APPENDIX F: TRANQUILITY ANALYSIS; REQUIRED LENGTH OF BREAKWATER FOR BOJONEGARA PORT DEVELOPMENT

F.1 Wave Characteristics at Bojonegara

Technical Standards for Port and Harbour Facilities in Japan (2002) stipulates that for basins used for accommodating or mooring vessels shall achieve the calmness for 97.5 % or more of the days of a year (Operational Cover Ratio). The threshold wave height ($H_{1/3}$) in front of mooring facilities for container handling is defined generally as 0.5 m.

Wave conditions for the study of Bojonegara Port Development was prepared by the method of Wave Hindcast using the 5-year wind records at Cengkareng (1997～2001; **Appendix D**) and the combined occurrences of wave height, wave period and wave incidence direction in front of the assumed breakwater at the Bojonegara Development site are shown in the table (**Table F-1**).

According to the occurrence probability of wave height of the table, the cumulative occurrence of the incident waves lower than 0.5 m is about 93 % at Bojonegara. This wave characteristic indicates that the construction of breakwater is necessary to secure the targeted calmness (0.5 m) and the operational days of cargo handling (97.5 %) in the Bojonegara Port development.

Figure F-1 gives the flowchart of the breakwater planning using tranquility analysis and operational cover ratio.

F.2 Alignment of Breakwater

The alignment of breakwater to be studied has three phases of development (Phase I, II and III; refer to the attached **Figures F-2 --- F-4**). Alignment plan of the breakwater has the features in offshore breakwater and approach channel at north entrance of the harbor. Future expansion of container berths is planned alongshore.

- Phase I: Ro-Ro Wharf (-8.0 m), General Cargo Wharf (-10.0 m) and Container Wharf (-12.0 m; B1 and B2) without breakwater
- Phase II: Expansion of Container Wharf (B3 and B4) and extension of Breakwater
- Phase III: Offshore development of container terminal (B5, B6, B7 and B8)

F.3 Tranquility Analysis

F.3.1 Methods

Harbor tranquility analysis is carried out based on the hindcast waves as the incident waves to be input and considering refraction and shoaling of waves in the shallow water conditions. The diffraction of irregular waves and reflection at the quay walls, breakwaters and seashore are numerically computed using Takayama's method (1981).

The reflection coefficients at the port facilities and seashore are given as follows and the results of the tranquility analysis on each phase are shown in **Tables F-2 --- F-4**.

Reflection coefficients

Quay wall (erect Caisson type):	0.9
Breakwater (rubble mound slope type):	0.6
Seashore:	0.2

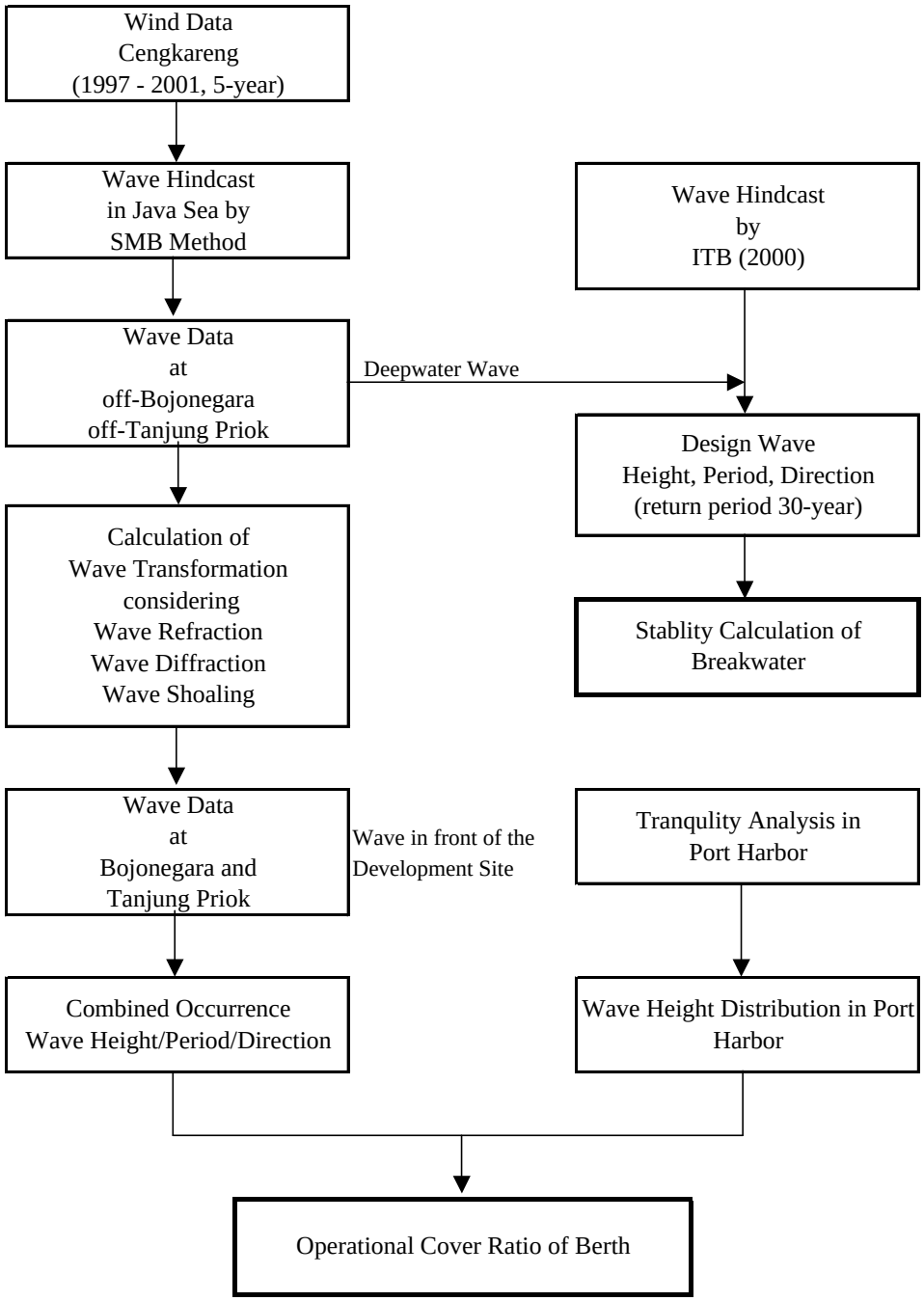

Figure F-1 Flowchart of Breakwater Planning by Tranquility Analysis

F.3.2 Phase I without Breakwater

(refer to **Figure F-2**, **Table F-2**)

The port facilities in Phase I are assumed to be constructed in the first stage of the development. And the operational cover ratio at the water area in front of each wharf for the target wave height (0.5 m) is examined by tranquility analysis under the condition without breakwater.

Some 98 - 99 % of operational cover ratio is secured by the sheltering effect of the small island (Pulau Kali) in front of the development site at the multi purpose berth MPT. Although the operational cover ratio at the first container berth CT1 does not achieve the 97.5 % due to the incident waves from NNE - E directions, the cover ratio is secured at the level of 95.4 % (tranquility under 0.5 meter over 348 days of a year).

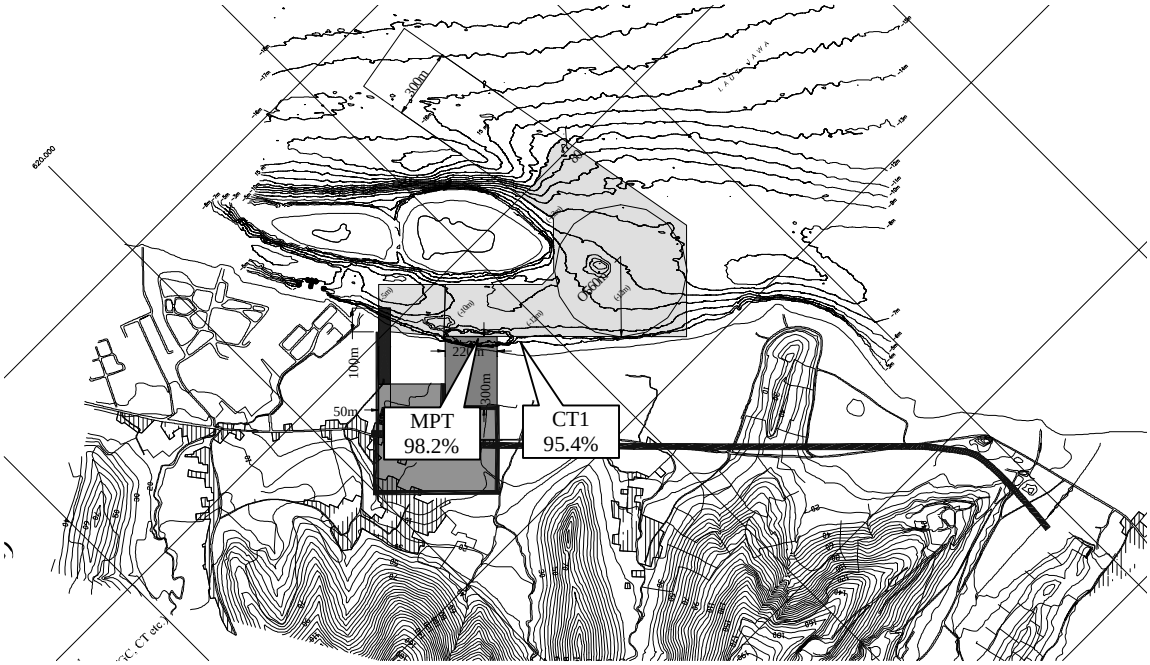

Figure F-2 Operational Cover Ratio of Bojonegara Port (Phase I)

F.3.3 Phase II

(refer to **Figure F-3**, **Table F-3**)

The effect of the alignment of the breakwater and port facilities shown in **Figure F-3** is examined in the tranquility analysis for Phase II (Length of breakwater: 840 + 200 = 1,040 m). The operational cover ratio at the berth CT3 is 93.8 % and does not achieve the target level.

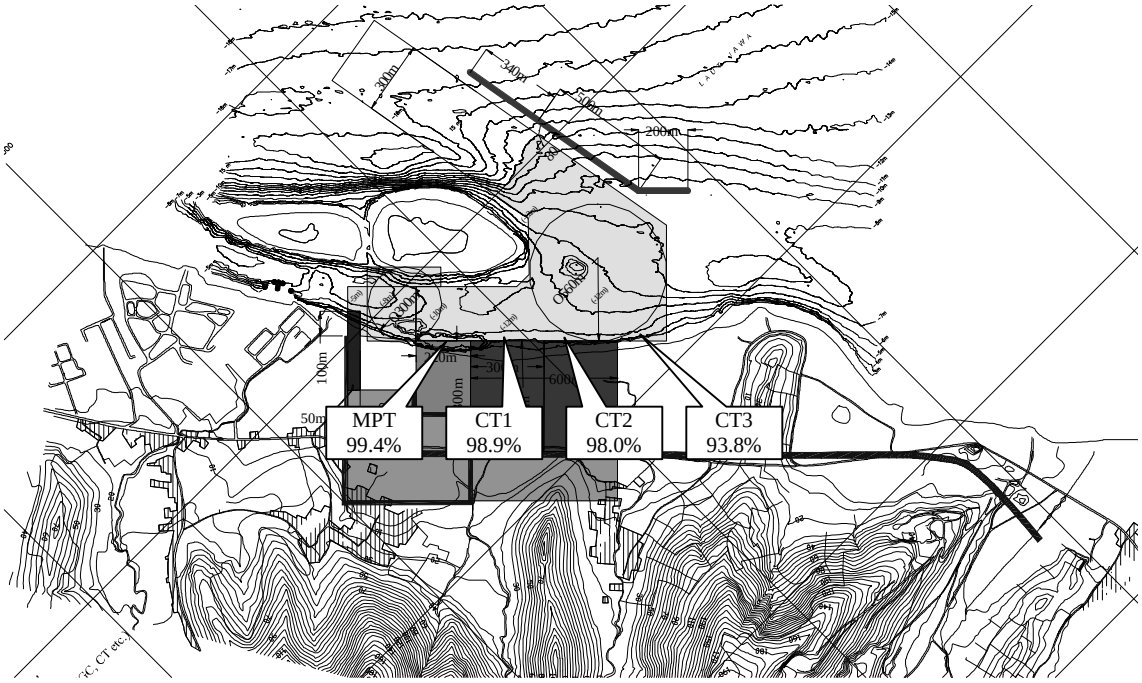

Figure F-3 Operational Cover Ratio of Bojonegara Port (Phase II)

F.3.4 Phase III

(refer to **Figure F-4**, **Table F-4**)

The effect of the alignment of the breakwater and port facilities shown in **Figure F-4** is examined in the tranquility analysis for Phase III (Length of breakwater: 840 + 1,600 = 2,440 m). The operational cover ratio at all the eight berths achieve the target level 97.5 % including the berth CT7 at the eastmost.

The performance at CT3 shows 97.8 % and is lower than those of the next berths on both sides, CT2 (99.5 %) and CT4 (98.3 %). This result denotes that the berth CT3 is located confronting the opening of the breakwater alignment and is greatly affected by the incident waves from north direction.

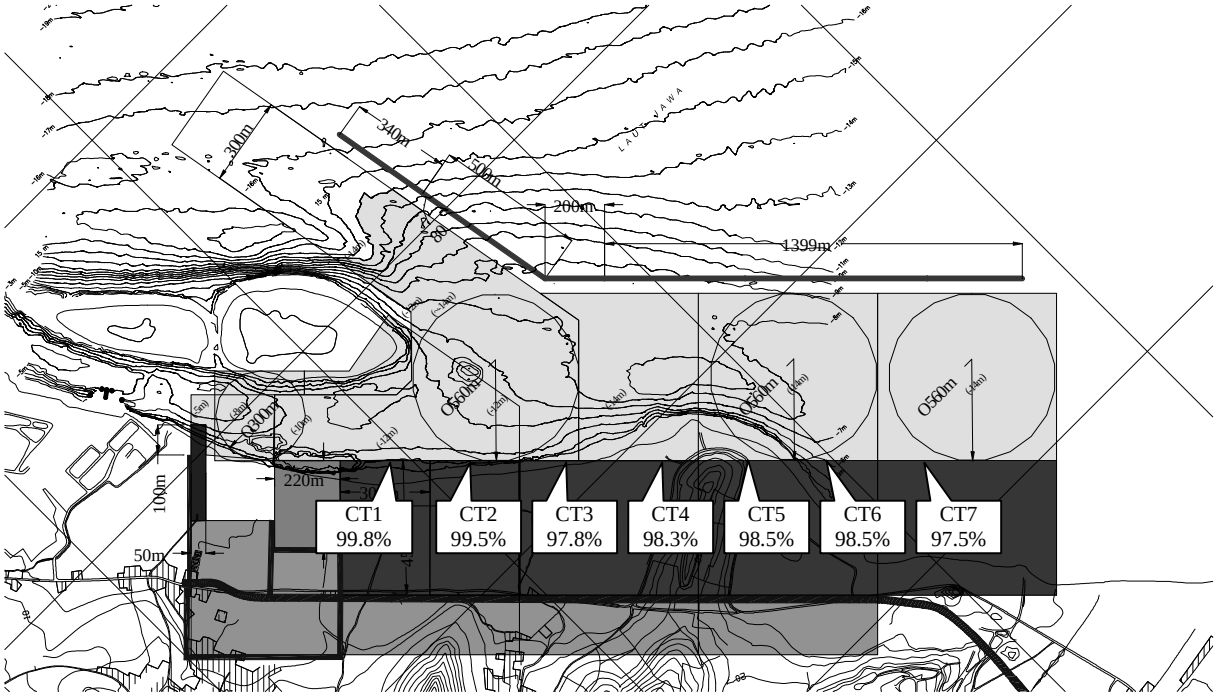

Figure F-4 Operational Cover Ratio of Bojonegara Port (Phase III)

Table F-1 Combined Occurrence of Wave Height/Period/Direction at Bojonegara

Combined Occurrence of Wave Height and Period (%) (Unit: meter and second)

Period / Height (m)	0 s	2 s	3 s	4 s	5 s	6 s	7 s	8 s	> 8 s	Total	Cumu-lative
Calm										68.55	68.55
0≦H<0.25	8.02	4.33	0.44	0.00	0.00					12.79	81.35
0.25≦H<0.5	2.41	6.60	2.48	0.10	0.00					11.58	92.93
0.5≦H<0.75		2.34	1.82	0.24	0.00					4.39	97.32
0.75≦H<1.0		0.04	1.33	0.24	0.00					1.61	98.94
1.0≦H<1.25			0.31	0.33	0.00					0.64	99.58
1.25≦H<1.5			0.01	0.19	0.04					0.24	99.82
1.5≦H<1.75				0.06	0.04					0.10	99.92
1.75≦H<2.0				0.02	0.04					0.06	99.99
2.0≦H<2.5				0.01	0.00					0.01	100.00
2.5≦H<3.0											
3.0≦H<3.5											
3.5≦H<4.0											
4.0≦H											
Total	10.43	13.31	6.39	1.19	0.13	0.00	0.00	0.00	0.00	31.45	

Combined Ocurrence of Wave Height and Direction (%) (Unit: meter)

Direction / Height (m)	W	WNW	NW	NNW	N	NNE	NE	ENE	E	Total	Cumu-lative
Calm										68.55	68.55
0≦H<0.25			7.58	2.47	0.82	0.60	0.49	0.38	0.45	12.79	81.35
0.25≦H<0.5			2.78	2.16	1.78	1.53	1.73	0.99	0.60	11.58	92.93
0.5≦H<0.75			0.39	0.77	0.43	0.65	1.17	0.72	0.25	4.39	97.32
0.75≦H<1.0			0.09	0.21	0.09	0.23	0.50	0.38	0.12	1.61	98.94
1.0≦H<1.25			0.03	0.05	0.02	0.08	0.23	0.19	0.04	0.64	99.58
1.25≦H<1.5				0.03	0.01	0.03	0.08	0.08	0.01	0.24	99.82
1.5≦H<1.75				0.01	0.00	0.01	0.04	0.04	0.01	0.10	99.92
1.75≦H<2.0					0.00	0.01	0.03	0.02	0.00	0.06	99.98
2.0≦H<2.5							0.00	0.01		0.01	100.00
2.5≦H<3.0											
3.0≦H<3.5											
3.5≦H<4.0											
4.0≦H											
Total			10.87	5.70	3.16	3.14	4.28	2.82	1.47	31.44	

Table F-2 Operational Cover Ratio of Bojonegara Port Development (Phase I)

Phase I Target Wave Height: 0.50 (m)

Area	Description	Wave Incidence Direction							Summary
		NW	NNW	N	NNE	NE	ENE	E	
	Wave Ratio	0.023	0.035	0.040	0.073	0.103	0.520	1.040	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.9
	Cover Ratio (%)	100.0	100.0	100.0	100.0	100.0	99.6	99.5	99.1
MPT	Wave Ratio	0.085	0.122	0.170	0.395	0.508	0.775	1.020	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.4	1.0	0.4	1.8
	Cover Ratio (%)	100.0	100.0	100.0	100.0	99.6	99.0	99.6	98.2
CT1	Wave Ratio	0.218	0.268	0.425	0.625	0.902	1.218	1.265	
	Occurrence (%)	0.0	0.0	0.0	0.3	1.8	1.9	0.6	4.6
	Cover Ratio (%)	100.0	100.0	100.0	99.7	98.2	98.1	99.4	95.4

Table F-3 Operational Cover Ratio of Bojonegara Port Development (Phase II)

Phase II Target Wave Height: 0.50 (m)

Area	Description	Wave Incidence Direction							Summary
		NW	NNW	N	NNE	NE	ENE	E	
	Wave Ratio	0.093	0.088	0.083	0.143	0.225	0.408	0.635	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.4
	Cover Ratio (%)	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.6
MPT	Wave Ratio	0.083	0.085	0.083	0.167	0.260	0.475	0.775	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.6
	Cover Ratio (%)	100.0	100.0	100.0	100.0	100.0	99.7	99.7	99.4
CT1	Wave Ratio	0.073	0.070	0.073	0.197	0.332	0.602	0.885	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.1	0.6	0.4	1.1
	Cover Ratio (%)	100.0	100.0	100.0	100.0	99.9	99.4	99.6	98.9
CT2	Wave Ratio	0.412	0.378	0.388	0.477	0.592	0.677	1.015	
	Occurrence (%)	0.0	0.0	0.0	0.1	0.7	0.8	0.4	2.0
	Cover Ratio (%)	100.0	100.0	100.0	99.9	99.3	99.2	99.6	98.0
CT3	Wave Ratio	0.918	0.813	0.790	0.808	0.903	1.153	1.172	
	Occurrence (%)	0.4	0.6	0.3	0.7	1.8	1.8	0.6	6.2
	Cover Ratio (%)	99.6	99.4	99.7	99.3	98.2	98.2	99.4	93.8

Table F-4 Operational Cover Ratio of Bojonegara Port Development (Phase III)

Phase III Target Wave Height: 0.50 (m)

Area	Description	Wave Incidence Direction							Summary
		NW	NNW	N	NNE	NE	ENE	E	
	Wave Ratio	0.148	0.140	0.133	0.160	0.178	0.320	0.545	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
	Cover Ratio (%)	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.8
MPT	Wave Ratio	0.135	0.132	0.122	0.173	0.195	0.368	0.627	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
	Cover Ratio (%)	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.8
CT1	Wave Ratio	0.110	0.103	0.102	0.158	0.187	0.365	0.627	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2
	Cover Ratio (%)	100.0	100.0	100.0	100.0	100.0	99.9	99.9	99.8
CT2	Wave Ratio	0.420	0.390	0.383	0.390	0.348	0.422	0.637	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.5
	Cover Ratio (%)	100.0	100.0	100.0	100.0	99.9	99.8	99.8	99.5
CT3	Wave Ratio	0.857	0.807	0.737	0.630	0.478	0.480	0.685	
	Occurrence (%)	0.3	0.6	0.2	0.3	0.3	0.3	0.2	2.2
	Cover Ratio (%)	99.7	99.4	99.8	99.7	99.7	99.7	99.8	97.8
CT4	Wave Ratio	0.817	0.738	0.650	0.533	0.402	0.467	0.720	
	Occurrence (%)	0.3	0.5	0.1	0.2	0.1	0.3	0.2	1.7
	Cover Ratio (%)	99.7	99.5	99.9	99.8	99.9	99.7	99.8	98.3
CT5	Wave Ratio	0.725	0.652	0.573	0.460	0.377	0.523	0.807	
	Occurrence (%)	0.2	0.3	0.1	0.1	0.1	0.4	0.3	1.5
	Cover Ratio (%)	99.8	99.7	99.9	99.9	99.9	99.6	99.7	98.5
CT6	Wave Ratio	0.577	0.510	0.415	0.382	0.405	0.642	0.913	
	Occurrence (%)	0.1	0.1	0.0	0.0	0.2	0.7	0.4	1.5
	Cover Ratio (%)	99.9	99.9	100.0	100.0	99.8	99.3	99.6	98.5
CT7	Wave Ratio	0.260	0.220	0.252	0.392	0.612	0.920	1.055	
	Occurrence (%)	0.0	0.0	0.0	0.0	0.7	1.3	0.5	2.5
	Cover Ratio (%)	100.0	100.0	100.0	100.0	99.3	98.7	99.5	97.5

F.4 Required Length of Breakwater

F.4.1 Phase I

(refer to **Figure F-5**, **Figure F-7**)

The length of breakwater at the development stage of Phase I is examined which can secure the required operational performance 97.5 % at the berth B2 (=CT1).

Figure F-5 shows the results of the tranquility analysis calculated with the several setting of the breakwater length. It is confirmed that the target level of the operational cover ratio is achieved by the 500 m extension of the breakwater given in **Figure F-7**.

Phase I	Breakwater Length (m) 0	400	500	600
B1	98.2%	99.1%	99.1%	99.1%
B2	95.4%	96.6%	97.7%	98.3%

B1: Multi Purpose Terminal (MTP)
B2: Container Terminal (CT1)

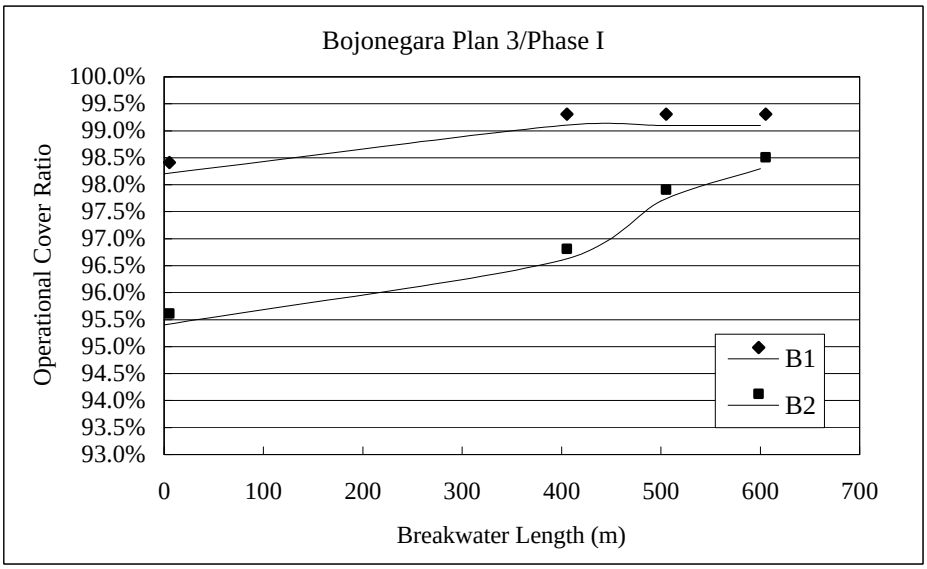

Figure F-5 Required Length of Breakwater (Phase I)

F.4.2 Phase II

(refer to **Figure F-6**, **Figure F-8**)

The length of breakwater at the development stage of Phase II is examined which can secure the required operational cover ratio 97.5 % at the berth B4 (=CT3).

Figure F-6 shows the results of the tranquility analysis calculated with the several setting of the breakwater length. It is confirmed that the target level of the operational cover ratio is achieved by the extension of the breakwater 1,940 m (840 + 1,100 m) as given in **Figure F-8**.

Breakwater Length (m)					
Phase II	1,040	1,440	1,640	1,840	2,040
B1	99.4%	99.6%	99.7%	99.8%	99.8%
B2	98.9%	99.6%	99.6%	99.7%	99.8%
B3	98.0%	98.9%	99.3%	99.4%	99.5%
B4	93.8%	96.4%	97.0%	97.3%	97.7%

B1: Multi Purpose Terminal (MTP)
B2: Container Terminal (CT1)
B3: CT2
B4: CT3

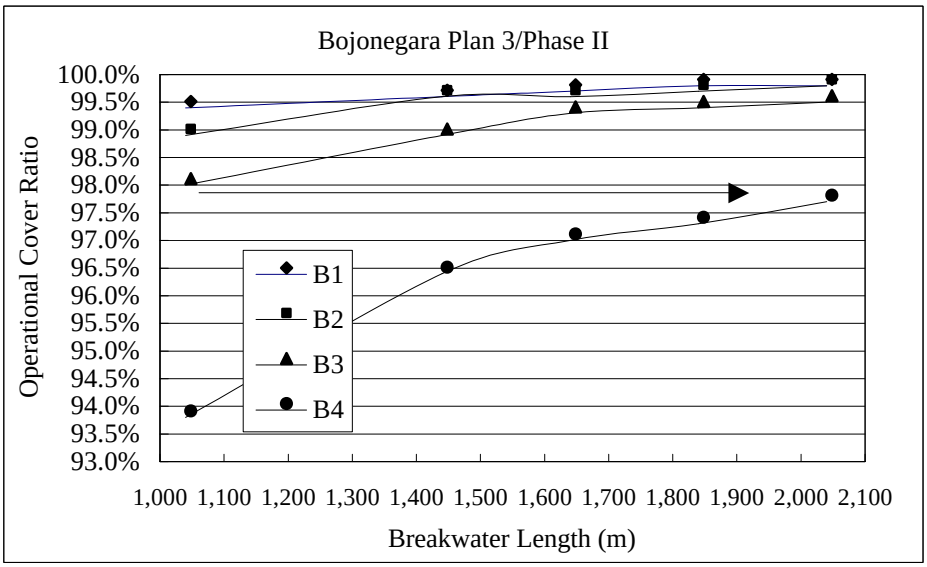

Figure F-6 Required Length of Breakwater (Phase II)

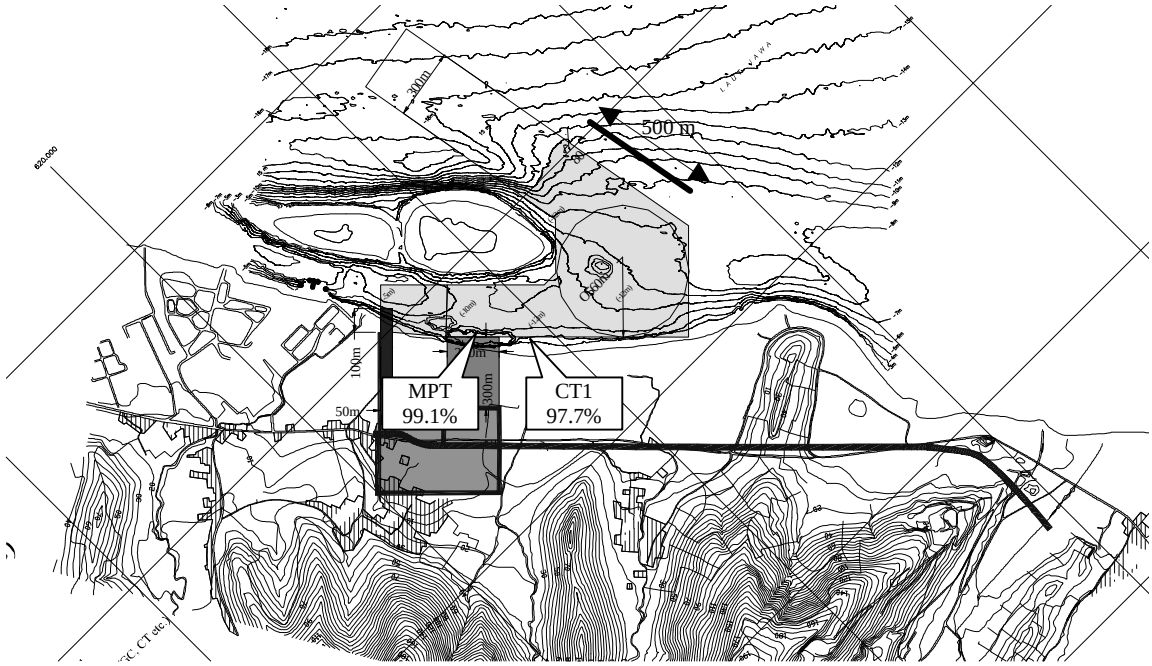

Figure F-7 Breakwater (500 m) and Operational Cover Ratio (Phase I)

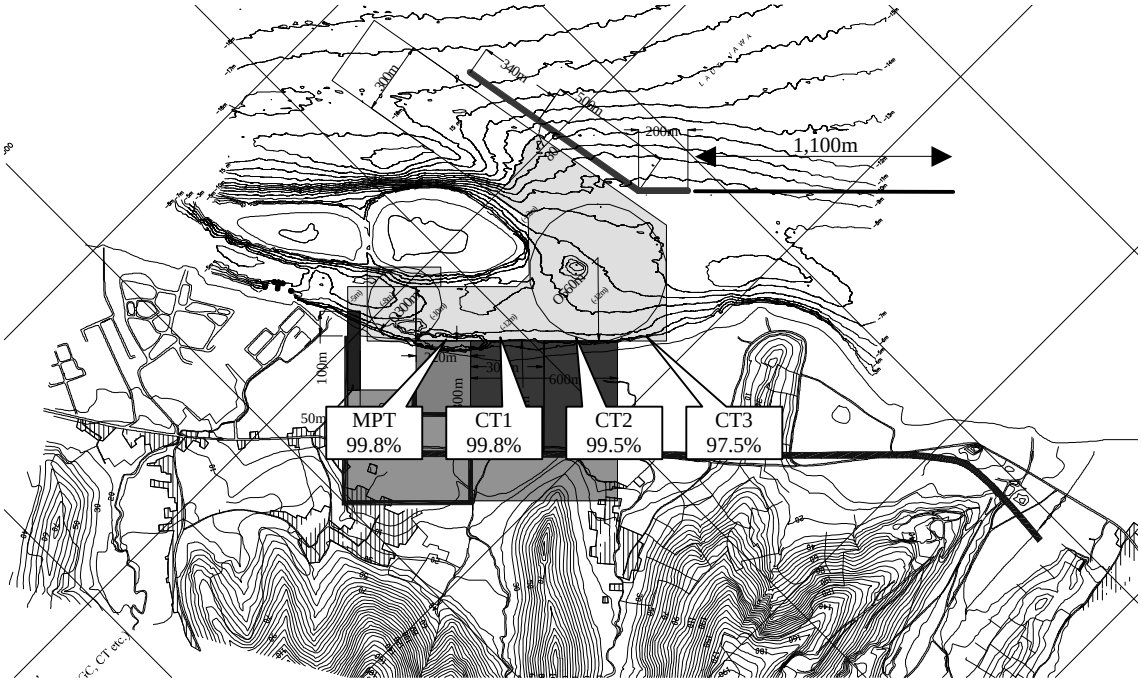

Figure F-8 Breakwater (1,940 m) and Operational Cover Ratio (Phase II)