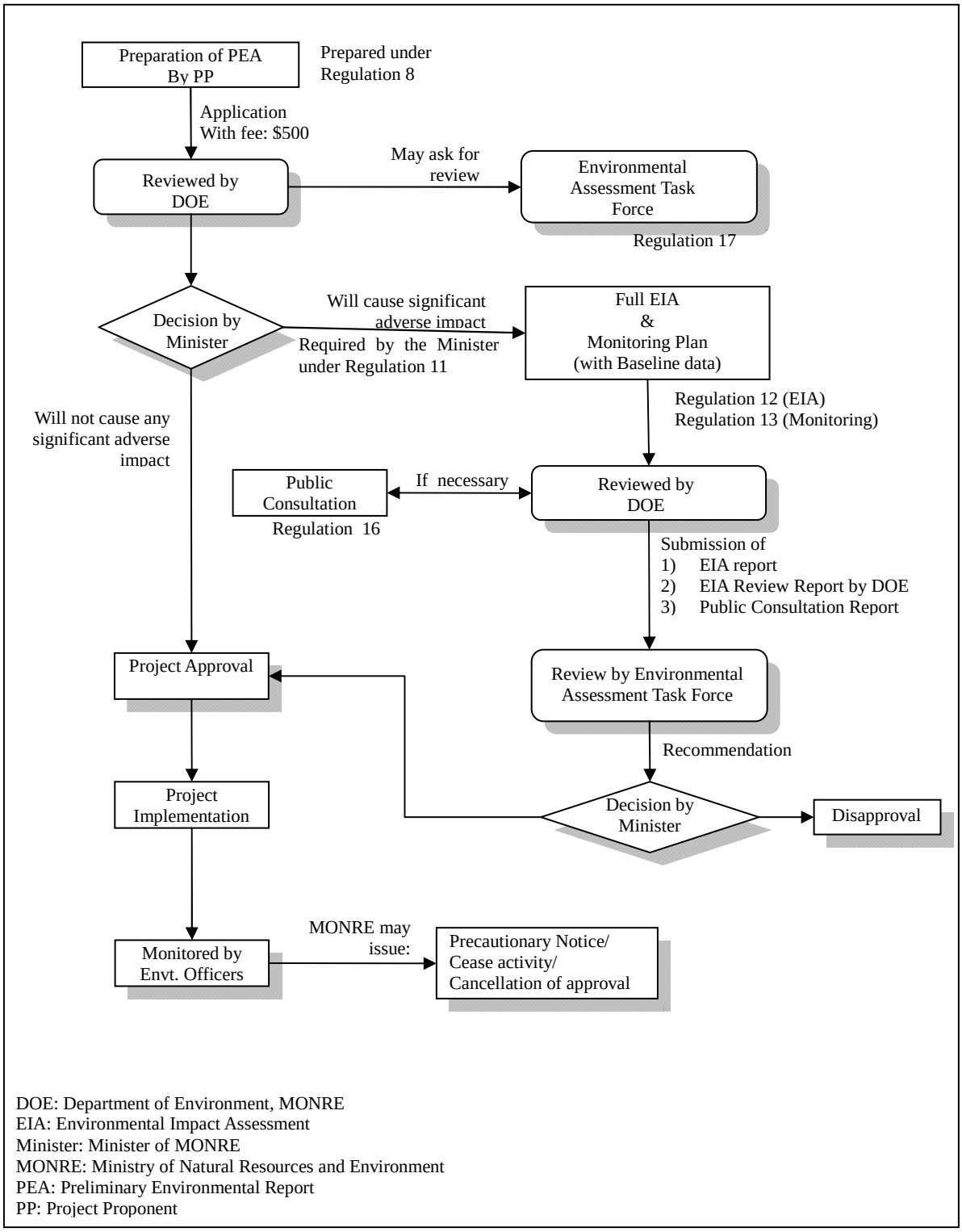


Figure 11.1 Draft EIA Procedure of Tuvalu

11.2.3 Environmental Impact Assessment (EIA)

Unless otherwise directed by the Director in writing, an Environmental Impact Assessment (EIA) Report shall contain the following particulars.

(a) A summary of the development proposal and its consequences, including :
  (i) a statement of all major conclusions;
  (ii) an outline of any issues that are controversial;
  (iii) an outline of issues that remain to be resolved;
  (iv) an outline of the preferred choice among any alternatives; and
  (v) details of any proposals to mitigate significant adverse impacts.

(b) A description of the development proposal (including any phasing or sequencing of activities), a statement of its underlying purpose, and the long-term and short-term objectives sought by the proponent.

(c) Further details of the description of the development proposal, including:
  (i) a general description of the proposal's technical, economic, and environmental characteristics, taking into consideration current engineering and supporting utility / infrastructural data;
  (ii) the precise location and boundaries of the proposal shown on a detailed map; and
  (iii) a justification of the rationale for the proposal including such supporting information as is appropriate.

(d) A review of the environmental impacts of the development proposal and any practical alternatives to the proposal, and in this section the proponent shall -
  (i) review and evaluate all reasonable alternatives, including locations and methods, and the alternative of no action;
  (ii) identify the proponent's preferred alternative or alternatives;
  (iii) identify appropriate mitigation measures to minimise any significant environmental impacts arising from the preferred alternative; and
  (iv) identify any significant environmental impacts that cannot be avoided.

(e) A description of the affected environment, including -
  (i) a description of the local environment in the vicinity of the proposal as it exists before commencement of the proposal;
  (ii) a description of potential cumulative impacts that might arise in conjunction with other activities in the location;
  (iii) a review and evaluation of possible conflicts or inconsistencies between the development proposal and relevant applicable objectives of national, regional or local land use and marine / coastal plans and policies.

(f) Analysis of the environmental consequences of the development proposal which may include the following -

(i) a review of direct and indirect environmental effects, their significance, and risks;
(ii) a consideration of cumulative environmental impacts;
(iii) a consideration of the environmental effects of alternative;
(iv) an assessment of the likely need for additional infrastructure, including energy and public utilities;
(v) an assessment of impacts on the area's physical locality and amenity (including visual quality), its historic and cultural resources, and the design of the built environment;
(vi) an assessment of social impacts on the local population and its uses of the land;
(vii) an assessment of the implications of the use of potential environmental pollutants;
(viii) a review of options proposed to mitigate adverse environmental impacts;
(ix) a description of any unavoidable adverse environmental impacts, including any permanent change in the physical, biological, social or cultural characteristics of the affected environment or in the possible future use of that environment;
(x) an analysis of the costs and benefits that may result from the development proposal;
(xi) the identification of any irreversible or irretrievable commitments of resources required for the development proposal; and

(g) A list of all persons who prepared the EIA, their qualifications, and organisations and persons who were consulted.

According to the EIA guideline, foreign EIA guideline may be utilized with the Minister's approval.

11.3 Draft of Preliminary Environment Assessment (PEA) Report

11.3.1 Project Description

[PROJECT TITLE]

"The Study for Assessment of Ecosystem, Coastal Erosion and Protection/ Rehabilitation of Damaged Area in Tuvalu"

11.3.2 Objectives

[OBJECTIVES OF THE STUDY]

(1) To assess ecosystem, coastal erosion and protection/rehabilitation of the damaged area;
(2) To make a plan on sustainable measures for coastal protection/rehabilitation; and
(3) To strengthen capacity of institutions and communities for coastal management.

Among the three objectives above, only the second item includes structure design and modification of land, which is subject to the Preliminary Environmental Assessment (herein after referred as "PEA") of Tuvalu, according to Schedule 1 of Development Activities, in Environment Protection (Environmental Impact Assessment) Regulations 2007 [Draft] (herein after referred as the Guideline).

[OBJECTIVES OF THE STRUCTURE]

The coastal protection structure is designed to prevent one in ten-year scale wave at lagoon side of central Fongafale Islet. Since it is an emergency remedy, the target year is set as 2020.

11.3.3 Design of Coastal Protection Measures

The proposed coastal protection structure is so called "soft structure" which is made of unconsolidated gravel, nourished (piled up) at sections on lagoon side of Fongafale Islet. The cross sections and length are shown in **Figure 11.2**.

The gravel nourishment is planned to protect the most densely populated area of the Fongafale Islet. The project site is divided into two parts: one (Project site D1) is in front of Senala District, (partly Fakai Fou District) public facilities are built in the hinterland; the other (Project site D3) is in front of Alapi and Viaku District.

The gravel is transported from side area of runway, and three outer islets: Funamanu, Falefatu, and Mateika. The gravel is exchanged to sand, which is to be excavated from middle of Funafuti lagoon (**Figure 11.4** and **Figure 11.5**).

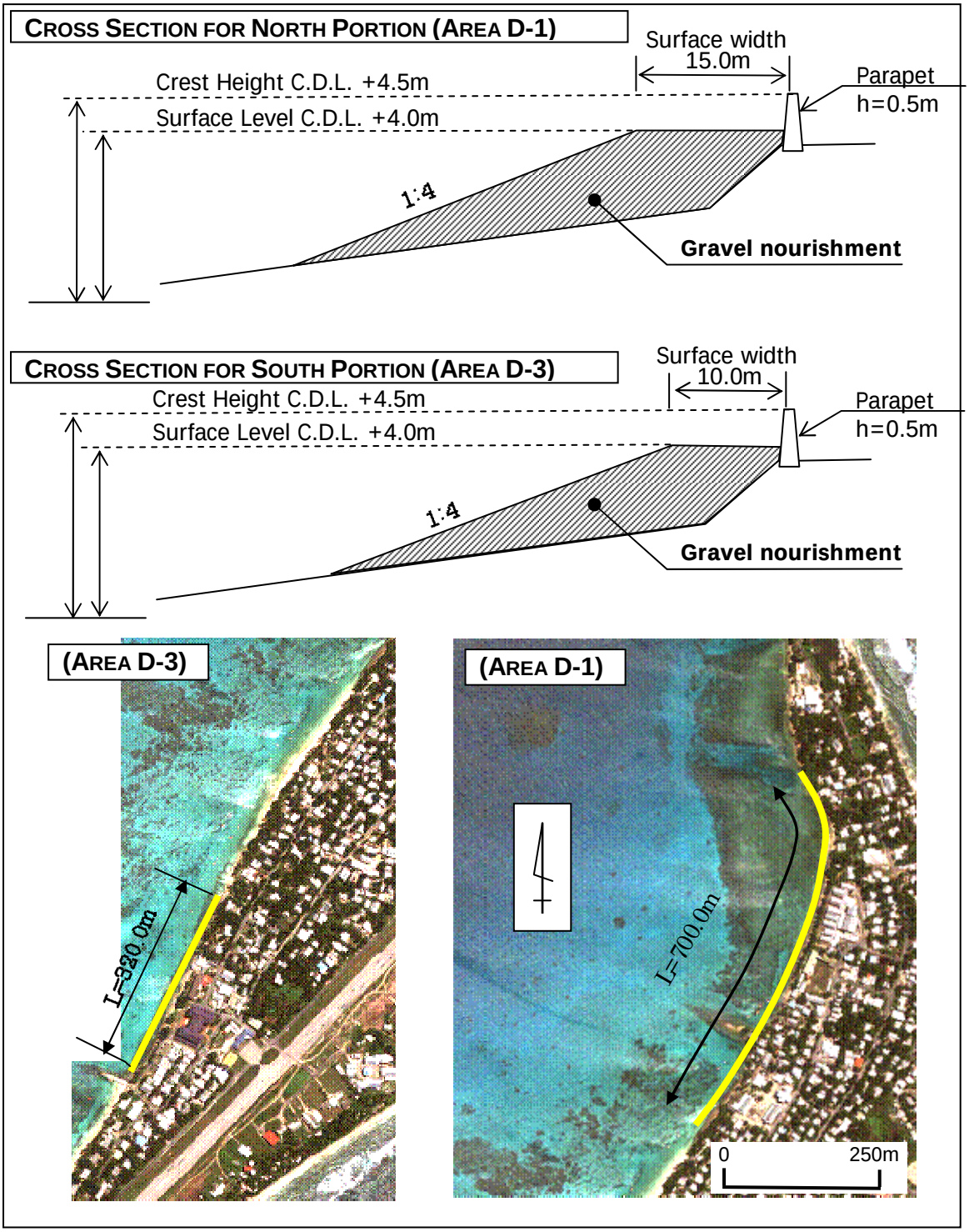


Figure 11.2 Proposed Structure

This project plans to fill offshore pits together with gravel nourishment. These pits (**Figure 11.3**) are created by Sea Bees of U. S. Navy during the Pacific War as PT boat moorings. Although, at present, these pits are being used as mooring fishing boats and bathing by the neighbors, these pits are thought to amplify waves at the site and proposed to bury by gravels. Figure 10.3 shows BP-1 and BP-2 is deeper than BP-3 and BP-4. The volume necessary for filling the pits are over 30,000 m^3.

Table 11.2 Volume of Gravel Necessary for Filling Pits

Location	Volume (m^3)
BP1	15,505
BP2	7,119
BP3 (the north side)	1,140
Total	23,764

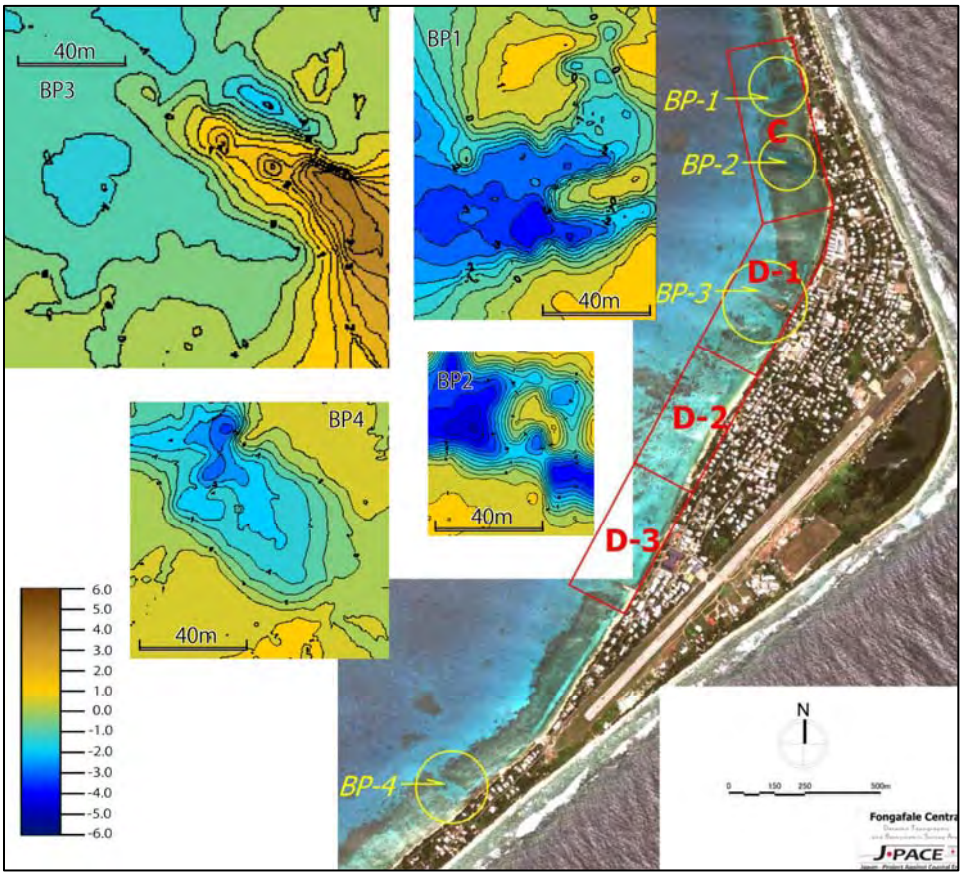


Figure 11.3 Location of Pits

Figure 11.4 Gravel and Sand Transportation Plan

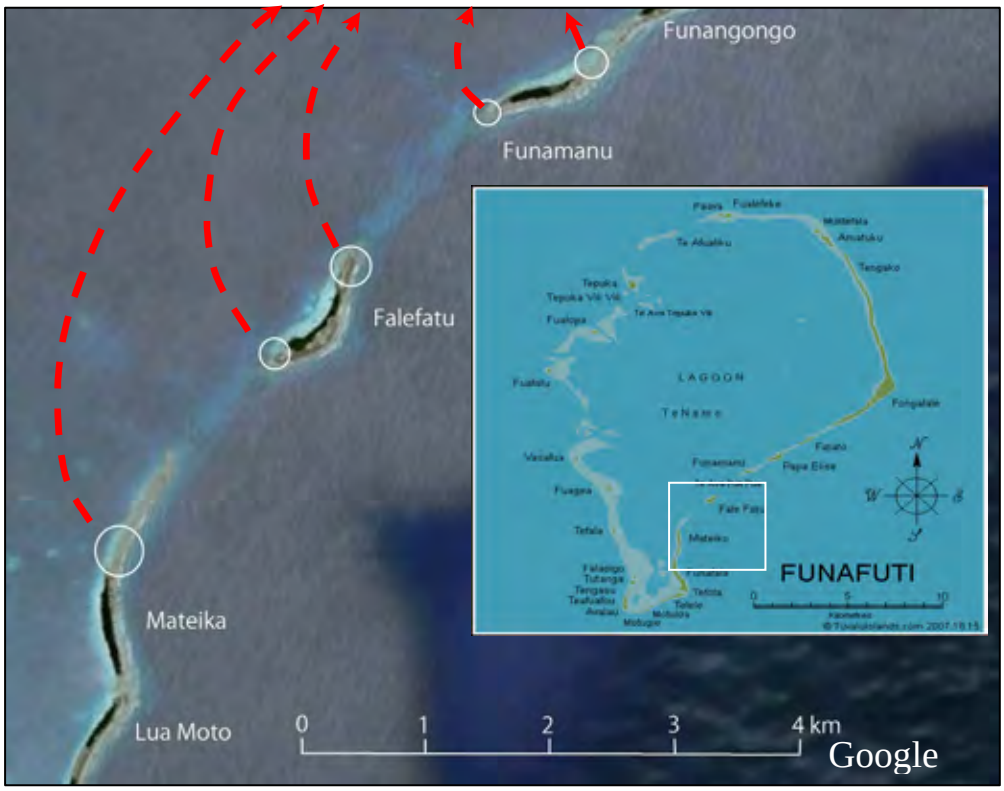


Figure 11.5 Gravel Transportation Plan from Outer Islet

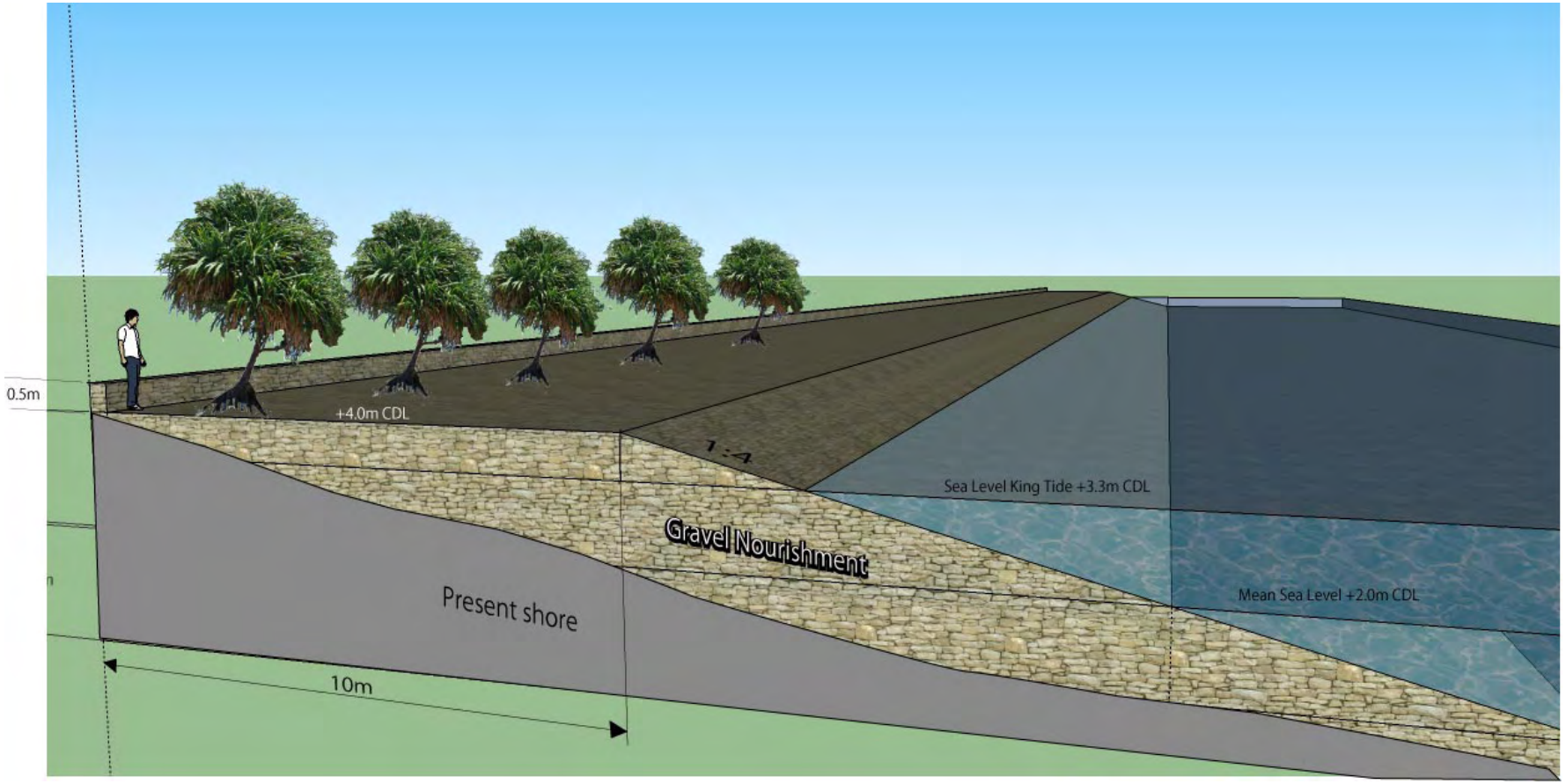


Figure 11.6 Bird's View of Completed Gravel Nourishment

11.3.4 Site Description

[Location]

Tuvalu is consisted of 9 major islands. The project site is on Fongafale Islet of Funafuti Atoll, in which the capital of Tuvalu is located.

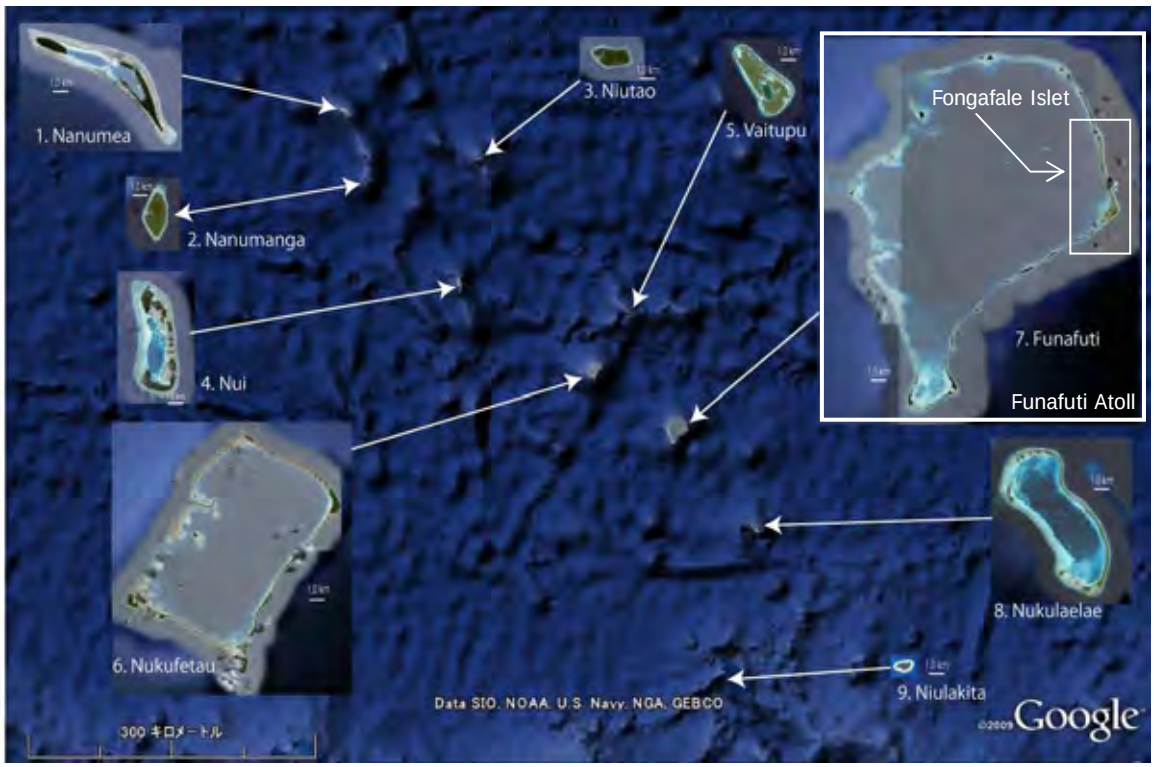


Figure 11.7 Funafuti Atoll in Tuvaluan Islands

Table 11.3 Statistics of Funafuti Atoll and Fongafale Islet

Population	4,492
Households	639
Land Area	2.79 km^2
Land Area of Fongafale Islet	1.42 km^2
Pop. Density of Fongafale Islet	3,163 /km^2
Island Type	Atoll
Remarks	Capital, International Airport, International Port

Source: Tuvalu 2002 National Census

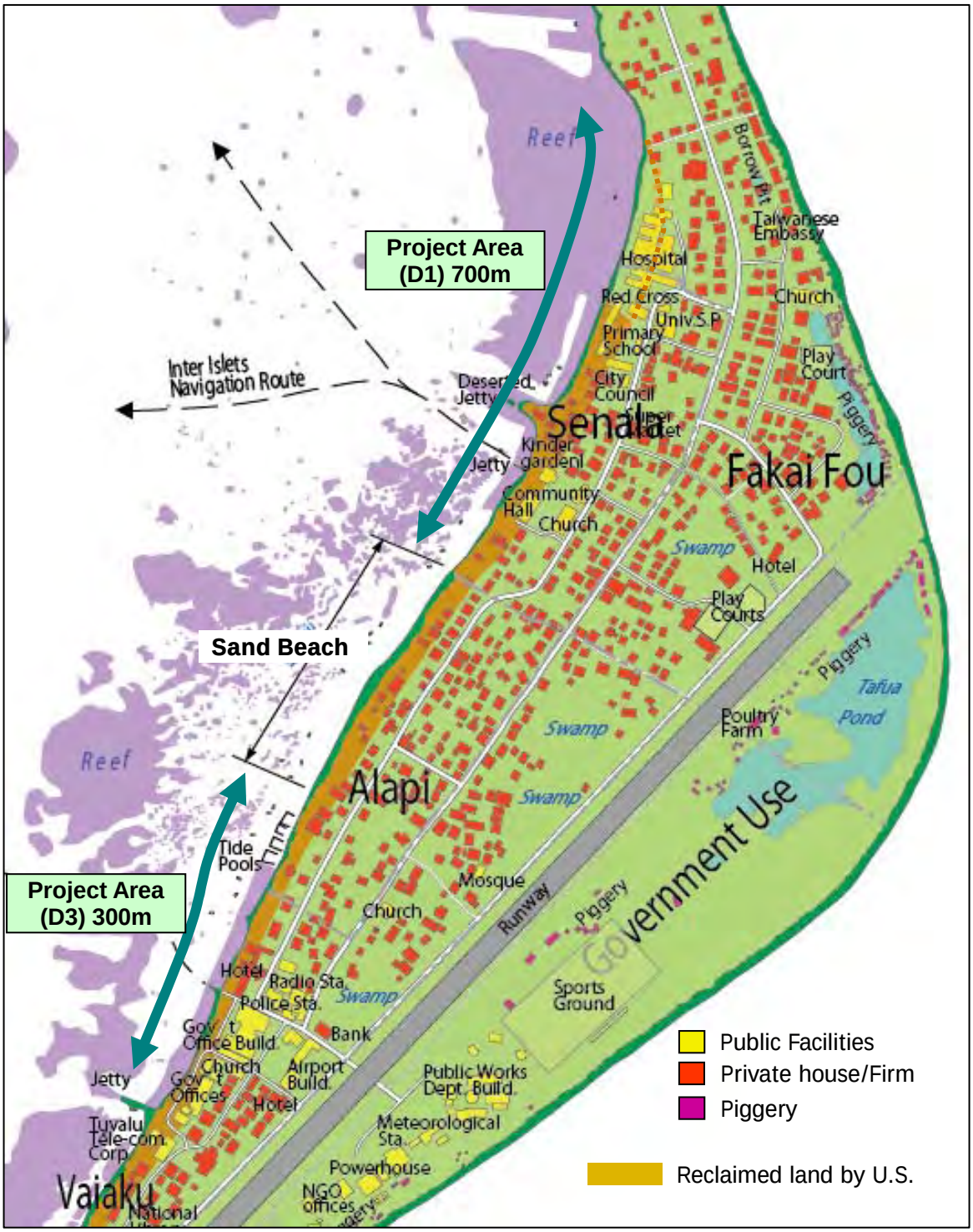


Figure 11.8 Locations of the Coastal Protection Structure

11.3.5 Related National Plans and Programme

(1) National Strategy for Sustainable Development: 2005 – 2015 (TEKAKEEGA II)

TEKAKEEGA II finds two key issues for environmental management:

1) growing urbanisation of Funafuti, and
2) impacts associated with climate change and sea level rise, specifically salt-water inundation of *pulaka* pits, **coastal erosion** and flooding

Strategies (2005 to 2015) for the key issues are:

* Develop and implement an urban and waste management plan for Funafuti.
* Establish national climate change **adaptation** and mitigation policies.
* Encourage international adoption of Multilateral Environmental Agreements, including the Kyoto Protocol.
* Increase the number of conservation areas and ensure regulatory compliance.

Coastal protection is one form of the adaptation measure for climate change stated in TEKAKEEGA II

(2) Tuvalu National Adaptation Programme of Action (NAPA, DoE, UNDP-Global Environmental Facility, 2007)

Coastal Erosion measure is designated as first of seven projects of NAPA projects as follows; and 'Project 6' has strong relationship with coastal disaster.

NAPA Project 1

Title	Increasing resilience of Coastal Areas and Community Settlement to climate change
Rationale/ Justification	NAPA document clearly show the vulnerability of the island's western coastal areas to erosion due to climate change and sea level rise.
Goal	Increasing resilience of coastal areas and community settlement to climate change.
Objectives	*Increased protection of coastal areas from erosion *Increased protection of coastal communities from natural phenomenon.

NAPA Project 6

Title	Strengthening Community Disaster Preparedness and Response Potential.
Rationale/ Justification	The vulnerability of Tuvalu to natural disasters is high. Climate change increases the frequency of natural hazards.
Goal	Strengthening of Community Disaster preparedness and response capability.
Objectives	* To ensure community preparedness and effective response to disasters; * To ensure that climate hazard risks on island communities reduced.

11.3.6 Social Environment

Followings are the land use of the hinterland and shoreline.

Fakai Fou District:	Prince Margaret Hospital and private houses at the north end
Senala District:	Prince Margaret Hospital, Funafuti Primary School, Funafuti council, University of South Pacific, Community Hall, Church,

	private houses
Alapi District:	Private households and offices, Viaku-lagi Hotel, Radio station, Police office
Viaku District:	Federal governmental complexes, there are principal public function
Fishery:	The beach area of Alapi District and Senala District are heavily used for fishing boat loading and unloading directly from fishermen's yards.
Commuting:	Jetty, built by Tuvalu Maritime Training Institute (TMTI) for daily communication, is in Senala District. There is another jetty in use in front of Viaku-lagi Hotel of Viaku District.

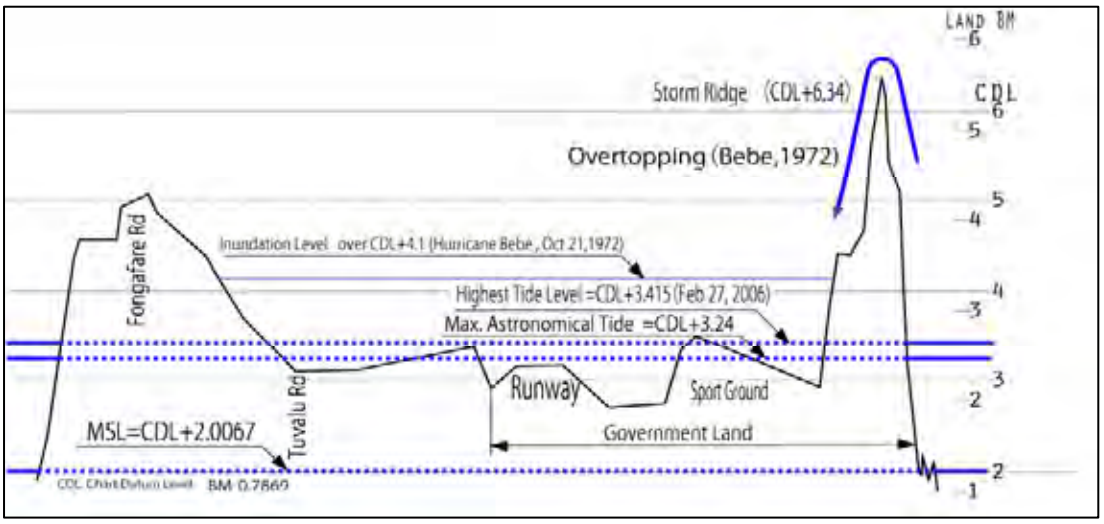
The houses are at very low elevation (2-3m above mean sea level): most of the houses were inundated during hurricane Bebe in1972. The population is growing at high rate due to immigrants from other island in Tuvalu and returners from Nauru and Kiribati. These people are building houses at outside of the old villages.

11.3.7 Natural Environment

The Fongafale Islet is a narrow strip of land, made mainly of rabbles of coral. The altitude is extremely low; most of the land is only 1-3 m above mean sea level (**Figure 11.9**).

All of the stretch behind the project site is artificially reclaimed land, approximately 30m of width, with quay created and used by the U.S. NAVY for their naval base during World War II. The hinterland area before the war was wide beach with shallow water area and 3-5 feet high sand dune behind it before the War[1]. Most of the sand is excavated to keep the depth for war vessels and for filling Tafua Pond for construction of Air field. As the temporary made wooden quay deteriorated, erosion has begun. There was an effort to protect the reclaimed coastline; however, the blocks used for protection was not appropriately designed and most of them were destroyed by waves (**Photo 11.1**).

[1] J-PACE survey with elderly in Fongafale Islet



Source: J-PACE (2010)

Figure 11.9 Elevation of Fongafale Islet

Photo 11.1 Collapsed Seawall (Unconsolidated Cube-type Blocks)

11.3.8 Justification of the Project

Prevention of coastal disaster at Funafuti is being one of the biggest issues locally, and it is recognized by the National government.

Local request: Funafuti Kauple expressed their opinion at an official meeting[2] that "Project to deal with coastal erosion appears to be most pressing issue".
NAPA: Coastal Erosion measure is designated as first of seven projects of NAPA projects as follows; and Project 6 has strong relationship with coastal disaster.

Residents of Funafuti are living at unusually low elevation area and vulnerable to and high waves during storm surges. Although the erosion is a result of "collapsing of artificial U.S. NAVY embankment", there are many buildings already and they should be protected from high waves.

Photo 11.2, Photo 11.3, Photo 11.4 Lagoon side of Fongafale Islet in influence of tropical storm Tomas, March 2010

[2] Tuvalu National Adaptation Programme of Action (NAPA) Project Preparation Grant (PPG) Launch and Stakeholder Consultations (Funafuti, April 2009), Funafuti Kauple, chaired by Teo Pasifeka

11.3.9 Impacts Assessment

Preliminary environmental assessment check list was modified according to Tuvaluan Guideline.

Table 11.4 Preliminary Environmental Assessment (PEA) Check List (Social Environment)

	S/N	Impacts on:	Phase		Positive & Negative Impacts
			Construction	In use	
Social Environment	1.	Involuntary Resettlement	-d	-d	Resettlement is not needed
	2.	Local economy such as employment and livelihood	+a	+a	*Many employments will be created during construction *Security of hinterland is raised during storm.
	3.	Land use and utilization of local resources	-d	-d	*The gravel nourishment works will not use public road but will be done from ocean side
	4.	Local communities and decision-making institutions	-d	-d	No impact is expected
	5.	Existing infrastructures and services	-d	-b	*Enlarged beach and a parapet may be the obstacle to loading/unloading of fishing boats * Deep area used for mooring and navigation channel for fishing boat must be preserved. * Gravel will bury Jetty for Amatuku commuting boats. The jetty must be replaced and the function has to be kept.
	6.	The poor/ indigenous/ ethnic minority/ women/ children	-d	-d	No impact expected; however, there are many residents whose origin is not Funafuti. These people have strong ties each other and also have their representative. The Funafuti Kauple needs to consult with the out islanders carefully.
	7.	Misdistribution of benefit and social cost	-d	-d	No misdistribution of social cost is expected. However, the gravel nourishment protects only the center part of Fongafale Islet. Ocean side and north/south area is not receive the benefit.
	8.	Historical/ cultural heritage	-d	-d	There is no historical/cultural heritage at the project site.
	9.	Local conflict of interests	-d	-a	Land tenure of nourished area could well be controversial. Legal land owner and utilization rights must be clarified before construction.
	10.	Water usage, Water rights, Communal rights	-d	-b	Commuting use, fishery use (including mooring), and free access to the beach should be maintained.
	11.	Sanitation	-d	-d	Degradation of sanitation environment will not occur
	12.	Health Hazards/Risk, Infectious Diseases such as HIV/AIDS	-d	-d	Degradation in Health environment is not expected even during the construction given normal management of construction site is conducted.

Table 11.5 Preliminary Environmental Assessment (PEA) Check List (Natural Environment)

	S/N	Impacts on:	Phase		Positive & Negative Impacts
			Const-ruction	In-use	
Natural Environment	13.	Important/ valuable geographical and geological features/ resources	-d	-d	Important geological or geographical site do not exist
	14.	Soil erosion	-d	+a	Gravel nourishment is designed to prevent over topping of waves but it also is effective for protecting the shore from soil erosion
	15.	Amount and quality of groundwater	-d	-d	There is no impact on ground water.
	16.	Amount of natural reservoir/flow	-d	-d	There is no reservoir in the Islet.
	17.	Coastal zone	-	-	(Refer all other items)
	18.	Flora, Fauna, Biodiversity	-b	-d	When gravels are to transport from sand spit of Funamanu Islet, Falefatu Islet, and Mateika Islet, bulge might interfere with coral around of the islets. Appropriate transplanting work must be carried out.
	19.	Meteorology/climate	-d	-d	There would be no impact on metrology/climate by the gravel nourished structure
	20.	Aesthetic landscape	-d	+b	At present, rubbles of broken seawall is allover the shore. The new protection with coral gravels will be formed in shape and planting of trees such as *pandanus* on it is planned.
	21.	Global warming	-d	-d	There would be no GHG emissions from the gravel nourished structure

Table 11.6 Preliminary Environmental Assessment (PEA) Check List (Pollution)

	S/N	Impacts on:	Phase		Positive & Negative Impacts
			Const-ruction	Opera-tion	
Pollution	22.	Air pollution	-d	-d	The emission from the construction machines is negligibly small.
	23.	Water pollution	-d	-d	Water pollution will not occur during construction stage if the construction body conducts normal water effluent treatment practice.
	24.	Soil contamination	-d	-d	Soil contamination will not occur during construction and after completion of it.
	25.	Solid waste amount increase	-d	-d	There is no impact on solid waste management.
	26.	Increase of noise and vibration	-d	-d	Noise and vibration during construction is short period and negligibly small.
	27.	Ground level subsidence	-d	-d	Ground level subsidence by the structure will not occur.
	28.	Offensive odor	-d	-d	Occurrence of offensive odor is not expected.
	29.	Sedimentation	-d	+a	Sedimentation of sand at the coastal line is the purpose of this project
	30.	Increase of Accidents	-d	-d	Increase of accident is not expected even in during construction period because the work is not take place in terrestrial area.

Grade:
[Negative Impact]
-a: Serious impact(s) is (are) expected
-b: Less serious impact(s) is (are) expected
-c: Impact not known without further research
Note: Progress of project itself may reveal the impact (further research is not necessary, in this case)
-d: Negligible impacts are expected or no impact is expected

[Positive Impact]
+a: Strong and positive impact(s) is (are) expected
+b: Positive impact(s) is (are) expected
+c: Impact not known without further research
Note: Progress of project itself may reveal the impact (further research is not necessary, in this case)
+d: Slight positive impacts are expected or no impact is expected

11.3.10 Possible Alternatives

Before gravel nourishment was chosen, there were other alternatives to compare for the best form of protection of the shore. Followings are the pros and cons for each alternative. They are not chosen for their disadvantages.

[SAND NOURISHMENT]

Pros	● There was sandy beach at lagoon side of the Central part of Fongafale (from the hospital to the south end of air field) before the Pacific war. ● It is easy to excavate sand at the lagoon and then nourish it to the project sites.
Cons	● Sand does not stay in place. It has to be nourished periodically, and it is not practically possible. ● Sand is stabilized only in gentle slope: it means large amount of sand is necessary to protect the shore, or solid structure to hold the sand at the foreshore (sand retaining wall) is required.

[SET BACK/ZONING]

Pros	● This is a soft measure, and it does not require any structures. ● It is effective for secure the hinterland from coastal disasters
Cons	● Resettlement is needed ● It is impossible to secure new place for the residents. There is no place left.

[SEA WALL]

Pros	● It is relatively easy to construct the seawall. ● Many residents support seawall.
Cons	● Seawall will totally change the nature of the shoreline: difficult to access lagoon, scenery will be different, it divide lagoon and the hinterland ● Sea wall reflects wave energy effectively, but at the same time, it accelerates erosion at its foot.

[BREAKWATER (INCLUDING DETACHED BREAKWATER)]

Pros	● It is relatively easy to construct the breakwater. ● It dissipate waves effectively.
Cons	● It changes the nature of the shoreline. No waves approach to the shore any more. ● It changes nature of shallow water. The water quality will be degraded. ● It will have unfavorable artificial looking to many residents and especially to visitors.

[NO PROJECT]

Pros	● It does not cost any money ● Gravel does not have to be excavated at air fields and from other islets. ● Coral transplanting does not have to be taken place. ● No extra-work for making new rules for new reclaimed land.
Cons	● The hinterland is always endangered every year during high tidal season, and if sea

	level rises, the disaster will be worsened. ● Coastal erosion will progress year by year. ● Ugly looking of shoreline continuous

11.3.11 Mitigation Measures

Following particulars listed in **Table 11.7** were marked as either "-a" or "-b", which means they may be affected by the project. The marking means:

-a: Serious impact(s) is (are) expected
-b: Less serious impact(s) is (are) expected

Mitigation measure for each is considered.

Table 11.7 List of Impacts Mitigation Required

S/N	Impacts on:	Phase		Negative Impacts	Mitiga-Tion No.
		Const-ruction	Opera-tion		
5.	Existing infrastructures and services	-d	**-b**	* Enlarged beach and a parapet may be the obstacle to loading/unloading of fishing boats	(1)
				* Deep area used for mooring and navigation channel for fishing boat must be preserved.	(2)
				* Gravel will bury Jetty for Amatuku commuting boats. The jetty must be replaced and the function has to be kept.	(3)
9.	Local conflict of interests	-d	**-a**	* Land tenure of nourished area could well be controversial. Legal land owner and utilization rights must be clarified before construction.	(4)
10.	Water usage, Water rights, Communal rights	-d	**-b**	* Commuting use, fishery use (including mooring), and free access to the beach should be maintained.	(5)
18.	Flora, Fauna, Biodiversity	**-b**	-d	* When gravels are to transport from sand spit of Funamanu Islet, Falefatu Islet, and Mateika Islet, bulge might interfere with coral around of the islets. Appropriate transplanting work must be carried out.	(6)

(1) EXISTING INFRASTRUCTURES AND SERVICES (S/N 5)

Negative impact: Enlarged beach and a parapet may be the obstacle to loading/ unloading of fishing boats

[MITIGATION MEASURES]

- Construction of concrete slopes where its necessary, or
- Providing of ladders rails, or other gears for unloading/uploading boats
- Ramps for parapet

Ladder Slope

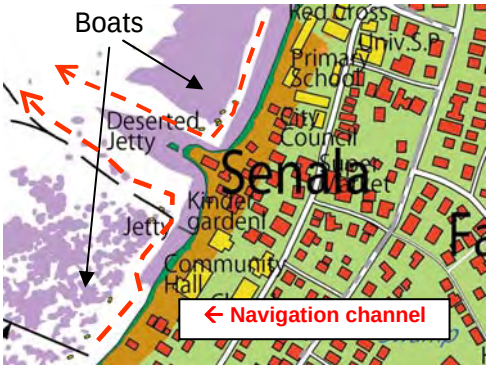
Ramps over parapet

(2) DEEP AREA USED FOR MOORING AND NAVIGATION CHANNEL FOR FISHING BOAT MUST BE PRESERVED (S/N 5)

[MITIGATION MEASURES]

- Make sure cross section of gravel nourishment does not interfere with passage way of the fishing boats

Deep navigation channel is being used for mooring and passage in low tide



(3) GRAVEL WILL BURY JETTY FOR AMATUKU COMMUTING BOATS. THE JETTY MUST BE REPLACED AND THE FUNCTION HAS TO BE KEPT (S/N 5)

TMTI is operating commuting shuttle boats 3-4 trip daily to Amatuku Islet.

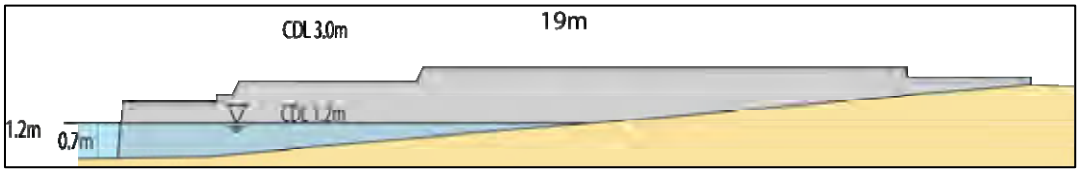


Figure 11.10 Cross Section of Luapou Jetty Made by TMTI (During Low Tide)

[MITIGATION MEASURES]

- Make sure to keep the function of jetties by construction of new jetties at the same location.

Luapou Jetty

Viaku Jetty

(4) LOCAL CONFLICT OF INTERESTS (S/N 5)

Land tenure of nourished area could well be controversial. Legal land owner and utilization rights must be clarified before construction.

Land owners may claim ownership of reclaimed land (Nourished gravel). In order to prevent encroachment and keep it clear as buffer zone for safety reason, privatization is not recommended.

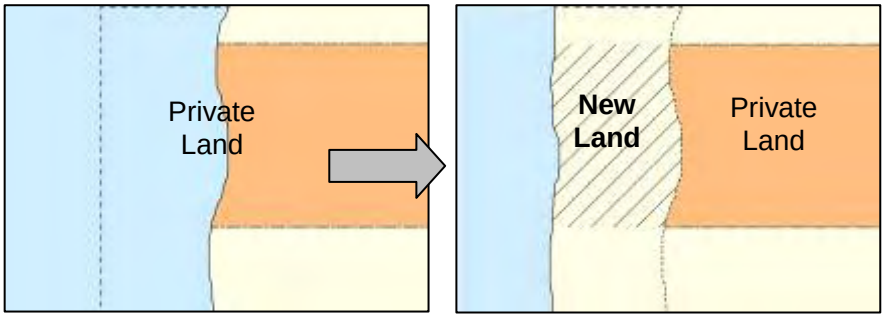


Figure 11.11 New Land to be Created by Reclamation

[MITIGATION MEASURES]

- A statute/by-law shall be enacted to define that the land will be Crown Land before construction.

(5) WATER USAGE, WATER RIGHTS, COMMUNAL RIGHTS (S/N 10)

Commuting use, fishery use (including mooring), and free access to the beach should be maintained. Is the same with (2) and (3).

(6) FLORA, FAUNA, BIODIVERSITY (S/N 18)

When gravels are to transport from sand spit of Funamanu Islet, Falefatu Islet, and Mateika Islet, bulge might interfere with coral around of the islets. Appropriate transplanting work must be carried out.

As it is shown in **Figure 11.5**, gravel are planned to be excavated at fringes of the above three islets. Cover-up ratio of coral is shown in **Figure 11.12**. The best method of transportation from the islets will be studied carefully in next stage, and receive an approval from Department of Environment and Funafuti Kauple before final method is determined.

[MITIGATION MEASURES]

- Minimize required amount of gravel as little as it can be. The pits are getting shallower ever since the end of war. It is obvious that they will eventually be buried by sand. In order to assess the necessity or degree of emergency, damages of the hinterland should be assessed for reducing unnecessary works.
- Figure out the transportation method which does not interfere with corals.
- Transplant unavoidable corals and replant it to the original position after work is done.

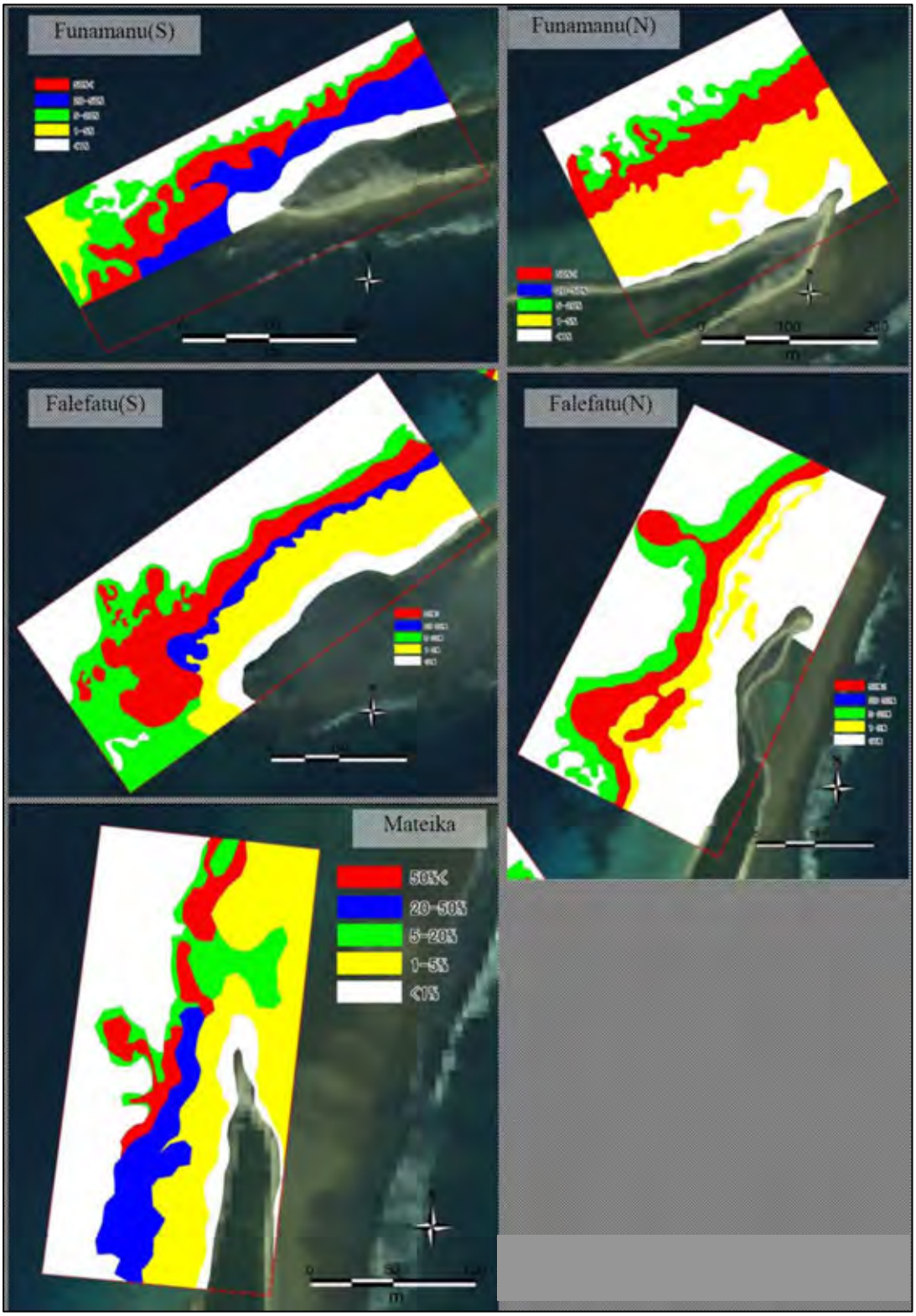


Figure 11.12 Coral Cover-up Ratios

11.4 Summary and Conclusions

Preliminary Environmental Assessment (PEA) was conducted by Department of Environment (DOE) with support of the JICA Study Team. Major impacts estimated by DOE on social and environment by the proposed project are described in **Table 11.7.** The next works to follow are: DOE (being the Project Proponent also) will evaluate the PEA, and the responsible Minister will decide the necessity of detailed environmental assessment (EIA). If the DOE/Minster find significant impact(s) is/are expected, EIA will be conducted according to Regulation 12 of the EIA Guideline.

CHAPTER 12 SUMMARY

12.1 Urgency of the Protection of the Coastal Area

Implementation of measures based on the sand production/movement/deposition mechanisms is required to protect the atoll island. Additionally, it is necessary to strengthen the island's sustainability by mitigating adverse effects on these mechanisms considering future sea level rises. Long-term measures to increase the island's sustainability must be considered. Nonetheless, the coastal area of the atoll has already been eroded, with reports of residents' lives being affected, and for these areas, urgent measures are required in a short-term. Surveys on the impact of coastal erosion and flood, and the planning of countermeasures to overcome them, are particularly pressing in Fongafale Island, where the capital Funafuti is located, and 45% of Tuvalu's total population

12.2 Priority of the Target Areas for the Implementation of Counter Measures and the Guidelines for Selection of the Construction Methods

Based on the field reconnaissance surveys, the Questionnaire Survey on the coastal disasters and the study of situations in the hinterlands, the policies for coastal protection on the each target area of the Fongafale Island have been developed. The observation surveys in the afflicted areas with overtopping waves, identified by the result of the Questionnaire Survey, have conducted during the season prevailing strong westerly winds. And the degree of urgency for protection measures in each area have been pigeonholed with the enormity of disasters, overtopping heights of waves, and conditions of the hinterlands for prioritization of areas.

After ranking the areas in degree of urgency for prevention of disasters（erosion, height of waves overtopping, experiences of disasters, etc.）, area of importance（density of houses, public facilities, etc.）, compiling in a integrated matrix to evaluate, the priority areas have been qualified taking into consideration of requests by local residents.

The areas where there are important infrastructures, such as the Government House, the Hospital, the School, and main roads, and the high density of people have been given the highest priority. Thus, the first priority has been given to the L-D area, in the center of the Island, where there are several important public facilities such as the Government House and the School, followed by the L-C area in the second highest priority, where there is a road connecting between the Funafuti Port and the center of the Fongafale Islands.

The coastal protection measures in the target areas of the Project have been selected in accordance with the following guidelines.

- The coastal protection measures shall keep the traditional scenery of the islet.
- The coastal protection measures shall have nature to promote sand movement/deposition

from outside fringe of the atoll and free from disturbance of sand drift along the shore for future accumulation.

- Consideration shall also be given to: daily usage of the shore by the residents, natural ecosystems, and navigation along the coastal area.

After studying details of comparison of the coastal protection works which might be applicable in Tuvalu, the beach nourishment with gravels, which has no risk of loss by drifting off the shore, and which can be the basis of regeneration of sandy beach generated by foraminifera, has been selected as the most appropriate measure.

12.3 Coastal Protection Works Tailored to Each Area

The survey area of the Fongafale Island has been divided into seven sub-areas. For each sub-area, alternative measures for coastal protection, including zero option, have been prepared and scrutinized to select optimal plans. In the areas with an urgency level of 1 to 3, both facility-based and regulatory measures will be implemented to prevent the hazards caused by wave overtopping. While in the areas with an urgency level of 4 or lower, only regulatory measures will be implemented. In the areas where damage has been done on the ocean side, the leveling of the far ends of storm ridges, where people should avoid living in, for the construction of houses has contributed significantly to the increase in overtopping damage.

The implementation of large-scale facility-based measures (such as revetment work) to protect against overtopping on the ocean side will take a long time because of the possible need to relocate the people living there. Therefore, while partial restoration of the storm ridges (raising of the storm ridges by stone masonry) will be implemented as a facility-based measure to protect against wave overtopping on the ocean side, regulatory measures against the illegal collection and mining of gravel and the illegal cutting of vegetation together with activities to educate residents on the causes of and countermeasures against coastal disasters will be included in the project plan, so that human activities do not interfere with the natural process of the creation of reef edges (the washing-up of coral gravel and strengthening of storm ridges by vegetation). Based on the basic policy, construction plans for gravel beach nourishment, planting on back beach, back-filling of the coastal borrow pits and partial restoration of storm ridges in each sub-area, have been studied and four alternative plans are developed in conjunction with the estimate of the construction costs.

The respective coastal protection work to be implemented in alternative plans are shown in the following table.

Table 12.1 Coastal Protection Works in Alternative Plans

Coastal Protection Works	Plan-1	Plan-2	Plan-3	Plan-4
Gravel Beach Nourishment (D-1 & D-3 areas)	○	○	○	○
Gravel Beach Nourishment (C area)				○
Planting on back beach	○	○	○	○
Back-filling of the coastal borrow pits((in front of D-1 & D-3 areas)		○	○	○
Back-filling of the coastal borrow pits((in front of C area)		○	○	○
Stone Masonry (Parapet)	○	○	○	○
Partial Restoration of storm ridges			○	○

12.4 Guidelines for Implementation of the Project and the Implementation Schedule

In order to establish a sustainable coastal management system with a long-term perspective, including an evaluation of the effects of this project and a review of its planning, the basic policy of the project is implementation based on the adaptive management (Plan-Do-Check-Action : PDCA) cycle.

The coastal protection and regeneration project formulated in this study comprises a short-term emergency project for preventing coastal erosion and a seashore improvement project aiming at the prevention of wave overtopping disasters caused by ten-year wave equivalents. The completion of the project is scheduled for 2020.

The implementation schedule of the Project is proposed as shown below.

The first year : A part of the work will be implemented as the pilot project
The second year : The area of the pilot project will be monitored, and reviewed the detail construction plan.
The third year : Construction work for other areas and monitoring during the work
The fourth year : Continue Construction work to complete and monitoring during the work
After completion : Monitoring shall be continued

12.5 Effects of the Project and the Expected Outcomes

The following effects and impacts are expected from implementation of the respective coastal protection measures.

Table 12.2 Effects Expected from the Coastal Protection Measures and Impact during and after Completion of the Works

Counter measure	Expected effects
Gravel beach nourishment	Prevention of wave overtopping Prevention of movement of gravel to the land Facilitation of transport and accumulation of sand.
Planting	Compacting of gravel beaches Improvement of the scenery
Back-filling	Prevention of wave overtopping Facilitation of transport and accumulation of sand

When the Project including these coastal protection measures has been implemented, and the effects have realized, the following outcomes are expected.

- Damages to the houses, to the furniture and household goods, to the assets for business, to the planting and to the infrastructure, which the residents in the coastal area of the lagoon side have been suffered from annual floods by ten-year equivalent wave, will be prevented.
- Risks to people, such as injuries, fears and stresses to the vulnerable residents in the coastal area of the lagoon side, due to floods by the waves not bigger than the once for ten years return period, will be prevented.
- After reclamation of gravel beach, about 20,000m^2 of land will be created in the coastal area of the lagoon side and an ancient landscape of the atoll beach will be restored, which will make the scenery of the landscape of Funafuti improved.
- The newly reclaimed land also could be used for sports and recreation for the residents. After accumulation of sand on the gravel beach in the future, the atoll sand beach could be an attractive tourist spot for visitors from overseas.
- With the nourishment of gravel beach, the existing lands will be protected and the coastal erosion will be prevented by the gravel beach which will weaken the wave strength.

12.6 Evaluation of the Project

The benefits of the Project will be measured as the direct disaster damages by flood to be avoided, the cost of emergency measures in household to be avoided, the intangible damages to be avoided and the value of the land to be created. EIRRs of the Project are estimated at 11.6 % for the Plan-1, 7.25 % for the Plan-2, and 6.77 % for the Plan-3, and these plans deem feasible except Plan-4, of which EIRR is estimated as low as 4.23%.

For implementing the Project, social influences such as relocation of the residents are not

envisaged. In the public hearings conducted several times during the survey periods, most of the people attended expressed their wish for the earliest implementation of the Project. The environmental impacts of the Project are not deemed substantial, and impacts against the lagoon ecosystem with the construction works could be minimized to a recoverable extent, provided the coral transplanting and other measures would be applied.

The Project is a feasible coastal protection work for prevention of flooding due to overtopping waves, the environmental impacts of it to the lagoon ecosystem could be recoverable, and after completion of it, release from fear, stresses and traumas of the residents, in the atoll where no refuge is found, due to the flooding by overtopping waves which reach as high as the land of the residents could be secured. In consideration of the above, the earliest implementing of the Project is recommended.

CHAPTER 13 RECOMMENDATIONS AND FURTHER ISSUES

(1) Clarification of Land Ownership of the Beach Reclaimed through This Project

On the assumption of the conduct of this project, regarding the beach reclaimed by this project, the improvement of following regulations and laws is required, the possessive rights is not allowed for neighboring land owners and the promotion of the laws and regulations of possessive rights of this reclaimed beach will be needed as the control by the governments and Fale Kaupule.

Through the second and the third field survey, this project team suggested this issue and each opinion have been exchanged with Tuvaluan side. As a result, the opinion in which possessive rights of this beach should be entrusted for Fale Kaupule belonged to the largest group.
Also, the request letter is presented and submitted from Fale Kaupule to Tuvaluan Government as follows, the possessive rights of the beach is taken up by Fale Kaupule as community Land.

In the future, through the cooperative consultation between Tuvaluan government and Fale Kaupule, Laws and regulations with possessives rights of this beach is clarified urgently is needed to improve.

(2) Gravel Collection Construction on the Safety Zone of the Runway and the Displacement Construction by Sea Sand

Regarding the collection construction at the safety zones on the runway and the displacement construction by sea sand, the excavation and discharge of earth and sand which mainly include gravels from eastern safety zones in accord with an operational schedule of the existing runway, and the installation of dredged soil, homogenization and surface compaction will be completed. All materials for the construction are pulled out and then cleaning work must be finished. In September, 2010, due to operating regular services for twice-weekly for Tuesday and Thursday by the airplanes for landing and takeoff, short working cycle for a few days will be conducted repeatedly.

This project team has been promoting dialogue with related organization such as PWD, Civil Aviation Bureau, and Fale Kauple.

In the future, in the conduct of the detailed design and the construction, cooperative consultation regarding the outline of the plan, operational process, and safety control will be needed with civil aviation department in Tuvalu and Fiji.

(3) Soft Components Countermeasure regarding Coastal Disaster

Each item needed for operation and maintenance was already implemented as a part of beach

conservation in the island on a basis of Fale Kaupule.
Although Fale Kaupule currently enforces to control illegal harvesting for coarse aggregate and logging, their crackdown are not functioned effectively. Not only the reason that system of surveillance by Fale Kaupule is imperfect but also the shortage of consciousness of Tuvaluan people for beach conservation for controlling illegal harvesting for coarse aggregate and logging , In sum, it is largely a result of the shortage of consciousness for coastal conservation.

In order to improve local consciousness of coastal conservation, the awareness against coastal disaster and safety countermeasure is conducted as one of soft components, which is needed to promote the effectiveness of gravel beach nourishment and planting through this project.

(4) Operation of Pilot Construction

Gravel beach nourishment is designed based on scientific evidence from the result of field survey. This countermeasure secures consensus among local residents though the seminar and public hearing.
However, external force with ocean waves has been changed gradually. The result of the external force may not come up to its expectations. Also, depending on gravel characteristics sourced, there is a possibility that this accomplishment will be different from their widely known image through the public hearing and seminar. Therefore, considering an unexpected case due to the nature with uncertainty and the change of procurement circumstances in advance, the pilot construction will be conducted. After this result is grasped through the monitoring, it will be extended to other priority areas for the countermeasures.

(5) Development of the Organization of Operation and Maintenance

After this project is completed, unless operation and maintenance are conducted properly, it becomes less effectiveness. In the case of inappropriate use, the coastal landscape would not meet with the living space of the local residents.
Therefore, in order to conduct improvement and maintenance shore protection facilities, the related organizations and institution will be needed to be built.
For such occasions, it is desired that coastal operation and maintenance organization will be established. In addition, this “coastal operation and maintenance organization” requires the cooperation with positive participatory from every direction and the consideration of the active topics.

(6) Capacity Strengthening of Monitoring Technology

With regard to monitoring survey to comprehend the effects and impacts by each countermeasure work, Tuvaluan public agencies such as government and Fale Kaupule have no experiences to survey. Furthermore, local residents have poor experiences about participatory

project and environmental monitoring. Therefore, capacity strengthening regarding monitoring technology will be needed in order to build the monitoring system.

・Training technologies for Tuvaluan government and Fale Kaupule
・Training participatory monitoring
・Technological transfer for participatory planting on the coast

(7) Development of Environmental Impact Assessment in Tuvalu

In Tuvalu, according to the guideline for "Environment Protection (Environmental Impact Assessment) Regulations 2007", enviromental imapct assessment is required. However, the signature of Minister of the natural resources is not yet gained, at this time, it has been awaited the entry into force of the effect officially.

Consequently, regarding this EIA guideline, the apporoval procedure by minister of the natural resources newly elected should be carried forward. Then it is desired that environemntal impact assessment system is established as soon as posiible.

(8) Setting the Ramp

In the priority areas, 9 rams made of accumulated concretes and blocks exist. Of this, some are already destroyed and unavailable. If gravel nourishment is conducted, these rams are buried and unavailable. Therefore, public hearing at the third field survey, especially, fisherman group strongly requested that the ramp for small fishing boats is set up.

In the future, the setup method of the ramp may be in the following.
1. The ramp also includes the edge treatments.
2. After gravels become stable shapes, the head of gravel should be formed in order to minimize the influence of the coastal sand drift.