CHAPTER 4

SILTATION ANALYSIS OF THE ACCESS CHANNEL

Chapter 4 Siltation Analysis of the Access Channel

4.1 Analysis of Sounding Maps

4.1.1 Bottom Configuration of the Access Channel

Figure 4.1.1-1 shows the series of time change in the cross section of the Access Channel at the distance of 5,100 m in E8, 8,700 m and 10,700 m in E10 and 20,100 m in E14, where the distance is that from the boundary between E4 and E6 as shown in Figure 3.5-1 and the land side corresponds to the side of the city of Beira. At the distance of 5,100 m, the channel became shallow up to about 8 m one year after the capital dredging carried out in 1990 when it was dredged to a depth of 9 m below CDL. In April 1996, it was completely buried to return to the past configuration before the capital dredging.

At the distance of 8,700 m, sand deposits from the land side so that the slope shifts to the inside of the Channel. However, the part of 10 m deep still exists in the seaward side of the channel. At the distance of 10,700 m, sand deposits in the same manner but from the sea side. At the distance of 20,100 m, where the sea bottom was not excavated in the capital dredging, the channel is shoaled very slightly as same as the neighboring sea bottom. The cross sections surveyed in February and July 1997 are respectively deeper and shallower than the survey in April 1996.

Dividing the Channel into the land and sea sides at the channel center axis, the mean water depth of each 200 m in the direction of the Channel was calculated. Figures 4.1.1-2 and 4.1.1-3 show such mean water depth based on the sounding maps in August 1990, August 1991 and April 1996. Remarkable sedimentation is recognized in E9 and E10, to which E8 follows. The most remarkable sedimentation appears at E10, where sedimentation occurs so that the slope invades the channel in the preceding figure.

At almost all Sections from E6 to E12, the water depth of the survey map in February 1997 is deeper by 1 to 2 m than April 1996 and the water depth in July 1997 is a little shallower than April 1996 at many parts.

Figure 4.1.1-4 shows the depth change of Sections E13 and 14, where the data marked as (Emo) and (Ina) are mutually different in the manner to take into consideration of the tidal angle during the sounding survey. (Emo) took changeable tidal angles according to the distance from the tide gauge station. And (Ina) adopted a constant tidal angle through the Macuti Coast. The depth difference between (Emo) and (Ina) is about 0.5 m in maximum between both manners.

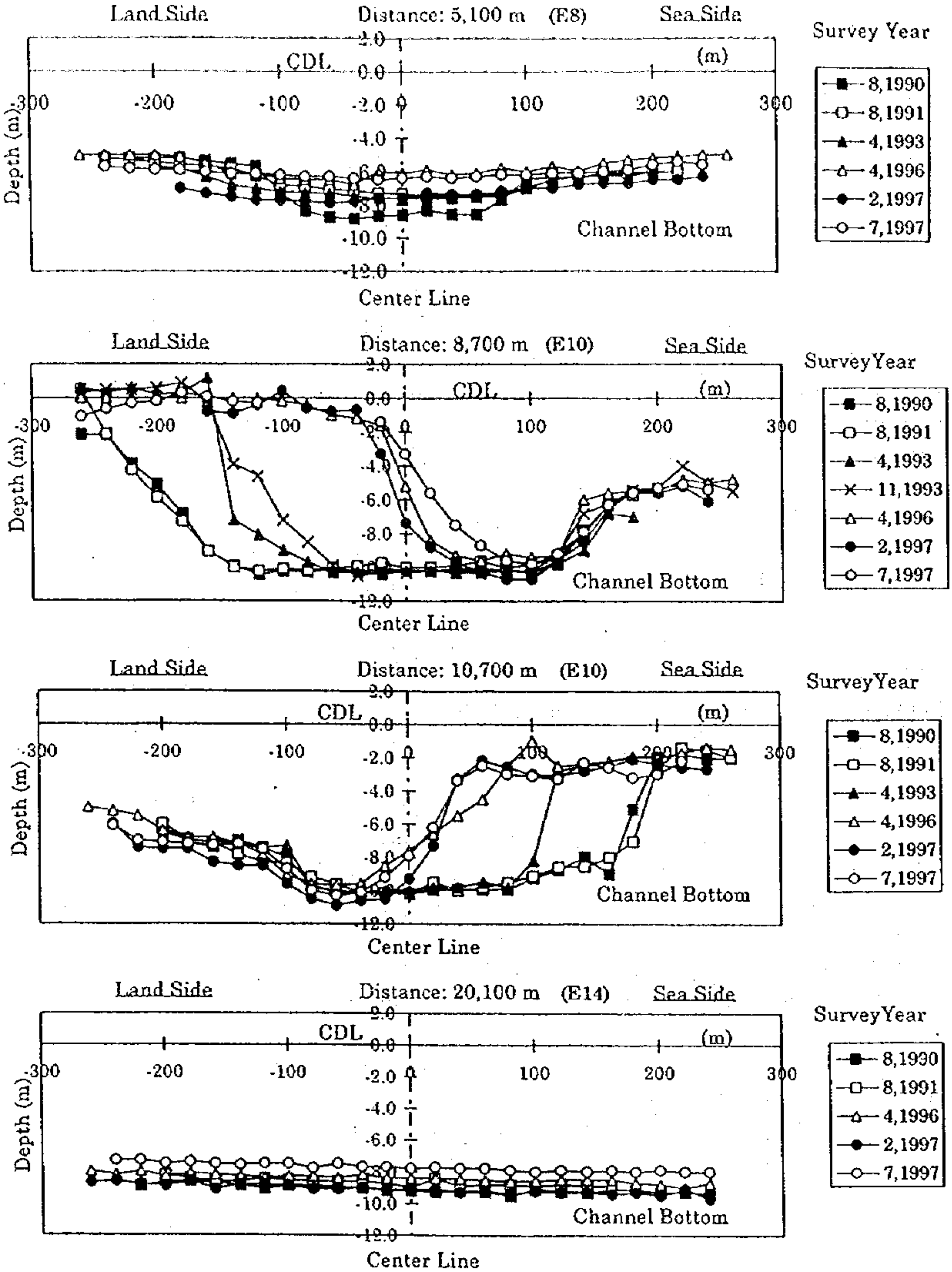

Figure 4.1.1-1 Change of Cross Sections of the Access Channel

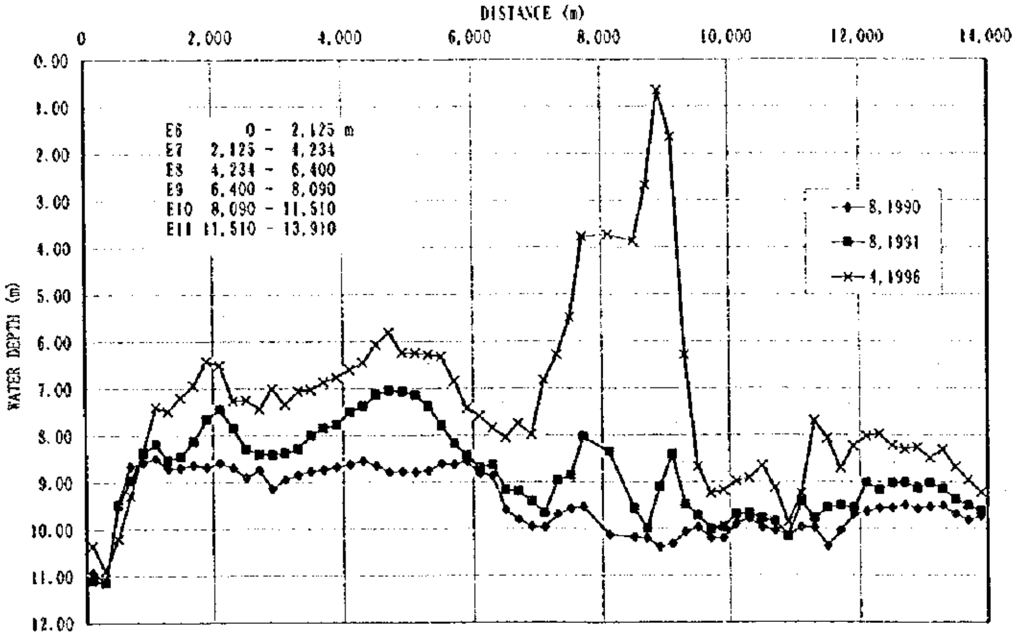

Figure 4.1.1-2 Change of Water Depth along the Access Channel of E6 to E11 (Land Side)

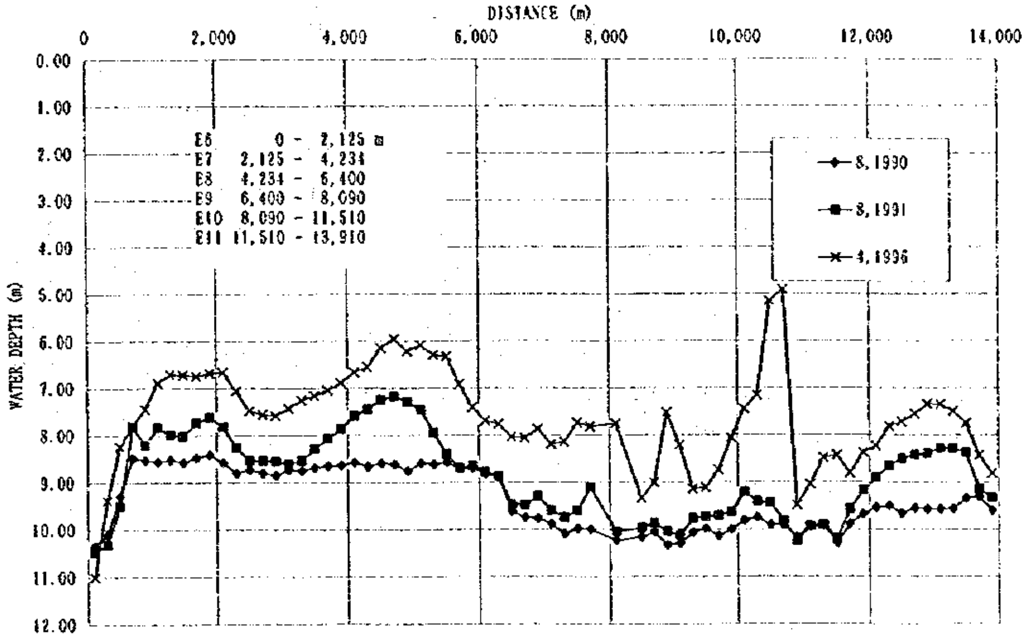

Figure 4.1.1-3 Change of Water Depth along the Access Channel of E6 to E11 (Sea Side)

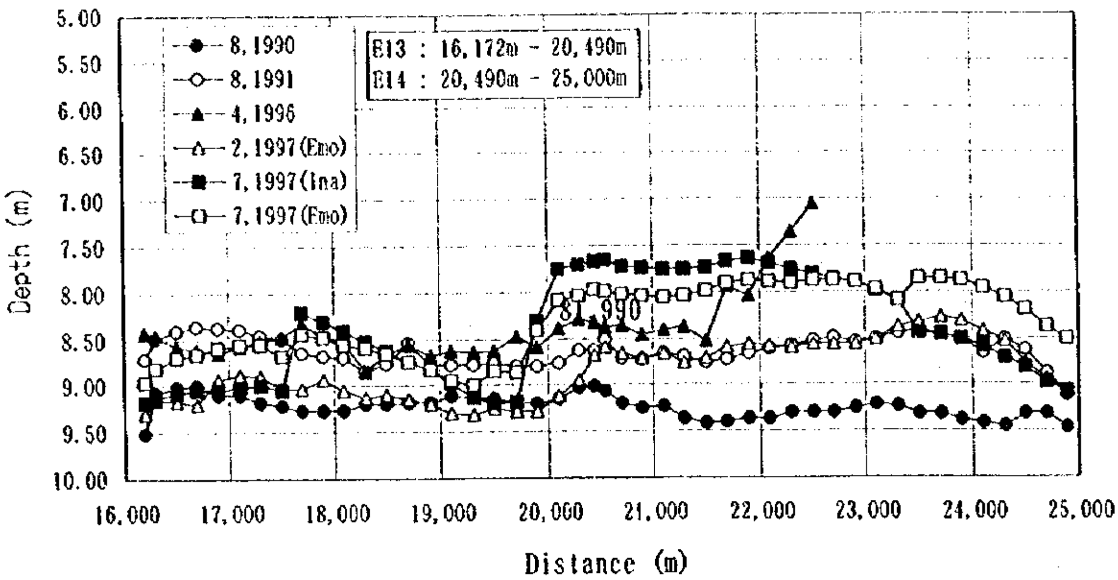

Figure 4.1.1-4 Change of Water Depth along the Access Channel of E12 to E14

Concerning the distance from 16,000 to 19,500 m, the water depths of April 1996 and July 1997 (Emo) in the dry season are nearly equivalent to the water depth of August 1991. And the water depth of February 1997 in the wet season is equal to it of August 1990. But, concerning the further distance, the depth of February 1997 (Emo) in the wet season is nearly equal to August 1991 and it of July 1997 in the dry season is shallower by about 1 m at maximum. Moreover, the water depth sharply changes in July 1997 at the distance of about 20,000 m and in April 1996 at the distance of about 21,500 m. From these depth changes, it is observed that the vicinity of E14 has a tendency to become shallower in the dry season and to become deeper in the wet season. Namely, in the vicinity of E14, it would be supposed that fine sand and silt deposit in the dry season and are transported to the further offshore or toward the Macuti Shoal by severe waves and currents in the wet season.

4.1.2 Sedimentation Volume of the Access Channel

At first, each cross section of every 200 m long segment in the direction of the Access Channel was divided into four parts as shown in Figure 4.1.2-1. The mean depth of each part was calculated and its bottom area was multiplied to calculate the sedimentation volume between two sounding maps. The width of slope in the figure was taken as 100 m in all Sections, although taken as 50 m in Section E11 and as zero in Sections E12,13 and 14.

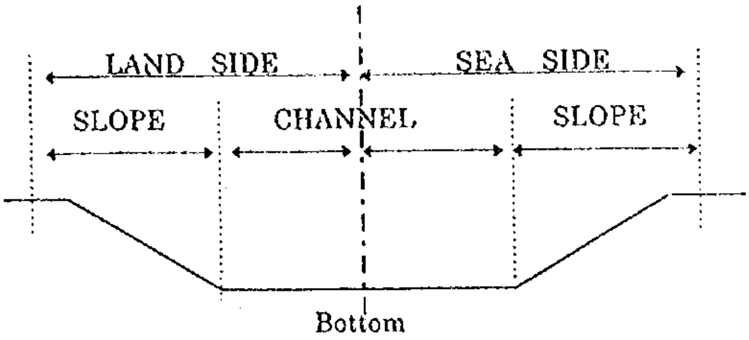

Figure 4.1.2-1 Division of the Cross Section of the Access Channel

(1) Sedimentation Volume between August 1990 and August 1991

Table 4.1.2-1 shows the sedimentation volume of the Access Channel for about one year from August 1990 to August 1991. The second column of the table is the volume calculated by the Beira Corridor Authority (BCA). The third and forth columns respectively refer to the value of the sum of the slope and channel and to the value of the channel only. Comparing the third and forth columns, it is seen that sedimentation occurs more in the channel portion than in the slope portion. The fifth column is the sum of only accumulation parts excluding erosion parts.

From the table, it is clear that high sedimentation occurred in Sections E9 and E10 near the bending corner of the Channel. Also, the sedimentation volume indicated on the third and fifth columns are nearly equal to 3,735,000 m^3 of the second column calculated by BCA.

(2) Sedimentation Volume between August 1991 and April 1996

Table 4.1.2-2 shows the sedimentation volume in the period from August 1991 to April 1996 calculated excluding erosion parts in the same manner as the fifth column of Table 4.1.2-1. The sedimentation volume occurring during the period from August 1990 to August 1991 in Table 4.1.2-1 is also mentioned in the table. Also the mean depth given in the table is merely the mean value of depths at the two times, during which the sedimentation is shown in the table.

The sedimentation between August 1991 and April 1996 shows a negative value in Sections E4, E5 and E15, which seems to depend on the deepening of the basin in front of the new oil terminal in 1994. Also, the sedimentation in Section E14 was calculated on the assumption that the ratio of sedimentation until 22,600 m point against the one until 25,000 m point is the same as that

Table 4.1.2-1 Sedimentation between August 1990 and August 1991

(Volume in m³)

Calculated by	BCA	This Study		
Portion	Channel and Slope	Channel and Slope (w/erosion volume)	Channel (w/ erosion volume)	Channel and Slope (w/o erosion volume)
E4	507,799	471,638	442,339	491,879
E5	198,189	214,617	186,722	214,617
E15	314,409	333,099	233,414	333,099
E4+E5+E15	1020,397	1019,354	862,475	1,039,595
E6	115,826	99,247	93,507	159,404
E7	173,157	109,108	180,621	185,411
E8	286,990	249,591	268,401	283,540
E6+E7+E8	575,972	457,946	542,529	628,355
E9	451,275	394,506	220,806	448,641
E10	481,227	521,270	245,161	531,762
E11	258,550	271,439	227,170	290,739
E9+E10+E11	1,191,052	1,187215	693,137	1,271,142
E12	81,915	81,023	81,023	83,783
E13	336,944	346,148	346,148	346,148
E14	529,027	502,050	502,050	502,050
E12+E13+E14	947,886	929,221	929,221	931,981
Total	3,735,307	3,593,736	3,027,362	3,871,073

during from August 1990 to August 1991. The total volume from E6 to E14 is calculated as 1,400 x 10^3 m^3/year against 2,800 x 10^3 m^3/year between 1990 and 1991.

Table 4.1.2.-2 Sedimentation between August 1991 and April 1996

	August 1990 to August 1991		August 1991 to April 1996		
Section	Annual Rate (m^3/yr.)	Mean Depth (m)	per 4.67 yr. (m^3)	Annual Rate (m^3/yr.)	Mean Depth (m)
E4	491,879	8.65	-65,350		8.44
E5	214,617	5.91	-96,688		5.57
E15	333,099	6.92	-10,237		7.79
E4+E5+E15	1,039,595		-172,275		
E6	159,404	8.85	476,865	102,112	8.32
E7	185,411	8.41	542,827	116,237	7.56
E8	283,540	8.23	627,721	134,416	7.24
E6+E7+E8	628,355		1,647,413	352,765	
E9	448,641	9.42	1,213,996	259,956	7.98
E10	531,762	9.90	2,593,833	555,425	8.61
E11	290,739	9.37	426,223	91,268	8.70
E9+E10+E11	1,271,142		4,234,052	906,649	
E12	83,783	9.67	143,077	30,637	9.27
E13	346,148	8.90	102,472	21,943	8.56
E14	502,050	8.97	495,075	106,012	8.33
E12+E13+E14	931,981		740,624	158,592	
E6 to E14	2,831,478		6,622,089	1,418,005	
E4 to E15	3,871,073				

(3) Characteristics of Sedimentation

The same calculations of sedimentation volume for other periods have been conducted, and the following caracteristecs have been estimated.

(a) The annual sedimentation volume is greatly influenced by the river flow of the Pungue River and the frequency and scale of cyclones attacking Beira,

(b) The most remarkable sedimentation occurs at E9 and E10 in the vicinity of the bending corner and E8 follows them. E11 to E13 are smaller in sedimentation compared with the their vicinity,
(c) In the vicinity of 8,700 m and 10,700 m of E10, sedimentation occurs so that the slope of land side and the slope of sea side shift inside of the channel, respectively.
(d) The Channel seems to have a tendency to be scoured in the wet season and shoaled in the dry season. Therefore, in the wet season, sediment transported from the rivers and from the northern coast seems to deposit in the estuary of the rivers and the shoal area around the Access Channel and to enter into the Channel comparatively early in the dry season.
(e) In the vicinity of E14, a tendency of erosion in the wet season and sedimentation in the dry season is remarkable.

Some of these characteristics would not get beyond a presumption because of insufficient data on sounding survey and others. Therefore, it should be confirmed by further investigations.

4.2 Computer Simulation

Numerical Simulation on the sedimentation has been carried out on and in the vicinity of the Sections E6 to E11 of the Access Channel, adopting the observed distributions of tidal currents and waves. The tidal current distributions are calculated under the condition of the mean spring tide of 2.8 m in amplitude and storm waves of 2.0 m in height and 10 seconds in period at the offshore. Figure 4.2-1 is an example of the calculated distribution of tidal currents. Bijker's model was applied in the simulation of sedimentation volume in the Access Channel.

In applying the Bijker's model in the Access Channel, each portion of Sections E6 to E11 was divided into segments of 200 m in length along the Channel and the siltation was calculated in each segment. At the first step, the rate of the annual sedimentation volume against the calculated sedimentation volume during one tidal cycle was estimated on the basis of the annual sedimentation volume obtained in the above-mentioned analysis of the sounding survey maps of August 1990 and August 1991. Figure 4.2-2 shows the calculated volume by using the above rate and the analyzed volume.

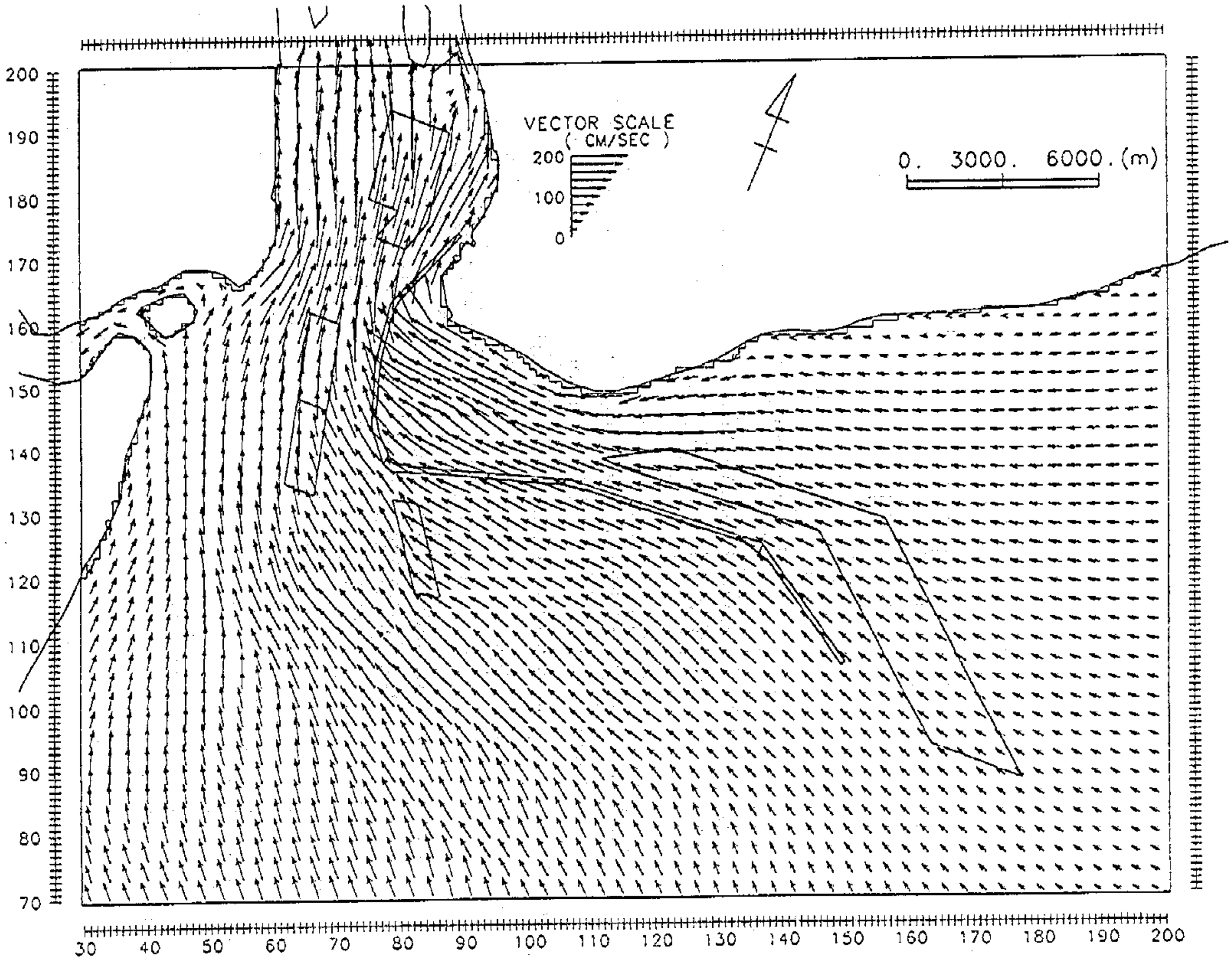

Figure 4.2-1 Calculated Tidal Current Distribution at Flood Tides

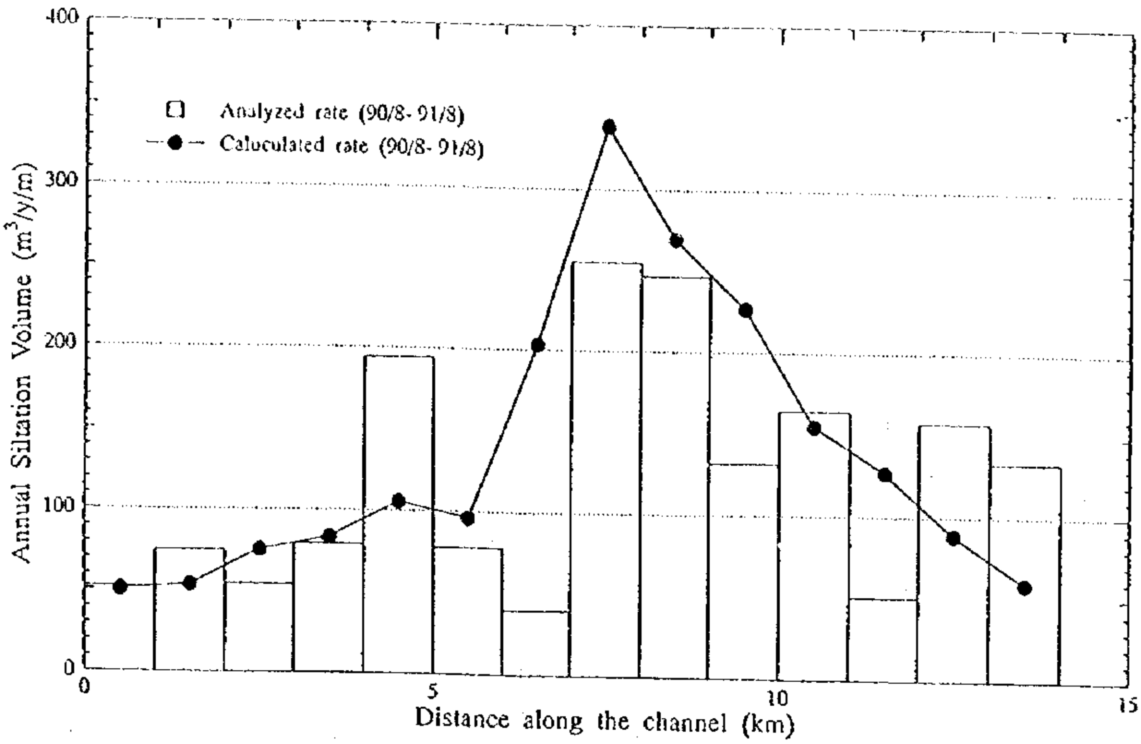

Figure 4.2-2 Calculated and Analysed Annual Sedimentation Volume (from August 1990 to August 1991)

Table 4.2-1 shows the annual sedimentation volumes for different depths of the Access Channel calculated in the same manner as mentioned above. From the table, it can be observed that the sedimentation volume decreases with the water depth of the Channel.

Table 4.2-1 Annual Sedimentation Volume for Different Depths of the Access Channel

Case	Depth of Channel	Volume of E6-E8 (m^3)	Volume of E9-E11 (m^3)	Volume of E6-E11 (m^3)
Y-1	E6-E11:9.0 m	580,000	1,088,000	1,672,000
Y-2	E6-E11:8.0 m	387,000	901,000	1,288,000
Y-3	E6-E11:7.0 m	185,000	706,000	891,000
Y-4	E6-E11:6.0 m	43,000	527,000	560,000
Y-5	E6-E11:5.0 m	0	361,000	361,000

4.3 Consideration on Maintenance Dredging Volume

4.3.1 Average Annual Maintenance Dredging Volume

The channel sections from E12 to E14 show a little sedimentation and have kept the channel depth more than 8 m below CDL since one year after the capital dredging, though there was a remarkable seasonal change as described in Chapter 4.1.1. Moreover, the sedimentation during the first one year immediately after the capital dredging was more severe compared with the sedimentation during the whole period after it. It is because all Sections had a depth allowance of more than one meter against the design water depth at the completion stage of the capital dredging. Consequently, considering the maintenance dredging volume for the channel of 8 m below CDL, it seems that the sedimentation volume of E12+E13+E14 would be able to be subtracted from the total volume of 3,735,000 m^3 calculated by BCA in Table 4.1.2-1. That is,

$$3{,}735{,}000-948{,}000= 2{,}787{,}000 \text{ m}^3 \qquad (4.3.1\text{-}1)$$

On the other hand, for the period of August 1991 and April 1996 in Table 4.1.2-2, the sedimentation ratio of E4+E5+E15 against E6+E7+E8 between August 1991 and April 1996 is assumed to be equal to the ratio between August 1990 and August 1991 and the volume dredged in Sections from E7 to E11 during the period, shown in Table 2.3.3-2, is added. That is,

$$\begin{aligned}&1{,}418{,}005+1{,}039{,}595\times 352{,}765/628{,}355\\&\qquad +(126{,}766+49{,}889+453{,}751)/4.67\\&=1{,}418{,}005+583{,}640+132{,}438 \text{ m}^3\\&=2{,}136{,}637 \text{ m}^3 \qquad (4.3.1\text{-}2)\end{aligned}$$

In Equation (4.3.1-2), 583,640 m^3 is the volume for E4+E5+E15 and 132,438 m^3 is the dredged volume. The sedimentation volume of Equation (4.3.1-1) would be greater than the expected average sedimentation volume for the channel of 8 m deep because it is the volume just after the capital dredging. That of Equation (4.3.1-2) would be smaller than the expected volume because the depth of the channel was shallower than 8 m below CDL in some parts of the Channel. After all, the average annual maintenance dredging volume has been determined as 2,500,000 m^3 which will be adopted to establish the dredging plan later. The maintenance dredging volume of 2,500,000 m^3 was allocated in each section of the Access Channel as shown in Table 4.3.1-1. The difference of 2,500,000 m^3 and 2,136,637 m^3 in Table 4.3.1-1 has been added to the values of E13 and E14 according to the ratio between them.

The actual maintenance dredging volume for each year is expected to vary in the order of more or less 50 % owing to the fluctuation of cyclones and river flows.

Table 4.3.1-1 Average Annual Maintenance Dredging Volume

(Volume in m^3)

Section	Sedimentation Volume by Equation (4.3.1-2)	Maintenance Dredging Volume
E4	276,146	276,146
E5	120,488	120,488
E15	187,005	187,005
E4+E5+E15	583,640	583,640
E6	113,057	113,057
E7	128,696	128,696
E8	148,823	148,823
E6+E7+E8	390,576	390,576
E9	287,820	287,820
E10	614,958	614,958
E11	101,051	101,051
E9+E10+E11	1,003,829	1,003,829
E12	30,637	30,637
E13	21,943	62,313
E14	106,012	429,005
E12+E13+E14	158,592	521,955
Total	2,136,637	2,500,000

4.3.2 Estimation of Maintenance Dredging Volume for Different Channel Depth

The sedimentation volumes by different channel depths for Sections E6+E7+E8 and E9+E10+E11 in Table 4.2-1 are plotted in Figure 4.3.2-1.

Based on Figure 4.3.2-1, the annual sedimentation volume for Sections from E6 to E11 by different channel depths is estimated as shown in Table 4.3.2-1. In each channel, the depth of E9+E10+E11 is deeper by 0.5 m than E6+E7+E8 as shown in Section 5.2.

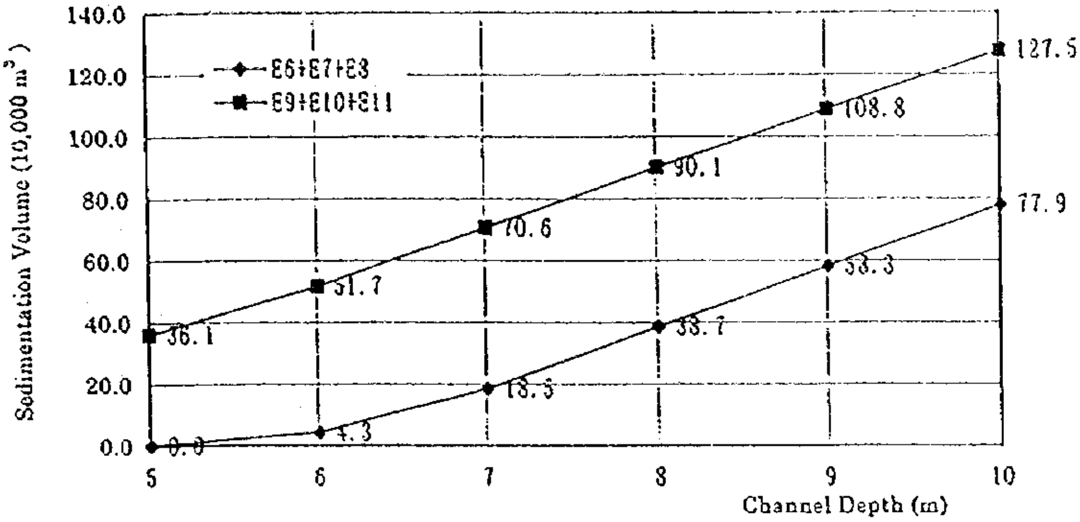

Figure 4.3.2-1 Annual Sedimentation Volume by Channel Depth

Based on the annual maintenance volume of 2,500,000 m³ for the 8M Channel, the annual maintenance volumes for other channels are calculated by using the ratios in Table 4.3.2-1, as shown in Table 4.3.2-2. In the table, the calculation for the sections of E4+E5+E15 and E12+E13+E14 was made as follows:

(1) The calculation for E4+E5+E15 is executed using Ratio 1,

(2) The calculation for E12+E13+E14 is ;

For the 5M and 6 M Channels:

The volume is zero, because the surrounding water depth is currently deeper than 7m deep,

For the 7M Channel:

Ratio 2 is used,

For the 9M Channel:

Dredging volumes are calculated from the volume of E9+E10+E11 by the ratio of E12+E13+E14 against E9+E10+E11 of BCA in Table 4.1.2-1, because the depth change is assumed to be the same as the period of one year after the capital dredging.

Table 4.3.2-1 Annual Sedimentation Volume by Channel Depth for E6 to E11

Channel	Sedimentation Volume					
	E6+E7+E8			E9+E10+E11		
	Depth (m)	Volume (x 10⁴ m³)	Ratio	Depth (m)	Volume (x 10⁴ m³)	Ratio
5M	5.0	0	0.000	5.5	43.9	0.441
6M	6.0	4.3	0.111	6.5	61.15	0.615
7M	7.0	18.5	0.478	7.5	80.35	0.808
8M	8.0	38.7	1.000	8.5	99.45	1.000
9M	9.0	58.3	1.506	9.5	118.15	1.188

Table 4.3.2-2 Estimated Maintenance Dredging Volume by Channel Depth

	Maintenance Dredging Volume (m^3)				
Channel	9M	8M	7M	6M	5M
Ratio 1	1.506	1.000	0.478	0.111	0.000
Ratio 2	1.188	1.000	0.808	0.615	0.441
E4	415,876	276,146	131,998	30,652	
E5	181,455	120,488	57,593	13,374	
E15	281,630	187,005	89,388	20,758	
E4+E5+E15	878,962	583,640	278,980	64,784	
E6	170,264	113,057	54,041	12,549	
E7	193,816	128,696	61,517	14,285	
E8	224,127	148,823	71,137	16,519	
E6+E7+E8	588,207	390,576	186,695	43,354	
E9	321,783	287,820	232,559	177,009	126,929
E10	687,523	614,958	496,886	378,199	319,778
E11	112,975	101,051	81,649	62,146	52,547
E9+E10+E11	1,122,281	1,003,829	811,094	617,355	521,991
E12	77,201	30,637	24,755		
E13	317,553	62,313	50,349		
E14	498,582	429,005	346,636		
E12+E13+E14	893,336	521,955	421,740		
Total	3,482,786	2,500,000	1,698,509	725,493	521,991

CHAPTER 5

DESIGN OF THE ACCESS CHANNEL

Chapter 5 Design of the Access Channel

5.1 Ship Traffic Forecast

5.1.1 Port Cargo Forecast

According to the trend on the cargo volume of Beira Port from 1978 to 1997 excluding drought relief as temporary factor, the average growth rate of cargo volume per annum is 7.4 % during 1987-1996 and 5.4 % during 1978-1996. The actual cargo volume of Beira Port in 1996 including drought relief was 2,603,300 tons in total, which consists of Mozambican traffic of 357,100 tons (13.7 %) and transit traffic of 2,246,200 tons (86.3 %).

On February 1997, Southern Africa Transport and Communication Commission (SATCC) published the expected transit port cargo volume by inter-SADC (Southern Africa Development Community) and extra-SADC in 2002, 2007 and 2017 based on the volume of 1995. According to the freight traffic growth factors by country (central-case) of SATCC, the forecast annual tonnage of Beira Port excluding petroleum, oil and lubricant (POL) is calculated at 1,275,000 tons in 2002, 1,475,000 tons in 2007 and 2,180,000 tons in 2017 based on 964,200 tons in 1995. The forecast of POL is conducted by using the growth-rate of import transit cargo of SATCC and the forecast of the Mozambican traffic was carried out employing the growth rate of Mozambique in the data of SATCC.

Then, on the demand forecast on cargo at Beira Port adopted the central-case forecast made by SATCC, the total cargo of Beira Port is forecast at 2,976,400 tons in 2002, 3,398,900 tons in 2007 and 4,874,900 tons in 2017. The average growth rate per annum of the total cargo is forecast at 2.6 % both in 2002, 2007 and 3.7 % in 2017, less than 5.4 % during 1978 to 1996.

The shift of cargo traffic from Harare-Maputo route to Harare-Beira route is calculated to be 298,000 tons in 2002 in the case of the improvement of waiting time of Beira Port. Then, the forecast volume of these transit container cargo of Zimbabwe during 2000-2025 should be added to the demand forecast by SATCC.

Table 5.1.1-1 shows the forecast of cargo by type of traffic on Beira Port during 2000-2025 with the container volume fixed at 100,000 TEU under the handling capacity per annum after 2010.

Table 5.1.1-1 Forecast of Cargo by Traffic Type on Beira Port in 2000 - 2025

Forecast of Cargo by Type of traffic on Beira port in 2000-2025

year	(A+B) Container Cargo (TEU)			Container Cargo (tonnes)			Dry Cargo			POL	Cabotage			①+②+③
	export	import	total	export	import	total	export	import	total	import	①	② export	③ import	total
1995	16,916	10,330	27,246	147,850	90,270	238,120	281,750	788,130	1,069,880	1,126,900	53,300	429,600	2,005,300	2,488,200
1996	19,632	14,204	33,836	162,160	117,370	279,530	490,640	690,530	1,181,170	1,089,700	52,900	652,800	1,897,600	2,603,300
1997	19,565	13,866	33,431	168,451	119,389	287,840	428,971	753,889	1,182,860	1,108,626	55,242	597,422	1,981,904	2,634,567
1998	20,324	14,105	34,429	174,986	121,443	296,430	445,663	764,346	1,210,008	1,127,880	57,687	620,649	2,013,669	2,692,005
1999	21,112	14,348	35,460	181,775	123,532	305,308	463,004	774,948	1,237,952	1,147,469	60,241	644,779	2,045,949	2,750,969
2000	48,261	25,836	74,098	415,531	222,449	637,981	481,021	785,696	1,266,717	1,167,398	62,907	896,552	2,175,543	3,135,003
2001	49,566	26,399	75,965	426,763	227,299	654,062	499,738	796,594	1,296,332	1,187,673	65,692	926,501	2,211,566	3,203,759
2002	50,919	26,975	77,895	438,416	232,257	670,673	519,184	807,643	1,326,827	1,208,300	68,600	957,600	2,248,200	3,274,400
2003	52,360	27,690	80,051	450,823	238,413	689,236	533,936	827,528	1,361,464	1,241,612	69,872	984,759	2,307,553	3,362,183
2004	53,842	28,424	82,267	463,583	244,733	708,316	549,107	847,902	1,397,009	1,275,842	71,167	1,012,690	2,368,477	3,452,335
2005	55,367	29,178	84,544	476,707	251,220	727,927	564,710	868,778	1,433,487	1,311,016	72,487	1,041,417	2,431,014	3,544,918
2006	56,934	29,951	86,886	490,205	257,880	748,086	580,755	890,167	1,470,923	1,347,160	73,831	1,070,961	2,495,207	3,639,999
2007	58,547	30,745	89,293	504,092	264,717	768,809	597,258	912,083	1,509,341	1,384,300	75,200	1,101,350	2,561,100	3,737,650
2008	60,912	31,926	92,839	524,454	274,887	799,341	620,763	943,225	1,563,987	1,435,096	77,343	1,145,217	2,653,208	3,875,768
2009	63,373	33,153	96,526	545,639	285,449	831,088	645,192	975,430	1,620,622	1,487,757	79,547	1,190,831	2,748,636	4,019,014
2010	66,280	33,719	100,000	566,937	288,423	855,360	670,584	1,008,735	1,679,318	1,542,349	81,815	1,237,520	2,839,507	4,158,842
2011	66,280	33,720	100,000	570,675	290,325	861,000	695,974	1,043,177	1,740,151	1,598,945	84,146	1,267,649	2,932,447	4,284,242
2012	66,280	33,720	100,000	570,675	290,325	861,000	724,403	1,078,795	1,803,198	1,657,618	86,544	1,295,078	3,026,728	4,408,360
2013	66,280	33,720	100,000	570,675	290,325	861,000	752,911	1,115,629	1,868,541	1,718,444	89,011	1,323,586	3,124,398	4,536,995
2014	66,280	33,720	100,000	570,675	290,325	861,000	782,542	1,153,721	1,936,263	1,781,501	91,548	1,353,217	3,225,547	4,670,312
2015	66,280	33,720	100,000	570,675	290,325	861,000	813,338	1,193,113	2,006,452	1,846,873	94,157	1,384,013	3,330,311	4,808,481
2016	66,280	33,720	100,000	570,675	290,325	861,000	845,347	1,233,851	2,079,198	1,914,643	96,840	1,416,022	3,438,319	4,951,681
2017	66,280	33,720	100,000	570,675	290,325	861,000	878,615	1,275,980	2,154,595	1,984,900	99,600	1,449,290	3,551,205	5,100,095
2018	66,280	33,720	100,000	570,675	290,325	861,000	913,192	1,319,547	2,232,739	2,057,735	102,439	1,483,867	3,667,607	5,253,913
2019	66,280	33,720	100,000	570,675	290,325	861,000	949,131	1,364,601	2,313,732	2,133,243	105,358	1,519,806	3,788,169	5,413,333
2020	66,280	33,720	100,000	570,675	290,325	861,000	986,483	1,411,194	2,397,677	2,211,521	108,361	1,557,158	3,913,040	5,578,559
2021	66,280	33,720	100,000	570,675	290,325	861,000	1,025,305	1,459,377	2,484,683	2,292,672	111,449	1,595,980	4,042,375	5,749,804
2022	66,280	33,720	100,000	570,675	290,325	861,000	1,065,656	1,509,206	2,574,862	2,376,801	114,625	1,636,331	4,176,332	5,927,288
2023	66,280	33,720	100,000	570,675	290,325	861,000	1,107,594	1,560,736	2,668,330	2,464,017	117,892	1,678,269	4,315,078	6,111,239
2024	66,280	33,720	100,000	570,675	290,325	861,000	1,151,183	1,614,026	2,765,208	2,554,433	121,252	1,721,858	4,458,784	6,301,893
2025	66,280	33,720	100,000	570,675	290,325	861,000	1,196,487	1,669,135	2,865,621	2,648,167	124,707	1,767,162	4,607,627	6,499,496
Handling capacity per annum 100,000TEU						Handling capacity per annum			2,950,000					
Growth-rate % per annum for 1996-200				2.6595%	2.1788%		3.8912%	1.3870%		1.7368%	4.4267%			
Growth-rate % per annum for 2002-200				2.8311%	2.6509%		2.8414%	2.4620%		2.7569%	1.8542%			
Growth-rate % per annum for 2007-201				4.0397%	3.8443%		3.9354%	3.4144%		3.6695%	2.8500%			

note-1 : 1TEU=10 tons, Empty rate=13.9% (Actual rate in 1995)

note-2 : Container Cargo after 2000 involves the Shifting Cargo from Maputo-Harare Route to Beira-Harare Route.

note-3 : Handling Capacity per annum of Container is 100,000TEU after 2010.

note-4 : Handling Capacity per annum of Dry Cargo is 2,950,000 tons.

5.1.2 Ships' Call Forecast

The future ship traffic volume is derived by converting the forecast cargo volume into a number of ship's calls, based on the ship and the cargo volume in 1996.

(1) Forecast of Ship Size by Ship Type

Regarding a forecast of ship size, it can be presumed that small sized ships currently operating will decrease in size and shift to the bigger size, where a shear of calling ships of more than 20,000 of DWT has increased from 3.3 % in 1991 to 12.9 % in 1996. The increasing trend in ship size will be accelerated with the improvement of the accessibility and maneuverability at the port as a result of maintenance dredging of the Access Channel. Calling ships are restricted by the dimension of the Access Channel and the port facilities, and regulated below the dimensions of the design ship.

(2) Forecast of Ships' Call by Ship Type

In regard to the forecast of ship's call, ship numbers, ship types and cargo volume in 1996 are used as base data. The number of ships' call in the years 2000 to 2025 is calculated by multiplying the ships' call of each category of the year 1996 by the respective increment ratios of those forecast years as shown in Table 5.1.2-1.

Table 5.1.2-1 Forecast Number of Ship's Calls in 1996 to 2025

Year	1996	2000	2002	2007	2012	2017	2022	2025
Tanker	62	62	69	79	98	112	136	150
Container	152	334	350	403	453	453	453	453
Dry-Cargo	109	113	114	141	176	198	238	259
Cabotage	41	48	53	58	67	78	88	97
Total	364	557	586	681	794	841	915	959

5.1.3 Channel Traffic Simulation

The waiting time to enter and to leave the port is estimated using the channel traffic simulation. The channel traffic is closely affected by the channel depth which is maintained by economically acceptable dredging.

(1) Premise of the Model

Ships adopted to the simulation model are categorized based on the forecast of cargo potentials and ship types from 2000 to 2025. The calling ships are categorized into 4 groups with different drafts based on the ship's call forecast. Regarding berthing rules, the normal procedure in admitting ships to the specific quay is based on the first come first serve rule within the specific ship group and non-occupied any quay is allocated for ships in the case that there is no specified berthing space for them. Cargo handling time is taken into account according to the actual cargo flow. Accessibility to the port is limited by draft restriction considering tide level and prohibition of night navigation.

(2) Computation Results of the Model

Figure 5.1.3-1 shows a characteristic of the tide waiting time with respect to the different channel depths for total calling ships. The tide waiting time is affected distinctly by the channel water depth. The waiting times under the condition of 5.0 m and 6.0 m channel water depth are significantly very high. The tide waiting times of the channel depth more than 8.0 m are reduced to a drastically small number of hours and become almost allowable.

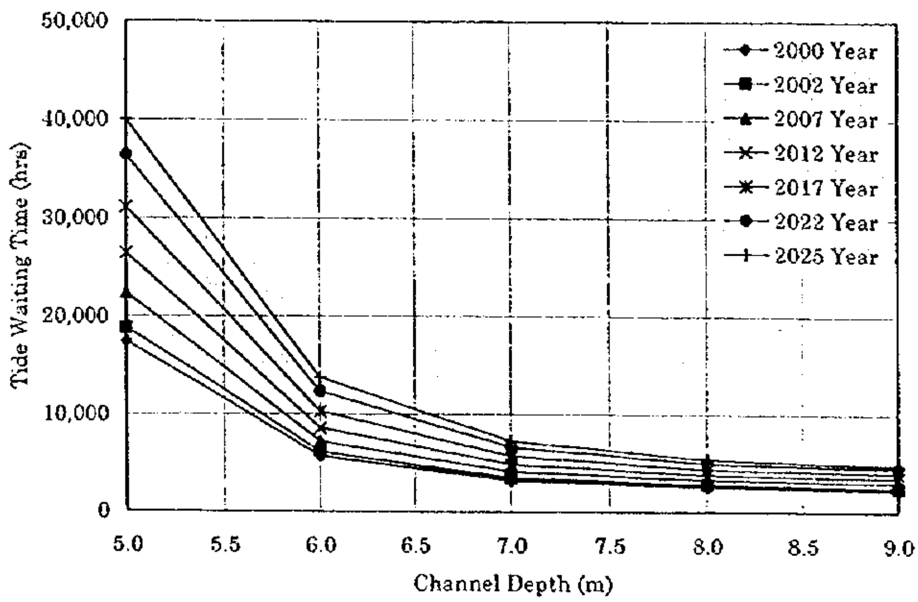

Figure 5.1.3-1 Forecast of Tide Waiting Time of Total Ship's Call

5.2 Improvement Plan of the Access Channel

5.2.1 Problem and Improvement Policy

The basic direction of maintenance and improvement of the Access Channel of Beira Port in this Project is to restore the existing silted channel to the dimensions which allow safe navigation to the port for the largest ships calling the port. The existing channel was designed in 1989 and such changes occurred thereafter as cargo volume, number of ship's call, ship's size will be given a consideration with up-to-date data.

For the period until the introduction of the new dredger, it is assumed that the maintenance dredging work (interim dredging) to keep the existing channel to the original design depth is to be done by EMODRAGA.

5.2.2 Original Design of the Access Channel

The original layout of the channel is shown in Figure 5.2.2-1 and its design is discussed in this chapter.

Improvement of the Channel to Beira Port was studied in "Access Channel Study" in 1982 and following the study "Master Plan Study for the Port of Beira" was carried out by NEDECO to deepen the Channel from -6.0 m CDL in 1984.

(1) Design Ship

In Master Plan Study, various sizes of ships were examined in phased development plans. The existing channel was deepened according to the first phase development plan with the design ship as shown below;

The ship size for designing the channel is determined as below;

Ship Size	Length	Beam	Full Draft	Draft in Ballast
30,000 DWT	200 m	27 m	11 m	7.2 m

(2) Alignment of the Access Channel

Two alternate layouts of the Access Channel, namely the Macuti Channel and the Rambler-Portela Channel, were examined in the above study. Macuti Channel was selected through consideration of mainly construction and maintenance costs as summarized below;

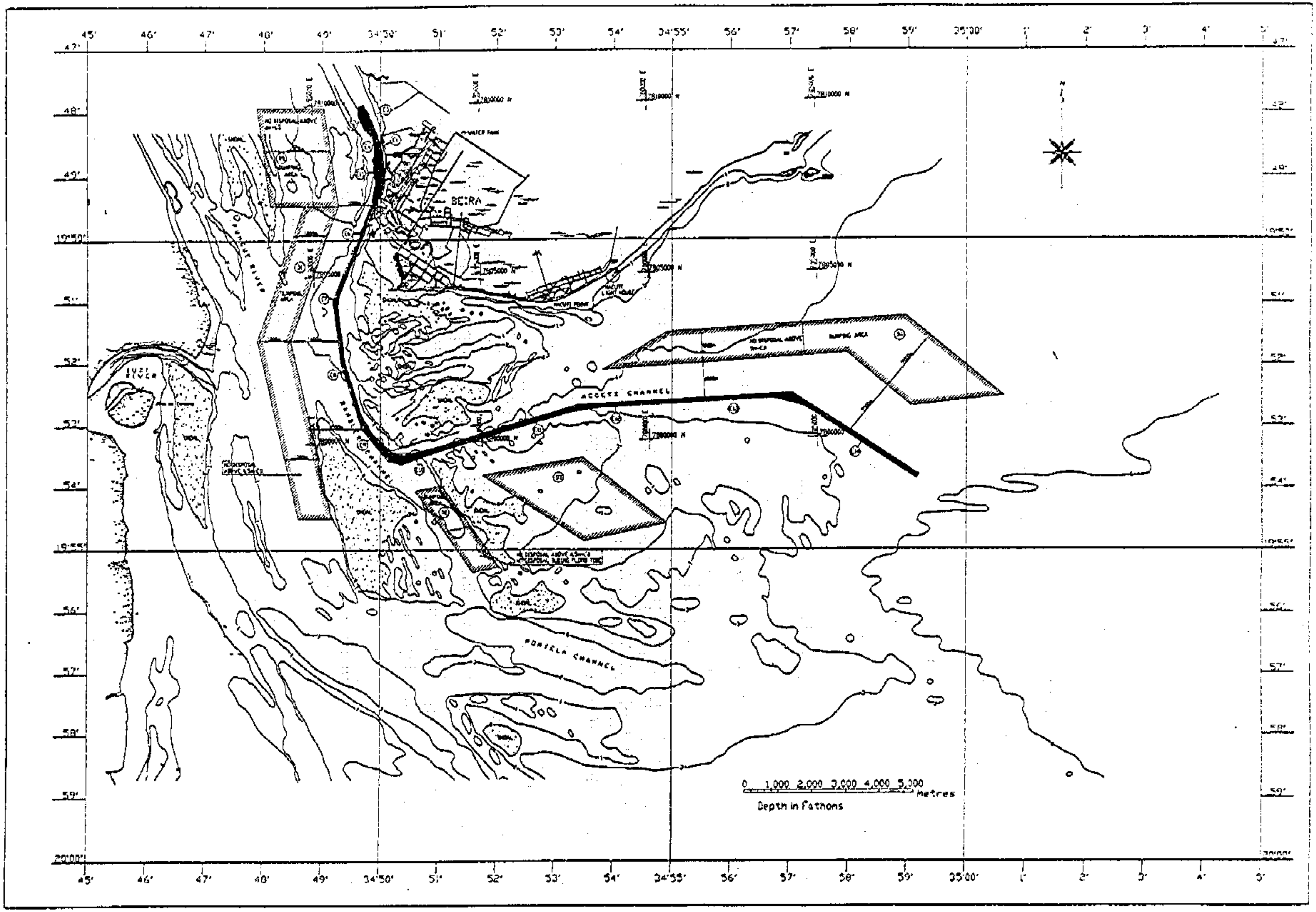

Figure 5.2.2-1 Layout of the Access Channel

Capital and Maintenance Volume and Cost

	Capital Dredging		Maintenance Dredging	
	Volume (million m³)	Cost (million US$)	Volume (million m³)	Cost (million US$)
Macuti Channel	3.4	7.77	3.55	4.85
Rambler-Portela Channel	10.4	21.40	7.28	6.25

(3) Dimension of the Access Channel

According to the channel design proposed in Beira Port Study, the capital dredging work was designed in December 1986 as shown in Figure 5.2.2-1 and outlined below;

Channel Depth and Width (m)

Section	E1	E2	E3	E4	E5	E6	E7	E8
Length	1,063	645	360	3,050	970	2,134	2,106	2,186
Accumulated Length				3,050		5,184	7,290	9,476
Width	50	50	50	200	200	135	135	135
Depth	9.5	12.0	12.3	8.0	5.5	8.0	8.0	8.0
Remarks	Q6-11	Q2-5	Oil.B		T.Basin			

Section	E9	E10	E11	E12	E13	E14	E15
Length	1,614	3,394	2,428	2,224	4,375	3,700	970
Accumulated Length		11,090	14,484	16,912	19,136	23,511	27,211
Width	250	155	155	140	140	160	150
Depth	8.8	9.2	8.7	8.8	8.5	8.7	7.5
Remarks	Corner						T.Basin

5.2.3 Design of the Access Channel

The design depth and width of the Access Channel is examined on the basis of the size of calling ships and the capacity of the port quay facilities as well as the additional tidal benefit of a very wide excursion range to the channel depth.

(1) Capacity of Port Quay Facilities

Allowable ship sizes of the port quay facilities are estimated by the dimensions of the water depth. The ship size of the New Oil Terminal is stated on the document published by CFM-C as 50,000 DWT. The dead weight tonnage of 30,000 tons of a cargo carrier is the maximum size for the quays of Multipurpose and Container Terminal.

(2) Design Ship for Original Access Channel

A standard full load design draft/breadth of 30,000 DWT cargo carrier and 50,000 DWT tanker are stipulated respectively as 10.9 m/27.1 m and 12.7 m/33.1 m in "Technical Standards of Port and Harbor Facilities in Japan". The full load draft of tankers and cargo carriers give the same number of 10.9 m, which is almost equivalent to the full load draft applied for the original design of the Access Channel.

(3) Tide Condition

The tidal excursion range is extremely wide at Beira Port; thus, calling ships enter the port with a tidal benefit in addition to the water depth of the Access Channel. The tidal ranges of the mean spring tide and the mean neap tide are 5.6 m (MHWS - MLWS) and 1.5 m (MHWN - MLWN), respectively. The tide level reaches MHWN every day throughout the year. The number of days when the tide level does not exceed MHWS (CDL +6.5 m) is 87 %. While, the number of the days when the tide level become over MHWS is 47 days throughout the year.

(4) Calculation of Water Depth of the Access Channel

The water depth of the Access Channel is calculated by a full load draft of the design ship, the channel depth and an additional tide level.

The nautical vessel depth of 30,000 DWT of cargo carriers and 50,000 DWT of tankers are calculated with a tolerance for squat, trim and wave motion of ship. And a required channel depth is obtained by subtracting the water level of MHWN (CDL +4.2 m), expected daily occurrence throughout a year, from the nautical vessel depth, which means that the aforementioned design ships are enabled to enter or leave the port every day throughout the year. The required water depths for 30,000 DWT cargo carriers and 50,000 DWT tankers are determined respectively at CDL -8.0 m and CDL -10.0 m with a tolerance equivalent to 10 % of the full load draft and an allowance of 0.2 m.

(5) Evaluation of Water Depth of the Access Channel

Water depth of the Access Channel is determined from the view points of accessibility of the design ships, annual maintenance dredging volume and tide waiting time. Evaluation results of the channel depth in terms of the previous factors are summarized in Table 5.2.3-1. The water depth of CDL -8.0 m is concluded to be more appropriate and reasonable for Beira Port.

Table 5.2.3-1 Evaluation of Water Depth of the Access Channel

	Access Channel Depth		
Items	CDL -7.0 m	CDL -8.0 m	CDL -9.0 m
M. Dredging Volume	◎	○	△
Accessibility	△	○	◎
Tide Waiting Time	△	○	◎
Total Evaluation		1 st	

◎: Better ○: Good △: Fair

(6) Water Depth along the Access Channel

The design water depth of the Access Channel is calculated by a tolerance for siltation, ripples and survey accuracy in addition to the required water depth mentioned above. Taking the availability of a dredger on standby basis into account, the design water depth along the Access Channel is determined with an additional tolerance for wave motion at the sections from E9 to E14, where the channel section is severely affected by direct wave intrusion. The water depth and the additional tolerance of each channel section are determined as shown in Table 5.2.3-2.

Table 5.2.3-2 Design Water Depth along the Access Channel

	Design Water Depth		
Channel Section	E6, E7, E8	E9, E10, E11	E12, E13, E14
Location	Near Port	Bending Point	Near Entrance
Required Water Depth	8.0 m	8.0 m	8.0m
Additional Tolerance	...	0.5 m	0.7 m
Design Water Depth	8.0 m	8.5 m	8.7 m

(7) Width of the Access Channel

The width of the Access Channel is determined at the same as the original design width stipulated in "Beira Port Study, Access Channel Study, NEDECO". The required channel width is set on conditions of one-lane traffic for the largest vessels in consideration of the design traffic situation and the design vessel of fully laden bulk carriers leaving the port.

The width of the maneuvering lane can be supposed to be a width of between 1.8 and 2.0 times of the ship's breadth. Channel widths of each sections are presented in Table 5.2.3-3. These widths should be available in the ship's keel plane.

Table 5.2.3-3 Design Width of the Access Channel

Channel Section	E6, E7, E8, E9	E10, E11	E12, E13	E14
Design Width	135 m	155 m	140 m	160 m

5.2.4 Maintenance Works of the Access Channel

In general, maintenance dredging work is a fundamental countermeasure for maintenance of a navigation channel suffering severe shoaling. In order to reduce a maintenance dredging volume, supplementary countermeasures should be installed according to a sedimentation condition of the channel, efficiency and applicability of the countermeasures.

(1) Groin and Jetty

Groins are coastal structures constructed perpendicularly or obliquely to a beach line for the purpose of preventing beach erosion as well as preventing alongshore sand drift from entering to the channel. However, its effect against the approach channel is restricted in very local portion adjacent to the beach and is substantially negligible. The groins of relatively short extension constructed besides the Macuti Coast is concluded not to be effective for the channel siltation.

A jetty sized much bigger and longer is a structure prolonged seawards from the coast line. The location suitable for a jetty installation is at the Macuti Beach adjacent to the river mouth. A jetty of a rubble mound type will cost in the order of ten thousand US dollars per meter. Considering the site condition of the Access Channel, a construction of the jetty is economically unfeasible as a supplementary maintenance works.

(2) Submerged Breakwater

The submerged breakwater as shown in Figure 5.2.4-1 is installed to prevent bed load moving on sea bottom. The submerged breakwater also is not recommendable as a countermeasure, because of the high construction cost estimated at several thousand US dollars per meter and maritime safety of ship traffic in the Channel.

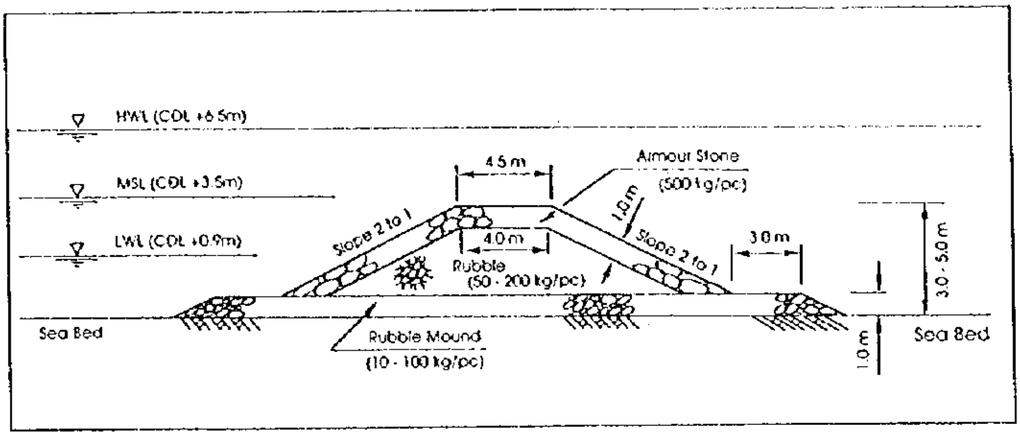

Figure 5.2.4-1 Typical Cross Section of Submerged Breakwater

(3) Sand Trap

Where the source of sediment materials is clear, sand trap placed upstream of the sediment flow is an alternate countermeasure to prevent sand deposition before invasion of the sediment material into a basin and the access channel. In the most severe shoaling sections E9 and E10 of Group II, the sand trap method is more effective, because bed load seems to be so predominant that the channel slope shifts into the channel in those sections.

(4) Over Dredge

In the maintenance dredging of the Access Channel, over dredge is not necessary in addition to the original design water depth of the Channel, considering the current port traffic condition and the newly introduced dredger on standby basis at the Port.

(5) Dredgers

A trailer suction hopper dredger is adopted to the Access Channel of Beira Port, which is utilized widely for the maintenance works of active navigation channels throughout the world, because of no supplemental works such as discharge pipe installation and anchorage wiring or spud.

CHAPTER 6

MAINTENANCE DREDGING PLAN

Chapter 6 Maintenance Dredging Plan

6.1 Design of Dredger

6.1.1 Basic Design Criteria

In order to make the design of the dredger for maintenance dredging of the Access Channel to Beira Port, the following design criteria are established.

(1) Type of Dredger

Since the dredger to be planned under this Project is intended to engage fully in the maintenance dredging of the Access Channel of the port, the dredger is required to be able to fulfil the dredging work without hindering navigation of incoming/outgoing vessels and also to maintain her own safe navigation and to avoid such marine risks as collision without any difficulty. To comply with such requirements, the concept design has been worked out that the dredger shall be of a self-propelled trailing suction type vessel with hopper tank for loading of dredged soil and dump it in the prescribed dump sites by shuttling between the dredging sites and the dump sites.

(2) Basic Data from Siltation Analysis and Dredging Plan

Necessary data for setting up the concept of the dredger, the following design conditions are adopted.

1) Soil volume to be dredged per annum		2,500,000 m^3
2) Maximum dredging depth at light load condition		21.0 m
3) Minimum water depth at dredging area and sailing route		6.0 m
4) Minimum water depth at dumping point		7.0 m
5) Loading rate of dredged soil in hopper	Silt	55 %
	Sand	75 %

(3) Conditions for Dredging Work Schedule

Dredging work schedule is established according to the following work conditions.

1) Working days per week	5 days
2) Working weeks per annum	44 weeks
3) Binding hours of a day	24 hours
4) Actual expectant working hour (working ratio 0.8)	19.2 hours
5) Manning schedule of dredging works (2-shift)	each 24 persons

6.1.2 Concept of Dredger

(1) Principal Dimensions

Length overall (Loa)	about 83 m
Length between perpendiculars (Lpp)	80.0 m
Breadth, moulded (B)	15.0 m
Depth, moulded (D)	6.2 m
Designed fully loaded draft, extreme (d)	5.5 m

(2) Dead Weight at (d) about 3,650 t

(3) Cargo Weight at (d) about 3,200 t

(4) Hopper Capacity for Dredged Soil about 2,000 m^3

(5) Speed

(5) Speed	free running speed on full load condition	10.2 knots
	free running speed on empty hopper condition	10.8 knots
	maximum dredging speed on full load condition	6.5 knots

(6) Accommodation for 48 persons

(7) Machinery

Twin propulsion plant (2-engine and 2-screw propeller)
1-bow thruster
1-deck crane
1-work boat
2-main and 1-Harbor use generating plant

(8) Dredging Apparatus

1-dredging pump, direct driven by diesel engine
1-drag arm (starboard side)
14-sets Hopper door, hinge type, hydraulic cylinder driven
1-swell compensator

6.1.3 Cost of Dredger

Preliminary Cost of Dredger is estimated at about 25,391,000 US$ under the following conditions.

- The ship will be built by a Japanese shipbuilder
- Delivery of the ship will be at the end of 1999
- Exchange rate is 116.8 Yen/US$

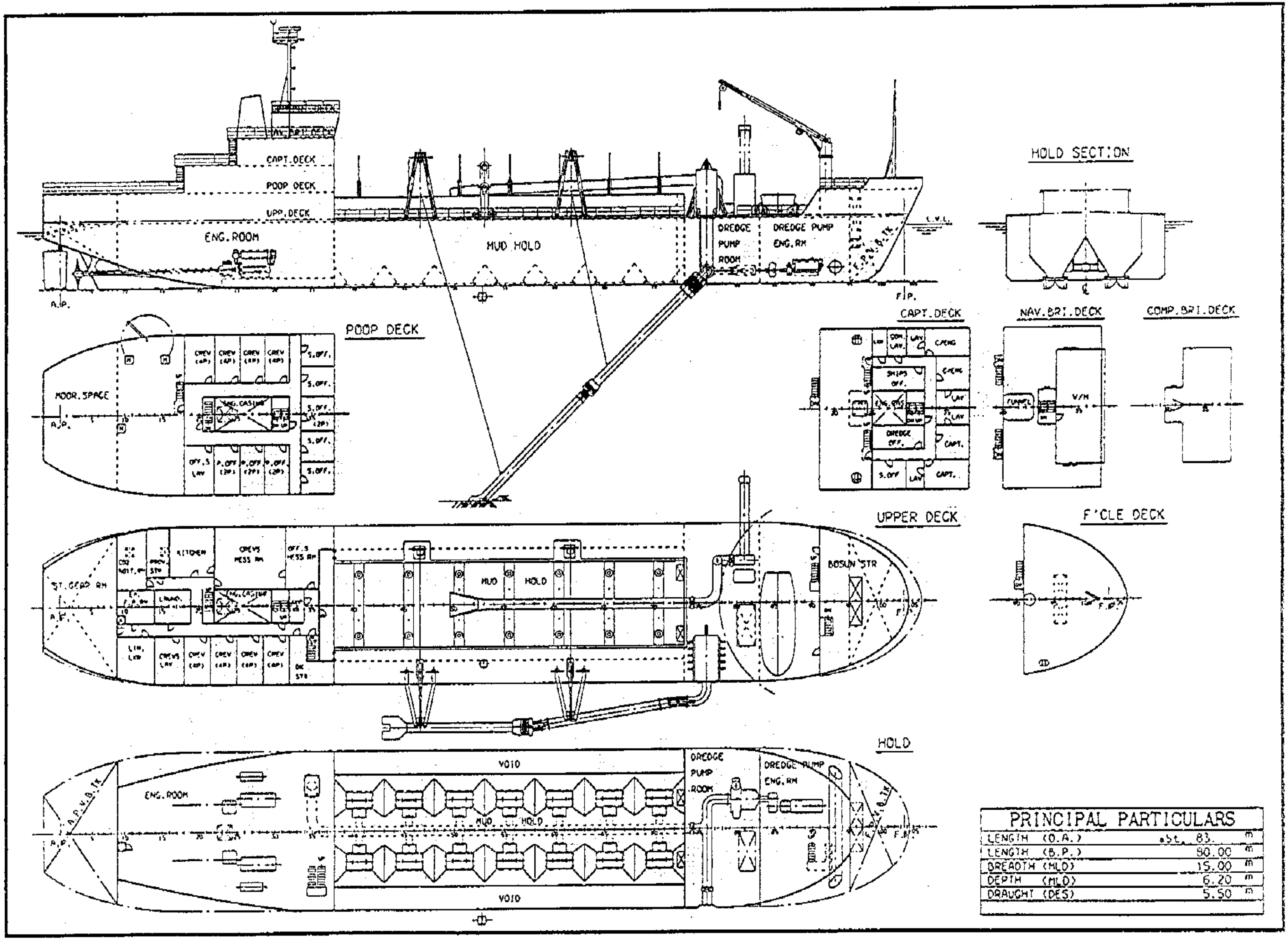

Figure 6.1.2-1 General Arrangement of New Dredger

6.2 Maintenance Dredging Plan

6.2.1 Siltation and Dredging Works

(1) Dredging Area and Dredger

1) Access Channel

The trailing suction hopper dredger with specifications detailed in the previous section is considered to be an optimal option for the purpose of maintaining the Access Channel of Beira Port at the depth of 8.0 m with dredging volume of 2.5 million m^3.

The proposed dredger is of a hopper capacity of 2,000 m^3 and draws a full draft of 5.5 m requiring depth of 7.0 m at dumping area. The minimum depth of dumping area is about 4.0 m not allowing dumping operation at low tide. A small dredger with shallower draft has an advantage of less influence from low tide. In this regard, though it is obviously not economical due to higher running costs, in order to achieve a higher operational efficiency brought by a shallower draft, a combination of 2 dredgers with the same total hopper capacity, eg. 2 dredgers of 1,000 m^3 hopper, can be an alternative option.

Dredging fleet formations of one dredger with hopper capacity 2,000 m^3 and two 1,000 m^3 dredgers are compared as below;

	1 x 2,000 m^3 dredger	2 x 1,000 m^3 dredgers
Full Draft	5.5 m	4.0 m
Time affected by Low Tide	40 %	10 %
Maneuverability/safety	Good	Excellent
Purchase/introduction	One time	Can be phased
Docking/repair downtime	Inevitable	Avoidable

The dredging fleet formation of two 1000 m^3 dredgers is not recommended due solely to higher capital and running costs.

However, besides the economic viewpoint, a 1,000 m^3 dredger is of such essential and valuable advantages such as a possibility of phased purchase/introduction, lower effect to operation by low tide, thereby higher efficiency and safety of dredging/dumping operation and higher flexibility of docking/repair scheduling. Phased introduction is to allow a lower financial and managerial burden, while shallower draft permits higher productivity and safety in dredging works.

Therefore, in case that any difficulty or delay in financial and personnel arrangement is expected, the fleet formation of two 1000 m^3 dredgers shall be given thorough consideration from the perspective economical, financial and operational aspects.

2) Front Area of Quay

The area of immediate frontage of the existing quay is silted at an annual rate of about 100 thousand m^3. The area is not accessible by a trailing suction hopper dredger and the dredging work there is assumed to be done by the grab dredger owned by EMODRAGA as done at present. The dredging fleet of one grab dredger, 3 soil barges and 2 tug boats are available in Beira Port for this purpose. The annual dredging capacity is estimated at about 120 thousand m^3.

(2) Dredging Volume

1) Backlog

The existing channel has been silted up with the minimum water depth of less than 5.0 m. The dredging volume required to deepen the channel to the depth of 8.0 m from the depth sounded in April 1996 is calculated at about 4.0 million m^3.

Two Sections, namely E9 and E10, at the channel bend occupy large dredging volumes especially in deepening work to 6.0 and 7.0 m. Interim dredging shall concentrate on these sections at the bend in the first stage and then on the sections upstream from the bend.

2) Maintenance Dredging Volume

Besides the above, the Channel is under continuous siltation at various rates increasing with increase of depth as shown in Table 4.3.2-2.

The highest siltation rate occurs at E9 and E10 of the Macuti corner and a relatively higher siltation is estimated at innermost and outermost parts of the Channel.

(3) Dumping Area

Along the Channel, five dumping sites for dredged soil were designated in the capital dredging work of PA1 within the distance less than 3 km from the Channel as shown in Figure 5.2.2-1 and the minimum depths until which dumping operation is allowed are indicated for each dumping site as below;

Area, Minimum Depth and Distance of Dumping Site

Dumping Site	D1	D2	D3	D4	D5
Area (km^2)	9.9	2.9	8.8	24.1	6.8
Minimum Depth (m)	-0.5	-0.5	+2.0	- 5.0	+2.0
Dumping Distance (km)	1.8	2.7	2.4	1.6	2.5

Dumping distance is an approximate distance to a center of the dumping areas from the Channel. Dumping during flood tide is not allowed for the dumping site D2. Dumping area D1 for the N-S reach of the Channel is very shallow not allowing efficient dumping operation.

The above dumping sites and locations have been reviewed and determined as below based on the latest sounding survey carried out in this study.

Dumping Site	Location	Current Depth
D1	southernmost part only	4.0 m
D2	northern half area only	5.0 m
D3	not used due to insufficient depth	
D4	widened to west	6.0 m
D5	not used due to insufficient depth	

Location and depth of dumping site are key factors governing the efficiency of dredging operations and a sounding survey covering a wide area shall be carried out to evaluate appropriateness of current sites and find better alternate sites based on the results of natural condition survey.

6.2.2 Dredging Schedule

As discussed in the previous sub-section, the dredging works required in Beira Port include a backlog dredging and a maintenance dredging. These two dredging works are discussed below.

(1) Interim Dredging

CFM planned to restore the channels in Beira, Maputo and Quilimane Ports to the original depth in three years from 1997 as below;

	Interim Dredging Plan (million m³)				
	1997	1998	1999	Total	
Beira					
Channel	3.3	3.3	3.3	9.9	(by a chartered dredger)
Berth	0.1	0.1	0.1	0.3	(by Lurio)
Maputo					
Channel	1.5	1.5	1.5	4.5	(by Rovuma)
Berth	0.15	0.15	0.15	0.45	(by Tembe)
Quilimane	0.15	0.15	0.15	0.45	(by Lurio)
Total	5.2	5.2	5.2	15.6	

The above original plan of the interim dredging was not implemented due to financial constraints, and the plan has been changed to 0.5 million m^3 to be dredged in 1997 and 1.5 million m^3 in 1998/99. This change has led to the situation that the new dredger has to be put in a backlog dredging in addition to the maintenance dredging.

As detailed in the following section, the new dredger with a hopper capacity of 2,000 m^3 has an annual dredging capacity of 2.5 million m^3 with total annual working time of 4,224 hours under a working condition of 5 days a week, 44 weeks a year and working efficiency of 0.8. The dredging capacities in the case of increased working hours are calculated as below;

6 days a week, 44 weeks a year	3.232 million m^3/year
6 days a week, 46 weeks a year	3.379 million m^3/year

The interim dredging is planned as below assuming that the new dredger will be operated 6 days a week and 44 weeks a year.

Dredging Volume (x1,000 m^3)

Year	Channel Depth before Dredging	Dredging Volume	Channel Depth after Dredging
1997	5.0 m	0.500	5.0 m
1998	5.0 m	1,500	5.8 m
1999	5.8 m	1,500	6.1 m
2000	6.1 m	3,232	6.9 m
2001	6.9 m	3,232	7.2 m
2002	7.2 m	3,232	7.5 m
2003	7.5 m	3,232	7.8 m
2004	7.8 m	3,232	8.0 m
2005	8.0 m	2,500	8.0 m

As shown in the above, the new dredger has to work 6 days a week for the first 5 years to clear the backlog up and from 2005 onward the channel will be maintained to the depth of 8.0 m with constant annual volume of 2.5 million m^3. In the case that it is worked 6 days a week and 46 weeks a year, the depth of the Channel will reach to 8.0 m one year earlier.

The interim dredging and backlog dredging shall be implemented as quickly as possible to provide best services to the port users.

(2) Maintenance Dredging by New Dredger

The maintenance dredging plan is worked out based on the results from the siltation analysis and summarized in Tables 6.2.2-1 and 6.2.2-2. As shown in the tables, a trailing suction hopper dredger with hopper capacity of 2,000 m^3 meets the dredging requirements in Beira Port. The maintenance dredging plan is described below.

1) Annual Siltation Rate

The annual siltation rates for twelve sections along the access channel have been estimated totaling at 2.5 million m^3/year (in situ volume). The most upstream three Sections E5, E15 and E4 occupy 23 %, two Sections E9 and E10 at the bend 37 % and E14 at the channel entrance 17 %. While two Sections E12 and E13 near the entrance account for only 1 and 2 % respectively due mainly to the flushing effect of tidal current flowing in these sections.

The siltation rate in terms of thickness of sedimentation layer is calculated by dividing the siltation volume by the area of each Section of the Channel. Three Sections of E15, E9 and E10 exceed the annual rate of 1 m. While two Sections of E12 and E13 are silted at an annual rate of about 10 cm requiring maintenance dredging work, say every 5 years.

2) Characteristics of Soil

Soil silted along the channel is classified according to the location of each section based on the results of seabed material investigation presented in Chapter 3. The siltation consists of 45 % of silt mainly in a berth area and 55 % of sand in the remaining middle and outer reaches. Since it is impossible to take an undisturbed sample of soil from the seabed, in situ bulk density can not be measured. In situ bulk densities of silt and sand are determined according to the results of laboratory test of sea bed materials over an estuary area.

Bulk Density of Soil (ton/m^3)

Soil	In Situ	In Hopper (after overflow)
Silt	1.50	1.29
Sand	1.80	1.60

3) Dredging and Turning Time

Time required for dredging is assumed at 1.0 hour for silty sea bed material and 1.25 hours for sand including overflow to obtain the above bulk density in hopper based on the past dredging records with similar soil characteristics in Japan. Time for turning the dredger to sail to a dumping area after dredging is assumed at 0.25 hours.

In case of dredging soft clay, it can be more economical to reduce dredging time and thereby increase the number of cycles. The most efficient dredging time schedule shall be worked out by analyzing dredging records. On board tests shall be carried out in sections with different characteristics involving such simultaneous measurements as ship speed, drag head contact pressure, pump revolutions, pump pressure in/out, pump discharge, soil content, soil volumes pumped/loaded, ship's draft, water level in hopper, soil laboratory test, etc. The results of the tests will give optimum operating conditions of the dredger so as to maximize the efficiency of the dredging work for various types of soil along the Channel.

Total dredging and turning time a year is calculated as 2,654 hours accounting for 68 % of the total working hours.

4) Soil Volume in Hopper

Soil loaded in a hopper increases in volume when dredged from sea bed due to the bulging effect by disturbance and a 2,000 m^3 hopper fully loaded with dredged soil is assumed to contain 1,500 m^3 of sand in situ (75 % of hopper capacity) and 1,100 m^3 of silt in situ (55 % of hopper capacity), respectively. The annual average volume of soil in hopper is calculated as 1,280 m^3.

5) Dumping Area

Five dumping areas were provided in the capital dredging work of PA1 as shown in Figure 5.2.2-1. Of these dumping areas, D5, the upper part of D1 and D3 are planned not to be used in this Study due to the current insufficient depths leaving three dumping areas of the lower part of D1, D2 and D4. Dumping area

D1, 4.0 m deep below CDL is used for dumping dredged soil from the upper reach of the channel up to E8, D2, 5.0 m deep for E9 and E10 and D4, 6.0 m deep for E11 to E14. Mean Low Water Spring Tide is +0.9 m above CDL in Beira Port, which means the water level over the channel area is one meter deeper than the figure indicated in a sounding chart almost all the time throughout the year. Extreme low water levels from +0.2 to +0.3 occur several times in Spring or Autumn and should be taken into consideration in planning dumping operations.

Dumping areas D1 and D2 can not be used due to the draft restriction at low tide, and D4 is used when the dredger can not dump dredged soil with full draft.

Draft of the dredger is 5.5 m when fully loaded with 3,200 tons of sand and 5.0 m for 2,570 tons of silt. Required depth of dumping area is calculated as the sum of a full draft, 5.5 m, swing reach of opening hopper doors, 1.0 m and under keel clearance of 0.5 m.

Restriction of dumping work due to low tides is analyzed for each section for all the dredging cycles in two weeks of annual average tide. The results are summarized below;

D1 (-4.0 m CDL): Silt and sand can be dumped with full load for 75 % and 60 % of working time respectively and D4 has to be used for the remainder.

D2 (-5.0 m CDL): Sand can be dumped with full load for 80 % of working time and D4 has to be used for the remainder.

D4 (-6.0 m CDL): Silt and sand can be dumped with full load at any tide.

Two options can be adopted for dredging work in the Sections from E5 to E10 at low tide. For example, Section E4 can be worked in two different ways as follows;

	Tide	Dredging Area	Dumping Area	Dumping Distance	Sailing Time
i)	High	E4	D1	9.7 km	0.99 hr
	Low	E4	D4	15.5 km	1.60 hr
ii)	High	same as i)			
	Low	E11~E14	D4	1.5 km	0.16 hr

As shown in the above, in the case of dredging (not sticking to E4) one of the Sections from E11 to E14 which are close to deeper dumping area D4, sailing time can be saved by about 1.5 hours per cycle. Dredging operation of option ii) is detailed in Table 6.2.2-2. As shown in the tables, annual working hours reduce from 4,087 hours in option i) to 3,921 hours in option ii) saving 166 hours or 7 days. Dredging work for the Sections E11 to E14 requires about 850 hours (20 % of total working hours) and can absorb all the working hours at low tide for the Sections E5 to E10. Option i) is simpler in planning and operating but does not give the maximum productivity. "Rovuma" was operated by option ii) and in this study, option ii) is taken as a dredging method.

According to option ii), dredged soil is to be dumped to each dumping area as follows;

Volume of Dumped Soil (m^3)

D1	D2	D4
974,215	902,778	623,006
39 %	36 %	25 %

Dumping area D1 receives the largest volume of soil, but it is shallow in depth and its depth shall be periodically checked.

As mentioned previously, a combination of 2 dredgers with a hopper capacity of 1,000 m^3 has merit of less effect from low tide. Dredging plan of 1,000 m^3 dredger is examined in the way as same as 2,000 m^3 dredger and the results are presented in Appendix.

6) Sailing Distance

The sailing distance between a dumping area and each section of the channel is a controlling factor of dredging efficiency and varies from 16.8 km to 1.5 km as shown in Table 6.2.2-2. Sailing time to a dumping area is longer than sailing time from the dumping area due to the different load conditions of full (ship speed: 10.2 knots) and empty (10.8 knots). For the uppermost sections, sailing time is almost the same (90 %) as the dredging and turning time. In addition, an appropriate selection of dumping areas is a controlling factor of efficiency of dredging operation. For the entire reach of the channel, sailing time counts for 23 % of total working hours. The reduction of non-productive time for sailing to/from dumping areas shall be given thorough consideration.

7) Dumping Time

Dumping time of silt is assumed as 0.15 hours being shorter than 0.25 hours of dumping sand due to higher fluidity of silt.

8) Cycle Time

One complete cycle of the dredging operation consists of dredging, turning, sailing to a dumping area, dumping and sailing back to dredging site. Annual average cycle time is calculated as 2.02 hours.

9) Required Number of Cycle

Required annual cycle number of dredging operations for each section is given by dividing an annual siltation volume by a soil volume in hopper. Annual total number of cycles is calculated as 1940.

10) Annual Working Time

Annual working time of each section is given by multiplying the required annual cycle number of dredging operation with a cycle time. Remarkable feature of dredging operation in terms of working time is a very high share of about 37 % in a berth area and 35 % in Sections E9 and E10 at the channel bend.

Total annual workable hours are 4,224 hours and the required annual working hours for the trailing hopper suction dredger of 2,000 m^3 hopper capacity are 3,921 hours giving a ratio of 0.93 less than 1.0 which means the hopper capacity of 2,000 m^3 is appropriate for dredging work of 2.5 million m^3 with an acceptable allowance.

Table 6.2.2-1 Maintenance Dredging Plan (1)
(soil to be dumped at a distant site at low tide)

Hopper Capacity = 2000 m3   Dredging Time Silt 1.00 hr   Sand 1.25 hr   Turning Time 0.25 hr
Ship speed full 10.2 kt,   ballast 10.8 kt

Section	E5		E15		E4		E6		E7		E8		E9		E10		E11	E12	E13	E14	Total
Siltation Vol m³/y	120,488		187,005		276,146		113,057		128,696		148,823		287,820		614,958		101,051	30,637	62,313	429,005	2,499,999
Siltation Vol %	5		7		11		5		5		6		12		25		4	1	2	17	100
Silt'n Thickness m/y	0.78		1.20		0.57		0.33		0.38		0.43		1.11		1.13		0.26	0.09	0.09	0.72	
Soil: Silt or Sand	Silt		Silt		Silt		Silt		Sand		Sand		Sand		Sand		Sand	Sand	Sand	Silt	
Dred'g/Turn'g Time hr	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.25	
Soil in Hopper %	55		55		55		55		75		75		75		75		75	75	75	55	
Soil in Hopper m3	1,100		1,100		1,100		1,100		1,500		1,500		1,500		1,500		1,500	1,500	1,500	1,100	
Dumping Area	D1(75%)	D4	D1(75%)	D4	D1(75%)	D4	D1(75%)	D4	D1(60%)	D4	D1(60%)	D4	D2(85%)	D4	D2(85%)	D4	D4	D4	D4	D4	
Sailing Distance km	11.0	16.8	9.2	15.0	9.7	15.5	6.9	12.8	4.9	10.7	3.0	8.5	2.7	6.4	1.7	4.3	1.8	1.5	1.5	1.5	
Sailing Time to DA hr	0.58	0.89	0.48	0.79	0.51	0.82	0.37	0.68	0.26	0.57	0.16	0.45	0.14	0.34	0.09	0.23	0.10	0.08	0.08	0.08	
Dumping Time hr	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.15	
Sailing Time fm DA hr	0.55	0.84	0.46	0.75	0.48	0.78	0.35	0.64	0.24	0.54	0.15	0.43	0.14	0.32	0.08	0.21	0.09	0.08	0.08	0.08	
Cycle Time hr	2.53	3.13	2.34	2.95	2.39	3.00	2.11	2.71	2.25	2.85	2.06	2.63	2.03	2.41	1.92	2.19	1.94	1.90	1.90	1.55	
Av Cycle Time hr	2.68		2.49		2.54		2.26		2.49		2.29		2.09		1.96						
Required No of Cycle	110		170		251		103		86		99		192		410		67	20	42	390	1940
Req'd Working Hour hr	293.4		423.9		638.9		232.4		213.7		226.8		400.1		803.6		130.4	38.9	79.1	606.3	4,087
Working Hour Ratio %	7.2		10.4		15.6		5.7		5.2		5.5		9.8		19.7		3.2	1.0	1.9	14.8	100.0
T.Dred/Turn'g Time hr	136.9		212.5		313.8		128.5		128.7		148.8		287.8		615.0		101.1	30.6	62.3	487.5	2,653.5
Sailing Time hr	140.1		185.9		287.4		88.5		63.6		53.2		64.3		86.2		12.5	3.2	6.4	60.3	1,051.4
Dumping Time hr	16.4		25.5		37.7		15.4		21.4		24.8		48.0		102.5		16.8	5.1	10.4	58.5	382.6
																				Total	4,087.5

Silt/Sand Ratio %	
Silt	45
Sand	55

Average Cycle Time 2.11 hr

Annual Working Hours	
Week	44
Day	5
Hour	24
Efficiency	0.8
	4,224 hr

Annual Required Working Hours		
Dred'g/Turn'g Time	2,654 hr	65%
Sailing Time	1,051 hr	26%
Dumping Time	383 hr	9%
Total	4,087 hr	100%

Required Working Hours 4,087 hr

Required/Annual Working Hours Ratio 97 %

Table 6.2.2-2 Maintenance Dredging Plan (2)
(Sections E11-E14 to be dredged at low tide)

Hopper Capacity = 2000 m3	Dredging Time	Silt	1.00 hr	Sand	1.25 hr	Turning Time 0.25 hr
Ship speed full 10.2 kt.	ballast 10.8 kt					

Section	E5	E15	E4	E6	E7	E8	E9	E10	E11	E12	E13	E14	Total
Siltation Vol m^3/y	120,488	187,005	276,146	113,057	128,696	148,823	287,820	614,958	101,051	30,637	62,313	429,005	2,499,999
Siltation Vol %	5	7	11	5	5	6	12	25	4	1	2	17	100
Soil: Silt or Sand	Silt	Silt	Silt	Silt	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Silt	
Dred'g/Turn'g Time hr	1.25	1.25	1.25	1.25	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.25	
Soil in Hopper %	55	55	55	55	75	75	75	75	75	75	75	55	
Soil in Hopper m3	1,100	1,100	1,100	1,100	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,100	
Dumping Area	D1	D1	D1	D1	D1	D1	D2	D2	D4	D4	D4	D4	
Sailing Distance km	11.0	9.2	9.7	6.9	4.9	3.0	2.7	1.7	1.8	1.5	1.5	1.5	
Sailing Time to DA hr	0.58	0.48	0.51	0.37	0.26	0.16	0.14	0.09	0.10	0.08	0.08	0.08	
Dumping Time hr	0.15	0.15	0.15	0.15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.15	
Sailing Time fm DA hr	0.55	0.46	0.48	0.35	0.24	0.15	0.14	0.08	0.09	0.08	0.08	0.08	
Cycle Time hr	2.53	2.34	2.39	2.11	2.25	2.06	2.03	1.92	1.94	1.90	1.90	1.55	
Av Cycle Time hr													
Required No of Cycle	110	170	251	103	86	99	192	410	67	20	42	390	1940
Req'd Working Hour hr	276.9	398.3	601.0	217.0	193.0	204.3	389.2	787.1	130.4	38.9	79.1	606.3	3,921
Working Hour Ratio %	7.1	10.2	15.3	5.5	4.9	5.2	9.9	20.1	3.3	1.0	2.0	15.5	100.0
T.Dred/Turn'g Time hr	136.9	212.5	313.8	128.5	128.7	148.8	287.8	615.0	101.1	30.6	62.3	487.5	2,653.5
Sailing Time hr	123.6	160.3	249.6	73.1	42.9	30.7	53.4	69.7	12.5	3.2	6.4	60.3	885.4
Dumping Time hr	16.4	25.5	37.7	15.4	21.4	24.8	48.0	102.5	16.8	5.1	10.4	58.5	382.6
												Total	3,921.4

Silt/Sand Ratio %		Annual Working Hours		Annual Required Working Hours			Required Working Hours
Silt	45	Week	44	Dred'g/Turn'g Time	2,654 hr	68%	3,921 hr
Sand	55	Day	5	Sailing Time	885 hr	23%	
		Hour	24	Dumping Time	383 hr	10%	Required/Annual Working
Average Cycle Time		Efficiency	0.8	Total	3,921 hr	100%	Hours Ratio 93 %
2.02 hr			4,224 hr				

6.2.3 Dredging Cost

A dredging cost is estimated by summing such expenses as depreciation of the dredger, insurance, repair and periodical maintenance, fuel and lubricant, salary and support to crew, survey and administration, etc.

The dredging cost by a foreign contractor is likely to vary between 3 - 4 US$/m^3 (in situ), which indicates there is an economic viability if the dredging works are conducted by EMODRAGA. The current preliminary estimation suggests the maintenance dredging cost of EMODRAGA less than 2 US$/m^3 as outlined below:

Annual Dredging Cost (US$)

Crew	384,840	
Fuel & Lub	943,680	
Maintenance	500,000	
Overhead	672,600	
Depreciation	900,000	
Total	3,401,120	(1.36 US$/m^3)

6.3 Operation and Management

6.3.1 Proposed Organization

(1) Existing Organization

During the colonial period, all the dredging works were carried out by the dredging service department under direct control of the colonial government. In 1980, EMODRAGA was established under the Ministry of Transport and Communications. In 1987, EMODRAGA moved its head office from Maputo to Beira where an administration office, a workshop and a wide storage yard are provided.

In 1982, the Governments of the Netherlands and Mozambique agreed on a technical and financial assistance project to improve the dredging services of EMODRAGA.

In May 1989, the government of Mozambique transferred the ownership and management responsibility of the ports and railways system to CFM State Enterprise. CFM established four regional Executive Directorates, Executive Directorate CFM-S, Executive Directorate CFM-C, Executive Directorate CFM-Z and Executive Directorate CFM-N. The Executive Directorate CFM-C is in charge of the administration of Beira Port. CFM is fully responsible for the management and operation of all the major port. It is a contracting party for maintenance dredging works and the related costs are payable by its own revenues. The Beira Corridor Authority supported CFM in various projects implemented for Beira Port until its dissolution in 1995.

In 1997, EMODRAGA moved its office to the previous office building of the Beira Corridor Authority.

The existing organization of EMODRAGA is shown in Figure 2.2.5-2. The job description of each division is outlined below.

1) Production Division is in charge of planning and control of dredging works with 35 engineers.

2) Maintenance Division is in charge of repair and maintenance of EMODRAGA's dredging fleet with 40 engineers.

3) Administration Division is responsible for all the matters related to accounting and management with 23 staffs.

The total number of a crew operating "Rovuma" is 28 consisting of Captain, Engineer, Dredge Master, First Engineer, First Mate, Second Engineer, Dredge Operator, Electrician, Sailor, Greaser and others.

(2) Required Reinforcement

To operate a new dredger, an additional dredging crew to the existing one is required. Onshore staffs of management and maintenance and survey team can take on new responsibilities in the new dredger with nominal reinforcement. Substantial reinforcement shall be effected to the dredging crew running the new dredger. When the interim dredging is implemented under the joint venture between EMODRAGA and Selmer, EMODRAGA will have a good opportunity to recruit and train dredging crew in addition to the crew of Rovuma.

The tentative plan of crew formation of the new dredger is shown below;

Work Shift : 3 gangs (24 crew each), total working 12 hour 2 shifts with 2 gangs on board for continuous 1 week with 1 gang out of 2 to be replaced in each week end with the third gang on holiday onshore. The dredge masters are readily available from the existing crew of Rovuma and the captains from the shipping market.

Crew	No. (per 3 gangs)
Captain	3
Engineer	3
Dredge Master	3
First Engineer	3
First Mate	3
Second Engineer	3
Dredge Operator	3
Electrician	3
Sailor	20
Greaser	20
Other	8
Total	72

6.3.2 Proposed Operation and Management

(1) Efficient Operation

Efficiency of dredging work depends on such various factors as an adequate dredging plan, dredging technical level, location and depth of dumping areas, tide and wave conditions, soil conditions, seasonal changes of siltation, down time due to holiday and docking for periodical maintenance and repair, etc.

1) On Board Test of Dredging Operation

On board tests of dredging operation shall be conducted at the early stage after introduction of the new dredger to obtain the characteristics of the dredging performance which is affected by various factors such as ship's speed, contact pressure of drag head, soil property, pump discharge, overflow, etc. Based on the results of the on board tests, an efficient dredging plan can be worked out.

2) Dumping Area

Location and depth of dumping area is one of the most important factors controlling dredging efficiency and periodical sounding surveys over all the dumping areas as well as the channel and wide estuary area of 20 x 30 km^2 shall be conducted. Depth of the dumping area will get shallow with large quantities of dumped soil and shall be periodically sounded to avoid the grounding of the dredger. Sounding surveys of wide area on both sides of the Channel gives information on new deep areas which can be advantageously used.

3) Overflow

The efficiency of overflow depends on soil condition (sand, silt or clay) and sailing time to/from a dumping area and the optimal working condition shall be sought through daily dredging records. Laboratory tests of dredged soil shall be conducted together with other dredging tests to improve the dredging efficiency. Agitation dredging can be efficient especially for the dredging of soft clay in a section remoted from a dumping site and shall be examined for its feasibility.

Agitation dredging is one of the dredging methods, employed in removing soft silty seabed material. In this method, pumped soil overflows and is carried away from the dredging area before it settles down to the bottom. This method could be employed in Section E14 during ebb tide.

4) Seasonal and Monthly Dredging Schedule

The change of siltation in the dry and wet seasons shall be given thorough consideration, in planning an annual dredging schedule. Siltation rate in the wet season is three times higher than that in the dry season. Periodical docking and major repair are to be adequately scheduled in consideration of dredging efficiency in each month due to weather and sea condition, dock availability, crew convenience and etc.

5) Natural Condition Survey

Bathymetric survey shall cover the Access Channel and the dumping areas. Bottom sediment shall be at 2 points at each Section of the Access Channel. For accurate positioning, a DGPS or a radio positioning system shall be used.

a) Bathymetric Survey

Seasonal surveys shall be carried out in March and September of every year to analyze siltation conditions in the Access Channel and dumping areas. Sounding surveys before and after dredging works shall be conducted for planning and inspection of the dredging works.

b) Bottom Sediment Survey

Dredged material shall be sampled onboard to analyze grain size distribution, moisture content, bulk density, dry density and etc.

6) Berthing Facility

Facility for berthing and maintenance shall be appropriately arranged and well organized. The outer berth at the fishery port is in an adequate location and planned to be allocated to the new dredger.

7) Dredging in front of Berths

Dredging work along the immediate frontage of berths is planned to be done by Lurio with three soil barges.

(2) Appropriate Management

Efficient management can be achieved with an adequate arrangement and provision of personnel, facilities and budget.

1) Personnel

The new dredger is operated by three gangs of 72 crews. Recruitment and training of a new crew and shift of existing experienced crews shall be planned and implemented well before the introduction of the new dredger. Survey and engineering sections therefore work out an appropriate and efficient dredging plan shall be established. The existing management staffs have already acquired necessary knowledge required for dredging operation and can afford increase of jobs brought by the introduction of the new dredger. The crew required for the interim dredging to be executed by EMODRAGA can be advantageously transferred to the new dredger.

2) Facilities

Facilities for office, maintenance, storage, etc. are already available and a berthing facility shall be secured and improved as required. A survey boat for sounding depth of the channel and dumping areas is indispensable equipment for planning adequate maintenance dredging and securing safety of channel navigation.

3) Budget

The annual operating cost of the new dredger is estimated at about 3.5 million US$ which exceeds the current budget of EMODRAGA. CFM shall allocate this operating cost to EMODRAGA. The improvement of the channel by the new dredger is to bring significant benefits to port users and CFM could increase port tariffs to cover the costs.

6.3.3 Training Program

Since EMODRAGA has sufficient staff with experiences acquired through dredging works carried out under its own management and operation using various types of trailing hopper suction, cutter suction, grab and backhoe dredgers, primary training for basic dredging operation is not necessary. Instead, to further improve the efficiency of dredging works, training at advanced level course like periodical sounding surveys, siltation analysis based on the surveys, soil investigation, planning of optimal and efficient dredging and dumping works through detailed examination of siltation and soil characteristics, improvement of dredging methods, (e.g. agitation dredging, study of overflow, dredging speed, pumping rate, drag head pressure, etc.), overseas training for the crew and training by expatriate staff, scheduling of repair and docking, etc. are required. The existing training school in Maputo can be efficiently used for this purposes. Special training for a dredge master and mechanics is essential. In addition to it, an on-site training during building work of a dredger will be very useful in acquiring practical knowledge for mechanics.

CHAPTER 7

ENVIRONMENTAL ASSESSMENT

Chapter 7 Environmental Assessment

7.1 Initial Environmental Examination

Marine environmental field surveys on Initial Environmental Examination (IEE) in the vicinity of Beira Port were carried out to investigate water quality, seabed materials and benthic macrofaunal community structure.

(1) Natural Environment

In the vicinity of Beira Port, the water quality and seabed materials are affected mainly by tidal current force and variations in climate. Throughout all seasons, land-originated suspended substance here is abundant and the sources of water pollution are originated from the release of domestic, industrial and agricultural effluents through the Pungue River. The distribution of aquatic animal as shrimp is directly related to the existence of mangroves which are regarded as nurseries for the fisheries farming.

Mozambique was considered as one of the African country with rich fauna potential, because of both the quantity and the diversity of wild species. Among the pedogenetically immature soil, the alluvial soils are those which posses the greatest agricultural potential as well as covering considerable areas along the banks of the Pungue River. While, soil erosion is a matter of primary in the environmental problems in the vicinity of Beira.

(2) Beach Erosion of Macuti Coast

In Figure 3.5-1, the amount of sand drift passing the shoal area in front of the Macuti Beach and reaching the Macuti Channel is nearly equal before and after the deepening of the Channel. The amount of sand drift crossing the channel and reaching the Macuti Shoal from the Pelican and the Rambler Shoals decreases after the deepening of the Channel. However, most of the materials which can cross beyond the Channel from the south are fine sand and silt. But, fine sand and silt, in general, do not contribute so much to the formation of beach. While, a part of the dredged materials dumped in the north side of the Channel in this Project will be transported towards the Macuti Beach. This amount of sand moving towards the Macuti Beach will be more than the decreasing amount of sand crossing the Channel from the south. Regarding the countermeasure for beach erosion in the Macuti Coast, it is recommended to construct a long jetty of more than 200 m long at the west end of the Macuti Coast. And in order to prevent sand moving out offshore-ward from the beach, it is effective to construct the groins in T-shape.

(3) Bottom Sediment Materials

In the vicinity area of Beira Port, silty sand is predominant and the mixture with mud and sand covers the seabed around the river mouth of the Pungue River. Furthermore, the seabed offshore and at the river mouth are mainly covered with a variety of well sorted sands made up of origins of the same diameter. The content of the heavy metals and organic substance in the muddy sediment can be considered more than in the sandy sediment. But this concentration is the same level as the coastal sediment of South Africa and is also under the acceptable base level.

(4) Water Quality

In the vicinity of Beira, the estuarine environment is dominated by the fresh water input whereas during the dry season it is dominated by the input of marine water from the shelf.

In regard to coliforms, its high contamination may be caused by lower river flow and the use of the river by local residents and their livestock, as well as drainage water from household under the poor sanitary condition. The strong tidal currents due to wide tidal range, which persist through all seasons, would play a significant role in maintaining suspended material in the water column.

The nutrient levels are observed within the assimilative capacity of the area. For the trace metals, the results for both surveys are generally low and, in many cases, fell below the detection limits of the instrumentation. In regard to toxic organic materials, the results of surveys show a very low concentration of all parameters measured by using a higher detection system.

(5) Benthic Macrofauna around the Dumping Areas

The survey carried out during the dry season aimed to assess the benthic macrofauna at dredging area and dumping site. No rare or endangered species were detected. Many of the samples contained very few species and the population densities were generally low. Therefore, it is assumed that the benthos condition would be poor in this area.

(6) Fishery Resources

The fisheries potential is estimated at 10,000 tons per year, consisting of mainly crustaceans, pelagic fish, shellfish and others. Crustaceans are the most important resources, giving emphasis on shallow-water shrimps along the Macuti Coast in the vicinity of Beira. The distribution of shrimps is directly related to the existence of mangroves in the estuary which are regarded as nurseries for the young.

(7) Employment Opportunity

The total wage of the employee of EMODRAGA will be estimated about 289,800 US$ in this Project. Direct impact of increment of employees can be expected to 33.8 % in term of number of employee and 125.5 % in term of wage as compared to present scale. This impact will bring certain positive effect on the economy of Beira area.

(8) Conclusion of IEE

Apart from some significant faecal contamination, the environment is considered relatively pristine. The water quality parameters of all aspects were within acceptable limits. The high tidal range and the seasonal influx of massive quantities of fresh water, principally via the Pungue River, play a dominant role in forming the environmental condition. Macrobenthic communities are found to be poorly developed. This is evidently due to the wide fluctuations in salinity and high tidal flows which are experienced in the area. The data presented here serve as a baseline of present environmental condition to evaluate the future changes.

7.2 Environmental Impact Assessment

As there are no guidelines of Environmental Impact Assessment (EIA) released publicly in Mozambique, the Japanese guideline is introduced, which comply with the international standards in order to conduct the EIA on the dredging works of the Access Channel.

(1) Diffusion of Suspended Solids through Dredging.

The results of numerical simulation show that the diffusion of suspended solids created by dredging works is quite negligible.

(2) Beach Erosion of the Macuti Coast

Some part of materials dumped in the north side of the Access Channel will serve to nourish the Macuti Beach as mentioned in the previous section. Such amount of sand will be more than the decreasing amount of sand crossing the Access Channel from the south, which is caused by the deepening of the Access Channel in this Project.

(3) Effects of Dredging on Aquatic Life

Effects of turbidity created by dredging works to marine animals living on the seabed will not be serious in the vicinity of Beira Port. The crustaceans and shellfish, generally, are resistant to turbidity. Marine animals, which can live in the low saline and high turbidity water, are predominant here. Therefore, the effects of additional turbidity caused by dredging works to the main marine animals such as the crustaceans and shellfish are assumed to be negligible.

(4) Others

The waste oil from the dredger shall be dehydrated on board. Then, treated waste oil shall be burned and treated water shall be discharged offshore.

The dissolution of metal from seabed sediment by dredging operations is relatively not activated, because of small metal-dissolution rate and property of seabed materials.

(5) Conclusion of EIA

Through the environmental examination described above, it is concluded that the dredging of the Access Channel would not be expected to generate any significant impact on the environment.

CHAPTER 8

ECONOMIC AND FINANCIAL ANALYSIS

Chapter 8 Economic and Financial Analysis

8.1 Economic Analysis

8.1.1 Costs of the Project

(1) Methodology

The economic internal rate of return (EIRR) based on a cost-benefit analysis is applied to appraise the economic feasibility of the project. The EIRR is the discount rate which makes the costs and benefits of the project equivalent during the project life.

The project costs and benefits are evaluated in terms of economic prices (shadow prices) converted from market prices by the conversion factor (0.94) as shown in Table 8.1.1-1.

All the benefits and costs in the analysis are based on the prices in 1997. The project life in the economic analysis is assumed to be 25 years derived from the durable length of time on the dredger being used now by EMODRAGA. The exchange rates adopted for this analysis are as follows.

US$ 1.00 = MT 11,300 MT (Mozambique Meticals)
US$ 1.00 = ¥ 116.84.

The Project is evaluated by means of cost-benefit analysis, comparing the case of achievement of the project (with-case) with the present case of non-achievement of the project (without-case). Using discounted cash flow method, economic internal rate of return (EIRR) will be calculated by means of comparing benefits and costs. And EIRR will be evaluated more deeply by sensitivity analysis.

In "without-case", the channel water depth is maintained to 5.0 m, which is the same as in 1997 for the study by dredging soil volume of 521,991 m^3 a year under outside contract. In base "with-case", one new dredger will be introduced and dredge the soil volume of 2,500,000 m^3 a year under operation by EMODRAGA so that the channel water depth is maintained to 8.0 m, which is the same as the depth in 1991.

(2) Investment Cost

In this Project, a new dredger shown in Table 8.1.1-1 is assumed to be introduced by the foreign currency portion at the end of 1999. As investment costs shown in Table 8.1.1-1 do not include any transfer items such as customs duties and the foreign exchange rate is a float one, it is not necessary to convert into shadow prices. Therefore, the manufacturing cost of the new dredger introduced in this Project is estimated to be US$ 24,251,000 and the total capital investment cost is estimated at US$ 26,761,000.

(3) Operation Cost

In order to dredge the soil volume of 2,500,000 m^3, operation costs shown in Table 8.1.1-1 are needed every year. The annual operation costs consist of labor costs of crew, provisions of food for local crew onboard, fuel oil costs, lubricating oil costs, maintenance and repair costs, and other administration costs. As the crew of new dredger consist of 72 skilled persons, the labor cost should be converted in shadow prices (US$ 272,412) by multiplying market prices (US$ 289,800) by the conversion factor (0.94). Other costs in shadow prices are calculated in the same manner as labor costs and the annual operation costs amount to US$ 2,351,053 in shadow prices, as shown in Table 8.1.1-1.

In the year from 2000 to 2004 after the Interim Dredging, the soil volume to be dredged amounts to 3,231,714 m^3 for 264 days every year. Therefore, labor costs, provisions for crew onboard and fuel costs from 2000 to 2004, are increased to US$ 339,002, US$ 107,205 and US$ 1,064,535 respectively, so that the annual operation costs from 2000 to 2004 increase to US$ 2,612,986 in shadow prices as shown in Table 8.1.1-1.

Table 8.1.1-1 Operation Costs and Investment Costs

(unit : US$)

	Local Portion		
item	Market Price US$	Conversion Factor	Shadow Price US$
Labor Cost (skilled 72 Persons)	289,800	0.94	272,412
Provisions for crew onboard (=9 US$/day×48persos×220days	95,040	0.94	89,338
Fuel Oil Cost (=12,767kg/day×220days×US$280/ton)	786,400	0.94	739,216
Lublicating Oil Cost(=Fuel×0. 2)	157,280	0.94	147,843
Maintenance & Repairing Cost	500,000	0.94	470,000
Administration Cost	672,600	0.94	632,244
Operation Cost / Year 2005~2024Total	2,501,120		2,351,053
Operation Cost / Year 2000~2004Total	•		2,612,986
Labor Cost = 272,412(1+1/12/30×200%×44) = 339,002 US$			
Provisions for Crew Onboard = 9 US$/day×48persons×264days ×0.94 = 107,205 US$			
Fuel Cost = (12,767kg/day×264days×US$280/ton) ×1.2 ×0.94 = 1,064,535 US$			
Investment Cost	26,761,000	1.00	26,761,000

8.1.2 Benefits of the Project

Considering the "With" and "Without" cases, the following items are identified as major benefits of the Maintenance and Improvement Plan of the Access Channel of Beira Port from a viewpoint of the national economy.

(1) Saving in Ship Staying Costs

The forecast of waiting time for calling ships from 2000 to 2025 by Channel Traffic Simulation is shown by ship type in the chapter 5.1.3. The difference between without-case (the channel water depth of 5.0 m) and with-case (the channel water depth of 8.0 m) is the benefit on waiting time and the ship staying cost is calculated by multiplying the waiting time by the charterage by each ship type at Beira Port. As the charterage at Beira Port is given in foreign currency at international shipping company rates, the ship staying cost is expressed in economic price. And the rate belonging to the national economy of Mozambique is to be 50 % of the total benefits. Benefits of saving in ship staying cost with the channel water depth of 8.0 m is shown in Table 8.1.2-1.

Table 8.1.2-1 Benefits of Saving in Ship Staying Cost, etc. (in Base Case of 8.0 m Channel Depth)

(unit : US$)

Year	Ship Staying Cost	Cost up of transportation		Dredging Cost to maintain 5 m	Total
		by other port	by Tanker		
2000	3,229,798	1,419,577	768,992	1,565,973	6,984,340
2002	3,512,173	1,493,190	811,978	1,565,973	7,383,314
2007	4,227,904	1,694,358	930,250	1,565,973	8,418,485
2010	4,852,057	1,902,625	1,036,459	1,565,973	9,357,114
2017	4,852,057	1,902,625	1,036,459	1,565,973	9,357,114
2022	4,852,057	1,902,625	1,036,459	1,565,973	9,357,114
2024	4,852,057	1,902,625	1,036,459	1,565,973	9,357,114

(2) Saving in Costs of Transportation by Using the Other Port

The cargo volume for trade goods from Zimbabwe in 2002 shiftable to Harare-Beira from Harare-Maputo by the improvement of waiting time at Beira Port is estimated at 298,000 tons. The freight of container by railway is 368.1 Zimbabwe Dollar (Z$) per ton for imports and 286.2 Z$ per ton for exports between Harare-Maputo for the distance of 1,270 km. On the other hand, the freight between Harare-Beira with the distance of 600 km is 238.3 Z$ per ton for imports and 197.5 Z$ per ton for exports. Therefore, by using Maputo Port instead of Beira Port, the cost of transportation in the import of goods and the export of goods for Zimbabwe is estimated to rise to 129.8 Z$ (= US$ 12.5) /ton and 88.7 Z$ (= US$ 8.5) /ton, respectively. Then, by multiplying the cost up/ton by the shiftable cargo tonnage, the total cost up amounts to US$ 3,177,000 as the market price, of which the economic price amounts to US$ 2,986,380 by multiplying by the conversion factor of 0.94. 50 % of this benefit seems to belong to Mozambique. Therefore, as shown in Table 8.1.2-1, the benefit in 2002 amounts to US$ 1,493,190 which is 50 % of US$ 2,986,380.

(3) Saving in Transportation Costs by Tanker

The Beira Port has the Oil Terminal and the Oil Pipe Line to Zimbabwe. Under the channel water depth of 7.0 m, tankers of 50,000 DWT cannot be accommodated and tankers of 30,000 DWT with the limitation of maximum loading oil of 25,000 tons are received. According to the data of shipping agency in Beira Port, the distance from Aden to Beira is 3,500 km and a voyage of tanker takes 14 days. With the channel water depth of 8.0 m, a tanker of 50,000 DWT is able to be used and the cost of transportation becomes less by 15 % than the cost of a 30,000 DWT tanker. Therefore, saving in unit cost of transportation by tanker is calculated as follows :

Staying Cost of the tanker of 30,000 DWT (16,000 US$/day) x 14 days
/ 25,000 tons = US$ 8.96 / ton (cost/ton of oil transportation)

US$ 8.96 / ton (cost/ton of oil transportation) x 15 % = US$ 1.344 / ton

As the ratio belonging to Mozambique economy is to be 50 % of the total benefits, the benefit is calculated as follows :

US$ 1.344 / ton x 50 % = US$ 0.672 / ton

US$ 0.672 / ton x 1,208,300 tons (oil cargo in 2002) = US$ 811,978

(4) Saving in Dredging Costs to Maintain the 5.0 m Channel Depth

In the without-case in which no dredger is introduced, dredging costs to maintain the channel water depth of 5.0 m are needed for an outside contract. The unit dredging price by an outside contract is about US$ 3.00 with the economic price as the foreign currency. Therefore, saving in dredging costs to maintain the channel water depth of 5.0 m is calculated as follows:

Soil volume to be dredged per annum

521,991 m^3 × US$ 3.00 = US$ 1,565,973

The following benefits are considered intangible.

- Saving in costs of cargo inventory by shortening tide waiting time
- Improvement of safe navigation for entry and departure
- Possibility of sailing on schedule of large-scale ships
- Increase in cargo volume, employment opportunities and incomes.

8.1.3 Calculation of EIRR and Evaluation

(1) Calculation of EIRR

From the view point of the national economy, the costs and benefits are discounted by the social discount rate which is commonly set up at a rate higher than the opportunity cost of capital. According to the Staff Appraisal Report by the World Bank in 1994, all Projects for Trunk Roads of Mozambique had the EIRR between 17.5 % and 22.9 % in excess of the estimated opportunity cost of capital (12 %). The EIRR as 24.38 % at the shadow price of this project is much higher than the estimated opportunity cost of capital (12 %) and in excess of EIRR for Trunk Roads of Mozambique.

(2) Sensitivity Analysis

In order to evaluate whether the project is feasible against possible changes of calculation conditions, a sensitivity analysis is made for 7 alternatives of Case A to Case G as shown in Tables 8.1.3-1 and 8.1.3-2. The sensitivity analysis for 3 alternatives of Cases A-C is calculated by using the same formula as the basic case and the results are summarized in Table 8.1.3-1. Table 8.1.3-2 shows the results of the sensitivity analysis for fluctuations of the investment costs and project life.

Table 8.1.3-1 EIRR by Sensitivity Analysis of Channel Depth

(unit : US$)

Case	Channel Water Depth (m)	EIRR (%)	Maintenance Dredging Volume (m^3)	Cost of the Project		Total Benefits
				Investment Cost	Operation cost	
Case C	6.0 m	21.55%	725,493	18,700,000	1,758,780	141,147,755
Case B	7.0 m	22.52%	1,698,509	22,400,000	2,105,580	178,171,717
Base Case	8.0 m	24.38%	2,500,000	26,761,000	2,351,053	220,116,734
Case A	9.0 m	21.97%	3,482,786	29,300,000	2,473,015	221,396,648

Table 8.1.3-2 EIRR by Sensitivity Analysis of Investment Cost and Project Life

Case D	Investment Cost × 1.1	EIRR = 21.97%
Case E	Investment Cost × 0.9	EIRR = 27.37%
Case F	Project Life of 20 Years	EIRR = 24.06%
Case G	Project Life of 30 Years	EIRR = 24.48%

(3) Economic Evaluation

As shown in Table 8.1.3-1, the effect of investment of the Project introducing the new dredger is very high and the basic case is evaluated as the best comparing with the other alternatives of Case A to Case C.

Further, as shown in Table 8.1.3-2, the EIRR is high in spite of fluctuations of the investment costs and the project life. Therefore, this Project is judged to be feasible from an economic viewpoint.

8.2 Financial Analysis

8.2.1 Discount Cash Flow Analysis

This study aims at analyzing the profitability of the Project itself, seeking the financial internal rate of return (FIRR) by the Discount Cash Flow Method. The FIRR is a discount rate which makes the net present value of the cash flow (income minus cost) equal to zero.

As the objectives of this Project is maintenance and improvement of the Access Channel of Beira Port, the income of this Project is assumed to be paid from the Port Department of CFM-C. The income of EMODORAGA by this Project should consist of the fixed revenues equivalent to the fixed cost (labor costs, maintenance costs, repair costs, administration costs and depreciation) and the variable revenues in proportion with the dredged soil volume by US\$ 0.57 / m^3. As shown in Table 8.2.1-1, the income of EMODRAGA on and after 2005 is assumed to amount at US\$ 3,850,796 including the continuing profit of 10 %. Therefore, the dredging unit cost is calculated at 1.54 US\$/m^3, dividing the above income by dredging soil volume of 2,500,000 m^3.

The FIRR becomes 2.28 % between 2% and 3%, the same level as the interest rate of foreign loans, as shown in Table 8.2.1-2. Also, Table 8.2.1-2 shows the results of the sensitivity analysis for fluctuations of the income and the investment costs.

Table 8.2.1-1 Income for Costs and Benefits

(unit : US$)

Year	Dredged Soil Volume	US$ 0.57/m^3	Fixed Cost	Total Income	Operation Cost	Investment Cost
2000	3,231,714	1,842,077	2,425,796	4,267,873	2,779,772	26,761,000
2001	3,231,714	1,842,077	2,425,796	4,267,873	2,779,772	0
2002	3,231,714	1,842,077	2,425,796	4,267,873	2,779,772	0
2003	3,231,714	1,842,077	2,425,796	4,267,873	2,779,772	0
2004	3,231,714	1,842,077	2,425,796	4,267,873	2,779,772	0
2005	2,500,000	1,425,000	2,425,796	3,850,796	2,501,120	0
2006	2,500,000	1,425,000	2,425,796	3,850,796	2,501,120	0
↓	↓	↓	↓	↓	↓	↓
2024	2,500,000	1,425,000	2,425,796	3,850,796	2,501,120	0

Note-1 : Fixed Cost= Labor Cost +Maintenance & Repair Cost
+Administration Cost +Depreciation = US$ 2,425,796

Note-2 : Labor Cost in 2000~2004 = 289,800(1+1/12/30×200%×44) = 360,640 US$
Provisions for Crew Onboard in 2000~2004 = 9 US$/day×48persons×264days= 114,048 US$
Fuel Cost in 2000~2004 =(12,767kg/day×264days×US$280/ton)×1.2= 1,132,484 US$

Table 8.2.1-2 FIRR by Sensitivity Analysis

Base Case		FIRR=	2.28%
Case A	Investment Cost × 1.1	FIRR=	1.38%
Case B	Investment Cost × 0.9	FIRR=	3.32%
Case C	Income per annum × 1.05	FIRR=	3.74%
Case D	Income per annum × 0.95	FIRR=	0.85%

8.2.2 Analysis of Financial Statement

At the end of the project life, the Project is to gain Current Assets estimated at 29.3 million US$ which can recover the initial investment of 26.76 million US$ and can use the new funds of 5.2 million US$, as shown in Table 8.2.2-1. Therefore, this Project is considered to be feasible enough in spite of the low level of FIRR.

8.2.3 Financial Management

Table 8.2.3-1 shows the trend of profit and loss (P/L) on the Port Section of CFM-C during 2000-2024 and the source of funds to pay for the operation and maintenance cost of this Project in the case of gaining a marginal profit under a certain fixed cost.

The rate of expenses for new dredging (= Revenues for EMODRAGA of this

Project) against the source of funds for CFM-C, out of which the operation and maintenance costs of this Project can be paid for, will decrease from 19.7 % in 2000 to 9.8 % in 2024 as a result of an increased cargo volume of Beira Port. Generally, the profit of enterprises is to be divided as follows :

1) 1/3: the source for the rise in the labor cost and other expenses for next year
2) 1/3: the source for the short-term operational funds as dredging cost or maintenance cost, etc. in the next year
3) 1/3: the source of the long-term investment in the future

The rate of②/① as shown in Table 8.2.3-1 is calculated at 14.1 % in 2007 and increase year by year. If the cargo volume of Beira Port will not increase against the demand forecast of SATTC, the raising of the Port Charge has to be investigated.

In the data of shipping tariffs of Beira Port, the ratio of maintenance costs of navigation aids by INAHINA is about 40 %. As the improvement of the Access Channel of Beira Port increase the safety of channel navigation to the Port, a part of the tariff shall be paid to EMODRAGA as a dredging cost.

If the transportation time of a container cargo of Zimbabwe becomes shortened, the cargo owners will gain the profit of US$ 12.5 /ton for import and of US$ 8.5 /ton for export as shown in the Chapter 8.1.2. If these profits are absorbed to raise the port charge of container cargo, the increase of tariffs amounts to US$ 6,312,626 in 2000 which is 148 % of the new revenue for EMODRAGA in this Project.

Total benefit of saving in ship staying cost in the case of channel water depth with 8.0 m through the execution of this Project is estimated to amount to US$ 112,117,960 for 25 years. In 2007, these benefits reach a total of US$ 4,227,904 and the benefit per ship of tanker with shipping tariffs from US$ 10,000 to 14,000 amounts to US$ 25,506. These benefit will justify the raising of port charges by CFM-C.

Table 8.2.2-1 P/L, B/S, Statement of Source and Application of Funds of EMODRAGA

(unit : US$)

P/L		→	
Fiscal Year	2000	→	2024
(A) Revenue	4,267,873		3,850,796
(B) Expenses	2,779,772		2,501,120
(C) Depreciation	963,396		963,396
(A-B-C) Profit & Loss	524,705		386,280
Net Profit after Income Tax	262,353		193,140
Accmulated Profit & Loss	262,353		5,174,563

B/S		→	
Fiscal Year	2000	→	2024
Current Assets	1,225,748		29,259,462
Fixed Assets	25,797,604		2,676,100
(A) Assets	27,023,352		31,935,562
(B) Liability	0		0
(C) Capital	26,761,000		26,761,000
(A-B-C) Surplus	262,352		5,174,562

Statement of Source and Application of Funds			
Fiscal Year	2000	→	2024
Net Profit after Tax etc.	262,353		193,140
Depreciation	963,396		963,396
Capital	26,761,000		0
(A) Source of Funds	27,986,749		1,156,536
Initial Investment	26,761,000		0
Repayment of Loan	0		0
(B) Application of Funds	26,761,000		0
(A-B) Increase of Current Asset	1,225,749		1,156,536

Table 8.2.3-1 Operation and Maintenance Cost for New Dredger of EMODRAGA

(unit : 1000 US$,metric tons)

	2000	2002	2007	2012	2017	2022	2024
Cargo Volume of Beira Port(tons)	3,072,096	3,274,400	3,737,650	4,408,360	5,100,095	5,927,288	6,301,893
(A) Operational Revenue	37,667	40,028	45,767	52,470	56,273	60,819	62,877
(B) Direct (Variable) Expenses	12,155	12,917	14,769	16,932	18,159	19,626	20,290
(A-B) Marginal Profit	25,512	27,111	30,998	35,538	38,114	41,193	42,587
F. Fixed Expenses	4,221	4,221	4,221	4,221	4,221	4,221	4,221
(G=A-B-F) Continuing Profit	21,291	22,890	26,777	31,317	33,893	36,972	38,366
①=Source of ②	21,618	23,279	27,316	32,030	34,705	37,903	39,350
②=Payment to EMODRAGA	4,268	4,268	3,851	3,851	3,851	3,851	3,851
Rate(%) of ②/①	19.7%	18.3%	14.1%	12.0%	11.1%	10.2%	9.8%

Note : ②=Operation and Maintenance Cost for the new dredger(included Depreciation), (B)=(A)×32.27%

CHAPTER 9

IMPLEMENTATION PLAN

Chapter 9 Implementation Plan

9.1 Manufacturing of the Dredger

9.1.1 Scope of Works

When the construction work of the recommended dredger is executed, the scope of works of the shipbuilder, the consultant and the owner may be as follows.

(1) Scope of Works of the Consultant
- Detailed design, tendering work and construction supervision.

(2) Scope of Works of the Shipbuilder
- Procurement and construction
- Required tests and trials.
- Training of crew.
- Mobilization of the dredger.

(3) Scope of Works of the Owner
- Authorization and permissions required for implementation
- Provisional nationality certificate and necessary documents
- Quay for safe mooring of the dredger
- Necessary procedures to accept the dredger and registration

9.1.2 Manufacturing Schedule of the Dredger

For the construction of the dredger, approximately 20 months are required after contracting. And further 3 months will be necessary for mobilization to Beira Port and for delivery as shown in Figure 9.1.1-1.

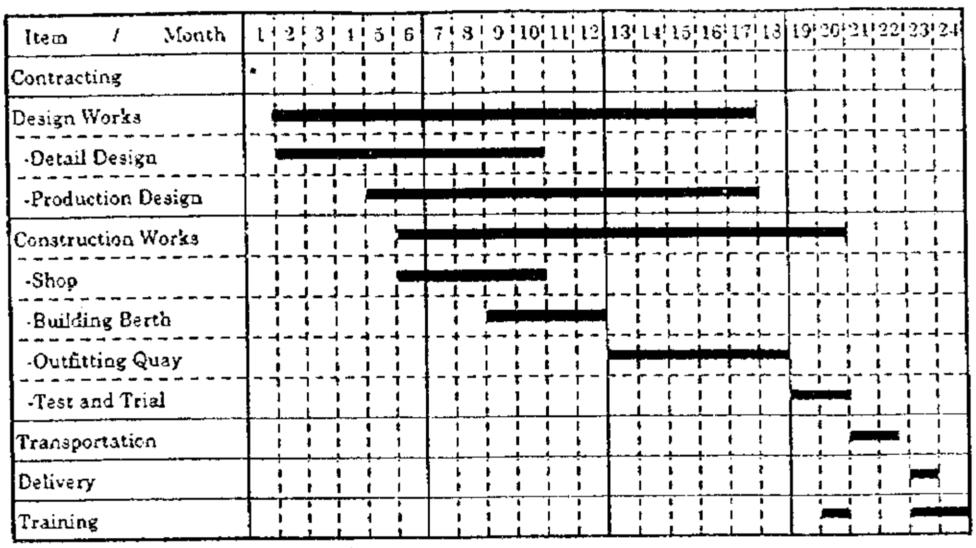

Figure 9.1.1-1 Expected Implementation Schedule of Dredger

9.1.3 Raising Funds

According to the Study, a new dredger is necessary to maintain and improve the Access Channel of Beira Port. And introduction of a new dredger has been evaluated to be financially sound in terms of FIRR. The required funding shall be raised from foreign sources at a low interest rate or on a grant basis.

9.2 Dredging Operation and Management

9.2.1 Management of the Dredger and Relevant Equipment

(1) Dredger

Regular maintenance and repair in addition to daily inspection are most important for a trailer suction hopper dredger, not only interms of dredging parts but also in terms of sailing parts. Measuring devices such as water flow, concentration and draft meters in a dredger are sensitive and annual maintenance by the staff of the manufacturer will be necessary.

(2) Survey Equipment

A survey boat in good condition is necessary to make soundings survey on the bathymetric condition of the Access Channel and the dredging performance, in which a complete array of survey equipment including a data processor is installed.

(3) Navigation Aids

For safe navigation of ships in the Access Channel, regular maintenance, accident prevention and remedy of accident are to be undertaken at appropriate intervals.

9.2.2 Operation and Management

Regarding the operation and management of maintenance dredging, the following points are recommended in order to make the maintenance dredging more effectively.

(1) Supporting and Upgrading Communications

Supporting and upgrading communications between the relevant organizations should be taken into consideration as follows.

- Budget of maintenance dredging
- Fulfillment of each body's responsibility for maintenance dredging

(2) Operation and Management System

Strengthening the operation and management system of EMODRAGA should take the following points into consideration.

- Monitoring system for dredging operation
- Maintenance and repair program
- Procurement of spare parts and materials

(3) Training of Personnel

The training program is aimed at establishing a systematic dredging operation, from the drawing up of the dredging program based on an appropriate monitoring system, priority of demand and budgeting constraints to how to execute the maintenance dredging for the highest productivity level. To this end, the training of personnel in all the relevant dredging authorities is required.

CHAPTER 10

CONCLUSION AND RECOMMENDATION

Chapter 10 Conclusion and Recommendation

10.1 Conclusion

Present Situation and Problems of Beira Port

Mozambique is situated in the east coast of Southern Africa. In 1995, the population was 17.4 million and the GNP per capita was about US$ 90. Nacala Port in the northern part, Beira Port in the central part and Maputo Port in the southern part are the major ports in Mozambique.

Beira Port is located at the estuary of the Punque River and has container and general cargo berths of 1,632 m in total length and an oil berth. Beira Port is playing an important role as a gateway of sea transport not only for Mozambique but also for inland countries such as Zimbabwe, Malawi, etc. through railways, roads and oil pipe lines. The total cargo handled at Beira Port was about 2.6 million ton in 1996, of which about 80 % were transit cargoes to and from the inland countries, and is estimated to increase double to 5 million ton after 20 years.

Port facilities has a enough capacity for the future increase of cargo, but the shoaling due to the sedimentation in the Access Channel is so severe that is a bottleneck for the navigation of a large ships such as tankers and bulk-carriers. This is a serious factor to impede the sound development of Beira Port. The tidal range in Beira Port is very large and is beyond 6 m, so that large ships pass the Access Channel taking advantage of the high tide.

In 1990, the Access Channel of 28 km in length was dredged to 8 m deep below CDL taking the 30,000 DWT tanker and general cargo ship as the design ship under a grant aid by the Netherlands. Thereafter, its maintenance dredging scarcely has been executed, so that at present the shallowest water depth reaches until about CDL -5 m. Therefore, large ships are compelled to do uneconomical transportation due to a long tide waiting and a decrease of ship draft by partially loaded cargo. In 1990, the average tide waiting hour of large ships more than 5 m in draft was recorded as 30 hours.

The maintenance dredging at all ports in Mozambique is being executed by EMODRAGA under the budget of CFM. EMODRAGA has one grab dredger in Beira Port, but it is obsolescent and engages only in dredging the mooring basin in front of the berth. The trailing suction hopper dredger "Rovuma", which operates mainly at Maputo Port, is also obsolescent and has not remaining a capacity to dredge the Access Channel in Beira Port besides Maputo Port.

Maintenance Dredging Volume of the Access Channel

The channel traffic simulation based on the forecast cargoes has made clear that the tide waiting time of ships is significantly very high for the cases of 5 and 6 m in channel depth and that it is within the permissible limit for the case of 8 m. That is, the average tide waiting time becomes to more or less 5 hours per ship for the case of 8 m channel depth.

Based on the sedimentation characteristics and its volume obtained from field observations, analysis of sounding maps and past data, and computer simulation, the average annual maintenance dredging volume for the case of 8 m has been estimated at 2,500,000 m^3. However, the actual maintenance volume for each year seems to vary more or less 50 % owing to the fluctuation of river flows and cyclones attacking Beira Port.

Countermeasure of Improvement and Maintenance of the Access Channel

The introduction of a trailing suction hopper dredger with hopper capacity of 2,000 m^3 is judged to be the most appropriate and optimal option for the purpose of restoring and maintaining the Access Channel to 8 m deep. Its construction cost is estimated at US$ 25 million and the operation cost is approximately US$ 3.4 million. The dredging fleet formation of two dredgers with hopper capacity of 1,000 m^3 can be considered as an alternative. However, it is not recommended due to higher capital and running cost, though it has such advantages as the possibility of phased purchase and introduction, and the higher operation efficiency in the low tide by its shallower draft.

The concepts of the recommendable dredger are as follows

Hopper capacity	2,000 m^3
Length overall	83.0 m
Breadth mould	15.0 m
Fully loaded draft	5.5 m
Running speed under full load	10.2 knots

Environmental Evaluation

In environmental examination, there was not found any injurious substances complying to the level of the international standards in the quality of water and bottom sediments. Also, it is concluded that this Project would not be expected to generate any significant damaging impact on the environment.

Economic and Financial Evaluation

The economic internal rate of return (EIRR) of this Project has been calculated to be 24.38 % at the shadow price, so that this Project is expected to generate a enough high economic effect to Mozambique. On the financial management, the operation cost is paid from the revenue increase of CFM by the ship cargoes increase, so that this Project is also judged to be sound and appropriate from the view point of finance.

From the above mentioned, through consideration of important role of Beira Port for the sea transport of Mozambique and neighboring inland countries, the urgent implementation of the maintenance and improvement of the Access Channel to Beira Port in this Project is considered to be essential and significant.

10.2 Recommendation

The followings are recommended for the maintenance and improvement of the Access Channel to Beira Port:

(a) For the purpose of improving the efficiency and safety on navigation of calling ships, it is recommended urgently to introduce the above mentioned dredger in order to recover and maintain the Access Channel to -8 m below CDL by using it,

(b) For the effective operation of the dredger, recruitent of new crews and shifting of existing experienced crews shall be planned and implemented well before the introduction of the new dredger,

(c) The training program of crews of the new dredger and engineers in charge of dredging plan and oceanographic survey should be appropriately arranged and should be begun before introducing the new dredger,

(d) The location of dumping areas is an important factor controlling the efficiency of dredging operation. Therefore, sounding surveys of the dumping areas shall be conducted as often as possible in order to establish the appropriate dredging and damping plan,

(e) The sedimentation volume in the Access Channel is very changeable by season and year, so that it is very important to establish an appropriate dredging plan on the careful study of the result of sounding surveys,

(f) In order to clarify the sedimentation phenomenon of the Access Channel, the extensive hydraulic surveys including its surrounding area shall be carried out at the wet and dry seasons every year,

(g) The dredging works are executed under the contract between CFM and EMODRAGA. The contract forms after the introduction of a new dredger should be studied carefully and prepared in advance by them in order to secure the sound finance of EMODRAGA.

APPENDICES

A-1 Advisory Committee, Study Team and Study Schedule

1. Advisory Committee

The Advisory Committee consists of three experts.

Name	Assignments
Mr. Hozumi KATSUTA	Team Leader
Mr. Tetsuya SHIRAISHI	Member
Mr. Yasuyuki NAKAGAWA	Member

2. Study Team

The Study Team consists of nine experts.

Name	Assignments
Dr. Shoji SATO	Chief Consultant, Waterway Planning and Environmental Assessment
Mr. Hisanori KATO	Port Planning and Dredging Plan
Mr. Yutaka OCHI	Access Channel Protection Work
Mr. Katsuhiro SATO	Siltation Analysis
Mr. Shinji OKADA	Natural and Environmental Condition Survey
Mr. Masakiyo MURAOKA	Natural Condition Survey
Mr. Toshimasa SUZUKI	Dredging Design and Cost Estimate
Mr. Masakazu ISHIHARA	Economic and Financial Analysis
Dr. Mohan Prasad SHARMA	Coordinator

3. Study Schedule

Study in the Mozambique was conducted as follows;

Field Study	Period	Activities
First Field Study	Jan 14-Mar 27,1997	Submission of Inception Report, Data Collection and Natural Condition Survey
Second Field Study	Apr 18-May 2,1997	Supplementary Survey on Natural Condition
Third Field Survey	Jul 17-Sept 9,1997	Submission of Interim Report, Data Collection and Natural Condition Survey
Fourth Field Survey	Jan 25-Feb 13,1998	Submission of Draft Final Report

Table A-1 Maintenance Dredging Plan

(soil to be dumped at a distant site at low tide)

Hopper Capacity = 1000 m3 | Dredging Time Silt 1.00 hr | Sand 1.25 hr | Turning Time 0.25 hr

Ship speed full 10.2 kt. | ballast 10.5 kt

Section	E5		E15		E4		E6		E7		E8		E9		E10		E11	E12	E13	E14	Total
Siltation Vol m^3/y	120,488		187,005		276,146		113,057		128,696		148,823		287,820		614,958		101,051	30,637	62,313	429,005	2,499,999
Siltation Vol %	5		7		11		5		5		6		12		25		4	1	2	17	100
Soil: Silt or Sand	Silt		Silt		Silt		Silt		Sand		Sand		Sand		Sand		Sand	Sand	Sand	Silt	
Dred'g/Turn'g Time hr	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.50	1.50	1.50	1.50	1.50		1.50		1.50	1.50	1.50	1.25	
Soil in Hopper %	55		55		55		55		75		75		75		75		75	75	75	55	
Soil in Hopper m3	550		550		550		550		750		750		750		750		750	750	750	550	
Dumping Area	D1 (98%)	D2	D1 (98%)	D2	D1 (98%)	D2	D1 (98%)	D2	D1 (90%)	D2	D1 (90%)	D2	D2 (100%)		D2 (100%)		D4	D4	D4	D4	
Sailing Distance km	11.0	13.1	9.2	11.3	9.7	11.8	6.9	9.0	4.9	10.7	3.0	8.5	2.7		1.7		1.8	1.5	1.5	1.5	
Sailing Time to DA hr	0.58	0.69	0.48	0.60	0.51	0.62	0.37	0.48	0.26	0.57	0.16	0.45	0.14		0.09		0.10	0.08	0.08	0.08	
Dumping Time hr	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.25	0.25	0.25	0.25	0.25		0.25		0.25	0.25	0.25	0.15	
Sailing Time fm DA hr	0.56	0.67	0.47	0.58	0.50	0.60	0.36	0.46	0.25	0.55	0.15	0.44	0.14		0.08		0.09	0.08	0.08	0.08	
Cycle Time hr	2.54	2.76	2.36	2.58	2.41	2.63	2.12	2.34	2.26	2.87	2.06	2.64	2.03		1.92		1.94	1.91	1.91	1.56	
Av Cycle Time hr	2.55		2.36		2.41		2.13		2.32		2.12		2.03		1.92						
Required No of Cycle	219		340		502		206		172		198		384		820		135	41	83	780	3879
Req'd Working Hour hr	558.2		802.5		1211.2		436.8		397.7		420.8		779.8		1576.2		261.1	77.9	158.4	1214.2	7,895
Working Hour Ratio %	7.1		10.2		15.3		5.5		5.0		5.3		9.9		20.0		3.3	1.0	2.0	15.4	100.0
T.Dred/Turn'g Time hr	273.8		425.0		627.6		256.9		257.4		297.6		575.6		1229.9		202.1	61.3	124.6	975.0	5,307.0
Sailing Time hr	251.5		326.4		508.3		149.1		97.4		73.6		108.2		141.3		25.3	6.4	13.0	122.2	1,822.8
Dumping Time hr	32.9		51.0		75.3		30.8		42.9		49.6		95.9		205.0		33.7	10.2	20.8	117.0	765.1
																				Total	7,894.9

Silt/Sand Ratio %

Silt	45
Sand	55

Average Cycle Time

2.04 hr

Annual Working Hours

Week	44
Day	5
Hour	24
Efficiency	0.8
	4,224 hr

Annual Required Working Hours

Dred'g/Turn'g Time	5,307 hr	67%
Sailing Time	1,823 hr	23%
Dumping Time	765 hr	10%
Total	7,895 hr	100%

Required Working Hours

7,895 hr

Required/Annual Working Hours Ratio 187 %

Working ratio of 2 x 1000 m3 dredgers is 93 %.

Table A-2 Maintenance Dredging Plan

(Sections E9-E14 to be dredged at low tide)

Hopper Capacity = 1000 m3 Ship speed full 10.2 kt.

Dredging Time Silt 1.00 hr Sand 1.25 hr Turning Time 0.25 hr

ballast 10.5 kt

Seciton	E5	E15	E4	E6	E7	E8	E9	E10	E11	E12	E13	E14	Total
Siltation Vol m^3/y	120,488	187,005	276,146	113,057	128,696	148,823	287,820	614,958	101,051	30,637	62,313	429,005	2,499,999
Siltation Vol %	5	7	11	5	5	6	12	25	4	1	2	17	100
Soil: Silt or Sand	Silt	Silt	Silt	Silt	Sand	Sand	Sand	Sand	Sand	Sand	Sand	Silt	
Dred'g/Turn'g Time hr	1.25	1.25	1.25	1.25	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.25	
Soil in Hopper %	55	55	55	55	75	75	75	75	75	75	75	55	
Soil in Hopper m3	550	550	550	550	750	750	750	750	750	750	750	550	
Dumping Area	D1	D1	D1	D1	D1	D1	D2(100%)	D2(100%)	D4	D4	D4	D4	
Sailing Distance km	11.0	9.2	9.7	6.9	4.9	3.0	2.7	1.7	1.8	1.5	1.5	1.5	
Sailing Time to DA hr	0.58	0.48	0.51	0.37	0.26	0.16	0.14	0.09	0.10	0.08	0.08	0.08	
Dumping Time hr	0.15	0.15	0.15	0.15	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.15	
Sailing Time fm DA hr	0.56	0.47	0.50	0.36	0.25	0.15	0.14	0.08	0.09	0.08	0.08	0.08	
Cycle Time hr	2.54	2.36	2.41	2.12	2.26	2.06	2.03	1.92	1.94	1.91	1.91	1.56	
Av Cycle Time hr	2.54	2.36	2.41	2.12	2.26	2.06	2.03	1.92					
Required No of Cycle	219	340	502	206	172	198	384	820	135	41	83	780	3879
Req'd Working Hour hr	557.3	801.0	1209.0	435.9	387.2	409.4	779.8	1576.2	261.1	77.9	158.4	1214.2	7,867
Working Hour Ratio %	7.1	10.2	15.4	5.5	4.9	5.2	9.9	20.0	3.3	1.0	2.0	15.4	100.0
T.Dred/Turn'g Time hr	273.8	425.0	627.6	256.9	257.4	297.6	575.6	1229.9	202.1	61.3	124.6	975.0	5,307.0
Sailing Time hr	250.6	325.0	506.1	148.1	86.9	62.2	108.2	141.3	25.3	6.4	13.0	122.2	1,795.4
Dumping Time hr	32.9	51.0	75.3	30.8	42.9	49.6	95.9	205.0	33.7	10.2	20.8	117.0	765.1
												Total	7,867.5

Silt/Sand Ratio %
Silt 45
Sand 55

Average Cycle Time
2.03 hr

Annual Working Hours
Week 44
Day 5
Hour 24
Efficiency 0.8
4,224 hr

Annual Required Working Hours

Dred'g/Turn'g Time	5,307 hr	67%
Sailing Time	1,795 hr	23%
Dumping Time	765 hr	10%
Total	7,867 hr	100%

Required Working Hours
7,867 hr

Required/Annual Working Hours Ratio 186 %

Working ratio of 2 x 1000 m3 dredgers is 93 %.

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