APPENDIX-4

WATER AND SEDIMENT QUALITY SURVEY

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APPENDIX 4

WATER AND SEDIMENT QUALITY SURVEY

A4.1 RESULTS OF THE WATER AND SEDIMENT QUALITY SURVEY

The results of the water and sediment quality survey are shown in the following tables and figures. These results are summarized in Chapter 3 (Volume II Main Report, Part I Master Plan).

Table A4. 1 Summary of Analysis Results for Water Quality in Tributary Rivers of Havana Bay (Wet Season)

Parameters \ Location		Luyano River			Martin Perez River			Tadeo River			Standards
		Up	Mid	Down	Up	Mid	Down	Up	Mid	Down	NC27
1	Sampling Time	2002/10/17			2002/10/18			2002/10/19			-
2	Air Temperature, ℃	28			28			28			-
3	Flow Rate, m^3/d	11,901	25,920	312,999	2,753	12,847	44,027	1,376	6,764	11,122	-
4	pH	8.1	8.1	7.9	8.1	8.0	8.0	8.0	7.9	8.0	6-9
5	Water Temp, ℃	27.3	27.6	27.5	25.9	26.0	26.2	26.7	26.4	26.3	50
6	Conductivity, μS/cm	650	700	820	810	775	790	710	790	830	3,500
7	COD, mg/L	16	20	26	20	24	22	41	27	35	120
8	BOD_5, mg/L	7	6	7	6	7	7	14	9	14	60
9	DO, mg/L	6.99	4.96	1.08	5.89	3.76	1.19	2.05	2.60	0.90	-
10	SS, mg/L	28	24	46	28	40	44	28	26	40	-
11	SO_4^{2-}, mg/L	43	43	43	78	76	68	36	58	52	-
12	Total Nitrogen (T-N), mg/l	1.00	3.60	5.10	1.50	3.20	4.80	8.90	14.10	8.80	20
13	NH_3-N, mg/L	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	-
14	NO_2^--N, mg/L	<0.001	<0.001	0.005	0.003	0.013	<0.001	<0.001	<0.001	<0.001	-
15	NO_3^--N, mg/L	1.20	3.40	4.70	1.80	3.70	5.20	8.90	13.50	8.90	-
16	Total Phosphorus (T-P), mg/l	0.45	0.43	0.65	0.25	0.53	0.63	1.02	1.19	1.13	10
17	PO_4^{3-}-P, mg/L	0.20	0.30	0.50	0.04	0.30	0.50	0.60	0.80	0.70	-
18	SiO_2, mg/L	20.7	18.7	17.6	24.5	19.9	19.8	54.8	38.1	38.2	-
19	Petroleum Hydrocarbon, mg/L	0.200	0.100	0.100	<0.001	0.170	0.100	0.290	0.270	0.210	30
20	Total Coliform, MPN/100mL	50×10^3	30×10^4	24×10^4	16×10^5	30×10^4	80×10^3	50×10^5	30×10^5	16×10^6	-
21	Fecal Coliform, MPN/100mL	50×10^3	23×10^4	24×10^4	80×10^4	23×10^4	80×10^3	50×10^5	30×10^5	16×10^6	-
22	Phenol, mg/L	0.17	0.25	0.27	<0.1	0.20	0.18	0.13	<0.1	0.15	-
23	Arsenic (As), mg/L	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	<0.5
24	Cadmium (Cd), mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.3
25	Cobalt (Co), mg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	-
26	Chromium (Cr), mg/l	0.021	<0.020	<0.020	<0.020	0.021	<0.020	<0.020	0.024	0.022	2.0
27	Copper (Cu), mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<5.0
28	Iron (Fe), mg/L	0.07	0.07	0.06	<0.02	<0.02	0.05	0.04	0.05	0.06	-
29	Total Mercury (Hg), mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.01
30	Manganese (Mn), mg/L	0.06	0.12	0.14	0.06	0.10	0.13	0.06	0.11	0.13	-
31	Nickel (Ni), mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
32	Lead (Pb), mg/L	0.09	0.09	0.08	0.09	0.09	0.09	0.08	0.09	0.10	1.0
33	Vanadium (V), mg/L	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	-
34	Zinc (Zn), mg/L	0.005	0.007	0.010	0.005	0.010	0.007	0.020	0.030	0.040	5.0

Table A4. 2 Summary of Analysis Results for Water Quality in Tributary Rivers of Havana Bay (Dry Season)

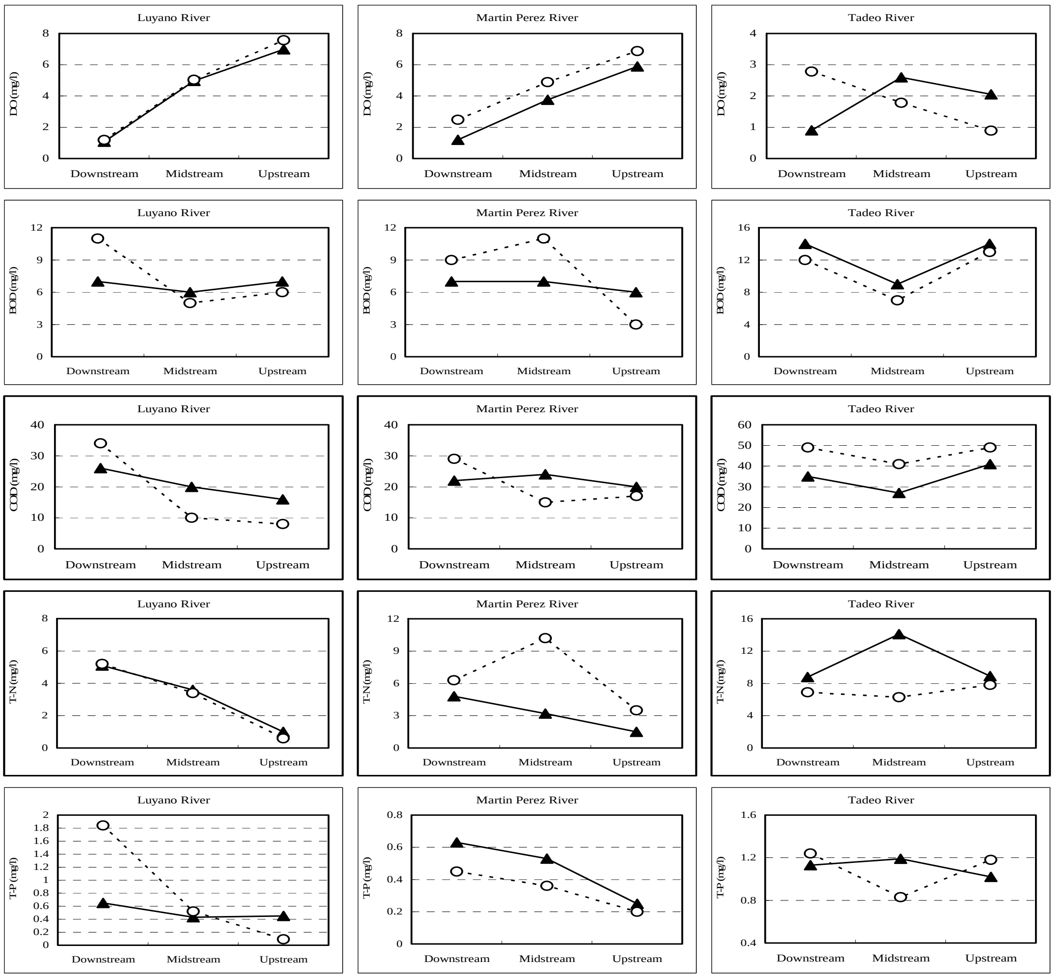
Parameters \ Location		Luyano River			Martin Perez River			Tadeo River			Standards
		Up	Mid	Down	Up	Mid	Down	Up	Mid	Down	NC27
1	Sampling Time	2002/12/22			2002/12/21			2002/12/23			-
2	Air Temperature, ℃	27			26			28			-
3	Flow Rate, m^3/d	6,123	58,614	232,228	5,194	15,202	98,564	937	6,778	19,916	-
4	pH	8.3	8.2	8.0	8.2	8.1	8.2	7.9	7.8	7.9	6-9
5	Water Temp, ℃	22.0	23.8	25.3	22.4	22.7	22.6	25.7	25.8	25.3	50
6	Conductivity, μS/cm	730	740	760	950	950	925	950	1,000	910	3,500
7	COD, mg/L	8	10	34	17	15	29	49	41	49	120
8	BOD_5, mg/L	6	5	11	3	11	9	13	7	12	60
9	DO, mg/L	7.56	5.04	1.18	6.87	4.88	2.48	0.89	1.78	2.78	-
10	SS, mg/L	18	36	50	62	62	68	58	40	22	-
11	SO_4^{2-}, mg/L	42	42	41	87	83	88	38	44	40	-
12	Total Nitrogen (T-N), mg/l	0.60	3.40	5.20	3.50	10.20	6.30	7.80	6.30	6.90	20
13	NH_3-N, mg/L	0.29	2.00	0.48	1.60	6.55	2.85	7.10	5.75	6.00	-
14	NO_2^--N, mg/L	0.009	0.210	0.271	0.044	0.736	0.565	0.009	0.146	0.124	-
15	NO_3^--N, mg/L	0.40	1.20	0.30	0.80	2.20	1.50	0.30	0.40	0.40	-
16	Total Phosphorus (T-P), mg/l	0.09	0.52	1.84	0.20	0.36	0.45	1.18	0.83	1.24	10
17	PO_4^{3-}-P, mg/L	0.08	0.42	0.47	0.09	0.28	0.50	0.93	0.60	0.74	-
18	SiO_2, mg/L	15.0	13.5	12.6	18.5	16.8	16.3	54.3	35.0	29.6	-
19	Petroleum Hydrocarbon, mg/L	<0.001	0.035	0.840	0.290	0.760	0.340	0.770	0.026	0.120	30
20	Total Coliform, MPN/100mL	17×10^3	28×10^4	30×10^5	17×10^5	30×10^4	50×10^5	24×10^5	17×10^5	13×10^5	-
21	Fecal Coliform, MPN/100mL	70×10^2	22×10^4	30×10^5	70×10^4	30×10^4	17×10^5	24×10^5	17×10^5	13×10^5	-
22	Phenol, mg/L	<0.1	0.25	<0.1	<0.1	<0.1	<0.1	<0.1	0.36	<0.1	-
23	Arsenic (As), mg/L	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.5
24	Cadmium (Cd), mg/L	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.3
25	Cobalt (Co), mg/L	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	-
26	Chromium (Cr), mg/l	-	-	-	-	-	-	-	-	-	2.0
27	Copper (Cu), mg/L	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<5.0
28	Iron (Fe), mg/L	0.186	0.229	0.267	0.339	0.459	0.358	0.267	0.304	0.18	-
29	Total Mercury (Hg), mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.01
30	Manganese (Mn), mg/L	0.101	0.202	0.242	0.264	0.27	0.227	0.129	0.235	0.120	-
31	Nickel (Ni), mg/L	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	-
32	Lead (Pb), mg/L	<0.03	<0.03	0.057	0.04	<0.03	<0.03	<0.03	<0.03	0.046	1.0
33	Vanadium (V), mg/L	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	-
34	Zinc (Zn), mg/L	0.02	0.076	0.075	0.030	0.030	0.070	0.051	0.058	0.096	5.0

Table A4. 3 Water Quality Seasonal Change in Tributary Rivers of Havana Bay

Luyano	DO		BOD		COD		T-N		T-P	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Downstream	1.08	1.18	7	11	26	34	5.1	5.2	0.65	1.84
Midstream	4.96	5.04	6	5	20	10	3.6	3.4	0.43	0.52
Upstream	6.99	7.56	7	6	16	8	1	0.6	0.45	0.09

Martin Perez	DO		BOD		COD		T-N		T-P	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Downstream	1.19	2.48	7	9	22	29	4.8	6.3	0.63	0.45
Midstream	3.76	4.88	7	11	24	15	3.2	10.2	0.53	0.36
Upstream	5.89	6.87	6	3	20	17	1.5	3.5	0.25	0.2

Tadeo	DO		BOD		COD		T-N		T-P	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Downstream	0.9	2.78	14	12	35	49	8.8	6.9	1.13	1.24
Midstream	2.6	1.78	9	7	27	41	14.1	6.3	1.19	0.83
Upstream	2.05	0.89	14	13	41	49	8.9	7.8	1.02	1.18



Regend: ▲Wet Season ○Dry Season

Figure A4. 1 Water Quality Seasonal Change in Tributary Rivers of Havana Bay

Table A4. 4 Summary of Analysis Results for Water Quality in Drainage Pipelines (Wet Season)

	Parameters / Location	Caballeria	Matadero	Agua Dulce	Standards NC27
1	Sampling Date	2002/10/9	2002/10/10	2002/10/12	-
2	Air Temperature, ℃	28	28	26	-
3	Flow Rate, m^3/d	669,967	71,496	85,190	-
4	pH	7.5	7.9	8.0	6-9
5	Water Temp, ℃	27.5	27.5	27.4	50
6	Conductivity, µS/cm	4,400	2,150	1,270	3,500
7	COD, mg/L	73	62	44	120
8	BOD_5, mg/L	30	32	22	60
9	DO, mg/L	0.18	0.50	0.82	-
10	SS, mg/L	71	89	61	-
11	SO_4^{2-}, mg/L	201	87	56	-
12	Total Nitrogen (T-N), mg/l	6.50	10.00	7.50	20
13	Organic-N, mg/l	0.3	3.5	0.5	-
14	NH_3-N, mg/L	0.17	<0.06	<0.06	-
15	NO_2^--N, mg/L	0.05	0.01	0.03	-
16	NO_3^--N, mg/L	6.00	6.50	7.00	-
17	Total Phosphorus (T-P), mg/l	5.4	1.0	1.3	10
18	PO_4^{3-}-P, mg/L	3.2	0.2	0.3	-
19	SiO_2, mg/L	201	87	56	-
20	Petroleum Hydrocarbon, mg/L	2.07	3.02	2.78	30
21	Total Coliform, MPN/100mL	17×10^6	70×10^5	90×10^5	-
22	Fecal Coliform, MPN/100mL	17×10^6	30×10^5	50×10^5	-
23	Phenol, mg/L	0.14	0.19	0.12	-
24	Arsenic (As), mg/L	<0.0003	<0.0003	<0.0003	<0.5
25	Cadmium (Cd), mg/L	<0.002	<0.002	<0.002	<0.3
26	Cobalt (Co), mg/L	<0.04	<0.04	<0.04	-
27	Chromium (Cr), mg/l	<0.020	0.028	<0.020	2.0
28	Copper (Cu), mg/L	<0.006	<0.006	<0.006	<5.0
29	Iron (Fe), mg/L	0.14	0.14	0.03	-
30	Total Mercury (Hg), mg/L	<0.02	<0.02	<0.02	<0.01
31	Manganese (Mn), mg/L	0.07	0.06	0.07	-
32	Nickel (Ni), mg/L	0.040	<0.01	<0.01	-
33	Lead (Pb), mg/L	0.09	0.07	0.08	1.0
34	Vanadium (V), mg/L	<4.0	<4.0	<4.0	-
35	Zinc (Zn), mg/L	0.050	0.040	0.020	5.0

Table A4. 5 Summary of Analysis Results for Water Quality in Drainage Pipelines (Dry Season)

Parameters \ Location		Caballeria	Matadero	Agua Dulce	Standards NC27
1	Sampling Date	2002/12/16	2002/12/17	2002/12/18	-
2	Air Temperature, ℃	22	23	23	-
3	Flow Rate, m^3/d	359,986	75,330	85,925	-
4	pH	7.7	8.0	7.9	6-9
5	Water Temp, ℃	25.5	25.4	25.3	50
6	Conductivity, μS/cm	2,400	770	1,200	3,500
7	COD, mg/L	33	98	106	120
8	BOD_5, mg/L	15	30	29	60
9	DO, mg/L	0.45	1.62	1.31	-
10	SS, mg/L	66	58	86	-
11	SO_4^{2-}, mg/L	128	39	59	-
12	Total Nitrogen (T-N), mg/l	8.50	8.40	9.20	20
13	NH_3-N, mg/L	7.00	4.55	7.25	-
14	NO_2^--N, mg/L	0.29	0.24	0.30	-
15	NO_3^--N, mg/L	1.40	2.00	0.90	-
16	Total Phosphorus (T-P), mg/l	1.2	0.6	0.9	10
17	PO_4^{3-}-P, mg/L	1.0	0.2	0.6	-
18	SiO_2, mg/L	11	9	11	-
19	Petroleum Hydrocarbon, mg/L	0.46	0.43	0.77	30
20	Total Coliform, MPN/100mL	30×10^5	11×10^5	50×10^5	-
21	Fecal Coliform, MPN/100mL	30×10^5	40×10^3	30×10^5	-
22	Phenol, mg/L	<0.1	<0.1	0.19	-
23	Arsenic (As), mg/L	<0.0001	<0.0001	<0.0001	<0.5
24	Cadmium (Cd), mg/L	<0.002	<0.002	<0.002	<0.3
25	Cobalt (Co), mg/L	<0.04	<0.04	<0.04	-
26	Chromium (Cr), mg/l	-	-	-	2.0
27	Copper (Cu), mg/L	<0.03	<0.03	<0.03	<5.0
28	Iron (Fe), mg/L	0.446	0.151	0.116	-
29	Total Mercury (Hg), mg/L	<0.02	<0.02	<0.02	<0.01
30	Manganese (Mn), mg/L	0.180	0.054	0.064	-
31	Nickel (Ni), mg/L	0.020	<0.01	0.010	-
32	Lead (Pb), mg/L	<0.03	<0.03	<0.03	1.0
33	Vanadium (V), mg/L	<4.0	<4.0	<4.0	-
34	Zinc (Zn), mg/L	0.050	0.040	0.020	5.0

Table A4. 6 Summary of Analysis Results for Sediment Quality in Tributary Rivers of Havana Bay

Parameters \ Location		Luyano River					Martin Perez River			Tadeo River	
		(LS1)	(LS2)	(LS3)	(LS4)	(LS5)	(MS1)	(MS2)	(MS3)	(TS1)	(TS2)
1	Sampling Date	2002/10/16					2002/10/17			2002/10/17	
2	Water Content, %	2.30	2.90	6.90	19.00	28.30	16.98	4.23	4.98	4.47	22.31
3	Grain Size Distribution	See the following figure									
4	Total Nitrogen (T-N), mg/kg	1,600	1,600	1,900	1,900	1,900	2,500	1,900	2,200	1,600	2,200
5	Total Organic Matter, mg/kg	10,266	53,766	23,142	49,416	98,400	69,078	38,628	57,768	66,990	100,398
6	TOC, mg/kg	5,900	30,900	13,300	28,400	57,900	39,700	22,200	33,200	38,500	57,700
7	Total Volatile Solids (TVS), %	9.8	8.7	11.6	11.7	18.5	10.8	15.1	6.2	6.9	18.4
8	Total Phosphorus (T-P), mg/kg	89.7	567.7	643.8	358.1	1058.3	311.9	207.1	425.2	282.6	743.8
9	Petroleum Hydrocarbon, mg/kg	416	518	480	1,044	2,865	70	1,373	203	1,269	815
10	Clostridium Perfringens, MPN/100 ml	24×10^4	24×10^4	80×10^4	13×10^5	50×10^4	27×10^3	50×10^4	22×10^3	30×10^4	26×10^4
11	Arsenic (As), mg/kg	0.3	0.4	0.3	0.3	0.3	0.2	0.3	<0.2	<0.2	0.2
12	Cadmium (Cd), mg/kg	3.0	5.3	5.4	4.1	9.9	3.5	4.6	5.1	5.1	4.3
13	Cobalt (Co), mg/kg	15.4	15.3	14.2	14.9	13.5	15.7	16.3	23.8	24.2	14.9
14	Copper (Cu), mg/kg	141	94	105	136	168	87	161	89	146	135
15	Iron (Fe), %	2.9	2.5	2.6	2.7	2.7	3.0	2.9	2.5	2.7	2.9
16	Total Mercury (Hg), mg/kg	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
17	Manganese (Mn), mg/kg	948	727	1,233	827	556	836	532	378	376	476
18	Nickel (Ni), mg/kg	43.9	42.9	45.5	48.8	47.9	53.5	65.6	286.0	381.0	68.9
19	Lead (Pb), mg/kg	96	144	124	189	227	131	190	479	134	189
20	Vanadium (V), mg/kg	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
21	Zinc (Zn), mg/kg	168	211	286	359	414	202	422	333	326	304

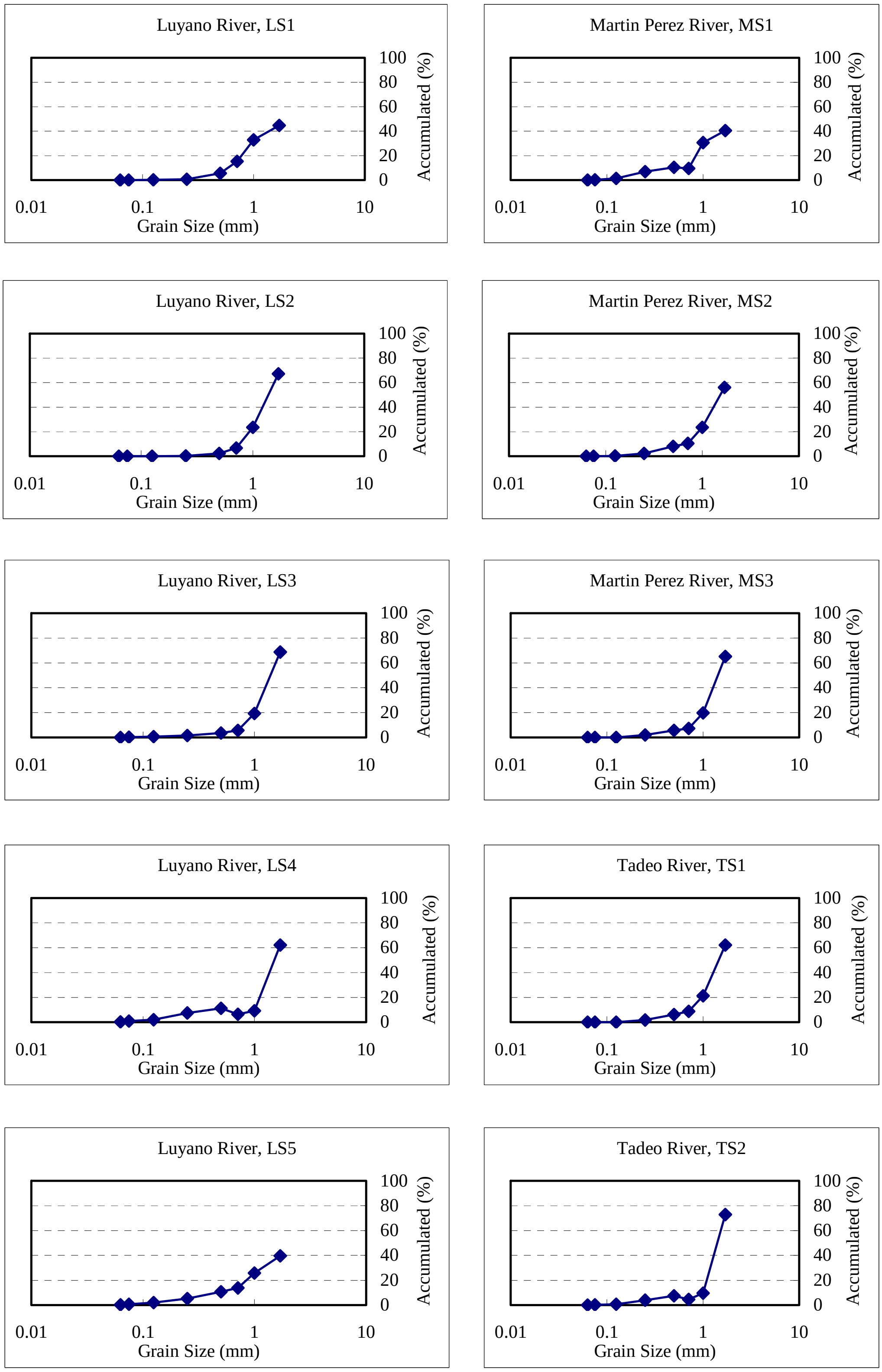


Figure A4. 2 Grain Size Distribution of Sediment in Tributary Rivers of Havana Bay

Table A4. 7 Summary of Analysis Results for Water Quality in Havana Bay (Wet Season 1/3)

Parameters \ Location		Atares (W1)			Guasabacoa (W2)		
		0.5 m from surface	Middle	1.0 m from bottom	0.5 m from surface	Middle	1.0 m from bottom
1	Sampling Time	9:00-9:50, 2002/10/3			10:15-10:50, 2002/10/3		
2	Air Temperature, ℃	28.8			30.0		
3	pH	7.2	7.6	8.0	7.7	8.4	8.4
4	Water Temp, ℃	28.7	28.2	28.6	29.1	28.8	28.6
5	Conductivity, mS/cm	52	57	58	53	58	58
6	Salinity, ‰	32.39	35.11	35.64	33.01	35.05	35.62
7	COD, mg/L	8.83	2.68	4.22	5.14	5.75	5.91
8	BOD_5, mg/L	19.88	14.68	1.88	2.72	6.00	9.08
9	DO, mg/L	1.26	0.22	1.45	1.63	2.14	3.42
10	SS, mg/L	51	52	56	57	66	79
11	SO_4^{2-}, mg/L	689.8	1,077.4	1,791.5	490.0	424.0	483.0
12	Total Nitrogen (T-N), mg/l	4.56	5.69	6.79	3.43	2.30	2.30
13	Organic-N, mg/l	4.190	5.340	6.530	3.170	2.128	2.150
14	NH_3-N, mg/L	0.290	0.260	0.190	0.190	0.112	0.090
15	NO_2^--N, mg/L	0.012	0.004	0.001	0.001	0.004	0.001
16	NO_3^--N, mg/L	0.070	0.090	0.070	0.070	0.060	0.060
17	Total Phosphorus (T-P), mg/l	0.092	0.085	0.031	0.070	0.050	0.035
18	PO_4^{3-}-P, mg/L	0.060	0.040	0.010	0.060	0.033	0.029
19	SiO_3-Si, mg/L	0.360	0.330	0.280	0.395	0.318	0.303
20	Petroleum Hydrocarbon, mg/L	0.840	0.090	0.090	0.030	0.080	0.010
21	Chlorophyll-a, mg/m^3	64.83	60.72	42.10	1.02	0.20	0.16
22	Plankton Biomass, $\times 10^3$ cell/l	58.8	27.6	19.2	324	75.2	100.4
23	Fecal Coliform, MPN/100mL	33×10^4	17×10^3	23×10^2	33×10^2	17×10^2	23×10^2
24	Phenol, mg/L	0.10	<0.10	0.13	0.10	0.10	<0.10
25	Arsenic (As), mg/L	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
26	Cadmium (Cd), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
27	Cobalt (Co), mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
28	Chromium (Cr), mg/l	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
29	Copper (Cu), mg/L	0.029	0.011	0.023	<0.010	<0.010	<0.010
30	Iron (Fe), mg/L	0.276	0.144	0.115	0.113	0.161	0.408
31	Total Mercury (Hg), mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
32	Manganese (Mn), mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
33	Nickel (Ni), mg/L	0.014	<0.010	<0.010	0.022	<0.010	<0.010
34	Lead (Pb), mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
35	Vanadium (V), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
36	Zinc (Zn), mg/L	0.088	<0.010	0.014	<0.010	0.017	0.018

Table A4. 8 Summary of Analysis Results for Water Quality in Havana Bay (Wet Season 2/3)

Parameters \ Location		Marimelena (W3)			Centro (W4)		
		0.5 m from surface	Middle	1.0 m from bottom	0.5 m from surface	Middle	1.0 m from bottom
1	Sampling Time	11:15-11:50, 2002/10/3			12:05-12:30, 2002/10/3		
2	Air Temperature, ℃	29.6			30.0		
3	pH	8.3	8.5	8.2	8.3	8.3	8.1
4	Water Temp, ℃	29.2	28.8	28.6	29.1	28.8	28.5
5	Conductivity, mS/cm	54	58	58	54	58	58
6	Salinity, ‰	33.98	35.87	35.86	32.64	35.44	36.15
7	COD, mg/L	1.91	2.68	2.68	4.22	9.75	2.84
8	BOD_5, mg/L	8.52	9.48	0.50	5.68	3.60	1.60
9	DO, mg/L	0.25	1.35	3.05	2.30	1.14	3.48
10	SS, mg/L	62	61	58	42	46	50
11	SO_4^{2-}, mg/L	417.4	274.3	452.1	463.0	492.0	515.0
12	Total Nitrogen (T-N), mg/l	3.41	2.28	2.28	2.29	3.42	3.41
13	Organic-N, mg/l	3.213	2.130	2.100	2.050	3.196	3.233
14	NH_3-N, mg/L	0.147	0.110	0.140	0.190	0.164	0.127
15	NO_2^--N, mg/L	0.014	0.002	0.002	0.002	0.004	0.001
16	NO_3^--N, mg/L	0.040	0.040	0.040	0.043	0.060	0.048
17	Total Phosphorus (T-P), mg/l	0.050	0.030	0.030	0.081	0.030	0.021
18	PO_4^{3-}-P, mg/L	0.027	0.010	0.010	0.053	0.025	0.010
19	SiO_3-Si, mg/L	0.11	0.09	0.10	0.22	0.17	0.10
20	Petroleum Hydrocarbon, mg/L	0.730	0.060	0.090	0.130	0.320	0.050
21	Chlorophyll-a, mg/m^3	0.56	0.56	0.23	1.19	0.41	0.11
22	Plankton Biomass, $\times 10^3$ cell/l	54.0	164.8	31.6	136.8	38.8	44.0
23	Fecal Coliform, MPN/100mL	22×10	80	2	79×10^2	13×10^2	40×10^2
24	Phenol, mg/L	<0.10	0.10	<0.10	<0.10	0.10	<0.10
25	Arsenic (As), mg/L	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
26	Cadmium (Cd), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
27	Cobalt (Co), mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
28	Chromium (Cr), mg/l	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
29	Copper (Cu), mg/L	0.013	0.013	0.024	0.021	<0.010	0.032
30	Iron (Fe), mg/L	<0.020	0.022	0.048	0.065	0.068	<0.020
31	Total Mercury (Hg), mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
32	Manganese (Mn), mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
33	Nickel (Ni), mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
34	Lead (Pb), mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
35	Vanadium (V), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
36	Zinc (Zn), mg/L	0.021	<0.010	0.041	0.025	<0.010	0.018

Table A4. 9 Summary of Analysis Results for Water Quality in Havana Bay (Dry Season 1/3)

Parameters \ Location		Atares (W1)			Guasabacoa (W2)		
		0.5 m from surface	Middle	1.0 m from bottom	0.5 m from surface	Middle	1.0 m from bottom
1	Sampling Time	10:50-11:00, 2002/12/18			11:50-12:15, 2002/12/18		
2	pH	8.0	8.1	7.1	8.2	8.2	8.2
3	Water Temp, ℃	28.8	27.3	27.6	25.9	27.7	27.1
4	Conductivity, mS/cm	52	54	55	55	59	60
5	Salinity, ‰	22.38	35.04	35.53	31.74	35.92	35.62
6	COD, mg/L	14.00	4.40	2.20	5.90	4.40	3.60
7	BOD_5, mg/L	17.00	5.00	4.00	2.90	1.70	1.20
8	DO, mg/L	1.92	0.32	0.33	5.38	2.37	1.75
9	SS, mg/L	34	57	74	55	58	37
10	SO_4^{2-}, mg/L	431.0	451.0	384.0	533.0	419.0	546.0
11	Total Nitrogen (T-N), mg/l	2.430	3.543	4.509	2.327	2.389	3.444
12	Organic-N, mg/l	1.901	3.275	4.419	2.218	2.222	3.337
13	NH_3-N, mg/L	0.339	0.085	0.061	0.022	0.018	0.023
14	NO_2^--N, mg/L	0.055	0.032	0.023	0.039	0.092	0.083
15	NO_3^--N, mg/L	0.135	0.151	0.006	0.048	0.057	0.001
16	Total Phosphorus (T-P), mg/l	0.224	0.162	0.037	0.103	0.157	0.030
17	PO_4^{3-}-P, mg/L	0.096	0.086	0.025	0.079	0.089	0.019
18	SiO_3-Si, mg/L	0.058	0.042	0.038	0.232	0.281	0.235
19	Petroleum Hydrocarbon, mg/L	0.300	0.032	<0.001	0.200	0.210	0.015
20	Chlorophyll-a, mg/m^3	31.52	1.34	0.52	93.75	2.81	0.73
21	Plankton Biomass, $\times 10^3$ cell/l	4448.5	213.1	236.2	12,256	295.60	60.80
22	Fecal Coliform, MPN/100mL	11×10^4	17×10^3	20×10^2	70×10^2	50×10	50×10
23	Phenol, mg/L	0.17	<0.10	<0.10	2.99	<0.10	<0.10
24	Arsenic (As), mg/L	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
25	Cadmium (Cd), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
26	Cobalt (Co), mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
27	Chromium (Cr), mg/l	<0.020	<0.020	0.028	<0.020	<0.020	<0.020
28	Copper (Cu), mg/L	0.015	<0.010	0.010	0.013	0.018	0.040
29	Iron (Fe), mg/L	0.327	0.138	0.140	0.223	0.189	0.501
30	Total Mercury (Hg), mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
31	Manganese (Mn), mg/L	<0.006	<0.006	<0.006	<0.006	0.009	0.023
32	Nickel (Ni), mg/L	0.017	<0.010	<0.010	<0.010	<0.010	<0.010
33	Lead (Pb), mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
34	Vanadium (V), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
35	Zinc (Zn), mg/L	0.172	0.033	0.020	0.022	0.028	0.105

Table A4. 10 Summary of Analysis Results for Water Quality in Havana Bay (Dry Season 2/3)

Parameters \ Location		Marimelena (W3)			Centro (W4)		
		0.5 m from surface	Middle	1.0 m from bottom	0.5 m from surface	Middle	1.0 m from bottom
1	Sampling Time	12:30-13:00, 2002/12/18			13:24-13:50, 2002/12/18		
2	pH	8.4	8.2	8.4	8.3	8.4	8.4
3	Water Temp, ℃	25.3	27.1	27.0	26.7	26.9	26.9
4	Conductivity, mS/cm	52	59	59	51	59	59
5	Salinity, ‰	33.19	34.25	35.91	30.15	34.59	35.66
6	COD, mg/L	2.90	2.20	1.40	4.40	3.60	2.90
7	BOD_5, mg/L	2.55	1.90	1.90	1.54	3.35	1.05
8	DO, mg/L	6.53	3.93	3.40	6.45	5.21	4.95
9	SS, mg/L	67	68	71	43	67	100
10	SO_4^{2-}, mg/L	373.0	291.0	500.0	343.0	451.0	633.0
11	Total Nitrogen (T-N), mg/l	2.312	3.528	3.423	3.528	2.287	3.549
12	Organic-N, mg/l	2.169	3.359	3.348	3.337	2.230	3.332
13	NH_3-N, mg/L	0.071	0.001	0.012	0.023	0.010	0.028
14	NO_2^--N, mg/L	0.068	0.051	0.021	0.115	0.009	0.001
15	NO_3^--N, mg/L	0.004	0.117	0.042	0.053	0.038	0.188
16	Total Phosphorus (T-P), mg/l	0.257	0.052	0.029	0.164	0.030	0.189
17	PO_4^{3-}-P, mg/L	0.047	0.042	0.024	0.084	0.021	0.038
18	SiO_3-Si, mg/L	0.07	0.05	0.06	0.23	0.16	0.08
19	Petroleum Hydrocarbon, mg/L	0.330	0.020	<0.001	0.010	<0.001	0.060
20	Chlorophyll-a, mg/m^3	14.19	0.63	0.32	17.66	1.62	1.62
21	Plankton Biomass, $\times 10^3$ cell/l	4,048	113.2	25.2	4,779	130	40.8
22	Fecal Coliform, MPN/100mL	70	49×10	17×10	70×10	20×10	17×10^2
23	Phenol, mg/L	<0.10	<0.10	<0.10	0.17	<0.10	<0.10
24	Arsenic (As), mg/L	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
25	Cadmium (Cd), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
26	Cobalt (Co), mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
27	Chromium (Cr), mg/l	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
28	Copper (Cu), mg/L	0.010	0.015	<0.010	<0.010	0.025	<0.010
29	Iron (Fe), mg/L	0.235	0.171	0.181	0.292	0.740	0.451
30	Total Mercury (Hg), mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
31	Manganese (Mn), mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
32	Nickel (Ni), mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
33	Lead (Pb), mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
34	Vanadium (V), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
35	Zinc (Zn), mg/L	0.023	0.020	0.022	0.027	0.023	0.017

Table A4. 11 Summary of Analysis Results for Water Quality in Havana Bay (Dry Season 3/3)

	Parameters / Location	Canal (W5)			Outlet of Canal (W6)		
		0.5 m from surface	Middle	1.0 m from bottom	0.5 m from surface	Middle	1.0 m from bottom
1	Sampling Time	14:00-14:40, 2002/12/18			10:15-11:20, 2002/12/20		
2	pH	8.4	8.4	8.4	8.3	8.4	8.4
3	Water Temp, ℃	26.8	26.9	26.9	26.9	26.9	26.9
4	Conductivity, mS/cm	53	59	59	58	59	59
5	Salinity, ‰	33.02	35.76	35.50	35.65	35.83	35.51
6	COD, mg/L	3.60	4.40	3.60	2.20	1.40	0.73
7	BOD_5, mg/L	5.08	0.92	3.08	3.15	0.00	1.00
8	DO, mg/L	6.56	5.03	5.09	5.55	5.56	5.58
9	SS, mg/L	53	78	86	12	27	27
10	SO_4^{2-}, mg/L	332.0	402.0	555.0	447.0	434.0	478.0
11	Total Nitrogen (T-N), mg/l	3.551	2.283	3.387	1.167	1.181	1.185
12	Organic-N, mg/l	3.291	2.214	3.358	1.116	1.115	1.104
13	NH_3-N, mg/L	0.069	0.026	0.002	0.004	0.005	0.016
14	NO_2^--N, mg/L	0.105	0.007	0.008	0.004	0.004	0.004
15	NO_3^--N, mg/L	0.086	0.036	0.019	0.043	0.057	0.061
16	Total Phosphorus (T-P), mg/l	0.083	0.020	0.131	0.025	0.019	0.008
17	PO_4^{3-}-P, mg/L	0.047	0.017	0.009	0.017	0.014	0.004
18	SiO_3-Si, mg/L	0.30	0.21	0.09	0.01	0.00	0.00
19	Petroleum Hydrocarbon, mg/L	0.190	0.340	0.016	0.070	0.001	0.084
20	Chlorophyll-a, mg/m^3	9.38	1.00	0.53	0.87	0.67	0.12
21	Plankton Biomass, $\times 10^3$ cell/l	2,130.8	205.4	146.4	123.2	72.8	20.4
22	Fecal Coliform, MPN/100mL	49×10	49×10^2	33×10^2	22×10	13×10	79×10
23	Phenol, mg/L	<0.10	<0.10	0.10	<0.10	<0.10	1.06
24	Arsenic (As), mg/L	<0.080	<0.080	<0.080	<0.080	<0.080	<0.080
25	Cadmium (Cd), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
26	Cobalt (Co), mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
27	Chromium (Cr), mg/l	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
28	Copper (Cu), mg/L	<0.010	<0.010	<0.010	0.013	0.021	0.025
29	Iron (Fe), mg/L	0.138	0.142	0.128	0.244	0.254	0.156
30	Total Mercury (Hg), mg/L	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
31	Manganese (Mn), mg/L	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
32	Nickel (Ni), mg/L	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
33	Lead (Pb), mg/L	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
34	Vanadium (V), mg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
35	Zinc (Zn), mg/L	0.017	0.016	0.019	0.050	0.044	0.019

Table A4. 12 Vertical Variations of DO, Organics, Nutrients in Havana Bay in Wet Season

Location	DO			BOD			COD			T-N			T-P		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
Atares	1.3	0.2	1.5	19.9	14.7	1.9	8.8	2.7	4.2	4.56	5.69	6.79	0.092	0.085	0.031
Guasabacoa	1.6	2.1	3.4	2.7	6.0	9.1	5.1	5.8	5.9	3.43	2.30	2.30	0.070	0.050	0.035
Marimelena	0.3	1.4	3.1	8.5	9.5	0.5	1.9	2.7	2.7	3.41	2.28	2.28	0.050	0.030	0.030
Centro	2.3	1.1	3.5	5.7	3.6	1.6	4.2	9.8	2.8	2.29	3.42	3.41	0.081	0.030	0.021
Canal	4.7	3.1	5.9	2.3	2.0	3.3	6.5	5.0	3.5	1.19	2.29	2.29	0.040	0.080	0.016
Outlet of Canal	6.1	5.9	5.7	5.1	0.6	0.2	6.5	1.2	1.3	1.12	2.24	2.24	0.030	0.040	0.030

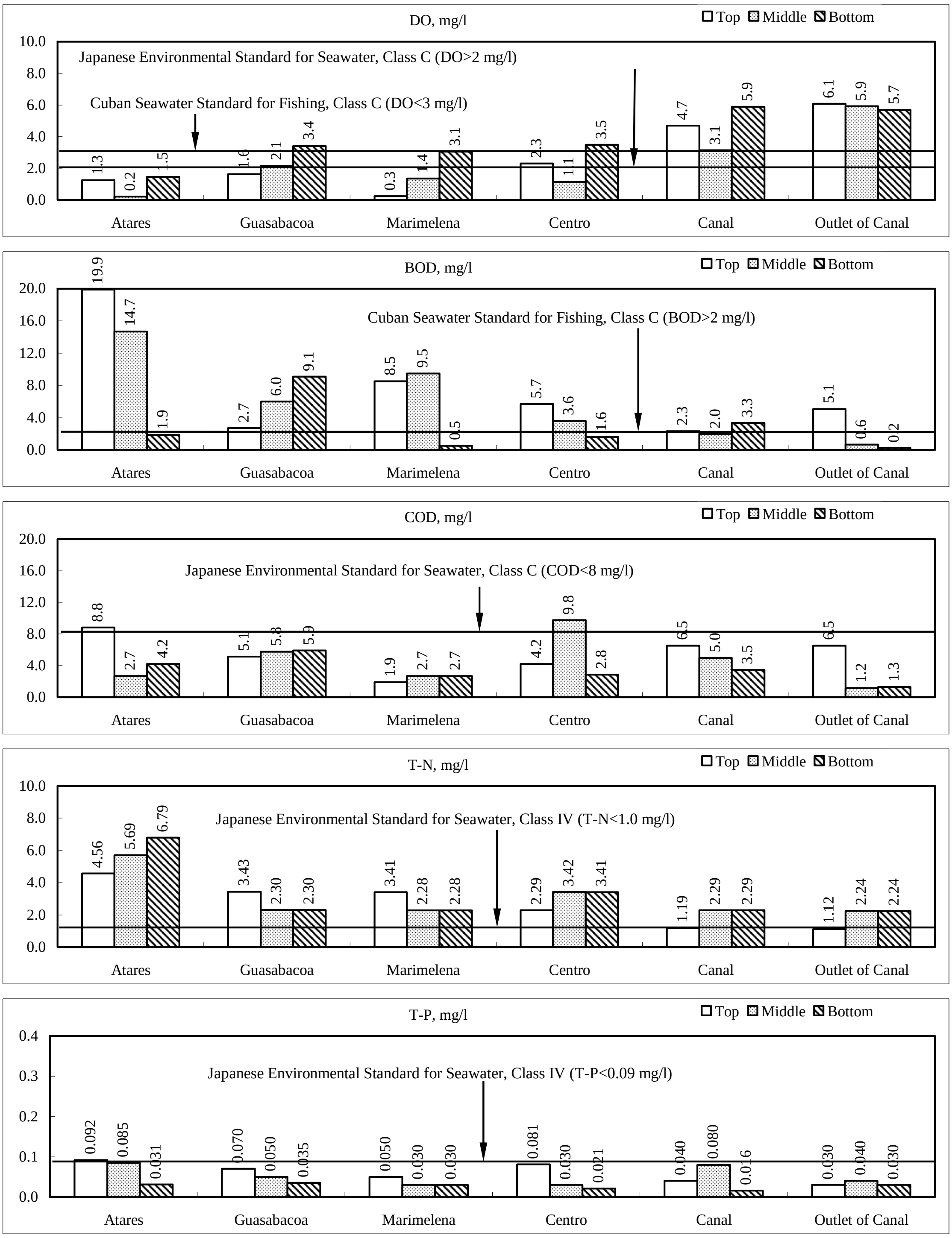


Figure A4. 3 Vertical Variations of DO, Organics, Nutrients in Havana Bay in Wet Season

Table A4. 13 Vertical Variations of DO, Organics, Nutrients in Havana Bay in Dry Season

Location	DO			BOD			COD			T-N			T-P		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
Atares	1.9	0.3	0.3	17.0	5.0	4.0	14.0	4.4	2.2	2.43	3.54	4.51	0.224	0.162	0.037
Guasabacoa	5.4	2.4	1.8	2.9	1.7	1.2	5.9	4.4	3.6	2.33	2.39	3.44	0.103	0.157	0.030
Marimelena	6.5	3.9	3.4	2.6	1.9	1.9	2.9	2.2	1.4	2.31	3.53	3.42	0.257	0.052	0.029
Centro	6.5	5.2	5.0	1.5	3.4	1.1	4.4	3.6	2.9	3.53	2.29	3.55	0.164	0.030	0.189
Canal	6.6	5.0	5.1	5.1	0.9	3.1	3.6	4.4	3.6	3.55	2.28	3.39	0.083	0.020	0.131
Outlet of Canal	5.6	5.6	5.6	3.2	0.0	1.0	2.2	1.4	0.7	1.17	1.18	1.19	0.025	0.019	0.008

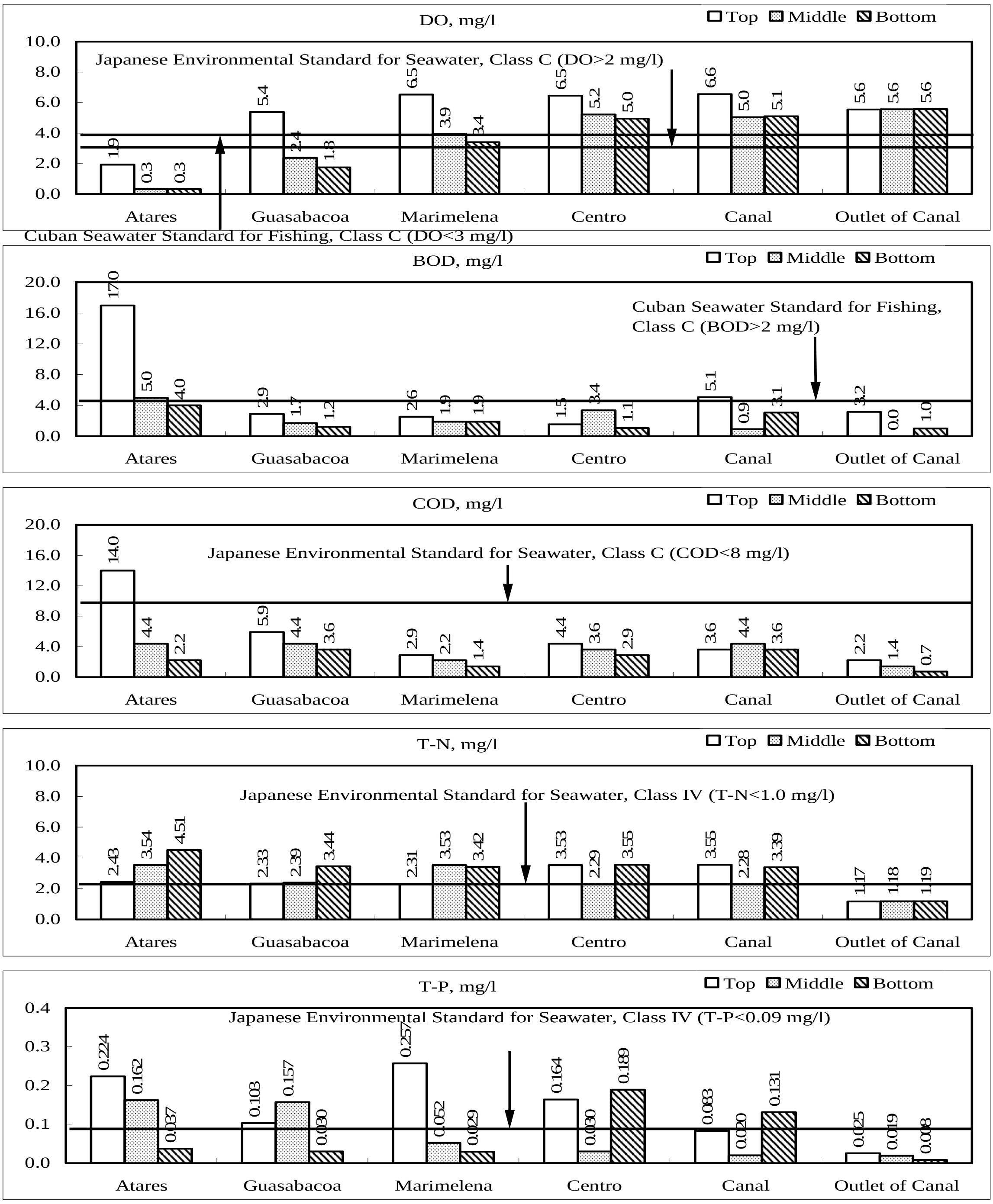


Figure A4. 4 Vertical Variations of DO, Organics, Nutrients in Havana Bay in Dry Season

Table A4. 14 Vertical Variations of Chlorophyll-a and Fecal Coliforms in Havana Bay in Wet and Dry Season

Location	Chlorophyll-a (Wet)			Fecal Coliform (Wet)			Chlorophyll-a (Dry)			Fecal Coliform (Dry)		
	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom	Top	Middle	Bottom
Atares	64.8	60.7	42.1	330,000	17,000	2,300	31.5	1.3	0.5	110,000	17,000	2,000
Guasabacoa	1.0	0.2	0.2	3,300	1,700	2,300	93.8	2.8	0.7	7,000	500	500
Marimelena	0.6	0.6	0.2	220	80	2	14.2	0.6	0.3	70	490	170
Centro	1.2	0.4	0.1	7,900	1,300	4,000	17.7	1.6	1.6	700	200	1,700
Canal	1.0	0.4	0.1	790	80	2	9.4	1.0	0.5	490	4,900	3,300
Outlet of Canal	1.1	0.9	0.6	110	490	330	0.9	0.7	0.1	220	130	790

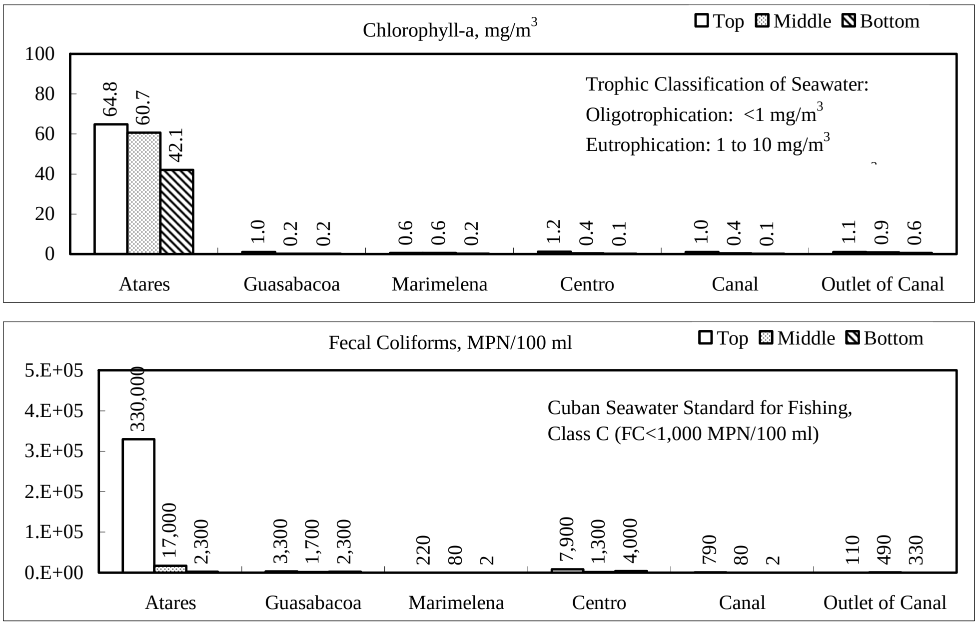


Figure A4. 5 Vertical Variations of Chlorophyll-a and Fecal Coliforms in Havana Bay in Wet Season

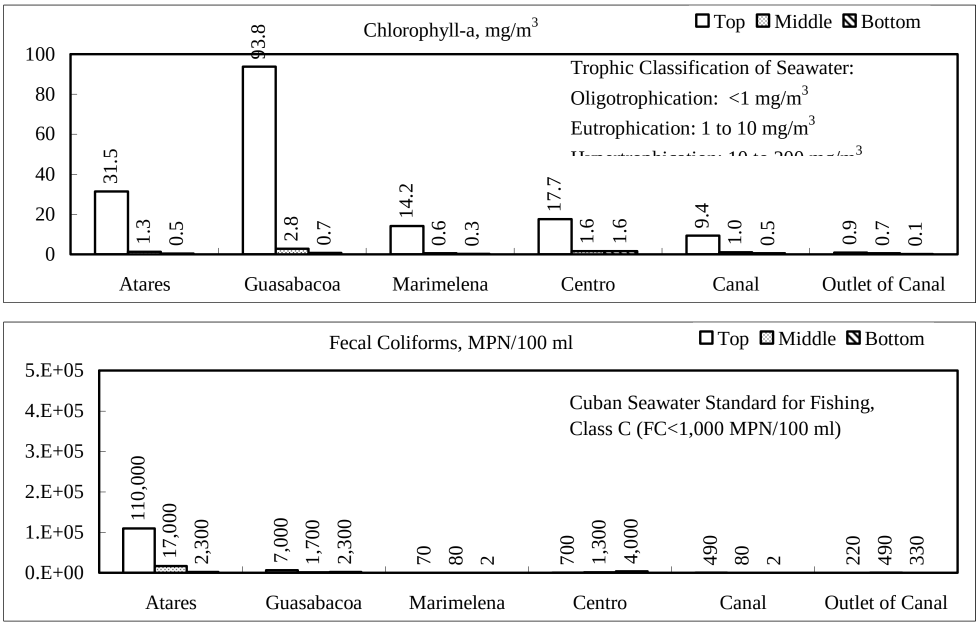


Figure A4. 6 Vertical Variations of Chlorophyll-a and Fecal Coliforms in Havana Bay in Wet Season

Table A4. 15 Summary of Analysis Results for Sediment Quality in Havana Bay

Parameters / Location		Atares	Guasabacoa	Marimelena	Centro
1	Sampling Date	2002/10/3			
2	Color	Black	Dark gray	Dark gray	Dark gray
3	Odor	H_2S	H_2S	No	No
4	Texture	Muddy	Muddy	Sand with little stones	Sand with little stones
5	Water Content, %	85.07	59.02	38.57	52.55
6	Grain Size Distribution	See the following Figure			
7	Total Nitrogen (T-N), mg/kg	5,000	1,400	1,100	1,600
8	Total Organic Nitrogen (TON)*, mg/kg	4,675	1,384	1,092	1,595
9	Total Organic Matter, mg/kg	213,672	59,856	72,906	117,798
10	TOC, mg/kg	122,800	34,400	41,900	67,700
11	COD,* mg/kg	170,000	94,000	24,000	70,000
12	Total Volatile Solids (TVS), %	79.1	5.1	1.7	4.4
13	Total Phosphorus (T-P), mg/kg	664.2	94.8	40.3	194.5
14	Petroleum Hydrocarbon, mg/kg	1,759	1,230	1,660	1,290
15	Clostridium Perfringens, MPN/100 ml	20×10^3	11×10^3	40×10	40×10^2
16	Arsenic (As), mg/kg	6.00	3.00	11.00	15.00
17	Cadmium (Cd), mg/kg	1.04	<0.005	<0.005	<0.005
18	Cobalt (Co), mg/kg	22.50	25.00	26.25	21.25
19	Chromium (Cr), mg/kg	62.75	54.50	45.50	41.45
20	Copper (Cu), mg/kg	148.75	82.00	72.75	48.50
21	Iron (Fe), %	1.91	3.70	4.20	2.53
22	Total Mercury (Hg), mg/kg	<5.00	<5.00	<5.00	29.00
23	Manganese (Mn), mg/kg	249.00	568.75	583.75	264.00
24	Nickel (Ni), mg/kg	62.55	62.55	62.57	52.20
25	Lead (Pb), mg/kg	193.88	39.88	2.38	303.88
26	Vanadium (V), mg/kg	66.50	107.50	124.25	66.00
27	Zinc (Zn), mg/kg	764.25	160.00	107.00	133.50

*: The parameters measured by the laboratory of Nihon Suido Consultants CO., LTD

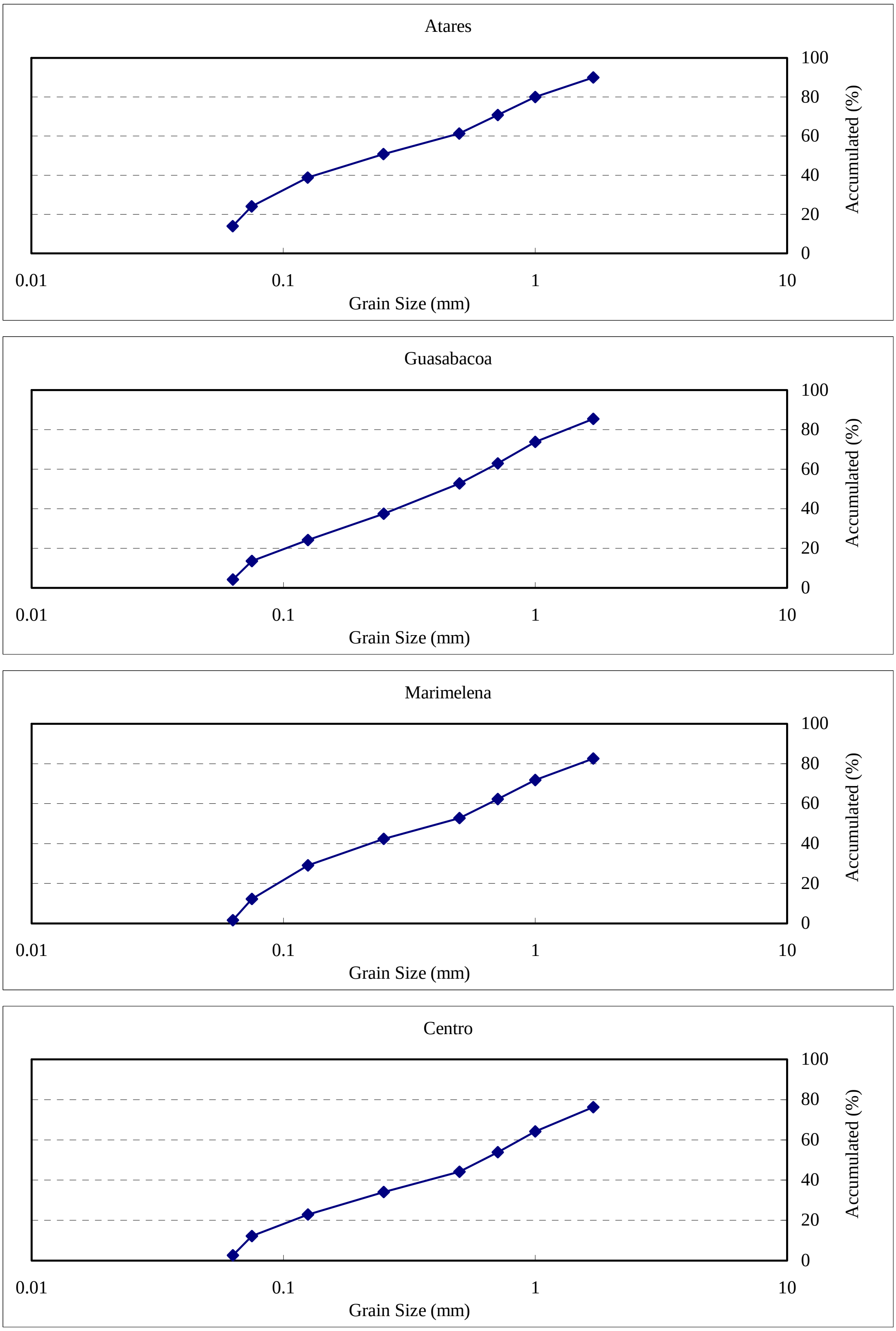


Figure A4. 7 Grain Size Distribution of Sediment in Havana Bay

Table A4. 16 Summary of Analysis Results for Water Quality of Public Water Supply Source (Dry Season)

	Parameters \ Location	Groundwater		Waterwork	Cuban Drinking
		Well 1	Well 2	Network	Water Standards
1	Sampling Time	2003/1/20	2003/1/20	2003/1/21	-
2	pH	7.3	7.6	7.2	-
3	Water Temp, ℃	23.6	22.9	22.1	-
4	Conductivity, μS/cm	530	470	670	-
5	COD, mg/L	5	3	3	-
6	BOD_5, mg/L	2	2	2	-
7	SS, mg/L	28	46	42	-
8	SO_4^{2-}, mg/L	16	6	24	-
9	Total Nitrogen (T-N), mg/l	0.70	0.20	0.40	-
10	Organic-N, mg/l	-	-	-	0
11	NH_3-N, mg/L	0.50	<0.06	<0.03	0
12	NO_2^--N, mg/L	0.0	<0.001	<0.001	0
13	NO_3^--N, mg/L	0.0	0.00	0.10	45
14	Total Phosphorus (T-P), mg/l	0.01	0.03	0.04	-
15	PO_4^{3-}-P, mg/L	0.079	0.036	0.065	-
16	SiO_2, mg/L	8.4	6.7	5.4	-
17	Total Coliform, MPN/100mL	30	<2	<2	-
18	Fecal Coliform, MPN/100mL	2	<2	<2	-
19	Phenol, mg/L	-	-	-	-
20	Arsenic (As), mg/L	<0.0001	<0.0001	<0.0001	0.05
21	Cadmium (Cd), mg/L	<0.002	<0.002	<0.002	0.005
22	Cobalt (Co), mg/L	<0.04	<0.04	<0.04	1
23	Chromium (Cr), mg/l	-	-	-	-
24	Copper (Cu), mg/L	<0.03	<0.03	<0.03	1
25	Iron (Fe), mg/L	0.105	0.125	0.123	0.3
26	Total Mercury (Hg), mg/L	-	-	-	0.001
27	Manganese (Mn), mg/L	<0.005	0.042	<0.005	0.1
28	Nickel (Ni), mg/L	<0.01	<0.01	<0.01	0.02
29	Lead (Pb), mg/L	<0.03	<0.03	<0.03	0.05
30	Vanadium (V), mg/L	<4.0	<4.0	<4.0	0.1
31	Zinc (Zn), mg/L	0.026	<0.002	<0.002	15.0

Table A4. 17 Summary of Analysis Results for Water Quality in Sewers (Dry Season), Before Noon

	Parameters \ Location	Matadero Downstream (N1)	Matadero Midstream (N2)	Drainage Orengo Downstream (N3)	Sewer PTO-70 (N4)	Standards NC27
1	Sampling Date	2003/1/31, 09:30	2003/1/31, 10:05	2003/1/31, 10:35	2003/1/31, 11:15	-
2	Flow Rate, m^3/d	100,302	89,502	24,175	6,731	-
3	pH	7.9	7.8	7.7	7.5	6-9
4	Water Temp, ℃	24.4	24.3	24.5	24.2	50
5	Conductivity, μS/cm	1,200	790	820	600	3,500
6	COD, mg/L	59	67	89	52	120
7	BOD_5, mg/L	14	15	40	14	60
8	DO, mg/L	1.1	1.7	1.6	4.0	-
9	SS, mg/L	46	54	74	62	-
10	SO_4^{2-}, mg/L	43	33	36	20	-
11	Total Nitrogen (T-N), mg/l	5.7	5.3	9.8	6.1	20
12	Total Phosphorus (T-P), mg/l	1.94	0.90	1.92	1.05	10
13	Air Temperature, ℃*	23.0	23.0	23.0	23.4	
14	Water Temp, ℃*	25.0	24.9	25.2	24.9	
15	pH*	8.0	8.0	7.8	7.5	
16	DO, mg/L*	1.3	2.6	1.7	6.3	
17	Conductivity, μS/cm*	1,500	1,000	500	630	
18	Salinity, %*	0.07	0.04	0.04	0.03	
19	Observation*	Much Floatables	Much Floatables	Little Floatables	Little Floatables	
20	Others*	0		0	0	

*: Measured by Study Team on-site.

Table A4. 18 Summary of Analysis Results for Water Quality in Sewers (Dry Season), After Noon

	Parameters / Location	Matadero Downstream (N1)	Matadero Midstream (N2)	Drainage Orengo Downstream (N3)	Sewer PTO-70 (N4)	Standards NC27
1	Sampling Date	2003/1/31, 14:30	2003/1/31, 14:50	2003/1/31, 15:40	2003/1/31, 16:05	-
2	Flow Rate, m^3/d	103,896	86,841	26,585	4,216	-
3	pH	7.6	8.9	7.6	7.5	6-9
4	Water Temp, ℃	25.2	25.0	25.3	25.0	50
5	Conductivity, µS/cm	1,200	790	770	740	3,500
6	COD, mg/L	104	96	81	52	120
7	BOD_5, mg/L	26	32	29	6	60
8	DO, mg/L	1.1	1.2	1.5	3.5	-
9	SS, mg/L	38	54	58	30	-
10	SO_4^{2-}, mg/L	42	38	36	30	-
11	Total Nitrogen (T-N), mg/l	11.3	6.2	7.2	6.0	20
12	Total Phosphorus (T-P), mg/l	1.31	0.99	1.01	0.77	10
13	Air Temperature, ℃*	24.0	24.0	24.0	23	
14	Water Temp, ℃*	25.3	25.3	25.3	25.6	
15	pH*	7.8	8.9	7.8	7.8	
16	DO, mg/L*	2.5	2.4	2.0	5.7	
17	Conductivity, µS/cm*	1,400	1,000	900	790	
18	Salinity, %*	0.06	0.04	0.04	0.03	
19	Observation*	Much Floatables	Much Floatables	Little Floatables	Little Floatables	
20	Others*					

*: Measured by Study Team on-site.

APPENDIX-5

INDUSTRIAL POLLUTION SOURCE SURVEY

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INDUSTRIAL POLLUTION SOURCE SURVEY

A5.1 RESULTS OF INDUSTRIAL POLLUTION SOURCE SURVEY

The results of the industrial pollution source survey are shown in the following. These results are summarized in Table 3.17 (The Main Features of 10 Selected Factories), Volume II Main Report, Part I Master Plan).

1) NICO LOPEZ (OIL REFINERY FACTORY)

The production processes in Nico Lopez include the distillation process, crack catalytic process, polymerization and hydro-desulphurization process.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.1 Outline of Nico Lopez (Oil Refinery Factory)

• Type of Industry	• Oil Refinery
• Main Raw Materials	• Crude Oil
• Main Products	• Gasoline and Derivates, 1.6 M ton/year
• No. of Employees	• 1,326 Persons
• Operation Time	• 24 Hours Continuous Operation

b) Water Supply Source and Consumption

The industrial water is supplied from two (2) sources: Havana Bay through the factory's own intake system and the municipal water supply system. The present water consumption of the factory is summarized below by purpose and water source.

Table A5.2 Water Consumption by Source and Purpose, Nico Lopez

Source	Purpose	Quantity
Sea Water		150,398 m^3/d
(Havana Bay)	Cooling Water	130,500 m^3/d
	Others	19,898 m^3/d
Municipal Water		6,406 m^3/d
	Flushing Water	27 m^3/d
	Boiler Feed Water	6,240 m^3/d
	Domestic Water	139 m^3/d
Total		156,804 m^3/d

c) Wastewater discharge system

Wastewaters from the factory include industrial process wastewater, cooling water, washing water and sanitary wastewater. As shown in Figure A5.1, the wastewaters of Zone 2, Zone 1 and North are discharged into Havana Bay directly, the wastewaters of Tank 40, Circular, South and Cracking Oil are firstly discharged into a natural oil separator where free oil is floated to the surface of the Bay and then skimmed off, finally the treated wastewater is discharged into Havana Bay. The results of wastewater flow measurement at each outlet are summarized as follows, which indicates that Separator South contributes 87% of total wastewater quantity (139,381 m^3/d).

d) Wastewater quality

The results of water quality analysis of a 24-h composite sample and the existing water quality information are summarized as follows:

Table A5.3 Comparison of Water Quality Data and Estimated Pollutant Loads, Nico Lopez

Para-meters	Flow	Pollutant Concentration, mg/l						Pollution Load, kg/d					
	m^3/d	BOD	COD	T-N	T-P	SS	HC	BOD	COD	T-N	T-P	SS	HC
This Survey	139,381 97.8%	18	38.39	3.41	31.56	260	42	2,509 78%	5,351 68%	475 93%	4,399 99.5%	36239 97%	5,854 98.2%
GEF (1997)	62,134 94.5%	362	–	–	–	–	230	22,500 83.6%	– –	– –	– –	– –	14,300 84.8%

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.3, Nico Lopez contributes 97.8% of total wastewater quantity of the 10 selected factories (142,511 m^3/d). The concentrations of total phosphorus (T-P), suspended solids (SS) and hydrocarbon (HC) in the effluent are considered to be a relatively high level. On the other hand, even though BOD and hydrocarbon concentrations of the wastewater are reduced sharply comparing with the results measured by GEF in 1997, Nico Lopez still contributes more than 70% of total industrial pollution load discharged from the 10 selected factories, as show in Figure 3.13 (Volume II, Part 1, Chapter 3).

The survey results mentioned above indicate that the treatment efficiency of wastewater treatment facilities (API system, a kind of gravity separator in which only free floatable oil (>0.15 to 0.2 mm) can be removed by gravity separation) in Nico Lopez is not satisfactory, therefore, it is recommended to install a second-stage treatment facility (such as coalescing gravity separator or dissolved air flotation system) to remove emulsified oil having smaller oil globule (<0.1mm).

2) CURBELO (GAS FACTORY)

The factory produces gas from naphtha and natural gas for domestic use.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.4 Outline of Cubelo (Gas Factory)

Type of Industry	Gas Production
Main Raw Materials	Naphtha and Natural gas
Main Products	Gas, 125.4 Mm^3/year
No. of Employees	137 Persons
Operation Time	24 Hours Continuous Operation

b) Water Supply Source and Consumption

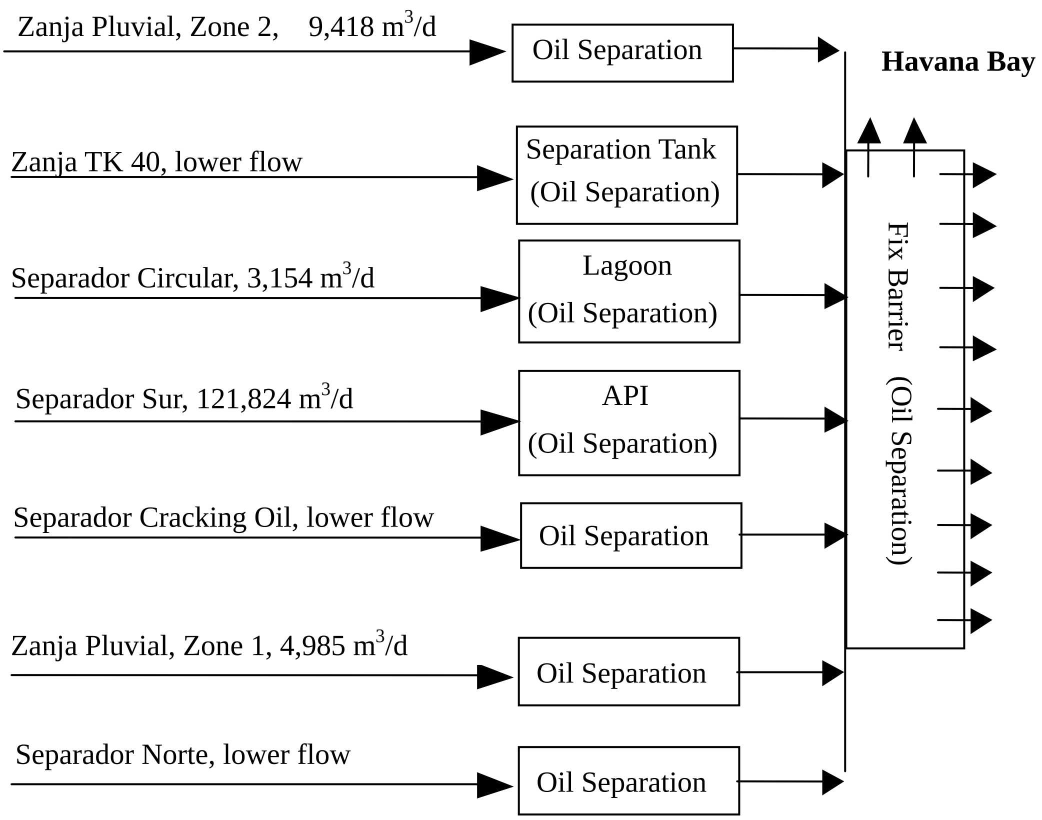
Approximately 700 m^3 per day is supplied from the municipal water supply system for industrial (cooling and boiler) and domestic (toilet flushing, cooking and bathing) water purposes. The existing water consumption of the factory is summarized below by purpose.

Table A5.5 Water Supply Source and Consumption, Cubelo

Source	Purpose	Quantity
Municipal Water	Cooling Water	330 m^3/d
	Boiler Feed Water	374 m^3/d
	Domestic Water	4 m^3/d
Total		708 m^3/d

c) Wastewater discharge system

Wastewater from the factory is firstly treated by a separator to remove oil, and then is treated by a biological treatment process (lagoon). Finally the treated wastewater is discharged into Havana Bay through Luyano River. (see Fig. A5.2)



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A5.1 Industrial Discharge System of Nico Lopez (Oil Refinery Factory)
JAPAN INTERNATIONAL COOPERATION AGENCY	

1. Nico Lopez (Oil Refinery)

2. Curbelo (Gas Production)

3. Prodal (Food Production)

4. Indal (Fishery Processing)

5. Lucero (Milk Processing)

6. Vega Saanchez (Train Repairing)

7. Debon-Suchel (Detergent Production)

8. Jaiper-Suchel (Detergent Production)

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A5.2 Wastewater Discharge Outlets of the Factories Selected for Industrial Wastewater Survey
JAPAN INTERNATIONAL COOPERATION AGENCY	

d) Wastewater quality

The results of water quality analysis of a 24-h composite sample and the existing water quality information are summarized as follows:

Table A5.6 Comparison of Water Quality Data and Estimated Pollutant Loads, Cubelo

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l BOD	COD	T-N	T-P	SS	HC	Pollution Load, kg/d BOD	COD	T-N	T-P	SS	HC
This Survey	175 0.1%	175	234	7.21	5.53	11	0.48	31 1.0%	41 0.5%	1.3 0.2%	1.0 0.02%	1.9 0.01%	0.1 0.00%
GEF (1997)	1,010 1.5%	–	–	–	–	–	198	– –	– –	– –	– –	– –	200 1.2%

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.6, both of flow-rate and hydrocarbon concentration of the wastewater are reduced sharply comparing with the results measured by GEF in 1997. The existing information about organic matters and nutrients is unavailable, therefore, it is impossible to compare them with the results of this survey. However, the concentrations of organic matters, nutrients, suspended solids (SS) and hydrocarbon (HC) in the effluent are considered to be a lower level.

3) PRODAL (FOOD PRODUCTION FACTORY)

The factory produces sausage and various deep-fried foods using fish, shrimp, cheese, chicken meat and turkey. The quantity of production varies with the supply of raw materials.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.7 Outline of Prodal (Food Production Factory)

• Type of Industry	• Food
• Main Raw Materials	• Fresh fish, shrimp and chicken meat
• Main Products	• Sausage and various deep-fried foods, 6,500 ton/year
• No. of Employees	• 926 Persons
• Operation Time	• 24 Hours Continuous Operation

b) Water Supply Source and Consumption

Approximately 800 m^3 per day is supplied from the municipal water supply system for industrial (washing and raw materials) and domestic (toilet flushing, cooking and bathing) water purposes.

c) Wastewater discharge system

The industrial wastewater from the factory is discharged into Havana Bay without any treatment, and domestic wastewater is firstly treated by a septic tank and then discharged into Havana bay. (see Fig. A5.2)

d) Wastewater quality

The results of water quality analysis of a 24-h composite sample and the existing water quality information are summarized as follows:

Table A5.8 Comparison of Water Quality Data and Estimated Pollutant Loads, Prodal

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l						Pollution Load, kg/d					
		BOD	COD	T-N	T-P	SS	HC	BOD	COD	T-N	T-P	SS	HC
This Survey	217 0.2%	800	4,284	26.14	31.49	356	56	174 5.4%	930 11.7%	5.7 1.1%	6.8 0.2%	77 0.2%	12 0.2%
GEF (1997)	360 0.5%	4,611	6,000	311	78	658	3,831	1,660 6.5%	2,160 –	112 –	28 –	237 –	1,379 8.2%

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.8, the concentrations of organic matters, nutrients, suspended solids (SS) and hydrocarbon (HC) in the effluent are reduced to a certain extent comparing with the results measured by GEF in 1997, but these values show a high level, especially for the concentrations of BOD and COD.

Considering the fact that the industrial wastewater from the factory is discharged into Havana Bay without any treatment, it is recommended to install a pretreatment process to remove pollutants before discharging into municipal sewerage system.

4) INDAL (FISHERY PROCESSING FACTORY)

This factory produces canned food from fresh fish for the domestic consumption and for exportation.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.9 Outline of Indal (Fish Processing Factory)

• Type of Industry	• Fishery Processing
• Main Raw Materials	• Fresh Fish
• Main Products	• Canned Fish, 4 to 5 ton/year
• No. of Employees	• 300 Persons
• Operation Time	• 8 Hours

b) Water Supply Source and Consumption

Approximately 214 m^3 per day is supplied from municipal water supply system for industrial (cleaning and raw materials) and domestic (toilet flushing, cooking and bathing) water purposes.

c) Wastewater discharge system

Wastewater from the factory is discharged into Havana Bay through Luyano River without any treatment. (see Fig. A5.2)

d) Wastewater quality

The results of water quality analysis of an 8-h composite sample and the existing water quality information are summarized as follows:

Table A5.10 Comparison of Water Quality Data and Estimated Pollutant Loads, Indal

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l BOD	COD	T-N	T-P	SS	HC	Pollution Load, kg/d BOD	COD	T-N	T-P	SS	HC
This Survey	43 0.03%	200	455	18.54	8.94	72	5.8	8.6 0.3%	20 0.3%	0.8 0.2%	0.4 0.01%	3.1 0.01%	0.2 0.00%
GEF (1997)	400 0.6%	2,400	3,100	135	68	1,240	1,050	960 3.7%	– –	– –	– –	– –	420 2.5%

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.10, both of flow-rate and the concentrations of organic matters, nutrients, suspended solids (SS) and hydrocarbon (HC) in the effluent have declined sharply comparing with the results measured by GEF in 1997. The pollution load discharged from Indal is considered to be a relatively low level.

However, considering the fact that the pollutants concentration in the wastewater from Indal shown a very high level in previous survey, therefore, it is recommended to install a pretreatment process to remove pollutants before discharging into municipal sewerage system.

5) ALBERTO ALVAREZ (FOOD PROCESSING FACTORY)

The factory is a joint venture with an Italian enterprise. In this factory the vegetable food oil is refined for human consumption.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.11 Outline of Alberto Alvarez (Food Processing Factory)

• Type of Industry	• Food Oil
• Main Raw Materials	• Raw Oil
• Main Products	• Vegetable Oil, 100 ton/day
• No. of Employees	• 180 Persons
• Operation Time	• 24 Hours Continuous Operation (including Sunday)

b) Water Supply Source and Consumption

Approximately 200 m^3 per day is supplied from the municipal water supply system for industrial and domestic (toilet flushing, cooking and bathing) water purposes.

c) Wastewater discharge system

Wastewater from the factory is firstly treated by a physical and chemical treatment process, then is treated by a biological treatment process (contact aeration). Finally the treated wastewater is discharged into Havana Bay. The treatment facilities are planed to be put into operation in October to November 2002.

The design figures of treatment facilities is summarized as follows:

Table A5.12 Design Parameters of Wastewater Treatment Facilities

Designer	Idrabel Italia	
Capacity	72 m^3/d	
Design Parameters	Influent	Effluent
pH	4-9	5.5-9.5
COD	<6,000 mg/l	<160 mg/l
Oil and Grease	50-240 mg/l	20 mg/l
SS	-	<80 mg/l

On the other hand, domestic wastewaters are discharged into Havana Bay through a drainage system without any treatment.

d) Wastewater quality

The results of water quality survey in this Study and the existing water quality information are summarized and compared in Table A5.13.

Table A5.13 Comparison of Water Quality and Estimated Pollutant Loads, Alberto Alvarez

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l						Pollution Load, kg/d					
		BOD	COD	T-N	T-P	SS	HC	BOD	COD	T-N	T-P	SS	HC
This Survey	350 0.2%	240	863	18.7	5.3	533	236	84 2.6%	302 3.8%	6.5 1.3%	1.9 0.04%	187 0.5%	83 1.4%
GEF (1997)	205 0.3%	976	1,677	11	9	4,236	2,610	200 0.7%	344 –	2 –	2 –	868 –	535 3.2%

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.13, the concentrations of organic matters, nutrients, suspended solids (SS) and hydrocarbon (HC) in the effluent have declined a certain extent comparing with the results measured by GEF in 1997.

It should be noted that a physical and chemical treatment process and a biological treatment process have been installed to treatment the wastewater from production process in the beginning of 2002. However, up to now the biological treatment facilities have been not put into operation due to technical reason.

6) PARELLADA (THERMAL POWER PLANT)

The factory uses petroleum as raw materials to generate electricity. Major pollutants in the effluent are inorganic matters (heavy metals) coming from the cleaning process of heaters.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.14 Outline of Parellada (Thermal Power Plant)

• Type of Industry	• Electricity
• Main Raw Materials	• Fuel Oil
• Main Products	• 64 MW/h
• No. of Employees	• 243 Persons
• Operation Time	• 24 Hours Continuous Operation

b) Water Supply Source and Consumption

The industrial water is supplied from two (2) sources: Havana Bay through the factory's own intake system for cooling water purpose and the municipal water supply system (approximately 300 m^3 per day) for boiler feed water purpose.

c) Wastewater discharge system

Wastewater from the factory is discharged into Havana Bay directly without any treatment.

d) Wastewater quality

The results of water quality survey in this Study and the existing water quality information are summarized and compared in Table A5.15.

Table A5.15 Comparison of Water Quality and Estimated Pollutant Loads, Parellada

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l						Pollution Load, kg/d					
		BOD	COD	T-N	T-P	SS	HC	BOD	COD	T-N	T-P	SS	HC
This Survey	1,000 0.7%	6.0	16	7.19	4.03	82	0.09	6.0 0.2%	16 0.2%	7.2 1.4%	4.0 0.1%	82 0.2%	0.1 0.0%
GEF (1997)	312 0.4%	–	–	–	–	–	–	– –	– –	– –	– –	– –	– –

Note: Figures in percentage show a ratio among the 10 selected factories

The existing information about the wastewater quality of the plant is unavailable, therefore, it is impossible to compare them with the results of this survey. However, as shown in the above table, the concentrations of organic matters, nutrients, suspended solids (SS) and hydrocarbon (HC) in the effluent are considered to be a relatively low level.

It should be noted that the plant is planed to relocate from existing location to another place out of Havana Bay in 2005.

7) LUCERO (MILK PROCESSING FACTORY)

The factory produces milk products for domestic use, at the same time it discharge big volumes of wastewater containing organic matter.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.16 Outline of Lucero (Milk Processing Factory)

• Type of Industry	• Milk Processing
• Main Raw Materials	• Fresh Milk, Powder Milk and Soybean
• Main Products	• Pasteurized Milk, 40 m^3/d; Soy Milk, 30 m^3/year
• No. of Employees	• 350 Persons
• Operation Time	• 24 Hours Continuous Operation

b) Water Supply Source and Consumption

The water is supplied from the municipal water supply system for industrial (cleaning) and domestic (toilet flushing, cooking and bathing) water purposes. However, the water consumption per day in this factory is unavailable.

c) Wastewater discharge system

Wastewater from the factory is discharged into Luyano River without any previous treatment. (see Fig. A5.2)

d) Wastewater quality

The results of water quality analysis of a 24-h composite sample and the existing water quality information are summarized as follows:

Table A5.17 Comparison of Water Quality and Estimated Pollutant Loads, Lucero

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l						Pollution Load, kg/d					
		BOD	COD	T-N	T-P	SS	HC	BOD	COD	T-N	T-P	SS	HC
This Survey	667 0.1%	500	1,632	15.9	7.92	945	13.4	334 10.4%	1,089 13.8%	11 2.1%	5.3 0.1%	630 1.7%	8.9 0.2%
GEF (1997)	500 –	1,450	1,800	124	–	386	–	725 –	900 –	62 –	– –	193 –	– –

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.17, the concentrations of organic matters (BOD and COD) and suspended solids (SS) in the effluent show a relatively high level. Moreover, Lucero also contributes 10.7% of BOD load and 14.3% of COD load of the total pollution load of the 10 selected factories, as shown in Figure 3.14. On the other hand, the concentrations of nutrients (T-N and T-P) and hydrocarbon (HC) in the effluent are considered to be a lower level.

8) VEGA SAANCHEZ (TRAIN REPAIRING FACTORY)

The main activity of the factory is the repair and maintenance of passengers' boxcars.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.18 Outline of Vega Saanchez (Train Repairing Factory)

• Type of Industry	• Train Repairing
• Main Raw Materials	•
• Main Products	•
• No. of Employees	• 350 Persons
• Operation Time	• 12 Hours

b) Water Supply Source and Consumption

Approximately 200 m^3 per day is supplied from the municipal water supply system for industrial (cleaning) and domestic (toilet flushing, cooking and bathing) water purposes. The existing water consumption of the factory is summarized below by purpose.

Table A5.19 Water Supply Source and Consumption, Vega Saanchez

• **Source**	• **Purpose**	• **Quantity**
• Municipal Water	• Cleaning Water	• 123 m^3/d
•	• Domestic Water	• 80 m^3/d
• Total	•	• 203 m^3/d

c) Wastewater discharge system

Wastewater from the factory is discharged into Havana Bay through Luyano River without any previous treatment. (see Fig. A5.2)

d) Wastewater quality

The results of water quality analysis of a 12-h composite sample and the existing water quality information are summarized as follows:

Table A5.20 Comparison of Water Quality and Estimated Pollutant Loads, Vega Saanchez

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l						Pollution Load, kg/d					
		BOD	COD	T-N	T-P	SS	HC	BOD	COD	T-N	T-P	SS	HC
This Survey	259 0.2%	235	490	9.39	9.37	30	3.7	61 1.9%	127 1.6%	2.4 0.5%	2.4 0.1%	7.8 0.02%	1.0 0.02%
GEF (1997)	203 –	–	104	–	–	133	33	– –	21 –	– –	– –	27 –	7 –

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.20, no apparent difference in the flow-rate of the wastewater is observed in this survey. Moreover, the concentrations of organic matters, nutrients, suspended solids (SS) and hydrocarbon (HC) in the effluent are considered to be a low level.

9) DEBON-SUCHEL (DETERGENT PRODUCTION FACTORY)

The factory produces various detergents such as synthetic detergent, soap and shampoo etc..

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.21 Outline of Debon-Suchel (Detergent Production Factory)

• Type of Industry	• Detergent
• Main Raw Materials	• Sulfonic Acid, Sodium Tripolyphosphate and Sodium Sulfate
• Main Products	• Detergent, 13,000 ton/year
• No. of Employees	• 270 Persons
• Operation Time	• 16 Hours

b) Water Supply Source and Consumption

Approximately 460 m^3 per day is supplied from the municipal water supply system for industrial (boiler and raw materials) and domestic (toilet flushing, cooking and bathing) water purposes. The existing water consumption of the factory is summarized below by purpose.

Table A5.22 Water Supply Source and Consumption, Debon-Suchel

• **Source**	• **Purpose**	• **Quantity**
• Municipal Water	• Raw Materials	• 40 m^3/d
•	• Flushing Water	• 7 m^3/d
•	• Boiler Feed Water	• 400 m^3/d
•	• Domestic Water	• 8 m^3/d
•	• Others	• 5 m^3/d
• Total	•	• 460 m^3/d

c) Wastewater discharge system

Wastewater from the factory is discharged into Havana Bay through a drainage channel named as Matadero without any previous treatment. (see Fig. A5.2)

d) Wastewater quality

The results of water quality analysis of a 16-h composite sample are summarized as follows:

Table A5.23 Comparison of Water Quality and Estimated Pollutant Loads, Debon-Suchel

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l						Pollution Load, kg/d					
		BOD	COD	T-N	T-P	SS	HC	BOD	COD	T-N	T-P	SS	HC
Results	380 0.3%	10	81	9.32	1.37	13	8	3.8 0.1%	31 0.4%	3.5 0.7%	0.5 0.01%	4.9 0.01%	3.0 0.05%

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.23, the concentrations of organic matters, nutrients, suspended solids (SS) and hydrocarbon (HC) in the effluent are considered to be a low level comparing with the typical wastewater quality of detergent production factory. Moreover, the pollutant loads discharged from this factory show a lower level, as shown in Figure 3.13 (Volume II, Part I, Chapter 3), because wastewater quantity is low.

10) JAIPER-SUCHEL (DETERGENT PRODUCTION FACTORY)

The factory produces soap, shampoo, toothpaste, hair gel and deodorant etc. for domestic use.

a) Outline of the factory

The main features of the existing industrial activities are summarized below.

Table A5.24 Outline of Jaiper-Suchel (Detergent Production Factory)

• Type of Industry	• Detergent
• Main Raw Materials	•
• Main Products	• Soap, shampoo and toothpaste etc., 11,700 ton/year
• No. of Employees	• 600 Persons
• Operation Time	• 12 Hours

b) Water Supply Source and Consumption

Approximately 40 m^3 per day is supplied from the municipal water supply system for industrial (cleaning and raw materials water etc.) and domestic (toilet flushing, cooking and bathing) water purposes.

c) Wastewater discharge system

Wastewater from the factory is discharged into Havana Bay through a drainage channel named as Agua Dulce without any previous treatment. (see Fig. A5.2)

d) Wastewater quality

The results of water quality analysis of a 12-h composite sample are summarized as follows:

Table A5.25 Comparison of Water Quality and Estimated Pollutant Loads

Para-meters	Flow m^3/d	Pollutant Concentration, mg/l						Pollution Load, kg/d					
		BOD	COD	T-N	T-P	SS	HC	BOD	COD	T-N	T-P	SS	HC
This Survey	39 0.03%	130	184	9.32	11.14	52	13.5	5.1 0.2%	7.2 0.1%	0.4 0.1%	0.4 0.01%	2.0 0.01%	0.5 0.01%

Note: Figures in percentage show a ratio among the 10 selected factories

As shown in Table A5.25, the concentrations of organic matters, nutrients, suspended solids (SS) and hydrocarbon (HC) in the effluent are considered to be a relative low level comparing with the typical wastewater quality of detergent production factory. Moreover, as shown in Figure 3.13 (Volume II, Part I, Chapter 3), the pollutant loads discharged from this factory show a lower level because wastewater quantity is very low.

APPENDIX-6

TIDAL CURRENT MEASUREMENT SURVEY AND SOUNDING SURVEY

Contents

A6.1 INTRODUCTION

Tidal current measurement and sounding survey were carried out in Havana Bay to confirm the tidal current characteristics in the Havana Bay during flood tide and ebb tide. The work was subcontracted to CIMAB and the reports for wet season (October 2002) and dry season (December 2002) are presented in this Appendix.

CENTRO DE INGENIERÍA Y MANEJO AMBIENTAL DE BAHÍAS Y COSTAS (CIMAB)

Departamento de Ordenamiento Litoral

Final Report

OCEANOGRAPHIC SURVEY IN HAVANA BAY

Wet Season

Stage 1

AUTHORS

René GARCIA GALOCHA
Héctor QUINTANA NOY

Havana City, November of 2002

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1. INTRODUCTION

The Bay of Havana this located in the 23° 09´ of North Latitude and in the 82° 21´ of Longitude West. It is a typical sack bay with a perimeter of 18 km, shaped by three coves: Atares, Guasabacoa and Marimelena. The Bay has a total area 5.2 km^2 and a mean depth 9.2 m, and its able to store a water volume of approximately 47 x 10^6 m^3. The tides and the fresh water inputs through rivers and drainages to the bay, have played an important role in the water dynamics and has determine that the Havana Bay behaves as an estuary.

Havana Bay was object of a multidisciplinary study in the framework of the Project CUB/80/001 (UNDP-UNEP-UNESCO) "Investigation and control of the marine pollution in Havana Bay", carried out between 1980 and 1985. Among the main results of this project can be highlighted the physical oceanography studies, guided to establish the dynamics of the Bay water and the main mixing processes and mechanisms of transport of polluting substances.

During the years 1996 and 1998, the Havana Bay was included in the Regional Project GEF/RLA/93/G41 "Planning and Management of and Heavily Contaminated Bays and Coastal Areas in the Wider Caribbean"; and among the results obtained were carried out the studies to identify the environmental condition of the bay and the establishment of the water circulation pattern in the bay.

An important limitation to carry out the water dynamics studies in the Havana harbor was the intense ship traffic and the prohibition of the installation of recording current meter by fixed buoy stations. Due to this, the studies developed were conducted at a point fashion in previously selected stations, so that didn't constitute an obstacle for sailing security.

The present study has as purpose to carry out the physical oceanography studies to obtain updated information that will allow to characterize the vertical structure of the water column and to establish the water circulation pattern in the bay, due to the influence of the tidal wave (ground truth) for its later use in the mathematical models.

This stage of the investigation shows the results obtained during the wet season and was carried out between the 7 and 22 of October, 2002 by the Littoral Management Department of CIMAB for the Nihon Suido Consultants Co. Ltd., as requested by the Japan International Cooperation Agency (JICA), in the framework of the Project "Development Study on the Improvement of the Sewerage and Drainage System for Havana Bay in the Republic of Cuba.

2. MATERIALS AND METHODS

For the characterization of the main oceanographic parameter that impact the water circulation of Havana Bay during the wet season a network of 12 stations which covered the whole bay was established (Fig. 2.1).

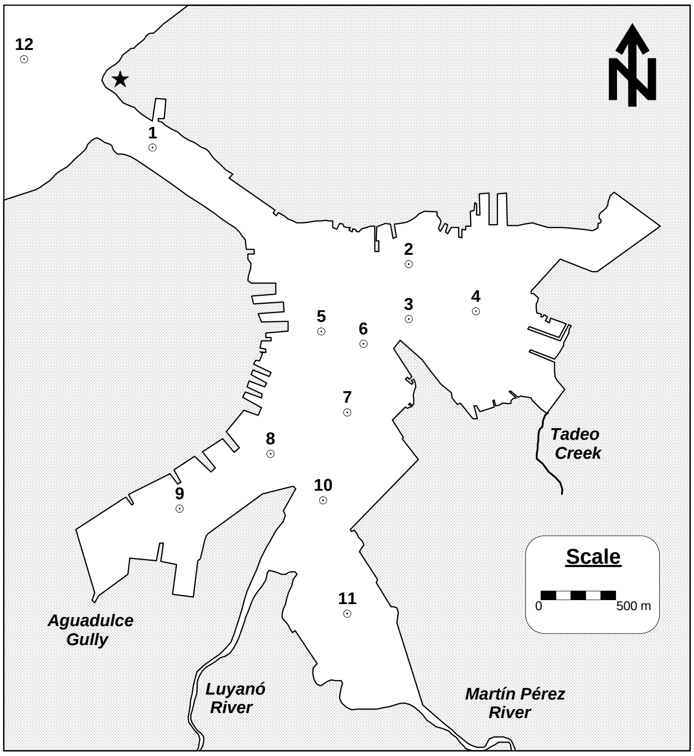


Figure 2.1: Oceanographic Stations Network in Havana Bay.

Positioning of stations in the sea was carried out with the aid of a GPS-2000 and the depths were measured directly with an lead line. The geographical position and depths of the sampling stations are shown in the following table:

Stations	Depths (meter)	Latitude N	Longitude W	X	Y
1	12.5	23º 08´ 46.0´´	82º 21´ 14.8´´	361296.87	369046.04
2	10.5	23º 08´ 21.0´´	82º 20´13.2´´	363014.72	368264.00
3	12.0	23º 08´ 11.0´´	82º 20´ 14.7´´	363014.72	367895.49
4	13.0	23º 08´ 10.0´´	82º 19´ 59.0´´	363464.62	367947.29
5	13.5	23º 08´ 05.3´´	82º 20´ 35.4´´	362427.75	367811.91
6	11.5	23º 08´ 02.7´´	82º 20´ 25.4´´	362711.54	367729.40
7	11.5	23º 07´ 47.7´´	82º 20´ 29.1´´	362602.17	367268.92
8	12.5	23º 07´ 40.9´´	82º 20´ 46.4´´	362087.73	366991.43
9	12.5	23º 07´ 26.4´´	82º 21´ 08.4´´	361478.15	366623.71
10	11.0	23º 07´ 28.5´´	82º 20´ 34.6´´	362440.42	366679.70
11	11.0	23º 07´ 06.9´´	82º 20´ 28.6´´	362601.99	365919.50
12	30.0	23º 09´ 10.8´´	82º 21´45.4´´	360435.19	369638.10

In each station the information of the different hydrological parameters was collected with a view to establishing the zonal differences, as well as the water vertical structure in the bay. To measure the temperature and salinity of the water a temperature/salinity meter YSI-30M was used; from this data the density was calculated (Galocha, 1984).

The transparency and color of the water were measured, with a Secchi disk and the Forel-Ulle scale, respectively.

The collection of data in each station was carried out at surface, 5 and 10 m of depths. In the station 1 (located in the entrance channel of the Bay), the information was collected at intervals of 1 meter, from the surface to the bottom. In the station 12 (reference), only the temperature and salinity of the water at surface, 5, 10 and 15 m of depths were measured.

Simultaneously, in each station (excluding station 12), were carried out point measurements of the velocity and direction of the marine current. The collection of data was carried out in the same horizons of the hydrological parameters and were performed with the aid of a portable current meter CM-2. The survey vessel was anchored during the samplings to avoid that the vessel's drift influenced in the measurements.

The oceanographic samplings were carried out during the flood and ebb phases of the tide. A 24 hours sampling was also carried out, at intervals of 2 hours, in the stations 1, 3 and 5 in the bay to determine the variation of the different parameters through the time.

As a complementary information, during the samplings minor meteorology information was collected aboard the vessel. The parameters measured in each station were: velocity and direction of the wind; air temperature (dry and humid), from which the relative humidity was calculated; atmospheric pressure; cloudiness and state of sea. For this task were used a portable anemometer, an aspersion psychrometer MB-4M and an aneroid barometer M-67. The registrations of the cloudiness and the sea state were carried out by means of direct observation.

Finally, with a view of evaluating the behavior of the bay in this period and the main hydrodynamic characteristics a continuous circulation-stratification spectrum was applied (Hansen & Rattray, 1966).

3. RESULTS

The results obtained during the data collection in the wet season (October 2002), evidence the existence of two water layers in the bay with unequal behavior, which are influenced by the incident solar radiation, the fresh water inputs to the bay and the tidal wave.

3.1. Minor Meteorology

The samplings carried out during the flood phase showed a mean air dry temperature with values of 28.4 ± 1.2 ºC and the mean humid temperature was of 26.0 ± 0.6 ºC, for a relative humidity of 82.3 ± 3.4%. The atmospheric pressure showed mean values of 760.5 ± 0.8 mmHg. The winds had a predominant direction of the first quadrant and their velocities were variable, even alternating with periods of calms. The mean velocity was of 2.3 ± 1.8 $m.sec^{-1}$.

The samplings conducted during the ebb phase showed mean values for the dry temperature of the air of 26.7 ± 1.3 ºC and the mean humid temperature was of 24.9 ± 0.5 ºC, for a relative humidity of 86.8 ± 2.0%. The atmospheric pressure showed mean values of 760.5 ± 0.6 mmHg. During the samplings the winds were very weak and in most of the stations were registered calms, the mean velocity was of 0.2 ± 0.3 $m.sec^{-1}$.

During 24 hours samplings, the mean values among the stations were: air dry temperature 28.3 ± 2.2 ºC and the humid temperature 25.2 ± 0.8 ºC, for a relative humidity of 79.6 ± 6.8%. The atmospheric pressure showed mean values of 759.8 ± 0.5 mmHg. The winds had a mean velocity among the stations of 2.0 ± 1.9 m.sec-1.

In all the cases the cloudiness varied between 1/8 and 5/8, while the sea was calm.

3.2. Temperature

The water surface temperatures increased gradually toward the inner part of the bay (Fig. 3.1) during the ebb or flood. The temperatures are greatly influenced by the incident solar radiation that determine that the surface water behave as a black body, accumulating heat along the day and radiate out in hours of the afternoon and night, as will be discussed later on.

During the flood phase the surface water showed minimum temperatures of 28.5 ºC and maximum of 30.2 ºC in different points of the bay, for a mean value (expressed in terms of $\bar{x} \pm s$) of 29.5 ± 0.6 ºC. In the ebb phase the surface water showed minimum temperatures of 28.8 ºC and maximum of 30.9 ºC in different points of the bay, for a mean value of 30.2 ± 0.7 ºC.

The above-mentioned results indicate a slight influence of the tidal wave on the surface temperatures; originating a decrease of the temperatures as a consequence of the entrance of oceanic water to the bay.

At some parts of the bay due to the rainfall, can take place discreet decreases in the surface temperatures because of fresh water inputs from the rivers. For example, in Guasabacoa Cove during the sampling carried out in the flood phase, because of rainfalls that took place at the basin in previous days, was verified a slight reduction of the surface temperatures in this area. Indicating the link between the water surface layer of the bay with the fresh water inputs through rivers and storm drains.

Starting from the 5 m depth and to the bottom, the temperatures are less than those of the surface and present a much more regular behavior in all the points of the bay, registering values similar to the outer water of the bay, so much in the flood phase as in the ebb phase (Fig. 3.2).

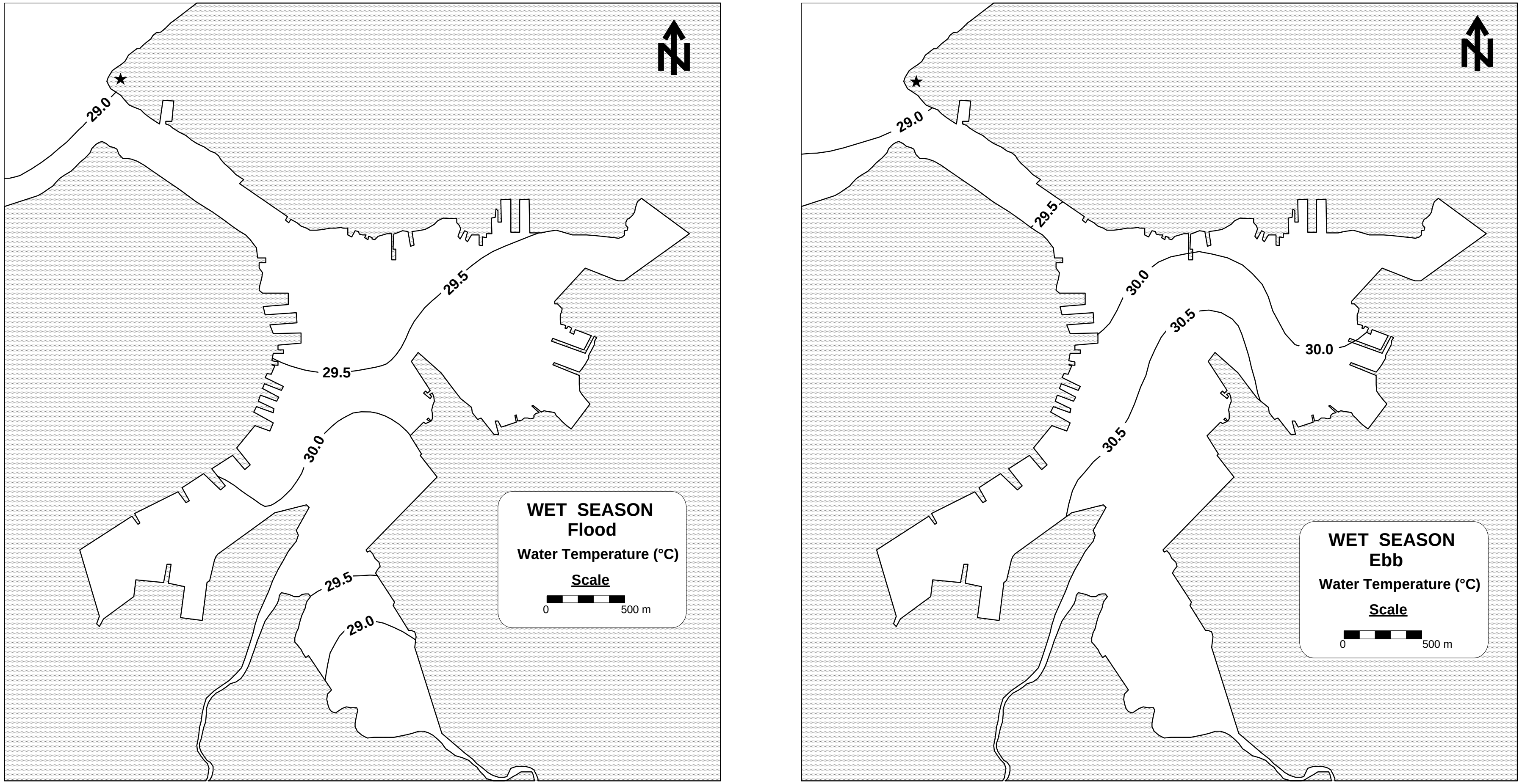


Figure 3.1: Surface Temperatures in Havana Bay. Wet season (October/ 2002).

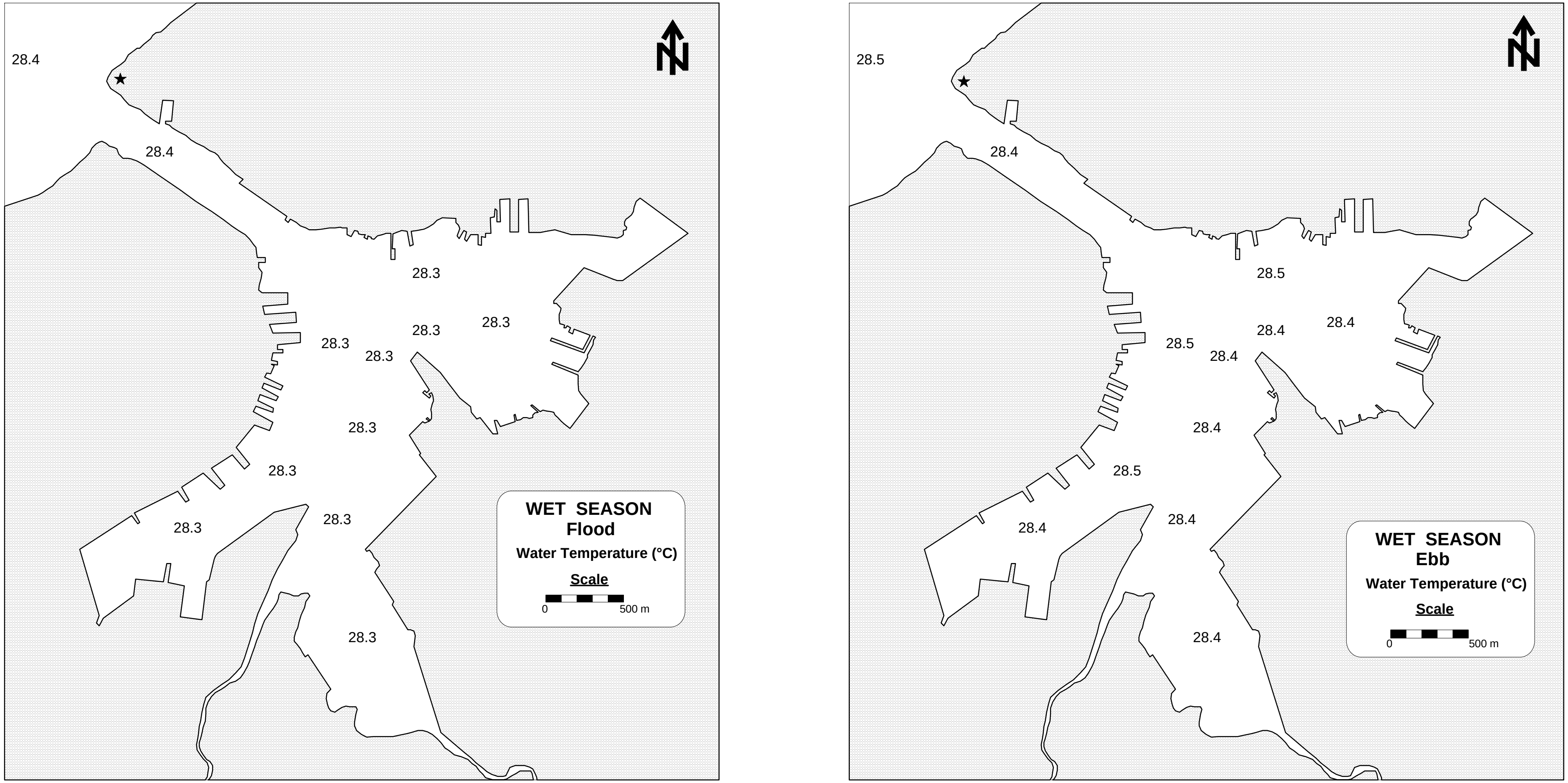
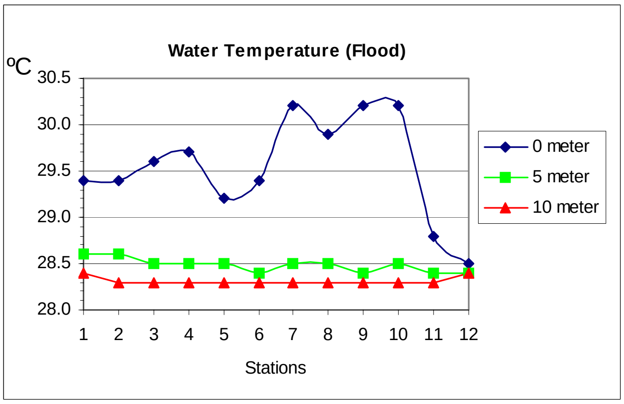


Figure 3.2: Temperatures at 10 m of depth in Havana Bay. Wet season (October/2002).

During the flood phase, the water at 5 m of depth, showed minimum temperatures of 28.4 ºC and maximum of 28.6 ºC in different points of the bay, for an mean value of 28.5 ± 0.1 ºC. At 10 m of depth, the water showed minimum temperatures of 23.3 ºC and maximum of 28.4 ºC in different points of the bay, for an mean value of 28.3 ± 0.0 ºC.

The water at 5 m of depth showed minimum temperatures of 28.4 ºC and maximum of 28.7 ºC, during the ebb phase in different points of the bay, for an mean value of 28.6 ± 0.1 ºC. To the 10 m of depth, the water showed minimum temperatures of 23.4 ºC and maximum of 28.5 ºC in different points of the bay, for an mean value of 28.4 ± 0.0 ºC.

With the help of the above-mentioned, it can be assumed that in the flood as well as at the ebb phases, the bay's water are stratified and at least two well differentiated layers are observed; a surface layer more variable and a sub-surface layer (from 5 m of depth), more homogeneous and linked to the outer water of the bay (Fig. 3.3).



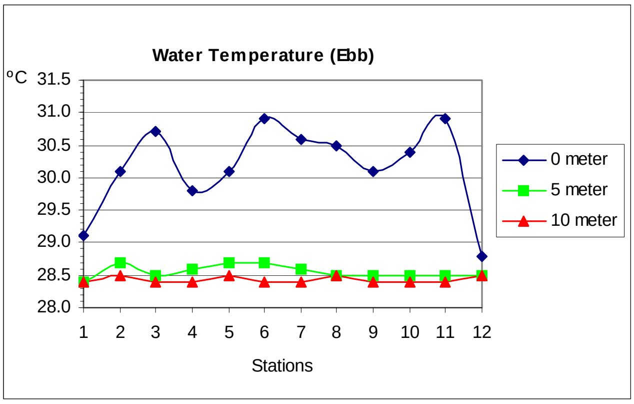


Figure 3.3: Variation of the Temperatures in Havana Bay by Stations. Wet season (October/2002).

The water surface temperatures in the bay throughout the day experience significant variations that are related directly with the incident solar radiation and in a lesser way from the influence of the tidal wave, as was verified in 3 sampling stations inside the bay during 24 hours of observation (Fig. 3.4). Throughout the whole period the temperatures of the sub-surface layer showed a more homogeneous behavior and well related with the outer water of the bay.

Mainly, the thermal gradients (horizontal and vertical) more significant of the bay's water are observed in the surface layer and differ with those of the sub-surface layer.

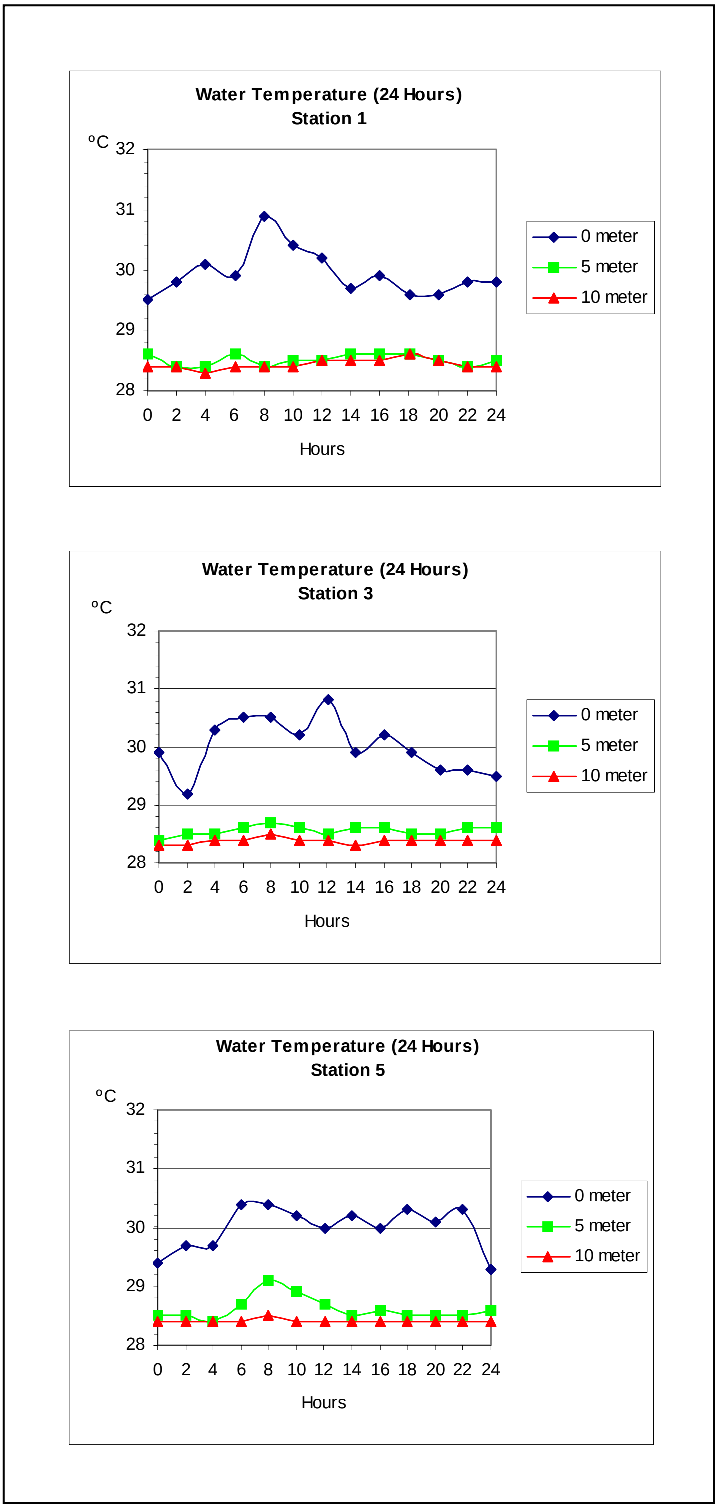


Figure 3.4: Variation of the Temperatures at Havana Bay in 24 hours. Wet season (October/2002).

3.3 Salinity

The surface salinity of the water in the bay (Fig. 3.5), decreases gradually toward the inside of the Bay, during the flood as well as in the ebb. The salinities are influenced directly by the fresh water inputs from the rivers and storm drains to the bay.

During the flood phase, the surface water showed a minimum salinity of 30.2 ppt and maximum of 34.8 ppt in different points of the bay, for a mean value (expressed in terms $\bar{x} \pm s$) of 32.4 ± 1.5 ppt. During the ebb phase, the surface water showed a minimum salinity of 32.0 ppt and maximum of 35.2 ppt in different points of the bay, for a mean value of 33.3 ± 0.9 ppt.

The rainfall occurred (although slight) in the upper part of the rivers basin and drainages in days previous to the execution of the samplings in the bay, have contributed with the inputs of fresh water which influenced the surface water of the bay, reducing slightly the salinity. The isohalines outlined in the Guasabacoa and Atarés Coves during the flood sampling (7/10/2002) and in the Guasabacoa Cove and the western part of the bay's central body the during the ebb sampling (11/10/2002), are an example of this.

The water salinity in the bay increases with the depth and from the 5 m, its behavior in the whole bay is more homogeneous than at the surface layer, registering values similar to those of the outer water of the bay, during flood phase as well as in the ebb phase (Fig. 3.6).

During the flood phase, the water at 5 m of depth showed a minimum salinity of 35.6 ppt and a maximum of 36.0 ppt in different points of the bay, for a mean value of 35.8 ± 0.1 ppt. At 10 m of depth, the water showed a minimum salinity of 35.7 ppt and a maximum of 36.1 ppt in different points of the bay, for a mean value of 35.9 ± 0.1 ppt.

The water at 5 m depth showed a minimum salinity of 35.8 ppt and a maximum of 36.1 ppt during the ebb phase, as well as a mean value of 35.9 ± 0.1 ppt. To the 10 m depth, the water showed a minimum salinity of 35.9 ppt and a maximum of 36.1 ppt, for a mean value of 36.0 ± 0.2 ppt.

From the above-mentioned, for the flood phase as well as for ebb, can be assumed that the water of the bay are stratified and two well differentiated layers are observed; a surface layer more variable and another sub-surface one (starting from the 5 m of depth), more homogeneous and linked to the outer water of the bay (Fig. 3.7).

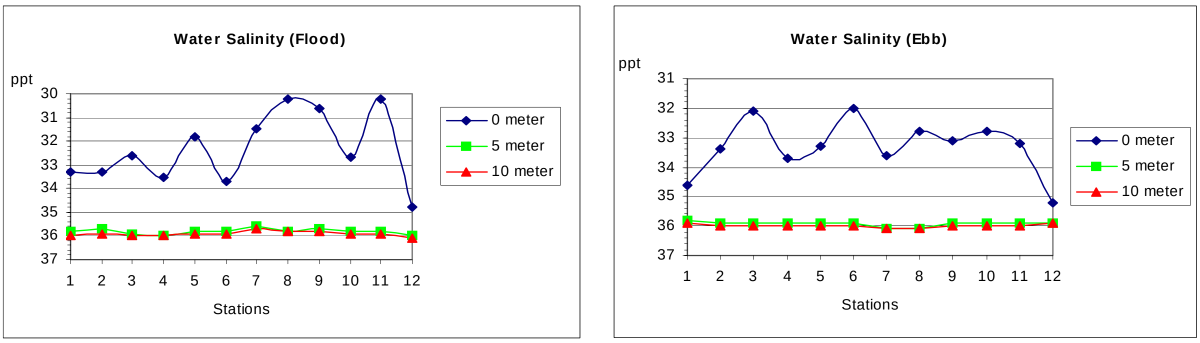


Figure 3.7: Variation of the Salinity in Havana Bay by stations. Wet season (October/2002).

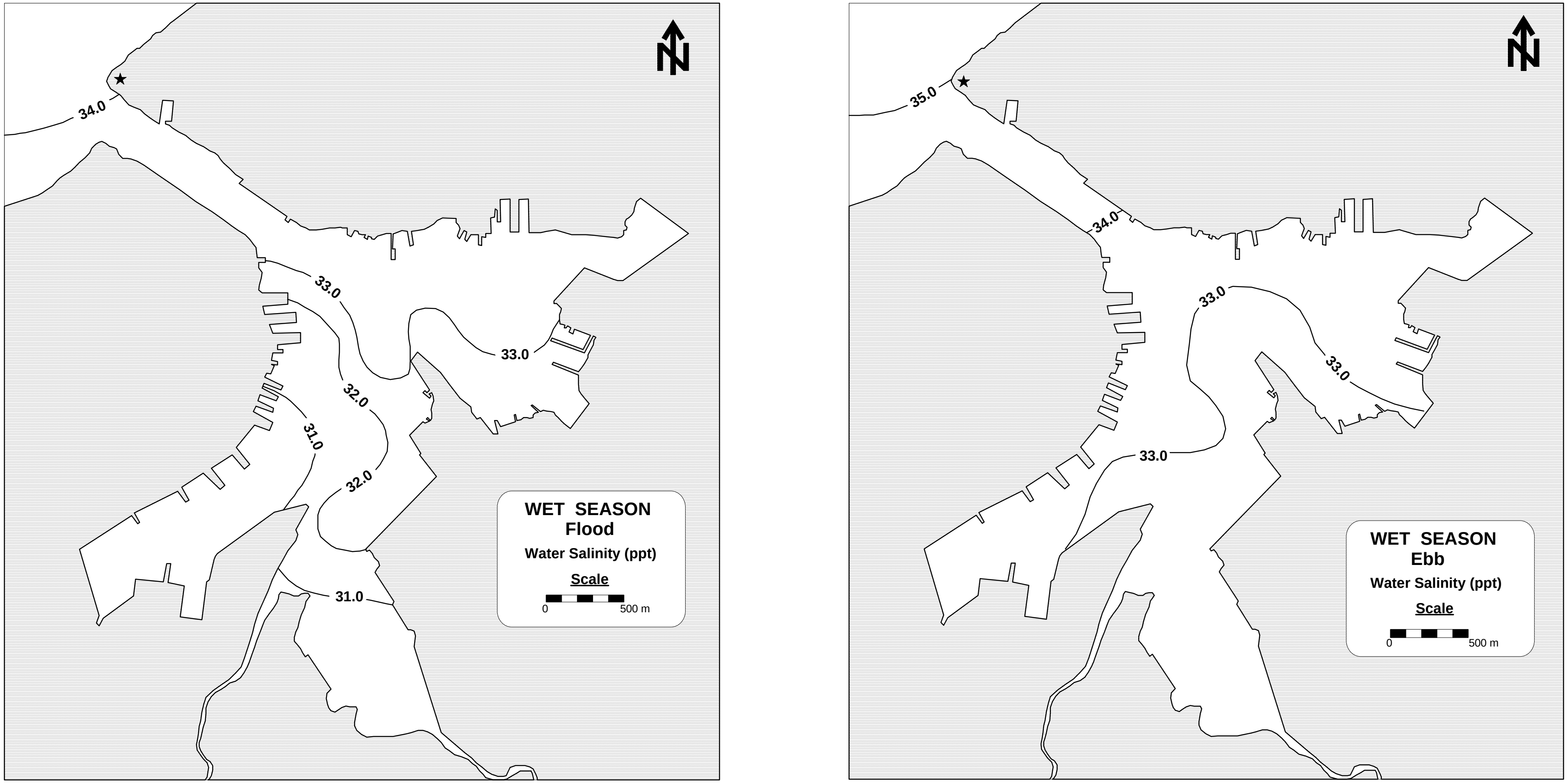
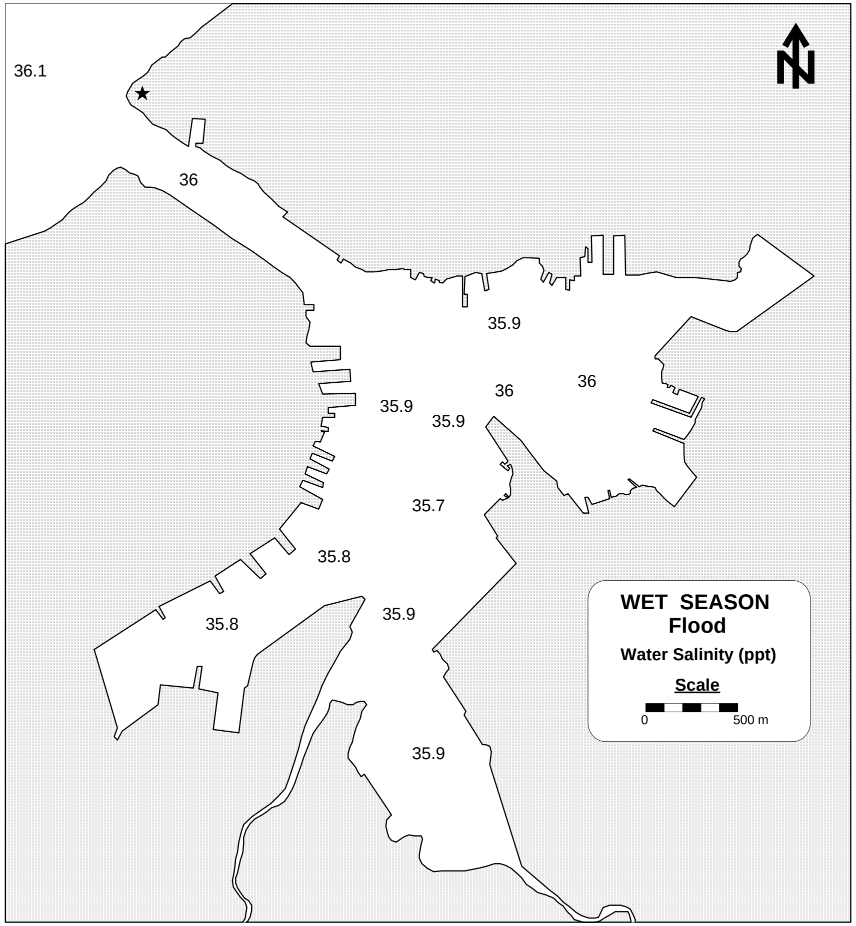


Figure 3.5: Surface Salinity in Havana Bay. Wet season (October/2002).



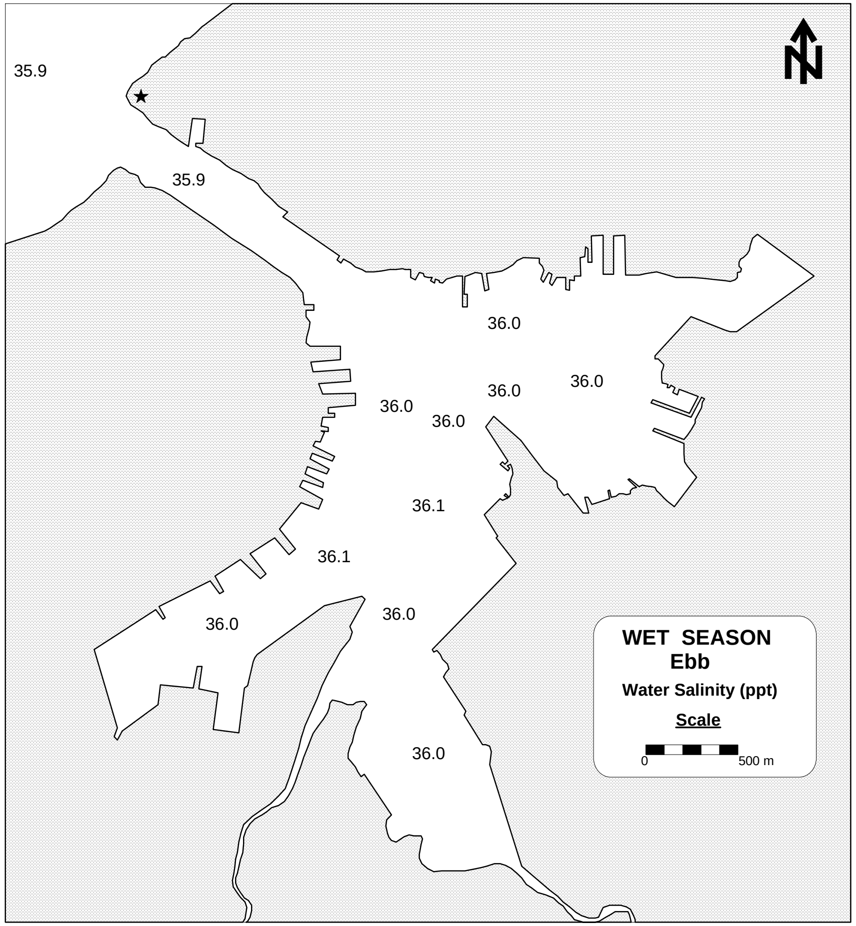


Figure 3.6: Salinity at 10 m of depth in Havana Bay. Wet season (October/2002).

The surface water salinity in the bay through the day experiences significant variations that are related directly with the contributions of fresh water that inputs to the bay and in smaller scale by the influence of the tidal wave, as verified in 3 sampling stations inside the bay during 24 hours of observation (Fig. 3.8). The salinity of the bottom layer showed throughout the whole period a very homogeneous behavior and well related with the outer water of the bay.

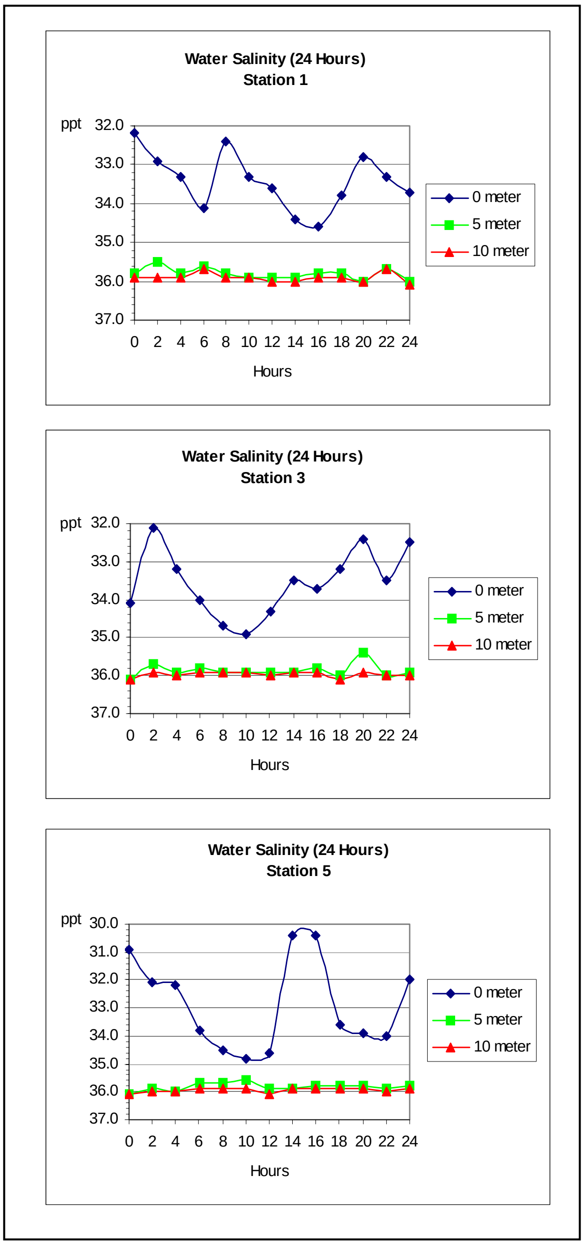


Figure 3.8: Variation of the salinity in Havana Bay during 24 hours. Wet season (October/2002).

In general, the halines gradients (horizontal and vertical) more significant of the bay water are observed in the surface layer and differs with those of the bottom layer.

3.4 Density

Mainly, the density variation in the bay is in total correspondence with the behavior of the salinity variation.

The water surface densities in the bay increases gradually toward the open sea as shown by the equal density isolines, during flood as well as in ebb phases (Fig. 3.9). The densities are basically governed by the water salinity and in a low profile by the tidal wave.

The above-mentioned indicates the importance of fresh water inputs for the bay; being able to establish a significant horizontal gradient, which contributes to the development of a surface circulation toward the open sea, and that will be discussed in Section 3.6.

The surface water showed a minimum density of 18.2 kg/m^3 and a maximum of 22.1 kg/m^3 in different points of the bay during the flood phase, for a mean value 19.9 $\pm$ 1.2 kg/m^3. During the ebb phase, the surface water showed minimum densities of 19.2 kg/m^3 and maximum of 22.3 kg/m^3 in different points of the bay, for a mean value of 20.4 $\pm$ 0.9 kg/m^3.

The water density in the bay increases with the depth, as well as, the temperature and salinity fields; from the 5 m of depth the behavior in the whole bay is more homogeneous than the surface water, registering values similar to those of the outer water of the bay, in the ebb or flood phases (Fig. 3.10).

The water located at 5 m of depth, showed a minimum density of 22.7 kg/m^3 and a maximum of 23.0 kg/m^3 in different points of the bay during the flood phase, for a mean value of 22.9 $\pm$ 0.1 kg/m^3. To the 10 m of depth, the water showed a minimum density of 22.8 kg/m3 and a maximum of 23.1 kg/m3 for a mean value of 23.0 $\pm$ 0.1 kg/m^3.

During the ebb phase, the water located at 5 m of depth, showed a minimum density of 22.9 kg/m^3 and a maximum of 23.1 kg/m^3, as well as a mean value of 22.9 $\pm$ 0.1 kg/m^3. To the 10 m of depth, the density of the water showed a minimum value of 22.3 kg/m^3 and maximum of 23.1 kg/m^3, for a mean value of 23.0 $\pm$ 0.2 kg/m^3.

As already mentioned in Section 3.3 and substantiated, during ebb or flood, the bay water show a certain degree of stratification and two well differentiated layers were observed; a surface layer more variable and a bottom layer, more homogeneous and linked to the outer water of the bay (Fig. 3.11).

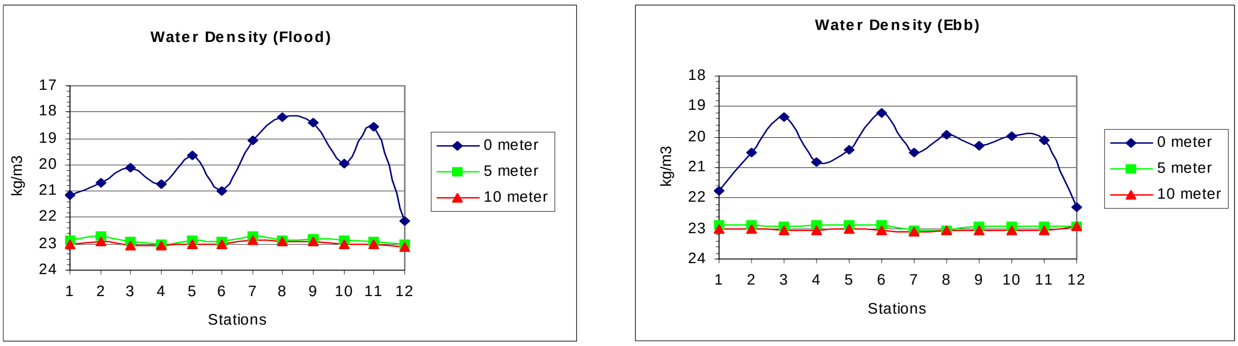


Figure 3.11: Variation of the density in Havana Bay by stations. Wet season (October/2002).

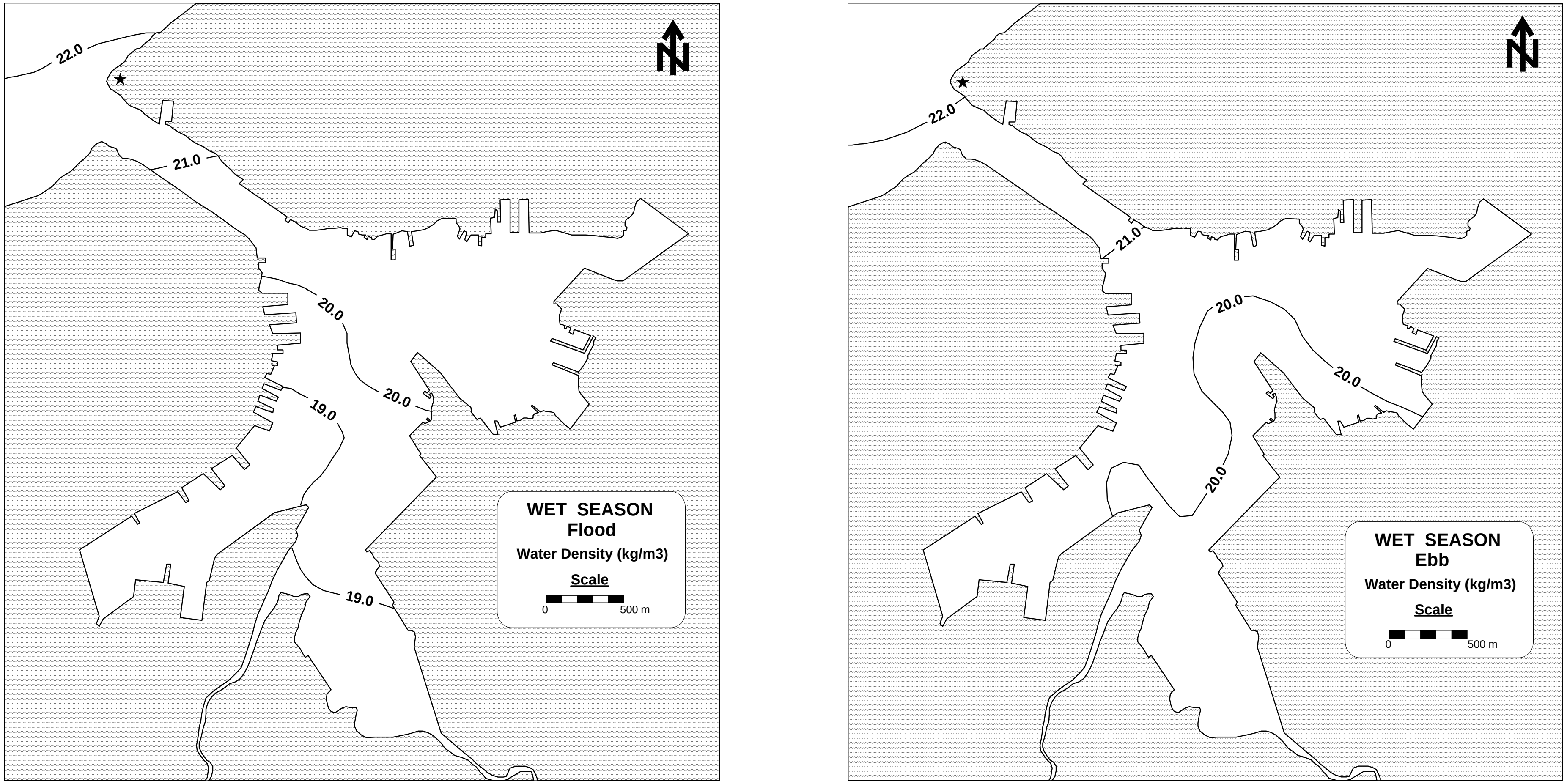


Figure 3.9: Surface Density in Havana Bay. Wet season (October/2002).

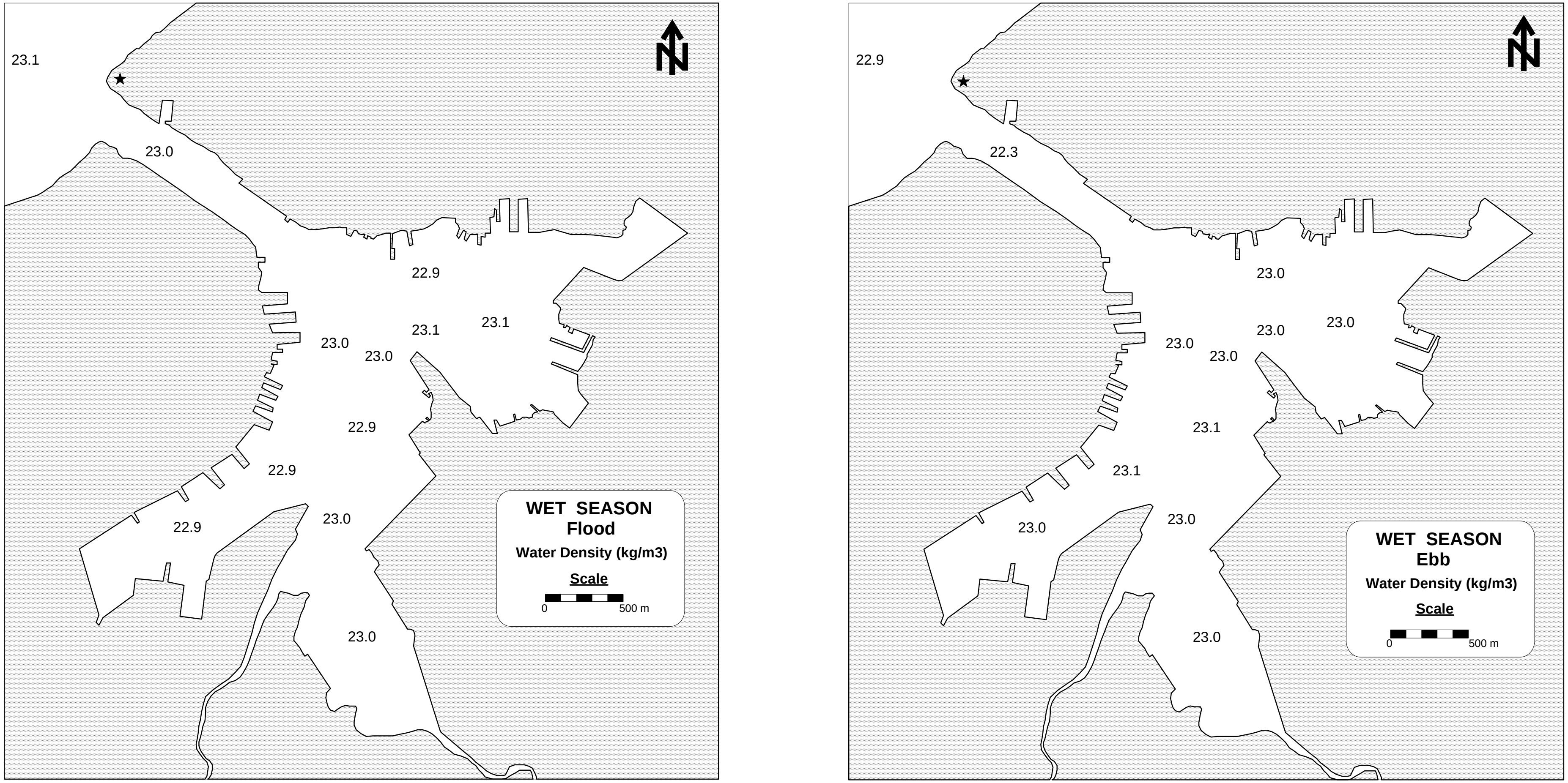


Figure 3.10: Density at 10 m of depth in Havana Bay. Wet season (October/2002).

The density of the surface water in the bay throughout the day experiences significant variations that are related directly with the fresh water inputs to the bay and influence to a lesser degree by the tidal wave, as verified in 3 sampling stations inside the bay during 24 hours of observation (Fig. 3.12). The density of the bottom layer showed throughout the study period a very homogeneous behavior and strongly influenced by the outer water of the bay.

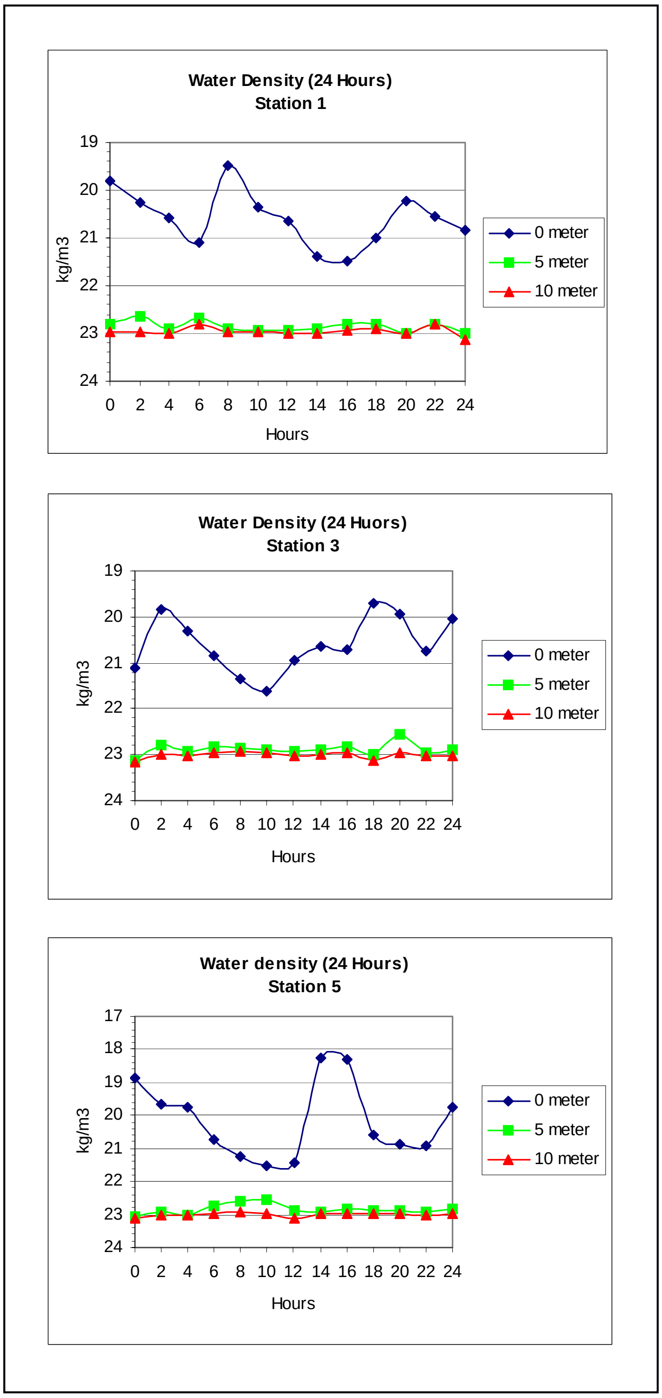


Figure 3.12: Variation of the Density at Havana Bay in 24 hours. Wet season (October/2002).

3.5 Transparency and water color.

The transparency of the water in the bay is reduced and varied between 1.4 and 2.4 m. The color of the water, according to the scale Forel-Ulle, varied between a value 11 and 13. The above values was in contrast with the values obtained at station 12 (reference), located in the outer water of the bay and where the transparency was of 6 m and the color 8 (Fig. 13).

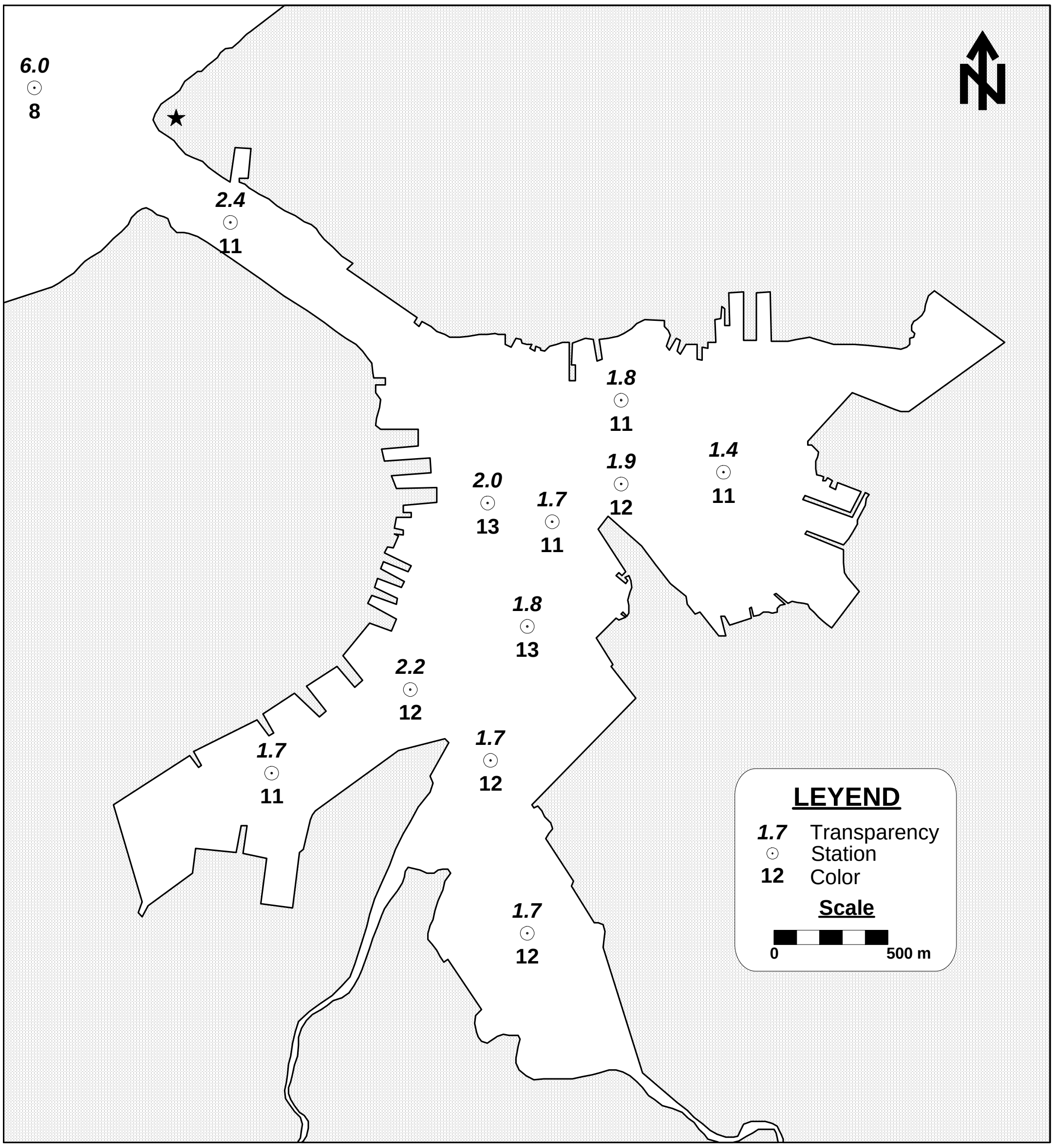


Figure 3.13 -: Transparency and water color in Havana Bay. Wet season (October/2002).

Should be highlighted that the transparency values and water color could not been carried out in hours of the night during the ebb sampling.

3.6. Marine current.

The data collection of the current velocity and direction was executed in the flood and ebb phases, with the view to discuss a stationary theoretical state. The samplings in each tide phase had an approximate duration of 3 hours and were executed at the tides middle stage, when the circulation is reinforced at short term due to the influence of the tidal wave.

Mainly, the water circulation in the bay not had a very defined behavior; although was observed a tendency of a net surface circulation toward to the open sea and through the bottom a tendency of water inputs from the open sea. The current velocity didn't exceed the 32 $cm.sec^{-1}$, registering the highest value in the entrance channel and the smallest toward the inner coves of the bay.

During the flood phase (Fig. 3.14), the surface water showed in the entrance channel of the bay currents with direction toward the open sea and velocities that varied between the 24 and 32 $cm.sec^{-1}$. On the contrary, toward the interior of the bay, the currents have a more unstable direction, although was observed a tendency of a surface circulation toward the interior of the bay's coves, with velocities that varied between 3 and 14 $cm.sec^{-1}$, even without any current in station 8 at the entrance of the Atarés Cove. The mean velocity of the surface current in the bay during the flood phase was of 8.6 ± 6.5 $cm.sec^{-1}$.

However, in the bottom layer and in all the stations was observed a tendency of the circulation in direction toward the interior of the bay, presenting lower velocities to those of surface, with 16 $cm.sec^{-1}$ in the entrance channel that decreases gradually toward the inside of the bay, until being annulled totally inside the Atarés and Guasabacoa Coves (stations 9 and 11, respectively). The mean velocity at 5 m of depth was of 7.2 ± 6.6 $cm.sec^{-1}$ and to the 10 m of depth, the mean velocity was of 5.0 ± 5.0 $cm.sec^{-1}$.

The behavior observed in the surface layer, during the sampling carried out in the flood phase, was due to the highest influence of the tidal wave upon the horizontal circulation cause by the density gradients. It must be considered that the samplings were carried out at the tides middle stage, when it was more reinforced by flood current, what can cause that the whole water column moves according to the tide. This situation has been reported previously for the Havana Bay (Galocha, 1985).

During the ebb phase (Fig. 3.15), could be observed that the surface water in the whole bay showed a net circulation direction toward the open sea. The velocities in the channel were of 15 $cm.sec^{-1}$, decreasing toward the interior of the bay and varying between the 3 and 5 $cm.sec^{-1}$. The mean velocity of the surface layer was of 5.2 ± 3.4 $cm.sec^{-1}$.

The current direction with the depth, showed a circulation tendency toward the inside of the bay; with the exception of the stations in Marimelena that showed a tendency of the water toward outside of the cove.

The bottom velocities were smaller than in surface and, for the whole bay, varied between the 3 and 10 $cm.sec^{-1}$; even in some stations of the Marimelena and Guasabacoa coves didn't register currents. The mean velocities of the currents registered at 5 m of depth in the bay were of 4.5 ± 2.4 $cm.sec^{-1}$, while to the 10 m of depth, the mean velocities were of 2.5 ± 1.8 $cm.sec^{-1}$.

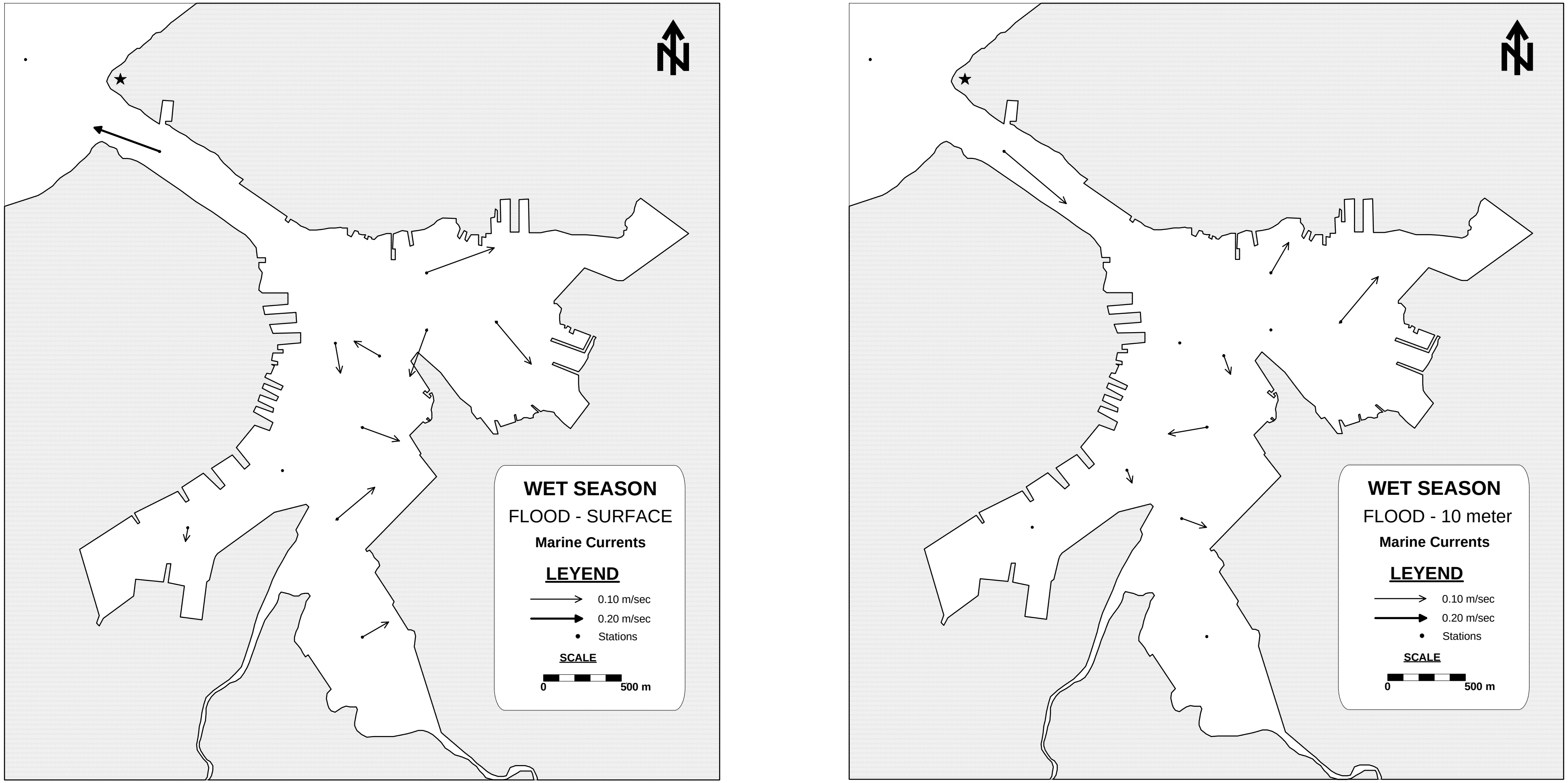
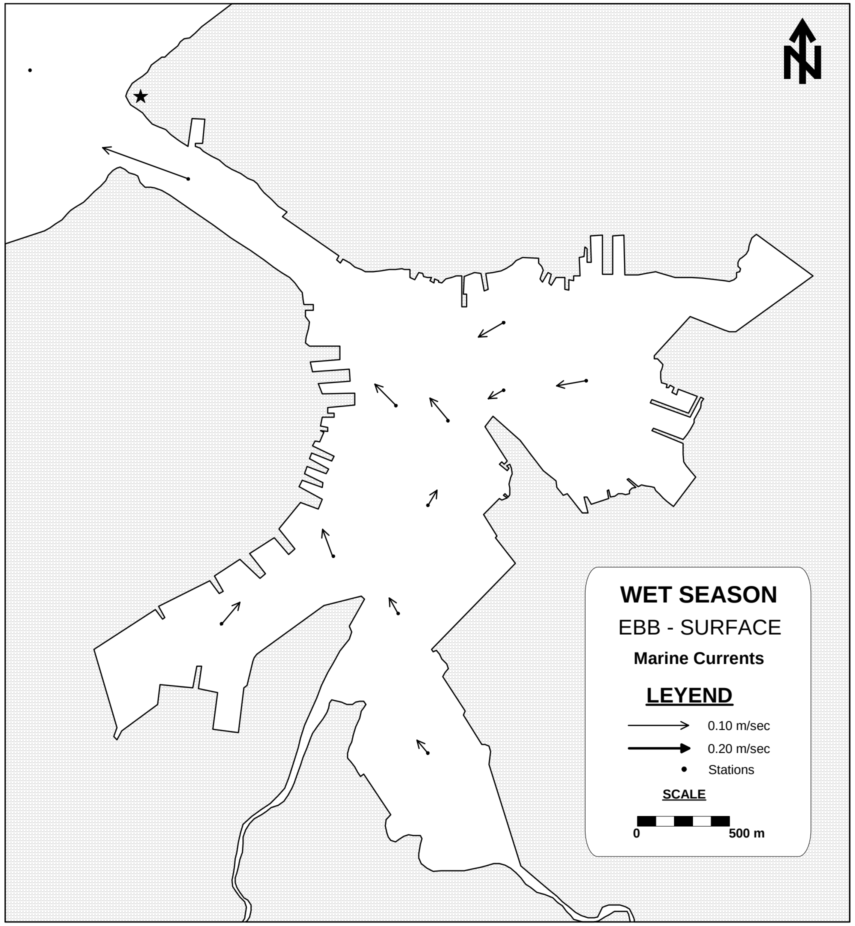


Figure 3.14: Spatial Distribution of the current during the flood phase in Havana Bay. Wet season (October/2002).



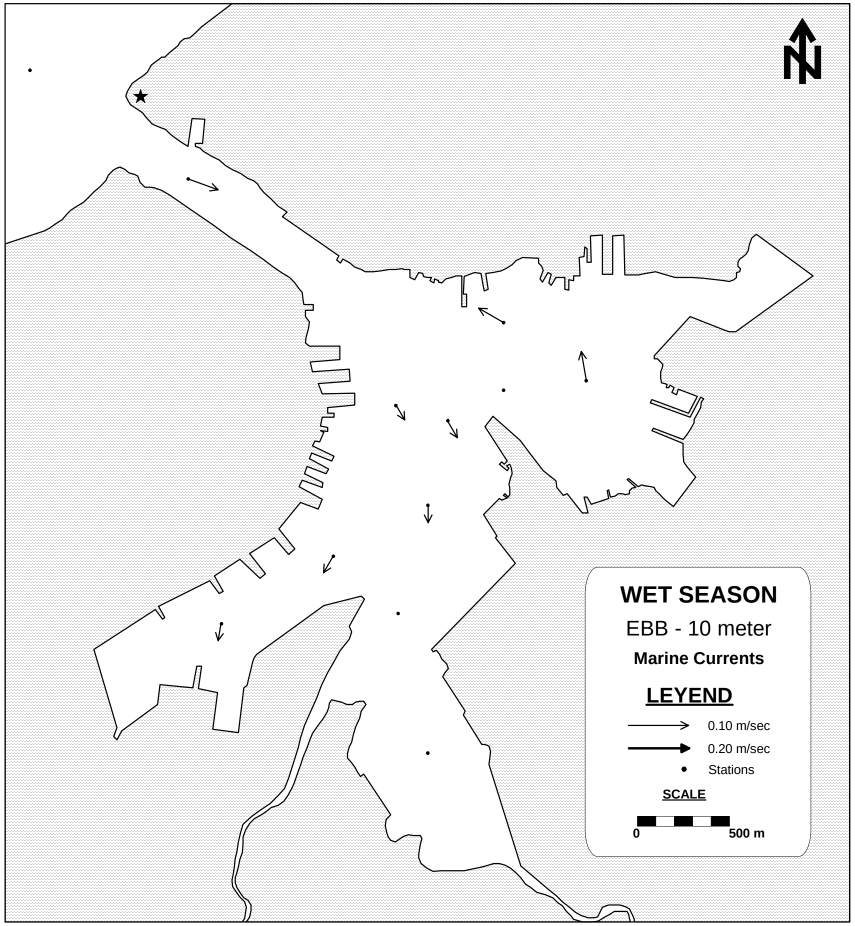


Figure 3.15: Spatial distribution of the current during the ebb phase in Havana Bay. Wet season (October/2002).

However, throughout the day and for the whole bay is usual the existence of two water layers with a quite defined net circulation, toward the outer part of the bay by the surface and to the inside of the bay through the bottom. The above-mentioned can be verified with the aid of the results obtained during 24 hours samplings in the stations 1, 3 and 5 (Fig. 3.16).

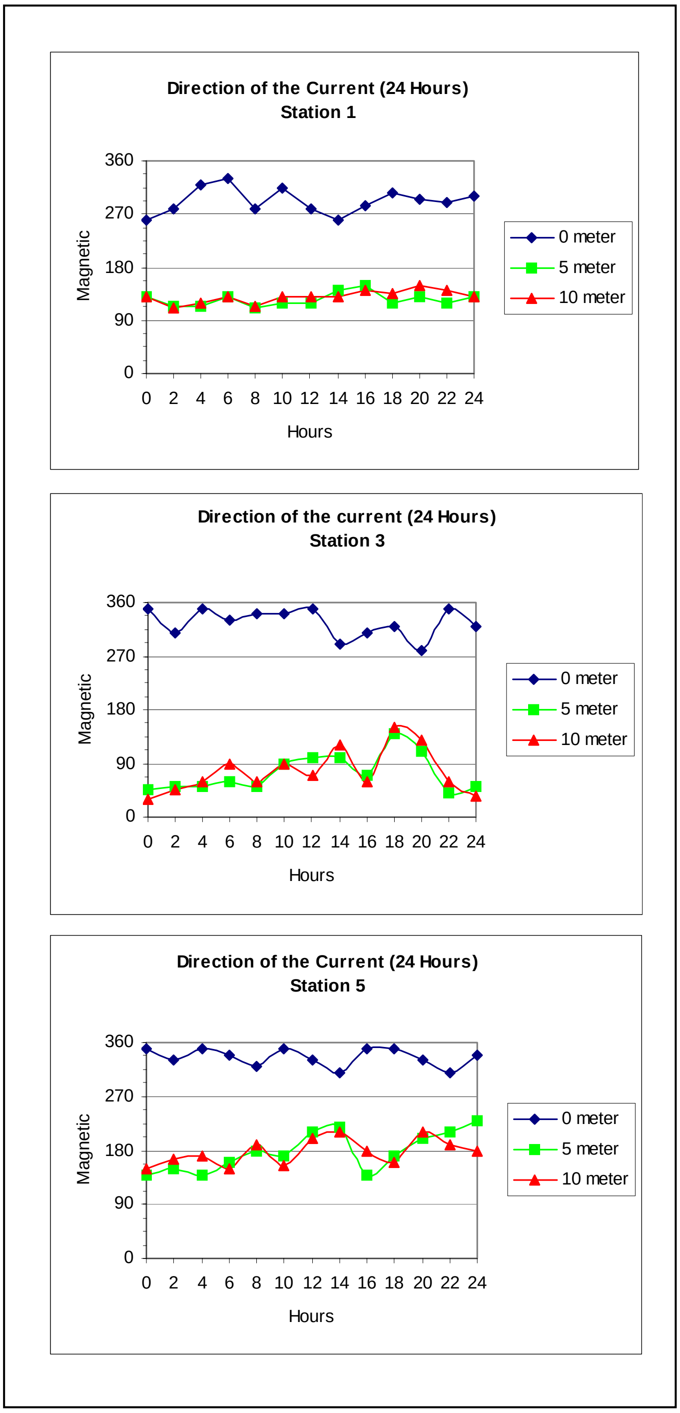


Figure 3.16: Direction of the current in Havana Bay during 24 hours. Wet season (October/2002).

The following table sum up the mean velocities (cm.sec^{-1}) and directions (azimuth) of the current during a 24 hours cycle for the stations 1, 3 and 5. In the table are related the results of velocity and direction versus the sampling depths.

Depth	Station 1		Station 3		Station 5	
	Speed	Direction	Speed	Direction	Speed	Direction
Surface	11.5 ± 5.2	292 ± 21	6.7 ± 2.3	326 ± 24	8.2 ± 4.9	335 ± 15
5 m	11.0 ± 7.3	125 ± 11	4.1 ± 1.3	73 ± 31	7.9 ± 5.1	178 ± 32
10 m	11.2 ± 6.6	130 ± 11	4.5 ± 1.7	77 ± 37	7.7 ± 5.0	178 ± 21

3.7. Relationship stratification - circulation.

Between June of 1982 and May of 1983 in Havana Bay an intense monitoring plan for the oceanographic characterization of the bay was carried out (Galocha, 1985).

In the above mentioned studies which established the main hydrological and hydrodynamic characteristics of the bay and that the studied year had an extremely rainy behavior (19826.2 mm in total), exceeding the rainfall in 17.8 times the mean annual rainfall (1113.0 mm), which determined that the bay had a partially mixed and mixed estuary behavior, being observed a surface layer of approximately 5 m of thickness with net flow toward the open sea and a bottom layer with net flow toward the inside of the bay. Also was establish that the water circulation patterns are governed by the fresh water inputs to the system, the tidal wave and in a smaller degree by the bottom topography.

During the month of August of 1996 a sampling survey (Galocha, 1997) was carried out. The samplings were conducted at the wet season and the rainfall corresponded to the mean annual (1113.0 mm).

However, it was observed that the surface water salinity of the bay in both periods were similar (Fig. 17); with values of 32.4 ppt and 32.8 ppt for julio/82 and agosto/96, respectively.

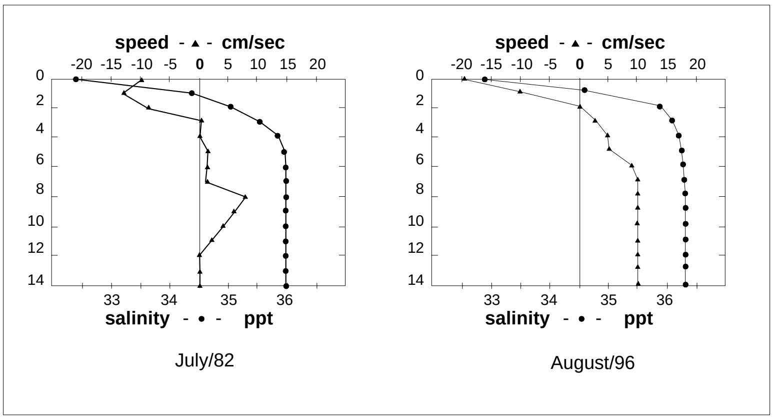


Figure 3.17: Vertical distribution of the salinity and current velocity in the central station of the entrance channel of Havana Bay (October/2002). The negative values of the velocity indicates the flow of the water toward the open sea.

The bay water in both cases were stratified, with a surface layer with an approximate thickness of 5 m during july/82 and of 2 m during august/96, due to the different volumes of fresh water inputs to the bay in both periods. The bottom layer in both periods showed a similar salinity to that of the open sea

This undoubtedly illustrates the important role that plays the fresh water contributions that arrive to the bay through the urban-industrial runoff.

The samplings carried out during the month of october/2002 (Fig. 3.18), establishes that the bay's water were also stratified, presenting a surface water salinity highest than those reported for july/82 and august/96; while the bottom water salinity was similar to those of the open sea as same as in july/82 and august/96.

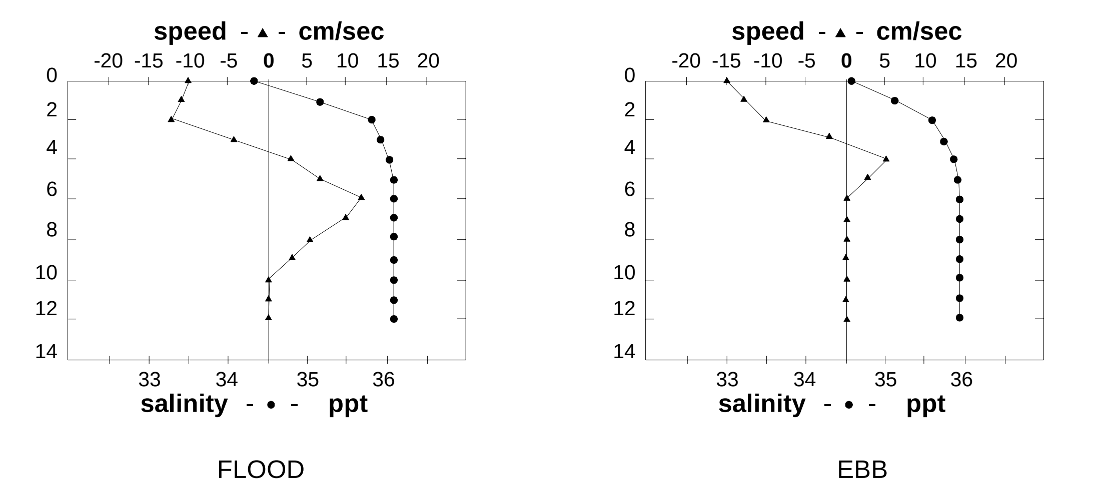


Figure 3.18: Vertical distribution of the salinity and current velocity at station 1 in the entrance channel of Havana Bay. October / 2002. The negative values of the velocity indicates the flow of the water toward the open sea.

The above-mentioned can be a function lack of rainfall during this period and/or a decrease in the fresh water inputs from urban-industrial origin, due to actions carried out for the improvement of Havana Bay in the city's sewer system and the relocation of industries at the bay's periphery.

Mainly, the current showed a similar behavior for all sampling periods. With an outgoing surface layer and an ingoing bottom layer. However, significant differences are observed in the magnitude of this two layers, that basically is determined by the difference of the tide amplitude during the sampling periods.

During the studies carried out in the framework of the projects CUB/80/001 and GEF, was established that the highest current velocities took place in middle tide stage, decreasing this velocities at flood or ebb tides. This was corroborated during the present survey (october/2002).

In correspondence with the above-mentioned and with the aid of the results obtained in the different studied periods, was applied the continuous spectrum of classification for estuaries (Hansen & Rattray, 1966); based on the relationship stratification-circulation, which allows to discriminate the forms of interaction of the different dynamic characteristics of the bay in a certain period.

The stratification parameter ($\delta S/\langle \bar{S} \rangle$) is the difference between the surface and bottom salinity with the depth mean salinity. The salinity is firstly averaged on a complete tide cycle. The circulation parameter ($\bar{V}s/\langle \bar{V}x \rangle$) is also the difference between the surface net flow and the mean flow of the studied section. The surface net flow is taken as the representative value of the cross section, assuming a stationary state.

After performing the corresponding calculations for each period and to represent them on the circulation-stratification diagram (Fig. 3.19), was determined that the bay has an moderately estuary stratification behavior (type 3a), as a weakly stratified estuary (type 2b) and as an estuary well mixed (type 2a), during july/82, august/96 and october/02, respectively.

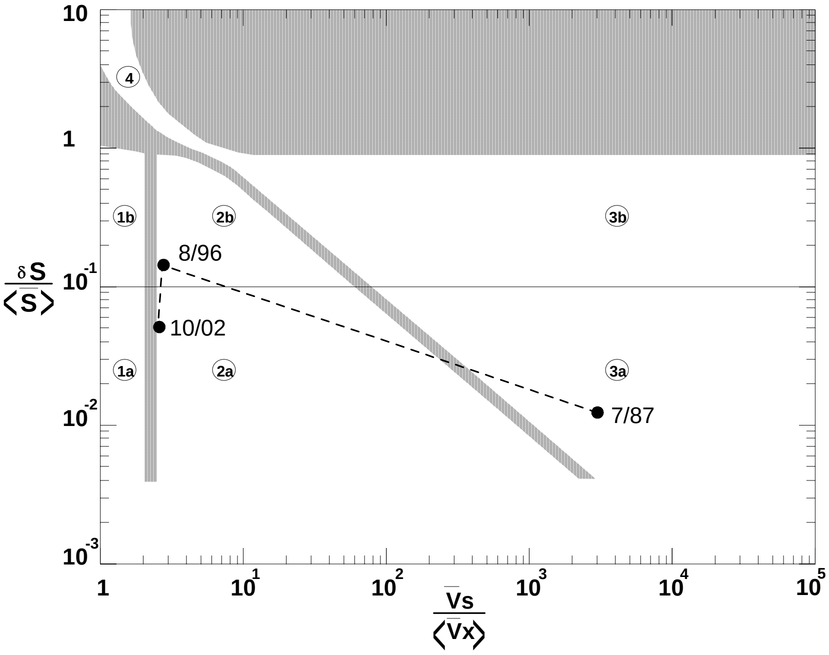


Figure 3.19: Continuous spectrum of circulation-stratification.

Class 2 includes almost all the estuaries studied. The **type 2a** are estuaries well mixed and the **type 2b** is characterized by a well developed gravitational circulation and longitudinal mixing; due to the diffusion and advection mechanisms.

The **type 3a** is characterized by a well developed gravitational circulation and where the advection processes are responsible for 99% of the saline transport and 1% remaining is due to diffusive processes.

The above mentioned supposes the existence of a surface layer of less saline water, with a net flow toward the open sea and a deepest layer with salinities similar to those of the open sea, with a net flow toward the inside of the Bay. In both cases the prevalence of the advection and/or diffusion processes are determined by the fresh water that inputs to the system and the influence of the tidal wave.

4. CONCLUSIONS.

1. The behavior of the hydrologic parameters during this period in the bay, were very similar to those registered in the other surveys. However, it should be highlighted that the surface salinity of the water in October/2002 was highest than the earlier periods.

2. The fresh water inputs to the system and the influence of the tidal wave are the main features which determines the hydrologic and hydrodynamic characteristics of Havana Bay.

3. The marine currents in this period (October, 2002) did not show a defined behavior at the inside of the Bay as during the earlier periods. The currents magnitude decreased with the depths and were lesser than the earlier periods.

4. The Havana Bay according to its hydrodynamic characteristic behaves as an estuary, which fluctuates between a partially stratified (type 2b), moderately stratified (type 3a), and well mixed (type 2a), based on volume of fresh water inputs to the system.

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6. APPENDIX

- Includes a magnetic copy of the Draft Final Report and Database of the campaign for wet season.

CENTRO DE INGENIERÍA Y MANEJO AMBIENTAL DE BAHÍAS Y COSTAS (CIMAB)

Departamento de Ordenamiento Litoral

Final Report

OCEANOGRAPHIC SURVEY IN HAVANA BAY

Dry Season

Stage 2

AUTHORS

René GARCIA GALOCHA
Héctor QUINTANA NOY

Havana City, January of 2002

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1. INTRODUCTION

Havana Bay is located in the 23° 09´ of North Latitude and in the 82° 21´ of Longitude West. It is a typical sack bay with a perimeter of 18 km, shaped by three Coves: Atarés, Guasabacoa and Marimelena. The Bay has a total area 5.2 km^2 and a mean depth of 9.2 m, and its able to store a water volume of approximately 47 x 10^6 m^3. The tides and the fresh water inputs through rivers and drainages to the bay, have played an important role in the water dynamics and has determined that the Havana Bay behaves as an estuary.

Havana Bay was object of a multidisciplinary study in the framework of the Project CUB/80/001 (UNDP-UNEP-UNESCO) "Investigation and control of the marine pollution in Havana Bay carried out between 1980 and 1985. Among the main results of this project can be highlighted the physical oceanography studies, guided to establish the dynamics of the Bay water and the main mixing processes and mechanisms of transport of polluting substances.

During the years 1996 and 1998, the Havana Bay was included in the Regional Project GEF/RLA/93/G41 "Planning and Management of and Heavily Contaminated Bays and Coastal Areas in the Wider Caribbean"; and among the results obtained were carried out the studies to identify the environmental condition of the bay and the establishment of the water circulation pattern in the bay.

An important limitation to carry out the water dynamics studies in Havana Bay was the intense ship traffic and the prohibition of the installation of recording current meter by fixed buoy stations. Due to this, the studies developed were conducted at a point measurement fashion in previously selected stations, so that didn't constitute an obstacle for sailing security.

The show study has as purpose to carry out the physical oceanography studies to obtain updated information that will allow to characterize the vertical structure of the water column and to establish the water circulation pattern in the bay, due to the influence of the tidal wave (ground truth) for its later use in a mathematical models.

This stage of the investigation shows the results obtained during the dry season and was carried out between the 13 and 18 of December, 2002 by the Littoral Management Department of CIMAB for the Nihon Suido Consultants Co. Ltd., as requested by the Japan International Cooperation Agency(JICA), in the framework of the Project "Development Study on the Improvement of the Sewerage and Drainage System for Havana Bay in the Republic of Cuba.

2. MATERIALS AND METHODS

For the characterization of the main oceanographic parameters that impact in the water circulation of Havana Bay during the dry period a network of 12 stations which covered the whole bay was established (Fig. 2.1).

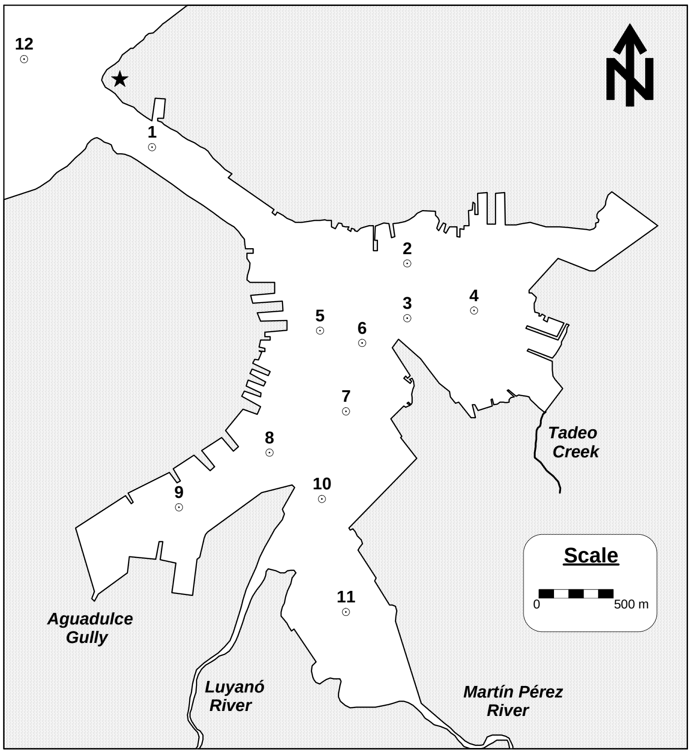


Figure 2.1: Oceanographic Stations Network in Havana Bay.

Positioning of stations in the sea was carried out with the aid of a GPS-2000 and the depths were measured directly with an lead line. The geographical position and depths of the sampling stations are shown in the following table:

Stations	**Depth** (meter)	**Latitude N**	**Longitude W**	**X**	**Y**
1	12.5	23º 08´ 46.0´´	82º 21´ 14.8´´	361296.87	369046.04
2	10.5	23º 08´ 21.0´´	82º 20´13.2´´	363014.72	368264.00
3	12.0	23º 08´ 11.0´´	82º 20´ 14.7´´	363014.72	367895.49
4	13.0	23º 08´ 10.0´´	82º 19´ 59.0´´	363464.62	367947.29
5	13.5	23º 08´ 05.3´´	82º 20´ 35.4´´	362427.75	367811.91
6	11.5	23º 08´ 02.7´´	82º 20´ 25.4´´	362711.54	367729.40
7	11.5	23º 07´ 47.7´´	82º 20´ 29.1´´	362602.17	367268.92
8	12.5	23º 07´ 40.9´´	82º 20´ 46.4´´	362087.73	366991.43
9	12.5	23º 07´ 26.4´´	82º 21´ 08.4´´	361478.15	366623.71
10	11.0	23º 07´ 28.5´´	82º 20´ 34.6´´	362440.42	366679.70
11	11.0	23º 07´ 06.9´´	82º 20´ 28.6´´	362601.99	365919.50
12	30.0	23º 09´ 10.8´´	82º 21´45.4´´	360435.19	369638.10

In each station the information of the different hydrological parameters was collected with a view to establishing the zonal differences, as well as the water vertical structure in the bay. To measure the temperature and salinity of the water a temperature/salinity meter YSI-30M was used; from this data the density was calculated (UNESCO, 1987). The transparency and color of the water were measured, with a Secchi disk and the Forel-Ulle scale, respectively.

The collection of data in each station was carried out at surface, 5 and 10 m of depths. In the station 1 (located in the entrance channel of the Bay), the information was collected at intervals of 1 meter, from the surface to the bottom. In the station 12 (reference), only the temperature and salinity of the water at surface, 5, 10 and 15 m of depths were measured.

Simultaneously, in each station (excluding station 12), were carried out point measurements of the velocity and direction of the marine current. The collection of data was carried out in the same horizons of the hydrological parameters and were performed with the aid of a portable current meter CM-2. The survey vessel was anchored during the samplings to avoid that the vessel's drift influenced in the measurements.

The oceanographic samplings were carried out during the flood and ebb phases of the tide. Also was carried out a 24 hours sampling, at intervals of 2 hours, in the stations 1, 3 and 5 in the bay to determine the variation of the different parameters through the time.

As a complementary information, during the samplings minor meteorology information was collected aboard the vessel. The parameters measured in each station were: velocity and direction of the wind; air temperature (dry and humid), from which the relative humidity was calculated; atmospheric pressure; cloudiness and state of sea. For this task were used a portable anemometer, an aspersion psychrometer MB-4M and an aneroid barometer M-67. The registrations of the cloudiness and the sea state were carried out by means of direct observation.

Finally, with a view of evaluating the behavior of the bay in the dry period and the main hydrodynamic characteristics a continuous circulation-stratification spectrum was applied (Hansen & Rattray, 1966).

3. RESULTS

The results obtained during the collection of data in the dry period (December 2002), as in the wet season, evidences the existence of two water layers in the bay with unequal behavior, influenced by the incident solar radiation, the fresh water inputs to the bay and the tidal wave.

3.1. Minor Meteorology

The samplings carried out during the flood phase showed a mean air dry temperature with values of 29.2 ± 0.4 ºC and the mean humid temperature was of 24.7 ± 0.3 ºC, for a relative humidity of 82.3 ± 3.4%. The atmospheric pressure showed mean values of 760.7 ± 3.4 mmHg. The winds had a predominant direction of the first and second quadrant and their velocities were variable, even alternating with periods of calms. The mean velocity was of 2.3 ± 1.3 m.sec-1.

The samplings conducted during the ebb phase showed mean values of the air dry temperature of 21.5 ± 0.6 ºC and the mean humid temperature was of 17.0 ± 0.4 ºC, for a relative humidity of 86.2

± 2.0%. The atmospheric pressure showed mean value of 764.0 mmHg. During the samplings the winds were of the second quadrant and the mean velocity was of 3.5 ± 0.6 m.sec-1.

During the 24 hours samplings, the mean values among stations were: air dry temperature 23.0 ± 1.3 ºC and the humid temperature 19.4 ± 0.5 ºC, for a relative humidity of 79.6 ± 8.7%. The atmospheric pressure showed mean values of 762.2 ± 0.9 mmHg. The winds were of the first and second quadrant, and showed a mean velocity among the stations of 1.2 ± 0.8 m.sec-1.

In all the cases cloudiness varied between 3/8 and 5/8. Inside the bay the sea was in calm and outside of the bay (station 12), the sea showed a force (Beaufort scale) that varied between 2 and 3 during the ebb and flood samplings, respectively.

3.2. Temperature

The surface water temperatures showed a very homogeneous behavior in the whole Bay (Fig. 3.1), although was observed a tendency of an increase of the temperature toward the inner part of the bay during the flood and toward the open sea during the ebb. The temperatures are influenced by the incident solar radiation, the tidal wave and the fresh water inputs to the bay, as will be discussed later on.

During the flood phase the surface water showed minimum temperatures of 27.2 ºC and maximum of 27.9 ºC in different points of the bay, for a mean value (expressed in terms of $\bar{x} \pm s$) of 27.5 ± 0.3 ºC. In the ebb phase the surface water showed minimum temperatures of 23.0 ºC and maximum of 25.7 ºC in different points of the bay, for a mean value of 24.7 ± 0.9 ºC.

Because of a cold front arrival at previous days, and due to the strong existent winds, the bay's surface layer showed slightly smaller temperatures to those of the exterior, as well as in the underlying layer, producing a thermal inversion in the water column during the ebb sampling.

The fresh water inputs to the bay through the Luyanó and Martin Perez Rivers, contributed to the decrease of the surface water temperatures in the area of Guasabacoa Cove.

The tidal wave contributes to homogenize the water surface temperatures, mobilizing the warmer outer water and the colder that inputs to the bay through the rivers Martin Perez and Luyanó. From the 5 m of depth and down to the bottom, the water temperatures have a more regular behavior in all the points of the bay, registering values similar to those of the outer water, for the ebb as well as for the flood (Fig. 3.2).

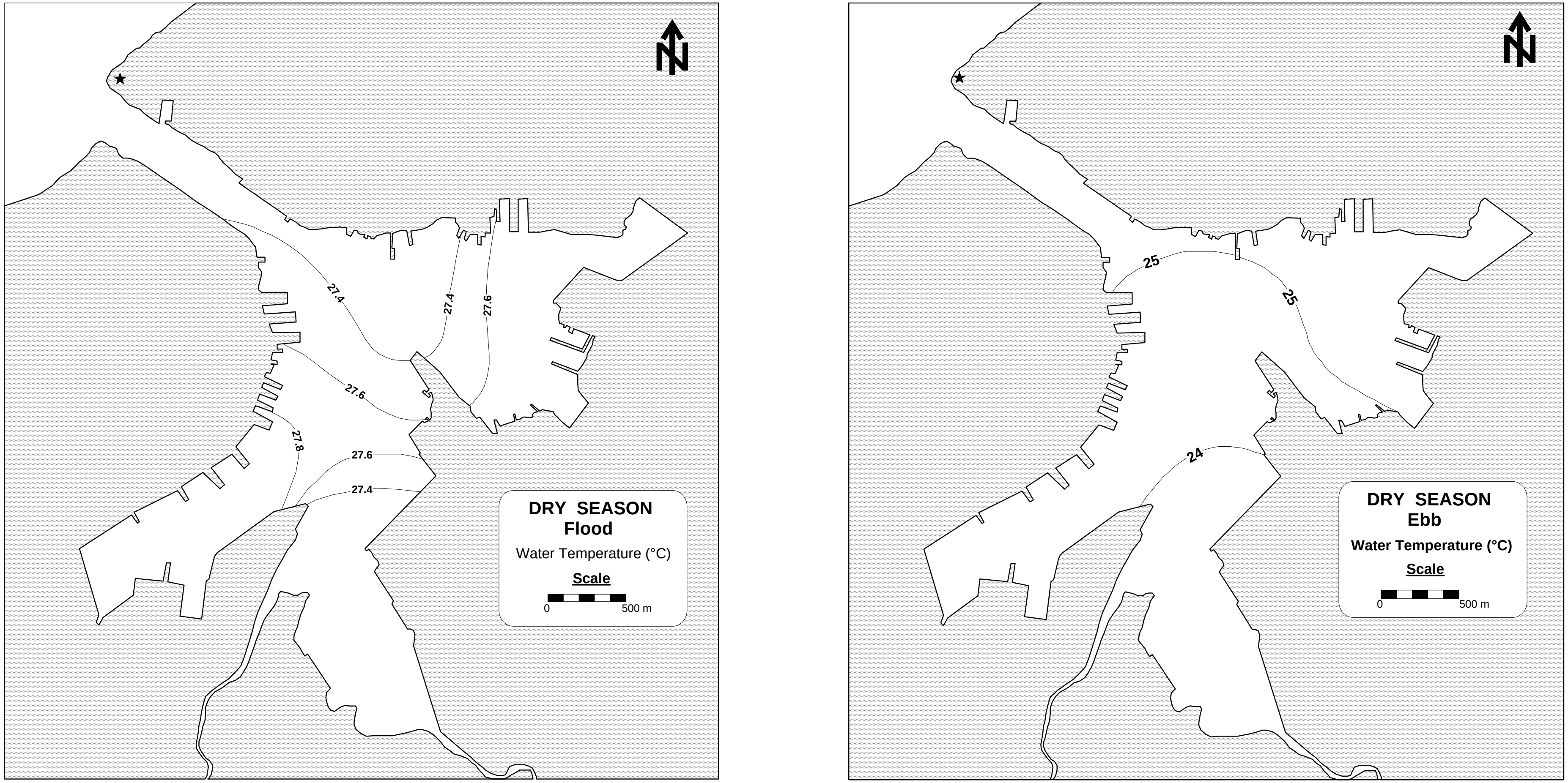


Figure 3.1: Surface Temperatures in Havana Bay. Dry period (December/2002).

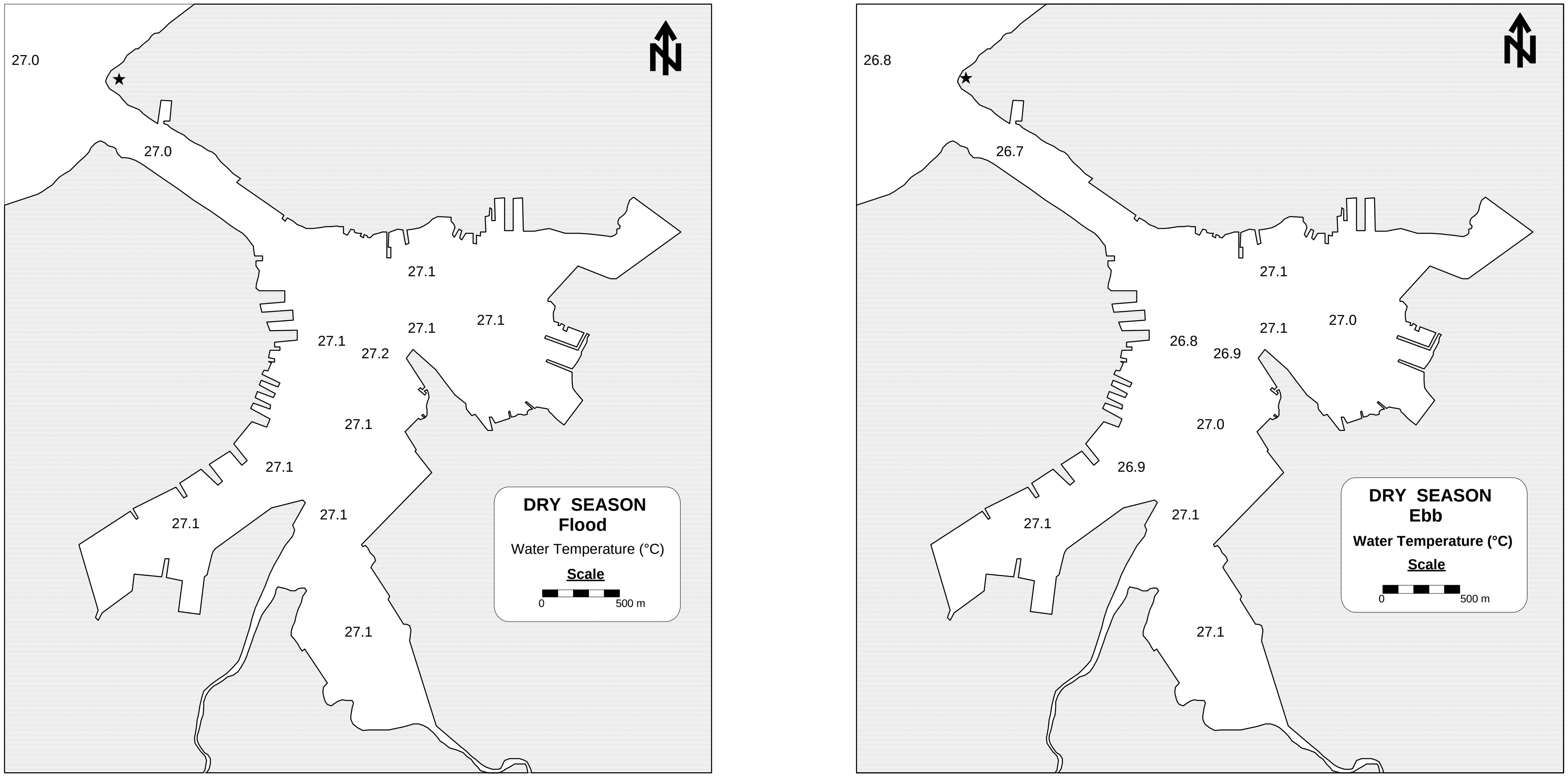


Figure 3.2: Temperatures at 10 m of depth in Havana Bay. Dry period (December/2002).

During the flood phase, the water at 5 m of depth showed minimum temperatures of 27.1 ºC and maximum of 27.3 ºC in different points of the bay, for a mean value of 27.2 ± 0.1 ºC. At 10 m of depth, the water showed minimum temperatures of 27.0 ºC and maximum of 27.2 ºC in different points of the bay, for a mean value of 27.1 ± 0.1 ºC.

The water at 5 m of depth showed minimum temperatures of 26.9 ºC and maximum of 27.2 ºC, during the ebb phase in different points of the bay, for a mean value of 27.1 ± 0.1 ºC. To the 10 m of depth, the water showed minimum temperatures of 26.7 ºC and maximum of 27.1 ºC in different points of the bay, for a mean value of 27.0 ± 0.1 ºC.

With the help of the above-mentioned, it can be assumed that so much in the flood as well as in the ebb phases, the water of the bay are stratified and at least two well differentiated layers were observed; a surface layer more variable and a sub-surface layer (from the 5 m of depth), more homogeneous and linked to the outer water of the bay. It is worth to highlight the thermal inversion of the surface water of the bay during the ebb phase because of the arrival of a cold front (Fig. 3.3).

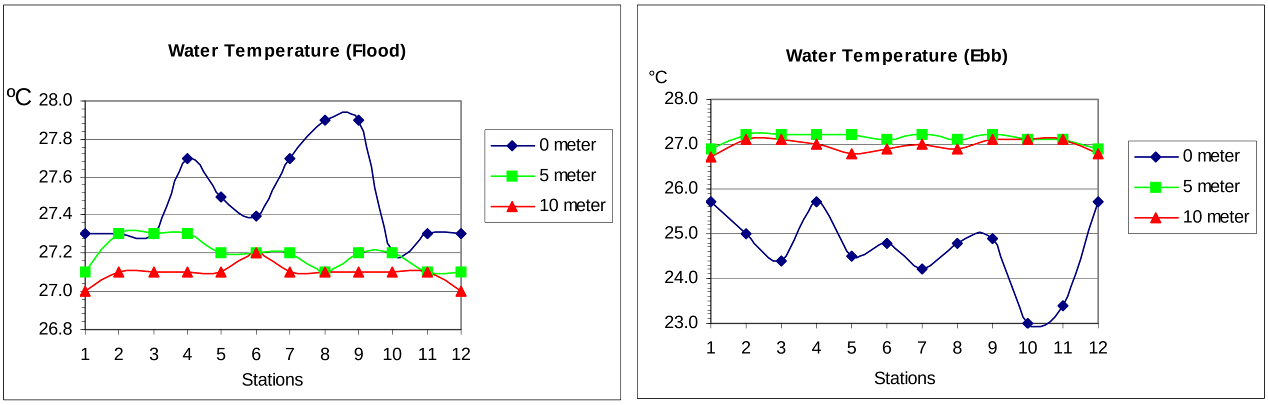


Figure 3.3: Variation of the Temperatures in Havana Bay by stations. Dry period (December/2002).

The water surface temperatures in the bay throughout the day experience significant variations that are related directly with the incident solar radiation, the temperature of the air and in a smaller way from the influence of the tidal wave, as was verified in 3 sampling stations inside the bay during 24 hours of observation (Fig. 3.4). The thermal inversion of the water surface in station 1 was observed during the whole sampling period. Throughout the whole period the temperatures of the sub-surface layer showed a more homogeneous behavior and a great relationship with the outer water of the bay.

In general, the thermal gradients (horizontal and vertical) more significant of the water in the bay were observed in the surface layer and differ with those of the sub-surface layer.

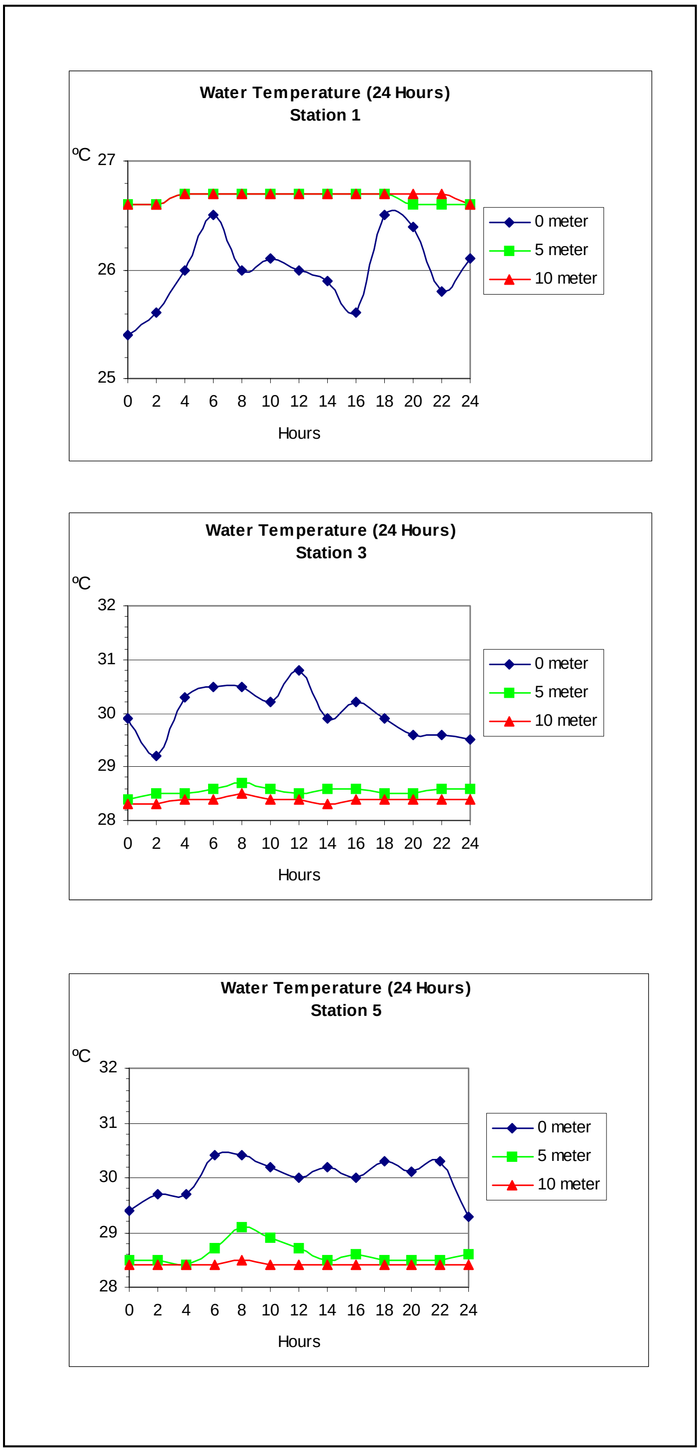


Figure 3.4: Variation of the Temperatures at Havana Bay in 24 hours. Dry period (December/2002).

3.3. Salinity

The surface salinity of the water in the bay (Fig. 3.5), decreases gradually toward the inside of the bay, during the flood as well as in the ebb. The salinities are influenced directly by the fresh water inputs from the rivers and storm drains to the bay.

During the flood phase, the surface water showed a minimum salinity of 31.4 ppt and maximum of 34.3 ppt in different points of the bay, for a mean value (expressed in terms of $\bar{x} \pm s$) of 32.2 ± 1.0 ppt. During the ebb phase, the surface water showed a minimum salinity of 23.1 ppt and maximum of 34.0 ppt in different points of the bay, for a mean value of 30.3 ± 3.5 ppt.

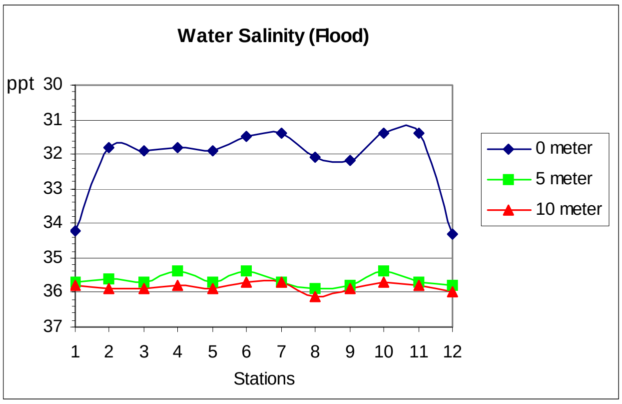
Due to the cold fronts arrivals occurred much rainfalls in the basins of the Luyanó and Martin Perez Rivers that contributed with great amounts of fresh water to reduce the salinity of the surface water of the bay, being increased the horizontal gradient of this parameter in a significant way, as can be observed by the isohalines outlined during the ebb phase.

The water salinity in the bay increases with the depth and from the 5 m of depth, its behavior in the whole bay is more homogeneous than at the surface layer, registering values similar to those of the outer water of the bay, during flood phase as well as in the ebb phase (Fig. 3.6).

During the flood phase, the water at 5 m of depth showed a minimum salinity of 35.4 ppt and a maximum of 35.9 ppt in different points of the bay, for a mean value of 35.7 ± 0.2 ppt. At the 10 m of depth, the water showed a minimum salinity of 35.7 ppt and a maximum of 36.1 ppt in different points of the bay, for a mean value of 35.9 ± 0.1 ppt.

The water at 5 m depth showed a minimum salinity of 35.7 ppt and a maximum of 35.8 ppt during the ebb phase, as well as a mean value of 35.5 ± 0.3 ppt. To the 10 m of depth the water showed a minimum salinity of 35.6 ppt and a maximum of 36.0 ppt, for a mean value of 35.8 ± 0.1 ppt.

From the above-mentioned, for the flood phase as well as for the ebb, can be assumed that the water of the bay are stratified and two well differentiated layers are observed; a surface layer more variable and another sub-surface layer (from the 5 m of depth), more homogeneous and linked to the outer water (Fig. 3.7).



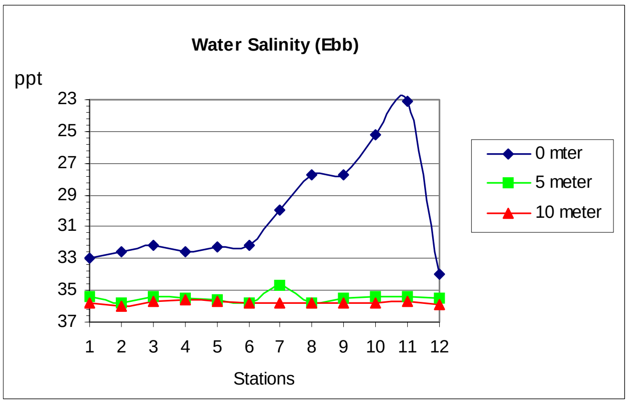
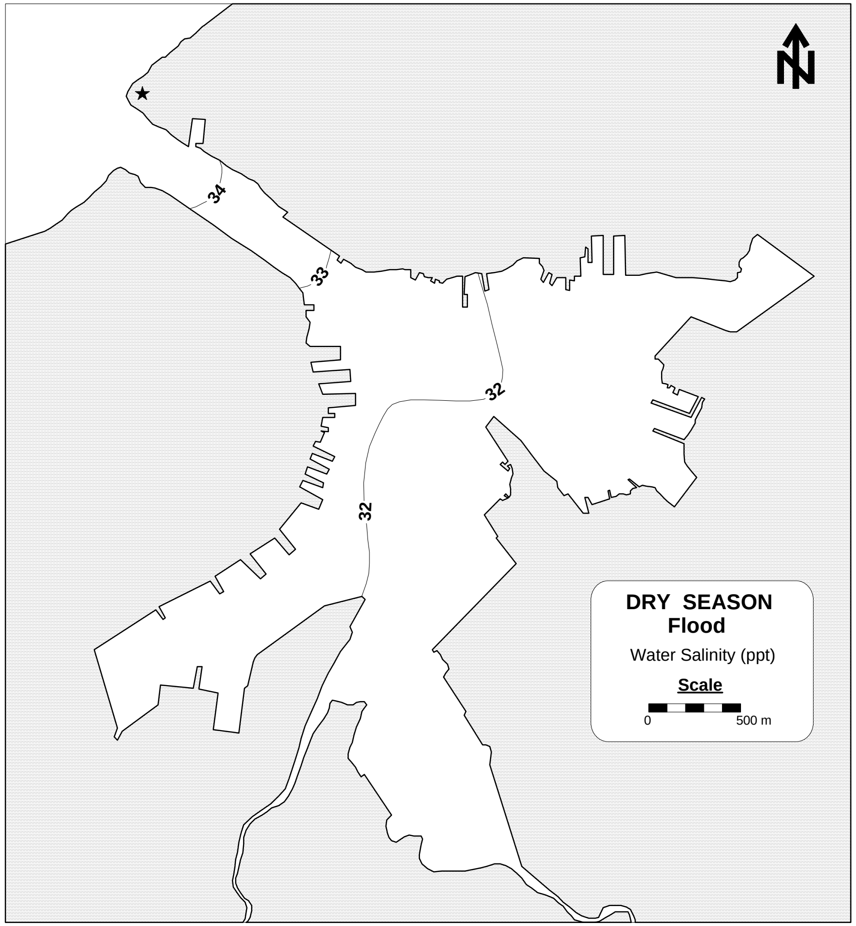


Figure 3.7: Variation of the Salinity in Havana Bay by stations. Dry period (December/2002).



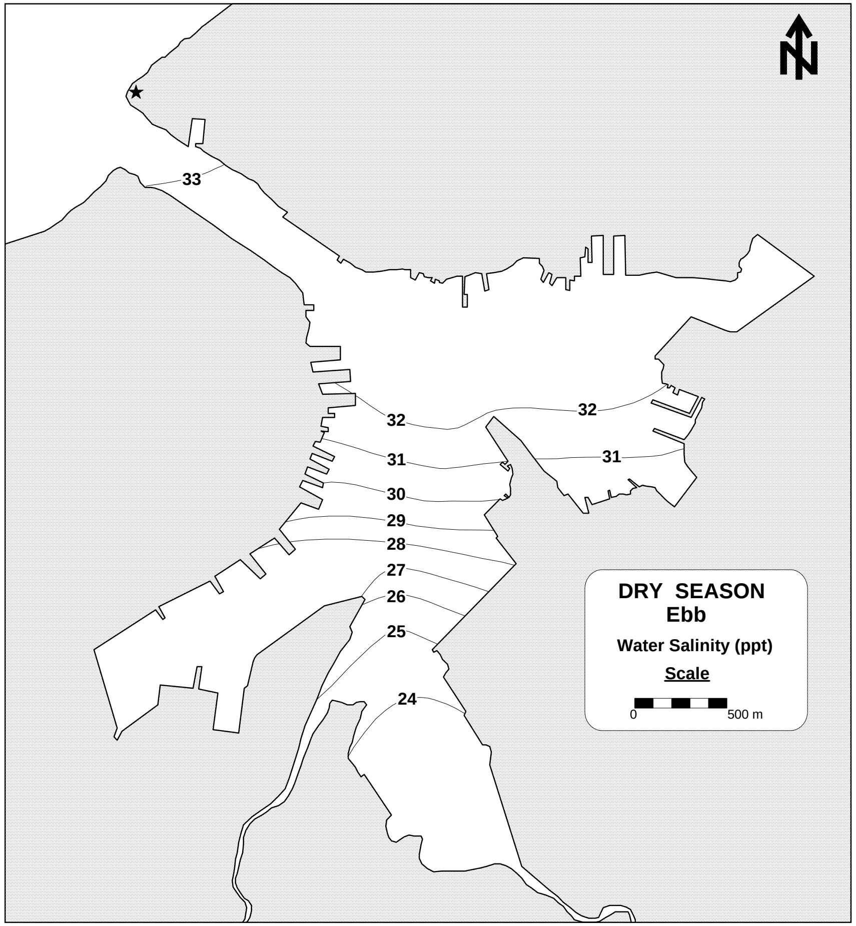
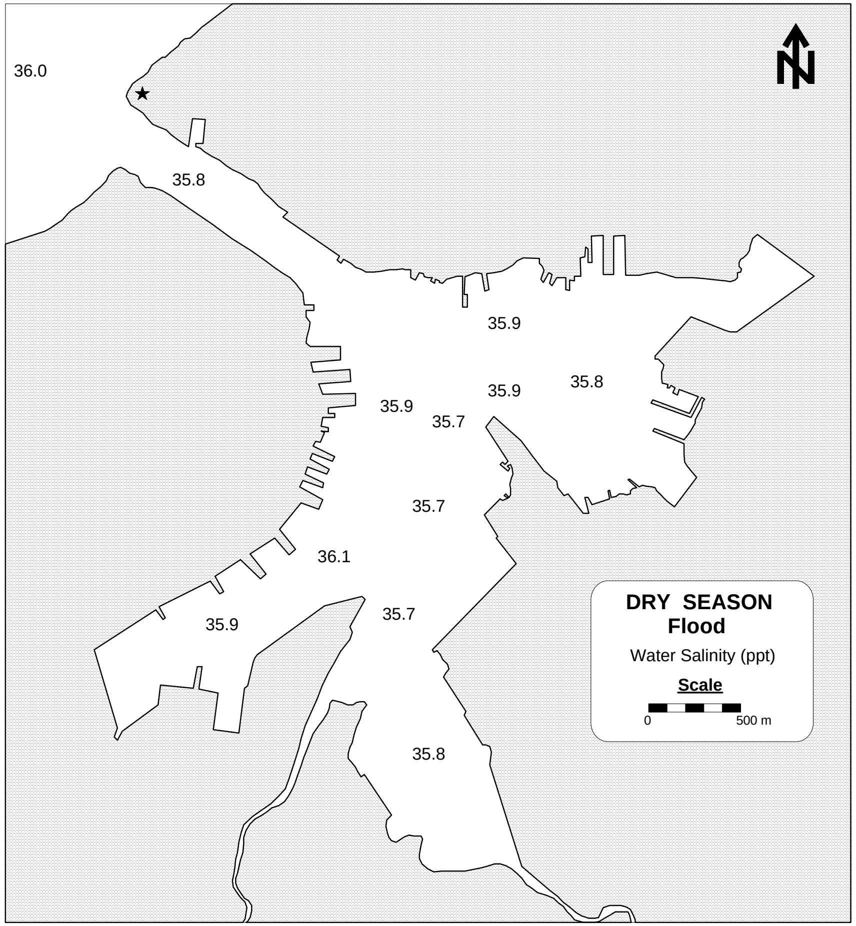


Figure 3.5: Surface Salinity in Havana Bay. Dry period (December/2002).



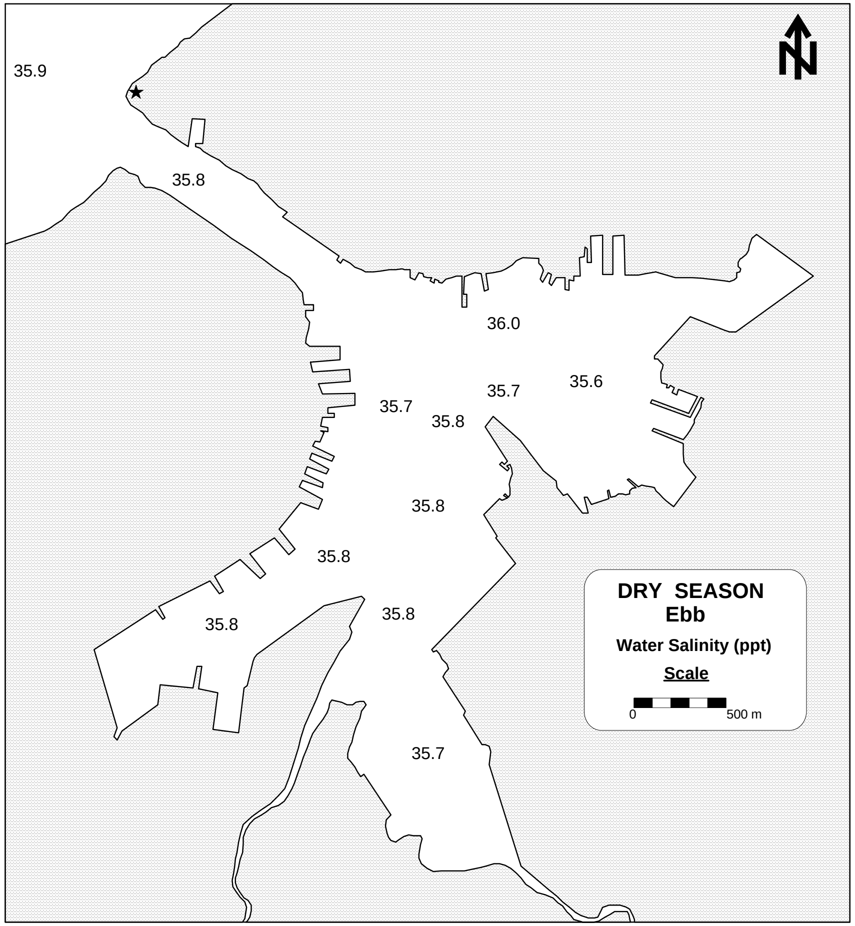


Figure 3.6: Salinity at 10 m of depth in Havana Bay. Dry period (December/2002).

The surface water salinity in the bay through the day experiences significant variations that are related directly with the contributions of fresh water that enter to the bay and in smaller scale by the influence of the tidal wave, as verified in 3 sampling stations inside the bay during 24 hours of observation (Fig. 3.8). The salinity of the bottom layer shows throughout the period a very homogeneous behavior and a great relationship with the outer water of the bay.

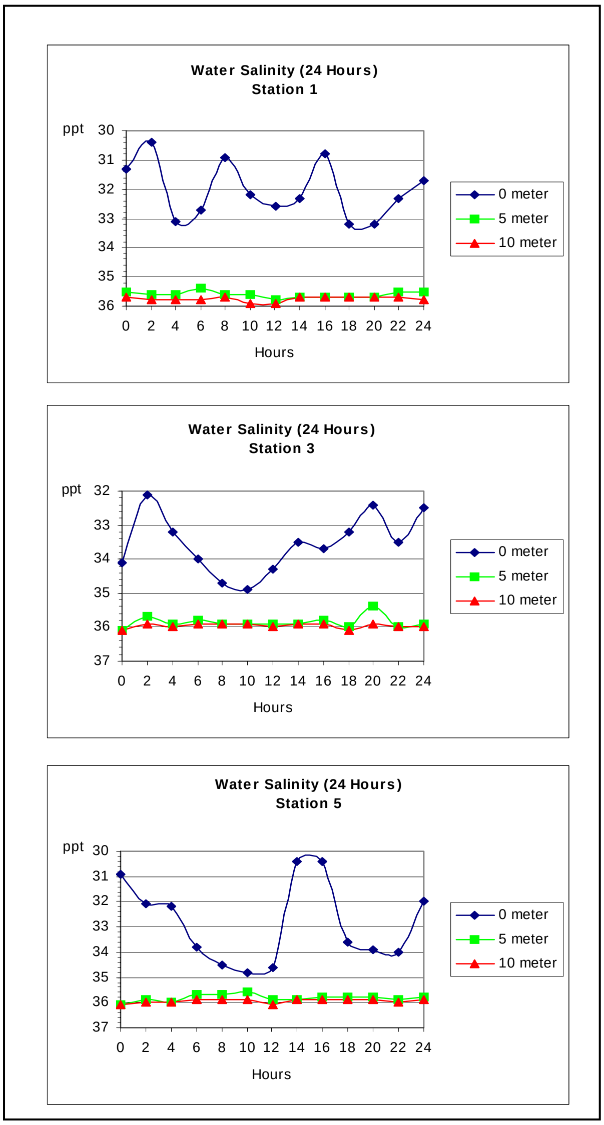


Figure 3.8: Variation of the salinity in Havana Bay during 24 hours. Dry period (December/2002).

In general, the halines gradients (horizontal and vertical) more significant of the bay water are observed in the surface layer and differ with those of the bottom layer.

3.4. Density

Mainly, the density variation in the bay is in total correspondence with the behavior of the salinity variation.

The surface water densities decreases gradually toward the interior of the bay as shown by the equal density isolines, during flood as well as in ebb phases (Fig. 3.9). The densities are basically governed by the water salinity of the and in a low profile by the tidal wave.

The above-mentioned indicates the importance of fresh water inputs to the bay; and as been announced previously with the help of the results of the humid period, can be established a significant horizontal gradient, which contributes to the development of a surface circulation in direction to the open sea, and that will be discussed in Section 3.6.

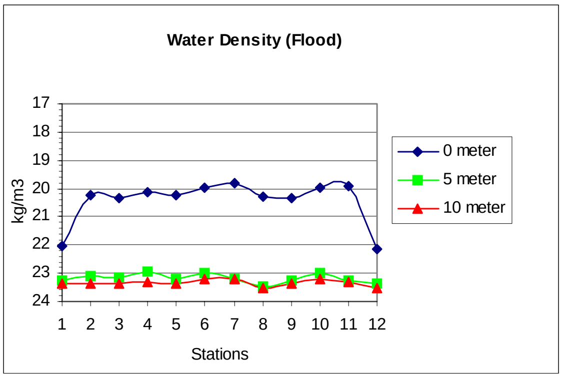
The surface water showed a minimum density of 19.8 kg/m3 and a maximum of 22.1 kg/m3 in different points of the bay during the flood phase, for a mean value of 20.5 ± 0.8 kg/m3. During the ebb phase, the surface water showed minimum densities of 14.9 kg/m3 and maximum of 22.4 kg/m3 in different points of the bay, for a mean value a 19.7 ± 2.4 kg/m3, due to the occurrence of rainfall in this surveying period.

The water density in the bay increases with the depth and the same occurs with the salinity fields; at 5 m of depth the behavior in the entire bay is more homogeneous than the surface water, registering values similar to those of the outer water of the bay, in the ebb or flood phases (Fig. 3.10).

The water located at 5 m of depth, showed a minimum density of 22.9 kg/m3 and a maximum of 23.5 kg/m3 in different points of the bay during the flood phase, for a mean value of 23.2 ± 0.2 kg/m3. To the 10 m of depth, the water showed a minimum density of 23.2 kg/m3 and a maximum of 23.5 kg/m3 for a mean value of 23.4 ± 0.1 kg/m3.

During the ebb phase, the water located at 5 m of depth showed a minimum density of 22.5 kg/m3 and a maximum of 23.3 kg/m3, as well as a mean value of 23.1 ± 0.2 kg/m3. To the 10 m depth, the density of the water showed minimum values of 22.2 kg/m3 and maximum of 23.5 kg/m3, for a mean value of 23.3 ± 0.1 kg/m3.

As already mentioned in the Section 3.3 and substantiated, during ebb or flood, the water of the bay show certain degree of stratification and two well differentiated layers were observed; a surface layer more variable and a bottom layer, more homogeneous and linked to the outer water of the bay (Fig. 3.11).



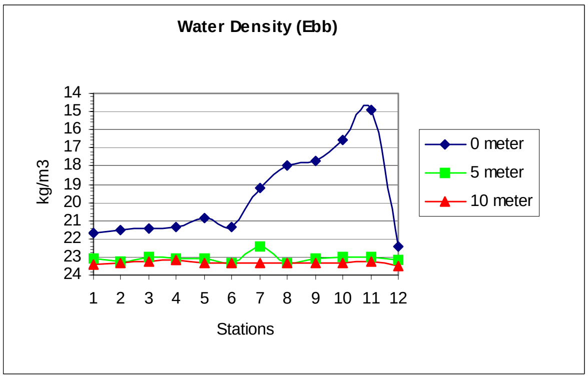


Figure 3.11: Variation of the density in Havana Bay by stations. Dry period (December/2002).

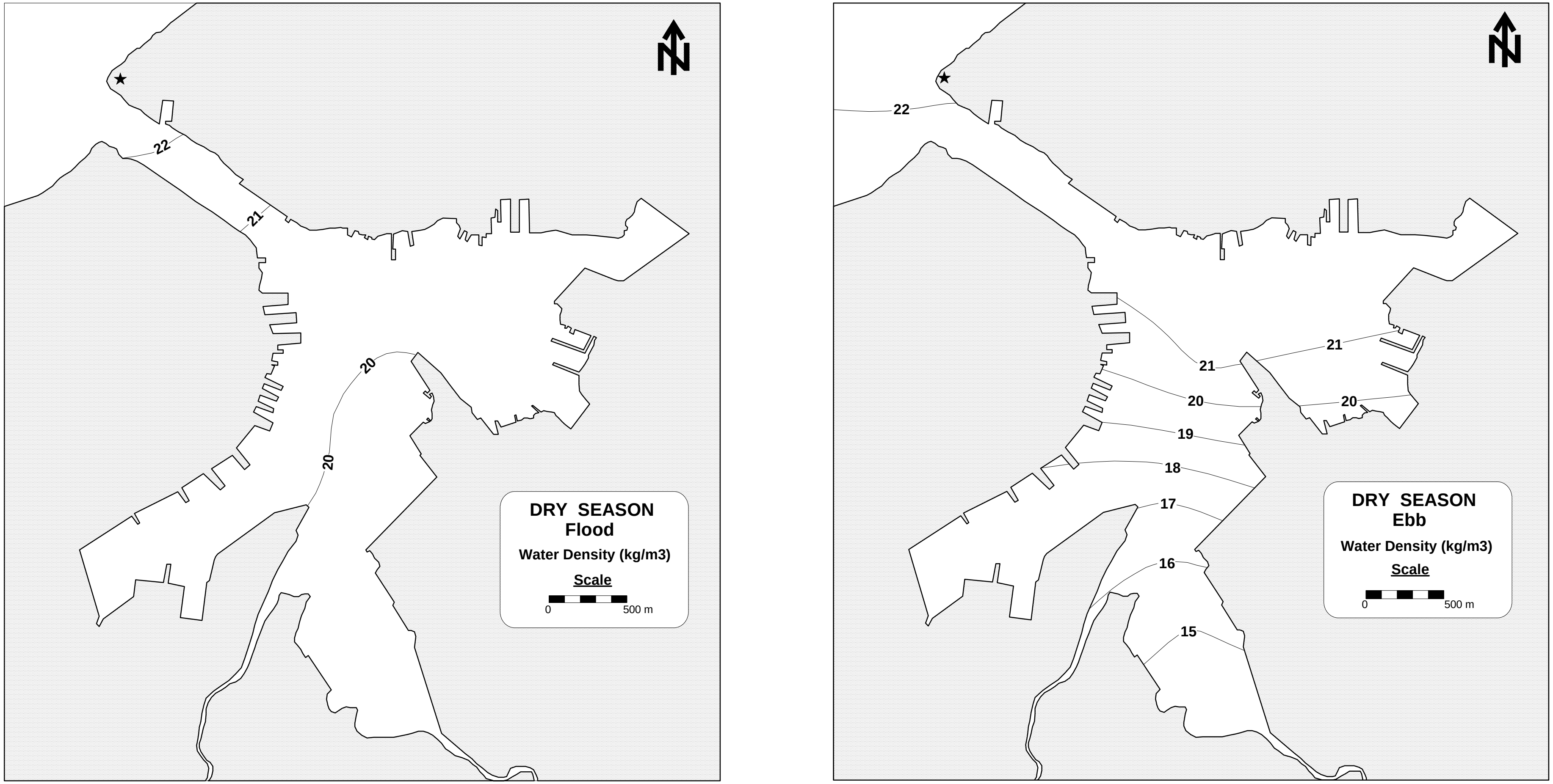
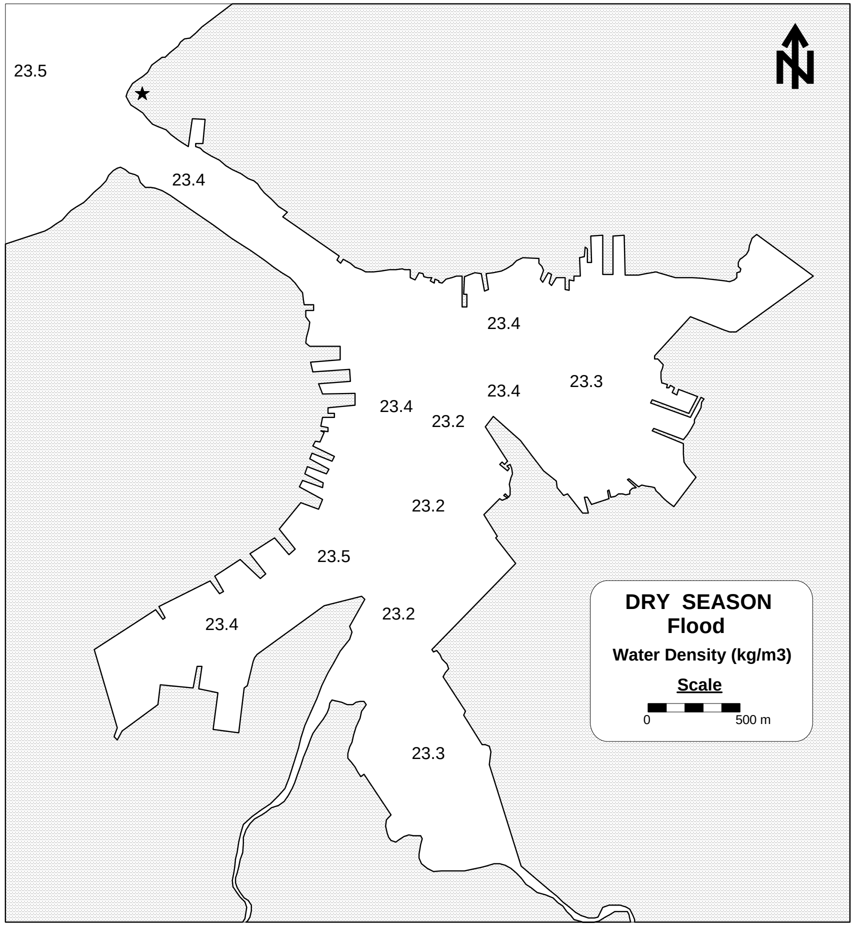


Figure 3.9: Surface Density in Havana Bay. Dry period (December/2002).



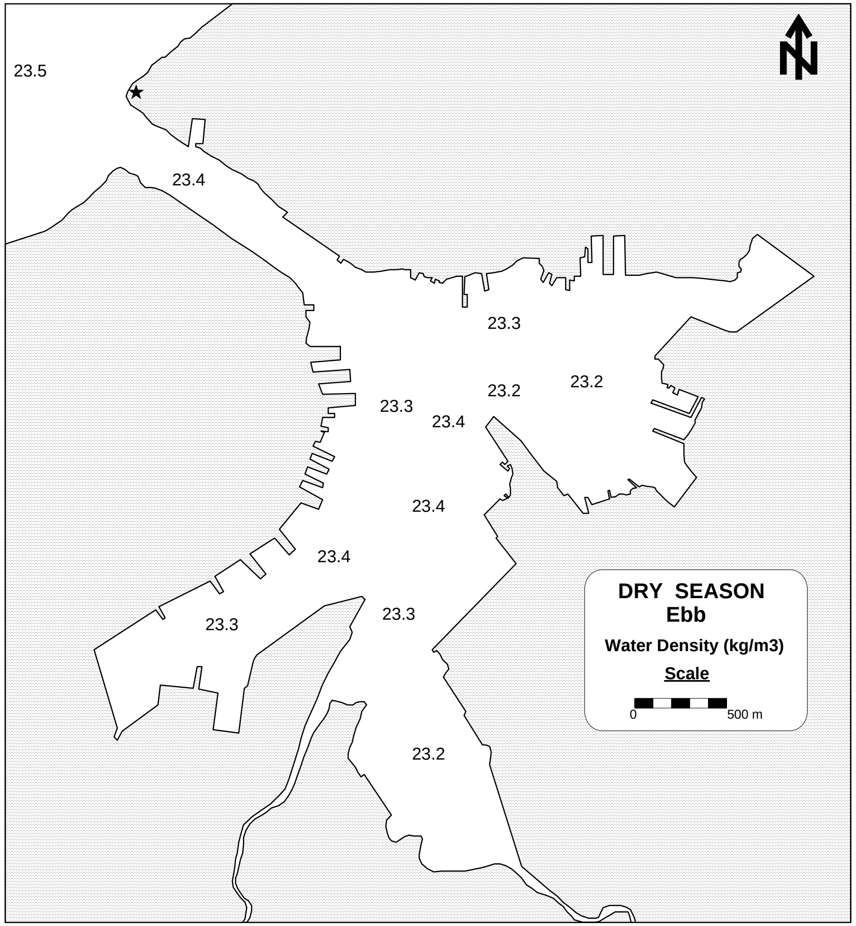


Figure 3.10: Density at 10 m of depth in Havana Bay. Dry period (December/2002).

The density of the surface water in the bay throughout the day experiences significant variations that are related directly with the contributions of fresh water that enter to the bay and influence to a lesser degree by the tidal wave, as verified in 3 sampling stations inside the bay during 24 hours of observation (Fig. 3.12). The density of the bottom layer showed throughout the period of study a very homogeneous behavior and strongly influence by the outer water of the bay.

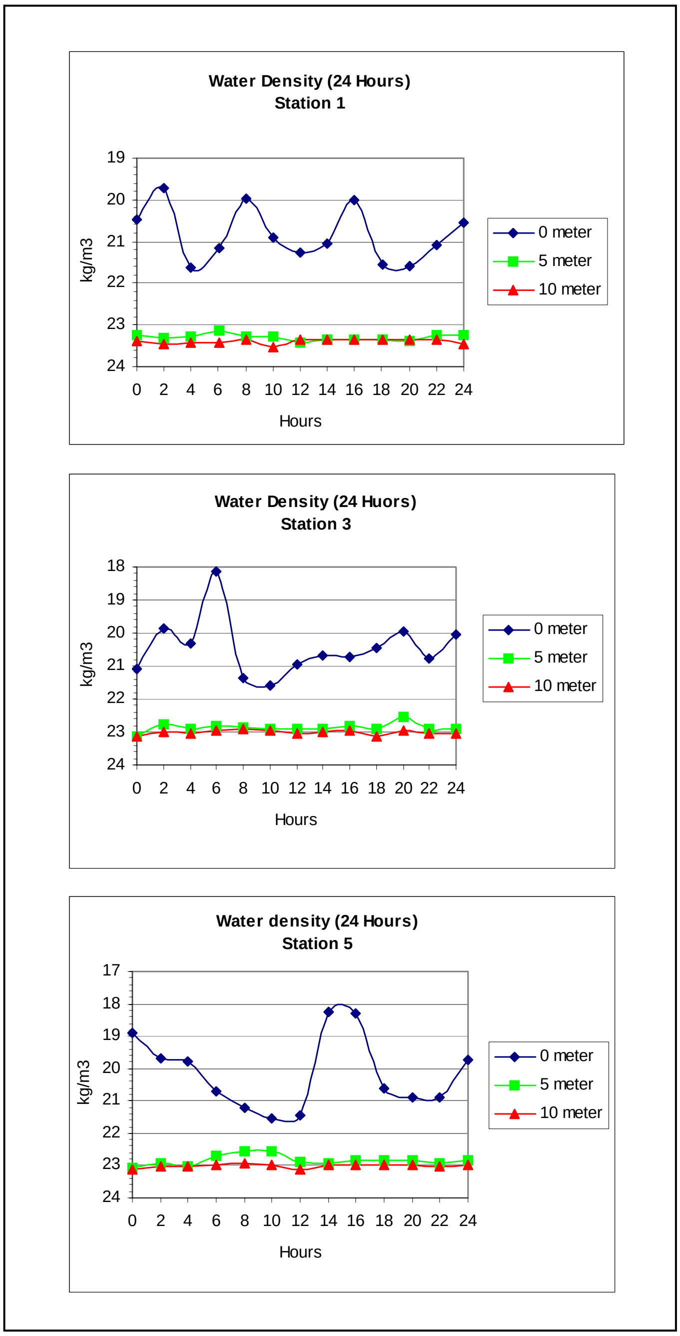


Figure 3.12: Variation of the Density at Havana Bay in 24 hours. Dry period (December/2002).

3.5. Transparency and water color.

The transparency of the water in the bay is reduced and varied between 1.3 and 3.5 m. The color of the water, according to the scale Forel-Ulle, varied between 11 and 14. The above values was in contrast with the values obtained in the station 12 (reference), located in the outer water of the bay and where transparencies and colors obtained varied, in ebb and flood, between 6 and 8 m and the water color between 6 and 8 (Fig. 3.13).

Should be highlighted that the transparency values and color of the water before mentioned correspond to those obtained during the flood and ebb phases at daylight; because these measurements could not been carried out in hours of the night during the 24 hours sampling.

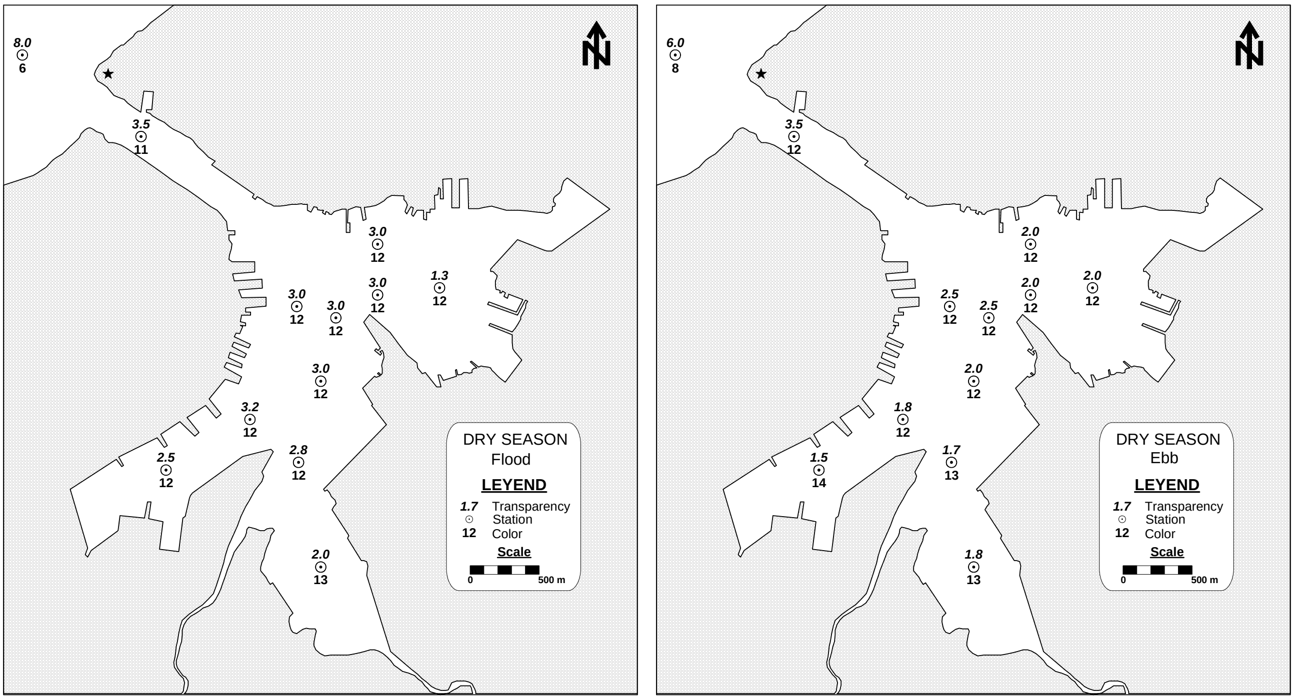


Figure 3.13: Transparency and water color in Havana Bay. Dry period (December/2002).

3.6. Marine current.

The data collection of the current velocity and direction was performed in the ebb and flood phases, with the view of discussing a stationary theoretical state. The samplings in each tide phase had a duration of approximately 3 hours and were executed at the tides middle stage, when the circulation is more reinforced at a short term due to the influence of the tidal wave.

In general, the water circulation in the bay had not a very defined behavior; although was observed a tendency of a net surface circulation toward the open sea and through the bottom a tendency of water inputs from the open sea. The current velocity didn't exceed the 25 cm. sec^{-1}, registering the highest value in the entrance channel and the smallest toward the inner coves of the bay.

During the flood phase (Fig. 3.14), the surface water showed in the entrance channel of the bay currents with direction toward the open sea, with velocities that varied between the 5 and 15

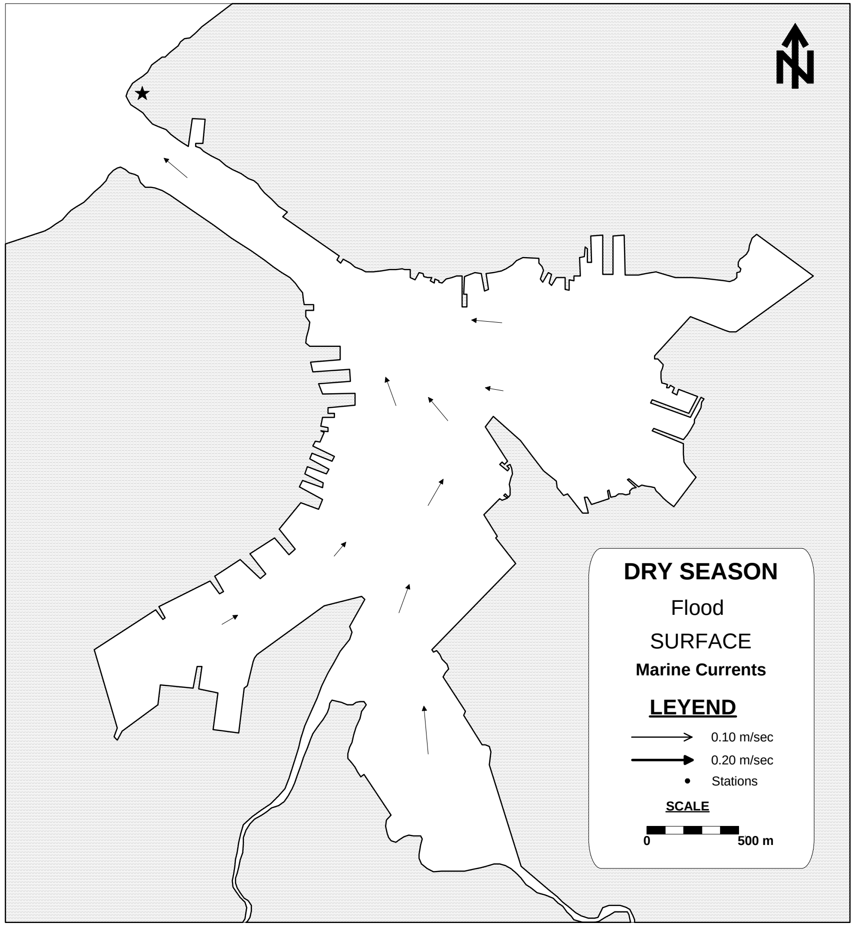
$cm.sec^{-1}$. On the contrary, toward the interior of the bay, the currents have a more unstable direction, although was observed the tendency of a surface circulation toward the exterior of the bays with velocities that varied between 3 and 8 $cm.sec^{-1}$, even with absence of current in station 4 at Marimelena Cove. The mean velocity of the surface current in the bay during the flood phase was of 4.5 ± 2.0 $cm.sec^{-1}$.

Below the surface layer and in all the stations, was observed a tendency of the circulation in direction to the inner part of the bay, showing velocities much smaller than those of surface and of 15 $cm.sec^{-1}$ in the entrance channel, that decreases and varied gradually toward the interior of the bay, until being annulled in station 11 of the Guasabacoa Cove. The mean velocity at 5 m of depth was of 8.4 ± 4.8 $cm.sec^{-1}$ and to the 10 m of depth, the mean velocity was of 5.3 ± 2.7 $cm.sec^{-1}$.

During the ebb phase (Fig. 3.15), was observed that the surface water in the whole bay showed a net circulation direction toward the open sea. The current velocity in the channel was of 15 $cm.sec^{-1}$, decreasing toward the interior of the bay and varying between the 5 and 10 $cm.sec^{-1}$. The mean velocity of the surface layer was of 8.7 ± 3.7 $cm.sec^{-1}$.

The current direction with the depth, showed a circulation tendency toward the inside of the bay and also a decrease of the velocities.

The bottom velocities were smaller than in surface and, for the whole bay, varied between the 3 and 10 $cm.sec^{-1}$; even in some stations of the Marimelena and Guasabacoa Coves (stations 9 and 11) didn't register currents. The mean velocity of the current registered at 5 m depth in the bay was of 6.2 ± 2.3 $cm.sec^{-1}$, while to the 10 m of depth, the mean velocity was of 4.8 ± 3.3 $cm.sec^{-1}$.



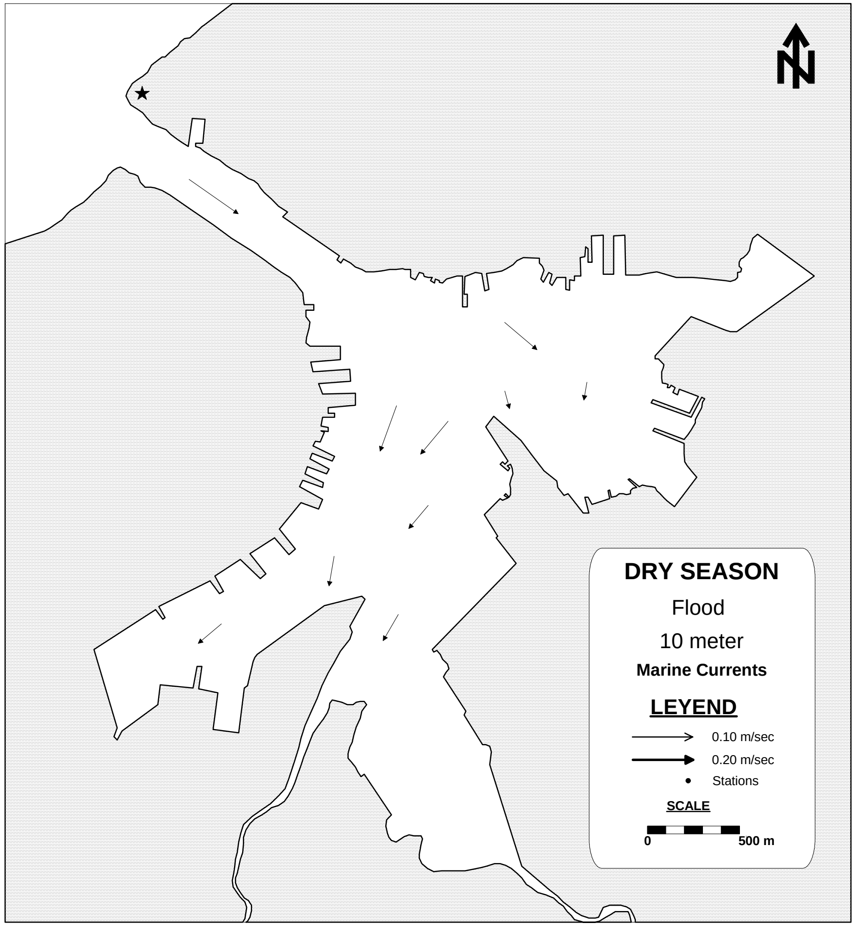
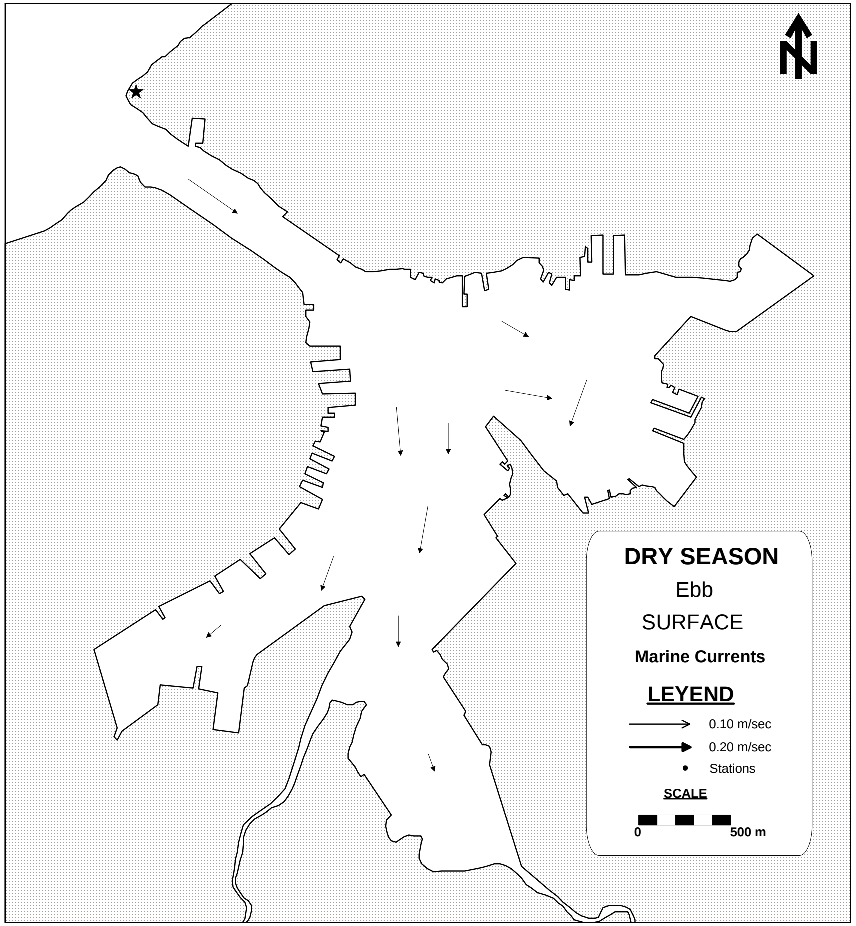


Figure 3.14: Spatial Distribution of the current during the flood phase in Havana Bay. Dry period (December/2002).



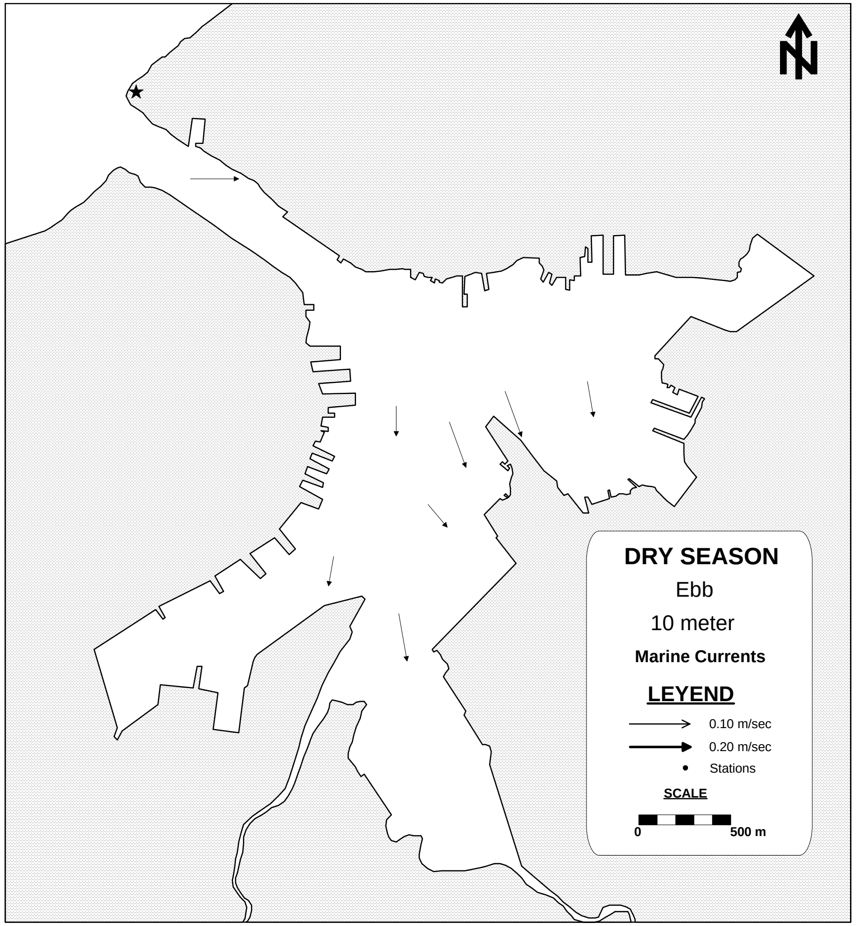


Figure 3.15: Spatial Distribution of the current during the ebb phase in Havana Bay. Dry period (December/2002).

However, as had already been reported during the samplings carried out at the rainy period, throughout the day and for the whole bay is usual the existence of two water layers with a clear defined net circulation, toward the outer part of the bay by the surface and to the inner part through the bottom. The above-mentioned can be verified with the aid of the results obtained during the 24 hours samplings in the stations 1, 3 and 5 (Fig. 3.16).

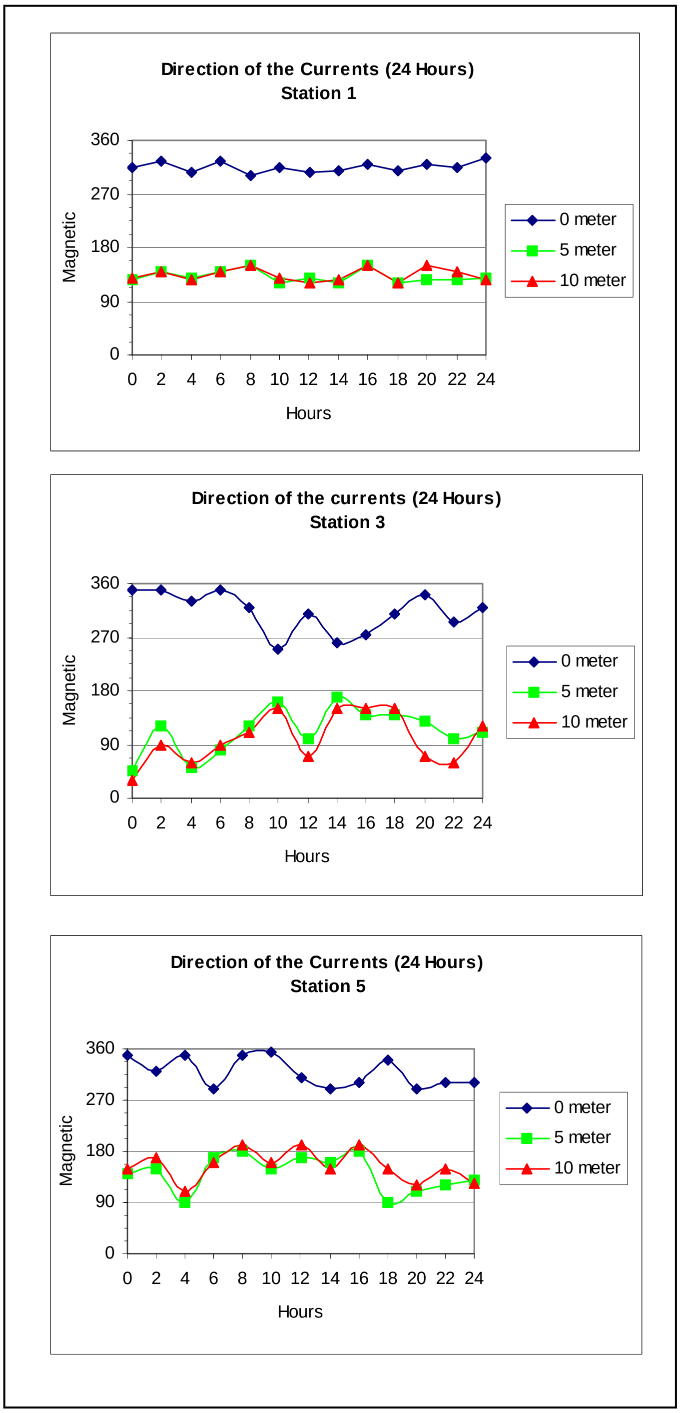


Figure 3.16: Direction of the current in Havana Bay during 24 hours. Dry period (December/2002).

The following table sum up the mean velocities ($cm.sec^{-1}$) and directions (azimuth) of the current during a 24 hours cycle for the stations 1, 3 and 5. In the table are related the results of velocity and direction versus the sampling depths.

Depth	Station 1		Station 3		Station 5	
	Velocity	Direction	Velocity	Direction	Velocity	Direction
Surface	15.9 ± 7.8	315 ± 9	5.2 ± 2.2	312 ± 34	5.6 ± 2.0	319 ± 26
5 m	16.3 ± 5.6	131 ± 11	6.5 ± 5.9	113 ± 38	5.8 ± 5.2	142 ± 32
10 m	17.1 ± 7.0	134 ± 11	3.6 ± 4.3	100 ± 41	3.9 ± 4.3	155 ± 26

3.7. Relationship stratification - circulation.

The results obtained during the rainy period (Octubre/2002), evidenced that the water of the bay was stratified, with a surface layer of approximately 2 m of thickness. Showing the bay a hydrodynamic behavior as a well mixed estuary of the type 2a.

The results obtained during the samplings carried out in the dry period (December/2002), show that the water of the bay are also stratified and show a surface layer varying between 2 and 3 m of thickness (Fig. 3.17).

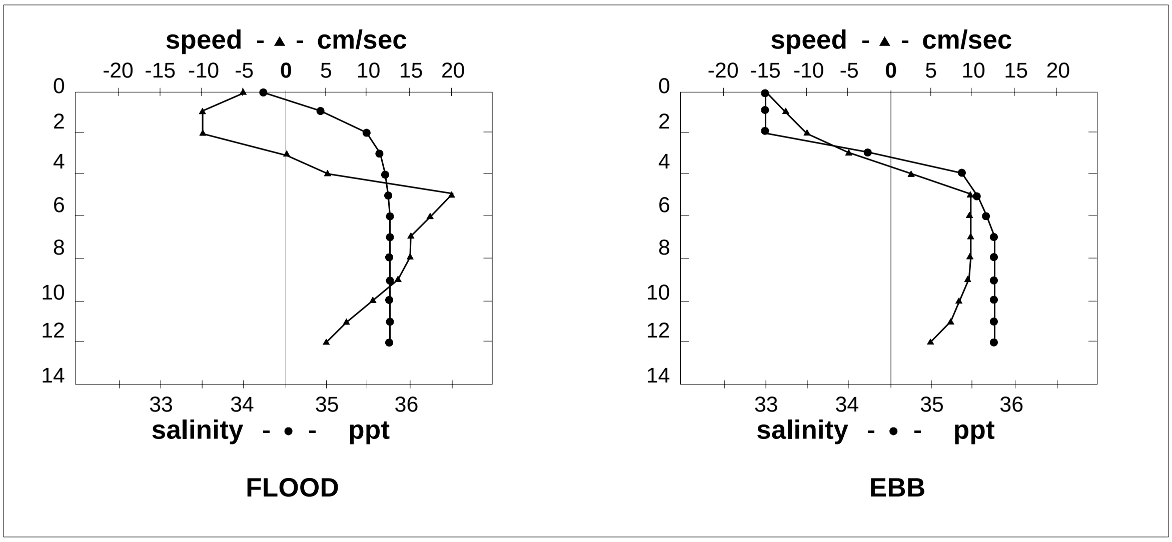


Figure 3.17: Vertical distribution of the salinity and current velocity in the central station of the entrance channel of Havana Bay (December/2002). The negative values of the velocity indicates the flow of the water toward the open sea.

In this period, the sampling carried out during the flood phase, show that the behavior of the salinity was similar to those reported for octubre/2002. However, during the samplings conducted at the

ebb phase, a significant decrease of the surface water salinity was evidenced, due to the occurrence of high levels of rainfall as a consequence of cold fronts arrivals in this period.

Mainly, the current showed a similar behavior for all the sampling periods. With an outgoing surface layer and an ingoing bottom layer. However, was observed that the water circulation in this period was more reinforced, evidencing significant differences in the magnitude of both currents; that basically is determined by the influence of the tidal wave.

In correspondence with the above-mentioned and with the aid of the results obtained in this sampling period, was applied the continuous spectrum of classification for estuaries (Hansen & Rattray, 1966); based on the relationship stratification-circulation which allows to discriminate the forms of interaction of the different dynamic characteristics of the bay in a certain period.

After performing the corresponding calculations and to represent them on the circulation-stratification diagram (Fig. 3.18), was determined that the bay during the dry period behaved as a well mixed estuary (type 2a).

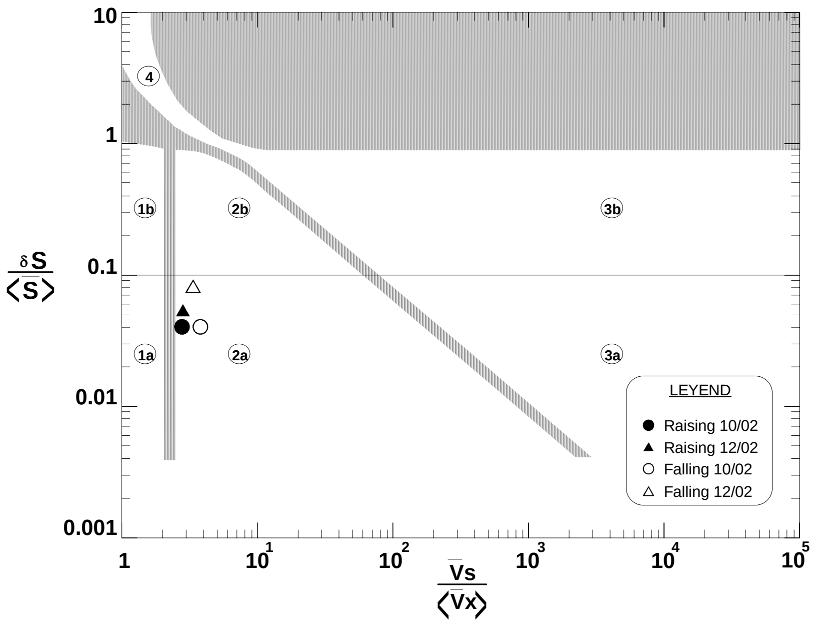


Figure 3.18: Continuous Spectrum of circulation-stratification.

However, a slight increase was observed in the water stratification with regard to octubre/2002. Mainly during the ebb, in agreement with the contributions of fresh water that entered to the bay (mainly at Guasabacoa Cove) as a consequence of the rainfall related with the entrance of cold fronts.

4. CONCLUSIONS.

1. The behavior of the hydrological parameters during the dry period was similar to those registered during the rainy period. However, should be highlighted that the salinity of the water, mainly, during the ebb, was slightly inferior to that of the rainy, due to the heavy rainfall occurrence in this period.

2. The marine current in this period showed a more defined behavior that in the rainy period. The current magnitude was higher in the whole water column, although in a general way decreases with the depth.

3. Was corroborated that the contributions of fresh water that inputs to the bay and the influence of the tidal wave are the main agents that determine the hydrological and hydrodynamic characteristics of Havana Bay.

4. Havana Bay, according to the results obtained in December/2002, behaved as a well mixed estuary (Type 2a), although with a slight increase in the water stratification; basically in function of the volume of fresh water that inputs to the bay.

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6. APPENDIX

- Includes an magnetic copy of the Draft Final Report and Database of the campaign for dry season.

APPENDIX-7

WATER QUALITY SIMULATION

APPENDIX A7 WATER QUALITY SIMULATION

Contents

Figures:

Tables:

APPENDIX A7 WATER QUALITY SIMULATION

A7.1 INTRODUCTION

Results of the water quality simulation are described in this Appendix. Water quality simulation was carried out to decide on the wastewater treatment level in case of discharging treated wastewater from the New Sewerage System to the bay and to estimate the improvement that can be achieved by the proposed M/P and F/S.

A7.2 POLLUTION CONTROL SCENARIOS

Various pollution control scenarios are studied to determine appropriate wastewater treatment level required when wastewater from the new sewerage system are is discharged to the bay. Figure A7.1 shows the schematic of scenarios studied and the time horizon required for their implementation.

Scenarios are described in the followings:

Case 1	- Existing conditions in year 2002 based on the measured data
Case 2	- Future (2020) with implementation of only GEF/UNDP Projects (Zone 4 and Zone 6)
Case 3	- Future with implementation of wastewater treatment plant in Tadeo and Martin Perez (abajo) and elimination of wastewater flow through Arroyo Matadero
Case 4	- Secondary treatment in all areas of new sewerage system and elimination of cross-connections in existing sewerage system
Case 5	- Primary treatment in all areas of new sewerage system and elimination of cross-connections in existing sewerage system
Case 6	- Advanced treatment in all areas of new sewerage system and elimination of cross-connections in existing sewerage system
Case 7	- Marine outfall of all wastewater with either primary and secondary treatment
Case 8	- 50% reduction in refinery load with the implementation of Case 4 (secondary treatment)
Case 9	- 50% reduction in internal sediment load with the implementation of Case 4 (secondary treatment)

Case 1 shows the existing conditions in year 2002 and is based on the measured data and is used to compare with the future prognosis.

Case 2 represents future condition in year 2020 with on-going GEF/UNDP projects for Zone 4 and Zone 6 are completed and without implementation of any other projects. In this case, pollutant load reduction will be for Dren Agua Dulce which will be diverted and treated together with industrial wastewater near the mouth of Rio Luyano and for part of the areas in Luyano-Abajo (Zone 6).

Case 3 represents an option when the treatment to the wastewaters from Tadeo and Martn Perez abajo Sewer Districts are carried out.

In Case 4, provision of secondary wastewater treatment in all of the sewer districts in Rio Luyano, Rio Martin Perez and in Arroyo Tadeo and elimination of pollution load discharged through stormwater drains generated in the existing sewerage system through improvement of cross-connections is considered. Case 4 signifies what could be achieved by new wastewater treatment system proposed in terms of organic pollution load reduction.

In Case 5, wastewater treatment level in the new sewerage system if primary treatment is provided in the new sewerage system instead of secondary treatment as in Case 4. Therefore, organic pollution load reduction will be less than that can be achieved in Case 4.

Case 6 in which effect of enhanced removal of nutrients through advanced treatment to the wastewater generated in the new sewerage system is considered.

Case 7 represents an entirely new alternative in which all wastewater generated in the new sewerage system is discharged to sea and therefore eliminate all wastewater pollution load. Naturally in addition to the elimination of pollution load, flow quantity will also be reduced.

Case 8 represents contribution of other sectors namely industrial sector (refinery) in addition to wastewater treatment by secondary treatment level (Case 4).

Case 9 also represents other pollution control measures i.e. by reduction of internal sediment load in addition to wastewater treatment by secondary treatment level (Case 4).

Latter two cases,

A7.3 BASIC CONDITIONS AND ASSUMPTIONS

Following basic conditions and assumptions are applied in the estimation of pollutant load.

1. Industrial and domestic wastewater constitute approximately 25% of river flow in Rio Luyano and Rio Martin Perez presently based on an analysis by CIMAB and DPAA (1998). For Arroyo Tadeo which is an urban stream, the ratio is assumed to be 90% due to extremely small catchment (2.6 km^2) and its urban nature. Based on these river flow, which results from natural processes was separated from the contribution of industrial and domestic wastewaters. Table A7.1 shows the natural and non-natural flow in Luyano and Martin Perez river basins.

Table A7.1 Natural and Non-Natural River Flow

Item	Luyano River	Martin Perez River
Natural flow, (m^3/d)	86,120	46,592
Wastewater flow (m^3/d)		
Luyano Abajo Sewer District	46,168	
Luyano Arriba Sewer District	21,349	
Martin Perez Abajo Sewer District	*13,846*	*(13,486)*
Martin Perez Arriba Sewer District		24,250
Total	167,123	70,842

It is important to note that in the M/P only 13,486 m^3/d (daily average flow) from Martin Perez Abajo Sewer District will be diverted to Luyano River basin and its effect on the flow of Luyano River is insignificant compared with the natural flow of Luyano River (86,120

m^3/d) and wastewater generated in Luyano Arriba and Abajo Sewer Districts (21,349 + 46,168 = 67,517 m^3/d). The total flow of Luyano River will be 167,123 m^3/d including the diverted flow of Martin Perez Abajo Sewer District. For the Martin Perez River, diversion means that the increase in wastewater generation in the basin up to the year 2020 will be reduced if there is no diversion (wastewater of 15,531 m^3/d in 2002 to 24,250 m^3/d in 2020 with diversion and if no diversion wastewater flow will be 37,736 m^3/d in 2020). Further, both Luyano and Martin Perez discharging to Guasabacoa though discharge point of Martin Perez is the most remotest.

2. Water quality of river due to natural processes is assumed to be the values measured at the most upstream water sampling points in this Study. River flow and its quality or load were estimated by considering the natural portion of river flow and that contributed by wastewater. Table A7.1 shows the assumed river quality.

Table A7.2 Upstream River Quality

Parameter	Rio Luyano	Rio Martin Perez	Arroyo Tadeo
River flow (excluding wastewater), m^3/d	86,120	46,590	800
BOD, mg/L	6	3	13
T-N, mg/L	0.6	3.5	7.8
T-P, mg/L	0.09	0.2	1.2
SS, mg/L	18	62	58
DO, mg/L	7	7	1

Source: Study Team

2. For the cases without implementation of any project other than GEF/UNDP, wastewater load generated is expected to undergo degradation prior to reaching the bay. To account of this degradation, load generated is multiplied by a factor defined as run-off ratio which is the ratio between load discharged to the load generated. Run-off ratio in each sewer district is assumed at 90%.

3. Wastewater treatment efficiency for various level of wastewater treatment is assumed as follows:

Table A7.3 Wastewater Treatment Efficiency (Assumed)

Parameter	Primary Treatment	Secondary Treatment*	Advanced Treatment
BOD_5	40 %	90 %	95%
SS	50 %	90 %	95%
T-N	15 %	15 %	65%
T-P	15 %	15 %	75%

* - conventional activated sludge process

4. Wastewater treatment efficiency for treatment plants at Zone 4 and Zone 6 area are based on treatment plant design data. Average influent and effluent concentrations are as follows:

Table A7.4 Influent and Effluent Quality for Zone 6 WWTP (UNDP)

Parameter	Influent	Effluent
BOD_5, mg/L	90	30
T-N*, mg/L	26	5
T-P, mg/L	10	5

* Kjeldahl Nitrogen

Table A7.5 Influent and Effluent Quality for Zone 4 WWTP (Italian)

Parameter	Influent	Effluent
BOD_5, mg/L	109	20
T-N*, mg/L	20**	14**
T-P, mg/L	5**	2.5**

* Kjeldahl Nitrogen

** calculated based on design data available for influent loads and % removals

5. Degradation of treated wastewater effluent between the point of WWTP discharge and the point of entry to bay is assumed to be negligible due to very short travel time (within a few hours) and lower concentration of organic matter remaining in secondary treated wastewater effluent for further biodegradation.

6. Light extinction coefficient, inorganic nitrogen and phosphorous release from the sediments are set to vary regionally across the bay to reflect the existing conditions of sediments. Regional variations are shown in Annex 7 - Figures A7.78 to A7.80.

A7.4 RESULTS FOR POLLUTION CONTROL SCENARIOS

Table A7.5 shows the pollution load input to the bay for each source of pollution for Case 1 through 9.

Figures A7.2 through A7.46 show the results of simulation for nine cases namely Case 1 through Case 9 and five water quality parameters namely dissolved oxygen (DO), dissolved bio-chemical oxygen demand (BODd), ammonia nitrogen (NH_4-N), phosphates (PO_4-P) and chlorophyll-a (Chl-a). In each figure, results for high tide and low tide are also shown.

1) DO

Significant improvement in DO can be observed between Case 2 and Case 4. DO levels reach 3 mg/L in Atares which is the most polluted part of the bay in terms of organic pollution. With Case 3 i. e. primary treatment DO levels in Atares and in Guasabacoa fall below 3 mg/L and therefore not sufficient to achieve water quality goals. Improvement of DO levels in Atares in Case 4 is due to improvement of DO levels resulting in Guasabacoa with secondary treatment as there will be no change in the pollution input to Atares which receives wastewater through drains. Further, in the absence of inflow to Atares, some mixing of outward surface flow from Guasabacoa to Atares can be observed from the simulation and this phenomenon is one of the cause which subdues further improvement of DO levels in Atares in addition to that caused by the internal sediment load which is also the highest in Atares. In Atares, reduction of load (approximately one third of the total load to bay in terms of BOD_5) overweighs the reduction in flow.

In the Canal Entrada area, improvement to Class D level (above 4 mg/L) can be expected with Case 4.

Case 6 in which advanced treatment is considered, improvement in DO levels is observed mainly in Guasabacoa compared to Case 4 where secondary treatment is considered since all the treated wastewater from new sewerage system is discharged to Guasabacoa.

Improvement expected by Case 7 by discharge of all wastewater outside bay shows improvement in DO levels Compared to Case 2. However, improvement in DO levels compared to Case 4 is smaller. Reasons for this is considered to be the reduction in mixing within the bay, existence of internal sediment load and continued discharge of natural load of rivers (approximately one fourth of treated wastewater load in terms of BOD_5).

Improvement of DO levels in Marimelena is observed in Case 8 in which a 50% reduction in load from refinery load is assumed. Compared to Guasabacoa and Atares coves, Marimelena is the most closest to the entrance to the bay and DO levels are augmented by increased mixing with sea water.

As expected, Case 9 shows significant improvements in all parts of the bay due to reduction in in organic load by secondary wastewater treatment as well as by reduction of internal sediment load. In Case of Atares, pollution load input is eliminated in Case 3, and the improvement of DO level following that is only pronounced in Case 9 with reduction in internal sediment load.

2) BODd

Difference in BODd concentration (dissolved bio-degradable organic matter) in Guasabacoa between Case 4 (secondary treatment) and Case 5 (primary treatment) is due to level of treatment whereas no significant improvement between Case 4 (secondary treatment) and Case6 (advanced treatment) can be observed.

3) NH_4-N and PO_4-P

In case of nutrients, significant improvement in Gusabacoa can be observed in Case 6 (advanced treatment) due to removal of nutrients.

4) Chl-a

Simulated Chl-a concentration in Case 4 (secondary treatment) is approximately 6 µg/L which is similar to the levels observed outside the bay. With Case 6 (advanced treatment) overall reduction of Chl-a concentration in all parts of the bay is expected. However, the levels of Chl-a with Case 4 does not indicate trend of eutrophication in which case advanced treatment will become necessary.

A7.5 RESULTS FOR M/P AND F/S

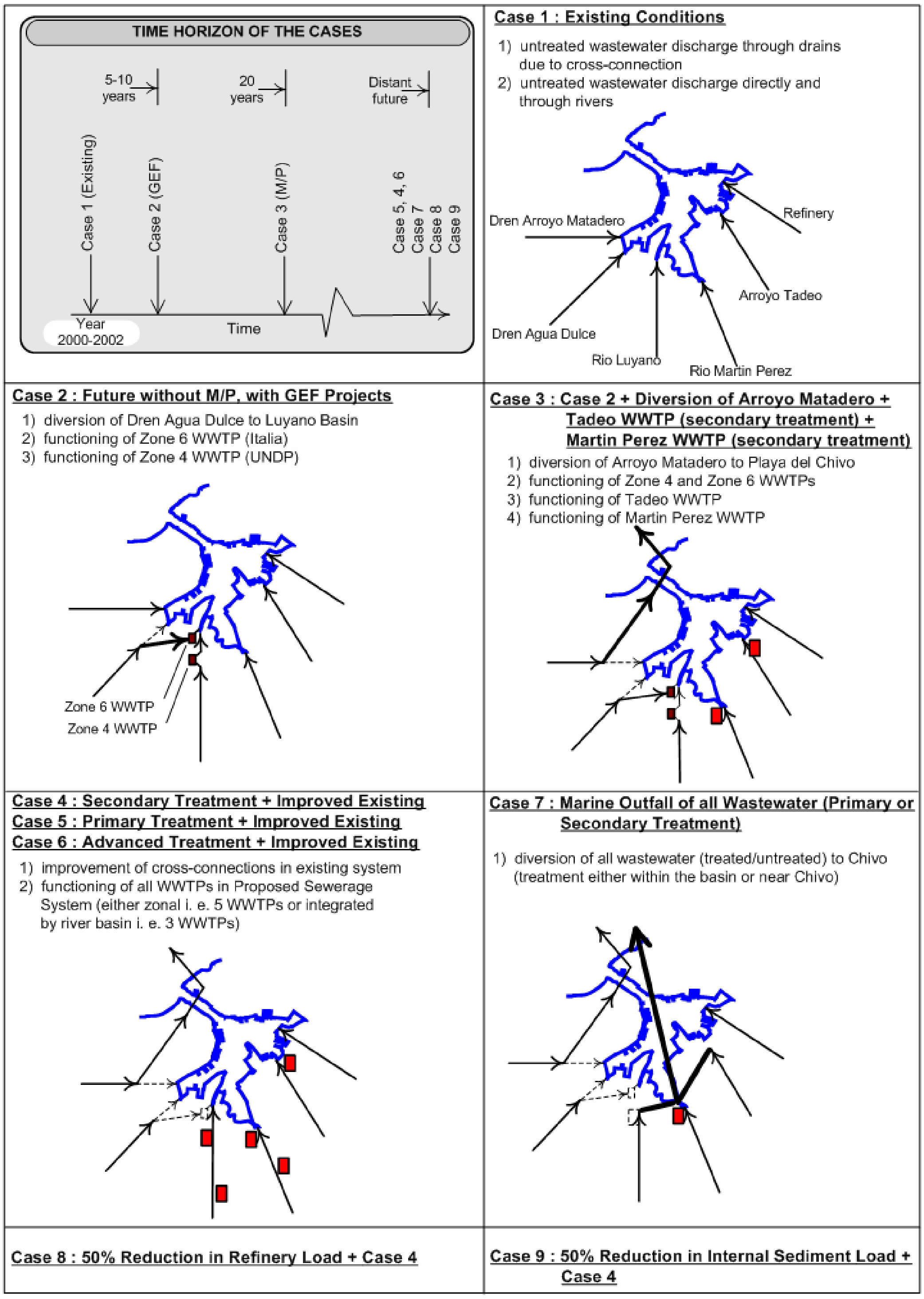
Figures A7.47 through A7.57 show the results of simulation for M/P and F/S for five water quality parameters namely dissolved oxygen (DO), dissolved bio-chemical oxygen demand (BODd), ammonia nitrogen (NH_4-N), phosphates (PO_4-P) and chlorophyll-a (Chl-a). In each figure, results for high tide and low tide are also shown. Results when the Luyano Left Bank Area A is discharged through the Central System (M/P-alt) is also shown in Figures A7.58 through A7.61.

Water quality simulation results show that with the implementation of M/P, DO levels in Atares will improve to Class F (minimum 2 mg/L) from the existing level below Class F. This will be the first step in improving the water quality of the bay towards the water quality goal of 3 mg/L of DO when secondary treatment is provided (Case 4) to all the wastewater generated in the New Sewerage System area.

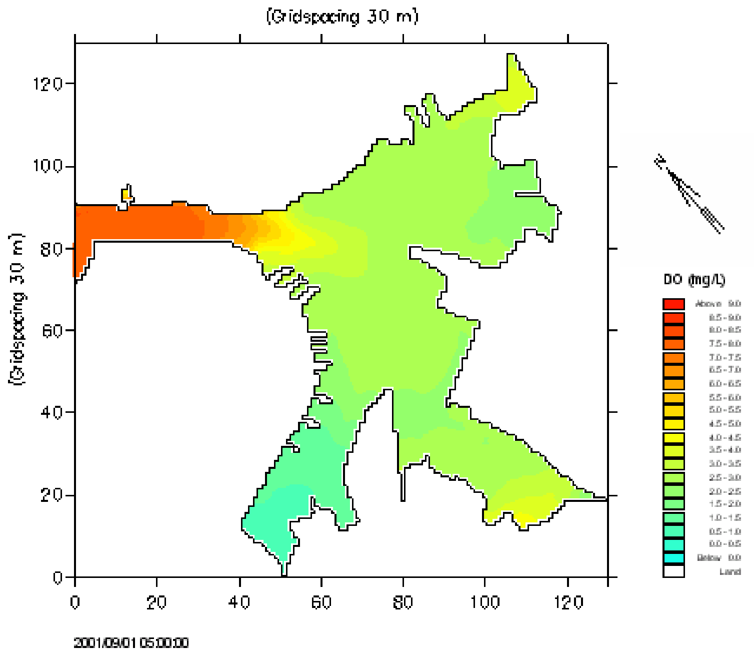
A7.6 CURRENT PATTERN

Due to variation in inflow quantity and its location of discharge to the bay vary for different cases, simulated current pattern for selected cases are presented for reference. Figure A7.62 through A7.65 shows the current pattern for Case 2 and Case 7 each for high tide and for low tide. Case 2 (with the implementation of GEF/UNDP project and without M/P) represents the variation in flow pattern due to diversion of Agua Dulce discharge from Atares to Guasabacoa and the increase of non-natural flow of rivers due to wastewater at year 2020 conditions. Case 7 (marine outfall) represents diversion of all wastewater due to increase of non-natural flow of rivers as well as elimination of wastewater flow to bay through drains.

Results are also presented for the case of M/P, F/S and M/P-alt in Figure A7.64 through A7.77 each for combination of surface layer and second layer with high tide and with low tide.



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.1 Pollution Control Scenarios
JAPAN INTERNATIONAL COOPERATION AGENCY	



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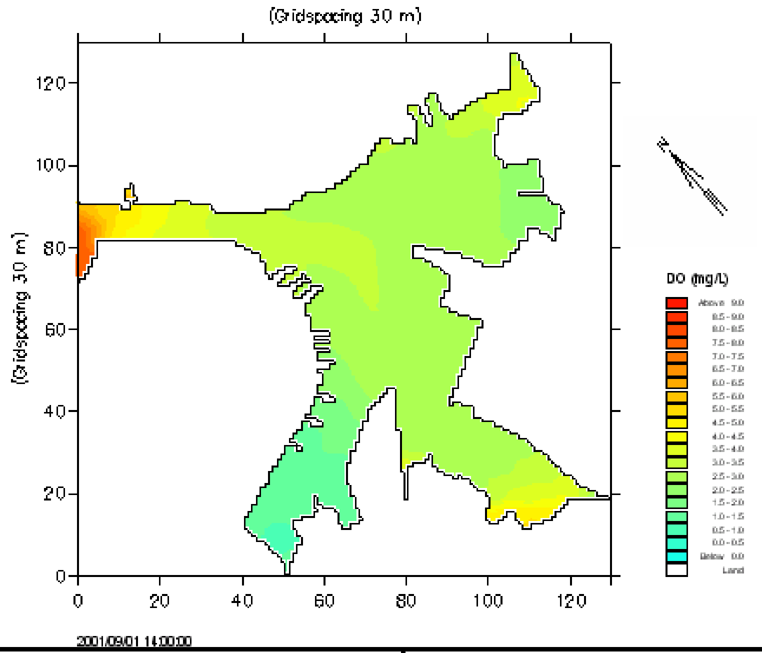
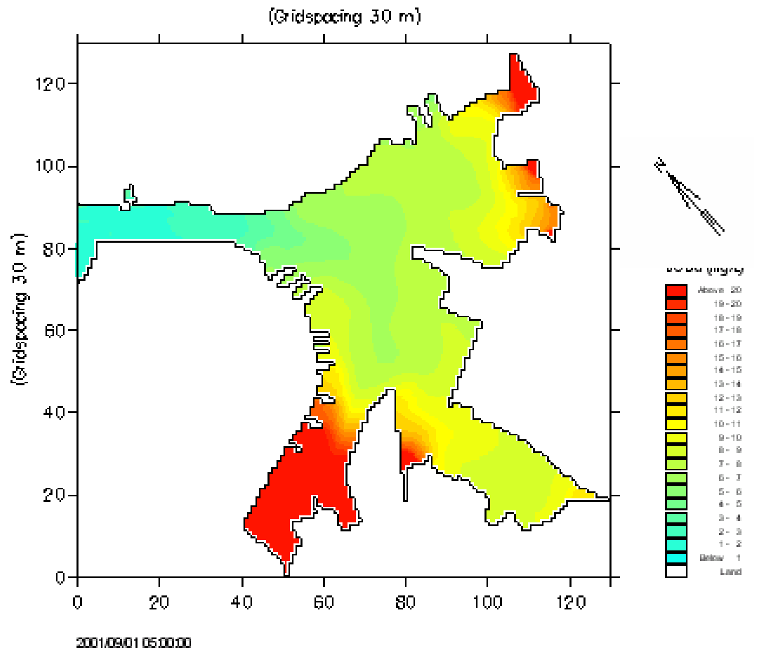


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.2 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case1
JAPAN INTERNATIONAL COOPERATION AGENCY	



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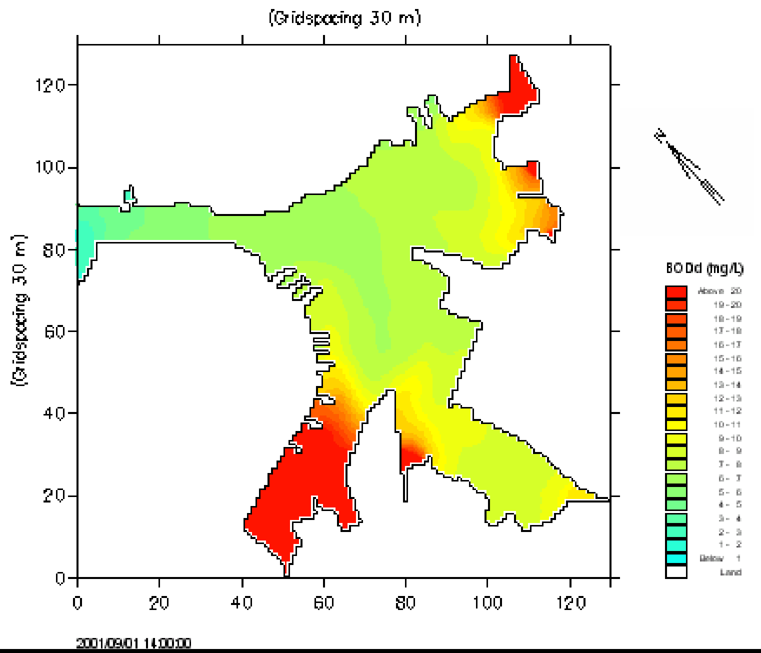
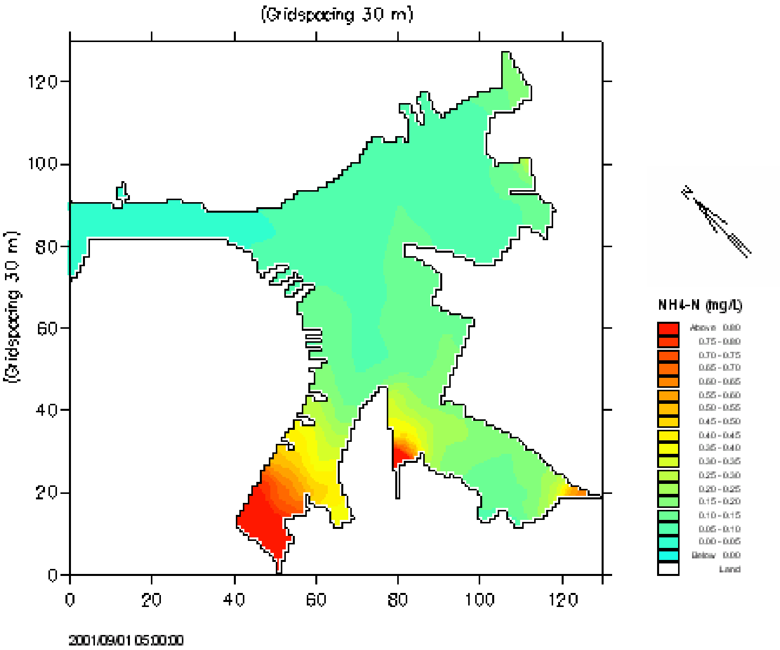


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.3 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case1
JAPAN INTERNATIONAL COOPERATION AGENCY	



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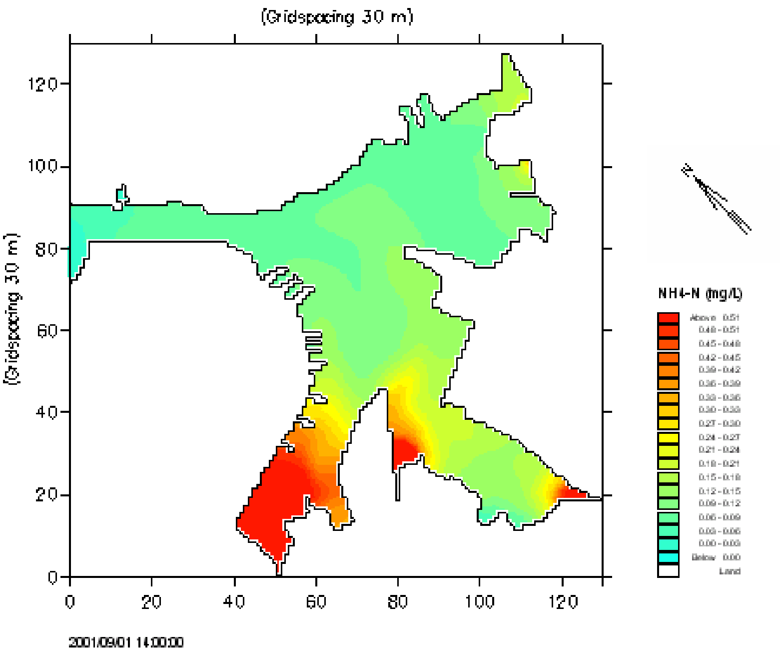
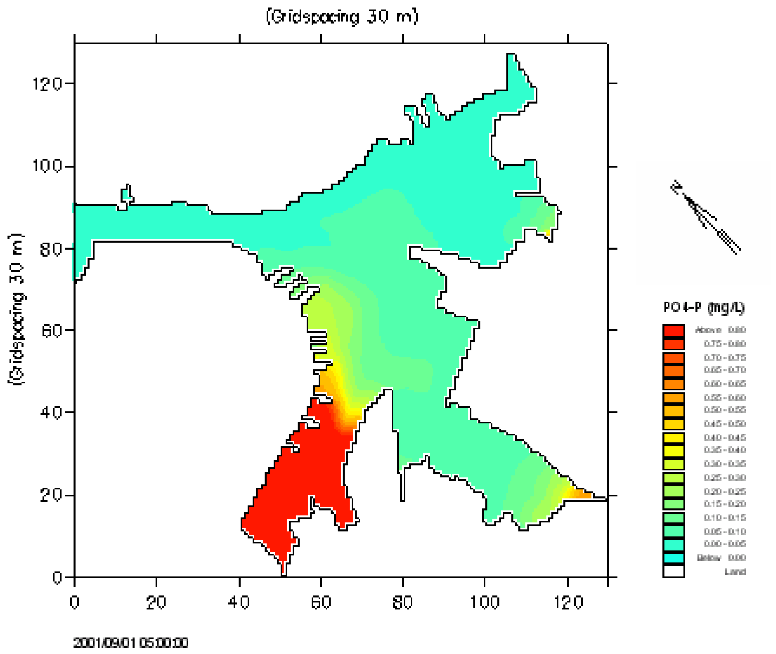


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.4 Concentration Distribution of Ammonia (NH_4-N) in Havana Bay (Surface Layer) for the Case1.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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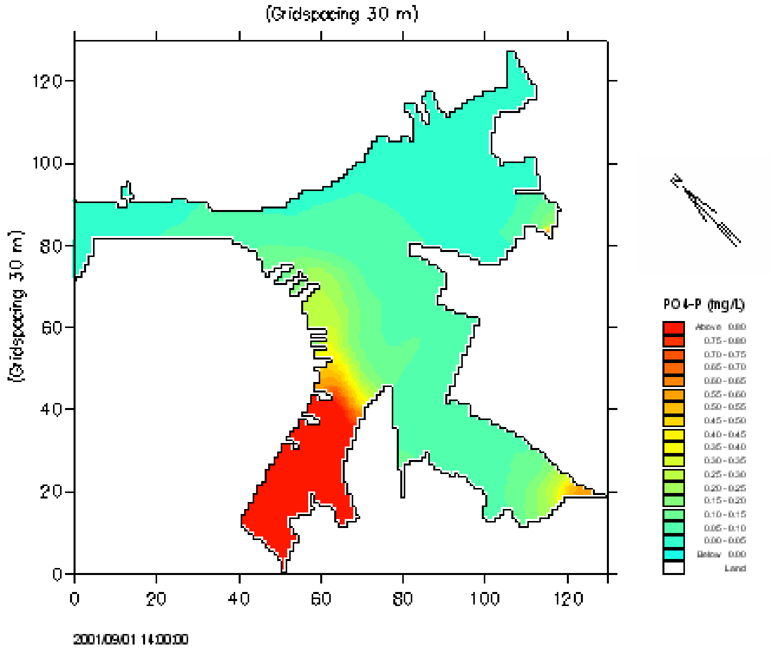
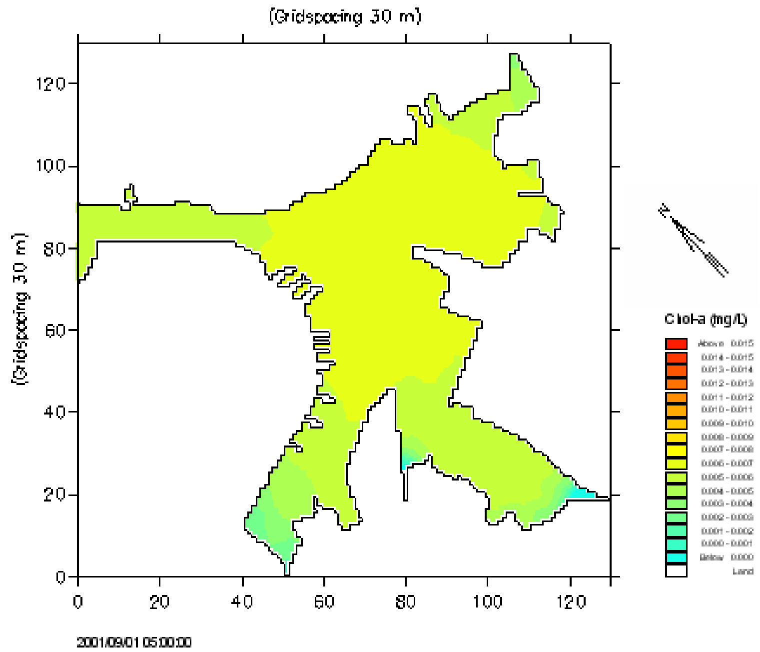


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure A7.5
Concentration Distribution of Phosphate (PO_4-P) in Havana Bay (Surface Layer) for the Case1



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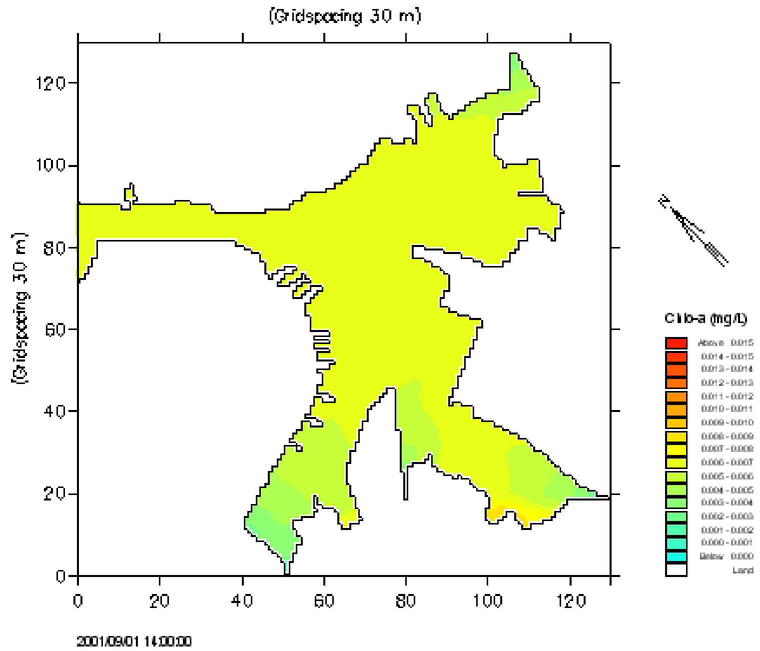
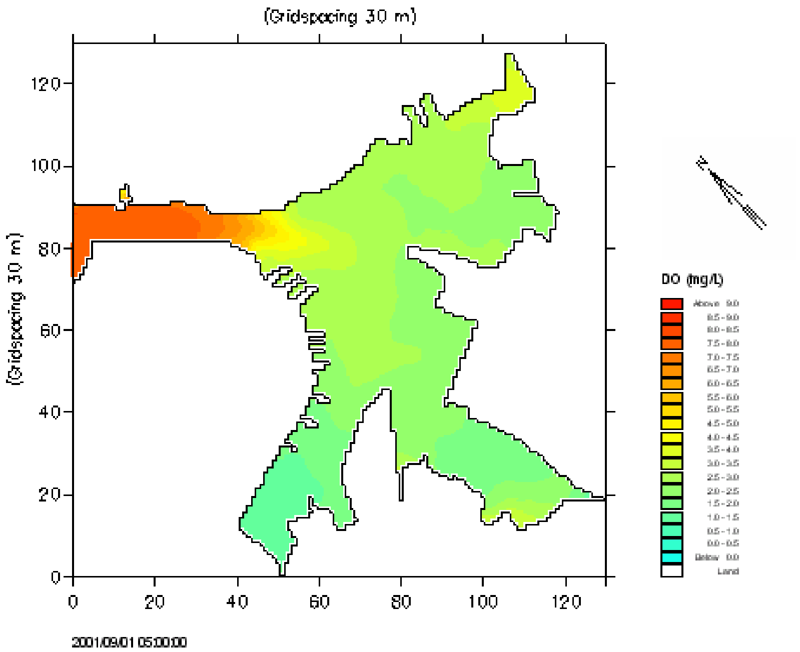


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.6 Concentration Distribution of Chlorophyll-a (Chl-a) in Havana Bay (Surface Layer) for the Case1.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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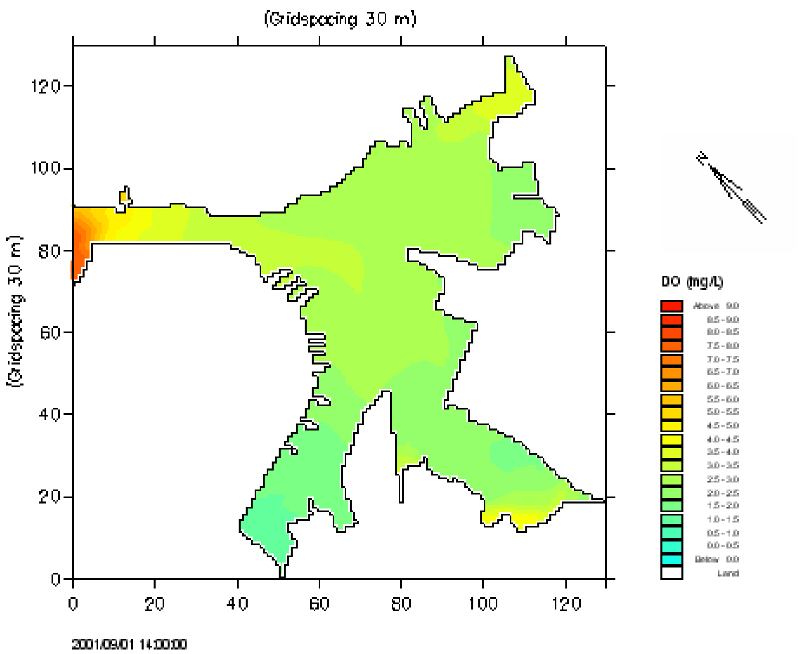
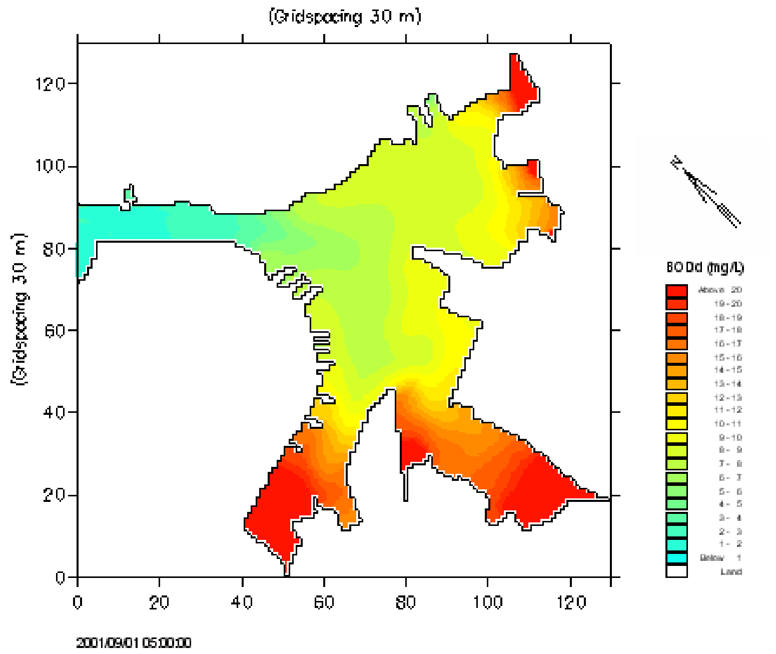


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.7 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case2
JAPAN INTERNATIONAL COOPERATION AGENCY	



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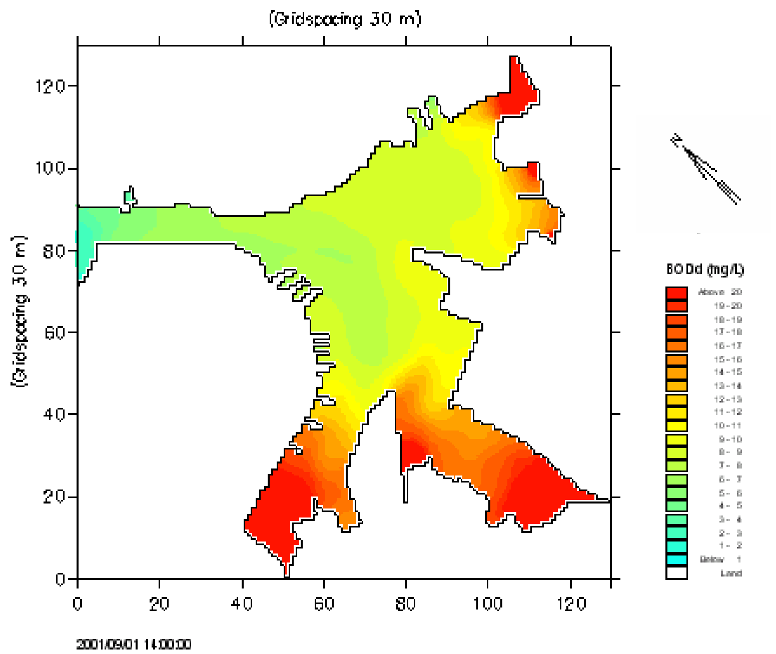
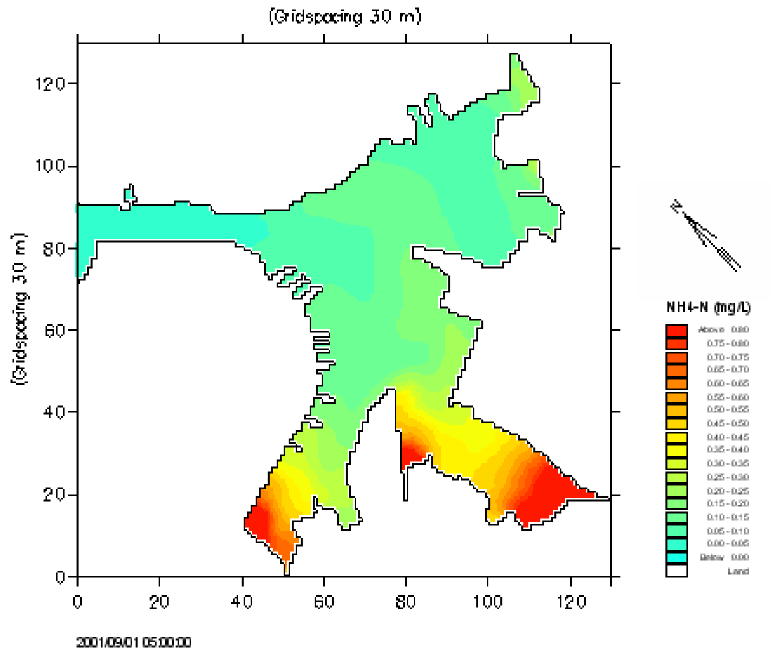


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.8 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case2.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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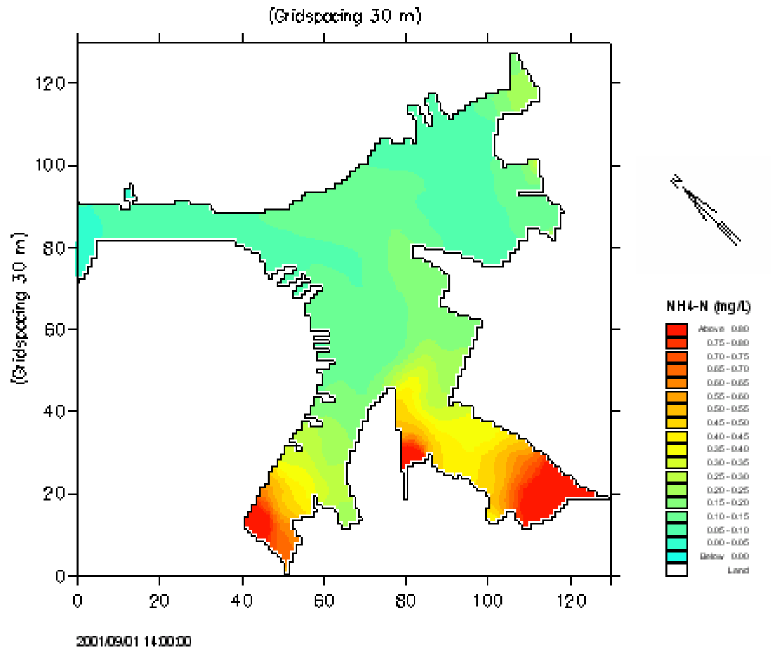
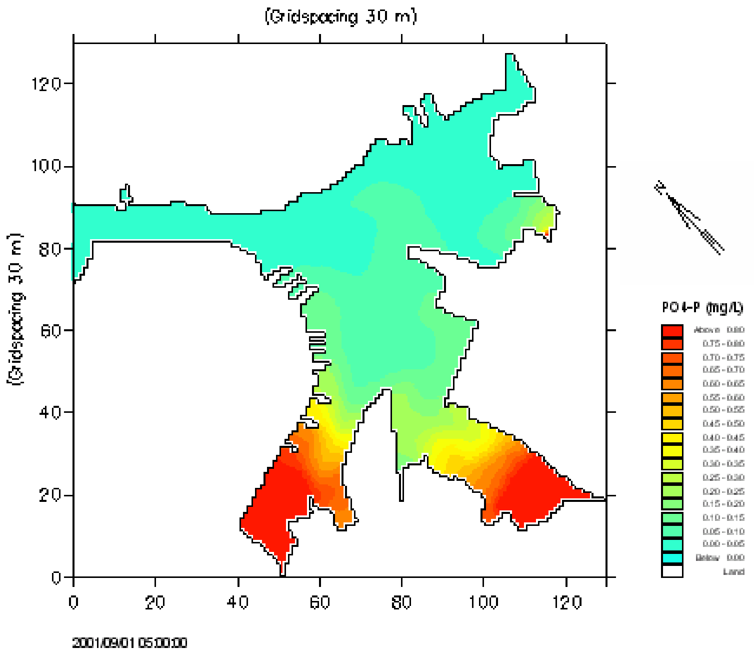


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.9 Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case2.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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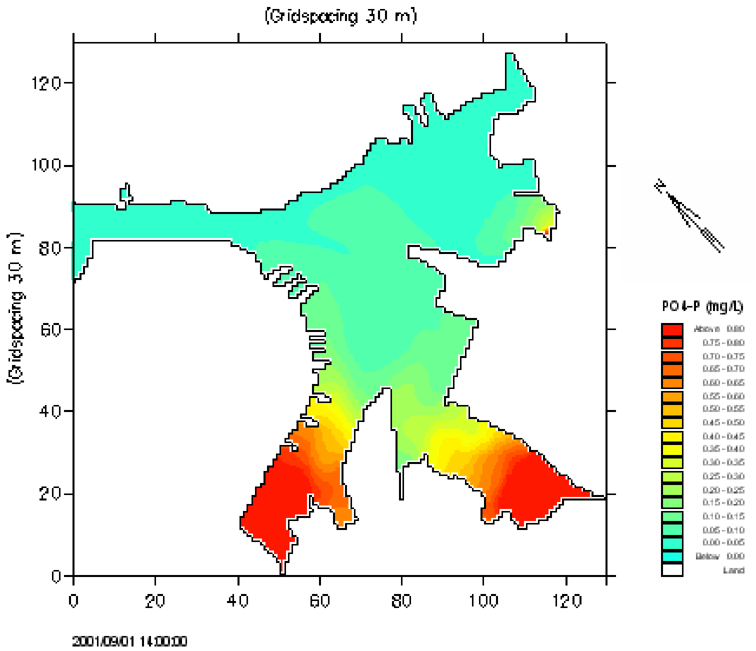
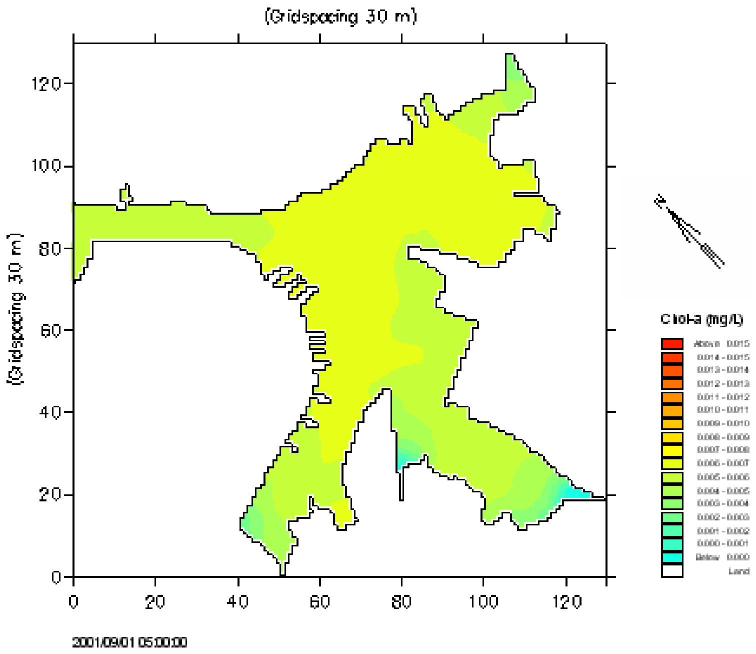


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.10 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case2.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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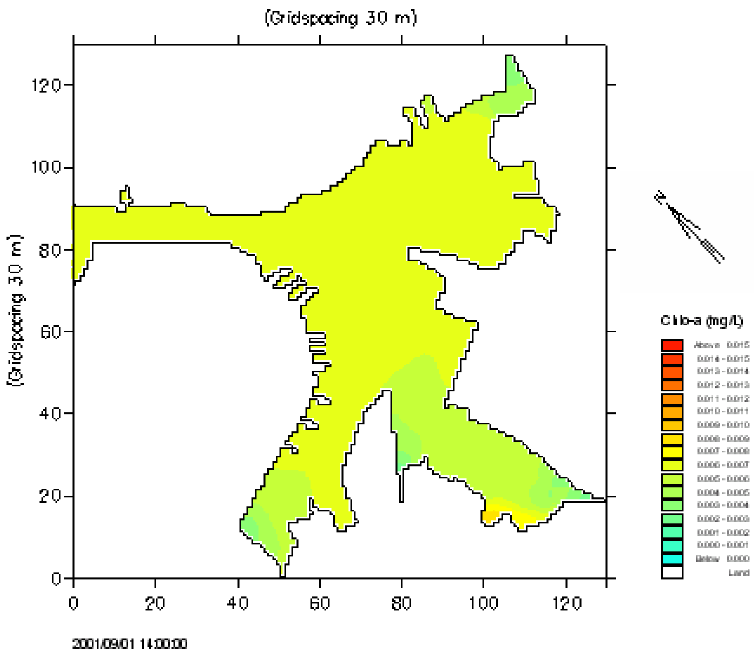
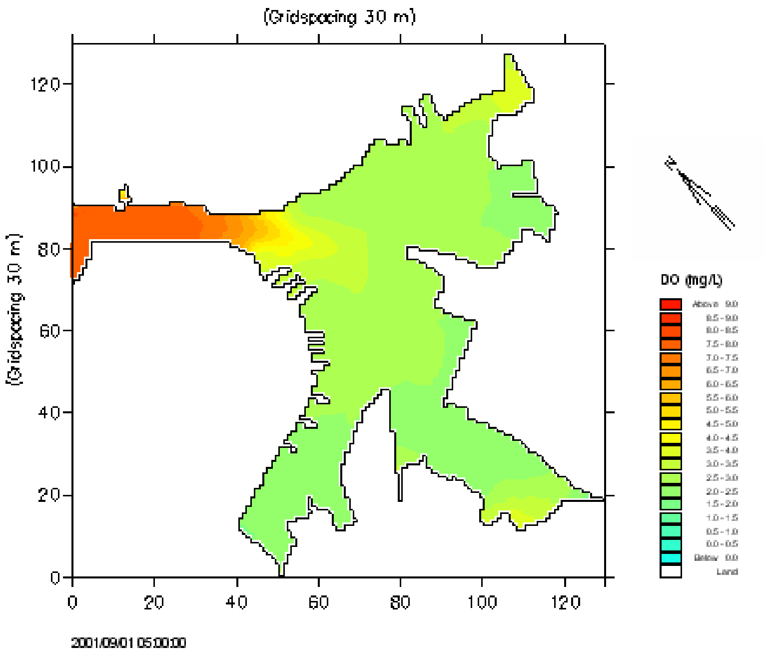


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.11 Concentration Distribution of Chlorophyll-a (Chl-a) in Havana Bay (Surface Layer) for the Case 2.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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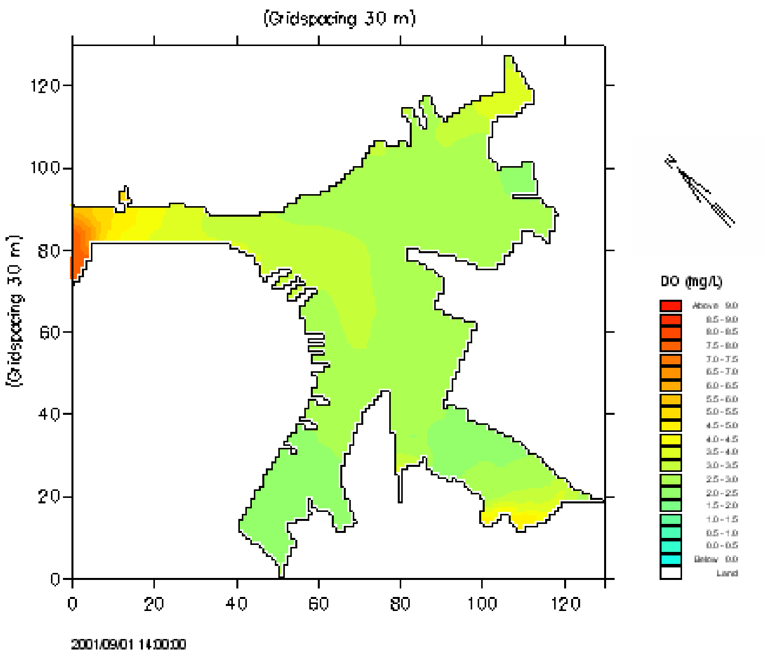
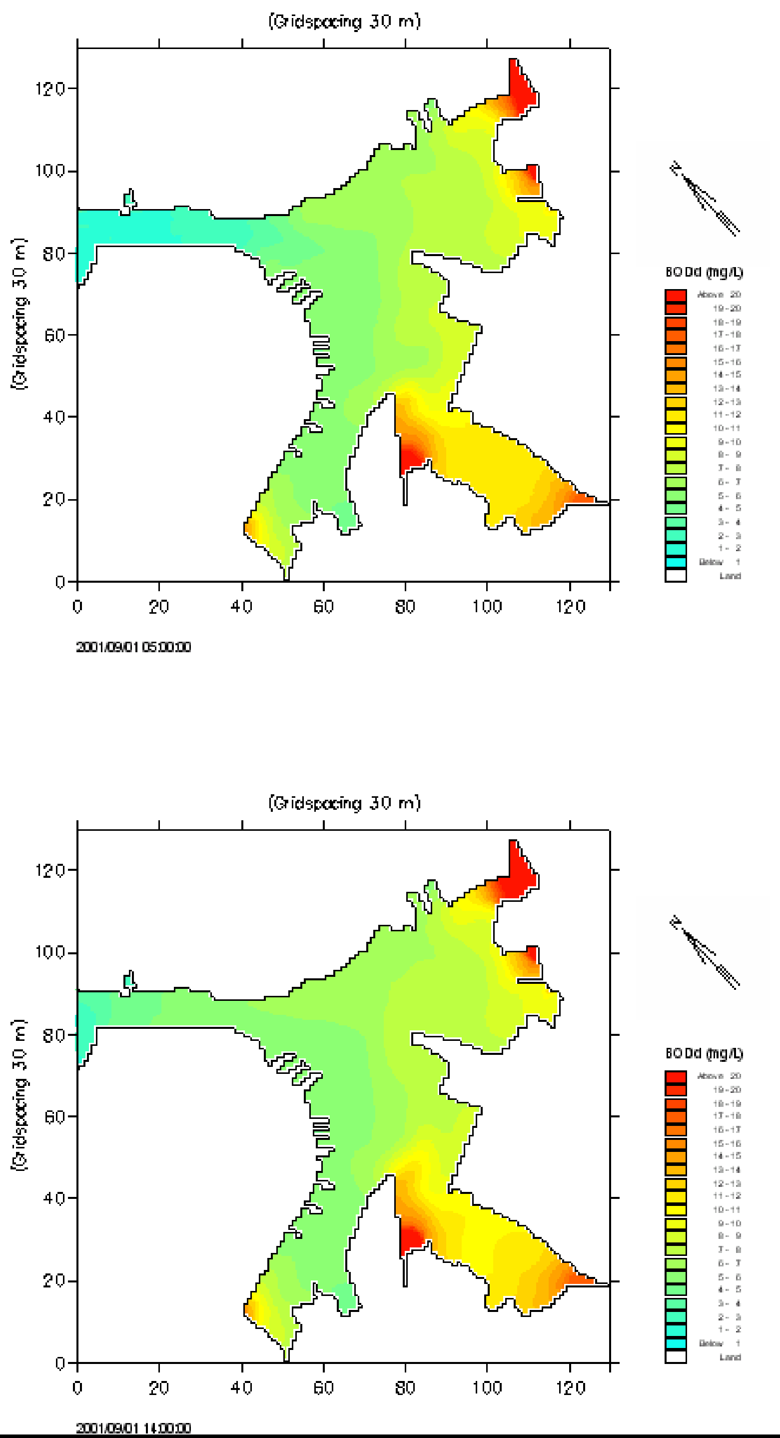


low tide

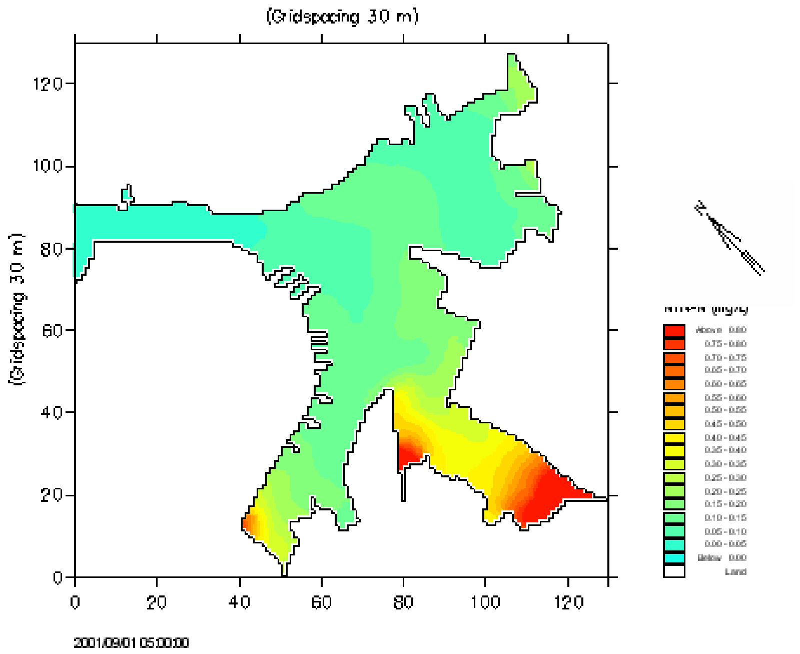
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.12 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case3
JAPAN INTERNATIONAL COOPERATION AGENCY	



high tide

low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.13 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case3
JAPAN INTERNATIONAL COOPERATION AGENCY	



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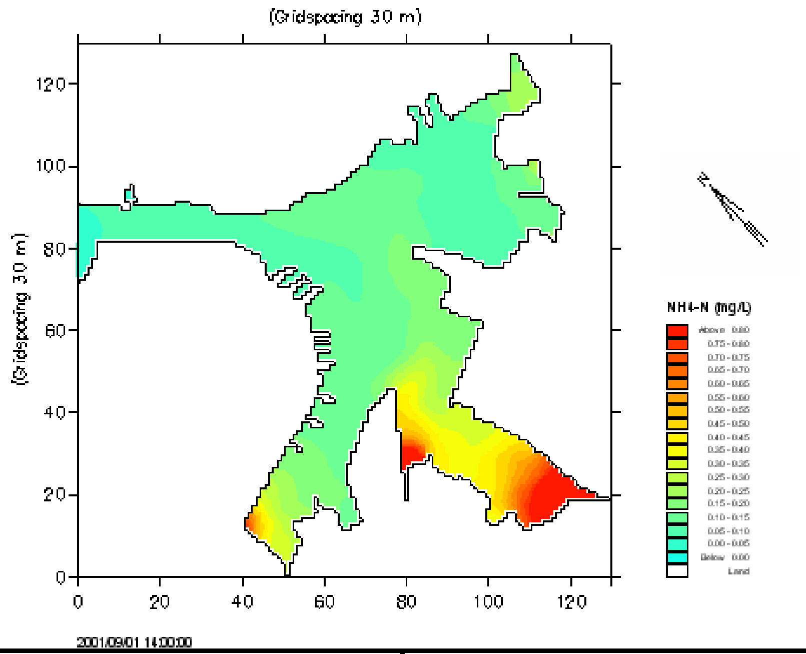
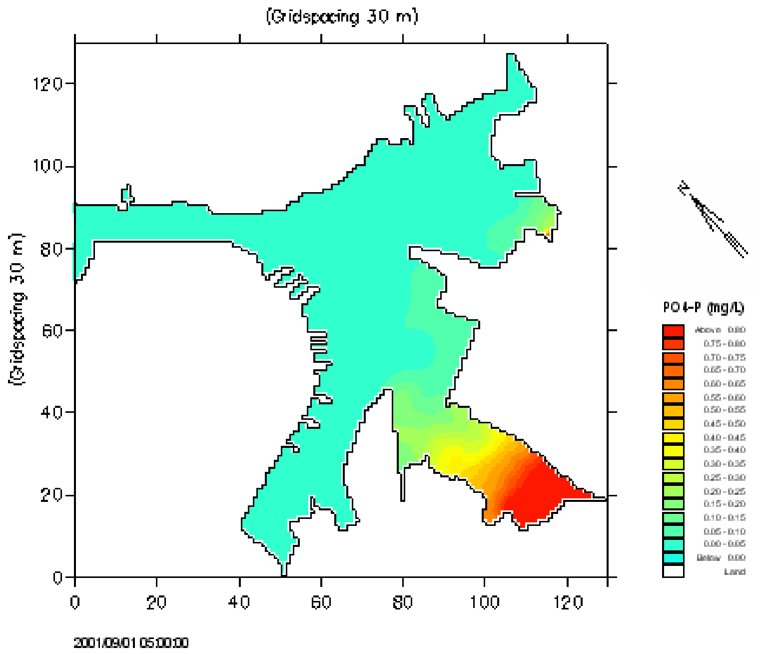


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.14 Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case3
JAPAN INTERNATIONAL COOPERATION AGENCY	



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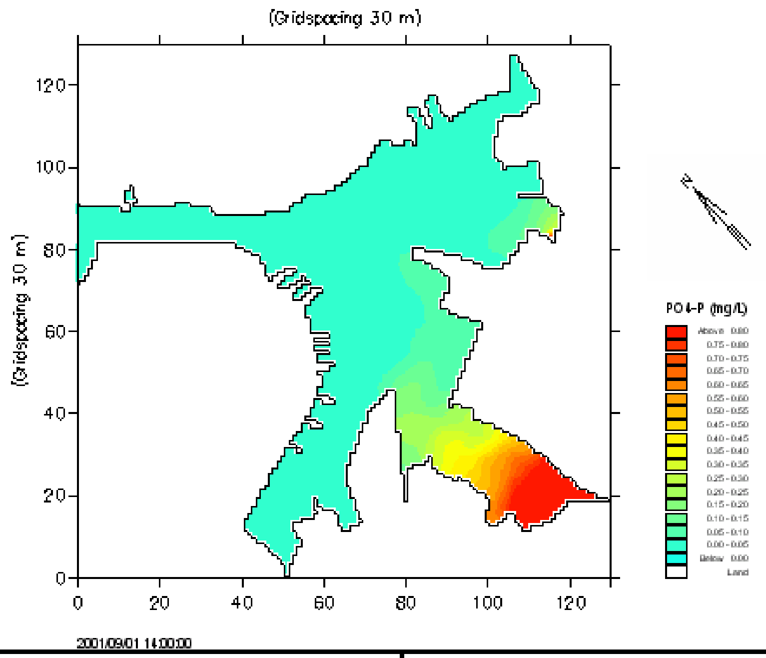
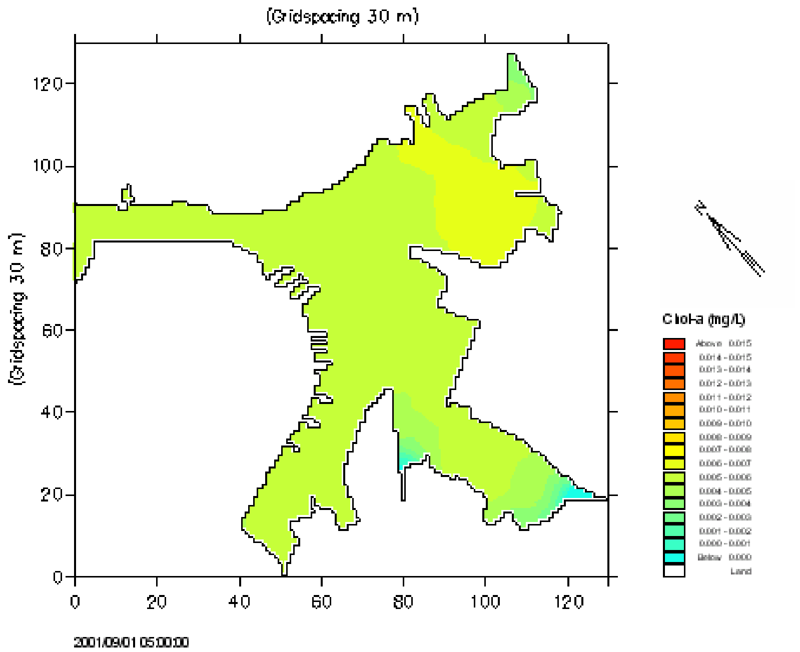


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.15 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case3.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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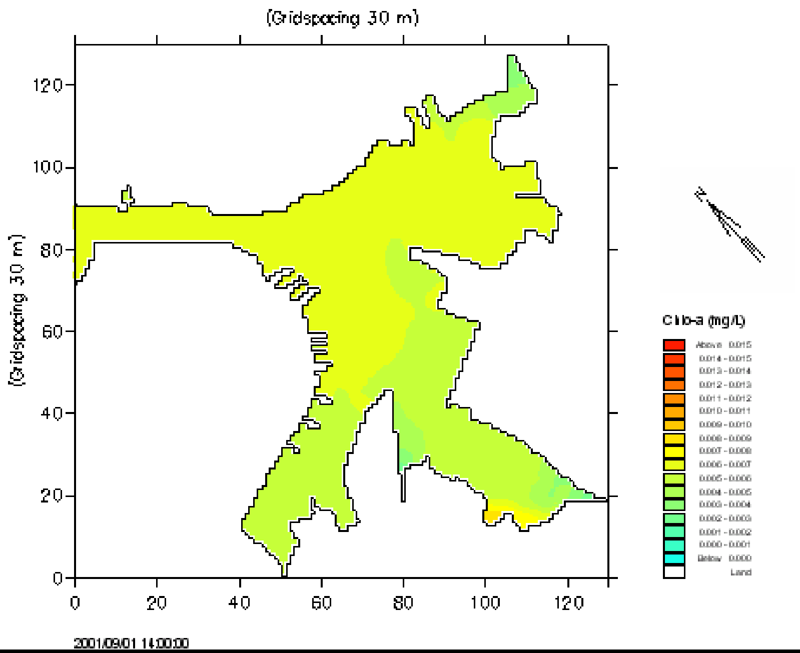
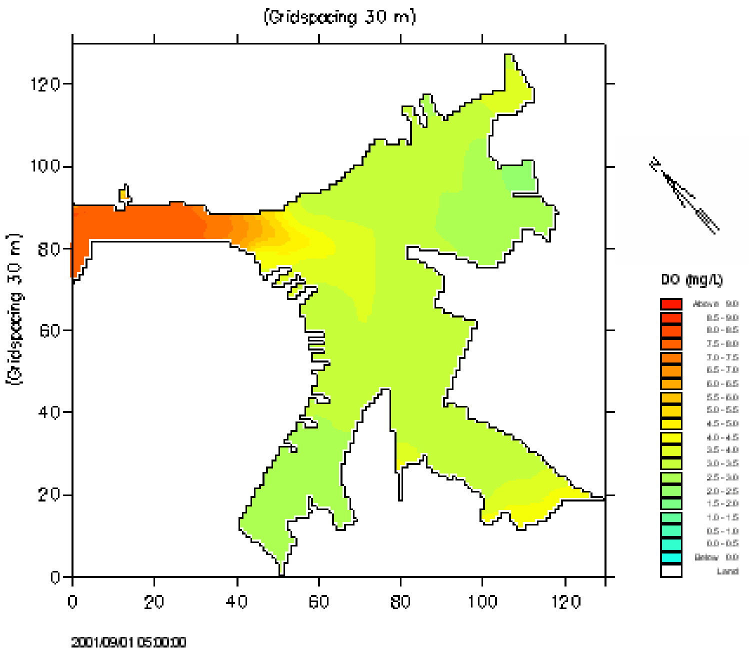


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.16 Concentration Distribution of Chlorophyll-a (Chl-al) in Havana Bay (Surface Layer) for the Case3.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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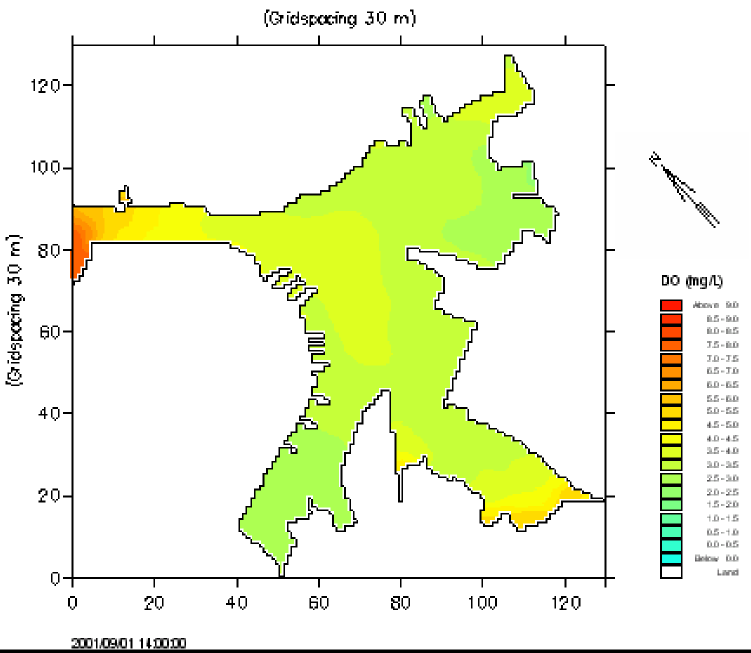
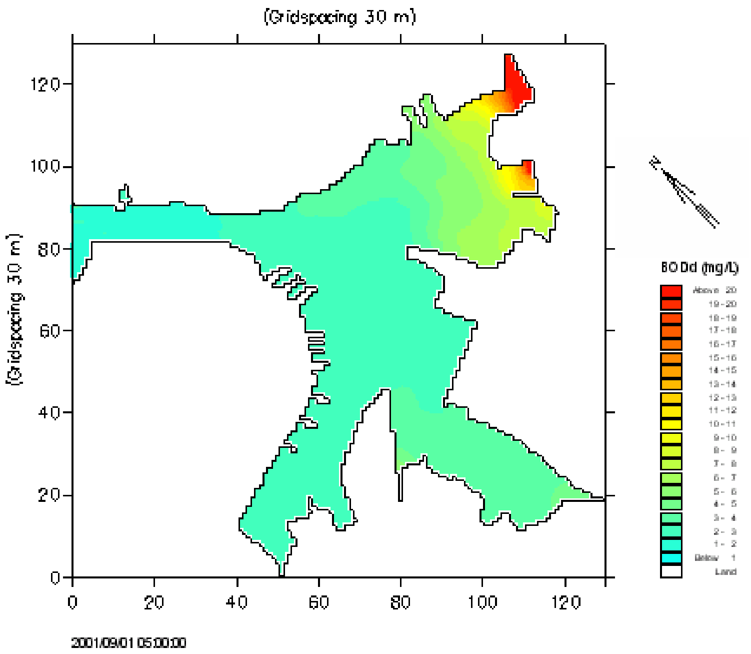


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure A7.17 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case4.



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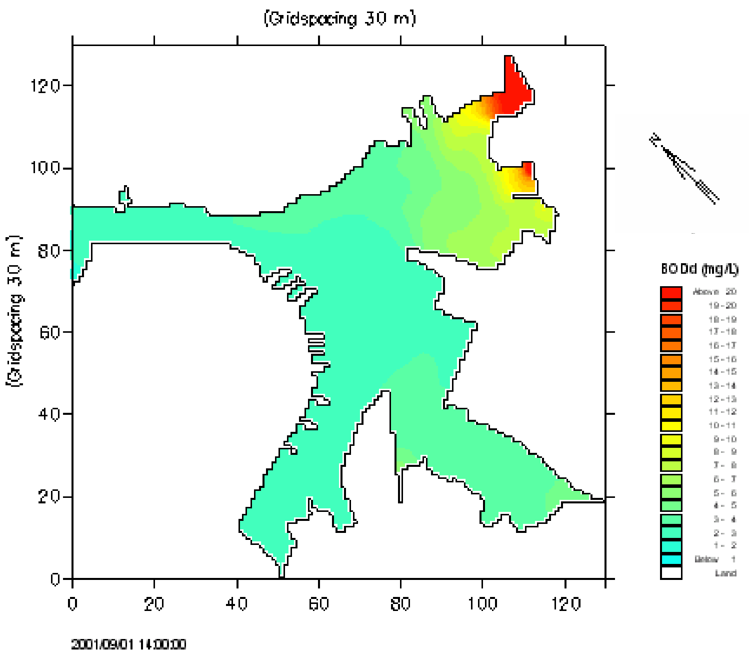
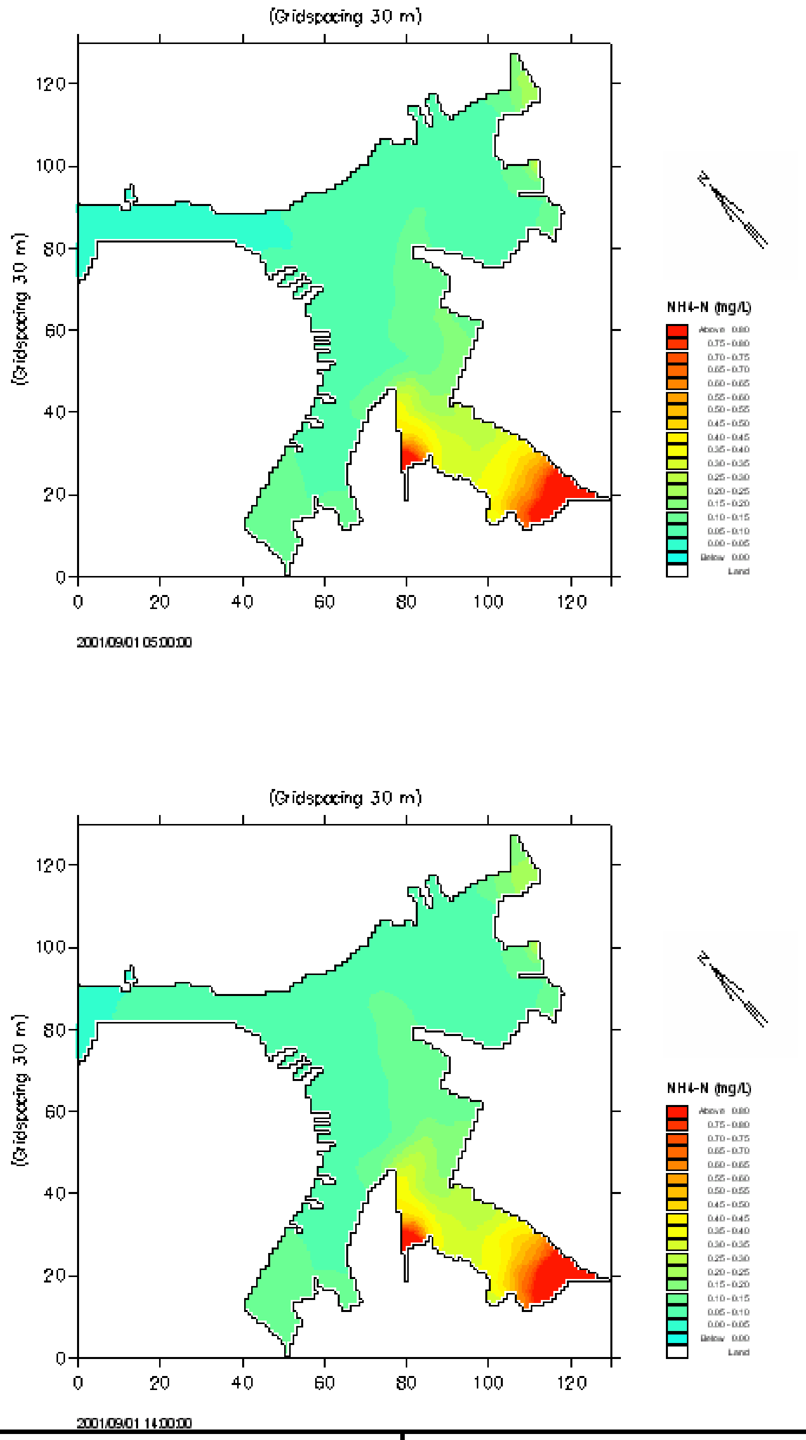


low tide

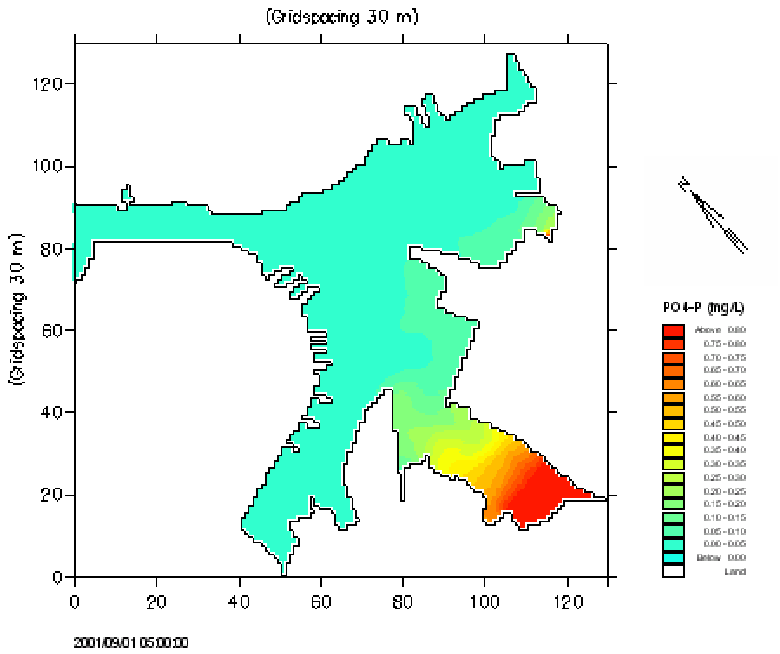
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.18 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case4.
JAPAN INTERNATIONAL COOPERATION AGENCY	



high tide

low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.19 Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case4.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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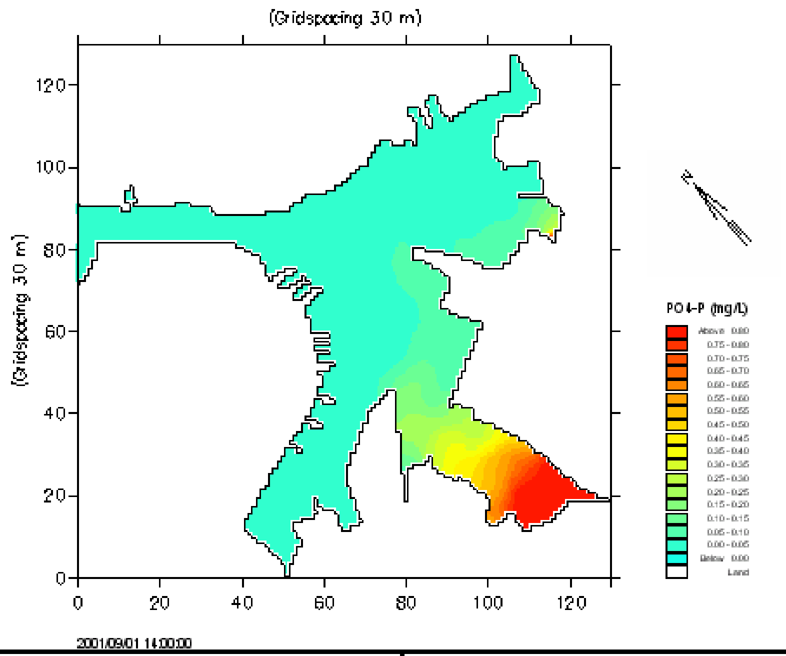
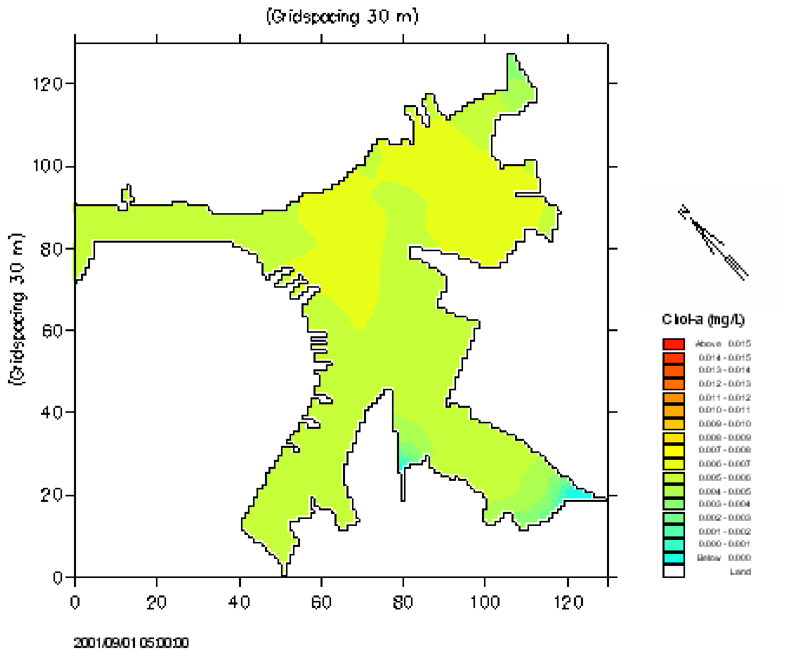
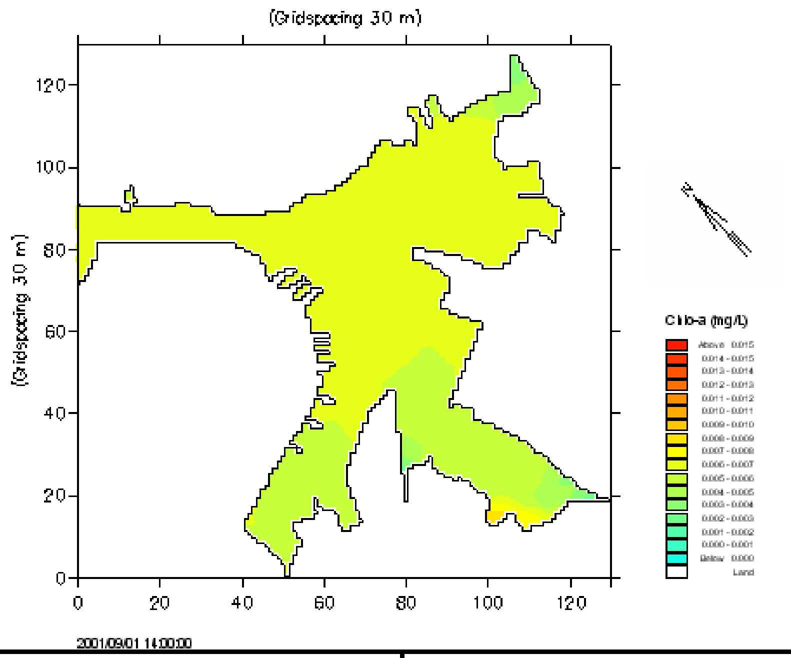


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.20 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case4.
JAPAN INTERNATIONAL COOPERATION AGENCY	



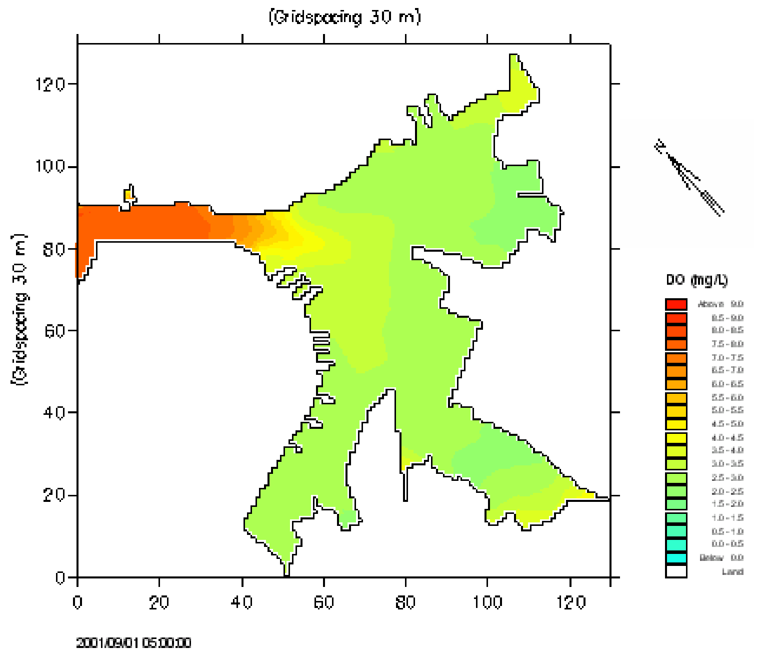
high tide



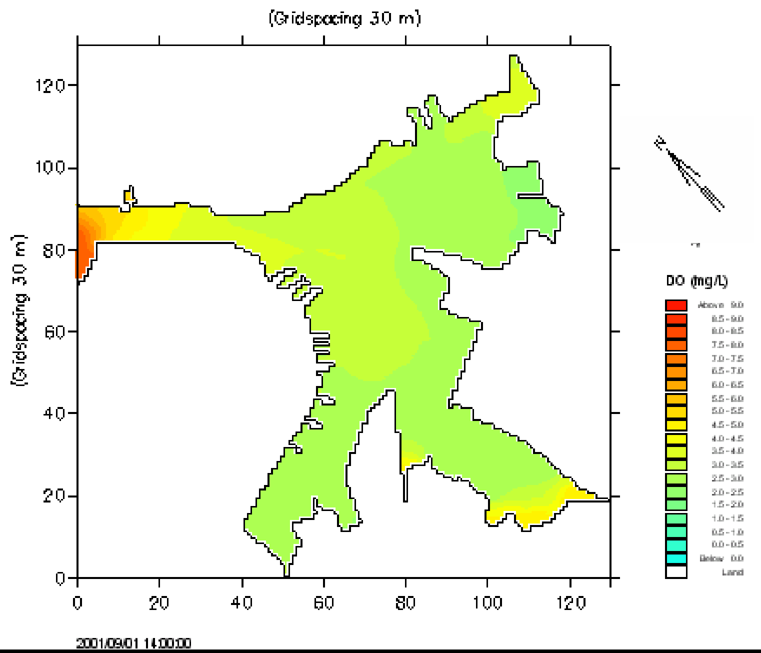
low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY JAPAN INTERNATIONAL COOPERATION AGENCY	Figure A7.21 Concentration Distribution of Chlorophyll-a (Chl-al) in Havana Bay (Surface Layer) for the Case4.

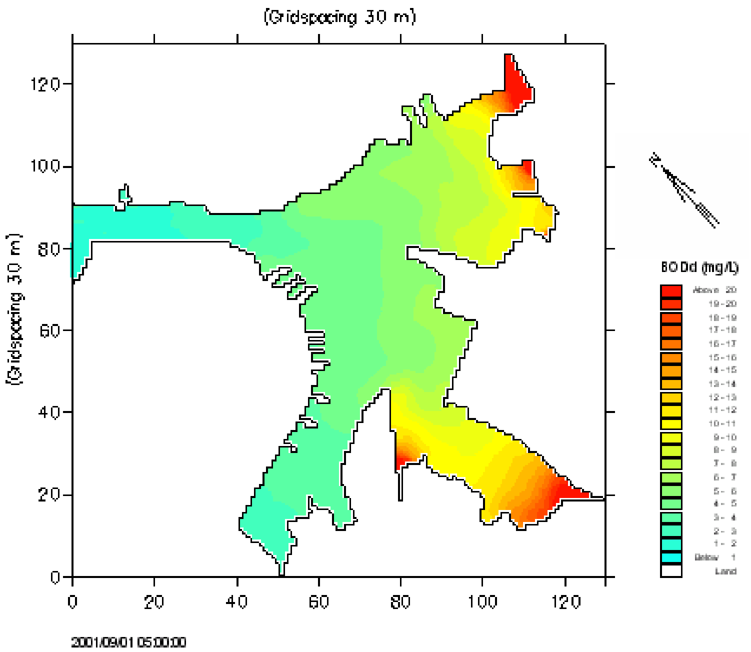
high tide



low tide



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.22 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case5.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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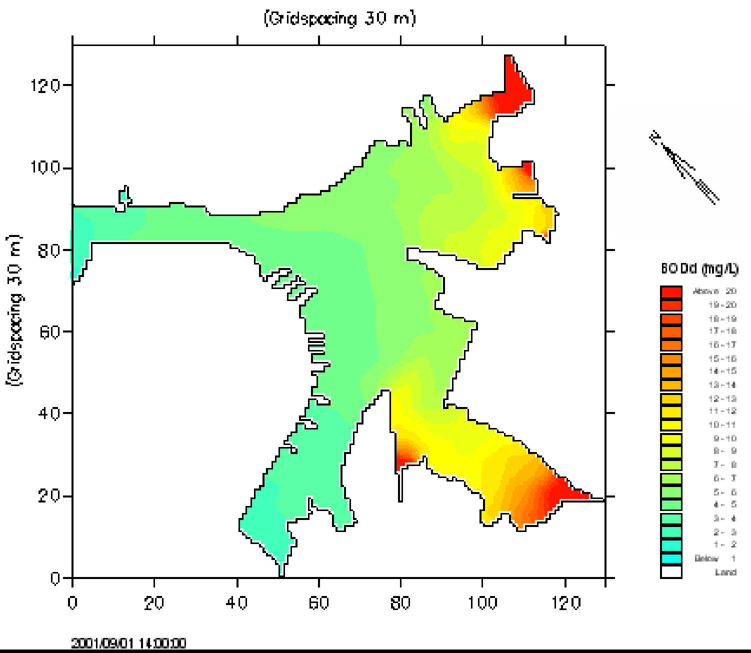
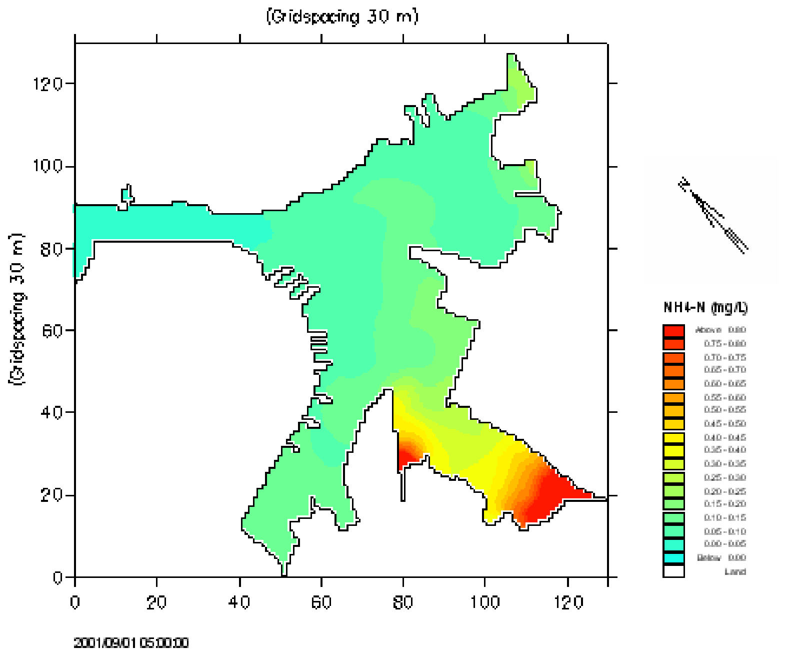


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.23 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case5.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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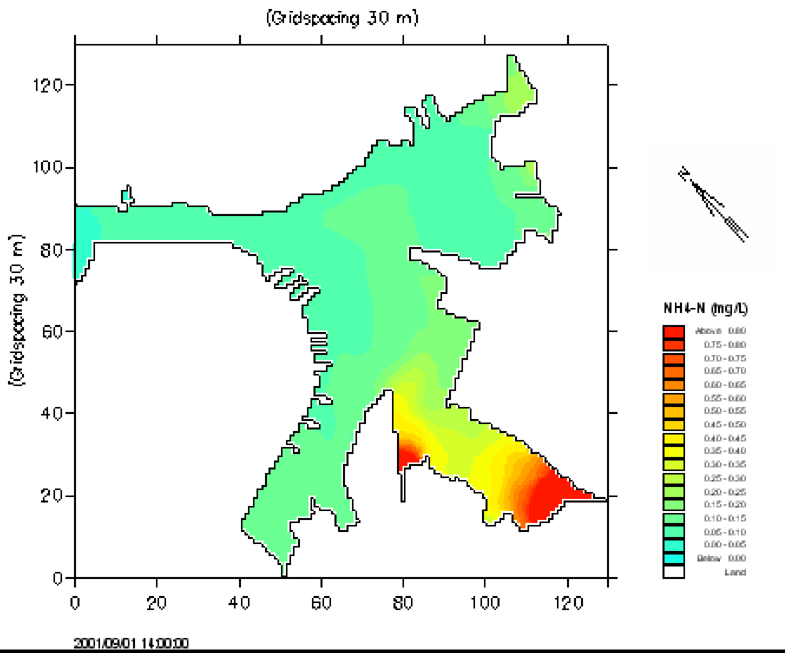
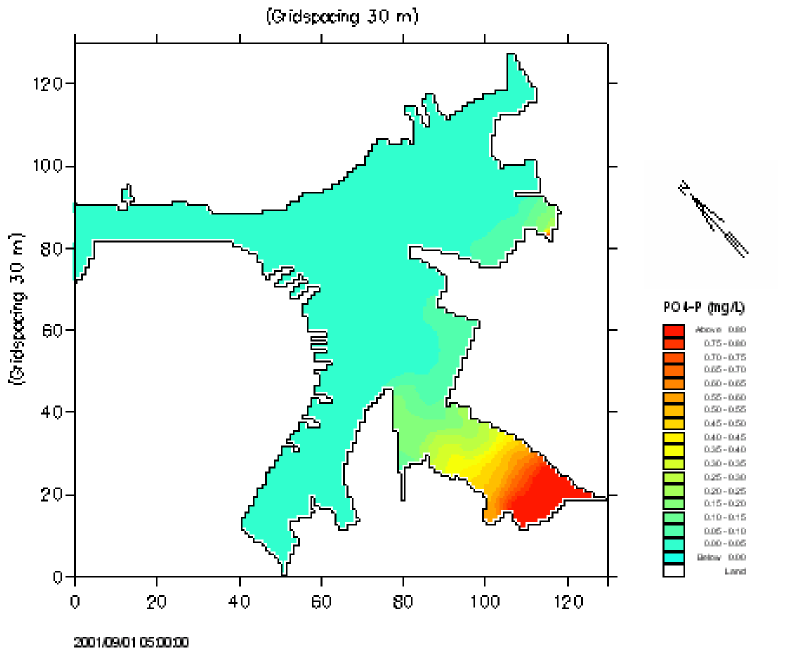
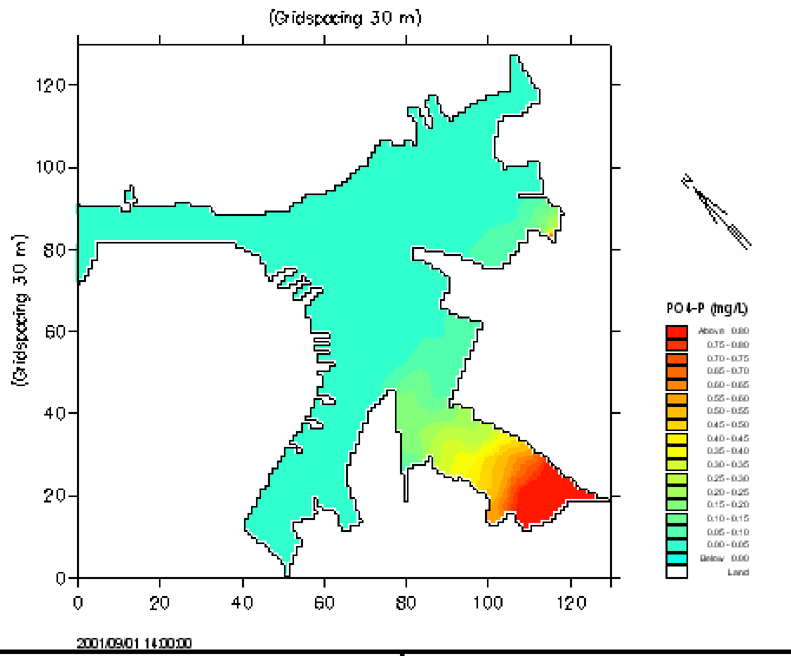


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.24 Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case5.
JAPAN INTERNATIONAL COOPERATION AGENCY	

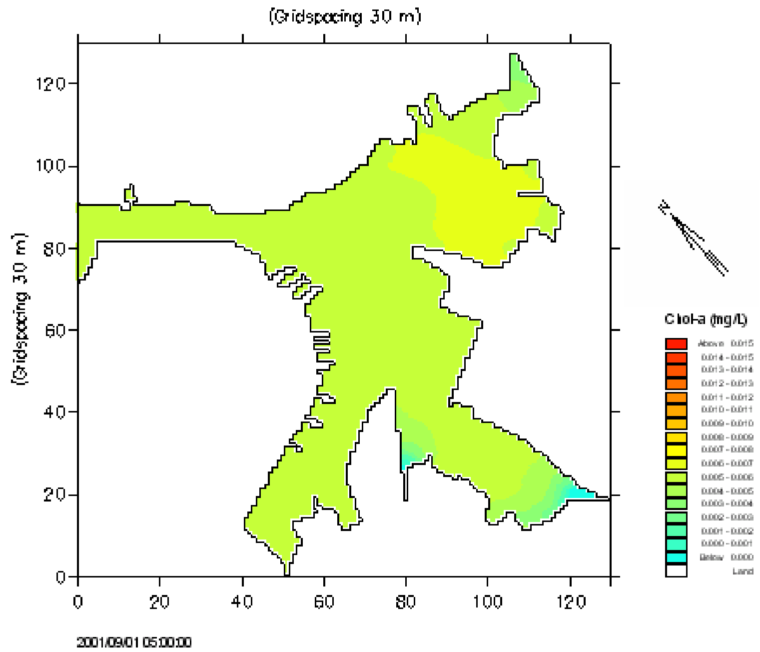


high tide

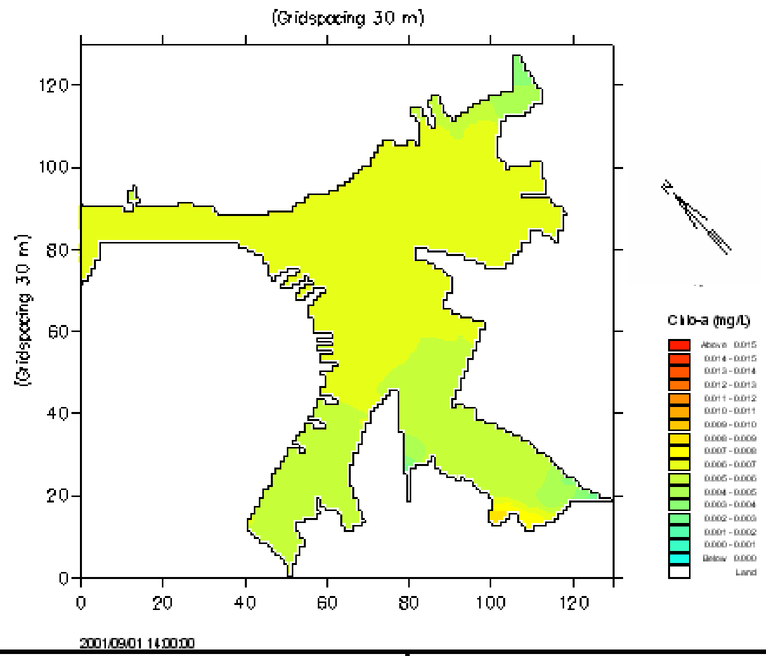


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.25 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case5.
JAPAN INTERNATIONAL COOPERATION AGENCY	

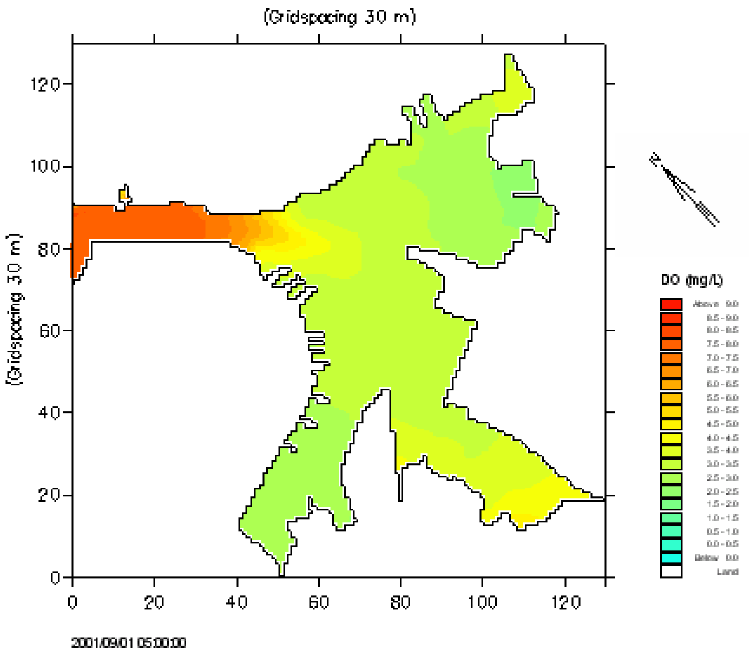


high tide

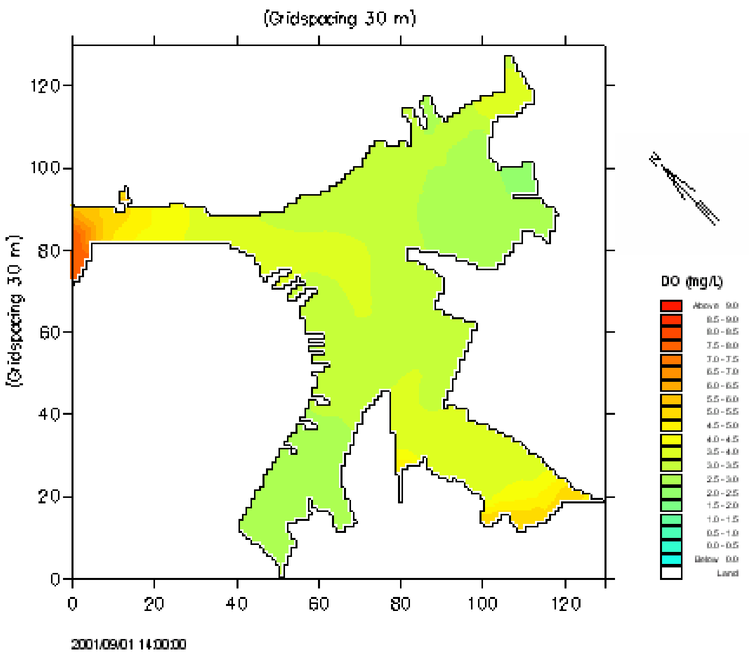


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.26 Concentration Distribution of Chlorophyll-a (Chl-al) in Havana Bay (Surface Layer) for the Case5.
JAPAN INTERNATIONAL COOPERATION AGENCY	

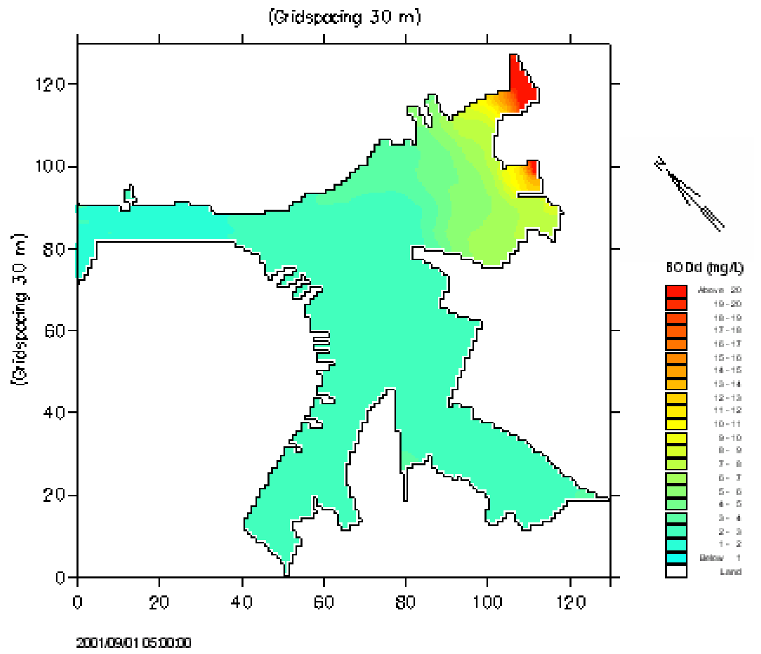


high tide

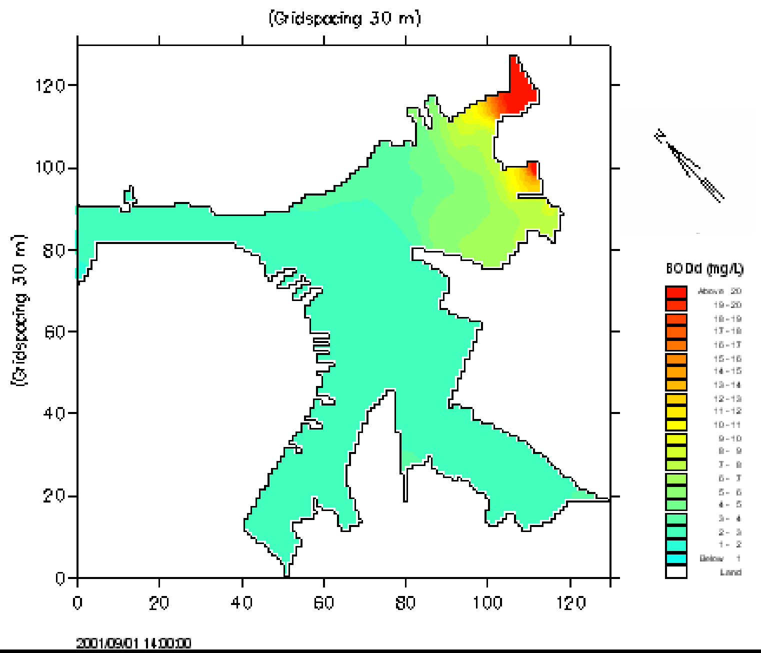


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.27 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case6.
JAPAN INTERNATIONAL COOPERATION AGENCY	

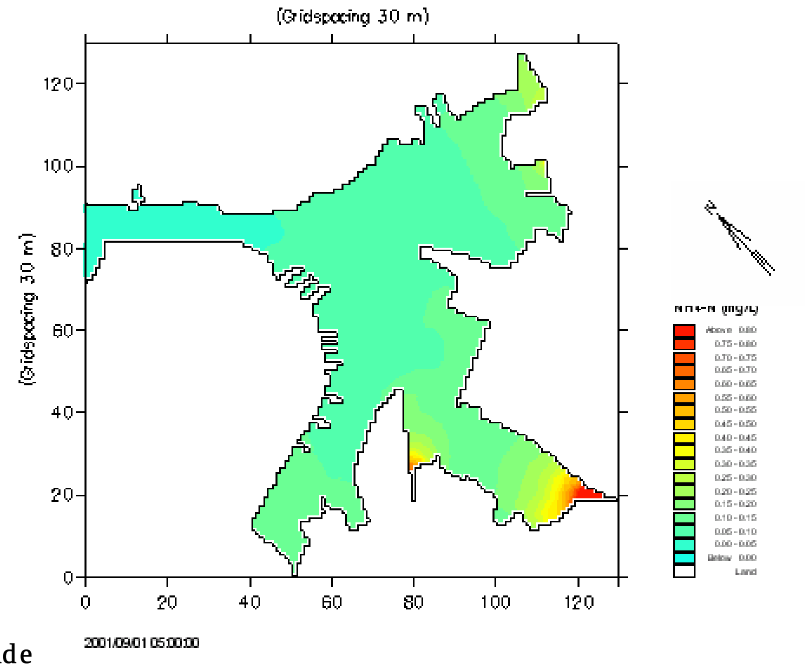


high tide

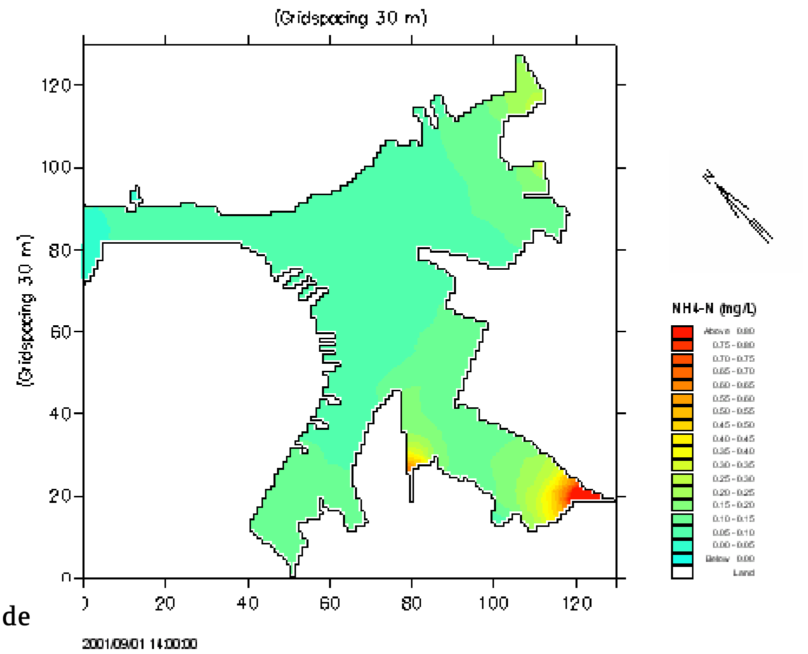


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.28 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case6.
JAPAN INTERNATIONAL COOPERATION AGENCY	



high tide

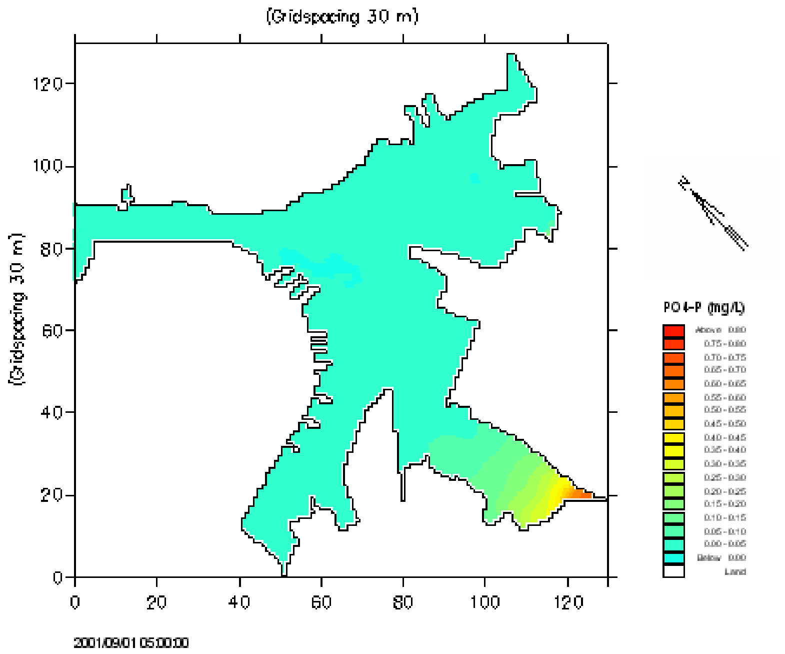


low tide

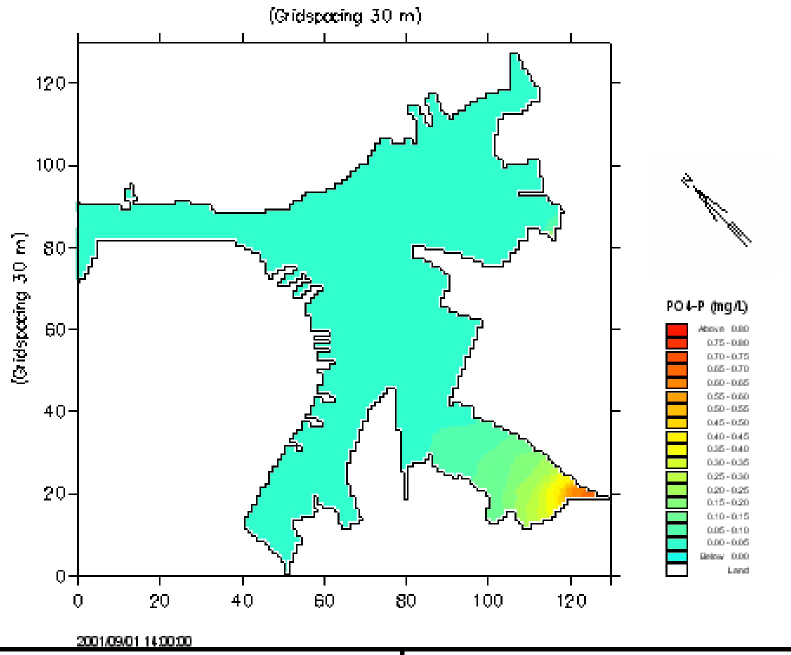
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure A7.29
Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case6.



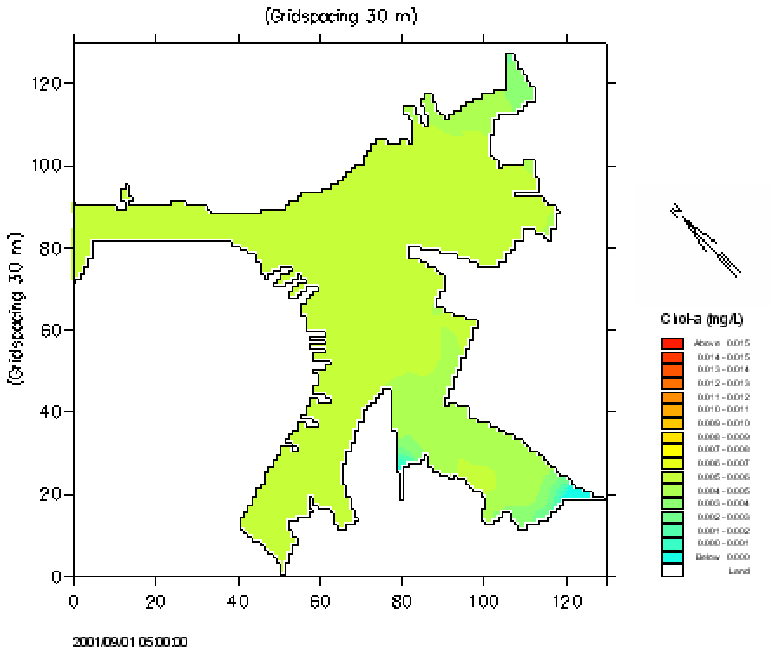
high tide



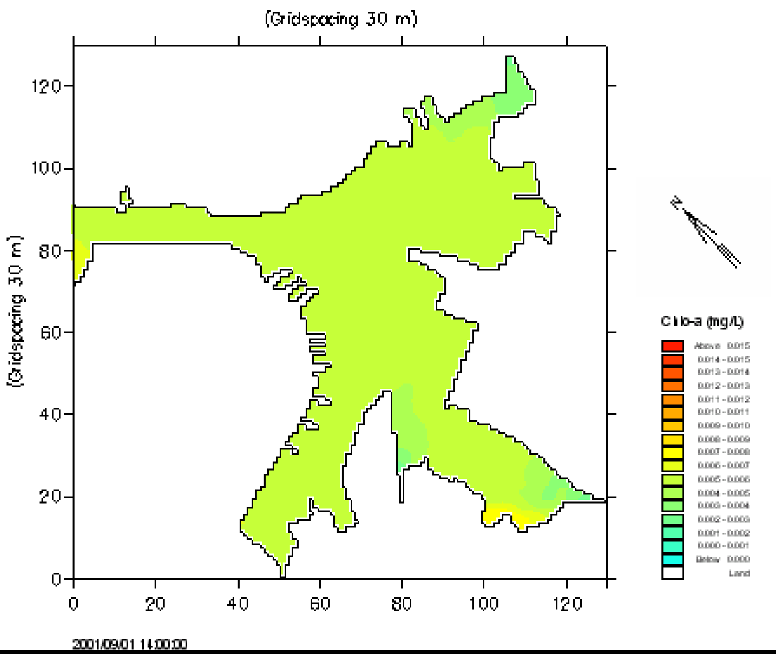
low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.30 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case6.
JAPAN INTERNATIONAL COOPERATION AGENCY	

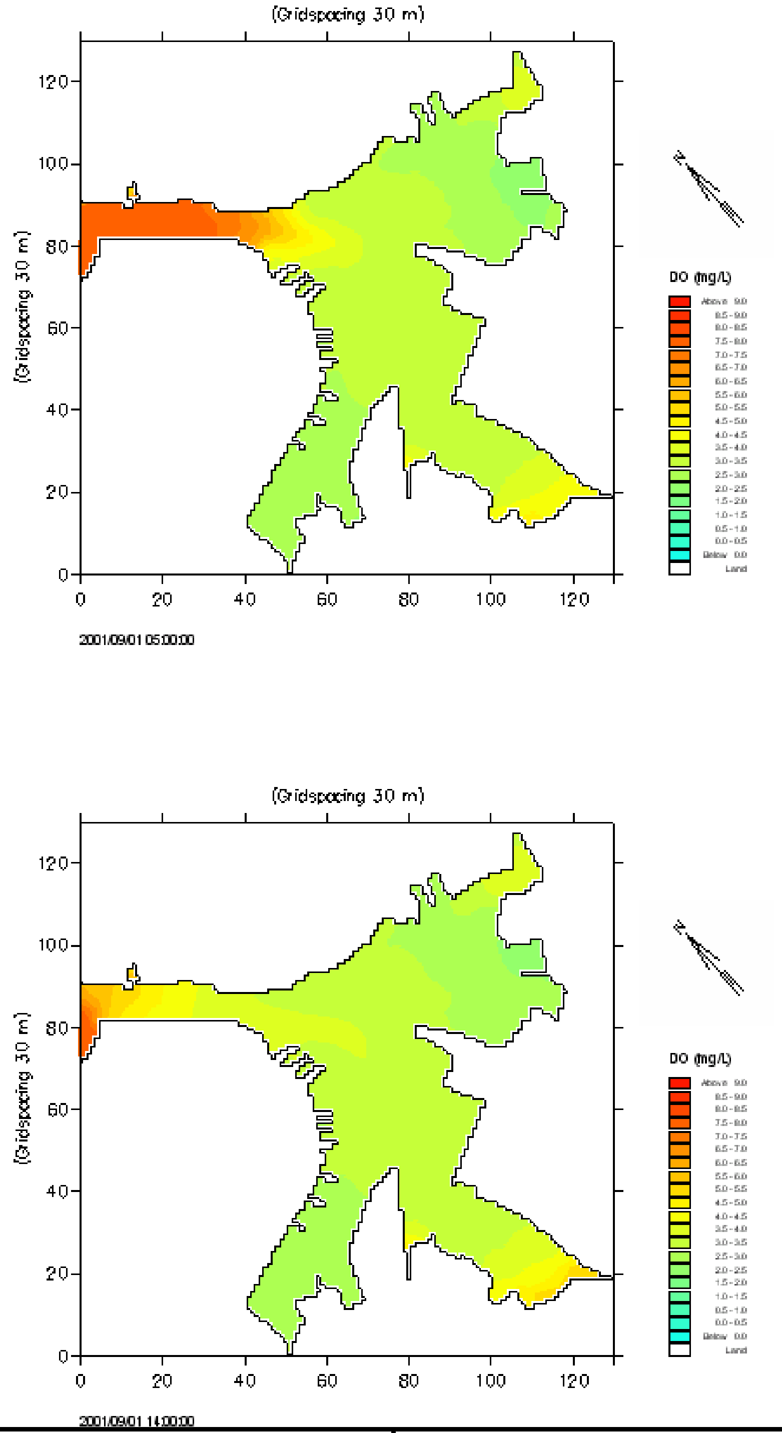
high tide



low tide



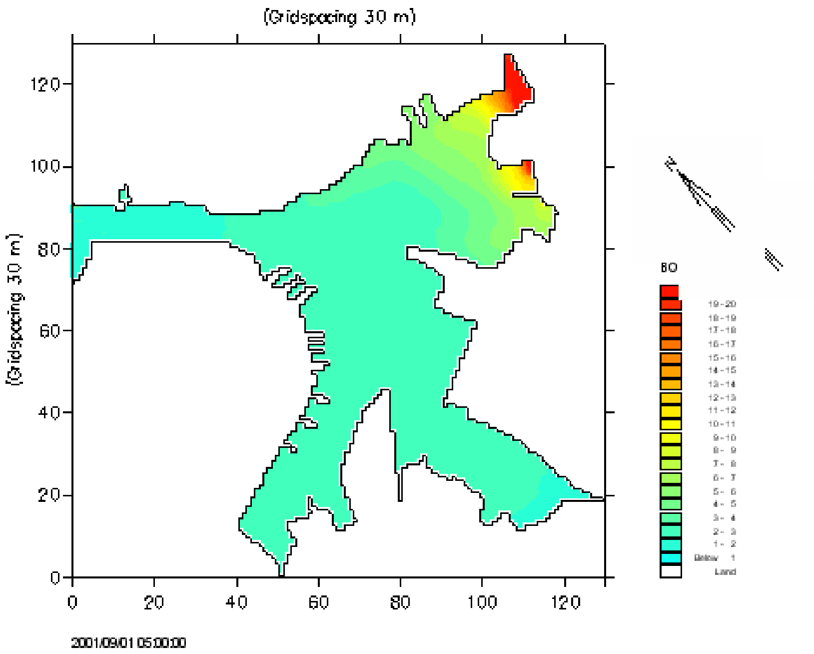
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.31 Concentration Distribution of Chlorophyll-a (Chl-al) in Havana Bay (Surface Layer) for the Case6.
JAPAN INTERNATIONAL COOPERATION AGENCY	



high tide

low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.32 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case7.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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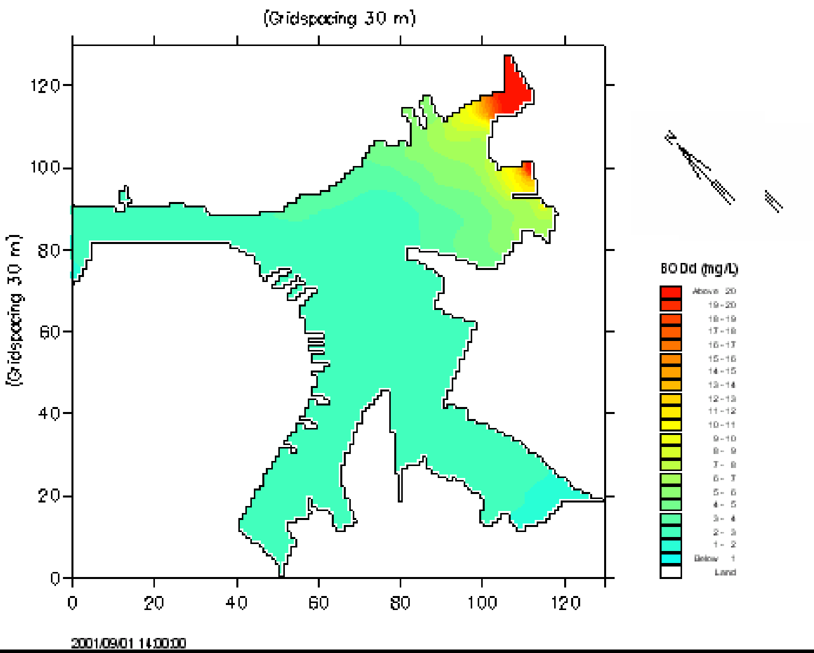
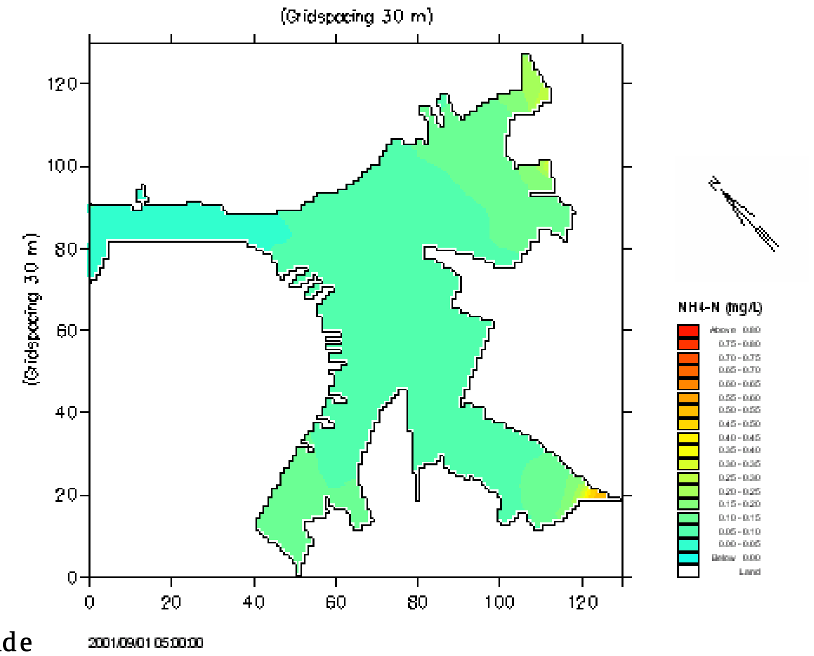
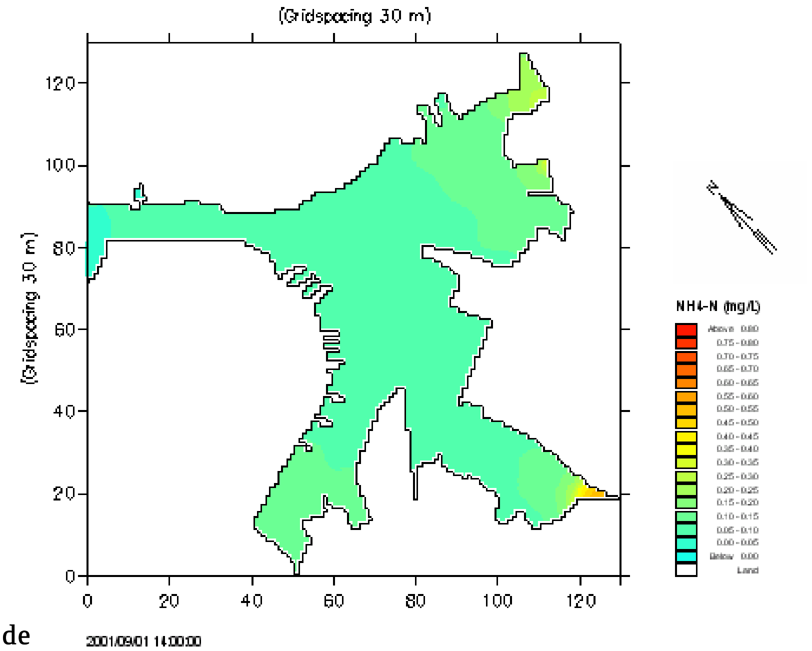


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.33 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case7.
JAPAN INTERNATIONAL COOPERATION AGENCY	

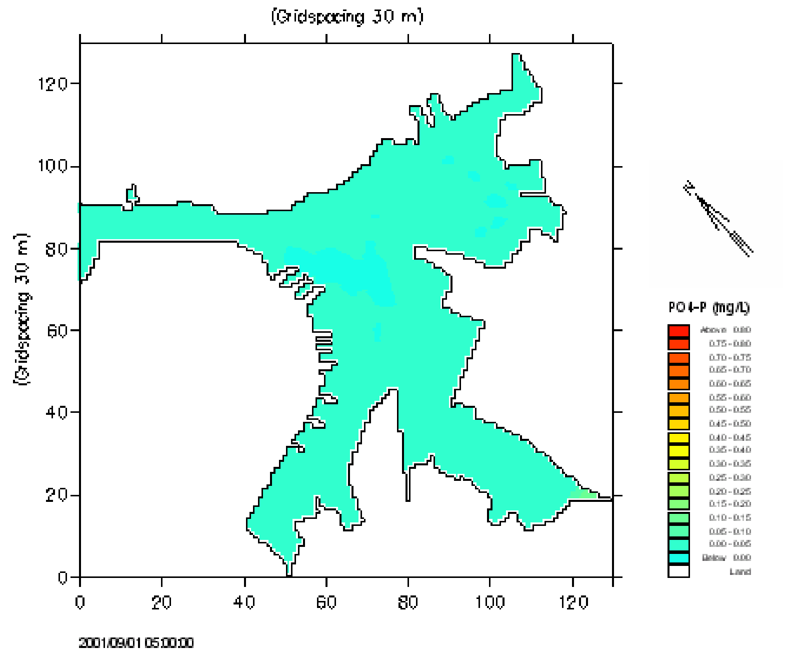


high tide

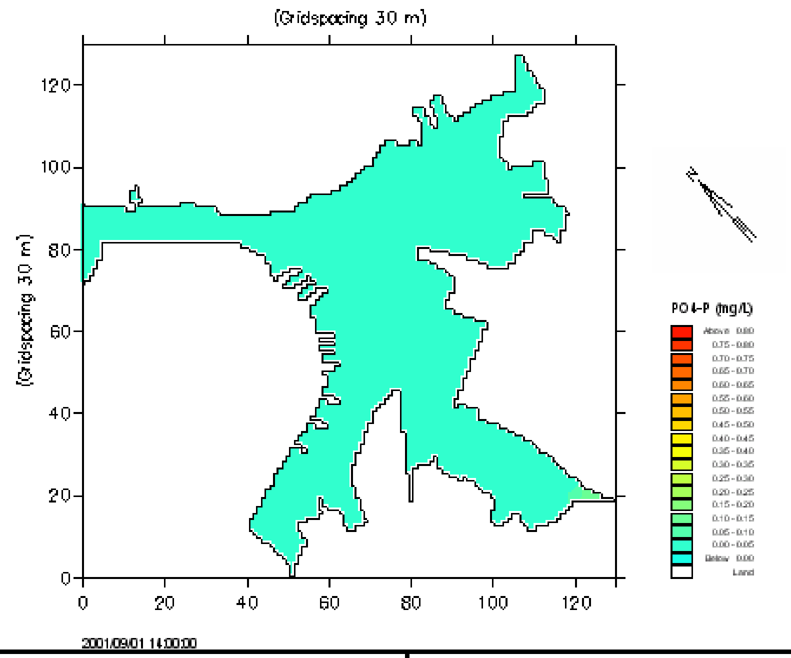


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.34 Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case7.
JAPAN INTERNATIONAL COOPERATION AGENCY	

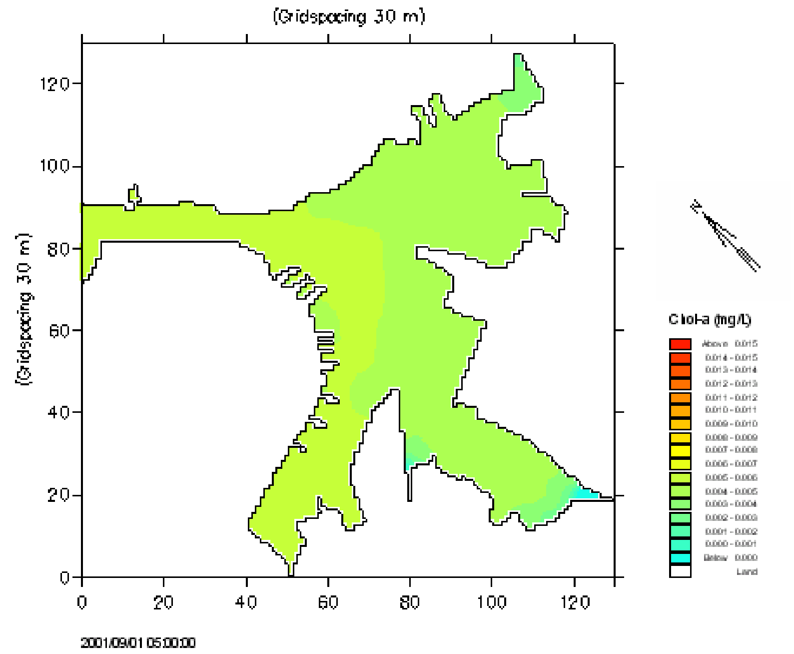


high tide

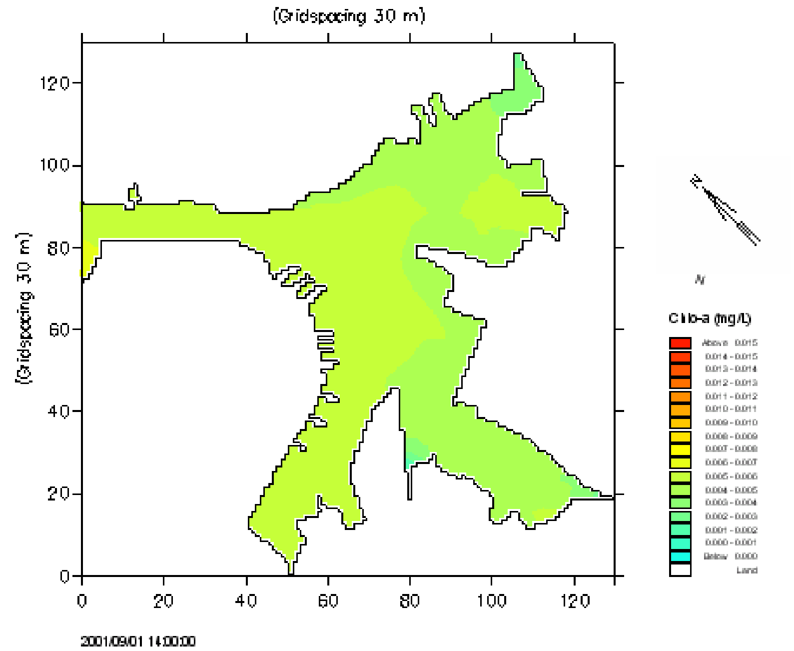


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.35 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case7.
JAPAN INTERNATIONAL COOPERATION AGENCY	

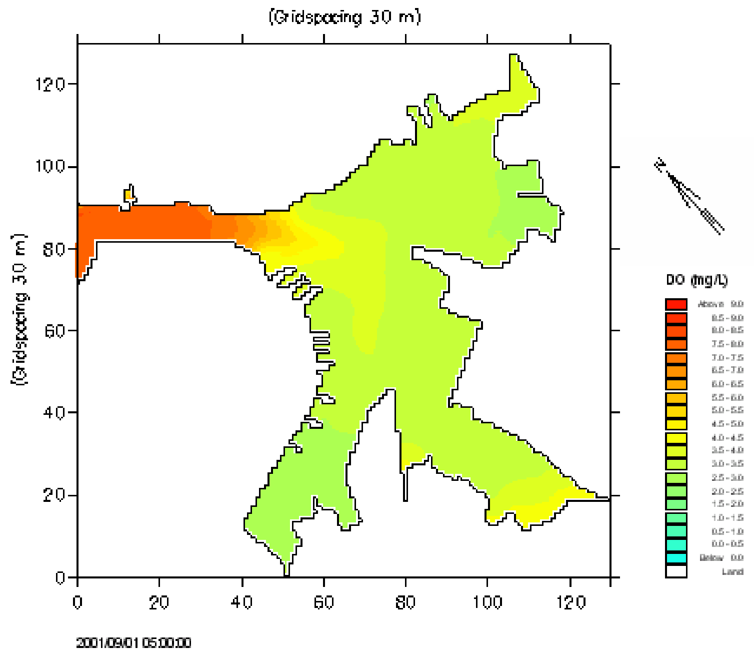


high tide

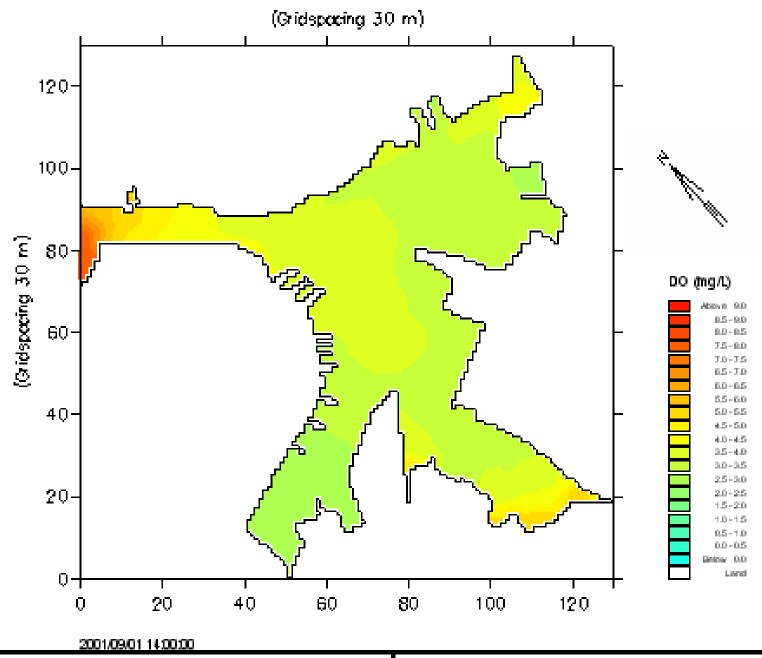


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.36 Concentration Distribution of Chlorophyll-a (Chl-a) in Havana Bay (Surface Layer) for the Case7.
JAPAN INTERNATIONAL COOPERATION AGENCY	

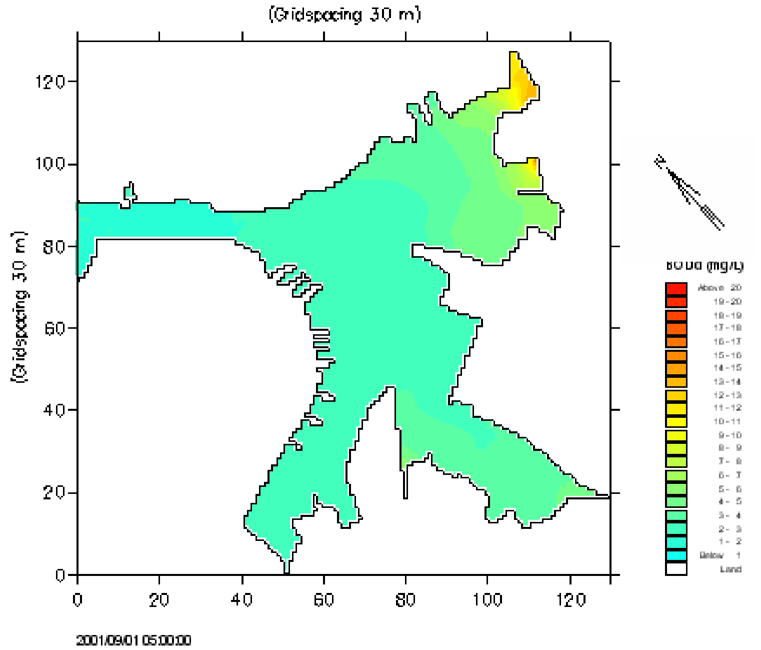


high tide

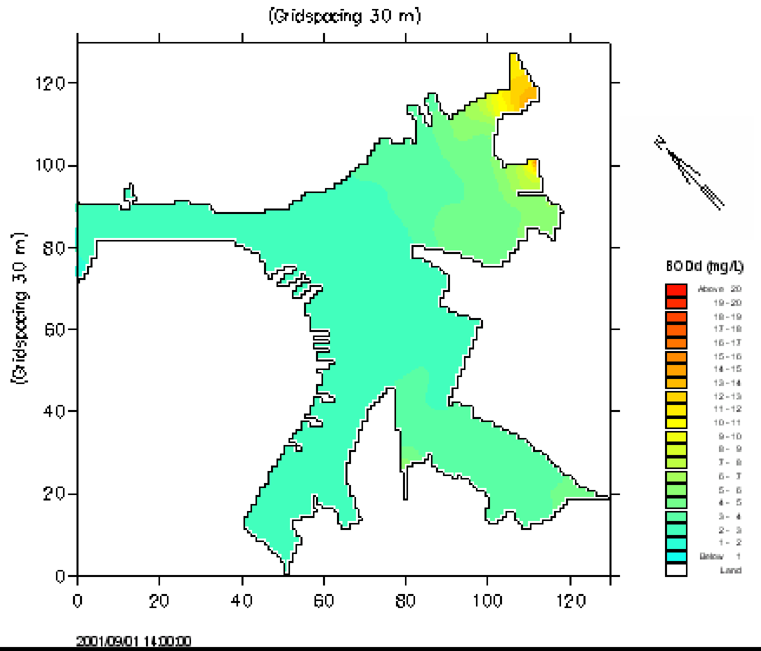


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.37 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case8.
JAPAN INTERNATIONAL COOPERATION AGENCY	

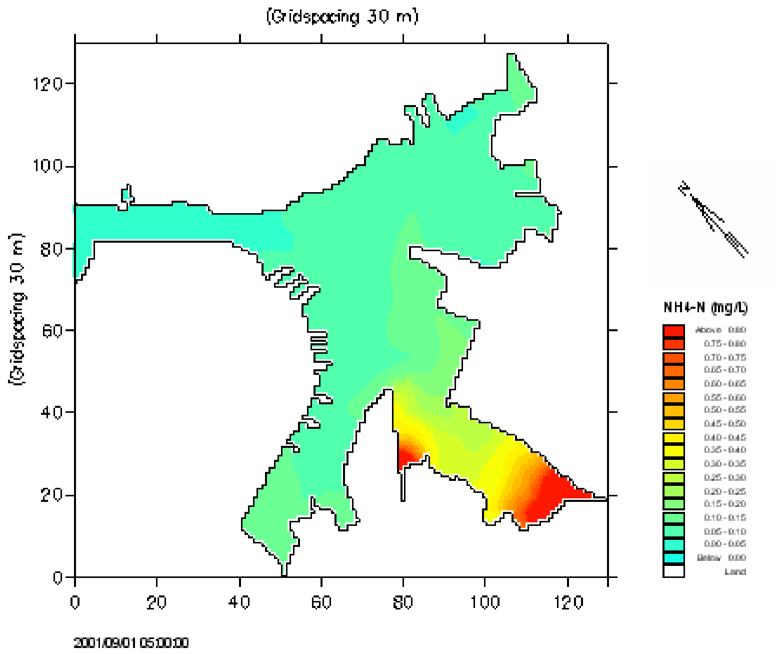


high tide

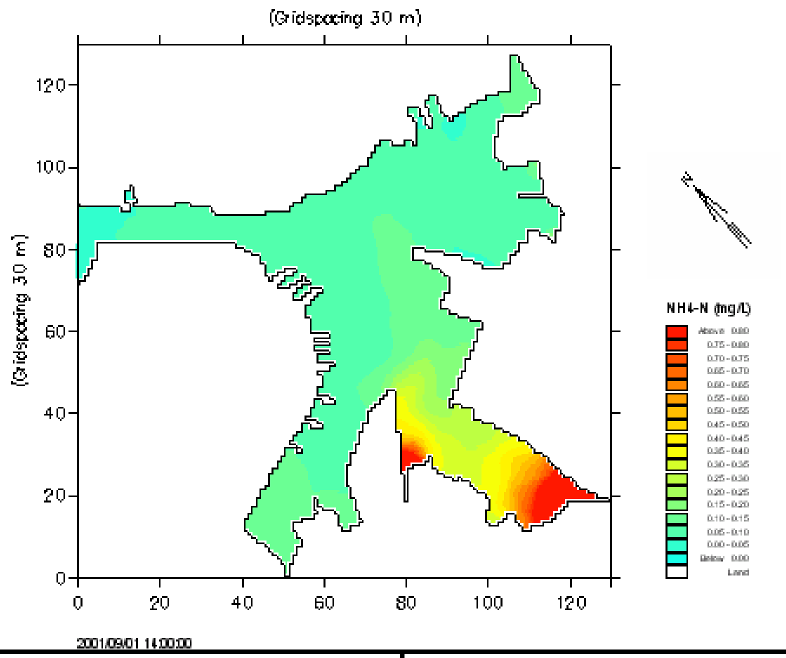


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.38 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case8.
JAPAN INTERNATIONAL COOPERATION AGENCY	

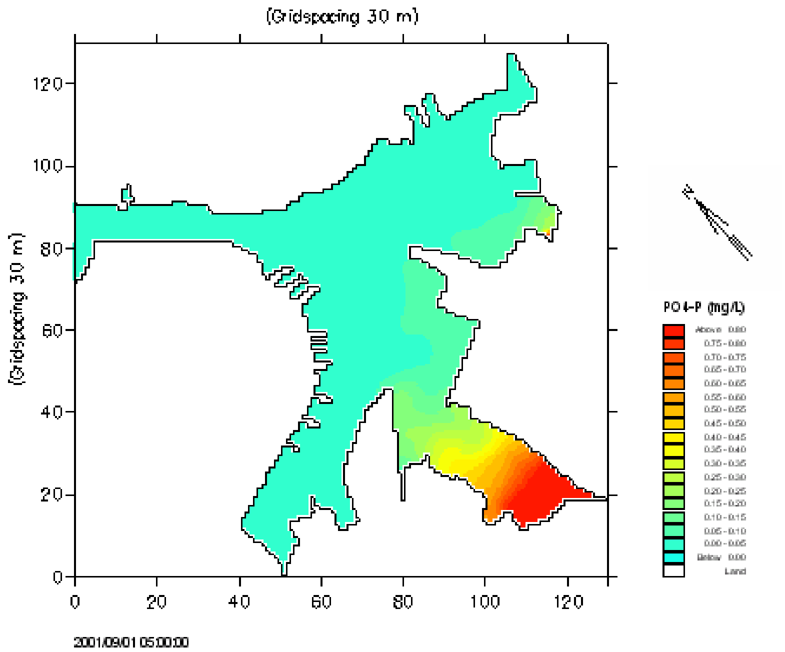


high tide



low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.39 Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case8.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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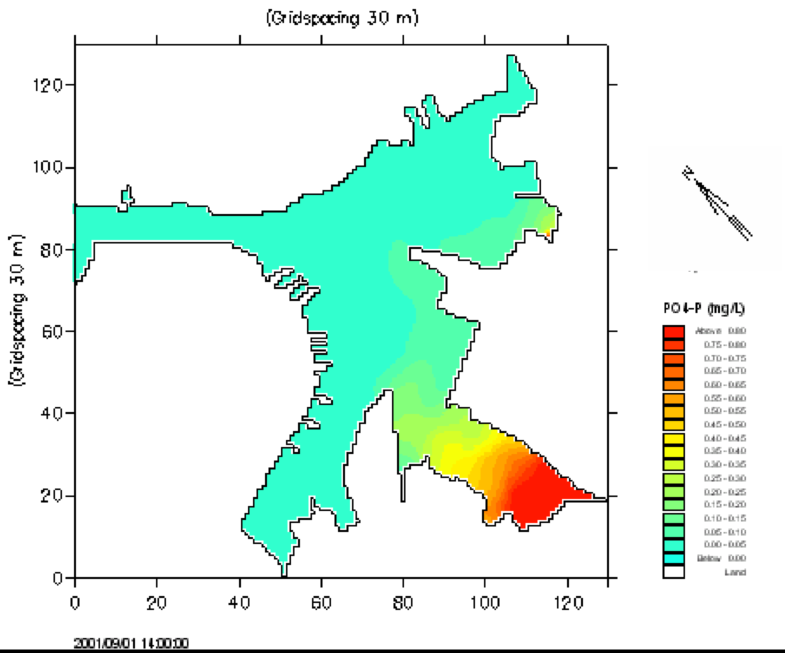
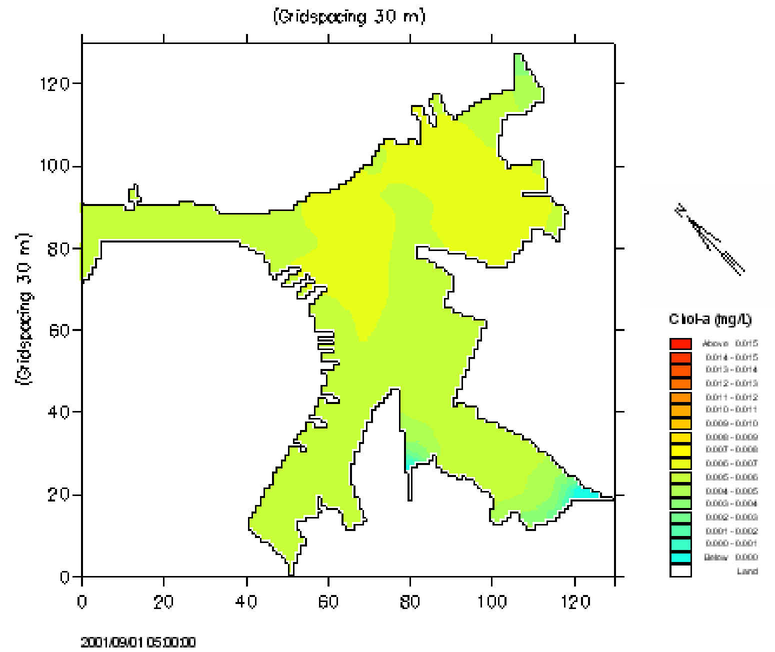
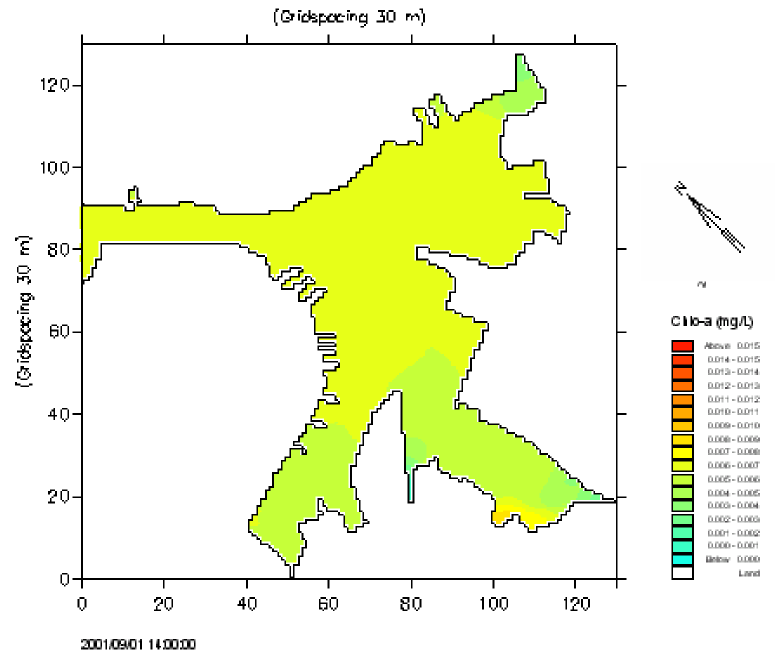


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.40 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case8.
JAPAN INTERNATIONAL COOPERATION AGENCY	



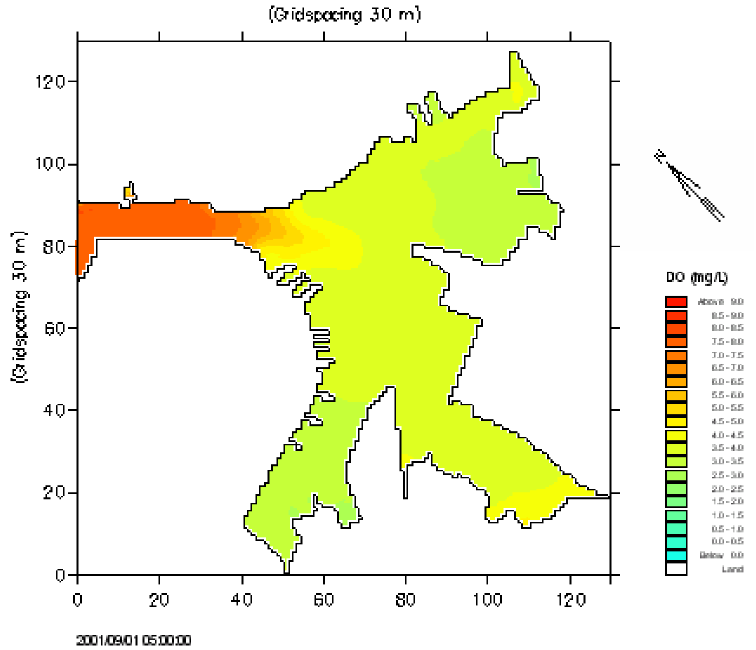
high tide



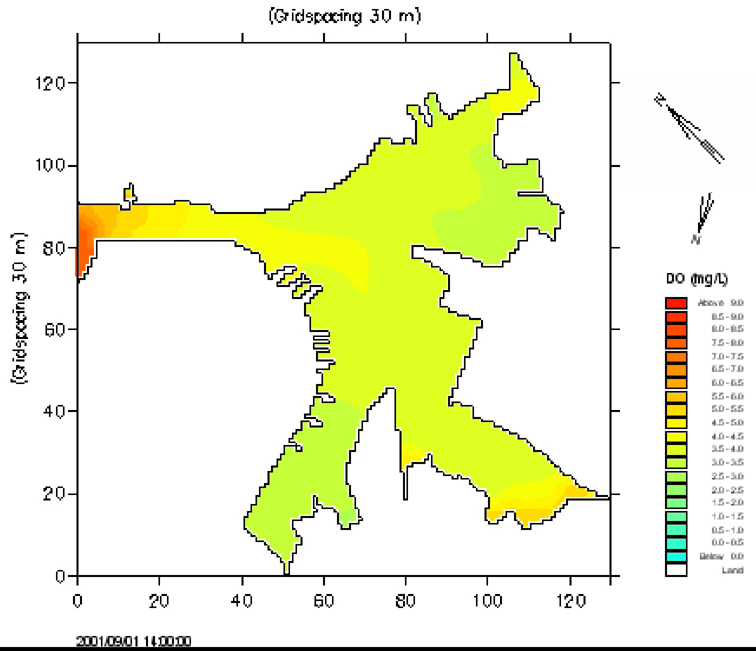
low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.41 Concentration Distribution of Chlorophyll-a (Chl-a) in Havana Bay (Surface Layer) for the Case8.
JAPAN INTERNATIONAL COOPERATION AGENCY	

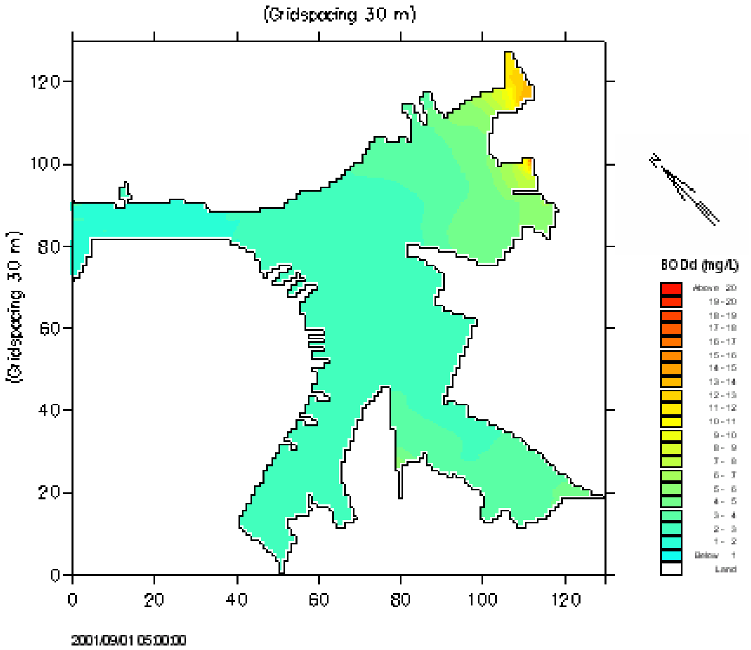
high tide



low tide



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.42 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case9.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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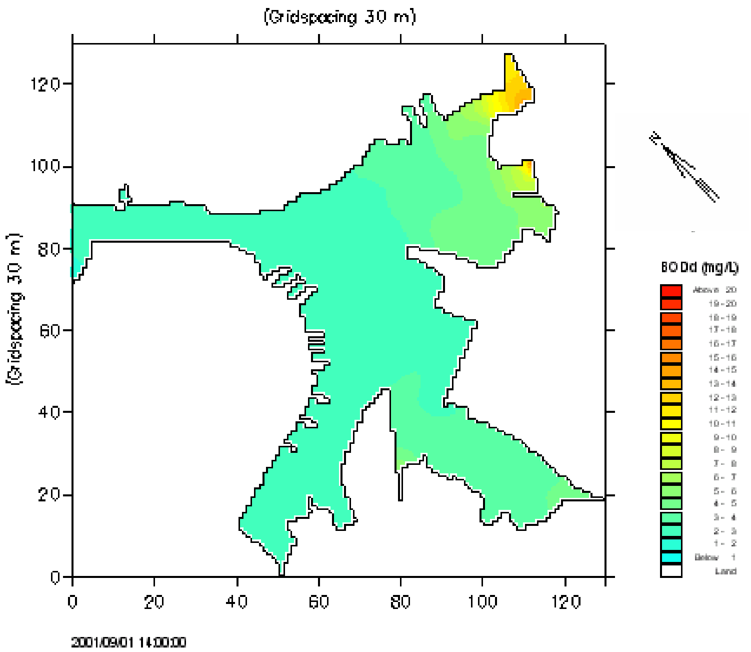
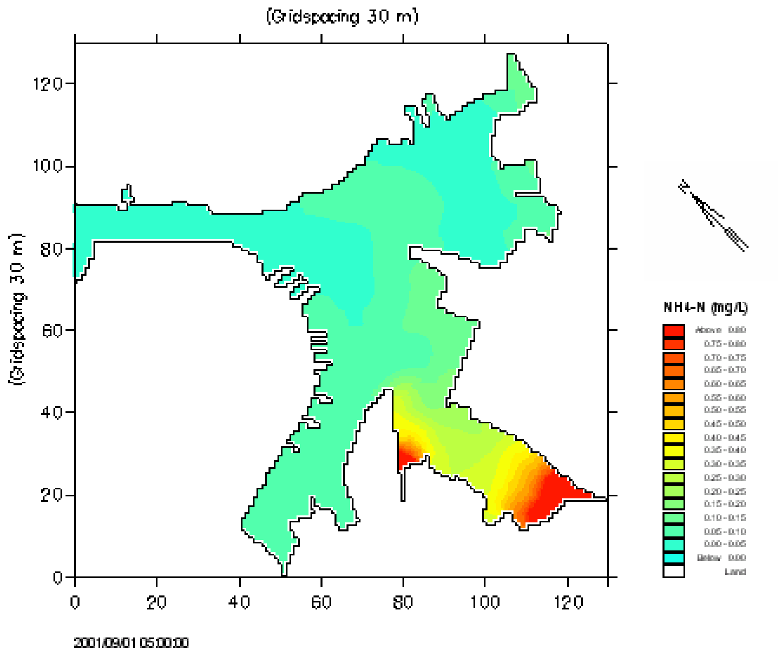
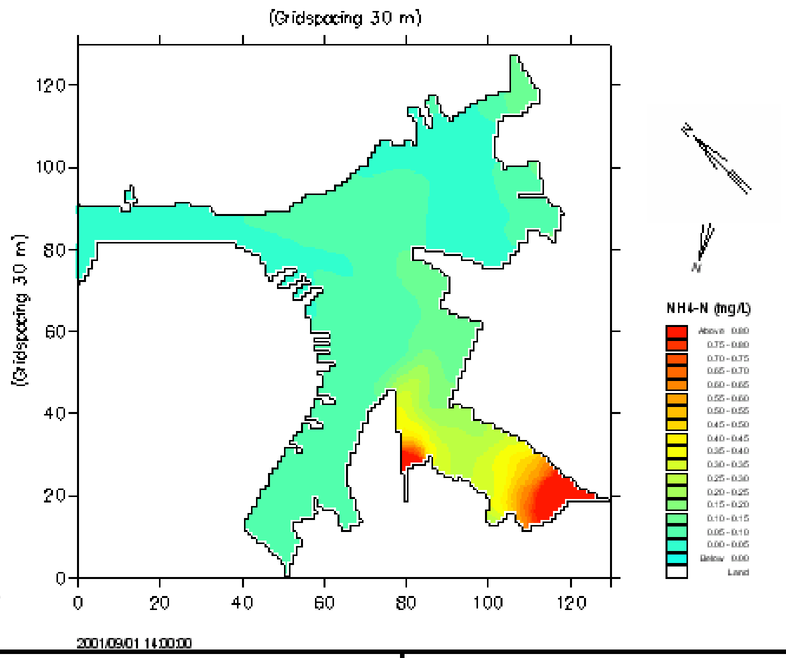


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.43 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case9.
JAPAN INTERNATIONAL COOPERATION AGENCY	



high tide

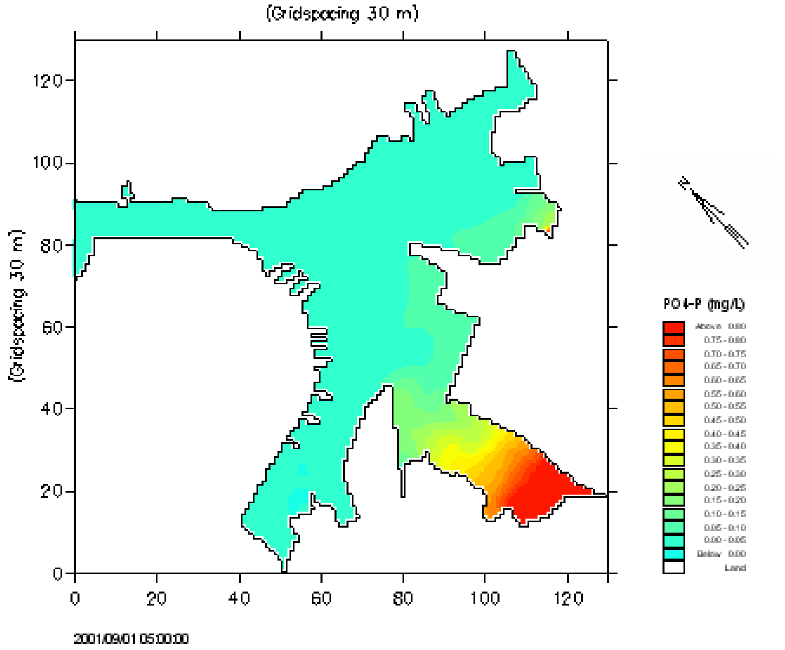


low tide

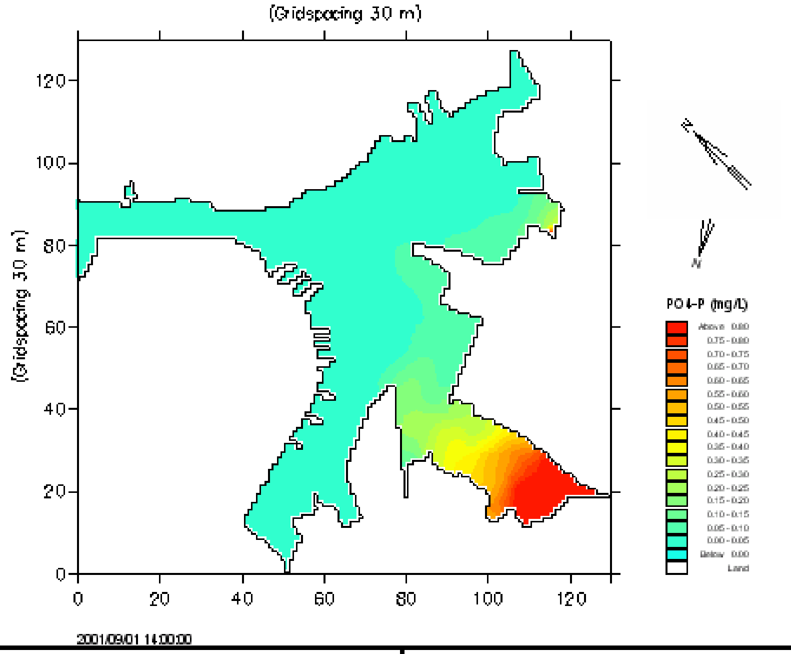
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure A7.44
Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case9.

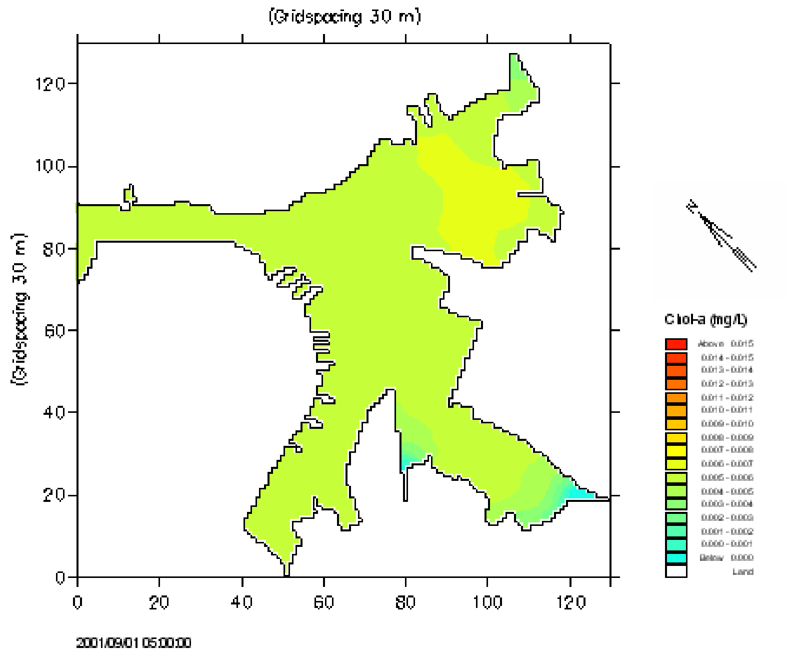


high tide



low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.45 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case9.
JAPAN INTERNATIONAL COOPERATION AGENCY	



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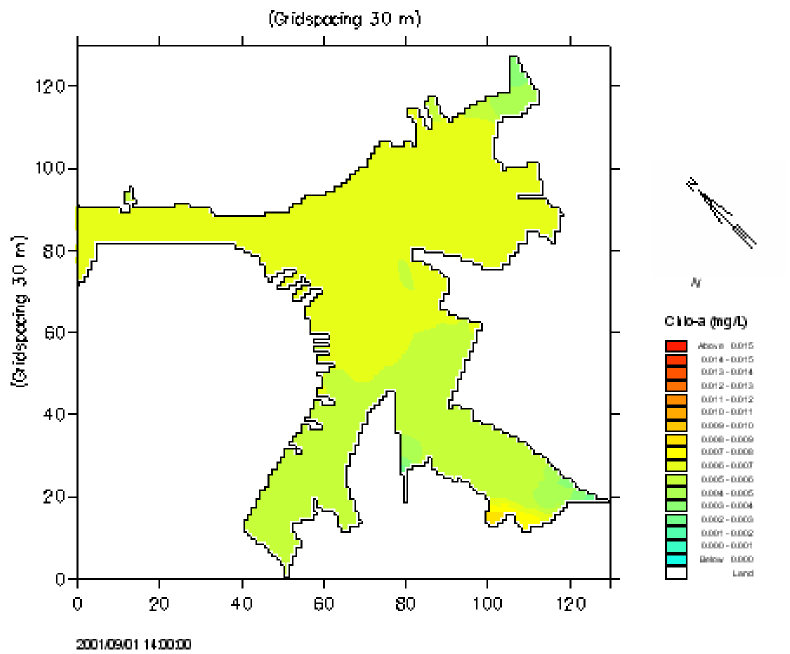
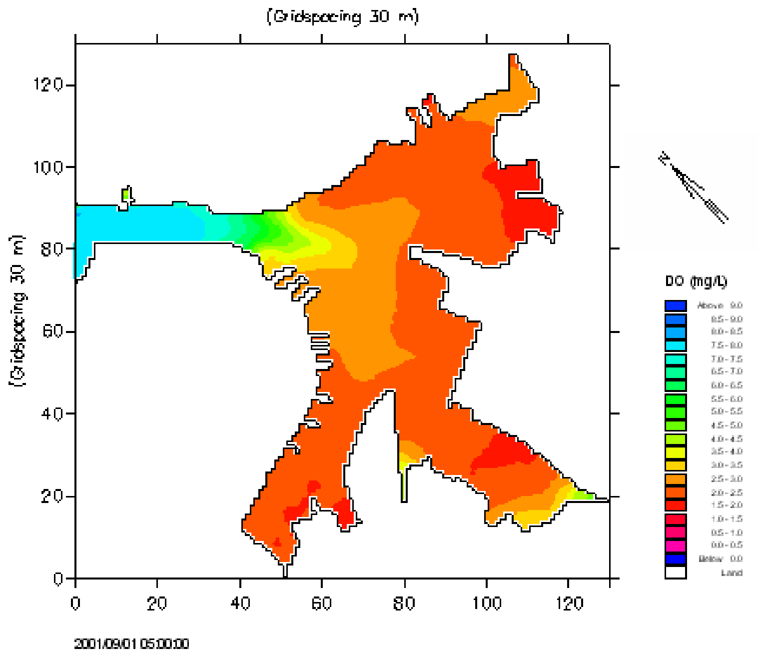
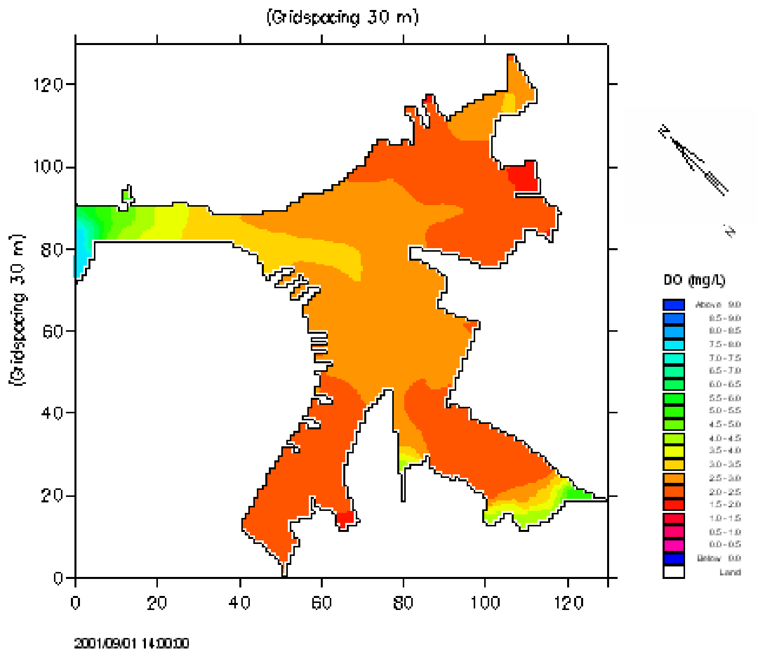


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure 7.46 Concentration Distribution of Chlorophyll-a (Chl-a) in Havana Bay (Surface Layer) for the Case9.
JAPAN INTERNATIONAL COOPERATION AGENCY	

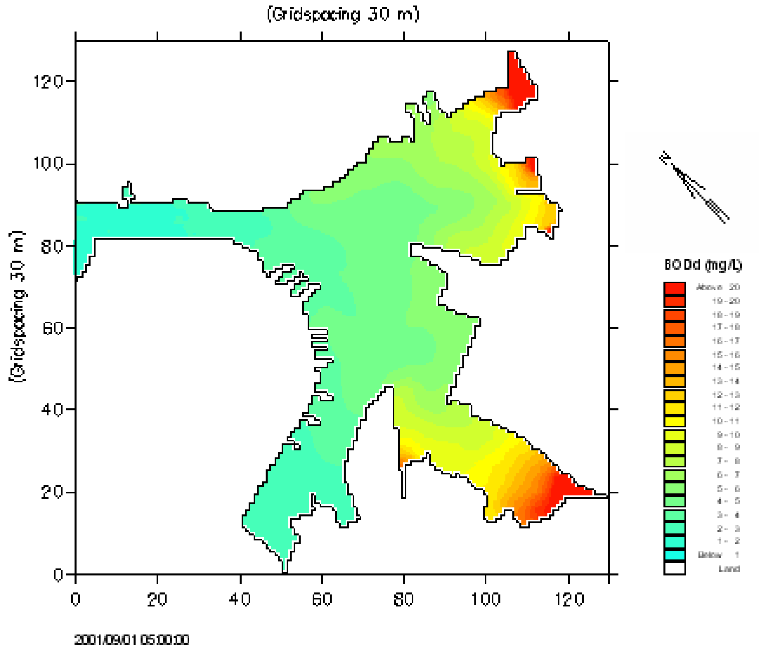


high tide

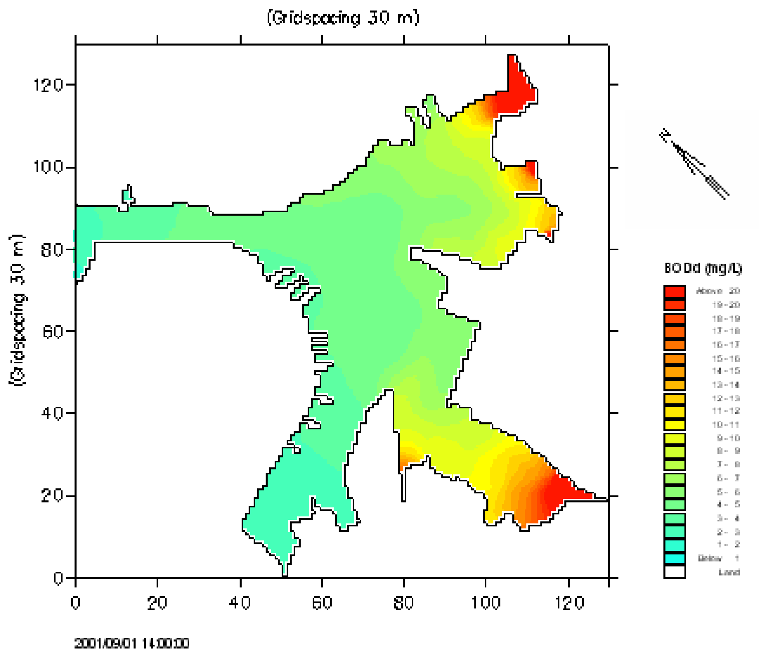


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.47 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case MP
JAPAN INTERNATIONAL COOPERATION AGENCY	

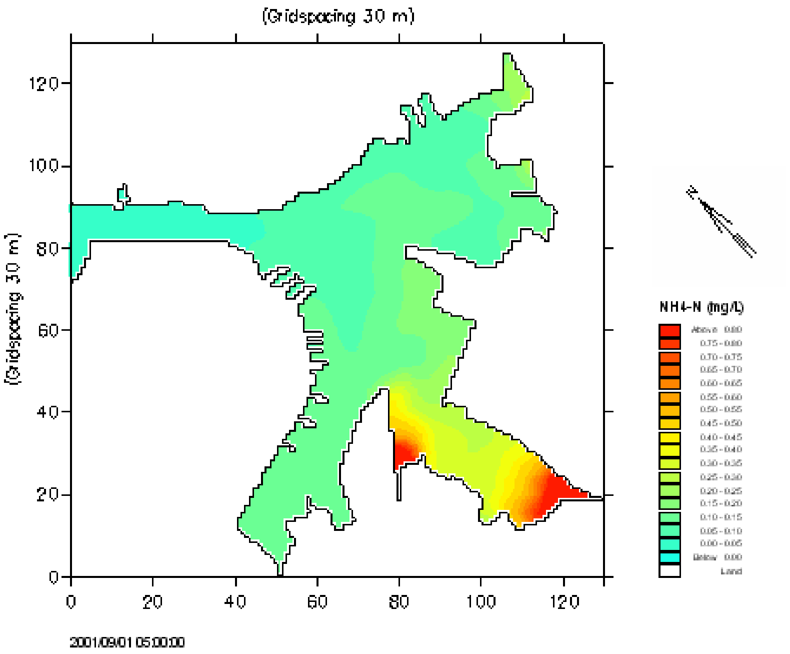


high tide

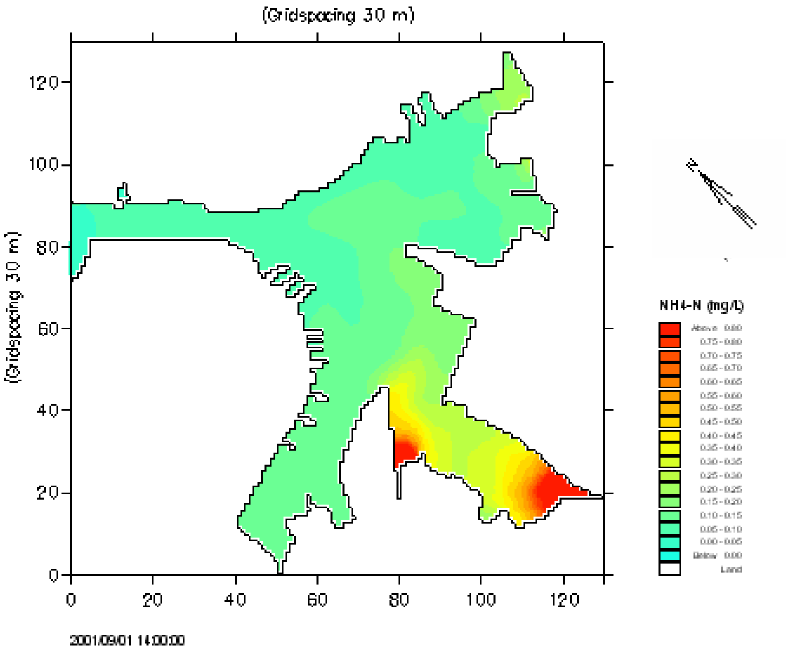


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.48 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case MP.
JAPAN INTERNATIONAL COOPERATION AGENCY	



high tide

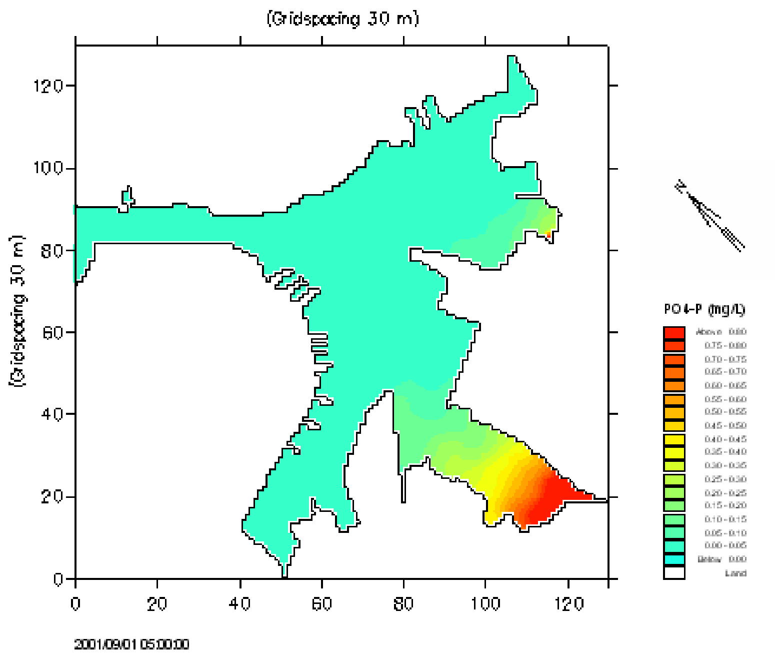


low tide

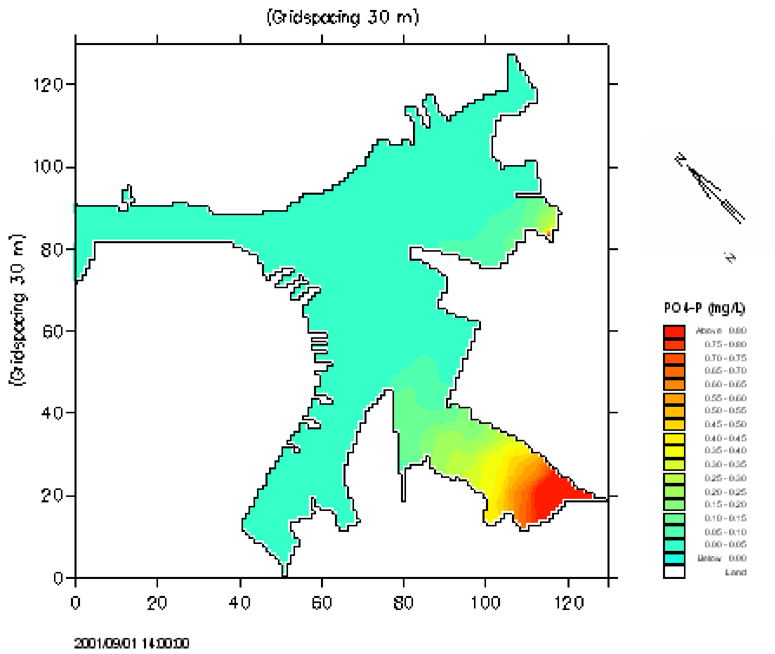
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure A7.49
Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case MP.

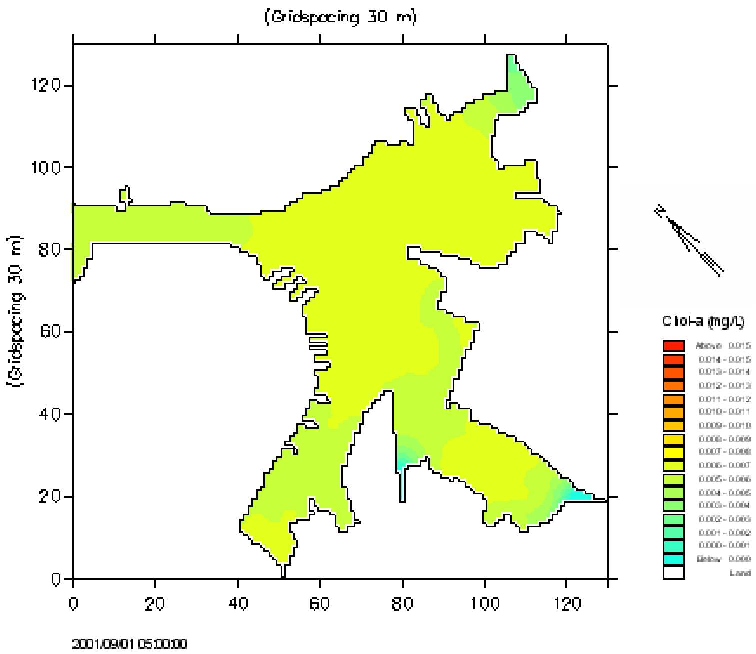


high tide

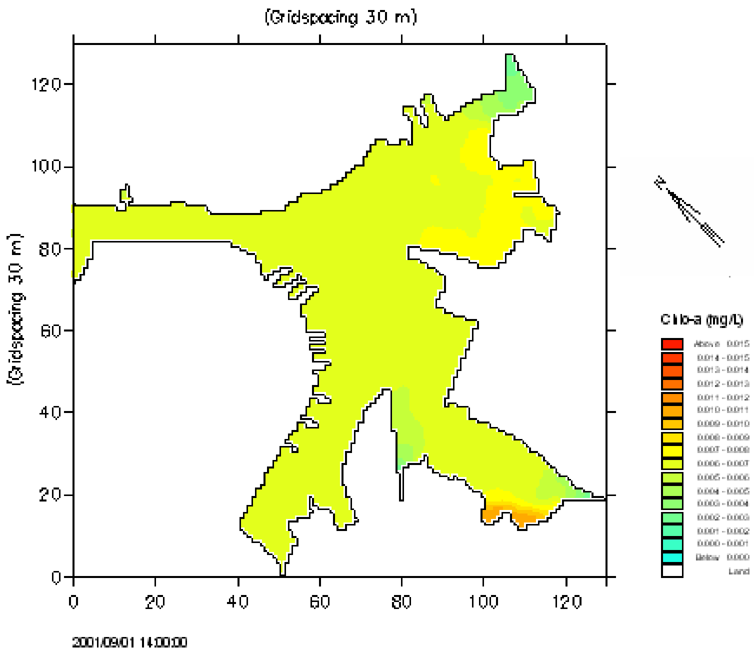


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.50 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case MP.
JAPAN INTERNATIONAL COOPERATION AGENCY	

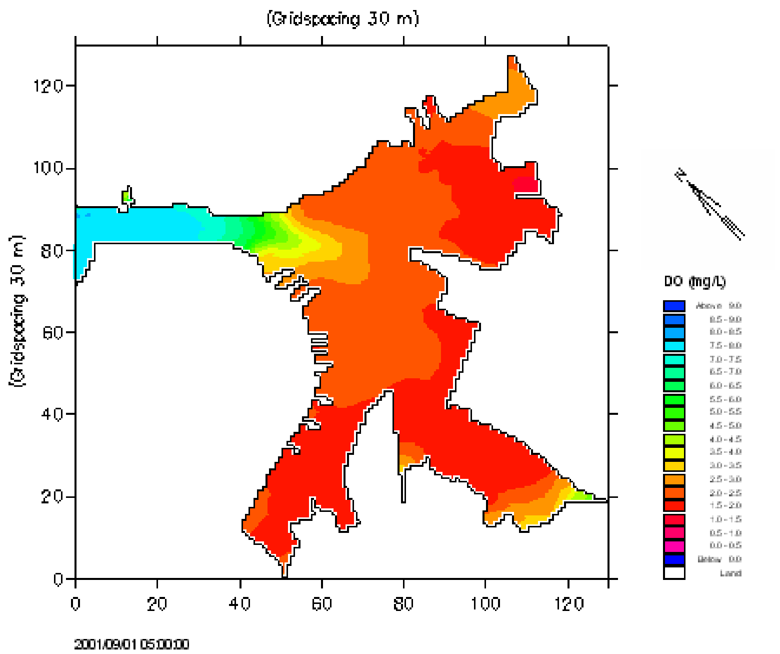


high tide

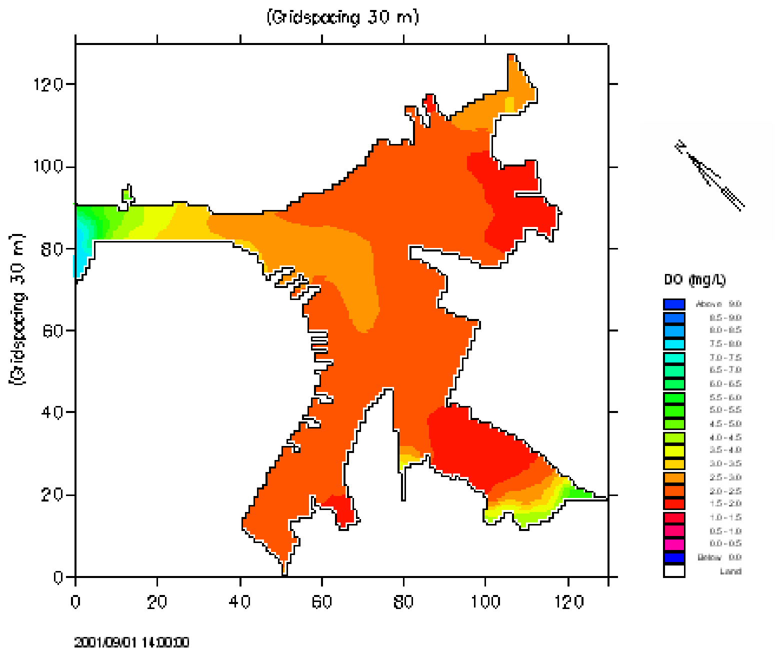


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.51 Concentration Distribution of Chlorophyll-a (Chlo_al) in Havana Bay (Surface Layer) for the Case MP.
JAPAN INTERNATIONAL COOPERATION AGENCY	

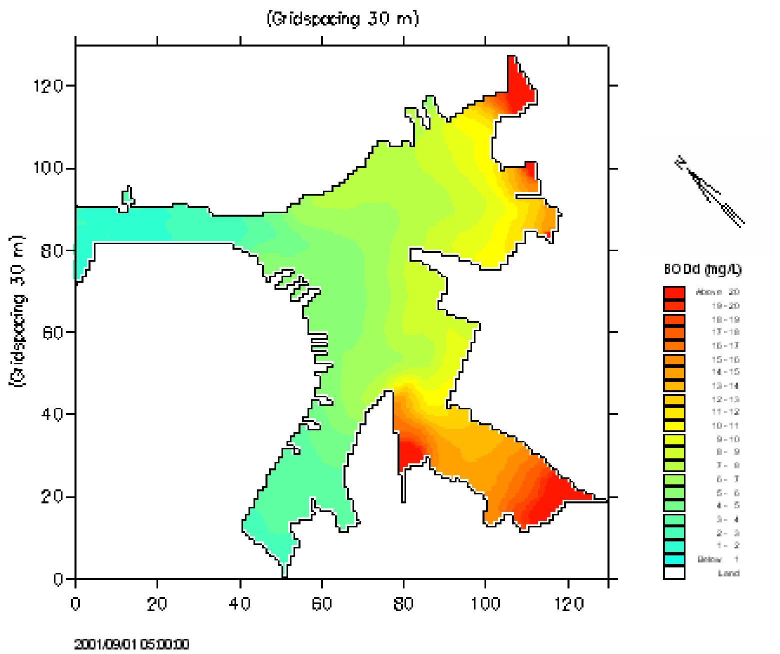


high tide

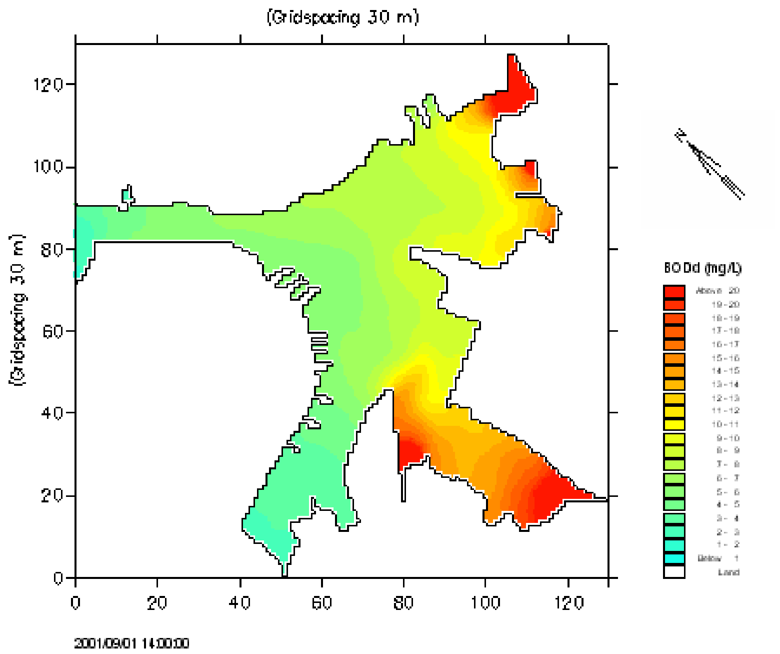


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.52 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the Case F/S.
JAPAN INTERNATIONAL COOPERATION AGENCY	



high tide

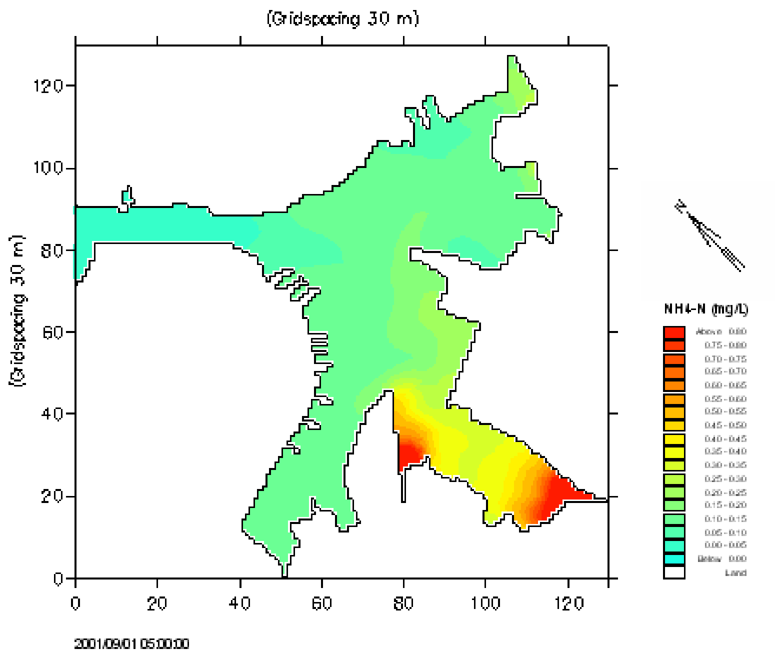


low tide

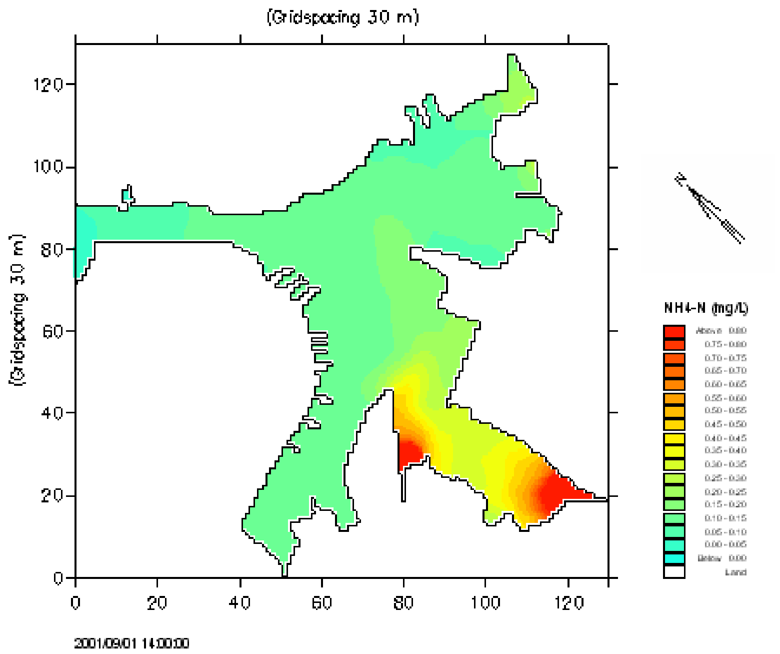
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure A7.53
Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the Case F/ S.

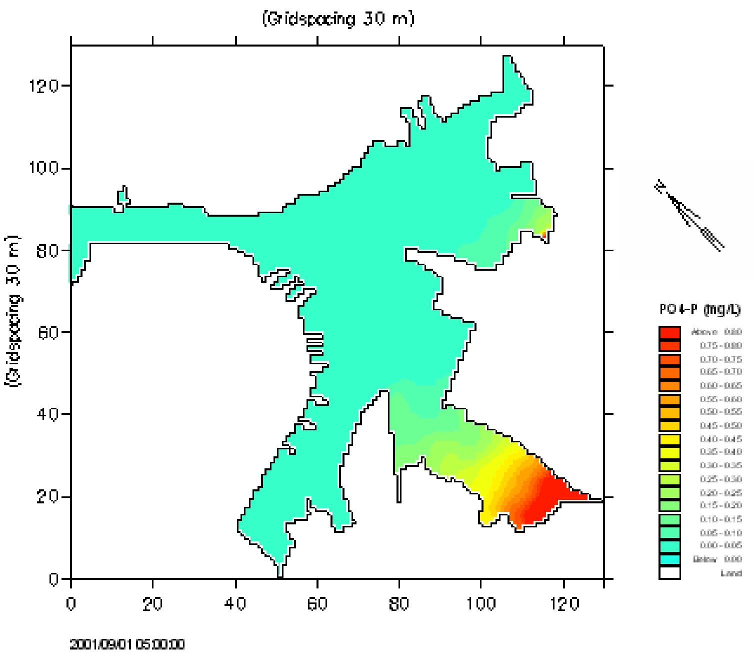


high tide

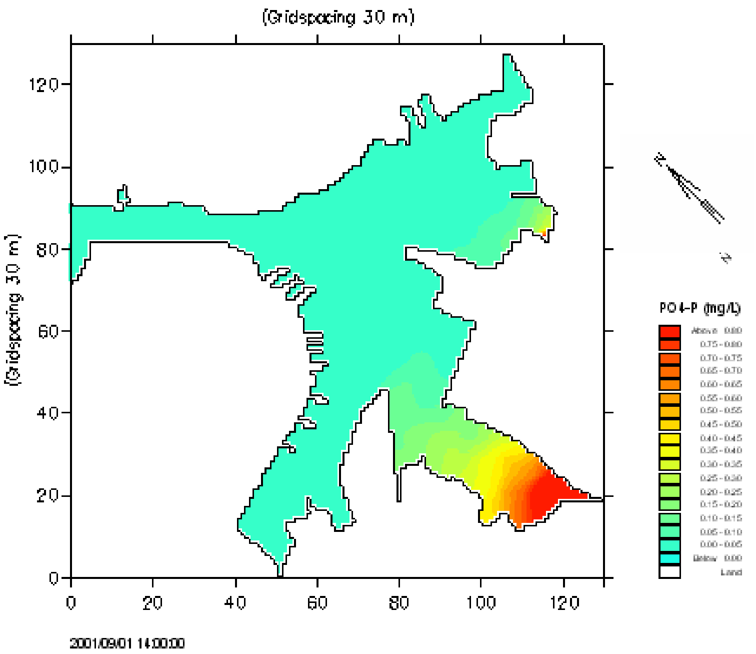


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.54 Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the Case F/ S.
JAPAN INTERNATIONAL COOPERATION AGENCY	

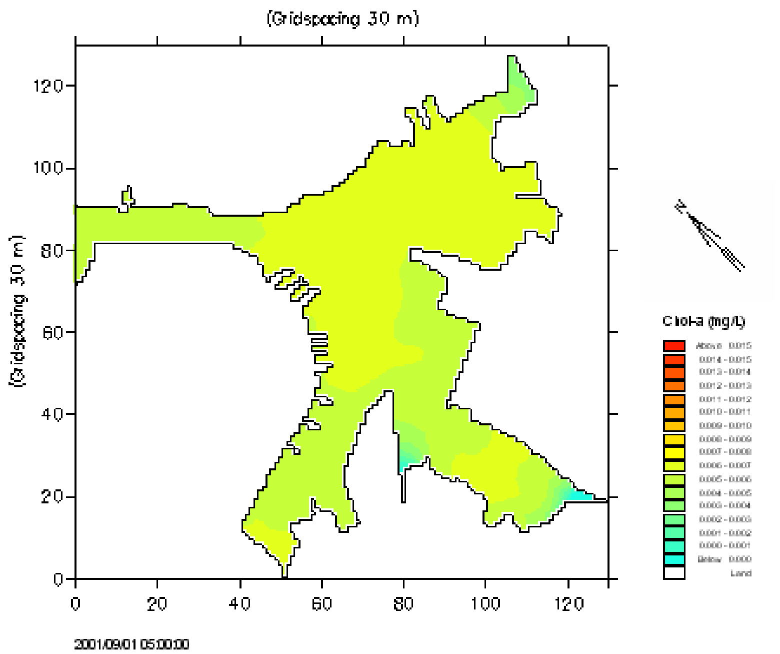


high tide

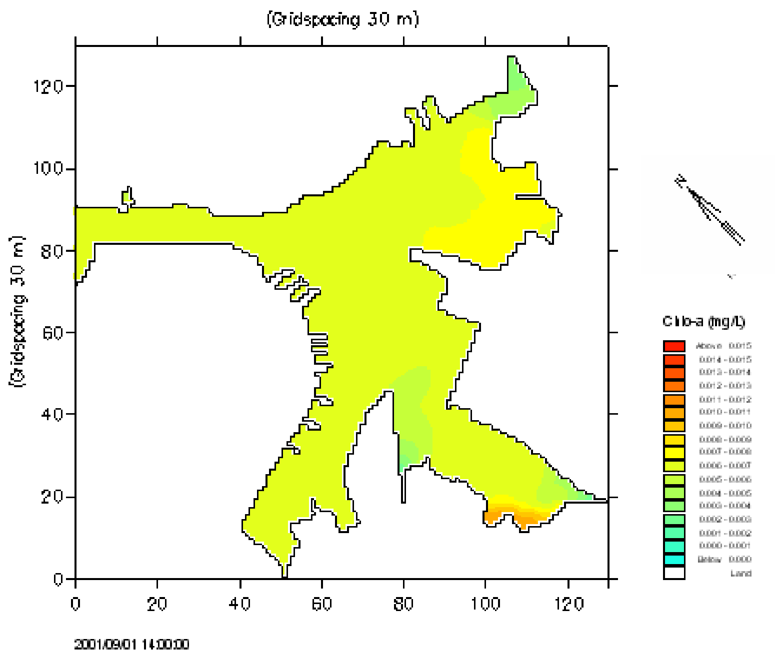


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.55 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the Case F/ S.
JAPAN INTERNATIONAL COOPERATION AGENCY	

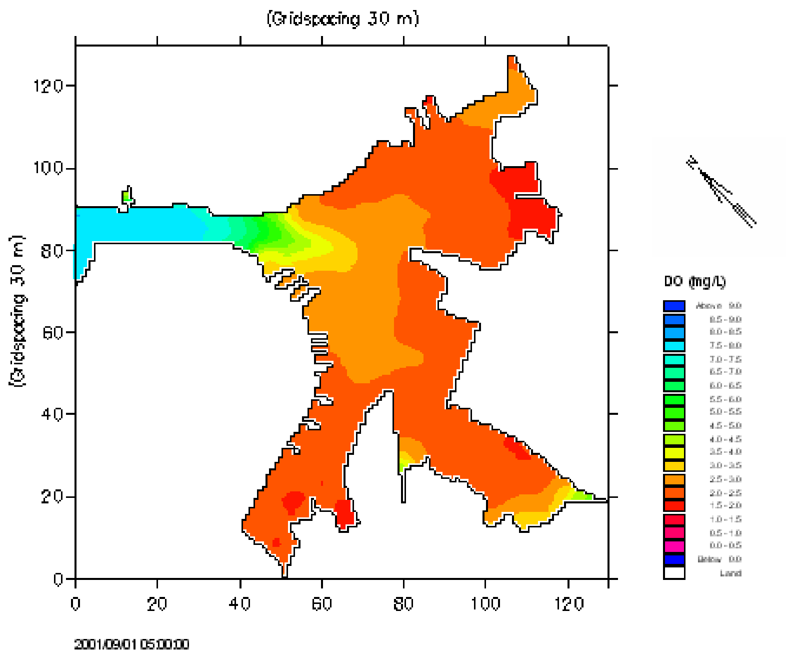


high tide

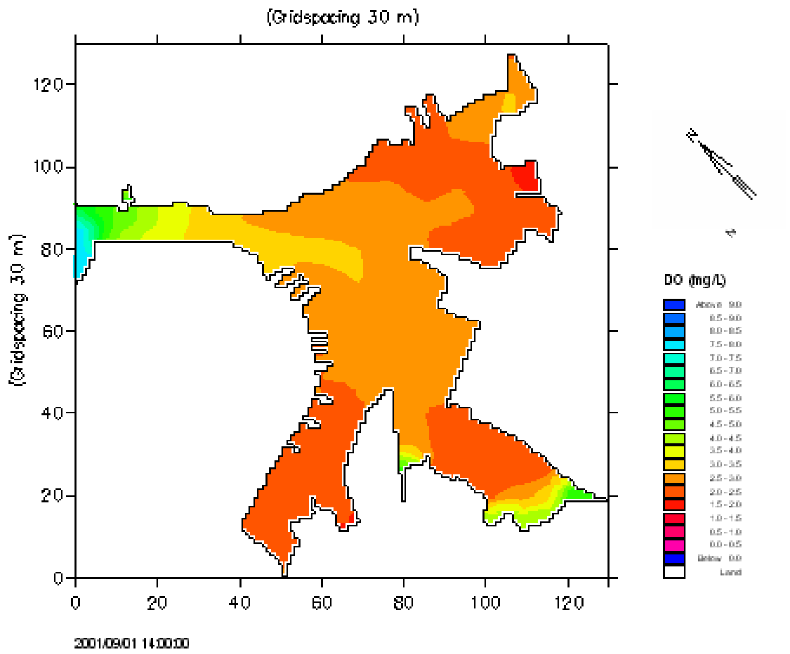


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.56 Concentration Distribution of Chlorophyll-a (Chlo_al) in Havana Bay (Surface Layer) for the Case F/ S.
JAPAN INTERNATIONAL COOPERATION AGENCY	

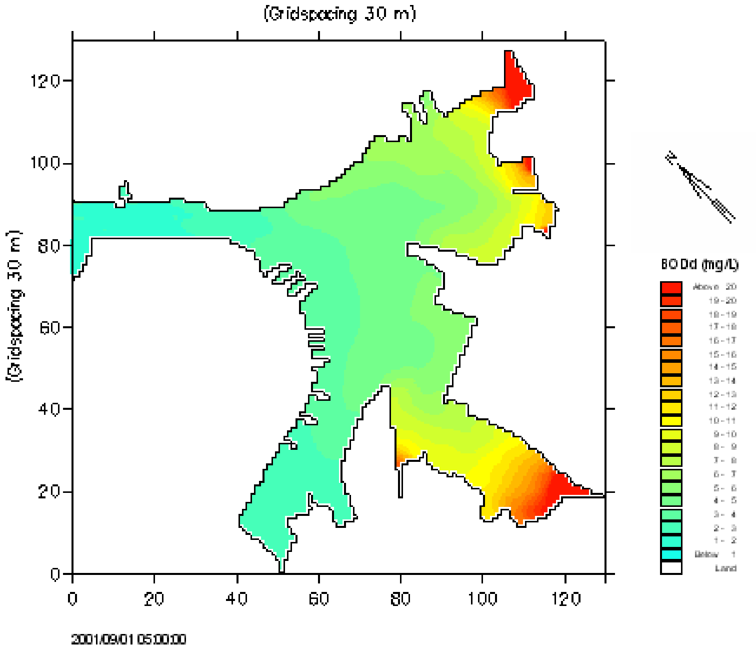


high tide

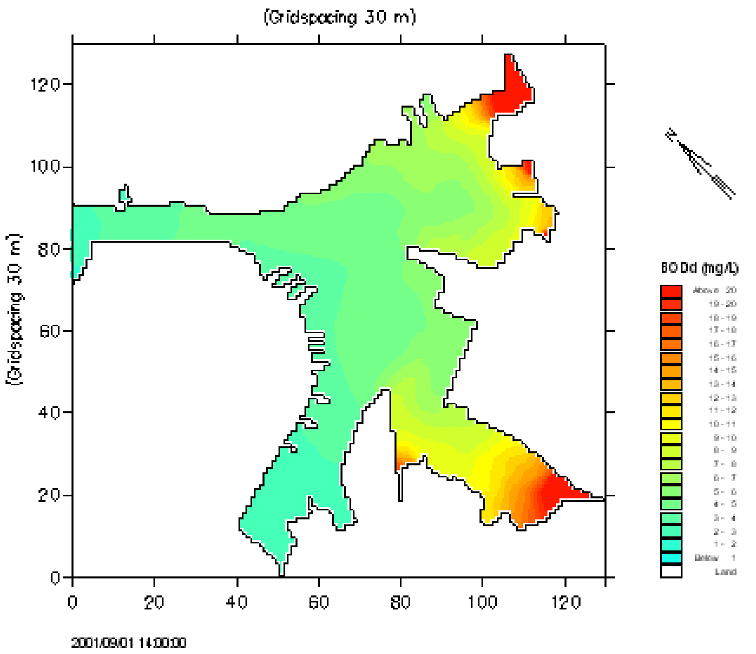


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.57 Concentration Distribution of Dissolved Oxygen (DO) in Havana Bay (Surface Layer) for the CaseMP-alt.
JAPAN INTERNATIONAL COOPERATION AGENCY	

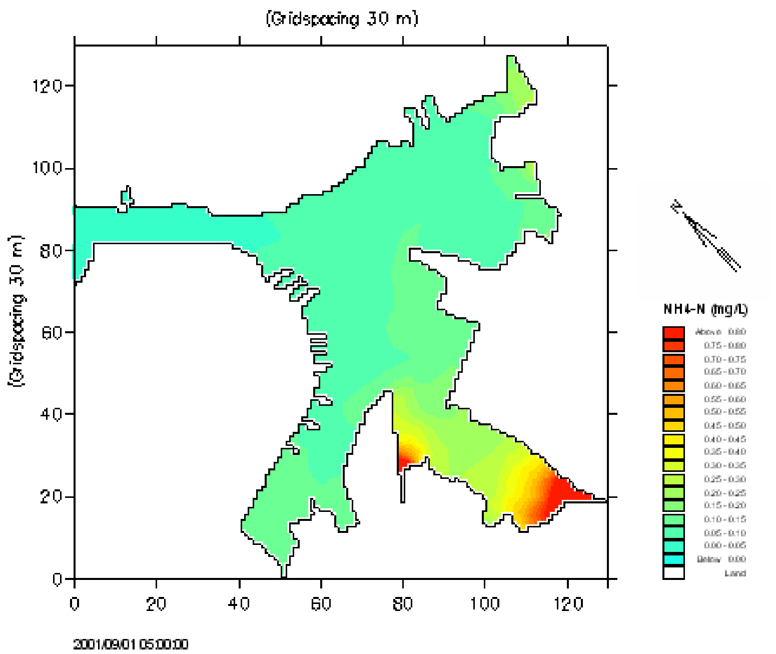


high tide

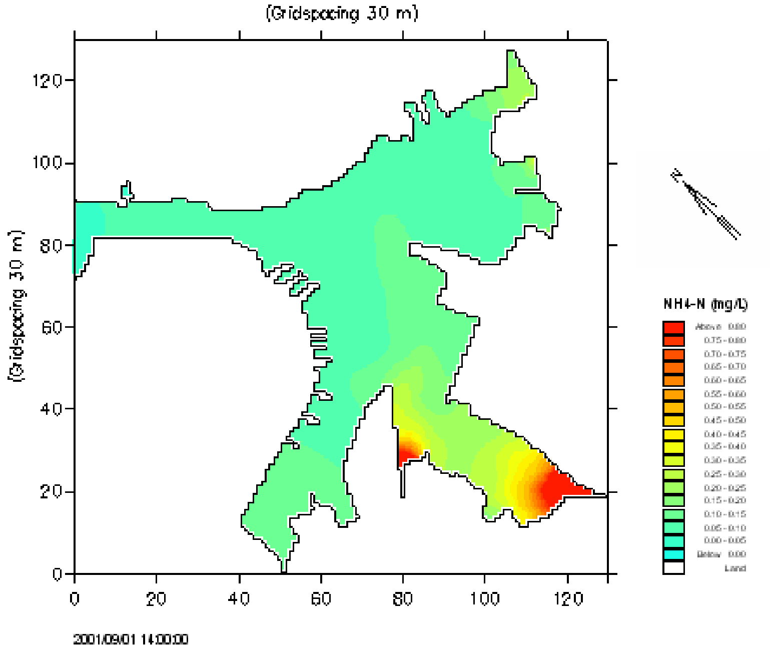


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.58 Concentration Distribution of Dissolved BOD (BODd) in Havana Bay (Surface Layer) for the CaseMP-alt.
JAPAN INTERNATIONAL COOPERATION AGENCY	

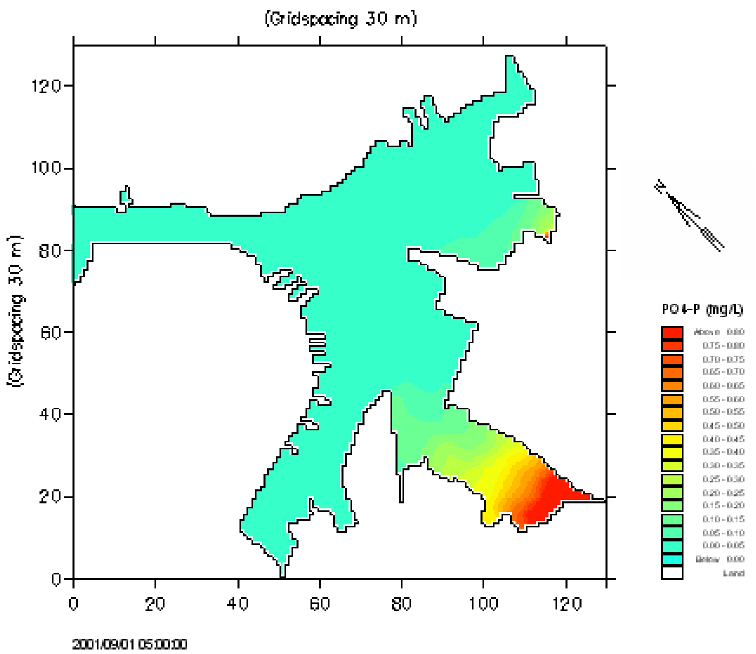


high tide

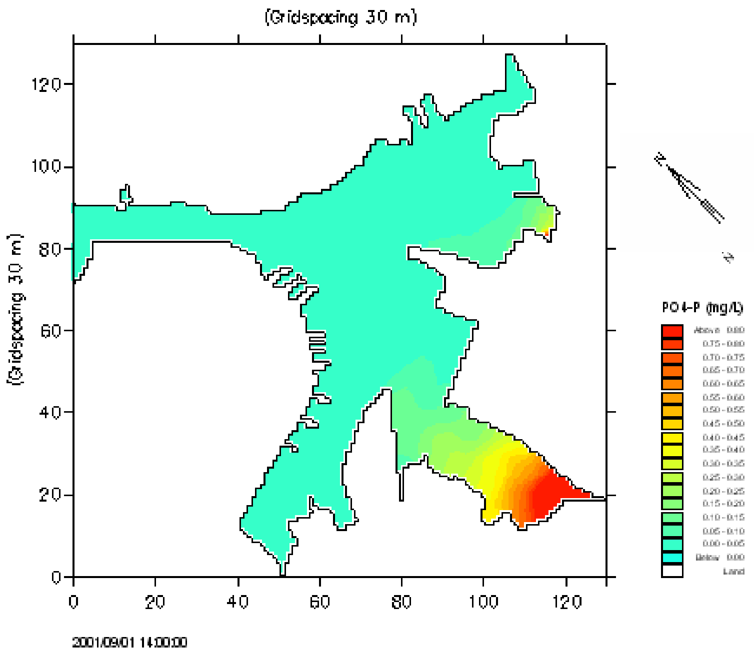


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.59 Concentration Distribution of Ammonia (NH4-N) in Havana Bay (Surface Layer) for the CaseMP-alt.
JAPAN INTERNATIONAL COOPERATION AGENCY	

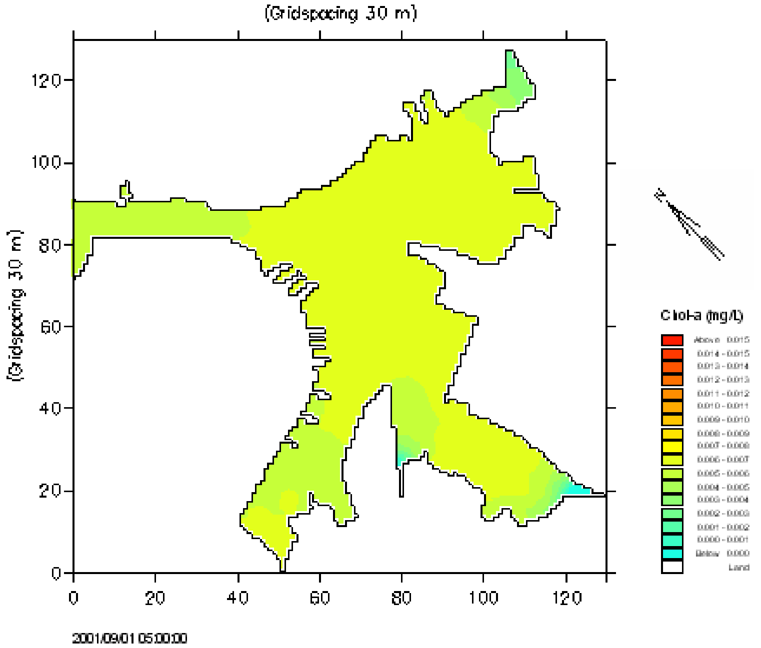


high tide

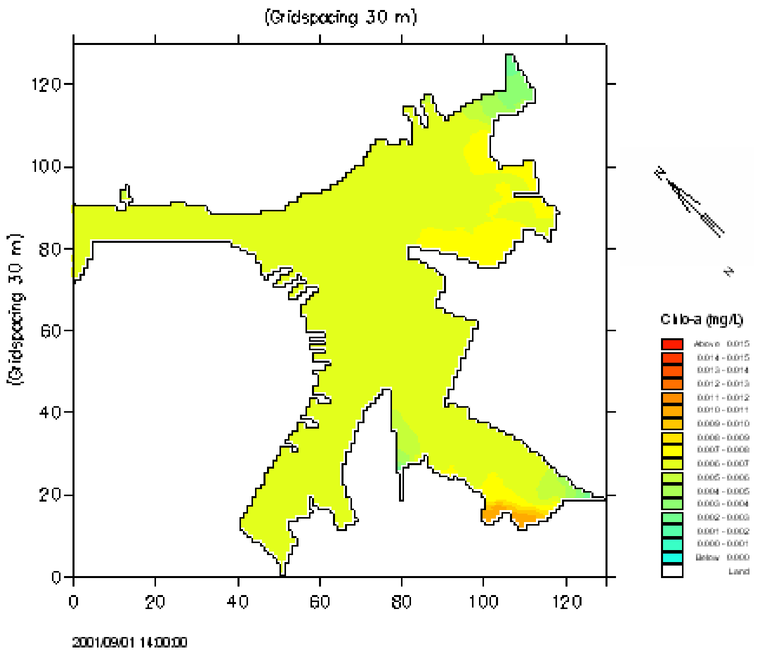


low tide

THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.60 Concentration Distribution of Phosphate (PO4-P) in Havana Bay (Surface Layer) for the CaseMP-alt.
JAPAN INTERNATIONAL COOPERATION AGENCY	

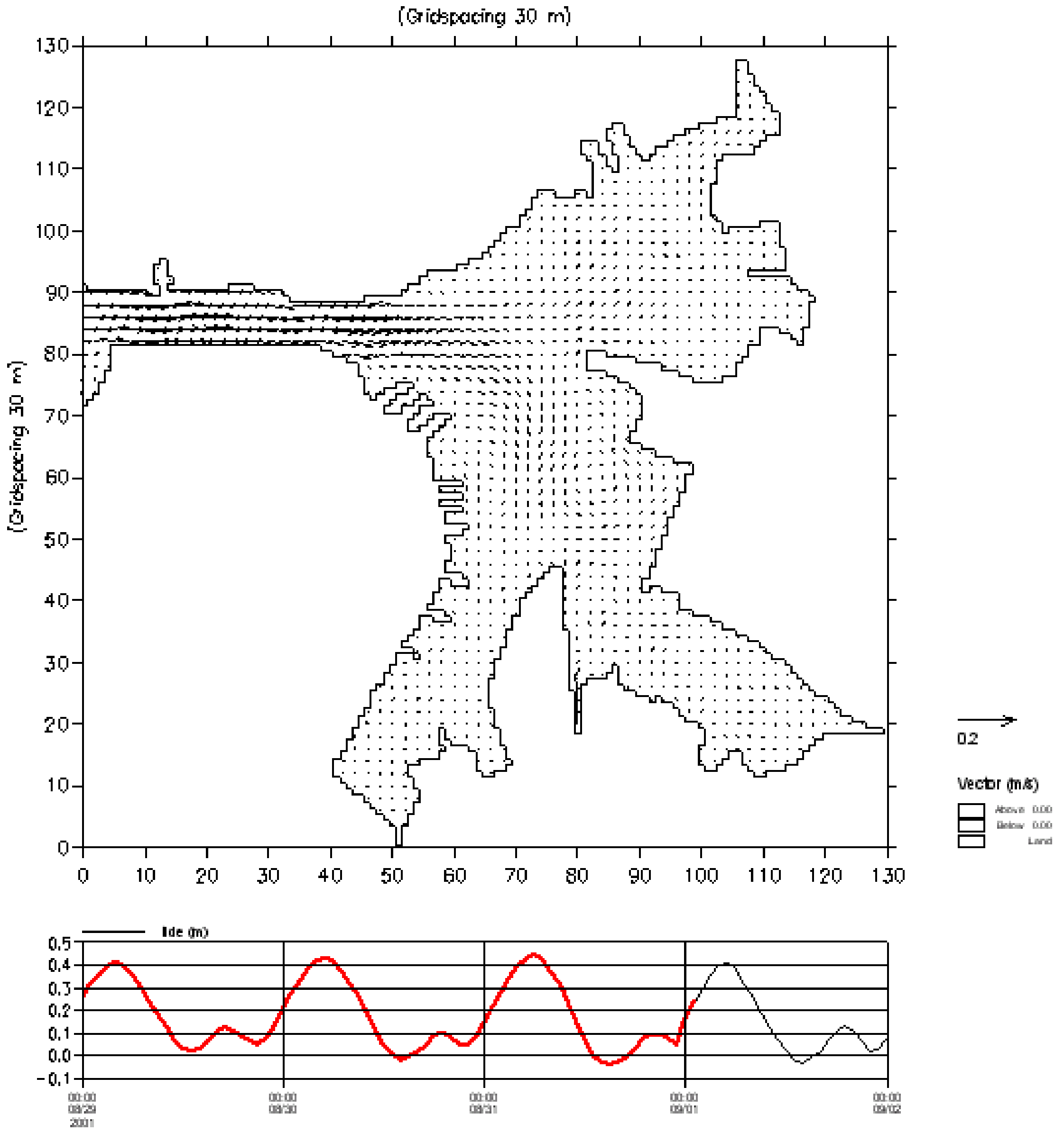


high tide

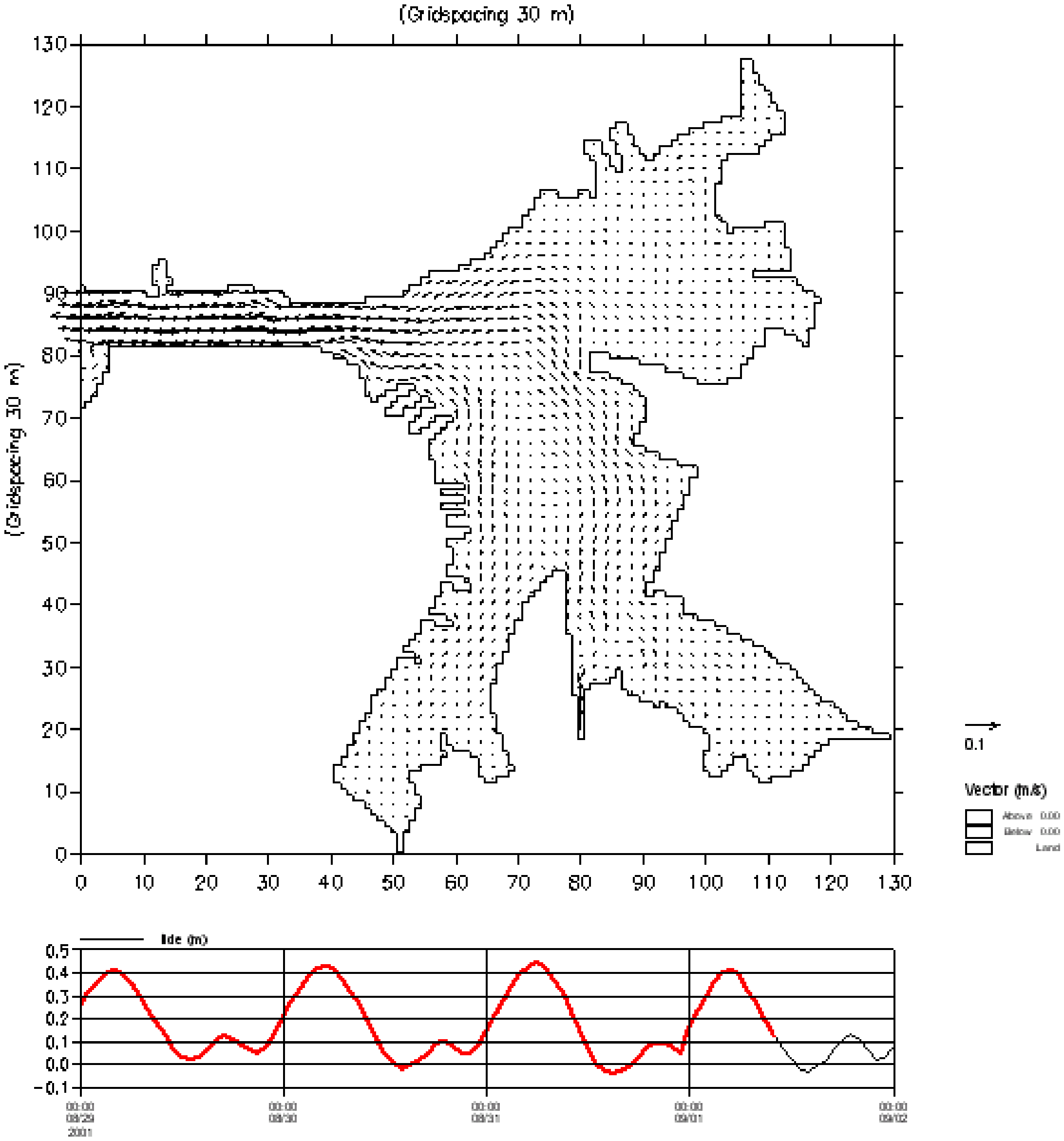


low tide

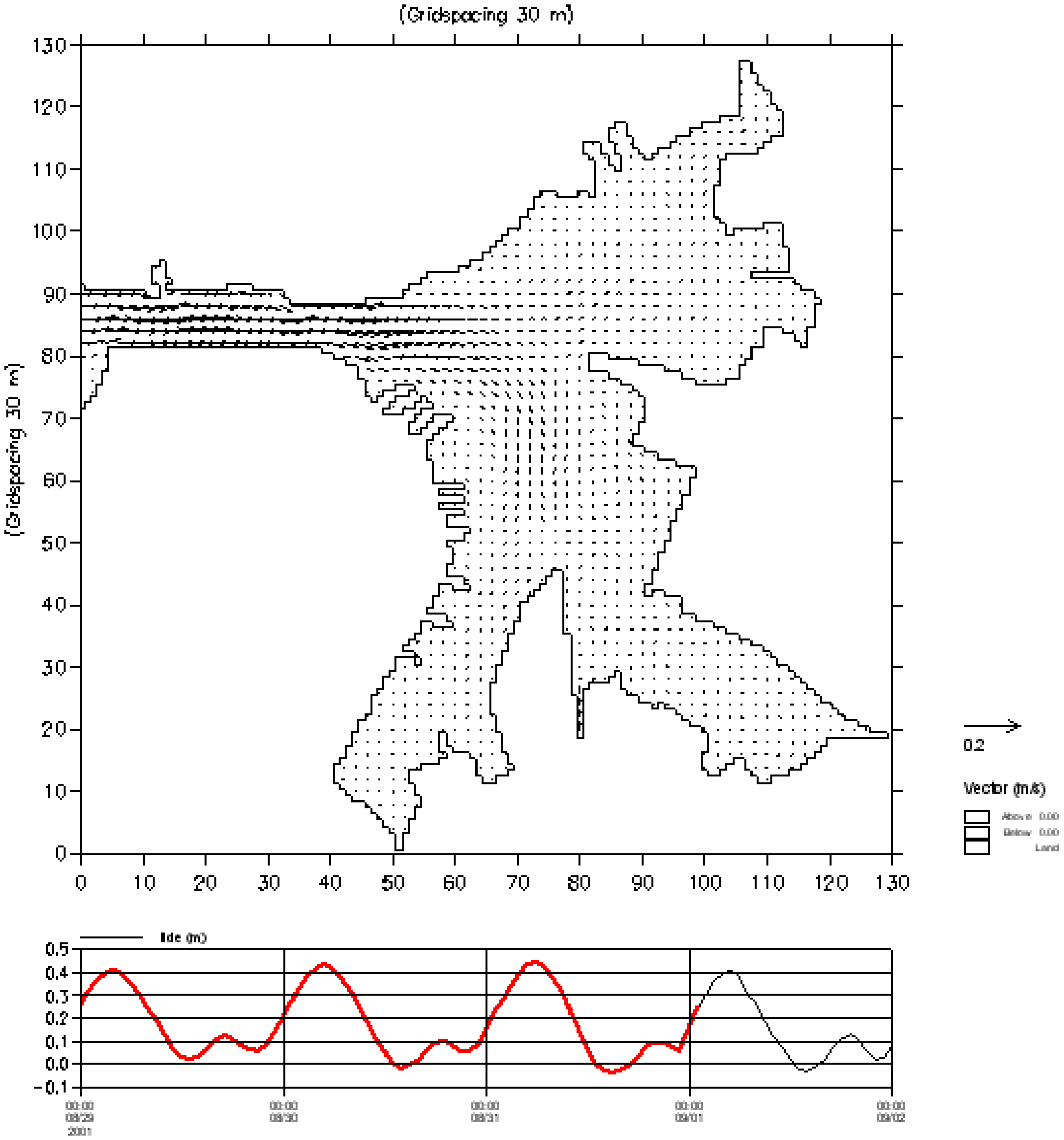
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.61 Concentration Distribution of Chlorophyll-a (Chlo_al) in Havana Bay (Surface Layer) for the Case MP-alt.
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.62 Simulation Results of the Currents in Havana Bay (Surface Layer, High Tide) for the Case2
JAPAN INTERNATIONAL COOPERATION AGENCY	



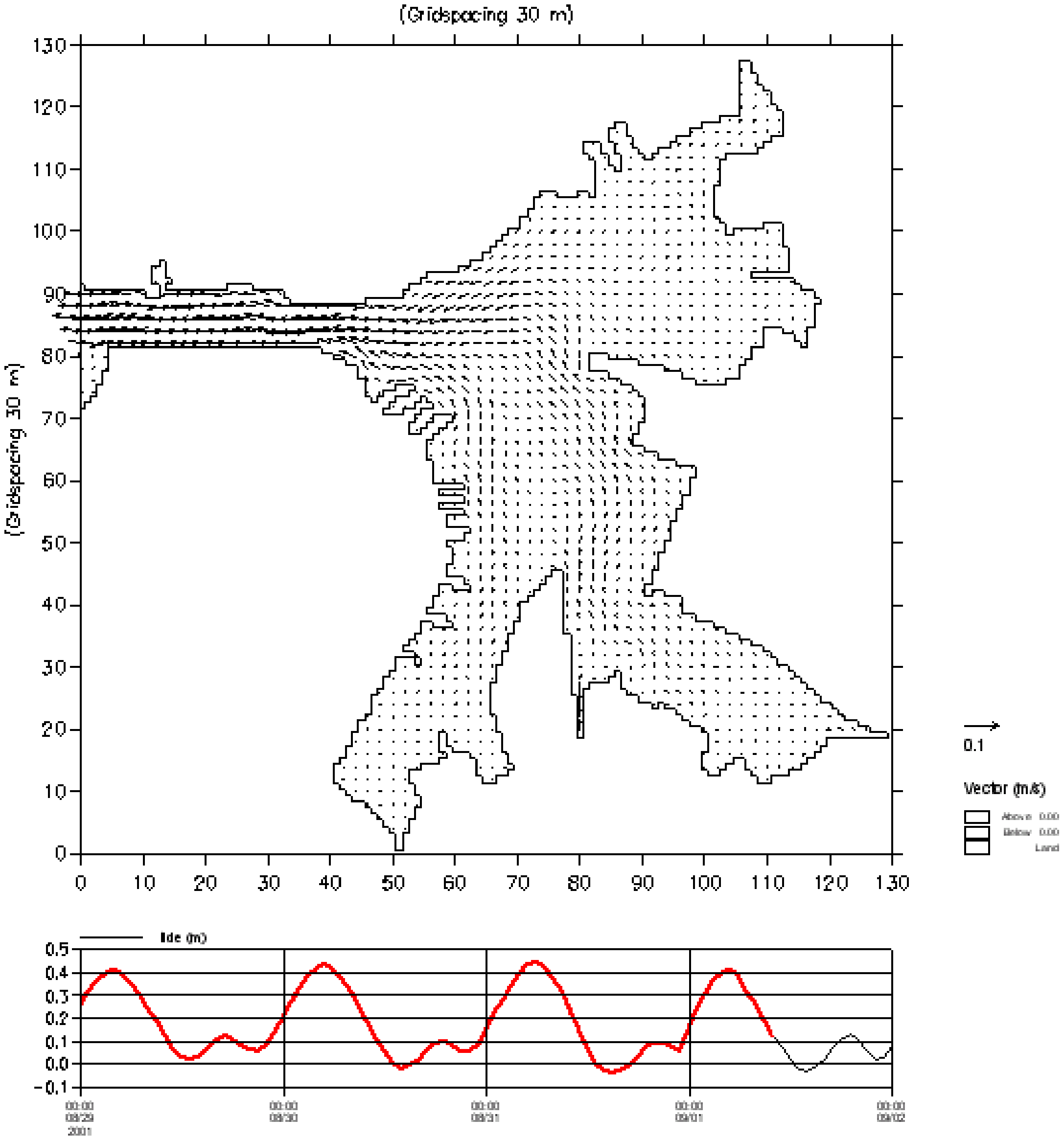
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.63 Simulation Results of the Currents in Havana Bay (Surface Layer, low Tide) for the Case2
JAPAN INTERNATIONAL COOPERATION AGENCY	



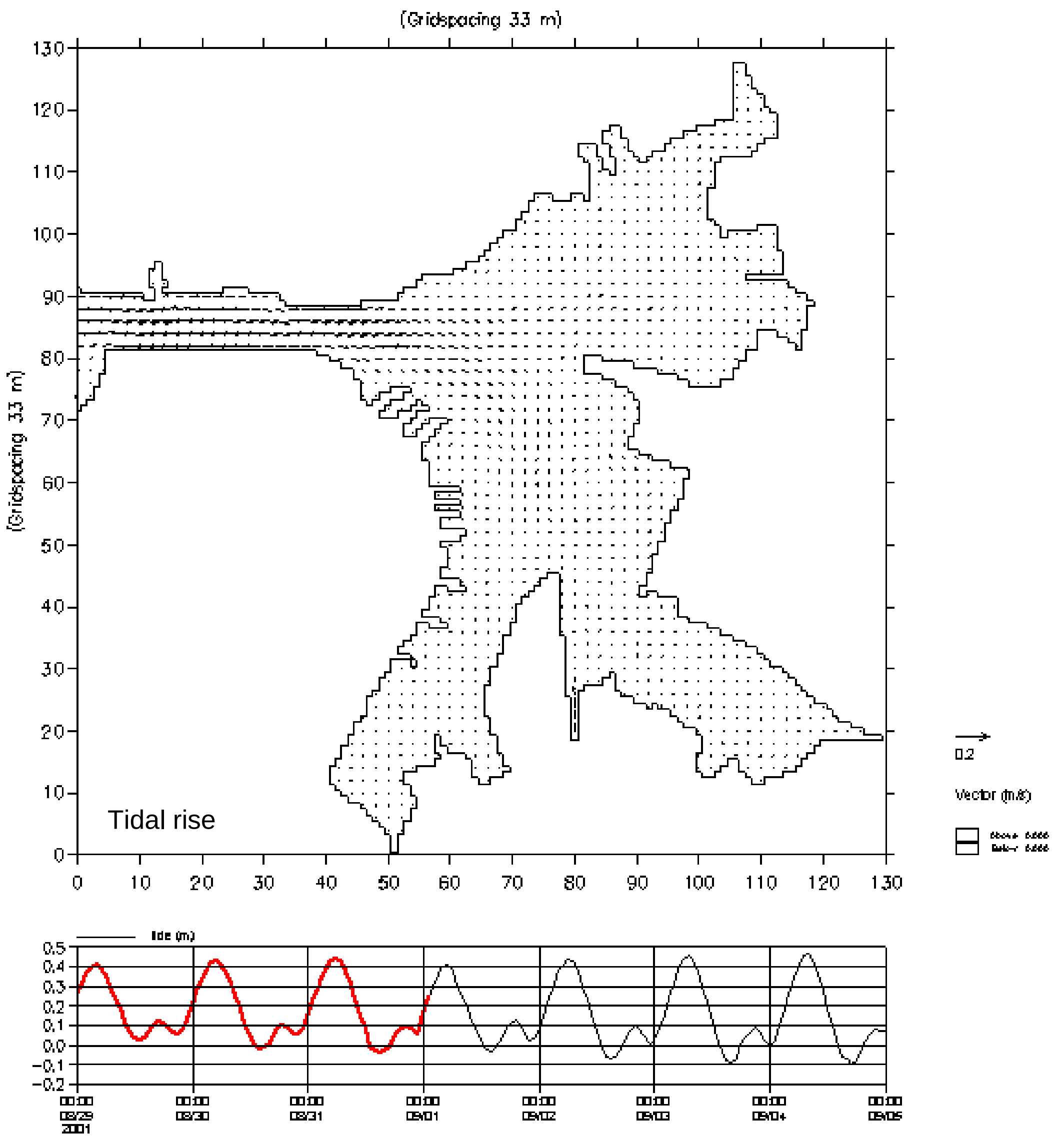
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

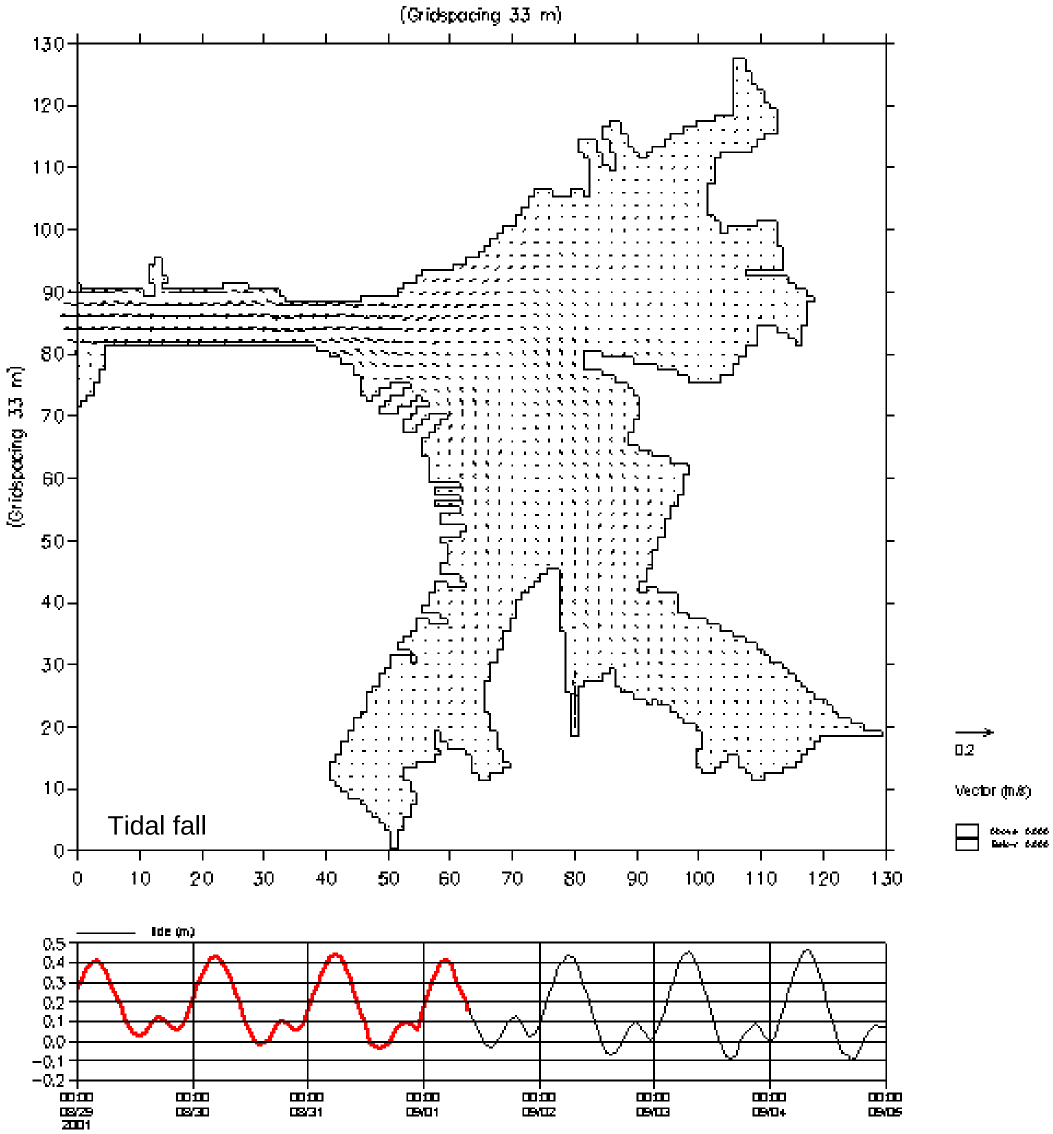
Figure A7.64
Simulation Results of the Currents in Havana Bay (Surface Layer, High Tide) for the Case7



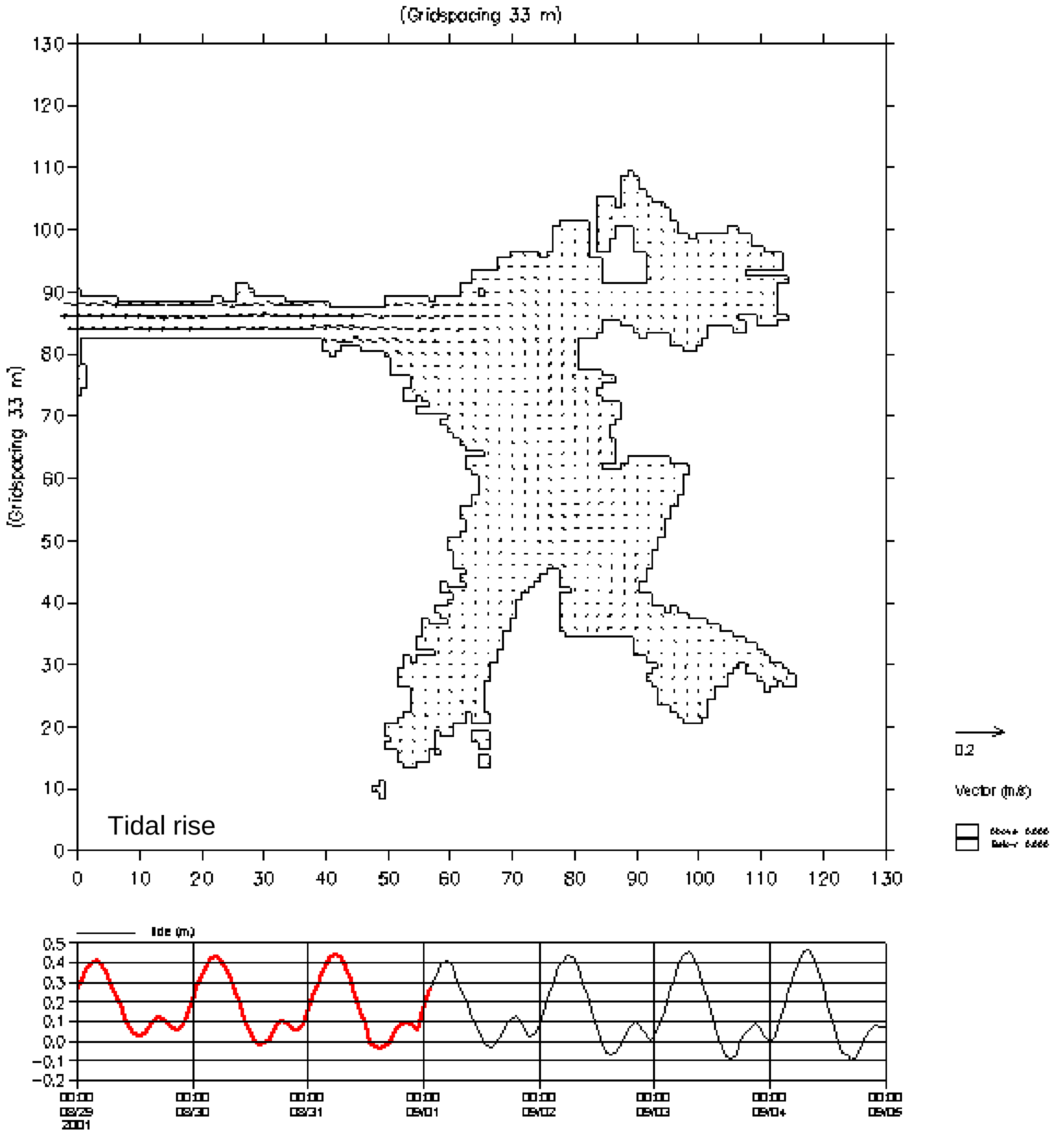
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.65 Simulation Results of the Currents in Havana Bay (Surface Layer, low Tide) for the Case7
JAPAN INTERNATIONAL COOPERATION AGENCY	



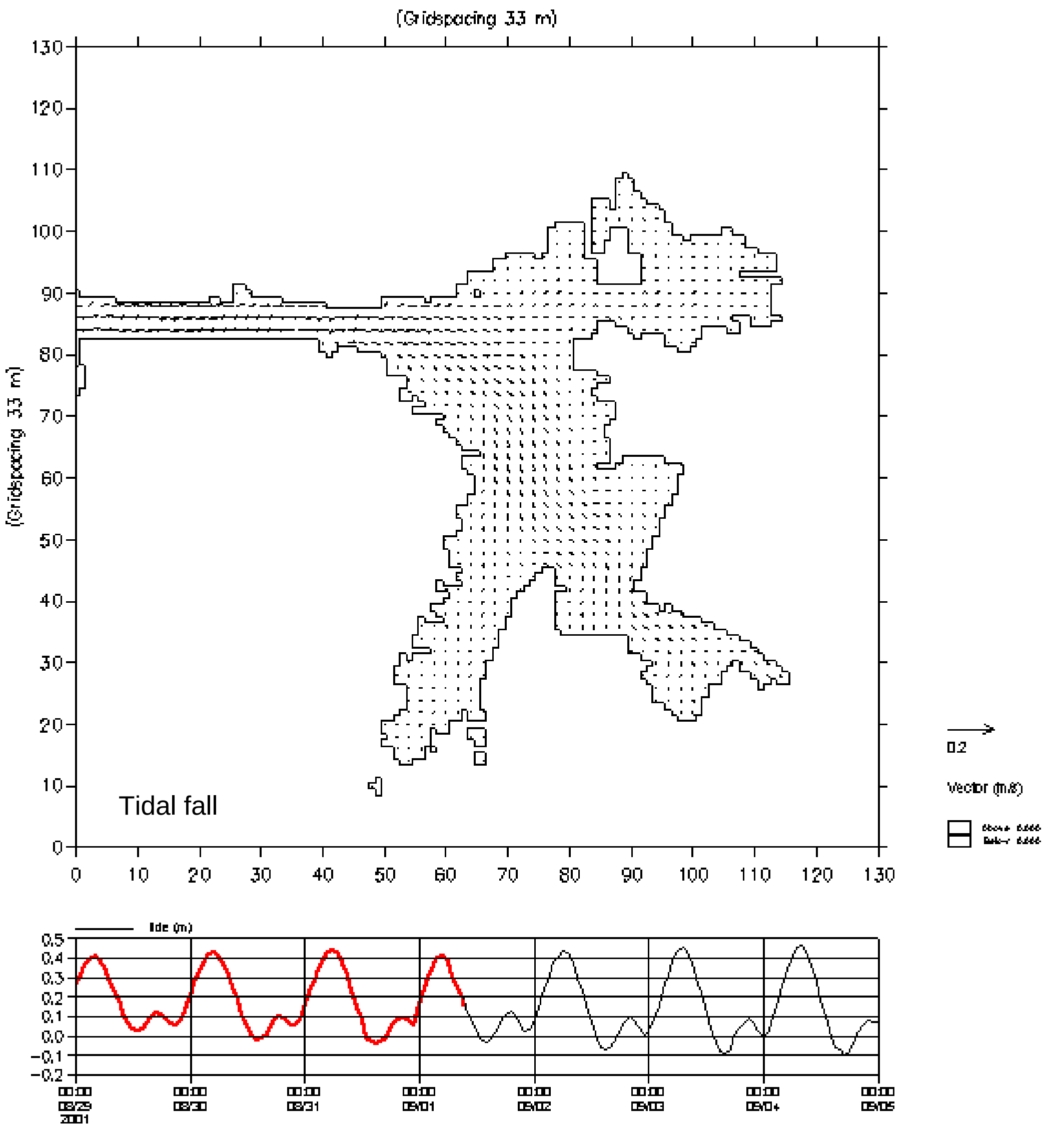
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.66 Simulation Results of the Currents in Havana Bay (Surface Layer) for Case MP
JAPAN INTERNATIONAL COOPERATION AGENCY	



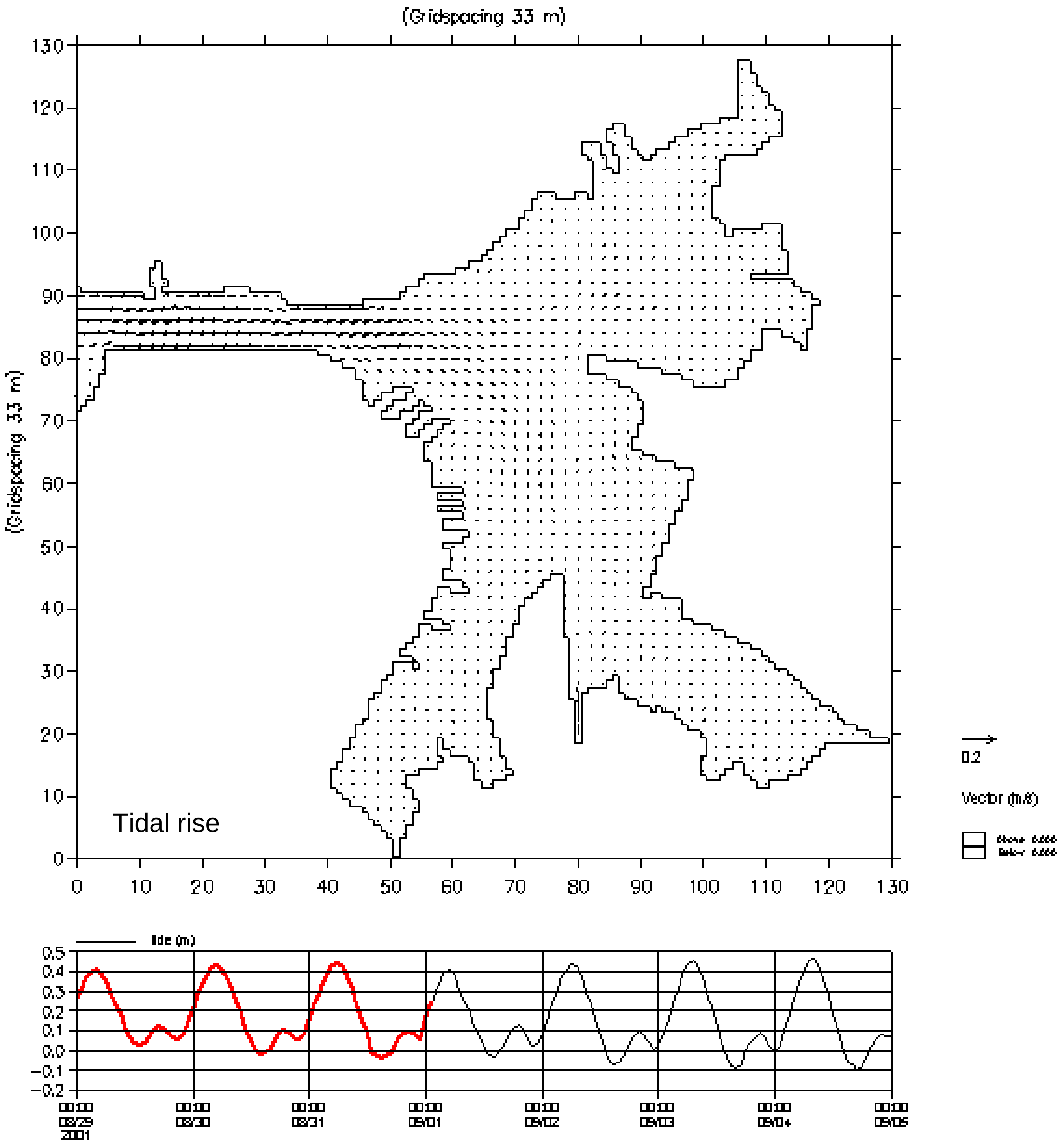
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.67 Simulation Results of the Currents in Havana Bay (Surface Layer) for Case MP
JAPAN INTERNATIONAL COOPERATION AGENCY	



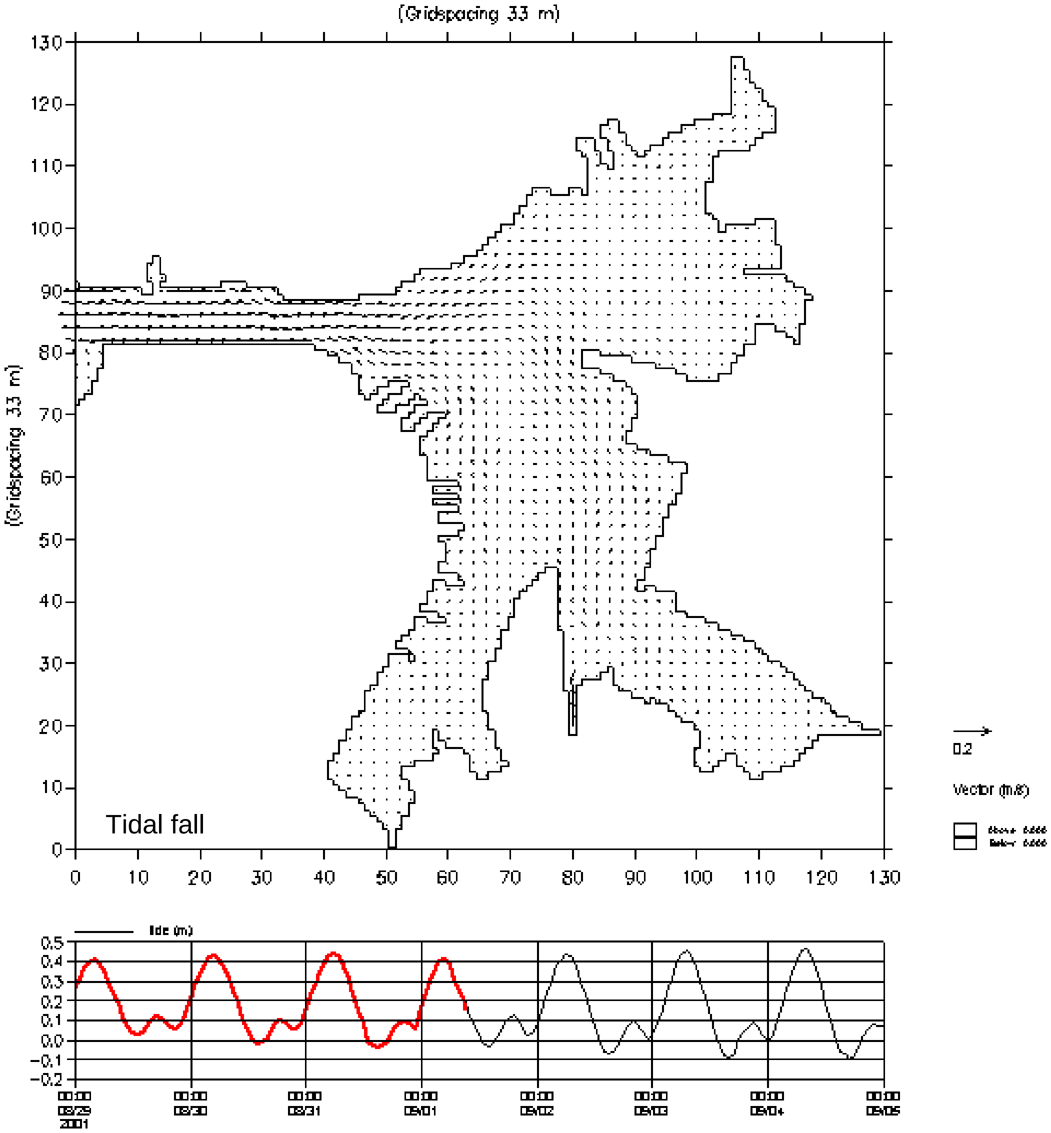
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.68 Simulation Results of the Currents in Havana Bay (The Second Layer) for Case MP
JAPAN INTERNATIONAL COOPERATION AGENCY	



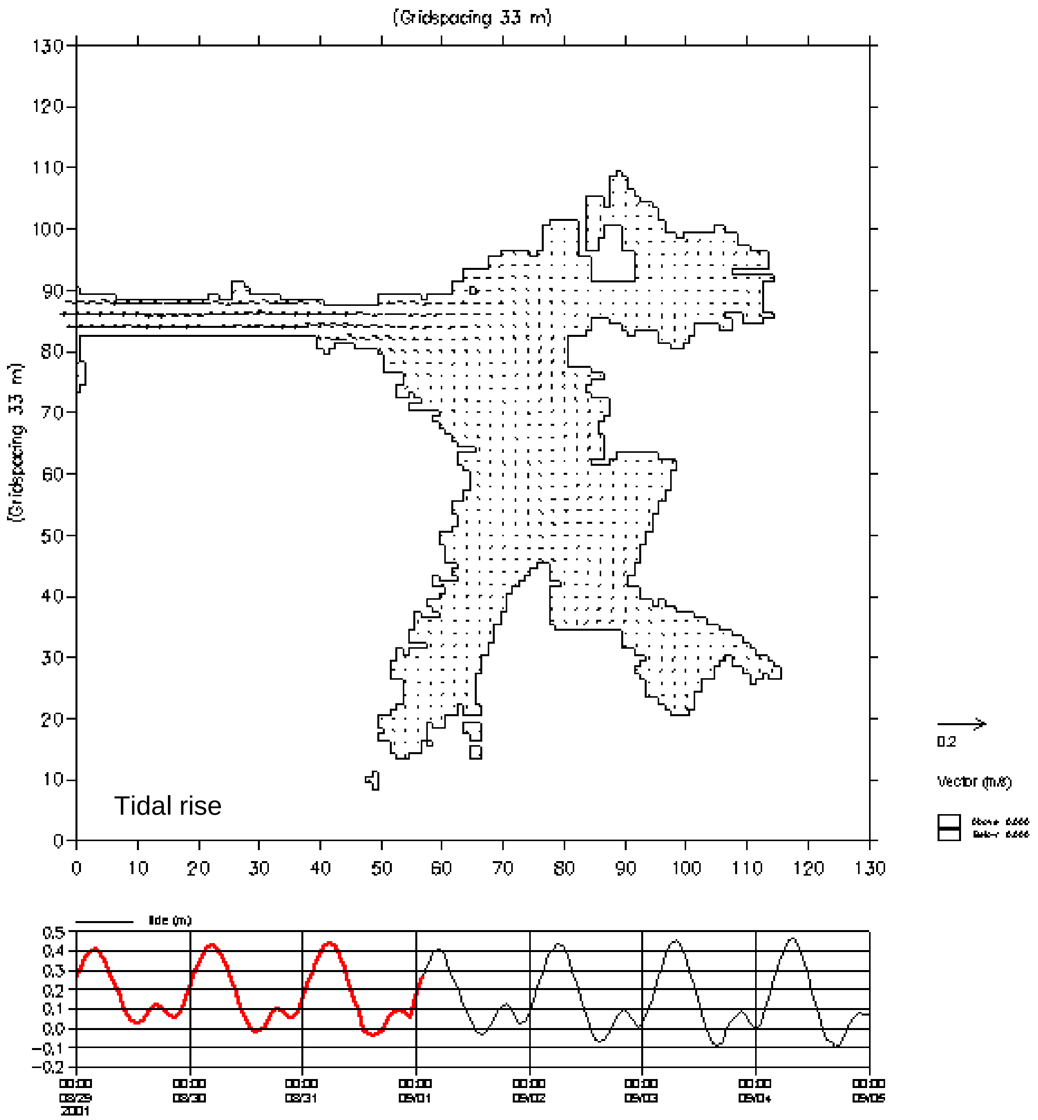
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.69 Simulation Results of the Currents in Havana Bay (The Second Layer) for Case MP
JAPAN INTERNATIONAL COOPERATION AGENCY	



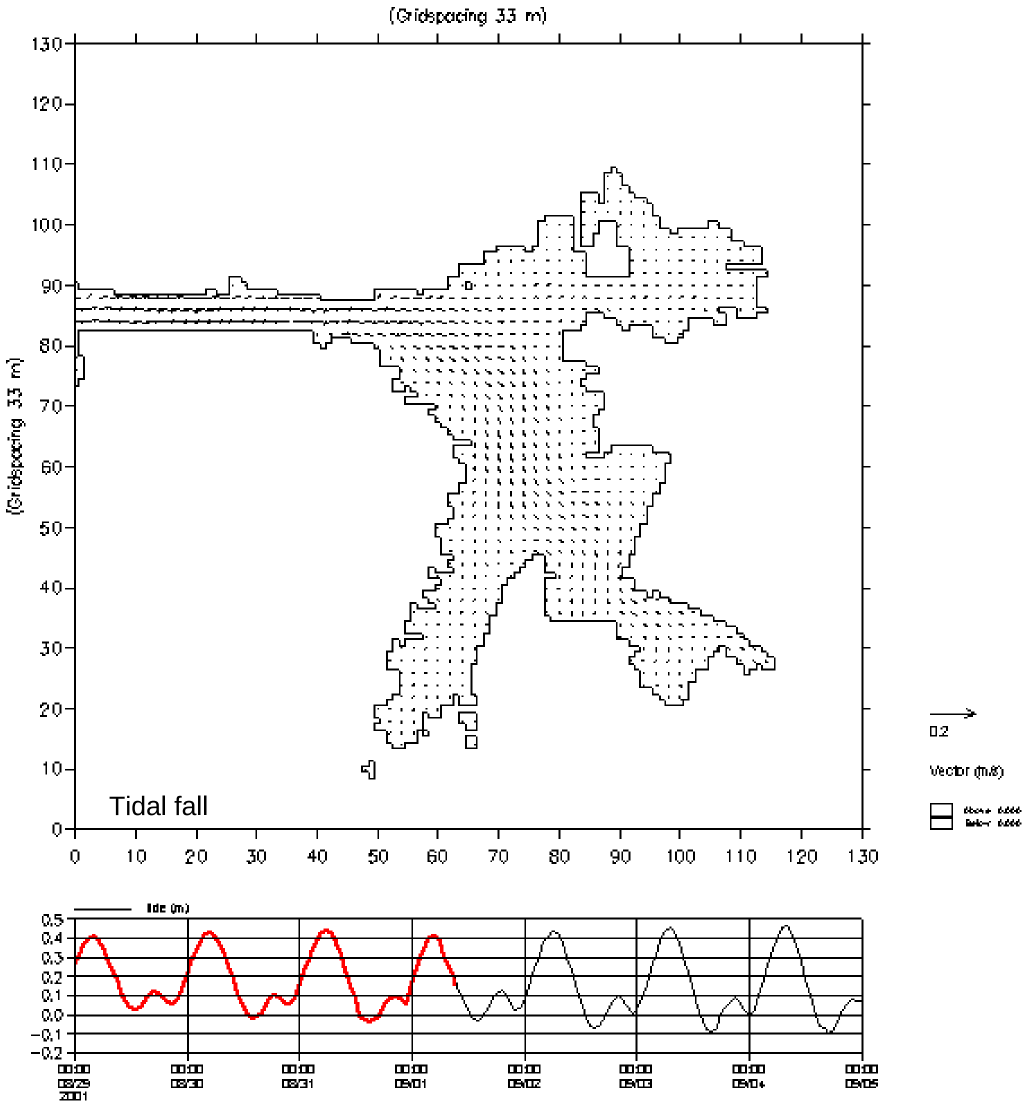
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.70 Simulation Results of the Currents in Havana Bay (Surface Layer) for Case F/S
JAPAN INTERNATIONAL COOPERATION AGENCY	



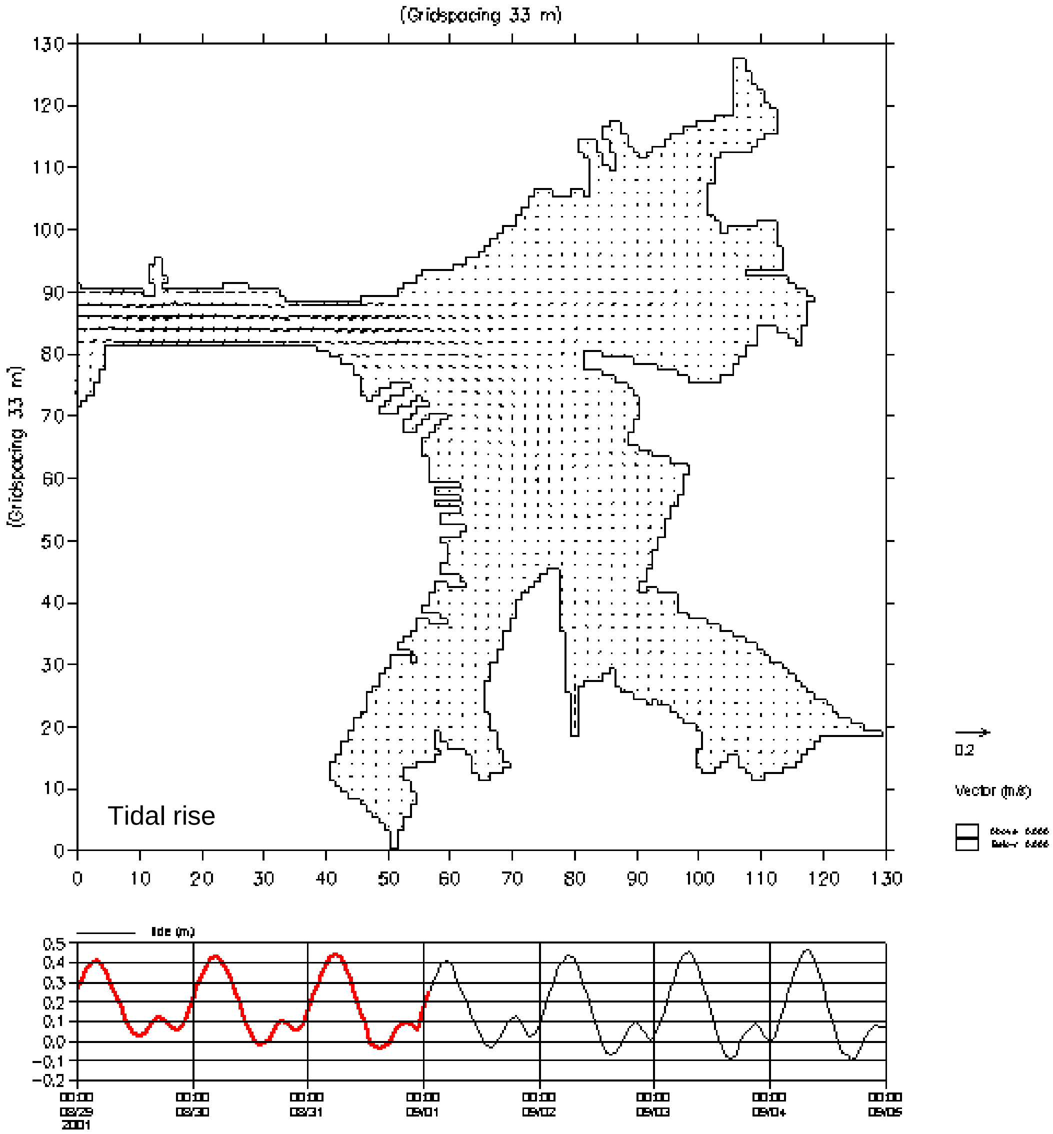
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.71 Simulation Results of the Currents in Havana Bay (Surface Layer) for Case F/S
JAPAN INTERNATIONAL COOPERATION AGENCY	



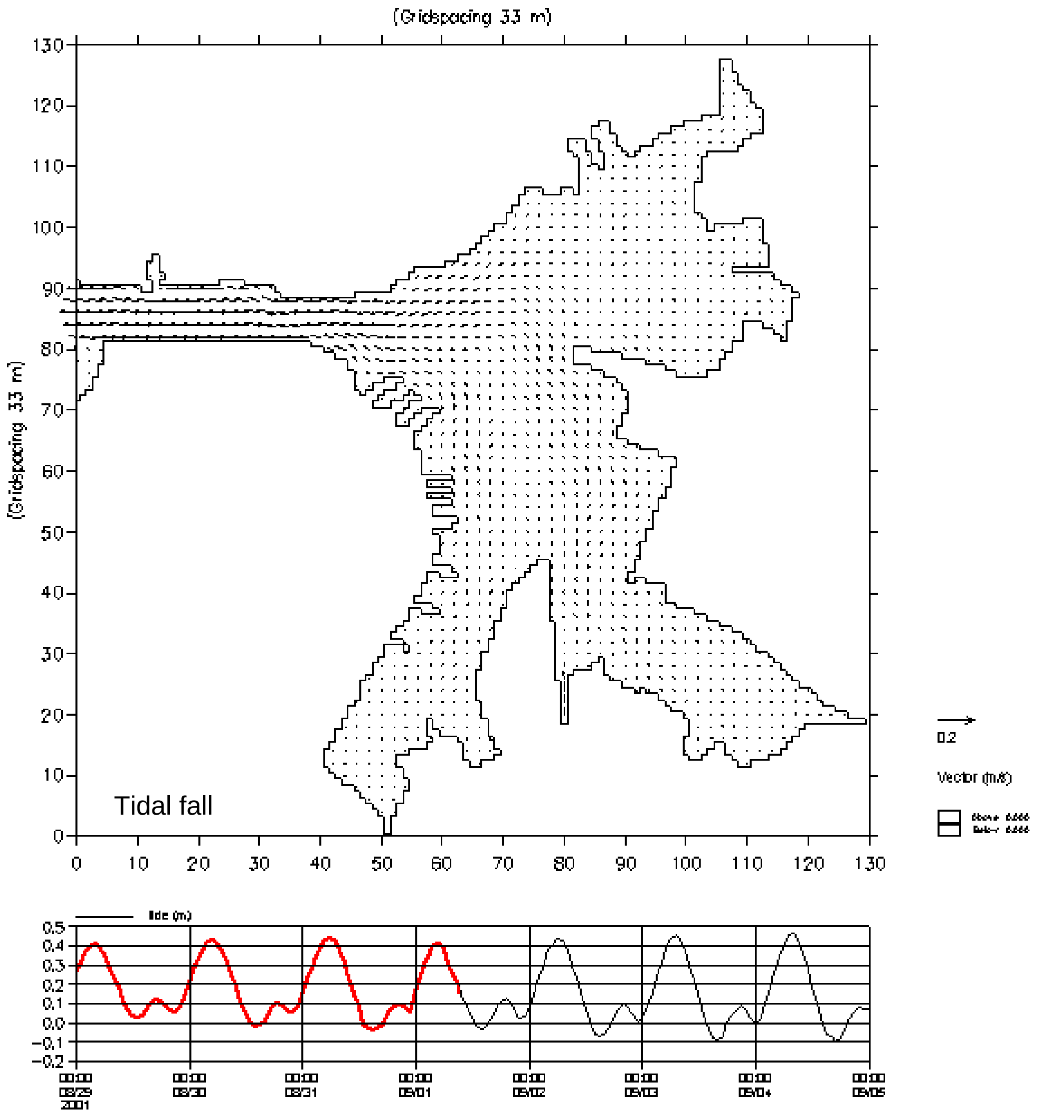
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.72 Simulation Results of the Currents in Havana Bay (The Second Layer) for Case F/S
JAPAN INTERNATIONAL COOPERATION AGENCY	



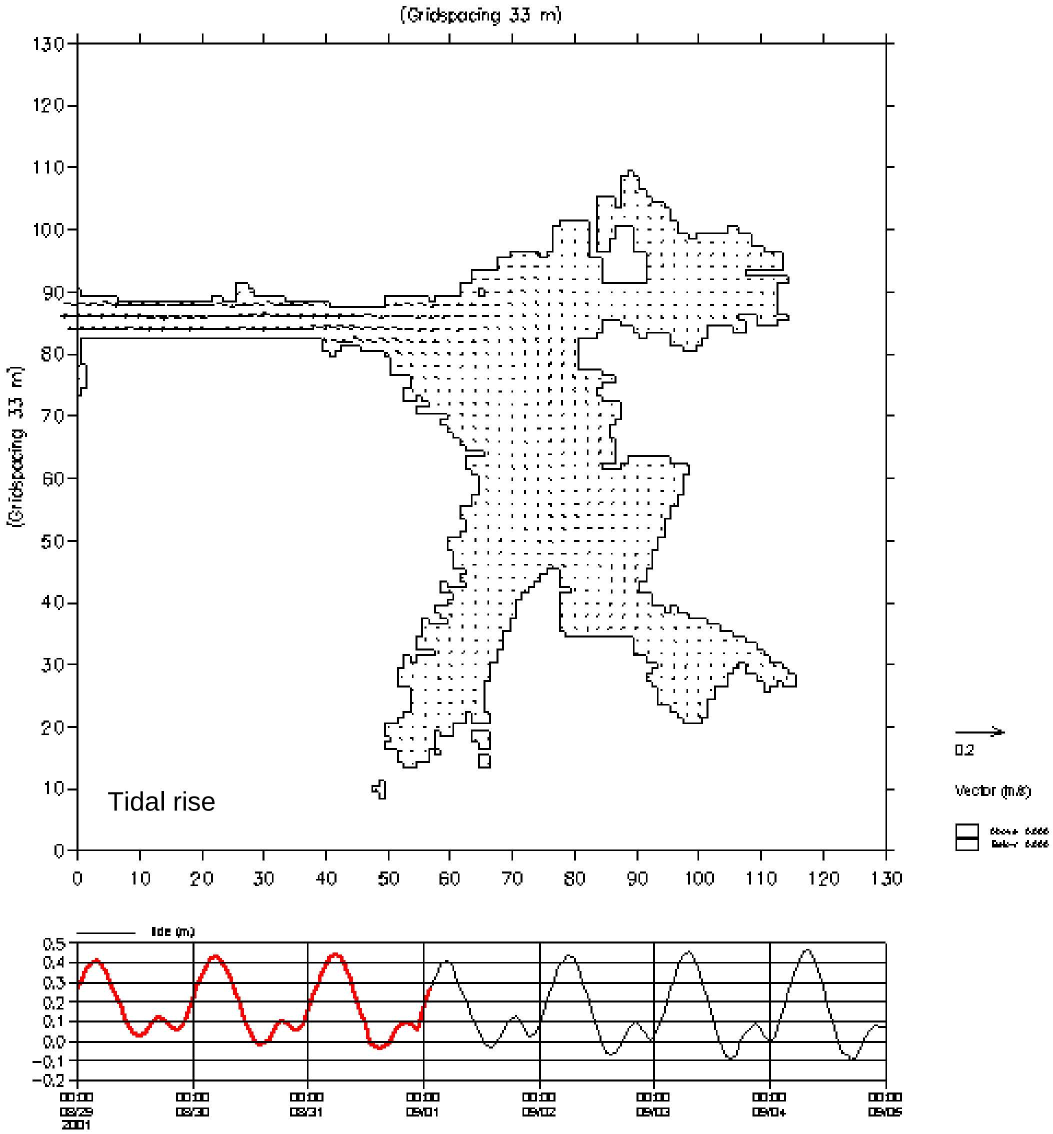
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.73 Simulation Results of the Currents in Havana Bay (The Second Layer) for Case F/S
JAPAN INTERNATIONAL COOPERATION AGENCY	



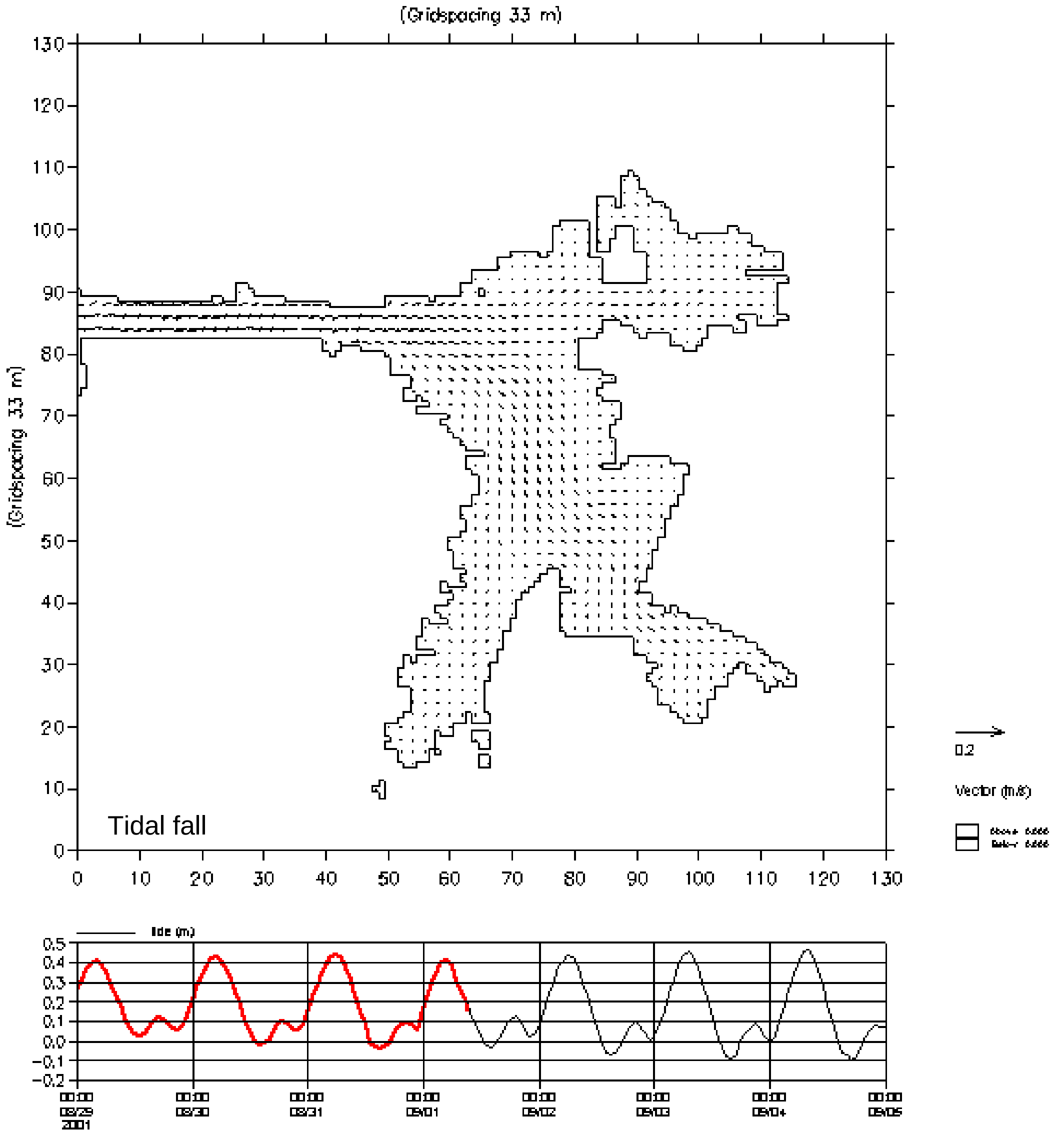
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.74 Simulation Results of the Currents in Havana Bay (Surface Layer) for Case MP-alt
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.75 Simulation Results of the Currents in Havana Bay (Surface Layer) for Case MP-alt
JAPAN INTERNATIONAL COOPERATION AGENCY	



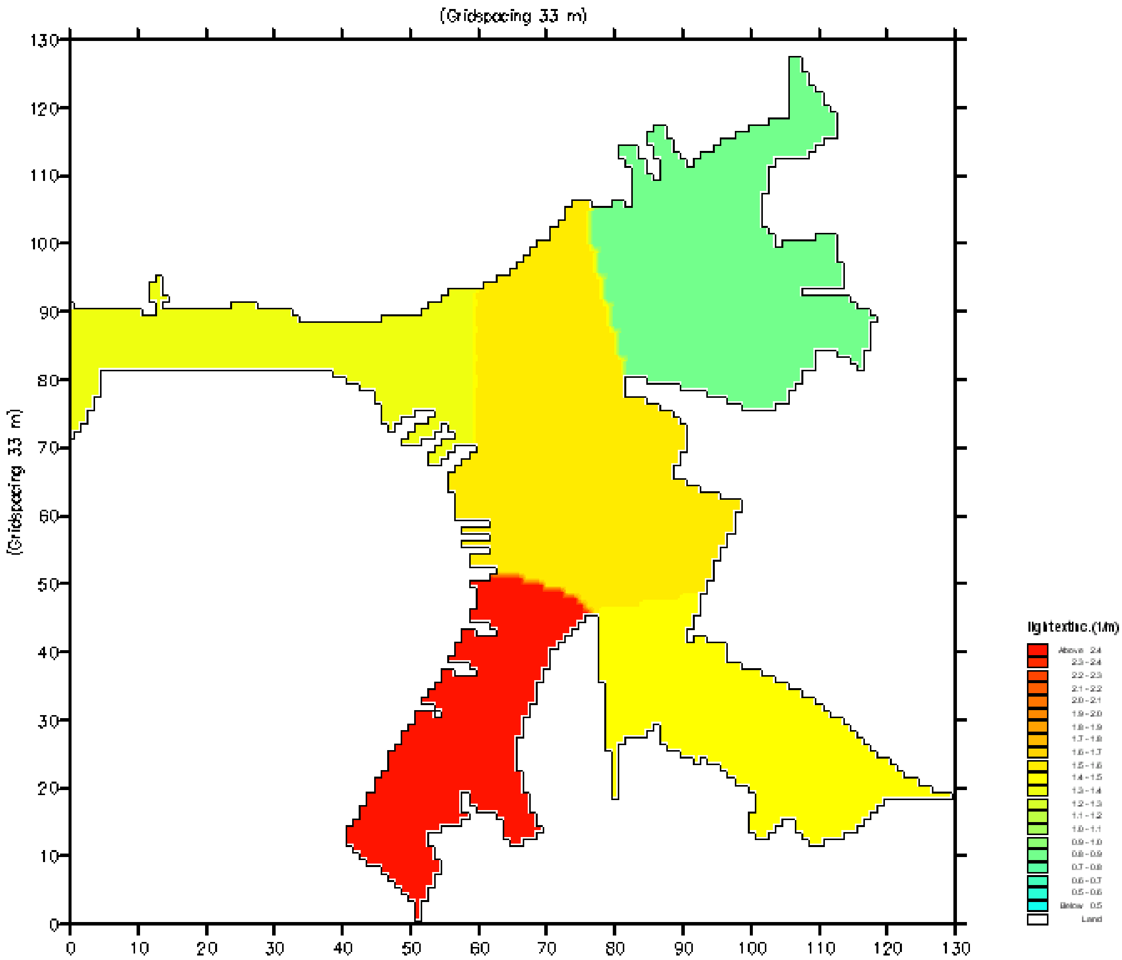
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.76 Simulation Results of the Currents in Havana Bay (The Second Layer) for Case MP-alt
JAPAN INTERNATIONAL COOPERATION AGENCY	



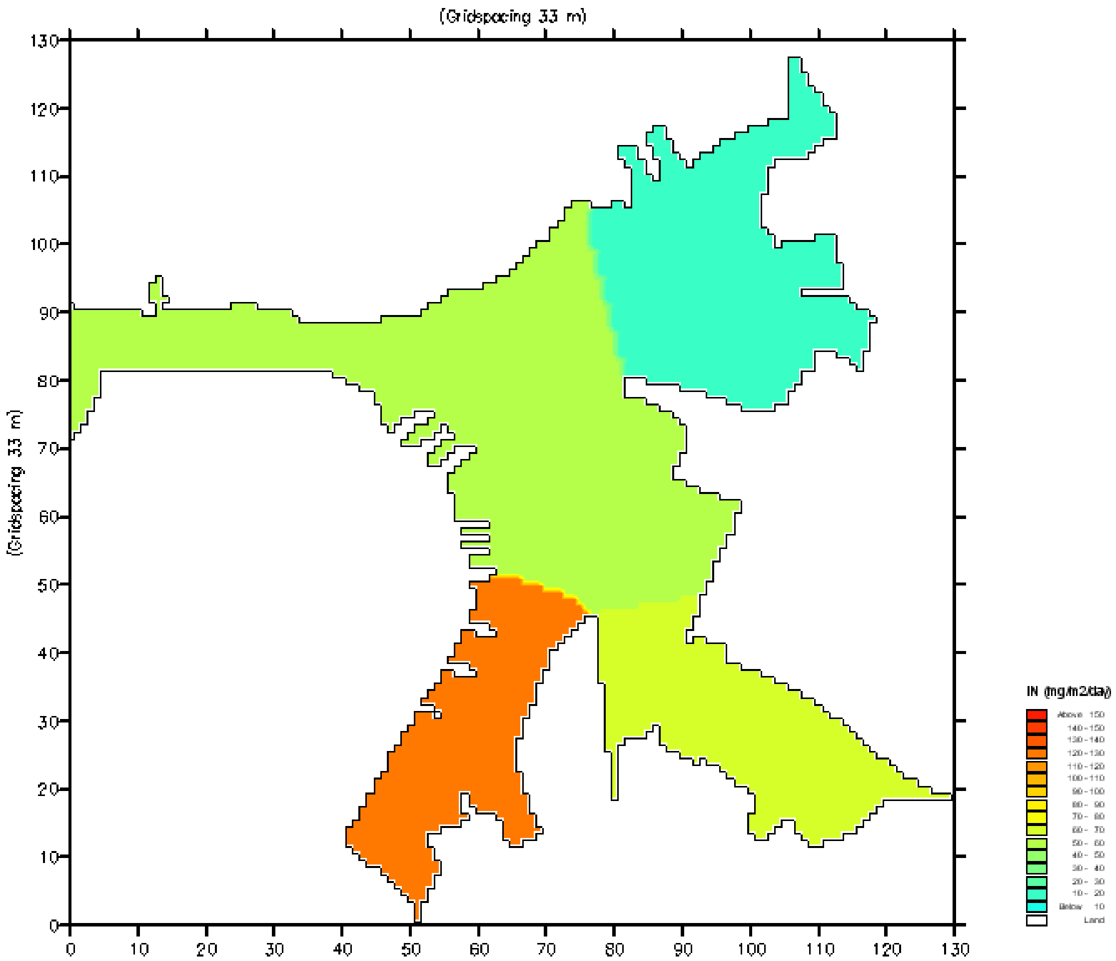
THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

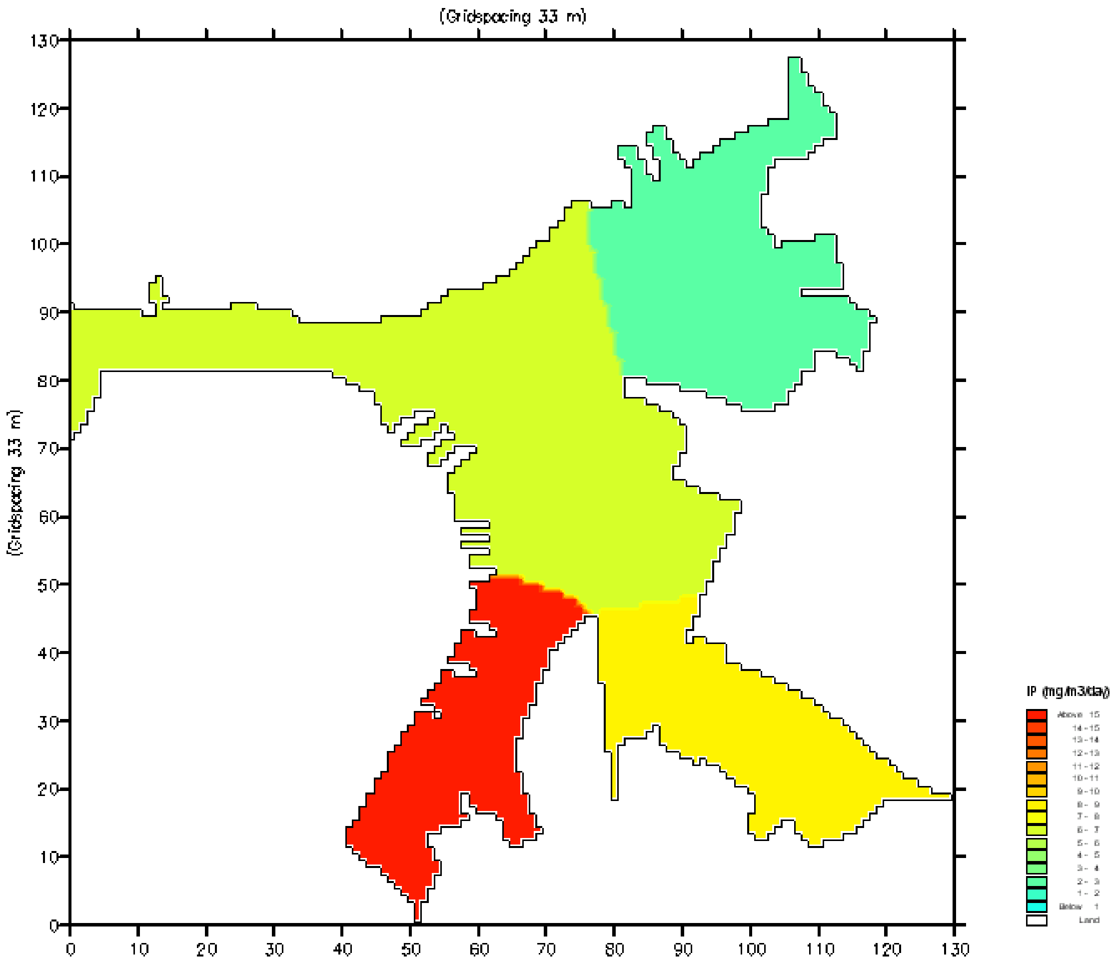
Figure A7.77
Simulation Results of the Currents in Havana Bay (The Second Layer) for Case MP-alt



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.78 Distribution of Light Extinction Coefficient Used in the Water Quality Simulation of Havana Bay
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.79 Release Rate Distribution of Inorganic Nitrogen Used in the Water Quality Simulation of Havana Bay
JAPAN INTERNATIONAL COOPERATION AGENCY	



THE DEVELOPMENT STUDY ON THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A7.80 Release Rate Distribution of Phosphate Used in the Water Quality Simulation of Havana Bay
JAPAN INTERNATIONAL COOPERATION AGENCY	

Table 7.6 Estimated Pollution Load for Scenarios

Case 1 **Existing conditions**

Zone	Source (River System)	Discharged to Bay Flow	BOD$_5$	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	114,826	9,784	1,627	***732***	3,875
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	62,122	1,518	245	55	1,066
Martin Pérez-						
Tadeo	Tadeo	8,517	1,812	104	46	98
Central	Central					
San Nicholas		8,554	1,320	145	79	352
Matadero		77,760	8,942	***610***	1,053	3,650
Agua Dulce		43,200	6,770	***529***	1,171	3,242
Refinery		*6,406*	*21,723*	*54*	*1*	
Total		321,385	51,869	3,314	3,137	12,283

Case 2 Future (2020) without M/P, with treatment at GEF Zone 6, UNDP Zo

Zone	Source (River System)	Discharged to Bay Flow	BOD$_5$	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	196,837	15,050	2,156	1,015	12,728
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	84,328	7,035	1,344	307	9,784
Martin Pérez-						
Tadeo	Tadeo	10,635	1,742	307	76	1,754
Central	Central					
San Nicholas		8,554	1,320	145	79	352
Matadero		77,760	8,942	610	1,053	3,650
Agua Dulce						
Refinery		*6,406*	*21,723*	*54*	*1*	
Total		384,519	55,811	4,616	2,531	28,267

Case 3 Case 2 + Complete Diversion of Dry Weather Flow of Arroyo Matad

Zone	Source (River System)	Discharged to Bay Flow	BOD$_5$	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	196,837	15,050	2,156	1,015	12,728
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	84,328	4,908	1,284	292	7,657
Martin Pérez-						
Tadeo	Tadeo	10,635	208	262	65	220
Central	Central					
San Nicholas		8,554	1,320	145	79	352
Matadero						
Agua Dulce						
Refinery		*6,406*	*21,723*	*54*	*1*	
Total		306,759	43,209	3,902	1,451	20,957

Case 4 Secondary treatment +Improved Existing System

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	153,637	1,838	1,755	449	2,872
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	84,328	906	1,167	263	3,655
Martin Pérez-						
Tadeo	Tadeo	10,635	208	262	65	220
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		*6,406*	*21,723*	*54*	*1*	*0*
Total		255,005	24,676	3,238	778	6,746

Case 5 Primary treatment +Improved Existing System

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	153,637	8,446	1,755	449	8,158
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	84,328	4,736	1,167	263	6,719
Martin Pérez-						
Tadeo	Tadeo	10,635	1,167	262	65	987
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		*6,406*	*21,723*	*54*	*1*	*0*
Total		255,005	36,073	3,238	778	15,864

Case 6 Advanced Treatment +Improved Existing System

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	153,637	1,178	753	138	2,211
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	84,328	523	576	84	3,272
Martin Pérez-						
Tadeo	Tadeo	10,635	113	114	20	124
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		*6,406*	*21,723*	*54*	*1*	*0*
Total		255,005	23,536	1,497	243	5,607

Case 7 MarineDischarge of all Wastewater

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	86,120	517	52	8	1,550
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	46,592	140	163	9	2,889
Martin Pérez-						
Tadeo	Tadeo	1,283	17	10	2	28
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		*6,406*	*21,723*	*54*	*1*	*0*
Total		140,400	22,396	279	20	4,467

Case 8 50% Reduction in Refinery Load + Case 4

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	153,637	1,838	1,755	449	2,872
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	84,328	906	1,167	263	3,655
Martin Pérez-						
Tadeo	Tadeo	10,635	208	262	65	220
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		6,406	10,862	27	1	
Total		255,005	13,814	3,211	777	6,746

Case 9 50% Reduction in Internal Sediment Load + Case 4

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	153,637	1,838	1,755	449	2,872
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	84,328	906	1,167	263	3,655
Martin Pérez-						
Tadeo	Tadeo	10,635	208	262	65	220
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		6,406	21,723	54	1	
Total		255,005	24,676	3,238	778	6,746

Case MP Luyano WWTP (821 L/s)

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	167,123	5,840	2,191	562	6,873
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	70,842	5,143	942	204	7,892
Martin Pérez-						
Tadeo	Tadeo	10,635	1,934	307	76	1,945
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		6,406	21,723	54	1	
Total		255,005	34,639	3,493	842	16,710
			10,551	**267**	**69**	**10,551**

Case MP-alt Luyano WWTP (407 L/s) + Diversion of Luyano Left Bank

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	133,902	5,188	1,349	344	6,221
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	70,842	5,143	942	204	7,892
Martin Pérez-						
Tadeo	Tadeo	10,635	1,934	307	76	1,945
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		6,406	21,723	54	1	
Total		221,784	33,987	2,652	625	16,058

Case F/S ***Priority Project***

Zone	Source (River System)	Discharged to Bay				
		Flow	BOD_5	T-N	T-P	SS
		m3/d	kg/d	kg/d	kg/d	kg/d
Luyanó-abajo	Luyanó	210,323	16,302	2,641	1,336	13,808
Luyanó-arriba						
Martin Pérez-abajo	Martin Pérez	70,842	5,143	942	204	7,892
Martin Pérez-						
Tadeo	Tadeo	10,635	1,934	307	76	1,945
Central	Central					
San Nicholas						
Matadero						
Agua Dulce						
Refinery		*6,406*	*21,723*	*54*	*1*	*0*
Total		298,205	45,102	3,943	1,617	23,645

APPENDIX-8

SEWERAGE PLANNING FRAMEWORK

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A8.1 PROJECTED POPULATION

The following tables and figure are supporting data of 11.3 Population (Main Report, Master Plan).

Table A8. 1 Population in the Havana Basin estimated based on the previous study

Municipality related Havana Basin	1996 Municipality Population	1996 Population within Basin	Population ratio	2001 Municipality Population	Population in Basin 2001	**Population in Basin 2001**
	person	person	%	person	person	**person**
Plaza de la revolucion	172,064	9,395	5.460%	172,045	9,394	**9,400**
Centro habana	165,058	86,106	52.17%	150,877	78,708	**78,700**
Habana vieja	102,831	105,178	100.00%	94,966	94,966	**95,000**
Regla	42,032	41,798	99.44%	42,390	42,154	**42,200**
La habana del este	180,308	15,025	8.33%	185,468	15,455	**15,500**
Guanabacoa	106,015	24,354	22.97%	106,374	24,436	**24,400**
San miguel del padron	155,436	145,880	93.85%	154,323	144,835	**144,800**
Diez de octubre	240,713	239,768	99.61%	229,626	228,725	**228,700**
Cerro	138,506	97,507	70.40%	135,261	95,223	**95,200**
Arroyo naranjo	195,954	31,087	15.86%	199,720	31,684	**31,700**
Total	**1,498,917**	**796,098**		**1,471,050**	**765,580**	**765,600**

Table A8. 2 Projection of Future Population in the municipality related to Havana Bay

Municipality related Havana Basin	*** 1996**	**2001**	**2005**	**2010**	**2015**	**Design population in 2020**
	person	person	person	person	person	**person**
Plaza de la revolucion	172,064	172,045	172,500	173,000	173,500	**174,000**
Centro habana	165,058	150,877	149,200	147,100	145,100	**143,000**
Habana vieja	102,831	94,966	94,300	93,600	92,800	**92,000**
Regla	42,032	42,390	43,400	44,600	45,800	**47,000**
La habana del este	180,308	185,468	197,600	212,700	227,900	**243,000**
Guanabacoa	106,015	106,374	110,700	116,100	121,600	**127,000**
San miguel del padron	155,436	154,323	159,500	166,000	172,500	**179,000**
Diez de octubre	240,713	229,626	228,900	227,900	227,000	**226,000**
Cerro	138,506	135,261	136,300	137,500	138,800	**140,000**
Arroyo naranjo	195,954	199,720	204,800	211,200	217,600	**224,000**
Total	1,498,917	1,471,050	1,497,200	1,529,700	1,562,600	**1,595,000**

Table A8. 3 Projected Year 2020 Population within Havana Bay Basin

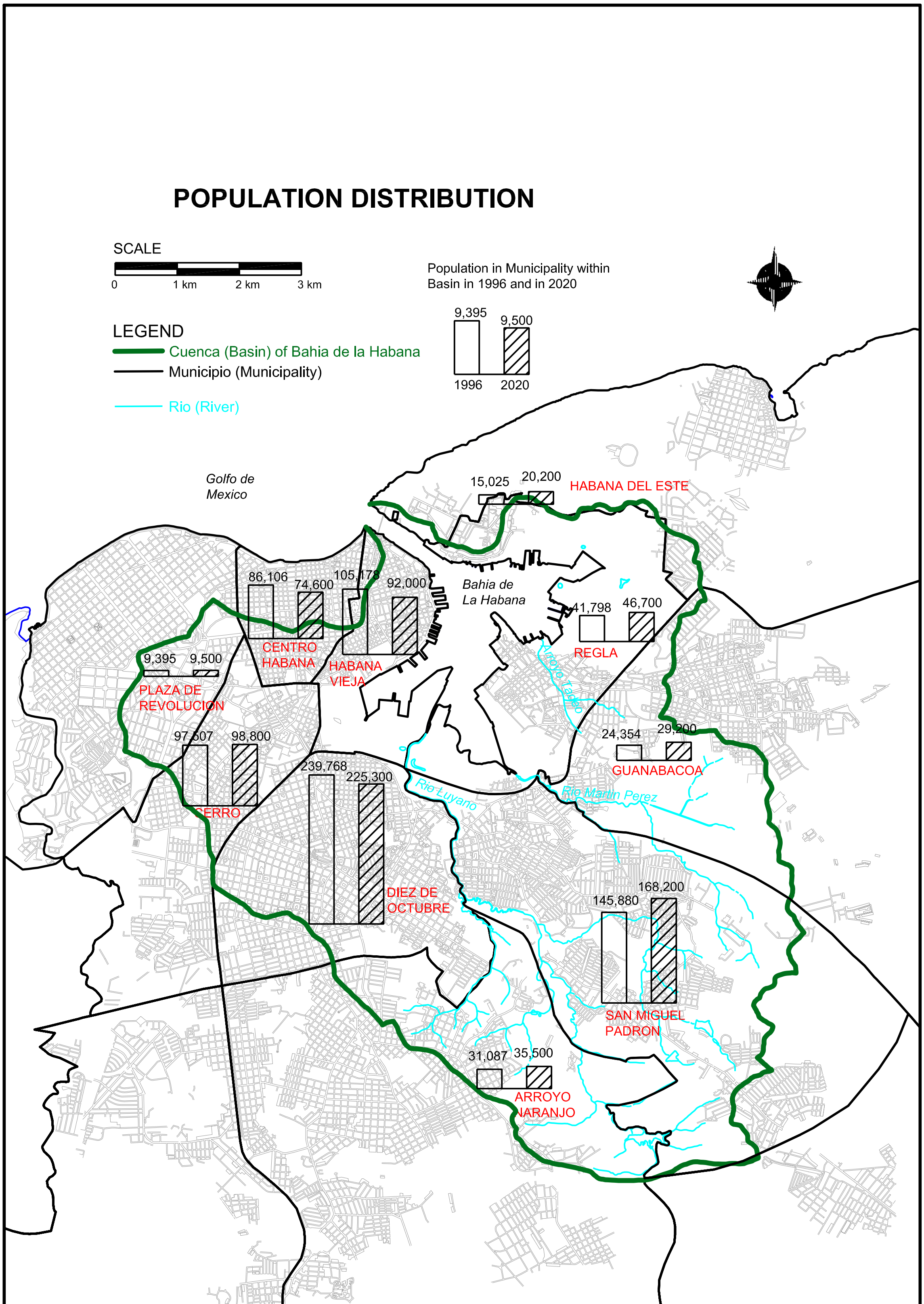
Municipality related Havana Basin	Population in each Municipality in 2020	Ratio between in and out with the Study Area	Caliculated Population in The Study Area	*Population in the Study Area in 1996	**Design population in 2020**
	person	%	person	person	**person**
Plaza de la revolucion	174,000	5.46	9,500	9,395	**9,500**
Centro habana	143,000	52.17	74,600	86,106	**74,600**
Habana vieja	92,000	100.00	92,000	105,178	**92,000**
Regla	47,000	99.44	46,700	41,798	**46,700**
La habana del este	243,000	8.33	20,200	15,025	**20,200**
Guanabacoa	127,000	22.97	29,200	24,354	**29,200**
San miguel del padron	179,000	93.85	168,000	145,880	**168,200**
Diez de octubre	226,000	99.61	225,100	239,768	**225,300**
Cerro	140,000	70.40	98,600	97,507	**98,800**
Arroyo naranjo	224,000	15.86	35,500	31,087	**35,500**
Total	**1,595,000**		**799,400**	**796,098**	**800,000**

*:**Estudio de Diagnostico sobre Asentamiento Humano en la Cuenca Bahia dela Habana**

Table A8. 4 Projected Future Population within Havana Bay up to the year 2020

Municipality related Havana Basin	*** 1996**	**2001**	**2005**	**2010**	**2015**	**2020**
Plaza de la revolucion	9,395	9,400	9,400	9,400	9,500	**9,500**
Centro habana	86,106	78,700	77,800	76,800	75,700	**74,600**
Habana vieja	105,178	95,000	94,400	93,600	92,800	**92,000**
Regla	41,798	42,200	43,100	44,300	45,500	**46,700**
La habana del este	15,025	15,500	16,500	17,700	19,000	**20,200**
Guanabacoa	24,354	24,400	25,400	26,700	27,900	**29,200**
San miguel del padron	145,880	144,800	149,700	155,900	162,000	**168,200**
Diez de octubre	239,768	228,700	228,000	227,100	226,200	**225,300**
Cerro	97,507	95,200	96,000	96,900	97,900	**98,800**
Arroyo naranjo	31,087	31,700	32,500	33,500	34,500	**35,500**
Total	796,098	765,600	772,800	781,900	791,000	**800,000**

*:**Estudio de Diagnostico sobre Asentamiento Humano en la Cuenca Bahia dela Habana**



THE DEVELOPMENT STUDY OF THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY	Figure A8.1 Projected Population by Municipality
JAPAN INTERNATIONAL COOPERATION AGENCY	

A8.2 DESIGN WASTEWATER FLOW

The following tables and figure are supporting data of 11.4 Wastewater Generation (Main Report, Master Plan).

Table A8. 5 Design Flow Calculation (2001)

Sewerage System	Treatment District	District	Area	Population	Per Capita Domestic Wastewater Generation	Domestic Wastewater	Per Capita Non-Domestic by Small Consumer	Non Domestic Wastewater by small consumer	Non-Domestic Wastewater by large consumer	Overall Wastewater Generation	Infiltration & Inflow Rate per Capita	Infiltration & Inflow	Overall Average Daily Flow		Overall Maximum Daily Flow = 1.2 x Wastewater Generation + Infiltration and Inflow		Peaking Factor by M Harmon Equation	Overall Maximum Hourly Flow = Peaking Factor x Wastewater Generation + Infiltration and Inflow		Overall Equivalent Population
			ha	person	lpcd	m^3/d	lpcd	m^3/d	m^3/d	m^3/d	lpcd	m^3/d	m^3/d	m^3/s	m^3/d	m^3/s	(-)	m^3/d	m^3/s	person
New Sewerage Development Area	1AB	A1	123.0	9,300	168	1,562	110	1,023	246	2,831	20	186	3,017	0.035	3,583	0.041	2.947	8,529	0.099	10,185
		A2	89.1	18,800	168	3,158	110	2,068	201	5,427	20	376	5,803	0.067	6,888	0.080	2.663	14,828	0.172	19,523
		A3	107.0	3,900	168	655	110	429		1,084	20	78	1,162	0.013	1,379	0.016	3.343	3,702	0.043	3,900
		A4	206.0	26,200	168	4,402	110	2,882		7,284	20	524	7,808	0.090	9,265	0.107	2.535	18,989	0.220	26,200
		A5	153.6	33,400	168	5,611	110	3,674	754	10,039	20	668	10,707	0.124	12,715	0.147	2.399	24,752	0.286	36,112
		B1	252.6	19,200	168	3,226	110	2,112	178	5,516	20	384	5,900	0.068	7,003	0.081	2.656	15,034	0.174	19,840
		B2	47.2	3,900	168	655	110	429	130	1,214	20	78	1,292	0.015	1,535	0.018	3.299	4,083	0.047	4,368
		B3	103.9	8,600	168	1,445	110	946		2,391	20	172	2,563	0.030	3,041	0.035	3.019	7,390	0.086	8,600
	Total	Zone 1	1,082.4	123,300		20,714		13,563	1,509	35,786		2,466	38,252	0.443	45,409	0.526	1.912	70,889	0.820	128,728
	2C	C1	175.0	13,500	168	2,268	110	1,485	119	3,872	20	270	4,142	0.048	4,916	0.057	2.811	11,154	0.129	13,928
		C2	54.8	4,300	168	722	110	473		1,195	20	86	1,281	0.015	1,520	0.018	3.305	4,035	0.047	4,300
		C3	76.3	5,900	168	991	110	649		1,640	20	118	1,758	0.020	2,086	0.024	3.178	5,330	0.062	5,900
		C4	105.5	8,200	168	1,378	110	902		2,280	20	164	2,444	0.028	2,900	0.034	3.040	7,095	0.082	8,200
		C5	68.7	5,400	168	907	110	594		1,501	20	108	1,609	0.019	1,909	0.022	3.214	4,932	0.057	5,400
		C6	154.6	11,200	168	1,882	110	1,232	55	3,169	20	224	3,393	0.039	4,027	0.047	2.898	9,408	0.109	11,398
		C7	131.7	4,900	168	823	110	539		1,362	20	98	1,460	0.017	1,732	0.020	3.253	4,529	0.052	4,900
	Total	Zone 2	766.6	53,400		8,971		5,874	174	15,019		1,068	16,087	0.186	19,090	0.221	2.233	34,605	0.401	54,026
	3D	D1	239.2	18,500	168	3,108	110	2,035	100	5,243	20	370	5,613	0.065	6,662	0.077	2.678	14,411	0.167	18,860
		D2	64.7	5,000	168	840	110	550		1,390	20	100	1,490	0.017	1,768	0.020	3.245	4,611	0.053	5,000
		D3	110.5	8,600	168	1,445	110	946		2,391	20	172	2,563	0.030	3,041	0.035	3.019	7,390	0.086	8,600
		D4	356.4	12,300	168	2,066	110	1,353	6,400	9,819	20	246	10,065	0.116	12,029	0.139	2.408	23,890	0.277	35,322
	Total	Zone 3	770.8	44,400		7,459		4,884	6,500	18,843		888	19,731	0.228	23,500	0.272	2.144	41,287	0.478	67,782
	4E	E1	148.1	11,900	168	1,999	110	1,309	576	3,884	20	238	4,122	0.048	4,899	0.057	2.809	11,148	0.129	13,972
		E2	265.0	9,300	168	1,562	110	1,023		2,585	20	186	2,771	0.032	3,288	0.038	2.986	7,905	0.091	9,300
		E3	18.9	1,600	168	269	110	176		445	20	32	477	0.006	566	0.007	3.659	1,660	0.019	1,600
		E4	113.3	8,300	168	1,394	110	913	332	2,639	20	166	2,805	0.032	3,333	0.039	2.977	8,022	0.093	9,494
	Total	Zone 4	545.3	31,100		5,224		3,421	908	9,553		622	10,175	0.118	12,086	0.140	2.420	23,740	0.275	34,366
	5F	F1	278.2	18,100	168	3,041	110	1,991	1,452	6,484	20	362	6,846	0.079	8,143	0.094	2.586	17,130	0.198	23,323
	Total	Zone 5	278.2	18,100		3,041		1,991	1,452	6,484		362	6,846	0.079	8,143	0.094	2.586	17,130	0.198	23,323
	Grand total	Integrated	3,443.3	270,300		45,409		29,733	10,543	85,685		5,406	91,091	1.054	108,228	1.253	1.649	146,701	1.698	308,225
Central System	Existing Area	S1	493.2	110,100	168	18,497	110	12,111	1,601	32,209	40	4,404	36,613	0.424	43,055	0.498	1.948	67,147	0.777	115,859
		S3	241.3	53,000	168	8,904	110	5,830		14,734	40	2,120	16,854	0.195	19,801	0.229	2.241	35,139	0.407	53,000
		S2	233.0	31,300	168	5,258	110	3,443	2,100	10,801	40	1,252	12,053	0.140	14,213	0.165	2.368	26,829	0.311	38,854
		SS1	57.1	17,100	168	2,873	110	1,881	259	5,013	40	684	5,697	0.066	6,700	0.078	2.698	14,209	0.164	18,032
		H1	176.3	37,600	168	6,317	110	4,136	1,081	11,534	40	1,504	13,038	0.151	15,345	0.178	2.341	28,505	0.330	41,488
		CE1	328.6	46,800	168	7,862	110	5,148	3,089	16,099	40	1,872	17,971	0.208	21,191	0.245	2.206	37,386	0.433	57,912
		CE2	68.1	26,100	168	4,385	110	2,871		7,256	40	1,044	8,300	0.096	9,751	0.113	2.537	19,452	0.225	26,100
		SS2	130.3	53,700	168	9,022	110	5,907	1,293	16,222	40	2,148	18,370	0.213	21,614	0.250	2.203	37,885	0.438	58,351
		SS3	84.7	25,400	168	4,267	110	2,794		7,061	40	1,016	8,077	0.093	9,489	0.110	2.549	19,014	0.220	25,400
		Total	1,812.6	401,100		67,385		44,121	9,423	120,929		16,044	136,973	1.585	161,159	1.865	1.563	205,056	2.373	434,996
	to Collector Sur		1,812.6	401,100		67,385		44,121	9,423	120,929		16,044	136,973	1.585	161,159	1.865	1.563	205,056	2.373	434,996
	within Study Area	N1+N2	110.3	25,600	168	4,301	110	2,816		7,117	40	1,024	8,141	0.094	9,564	0.111	2.545	19,137	0.221	25,600
	Out of Study Area	Norte	766.9	159,100	168	26,729	110	17,501	7,837	52,067	40	6,364	58,431	0.676	68,844	0.797	1.792	99,668	1.154	187,291
	to Siphon		2,689.8	585,800		98,415		64,438	17,260	180,113		23,432	203,545	2.356	239,567	2.773	1.475	289,099	3.346	647,887
	Connect to Casablanca PS	Casablanca	299.1	6,500	168	1,092	110	715	954	2,761	20	130	2,891	0.033	3,443	0.040	2.958	8,297	0.096	9,932
	to PS and Tunnel		2,988.9	592,300		99,507		65,153	18,214	182,874		23,562	206,436	2.389	243,010	2.813	1.472	292,753	3.388	657,819
within the Study Area			5,665.3	703,500		118,187		77,385	20,920	216,492		22,604	239,096	2.767	282,394	3.268		379,191	4.389	
from out of the Study Area			766.9	159,100		26,729		17,501	7,837	52,067		6,364	58,431	0.676	68,844	0.797		99,668	1.154	
Sewerage System Total			6,432.2	862,600		144,916		94,886	28,757	268,559		28,968	297,527	3.444	351,238	4.065		439,454	5.086	
Cojimal	Connect to Cojimal Zone	Cojimal	97.1	14,900	168	2,503	110	1,639		4,142										
Indipendent	Factory	Industry	235.6	0	168	0	110	0	6,406	6,406										
Sanitation		Fosa	851.0	47,400	168	7,963	110	5,214		13,177										
Not covered by the sewerage			1,183.7	62,300		10,466		6,853	6,406	23,725										
Study Area Total			6,849.0	765,800		128,653		84,238	27,326	240,217										
Grand Total			7,615.9	924,900		155,382		101,739	35,163	292,284										

Table A8. 6 Design Flow Calculation (2005)

Sewerage System	Treatment District	District	Area	Population	Per Capita Domestic Wastewater Generation	Domestic Wastewater	Per Capita Non-Domestic by Small Consumer	Non Domestic Wastewater by small consumer	Non-Domestic Wastewater by large consumer	Overall Wastewater Generation	Infiltration & Inflow Rate per Capita	Infiltration & Inflow	Overall Average Daily Flow		Overall Maximum Daily Flow = 1.2 x Wastewater Generation + Infiltration and Inflow		Peaking Factor by M Harmon Equation	Overall Maximum Hourly Flow = Peaking Factor x Wastewater Generation + Infiltration and Inflow		Overall Equivalent Population
			ha	person	lpcd	m^3/d	lpcd	m^3/d	m^3/d	m^3/d	lpcd	m^3/d	m^3/d	m^3/s	m^3/d	m^3/s	(-)	m^3/d	m^3/s	person
New Sewerage Development Area	1AB	A1	123.0	9,400	168	1,579	120	1,128	246	2,953	20	188	3,141	0.036	3,732	0.043	2.944	8,882	0.103	10,254
		A2	89.1	18,700	168	3,142	120	2,244	221	5,607	20	374	5,981	0.069	7,102	0.082	2.664	15,311	0.177	19,467
		A3	107.0	4,000	168	672	120	480		1,152	20	80	1,232	0.014	1,462	0.017	3.333	3,920	0.045	4,000
		A4	206.0	26,200	168	4,402	120	3,144		7,546	20	524	8,070	0.093	9,579	0.111	2.535	19,653	0.227	26,200
		A5	153.6	33,300	168	5,594	120	3,996	829	10,419	20	666	11,085	0.128	13,169	0.152	2.398	25,651	0.297	36,178
		B1	252.6	19,900	168	3,343	120	2,388	195	5,926	20	398	6,324	0.073	7,509	0.087	2.640	16,043	0.186	20,577
		B2	47.2	4,000	168	672	120	480	143	1,295	20	80	1,375	0.016	1,634	0.019	3.287	4,337	0.050	4,497
		B3	103.9	8,800	168	1,478	120	1,056		2,534	20	176	2,710	0.031	3,217	0.037	3.010	7,803	0.090	8,800
	Total	**Zone 1**	**1,082.4**	**124,300**		**20,882**		**14,916**	**1,634**	**37,432**		**2,486**	**39,918**	**0.462**	**47,404**	**0.549**	**1.909**	**73,944**	**0.856**	**129,973**
	2C	C1	175.0	14,000	168	2,352	120	1,680	119	4,151	20	280	4,431	0.051	5,261	0.061	2.796	11,886	0.138	14,413
		C2	54.8	4,400	168	739	120	528		1,267	20	88	1,355	0.016	1,608	0.019	3.296	4,264	0.049	4,400
		C3	76.3	6,100	168	1,025	120	732		1,757	20	122	1,879	0.022	2,230	0.026	3.164	5,681	0.066	6,100
		C4	105.5	8,500	168	1,428	120	1,020		2,448	20	170	2,618	0.030	3,108	0.036	3.024	7,573	0.088	8,500
		C5	68.7	5,500	168	924	120	660		1,584	20	110	1,694	0.020	2,011	0.023	3.206	5,188	0.060	5,500
		C6	154.6	11,600	168	1,949	120	1,392	61	3,402	20	232	3,634	0.042	4,314	0.050	2.883	10,040	0.116	11,812
		C7	131.7	5,000	168	840	120	600		1,440	20	100	1,540	0.018	1,828	0.021	3.245	4,773	0.055	5,000
	Total	**Zone 2**	**766.6**	**55,100**		**9,257**		**6,612**	**180**	**16,049**		**1,102**	**17,151**	**0.199**	**20,360**	**0.236**	**2.221**	**36,747**	**0.425**	**55,725**
	3D	D1	239.2	19,100	168	3,209	120	2,292	100	5,601	20	382	5,983	0.069	7,103	0.082	2.665	15,309	0.177	19,447
		D2	64.7	5,200	168	874	120	624		1,498	20	104	1,602	0.019	1,902	0.022	3.229	4,941	0.057	5,200
		D3	110.5	8,900	168	1,495	120	1,068		2,563	20	178	2,741	0.032	3,254	0.038	3.005	7,880	0.091	8,900
		D4	356.4	12,800	168	2,150	120	1,536	6,400	10,086	20	256	10,342	0.120	12,359	0.143	2.412	24,583	0.285	35,022
	Total	**Zone 3**	**770.8**	**46,000**		**7,728**		**5,520**	**6,500**	**19,748**		**920**	**20,668**	**0.239**	**24,618**	**0.285**	**2.140**	**43,181**	**0.500**	**68,569**
	4E	E1	148.1	12,200	168	2,050	120	1,464	634	4,148	20	244	4,392	0.051	5,222	0.060	2.796	11,842	0.137	14,401
		E2	265.0	9,600	168	1,613	120	1,152		2,765	20	192	2,957	0.034	3,510	0.041	2.972	8,410	0.097	9,600
		E3	18.9	1,600	168	269	120	192		461	20	32	493	0.006	585	0.007	3.659	1,719	0.020	1,600
		E4	113.3	8,600	168	1,445	120	1,032	332	2,809	20	172	2,981	0.035	3,543	0.041	2.965	8,501	0.098	9,753
	Total	**Zone 4**	**545.3**	**32,000**		**5,377**		**3,840**	**966**	**10,183**		**640**	**10,823**	**0.125**	**12,860**	**0.149**	**2.408**	**25,161**	**0.291**	**35,354**
	5F	F1	278.2	18,600	168	3,125	120	2,232	1,584	6,941	20	372	7,313	0.085	8,701	0.101	2.571	18,217	0.211	24,100
	Total	**Zone 5**	**278.2**	**18,600**		**3,125**		**2,232**	**1,584**	**6,941**		**372**	**7,313**	**0.085**	**8,701**	**0.101**	**2.571**	**18,217**	**0.211**	**24,100**
	Grand total	**Integrated**	**3,443.3**	**276,000**		**46,369**		**33,120**	**10,864**	**90,353**		**5,520**	**95,873**	**1.110**	**113,943**	**1.319**	**1.645**	**154,151**	**1.784**	**313,721**
Central System	Existing Area	S1	493.2	110,100	168	18,497	120	13,212	1,601	33,310	40	4,404	37,714	0.437	44,376	0.514	1.949	69,325	0.802	115,659
		S3	241.3	52,900	168	8,887	120	6,348		15,235	40	2,116	17,351	0.201	20,398	0.236	2.242	36,273	0.420	52,900
		S2	233.0	31,200	168	5,242	120	3,744	2,100	11,086	40	1,248	12,334	0.143	14,551	0.168	2.372	27,544	0.319	38,492
		SS1	57.1	17,000	168	2,856	120	2,040	259	5,155	40	680	5,835	0.068	6,866	0.079	2.701	14,604	0.169	17,899
		H1	176.3	37,600	168	6,317	120	4,512	1,081	11,910	40	1,504	13,414	0.155	15,796	0.183	2.342	29,397	0.340	41,353
		CE1	328.6	47,200	168	7,930	120	5,664	3,089	16,683	40	1,888	18,571	0.215	21,908	0.254	2.206	38,691	0.448	57,926
		CE2	68.1	26,100	168	4,385	120	3,132		7,517	40	1,044	8,561	0.099	10,064	0.116	2.537	20,115	0.233	26,100
		SS2	130.3	53,300	168	8,954	120	6,396	1,293	16,643	40	2,132	18,775	0.217	22,104	0.256	2.207	38,863	0.450	57,790
		SS3	84.7	25,200	168	4,234	120	3,024		7,258	40	1,008	8,266	0.096	9,718	0.112	2.552	19,530	0.226	25,200
		Total	**1,812.6**	**400,600**		**67,302**		**48,072**	**9,423**	**124,797**		**16,024**	**140,821**	**1.630**	**165,781**	**1.919**	**1.564**	**211,207**	**2.445**	**433,319**
	to Collector Sur		**1,812.6**	**400,600**		**67,302**		**48,072**	**9,423**	**124,797**		**16,024**	**140,821**	**1.630**	**165,781**	**1.919**	**1.564**	**211,207**	**2.445**	**433,319**
	within Study Area	N1+N2	110.3	25,400	168	4,267	120	3,048		7,315	40	1,016	8,331	0.096	9,794	0.113	2.549	19,662	0.228	25,400
	Out of Study Area	***Norte***	766.9	159,100	168	**26,729**	120	**19,092**	**7,837**	**53,658**	40	**6,364**	**60,022**	**0.695**	**70,754**	**0.819**	**1.793**	**102,573**	**1.187**	**186,312**
	to Siphon		***2,689.8***	***585,100***		**98,298**		**70,212**	**17,260**	**185,770**		**23,404**	**209,174**	**2.421**	**246,329**	**2.851**	**1.476**	**297,601**	**3.444**	***645,031***
	Connect to Casablanca PS	Casablanca	299.1	6,600	168	1,109	120	792	954	2,855	20	132	2,987	0.035	3,558	0.041	2.958	8,577	0.099	9,913
	to PS and Tunnel		***2,988.9***	***591,700***		***99,407***		***71,004***	***18,214***	***188,625***		***23,536***	***212,161***	***2.456***	***249,887***	***2.892***	***1.473***	***301,381***	***3.488***	***654,944***
within the Study Area			*5,665.3*	*708,600*		*119,047*		*85,032*	*21,241*	*225,320*		*22,692*	*248,012*	*2.871*	*293,076*	*3.392*		*393,597*	*4.556*	
from out of the Study Area			*766.9*	*159,100*		*26,729*		*19,092*	*7,837*	*53,658*		*6,364*	*60,022*	*0.695*	*70,754*	*0.819*		*102,573*	*1.187*	
Sewerage System Total			*6,432.2*	***867,700***		***145,776***		***104,124***	***29,078***	***278,978***		***29,056***	***308,034***	***3.565***	***363,830***	***4.211***		***455,532***	***5.272***	
Cojimal	Connect to Cojimal Zone	Cojimal	97.1	16,000	168	2,688	120	1,920		4,608										
Indipendent	Factory	Industry	235.6	0	168	0	120	0	6,406	6,406										
Sanitation		Fosa	851.0	48,900	168	8,215	120	5,868		14,083										
Not covered by the sewerage			**1,183.7**	**64,900**		**10,903**		**7,788**	**6,406**	**25,097**										
Study Area Total			**6,849.0**	**773,500**		**129,950**		**92,820**	**27,647**	**250,417**										
Grand Total			**7,615.9**	**932,600**		**156,679**		**111,912**	**35,484**	**304,075**										

Table A8. 7 Design Flow Calculation (2010)

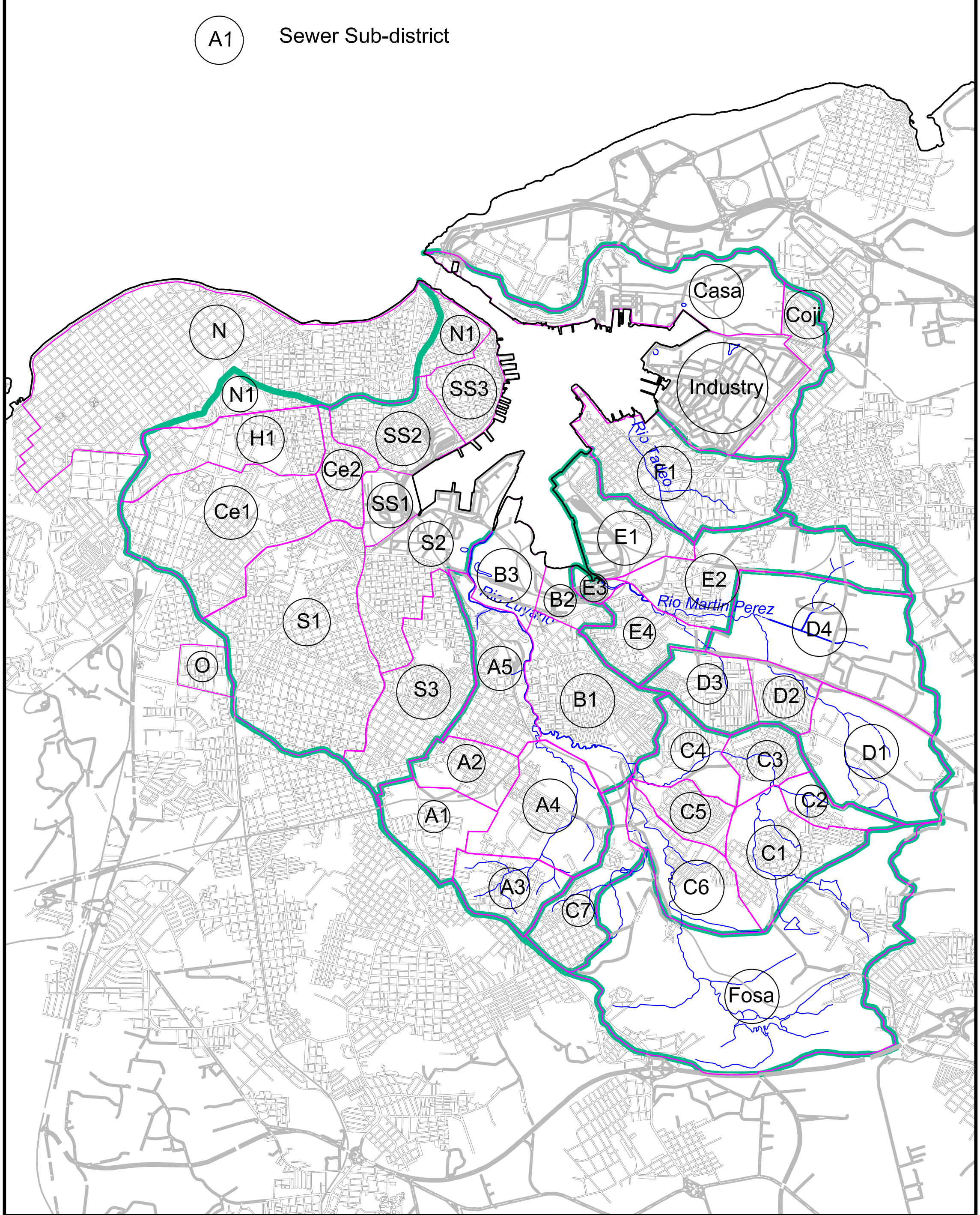
Sewerage System	Treatment District	District	Area	Population	Per Capita Domestic Wastewater Generation	Domestic Wastewater	Per Capita Non-Domestic by Small Consumer	Non Domestic Wastewater by small consumer	Non-Domestic Wastewater by large consumer	Overall Wastewater Generation	Infiltration & Inflow Rate per Capita	Infiltration & Inflow	Overall Average Daily Flow		Overall Maximum Daily Flow = 1.2 x Wastewater Generation + Infiltration and Inflow		Peaking Factor by M Harmon Equation	Overall Maximum Hourly Flow = Peaking Factor x Wastewater Generation + Infiltration and Inflow		Overall Equivalent Population
			ha	person	lpcd	m^3/d	lpcd	m^3/d	m^3/d	m^3/d	lpcd	m^3/d	m^3/d	m^3/s	m^3/d	m^3/s	(-)	m^3/d	m^3/s	person
New Sewerage Development Area	1AB	A1	123.0	9,400	168	1,579	130	1,222	246	3,047	20	188	3,235	0.037	3,844	0.044	2.945	9,161	0.106	10,226
		A2	89.1	18,700	168	3,142	130	2,431	261	5,834	20	374	6,208	0.072	7,375	0.085	2.662	15,904	0.184	19,576
		A3	107.0	4,100	168	689	130	533		1,222	20	82	1,304	0.015	1,548	0.018	3.324	4,144	0.048	4,100
		A4	206.0	26,200	168	4,402	130	3,406		7,808	20	524	8,332	0.096	9,894	0.115	2.535	20,317	0.235	26,200
		A5	153.6	33,200	168	5,578	130	4,316	980	10,874	20	664	11,538	0.134	13,713	0.159	2.394	26,696	0.309	36,489
		B1	252.6	20,700	168	3,478	130	2,691	231	6,400	20	414	6,814	0.079	8,094	0.094	2.621	17,188	0.199	21,475
		B2	47.2	4,100	168	689	130	533	169	1,391	20	82	1,473	0.017	1,751	0.020	3.273	4,635	0.054	4,667
		B3	103.9	9,100	168	1,529	130	1,183		2,712	20	182	2,894	0.033	3,436	0.040	2.995	8,304	0.096	9,100
	Total	**Zone 1**	**1,082.4**	**125,500**		**21,086**		**16,315**	**1,887**	**39,288**		**2,510**	**41,798**	**0.484**	**49,655**	**0.575**	**1.904**	**77,314**	**0.895**	**131,833**
	2C	C1	175.0	14,600	168	2,453	130	1,898	119	4,470	20	292	4,762	0.055	5,656	0.065	2.778	12,710	0.147	14,999
		C2	54.8	4,600	168	773	130	598		1,371	20	92	1,463	0.017	1,737	0.020	3.278	4,586	0.053	4,600
		C3	76.3	6,400	168	1,075	130	832		1,907	20	128	2,035	0.024	2,416	0.028	3.144	6,124	0.071	6,400
		C4	105.5	8,800	168	1,478	130	1,144		2,622	20	176	2,798	0.032	3,322	0.038	3.010	8,068	0.093	8,800
		C5	68.7	5,800	168	974	130	754		1,728	20	116	1,844	0.021	2,190	0.025	3.185	5,620	0.065	5,800
		C6	154.6	12,100	168	2,033	130	1,573	72	3,678	20	242	3,920	0.045	4,656	0.054	2.863	10,772	0.125	12,342
		C7	131.7	5,100	168	857	130	663		1,520	20	102	1,622	0.019	1,926	0.022	3.237	5,022	0.058	5,100
	Total	**Zone 2**	**766.6**	**57,400**		**9,643**		**7,462**	**191**	**17,296**		**1,148**	**18,444**	**0.213**	**21,903**	**0.254**	**2.205**	**39,286**	**0.455**	**58,041**
	3D	D1	239.2	19,900	168	3,343	130	2,587	100	6,030	20	398	6,428	0.074	7,634	0.088	2.647	16,359	0.189	20,236
		D2	64.7	5,400	168	907	130	702		1,609	20	108	1,717	0.020	2,039	0.024	3.214	5,279	0.061	5,400
		D3	110.5	9,300	168	1,562	130	1,209		2,771	20	186	2,957	0.034	3,511	0.041	2.986	8,460	0.098	9,300
		D4	356.4	13,400	168	2,251	130	1,742	6,400	10,393	20	268	10,661	0.123	12,740	0.147	2.413	25,346	0.293	34,877
	Total	**Zone 3**	**770.8**	**48,000**		**8,063**		**6,240**	**6,500**	**20,803**		**960**	**21,763**	**0.252**	**25,924**	**0.300**	**2.133**	**45,333**	**0.525**	**69,813**
	4E	E1	148.1	12,600	168	2,117	130	1,638	749	4,504	20	252	4,756	0.055	5,657	0.065	2.775	12,751	0.148	15,113
		E2	265.0	10,100	168	1,697	130	1,313		3,010	20	202	3,212	0.037	3,814	0.044	2.950	9,082	0.105	10,100
		E3	18.9	1,700	168	286	130	221		507	20	34	541	0.006	642	0.007	3.640	1,879	0.022	1,700
		E4	113.3	9,000	168	1,512	130	1,170	332	3,014	20	180	3,194	0.037	3,797	0.044	2.950	9,071	0.105	10,114
	Total	**Zone 4**	**545.3**	**33,400**		**5,612**		**4,342**	**1,081**	**11,035**		**668**	**11,703**	**0.135**	**13,910**	**0.161**	**2.388**	**27,020**	**0.313**	**37,027**
	5F	F1	278.2	19,200	168	3,226	130	2,496	1,848	7,570	20	384	7,954	0.092	9,468	0.110	2.549	19,680	0.228	25,401
	Total	**Zone 5**	**278.2**	**19,200**		**3,226**		**2,496**	**1,848**	**7,570**		**384**	**7,954**	**0.092**	**9,468**	**0.110**	**2.549**	**19,680**	**0.228**	**25,401**
	Grand total	**Integrated**	**3,443.3**	**283,500**		**47,630**		**36,855**	**11,507**	**95,992**		**5,670**	**101,662**	**1.177**	**120,860**	**1.399**	**1.638**	**162,905**	**1.885**	**322,115**
Central System	Existing Area	S1	493.2	110,200	168	18,514	130	14,326	1,601	34,441	40	4,408	38,849	0.450	45,737	0.529	1.949	71,534	0.828	115,572
		S3	241.3	52,600	168	8,837	130	6,838		15,675	40	2,104	17,779	0.206	20,914	0.242	2.244	37,279	0.431	52,600
		S2	233.0	31,000	168	5,208	130	4,030	2,100	11,338	40	1,240	12,578	0.146	14,846	0.172	2.377	28,190	0.326	38,047
		SS1	57.1	16,800	168	2,822	130	2,184	259	5,265	40	672	5,937	0.069	6,990	0.081	2.707	14,924	0.173	17,669
		H1	176.3	37,000	168	6,216	130	4,810	1,081	12,107	40	1,480	13,587	0.157	16,008	0.185	2.350	29,931	0.346	40,628
		CE1	328.6	47,600	168	7,997	130	6,188	3,089	17,274	40	1,904	19,178	0.222	22,633	0.262	2.205	39,993	0.463	57,966
		CE2	68.1	25,800	168	4,334	130	3,354		7,688	40	1,032	8,720	0.101	10,258	0.119	2.542	20,575	0.238	25,800
		SS2	130.3	52,700	168	8,854	130	6,851	1,293	16,998	40	2,108	19,106	0.221	22,506	0.260	2.212	39,708	0.460	57,039
		SS3	84.7	25,000	168	4,200	130	3,250		7,450	40	1,000	8,450	0.098	9,940	0.115	2.556	20,042	0.232	25,000
		Total	**1,812.6**	**398,700**		**66,982**		**51,831**	**9,423**	**128,236**		**15,948**	**144,184**	**1.669**	**169,832**	**1.966**	**1.566**	**216,766**	**2.509**	**430,321**
	to Collector Sur		**1,812.6**	**398,700**		**66,982**		**51,831**	**9,423**	**128,236**		**15,948**	**144,184**	**1.669**	**169,832**	**1.966**	**1.566**	**216,766**	**2.509**	**430,321**
	within Study Area	N1+N2	110.3	25,200	168	4,234	130	3,276		7,510	40	1,008	8,518	0.099	10,020	0.116	2.552	20,174	0.233	25,200
	Out of Study Area	***Norte***	766.9	159,100	168	**26,729**	130	**20,683**	**7,837**	**55,249**	40	**6,364**	**61,613**	**0.713**	**72,663**	**0.841**	**1.795**	**105,536**	**1.221**	**185,399**
	to Siphon		***2,689.8***	***583,000***		**97,945**		**75,790**	**17,260**	**190,995**		**23,320**	**214,315**	**2.480**	**252,515**	**2.923**	**1.478**	**305,611**	**3.537**	***640,920***
	Connect to Casablanca PS	Casablanca	299.1	6,700	168	1,126	130	871	954	2,951	20	134	3,085	0.036	3,675	0.043	2.959	8,866	0.103	9,901
	to PS and Tunnel		***2,988.9***	***589,700***		***99,071***		***76,661***	***18,214***	***193,946***		***23,454***	***217,400***	***2.516***	***256,190***	***2.965***	***1.474***	***309,330***	***3.580***	***650,821***
within the Study Area			*5,665.3*	*714,100*		*119,972*		*92,833*	*21,884*	*234,689*		*22,760*	*257,449*	*2.980*	*304,387*	*3.523*		*408,711*	*4.730*	
from out of the Study Area			*766.9*	*159,100*		*26,729*		*20,683*	*7,837*	*55,249*		*6,364*	*61,613*	*0.713*	*72,663*	*0.841*		*105,536*	*1.221*	
Sewerage System Total			*6,432.2*	***873,200***		***146,701***		***113,516***	***29,721***	***289,938***		***29,124***	***319,062***	***3.693***	***377,050***	***4.364***		***472,235***	***5.466***	
Cojimal	Connect to Cojimal Zone	Cojimal	97.1	17,300	168	2,906	130	2,249		5,155										
Indipendent	Factory	Industry	235.6	0	168	0	130	0	6,406	6,406										
Sanitation		Fosa	851.0	50,800	168	8,534	130	6,604		15,138										
Not covered by the sewerage			**1,183.7**	**68,100**		**11,441**		**8,853**	**6,406**	**26,699**										
Study Area Total			**6,849.0**	**782,200**		**131,413**		**101,686**	**28,290**	**261,388**										
Grand Total			**7,615.9**	**941,300**		**158,142**		**122,369**	**36,127**	**316,637**										

Table A8. 8 Design Flow Calculation (2015)

Sewerage System	Treatment District	District	Area	Population	Per Capita Domestic Wastewater Generation	Domestic Wastewater	Per Capita Non-Domestic by Small Consumer	Non Domestic Wastewater by small consumer	Non-Domestic Wastewater by large consumer	Overall Wastewater Generation	Infiltration & Inflow Rate per Capita	Infiltration & Inflow	Overall Average Daily Flow		Overall Maximum Daily Flow = 1.2 x Wastewater Generation + Infiltration and Inflow		Peaking Factor by M Harmon Equation	Overall Maximum Hourly Flow = Peaking Factor x Wastewater Generation + Infiltration and Inflow		Overall Equivalent Population
			ha	person	lpcd	m^3/d	lpcd	m^3/d	m^3/d	m^3/d	lpcd	m^3/d	m^3/d	m^3/s	m^3/d	m^3/s	(-)	m^3/d	m^3/s	person
New Sewerage Development Area	1AB	A1	123.0	9,500	168	1,596	142	1,349	246	3,191	20	190	3,381	0.039	4,019	0.047	2.942	9,578	0.111	10,294
		A2	89.1	18,600	168	3,125	142	2,641	302	6,068	20	372	6,440	0.075	7,654	0.089	2.662	16,525	0.191	19,574
		A3	107.0	4,300	168	722	142	611		1,333	20	86	1,419	0.016	1,686	0.020	3.305	4,492	0.052	4,300
		A4	206.0	26,200	168	4,402	142	3,720		8,122	20	524	8,646	0.100	10,270	0.119	2.535	21,113	0.244	26,200
		A5	153.6	33,000	168	5,544	142	4,686	1,131	11,361	20	660	12,021	0.139	14,293	0.165	2.393	27,847	0.322	36,648
		B1	252.6	21,500	168	3,612	142	3,053	267	6,932	20	430	7,362	0.085	8,748	0.101	2.604	18,481	0.214	22,361
		B2	47.2	4,200	168	706	142	596	195	1,497	20	84	1,581	0.018	1,880	0.022	3.259	4,963	0.057	4,829
		B3	103.9	9,400	168	1,579	142	1,335		2,914	20	188	3,102	0.036	3,685	0.043	2.981	8,875	0.103	9,400
	Total	**Zone 1**	**1,082.4**	**126,700**		**21,286**		**17,991**	**2,141**	**41,418**		**2,534**	**43,952**	**0.509**	**52,235**	**0.605**	**1.900**	**81,228**	**0.940**	**133,606**
	2C	C1	175.0	15,100	168	2,537	142	2,144	119	4,800	20	302	5,102	0.059	6,062	0.070	2.764	13,569	0.157	15,484
		C2	54.8	4,800	168	806	142	682		1,488	20	96	1,584	0.018	1,882	0.022	3.261	4,948	0.057	4,800
		C3	76.3	6,600	168	1,109	142	937		2,046	20	132	2,178	0.025	2,587	0.030	3.131	6,538	0.076	6,600
		C4	105.5	9,200	168	1,546	142	1,306		2,852	20	184	3,036	0.035	3,606	0.042	2.991	8,714	0.101	9,200
		C5	68.7	6,000	168	1,008	142	852		1,860	20	120	1,980	0.023	2,352	0.027	3.171	6,018	0.070	6,000
		C6	154.6	12,600	168	2,117	142	1,789	83	3,989	20	252	4,241	0.049	5,039	0.058	2.845	11,601	0.134	12,868
		C7	131.7	5,300	168	890	142	753		1,643	20	106	1,749	0.020	2,078	0.024	3.221	5,398	0.062	5,300
	Total	**Zone 2**	**766.6**	**59,600**		**10,013**		**8,463**	**202**	**18,678**		**1,192**	**19,870**	**0.230**	**23,606**	**0.273**	**2.190**	**42,097**	**0.487**	**60,252**
	3D	D1	239.2	20,700	168	3,478	142	2,939	100	6,517	20	414	6,931	0.080	8,234	0.095	2.631	17,560	0.203	21,023
		D2	64.7	5,600	168	941	142	795		1,736	20	112	1,848	0.021	2,195	0.025	3.199	5,665	0.066	5,600
		D3	110.5	9,600	168	1,613	142	1,363		2,976	20	192	3,168	0.037	3,763	0.044	2.972	9,037	0.105	9,600
		D4	356.4	14,000	168	2,352	142	1,988	6,400	10,740	20	280	11,020	0.128	13,168	0.152	2.416	26,228	0.304	34,645
	Total	**Zone 3**	**770.8**	**49,900**		**8,384**		**7,085**	**6,500**	**21,969**		**998**	**22,967**	**0.266**	**27,360**	**0.317**	**2.127**	**47,726**	**0.552**	**70,868**
	4E	E1	148.1	12,900	168	2,167	142	1,832	864	4,863	20	258	5,121	0.059	6,094	0.071	2.759	13,675	0.158	15,687
		E2	265.0	10,500	168	1,764	142	1,491		3,255	20	210	3,465	0.040	4,116	0.048	2.934	9,760	0.113	10,500
		E3	18.9	1,700	168	286	142	241		527	20	34	561	0.006	666	0.008	3.640	1,952	0.023	1,700
		E4	113.3	9,300	168	1,562	142	1,321	332	3,215	20	186	3,401	0.039	4,044	0.047	2.939	9,635	0.112	10,371
	Total	**Zone 4**	**545.3**	**34,400**		**5,779**		**4,885**	**1,196**	**11,860**		**688**	**12,548**	**0.145**	**14,920**	**0.173**	**2.375**	**28,856**	**0.334**	**38,258**
	5F	F1	278.2	19,800	168	3,326	142	2,812	2,112	8,250	20	396	8,646	0.100	10,296	0.119	2.529	21,260	0.246	26,613
	Total	**Zone 5**	**278.2**	**19,800**		**3,326**		**2,812**	**2,112**	**8,250**		**396**	**8,646**	**0.100**	**10,296**	**0.119**	**2.529**	**21,260**	**0.246**	**26,613**
	Grand total	**Integrated**	**3,443.3**	**290,400**		**48,788**		**41,236**	**12,151**	**102,175**		**5,808**	**107,983**	**1.250**	**128,417**	**1.486**	**1.632**	**172,558**	**1.997**	**329,597**
Central System	Existing Area	S1	493.2	110,300	168	18,530	142	15,663	1,601	35,794	40	4,412	40,206	0.465	47,365	0.548	1.949	74,175	0.859	115,465
		S3	241.3	52,500	168	8,820	142	7,455		16,275	40	2,100	18,375	0.213	21,630	0.250	2.245	38,637	0.447	52,500
		S2	233.0	30,900	168	5,191	142	4,388	2,100	11,679	40	1,236	12,915	0.149	15,251	0.177	2.381	29,044	0.336	37,674
		SS1	57.1	16,700	168	2,806	142	2,371	259	5,436	40	668	6,104	0.071	7,191	0.083	2.710	15,400	0.178	17,535
		H1	176.3	36,700	168	6,166	142	5,211	1,081	12,458	40	1,468	13,926	0.161	16,418	0.190	2.354	30,794	0.356	40,187
		CE1	328.6	48,000	168	8,064	142	6,816	3,089	17,969	40	1,920	19,889	0.230	23,483	0.272	2.205	41,542	0.481	57,965
		CE2	68.1	25,700	168	4,318	142	3,649		7,967	40	1,028	8,995	0.104	10,588	0.123	2.544	21,296	0.246	25,700
		SS2	130.3	52,100	168	8,753	142	7,398	1,293	17,444	40	2,084	19,528	0.226	23,017	0.266	2.217	40,757	0.472	56,271
		SS3	84.7	24,800	168	4,166	142	3,522		7,688	40	992	8,680	0.100	10,218	0.118	2.559	20,666	0.239	24,800
		Total	**1,812.6**	**397,700**		**66,814**		**56,473**	**9,423**	**132,710**		**15,908**	**148,618**	**1.720**	**175,161**	**2.027**	**1.567**	**223,865**	**2.591**	**428,097**
	to Collector Sur		**1,812.6**	**397,700**		**66,814**		**56,473**	**9,423**	**132,710**		**15,908**	**148,618**	**1.720**	**175,161**	**2.027**	**1.567**	**223,865**	**2.591**	**428,097**
	within Study Area	N1+N2	110.3	24,900	168	4,183	142	3,536		7,719	40	996	8,715	0.101	10,259	0.119	2.557	20,733	0.240	24,900
	Out of Study Area	***Norte***	766.9	159,100	168	**26,729**	142	**22,592**	**7,837**	**57,158**	40	**6,364**	**63,522**	**0.735**	**74,954**	**0.868**	**1.796**	**109,020**	**1.262**	**184,381**
		to Siphon	***2,689.8***	***581,700***		**97,726**		**82,601**	**17,260**	**197,587**		**23,268**	**220,855**	**2.556**	**260,374**	**3.014**	**1.479**	**315,499**	**3.652**	***637,378***
	Connect to Casablanca PS	Casablanca	299.1	6,800	168	1,142	142	966	954	3,062	20	136	3,198	0.037	3,810	0.044	2.960	9,200	0.106	9,877
	to PS and Tunnel		***2,988.9***	***588,500***		***98,868***		***83,567***	***18,214***	***200,649***		***23,404***	***224,053***	***2.593***	***264,184***	***3.058***	***1.476***	***319,562***	***3.699***	***647,255***
within the Study Area			*5,665.3*	*719,800*		*120,927*		*102,211*	*22,528*	*245,666*		*22,848*	*268,514*	*3.108*	*317,647*	*3.676*		*426,356*	*4.935*	
from out of the Study Area			*766.9*	*159,100*		*26,729*		*22,592*	*7,837*	*57,158*		*6,364*	*63,522*	*0.735*	*74,954*	*0.868*		*109,020*	*1.262*	
Sewerage System Total			*6,432.2*	***878,900***		***147,656***		***124,803***	***30,365***	***302,824***		***29,212***	***332,036***	***3.843***	***392,601***	***4.544***		***492,120***	***5.696***	
Cojimal	Connect to Cojimal Zone	Cojimal	97.1	18,700	168	3,142	142	2,655		5,797										
Indipendent	Factory	Industry	235.6	0	168	0	142	0	6,406	6,406										
Sanitation		Fosa	851.0	52,600	168	8,837	142	7,469		16,306										
Not covered by the sewerage			**1,183.7**	**71,300**		**11,978**		**10,125**	**6,406**	**28,509**										
Study Area Total			**6,849.0**	**791,100**		**132,905**		**112,336**	**28,934**	**274,175**										
Grand Total			**7,615.9**	**950,200**		**159,634**		**134,928**	**36,771**	**331,333**										

Table A8. 9 Design Flow Calculation (2020)

Sewerage System	Treatment District	District	Area	Population	Per Capita Domestic Wastewater Generation	Domestic Wastewater	Per Capita Non-Domestic by Small Consumer	Non Domestic Wastewater by small consumer	Non-Domestic Wastewater by large consumer	Overall Wastewater Generation	Infiltration & Inflow Rate per Capita	Infiltration & Inflow	Overall Average Daily Flow		Overall Maximum Daily Flow = 1.2 x Wastewater Generation + Infiltration and Inflow		Peaking Factor by M Harmon Equation	Overall Maximum Hourly Flow = Peaking Factor x Wastewater Generation + Infiltration and Inflow		Overall Equivalent Population
			ha	person	lpcd	m^3/d	lpcd	m^3/d	m^3/d	m^3/d	lpcd	m^3/d	m^3/d	m^3/s	m^3/d	m^3/s	(-)	m^3/d	m^3/s	person
New Sewerage Development Area	1AB	A1	123.0	9,600	168	1,613	154	1,478	246	3,337	20	192	3,529	0.041	4,196	0.049	2.939	9,999	0.116	10,364
		A2	89.1	18,500	168	3,108	154	2,849	342	6,299	20	370	6,669	0.077	7,929	0.092	2.662	17,138	0.198	19,562
		A3	107.0	4,400	168	739	154	678		1,417	20	88	1,505	0.017	1,788	0.021	3.296	4,758	0.055	4,400
		A4	206.0	26,300	168	4,418	154	4,050		8,468	20	526	8,994	0.104	10,688	0.124	2.534	21,984	0.254	26,300
		A5	153.6	32,900	168	5,527	154	5,067	1,282	11,876	20	658	12,534	0.145	14,909	0.173	2.390	29,042	0.336	36,881
		B1	252.6	22,300	168	3,746	154	3,434	302	7,482	20	446	7,928	0.092	9,424	0.109	2.587	19,802	0.229	23,238
		B2	47.2	4,400	168	739	154	678	221	1,638	20	88	1,726	0.020	2,054	0.024	3.238	5,392	0.062	5,086
		B3	103.9	9,600	168	1,613	154	1,478		3,091	20	192	3,283	0.038	3,901	0.045	2.972	9,378	0.109	9,600
	Total	Zone 1	1,082.4	128,000		21,503		19,712	2,393	43,608		2,560	46,168	0.534	54,889	0.635	1.895	85,197	0.986	135,431
	2C	C1	175.0	15,800	168	2,654	154	2,433	119	5,206	20	316	5,522	0.064	6,563	0.076	2.745	14,606	0.169	16,170
		C2	54.8	5,000	168	840	154	770		1,610	20	100	1,710	0.020	2,032	0.024	3.245	5,324	0.062	5,000
		C3	76.3	6,900	168	1,159	154	1,063		2,222	20	138	2,360	0.027	2,804	0.032	3.113	7,055	0.082	6,900
		C4	105.5	9,500	168	1,596	154	1,463		3,059	20	190	3,249	0.038	3,861	0.045	2.977	9,297	0.108	9,500
		C5	68.7	6,200	168	1,042	154	955		1,997	20	124	2,121	0.025	2,520	0.029	3.157	6,429	0.074	6,200
		C6	154.6	13,000	168	2,184	154	2,002	94	4,280	20	260	4,540	0.053	5,396	0.062	2.831	12,377	0.143	13,292
		C7	131.7	5,400	168	907	154	832		1,739	20	108	1,847	0.021	2,195	0.025	3.214	5,697	0.066	5,400
	Total	Zone 2	766.6	61,800		10,382		9,518	213	20,113		1,236	21,349	0.247	25,371	0.294	2.176	45,002	0.521	62,462
	3D	D1	239.2	21,400	168	3,595	154	3,296	100	6,991	20	428	7,419	0.086	8,817	0.102	2.617	18,723	0.217	21,711
		D2	64.7	5,900	168	991	154	909		1,900	20	118	2,018	0.023	2,398	0.028	3.178	6,156	0.071	5,900
		D3	110.5	10,000	168	1,680	154	1,540		3,220	20	200	3,420	0.040	4,064	0.047	2.955	9,715	0.112	10,000
		D4	356.4	14,600	168	2,453	154	2,248	6,400	11,101	20	292	11,393	0.132	13,613	0.158	2.418	27,134	0.314	34,476
	Total	Zone 3	770.8	51,900		8,719		7,993	6,500	23,212		1,038	24,250	0.281	28,892	0.334	2.121	50,271	0.582	72,087
	4E	E1	148.1	13,100	168	2,201	154	2,017	979	5,197	20	262	5,459	0.063	6,498	0.075	2.746	14,533	0.168	16,140
		E2	265.0	11,000	168	1,848	154	1,694		3,542	20	220	3,762	0.044	4,470	0.052	2.913	10,538	0.122	11,000
		E3	18.9	1,800	168	302	154	277		579	20	36	615	0.007	731	0.008	3.621	2,133	0.025	1,800
		E4	113.3	9,700	168	1,630	154	1,494	332	3,456	20	194	3,650	0.042	4,341	0.050	2.924	10,299	0.119	10,731
	Total	Zone 4	545.3	35,600		5,981		5,482	1,311	12,774		712	13,486	0.156	16,040	0.186	2.359	30,846	0.357	39,671
	5F	F1	278.2	20,400	168	3,427	154	3,142	2,375	8,944	20	408	9,352	0.108	11,141	0.129	2.510	22,857	0.265	27,776
	Total	Zone 5	278.2	20,400		3,427		3,142	2,375	8,944		408	9,352	0.108	11,141	0.129	2.510	22,857	0.265	27,776
	Grand total	Integrated	3,443.3	297,700		50,012		45,847	12,792	108,651		5,954	114,605	1.326	136,333	1.578	1.626	182,621	2.114	337,427
Central System	Existing Area	S1	493.2	110,300	168	18,530	154	16,986	1,601	37,117	40	4,412	41,529	0.481	48,952	0.567	1.950	76,790	0.889	115,272
		S3	241.3	52,200	168	8,770	154	8,039		16,809	40	2,088	18,897	0.219	22,259	0.258	2.247	39,858	0.461	52,200
		S2	233.0	30,700	168	5,158	154	4,728	2,100	11,986	40	1,228	13,214	0.153	15,611	0.181	2.386	29,827	0.345	37,222
		SS1	57.1	16,600	168	2,789	154	2,556	259	5,604	40	664	6,268	0.073	7,389	0.086	2.713	15,868	0.184	17,404
		H1	176.3	36,400	168	6,115	154	5,606	1,081	12,802	40	1,456	14,258	0.165	16,818	0.195	2.359	31,656	0.366	39,757
		CE1	328.6	48,400	168	8,131	154	7,454	3,089	18,674	40	1,936	20,610	0.239	24,345	0.282	2.205	43,112	0.499	57,993
		CE2	68.1	25,500	168	4,284	154	3,927		8,211	40	1,020	9,231	0.107	10,873	0.126	2.547	21,933	0.254	25,500
		SS2	130.3	51,500	168	8,652	154	7,931	1,293	17,876	40	2,060	19,936	0.231	23,511	0.272	2.223	41,798	0.484	55,516
		SS3	84.7	24,600	168	4,133	154	3,788		7,921	40	984	8,905	0.103	10,489	0.121	2.563	21,286	0.246	24,600
		Total	1,812.6	396,200		66,562		61,015	9,423	137,000		15,848	152,848	1.769	180,247	2.086	1.568	230,664	2.670	425,464
	to Collector Sur		1,812.6	396,200		66,562		61,015	9,423	137,000		15,848	152,848	1.769	180,247	2.086	1.568	230,664	2.670	425,464
	within Study Area	N1+N2	110.3	24,700	168	4,150	154	3,804		7,954	40	988	8,942	0.103	10,533	0.122	2.561	21,358	0.247	24,700
	Out of Study Area	*Norte*	766.9	159,100	168	26,729	154	24,501	7,837	59,067	40	6,364	65,431	0.757	77,244	0.894	1.798	112,566	1.303	183,439
	to Siphon		*2,689.8*	*580,000*		97,441		89,320	17,260	204,021		23,200	227,221	2.630	268,024	3.102	1.480	325,151	3.763	*633,603*
	Connect to Casablanca PS	Casablanca	299.1	7,000	168	1,176	154	1,078	954	3,208	20	140	3,348	0.039	3,990	0.046	2.956	9,623	0.111	9,963
	to PS and Tunnel		*2,988.9*	*587,000*		*98,617*		*90,398*	*18,214*	*207,229*		*23,340*	*230,569*	*2.669*	*272,014*	*3.148*	*1.477*	*329,417*	*3.813*	*643,566*
within the Study Area			*5,665.3*	*725,600*		*121,900*		*111,744*	*23,169*	*256,813*		*22,930*	*279,743*	*3.238*	*331,103*	*3.832*		*444,266*	*5.142*	
from out of the Study Area			*766.9*	*159,100*		*26,729*		*24,501*	*7,837*	*59,067*		*6,364*	*65,431*	*0.757*	*77,244*	*0.894*		*112,566*	*1.303*	
Sewerage System Total			*6,432.2*	*884,700*		*148,629*		*136,245*	*31,006*	*315,880*		*29,294*	*345,174*	*3.995*	*408,347*	*4.726*		*512,038*	*5.926*	
Cojimal	Connect to Cojimal Zone	Cojimal	97.1	19,900	168	3,343	154	3,065		6,408										
Indipendent	Factory	Industry	235.6	0	168	0	154	0	6,406	6,406										
Sanitation		Fosa	851.0	54,500	168	9,156	154	8,393		17,549										
Not covered by the sewerage			1,183.7	74,400		12,499		11,458	6,406	30,363										
Study Area Total			6,849.0	800,000		134,399		123,202	29,575	287,176										
Grand Total			7,615.9	959,100		161,128		147,703	37,412	346,243										



THE DEVELOPMENT STUDY OF THE IMPROVEMENT OF SEWERAGE AND DRAINAGE SYSTEM FOR THE HAVANA BAY

JAPAN INTERNATIONAL COOPERATION AGENCY

Figure A8.2
Sewer Districts

A8.3 INFLUENT QUALITY

The following tables are supporting data of 11.4 Wastewater Generation (Main Report, Master Plan).

Table A8. 10 Wastewater Generation

	Parameter	Unit	Zonal Sewerage System Improvement						Integrated
			Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	System
L1	Sewerage Service Population	(-)	128,000	61,800	51,900	35,600	20,400	297,700	297,700
L2	Domestic Wastewater Generation, calculated	(m^3/d)	21,504	10,382	8,719	5,981	3,427	50,013	50,014
L3	Non-domestic Wastewater Generation exept large industrial consumer, calculated	(m^3/d)	19,712	9,517	7,993	5,482	3,142	45,846	45,846
L4	Commercial and Institutional Wastewater Generation by Large Water Consumer, based on actual data	(m^3/d)	246	119	100	332	**133**	930	930
L5	Industrial Wastewater Generation by Large Water Consumer, based on actual data	(m^3/d)	2,147	94	**6,400**	979	2,242	11,862	11,862
L9	Wastewater Generation	(m^3/d)	43,609	20,112	23,212	12,774	8,944	108,651	108,652
L6	Infiltration and Inflow, calculated	(m^3/d)	2,560	1,236	1,038	712	408	5,954	5,954
L7	Above Total, Average Daily Flow	(m^3/d)	**46,169**	**21,348**	**24,250**	**13,486**	**9,352**	**114,605**	**114,606**
L8	(L2+L3+L4+L5) x L25+L6, Maximum Daily Flow	(m^3/d)	54,891	25,370	28,892	16,041	11,141	136,335	136,336
L7-2	Average Daily Flow	(m^3/s)	**0.534**	**0.247**	**0.281**	**0.156**	**0.108**	**1.326**	**1.326**
L8-2	Maximum Daily Flow	(m^3/s)	0.635	0.294	0.334	0.186	0.129	1.578	1.578
L16	L7/L1, Per capita average wastewater generation rate	lpcd	361	345	467	379	458	385	385
L17	(L3+L4)/L1, Per capita non-domesic and small industrial wastewater generation rate (lpcd)	lpcd	156	156	156	163	161	157	157
L21	Per Capita Domestic Wastewater Generation	lpcd	**168**						
L22	Per Capita No-Domestic Wastewater Generation exept large industrial consumer	lpcd	**154**						
L23	Infiltration and Inflow, new scheme	lpcd	**20**						
L24	Infiltration and Inflow, existing scheme	lpcd	**40**						
L25	Ratio of Maximum Daily Flow and Average Daily Flow	(-)	**1.2**						

Notes： * bolded figure in L4 is wastewater from staff of Nico Lopez * bolded figure in L5 is wastewater from factories at new industrial development a

Table A8. 11 BOD and SS Concentration Estimates

	Parameter	Unit	Zonal Sewerage System Improvement						Integrated
			Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	System
L51	BOD Load, Domestic Wastewater	kg/d	5,120	2,472	2,076	1,424	816	11,908	11,908
L52	BOD Load of Non-domestic Wastewater exept large industrial consumer	kg/d	3,390	1,637	1,375	943	540	7,885	7,886
L53	BOD Load of Commercial and Institutional Wastewater by Large Water Consumer	kg/d	42	20	17	57	23	159	160
L54	BOD Load of Industrial Wastewater by Large Water Consumer (kg/day)	kg/d	515	23	1,536	235	538	2,847	2,847
L55	Total BOD Load, L51+L52+L53+L54 (kg/day)		9,067	4,152	5,004	2,659	1,917	22,799	22,801
L56	Average BOD concentration (mg/L)		196	194	206	197	205	199	199
L58	Overall per capita BOD load (g/capita/d)		71	67	96	75	94	77	77
L61	Per capita BOD Load in domestic wastewater	g/capita/d	**40**						
L62	Estimated Ave. BOD conc. of Domestic Wastewater	mg/L	**238**						
L63	Toilet Water Per Capita	lpcd	**40**						
L64	Per capita BOD load in toilet water	g/capita/d	**18**						
L64	Grey Water Per Capita	lpcd	**128**						
L65	Per capita BOD load in grey water	g/capita/d	**22**						
L65	Ave. BOD conc. of Non-domestic Wastewater by Small Water Consumer = grey water	mg/L	**172**						
L64	Ave. BOD conc. of Commercial and Institutional Wastewater by Large Water Consumer = grey water	mg/L	172						
L65	Ave. BOD conc. of Industrial Wastewater by Large Water Consumer	mg/L	**240**						

Table A8. 12 T-N Concentration Estimates

	Parameter	Unit	Zonal Sewerage System Improvement						Integrated
			Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	System
L51	T-N Load, Domestic Wastewater	kg/d	947.2	457.3	384.1	263.4	151.0	2,203.0	2,203.0
L52	T-N Load of Non-domestic Wastewater exept large industrial consumer	kg/d	339.0	163.7	137.5	94.3	54.0	788.5	788.6
L53	T-N Load of Commercial and Institutional Wastewater by Large Water Consumer	kg/d	4.2	2.0	1.7	5.7	2.3	15.9	16.0
L54	T-N Load of Industrial Wastewater by Large Water Consumer (kg/day)	kg/d	85.9	3.8	256.0	39.2	89.7	474.6	474.5
L55	Total T-N Load, L51+L52+L53+L54 (kg/day)		1,376.3	626.8	779.3	402.6	297.0	3,482.0	3,482.1
L56	Average T-N concentration (mg/L)		29.8	29.4	32.1	29.9	31.8	30.4	30.4
L58	Overall per capita T-N load (g/capita/d)		10.8	10.1	15.0	11.3	14.6	11.7	11.7
L61	Per capita T-N Load in domestic wastewater	g/capita/d	**7.40**						
L62	Estimated Ave. T-N conc. of Domestic Wastewater	mg/L	**44.0**						
L63	Toilet Water Per Capita	lpcd	**40**						
L64	Per capita T-N load in toilet water	g/capita/d	**5.2**						
L64	Grey Water Per Capita	lpcd	**128**						
L65	Per capita T-N load in grey water	g/capita/d	**2.2**						
L65	Ave. T-N conc. of Non-domestic Wastewater by Small Water Consumer = grey water	mg/L	**17.2**						
L64	Ave. T-N conc. of Commercial and Institutional Wastewater by Large Water Consumer = grey water	mg/L	17.2						
L65	Ave. T-N conc. of Industrial Wastewater by Large Water Consumer	mg/L	**40**						

Table A8. 13 T-P Concentration Estimates

	Parameter	Unit	Zonal Sewerage System Improvement						Integrated
			Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Total	System
L51	T-P Load, Domestic Wastewater	kg/d	243.2	117.4	98.6	67.6	38.8	565.6	565.6
L52	T-P Load of Non-domestic Wastewater exept large industrial consumer	kg/d	92.6	44.7	37.6	25.8	14.8	215.5	215.5
L53	T-P Load of Commercial and Institutional Wastewater by Large Water Consumer	kg/d	1.2	0.6	0.5	1.6	0.6	4.5	4.4
L54	T-P Load of Industrial Wastewater by Large Water Consumer (kg/day)	kg/d	19.3	0.8	57.6	8.8	20.2	106.7	106.8
L55	Total T-P Load, L51+L52+L53+L54 (kg/day)		356.3	163.5	194.3	103.8	74.4	892.3	892.3
L56	Average T-P concentration (mg/L)		7.7	7.7	8.0	7.7	8.0	7.8	7.8
L58	Overall per capita T-P load (g/capita/d)		2.8	2.6	3.7	2.9	3.6	3.0	3.0
L61	Per capita T-P Load in domestic wastewater	g/capita/d	**1.90**						
L62	Estimated Ave. T-P conc. of Domestic Wastewater	mg/L	**11.3**						
L63	Toilet Water Per Capita	lpcd	**40**						
L64	Per capita T-P load in toilet water	g/capita/d	**1.3**						
L64	Grey Water Per Capita	lpcd	**128**						
L65	Per capita T-P load in grey water	g/capita/d	**0.6**						
L65	Ave. T-P conc. of Non-domestic Wastewater by Small Water Consumer = grey water	mg/L	**4.7**						
L64	Ave. T-P conc. of Commercial and Institutional Wastewater by Large Water Consumer = grey water	mg/L	4.7						
L65	Ave. T-P conc. of Industrial Wastewater by Large Water Consumer	mg/L	**9**						