APPENDIX G: TRANQUILITY ANALYSIS OF TANJUNG PRIOK MASTER PLAN

G.1 Study Procedure

Accompanying the plan of widening and deepening of the fairway channel of Tanjung Priok Port, the relocation of breakwaters of the port (demolition of the existing breakwaters, construction of new breakwaters at offshore side) is proposed for the master plan of the rehabilitation of Tanjung Priok. Since the relocation of breakwater is to be carried out under the operational condition of the port, the study on the sheltering effects of the planned breakwaters in the long construction process is necessary.

Tranquility analysis of the sheltered channels and harbor basins are carried out, and the operational cover ratio of the port facilities in the process of construction is examined based on the tranquility analysis.

Figure G-1 gives the flowchart of the study of tranquility analysis and breakwater planning based on operational cover ratio.

Wave transformation (wave refraction, shoaling) in the shallow water area off-Tanjung Priok is calculated with the numerical differentiation of Energy Equilibrium Equation (Karlsson, 1969) taking into account the multi-directional irregularity of wave.

The diffraction of irregular waves and reflection at the quay walls, breakwaters and seashore are numerically computed using Takayama’s method (1981).

G.2 Wave Characteristics

Wave conditions at the off-Tanjung Priok Port was prepared with Wave Hindcast by SMB method 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 are shown in **Figures G-2** and **G-3**.

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 93.5 % at off-Tanjung Priok (**Figure G-2**). 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 Tanjung Priok Port.

Incidence directions of the waves with wave height over 0.25 m and relatively higher wave energy show higher occurrence probability in NNE, NE, ENE. And wave occurrence is mainly concentrated in the zone of wave period of 2 - 4 seconds.

Out of the statistic analysis of these wave characteristics, the representative wave is defined as follows;

Wave height: H_m = 1.0 m (root-mean-square wave height), wave period: T_m = 3.5 sec.

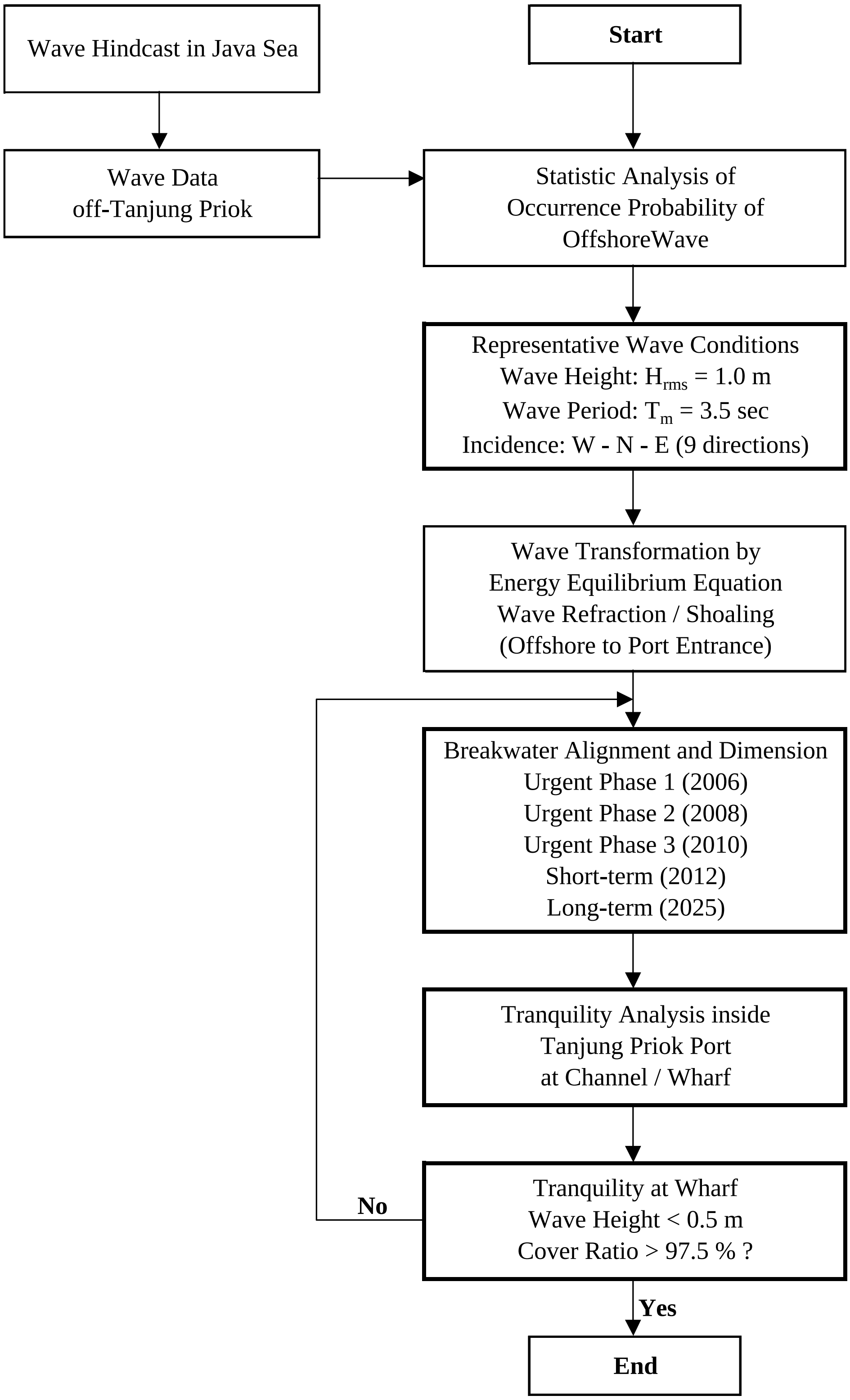


Figure G-1 Study Procedure of Tranquility Analysis and Breakwater Planning

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

Height \ Direction	W	WNW	NW	NNW	N	NNE	NE	ENE	E	Total	Cumu-lative
Calm										68.55	68.55
0≦H＜0.25	2.15	0.33	0.31	0.39	0.54	0.54	0.46	0.28	0.37	5.36	73.92
0.25≦H＜0.5	3.79	0.88	0.92	1.15	1.30	1.49	1.67	0.85	0.64	12.70	86.61
0.5≦H＜0.75	2.07	0.47	0.45	0.51	0.43	0.71	1.11	0.81	0.33	6.89	93.50
0.75≦H＜1.0	1.32	0.40	0.16	0.13	0.09	0.24	0.51	0.44	0.15	3.43	96.93
1.0≦H＜1.25	0.67	0.20	0.09	0.04	0.02	0.10	0.24	0.20	0.08	1.64	98.58
1.25≦H＜1.5	0.29	0.16	0.02	0.01	0.01	0.03	0.08	0.12	0.03	0.76	99.34
1.5≦H＜1.75	0.13	0.08	0.01	0.02	0.00	0.01	0.04	0.05	0.01	0.36	99.69
1.75≦H＜2.0	0.06	0.02	0.01	0.01		0.01	0.03	0.04	0.00	0.18	99.87
2.0≦H＜2.5	0.04	0.05	0.01					0.02	0.00	0.11	99.99
2.5≦H＜3.0		0.01						0.00		0.01	100.00
3.0≦H＜3.5											
3.5≦H＜4.0											
4.0≦H											
Total	10.52	2.59	1.97	2.26	2.40	3.14	4.14	2.81	1.62	100.00	

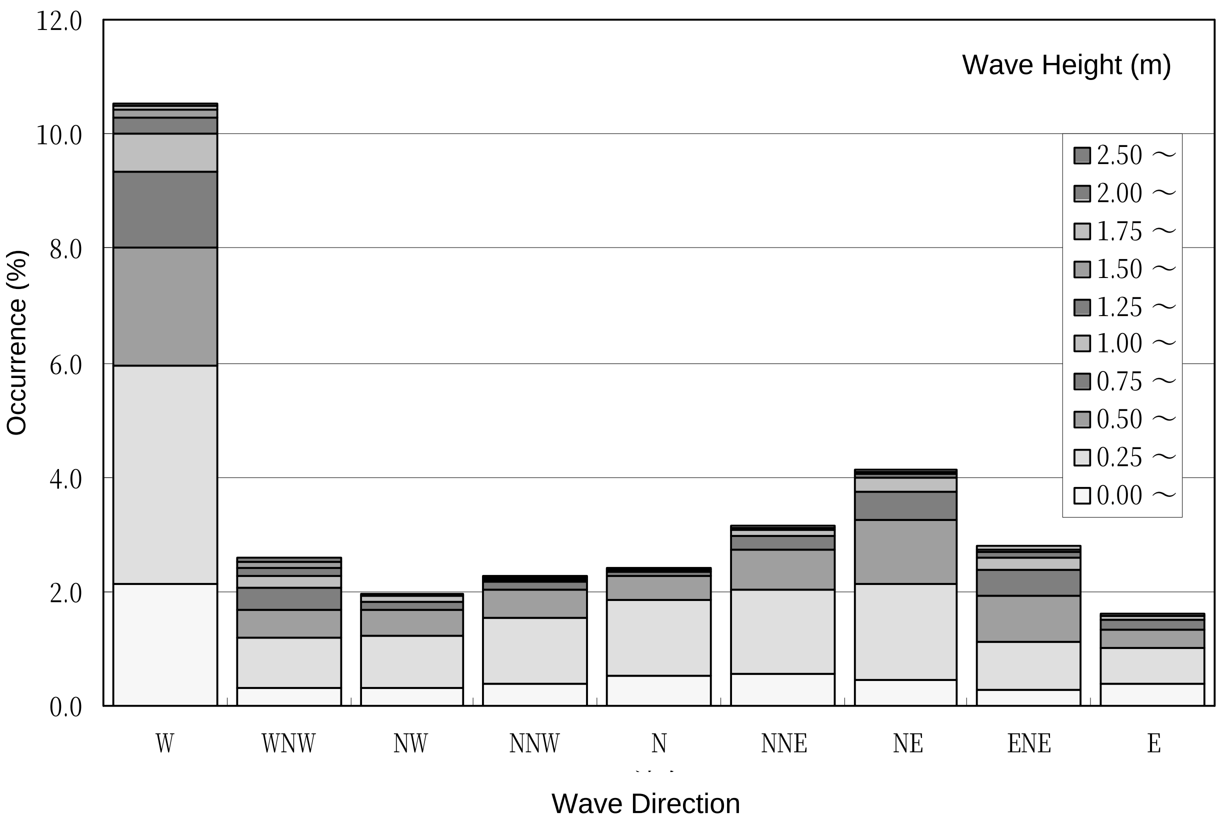


Figure G-2 Combined Occurrence of Wave Height and Wave Direction at Off-Tanjung Priok Port (1997 - 2001)

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

Height \ Period	0	2	3	4	5	6	7	8	9	Total	Cumu-lative
Calm										68.55	68.55
0≦H＜0.25	5.36									5.36	73.92
0.25≦H＜0.5	5.06	7.63								12.70	86.61
0.5≦H＜0.75		5.19	1.70							6.89	93.50
0.75≦H＜1.0		0.13	3.25	0.05						3.43	96.93
1.0≦H＜1.25			1.02	0.63						1.64	98.58
1.25≦H＜1.5			0.08	0.65	0.03					0.76	99.34
1.5≦H＜1.75				0.28	0.07					0.36	99.69
1.75≦H＜2.0				0.10	0.08					0.18	99.87
2.0≦H＜2.5				0.05	0.07					0.12	99.99
2.5≦H＜3.0				0.01						0.01	100.00
3.0≦H＜3.5											
3.5≦H＜4.0											
4.0≦H											
Total	10.43	12.95	6.05	1.77	0.25	0.00	0.00	0.00	0.00	100.00	

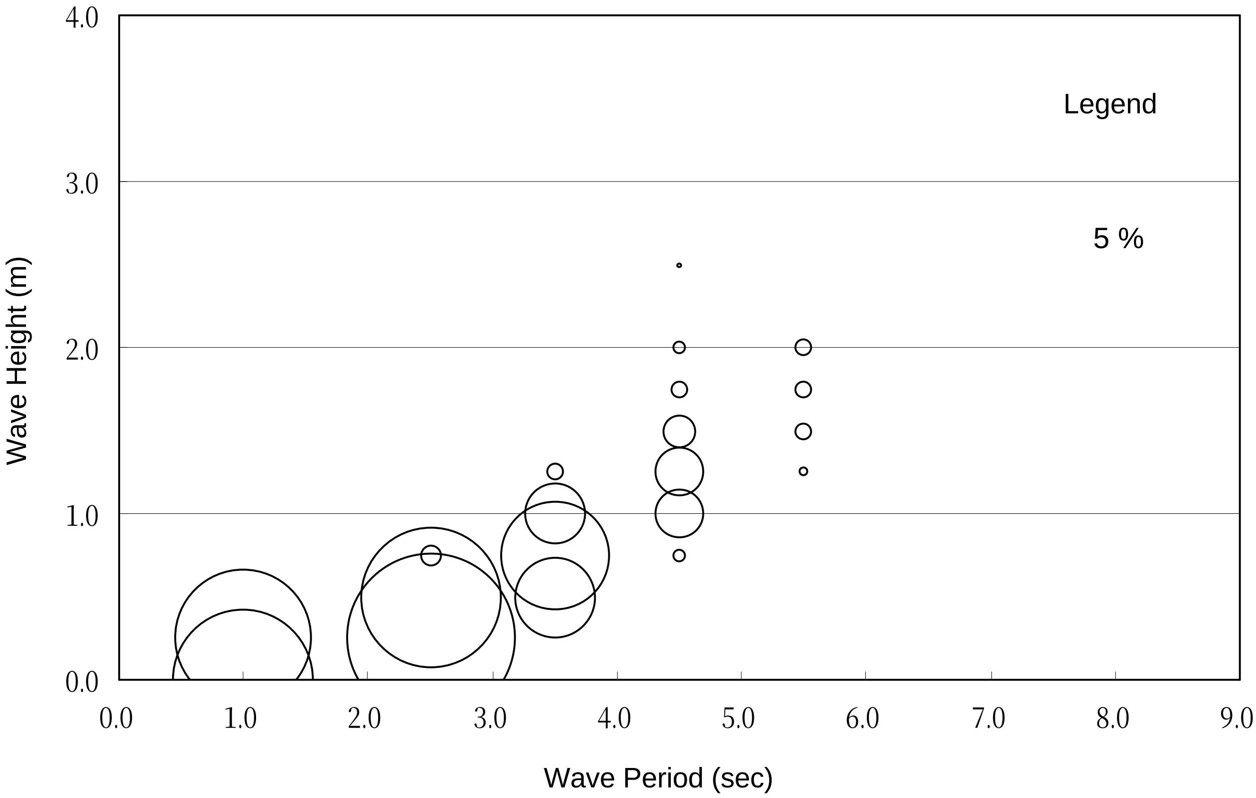


Figure G-3 Combined Occurrence of Wave Height and Wave Period at Off-Tanjung Priok Port (1997 - 2001)

G.3 Tranquility Analysis

Offshore waves are converted to the waves at the harbor entrances of Tanjung Priok Port by wave transformation calculation. Wave transformation (wave refraction, shoaling) in the shallow water area off-Tanjung Priok is calculated with the numerical differentiation of Energy Equilibrium Equation (Karlsson, 1969) taking into account the multi-directional irregularity of wave.

Water depth field of the wave transformation calculation is given in **Figure G-4**. The actual calculation was done for the offshore waves with the representative wave period T_m = 3.5 sec and incidence directions from 9 directions (W - NW - N - NE - E) giving the tide of Mean Sea Level (MSL = LWS + 0.6 m).

Wave characteristics (wave height, direction and wave period is represented by T_m = 3.5 sec) at the harbor entrances of Tanjung Priok Port are taken as the input for the tranquility analysis.

Tranquility analysis in the channels and basins inside Tanjung Priok Port is examined with Takayama's method (1981) computing the diffraction of irregular waves and reflection at the quay walls, breakwaters and miscellaneous port facilities.

Table G-1 Reflection Coefficients

Structure Types	Reflection Coefficients
Upright wall	0.7〜1.0
Submerged Upright Breakwater	0.5〜0.7
Rubble Mound	0.3〜0.6
Pre-cast wave -dissipating concrete blocks	0.3〜0.5
Upright wave-absorbing structure	0.3〜0.8
Natural beach	0.05〜0.2

Source: Technical Standards for Port and Harbour Facilities in Japan (2002), pp.71-72

Figures G-5 (1) --- (5) give the alignment of port facilities and given reflection coefficient which are taken into the tranqulity analysis in line with the staged schedule of the Tanjung Priok Port development.

G.4 Harbor Tranquility and Cover Ratio

Based on the tranquility analysis for the port facilities in accordance with the staged development plans, the wave height distribution is extracted at the specified output points along wharves, along fairway channel and harbor basin. The out points are shown in **Figures G-6 (1) --- (5)**.

The operational cover ratio at each point for the 5 cases of staged development plans is given in **Tables G-2 (1) --- (6)**.

The results show that the planned alignment of breakwaters and port facilities can secure the cover ratio over 99 % under the target wave height 0.5 m at every point in Tanjung Priok Port.

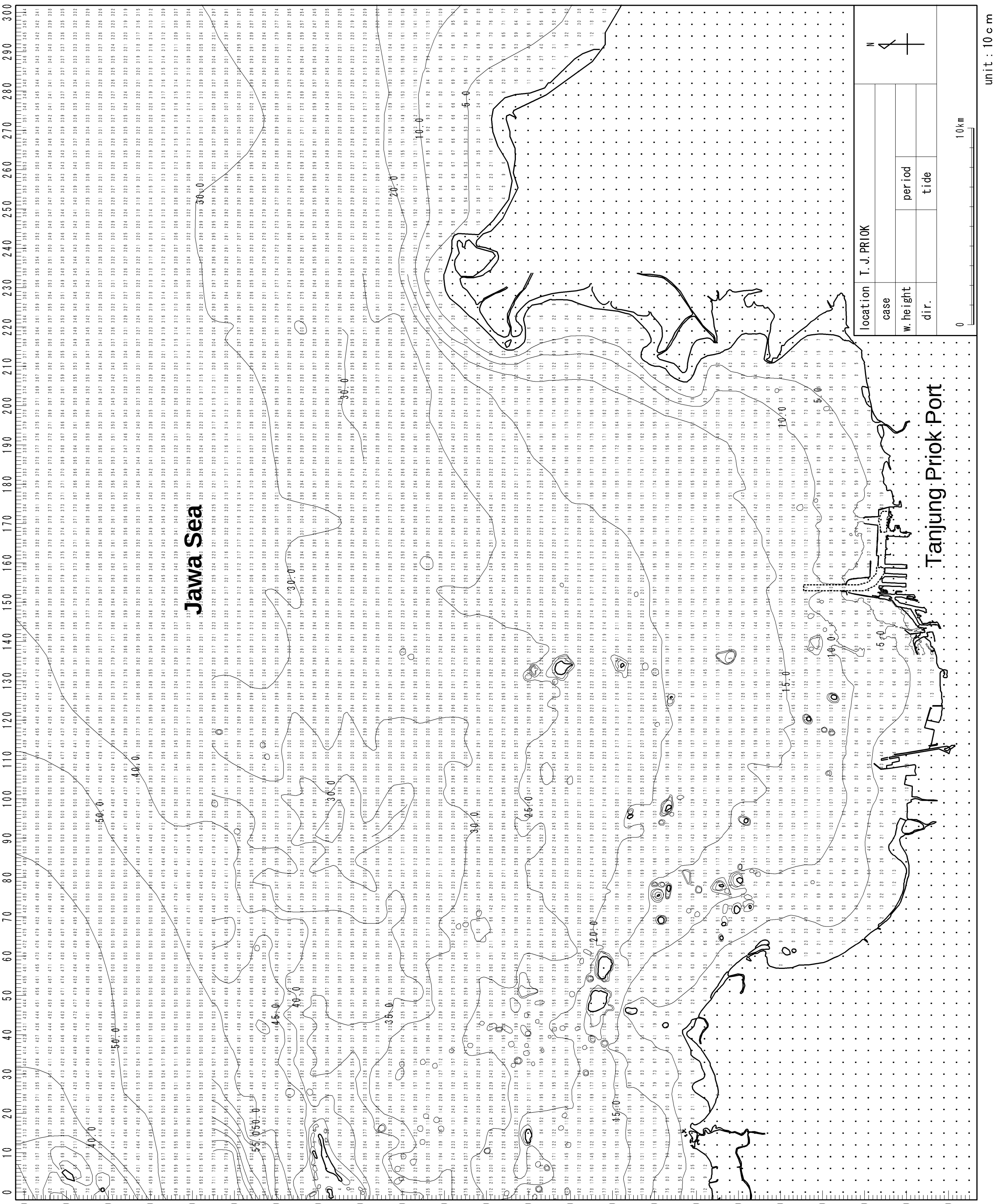


Figure G-4 Water Depth Field of Wave Transformation Calculation by Energy Equilibrium Equation

(Water depth in meter from LWS)

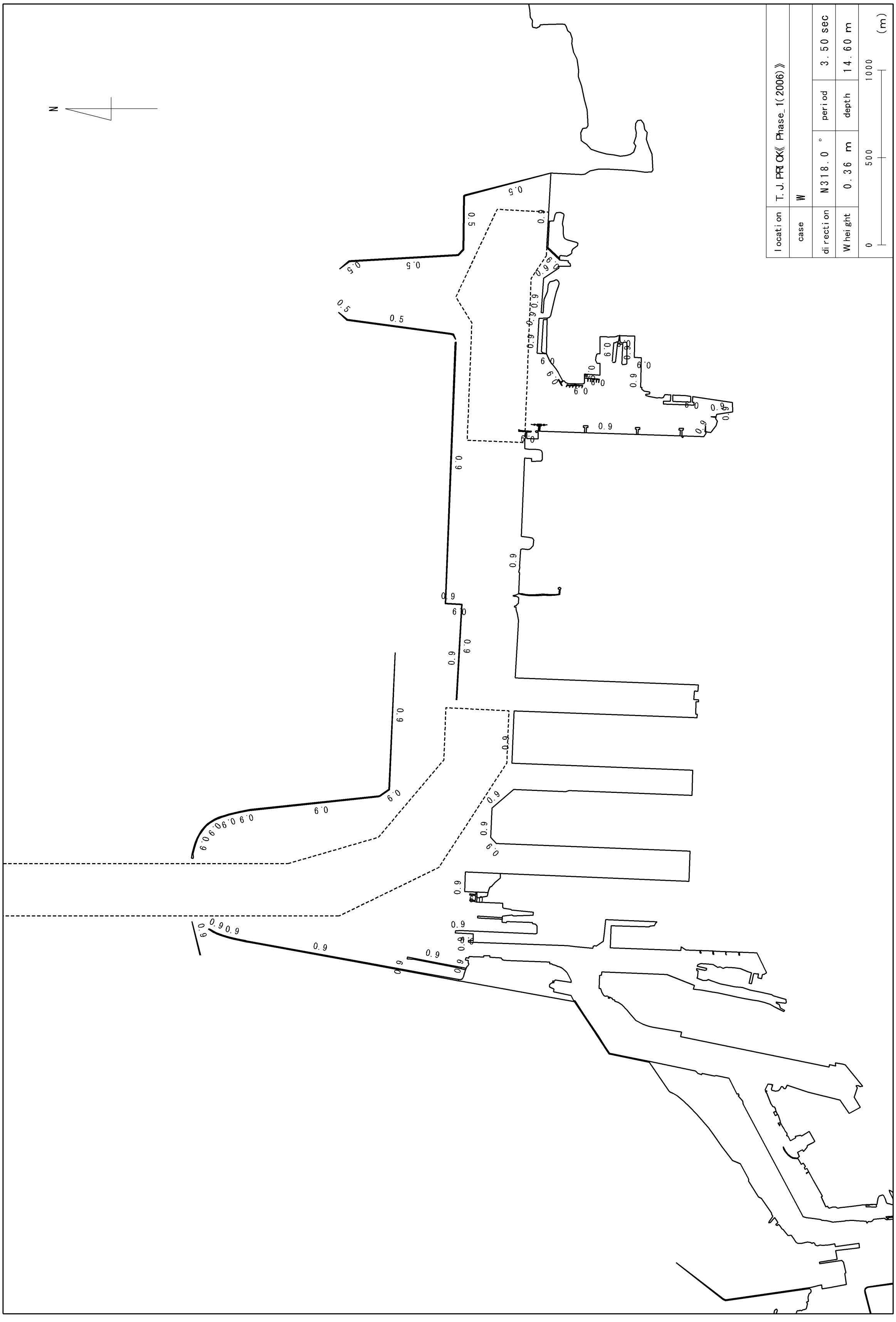


Figure G-5 (1) Alignment of Port Facilities and Reflection Coefficient
Urgent Phase 1 (2006)

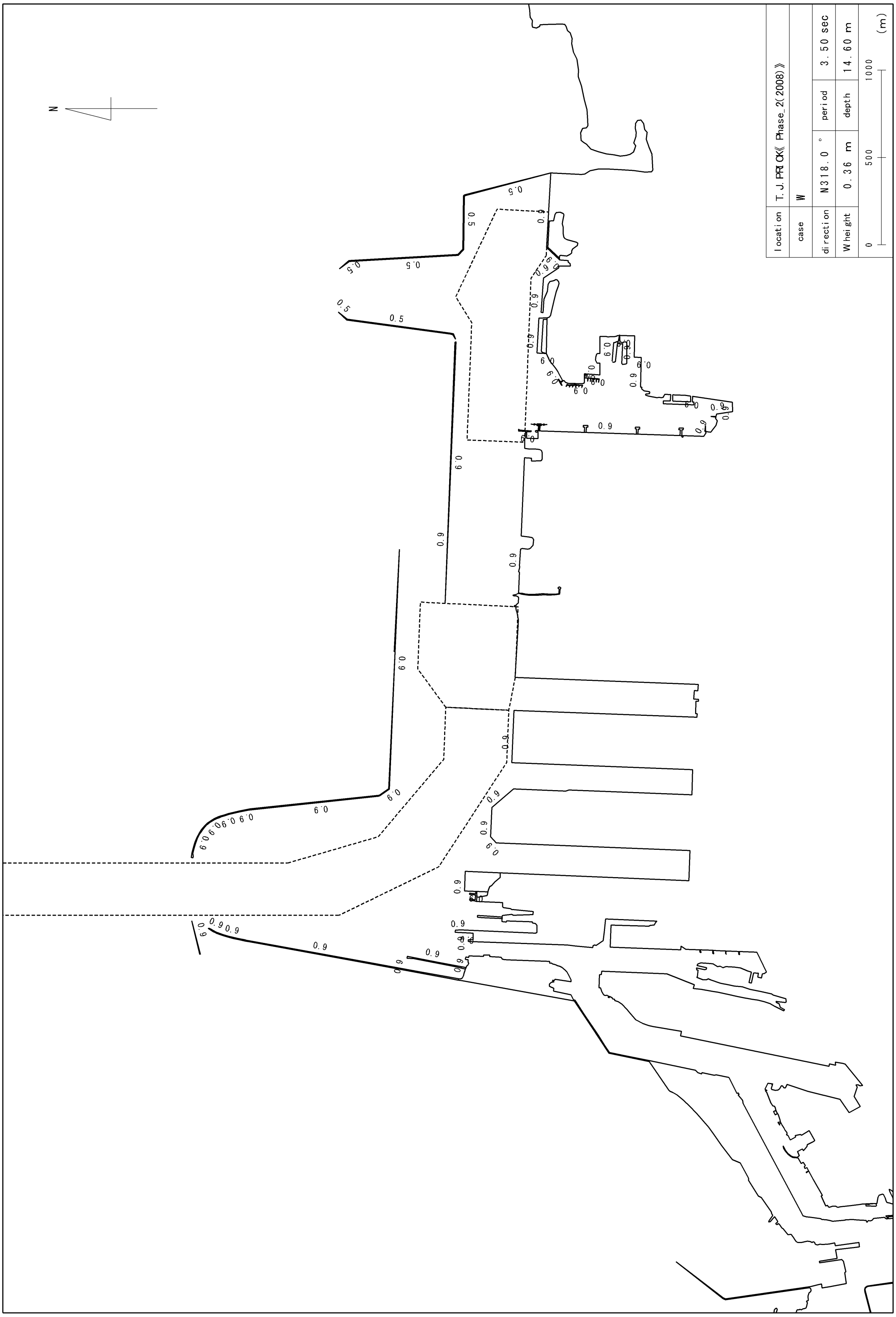


Figure G-5 (2) Alignment of Port Facilities and Reflection Coefficient
Urgent Phase 2 (2008)

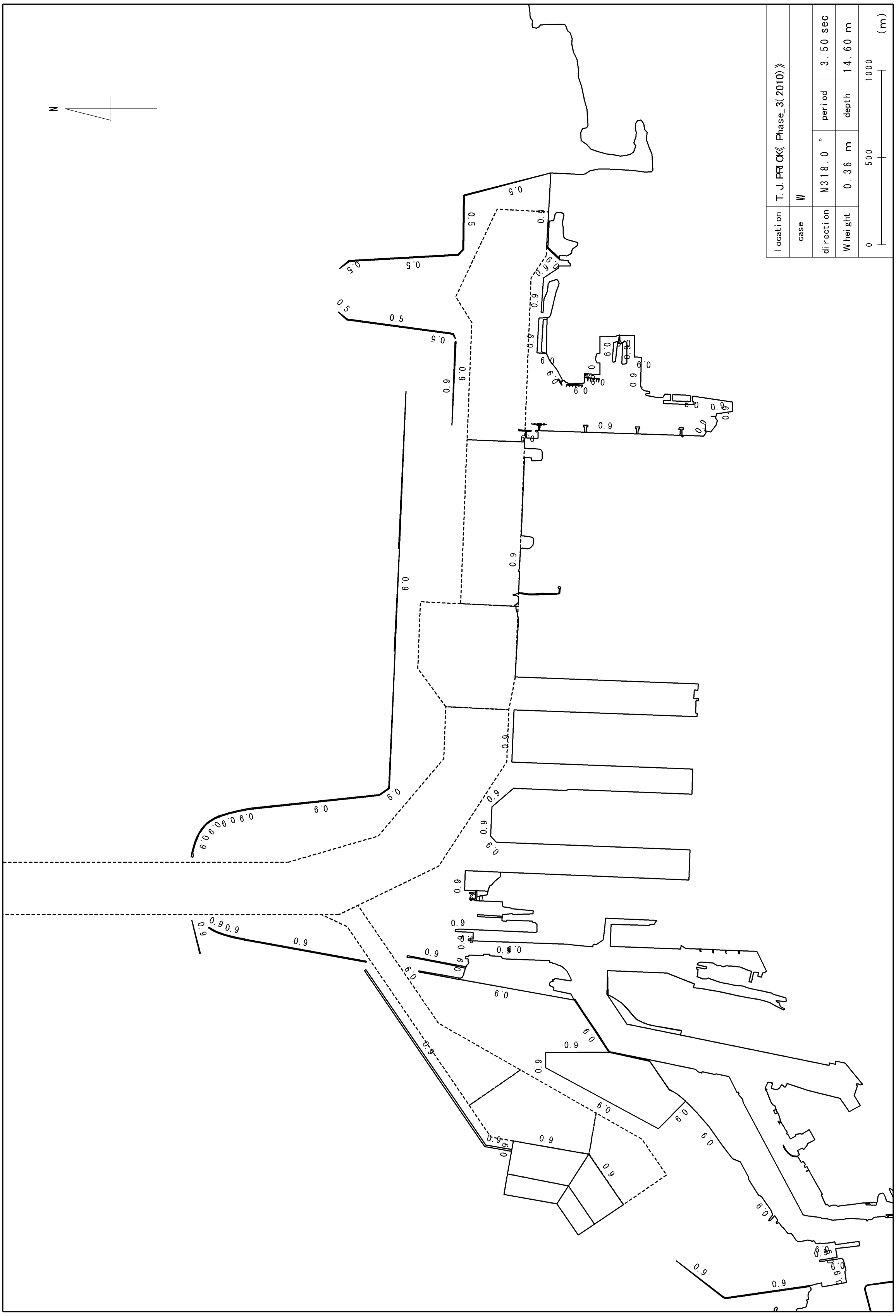


Figure G-5 (3) Alignment of Port Facilities and Reflection Coefficient
Urgent Phase 3 (2010)

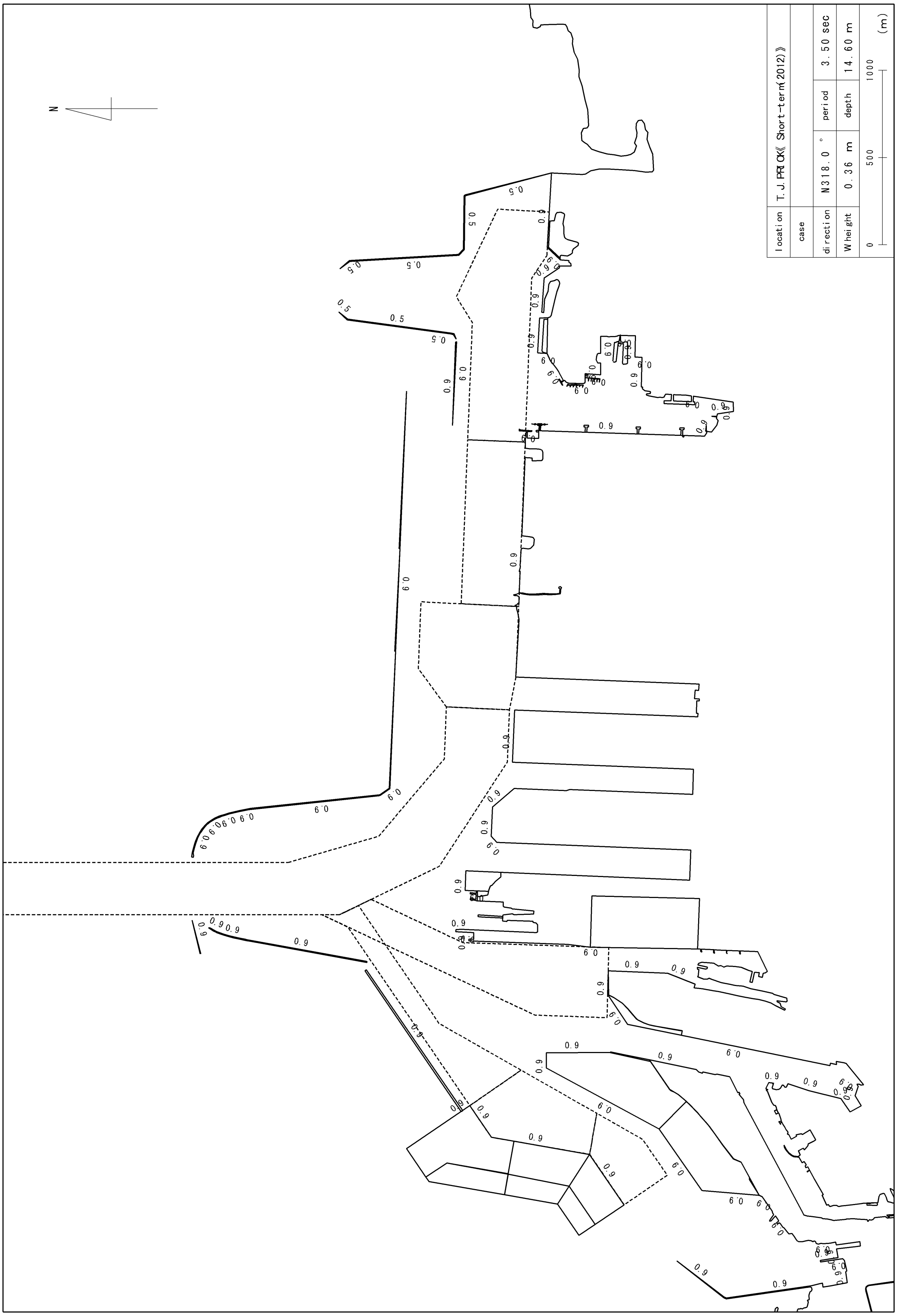


Figure G-5 (4) Alignment of Port Facilities and Reflection Coefficient Short-term (2012)

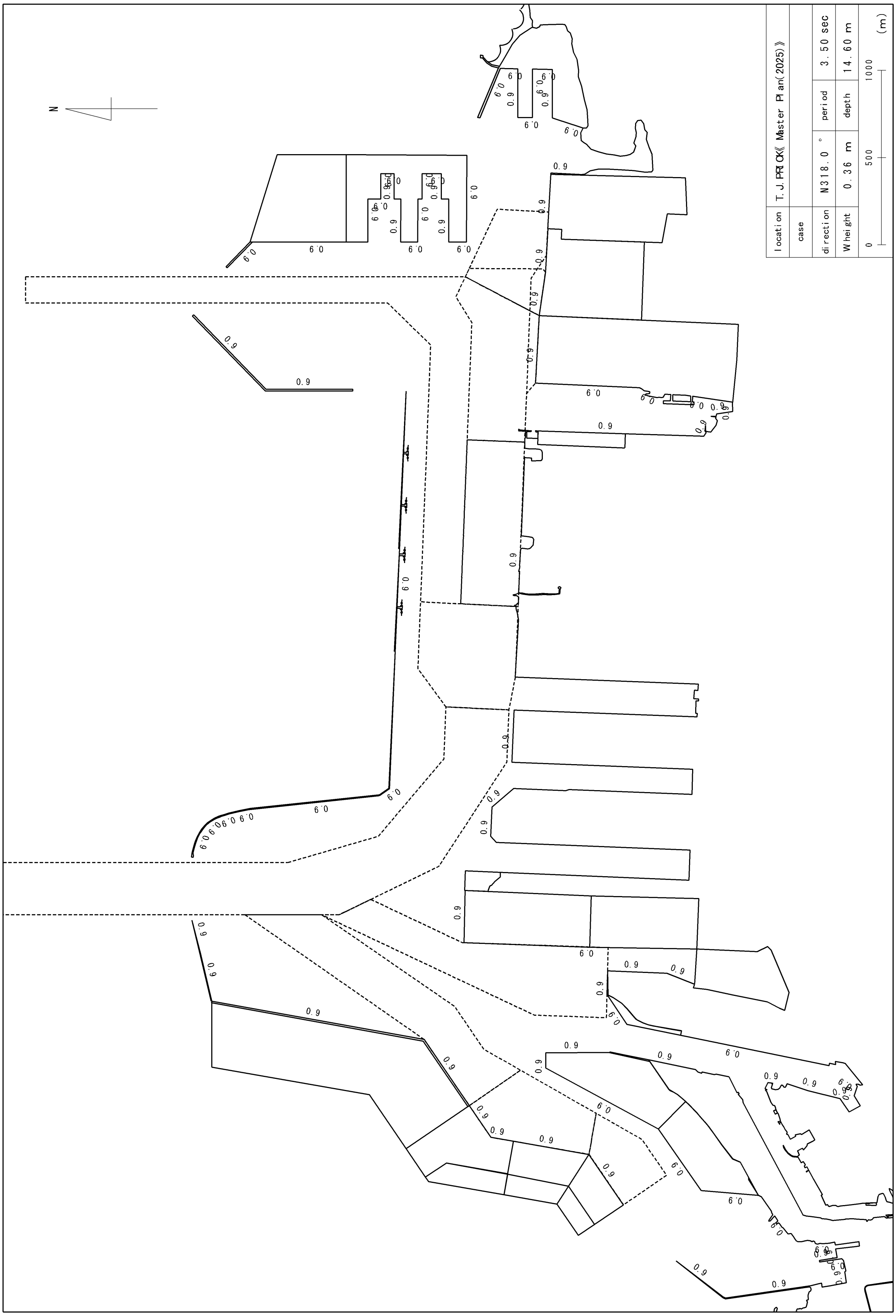


Figure G-5 (5) Alignment of Port Facilities and Reflection Coefficient
Long-term (2025)

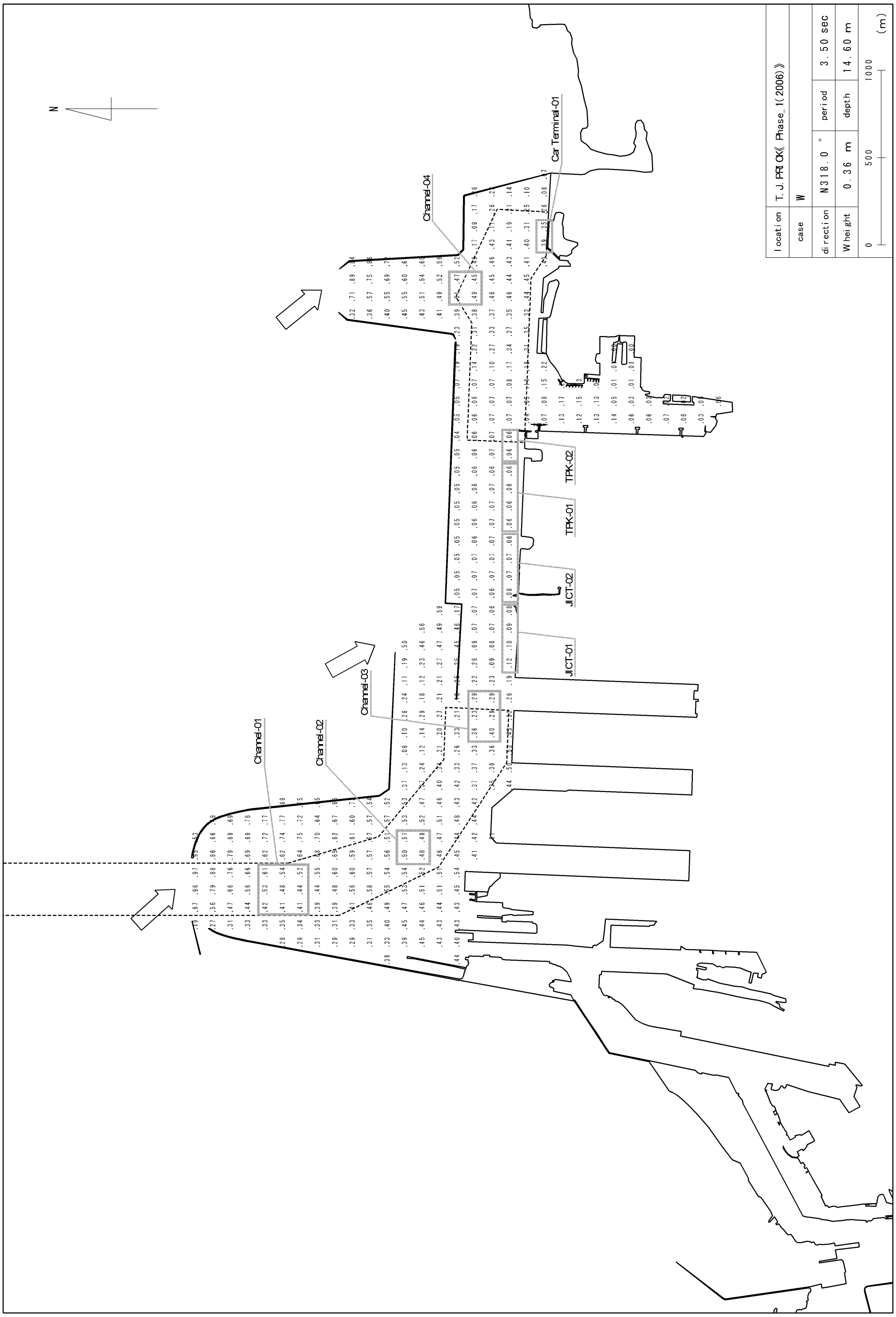


Figure G-6 (1) Output Points of Calculated Operational Cover Ratio Urgent Phase 1 (2006)

Table G-2 (1) Operational Cover Ratio: Urgent Phase 1 (2006)

Target Wave Height: H≦0.5m

Offshore Wave Direction		W	WNW	NW	NNW	N	NNE	NE	ENE	E	Total
Channel-01	wave ratio	0.174	0.246	0.426	0.517	0.556	0.524	0.423	0.254	0.165	
	occurrence (%)		0.1	0.1	0.1	0.1	0.2	0.2			0.8
	cover ratio (%)	100.0	99.9	99.9	99.9	99.9	99.8	99.8	100.0	100.0	99.2
Channel-02	wave ratio	0.179	0.252	0.363	0.416	0.452	0.412	0.337	0.205	0.128	
	occurrence (%)		0.1				0.1	0.1			0.3
	cover ratio (%)	100.0	99.9	100.0	100.0	100.0	99.9	99.9	100.0	100.0	99.7
Channel-03	wave ratio	0.112	0.162	0.261	0.303	0.368	0.399	0.345	0.213	0.132	
	occurrence (%)						0.1	0.1			0.2
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	99.9	99.9	100.0	100.0	99.8
Channel-04	wave ratio	0.173	0.248	0.377	0.444	0.470	0.415	0.325	0.175	0.110	
	occurrence (%)		0.1		0.1		0.1	0.1			0.4
	cover ratio (%)	100.0	99.9	100.0	99.9	100.0	99.9	99.9	100.0	100.0	99.6
JICT-01	wave ratio	0.035	0.047	0.071	0.090	0.090	0.086	0.070	0.043	0.028	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
JICT-02	wave ratio	0.025	0.034	0.054	0.069	0.073	0.073	0.061	0.036	0.024	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-01	wave ratio	0.022	0.029	0.047	0.060	0.063	0.062	0.053	0.032	0.021	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-02	wave ratio	0.022	0.030	0.050	0.059	0.064	0.059	0.049	0.028	0.018	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CarT.-01	wave ratio	0.133	0.185	0.252	0.300	0.286	0.242	0.188	0.101	0.063	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

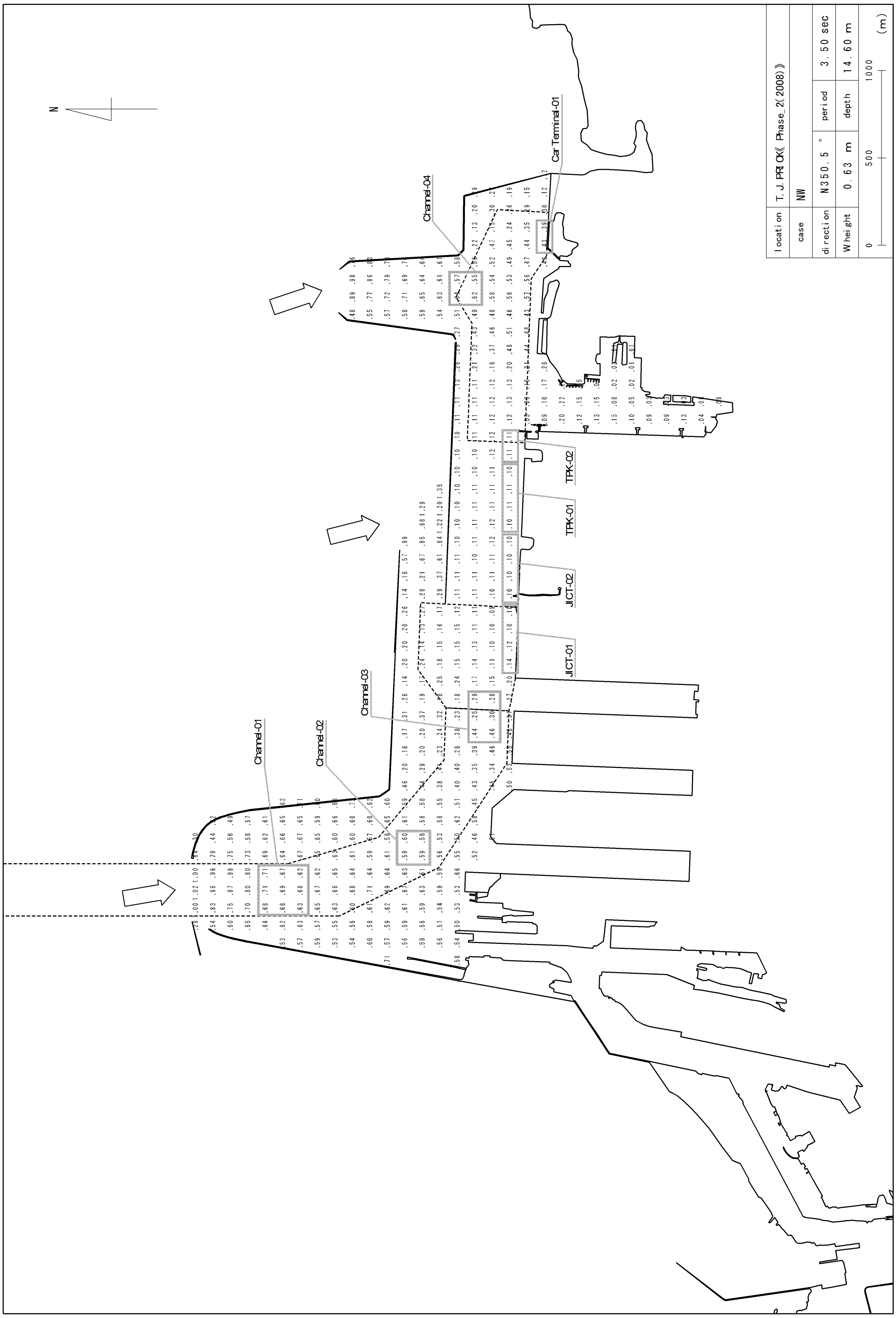


Figure G-6 (2) Output Points of Calculated Operational Cover Ratio Urgent Phase 2 (2008)

Table G-2 (2) Operational Cover Ratio: Urgent Phase 2 (2008)

Target Wave Height: H≦0.5m

Offshore Wave Direction		W	WNW	NW	NNW	N	NNE	NE	ENE	E	Total
Channel-01	wave ratio	0.174	0.246	0.425	0.515	0.552	0.519	0.417	0.250	0.162	
	occurrence (%)		0.1	0.1	0.1	0.1	0.2	0.2			0.8
	cover ratio (%)	100.0	99.9	99.9	99.9	99.9	99.8	99.8	100.0	100.0	99.2
Channel-02	wave ratio	0.184	0.259	0.371	0.423	0.452	0.394	0.316	0.190	0.118	
	occurrence (%)		0.1					0.1			0.2
	cover ratio (%)	100.0	99.9	100.0	100.0	100.0	100.0	99.9	100.0	100.0	99.8
Channel-03	wave ratio	0.105	0.148	0.211	0.232	0.256	0.234	0.197	0.121	0.074	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Channel-04	wave ratio	0.171	0.247	0.375	0.441	0.467	0.413	0.324	0.176	0.110	
	occurrence (%)		0.1		0.1		0.1	0.1			0.4
	cover ratio (%)	100.0	99.9	100.0	99.9	100.0	99.9	99.9	100.0	100.0	99.6
JICT-01	wave ratio	0.035	0.047	0.072	0.093	0.092	0.089	0.072	0.045	0.029	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
JICT-02	wave ratio	0.027	0.038	0.062	0.078	0.083	0.085	0.071	0.043	0.028	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-01	wave ratio	0.028	0.039	0.065	0.081	0.090	0.090	0.076	0.046	0.029	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-02	wave ratio	0.029	0.040	0.069	0.083	0.093	0.093	0.076	0.046	0.029	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
CarT.-01	wave ratio	0.135	0.189	0.260	0.310	0.301	0.261	0.205	0.112	0.070	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

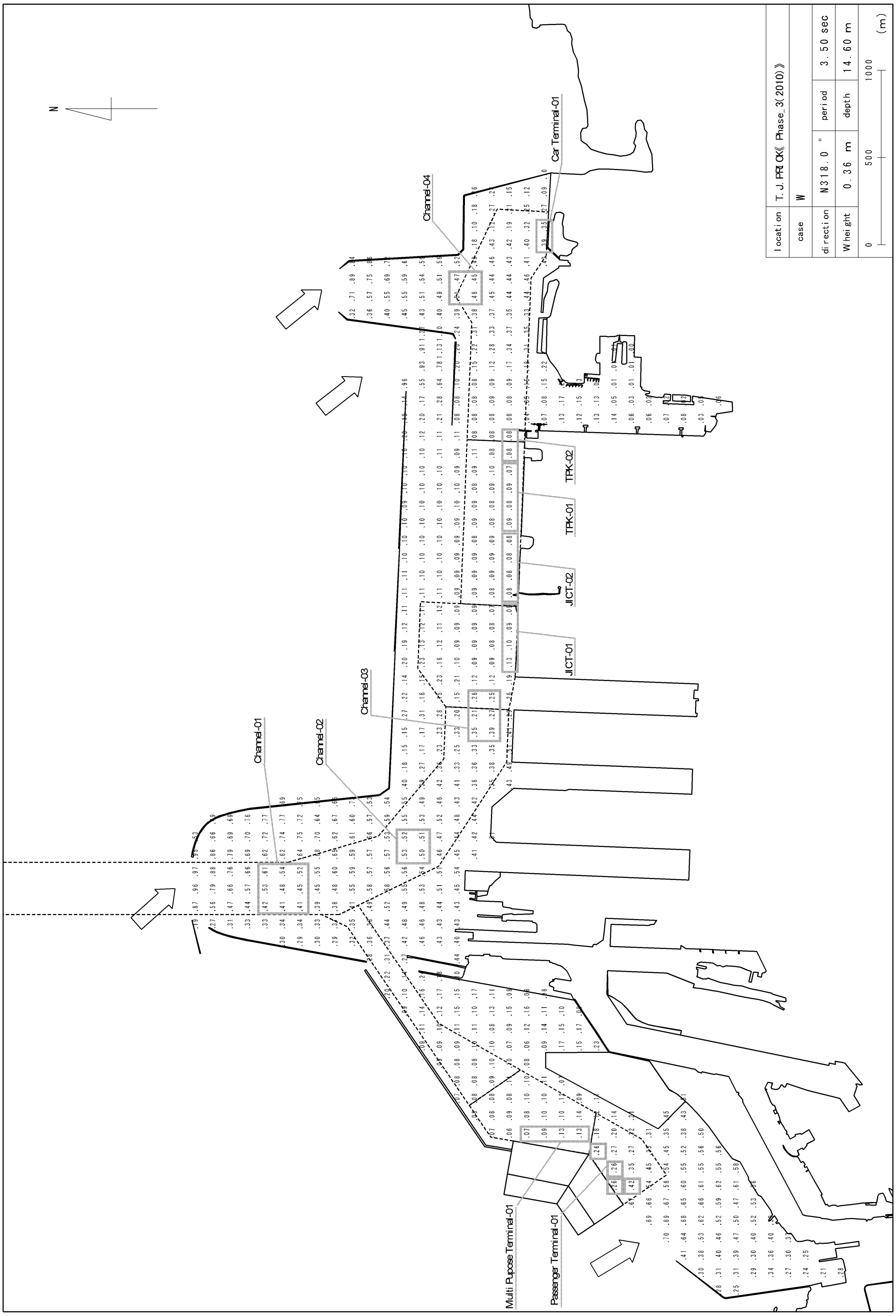


Figure G-6 (3) Output Points of Calculated Operational Cover Ratio
Urgent Phase 3 (2010)

Table G-2 (3) Operational Cover Ratio: Urgent Phase 3 (2010)

Target Wave Height: H≦0.5m

Offshore Wave Direction		W	WNW	NW	NNW	N	NNE	NE	ENE	E	Total
Channel-01	wave ratio	0.174	0.247	0.426	0.517	0.553	0.519	0.417	0.251	0.163	
	occurrence (%)		0.1	0.1	0.1	0.1	0.2	0.2			0.8
	cover ratio (%)	100.0	99.9	99.9	99.9	99.9	99.8	99.8	100.0	100.0	99.2
Channel-02	wave ratio	0.185	0.262	0.374	0.426	0.452	0.390	0.309	0.184	0.115	
	occurrence (%)		0.1		0.1			0.1			0.3
	cover ratio (%)	100.0	99.9	100.0	99.9	100.0	100.0	99.9	100.0	100.0	99.7
Channel-03	wave ratio	0.104	0.148	0.203	0.219	0.227	0.176	0.134	0.082	0.049	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Channel-04	wave ratio	0.171	0.247	0.375	0.441	0.467	0.413	0.324	0.175	0.110	
	occurrence (%)		0.1		0.1		0.1	0.1			0.4
	cover ratio (%)	100.0	99.9	100.0	99.9	100.0	99.9	99.9	100.0	100.0	99.6
JICT-01	wave ratio	0.037	0.050	0.074	0.095	0.094	0.087	0.072	0.043	0.028	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
JICT-02	wave ratio	0.029	0.040	0.066	0.082	0.089	0.089	0.076	0.044	0.028	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-01	wave ratio	0.030	0.042	0.077	0.094	0.112	0.116	0.101	0.057	0.036	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-02	wave ratio	0.029	0.040	0.070	0.082	0.094	0.092	0.076	0.046	0.029	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Car Terminal-01	wave ratio	0.134	0.187	0.257	0.305	0.294	0.253	0.198	0.107	0.068	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Passenger Terminal-01	wave ratio	0.108	0.153	0.180	0.195	0.156	0.131	0.096	0.054	0.034	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Multi purpose Terminal-01	wave ratio	0.038	0.053	0.059	0.064	0.052	0.044	0.035	0.021	0.013	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

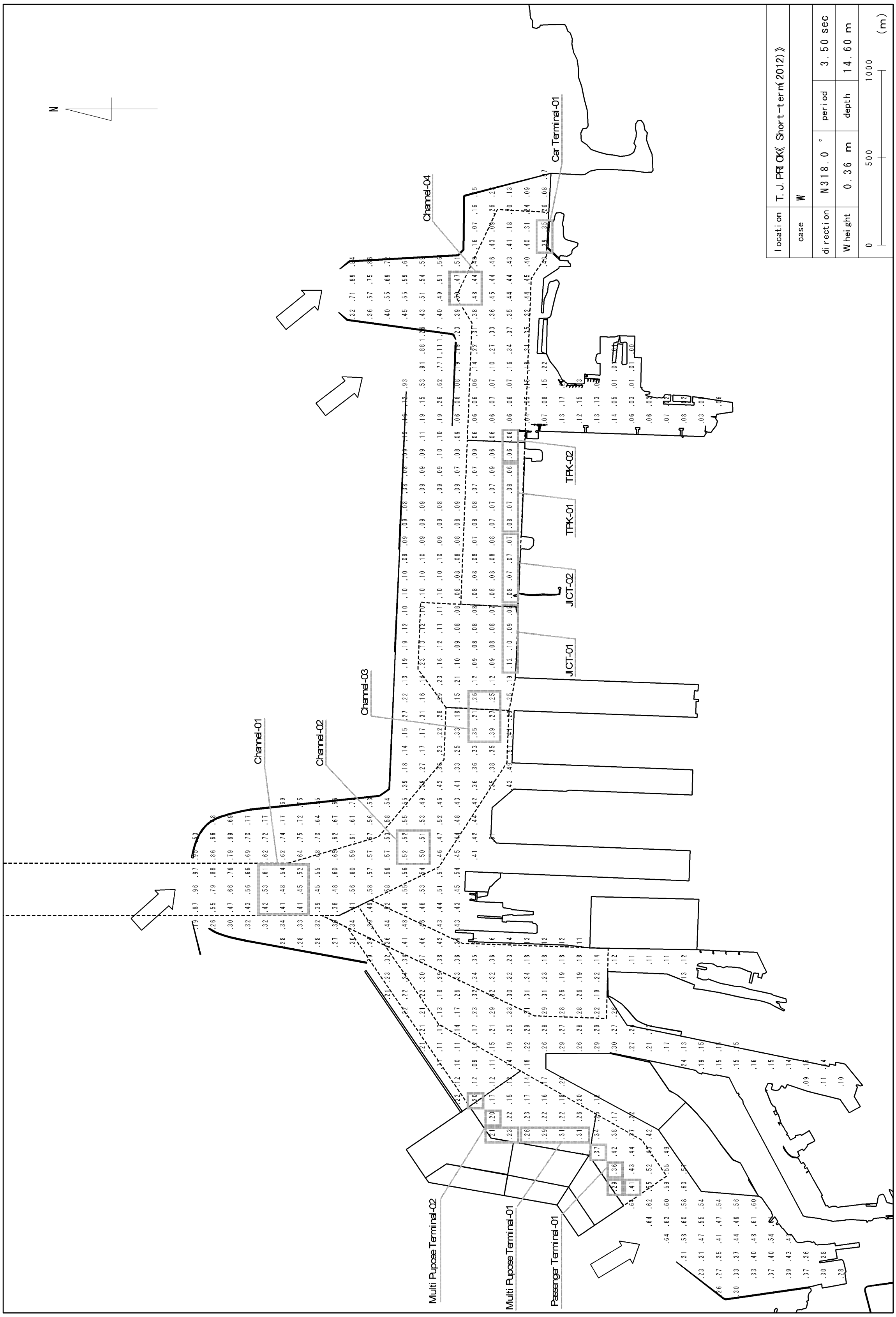


Figure G-6 (4) Output Points of Calculated Operational Cover Ratio Short-term (2012)

Table G-2 (4) Operational Cover Ratio: Short-term (2012)

Target Wave Height: H≦0.5m

Offshore Wave Direction		W	WNW	NW	NNW	N	NNE	NE	ENE	E	Total
Channel-01	wave ratio	0.174	0.247	0.425	0.515	0.552	0.518	0.417	0.251	0.162	
	occurrence (%)		0.1	0.1	0.1	0.1	0.2	0.2			0.8
	cover ratio (%)	100.0	99.9	99.9	99.9	99.9	99.8	99.8	100.0	100.0	99.2
Channel-02	wave ratio	0.185	0.262	0.373	0.426	0.452	0.389	0.309	0.184	0.114	
	occurrence (%)		0.1		0.1			0.1			0.3
	cover ratio (%)	100.0	99.9	100.0	99.9	100.0	100.0	99.9	100.0	100.0	99.7
Channel-03	wave ratio	0.104	0.147	0.202	0.218	0.225	0.173	0.132	0.080	0.048	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Channel-04	wave ratio	0.170	0.246	0.371	0.442	0.463	0.407	0.318	0.171	0.107	
	occurrence (%)		0.1		0.1		0.1	0.1			0.4
	cover ratio (%)	100.0	99.9	100.0	99.9	100.0	99.9	99.9	100.0	100.0	99.6
JICT-01	wave ratio	0.036	0.048	0.071	0.092	0.090	0.081	0.068	0.040	0.026	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
JICT-02	wave ratio	0.027	0.037	0.061	0.076	0.082	0.081	0.070	0.039	0.026	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-01	wave ratio	0.027	0.039	0.070	0.089	0.103	0.106	0.094	0.051	0.034	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-02	wave ratio	0.023	0.031	0.052	0.062	0.072	0.070	0.057	0.034	0.022	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Car Terminal-01	wave ratio	0.132	0.185	0.253	0.295	0.288	0.246	0.192	0.102	0.065	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Passenger Terminal-01	wave ratio	0.130	0.185	0.213	0.232	0.177	0.146	0.110	0.061	0.038	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Multi purpose Terminal-01	wave ratio	0.105	0.150	0.172	0.189	0.147	0.122	0.091	0.048	0.030	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Multi purpose Terminal-02	wave ratio	0.075	0.107	0.125	0.138	0.109	0.094	0.071	0.040	0.025	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

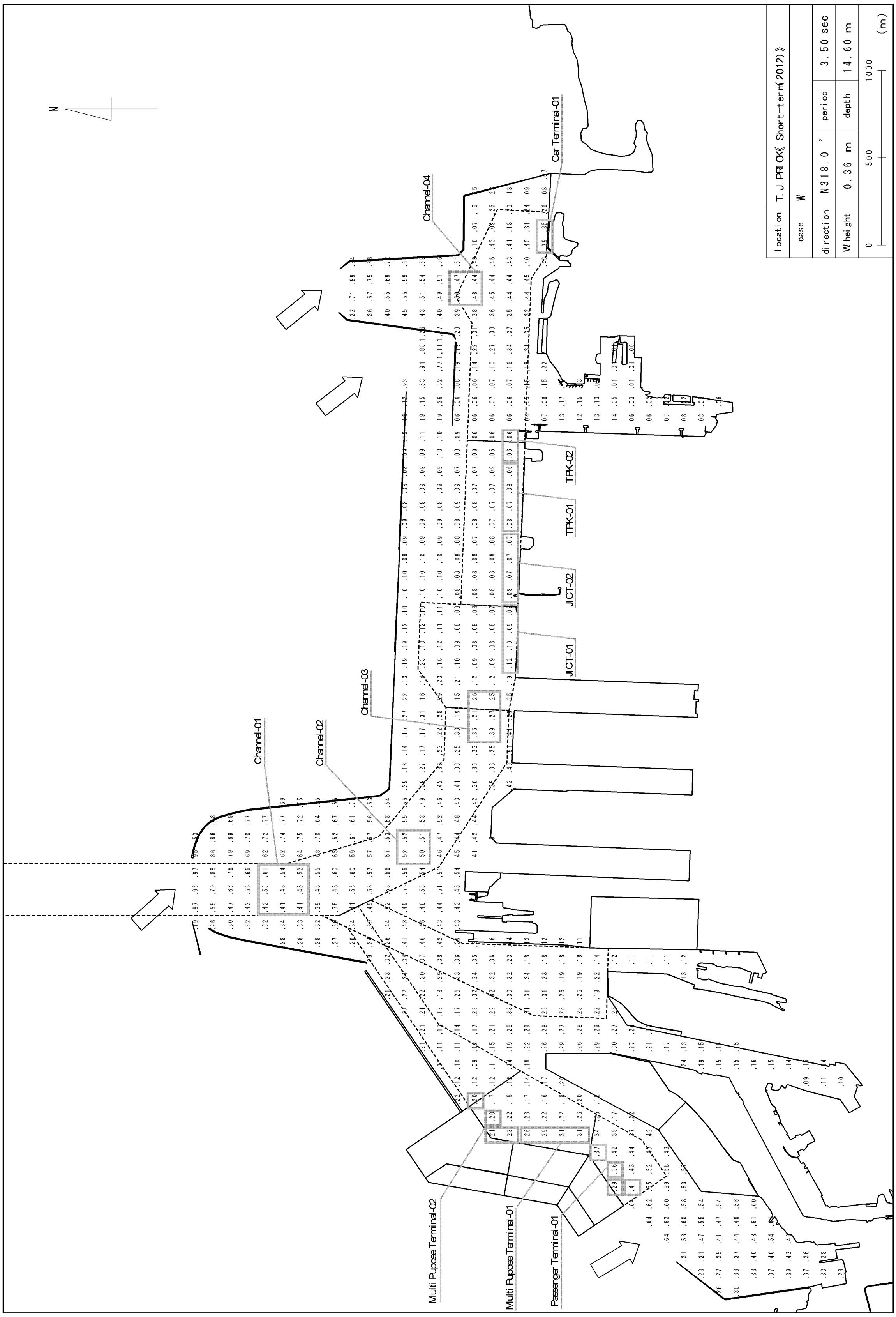


Figure G-6 (5) Output Points of Calculated Operational Cover Ratio Long-term (2025)

Table G-2 (5) Operational Cover Ratio: Long-term (2025)

Target Wave Height: H≦0.5m

Offshore Wave Direction		W	WNW	NW	NNW	N	NNE	NE	ENE	E	Total
Channel-01	wave ratio	0.173	0.244	0.420	0.505	0.538	0.502	0.404	0.245	0.157	
	occurrence (%)			0.1	0.1	0.1	0.2	0.2			0.7
	cover ratio (%)	100.0	100.0	99.9	99.9	99.9	99.8	99.8	100.0	100.0	99.3
Channel-02	wave ratio	0.184	0.259	0.360	0.407	0.427	0.362	0.289	0.172	0.106	
	occurrence (%)		0.1								0.1
	cover ratio (%)	100.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9
Channel-03	wave ratio	0.146	0.211	0.268	0.292	0.318	0.266	0.212	0.117	0.072	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Channel-04	wave ratio	0.215	0.303	0.425	0.503	0.496	0.464	0.375	0.201	0.123	
	occurrence (%)		0.1	0.1	0.1		0.1	0.1			0.5
	cover ratio (%)	100.0	99.9	99.9	99.9	100.0	99.9	99.9	100.0	100.0	99.5
Channel-05	wave ratio	0.112	0.159	0.321	0.389	0.439	0.465	0.397	0.245	0.155	
	occurrence (%)						0.1	0.1			0.2
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	99.9	99.9	100.0	100.0	99.8
Channel-06	wave ratio	0.118	0.167	0.216	0.267	0.273	0.271	0.211	0.124	0.068	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Channel-07	wave ratio	0.140	0.199	0.350	0.436	0.465	0.414	0.345	0.188	0.115	
	occurrence (%)				0.1		0.1	0.1			0.3
	cover ratio (%)	100.0	100.0	100.0	99.9	100.0	99.9	99.9	100.0	100.0	99.7
Channel-08	wave ratio	0.271	0.381	0.497	0.587	0.590	0.533	0.418	0.215	0.134	
	occurrence (%)	0.1	0.3	0.1	0.2	0.1	0.2	0.2			1.2
	cover ratio (%)	99.9	99.7	99.9	99.8	99.9	99.8	99.8	100.0	100.0	98.8
JICT-01	wave ratio	0.085	0.117	0.144	0.169	0.168	0.169	0.139	0.080	0.051	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
JICT-02	wave ratio	0.085	0.118	0.139	0.159	0.159	0.149	0.115	0.061	0.039	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-01	wave ratio	0.072	0.100	0.123	0.147	0.146	0.140	0.109	0.061	0.038	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
TPK-02	wave ratio	0.072	0.106	0.171	0.241	0.254	0.270	0.226	0.138	0.077	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table G-2 (6) Operational Cover Ratio: Long-term (2025)

Target Wave Height: H≦0.5m

For the offing waves		W	WNW	NW	NNW	N	NNE	NE	ENE	E	Total
Car Terminal-01	wave ratio	0.211	0.300	0.432	0.507	0.524	0.464	0.369	0.199	0.124	
	occurrence (%)		0.1	0.1	0.1	0.1	0.1	0.1			0.6
	cover ratio (%)	100.0	99.9	99.9	99.9	99.9	99.9	99.9	100.0	100.0	99.4
Car Terminal-02	wave ratio	0.207	0.293	0.430	0.503	0.522	0.462	0.376	0.197	0.121	
	occurrence (%)		0.1	0.1	0.1	0.1	0.1	0.1			0.6
	cover ratio (%)	100.0	99.9	99.9	99.9	99.9	99.9	99.9	100.0	100.0	99.4
Passenger Terminal-01	wave ratio	0.121	0.171	0.212	0.237	0.195	0.175	0.137	0.079	0.050	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Passenger Terminal-02	wave ratio	0.157	0.225	0.352	0.423	0.445	0.406	0.336	0.174	0.106	
	occurrence (%)						0.1	0.1			0.2
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	99.9	99.9	100.0	100.0	99.8
Multi purpose Terminal-01	wave ratio	0.079	0.112	0.140	0.171	0.141	0.134	0.107	0.063	0.044	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Multi purpose Terminal-02	wave ratio	0.060	0.084	0.106	0.129	0.103	0.096	0.077	0.046	0.030	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Multi purpose Terminal-03	wave ratio	0.062	0.086	0.133	0.170	0.169	0.173	0.145	0.091	0.060	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Multi purpose Terminal-04	wave ratio	0.083	0.118	0.244	0.293	0.348	0.392	0.343	0.212	0.136	
	occurrence (%)							0.1			0.1
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	99.9	100.0	100.0	99.9
Multi purpose Terminal-05	wave ratio	0.063	0.087	0.198	0.251	0.282	0.332	0.299	0.191	0.124	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Multi purpose Terminal-06	wave ratio	0.091	0.131	0.219	0.292	0.315	0.310	0.260	0.149	0.088	
	occurrence (%)										0.0
	cover ratio (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

APPENDIX H: MARINE GEOPHYSICAL SURVEY AT BOJONEGARA

H.1 Introduction

This is the report on the marine geophysical survey and soil investigation for the study for development of Bojonegara New Port. The area of the survey is located at Bojonegara at the Pulo Ampel Regency of Banten Province. The objective of the present survey is as follows.

1) To obtain sub-seabed lithography for the planning of dredging of channel of the seaport.
2) To check whether there is weak layer within rock formation underneath foundations of seawall or breakwater.

The scope of work to meet the above objective was thus as follows.

1) To conduct marine geophysical survey over an area of 750 m by 2,000m. The survey included seismic reflection survey, bathymetric survey and tidal observation.
2) To carry out offshore boring at 3 locations to the depths of 20 to 30 m below the seabed. Standard penetration tests and P-wave logging were conducted in the boreholes. Rock core samples were subjected to unconfined compression tests, point load tests, and Brazilian tests in laboratory.
3) To present the survey result in sounding maps including the result of the soil investigation.

This report consists of four sections. The program and procedure of the marine geophysical survey and the soil investigation are presented in the following section 2 and 3, respectively. Section 4 discusses the interpretation of the survey and investigation

H.2 Marine Geophysical Survey

H.2.1 Program of Marine Geophysical Survey

The program of marine geophysical survey consists of the following work items:

1) Seismic reflection survey, the main survey to identify stratigraphy within 10 m under the seabed.
2) Bathymetric survey to obtain seabed elevation of the fixed points used in the seismic reflection survey.
3) Tidal observation to obtain reference datum.
4) Installation of 2 additional bench marks for the reference points of the survey.

The above surveys were carried out in the period from 25 September to 1 October 2002. The survey area is geographically located within the South Latitudes of 05^{o} 54’ 11” to 05^{o} 54’ 44” and the East Longitude of 106^{o} 05’ 14” to 106^{o} 05’ 54”. Figure 1.1 shows the layout of the survey area. The quantity of work performed in the marine geophysical survey is summarized in **Table H-1**. The equipment used for the surveys is listed in **Table H-2**.

Table H-1 Work Quantity of Marine Geophysical Survey

Work Item	Quantity
1. Seismic reflection survey	40 km
2. Bathymetric survey	40 km
3. Tidal observation	15 days
4. Installation of bench mark	2 locations

Table H-2 Equipment Used for Marine Geophysical Survey

Description	Quantity	Purpose
Klein System 2000 sub-bottom profiling device	1 set	For seismic reflection survey
Atlas Deso 15 Echo sounder	1 set	For bathymetric survey
Trimble 4000 Ssi DGPS system for base station and mobile unit with radio-link system	1 set	For hydro-navigation survey and instant positioning data
Computer and printer with software of GPSurvey and HYDROnav	1 set	For positioning and navigation.
AM-2800 power generating set	1 unit	For electric supply of on board survey equipment
AOTT Kempten tidal self recorder and tide board	1 set	For tidal survey
Sokkisha B-2A auto level	1 set	For level survey
Wild T2 theodolite and EDM Di-1600	1 set	For bench mark positioning survey

H.2.2 Installation of Control Points

Prior to the marine geophysical survey, on land control points and a base station for DGPS system were installed for accurate positioning of the survey boat. Those control points were installed based on several existing reference bench marks specified by the client. The system and reference used in establishing control points and applied in the marine survey are briefed as below:

(1) Spheroid and Projection

The spheroid and projection applied in the present survey are as below:

- Spheroid : WGS-84 (World Geodetic System 1984)
- Projection : UTM (Universal Transverse Mercator)

(2) Datum Elevation

The datum elevation used in the present survey is LWS (Low Water Spring) with the following relationship:

- HWS (High Water Spring) : 1,200 mm (1.20 m)
- MSL (Mean Sea Level) : 600 mm (0.60 m)

- LWS (Low Water Spring) : 0 mm (0.00 m)

The reference point for the level control is the existing bench mark (BP-20) with the known elevation of 1.283m above LWS. The bench mark is located close to coast line, at the south-east boundary wall of PT. Risjad Brasali in Pulo Ampel Regency. The description of this reference bench mark is given in Appendix A.

(3) Reference Points for Horizontal Control

The main reference point for the horizontal control in the present survey was the existing bench marks GPS-0 in front of the Public Health Clinic (Puskesmas) of Pulo Ampel Regency. The other two existing bench marks GPS-1 and BM-E.01 were also used for checking. Additional two bench marks BM-01 and BM-02 were installed for the survey net work and the base station for the DGPS system of the marine geophysical survey. Appendix A shows the description of all the existing and the newly installed benchmarks. **Table H-3** summarizes the coordinates and elevation of the control points.

Table H-3 Coordinates and Elevations of Control Points

Designation	Coordinates UTM, WGS-84		Elevation (m)		Remark
	East (m)	North (m)	Ellipsoid Datum	LWS	
GPS-0	620,176.561	9,347,217.496	14.359		Control point for coordinates
BP-20	620,436.241	9,347,593.568	13.796	1.283	Control point for Elevation
BM-E.01	620,147.654	9,347,467.828	15.368		Existing bench mark
BM-01	620,358.011	9,347,367.302	14.020	1.500	Newly established bench mark
BM-02	621,600.853	9,346,379.228	14.584		Newly established bench mark

H.2.3 Seismic Reflection Survey

Seismic reflection survey was carried out to identify sub-bottom profile or stratum at the survey area. A Klein System 2000, which is capable for identifying sub-seabed lithology of 10 m, was employed in the present survey. The equipment was fixed on a boat together with echo sounder and Differential Global Positioning System (DGPS).

The survey was done in parallel lines at approximately 50 m spacing along north-east and east-west directions. The survey was also done in a few longitudinal directions at south-east direction and also surrounding Pulau Kali. The total survey length was approximately 40 km.

Along the survey lines, the acoustic signal was shot at sounding points with distances of approximately 20 m. The DGPS that was fixed on the survey boat was used to locate the position of the sounding points.

H.2.4 Bathymetric Survey

Bathymetric survey was carried out in parallel with the seismic reflection survey as both the equipment were installed in the same survey boat. The bathymetric survey was done to obtain accurate seabed elevation at the sounding points of the seismic reflection survey.

The survey was done using an Atlas Deso 15 Echo sounder. The survey lines were the same with the seismic reflection survey. Bar check was done every day before the starting of the sounding and at the end of the sounding.

H.2.5 Tide Observation

Tidal observation was carried out to determine the tidal reduction for the echo sounding in the bathymetric survey. A self tidal recorder and a tide board were installed at a temporary platform in a shallow water and safe area. The tidal was observed for 15 days from 27 September to 11 October 2002. Appendix D presents the tidal records as well as the harmonic analysis.

The observation indicates the tidal characteristic was mix tide and tends to be semi diurnal and the main tidal harmonics constituents were as below:

Tidal Harmonics	**S_0**	**M_2**	**S_2**	**N_2**	**K_1**	**O_1**	**M_4**	**MS_4**	**K_2**	**P_1**
Amplitude A (cm)	116	6	17	1	13	10	0	1	5	4
Phase Lag (^{o})	-	239	303	95	259	72	135	261	303	259

H.3 Offshore Soil Investigation

H.3.1 Program of Offshore Soil Investigation

The program of the offshore soil investigation consists of the following work items:

a) Positioning survey for the offshore drilling
b) Construct fixed platforms for offshore drilling
c) Offshore drilling at 3 locations
d) Standard penetration tests in soil formation and weathered rock formation
e) Downhole P-wave logging in rock formation
f) Unconfined compression tests, point load tests and Brazilian tests for rock samples

The field works was conducted in the period from 30 September to 19 October 2002, starting from the installation of the fixed platforms, the exploratory drilling, and the downhole P-wave logging. Table 2.1 summarizes the work quantity of the offshore soil investigation including the laboratory tests.

H.3.2 Exploratory Drilling

One rotary type drilling rig was mobilized to the site to perform the exploratory drilling at 3 locations (BH-1 to BH-3). The boreholes were advanced by coring technique. The drilling was done in soil formation at the upper part and was continued with rock coring in lower formation. The drilling depths were 30m in BH-1 and 20 m in BH-2 and BH-3. The core samples retrieved were stored in core boxes in depth order.

The description of soil samples was recorded by a geologist as presented in the borehole logs in

Appendix F. The core recovery and the rock quality designation (RQD) that describe the quality of rock mass were also recorded by the geologist.

H.3.3 Standard Penetration Test

The purpose of the standard penetration tests (SPT) is to determine relative density or consistency of subsoil and to obtain soil samples for visual description. The hammer used for the SPT was a free fall type with automatic triggering system.

In general, the SPTs were performed in the upper soil formation at 2m interval. SPTs were also conducted in the upper portion of the rock formation with highly to completely weathered conditions. The total quantity of SPTs conducted in the 3 boreholes was 20 tests with the breakdown at each borehole.

H.3.4 Downhole P-Wave Logging

Downhole p-wave logging was only conducted in rock formation with intention to classify the rock quality based on the p-wave velocity. A PS-logging device manufactured by OYO Corporation was employed in the present investigation.

The test was carried out by inserting inflatable geophone at the intended testing depths. A shock wave was generated by hammering the casing pipe that was installed up to the surface of the rock formation. Reference geophones were also installed in the casing pipe for the correction of the wave propagation along the casing pipe. The hammering was done several times to obtain the best signal recorded by the geophone. **Table H-4** summarizes the test result.

Table H-4 Summary of P-Wave Logging Results

Borehole No.	Depth Range (m)	Elevation (mLWS)	P-wave Velocity (km/sec)	Rock / Soil Type
BH-1	12.0 to 20.0	-18.5 to -26.5	2.5 - 3.3	Highly fractured Breccia
	20.0 to 30.0	-26.5 to -36.5	2.9 - 3.8	Highly fractured Breccia
BH-2	6.5 to 9.0	-13.6 to -16.1	1.8	Highly to completely weathered Breccia
	9.0 to 20.0	-16.1 to -27.1	2.4 - 3.3	Highly fractured Breccia
BH-3	10.0 to 13.0	-17.5 to -20.5	1.0 - 1.2	Stiff silty clay and sandy silt
	13.0 to 16.0	-20.5 to -23.5	1.6 - 2.0	Highly to completely weathered Breccia
	16.0 to 19.0	-23.5 to -26.5	2.3 - 5.0	Highly to completely weathered Breccia

H.3.5 Laboratory Test

Laboratory tests were carried out for rock core samples to obtain compression and tensile strength characteristics of the rock formation. The original program of laboratory tests consisted of unconfined compression tests to determine compressive strengths and Brazilian tests to indirectly determine tensile strengths. However, as majority of core samples were short and were unable to meet the required ratio of length to diameter for the unconfined compression tests, point load tests were assigned to short core samples to indirectly obtain the compressive strengths.

There were 4 unconfined compression tests, 9 point load tests and 11 Brazilian tests conducted on rock core samples in the present study. The core samples were collected from all the sound portion of the cores having the length of larger than 5 cm. It should be pointed out that almost all the core samples having the length larger than 5 cm were obtained below -15m LWS (the proposed dredging level) because the rock mass above –15mLWS confirmed in all the 3 boreholes was highly to completely weathered.

The strength characteristics of the rock core sample are summarized in **Table H-5** on the results of the unconfined compression test, point o load tests and Brazilian Tensile tests.

Table H-5 Strength Characteristics of Rock Core Samples

Borehole No.	Depth (m)	Elevation (mLWS)	Type of Test*	Strength (MN/m^2)	
				Compressive	Tensile
BH-1	12.13 to 12.19	-18.62 to -18.68	PL Test	105.19	-
	14.80 to 14.85	-21.29 to -21.34	PL Test	46.37	-
	17.65 to 17.75	-24.14 to -24.24	UC Test	44.12	-
	17.85 to 17.90	-24.34 to -24.39	BR Test	-	7.58
	19.50 to 19.60	-25.99 to -26.09	BR Test	-	5.18
	20.78 to 20.86	-27.27 to -27.35	BR Test	-	5.21
	20.86 to 20.91	-27.35 to -27.40	BR Test	-	3.61
	23.88 to 23.94	-30.37 to -30.43	BR Test	-	3.04
	23.94 to 24.00	-30.43 to -30.49	BR Test	-	4.04
	26.65 to 26.80	-33.14 to -33.29	UC Test	119.38	-
	27.50 to 27.65	-33.99 to -34.14	BR Test	-	2.91
	28.25 to 28.40	-34.74 to -34.89	UC Test	139.17	-
	28.50 to 28.70	-34.99 to -35.19	UC Test	112.76	-
	29.65 to 29.72	-36.14 to -36.21	BR Test	-	3.97
	29.72 to 29.80	-36.21 to -36.29	BR Test	-	9.98
BH-2	6.13 to 6.24	-13.25 to -13.36	PL Test	43.40	-
	8.55 to 8.58	-15.67 to -15.70	PL Test	57.07	-
	11.40 to 11.45	-18.52 to -18.57	PL Test	96.03	-
	12.50 to 12.55	-19.62 to -19.67	PL Test	60.02	-
	14.50 to 14.58	-21.62 to -21.70	PL Test	48.26	-
	15.25 to 15.33	-22.37 to -22.45	BR Test	-	7.44
	16.45 to 16.50	-23.57 to -23.62	BR Test	-	2.77
BH-3	14.00 to 14.23	-21.50 to -21.73	PL Test	3.69	-
	17.10 to 17.15	-24.60 to -24.65	PL Test	29.90	-

Note: * UC Test : Unconfined Compression Test
PL Test : Point Load Test
BR Test : Brazilian Test

H.4 Discussion of Survey Results

H.4.1 Sub-Seabed Stratigraphy

The sub-seabed materials were classified into the following 4 classifications:

Alluvium		Volcanic Rocks	
Soft or loose deposits	Medium to stiff or medium dense deposits	Highly to completely weathered	Moderately weathered

The soft and loose deposits consist of very soft to soft clay and occasionally very loose to loose sand. The sediments were judged to be the recent alluvium deposited on seabed. The soft and loose deposits are distributed over the entire survey area with various thickness except at the outcrop of volcanic rock.

In between the soft alluvium and the volcanic rock are the medium to stiff and medium dense deposits. The deposits were judged to be the sedimentation from volcanic rocks and consist of medium to stiff clay and medium dense sand with gravel. The medium to stiff deposits were not evenly deposited in the entire survey area but were confirmed randomly over the survey area.

Underlying the alluvium is the volcanic rock that was originated from the eruption of Mount Gede in Pleistocene. According to the geological map, the constituent materials of the volcanic rocks are lava, breccia and consolidated lahar. **Figure H-1** presents the contours of the bedrock surface. The figure indicates the area with rock surface higher than -15 m LWS at which dredging in rock is anticipated.

In general, the volcanic rocks confirmed up to the depth of the investigation can be divided into 2 zones, i.e., the highly to completely weathered rocks at the upper part and the moderately weathered rocks at the lower part.

The highly to completely weathered volcanic rocks consists of silt and sand matrix with gravel and cobble of andesite fragments. From the description of the previous boreholes, intercalation of Andesite layers was sometimes encountered in the highly to completely weathered zone. The Rock Quality Designation (RQD) in this highly to completely weathered zone is generally less than 20% and the p-wave velocity is 1.6 to 1.8 km/sec. According to the rock mass classification CRIEPI, this zone is generally classified as CM to D or soft rock to soil.

The moderately weathered zone of rock consists of highly fractured rock with sand and silt matrix as well. The RQD is 20% to 40% and occasionally as high as 60%. The p-wave velocities vary from 2.4 to 3.8 km/sec and occasionally as high as 5. This zone is classified as CH and CM based on CRIEPI classification or soft to relatively solid rocks. **Figure H-1** shows the area where the moderately weathered rocks are exposed on the rock surface. The moderately weathered rock confirmed at deeper ground beneath the rock surface was not shown in **Figure H-1.**

In the seismic reflection survey, the upper surfaces of medium to stiff alluvium and the completely weathered volcanic rock were generally well defined by the appearance of reflectors. However, the upper surface of the moderately weathered rocks was not always detected due to 2 reasons, i.e., (a) the weathering decreases linearly with depth and/or (b) the energy was not strong enough to penetrate deep zone of moderately weathered rock.

H.4.2 Rippability of Bedrock

The rippability of rock largely depend on the join condition. In general, highly fractured rock mass is easier to rip than solid and massive rock mass. The Rock Quality Designation (RQD) and the joint spacing are generally the important information for workability other than the strengths of the rock masses as shown in **Figures H-2** to **H-4**. The figures suggest that the rock mass with RQD values smaller than 20% and with close joint spacing of smaller than 50 mm are generally rippable without blasting.

The unconfined compressive strengths of the core samples obtained from BH-1 to BH-3 are plotted in **Figures H-2** to **H-4** together with the RQD values and joint spacing observed during the investigation. The elevations of the core samples are also plotted in the figures. As shown in the figures, the highly to completely weathered rocks above -22mLWS are generally rippable without blasting. Occasionally, chiseling or drilling to loosen the rock masses may be required if there are large size andesite fragments. For rock excavation at deeper zone, drilling or blasting to loosen the rock are necessary.

P-wave velocity generally serves as guidance for rippability for on land excavators as indicated by a few guide lines. For granite rocks, p-wave velocities larger than 1.8 km/sec are generally difficult to rip by medium size dozers. While large size dozers may be able to rip granite rocks with p-wave velocity as large as 2.3 km/sec. The p-wave velocity of the volcanic rocks at the upper 3 m below the rock surface were generally less 1.7 to 2 km/sec. Such magnitude of velocity suggests that the rock is rippable.

The information of the present 3 boreholes may not represent the condition of the entire site area. The nature of rock above 15 m LWS from the borehole information in the previous soil report was thus summarized in **Table H-5**. The table indicates that the expected thickness of the rock excavation at the site varies from 0.5 to 7.5m. The RQD values obtained from the present 3 boreholes and the previous boreholes of B-series, GA series and K-series are generally less than 20%.

Based on **Figure H-2**, ripping of such soft rock is possible. Nevertheless, as the remark with andesite intercalation was often given in the A-series boreholes, dredging with difficulty may be expected if large andesite fragments are encountered. Dredging difficulty may also be faced in minor areas where moderately weathered rocks are exposed on the bedrock surface as indicated in **Figure H-1**. Chiseling or pre-boring to loosen the rock before dredging may be necessary.

Based on guide line, grapper or dipper dredgers may be required for the dredging in the highly to completely weathered rocks. The efficiency factors of 0.3 to 0.5 are expected for the dipper dredger.

H.4.3 Possible Weaker Portion of Supporting Foundation

Caisson structure is expected to be constructed for quay wall. The caisson will be supported on the surface of the highly to completely weathered rock. There was a concern if there is weak zone in the ground under the surface of the weathered rock. The present soil investigation at 3 borehole indicates that there was no weak zone encountered up to 20 to 30m below the seabed.

H.4.4 Use of Alluvium as Reclamation Material

Dredged materials are sometime used as reclamation materials to save transporting and disposal costs. The alluvium at the site consists of silt and clay that is not sensitive according to the previous soil report and may be used as reclamation materials. Nevertheless, the low permeability of fine grained materials requires special treatment to accelerate consolidation process for the reclamation. Installation of vertical drains, or sandwiching imported sand and local dredged clay may need to be considered.

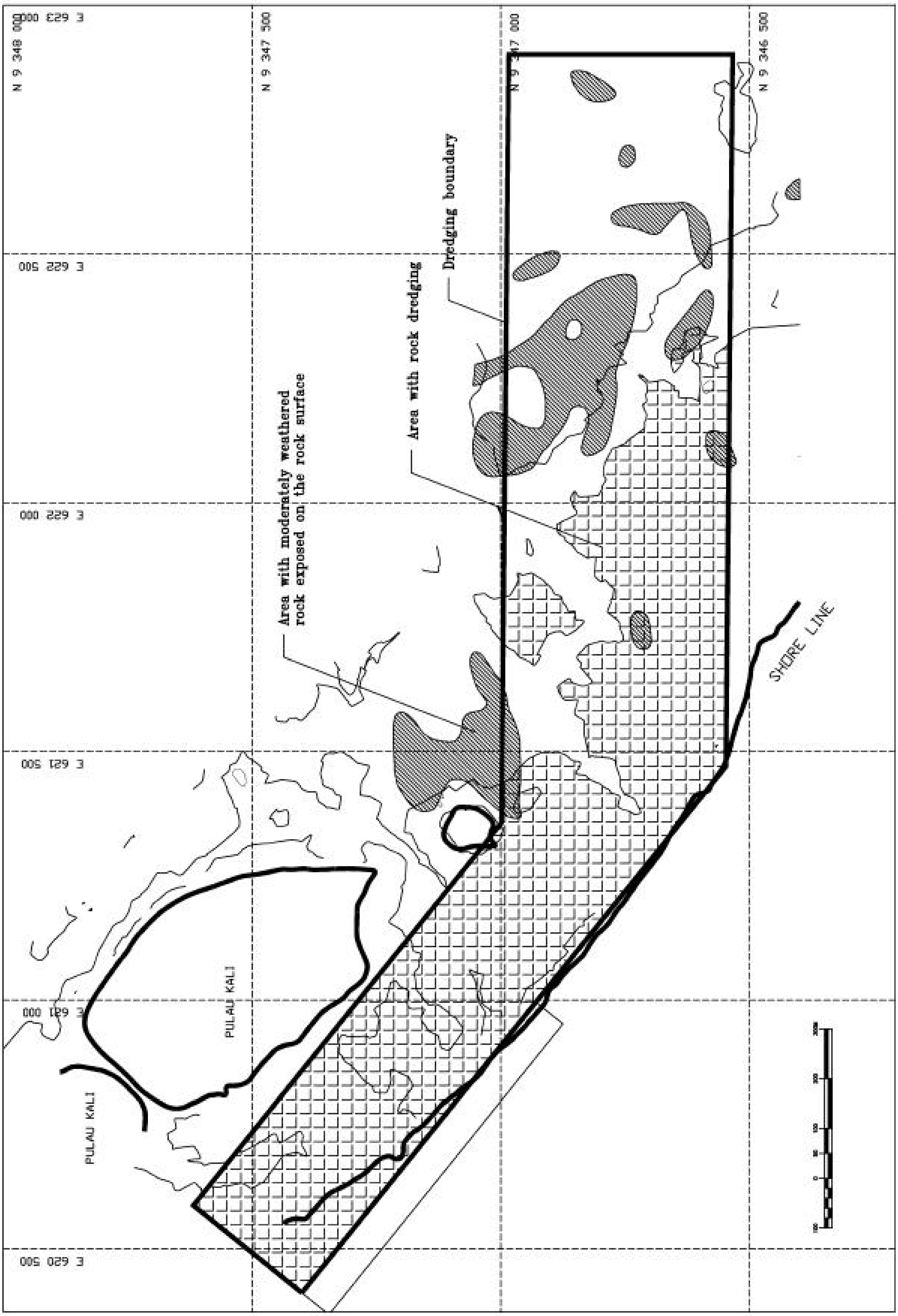


Figure H-1 Bedrock Surface Contours and Anticipated Area of Rock Dredging

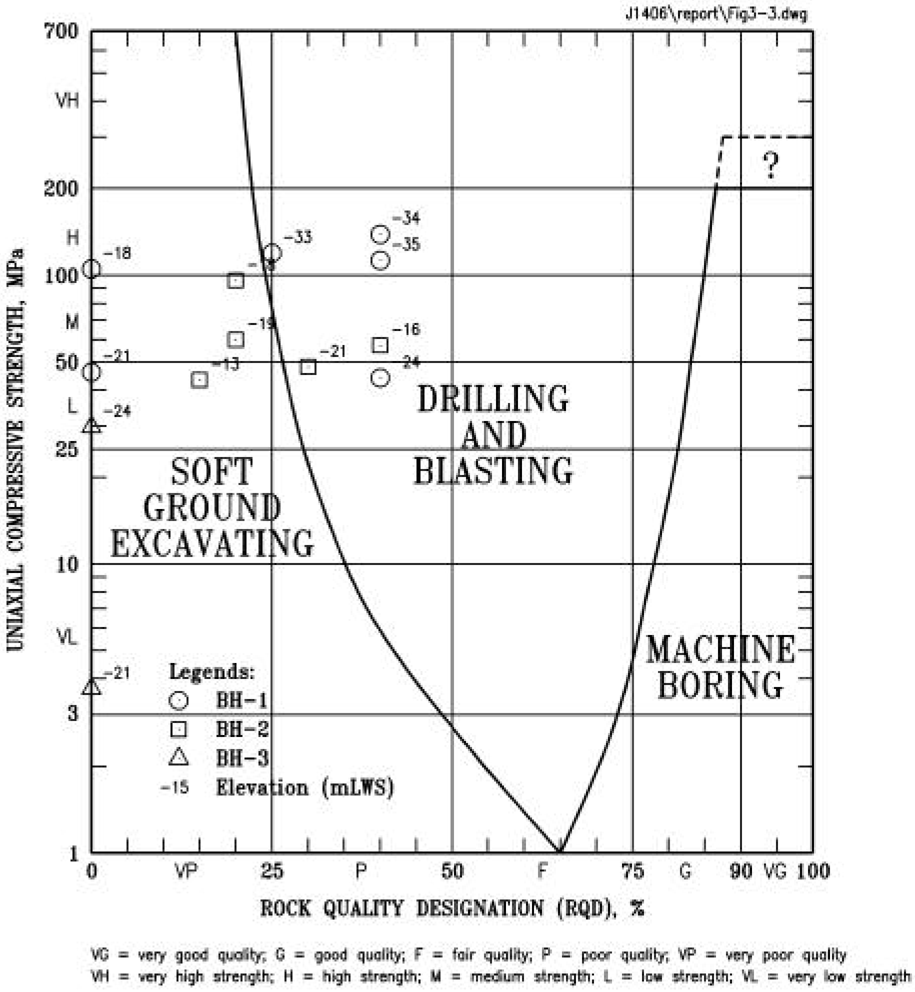


Figure H-2 Workability of Rock (after Muir Wood, 1972)

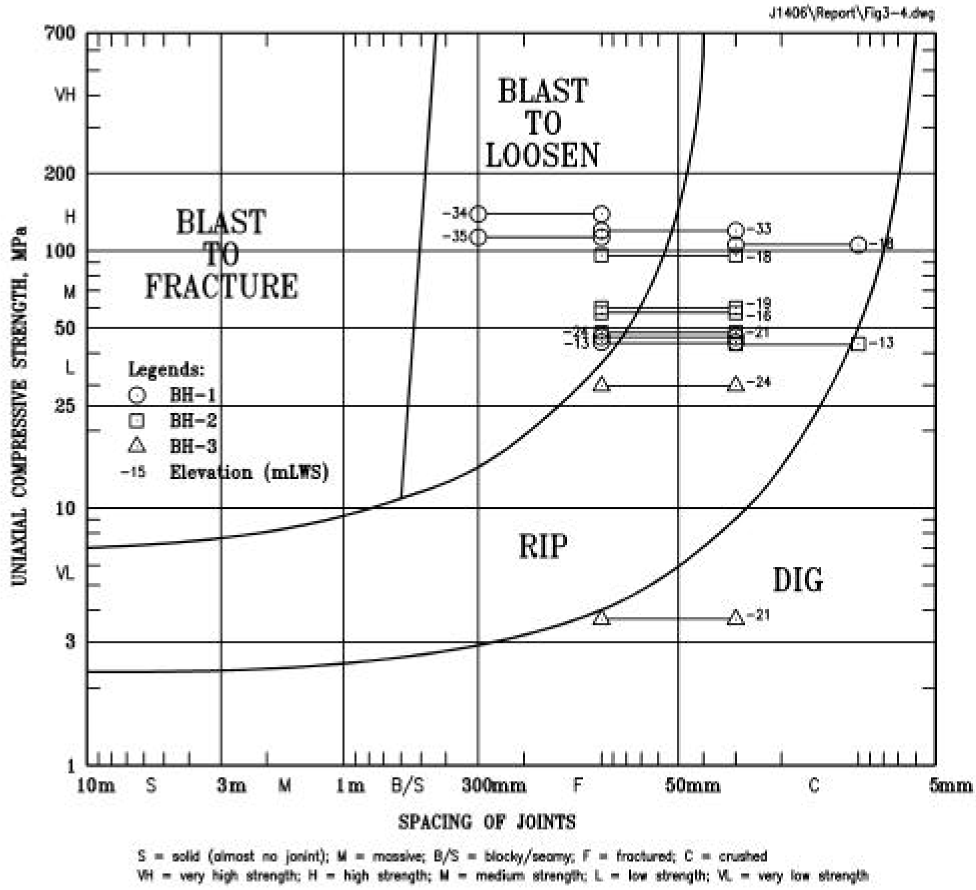


Figure H-3 Workability of Rock (after Franklin et al., 1971)

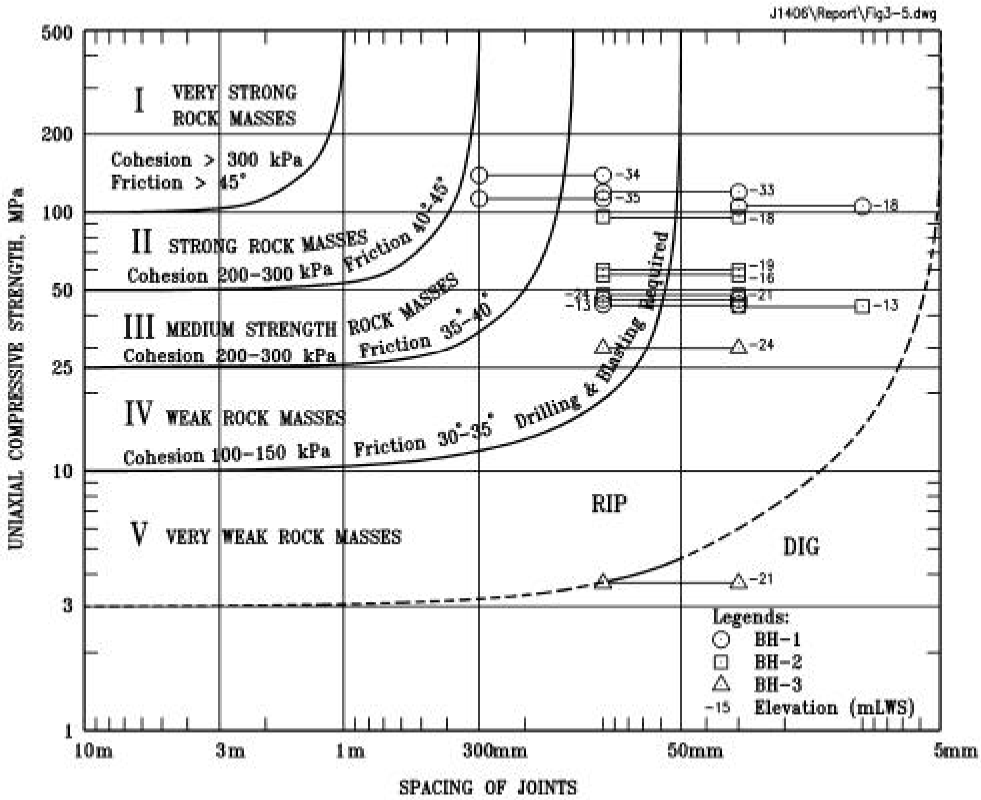


Figure H-4 Strength Diagram for Jointed Rock Masses (after Bieniawski, 1974)

Table H-5 Anticipated Materials to be Dredged up to -15 m LWS

Borehole No.	Seabed Elevation (mLWS)	Rock surface Elevation (mLWS)	Dredging Thickness in Alluvial Soil, (m)	Dredging in Volcanic Rock up to -15mLWS			
				Thickness (m)	RQD (%)	SPT N-Value	Nature of Rock According to the Soil report
BH-1	-6.49	-13.99	7.50	1.01	0	60	Clay, silt, sand with andesite fragments
BH-2	-7.12	-13.22	6.10	1.78	0 - 15	Rebound	Clay, silt, sand with andesite fragments
BH-3	-7.50	-21.25	13.75	No rock	-	-	-
A1	-6.75	-7.75	1.00	7.25	Not known	Rebound	Clayey silt with andesite fragments*
A2	-6.25	-11.25	5.00	3.75	Not known	Rebound	Clayey silt with andesite fragments*
A3	-7.10	-11.60	4.50	3.40	Not known	Rebound	Clayey silt with andesite fragments*
A4	-5.75	-13.75	8.00	1.25	Not known	44	Clayey silt with andesite fragments
A5	-3.00	-8.00	5.00	7.00	Not known	Rebound	Clayey silt with andesite fragments*
A6	-1.50	-14.50	13.00	0.50	Not known	28	Clayey silt with andesite fragments
A7	-1.75	-8.75	7.00	6.25	Not known	30 - 50	Clayey silt with andesite fragments
A8	-3.50	-13.00	9.50	2.00	Not known	25 - Rebound	Clayey silt with andesite fragments*
A9	-3.75	-11.75	8.00	3.25	Not known	40 - 50	Clayey silt with andesite fragments*
A10	-6.20	-11.20	5.00	3.80	Not known	40 - Rebound	Clayey silt with andesite fragments*
A11	-3.00	-15.00	12.00	No rock	Not known	27	Clayey silt with andesite fragments*
A12	-0.25	-14.25	14.00	0.75	Not known	Rebound	Clayey silt with andesite fragments
A13	-6.90	-14.40	7.50	0.60	Not known	30	Clayey silt with andesite fragments
A14	-7.40	-15.90	8.50	No rock	-	-	-
A15	-8.00	-18.00	10.00	No rock	-	-	-
B1	-8.94	-25.94	17.00	No rock	-	-	-
B2	-10.33	-27.33	17.00	No rock	-	-	-
B3	-4.32	-14.92	10.60	No rock	-	-	-
B4	-0.67	-12.47	11.80	2.53	0	50 - Rebound	Very dense volcanic rock
B5	-0.02	-9.17	9.15	5.83	0	-	Very dense volcanic rock
B6	-0.03	-10.53	10.50	4.47	15 - 60	Rebound	Very dense volcanic rock
B7	-0.43	-13.93	13.50	1.07	0	50	Very dense volcanic rock
B8	-5.02	-21.52	16.50	No rock	-	-	-
B9	-4.52	-15.52	11.00	No rock	-	-	-
B10	-1.02	-20.12	19.10	No rock	-	-	-
GA4	1.85	-	16.85	No rock	-	-	-
GA5	-4.07	-11.57	7.50	3.43	0	-	Highly to slightly weathered basalt
GA6	-6.26	-16.58	10.32	No rock	-	-	-
GA7	-5.27	-15.77	10.50	No rock	-	-	-
GA8	-6.27	-	8.73	No rock	-	-	-
GA9	-6.27	-	8.73	No rock	-	-	-
GA10	1.39	-	16.39	No rock	-	-	-
GA12	-1.47	-	>13.53	?	?	-	-
GA13	-2.54	-	12.46	No rock	-	-	-
GA14	-3.54	-	11.46	No rock	-	-	-
GA15	-3.14	-	11.86	No rock	-	-	-
GA15A	-3.08	-14.08	11.00	0.92	0	50	Highly weathered Basalt
GA16	-5.37	-15.77	10.40	No rock	0	50	Highly weathered Basalt
GA17	-5.30	-	9.70	No rock	-	-	-
GA18	-5.58	-10.16	4.58	4.85	Not known	-	Fractured basalt
GA28	-5.13	-	9.88	No rock	-	-	-
GA29	-7.30	-	7.70	No rock	-	-	-
K1	1.02	-16.48	17.50	No rock	-	-	-
K2	-2.46	-12.96	10.50	2.05	0	-	Very dense volcanic rock
K3	-3.95	-17.45	13.50	No rock	-	-	-
K4	-4.12	-21.72	17.60	No rock	-	-	-
K10	1.08	-14.72	15.80	No rock	-	-	-
Summary			1.00 to 19 m	0.5 to 7.5m	Generally < 20	25 to Rebound	

Note: * Intercalation with andesite sheeting or layer

APPENDIX I: DREDGING WORKS AT BOJONEGARA DEVELOPMENT

I.1 Seismic Surveys for Sub-Seabed Stratigraphy of Bojonegara

According to the results of seismic surveys and off-shore boring surveys at the development site of Bojonegara, the sub-seabed materials were classified into the following 4 layers:

Alluvium	Soft and loose deposits
	Medium to stiff or medium
Volcanic Rocks	Highly to completely weathered
	Moderately weathered

The soft and loose deposits consist of ‘very soft to soft’ clay and occasionally ‘very loose to loose’ sand. The sediments were judged to be the recent alluvium deposited on seabed. The soft and loose deposits are distributed over the entire survey area with various thicknesses except at the outcrop of volcanic rock

In between the soft alluvium and the volcanic rock are ‘medium to stiff and medium’ dense deposits. The deposits were judged to be the sedimentation from volcanic rocks and consist of medium to stiff clay and medium dense sand with gravel. The ‘medium to stiff’ deposits were confirmed randomly deposited over the survey area.

Underlying the alluvium is the volcanic rock that was originated from the eruption of Mount Gede in Pleistocene. According to the geological map, the constituent materials of the volcanic rocks are lava, breccia and consolidated lava.

In general, the layer of volcanic rocks can be divided into 2 zones, i.e., ‘highly to completely weathered’ rocks at the upper part and ‘moderately weathered’ rocks at the lower part.

The ‘highly to completely weathered’ volcanic rocks consist of silt and sand matrix with gravel and cobble of andesite fragments. The Rock Quality Designation (RQD) in this highly to completely weathered zone is generally less than 20% and the p-wave velocity is 1.6 to 1.8 km/sec.

The ‘moderately weathered’ zone of rock consists of highly fractured rock with sand and silt matrix as well. The RQD is 20% to 40% and occasionally as high as 60%. The p-wave velocities vary from 2.4 to 3.8 km/sec and occasionally as high as 5. The moderately weathered zone was confirmed to be distributing in a few areas.

I.2 Rippability of Bedrock

The unconfined compressive strengths of the core samples obtained from BH-1 to BH-3 are plotted in **Figure I-1** together with the RQD values observed during the investigation. The elevations of the core samples are also plotted in the figures. As shown in the figure, the ‘highly to completely weathered’ rocks above LWS-22 m are generally rippable without blasting. Occasionally, chiseling or drilling to loosen the rock masses may be required if there are large size andesite fragments.

Grab or dipper dredgers may be required for the dredging in the 'highly to completely weathered' rocks. The efficiency factors of 0.3 to 0.5 are expected for the grab and/or dipper dredger.

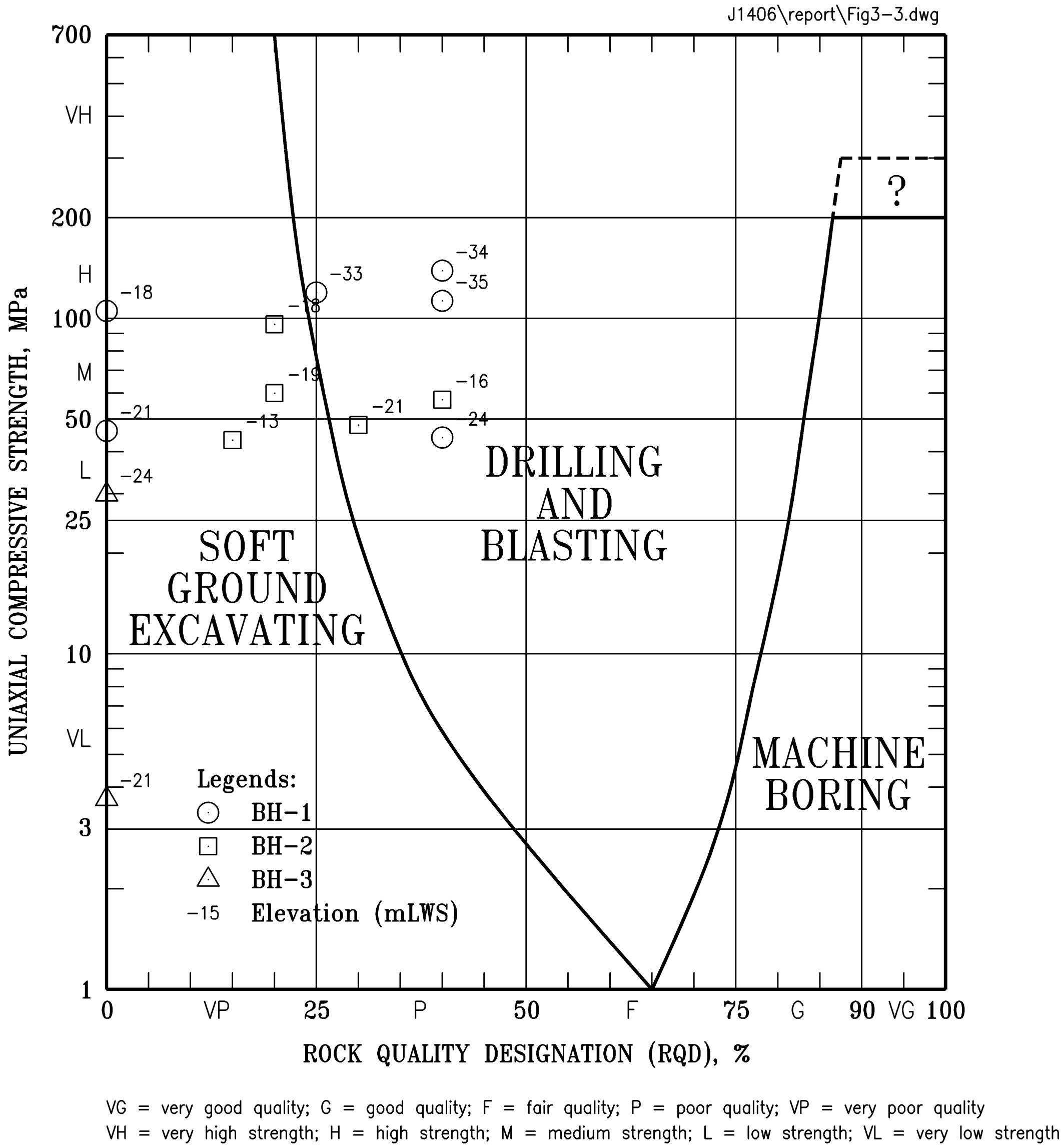
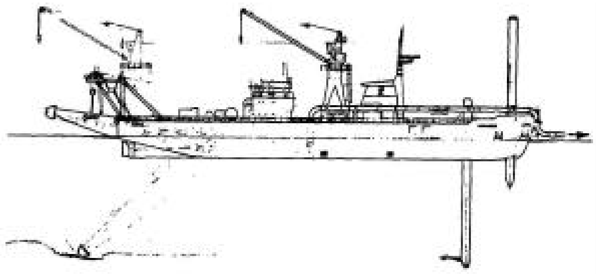


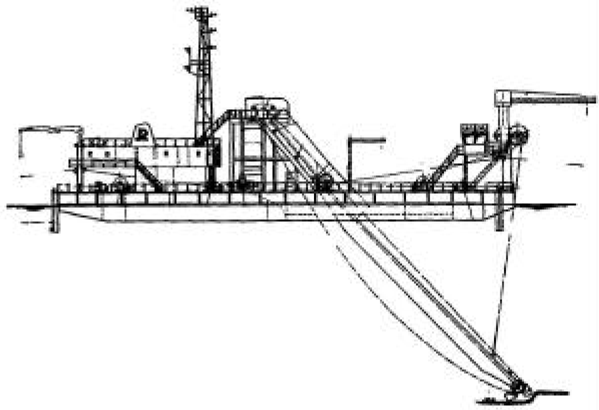
Figure I-1 Workability of Rock (after Muir Wood, 1972)

I.3 Selection of Dredger Type

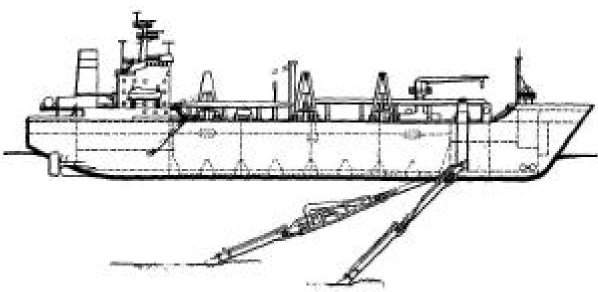
Mechanical/hydraulic dredgers (cutter suction dredger, bucket wheel dredger and trailing suction hopper dredgers are representatives) are usually employed on construction and maintenance purposes of harbor basin and navigation channel. They are characterized by high production rates and the ability to effectively dig silts, clays, sand, gravel and cobbles, fractured and sound rocks.



Cutter Suction Dredger



Bucket-wheel Dredger



Trailing Suction Hopper Dredger

Figure I-2 Mechanical/hydraulic Dredgers

Those mechanical/hydraulic dredgers are not suitable for dredging of ‘soft and loose’ deposit material as the dredging operation will produce silt slurry, and the agitated silt will be diffused and drifted by tidal current of the sea area. Similarly trailer suction dredger for weathered rock is also considered not suitable.

In addition to the advection diffusion problem of agitated silt slurry, the dredging of clayey material by the above dredgers will be highly inflated in the hopper. The inflation is assumed that the water content becomes 1.5 - 2 times compared with the seabed material. The inflated bulk volume of the dredged soil will make its transport and disposal works highly inefficient.

Hence, the economical and suitable method of dredging applied in the Bojonegara development is the combination of grab dredger and hopper barges. Lighter weight bucket will be used for dredging of the alluvium component of the seabed material, and heavier weight bucket can be used for dredging of the weathered rock component.

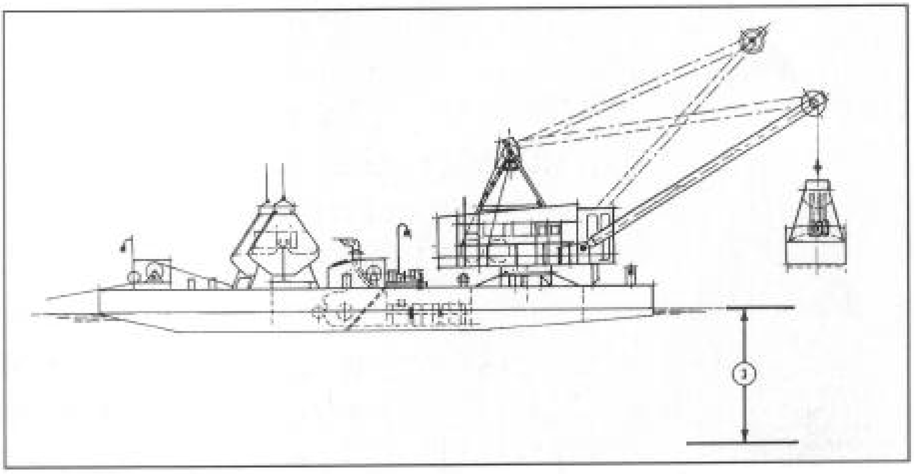


Figure I-3 Grab Dredger

I.4 Use of Dredged Material

Dredged materials are sometime used as reclamation materials to save transporting and disposal costs. The alluvium at the Bojonegara site consists of silt and clay derived from the soft alluvium. This material have water content several times the liquid limit, and according to the previous soil report, that is not sensitive and may be used as reclamation materials.

Nevertheless, it is preferred to limit the content of fine material to 10 % (or maximum 15 %) in dredged soil used for filling. The low permeability of fine grained materials requires special treatment to accelerate consolidation process for the reclamation.

Mud with higher content can be used for long-term reclamation, but this requires large areas of bunded ponds and very long time to enable dehydration and consolidation. Pre-loading and surcharging would usually be needed to make the reclaimed land usable. Installation of vertical drains, or soil improvement may need to be considered, but it will require high construction cost.

The excavated ‘highly or completely’ weathered rock will probably produce a substantial fraction of fairly hard ‘clay balls’ in dredged soil. Such material will be useless for fill in areas to be built on in the near future. It will need to be carefully treated in such a way that the clay balls are a minor component in any deposit.

Hence, the dredged material at the Bojonegara site is considered not suitable for the use of filling material.

I.5 Disposal of Dredged Material

As for the disposal problem of the dredged material, the two locations of the disposal areas were recommended in the previous process of Bojonegara development (refer to **Figure I-4**) and the use of those locations have been already approved by ADPEL (as of 30 May 1997).

Location 1: 06º 5´E, 5º 52´S, Location2: 106º 8´E, 5º 53.3´S

The two disposal areas are located about 5 km distant from the development site of Bojonegara and the water depth is over 30 m. The planned volume of the disposal soil was estimated as 2.5 million m^3, the dimension of the disposal area was planned as 500 x 1,000 m.

According to a rough estimation of the dredging volume within the first phase of the Bojonegara development, the volume of alluvium component amounts to about 2,640,000 m^3 and weathered rock component is about 580,000 m^3 (total 3,220,000 m^3). The dredging area has extension of about 650,000 m^2.

Since the estimate volume exceeds the condition of the previous plan of disposal area, the disposal plan of the dredged material should be examined again from the viewpoint of environmental consideration.

Albeit the above-mentioned problem, the dredging work is to be planned on the condition that offshore disposal of the dredged soil is available.

I.6 Proposed Dredger Fleet

Dredger fleet for the dredging work at the Bojonegara site is planned as follows. Dredger fleet is assumed to be mobilized totally from Singapore.

- Grab Dredger 800 GT Class, 1,600 HP
  - Light Bucket for dredging of soft clay (alluvium): 23 m^3 (weight 38-ton)
  - Heavy Bucket for dredging of Weathered Rock: 9 m^3 (weight 85-ton)
- Anchor Boat 65 GT Class, 150 HP
- Hopper Barge Capacity: 1,500 m^3
- Tug Boat (Pusher) 200 GT Class, 1,600 HP

I.7 Productivity

Productivity of the proposed dredging system is examined as follows (refer to **Table I-1**).

I.7.2 Alluvium Component

- Bucket Movement

  Swing-to-point ? Lower cable ? Grab and Lift ? Swing-away-point

  (0.5 min.) (0.5 min.) (1.5 min.) (0.5 min.) Total <u>3.0 min</u>.
- Grab Efficiency (0.7 is assumed for soft clay)

  Dredged volume per one Bucket Movement: 0.7 * 23 m^3 = 16.1 m^3/(3 min.)
- Time to fill the capacity of 1,500 m^3 Barge

  1,500 m^3/[16.1 m^3/(3 min.)] = 279.5 min. = 4.66 hours
- Disposal Cycles per day

  Working time is assumed as 21 hours/day

  21 (hours/day)/4.66 hours = 4.5 cycles/day.
- Volume of soils to be disposed of per day

  1,500 m^3 * 4.5 cycles/day = 6,750 m^3/day

  Working day is assumed as 28 days per month.

  6,750 m^3/day * 28 days/month = 189,000 m^3/month
- Overdredging

It is necessary to have an average overdredging depth of 0.5 m, empirically, so that the design depth can be achieved. As the dredging area is about 650,000 m^2, assumed overdredging volume amounts to 325,000 m^3 (0.5 m x 650,000 m^2). This volume is equivalent to about 10 % of the total dredging volume.

- Total period required for Dredging of Alluvium Component

  Gross dredging volume and total work period are calculated as follows considering overdredging.

  Gross volume: 2,640,000 m^3 x 110 % = 2,904,000 m^3 for Alluvium

  2,904,000 /189,000 = <u>15.4 month</u>

I.7.2 Weathered Rock Component

- Bucket Movement

  Swing-to-point ? Lower cable ? Grab and Lift ? Swing-away-point

  (0.5 min.) (0.5 min.) (2.0 min.) (0.5 min.) Total <u>3.5 min</u>.

- Grab Efficiency (0.4 is assumed for weathered Rock)

  Dredged volume per one Bucket Movement: 0.4 * 9 m^3 = 3.6 m^3/(3.5 min.)

- Time to fill the capacity of 1,500 m^3 Barge

  1,500 m^3/[3.6 m^3/(3.5 min.)] = 1,458.3 min. = 24.3 hours

- Disposal Cycles per day

  Working time is assumed as 21 hours/day

  21 (hours/day)/24.3 hours = 0.86 cycles/day.

- Volume of soils to be disposed of per day

  Soil within hopper barge is assumed 110 % saturated by water.

  1,500 m^3 * 0.86 cycles/day = 1,290 m^3/day

  Working day is assumed as 28 days per month.

  1,290 m^3/day * 28 days/month = 36,120 m^3/month

- Total period required for Dredging of Weathered Rock Component

  Gross dredging volume and total work period are calculated considering overdredging.

  Gross volume: 580,000 m^3 x 110 % = 638,000 m^3 for Weathered Rock

  638,000/36,120 = <u>17.7 month</u>

Considering the rough sea condition of Java Sea in rainy season, the total working period (for both alluvium component and weathered rock component; 15.4 + 17.7 = 33.1 months) may be required at least 36 months (3 years).

I.8 Unit Rate of Dredging

Based on the conditions described above, the unit rates of the dredging cost for the Bojonegara development are estimated as follows at this stage of the study.

- Dredging of Alluvium Component (2,640,000 m^3): 27,100 Rp./m^3 (or 3.0 USD/m^3)

- Dredging of Weathered Rock Component (580,000 m^3): 123,300 Rp./m^3 (or 13.7 USD/m^3)

  (direct cost and mobilization; exchange rate is assumed as 1 USD = 9,000 Rp.)

Table I-1 Productivity and Duration of Dredging Works

Description	**Alluvium**	**Weathered Rock**
Time of Bucket Movement	3.0 min	3.5 min
Swing to point	0.5 min	0.5 min
Lower cable	0.5 min	0.5 min
Grab and lift	1.5 min	2.0 min
Swing away point	0.5 min	0.5 min
Working Hour per day	21 hours/day	21 hours/day
Working Day per month	28 days/month	28 days/month
(Table 1 continued)	**Alluvium**	**Weathered Rock**
Grab Efficiency Factor	0.7	0.4
Bucket Size	23 m^3	9 m^3
Time to fill 1,500 m^3 Barge	4.7 hours	24.3 hours
Disposal Cycle per Day	4.5 cycles/day	0.86 cycles/day
Production per day	6,750 m^3/day	1,290 m^3/day
per month	189,000 m^3/month	36,120 m^3/month
Total Dredging Volume (design)	2,640,000 m^3	580,000 m^3
Gross Dredging Volume	2,904,000 m^3	638,000 m^3
Duration of Dredging Work	15.4 months	17.7 months
Total Working Period	33.1 months	

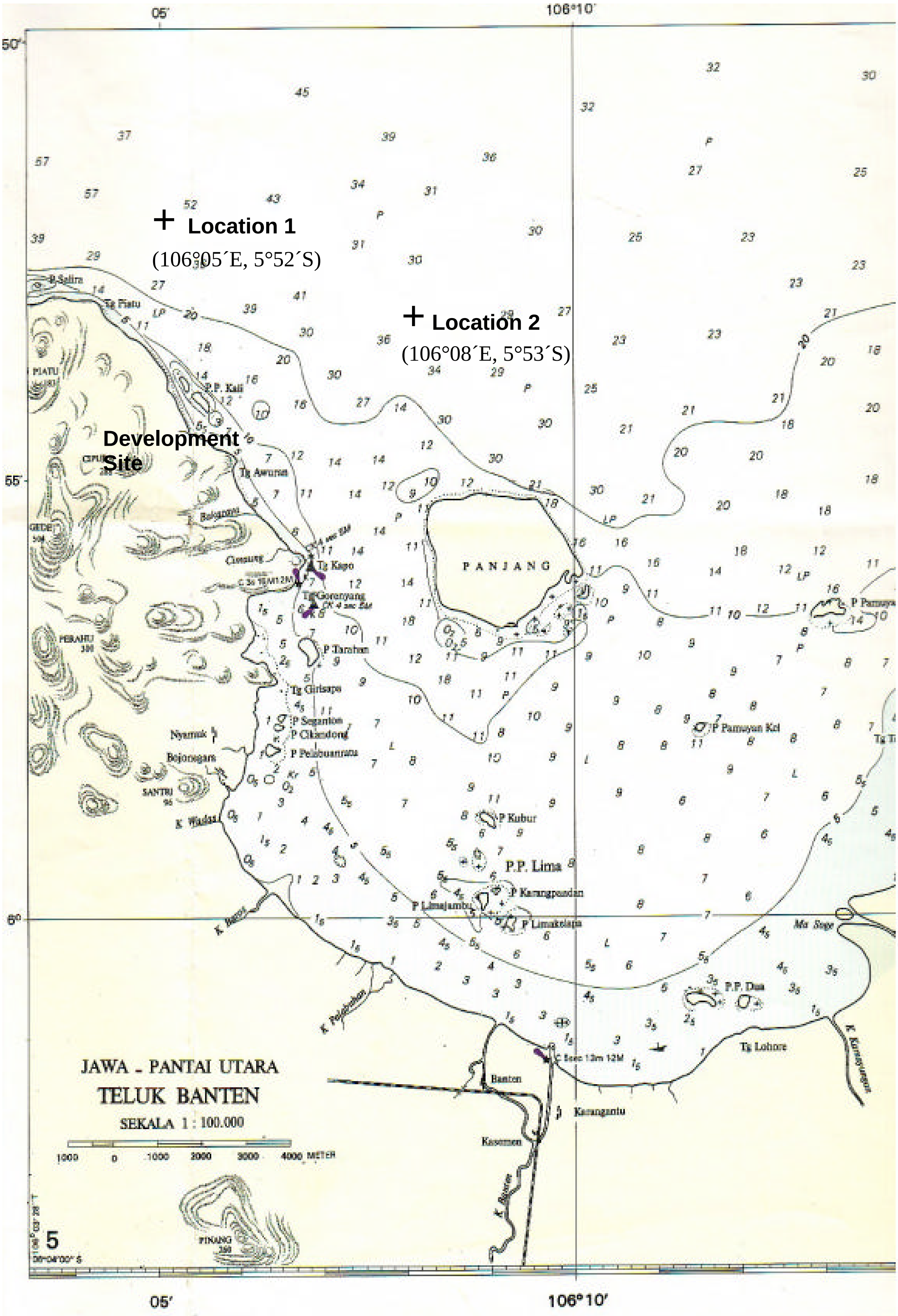


Figure I-4 Recommended Disposal Areas for Dredged Material of Bojonegara

(Source: Project Office of Bojonegara Development, IPC2)