8.6.3 Wave Calmness during Normal Climatic Condition: Avarua

Wave calmness at Avarua Harbour during the normal climatic condition was studied using similar method to Avatiu Harbour.

a) Wave Direction of Avarua

Wave direction of Avatiu is also used for the Avaura, since both harbours have similar natural conditions.

b) Wave Occurrence near the Port Entrance

Similar to Avarua Harbour, refraction coefficient is calculated to the wave direction of E10°N since the error in refraction diagram in the East direction will be large because this wave direction is almost parallel to the coast. Refraction coefficient at the entrance is obtained for three wave periods, T = 7 sec., 9 sec. and 11 sec.

Table 8-6-9 Refraction Coefficient at Entrance (Kr) Avarua

Wave Direction	East		
T. period (sec.)	7	9	11
Kr	0.22	0.13	0.33
Wave direction	N39°E	N17°E	N27°E

Note, Wave direction is those at the port entrance.

Refraction diagrams for three wave periods are shown in Figs. 8-6-10, 8-6-11 and 8-6-12.

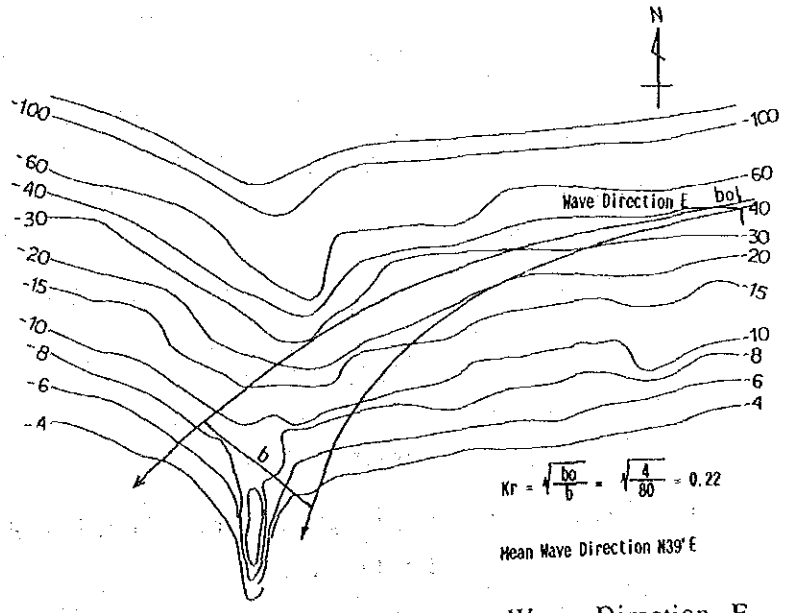


Fig. 8-6-10 Refraction Diagram, Wave Direction E
T : 7 sec.

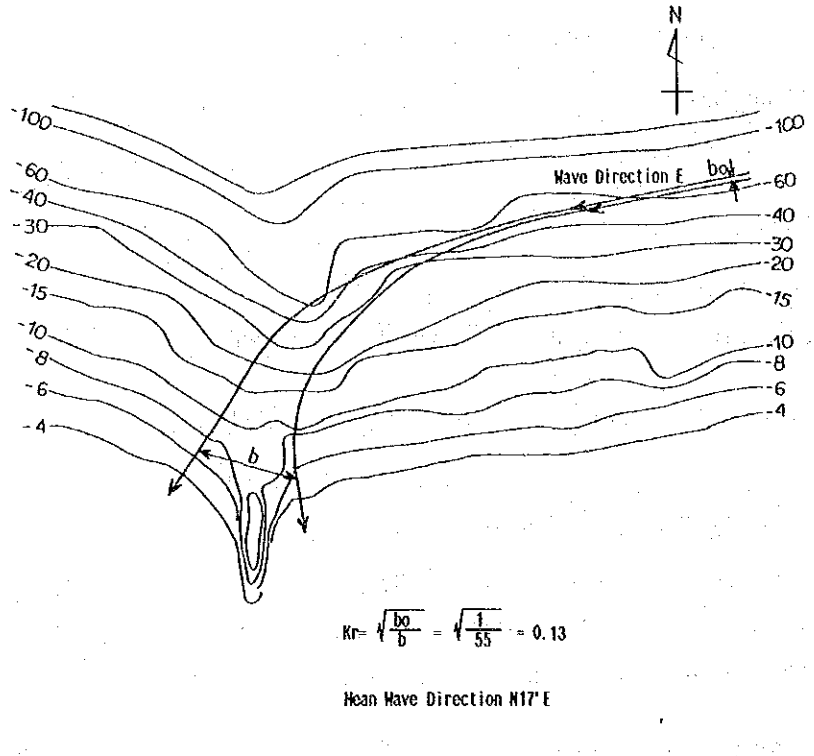


Fig. 8-6-11 Refraction Diagram, Wave Direction E
T : 9 sec.

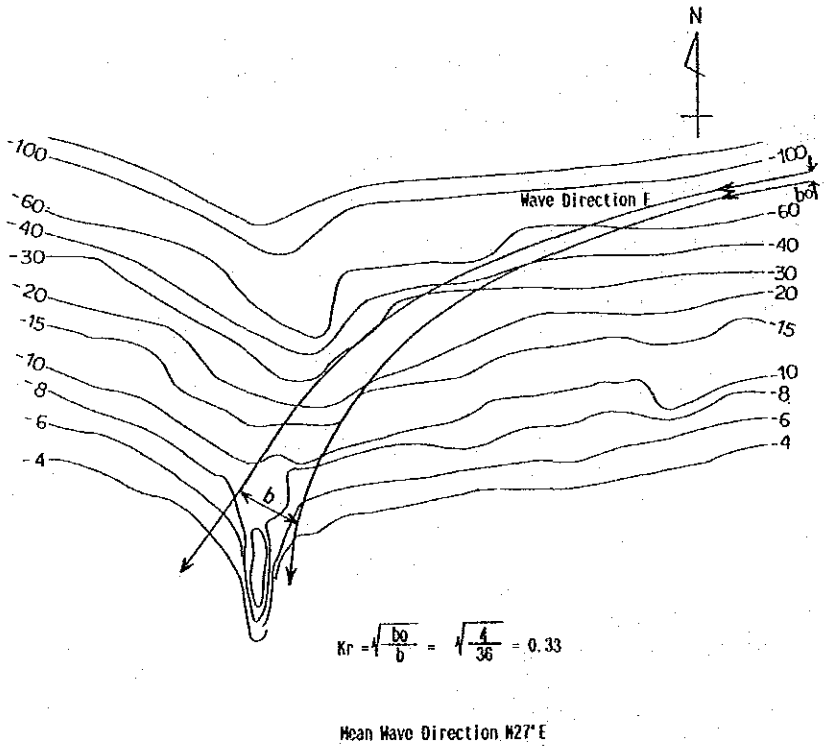


Fig. 8-6-12 Refraction Diagram, Wave Direction E
T : 11 sec.

Wave occurrence by wave direction and period can be calculated by combining both data in Tables 8-6-1 and 8-6-9.

Table 8-6-10 shows the wave occurrence by wave direction at the Avarua port entrance.

Table 8-6-10 Wave Occurrence by direction at Avarua port entrance

T (sec.) / Wave H (m)	Wave Direction, E			Total
	7	9	11	
< 0.5	30.7	26.7	39.2	96.6
0.5 ≦ H < 0.6	-	-	3.1	3.1
0.6 ≦ H < 0.7	-	-	0.4	0.4
0.7 ≦ H < 0.8	-	-	0.3	0.3
0.8 ≦ H < 0.9	-	-	0.2	0.2
0.9 ≦ H < 1.0	-	-	0.1	0.1
1.0 ≦ H < 1.1	-	-	-	-
1.1 ≦ H < 1.2	-	-	-	-
1.2 ≦	-	-	-	-
Wave Direction at the entrance	N39°E	N17°E	N27°E	100.7

c) Wave Calmness inside the Port

Port workability is calculated in both Case "Present" and Case "Extension" Four observation points are selected in the inner port basin.

(Note, Port workability in respect to wave effect is the percentage of days when the wave height is 0.3 meter or less.)

Case "Present"; The existing breakwater arrangement, Fig. 8-6-13~8-6-15

i Diffraction Coefficient KD and Shoaling Coefficient KS

Water depth (h) is -4.5 meter below MSL. Diffraction coefficients have been obtained from the irregular wave diffraction diagram (Smax = 75). Figs. 8-6-13 ~ 8-6-15 show KD in the X-Y grids by each wave direction. B = 2L for Figs. 8-6-13 and 8-6-14. B = 1L for Fig. 8-6-15.

Shoaling coefficient Ks are,

T = 7 sec. ---------- Ks = 1.00, h/Lo = 4.5/ 76.4 = 0.059
T = 9 sec. ---------- Ks = 1.10, h/Lo = 4.5/126.4 = 0.036
T = 11 sec. ---------- Ks = 1.23, h/Lo = 4.5/188.8 = 0.024

Table 8-6-11 Diffraction and Shoaling Coefficient in Case "Present", at Avarua Harbour

T (sec.)		7	9	11
Wave Dir.		N39°E	N17°E	N27°E
Pt. No.	1	0.25	0.30	0.32
	2	0.38	0.70	0.54
	3	0.65	0.70	0.68
	4	0.42	0.23	0.33
Ks		1.00	1.10	1.23

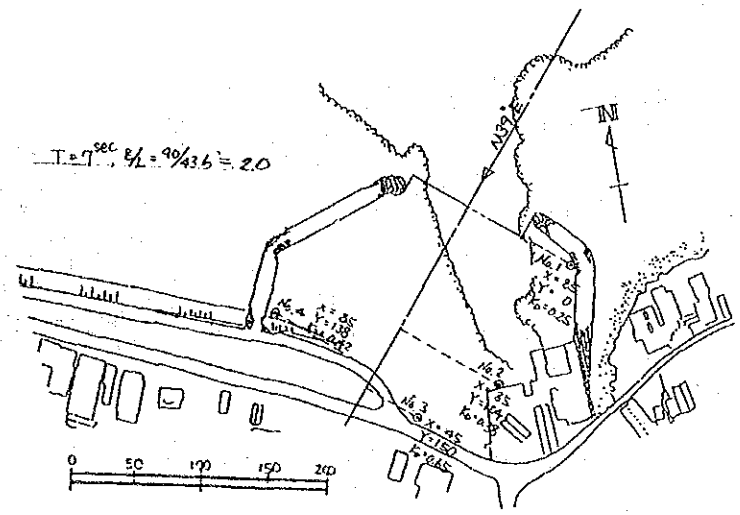


Fig. 8-6-13, Grid and Diffraction, Case "Present"
T = 7 sec., N39°E

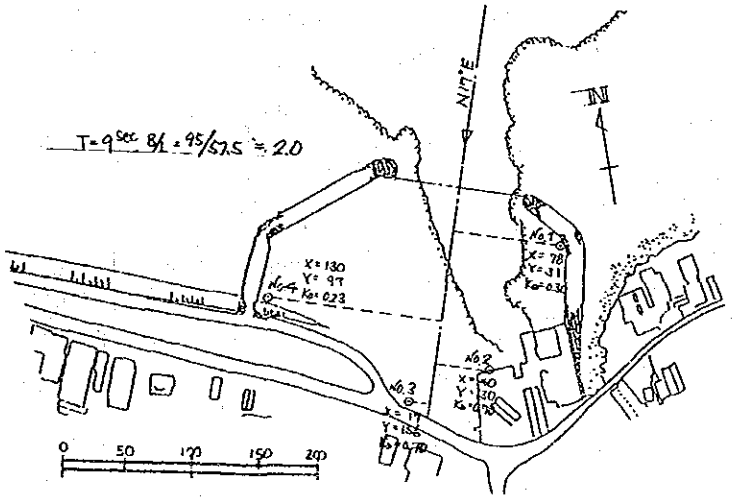


Fig. 8-6-14, Grid and Diffraction, Case "Present"
T = 9 sec., N17°E

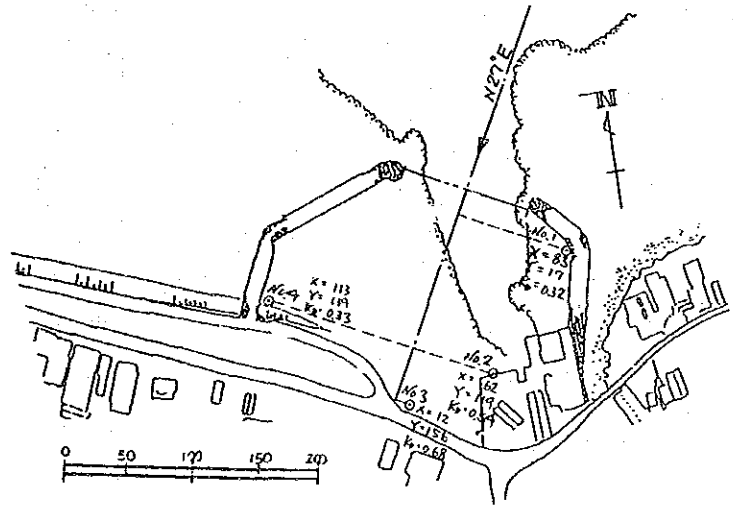


Fig. 8-6-15, Grid and Diffraction, Case "Present"
T = 11 sec., N27°E

ii Wave Occurrence by Wave Direction/Period

Wave occurrence at the observation points by wave direction and period can be obtained multiplying figures in Table 8-6-10 by KD·Ks in Table 8-6-11.

Table 8-6-12 shows wave occurrence by wave period at the specified four point.

Table 8-6-12 Wave Occurrence inside Avarua: Case "Present"

Pt - No. 1

T (sec)	7		9		11	
	K = 0.25		K = 0.33		K = 0.39	
H (m)	KH	Ni	KH	Ni	KH	Ni
0.5 ~						
0.6 ~						
0.7 ~					0.27~	0.6
0.8 ~			0.26~	-	0.31~	0.3
0.9 ~	0.23~	-	0.30~	-	0.35~	0.1
KH ≧ 0.3 m		-		-		0.5
KH ≧ 0.3 m = 0.5 %						

Pt - No. 2

T (sec)	7		9		11	
	K = 0.38		K = 0.77		K = 0.66	
H (m)	KH	Ni	KH	Ni	KH	Ni
0.5 ~			0.39~	-	0.33~	4.1
0.6 ~			0.46~	-	0.40~	1.0
0.7 ~	0.27~	-	0.54~	-	0.46~	0.6
0.8 ~	0.30~	-	0.62~	-	0.53~	0.3
0.9 ~	0.34~	-	0.69~	-	0.59~	0.1
KH ≧ 0.3 m		-		-		4.1
KH ≧ 0.3 m = 4.1 %						

Pt - No. 3

T (sec)	7		9		11	
	K = 0.65		K = 0.77		K = 0.84	
H (m)	KH	Ni	KH	Ni	KH	Ni
0.5 ~	0.33~	-	0.39~	-	0.42~	4.1
0.6 ~	0.39~	-	0.46~	-	0.50~	1.0
0.7 ~	0.46~	-	0.54~	-	0.59~	0.6
0.8 ~	0.52~	-	0.62~	-	0.67~	0.3
0.9 ~	0.59~	-	0.69~	-	0.76~	0.1
KH ≧ 0.3 m		-		-		4.1
KH ≧ 0.3 m = 4.1 %						

Pt - No. 4

T (sec)	7		9		11	
	K = 0.42		K = 0.25		K = 0.41	
H (m)	KH	Ni	KH	Ni	KH	Ni
0.5 ~						
0.6 ~						
0.7 ~	0.29~	-			0.29~	0.6
0.8 ~	0.34~	-			0.33~	0.3
0.9 ~	0.38~	-			0.37~	0.1
KH ≧ 0.3 m		-		-		0.6
KH ≧ 0.3 m = 0.6 %						

Note: Figure here is accumulated occurrence.
K = KD·Ks, Ni in percent.

From the Table 8-6-12 the port workability at each observation points will be as follows:

Point	Workability
No. 1	99.5 %
No. 2	95.9 %
No. 3	95.9 %
No. 4	99.4 %
Average	97.6 %

It is recommended to maintain workability in the marina 95% or more. Thus, it can be said that breakwater layout Case "Present" is not suitable. The existing breakwater should be rearranged for the better port quality.

Case "Extension"; Improved breakwater arrangement, Fig. 8-6-9.

Fig. 8-6-16 ~ 8-6-18 show new breakwater arrangement. As seen in the figure, diffraction coefficient KD is small due to narrow port entrance against the prevailing wave directions, by the extension of east breakwater.

Table 8-6-13 shows KD and KS.

Table 8-6-13 KD and KS; Case "Extension" Avarua Harbour

Wave Dir.		N39°E	N17°E	N27°E
T (sec.)		7	9	11
Pt. No.	1	0.15	0.20	0.22
	2	0.25	0.34	0.29
	3	0.28	0.50	0.35
	4	0.25	0.25	0.29
Ks		1.00	1.10	1.23

As seen in the table, only waves with 7 second period can be larger than the limit wave, 0.3 meter. Thus waves of 9 and 11 sec period larger than the limit height are considered for calmness analysis.

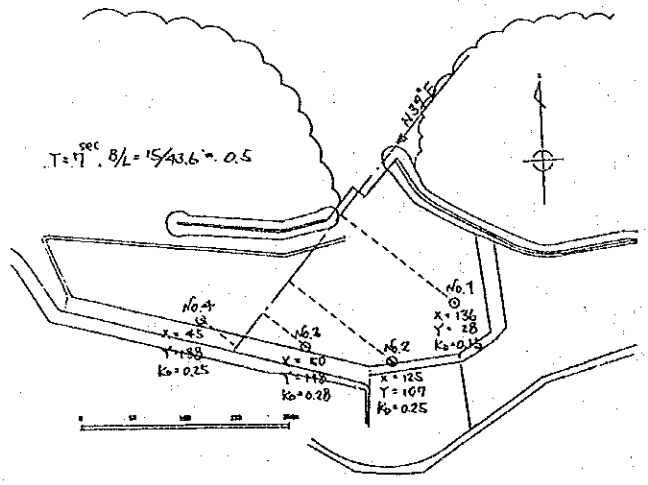


Fig. 8-6-16, Grid and Diffraction, Case "Extension"
T = 7 sec., N 39° E

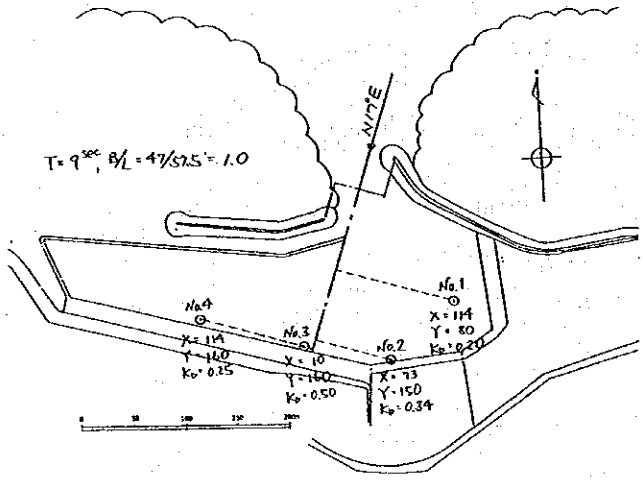


Fig. 8-6-17, Grid and Diffraction, Case "Extension"
T = 9 sec., N 17° E

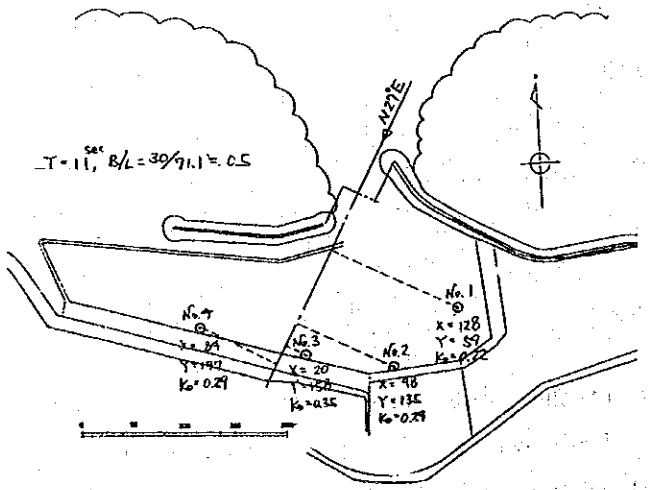


Fig. 8-6-18, Grid and Diffraction, Case "Extension"
T = 11 sec., N 27° E

Table 8-6-14 Wave Occurrence inside Avarua; Case "Extension"

Pt - No. 1						
T (sec)	7		9		11	
	K = -		K = 0.22		K = 0.27	
H (m)	KH	Ni	KH	Ni	KH	Ni
0.5 ~						
0.6 ~						
0.7 ~						
0.8 ~						
0.9 ~						
KH ≧ 0.3 m		-		-		-
KH ≧ 0.3 m = 0 %						

Pt - No. 2						
T (sec)	7		9		11	
	K = -		K = 0.37		K = 0.36	
H (m)	KH	Ni	KH	Ni	KH	Ni
0.5 ~						
0.6 ~						
0.7 ~						
0.8 ~			0.30~	-	0.29~	0.3
0.9 ~			0.33~	-	0.32~	0.1
KH ≧ 0.3 m		-		-		0.2
KH ≧ 0.3 m = 0.2 %						

Pt - No. 3						
T (sec)	7		9		11	
	K = -		K = 0.55		K = 0.43	
H (m)	KH	Ni	KH	Ni	KH	Ni
0.5 ~			0.28~	-		
0.6 ~			0.33~	-		
0.7 ~			0.39~	-	0.30~	0.6
0.8 ~			0.44~	-	0.34~	0.3
0.9 ~			0.50~	-	0.39~	0.1
KH ≧ 0.3 m		-		-		0.6
KH ≧ 0.3 m = 0.6 %						

Pt - No. 4						
T (sec)	7		9		11	
	K = -		K = 0.28		K = 0.36	
H (m)	KH	Ni	KH	Ni	KH	Ni
0.5 ~						
0.6 ~						
0.7 ~						
0.8 ~					0.39~	0.3
0.9 ~					0.32~	0.1
KH ≧ 0.3 m		-		-		0.2
KH ≧ 0.3 m = 0.2 %						

Note: Figure here is accumulated occurrence.
K = KD-KS, Ni in percent.

Pt No.	No. 1	No. 2	No. 3	No. 4	Average
Workability	100 %	99.8 %	99.4 %	99.8 %	99.7 %

Port workability in Case "Extension" is 99 % or more at every points and better than Case "Present", that it is also confirmed that extension of breakwater proposed here is a suitable scale and not over investment.

Table 8-6-15 shows difference of two schemes in respect to wave calmness during the normal climatic condition.

Table 8-6-15 Comparison of Calmness

Unit: %

Observation Point		Present	Extension	Balance
No.1	East Wharf	99.5	100.0	+0.5
No.2	South-East Corner	95.9	99.8	+3.9
No.3	South Wharf	95.9	99.4	+3.5
No.4	South Wharf	99.4	99.8	+0.4
	Average	97.6	99.7	+2.1

As seen in the table, calmness improvement by breakwater extension can be achieved.

8.7 Basic Layout of Avatiu Harbour

8.7.1 Formulation of Alternatives

It is not recommended to move the deep-sea berths at Avatiu Harbour to a new location because the construction cost would be very high. The LPG tanks, which handle for dangerous stuff, should be moved from the center to outside of the port. This measure would eliminate the possibility of major damage in the event of an explosion.

According to the cargo forecast in section 8.3, the volume of the container cargoes will reach about 26 thousand tons in the target year of the Master Plan, about 1.5 times larger than at present. Therefore, the container storage yard should be expanded and the CFS should be relocated behind the deep-sea wharves.

The function of the fishery port will be established at the Western side of Avatiu Harbour. The facilities of the fishery port consist of the landing wharf, the lay-by wharf, the fish market hall including parking space, ice-making plant, maintenance shop with slip way and other necessary open space which consists of the drying area used for fishing nets and the space of refuge for fishing boats during cyclone.

If the breakwater at the east side of Avatiu Harbour is not improved, the area of the fishery port is directly exposed to large waves because the direction of the prevailing waves at the harbour is ENE. So, the East breakwater will have to be expanded to ensure calmness in the western port basin.

There are two improvement alternatives concerning the configuration of the East breakwater as shown in Fig. 8.7.1 and Fig 8.7.2.
There is no large difference in the effects of breakwaters between case 1 and case 2.

For case 1 in Fig. 8.7.1, the construction cost of the breakwater is slightly larger than case 2 in Fig. 8.7.2 because of its greater length and the reclamation work arising from the configuration of the breakwater. But the reclamation area is very useful as a location for the empty containers.

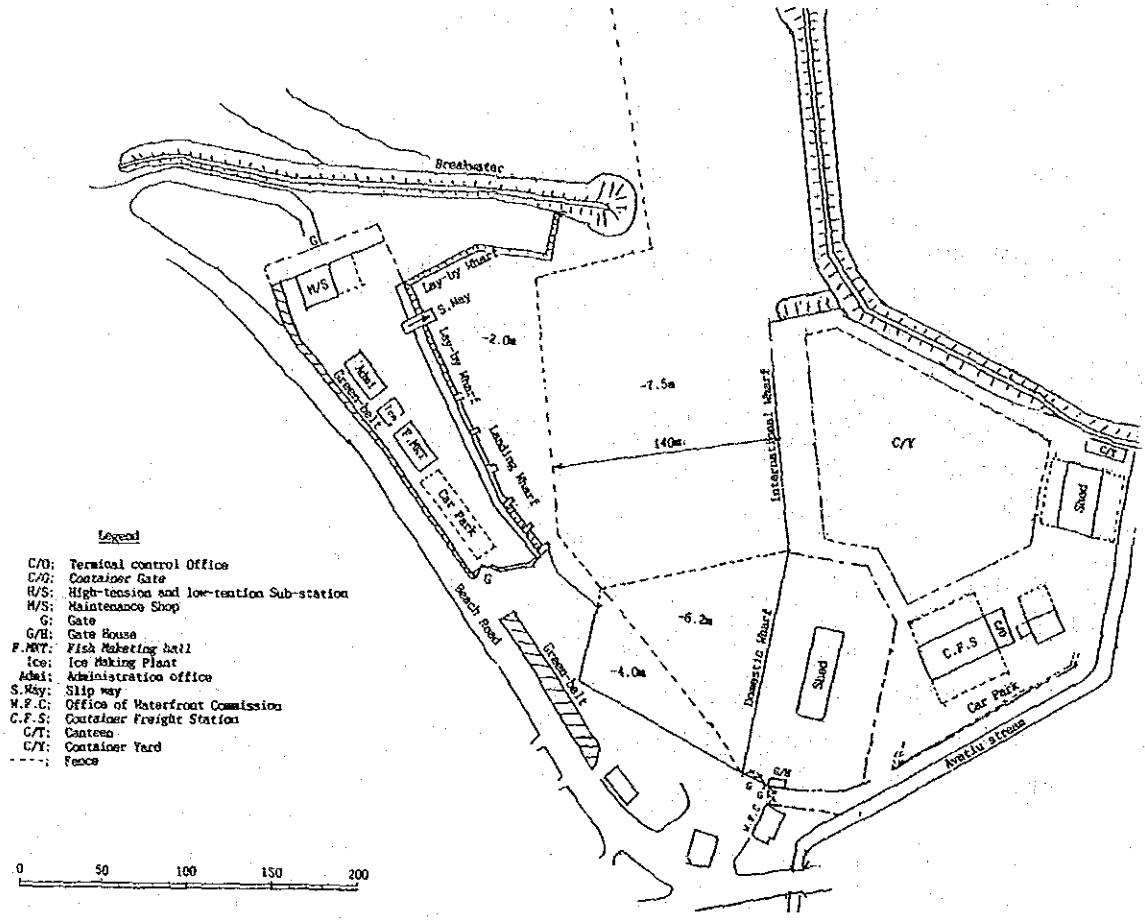


Fig. 8-7-1 Master Plan : Case - 1

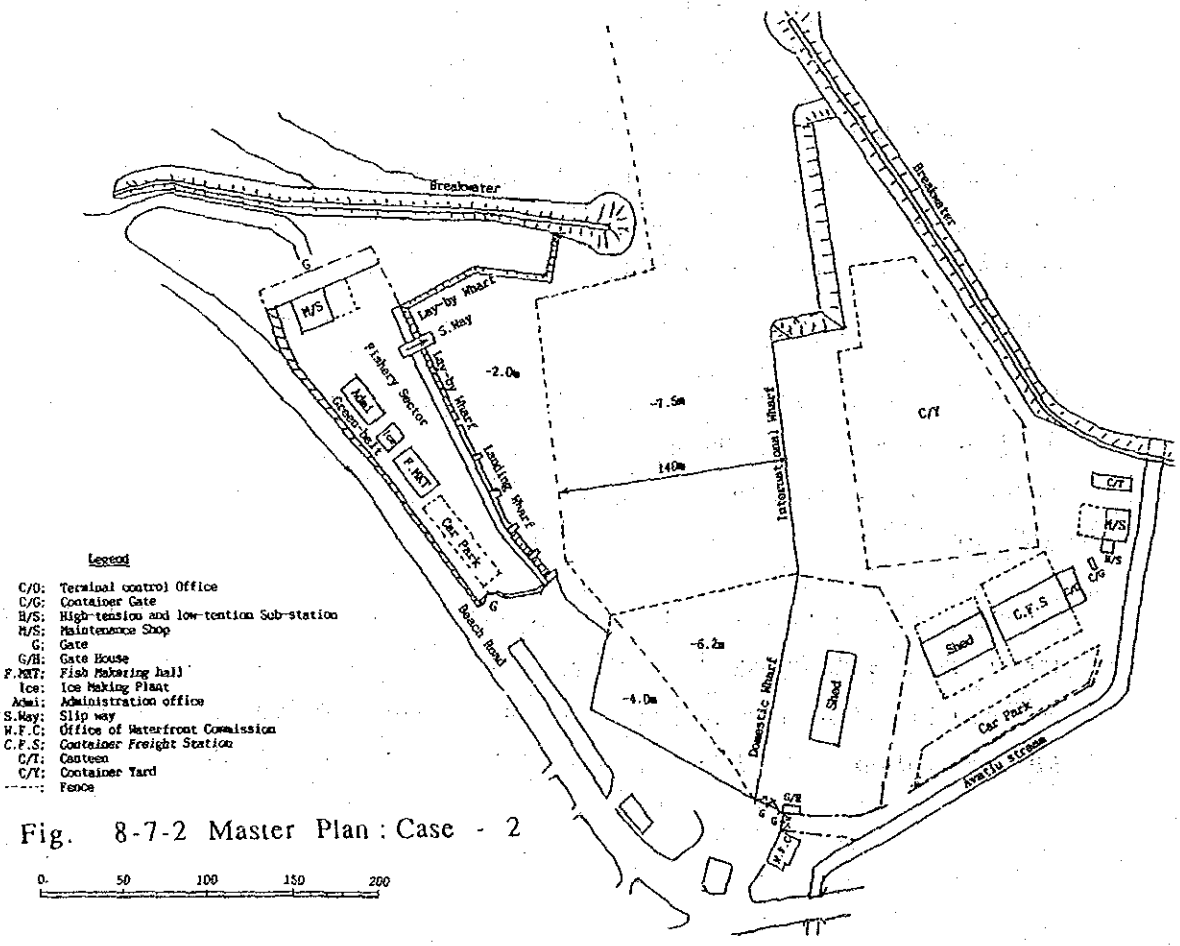


Fig. 8-7-2 Master Plan : Case - 2

8.7.2 Rough Cost Estimate

A summary of the construction costs for case 1 and case 2 is shown in Table 8-7-1.

Table 8-7-1 Summary of Construction Cost

(Unit : 1000 NZ$)

	Case 1	Case 2
Breakwater	3,567	2,465
Dredging	6,600	6,600
Reclamation in east B/W	168	0
Reclamation in west B/W	108	108
Quay wall	2,293	2,293
Container Facilities	4,384	4,384
Pavement for Domestic	680	680
Fisheries facilities	190	190
Others	500	500
Total	18,490	17,170

8.7.3 Evaluation

Table 8-7-2 shows the comparison of the alternatives.

Table 8-7-2 Comparative Table of Alternatives

Items	Case 1	Case 2
Construction cost	B	A
Calmness at the basin and the port entrance	A	B
Effect on the cargo handling	A	B
Total evaluation	A	B

Note: A: preferable, B: Normal

According to the comparative table, the construction cost of case 1 is higher than case 2. But, the difference is about 1,320 thousand NZ$, which is not large because it represents only about 7.7 percent of the total construction cost of case 2.

There is a little difference in the calmness at the basin between the two cases, however, it is slightly calmer at the port entrance in case 1.

There is a slightly greater effect on the cargo handling in case 1 because it has a larger area.

Based on the above evaluations, case 1 is judged better than case 2.

8.8 Basic Layout of Avarua Harbour

The development of a marina at Avarua Harbour will begin in earnest in the Master Plan stage. In the Short term development plan, a marina facility will be developed at Avarua Harbour to complement the function of Avatiu Harbour based on the port traffic forecast in section 8.3.

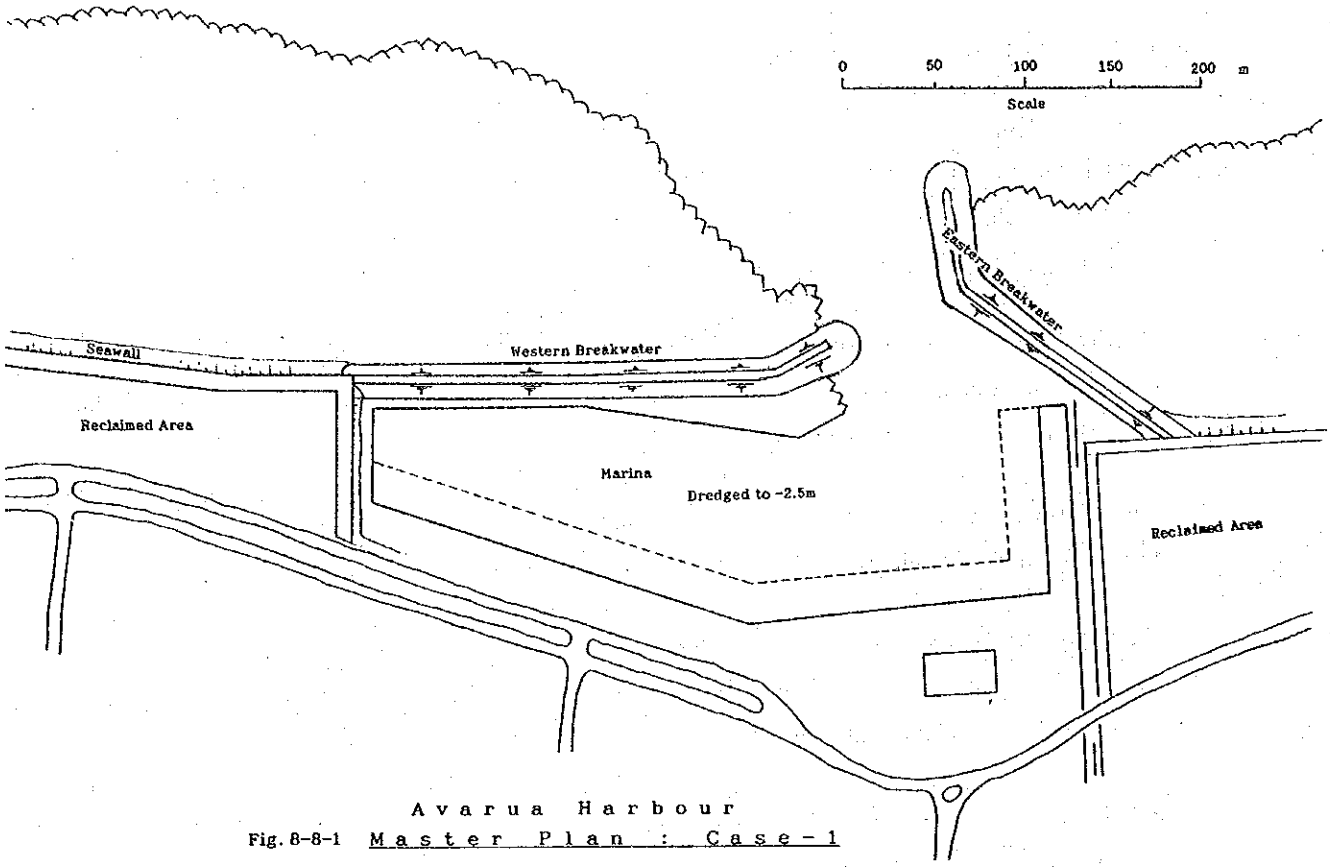
While, this area is selected as the urban areas where should provided by caostal protection works. This port area is selected in the coast where the urgent coastal protection is required.

Thus it is assumed that the coastal protection works should be arranged in the appropriate Master Plan of Avarua Harbour.

Accordingly, two alternative layout plans have been prepared. Figs. 7-26 and 7-27 show these alternatives together with general arrangement of the Port Park Complex and Avatiu Harbour.

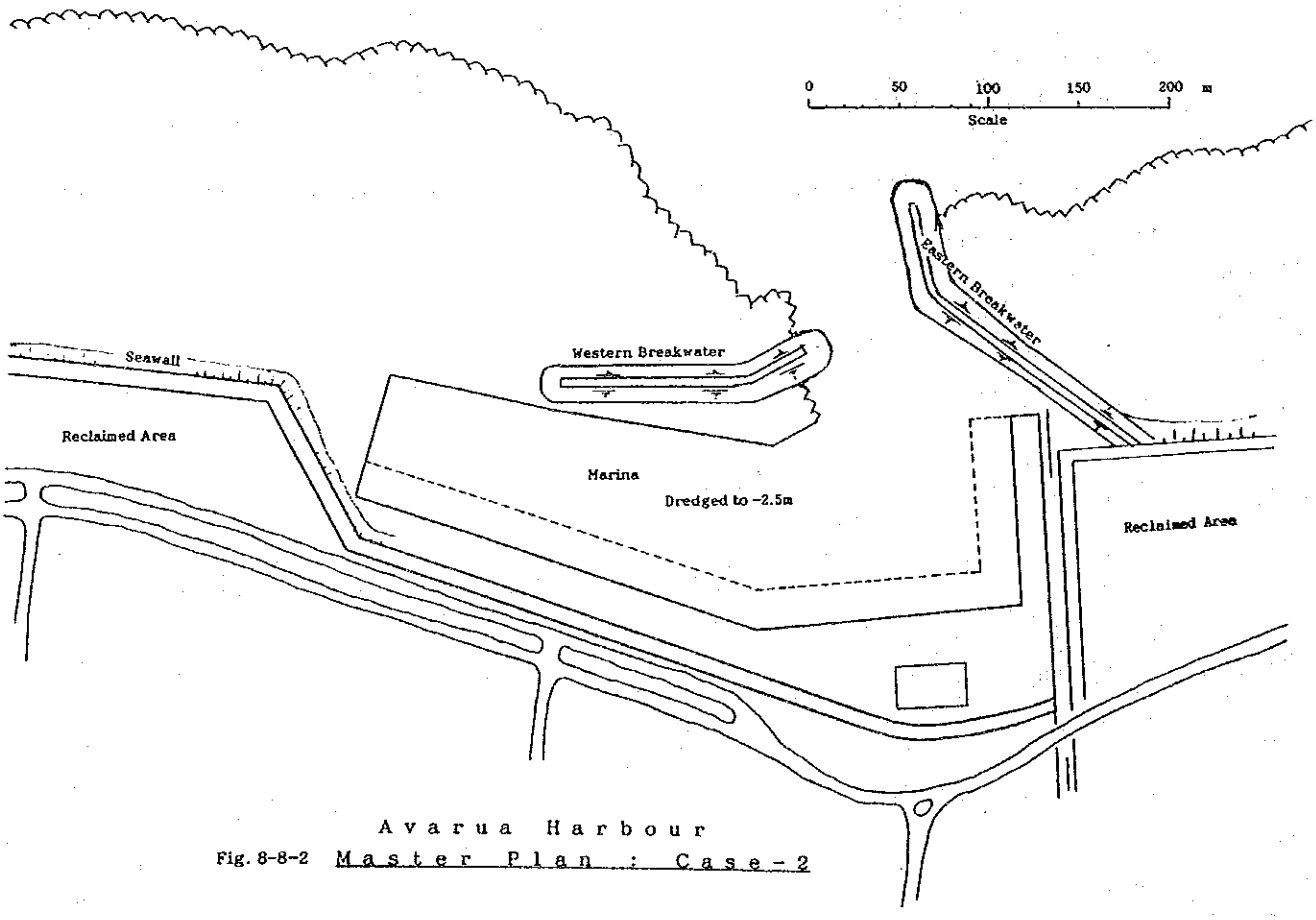
According to the projection of Port facility requirement in section 8.4, the required length of the quay wall for the yacht harbor is approximately 380 meters in year 2010. The required breadth of the channel is 1.5 times the length of the yacht. Therefore, the breadth of the channel is approximately 30 meters. Fig. 8-8-1 and 8-8-2 show the alternatives of the Master Plan for Avarua Harbour.

The study team proposes Case-2 for further study. Related discussion is made in section 10.4.



Avarua Harbour

Fig. 8-8-1 Master Plan : Case-1



Avarua Harbour

Fig. 8-8-2 Master Plan : Case-2

8.9 Basic layout of Port Park Complex

The Port Park Complex is defined as the reclaimed area between Avatiu Harbour and Avarua Harbour, excluding the ports area. The configuration of the reclamation area is determined by the requirement of coastal protection. Therefore, the land use plan is emphasized in this section.

Most important facility proposed for the coastal protection is a geavy seawall which is installed about 50 meters seaward from the existing coast. Behind the new seawall, a cylone buffer zone, public space and port expansion area will be established after reclamation.

Government officials of the Cook Islands recommended constructing a buffer zone. They also mentioned that the construction of large buildings, such as a hotel, a office and a large shop in the buffer zone is unsuitable because of the danger of unexpected large cyclones and the fact that these buildings would obstruct the current beautiful and natural view.

Therefore, a green belt entailing a beautiful park with a small nice restaurant and the required facilities for inland public transportation such as a bus terminal and parking area is scheduled in the Master Plan. The establishment of the parking area is priority because the parking area behind Avarua Harbour is insufficient to meet current demand. The required area for parking is calculated using the following formula.

$An = A \times N$

$N = Ns + (Nl \times a)$

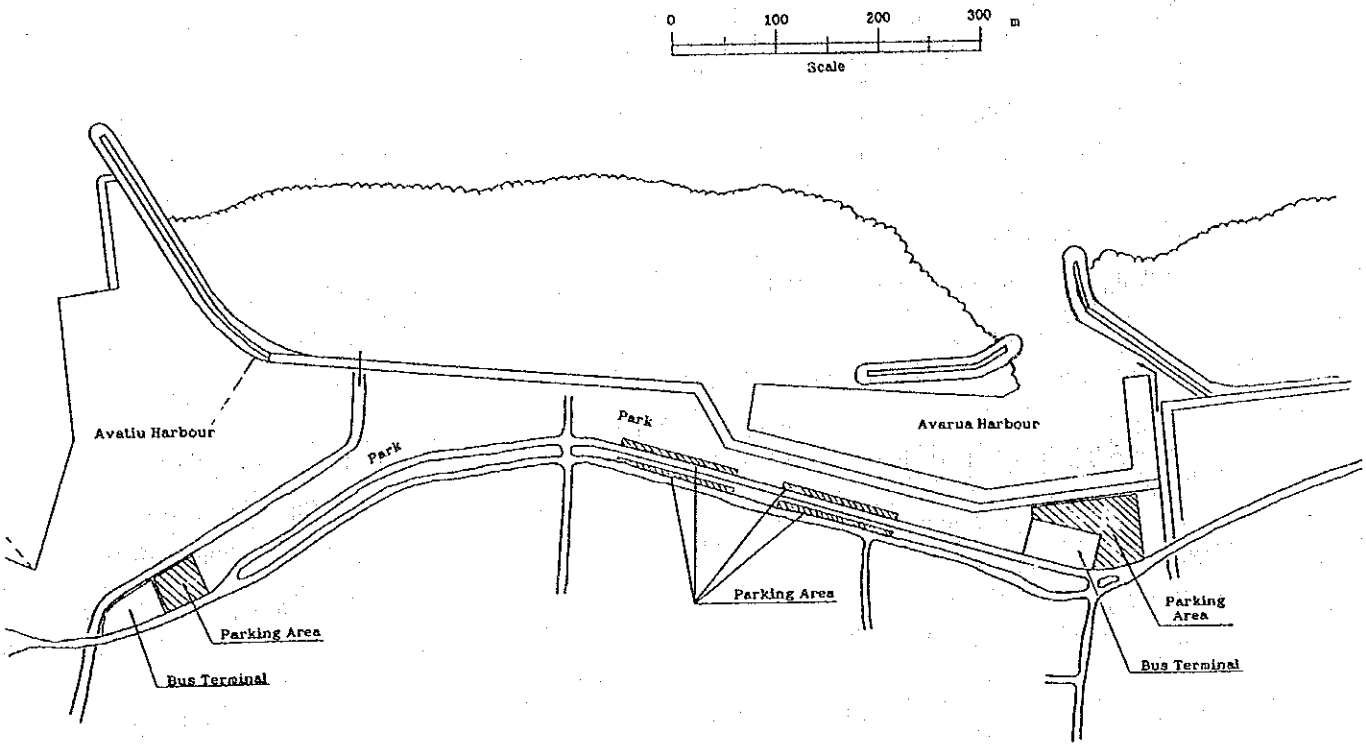
Where,
- An: Required parking area (sq.m)
- N: Number of parked cars (equivalent to small car) (270 cars)
- A: Required area for small parked cars (16.9 sq.m)
- Ns: Number of parked small cars (176 cars)
- Nl: Number of parked large cars (24 cars)
- a: Conversion facter (3.76)

$An = 16.9 \times 270 = 4,563\ m^2$

$N = 176 + (24 \times 3.76) = 226 \fallingdotseq 270$

The land use of the port park complex area in the Master Plan is shown in Fig. 8-9-1.

Fig. 8-9-1 Port Park Complex



8.10 Summary of Port Improvements

8.10.1 Master Plan Layout

Master Plan layout is shown in Fig. 7-27.

8.10.2 Required Facilities

The summary of the required facilities and cargo handling equipment in the Master Plan is shown in the following table.

Table 8.10.1 Summary of Main Port Facilities and Handling Equipment

Items	Quantity	Note
Avatiu Harbour		
Deep-sea Area		
Quay wall (-7.5 m)	139 m	
(-6.2 m)	125 m	
(-4.0 m)	115 m	
CFS	880 sq.m	
Cargo shed (No.1)	610 sq.m	
(No.3)	920 sq.m	
Container yard	11900 sq.m	
Maintenance shop	250 sq.m	including canteen
Fishing Port Area		
Landing wharf (-1.5 m)	50 m	
Lay-by wharf (-1.5 m)	180 m	
Facility of Ice maker	75 sq.m	
Sorting area, Market Hall	200 sq.m	
Maintenance shop	380 sq.m	as it is.
Slipway	1	
Eastern breakwater	310 m	
Western breakwater	240 m	
(Equipment)		
Tractor-trailer	2 sets	
Forklift 32 tons	3	
2.5 tons	6	
5 tons	4	

Items	Quantity	Note
Avarua Harbour		
Marina (Yacht harbor)		
Quay wall (-2.5 m)	380 m	
Club house	200 sq.m	
Eastern breakwater	110 m	
Western breakwater	140 m	
Port Park Complex		
Bus terminal at Avatiu	1,800 sq.m	
Bus terminal at Avarua	1,800 sq.m	
Parking Area	4,500 sq.m	

Note: Equipment cost is excluded from the cost estimation.

8.11 Rough Design of Port Facilities

Port improvement works for the two harbours have been designed based on past experience in similar projects and design condition as follows:

a) Breakwaters

Breakwater alignment has been arranged to provide required wave calmness in the port basin. Length of breakwaters are also scheduled to provide enough stopping distance for calling vessels.
Breakwater structure is designed to provide enough resistance against the design waves.

Special consideration on structural strength was given to the East Breakwater extension has been made in Avatiu Harbour, since the head of it will stand out of reef edge.

b) Wharf -7.5m in Avatiu Harbour

The main wharf at Avatiu Harbour (264 meters long) will be dredged to -7.5 meter depth from the existing -6.2 meter to accommodate large vessels. Steel sheet pile wall is recommended for this purpose.

c) Repairing of the existing -6.2m wharf in Avatiu Harbour

Repair works to the existing -6.2m wharf will be included in the Short-Term Plan. Repair works have have been completed, however, there are large gaps between the concrete sheet pile units. It is recommended to conduct periodical observation of the existing wharf to monitor damage before an entire reconstruction.

d) Wharf -2.5 m in Avarua Harbour

Wharf in Avarua Harbour will be gravity type sine the foundation soil is coral rock which is hard enough to carry structure. When necessary combined structure between rock mound and jetty.

e) Pavement

Asphalt pavement in this port is recommended in general. However concrete pavement should be provided in following areas.

- Wharf apron
- Maintenance shop area
- Loading point of containers.

8.12 Preliminary Cost Estimation

This section deals with the cost estimation for the port improvement works proposed in the Master Plan. Basic condition of cost estimates is similar to those for coastal protection works, as shown in subsection 7.9.2.

8.12.1 Unit Direct Cost

Unit cost for major work items are as follows.

Table 8-12-1 Unit Direct Cost for Port Improvement

No.	Work Item	Unit Direct Cost	Remarks
1.	Rock mound	64 $/m³	On the lagoon
2.	Rock mound	81 $/m³	Submerged
3.	Relocation of existing Breakwater	34 $/m³	
4.	Extension of breakwater (Avatiu East)	48,900 $/m	Concrete block type on rubble mound
5.	Same but Avarua	15,000 $/m	Concrete block type on rubble mound
6.	Dredging moderate materials	30 $/m³	Coral and sand in harbour basin
7.	Dredging hard coral bed	57 $/m³	Including blasting
8.	Reclamation	6 $/m³	by dredged material
9.	Reclamation	10 $/m³	from borrow area
10.	Quay Wall (-7.5 m)	6,750 $/m	Steel sheet pile wall
11.	Quay Wall (-1.5 m)	3,300 $/m	Fish landing wharf
12.	Quay Wall (-1.5 m)	1,850 $/m	Lay-by wharf
13.	Temporary Staging, Avatiu (-7.5 m)	7,220 $/m	Open structure
14.	Marina wharf (-2.5 m)	3,500 $/m	Gravity wall

8.12.2 Summary of Costs

Port improvement works are divided into two ports, namely works for Avatiu Harbour and Avarua Harbour. Total costs are shown in the table below.

Table 8-12-2 Cost Summary of Port Improvement in Master Plan

Unit Dollars

Port	Direct Cost	Total Cost
Avatiu	20,394,000	24,575,000
Avarua	7,065,000	8,513,000
Total	27,459,000	33,088,000

Note, Total cost = 1.205 x Direct cost.

1) Necessary Direct Cost for Avatiu Harbour

Table 8-12-3 shows breakdown of direct cost required for Avatiu Habour improvement.

Table 8-12-3 Preliminary Direct Cost Estimates for Avatiu Harbour Improvement

Work	Items	Q'ty	U. Price	Amount	Remarks
1.	Breakwater			($3,567,000)	
1-1	Upgrading of West B/W	240 m	$3,200	$768,000	
1-2	Relocation of East B/W	160 m	1,350	216,000	
1-3	Extension of East B/W (1)	120 m	9,300	1,116,000	Reef edge
1-4	Extension of East B/W (2)	30 m	48,900	1,467,000	B/W tip on deep sea
2.	Dredging			($7,500,000)	
2-1	Dredging by clamshell	50,000 m^3	$30	$1,500,000	-6.2m to -7.5m
2-2	Dredging with Blasting	100,000 m^3	60	6,000,000	Dreading of Lagoon to -7.5m or-1.5m

Work	Items	Q'ty		U. Price	Amount	Remarks
3.	Reclamation				($276,000)	Material from dredging
3-1	Recl. in East B/W	28,000	m^3	$6	$168,000	
3-2	Recl. in West B/W	18,000	m^3	6	108,000	Fisheries
4.	Quay Wall				($3,146,400)	
4-1	Upgrading of Commercial Quay	264	m	$6,750	$1,782,000	to -7.5m
4-2	Fish Landing	50	m	3,300	165,000	-1.5m
4-3	Lay-by Wharf	180	m	1,850	333,000	-1.5m
4-4	Temporary Wharf (Commercial Quay)	120	m	7,220	866,400	Avatiu
5.	Other Civil Works				($1,580,000)	
5-1	Relocation of Month of Avatiu Strm.	350	m	$4,000	$1,400,000	
5-2	Extra Reclamation on East Avatiu	30,000	m^3	6	100,000	Heightening for New Port area
6.	Container Handling Facilities				($3,635,500)	
6-1	Container Yard	11,900	m^2	$100	$1,190,000	
6-2	CFS (Including Terminal control office)	880	m^2	800	704,000	incl. office
6-3	transit shed	1,530	m^2	500	765,000	
6-4	Maintenance Shop	170	m^2	500	85,000	
6-5	Canteen	180	m^2	500	40,000	
6-6	Apron Pavement	5,120	m^2	100	512,000	
6-7	Other Pavement	6,790	m^2	50	339,500	
7.	Fisheries Facilities				($190,000)	
7-1	Market Hall	200	m^2	$400	$80,000	
7-2	Ice Making Plant	75	m^2	1,200	90,000	incl. office
7-3	Maintenance shop	(as it is)				
7-4	Slipway	1	nos.	20,000	20,000	
8.	Others				($500,000)	
8-1	Relocation of Oil Tank	1	LS.	$500,000	$500,000	
	Grand Total				$20,394,900	

2) Necessary Direct Cost for Avarua Harbour

Table 8-12-4 shows breakdown of direct cost required for Avarua Harbour improvement.

Table 8-12-4 Preliminary Direct Cost Estimation for Avarua Harbour Improvement

Work	Items	Q'ty	U. Price	Amount	Remarks
1.	Breakwater			1,093,000	
1-1	Relocation of West B/W	100 m	1,350	135,000	
1-2	Extension of West B/W	40 m	10,000	400,000	
1-3	Relocation of East B/W	80 m	1,350	108,000	
1-4	Extension of East B/W	30 m	15,000	450,000	
2.	Dredging			2,520,000	
2-1	Dredging with blasting -2.5	12,000 m^3	60	720,000	100 x 60 x 2.0
2-2	Dredging -2.5	30,000 m^3	60	1,800,000	250 x 60 x 2.0
3.	Reclamation	48,000 m^3	6	288,000	400 x 30 x 4.0
4.	Quay Wall			1,494,000	
4-1	Quay Wall -2.5	210	3,500	735,000	130 + 80
4-2	Quay Wall -2.5	230	3,300	759,000	
5.	Other Civil Works			1,070,000	
5-1	Relocation Stream	160	2,000	320,000	
5-2	Pavement	7,500 m^2	100	750,000	500 x 15
6.	Building			400,000	
6-1	Office, Club House	200 m^2	1,000	200,000	
6-2	Utility	L.S	1	200,000	
7.	Others	L.S	1	200,000	
	Grand Total			7,065,000	

Chapter 9: Cost Summary for Master Plan Stage

Chapter 9 Cost Summary for Master Plan Stage

This chapter deals with the cost summary which may be required for the coastal protection work together with port improvements for the year 2010.

9.1 Construction Cost Summary

The total cost is an accumulated construction cost for the coastal protection as shown in section 7.9 and the port improvements as shown in section 8.12. The required investment for the year 2010 will be 60.9 million dollars at 1992 current prices.

Sectorial breakdown of the costs is shown in table below.

Table 9-1 Total Construction Cost: Master Plan 2010

Sectors	Cost
Coastal Protection	27.8 million Dollars
Port Improvement	33.1 million Dollars
Total	60.9 million Dollars

The coastal protection cost here will cover about 39% of the coastal areas to be protected, while the port improvement will involve the existing two ports, Avatiu and Avarua.

Similar to subsection 7.9.2, the following conditions were considered when preparing the cost estimates:

a) Land cost was excluded.
b) Taxes were excluded.
c) Unit price was based on the current price and information provided by MOW, TLT and others.
d) Engineering cost are included as eight percents of the construction costs.
e) Physical contingency is included as twelve percent of the construction costs.
f) Training costs are included as 0.5 percent of the construction cost.

9.2 Major Project Components Proposed

The following works is proposed to be included in the Master Plan for the year 2010.

9.2.1 Coastal Protection

Coastal protection work will be undertaken at the coast of 5,468 m long.

1) Zone One: Urban Area

- Gravity seawall in 870 meter long with on-land buffer zone together with plantation with dike

2) Zone Two: Rural Area "A" (Existing beach road within 30 m from beach top)

- Flexible hollow slope in 500 meter long
- 585 meter long flexible gabion slope

3) Zone Three: Tourism Area

- Stepped slope in 280 meter long with gbion, beach nourishment and artificial passage
- Flexible gabion slope in 140 meter long with groin and beach nourishment

4) Zone Four: Rural Area "B"

- Rock mound seawall in 2,322 meter long with plantation with dike
- 555 meter long flexible hollow slope
- 216 meter long groin

9.2.2 Port Improvement

1) Avatiu Harbour

a) Breakwaters

- West breakwater 240 meter
- East " 310 meter

b) Dredging 150,000 cu. meter

c) Reclamation 76,000 cu. meter

d)	Quay Wall	
-	Quay wall -7.5m	264 meter
-	" -1.5m	230 meter
-	Temporary wharf -7.5m	120 meter
e)	Avatiu Stream Relocation	350 meter
f)	Container Yard	11,900 sq. meter
g)	CFS and Transit shed	2,410 sq. meter
h)	Building works	250 sq. meters
i)	Pavement	11,910 sq. meters
j)	*Fisheries*	
-	Market	200 sq. meters
-	Ice plant	25 sq. meters
-	Maintenance shop	as is
-	Slipway	1 unit
k)	Others	
-	Relocation of Oil Storage	1 unit

2) Avarua Harbour

a)	Breakwaters	
-	West breakwater	140 meter
-	East "	110 meter
b)	Dredging	42,000 cu. meter
c)	Reclamation	48,000 cu. meter
d)	Quay Wall(-2.5m)	440 meter
e)	Stream Relocation	160 meter
f)	Pavement	7,500 sq. meter
g)	Office	1 unit
h)	Utilities	1 unit
i)	Others	1 unit

9.3 Construction Period Required

It is estimated that the total period required to complete this work whole the works in Master Plan is four years if they are implemented during one stage.

Table 9-2 Construction and Disbursement Schedule

Sectors	Year				
	1	2	3	4	Total
1. Coastal Protection	7.0	7.0	7.0	6.8	27.8
2. Avatiu Harbour Improvement	9.0	9.0	6.6		24.6
3. Avarua Harbour Improvement				8.5	8.5
Annual expenditure in million dollars	16.0	16.0	13.6	15.3	60.9

However, work components which may require urgent implementation should be selected carefully.

The basic concept for selection of urgent works will be discussed in Chapter 10.

Chapter 10: Phased Development Plan

Chapter 10 Phased Development Plan

This chapter deals with the subdivision of the Master Plan into several parts considering urgent requirements. Selected priority components should be implemented even before the year 2010, because it is unknown when a younger sister of Sally will knock at the door.

10.1 General Description

According to the Master Plan cost estimates, it is proposed that an investment amounting to 60.9 million dollars should be made by the year 2010, 33.1 million dollars for port improvements and 27.8 million dollars for coastal protection. All of the port improvements will be made at two harbours, Avatiu and Avarua. The share of these two ports is 74 % and 26 % for Avatiu and Avarua respectively. Amount of the protection work for both the Avarua urban area and other rural areas will share 35.5 % and 64.5 % respectively.

The project contains various facilities from the construction of rock mound seawall to CFS for port facilities. (Note: CFS is container freight station.)

All the recommended works in the Master Plan are not necessarily given the same priority. Some work should be implemented urgently; however, other elements can be constructed later stage. As discussed in sections 7.8 and 8.10, the proposed work is combined with various components of different priorities.

In order to invest the limited resources effectively and to prevent the works from concentration in a short period, phasing of the work with proper arrangements should be scheduled.

10.2 Priority

The work is divided into two groups: Top Priority Group and Secondary Priority Group.

Character of Top Priority Works can be summarized as follows:

i) Protection work of high investment efficiency comparing the damage to be decreased and the necessary protection costs
ii) Any existing facility which can not be substituted by others if damaged by a cyclone
iii) Any existing facility already being damaged requiring urgent repairs because there is no other choice
iv) Any existing facility where the safety of the users can not be ensured

The scope of Top Priority Works to meet with above criteria is as follows:

a) Of the places where excessive wave overtopping by a Sally class cyclone is expected, the existing facilities properties are important and can not be substituted by others

- Private facilities along the beach road in Avarua Urbanized Areas
- Government offices and facilities along the beach road in the same
- Port facilities in Avatiu Harbour
- Fuel storage facilities near the airport
- Other the same

b) Of the places where excessive coastal erosion by a Sally class cyclone is expected, the existing facilities are important and can not be substituted by others

- Private and public facilities located immediately eastward of Avarua Harbour
- Airport runway at the westward end constructed on the reclaimed land
- Other the same

c) Of the existing port facilities, those that should be provided with urgent repair work:

- Repair work to the damaged quaywall at Avatiu Harbour
- Widening of the turning basin in Avatiu Harbour
- Fishery facilities in Avatiu Harbour
- Port facilities in Avarua Harbour
- Other the same

It is recommended that these works should be urgently implemented for sustaining the development of island. As the conclusion, the Top Priority Groups and the Second Priority Groups can be shown as below.

The former in coastal protection work is Disaster Grades I, II and III in the Avarua urban areas and its surrounding. The latter is other disasters.

While the former in the port improvement work is urgently required one in both Avatiu and Avarua Harbours. The latter is the remaining work in both Avatiu and Avarua Harbours.

10.3 Phased Development

The phased development plan has been prepared in order to implement gradually the Master Plan. Work components in the Master Plan have been classified into two phases.

Phase One

Work classified to meet the selection criteria for the Top Priority. These works will be included in the Short-term Development Plan to be excecuted by year 1997.

Phase Two

Remaining work components contained in the Master Plan and classified as the Secondary Priority.

Fig. 10-1 and 10-2 show the phased development plans for the coastal protection and port improvement respectively.

Coastal protection work in Phase One will concentrate on the northern coast from the eastern boundary at Village Puc to the west end of the existing airport. Among them, the Port Park Complex (defined as the Avarua coastal area between Villages Ngatipa and Avatiu) will be provided with continuous protection work. However, areas other than the Complex will partly be protected where required.

The port improvement work classified in Phase One will mainly be performed at Avatiu Harbour. Avarua Harbour will partly be improved as of the Phase One work.

Work components selected in Phase One must be those that will be evaluated by a feasibility study and will finally form the Short-term Development Plan of Coastal Protection and Port Improvement in Rarotonga Island.

10.4 Outline of the Short-term Development Plan

The detailed short-term plan should be justified by the feasibility study in Vol. II. For this purpose, the required cost will be compared with the benefit of the plan in order to evaluate the feasibility of the investment.

It is assumed that the work components proposed here for Phase One will be scheduled in the Short-term Plan. Thus this plan will be called as the Preliminary Short-term Plan.

The estimated total cost for the Preliminary Plan for the year 1997 is 21.1 million Dollars - 10.6 million Dollars for coastal protection and 10.5 million Dollars for port improvements.

The required construction period is estimated to be about three years. Thus, the work should commence prior to 1994.

1) Estimated Coastal Protection

The Preliminary Short-term Plan of coastal protection will concentrate on the northern coast of the island where major damage was inflict by Cyclone Sally.

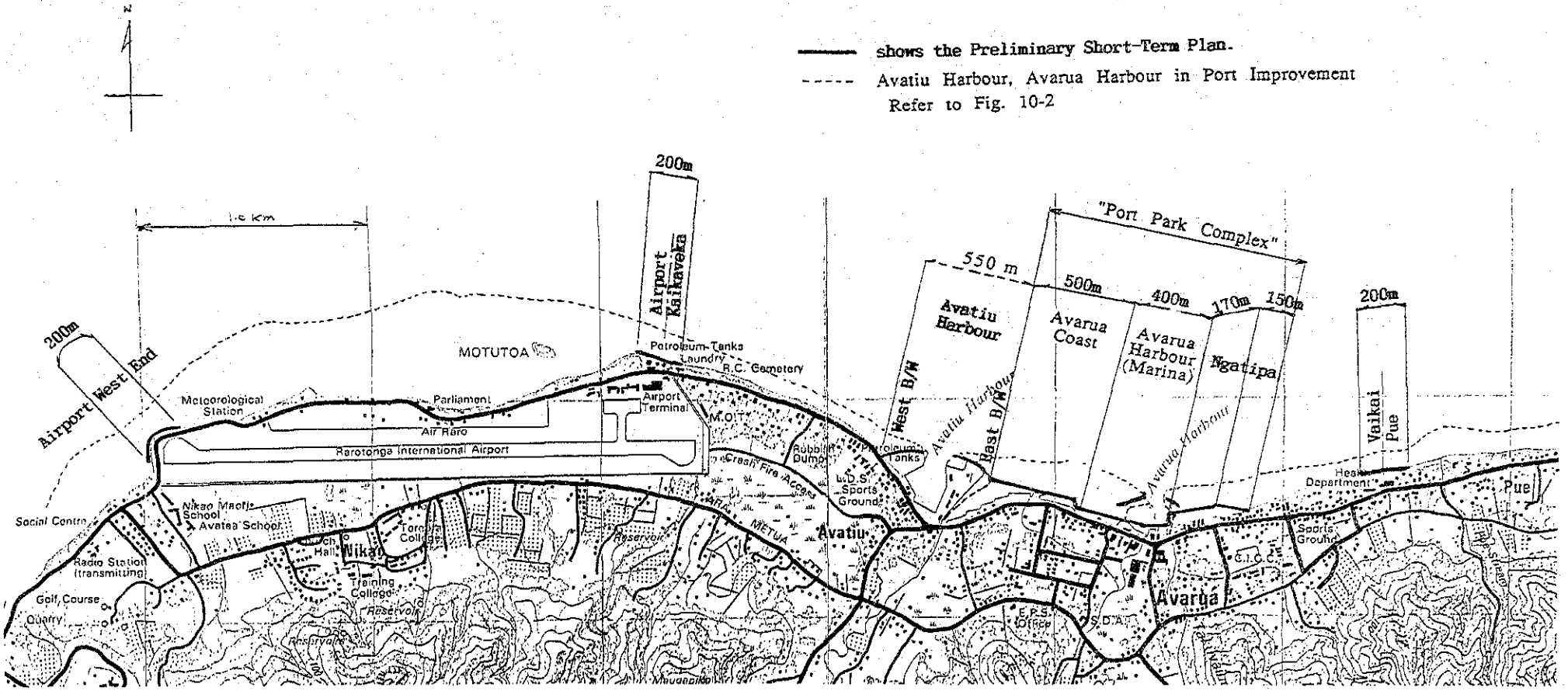
The total coast length to be protected is 1,420 meter long as shown in the Table below.

Table 10-1 Coast Length by Land Use and Disaster Grade

Land Use Zone	Coast Length (m)	Disaster Grade
Urban (1)	670	III for wave over-topping
Urban (2)*	(400)	III for wave over-topping
Rural	350	II for wave over-topping and beach erosion
Rural	400	III for wave over-topping
Total	1,420 meter	

Note: Urban (2) is the Avarua coastal area to be covered by the Avarua Harbour improvement works.

Fig. 10-1 Phased Development Plan : Coastal Projection, Phase One



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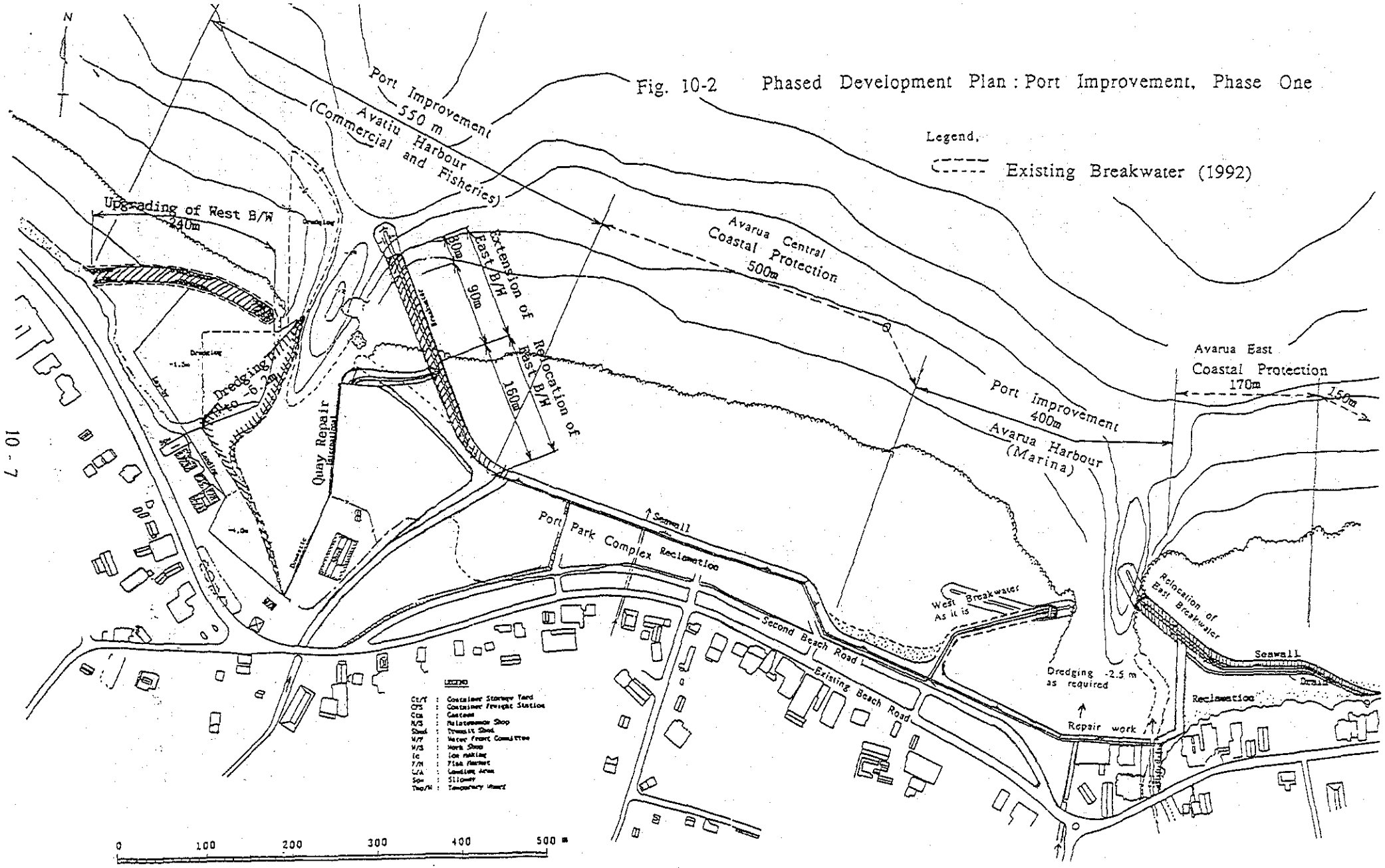

Fig. 10-2 Phased Development Plan : Port Improvement, Phase One

Table 10-2 shows the breakdown of the areas shown in Table 10-1. x

Table 10-2 Short-term Coastal Protection Areas

1) Village Matevera/Tupapa to mid of Village Pue
(No work will be made)

2) Mid of Village Pue to Village Ngatipa

V. Pue	100m	GII for Wave over-topping and Beach erosion
V. Vaikai	100m	GII for Wave over-topping and Beach erosion
V. Ngatipa	150m	GII for Wave over-topping and Beach erosion

3) Avarua-Ruatonga-Avatiu Areas, ---------- Port Park Complex

V. Ngatipa	170m	GIII for Wave over-topping, Urban (1)
Avarua	(400m)	GIII for Wave over-topping, Urban (2) by port sector
Avarua	500m	GIII for Wave over-topping, Urban (1)

4) Villages Atupa, Kaikaveka and "Airport" (200m of East end)

V. Atupa	100m	GIII for Wave over-topping
"Airport"	100m	GIII for Wave over-topping

5) West end "Airport" and Village Pokoinu

"Airport"	200m	GIII for Wave over-topping
V. Pokoinu	0m	GIII for Wave over-topping

The rough direct cost for the Preliminary Short-term Coastal Protection Plan is as follows:

Table 10-3 Rough Direct Cost : Preliminary Short-term Coastal Protection

unit : million Dollars

Land Use Zone	Disaster Grade	Coastal Length (m)	Unit Direct Cost ($/m)	Direct Cost	Remarks
Urban (1)	GIII	670	9,400	6.3	5,400 + 4,000
Urban (2)*	GIII	(400)	6,400	(2.6)	5,400 + 1,000
Rural	GII	350	3,100	1.1	2,400 + 700
Rural	GIII	400	3,400	1.4	2,400 + 1,000
	Total	1,420		8.8	

Note: Urban (2) should be covered by port improvement works.

Thus, the total direct cost for the Preliminary Short-term Coastal Protection Plan is 8.8 million dollars. The total coastal protection cost, after the indirect cost, will be:

8.8 x 1.205 = 10.6 million Dollars

2) Phased Development of Avarua Harbour

An entire improvement of Avarua Harbour will not be conducted during the Short-term Development Plan. Thus, an arrangement during the Short-term Plan will mainly be performed in respect to coastal protection. Systematical transformation of the existing Avarua Harbour into the Marina Port in Phase Two is studied.
For this purpose two alternative development sequences are given as below.

(a) Avarua Harbour Improvement Sequence, Case-P
This is a separate development among coastal protection and port improvement. Thus, seawall without breakwater will be constructed in Phase 1. Then new breakwaters will be provided with new Marina in Phase 2.

(b) Avarua Harbour Improvement Sequence, Case-H
This is a combined development between coastal protection and port improvement in order to prevent the investment from double construction. Thus, light seawall together with new breakwaters which meet with the Marina requirement will be constructed during the Phase 1 stage.

Avarua Harbour Short-term Plan Case P

i) An estimated 2.6 million Dollars will be invested to construct the heavy seawall having the required structural capability to provide protection from waves and surges without any assistance, such as from a breakwater.

ii) When it is decided to alter Avarua Harbour to a marina, the necessary investment for port facilities, including a breakwater, will be made.

iii) The seawall construction at the Phase 1 may cause a slight over-investment in respect to the coastal protection when Avarua Marina Harbour is protected by breakwaters in Phase 2.

iv) The initial cost is 2.6 million Dollars. An additional 7.1 million Dollars should be invested for the marina at a stage. Total investment 400 meter area in Avarua Harbour will be 9.7 million Dollars.

Avarua Harbour Short-term Plan Case H

i) The seawall and breakwater will be constructed at the outset. The former will be a lighter construction than in Case P due to wave energy absorption by the breakwaters. The latter will be constructed based on the master plan alignment; thus, neither breakwater modifications nor addition to will be necessary when the marina opens.

ii) When it is decided to alter the Avarua Harbour to a marina, the necessary investment for marina port facilities (excluding the breakwater) will be performed.

iii) Thus, the initial cost will be 2.9 million Dollars as shown in Table 10-4. An additional investment for the marina will be about 6.0 million Dollars. Total investment in the 400 meter area of Avarua Harbour will be 8.9 million Dollars.

Case H is proposed sequence for the Avarua Harbour Improvement Plan.

3) Port Improvement

The Preliminary Short-term Port Improvement Plan will concentrate on the facilities classified as Top Priority. It is understood that most of the existing Top Priority facilities are located in Avatiu Harbour. It is also understood that work concentration in one harbour is not to disperse the limited resources.

Thus, the Preliminary Short-term Port Improvement Plan is mainly for the urgent requirements in Avatiu Harbour.

However, Avarua Harbour will also be provided with urgently necessary work, although scale of work may be limited.

Urgent rehabilitation items of Avatiu Harbour may include;

i) Relocation (160 m) and extension (90 m) of the existing East breakwater

ii) Deepening the water depth for a safety turning basin to MSL-6.2 meter by dredging 30,000 m^3 coral bed

iii) Provision of urgent repair work to the existing 140 meter long international wharf

iv) Others

The estimated direct cost for Avatiu Harbour and Avarua Harbour Preliminary Short-term Plans are 5.81 million dollars and 2.90 million Dollars respectively as shown in Table 10-4.

Thus, the total cost, after the indirect cost, will be:

8.71 x 1.205 = 10.5 million Dollars

4) Modification of the plan

During the second visit of the study team to the island, discussions relating to these plans was conducted to fix the scope of work for the upcoming feasibility study.

During the discussion, the Committee basically agreed on the proposal. To extend Short-term Coastal Protection Plan at damaged coastal areas near the MET and the west end of runways was requested by the Committee based on the disasters by Cyclone Val/Wasa late of 1991.
The study team has agreed on the request and protection area was increased accordingly.
During the third visit, the study team was requested by the Committee to study an implementation of marina development of Avarua Harbour in early stage. The study team has agreed on the request.
Preliminary plans here will be refined into final plans by the feasibility study as shown in the Main Report, Volume II.

Table 10-4 Rough Direct Cost of Preliminary Short-term Port Improvement Plan

Unit : Dollars

Work Items	Quantity	Unit Direct Cost	Direct Cost
A. Avatiu Harbour			
1. Breakwater			-
1-1 Upgrading of West B/W	240 m	3,200	768,000
1-2 Relocation of East B/W	160 m	1,350	216,000
1-3 Extension of East B/W (1)	90 m	9,300	837,000
1-4 Extension of East B/W (2)	30 m	32,600	978,000
Subtotal			2,799,000
2. Dredging			
2-1 Dredging with blasting (-6.2)	40,000 m^3	60	2,400,000
3. Repair work of the existing wharf structure	140 m	1,000	140,000
4. Others (10% of above)	LS	1	475,000
Avatiu Total			5,814,000
B. Avarua Harbour			
1. Breakwater			
1-1 Relocation of East B/W	100 m	4,350	435,000
1-2 Relocation of West B/W	150 m	4,350	652,000
Subtotal			1,087,000
2. Protection Works			
2-1 MIC-1, Gravity Seawall	150 m	5,000	750,000
2-2 MAC-1, Buffer zone	150 m	1,000	150,000
2-3 MAC-3, Plantation	150 m	400	60,000
2-4 MIC-4, Flexible Hollow Slope	250 m	2,000	500,000
2-5 MAC-1, Buffer zone	250 m	1,000	250,000
2-6 MAC-3, Plantation	250 m	400	100,000
Subtotal			1,810,000
Avatiu Total			2,897,000
Grand Total			8,711,000