5. Demand Forecast

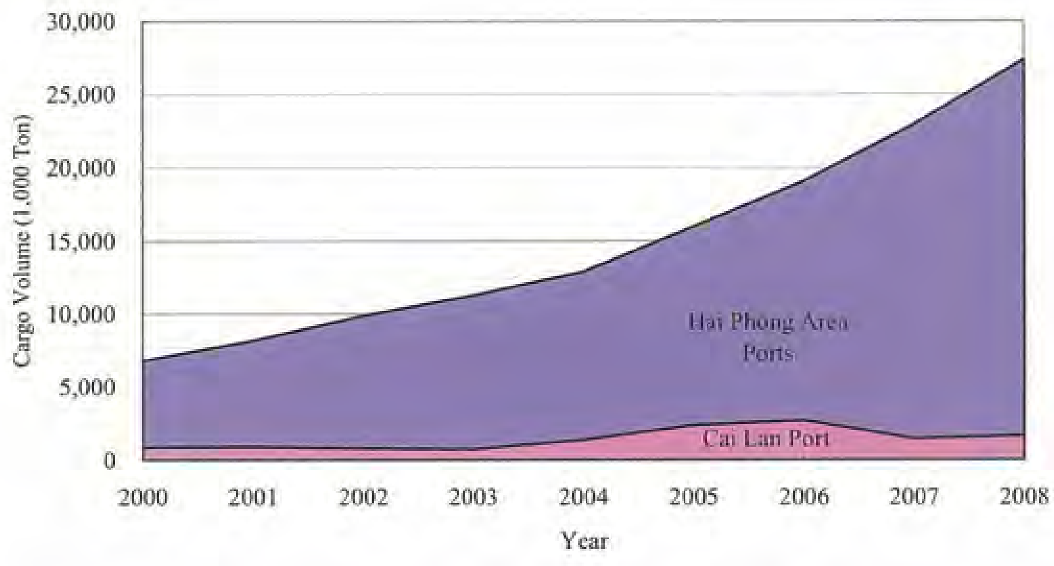
5.1 General

In this chapter, the method of the demand forecast is conducted by Macro forecast for whole cargo and Micro forecast for commodity-wise cargo in the Northern Vietnam Ports. And cargo demand Lach Huyen port is analyzed as overflowed cargo based on the cargo handling capacity of Northern Vietnam Ports including their future expansion. Consequently, detail container cargo volume is analyzed in the final section of this chapter in order to estimate the cargo traffic in terms of TEUs.

5.2 Cargo Throughputs of the Northern Ports in Vietnam

Northern Ports (without oil products, cement and fertilizer) in Vietnam are divided into 2 areas such as Hai Phong Area Port and Cai Lan Port. In 2008, total cargo throughputs of Northern Ports amounted to approximately 25 million ton as shown in Figure 5.2.1.

Total cargo throughput in 2008, 25,340 thousand ton is almost 3.9 times of volume (6,494 thousand ton) in 2000 with yearly average growth rate 19% from 2000.



Unit: 1,000 ton

Year		2000	2001	2002	2003	2004	2005	2006	2007	2008
Hai Phong Area Ports		5,606	7,006	8,920	9,775	10,527	11,176	13,087	19,836	23,777
Cai Lan Port		888	927	812	756	1,193	2,108	2,854	1,450	1,563
Total Cargo Throughput		**6,494**	**7,933**	**9,732**	**10,531**	**11,720**	**13,284**	**15,941**	**21,286**	**25,340**
	Growth Rate		22.2%	22.7%	8.2%	11.3%	13.3%	20.0%	33.5%	19.0%

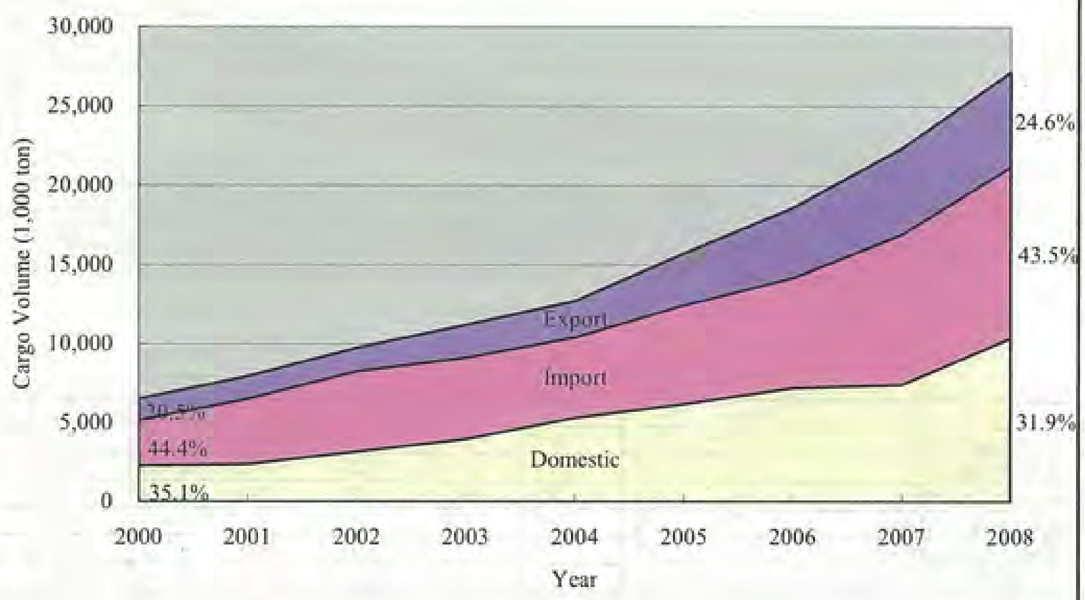
Note: Cargo Throughputs Volume is not including oil products, cement and fertilizer

Source: Original data from Hai Phong Port, Hai Phong private port and Cai Lan Port in the final report of "Port Capacity Reinforcement Plan in Northern Vietnam (Sep. 2009), and container data (2003-2008) by VINAMARINE

Figure 5.2.1 Total Cargo Throughputs in the Northern Ports in Viet Nam

5.3 Export, Import and Domestic Cargo Volume Share

In 2008, cargo volume share of Export, Import and Domestic in the Northern Ports were 24.6%, 43.5% and 31.9%, respectively. The share of Export gradually went up from 20.5% in 2000 to 24.6% in 2008 but the Import share marginally went down from 44.4% to 43.5%. The Domestic share went down from 35.1% 2000 in to 31.9% in 2008.



Unit: 1,000 ton

	Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export	**Volume**	1,334	1,438	1,470	1,656	1,708	2,381	3,117	4,307	6,233
	Share	20.5%	18.1%	15.1%	15.7%	14.6%	17.9%	19.6%	20.2%	24.6%
Import	**Volume**	2,883	4,126	5,103	4,693	5,042	5,727	6,405	8,855	11,024
	Share	44.4%	52.0%	52.4%	44.6%	43.0%	43.1%	40.2%	41.6%	43.5%
Domestic	**Volume**	2,278	2,370	3,159	4,182	4,970	5,176	6,419	8,124	8,083
	Share	35.1%	29.9%	32.5%	39.7%	42.4%	39.0%	40.3%	38.2%	31.9%
Total		6,494	7,933	9,732	10,531	11,720	13,284	15,941	21,286	25,340

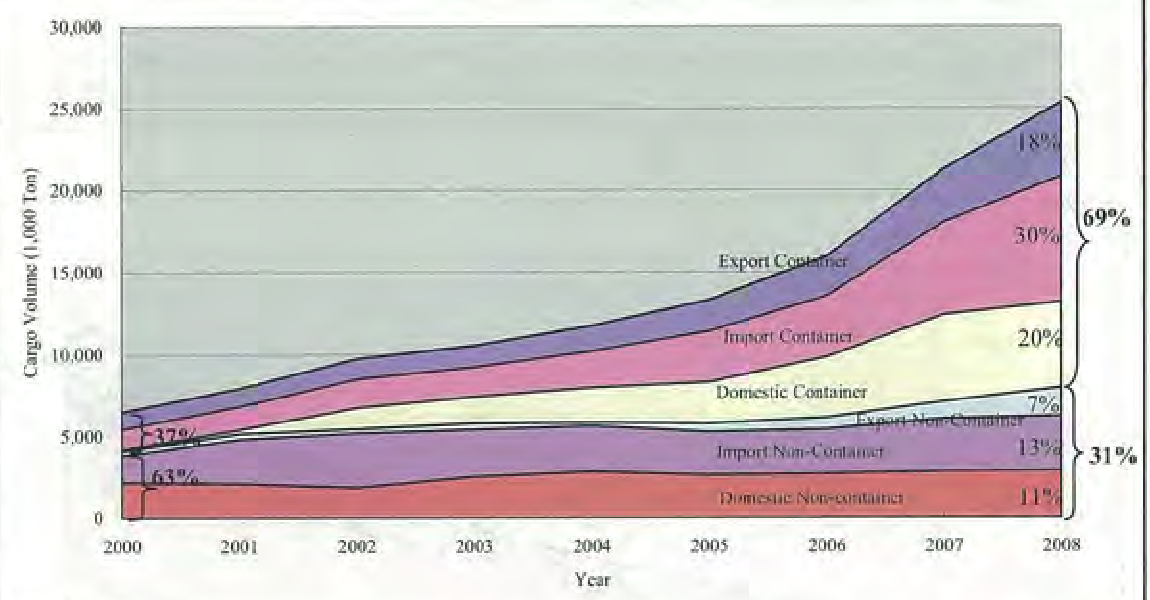
Note: Cargo Throughputs Volume is not including oil products, cement and fertilizer

Source: Original data from Hai Phong Port, Hai Phong private port and Cai Lan Port in the final report of "Port Capacity Reinforcement Plan in Northern Vietnam (Sep. 2009), and container data (2003-2008) by VINAMARINE

Figure 5.3.1 Export, Impart and Domestic Cargo in the Northern Ports in Viet Nam

5.4 Container and Non-container Cargo

In 2008, container cargo volume share in the Northern Ports are dramatically changed from 37% in 2000 to 69%, while on the other hand, non-container cargo share drop from 63% in 2000 to 31% in 2008. Another way of saying, container cargo volume is sharply increased from 2,387 thousand ton in 2000 to 17,382 thousand ton in 2008 with yearly average growth rate 29%, and non-container gradually increased from 4,105 thousand ton in 2000 to 7,958 thousand ton in 2008 with yearly average growth rate 9%. (Figure 5.4.1)



	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Container	1,037	1,087	1,201	1,294	1,510	1,865	2,421	3,253	4,504
Import Container	1,263	1,420	1,773	1,790	2,228	3,092	3,683	5,652	7,688
Domestic Container	88	244	1,285	1,653	2,127	2,539	3,719	5,276	5,190
Export Non-Container	297	350	269	362	199	516	697	1,054	1,729
Import Non-Container	1,621	2,705	3,330	2,903	2,814	2,635	2,722	3,203	3,336
Domestic Non-container	2,190	2,126	1,874	2,529	2,842	2,636	2,700	2,848	2,893
Total Container	2,387	2,752	4,259	4,737	5,865	7,496	9,822	14,181	17,382
	37%	*35%*	*44%*	*45%*	*50%*	*56%*	*62%*	*67%*	*69%*
Total Non-Container	4,107	5,182	5,473	5,795	5,855	5,787	6,119	7,105	7,958
	63%	*65%*	*56%*	*55%*	*50%*	*44%*	*38%*	*33%*	*31%*
Total	6,494	7,933	9,732	10,531	11,720	13,284	15,941	21,286	25,340

Figure 5.4.1 Container and Non-container Cargo in the Northern Ports in Viet Nam

5.5 Macro Demand Forecast

In general, cargo volume of international ports and GDP are close relationship, especially, in Viet Nam, import and export values are largely influenced to GDP. In 2008, based on GSO's preliminary figures, import values (goods and services) are comparable to 94.7% of National Amount (GDP), and export values are 78.2% of GDP. On the other hand, nowadays, hinterland of the Northern Ports is not only the Northern region of Viet Nam, but also all over the Viet Nam, because of closely-linked to central and southern regional connection by domestic sea transport. Therefore, in the method of Macro Demand Forecast are analyzed by correlation between GDP value and cargo volume.

According to General Statistics Office of Vietnam, the growth of Vietnam's GDP in 2009 reached to 5.32%. Also, MPI predicted long-term target in 2010-2020 by 2 options: (1) sustainable growth of economy as 6.5% and (2) growth of economy at high level as 7.5%. In the low-growth, VITRANSS 2 predicted 5.6%. Alternatives scenario of GDP growth rate for 2009-2020 are summarized as follows.

Table 5.5.1 GDP Alternative Scenarios

Alternative Scenarios \ Year	2009	2010-2020
High Growth Scenario	5.32%	7.5%
Sustainable Growth Scenario		6.5%
Low Growth Scenario		5.6%

5.6 Results of Macro Forecast

Very high correlation (R^2=0.9477) between cargo volume of the Northern Ports in the Vietnam and GDP show in the following Figure 5.6.1. The results of Macro Forecast with each alternative scenarios show in Figure 5.6.2.

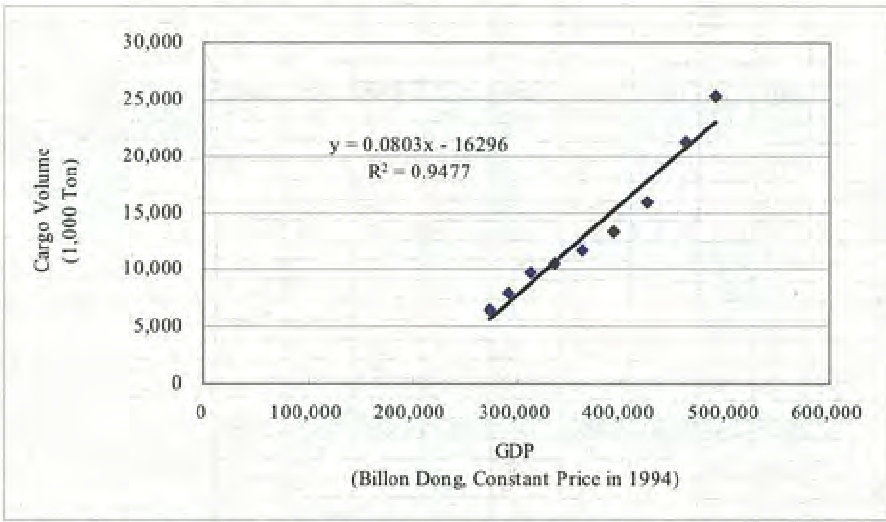


Figure 5.6.1 Correlation between Cargo Volume of the Northern Ports in the Vietnam and GDP

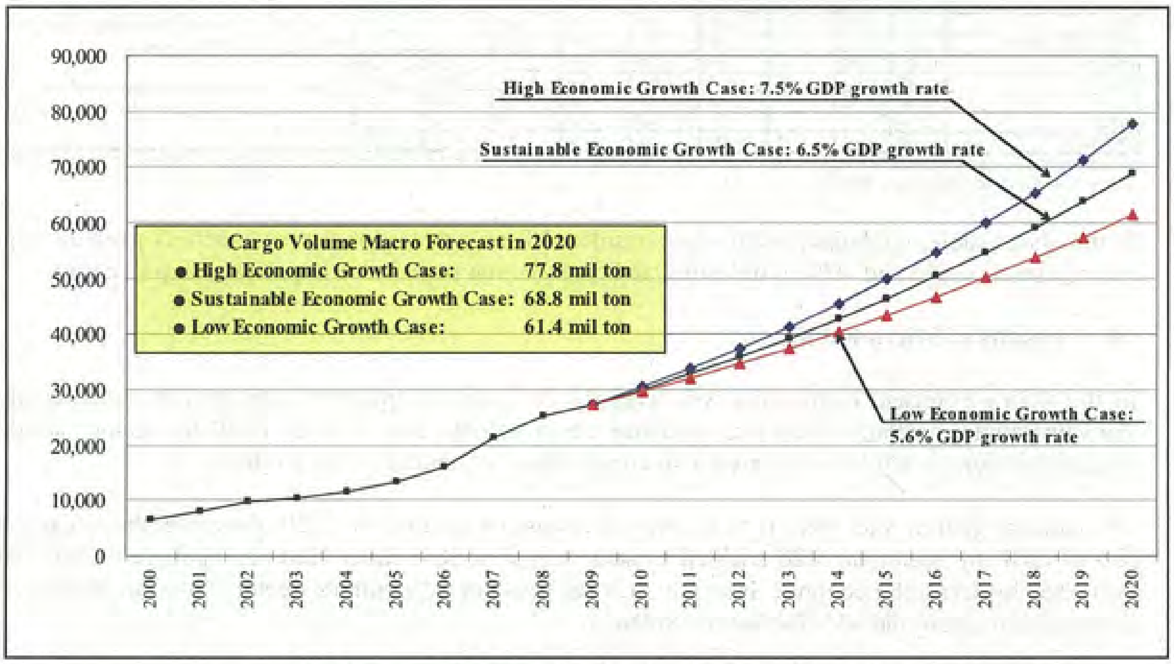


Figure 5.6.2 Results of Macro Forecast with Alternative Scenarios

5.7 Micro Demand Forecast

In the Micro Forecast, commodity-wise cargoes is firstly grouping by each sector, and secondly analyzing with correlation between grouping cargo volume and GDP or GDP by sector. Thirdly, containerization should be considered with compatibility of characteristic products.

Table 5.7.1 Commodity-wise Cargoes Grouping for Micro Forecast

Cargo Commodity \ Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	Micro Forecast Consideration
1. Export	**1,334**	**1,438**	**1,470**	**1,656**	**1,708**	**2,381**	**3,117**	**4,307**	**6,233**	
Container	1,037	1,087	1,201	1,294	1,510	1,865	2,421	3,253	4,504	Correlation of GDP
General	50	16	5	152	1	12	11	43	30	Correlation of GDP (convert to Container Cargo)
Timber	83	97	66	29	78	360	489	583	477	Correlation of Primary Sector GDP as Agriculture or Forestry Product
Food and vegetable	10	7	9	7	3	4	8	3	5	
Industrial Product	-	1	-	-	0	-	-	-	-	Correlation of Secondary Sector GDP as Industrial Product or Construction material (40% of forcast cargo convert to Container Cargo in 2020)
Equipment	8	7	11	2	6	10	10	18	46	
Construction Material	95	141	101	127	89	110	107	230	156	
Metal	3	2	7	1	2	3	0	13	331	
Foodstuff	25	28	20	12	6	-	1	60	80	
Apatite	2	-	-	2	2	-	46	76	261	Correlation of Secondary Sector GDP as Mining Product
Metallic ore	20	50	50	30	11	17	25	28	343	
2. Import	**2,883**	**4,126**	**5,103**	**4,693**	**5,042**	**5,727**	**6,405**	**8,855**	**11,024**	
Container	1,263	1,420	1,773	1,790	2,228	3,092	3,683	5,652	7,688	Correlation of GDP
General	98	86	290	45	20	6	6	9	10	Correlation of GDP (convert to Container Cargo)
Miscellaneous	-	-	-	3	-	1	3	17	24	Correlation of GDP (convert to Container Cargo)
Timber	14	42	36	47	72	21	42	13	19	Correlation of Primary Sector GDP as Agriculture or Forestry Product
Forest and native products	-	-	5	-	22	4	-	1	-	
Food and vegetable	13	317	227	114	135	149	145	145	-	
Foodstuff for cattle	42	185	273	763	445	664	872	937	832	
Cotton	129	-	-	-	-	-	-	-	-	Correlation of Secondary Sector GDP as Industrial Product or Construction material (40% of forcast cargo convert to Container Cargo in 2020)
Chemical	75	67	43	38	40	57	63	87	51	
Metal	1,018	1,620	1,974	1,535	1,607	1,426	1,220	1,410	1,819	
Construction Material	37	32	14	0	35	17	10	-	-	
Equipment	111	169	146	150	154	111	89	271	391	
Foodstuff	24	94	246	131	151	121	176	169	33	
Sulfur	-	-	-	-	-	58	97	95	96	Correlation of Secondary Sector GDP as Mining Product
Metallic ore	59	95	75	78	134	0	-	49	61	
3. Domestic	**2,278**	**2,370**	**3,159**	**4,182**	**4,970**	**5,176**	**6,419**	**8,124**	**8,083**	
Container	88	244	1,285	1,653	2,127	2,539	3,719	5,276	5,190	Correlation of GDP
General	1,006	834	511	271	207	86	50	60	75	Correlation of GDP (convert to Container Cargo)
Food and vegetable	44	77	67	35	38	31	21	16	7	Correlation of Primary Sector GDP as Agriculture or Forestry Product (40% of forcast cargo convert to Container Cargo in 2020)
Foodstuff for cattle	81	79	73	283	219	289	279	147	158	
Forest and native products	6	3	7	15	10	8	59	7	1	
Wheat	-	-	-	-	-	21	40	12	26	
Timber	28	25	8	80	90	189	168	98	84	
Flour	-	-	-	-	-	-	-	16	11	
Chemical	30	21	19	7	12	16	3	12	5	Correlation of Secondary Sector GDP as Industrial Product or Construction material
Metal	243	233	240	269	285	243	160	157	227	
Construction Material	305	341	198	251	154	143	106	114	48	
Foodstuff	278	340	572	199	250	61	-	53	20	
Equipment	42	27	98	989	1,364	1,379	1,640	2,000	1,841	
Apatit	68	62	53	90	99	114	114	109	136	Correlation of Secondary Sector GDP as Mining Product
Sulfur	-	-	-	-	62	3	8	2	6	
Metallic ore	60	84	27	39	51	54	51	45	248	

Source: Original data from Hai Phong Port, Hai Phong private port and Cai Lan Port in the final report of "Port Capacity Reinforcement Plan in Northern Vietnam (Sep. 2009), and container data (2003-2008) by VINMARINE

In the above table, containerization was considered from conventional cargo such as general cargo, miscellaneous cargo and 40% of industrial and construction material of Import and Export cargo.

5.8 Results of Micro Forecast

In the Micro Forecast, commodity-wise cargoes is firstly grouping by each sector, and secondly, analyzing with correlation between grouping cargo volume and GDP or GDP by sector. Thirdly, containerization should be considered with compatibility of characteristic products.

The national goal in Viet Nam is to become an industrial country by 2020, therefore, the component rate of GDP by sector in 2020 adapted to same target of Red River Delta component rate in 2010 estimated by Central Economic Institute such as 12% for Agriculture Sector, 45% for Industry & Construction sector and 43% for Service sector.

The GDP by Sector in 2000, 2008 and 2020 summarized as follows. In the Micro Forecast, GDP growth rate in 2010-2020 adapt to 6.5% of sustainable growth planning by MPI.

Table 5.8.1 Results of GDP by Sector in 2000, 2008 and 2020

GDP by Sector	2000	2008	2020	Remarks
Agriculture, forestry and fishery	63,717	86,082	128,078	Target Rate by MPI in 2010
Component Rate	*23%*	*18%*	*12%*	15-16%
Industry and construction	96,913	203,791	463,717	Target Rate by MPI in 2010
Component Rate	*35%*	*42%*	*45%*	43-44%
Service	113,036	199,960	439,526	Target Rate by MPI in 2010
Component Rate	*41%*	*41%*	*43%*	40-41%
GDP	273,666	489,833	1,031,346	

The results of Micro Forecast of 3 alternative scenarios shows in Table 5.8.2, Table 5.8.3 and Table 5.8.4. The high growth case estimated 1.2 times of increased volume of middle growth case and the low growth case 0.8 times of increased volume of middle growth case based on the results of Micro Forecast.

Table 5.8.2 Results of Micro Forecast (Middle Growth Case)

Category of Cargo	Type of Cargo	Unit	2008	2015	2020
1. Export			**6,233**	**11,712**	**16,192**
Container and Containerized Cargo	Container Cargo	1,000 ton	4,534	8,792	12,484
Agriculture, forestry Product	General Cargo	1,000 ton	482	1,132	1,597
Industry and construction material	General Cargo	1,000 ton	613	699	675
Mining Products	Dry Bulk Cargo	1,000 ton	604	1,089	1,435
2. Import			**11,024**	**22,766**	**30,349**
Container and Containerized Cargo	Container Cargo	1,000 ton	7,722	18,880	26,069
Agriculture, forestry Product	General Cargo	1,000 ton	851	1,808	2,492
Industry and construction material	General Cargo	1,000 ton	2,294	1,824	1,464
Mining Products	Dry Bulk Cargo	1,000 ton	157	254	323
3. Domestic			**8,083**	**18,318**	**25,245**
Container and Containerized Cargo	Container Cargo	1,000 ton	5,265	13,925	20,317
Agriculture, forestry Product	General Cargo	1,000 ton	287	605	832
Industry and construction material	General Cargo	1,000 ton	2,141	3,227	3,411
Mining Products	Dry Bulk Cargo	1,000 ton	390	562	684
Cargo Volume by Cargo Type					
Total Cargo Volume		1,000 ton	**25,340**	**52,796**	**71,785**
Container and Containerized Cargo		1,000 ton	17,521	41,597	58,871
		1,000TEU	1,434	3,586	5,075
General Cargo		1,000 ton	6,668	9,295	10,472
Dry Bulk Cargo		1,000 ton	1,151	1,904	2,442

Table 5.8.3 Results of Micro Forecast (Low Growth Case)

Category of Cargo	Type of Cargo	Unit	2008	2015	2020
1. Export			**6,233**	**10,616**	**14,200**
Container and Containerized Cargo	Container Cargo	1,000 ton	4,534	7,940	10,894
Agriculture, forestry Product	General Cargo	1,000 ton	482	1,002	1,374
Industry and construction material	General Cargo	1,000 ton	613	682	662
Mining Products	Dry Bulk Cargo	1,000 ton	604	992	1,269
2. Import			**11,024**	**20,418**	**26,484**
Container and Containerized Cargo	Container Cargo	1,000 ton	7,722	16,648	22,400
Agriculture, forestry Product	General Cargo	1,000 ton	851	1,617	2,164
Industry and construction material	General Cargo	1,000 ton	2,294	1,918	1,630
Mining Products	Dry Bulk Cargo	1,000 ton	157	234	290
3. Domestic			**8,083**	**16,271**	**21,812**
Container and Containerized Cargo	Container Cargo	1,000 ton	5,265	12,193	17,307
Agriculture, forestry Product	General Cargo	1,000 ton	287	541	723
Industry and construction material	General Cargo	1,000 ton	2,141	3,009	3,157
Mining Products	Dry Bulk Cargo	1,000 ton	390	527	625
Cargo Volume by Cargo Type					
Total Cargo Volume		1,000 ton	**25,340**	**47,305**	**62,496**
Container and Containerized Cargo		1,000 ton	17,521	36,782	50,601
		1,000TEU	1,434	3,171	4,362
General Cargo		1,000 ton	6,668	8,770	9,711
Dry Bulk Cargo		1,000 ton	1,151	1,754	2,184

Table 5.8.4 Results of Micro Forecast (High Growth Case)

Category of Cargo	Type of Cargo	Unit	2008	2015	2020
1. Export			**6,233**	**12,808**	**18,183**
Container and Containerized Cargo	Container Cargo	1,000 ton	4,534	9,643	14,074
Agriculture, forestry Product	General Cargo	1,000 ton	482	1,263	1,820
Industry and construction material	General Cargo	1,000 ton	613	716	687
Mining Products	Dry Bulk Cargo	1,000 ton	604	1,186	1,602
2. Import			**11,024**	**25,115**	**34,213**
Container and Containerized Cargo	Container Cargo	1,000 ton	7,722	21,112	29,739
Agriculture, forestry Product	General Cargo	1,000 ton	851	2,000	2,820
Industry and construction material	General Cargo	1,000 ton	2,294	1,730	1,299
Mining Products	Dry Bulk Cargo	1,000 ton	157	273	356
3. Domestic			**8,083**	**20,365**	**28,677**
Container and Containerized Cargo	Container Cargo	1,000 ton	5,265	15,657	23,328
Agriculture, forestry Product	General Cargo	1,000 ton	287	669	941
Industry and construction material	General Cargo	1,000 ton	2,141	3,444	3,665
Mining Products	Dry Bulk Cargo	1,000 ton	390	596	743
Cargo Volume by Cargo Type					
Total Cargo Volume		1,000 ton	**25,340**	**58,288**	**81,074**
Container and Containerized Cargo		1,000 ton	17,521	46,412	67,141
		1,000TEU	1,434	4,001	5,788
General Cargo		1,000 ton	6,668	9,821	11,232
Dry Bulk Cargo		1,000 ton	1,151	2,055	2,701

The results of Micro Forecast with each alternative scenarios show in Figure 5.8.1

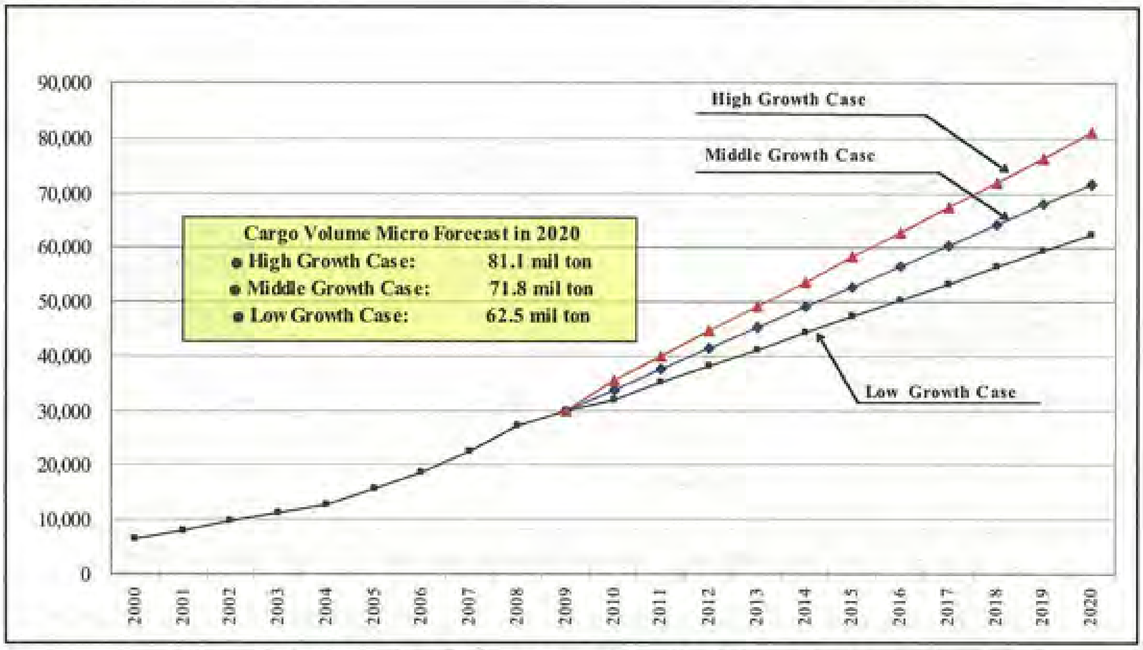


Figure 5.8.1 Results of Micro Forecast with Alternative Scenarios

5.9 Cargo Volume of Lach Huyen Port

5.9.1 Demand Forecast of Lach Huyen Port

Firstly, cargo demand of Lach Huyen port can be considered overflowed cargo more than cargo handling capacity volume of Northern ports in the Viet Nam. Moreover, the following items are the role of Lach Huyen Port in Vietnam Sea Port System for demand forecast.

(1) Lach Huyen Port will be a general port group used for handling of general cargoes, container cargoes, bulk cargoes and liquid cargoes (Petrol)

(2) Lach Huyen port will not be used for handling of specialized cargoes such as: coal (to be handled at Cam Pha), and military cargoes (a military port will be formed at South Do Son)

(3) Lach Huyen port belongs to the Northern sea port group (group 1) and play role as a key international gateway port of the North (Port of class I, to be ranked in accordance with Marine Law). Lach Huyen port is a main junction for cargo exchange of northern provinces to the countries in the region.

(4) In the future (after 2020) Lach Huyen port will likely to play more role of container transshipment for the northern area (together with Van Phong port in the Central, Cai Mep-Thi Vai or Ben Dinnh-Sao Mai port in the South).

Addition to above items, depend on the present circumstance of cargo handling system in the northern Vietnam, cargoes of cement and fertilizer handled in their own private port like DAP Fertilizer Jetty, Ching Fong Haiphong Cement Plant Jetty or Cam Pha port

The capacities of existing ports are estimated based on the existing port facilities and equipment for Haiphong ports group and Cai Lan port, and for Dinh Vu port additional container berths under construction are considered and for Cai Lan port 3 additional container berths which are decided to be constructed within a few years are also considered. Figure 5.9.1 shows the expansion plan of 3 additional berths in the existing Cai Lan port facilities.

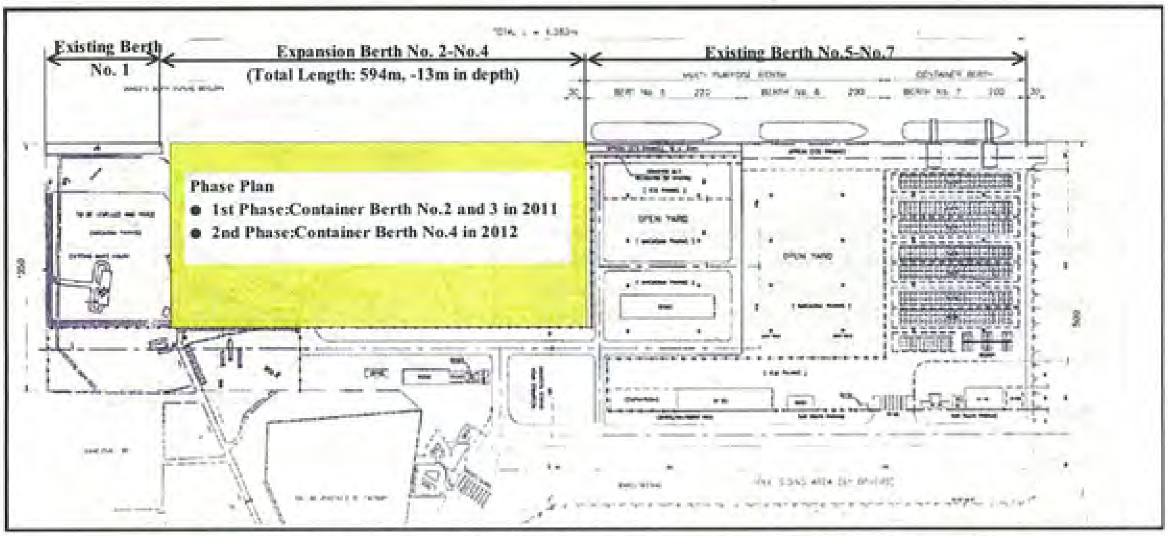
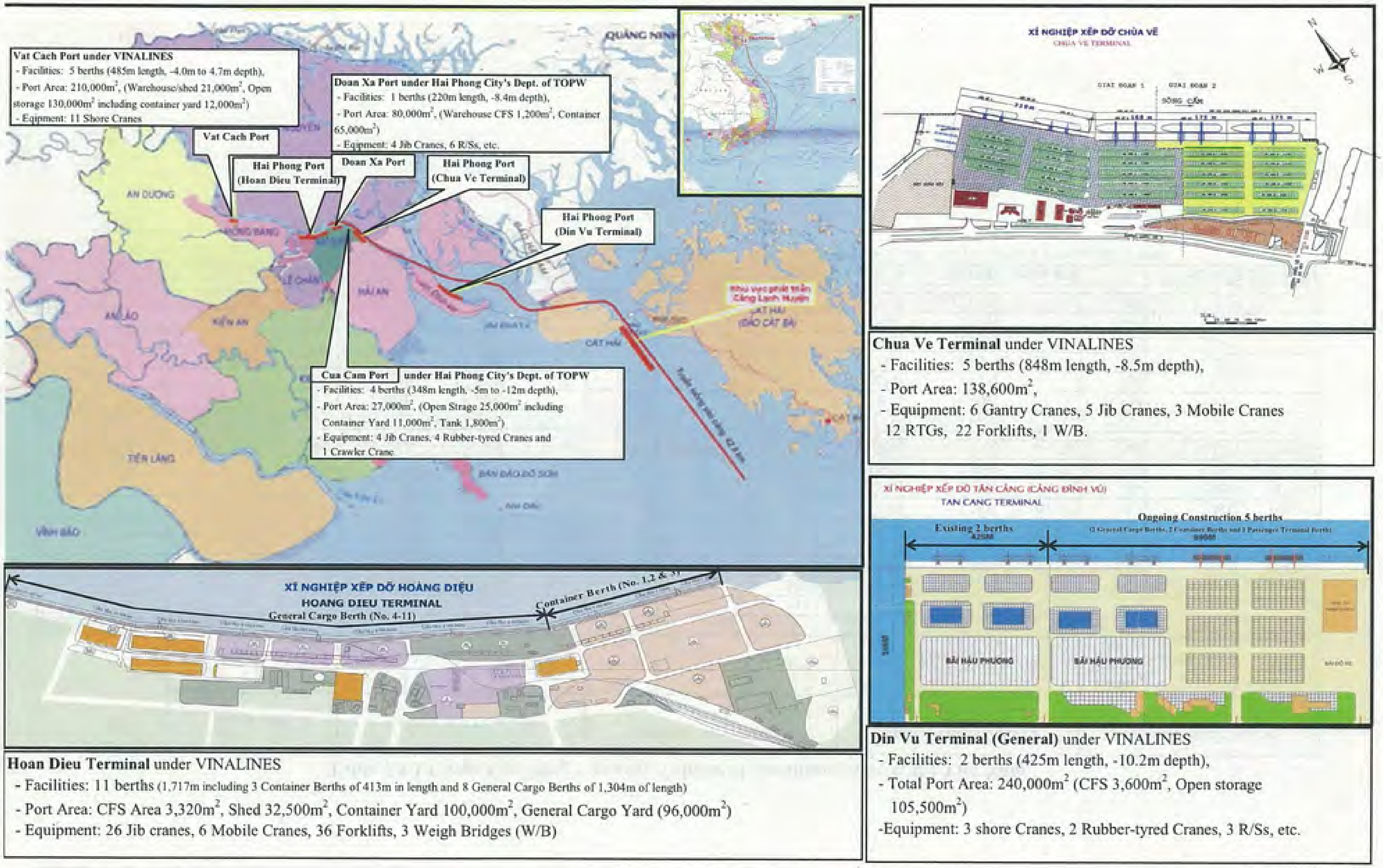


Figure 5.9.1 Existing Port Facilities and Expansion Plan of Cai Lan Port

Din Vu port also has phase plan of expansion plan as 1'st Phase 200m of berth length in 2010, 2nd Phase 200m of berth length in 2011 and 3rd Phase 202 m of berth length in 2012. Figure 5.9.2 shows the existing Hai Phong port location and on going plan.

The cargo handling capacity volume of Northern ports in Viet Nam is estimated in the following Table 5.9.1. In 2012, the capacity of the existing Northern ports is estimated 3,470 thousand TEU of container cargo and 12,600 thousand tons of conventional cargo.



Source: Hai Phong Port

Figure 5.9.2 Location of Hai Phong Area Ports and major berth condition

Table 5.9.1 Cargo Handling Capacity Volume of Northern ports in the Viet Nam

	Actual 2008		Existing Berth Capacity			Expansion Berth Capacity (2010)			Expansion Berth Capacity (2011)			Expansion Berth Capacity (2012-2020)		
	Ton (1,000 ton)	TEU	Berth Length (m)	Ton (1,000 ton)	TEU	Berth Length (m)	Ton (1,000 ton)	TEU	Berth Length (m)	Ton (1,000 ton)	TEU	Berth Length (m)	Ton (1,000 ton)	TEU
Container Handling Volume														
Chua Ve	7,731	729,978	848	8,210	707,786	848	8,210	707,786	848	8,210	707,786	848	8,210	707,786
Hoan Dieu			413	4,014	346,029	413	4,014	346,029	413	4,014	346,029	413	4,014	346,029
Dinh Vu (New)	2,715	218,269	400	2,635	227,191	600	5,271	454,381	800	7,906	681,572	1,002	10,542	908,762
Doan Xa	2,232	156,314	220	2,265	195,244	220	2,265	195,244	220	2,265	195,244	220	2,265	195,244
Transvina	1,371	115,771	165	1,642	141,557	165	1,642	141,557	165	1,642	141,557	165	1,642	141,557
Green	2,150	191,584	320	2,281	196,607	320	2,281	196,607	320	2,281	196,607	320	2,281	196,607
Le Chan	N.A	N.A	144	1,368	117,964	144	1,368	117,964	144	1,368	117,964	144	1,368	117,964
Cai Lan	425	35,028	200	2,373	244,667	200	2,373	244,667	596	7,906	681,572	794	9,933	856,334
Sub-Total	16,624	1,446,944	2,710	24,789	2,177,045	2,910	27,424	2,404,236	3,506	35,593	3,068,331	3,906	40,255	3,470,284
Conventional Cargo Handling Volume														
Hoan Dieu	6,238		1,304	6,408		1,304	6,408		1,304	6,408		1,304	6,408	
Cua Cam	566		220	577		220	577		220	577		220	577	
Vat Cach	1,501		485	1,887		485	1,887		485	1,887		485	1,887	
Dinh Vu (Gen)			525	1,165		525	1,165		525	1,165		525	1,165	
Cai Lan	2,289		646	2,563		646	2,563		646	2,563		646	2,563	
Sub-Total	10,594		3,180	12,600		3,180	12,600		3,180	12,600		3,180	12,600	
Total	**27,218**	**1,446,944**		**37,389**	**2,177,045**		**40,025**	**2,404,236**		**48,193**	**3,068,331**		**52,856**	**3,470,284**

Source: Original cargo data from Hai Phong Port, Hai Phong private port and Cai Lan Port in the final report of "Port Capacity Reinforcement Plan in Northern Vietnam (Sep. 2009), Vietnam Ports Association (VPA), Port operator data by VINAMARINE

5.9.2 Allocation of Cargo among Ports in the Area

The basic considerations of allocation of cargo among Haiphong port, Cai Lan port and Lach Huyen port are as follows:

(1) All container terminals in the existing ports are still very new constructed only 6 to 7 years ago and new four (4) container berths in Dinh Vu port will open soon and No.2 to No.4 container berths in Cai Lan port are determined to be completed within a few years. From national economic view point these facilities should be utilized effectively as much as possible.

(2) This Hai Phong International Gateway Port Development Project is planned to be implemented by Public Private Partnership (PPP). In PPP the public sector should provide incentives to private sector and should not interfere business activities of private sector as much as possible. Therefore, actual cargo volume to be handled at each port should be left for their free marketing efforts.

(3) When Lach Huyen port is opened and left for free competition among three ports, it will be highly provable that most cargoes will shift from the existing ports to Lach Huyen port, since all kind of vessels from small size to large size can enter at any tidal conditions with shortest distance from ocean route.

From above considerations, SAPROF team propose to allocate to Lach Huyen port the cargo which exceed the capacity of existing ports and the cargo equivalent to 10% of the existing ports capacity which will shift from the existing ports at 2015 and it will increase up to 20% by 2020 for development planning of Lach Huyen port, with consideration as actualization of container cargo handling for South East Asia/USA Trunk Line in Lach Huyen port.

Consequently, the allocation of cargo volumes among the three (3) ports will become as follows:

Table 5.9.2 Allocation of Cargo among Three Ports

Cargo Type	Unit	Haiphong Port		Cai Lan Port		Lach Huyen Port	
		2015	**2020**	**2015**	**2020**	**2015**	**2020**
High Growth Case							
Container	000 ton	27,290	24,258	8,940	7,946	10,182	34,937
	000TEU	2,352	2,091	771	685	878	3,012
GC +Bulk	000 ton	9,339	7,927	2,536	2,153	0	3,853
Total	000 ton	**36,629**	**32,185**	**11,476**	**10,099**	**10,182**	**38,790**
Middle Growth Case							
Container	000 ton	27,269	24,240	8,933	7,940	5,394	26,691
	000TEU	2,352	2,091	771	685	463	2,299
GC +Bulk	000 ton	8,808	7,927	2,392	2,153	0	2,834
Total	000 ton	**36,077**	**32,167**	**11,325**	**10,093**	**5,394**	**29,525**
Low Growth Case							
Container	000 ton	24,935	24,240	8,168	7,940	3,678	18,421
	000TEU	2,150	2,091	704	685	317	1,586
GC +Bulk	000 ton	8,276	7,484	2,248	2,032	0	2,379
Total	000 ton	**33,211**	**31,723**	**10,416**	**9,973**	**3,678**	**20,800**

In November 2009, 43 liner services in Hai Phong Port consist of Hong Kong route (47%), Singapore (21%), Busan route (9%), Kaohsiung route (14%) and other routes (9%). There is high possible that 70 % (Hong Kong, Busan and Kaohsiung route) in total liner services is gradually converted to South East Asia/USA Trunk Line through Lach Huyen Port from 2015 to 2020. (See Figure 5.9.3)

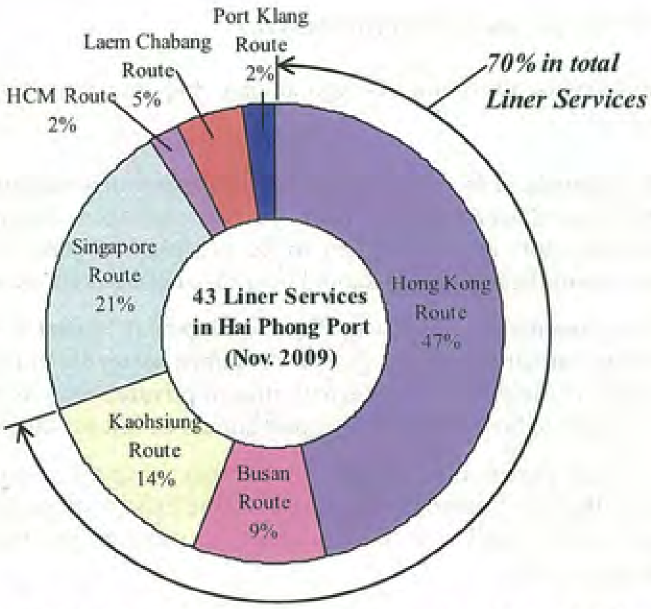


Figure 5.9.3 Liner Services in Hai Phong Port (Nov. 2009)

The demand forecast of Northern Ports, cargo handling capacities of Hai Phong and Cai Lan Port and required of cargo handling capacity of Lach Huyen Port are described in Figure 5.9.4.

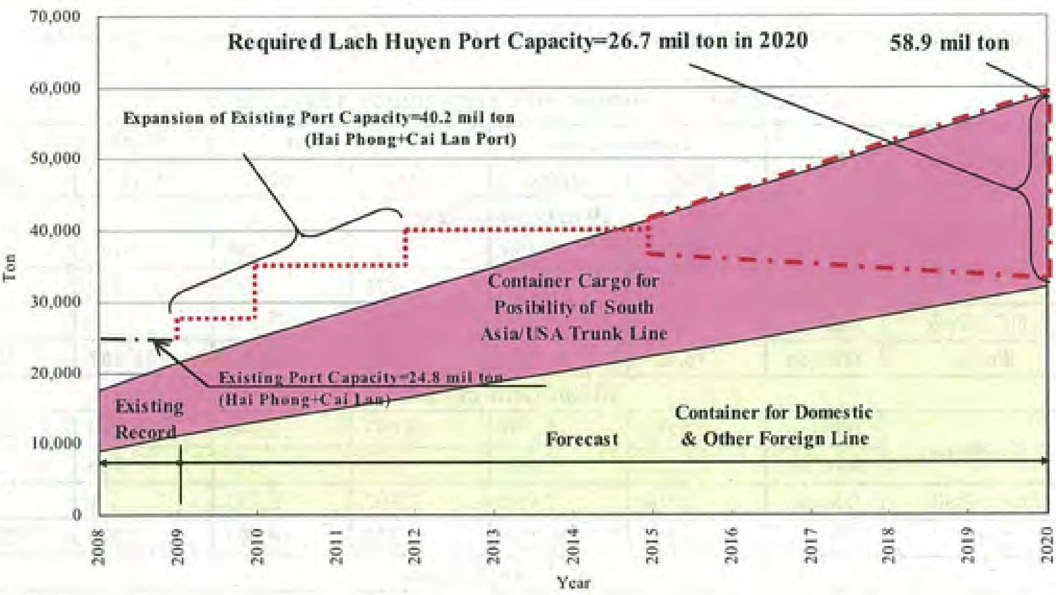


Figure 5.9.4 Container Demand Forecast of Northern ports in the Viet Nam and Lach Huyen Port (Middle Growth Case)

5.9.3 Cargo Volume of Lach Huyen Port

Yearly cargo volume of Lach Huyen port is forecast as shown in Table 5.9.3.

Table 5.9.3 Forecast Cargo Volume of Lach Huyen Port

Cargo Type	Unit	2015	2016	2017	2018	2019	2020
High Growth Case							
Container	1,000 ton	10,182	15,077	20,000	24,951	29,930	34,937
	1,000TEU	878	1,300	1,724	2,151	2,580	3,012
GC +Bulk	1,000 ton	-	-	1,947	2,610	3,246	3,853
Total	1,000 ton	**10,182**	**15,077**	**21,947**	**27,561**	**33,176**	**38,790**
Middle Growth Case							
Container	1,000 ton	5,394	9,607	13,843	18,102	22,385	26,691
	1,000TEU	463	826	1,191	1,559	1,928	2,299
GC +Bulk	1,000 ton	-	-	1,119	1,714	2,286	2,834
Total	1,000 ton	**5,394**	**9,607**	**14,962**	**19,817**	**24,671**	**29,525**
Low Growth Case							
Container	1,000 ton	3,678	4,741	7,660	11,228	14,815	18,421
	1,000TEU	317	409	658	966	1,275	1,586
GC +Bulk	1,000 ton	-	-	1,102	1,610	2,098	2,379
Total	1,000 ton	**3,678**	**4,741**	**8,762**	**12,838**	**16,914**	**20,800**

Consequently, cargo volume of Middle Growth case of Lach Huyen Port is estimated 2,299,000 TEU for container and 2,834,000 tons for general cargo and bulk cargo in 2020

The details of container forecast for Northern Viet Nam Ports and Lach Huyen Port are estimated in Table 5.9.4. In this estimation, TEU/Box ratio and empty container ratio are adapted with Hai Phong Port data. And Export and Import container is estimated to totally balance.

Table 5.9.4 Details of Container Forecast for Northern Viet Nam Ports and Lach Huyen Port

	Unit	Northern Viet Nam Port			Lach Huyen Port	Remarks
		2008	2015	2020	2020	
1. Export						
Container	1,000 ton	4,534	8,792	12,484	8,375	
Container	1,000TEU	504	1,245	1,719	1,092	Export and Import container volume was estimated to totally balance.
Loaded	1,000TEU	281	549	780	514	
Empty	1,000TEU	224	695	939	578	
40'	No.	168	415	573	364	TEU/Box ratio was estimated 1.5 based on latest 3 years of Hai Phong Port Data
20'	No.	168	415	573	364	
Box No.	No.	336	830	1,146	728	
2. Import						
Container	1,000 ton	7,722	18,880	26,069	16,861	
Container	1,000TEU	504	1,245	1,719	1,092	Export and Import container volume was estimated to totally balance.
Loaded	1,000TEU	478	1,180	1,629	1,034	
Empty	1,000TEU	26	65	90	58	Empty container ratio was for import container estimated 5.5% for import container based on latest 3 years of Hai Phong Data
40'	No.	168	415	573	364	TEU/Box ratio was estimated 1.5 based on latest 3 years of Hai Phong Port Data
20'	No.	168	415	573	364	
Box No.	No.	336	830	1,146	728	
3. Domestic						
Container	1,000 ton	5,265	13,925	20,317	1,455	
Container	1,000TEU	437	1,096	1,637	115	
Loaded	1,000TEU	326	870	1,270	89	
Empty	1,000TEU	111	200	292	26	
40'	No.	146	357	521	38	TEU/Box ratio was estimated 1.5 based on latest 3 years of Hai Phong Port Data
20'	No.	146	357	521	38	
Box No.	No.	292	714	1,042	76	
Total Container	1,000 ton	**17,521**	**41,597**	**58,871**	**26,691**	
	1,000TEU	**1,434**	**3,586**	**5,075**	**2,299**	Ton/TEU was estimated based 11.6 ton in 2009 based on VINAMARINE data

Note: Based on container data (year 2000 to Oct. 2009) of Hai Phong Port and VINAMARINE data, the Study Team estimated.

6. Necessity of the Project

6.1 Increase of Sea Borne Traffic Volume

In recent years the sea borne traffic volume in Northern Vietnam has been showing rapid increase. The general cargo volume excluding oil, coal, cement and clinker which are handled at dedicated ports was 25.3 million tons in total and of which container were 1.43 million TEUs in 2008. Its average growth rate during last 8 years was 19% for total cargo volume and the container cargo volume was increased drastically at 29% annum by TEU basis during the same period. These cargoes are forecasted to be 72 million tons and 5.1 million TEUs in 2020 respectively.

The existing main ports in Northern Vietnam for handling those cargoes are Hai Phong Port including Dinh Vu Port, and Cai Lan Port. Even if add the capacity of existing port development plans, namely 4 container berths of Dinh Vu Port and 3 container berths of Cai Lan Port, the total handling capacity of the existing ports are assessed at 53 million tons in which container cargo volume will be 40 million tons or 3.5 million TEUs and container cargo will be saturated in 2015 and non-container cargo 2017.

Since the port is a vital nation's infrastructure that contributes to the growth of Vietnamese economy, it should therefore be avoided that the port is saturated with the cargoes and can not provide any more services to the customers to the extent that would cause jeopardizing the nation's economy.

To cope with this situation, well before the critical moment comes to the reality, the development of sufficient capacity of additional port is necessary to absorb the spill-over cargoes from the ports of Hai Phong and Cai Lan.

6.2 Global Container Shipping Trend

What to be considered when developing a new port is the trend of global shipping market. The sharp increase in world container traffic throughout the decades wielded influence on many fields. The shipping industries sought to increase the scale of their service capacities by forming strategic consortium, acquiring other shipping lines, and throwing many large sized vessels in the market.

At the same time, these major shipping companies, as well as some of the ship financiers, have been continuing to order larger sized vessels to comply with growing customers' needs and seeking the economies of scale. As a result, ships slots number in service was increased from 4.8 million TEU to 12.1 million TEU in 8 years during 2000 – 2008 in total, or increased by 12 % annually in the same period. Also, a total of 1,201 larger sized vessels with more than 4,000 TEUs capacity, were in service in 2008, sharing 57% of the total capacity of the world container vessels, although their share was only 6.4% in 1997. Thus, it can be said that growing in ships slots and size is more prominent in future. In fact, 449 of over 4,000 TEU vessels, equivalent to 3.5 million TEUs or sharing 88% in total were ordered in the year 2007. These vessels will be delivered and in service within next few years.

From the geographic condition of Hai Phong Port, there is a high possibility that if deep-sea port is developed, the mother container vessels (4,000TEU – 8,000TEU) now plying in the Trans-Pacific trunk route between Hong Kong, Kaohsiung, etc and the west coast of USA will extend their service range up to Hai Phong Port. However, regarding the container vessels now plying Asia-Europe trunk route will not call Hai Phong Port in foreseeable future, since deviation time from trunk route is big, and the cargoes to/from Europe will be transshipped traditionally at Singapore, Tanjung Pelepas, etc., for the time being. However, for this feeder services, it is apparent that medium size mother ships (2,000TEU to 4,000TEU) currently deployed in the trunk routes are most likely to be cascaded down to the feeder routes. A necessity and rationale to construct a deep sea port is that the port must be ready to accommodate such redeployed larger and deep draft ships into the feeder routes.

On the other hand, the existing Hai Phong container ports are situated along the banks of Cam River and Bach Dang River and there is restriction in water depth of access channel that can provide up to around CDL – 7.0m. Therefore, Hai Phong ports can't accept such a cascaded mother container vessels.

Cai Lan Port was developed as a deep seaport of CDL -13m but it is necessary to pass the dredged access channel in Ha Long Bay which has been designated as the World Heritage by UNESCO. The water depth of the access channel is CDL -10m at present and further deepening is necessary to accept large container vessels. However, from the environmental considerations, the further deepening of this access channel will be impossible.

Therefore, to cope with the rapidly increasing sea borne traffic demand and global trends of ship size of container vessels, it is necessary to develop another port which can accommodate 50,000DWT to 100,00DWT (4,000TEU – 8,000TEU).

For the candidate site of new deep seaport in Northern Vietnam, Cam Pha area and Do Son area in addition to Lach Huyen area were studied and assessed from the viewpoints of natural conditions, access transportation to hinterland, future expansion potential, investment cost, environmental aspects, etc., by the Feasibility Study made by TEDI and selected Lach Huyen area as the most suitable site for a deep seaport by the reasons summarized below:

Cam Pha Site: This site has many advantages especially in natural conditions but has some limitations such as the acceptable ship size (less that 30,000DWT), space for future development, transportation system to hinterland, etc. Especially, inland waterway access from Hai Phong area has to pass through Ha Long Bay, world cultural heritage site.

Do Son Site: This site has advantage for access transportation to hinterland, however, has disadvantages for natural conditions (wave, siltation, sea depth) and physical and social environmental aspects. This site should be reserved for tourism and resort development as planned in Hai Phong's special development plan toward 2020.

Lach Huyen Site: This site can permit large ship enter and leave easily and has unlimited potential for port development in terms of expansion, and is not located in the Ha Long Bay and dose not affect the planned residential areas or tourist areas of Do son or Cat Ba eco-tour area. .

6.3 Vietnam Seaport System Development Master Plan

VINAMARINE (Vietnam Maritime Administration) has prepared the Master Plan of Vietnam Seaport System Development until 2020 toward to 2030, which was approved by the Prime Minister on December 24, 2009. In this master plan, the Hai Phong Port is designated to develop as an International Gateway Port as follows:

(1) By 2020 in a vision to 2030 to invest in synchronous system of seaports and access channels. To build: Van Phong transshipment container terminal for the vessels of 9.000 TEU to 15,000 TEU; international gateway ports in **Haiphong**, Baria - Vung Tau and Central focal economic zone (when it will be possible) for the vessels of 8,000DWT to 100,000 DWT, container vessel of 4,000TEU to 8,000 TEU.

(2) **Hai Phong Port**: International gateway port, national general hub port of the North with following functional areas:

- **Lach Huyen terminal**: it is the main terminal of Hai Phong port, mainly used for import-export container vessel of 4,000 TEU to 6,000 TEU and 50,000 DWT to 80,000 DWT, operated in far navigation transportation routes. Port infrastructures, cargo handling technology will be developed as synchronous and modern system at international level. The logistic park will be developed in services area behind the berth. Berth, technical infrastructures connecting to national network and service area behind the berth will be investment emphasis at the planning stage.

- **Dinh Vu area**: mainly for un-full general & container cargo vessel 20,000 DWT to 30,000 DWT. The dedicated terminals are arranged of factories and services enterprises inside Dinh Vu industrial zones.
- **Cam river area**: main function is locally general terminal for vessel of 5,000 DWT to 10,000 DWT, there is no plan for further development and expansion; for long term the port will change to other functions, the terminals in inner city will be reallocated. Main terminals in this area are Chua Ve and Vat Cach.
- **Chanh river area** (Yen Hung – Quang Ninh): main function is dedicated port with general container terminal for vessels of 10,000 DWT to 40,000 DWT. The port includes dedicated terminal for Yen Hung – Dam Nha Mac industrial zone, dedicated terminal for building and repairing of 100,000DWWT ships, dedicated terminal for oil product (at Qua Muom island).
- **Dedicated terminals and satellite terminals**: directly serve for industrial and services enterprises, the riverside terminals and local terminals service for local ships (incl. Diem Dien – Thai Binh, Hai Thinh – Nam Dinh). To be develop in accordance with general plan, to be satellite terminal of Hai Phong port.

(3) Sufficiently meet the market demand of volume of cargo and size of in/out vessel, ensuring the competitiveness in international market and regional market. At the same time to be the driving force for development of industrial, economical and urban zones of coastal areas. To develop container and other cargo receiving and forwarding centers in industrial and services zone behind the berths for maximum use of port capacity and regional public transport networks.

7. Natural Conditions

7.1 General

During the Works in Vietnam, data and project-related information on the natural conditions in and around Lach Huyen new international gateway port area were collected from both governmental and non-governmental sources of agencies. The data and information collected on the natural conditions will be used to determine the basis for port planning, preliminary design of port facilities, environmental impact study, etc., in order to formulate the medium term development plan or implementation plan as Japan's ODA Loan Project together with design, construction plan and cost estimate for various proposed port facilities.

In addition, a series of site surveys such as bathymetric survey in new port area, subsoil investigation at reclamation area and along breakwater/training dyke, seabed material survey, current and tide survey, were carried out during the 1st Work in Vietnam from October 2009 to January 2010. The results of these field surveys for natural conditions are presented in this sub-chapter in details.

7.2 Outline of Natural Conditions

7.2.1 Topography and Bathymetry

The proposed Project Site is located along the east edge of the Bay of Haiphong on the south of Cat Hai Island. The proposed site area is well sheltered by Cat Ba Island from the intruding northerly and easterly waves generated in the Gulf of Tonkin. The Bay bathymetry has being developed by the effects of the estuaries of such major rivers to follow into the bay as the Lach Huyen River, Cam river, Bach Dang river and Chanh river. The whole area of the Bay is much influenced by the estuary of these major rivers and the tides of the Gulf of Tonkin. The site mostly lies at tidal flats of the Haiphong Bay.

The bathymetry of Haiphong Bay is gradually sloped in an average slope of 0.04 to 0.08% to the directions of south-southeast. The sand bars and littoral dunes have been developed along the river estuaries, and appear at the low tide. The Project site for reclamation locates at the sand bars developed along the west bank of Lach Huyen river estuary and the water depth varies from CD+2.0 to ±0.0 m and gradually deepens to southeast direction.

7.2.2 Meteorological Feature

The Project site area belongs to the weather regime of tropical wind.

1) Temperature

The temperature observed at Cat Hai station shows is moderate. Table 7.2.1 shows the monthly change of the mean, highest and lowest temperatures. The monthly highest temperature records 38.0°C (in October) while the monthly lowest temperature is 3.7°C (in December). The difference between the highest and lowest monthly average temperatures is 34.3°C.

Table 7.2.1 Air Temperature at Cat Hai Station

(°C)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Mean
Highest	27.8	27.6	28.8	33.6	36.2	36.1	35.9	35.7	35.3	38.0	33.6	28.2	---
Mean	16.9	17.5	20.3	24.1	27.5	28.5	29.4	28.8	27.9	26.0	23.7	19.1	24.1
Lowest	14.6	5.3	7.1	13.4	15.9	18.4	23.4	23.1	16.6	14.0	9.0	3.7	---

Source: EIA Report, Lach Huyen Gateway Port Construction Project (2010-2015): Ministry of Transport, 2008

2) Humidity

The Humidity is very high at the project site area. The area experiences normally about 75 to 90 % all the year around.

Table 7.2.2 Air Humidity at Cat Hai Station

(%)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Mean
Mean	76.7	84.9	86.7	89.0	84.0	85.6	84.0	84.7	84.0	80.2	77.2	78.7	83.1

Source: EIA Report, Lach Huyen Gateway Port Construction Project (2010-2015): Ministry of Transport, 2008

3) Rainfall

The weather regime is divided into rainy season from May to October and dry season from November to April. The average rainfall at Cat Hai area is about 1,600 and 200 mm/year in the rainy season and the dry season respectively, and 1,800 mm/year through a year. TEDI F/S report indicates that the maximum rainfall of 320.5 mm/day was observed at Hon Dau area on July 14, 1992.

Rainy day defined as a day with rainfall of not less than 0.1 mm appears about 113 day annum (75 days in rainy season and 38 days in little rainy season) which is equivalent to about 31% of annual days.

Rainstorm with thunder discharge appears 44.3 days annum on average at Cai Hai area. According to the data below, storm season is from May to September. Rainstorm often causes strong rain, whirl winds and high waves.

Table 7.2.3 Average Monthly Number of Rainstorm Day

(day)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
Phu Lien	0.1	0.5	3.5	3.8	5.9	7.3	7.1	8.7	5.6	2.0	0.2	0.1	44.8
Hon Dau	0.2	0.3	3.4	3.8	5.1	6.3	5.7	9.4	6.2	3.3	0.3	0.1	44.1
Cat Hai	0.0	0.29	3.29	3.43	4.57	9.29	7.43	8.14	5.43	2.0	0.43	0.0	44.3
Bai Chay	0.2	0.4	3.5	3.8	5.8	8.5	7.6	13.2	6.3	3.9	0.1	0.1	53.4
Cua Ong	0.1	0.5	3.3	3.6	4.9	8.1	8.3	10.0	5.6	2.0	0.2	0.0	46.6

Source: Report on Environmental Impact Assessment for Lach Huyen Gateway port Construction Project, 2008, Original Data from The North-East Meteorological Station, 1975-2006

4) Fog

Fog occurrence concentrates in winter season from December to April. The frequency of foggy day is 21.2 days annum and 6.5 days in peak month of March as summarized below table.

In the month from January to April, fog with visibility of less than 1 km (Grade 0-3) occurs in an average of about 0.4 days per month while foggy day with visibility of less than 10 km (Grade 0- 6) occurs 4.3 days per month.

Table 7.2.4 Foggy Day Occurrence (1984-2004)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Mean
Max	15	9	20	16	3	0	2	0	6	2	5	15	61
Average	2.4	4.0	6.5	4.6	0.3	0	0.1	0	0.3	0.2	0.6	2.1	21.2

Source: Report on Port Capacity Reinforcement Plan in Northern Vietnam: Nippon Koei Co., Ltd. & Associates, September 2009

5) Winds

The climate in Northern Vietnam and the adjacent area is relatively calm except for stormy season which usually starts in June and finishes in November.

The wind in Viet Nam is normally governed by the prevailing seasonable climate character. The prevailing wind direction is north to northeast due to the northeast monsoon climate in dry season (September to February) while south to southeast wind due to southwest monsoon climate in rainy season (March to July). But, in the northern delta area, the northerly winds in dry season change to north-easterly or easterly while southerly winds in rainy season to southerly or south-easterly due to the local topography.

Table 7.2.5 below shows the annual frequency in occurrence of normal wind by speed and direction compiled from the wind data observed 3-year period from 2006 to 2008. These data show that the predominant wind directions range from East to South (about 45% of occurrence) and North (around 13%) of the whole winds. The wind of more than 15 m/s in speed is very rare in occurrence.

Table 7.2.5 Frequency in Occurrence of Normal Wind Speed by Direction

Wind Direction	Wind Speed (m/s)										Total	
	Calm		1.0 -4.0		5.0 – 9.0		10.0 – 15.0		> 15.0			
	N	%	N	%	N	%	N	%	N	%	N	%
N	---	---	432	9.97	132	3.05	4	0.09	0	0.00	---	---
NNE	---	---	89	2.05	36	0.83	1	0.02	0	0.00	---	---
NE	---	---	241	5.56	63	1.45	3	0.07	0	0.00	---	---
ENE	---	---	134	3.09	12	0.28	0	0.00	0	0.00	---	---
E	---	---	578	13.35	482	11.13	23	0.53	0	0.00	---	---
ESE	---	---	227	5.24	123	2.84	1	0.02	0	0.00	---	---
SE	---	---	307	7.09	132	3.05	4	0.09	0	0.00	---	---
SSE	---	---	87	2.01	126	2.91	36	0.83	0	0.00	---	---
S	---	---	180	4.16	144	3.32	11	0.25	0	0.00	---	---
SSW	---	---	21	0.48	51	1.18	13	0.30	0	0.00	---	---
SW	---	---	50	1.15	24	0.55	0	0.00	0	0.00	---	---
WSW	---	---	4	0.09	0	0.00	0	0.00	0	0.00	---	---
W	---	---	36	0.83	3	0.07	0	0.00	1	0.02	---	---
WNW	---	---	20	0.46	1	0.02	0	0.00	0	0.00	---	---
NW	---	---	155	3.58	15	0.35	0	0.00	0	0.00	---	---
NNW	---	---	108	2.49	16	0.37	1	0.02	0	0.00	---	---
Total	204	4.71	2,669	61.63	1,360	31.40	97	2.24	1	0.02	4,331	100

Source: Report on Port Capacity Reinforcement Plan in Northern Vietnam: Nippon Koei Co., Ltd. & Associates, September 2009

Monthly change in wind speed is summarized as follows. Occurrence of high wind prevails in rainy season from March to September.

Table 7.2.6 Wind Speed at Cat Hai Station

(m/sec)

	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Mean
Max	10	12	20	20	>20	>20	>20	>20	>20	20	14	12	>20
Average	3.9	3.9	3.9	3.1	3.2	3.1	3.0	3.7	3.3	3.3	3.2	3.0	3.4

Source: EIA Report, Lach Huyen Gateway Port Construction Project (2010-2015): Ministry of Transport, 2008

The extreme wind speed generated by tropical typhoons is about 40 -50 m/s. The predominant direction of these strong winds is southeast and observed 52 m/s at Hai Phong city during the storm Sarah on July 21, 1977. The probability of occurrence for extreme wind speed is summarized by wind direction as follows in TEDI F/S report.

Table 7.2.7 Extreme Wind Speed based on Hon Dau Station Wind Data

(m/sec)

Wind Direction	Return Period (Yr)					
	5	10	15	25	50	100
N	32.1	36.2	40.2	42.5	45.4	49.2
NE	36.7	42.2	47.4	50.4	54.2	59.3
E	**38.2**	43.3	**48.3**	**51.1**	**54.7**	**59.5**
SE	33.6	38.6	42.7	46.5	49.6	54.0
S	36.3	41.6	46.5	49.5	53.3	58.0
SW	36.6	41.3	45.5	48.0	51.5	56.5
W	31.2	36.9	42.0	45.0	49.3	54.5
NW	37.6	**43.3**	46.8	49.5	53.4	58.5
Maximum	38.2	43.3	48.3	51.1	54.7	59.5

Source: TEDI F/S Term-End Report

6) Seismic Conditions

The regional earthquake activities in and around Vietnam are deemed to be quite negligible. According to the statistical data by US Geological Survey Earthquake Hazards Program (1975-2006), a earthquake event of magnitude of 5.7 Richer Scale occurred at a place of about 151 km away from Lach Huyen on December 31, 1994. It is reported that maximum horizontal tremor intensity is estimated 0.024 for the earthquake.

TCXDVN 375; 2006 recommends to apply Level 3 (kh=0.04 or less for the projected area among 3 seismic activity levels in Vietnam.

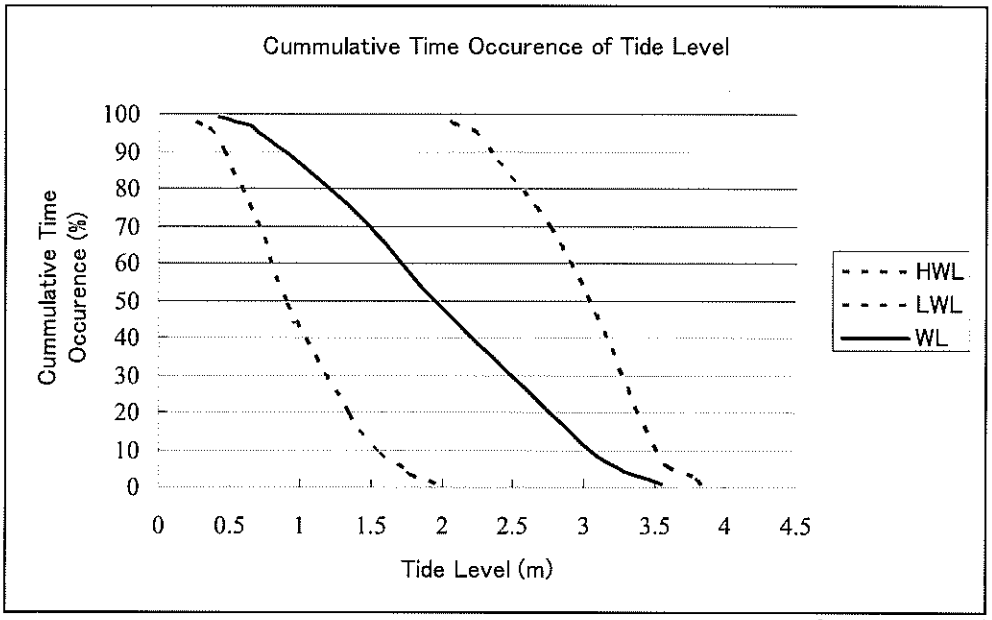
7.2.3 Oceanographic Feature

1) Tides

The tide regime at Hon Dau is usually diurnal. The tide level prediction at Hon Dau is given in the TEDI F/S report as follow.

- HWL : CD +3.55 m
- MHWL : CD +3.05 m
- MWL : CD +1.95 m
- MLWL : CD+0.91 m
- LWL : CD +0.43 m
- * CD referred and equals to Chart Datum.

In addition to the astronomical influence, the actual water levels may be significantly affected by barometric pressure, and wind and wave setup around Lach Huyen estuary area. The extreme water level at Hon Dau was observed CD+4.21 m for the highest on October 22, 1985 and CD +0.03 m for lowest on January 2, 1991, respectively. TEDI F/S report indicates that the extreme high sea water level at 1 % frequency of occurrence is CD+4.43 m, which is predicted by frequency theory based on the highest water levels from 1974 to 2004.



Source: TEDI F/S Report

Figure 7.2.1 Cumulative Time Occurrence of Tide Level

2) Currents

The current at Lach Huyen estuary is governed semi-diurnal tidal flow. The survey in January 1987 shows that average current speed is 0.3 -0.5 m/s. But due to the effects of wind and wave generated flow, the current becomes the maximum speed of 1.0 to 1.2 m/s at flood as well as ebb tide and may reach to the greatest speed at 1.5 to 1.8 m/s during ebb tides at the river estuaries. Sea chart on Hai Phong to Cam Pha indicates that the tidal stream is 2.6 knot (=1.34 m/s) highest speed 8 hours after high water along Cua Nam Trieu.

3) Waves

Hon Dau Station records (3-year period from 2006 to 2008) shows the following normal waves which are generated by local winds at the area. The wave height more than 1.0 m occupied 8.59% of occurrence. 60% of waves come from directions from E to S and prevailing wave direction is E to S. But high waves seem much prevail from SE and S directions.

Table 7.2.8 Frequency in Occurrence of Normal Wave Height by Direction

Wave Direction	Wave Height (m)										Total	
	0 – 0.25		0.25 – 0.5		0.5 – 1.0		1.0 – 1.5		> 1.5			
	Nr	%	Nr	%	Nr	%	Nr	%	Nr	%	Nr	%
N	---	---	3	0.09	57	1.74	8	0.24	1	0.03	---	---
NE	---	---	0	0.00	47	1.43	16	0.49	0	0.00	---	---
E	---	---	184	5.60	844	25.71	63	1.92	5	0.15	---	---
SE	---	---	37	1.13	429	13.07	89	2.71	6	0.18	---	---
S	---	---	4	0.12	149	4.54	75	2.28	13	0.4	---	---
SW	---	---	0	0.00	10	0.30	5	0.15	1	0.03	---	---
W	---	---	0	0.00	1	0.03	0	0.00	0	0.00	---	---
NW	---	---	0	0.00	10	0.30	0	0.00	0	0.00	---	---
Total	1,226	37.34	228	6.94	1,547	47.12	256	7.80	26	0.79	3,283	100

Source: Report on Port Capacity Reinforcement Plan In Northern Vietnam, September 2009: Nippon Koei Co., Ltd. & Associates

The following extreme high wave was observed at meteorological station in Hon Dau water in a period for 20 years from 1965 to 1985.

Wave Direction	South	East
Wave Height	5.6 m	5.6 m
Wave Length	210 m	96 m
Date	July 3, 1964	September 20, 1975

Source: TEDI F/S Term-End Report

According to the observation in the second half of 20th century, 13 numbers of tropical typhoon occurred on average per year in the East Pacific region, of which 7 numbers affected Viet Nam. Cat Hai area which locates the northern coastal area of the country was attacked at 0.92 times per annum on average. The wave data at Hon Dau observation station for 20 years from 1988 to 2008 were used to analyze the extreme wave height probability based on the Gumbel and Weibull distribution methods and obtained the following results.

Return Period (Yr)	Wave Height (m)	Wave Period (Sec)
1	1.22	5.8
5	3.18	8.9
10	3.71	9.7
30	4.45	10.8
50	4.77	11.3
75	5.01	11.7
100	5.18	12.0
120	5.28	12.1

Wave Period: estimated by the relationship T=1.5539H+3.9222

Source: Report on Port Capacity Reinforcement Plan in Northern Vietnam: Nippon Koei Co., Ltd. & Associates, September 2009

7.2.4 Geological Conditions

1) General Conditions

The Lach Huyen Port Development area is located in the lower reaches of the Red River (Coi River). Large amounts of soil and sand now come from the Nam Trieu River and the Lach Huyen River, resulting in a thick built-up of a soft clay layer.

This project area belongs to Cat Hai district, Haiphong city. It is situated on the right of Lach Huyen river. The right bank of the river, beginning from stone jetty in the south of Cat Hai island, is a big sand bar with the length of about 6,000m and the width of 1,000m, its altitude is from 0 to +1.0m. The opposite bank is Cat Ba island.

2) Geological Characteristics

In this region, the Feasibility Study Report for Hai Phong International Gateway Port Project, a geological and property survey was conducted by TEDI in 2007. And later on, five additional borings (PBH-1 to 5) and indoor soil property tests were conducted in 2008 by Nippon Koei.

The geological layers in this region are broken down into formations in the order of newer generations (Layer-I, Layer-2, Layer-8, etc.). The geological status for each layer, as well as the N-value distribution conditions, is shown in Table 7.2.9.

Table 7.2.9 Soil Properties and N-Value at Each Layer

Layer	Soil Description	N-Value	
		Range	Average
Layer-1	Grey small sand mixed clamshell **(Sand)**	4~8	6
Layer-2	Liquid plastic grey clay **(Clay)**	1~5	3
Layer-3	Plastic mixed sand **(Sand)**	-	-
Layer-4	Soft plastic clay **(Clay)**	4~8	6
Layer-5	Spotted clay (grey, yellow grey, red brown), tough plastic, semi-tough **(Clay)**	5~23	12
Layer-6	Green grey, grey, soft plastic clay **(Clay)**	4~9	7
Layer-7	Medium dense-yellow grey sand **(Sand)**	19~25	22
Layer-8	Clay/strongly to medium strongly weathered siltstone**(Clay)**	-	-

7.3 Natural Conditions Surveys in this Study

The following surveys have been carried out in this Study to check the existing data and obtain the latest information for reviewing the Feasibility Study Report implemented by TEDIPORT.

(1) Sub Soil Conditions Surveys

- Offshore Boring

  10 offshore borings at the first phase reclamation area and along the planned sand prevention groin.

- Seabed Material Survey

  80 location in and around the port development area

(2) Hydrographic Surveys

- Bathymetric Survey

  420 km long (1km long per section in every 50 m interval, which is perpendicular to navigation channel)

- Tidal Observation

  1 location at Ben Got Jetty in Cat Hai Island, Observation for 15 consecutive days

(3) Current Observations

- Current Measurement

  4 locations along the navigation channel

- Cylinder Sampling

  4 locations along the navigation channel

- Water Sampling

  4 locations along the navigation channel

7.3.1 Subsoil Conditions Survey

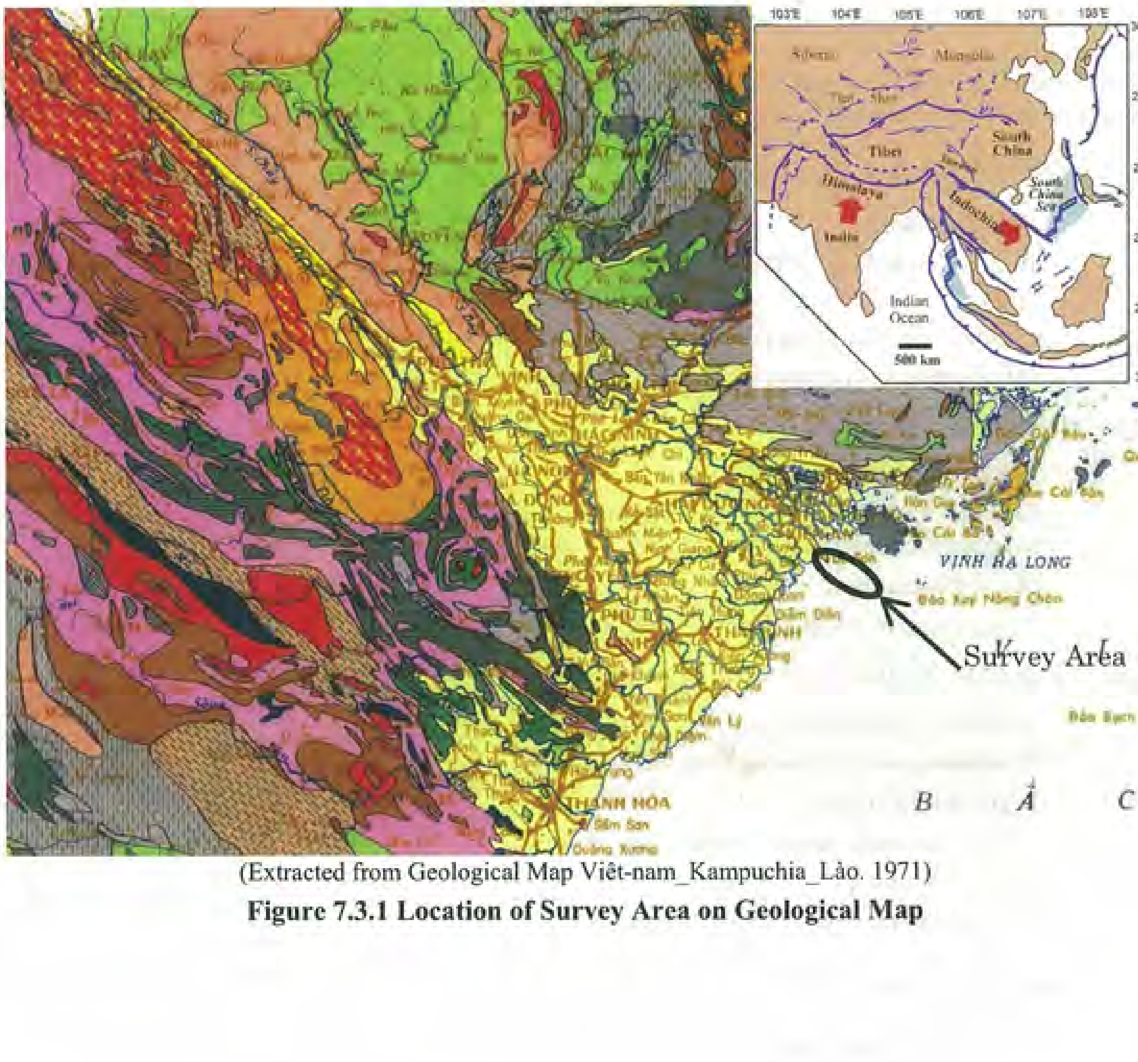
1) Location, Topography and Geology

Hai Phong is a port city, located in the east of northern coastal area, approximately 120 km away from Hanoi Capital. The investigation area locates in Cat Hai Island that is 13 km away from Hai Phong downtown in the east.

Location of the project site is shown in Figure 7.3.1 and Figure 7.3.2.

Survey area is located at the sea side of south end of Cat Hai Island which is at the front end of delta area of Red River. Large amount of soil and sand flow in from the Nam Trieu River and Lach Huyen River, resulting in a thick buildup of a soft clay layer. At ground surface, sand can be seen in Cat Hai Island and at its surrounding areas and shellfish which lives in seabed sand are landed at Ben Got Jetty of Cat Hai Island as shown in Figure 7.3.3.

As shown in Figure 7.3.1, geological structure can be seen from north west to south east direction. Because the boundary of tectonic plate exists around this area from north west to south east direction as shown in the upper right map of Figure 7.3.1. Therefore some geological and structural boundary may exist between Cat Hai Island and Cat Ba Island. One symptom of this is outcrops observed in Cat Ba Island. Weathered lime stone which is main bed rock of Cat Ba Island can be seen as shown in Figure 7.3.3. However only silt/clay stone is identified as a bed rock of Lach Huyen survey area according to survey results including existing ones. It means Lach Huyen River is flowing along the geological or structural boundary between Cat Hai Island and Cat Ba Island.



(Extracted from Geological Map Việt-nam_Kampuchia_Lào. 1971)

Figure 7.3.1 Location of Survey Area on Geological Map

(Extracted from Google Earth)

Figure 7.3.2 Location of Survey Area

		
Sand beach near Ben Got Jetty at low tide	Stone revetment and sand beach in port reclamation area at low tide	Port reclamation area (view from sea side to land side)
		
Sand shoal at port reclamation area between SBH-1 and SBH-3	Dyke at east side of Cat Ba Island; sea at left and Saltpan at right side.	Wide saltpan area inside the Cat Hai Island
		
Shellfish living in sandy place is collected at Ben Got Jetty.	Outcrops of hard lime stone seen at the west seaside of Cat Ba Island.	Inclined outcrop of lime stone seen at the west seaside of Cat Ba Island

Figure 7.3.3 Photos at and near Survey Area

2) Offshore Boring

a) Location and co-ordinates of boring points

10 offshore borings has been carried out at the first phase reclamation area and along the planned sand prevention groin from November - 09th - 2009 to December - 05th - 2009. The locations of boring points and those quantities are tabulated in Table 7.3.1 and shown in the Figure 7.3.4.

Table 7.3.1 Co-ordinates, elevation and quantities of the boring investigation

No.	Bore-hole No.	Actual Coordinates (m) – VN2000		Elevation (m)	Depth (m)	Length of drilling(m)		Number of sample		Number of SPT	Remarks
		Northing	Easting			Soil	Rock	Undis-turbed	Dis - turbed		
1	SBH1	2301288	620055	-1.90	27.00	24.00	3.00	9	15	15	Offshore
2	SBH2	2301113	619715	-1.27	29.20	26.20	3.00	7	19	19	"
3	SBH3	2301053	620204	0.40	30.00	27.00	3.00	5	22	22	"
4	SBH4	2300859	619883	0.75	31.60	28.60	3.00	5	23	23	"
5	SBH5	2300223	619522	0.10	37.50	34.50	3.00	5	29	29	"
6	SBH6	2299377	620036	-0.90	41.80	38.80	3.00	7	31	31	"
7	SBH7	2298491	620565	-0.30	36.45	36.45	-	5	31	31	"
8	SBH8	2296864	623100	-3.30	33.70	30.70	3.00	3	27	27	"
9	SBH9	2295022	624596	-2.90	55.45	55.45	-	5	50	50	"
10	SBH10	2293121	625955	-3.60	51.45	51.45	-	4	47	47	"
Total					374.15	353.15	21.00	55	294	294	

Figure 7.3.4 Location of Boring Points

b) Boring Investigation Result

(1) Soil stratifications at Site

Soil stratifications have been identified due to the boring investigation results, which are tabulated in Table 7.3.2 with existing soil stratifications classified before.

Table 7.3.2 Soil Stratification at Project Site

Existing Investigation Result				Soil Stratification identified in this Study		
Layer Name	Soil Description	N-value Range	N-value Average	Layer Name	Color	N-Value
Layer-1	Grey small sand mixed clamshell (Sand)	4 - 8	6	Layer 1: Loose Sand (SP) - Clayey Sand (SC)	Grey, Light Grey	3 – 10 (6)
Layer-2	Liquid plastic grey clay (Clay)	1 - 5	3	Layer 2: Fat Clay with Sand (CH)	Brownish and Yellowish Grey	0 – 8 (2)
Layer-3	Plastic mixed Sand (Sand)	-	-	Layer 3: Clayey Sand (SC)	Light Grey, Greenish Grey	0 – 17 (6)
Layer-4	Soft plastic clay (Clay)	4 - 8	6	Layer 4: Stiff Sandy Lean Clay (CL)	Reddish and Yellowish Brown	2 – 23 (10)
Layer-5	Spotted clay (grey, yellow grey, red brown) tough plastic, semi-tough (Clay)	5 - 23	12			
Layer-6	Green grey, grey, soft plastic clay (Clay)	4 - 9	7	Layer 5: Firm Fat Clay with Sand (CH)	Grey, Yellowish Light Grey	0 – 15 (6)
-	-	-	-	Layer 6: Stiff - very Stiff Fat Clay with Sand (CH)	Grey	9 – 21 (14)
-	-	-	-	Layer 7: Stiff – very Stiff Sandy Lean Clay (CL)	Yellowish Grey, Light Grey	9 – 50 (22)
Layer-7	Medium dense, yellow grey sand (Sand)	19 - 25	22	Layer 8: Very Dense Sand (SP)	Yellowish Grey, Light Grey	9 – 50 (45)
Layer-8	Clay / strongly to medium strongly weathered silt stone	-	-	Layer 9: Completely Weathered Sand Stone	Reddish Brown	>50
Layer 9	Moderately Weathered Silt/Clay Stone	-	-	Layer 10: Highly – Moderately Weathered Silt/Clay Stone	Reddish Brown	-
Layer 10	Silt/ Clay Stone	-	-			

As shown in the above table, soil layers including bed rock at the site can be classified into 10 layers and distribution of each layer can be summarized in Table 7.3.3.

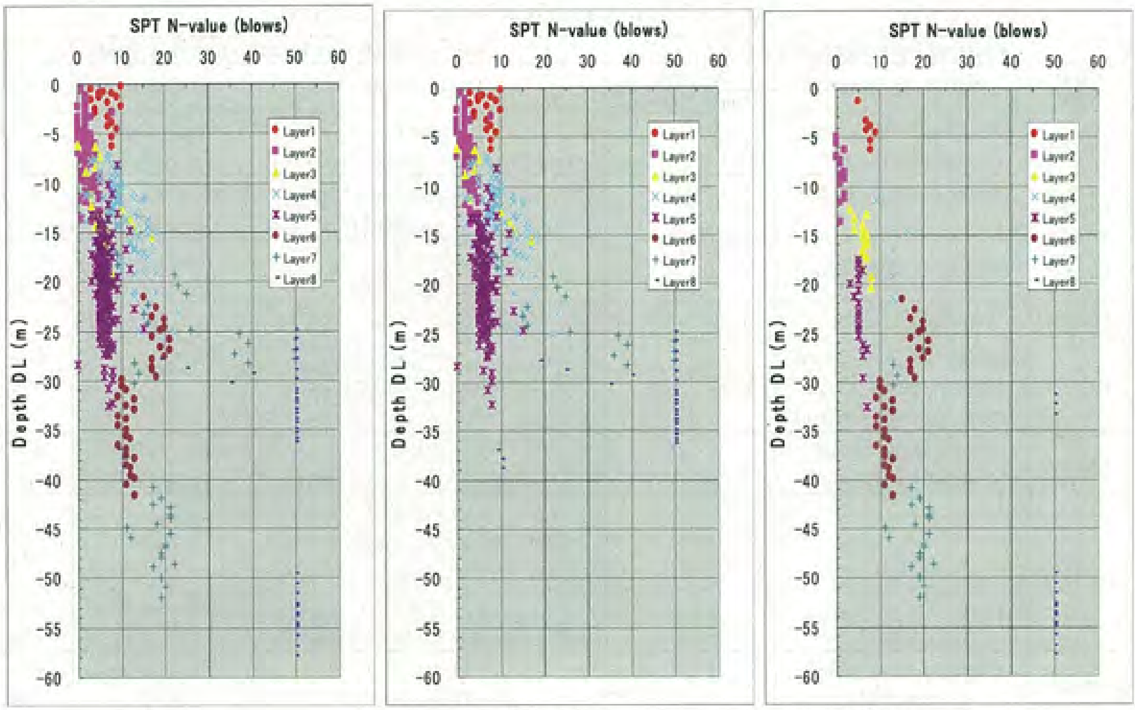
Borehole location map including existing boreholes is shown in Figure 7.3.5.

Representative soil profile with SPT-N values is shown in Figure 7.3.6 and all soil profiles prepared this time are shown in Appendix 7-1.

SPT –N value distribution with depth including existing boring results is shown in Figure 7.3.4.

Existing soil investigation results at study area referred for the preparation of this study report are as follows;

- CONTAINER TERMINAL DEVELOPMENT PROJECT IN HAI PHONG INTERNATIONAL GATEWAY PORT, FEASIBILITY STUDY, SOIL INVESTIGATION REPORT, January 2009, by NIPPON KOEI CO., LTD.
- REPORT ON HYDRO-METEODOLOGICAL, TOPOBATHYMETRIC MAPS AND SOIL INVESTIGATION DATA COLLECTION, November 2007, by TEDIPORT.
- HAI PHONG PORT REHABILITATION PHASE II PROJECT PROPOSED ACCESS CHANNEL ARE, GEOTECHNICAL INVESTIGATION REPORT, May 2000, by TEDI.



All data | Port Area (within 3km from shore line) | Off-Shore Area (more than 3km away from shore line)

Figure 7.3.5 SPT N-value Distribution with Depth

Figure 7.3.6 Locations of Boring Points including Existing Boreholes

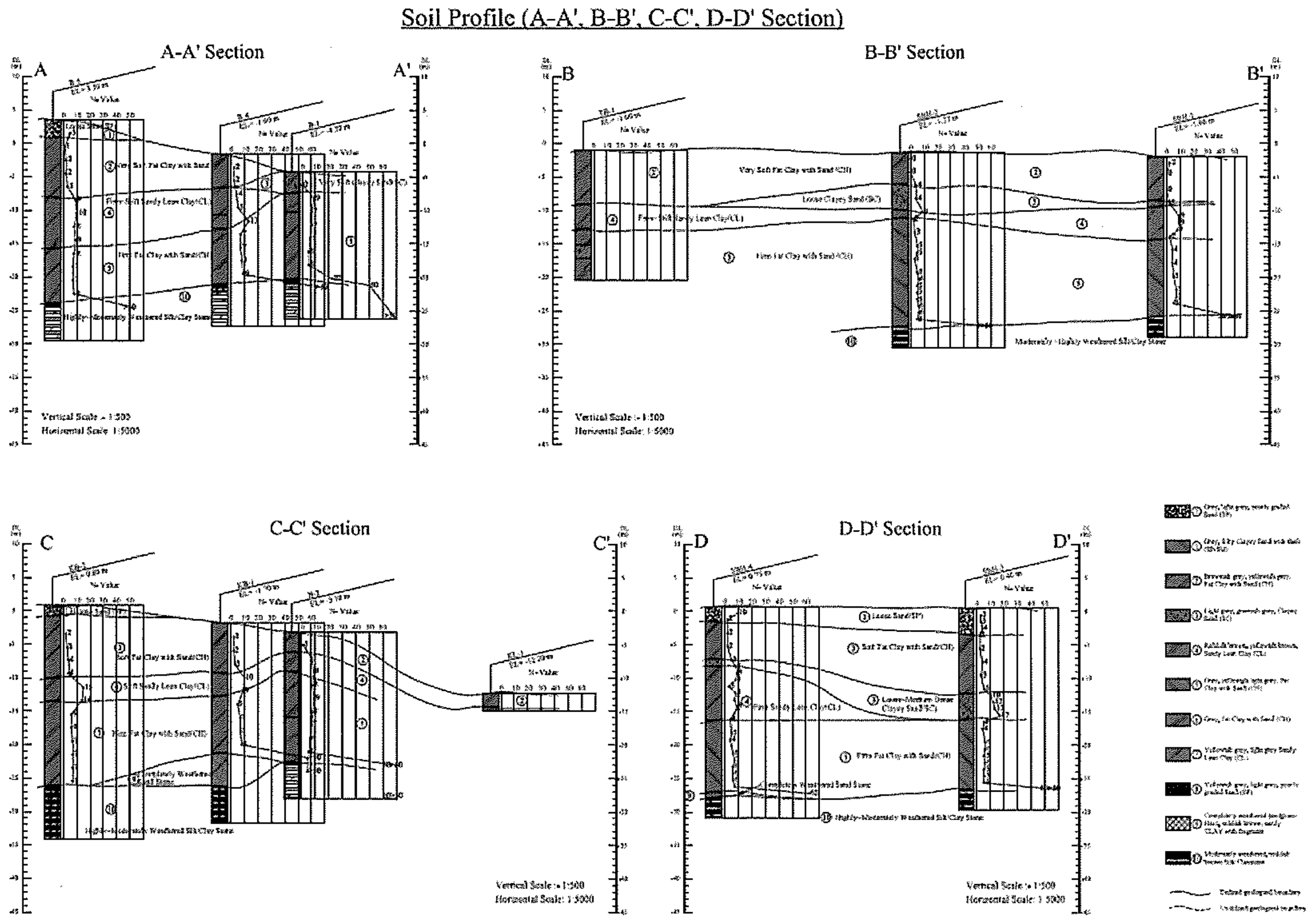


Figure 7.3.7 Soil Profile (A-A', B-B', C-C' and D-D' Section) (Including existing boring results)

Table 7.3.3 Distribution of Soil Layers

Layer Name		Features of Soil Layers: Distributed Area	Distributed Depth DL (m)	Distributed Thickness (m)
Layer 1	Loose Sand (SP) - Clayey Sand (SC)	Distributed at west side of navigation channel in 1km wide and 10km long from 27+200 to 37+500 along the navigation channel.	GL to -4	0.5 to 5.0
Layer 2	Fat Clay with Sand (CH)	Distributed at whole survey area. 1) Port Area (within about 3km from shore line) 2) Off-Shore Area (more than 3km away from shore line)	 +1 to -17 -3 to -14	 5.0 to 14.0 5.0 to 9.0
Layer 3	Clayey Sand (SC)	Distributed at the following two area; 1) Within 1km from shore line of Cat Hai Island. 2) Between 5km and 10km off shore side.	 -4 to -16 -13 to -21	 0.5 to 4.0 3.0 to 9.0
Layer 4	Stiff Sandy Lean Clay (CL)	Distributed at only Port Area. 1) Port Area (within about 3km from shore line) 2) Off-Shore Area (more than 3km away from shore line)	 -6 to -26 Not distributed	 1.0 to 16.0
Layer 5	Firm Fat Clay with Sand (CH)	Distributed at whole survey area. 1) Port Area (within about 3km from shore line) 2) Off-Shore Area (more than 3km away from shore line)	 -7 to -32 -17 to -28	 2.5 to 17.0 3.5 to 7.0
Layer 6	Stiff - very Stiff Fat Clay with Sand (CH)	Distributed at only off-shore area, confirmed at only SBH-9 and 10. 1) Port Area (within about 3km from shore line) 2) Off-Shore Area (more than 3km away from shore line)	 No distribution -21 to -42	17.5 to 21.0
Layer 7	Stiff – very Stiff Sandy Lean Clay (CL)	Distributed at west end of port area and off -shore area. 1) West end of Port Area (within about 3km from shore line) 2) Off-Shore Area (more than 3km away from shore line)	 -17 to -34 -28 to -53	 1.5 to11.5 3.5 to 12.0
Layer 8	Very Dense Sand (SP)	Distributed at west end of port area and off -shore area. 1) West end of Port Area (within about 3km from shore line) 2) Off-Shore Area (more than 3km away from shore line)	 -26 to -40 -31 to -60	 8.0 to 11.0 3.0 to 5.5
Layer 9	Completely Weathered Sand Stone	Distributed at port area only, it is not confirmed its existence at off-shore area. 1) Port Area (within about 3km from shore line) a) At SBH-2 and ABH-4 b) At KB-1 and KB-3	 -27 to -28 -21 to -30	 0.3 to 0.6 4.5 to 5.0
Layer 10	Highly-Moderately Weathered Silt/Clay Stone	Bed rock identified at almost all boreholes this time except SBH-7, 9, 10. 1) Port Area (within about 3km from shore line) 2) Off-Shore Area (more than 3km away from shore line)	 -21 to -38 -35 to < -60	-

: Sand Layer, : Clay Layer, : Weathered Rock

(2) Soil Properties

Laboratory test results including existing results are shown as a relationship between depth (D.L.) and each value in Appendix 7-2.

Soil properties obtained from subsoil condition surveys which have been carried out this time and from existing soil investigation results are tabulated in Table 7.3.4 and Table 7.3.5 and also in Appendix 7-2 which shows the soil properties of each layer at Port Area (within about 3km from shore line of south end of Cat Hai Island) and Off-shore Area (more than 3km away from shore line) respectively.

Table 7.3.4 Soil Properties of each Layer at Port Area

Layer No.	Soil Type	Type of Value	SPT N-value	Particle density D (g/cm³)	Fine Content (%)	Natural water content w (%)	Atterberg Limits: Liquid limit W_L (%)	Atterberg Limits: Plastic limit Wp (%)	Atterberg Limits: Plasticity index Ip (%)	Bulk density (g/cm³): Natural	Bulk density (g/cm³): Dry	Void ratio eo	Consolidation test: Cv (x 10⁻³ cm²/s) (1-2kgf/cm2)	Consolidation test: Cc	Consolidation test: Cr	Consolidation test: CR = Cc/(1+e0)	Consolidation test: RR = Cr/(1+e0)	Consolidation test: Pc (KG/cm²)	Unconfined compression test: qu (KG/cm²)	Unconfined compression test: εf (%)	Compressive strength of rock Rn (KG/cm²): Natural	Compressive strength of rock Rn (KG/cm²): Saturated
1a	Grey, light grey, poorly graded sand (SP)	Max	10	2.68	22.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	3	2.65	2.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	5.6	2.66	8.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1b	Grey, silty, clayey sand with shell (SM)	Max	10	2.66	39.0	-	36.3	30.6	8.7	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	7	2.65	27.3	-	32.4	25.5	5.7	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	8.5	2.66	31.8	-	34.3	27.7	6.5	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Brownish grey, yellowish grey, Fat Clay with sand (CH)	Max	8	2.73	99.7	84.8	65.3	35.5	52.6	1.91	1.46	2.31	1.92	0.90	0.194	0.68	0.068	1.57	0.80	12.8	-	-
		Min	0	2.67	35.2	25.5	25.2	14.6	6.9	1.50	0.81	0.83	0.27	0.09	0.013	0.05	0.007	0.36	0.05	2.0	-	-
		Average	2.6	2.69	90.9	60.1	54.0	26.4	27.6	1.71	1.14	1.41	0.77	0.52	0.119	0.22	0.047	0.93	0.32	6.7	-	-
3	Light grey, greenish grey, clayey sand (CS)	Max	17	2.68	66.1	35.3	40.9	21.5	23.5	1.99	1.60	0.96	1.86	0.47	0.058	0.25	0.031	1.74	0.43	-	-	-
		Min	0	2.67	31.3	21.4	22.3	14.5	6.3	1.85	1.37	0.67	0.93	0.14	0.019	0.07	0.011	1.06	0.43	-	-	-
		Average	7.0	2.67	49.9	27.3	31.0	17.0	13.9	1.91	1.47	0.82	1.27	0.26	0.033	0.14	0.018	1.38	0.43	-	-	-
4	Reddish brown, yellowish brown, sandy lean clay (CL)	Max	23	2.74	99.4	40.0	53.4	27.1	28.7	2.08	1.96	1.03	4.71	0.91	0.063	0.47	0.036	3.48	1.06	9.5	-	-
		Min	2	2.66	31.4	16.5	25.3	14.1	9.4	1.62	1.32	0.56	0.60	0.10	0.016	0.06	0.010	0.62	0.33	6.3	-	-
		Average	10.5	2.69	81.9	28.0	39.9	20.2	19.6	1.95	1.55	0.76	2.36	0.28	0.030	0.15	0.017	1.39	0.62	7.9	-	-
5	Grey, yellowish light Grey, fat clay with sand (CH)	Max	15	2.73	99.4	52.8	65.6	33.2	45.1	1.90	1.45	1.49	2.09	0.74	0.198	0.32	0.091	2.97	0.97	10.2	-	-
		Min	0	2.67	51.7	20.3	25.9	12.3	12.3	1.65	1.09	0.87	0.75	0.26	0.033	0.13	0.016	0.61	0.09	4.4	-	-
		Average	6.5	2.70	93.8	42.9	50.8	23.9	26.9	1.76	1.22	1.23	1.26	0.52	0.110	0.23	0.050	1.80	0.66	6.9	-	-
6	Grey, fat clay with sand (CH)	Max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Yellowish grey, light grey, sandy lean clay (CL)	Max	50	2.68	98.4	36.0	45.6	17.9	28.2	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	9	2.65	49.1	18.8	20.9	13.8	4.9	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	28.9	2.67	66.0	24.0	30.6	16.6	14.0	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Yellowish grey, light grey, poorly graded sand (SP)	Max	50	2.69	10.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	9	2.64	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	43.9	2.66	2.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	Reddish brown completely weathered sand stone	Max	50	2.77	86.0	27.3	42.2	21.9	20.2	2.36	1.56	0.76	-	-	-	-	-	-	-	-	-	-
		Min	50	2.73	52.4	15.1	33.2	21.3	12.0	1.99	1.56	0.76	-	-	-	-	-	-	-	-	-	-
		Average	50.0	2.74	68.8	21.2	37.5	21.6	15.9	2.18	1.56	0.76	-	-	-	-	-	-	-	-	-	-
10	Reddish brown highly to moderately weathered silt/claystone	Max	-	2.83	-	-	-	-	-	2.72	-	-	-	-	-	-	-	-	-	-	1081	686
		Min	-	2.70	-	-	-	-	-	2.40	-	-	-	-	-	-	-	-	-	-	71	61
		Average	-	2.76	-	-	-	-	-	2.60	-	-	-	-	-	-	-	-	-	-	388	341

Table 7.3.5 Soil Properties of each Layer at Off-shore Area

Layer No.	Soil Type	Type of Value	SPT N-value	Particle density D (g/cm³)	Fine Content (%)	Natural water content w (%)	Atterberg Limits: Liquid limit W_L (%)	Atterberg Limits: Plastic limit Wp (%)	Atterberg Limits: Plasticity index Ip (%)	Bulk density (g/cm³): Natural	Bulk density (g/cm³): Dry	Void ratio eo	Consolidation test: Cv (x 10⁻³ cm²/s) (1-2kgf/cm2)	Consolidation test: Cc	Consolidation test: Cr	Consolidation test: CR = Cc/(1+e0)	Consolidation test: RR = Cr/(1+e0)	Consolidation test: Pc (KG/cm²)	Unconfined compression test: qu (KG/cm²)	Unconfined compression test: εf (%)	Compressive strength of rock Rn (KG/cm²): Natural	Compressive strength of rock Rn (KG/cm²): Saturated
1a	Grey, light grey, poorly graded sand (SP)	Max	7	2.66	10.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	5	2.66	7.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	6.0	2.66	8.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1b	Grey, silty, clayey sand with shell (SM)	Max	8	2.66	30.3	-	37.0	30.6	6.7	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	7	2.65	26.4	-	30.8	25.2	5.6	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	7.8	2.66	28.0	-	33.9	27.8	6.2	-	-	-	-	-	-	-	-	-	-	-	-	-
2	Brownish grey, yellowish grey, Fat Clay with sand (CH)	Max	2	2.71	99.7	76.0	86.0	36.1	50.0	1.85	1.36	2.09	0.52	0.82	0.196	0.28	0.066	0.83	0.42	10.5	-	-
		Min	0	2.67	63.9	36.1	38.9	21.4	17.5	1.53	0.87	0.99	0.24	0.39	0.056	0.15	0.020	0.28	0.05	5.3	-	-
		Average	1.1	2.69	88.3	62.0	67.5	29.7	37.8	1.61	0.99	1.74	0.35	0.62	0.127	0.22	0.044	0.57	0.16	8.5	-	-
3	Light grey, greenish grey, clayey sand (CS)	Max	8	2.69	45.5	27.2	36.6	18.2	21.2	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	3	2.65	23.1	20.5	25.1	14.4	10.1	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	6.1	2.67	33.8	24.2	31.4	16.2	15.2	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Reddish brown, yellowish brown, sandy lean clay (CL)	Max	16	2.74	94.6	31.2	46.6	24.8	21.8	2.01	1.60	0.91	-	-	-	-	-	-	-	-	-	-
		Min	9	2.71	54.3	22.4	27.3	14.7	12.6	1.88	1.43	0.71	-	-	-	-	-	-	-	-	-	-
		Average	12.8	2.73	83.0	27.2	39.4	20.9	18.5	1.94	1.51	0.82	-	-	-	-	-	-	-	-	-	-
5	Grey, yellowish light Grey, fat clay with sand (CH)	Max	7	2.71	99.4	50.7	67.6	33.5	38.0	1.94	1.51	1.39	1.86	0.60	0.171	0.25	0.071	2.02	0.14	11.2	-	-
		Min	3	2.67	62.8	28.4	37.2	18.2	19.0	1.68	1.12	0.77	0.86	0.16	0.023	0.09	0.013	0.86	0.14	11.2	-	-
		Average	5.3	2.69	86.9	40.6	51.8	25.2	26.6	1.83	1.34	1.03	1.36	0.38	0.097	0.17	0.042	1.44	0.14	11.2	-	-
6	Grey, fat clay with sand (CH)	Max	21	2.70	99.6	58.0	70.7	33.3	39.6	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	9	2.67	61.9	21.7	26.0	17.5	8.5	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	14.0	2.68	84.4	41.9	52.3	25.5	26.8	-	-	-	-	-	-	-	-	-	-	-	-	-
7	Yellowish grey, light grey, sandy lean clay (CL)	Max	22	2.70	76.4	27.1	35.8	21.2	19.9	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	11	2.67	48.0	22.1	25.4	13.7	7.4	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	17.9	2.69	64.2	23.3	29.1	16.1	13.0	-	-	-	-	-	-	-	-	-	-	-	-	-
8	Yellowish grey, light grey, poorly graded sand (SP)	Max	50	2.68	2.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	50	2.65	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	50.0	2.66	1.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9	Reddish brown completely weathered sand stone	Max	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Min	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Average	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	Reddish brown highly to moderately weathered silt/claystone	Max	-	-	-	-	-	-	-	2.68	-	-	-	-	-	-	-	-	-	-	659	593
		Min	-	-	-	-	-	-	-	2.61	-	-	-	-	-	-	-	-	-	-	230	194
		Average	-	-	-	-	-	-	-	2.65	-	-	-	-	-	-	-	-	-	-	503	444

The following existing soil laboratory test results are referred for analyzing the data of Prot Area and Off-shore Area.

- Port Area: SBH-1 to 7 (by JICA Study), B-1 to 5 (by Nippon Koei), KB-1-10 (by TEDIPORT) ; Total 22 boreholes
- Off-shore Area: SBH-8 to 10 (JICA Study), KB-11, 12 (by TEDI) : Totally 5 borehole

According to soil test results obtained from the above survey results, differences of soil properties between Port Area and Off-shore Area are not recognized except Layer 2 (Soft Fat Clay with Sand).

Characteristics of soil properties of soil layers are described as follows;

a) Physical properties

i) Density of Soil Particle: D

Density of soil particle (D = Gs γw, Gs: Specific Gravity of soil, γw: unit weight of water) shows 2.70 g/cm3 in average through all soil layers at whole survey area and ranging between 2.64 and 2.74 g/cm3. This value shows that all soil layers at the survey area are composed of inorganic soils.

ii) Fine Content: Fc (Weight percentage passing 74μm Sieve) (Refer to Figure 7.3.8)

Fine content is one of the indices obtained form sieve analysis test. When it is more than 50%, we classify the soil as fine soil like silt or clay.

According to sieve analysis test result, Layer 2, 4, 5 can be classified as fine soils, however Layer 3 is classified as coarse and fine soils depending on samples. It means that the layer 3 should be considered as possible layer of consolidation settlement and also should not be considered as permeable layer from conservative point of view.

iii) Natural Water Content and Liquid Limit (Refer to Figure 7.3.8)

As for the Layer 2, average natural water content at Port Area is 50% which is 10% lower than one of Off-shore Area. Average natural water content of soil Layer 3, 4, 5, 6, 7 for whole area are 26, 28, 43, 42, 50% respectively. And also average value of Liquid Limit (LL) and Plasticity Index (IP) of Layer 2 at Port Area are 54% and 26% respectively which are also about 10% lower than ones of Off-shore Area. These results are suggestive of bigger void ratio and higher compressibility of Soil Layer 2 at Off-shore Area than ones at Port Area.

According to liquid limit test result as shown in the right end of Figure 7.3.8, liquid limits of soil Layer 2, 5, 6 are distributed between intermediate and very high, high and high plasticity respectively. Therefore clays of only these three layers have high plasticity.

iv) Bulk Density (Unit Weight) and Void Ratio (Refer to Figure 7.3.9)

Values of bulk density and void ratio are distributed with depth as shown in Figure 7.3.9 and those average values for each layers are tabulated in Table 7.3.6.

There is a theoretical correlation between bulk density (saturated) and void ratio as follows;

$$\gamma = (Gs+e0)\,\gamma w\,/(1+e0)$$

And also since e0 = Wn Gs,

$$\gamma = Gs(1+Wn)\,\gamma w\,/(1+Wn\,Gs)$$

Therefore if some physical properties can be known such as Gs, e0 or Wn, bulk density can be calculated from above formula.

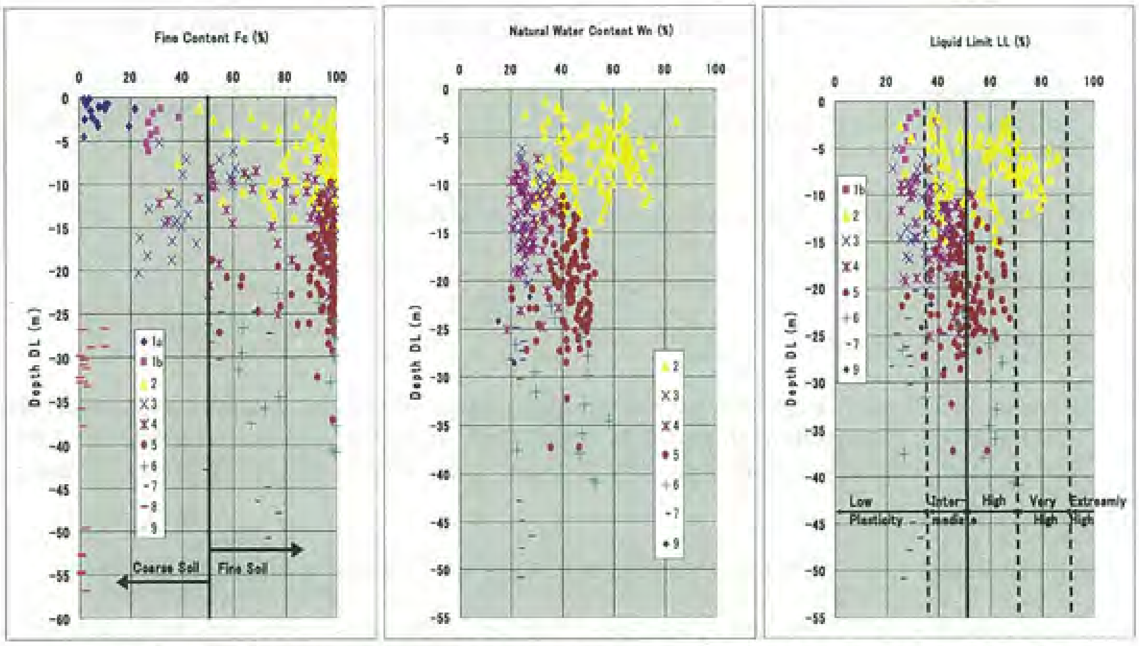


Figure 7.3.8 Fine Content, Natural Water Content and Liquid Limit with Depth (DL)

Table 7.3.6 Bulk Density and Void Ratio at Port Area and Off-shore Area

Layer Name	Bulk Density (g/cm3)			Void Ratio e0		
	Port Area	Off-shore Area	Whole Area	Port Area	Off-shore Area	Whole Area
Layer 2	1.71	1.61	1.69	1.41	1.74	1.46
Layer 3	1.91	-	1.91	0.82	-	0.82
Layer 4	1.95	1.94	1.95	0.76	0.82	0.76
Layer 5	1.76	1.83	1.76	1.23	1.03	1.21

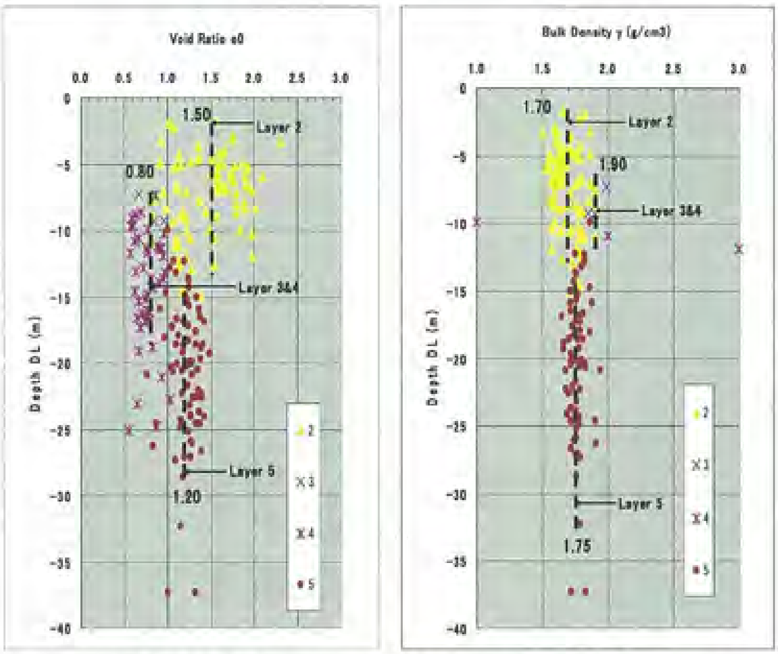


Figure 7.3.9 Void Ratio and Bulk Density with Depth (DL)

b) Mechanical Properties of Cohesive Soil

i) Shear Strength of Cohesive Soil

Unconfined compression test has been carried out in this survey, however that have not been carried out before in the existing surveys. In stead of unconfined compression test, direct shear tests were carried out in the existing surveys. In order to utilize the existing test result, shear strength (Cu, ϕu) obtained from direct shear test in the existing survey results are approximately converted to unconfined compression strength considering overburden pressure as follows;

$$qu = 2C = 2 \times (Cu + \sigma' \tan\phi u)$$

Where, qu: Unconfined compression strength, C: Cohesion, Cu, ϕu: Cohesion and friction angle obtained from direct shear test, σ': effective overburden pressure).

Unconfined compression strength and that failure strain are shown in Figure 7.3.10. Average unconfined compression strength of each layer at whole area is as follows;

Layer 2 : qu=0.3 kgf/cm2, Layer 3 & 4 : qu=0.5 kgf/cm2, Layer 5 : qu = 0.7 kgf/cm2

As shown in Figure 7.3.10, about half of failure strains (strain at peak strength of unconfined compression test) shows more than 7%. It means that about half of samples are disturbed during sampling, transportation and testing process. Therefore strength of half of samples shows the smaller strength than actual in-situ strength. Therefore the above average strength unconfined compression strength (qu) can be estimated to give the minimum or near minimum value of qu.

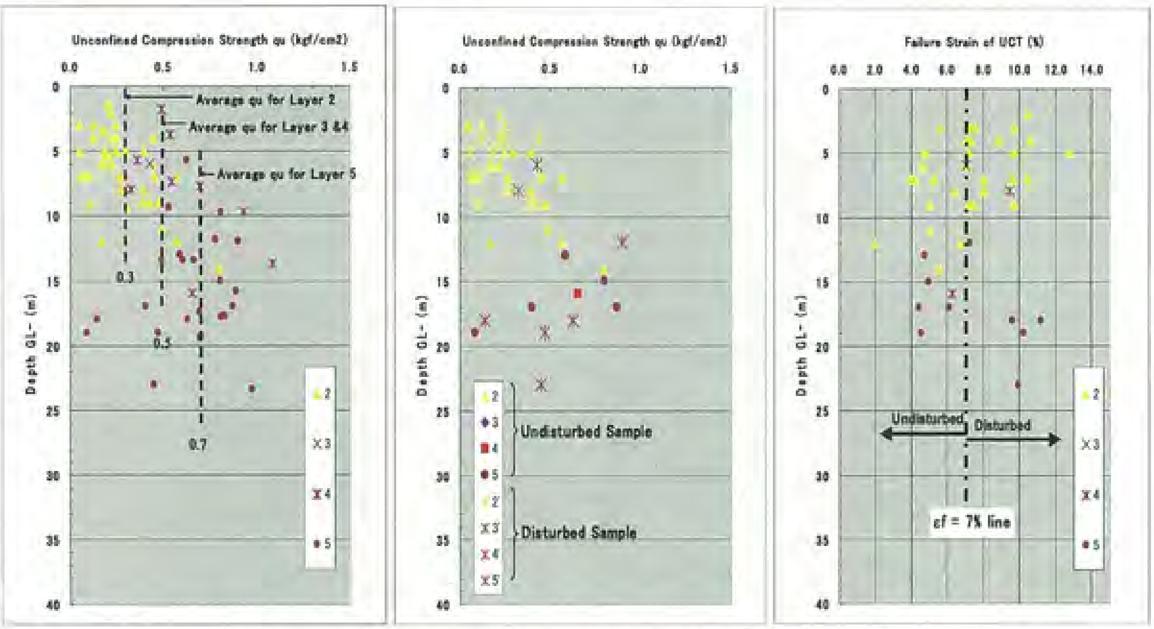


Figure 7.3.10 Unconfined Compression Strength and Failure Strain with Depth (GL: m)

Correlation between qu and SPT N-value are shown in Figure 7.3.11. Plot data are distributed between qu=N/4 line and N/12 line. Usually it is said that qu=N/8 proposed by Terzaghi and Peck (1948) gives minimum line of unconfined compression strength. However about half of plotted points are distributed under qu=N/8 line. From this fact, it can be considered that about half of qu results are underestimated due to disturbance of soil samples.

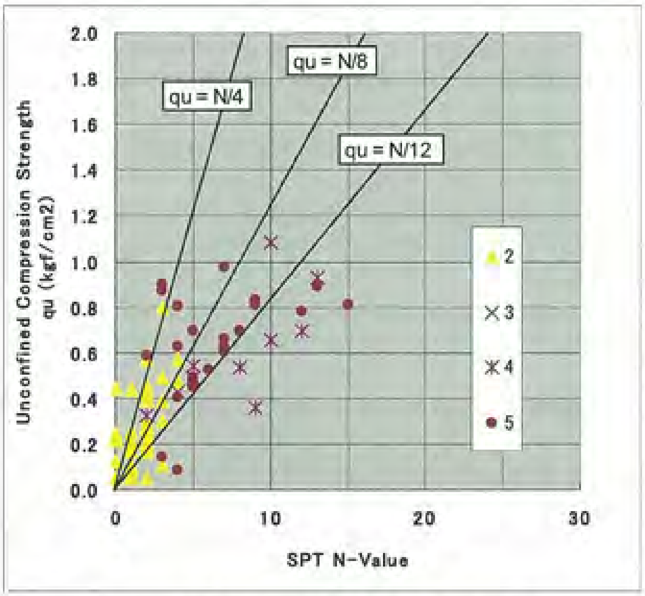


Figure 7.3.11 qu and SPT-N Relation

ii) Increase Rate of Undrained Strength (Cu/P)

From relationship between unconfined strength qu (= Cu/2) and pre-consolidation pressure Pc, increase rate of undrained strength (Cu/P) has been estimated.

As shown in Figure 7.3.12, the plotted data are distributed between Cu/P =0.1 line and 0.4 line in the qu- Pc graph. In case of in organic soil, Cu/P is usually between 0.25 and 0.45. However about half of plots are located below Cu/P=0.2 line. It is also considered that qu values are underestimated due to the disturbance of soil samples.

If the actual Cu/P is assumed as 0.3, as average Cu/P from the plots in Figure 7.3.12 is roughly about 0.2, Unconfined compression strength are roughly about 30 to 40% underestimated by the disturbance of soil samples.

Above estimation is carried out using the unconfined compression test and consolidation test results for Whole Area. About half of data are affected with disturbance and those values are underestimated. Therefore it has not much meaning to distinguish that samples are from Port Area or Off-shore Area.

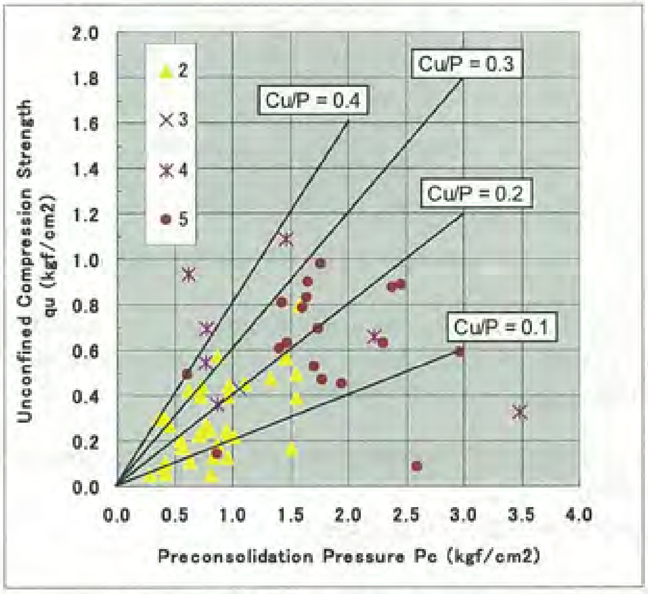


Figure 7.3.12 qu and Pc Relation

iii) Consolidation Characteristics of Cohesive Soil

(a) Preconsolidation Pressure Pc

Preconsolidation pressure Pc is distributing with depth as shown in Figure 7.3.13.

Possible consolidation settlement layers are Layer 2, 3&4 and 5 in the survey area. Remarkable point of these clay layers is that they are over consolidated. Even uppermost Layer 2 is also over-consolidated due to aging effect.

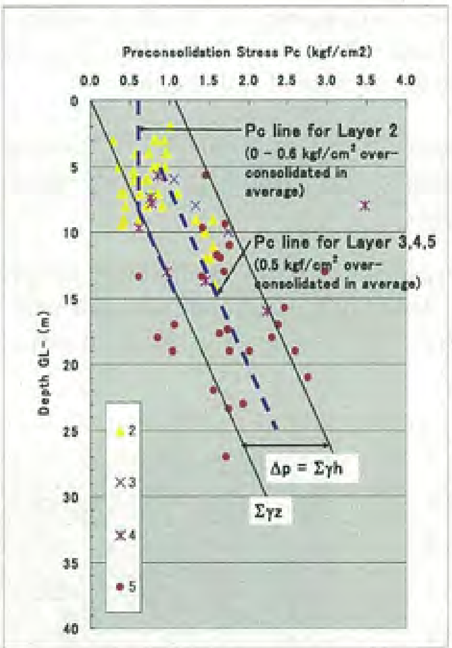


Figure 7.3.13 Pc with Depth (GL)

According to Figure 7.3.14, over consolidation ratio (OCR = σ0'/Pc, σ0'; existing overburden pressure) of above layers are ranging between 1 and 3. In average, the preconsolidation pressure of each layer can be approximately described as follows;

- Layer 2: Pc = 0.6kgf/cm2 (constant from GL 0 to -8m, normally consolidated (Pc = Σγz) deeper than -8m)
- Layer 3&4 and 5: Pc = Σγz + 0.5kgf/cm2

However even though above soil layers are over-consolidated, finally construction load about 1.2 kgf/cm2 will be working on them beyond the average Pc lines as shown in Figure 7.3.13.

Accordingly some extent of consolidation settlement due to above layers will be anticipated.

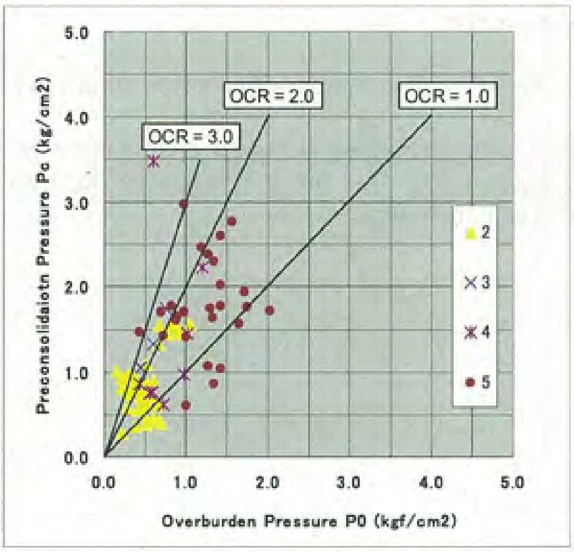


Figure 7.3.14 Pc and P0 Relation

(b) Compression Index Cc and Recompression Index Cr

Compression Index Cc and Recompression Index Cr are distributed with depth as shown in Figure 7.3.15.

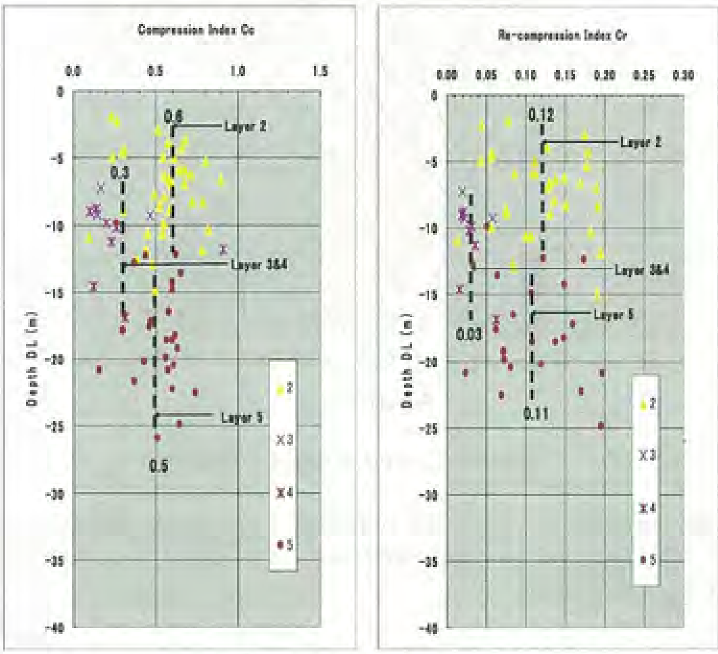


Figure 7.3.15 Cc and Cr with Depth (DL)

According to consolidation test results, the differences of Cc and Cr between Port Area and Off-shore Area are not so much that the average value of them for each layer at Whole Area is described as follows;

- Layer 2 : Cc = 0.6, Cr = 0.12
- Layer 3&4 : Cc = 0.3, Cr = 0.03
- Layer 5 : Cc = 0.5, Cr = 0.11

As shown in Figure 7.3.16, plots of Cr and Cc relation are distributing between Cr/Cc=0.1 and Cr/Cc=0.3. However for the evaluation of Cc, sample disturbance have to be taken into account. Usually Cc value becomes smaller than actual in-situ value when samples are affected by disturbance. Therefore it should be considered that above average value of Cc might give the smaller than actual in-situ one.

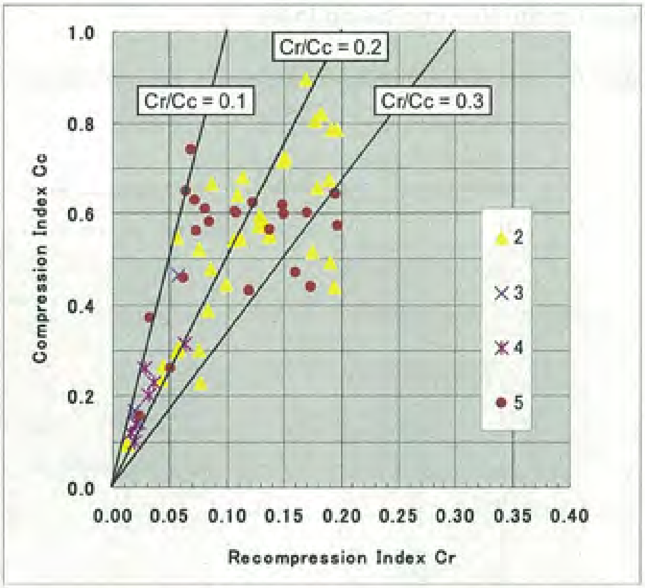


Figure 7.3.16 Cc and Cr Relation

There is a good correlation between Compression Index Cc and Plasticity Index Ip as shown in Figure 7.3.17. The figure shows the correlation Cc = (Ip-5)/55 can be applied for all layers at whole area of this survey area.

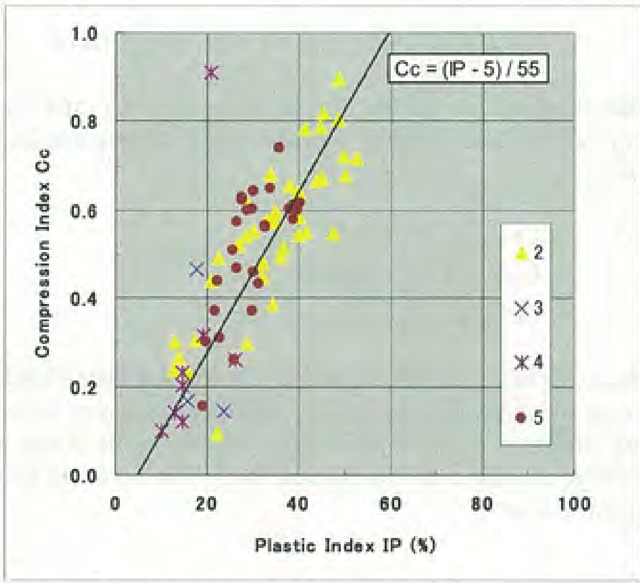


Figure 7.3.17 Cc and IP Relation

(c) Compression Ratio CR and Recompression Ratio RR

Compression Ratio CR and Recompression Ratio RR are generalized values of Cc and Cr transformed by the following formula; CR = Cc/ (1+e0), RR = Cr/ (1+e0).

As shown in Figure 7.3.18 average Value of CR and RR are as follows;

- Layer 2 : CR = 0.23, RR = 0.05
- Layer 3&4 : CR = 0.14, RR = 0.02
- Layer 5 : CR = 0.23, RR = 0.05

CR has some correlations with some index test results, for example, correlations between CR and IP is shown in Figure 7.3.19.

The figure shows the correlation CR = Ip/180 for Layer 2 and CR = IP/120 for Layer 3,4 and 5 under limited number of consolidation test results..

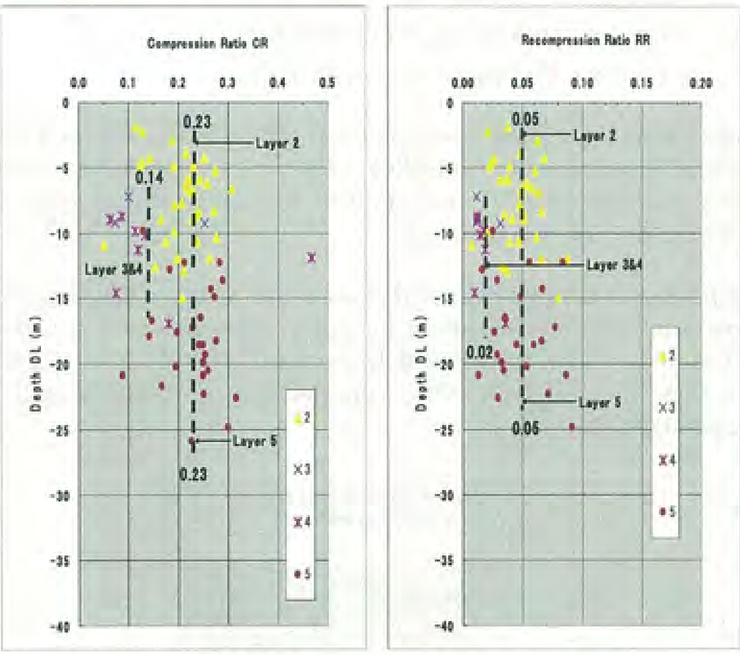


Figure 7.3.18 CR and RR with Depth (DL)

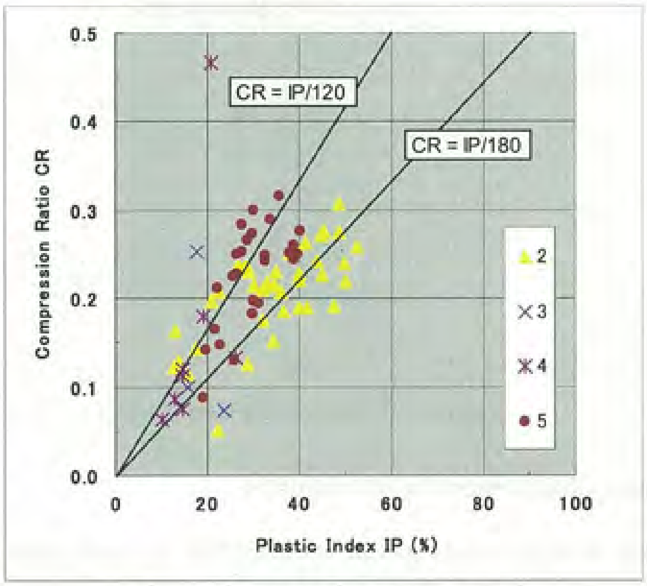


Figure 7.3.19 CR and IP Relation

(d) Coefficient of Consolidation Cv

Coefficient of consolidation Cv is one of the important consolidation factor which shows the speed of consolidation settlement. Cv is also not so much different depending on areas, Port Area and Off-shore Area. In Figure 7.3.20, Cv under load range between 1.0kgf/cm and 2.0kgf/cm2 are plotted with depth.

Average Cv value for each layer is as follows;

- Layer 2 : Cv = 0.6 x 10-3 cm/sec = 52 cm2/day
- Layer 3 : Cv = 2.3 x 10-3 cm/sec = 199 cm2/day
- Layer 4 : Cv = 1.3 x 10-3 cm/sec = 112 cm2/day
- Layer 5 : Cv = 0.8 x 10-3 cm/sec = 69 cm2/day

Above average values are selected based on Cv-Log P lines for each layer. These values look like a little conservative value for consolidation settlement evaluation. However reliability of some data including existing results is not so high that conservative value is considered to be appropriate for the evaluation at this stage.

And also the Layer 3 is actually classified as sand layer (Clayey Sand), however according to the sieve analysis result, which is already mentioned in other clauses, some of samples of this layer have more than 50% of fine content which is classified as silt or clay. Therefore it is better to count Layer 3 as fine soil layer when consolidation settlement should be considered from conservative point of view.

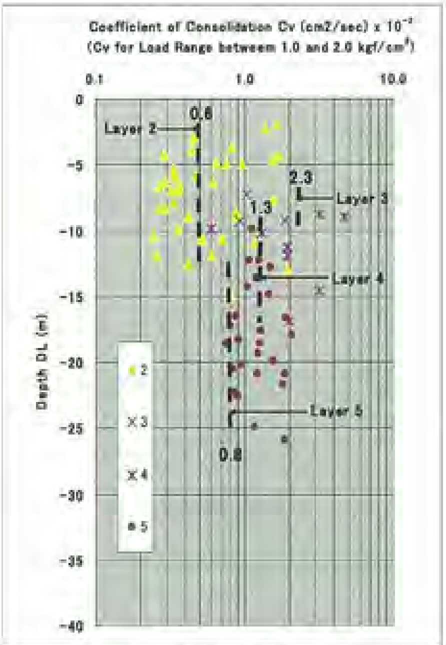


Figure 7.3.20 Cv with Depth (DL)

(d) Rate of Secondary Compression Cα (= Δεv/Δlogt)

In this study and existing investigation results, there has not been carried out any special consolidation tests for the evaluation of Secondary Compression Index Cα.

Therefore the following formula is applied for the evaluation of Cα;

Cα(NC)/ CR = 0.04+ 0.01 (after Ladd et al, 2003)
Adopted here, Cα(NC)/ CR = 0.030

Rate of Secondary Compression Cα obtained from average Cc for each layer and above formula is as follows;

- Layer 2 : Cα(NC) = 0.030 x CR = 0.030 x 0.23 = 0.007
- Layer 3&4 : Cα(NC) = 0.030 x CR = 0.030 x 0.14 =0.004
- Layer 5 : Cα(NC) = 0.030 x CR = 0.030 x 0.23 = 0.007

(e) Correlations between soil parameters

Correlations between soil parameters can be found in some physical and mechanical properties based on this survey and existing survey results as shown in Appendix 7-3. Correlations are summarized and tabulated in Table 7.3.7.

Table 7.3.7 Correlations between soil properties

Soil Properties		Plasticity Index IP (%) =	Liquid Limit LL (%) =	Void Ratio e0 =	Compression Index Cc =	Compression Ratio CR = (Cc/1+e0) =	Coefficient of Consolidation Log Cv = (10-3 cm2/sec)
Wn (%)	Layer 2	7(Wn - 20)/ 8	1.1Wn	2.70Wn/ 100	(Wn - 20)/ 70	(Wn - 10)/ 250	1.0 - 0.2Wn/9
	3,4,5	8(Wn - 10)/ 9	1.1Wn + 8		(Wn - 20)/ 50	(Wn - 10)/ 140	
IP (%)	Layer 2	-	1.5IP + 10	-	(IP - 5)/ 55	IP/ 180	1.0 - IP/30
	3,4,5	-		-		IP/ 120	
LL (%)	Layer 2	-	-	-	(LL - 20)/ 80	(LL - 20)/ 230	
	3,4,5	-	-	-		(LL - 20)/ 140	
e0	Layer 2	-	-	-	-	(e0 - 0.3)/ 6	1.0 - 0.8e0
	3,4,5	-	-	-	-	(e0 - 0.3)/ 4	

(Based on JICA study and existing survey results)

(3) Bed Rock Conditions at survey Area

Bed rock identified in the study area is silt/ clay stone which is highly to moderately weathered, and completely weathered one is identified at only small area within 500m from shore line of south end of Cat Hai Island.

Top level of highly to moderately weathered rock is changing depending on the distance from shore line as follows;

Distance from Shore Line		Top Level of Weathered Rock (DL; m)
0.0 to 1.5 km	Port Area	: 20 m to 35 m
1.5 to 3.0 km		: 30 m to 40 m
3.0 to 5.5 km	Off-shore Area	: 35 m to 40 m
5.5km and more far		: 40m to more than 55m (It could not be identified within investigated depth)

Compression test result of rock core samples is shown in Figure 7.3.21. As shown in this figure, compression strength is ranging from Ru = 50 to 800kgf/cm2 depending on location and weathered conditions. Average compression strength of rock core samples is 350 kgf/cm2.

Bulk density of rock core samples are shown in Figure 7.3.21. Bulk density plots with depth are ranging between 2.4 and 2.7 g/cm3. Average bulk density is 2.60 g/cm3

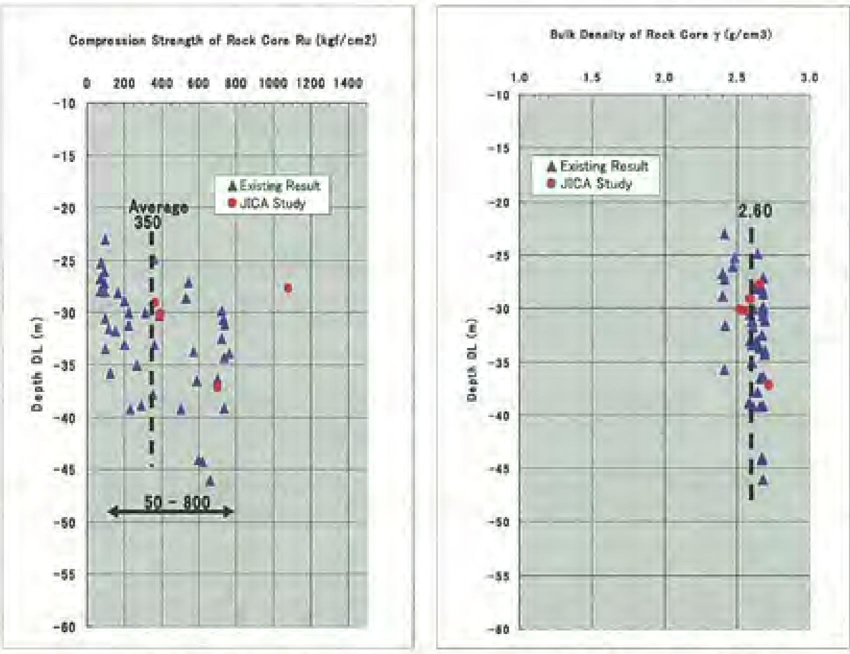


Figure 7.3.21 Ru and γ of Rock Core Sample with Depth (DL)

(4) Trial Calculation of Consolidation Settlement

Soil investigation result shows the cohesive soil layers, Layer 2, 3&4 and 5 are soft and firm layers which are possible layers of occurrence of consolidation settlement by reclamation load in port construction area. They are actually not very soft especially Layer 3&4 and 5 are firm. Layer 2, 3&4 and 5 are slightly to lightly over consolidated with 0 to 6tf/m2, 5tf/m2 and 5tf/m2 respectively. Therefore possibility of settlement should be checked to judge the necessity of soil treatment especially for Layer 3&4 and 5.

In this clause, trial settlement calculations for those layers are carried out assuming some provisional conditions based on soil investigation results and available information. And also calculation model are assumed based on soil investigation results as shown in Figure 7.3.22.

Concept of calculation of consolidation settlement for over-consolidated clay are shown in Figure 7.3.23

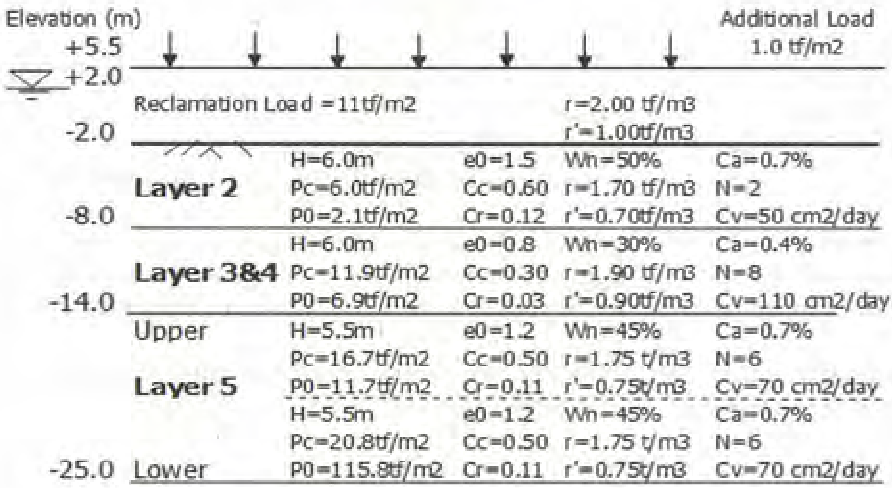
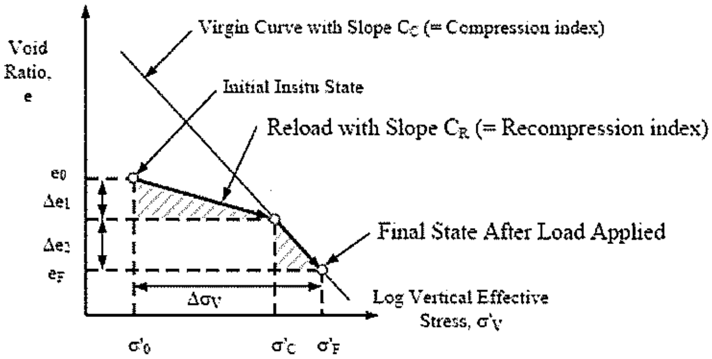


Figure 7.3.22 Model for Consolidation Settlement Calculation



*Total primary consolidation settlement

$$= \frac{C_R H}{1+e_0}\log\left(\frac{\sigma_c'}{\sigma_0'}\right) + \frac{C_c H}{1+e_0}\log\left(\frac{\sigma_0'+\Delta\sigma_v}{\sigma_c'}\right)$$

*Secondary compression

$$= \frac{C\alpha H}{1+e_0}\log\left(\frac{t_f}{t_p}\right)$$

(assumed tf/tp=6)

Figure 7.3.23 Concept of Calculation for Consolidation Settlement

As shown in Table 7.3.8, predicted total settlement by assumed calculation model and reclamation load is 1.4 meters which is consist of primary consolidation settlement 1.31 meters and secondary compression 0.12 meters.

Primary consolidation settlements of Layer 3&4 and Layer 5 are 23cm and 42cm respectively. And it will take more than one hundred years without any soil treatment to complete 90% of consolidation settlement under obtained coefficient of consolidation Cv by consolidation test results.

Settlement caused by Layer 3&4 and 5 is not so small to neglect them. Accordingly some treatment methods to both layers against their consolidation settlement should be considered if allowable residual settlement criteria can not accept those settlements by reclamation load.

Table 7.3.8 Consolidation Settlement Calculation Result

Layer	Primary Consolidation Settlement Sp (m)		Total of Sp by Layer (m)	Total Sp (m)	Secondary Compression Ss (m)	Total Ss (m)	Total Settlement Sp+Ss (m) by Layer	Total Settlement Sf (m)
	Sover	Snorm						
Layer 2	0.131	0.534	0.666	1.314	0.037	0.116	0.698	1.425
Layer 3&4	0.024	0.201	0.225		0.019		0.243	
Layer 5 Upper	0.043	0.190	0.233		0.030		0.263	
Layer 5 Lower	0.033	0.158	0.190		0.030		0.220	

Where, Sp: Primary consolidation settlement, Ss: Secondary compression, Sf: Final Settlement
Note: Above calculation result is based on some assumption on soil parameters, layers and load conditions. Further detailed investigations and calculations are essential to evaluate the consolidation settlement in the detail design stage.

(5) Summary and Comments on Subsoil Conditions

i) Soil Stratification

Typical soil stratification in survey area can be roughly classified by two area, Port Area (within about 3km from shore line of Cat Hai Island) and Off-Shore Area (more than 3km away from shore line) as follows;

Table 7.3.9 Typical Soil Stratification at Survey Area

(a) Port Area (within about 3km from shore line of Cat Hai Island)			(b) Off-Shore Area (more than 3km away from shore line)		
Layer 1	N=5.6	Loose poorly graded Sand (SP)	Layer 1	N=6.0	Loose poorly graded Sand (SP)
Layer 2	N=2.6	Soft fat clay with sand (CH)	Layer 2	N=1.1	Soft fat clay with sand (CH)
Layer 3	N=7.0	Loose- medium dense Clayey Sand (SC)	Layer 3	N=6.1	Loose-medium dense Clayey Sand (SC)
Layer 4	N=10.5	Firm sandy lean clay (CL)	Layer 5	N=5.3	Firm fat clay with sand (CH)
Layer 5	N=6.5	Firm fat clay with sand (CH)	Layer 6	N=14.0	Stiff- very stiff fat clay with sand (CH)
Layer 10	-	Moderately- highly weathered Silt/ Clay Stone	Layer 7	N=17.9	Stiff- very stiff sandy lean clay (CL)
-	-	-	Layer 8	N=50	Very dense poorly graded sand (SP)

N: SPT-N value

ii) Soil Parameters

Differences between soil parameters between Port Area and Off-shore area is not so much as explained the previous clauses. Therefore soil parameters selected as average values for Whole Area based on survey result including existing result are shown as follows;

Table 7.3.10 Soil Parameters Selected in Survey Area

Layer Name	Soil Type	SPT N	Wn (%)	γt (g/cm^3)	Shear Strength			Consolidation						
					Cu (kgf/cm^2)	ϕ' (o)	Cu/p	Cc	Cr	CR	RR	Cα (%)	Pc (kgf/cm^2)	Cv (cm^2/day)
Layer 1	Loose Sand	6	-	1.90	-	30	-	-	-	-	-	-	-	-
Layer 2	Soft Clay	2	50	1.70	0.15	0	0.30	0.6	0.12	0.23	0.05	0.7	0.6	50
Layer 3	Loose Clayey Sand	7	30	1.90	0.25	-	0.25	0.3	0.03	0.14	0.02	0.4	Σγh+0.5	110
Layer 4	Firm Clay	10	30	1.90	0.25	-	0.25	0.3	0.03	0.14	0.02	0.4	Σγh+0.5	110
Layer 5	Firm Clay	6	45	1.75	0.35	-	0.30	0.5	0.11	0.23	0.05	0.7	Σγh+0.5	70
Layer 6	Stiff- very Stiff Clay	14	40	1.80	0.9	-	-	-	-	-	-	-	-	-
Layer 7	Stiff- very Stiff Clay	23	25	2.00	1.4	-	-	-	-	-	-	-	-	-
Layer 8	Very Dense Sand	50	-	2.00	-	35	-	-	-	-	-	-	-	-
Layer 9	Completely Weathered Rock	50	-	2.20	-	35	-	-	-	-	-	-	-	-
Layer10	Moderately-Highly Weathered Rock			2.60	Ru=350 (50-800)	-	-	-	-	-	-	-	-	-

*) Some parameters which are not obtained in the survey are predicted based on the empirical correlations between soil properties.

iii) Consolidation Settlement in Reclamation Area and stability of Revetment

According to the Feasibility Study Report by TEDI, new port will be constructed by reclamation, so that primary consolidation settlement and consecutive secondary compression due to reclamation load on soft cohesive soils is one of important issues to be checked and solved to identify the necessity of soft ground treatment to meet the required construction period.

Soil investigation results show that Layer 2, 3&4 and 5 are soft and firm cohesive soil layer and are possible layers of consolidation settlement. As for Layer 3, sand content varies depending on locations, soils at some places have less than 50% of fine content but it is more than 50% at other places. Therefore from conservative point of views, Layer 3 should also be included as a possible layer for consolidation settlement.

Trial calculation shows that totally about 1.4 m subsidence will occur by reclamation load. If leaving them as it is without any soil treatment, of course, there are high possibilities to give harmful settlement to the structures which are constructed after reclamation work finished.

As for stability of revetment, uppermost soft clay layer (Layer 2) would not be able to support and maintain the stability of revetment. Therefore, based on soil investigation result, stability should be checked to clarify the necessity of soil treatment under revetment.

iv) Reliability of Soil Laboratory Test Result and Future Investigation

According to the survey results including the existing survey results, obtained test values are ranging very wide and more than half numbers of samples are affected by disturbance which is usually suffered during sampling, transportation, preservation and testing process. Therefore accuracy of soil test results of mechanical properties such as unconfined compression strength and consolidation parameters can be estimated as not high. It means the parameters selected this time may give conservative value (underestimated value) for shear strength and overestimated value for consolidation properties. This point is very important for design work to select the proper countermeasures against soft ground.

The number of borings is still not enough to cover all necessary reclamation area especially for exact locations of structures constructed after or during reclamation work. Therefore additional soil (boring investigation) will be necessary in the next stage. Especially, identification of in-situ actual shear strength of soft cohesive soil is important for proper economical structural design by applying in-situ tests such as CPTU (Cone Penetrometer Test with pore pressure measurement) and on-site vane share test, etc. to decrease the disturbance effect as much as possible.

The ground conditions are usually changing gradually and suddenly depending on locations therefore deviations of soil parameters between investigated points and uninvestigated points can not be avoided up to some extent. This deviation of design parameters should be solved and modified by monitoring the ground settlement and deformation during construction stage.

3) Seabed Material Sampling

a) Location and co-ordinates of seabed material sampling

Seabed material sampling has been carried out from 10th to 15th November 2009 at 80 locations as shown in the Figure 7.3.24. And those samples were sent to laboratory for chemical tests and physical property tests of soil.

b) Quantities of Seabed material sampling and Laboratory tests

Totally 80 Nos. of samples has been sent to laboratory to carry out the following tests;

- Chemical Test
  Organic Substance, COD, Copper, Cadmium, Arsenic, Chromium, Lead, Nickel, Zinc, Iron, Mercury, Manganese, Cyanides, Sulphate, Total Oil
- Physical Property Test
  Specific Gravity, Natural Moisture Content, Sieve Analysis, Atterberg Limit

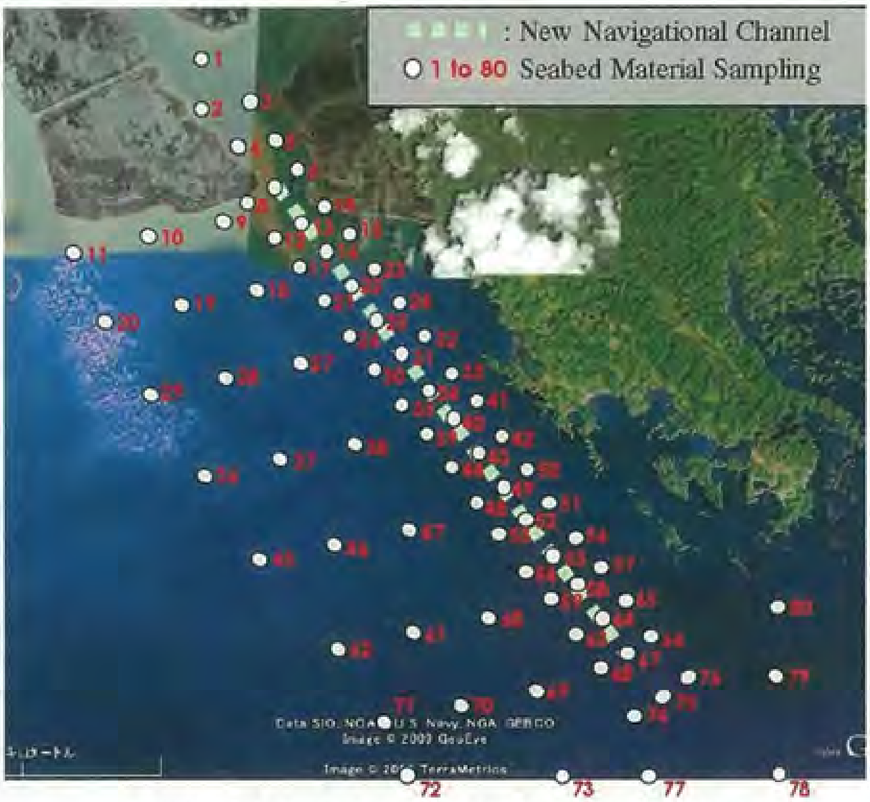


Figure 7.3.24 Location of Seabed Material Sampling

c) Laboratory Test Result

Chemical test and physical property test results are tabulated and each value at each sampling point is presented as graph chart in Appendix 7-4. Chemical content of seabed material surveyed this time are ranging as shown in Table 7.3.11. And also physical property values of seabed material surveyed this time are ranging as shown in Table 7.3.12.Among 80 samples, samples classified into sand or silty/clayey sand are only 10 samples.

Table 7.3.11 Chemical Test Result of Seabed Material

Item			Minimum	Maximum	Average (mg/kg dry)
Copper	Cu	:	5.39	69.06	22.96
Lead	Pb	:	15.89	95.46	49.56
Zinc	Zin	:	35.69	249.35	106.41
Cadmium	Cd	:	0.12	1.86	0.75
Arsenic	As	:	0.51	6.38	1.88
Mercury	Hg	:	0.13	1.47	0.45
Chromium	Cr	:	19.11	89.31	52.47
Nickel	Ni	:	10.00	52.90	29.03
Organic Substance		:	556	13,677	5,439
COD		:	432	4,301	2,195
Cyanide	CN	:	0.03	0.32	0.19
Total Oil		:	9.98	499.82	64.57
Sulphate	SO_4^{2-}	:	258	8,880	4,437
Iron II	Fe^{2+}	:	0.05	0.48	0.24
Iron III	Fe^{3+}	:	0.09	1.24	0.49
Manganese	Mn		0.00	0.07	0.02

Table 7.3.12 Physical Property Test Result of Seabed Material

Item			Minimum	Maximum	Average
Specific Gravity	Gs	:	2.65	2.71	2.68
Natural Moisture Content	Wn (%)	:	33.29	99.50	78.73
Fine Content	Fc (%)	:	0.81	99.82	77.51
Liquid Limit	LL (%)	:	23.62	73.54	46.65
Plastic Limit	PL (%)		2.63	29.51	22.12
Plastic Index	PI (%)		4.54	44.77	24.13

d) Seabed Sand Distribution

Sand distribution at seabed surface in this survey site based on this seabed material sampling result (carried out November, 2009), existing result (carried out by Nippon Koei, August, 2009) and boring investigation results are shown in Figure 7.3.25.

Surface sand is distributed at mainly west side of existing navigation channel with its width of 1km and length of 10km. According to boring investigation results, surface sand layer's thickness is ranging approximately between 0.5 meters and 5 meters with its average of about 2meters.

Shoal shallower than DL 0.0 meter distributed in 3km long from shore line of Cat Hai Island with 500 meter to 800 meter width is covered by sand distribution area as shown in Figure 7.3.25.

e) Physical Property of Seabed Materials along the Existing Navigation Channel

Physical property test result of seabed samples taken along the existing navigation channel is shown in Figure 7.3.26. In this graphs, existing data of boring (KL1 to KL12 carried out by TEDI in 2005) are included together with another existing data (carried out by Nippon Koei in August 2009).

According to Figure 7.3.26, physical properties of two data which were sampled in the same year by JICA Study this time and by Nippon Koei, shows almost similar tendency along the navigation channel. Two data shows clay or silt properties between 31km and 36 km chainage of navigation channel, but KL series data shows physical properties of sand. This is because most of sample of KL series were taken at deeper than 2meters, they were not taken at seabed surface. Therefore there might be some differences for KL series data from above two data.

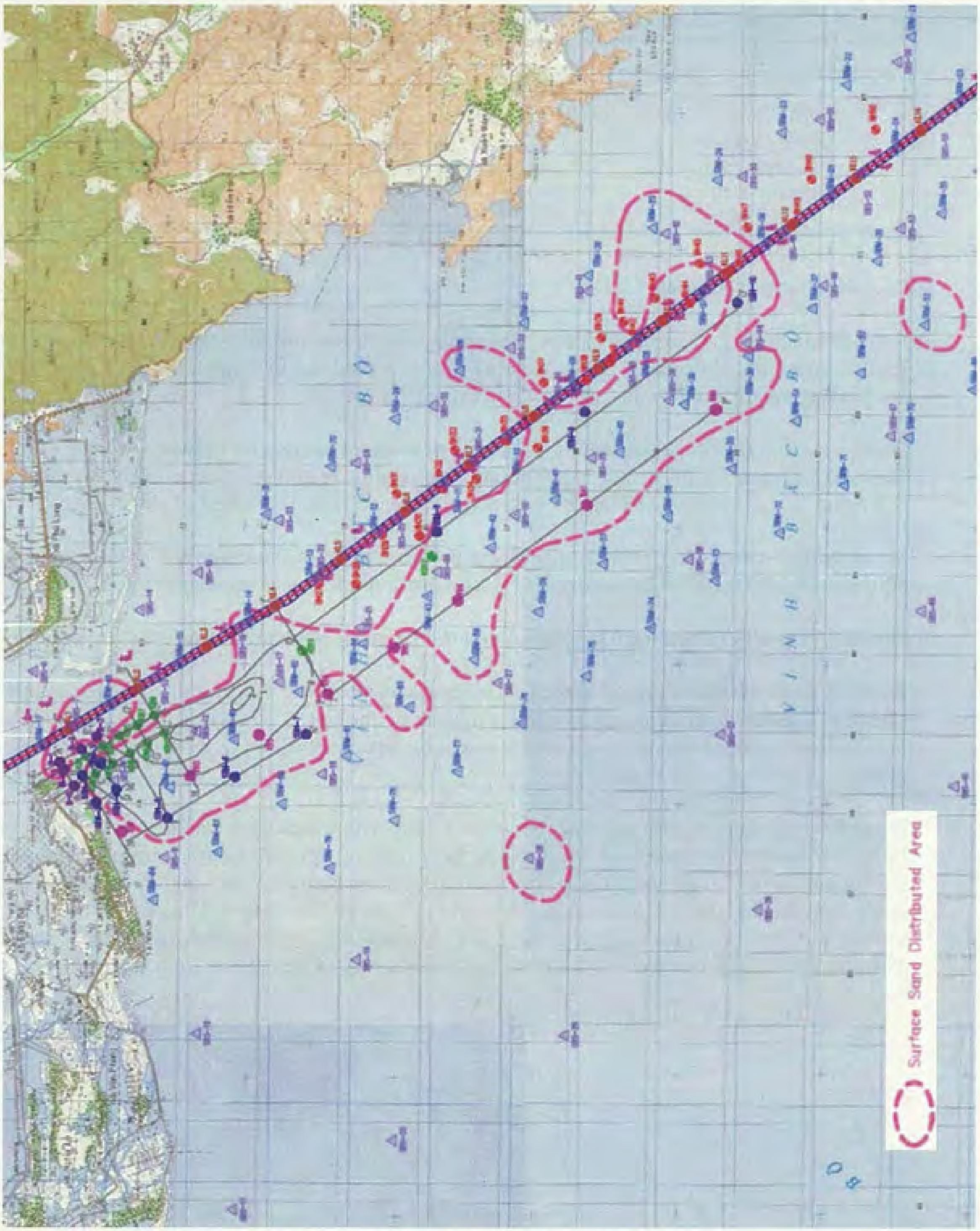


Figure 7.3.25 Surface Sand Distributed Area

(SBS: JICA Study in November, 2009, KL1-KL12: by TEDI in 2005, SBM: by Nippon Koei in August, 2009)

Figure 7.3.26 Physical Property Test Result of Seabed Material along the Navigation Channel

7.3.2 Hydrographic Surveys

1) Bathymetric Survey

a) Location of Bathymetric Surveys

The survey area is located along existing navigation channel from station Km26+000 to station Km47+000 with the width of 500m offset to both side from the center line of the existing navigation channel. (Refer to Figure 7.3.27)

Bathymetric survey has been carried out with two kinds of frequencies of echo, high (200 kHz) and low (30 kHz), to identify the fluid mud thickness on the seabed from 8th November to 19th November 2009.

Figure 7.3.27 Location of Bathymetric Survey Area

b) Quantities of Bathymetric Surveys

Bathymetric surveys have been carried out totally 420 km long with 1km long per section in every 50 m interval, which is perpendicular to navigation channel.

c) Bathymetric Survey Result

Seabed contour maps by dual frequency sounding are shown in Figure 7.3.28 and in Appendix 7-5.

Along the survey area, the depth is deeper from beginning of survey area (Km26+000) seaward, the lowest surveyed elevation is 17.8m below Chart Datum (-17.8m CD) at the end of survey area (Km47+000). All survey results are shown in Appendix 7-5.

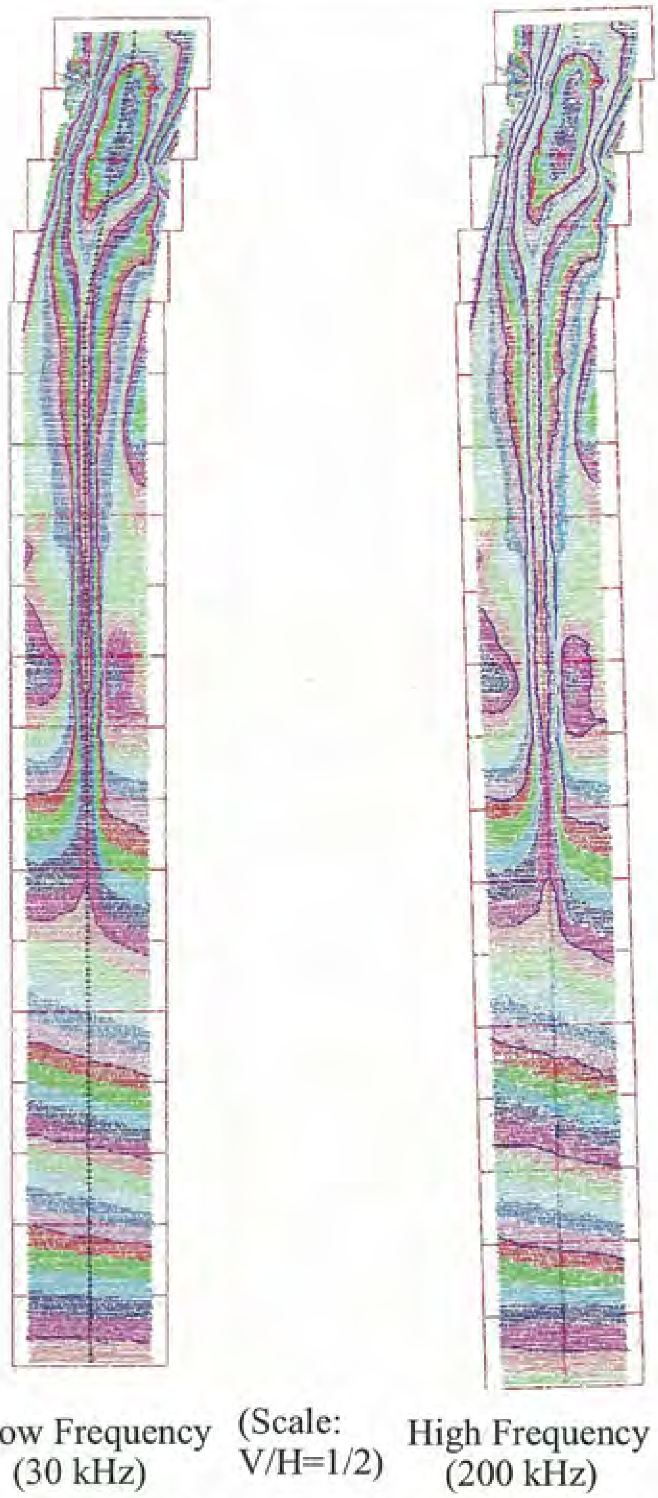


Figure 7.3.28 Bathymetric Survey Result with Echo of Dual Frequencies

As shown in Figure 7.3.29, along the navigation channel, clear dredging traces have been identified between Km 26+000 and Km 39+500.

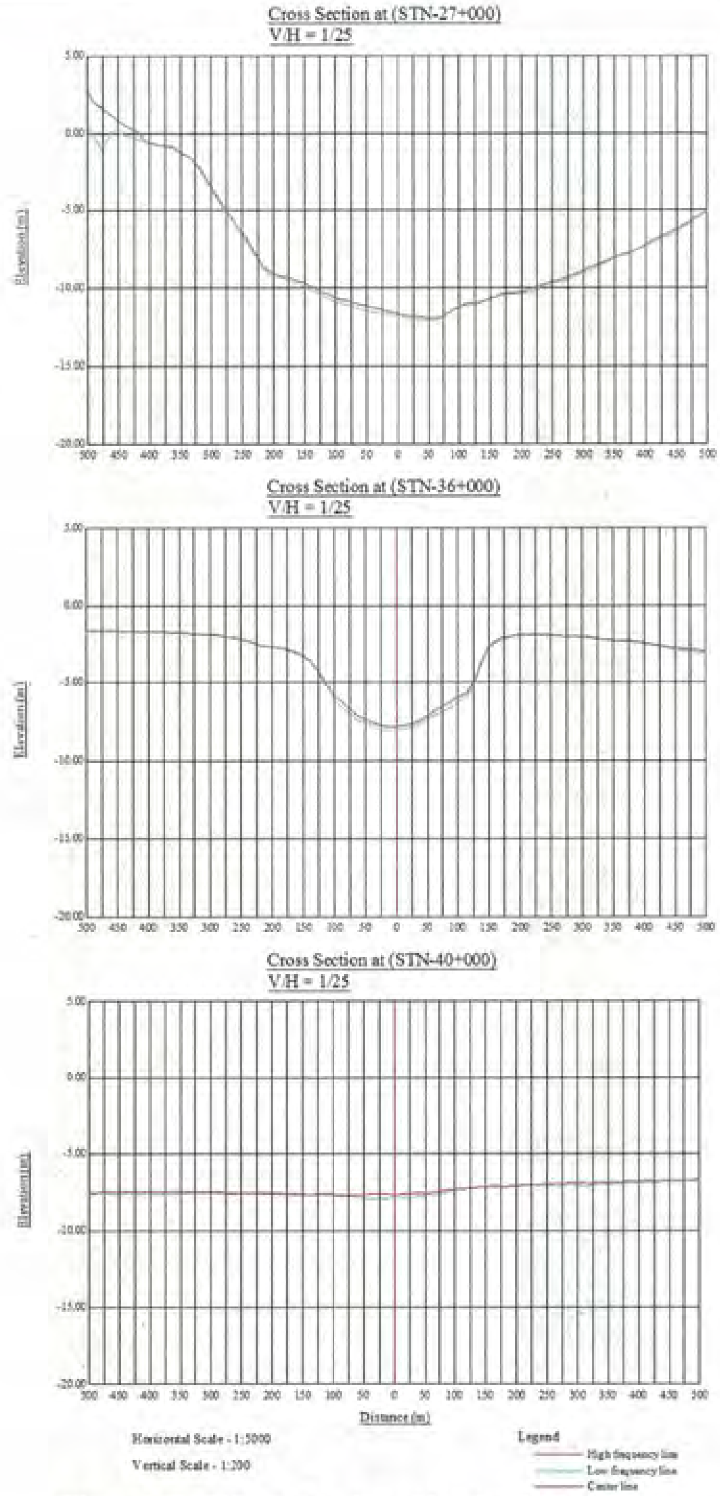


Figure 7.3.29 Cross Section of Navigation Channel

As shown in Figure 7.3.30, between Km 26+500 and Km 28+600 where tidal flow rate is higher than other sections due to narrow water flow area between Cat Ba and Cat Hai Island, seabed level along the navigation channel becomes between -12m and -10m CD which is much deeper than other sections. Then from Km 29+500 to Km 39+500, seabed level becomes constant with about -7m to -8m CD. Then from Km 39 +500, seabed level is gradually getting deeper then finally it reaches -17.8m CD at Km 47+000.

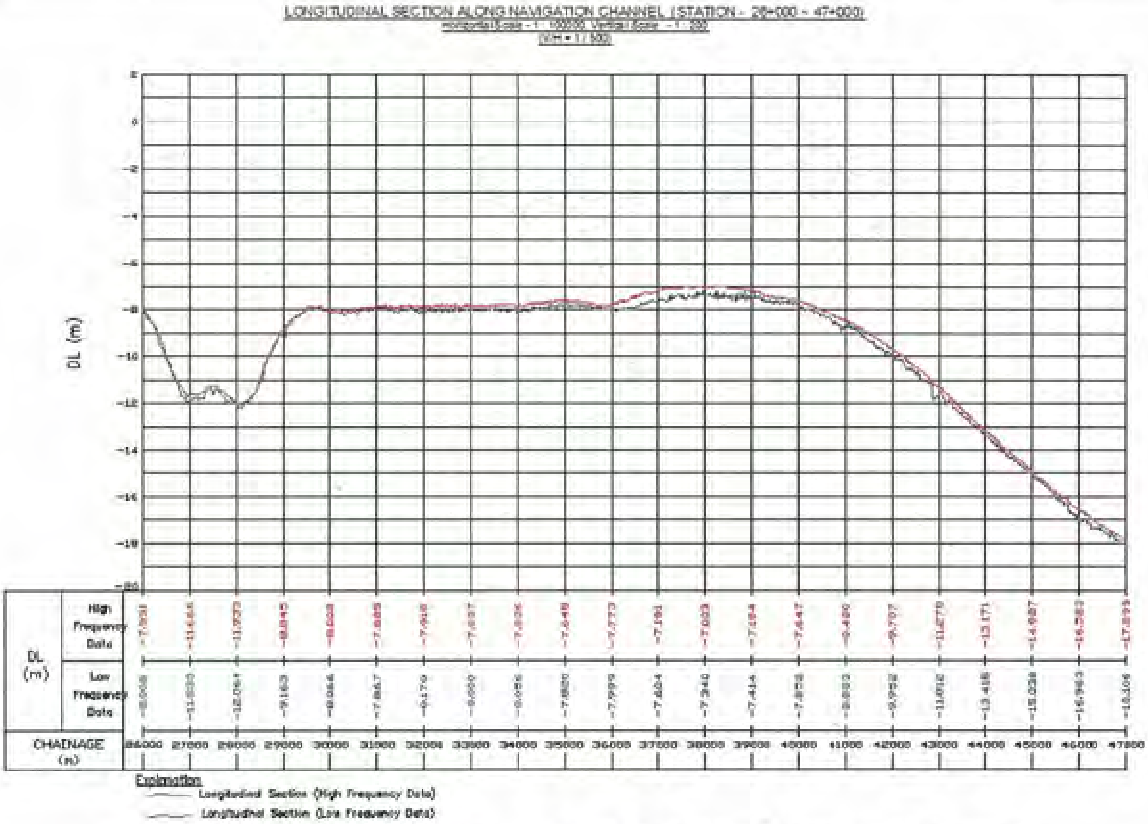


Figure 7.3.30 Longitudinal Section along the Existing Navigation Channel

According to dual frequency sounding (200 kHz and 30 kHz) survey result shown in Figure 7.3.31, fluid mud can be seen at almost whole bathymetric survey area. At Km 27+000 and from Km 32+000 to Km 41+300 km, existence of fluid mud, thickness of which is about from 20cm to 50cm, can be recognized continuously only along the center of navigation channel, then from Km 41+300 to Km 44+800, about 10cm to 50cm of fluid mud can be seen continuously at whole survey range, then from Km 44+800 to 45+800, thickness of fluid mud changes to less than 20cm at whole survey range in 1 km width, finally from Km 45+800 to Km 47+000, 10cm to 40cm thick fluid mud can be seen at whole survey range in 1km width. Between Km 34+000 and Km 39+500, no fluid mud area can be recognized remarkably.

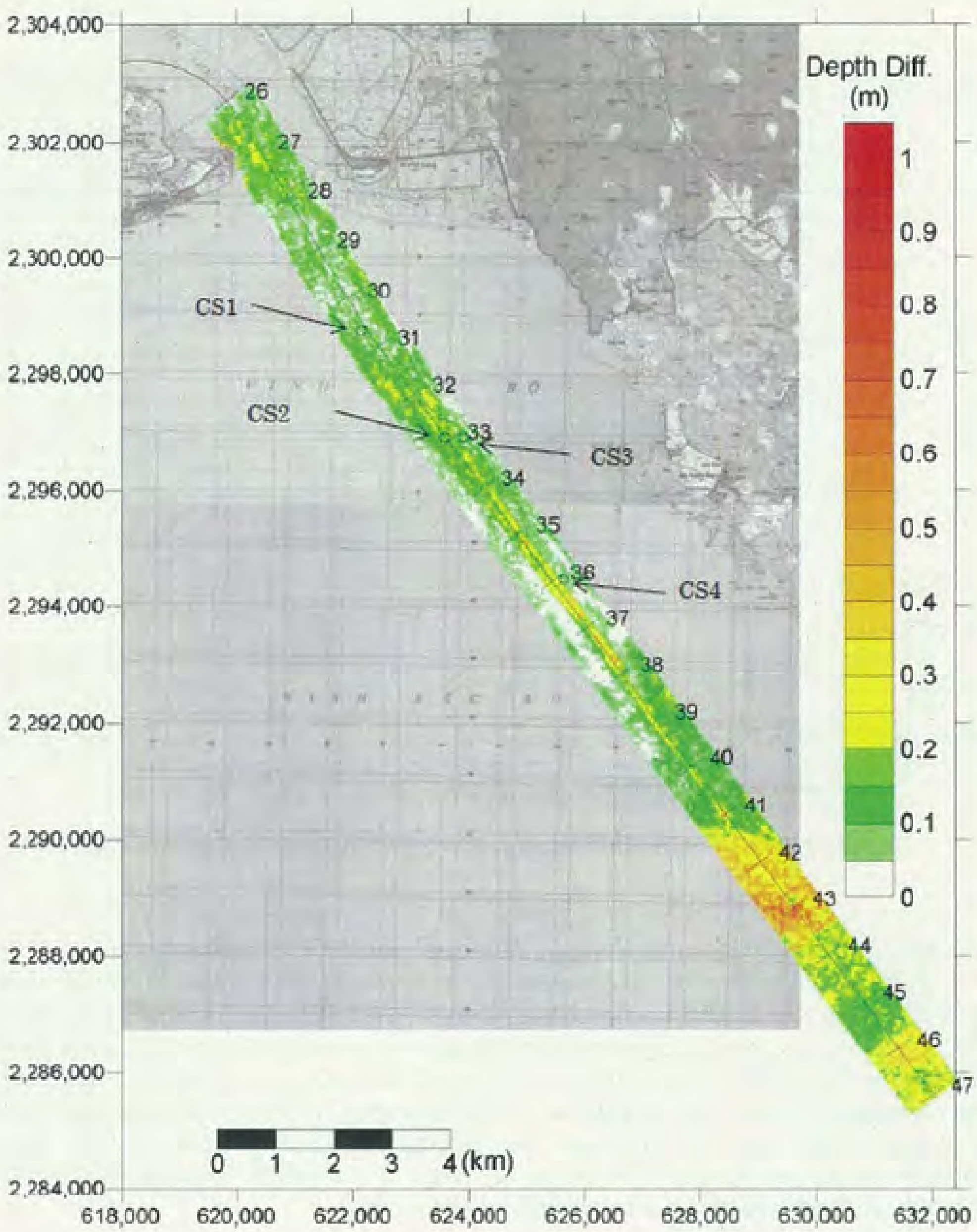


Figure 7.3.31 Depth Difference by Dual Frequency Sounding

2) Tidal Observation

a) Location and duration of tidal observation

In order to obtain the data for the design and engineering of the proposed port facilities, dredging of the channel and basin of the Lach Huyen Port Infrastructure construction, tidal observation has been carried out at Ben Got Jetty (E = 619886 m, N = 2301917 m, VN2000, CM 105045', Zone 30) in Cat Hai Island with observation period for 15 consecutive days from 11h30' 7th November to 15h50' 22nd November 2009.

b) Tidal observation result

The tidal observation result is shown in Figure 7.3.32. The water levels were also collected at

Hon Dau National Hydrographic Station in the same time as water levels observed at Ben Got. Based on water level collected at Hon Dau station (Chart datum) and water level observed at Ben Got-Lach Huyen station (Local Chart datum) from 12h 7th November to 15h 22nd November 2009, two data are compared as shown in the following figure.

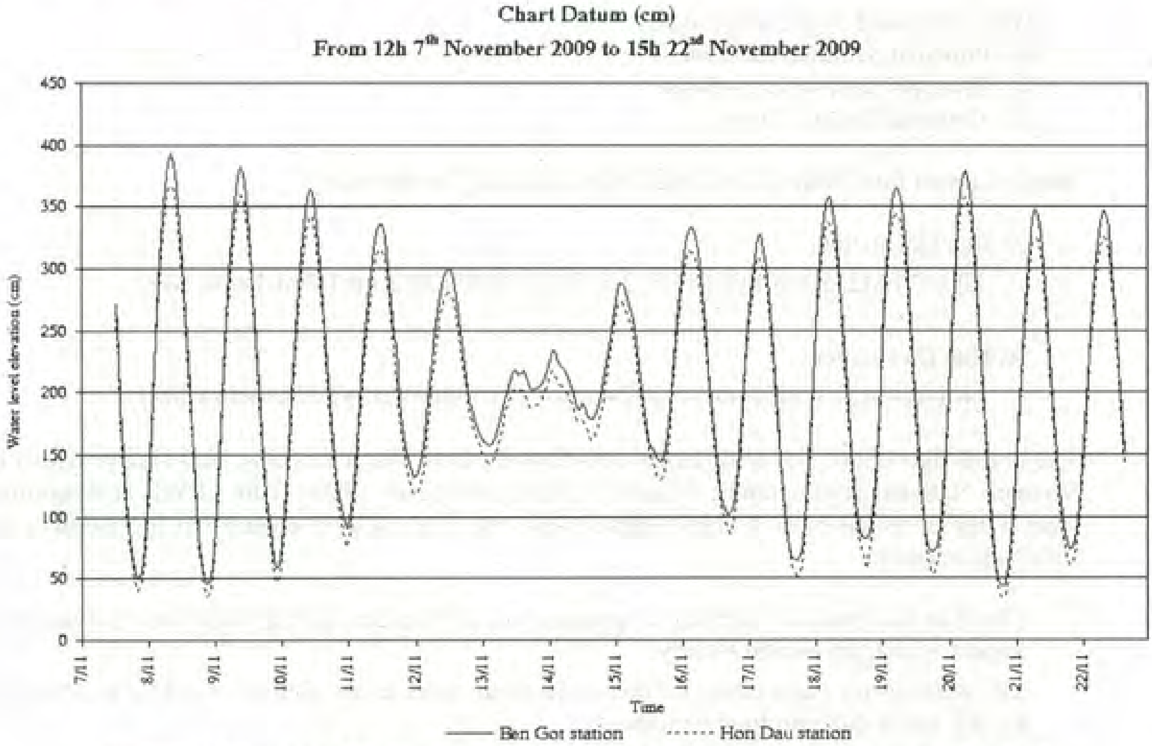


Figure 7.3.32 Tidal Observation Result (7th to 22nd Nov. 2009 at Ben Got Jetty)

The correlative equation is determined as following:

- H Ben Got = 1.024 x H Hon Dau + 7.948 (cm)
- Correlative coefficient R = 0.999

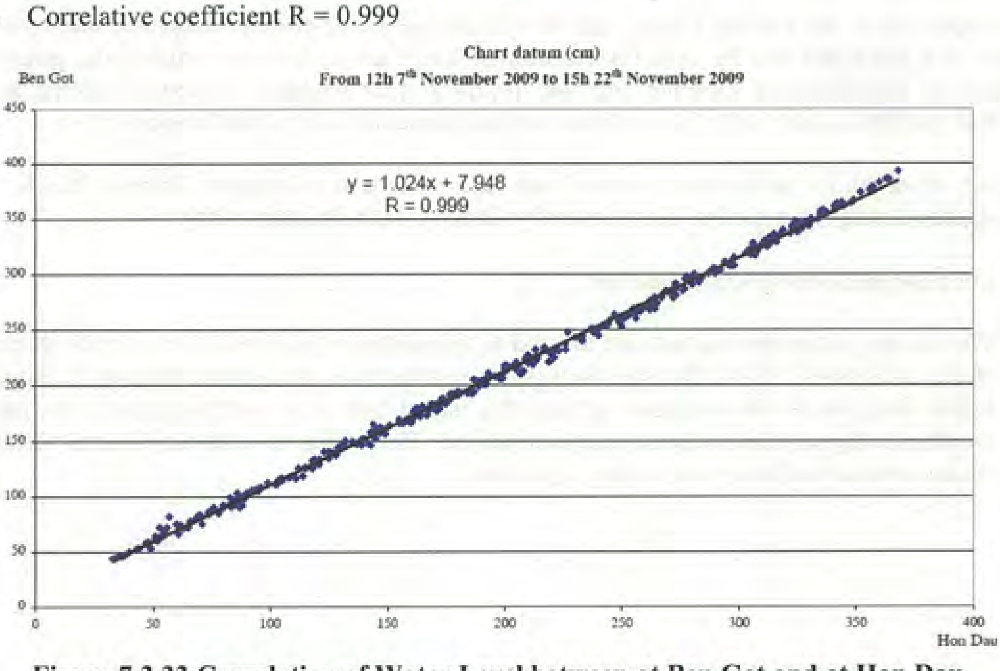


Figure 7.3.33 Correlation of Water Level between at Ben Got and at Hon Dau

c) Harmonic analysis result

Based on the tide observation records, harmonic analysis of tide has been executed and tidal constituents were calculated for the major four (4) constituents of tide including:

M2 - Principal Semidiurnal Lunar.
S2- Principal Semidiurnal Solar.
K1- Principal Diurnal Luni-Solar.
O1- Principal Diurnal Lunar.

Nearly Lowest Low Water Level (NLLW) is calculated as following:

- At Ben Got station:
  NLLW=M2+S2+K1+O1=6.5+2.5+82.6+78.6=170.2cm=1.70m below MSL

- At Hon Dau station:
  NLLW=M2+S2+K1+O1=5.3+2.4+80.4+76.9=165.0cm=1.65m below MSL

The above figures are a little different from Lowest Low Water Level at Hon Dau provided by Vietnam National Hydrographic Center (V.N.H.C) being of 1.86m. This LLWL is determined from water levels observed in many years at Hon Dau. The small difference may be caused by the following reasons:

- The Hon Dau station is located at open sea area of Hon Dau Island, while Ben Got station is located near Lach Huyen estuary.
- The water levels observation for this project and water levels used by V.N.H.C to determine LLWL are in different time periods.
- Short time of water level observation for this project (only 15 days)

7.3.3 Current Observations

1) Current Measurement

The objectives of the Current Survey are to measure the water current velocities, and to present the results in a form that can be used for the design. The Current Survey included the processing and analysis of the measured currents and tide levels at four locations; vector harmonic analysis to establish the tidal component of the currents and assessment of the no tidal residuals.

Current observations have been carried out using Acoustic Doppler Current Profiler (ADCP) instruments during the period of 10th November 2009 to 11th December 2009.

a) Location of Current Observations

The current observation points are located to the southwest of the Cat Ba islands Haiphong City (Refer to Figure 7.3.34). The site itself is the existing main navigation channel to Haiphong Port which lies just to the southeast of Cat Hai island and it is well protected from adverse sea conditions during the northeast monsoon period. The waters around the general vicinity of the access channel are busy with fishing activities.

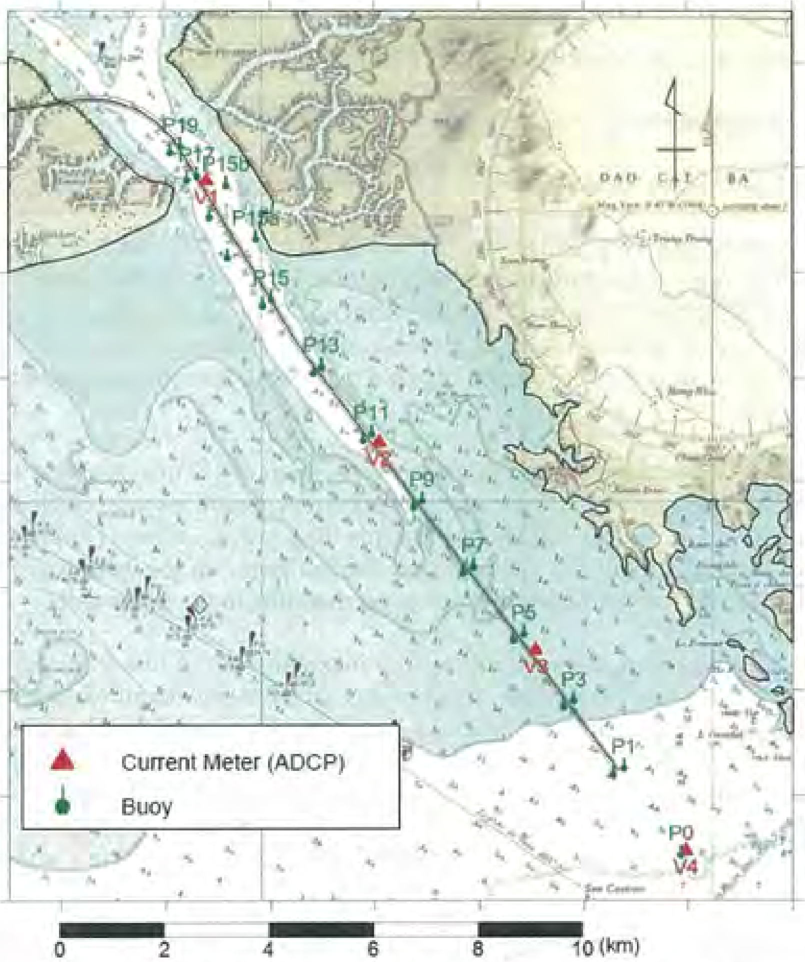


Figure 7.3.34 Locations of Current Observation Points

Table 7.3.13 Co-ordinates and Depth of Current Observation Points

Coordinate System : VN2000-105° 45'

East	North	Name	Depth m CD
620585	2301881	V1	-9.77 m CD
623743	2297059	V2	-3.83 m CD
626820	2292833	V3	-4.56 m CD
629550	2288929	V4	-10.66 m CD

b) Quantities of Current Observations

Current observations have been carried out at four locations during consecutive 30 days with 10 minutes interval.

Table 7.3.14 Principle Recording Parameters

Instrument	V1	V2	V3	V4
Operating Frequency	600 kHz	1,200 kHz	1,200 kHz	600 kHz
Recording Interval	10 minutes	10 minutes	10 minutes	10 minutes
Instrument Level	- 9.77 m CD	-3.83 m CD	-4.56 m CD	-10.66 m CD
Deployment Period	10th November - 11th December 2009	10th November - 11th December 2009	10th November - 11th December 2009	10th November - 11th December 2009

c) Result of Current Observations

(1) Presentation of Current Velocity Results

Current velocity vectors have been presented in Appendix 7-6.

(2) Description of Current Velocity Results

The V1 location has very strong current speeds up to a maximum of 1.8 m/s. Currents are constrained to flow within the channel between Cat Hai and Cat Ba islands, north-northwest on flood tides and ebbing towards the south-southeast. Around the times of low waters and high waters, the current speed reduces to close to zero. A rotation in the vectors was quite often observed, but the direction of rotation was not consistent: sometimes clockwise and other times anticlockwise.

Currents at the V2 location are strong, up to a maximum of 1.0 m/s on spring tides, though this is noticeably weaker than the V1 location. The current directions are much the same: flooding towards the north-northwest and ebbing towards the south-southeast. During neap tides, there is significant stratification of the currents (e.g. around noon on the 14th November, currents are ebbing in the upper half of the water column, but flooding in the lower half).

At the V3 location, current speeds are up to a maximum of 0.6 m/s at the sea surface on spring tides, up to 0.4 m/s near the seabed. This continues the progression of weaker currents away from the V1 location. Currents are very weak on neap tides, for example seldom faster than 0.1 m/s on 28th November. At the time of low water on spring tides, there was a reasonably well-developed anticlockwise rotation, with the rotation phased with depth (e.g. 17:00 – 20:00 3rd December).

Currents were very weak at the V4 location, mostly less than 0.1 m/s and only occasionally reaching 0.15 m/s.

(3) Wind-Driven Near-Surface Current Velocities

At all four locations, the top velocity vectors were often stronger than those immediately below, and they flowed towards the south-southwest. This is interpreted as caused by the effect of the dominant wind from the north east quadrant at this time of year.

(4) Comparison of Tidal and Non-Tidal Currents

There are usually a number of drivers of seawater currents. These include tidal gradients; density imbalances; winds blowing across the sea surface; Coriolis effects; and a number of usually smaller contributors. The relative importance varies with location and (often) with the season. Inspection of the current vectors and water surface levels as shown in Appendix 7-6 indicate that the tidal gradient was the main driver of the currents during this survey period. This section of the report quantifies this dominance.

The percentage values for all four locations and the selected water depths are tabulated below:

Table 7.3.15 Proportion of Currents Attributable to Tidal Forces

Vertical	V1	V2	V3	V4
Surface Currents	82.7%	79.9%	63.8%	47.6%
Mid-Depth Currents	83.5%	79.5%	63.6%	56.5%
Bottom Currents	80.2%	77.1%	59.3%	59.6%

It can be seen that the effects of the tide are most dominant at the V1 location (>80%) and decreases consistently towards the V4 location.

(5) Comparison of Tidal and Non-Tidal Drift Over Many Tidal Cycles

The mean velocities are tabulated below, presented as speed (cm/s) and direction (degrees clockwise from due north):

Table 7.3.16 Mean Measured Current Velocity Over Whole Recording Period

Vertical	V1		V2		V3		V4	
Surface Currents (cm/s & °)	8.9	123°	9.0	141°	2.9	142°	6.5	249°
Mid-Depth Currents (cm/s & °)	1.7	043°	4.5	135°	4.7	077°	4.0	050°
Bottom Currents (cm/s & °)	1.5	330°	1.3	181°	3.8	040°	3.8	046°

Much the strongest drift was in near-surface currents at the V1 and V2 locations, both towards the south east quadrant. By averaging over many tide cycles, this is a measure of the net near-surface flow towards the south east. The mean speeds at mid-depth and near the seabed were much smaller, showing a more balanced flow between flood and ebb tides. At the V3 location, there were gentle mean flows towards the south east (surface), east (mid-depth) and north east (bottom). At the V4 position, the mean surface current was gently towards the west south west; compared to east north east for the mid-depth and bottom currents.

(6) Residual Current Drift Over Many Tidal Cycles

The mean residual current velocities are tabulated below:

Table 7.3.17 Mean Residual Current Velocity Over Whole Recording Period

Vertical	V1		V2		V3		V4	
Surface Currents (cm/s & °)	0.86	335°	0.20	151°	0.15	248°	0.15	277°
Mid-Depth Currents (cm/s & °)	0.38	347°	0.23	220°	0.30	236°	0.43	263°
Bottom Currents (cm/s & °)	0.29	327°	0.20	227°	0.11	264°	0.20	263°

The net non-tidal drift at the V1 location was weak but consistently north north-west. This is interpreted tentatively as a minor density current replenishing salt up the channel.

The net non-tidal drift at the other three locations was also weak, mostly towards the south west. This is interpreted as the effect of winds blowing from the north east quadrant at this time of year.

(7) Comments

Tide levels are strongly diurnal. This area is an amphidromic zone for semidiurnal constituents. The measurements have confirmed very strong currents flow along the channel between Cat Hai and Cat Ba islands, up to 1.8 m/s at the V1 measurement location. Maximum current speeds decrease progressively along the line to the V4 measurement location.

Only minor stratification of currents was observed. Often the currents turned at the same time at all levels within the water column, indicating a reasonably well-mixed density structure at this time of year.

The currents were driven dominantly by the tides. The contribution of non-tidal current drivers (wind, density imbalance etc) was small compared to the currents caused by the tide.

2) Cylinder Sampling

a) Location of Cylinder Sampling Points and Quantities

To obtain the information of sedimentation along the navigation channel, Cylinder Sampling has been carried out on 11th November, 2009. The details of this works are as follows;

- Sampling at 04 locations: CS1, CS2, CS3, CS4 with cylinder sampling method (Refer to Figure 7.3.35). Detailed actual quantity of the field work is presented in Table 7.3.18.
- Laboratory testing was performed to characterize and assess the pertinent engineering properties of the on-site soils. Laboratory testing includes grain size analysis by sieving and hydrometer, water content, Atterberg limits, specific gravity. Detailed actual quantity of the laboratory test is presented in Table 7.3.19.

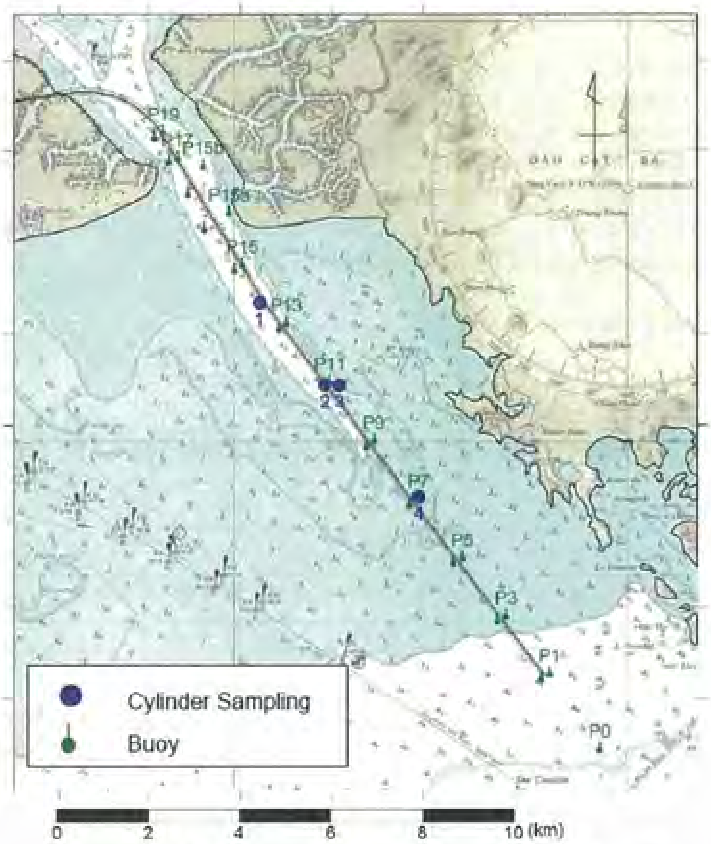


Figure 7.3.35 Location of Cylinder Sampling Points

Table 7.3.18 Quantities of Cylinder Sampling (Field Work)

No.	Location	Number of samples taken	Remarks
1	CS1	02	01 Upper, 01 Lower
2	CS2	02	01 Upper, 01 Lower
3	CS3	01	01Upper
4	CS4	02	01 Upper, 01 Lower
Total		07	

Table 7.3.19 Quantities of Cylinder Sampling (Laboratory Testing)

No.	Property/Test	Unit	Total
1	Water content	No	06
2	Specific gravity	No	07
3	Atterberg Limits	No	06
4	Grain Size Analysis by sieving	No	07
5	Grain Size Analysis by Hydrometer	No	06

Co-ordinates of the sampling points are listed in Table 7.3.20. Their locations are shown in investigation location plan as shown in Figure 7.3.35.

Table 7.3.20 Co-ordinates and elevation of the Cylinder Sampling points

No.	Borehole	Actual Coordinates (m) - VN2000		Remarks
		Northing	Easting	
1	SBH1	2298722	622166	Offshore
2	SBH2	2296913	623581	"
3	SBH3	2294475	625636	"
4	SBH4	2296909	623901	"

b) Equipment & sampling method

- Equipment

  Using a transparent acryl cylinder. Basic dimensions are as follows:

  Length : 1250mm;
  Inner diameter : 63mm;
  Weight (including 02 caps): 785g.

  One diver team with all necessary equipment (ship, air compressor, diver's instrument) was used.

- Sampling method

  Cylinder sampling was conducted manually with transparent acryl cylinder by a diver in the water as in the following figure:

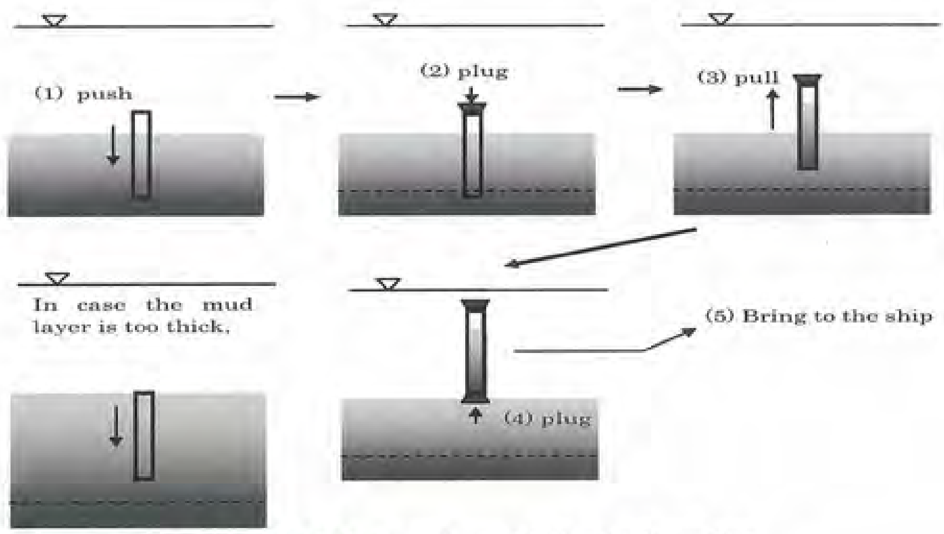


Figure 7.3.36 Procedure of Cylinder Sampling

c) Result of Laboratory Tests (Physical Property of Soil)

Laboratory test results of soil samples obtained by cylinder sampling are tabulated and shown in Table 7.3.21.

Table 7.3.21 Laboratory Test Result of Soil Samples obtained by Cylinder Sampling

No.	Location	Sample	Percent passed sieve size (mm)								Natural moisture content w (%)	Atterberg Limits				Particle density Δ (g/cm³)	Soil group	Description
			9.5	4.75	2.00	0.85	0.425	0.25	0.075	< 0.005		Liquid limit W_L(%)	Plastic limit Wp(%)	Plasticity index Ip (%)	Consistency (B)			
1	CS1	UPPER			100.00	99.8	98.86	98.15	94.20	38.53	63.90	63.31	26.82	36.49	1.02	2.67	CH	Brownish grey, Fat clay
2	CS1	LOWER			100.0	99.60	98.25	96.29	86.47	29.21	70.80	48.99	22.87	26.12	1.83	2.68	CL	Brownish grey, Lean clay
3	CS2	UPPER			100.0	99.98	99.82	99.18	98.11	35.21	88.30	60.18	26.74	33.44	1.84	2.69	CH	Brownish grey, Fat clay
4	CS2	LOWER			100.0	99.96	99.76	98.72	93.43	31.68	82.08	54.08	24.84	29.24	1.96	2.69	CH	Brownish grey, Fat clay
5	CS3	UPPER			100.0	99.6	99.10	97.04	2.26							2.66	SP	Yellowish brown, Poorly graded sand
6	CS4	UPPER			100.0	99.9	99.64	97.73	82.97	38.44	70.63	47.73	24.23	23.50	1.97	2.69	CL	Brownish grey, Lean clay with sand
7	CS4	LOWER			100.0	99.9	99.86	97.26	72.75	29.88	58.83	42.15	21.18	20.97	1.80	2.67	CL	Brownish grey, Lean clay with sand

3) Water Sampling

a) Location and co-ordinates of water sampling

Water sampling was conducted at four fixed points as the same location as current observation locations presented in the Figure 7.3.37 along the navigational channel to identified the suspended solid content in the sea water.

The water sampling was carried out at three depths per point at four locations in 2 times, first time: 18th November and second time: 8th December 2009.

b) Quantities of water sampling and testing

Water sampling and suspended solid analysis: 24 samples = 4 locations x 3 layers x 2 times.

Figure 7.3.37 Location of Water Sampling Points

c) Result of Suspended Solid Content Test

Results of suspended solid content of sea water samples obtained on 18th November and 8th December are tabulated and shown in Table 7.3.22 and Figure 7.3.38 respectively.

Table 7.3.22 Total Suspended Solid (SS) Test Result

Location	By Nippon Koei			By JICA Study					
	7th September, 2009			18th November, 2009			8th December, 2009		
	Upper	Middle	Lower	Upper	Middle	Lower	Upper	Middle	Lower
WS1 (at or near Buoy No. 17)	63	120	55	247	230	424	103	131	122
WS2 (at or near Buoy No. 11)	55	69	61	130	150	160	93	102	129
WS3 (at or near Buoy No. 5)	16	31	288	110	90	170	119	156	266
WS4 (at or near Buoy No. 0)	-	-	-	71	73	110	97	98	108

According to SS test results, slight tendencies can be seen as follows;

(1) There are not so much differences in SS values among three measurements, sampled in September, November and December.

(2) SS value becoming bigger when the location is closer to an estuary of Lach Huyen River.

(3) Sample taken at the lower of each points tends to show bigger SS value than SS values at upper depths, it might be due to influence of fluid mud existing on the seabed with about 20cm to 50 cm thick.

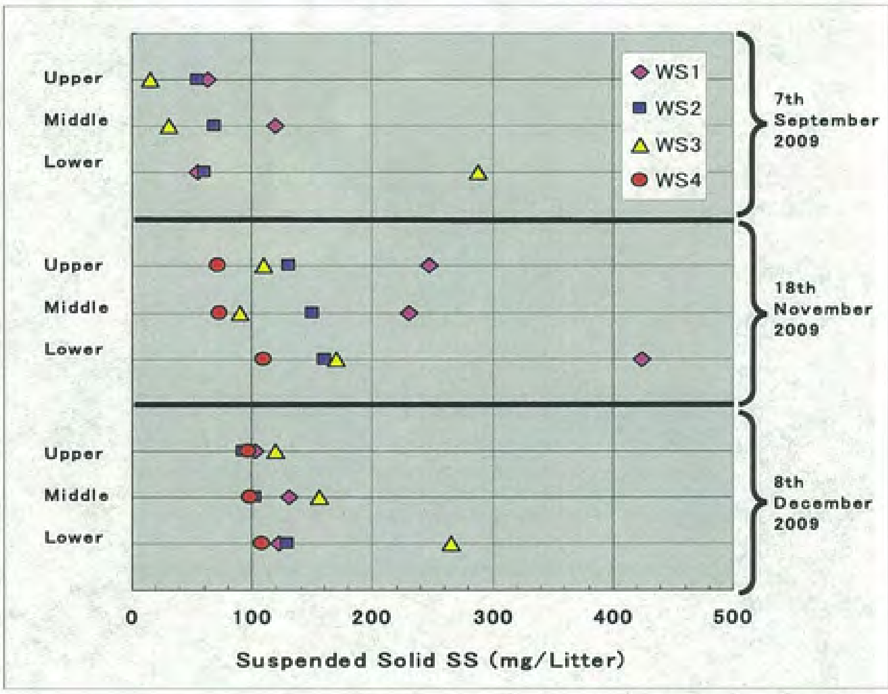


Figure 7.3.38 Total Suspended Solid (SS) Test Result