Appendix 4-1

Near Field Modelling Results

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1. INTRODUCTION

1.1.1 The VISJET model was used to simulate the near-field plume behaviour of the outfall discharges within a relatively short distance from the effluent discharge location. Hence, the zone of initial dilution (ZID) and vertical structure of the plume could be located. For a surface plume, initial dilution is defined as the dilution obtained at the centre line of the plume when the sewage reaches the surface. For a trapped plume, initial dilution is defined as the dilution obtained at the centre line of the plume where the plume reaches the maximum rise height when the vertical momentum / buoyancy of the plume becomes zero.

1.1.2 The near field results were also used to determine where the effluent loading from the Pillar Point Sewage Treatment Works (PPSTW) outfall would be placed within the far field model (both horizontally and vertically).

2. MODEL INPUT

2.1.1 Key input to the near-field model include:

- Outfall diffuser configuration
- Vertical density profile
- Ambient current speed
- Effluent flow rate

2.1.2 Under normal circumstances, the treated effluent would be discharged into the sea via the existing twin submarine outfalls, namely Pipeline A and Pipeline B, as shown in the as-built drawing provided in **Attachment I**.

2.1.3 In the event of emergency situations during operation phase of the Project such as shutdown of PPSTW or power failure, untreated effluent would be directly discharged into the sea via Pipeline A and Pipeline B. Under a very remote condition when malfunctioning of the twin outfalls occurs during the emergency situation, untreated effluent would be diverted to the sea via the emergency bypass as shown in the same as-built drawing provided in **Attachment I**.

2.1.4 Details of the diffuser configurations adopted for the twin submarine outfalls (Pipeline A&B) and the emergency bypass are given in **Table 2.1** and **Table 2.2** respectively.

Table 2.1 Diffuser Configurations for Twin Submarine Outfalls (Pipeline A&B)

Description	Value		Remarks
	Pipeline A	Pipeline B	
Diffuser length (m)	425		Total length for the twin submarine outfalls
Outfall diameter (m)	1.55	1.55	
Riser separation (m)	50	50	
No. of risers	9	9	
Riser height (m)	5.5	5.5	
Ports per riser	6	6	The horizontal angles of discharge for 6 ports are: 1st to 8th riser - 0°, 60°, 120°,180°, 240°, 300°; End riser - 30°, 90°, 150°, 210°, 270°, 330°;
Riser radius (m)	0.66 - 0.9	0.66 - 0.9	1st to 8th riser – 0.66m; End riser – 0.9m.
Port diameter (m)	0.26	0.26	

Table 2.2 Diffuser Configurations for Emergency Bypass

Description	Value	Remarks
Diffuser length (m)	50	
Outfall diameter (m)	2.16	
Riser separation (m)	25	
No. of risers	3	
Riser height (m)	7.1	
Ports per riser	4	The horizontal angles of discharge for 4 ports are: 45°, 135°, 225°, 315°.
Riser radius (m)	1.5	
Port diameter (m)	1.01	

2.1.5 The ambient setup was based on the far field hydrodynamic model output from the Delft3D Pillar Point Model. Simulation of the far field hydrodynamic model was performed for the 2012 Scenario and the Ultimate Development Scenario (UDS) and had taken into account the change of coastline configurations and Pearl River flow at these two different time horizons. Each far field hydrodynamic modelling scenario covered two 15-day full spring-neap cycles (excluding the spin-up period) for dry and wet seasons respectively. The vertical density profiles extracted from the far field hydrodynamic model are shown in **Table 2.3** and **Table 2.4** for the twin submarine outfalls and the emergency bypass respectively. The average model output over the 15-day far field simulation period was adopted for near field model input. The vertical density profiles for dry and wet seasons were assumed to have the same probability of occurrence.

2.1.6 The far field hydrodynamic model is 3 dimensional with a total of 10 vertical water layers. The thickness of each water layer is defined in the model as a percentage of the water depth where the total sum of all the vertical layers must be 100%. All the vertical layers of the hydrodynamic model were assigned to have the same vertical contribution. Thus, each of the vertical layers in the hydrodynamic model contributes 10% of the total water depth. The total water depths were assumed to be 16 m for the twin submarine outfalls and 11 m for the emergency bypass. **Table 2.3** and **Table 2.4** show the mean density values for each of the 10 vertical layers.

Table 2.3 Density Profile for Twin Submarine Outfalls (Pipeline A&B)

Vertical Water Layer	Depth from Water Surface (m)	Density (kg/m^3)			
		2012		UDS	
		Dry (D1)	Wet (W1)	Dry (D3)	Wet (W3)
1	0 – 1.6	1.0215	1.0045	1.0205	1.0040
2	1.7 – 3.2	1.0216	1.0052	1.0206	1.0050
3	3.3 – 4.8	1.0218	1.0075	1.0210	1.0077
4	4.9 - 6.4	1.0219	1.0090	1.0213	1.0094
5	6.5 – 8.0	1.0221	1.0107	1.0216	1.0109
6	8.1 – 9.6	1.0222	1.0121	1.0217	1.0124
7	9.7 – 11.2	1.0222	1.0139	1.0219	1.0141
8	11.3 – 12.8	1.0222	1.0155	1.0220	1.0155
9	12.9 – 14.4	1.0222	1.0168	1.0220	1.0165
10	14.5 - 16	1.0223	1.0172	1.0221	1.0169
	Probability:	**0.5**	**0.5**	**0.5**	**0.5**

Table 2.4 Density Profile for Emergency Bypass

Vertical Water Layer	Depth (m) Depth from Water Surface (m)	Density (kg/m^3)			
		2012		UDS	
		Dry (D2)	Wet (W2)	Dry (D4)	Wet (W4)
1	0 – 1.1	1.0222	1.0071	1.0215	1.0074
2	1.2 – 2.2	1.0222	1.0077	1.0216	1.0080
3	2.3 – 3.3	1.0223	1.0095	1.0218	1.0098
4	3.4 – 4.4	1.0223	1.0102	1.0218	1.0105
5	4.5 – 5.5	1.0223	1.0111	1.0219	1.0114
6	5.6 – 6.6	1.0223	1.0121	1.0219	1.0120
7	6.7 – 7.7	1.0223	1.0129	1.0219	1.0130
8	7.8 – 8.8	1.0223	1.0138	1.0220	1.0137
9	8.9 – 9.9	1.0224	1.0147	1.0220	1.0142
10	10.0 – 11.0	1.0224	1.0152	1.0220	1.0146

Vertical Water Layer	Depth (m) Depth from Water Surface (m)	Density (kg/m^3)			
		2012		UDS	
		Dry (D2)	Wet (W2)	Dry (D4)	Wet (W4)
	Probability:	**0.5**	**0.5**	**0.5**	**0.5**

2.1.7 The current velocity data were also extracted from the far field hydrodynamic model. The extracted current data were analyzed and calculated as 10, 50 and 90 percentile values for both dry and wet seasons, namely v10, v50 and v90 respectively as shown in **Table 2.5** and **Table 2.6**. It is assumed that v10 was representative of the current that occurred between the 0 and 20 percentile (20 percent) and the v90 was representative of the current that occurred between the 80 and 100 percentile (20 percent) whereas the v50 was representative of the remaining 60 percent. The outfalls are also assumed to be perpendicular to the orientation of the predominant current direction.

Table 2.5 Current Velocity at Twin Submarine Outfalls (Pipeline A&B)

Vertical Water Layer	Depth from Water Surface (m)	Current Speed (m/s)											
		2012						Ultimate Scenario					
		Dry			Wet			Dry			Wet		
		v10	v50	v90	v10	v50	v90	v10	v50	v90	v10	v50	v90
1	0 – 1.6	0.179	0.665	1.150	0.261	0.749	1.426	0.198	0.705	1.152	0.271	0.756	1.388
2	1.7 – 3.2	0.167	0.650	1.129	0.213	0.653	1.193	0.199	0.688	1.125	0.210	0.654	1.124
3	3.3 – 4.8	0.152	0.627	1.077	0.200	0.607	1.042	0.173	0.659	1.084	0.208	0.600	0.990
4	4.9 - 6.4	0.148	0.608	1.034	0.197	0.610	1.019	0.166	0.637	1.049	0.230	0.604	0.998
5	6.5 – 8.0	0.136	0.583	0.981	0.189	0.618	1.052	0.156	0.607	0.991	0.195	0.609	1.027
6	8.1 – 9.6	0.132	0.554	0.938	0.173	0.648	1.108	0.146	0.575	0.936	0.170	0.654	1.119
7	9.7 – 11.2	0.121	0.522	0.894	0.160	0.654	1.078	0.125	0.540	0.891	0.162	0.653	1.101
8	11.3 – 12.8	0.111	0.487	0.847	0.197	0.585	0.927	0.107	0.501	0.842	0.164	0.580	0.932
9	12.9 – 14.4	0.114	0.453	0.785	0.183	0.488	0.760	0.120	0.465	0.781	0.174	0.491	0.764
10	14.5 - 16	0.096	0.381	0.685	0.130	0.373	0.622	0.106	0.393	0.683	0.120	0.375	0.623
	Probability:	**0.2**	**0.6**	**0.2**	**0.2**	**0.6**	**0.2**	**0.2**	**0.6**	**0.2**	**0.2**	**0.6**	**0.2**

Table 2.6 Current Velocity at Emergency Bypass

Vertical Water Layer	Depth (m) Depth from Water Surface (m)	Current Speed (m/s)											
		2012						Ultimate Scenario					
		Dry			Wet			Dry			Wet		
		v10	v50	v90	v10	v50	v90	v10	v50	v90	v10	v50	v90
1	0 – 1.1	0.063	0.226	0.425	0.051	0.207	0.435	0.066	0.244	0.425	0.058	0.198	0.389
2	1.2 – 2.2	0.060	0.213	0.412	0.043	0.178	0.425	0.065	0.229	0.410	0.041	0.168	0.377
3	2.3 – 3.3	0.062	0.204	0.395	0.040	0.180	0.411	0.072	0.219	0.393	0.036	0.169	0.373
4	3.4 – 4.4	0.065	0.196	0.379	0.041	0.185	0.426	0.074	0.209	0.377	0.039	0.172	0.380
5	4.5 – 5.5	0.070	0.189	0.362	0.039	0.197	0.422	0.074	0.199	0.358	0.037	0.197	0.405
6	5.6 – 6.6	0.078	0.184	0.341	0.051	0.214	0.445	0.076	0.191	0.339	0.058	0.229	0.449
7	6.7 – 7.7	0.082	0.179	0.317	0.064	0.206	0.401	0.084	0.183	0.318	0.066	0.222	0.431
8	7.8 – 8.8	0.079	0.173	0.295	0.066	0.186	0.341	0.087	0.176	0.299	0.065	0.192	0.369
9	8.9 – 9.9	0.074	0.163	0.272	0.050	0.171	0.325	0.082	0.167	0.278	0.057	0.167	0.307
10	10.0 – 11.0	0.062	0.144	0.248	0.044	0.135	0.251	0.069	0.147	0.253	0.046	0.136	0.242
	Probability:	**0.2**	**0.6**	**0.2**	**0.2**	**0.6**	**0.2**	**0.2**	**0.6**	**0.2**	**0.2**	**0.6**	**0.2**

2.1.8 The effluent flow rates of 2012 and UDS were derived from the "Final Working Paper on Flow, Loads, Treatment Capacity and Performance Standard". For each assessment year, a set of three effluent flow rates, Q10, Q50 and Q90 were used, all based on the percentile of occurrence. The Q50 flow rate (the flow rate below which 50 percent of all effluent flow rates occur) was based on the average flow rate. The Q10 flow rate (the flow rate below which 10 percent of all flow rates occur) was calculated using a Q10 to Q50 ratio of 0.59. The Q90 flow rate was calculated using a Q90 to Q50 ratio of 1.26. These ratios are based on the operational record of PPSTW in 2004 and 2005. **Table 2.7** below summarizes the adopted effluent flows. The data in Table 2.7 below have taken into account the diurnal variation of hourly flow pattern presented in Table 4.9 in Section 4 of the EIA report.

Table 2.7 Effluent Flow Adopted in Near Field Model

Scenarios	ID	% of occurrence	Total Flow (m^3/d)	Flow per Riser (m^3/s)	Flow per Port (m^3/s)
2012	Q10	20	117,774	0.0757	0.0126
	Q50	60	199,000	0.1280	0.0213
	Q90	20	250,000	0.1608	0.0268
UDS	Q10	20	136,121	0.0875	0.0146
	Q50	60	230,000	0.1479	0.0246
	Q90	20	288,945	0.1858	0.0310
2012	Q10	20	117,774	0.4544	0.1136
	Q50	60	199,000	0.7677	0.1919
	Q90	20	250,000	0.9645	0.2411
UDS	Q10	20	136,121	0.5252	0.1313
	Q50	60	230,000	0.8873	0.2218
	Q90	20	288,945	1.1148	0.2787

3. MODELLING SCENARIOS

3.1.1 The near field impact was modelled for different combinations of vertical density profile, ambient current velocity and effluent flow rate for 2012 and UDS. Based on the input information in Section 2, a total of 18 model runs were carried out under each scenario as listed in **Table 3.1** and **Table 3.2**.

Table 3.1 Summary of Proposed Model Runs for 2012

Run ID	Effluent Flow		Density Profile		Ambient Current Velocity		Joint Probability of Occurrence
	ID	Probability of Occurrence	ID	Probability of Occurrence	ID	Probability of Occurrence	
Twin Submarine Outfalls (Pipeline A&B)							
D1-Q10-v10	Q10	0.2	D1	0.5	v10	0.2	0.020
D1-Q50-v10	Q50	0.6	D1	0.5	v10	0.2	0.060
D1-Q90-v10	Q90	0.2	D1	0.5	v10	0.2	0.020
D1-Q10-v50	Q10	0.2	D1	0.5	v50	0.6	0.060
D1-Q50-v50	Q50	0.6	D1	0.5	v50	0.6	0.180
D1-Q90-v50	Q90	0.2	D1	0.5	v50	0.6	0.060
D1-Q10-v90	Q10	0.2	D1	0.5	v90	0.2	0.020
D1-Q50-v90	Q50	0.6	D1	0.5	v90	0.2	0.060
D1-Q90-v90	Q90	0.2	D1	0.5	v90	0.2	0.020
W1-Q10-v10	Q10	0.2	W1	0.5	v10	0.2	0.020
W1-Q50-v10	Q50	0.6	W1	0.5	v10	0.2	0.060
W1-Q90-v10	Q90	0.2	W1	0.5	v10	0.2	0.020
W1-Q10-v50	Q10	0.2	W1	0.5	v50	0.6	0.060
W1-Q50-v50	Q50	0.6	W1	0.5	v50	0.6	0.180
W1-Q90-v50	Q90	0.2	W1	0.5	v50	0.6	0.060
W1-Q10-v90	Q10	0.2	W1	0.5	v90	0.2	0.020
W1-Q50-v90	Q50	0.6	W1	0.5	v90	0.2	0.060
W1-Q90-v90	Q90	0.2	W1	0.5	v90	0.2	0.020
Emergency Bypass							
D2-Q10-v10	Q10	0.2	D2	0.5	v10	0.2	0.020
D2-Q50-v10	Q50	0.6	D2	0.5	v10	0.2	0.060
D2-Q90-v10	Q90	0.2	D2	0.5	v10	0.2	0.020
D2-Q10-v50	Q10	0.2	D2	0.5	v50	0.6	0.060
D2-Q50-v50	Q50	0.6	D2	0.5	v50	0.6	0.180
D2-Q90-v50	Q90	0.2	D2	0.5	v50	0.6	0.060
D2-Q10-v90	Q10	0.2	D2	0.5	v90	0.2	0.020
D2-Q50-v90	Q50	0.6	D2	0.5	v90	0.2	0.060
D2-Q90-v90	Q90	0.2	D2	0.5	v90	0.2	0.020
W2-Q10-v10	Q10	0.2	W2	0.5	v10	0.2	0.020
W2-Q50-v10	Q50	0.6	W2	0.5	v10	0.2	0.060
W2-Q90-v10	Q90	0.2	W2	0.5	v10	0.2	0.020
W2-Q10-v50	Q10	0.2	W2	0.5	v50	0.6	0.060
W2-Q50-v50	Q50	0.6	W2	0.5	v50	0.6	0.180
W2-Q90-v50	Q90	0.2	W2	0.5	v50	0.6	0.060
W2-Q10-v90	Q10	0.2	W2	0.5	v90	0.2	0.020
W2-Q50-v90	Q50	0.6	W2	0.5	v90	0.2	0.060
W2-Q90-v90	Q90	0.2	W2	0.5	v90	0.2	0.020

Table 3.2 Summary of Proposed Model Runs for UDS

Run ID	Effluent Flow		Density Profile		Ambient Current Velocity		Joint Probability of Occurrence
	ID	Probability of Occurrence	ID	Probability of Occurrence	ID	Probability of Occurrence	
Twin Submarine Outfalls (Pipeline A&B)							
D3-Q10-v10	Q10	0.2	D3	0.5	v10	0.2	0.020
D3-Q50-v10	Q50	0.6	D3	0.5	v10	0.2	0.060
D3-Q90-v10	Q90	0.2	D3	0.5	v10	0.2	0.020
D3-Q10-v50	Q10	0.2	D3	0.5	v50	0.6	0.060
D3-Q50-v50	Q50	0.6	D3	0.5	v50	0.6	0.180
D3-Q90-v50	Q90	0.2	D3	0.5	v50	0.6	0.060
D3-Q10-v90	Q10	0.2	D3	0.5	v90	0.2	0.020
D3-Q50-v90	Q50	0.6	D3	0.5	v90	0.2	0.060
D3-Q90-v90	Q90	0.2	D3	0.5	v90	0.2	0.020
W3-Q10-v10	Q10	0.2	W3	0.5	v10	0.2	0.020
W3-Q50-v10	Q50	0.6	W3	0.5	v10	0.2	0.060
W3-Q90-v10	Q90	0.2	W3	0.5	v10	0.2	0.020
W3-Q10-v50	Q10	0.2	W3	0.5	v50	0.6	0.060
W3-Q50-v50	Q50	0.6	W3	0.5	v50	0.6	0.180
W3-Q90-v50	Q90	0.2	W3	0.5	v50	0.6	0.060
W3-Q10-v90	Q10	0.2	W3	0.5	v90	0.2	0.020
W3-Q50-v90	Q50	0.6	W3	0.5	v90	0.2	0.060
W3-Q90-v90	Q90	0.2	W3	0.5	v90	0.2	0.020
Emergency Bypass							
D4-Q10-v10	Q10	0.2	D4	0.5	v10	0.2	0.020
D4-Q50-v10	Q50	0.6	D4	0.5	v10	0.2	0.060
D4-Q90-v10	Q90	0.2	D4	0.5	v10	0.2	0.020
D4-Q10-v50	Q10	0.2	D4	0.5	v50	0.6	0.060
D4-Q50-v50	Q50	0.6	D4	0.5	v50	0.6	0.180
D4-Q90-v50	Q90	0.2	D4	0.5	v50	0.6	0.060
D4-Q10-v90	Q10	0.2	D4	0.5	v90	0.2	0.020
D4-Q50-v90	Q50	0.6	D4	0.5	v90	0.2	0.060
D4-Q90-v90	Q90	0.2	D4	0.5	v90	0.2	0.020
W4-Q10-v10	Q10	0.2	W4	0.5	v10	0.2	0.020
W4-Q50-v10	Q50	0.6	W4	0.5	v10	0.2	0.060
W4-Q90-v10	Q90	0.2	W4	0.5	v10	0.2	0.020
W4-Q10-v50	Q10	0.2	W4	0.5	v50	0.6	0.060
W4-Q50-v50	Q50	0.6	W4	0.5	v50	0.6	0.180
W4-Q90-v50	Q90	0.2	W4	0.5	v50	0.6	0.060
W4-Q10-v90	Q10	0.2	W4	0.5	v90	0.2	0.020
W4-Q50-v90	Q50	0.6	W4	0.5	v90	0.2	0.060
W4-Q90-v90	Q90	0.2	W4	0.5	v90	0.2	0.020

4. MODEL RESULTS

4.1 Model Output

4.1.1 Key model outputs include initial dilution, the plume depth, the plume half width, the plume thickness and the downstream distance at the edge of the ZID. **Table 4.1** and **Table 4.2** summarize the results from the VISJET simulations. Merging of plumes from adjacent risers was only found in 1 out of 72 model runs (Run ID: W4-Q90-v10). Merging of plumes from adjacent jets on individual riser was observed in nearly all model runs. The plume merging would reduce the initial dilution. The composite dilution of merged jets was determined by the VISJET model.

4.1.2 The predicted composite initial dilution was corrected for the background concentration build up due to the tidal effects. The basic assumption of any near field model is that the effluent plume is mixed with clean water. In actuality this is not true, particularly in a tidally mixed environment. The average tracer background build up concentrations were calculated from the far field Delft3D model. The build up was quantified by performing a conservative tracer run on the effluent. A conservative tracer, i.e. without decay or reaction, was used. The initial concentration of the tracer in the PPSTW effluent was set to be 1000 mg/l. The average of the far field tracer results were used for the background build up corrections. It should be noted that the results from the grid cell into which the tracer is loaded is not representative of the true background build up as this cell will always contain the background build up plus the continuous tracer loading. Therefore, the necessary far field tracer results were taken from a cell located adjacent to the outfall grid cells.

4.1.3 The average tracer results were predicted for the two different time horizons (2012 and UDS) and for both dry and wet seasons. **Table 4.3** shows an example of the background build up correction for the twin submarine outfalls under the 2012 Scenario.

Table 4.1 Summary of results from VISJET Simulations for 2012

Run ID	Effluent Flow		Density Profile		Ambient Current Velocity		Joint Prob. of Occurrence	Initial Dilution[1]	Corrected Initial Dilution[2]	Average Plume Depth from Surface (m)	Average Plume Thickness (m)	Average Plume Half-Width per Riser (m)	Downstream Distance at Edge of ZID measured from the centre of the Outfall (m)
	ID	Prob.	ID	Prob.	ID	Prob.							
Twin Submarine Outfalls (Pipeline A&B)													
D1-Q10-v10	Q10	0.2	D1	0.5	v10	0.2	0.020	634	426	11.1	14.7	6.5	79.5
D1-Q50-v10	Q50	0.6	D1	0.5	v10	0.2	0.060	562	392	8.9	19.5	8.0	77.5
D1-Q90-v10	Q90	0.2	D1	0.5	v10	0.2	0.020	395	303	8.3	19.4	9.1	70.5
D1-Q10-v50	Q10	0.2	D1	0.5	v50	0.6	0.060	1200	623	12.9	9.8	6.0	172.5
D1-Q50-v50	Q50	0.6	D1	0.5	v50	0.6	0.180	825	504	12.6	11.2	6.4	148.5
D1-Q90-v50	Q90	0.2	D1	0.5	v50	0.6	0.060	689	450	12.5	8.5	6.7	140.5
D1-Q10-v90	Q10	0.2	D1	0.5	v90	0.2	0.020	3769	963	13.1	10.1	5.9	388.5
D1-Q50-v90	Q50	0.6	D1	0.5	v90	0.2	0.060	1368	665	12.9	11.6	6.2	317.5
D1-Q90-v90	Q90	0.2	D1	0.5	v90	0.2	0.020	1349	660	12.8	10.8	6.5	297.5
W1-Q10-v10	Q10	0.2	W1	0.5	v10	0.2	0.020	298	258	14.5	8.7	4.9	27.5
W1-Q50-v10	Q50	0.6	W1	0.5	v10	0.2	0.060	226	202	14.2	9.1	5.3	26.5
W1-Q90-v10	Q90	0.2	W1	0.5	v10	0.2	0.020	204	**185**	14.1	9.7	5.7	25.5
W1-Q10-v50	Q10	0.2	W1	0.5	v50	0.6	0.060	855	593	14.9	8.1	4.8	122.5
W1-Q50-v50	Q50	0.6	W1	0.5	v50	0.6	0.180	588	451	14.8	8.4	5.2	102.5
W1-Q90-v50	Q90	0.2	W1	0.5	v50	0.6	0.060	511	404	14.7	8.6	5.4	95.5
W1-Q10-v90	Q10	0.2	W1	0.5	v90	0.2	0.020	1421	819	15.0	8.1	4.6	248.5
W1-Q50-v90	Q50	0.6	W1	0.5	v90	0.2	0.060	975	648	14.9	8.1	5.0	204.5
W1-Q90-v90	Q90	0.2	W1	0.5	v90	0.2	0.020	985	652	14.9	8.2	5.3	189.5
Emergency Bypass													
D2-Q10-v10	Q10	0.2	D2	0.5	v10	0.2	0.020	10	10	1.5	7.9	2.4	3
D2-Q50-v10	Q50	0.6	D2	0.5	v10	0.2	0.060	21	20	2.1	8.7	3.6	3
D2-Q90-v10	Q90	0.2	D2	0.5	v10	0.2	0.020	18	17	2.1	9.6	3.9	3
D2-Q10-v50	Q10	0.2	D2	0.5	v50	0.6	0.060	60	50	3.3	5.7	4.9	7
D2-Q50-v50	Q50	0.6	D2	0.5	v50	0.6	0.180	30	27	3.3	6.3	5.0	6
D2-Q90-v50	Q90	0.2	D2	0.5	v50	0.6	0.060	23	21	3.1	5.4	5.0	6
D2-Q10-v90	Q10	0.2	D2	0.5	v90	0.2	0.020	192	119	1.7	9.3	7.6	113
D2-Q50-v90	Q50	0.6	D2	0.5	v90	0.2	0.060	108	80	4.7	7.9	6.1	15
D2-Q90-v90	Q90	0.2	D2	0.5	v90	0.2	0.020	85	67	4.6	7.8	6.3	13
W2-Q10-v10	Q10	0.2	W2	0.5	v10	0.2	0.020	9	**9**	5.7	4.4	3.0	9
W2-Q50-v10	Q50	0.6	W2	0.5	v10	0.2	0.060	27	25	4.2	13.2	6.2	4
W2-Q90-v10	Q90	0.2	W2	0.5	v10	0.2	0.020	29	27	3.9	14.4	6.9	4
W2-Q10-v50	Q10	0.2	W2	0.5	v50	0.6	0.060	32	29	7.0	6.2	3.6	7
W2-Q50-v50	Q50	0.6	W2	0.5	v50	0.6	0.180	32	29	6.6	7.5	4.8	11
W2-Q90-v50	Q90	0.2	W2	0.5	v50	0.6	0.060	30	27	6.3	8.0	5.4	11
W2-Q10-v90	Q10	0.2	W2	0.5	v90	0.2	0.020	58	50	8.4	5.3	3.5	17
W2-Q50-v90	Q50	0.6	W2	0.5	v90	0.2	0.060	48	42	8.0	6.2	4.3	17
W2-Q90-v90	Q90	0.2	W2	0.5	v90	0.2	0.020	43	38	7.8	6.6	4.7	15

Note: 1. Values calculated by VISJET model. Bolded and shaded values indicated minimum initial dilution.
2. Initial dilution was corrected using the background buildup concentration predicted by the far field model for 2012. Bolded and shaded values indicated minimum initial dilution.

Table 4.2 Summary of results from VISJET Simulations for UDS

Run ID	Effluent Flow		Density Profile		Ambient Current Velocity		Joint Prob. of Occurrence	Initial Dilution[1]	Corrected Initial Dilution[2]	Average Plume Depth from Surface (m)	Average Plume Thickness (m)	Average Plume Half-Width per Riser (m)	Downstream Distance at Edge of ZID measured from the centre of the Outfall (m)
	ID	Prob.	ID	Prob.	ID	Prob.							
Twin Submarine Outfalls (Pipeline A&B)													
D3-Q10-v10	Q10	0.2	D3	0.5	v10	0.2	0.020	353	181	12.0	12.5	6.2	32.5
D3-Q50-v10	Q50	0.6	D3	0.5	v10	0.2	0.060	298	165	10.6	13.2	7.4	31.5
D3-Q90-v10	Q90	0.2	D3	0.5	v10	0.2	0.020	276	**158**	10.1	14.1	7.9	30.5
D3-Q10-v50	Q10	0.2	D3	0.5	v50	0.6	0.060	870	259	14.3	8.8	5.2	140.5
D3-Q50-v50	Q50	0.6	D3	0.5	v50	0.6	0.180	605	230	13.9	9.2	5.7	119.5
D3-Q90-v50	Q90	0.2	D3	0.5	v50	0.6	0.060	552	221	13.8	9.7	6.0	118.5
D3-Q10-v90	Q10	0.2	D3	0.5	v90	0.2	0.020	1359	290	14.5	8.3	5.0	288.5
D3-Q50-v90	Q50	0.6	D3	0.5	v90	0.2	0.060	946	266	14.3	8.8	7.3	248.5
D3-Q90-v90	Q90	0.2	D3	0.5	v90	0.2	0.020	933	265	14.2	9.2	5.7	235.5
W3-Q10-v10	Q10	0.2	W3	0.5	v10	0.2	0.020	316	269	14.3	9.1	5.2	26.5
W3-Q50-v10	Q50	0.6	W3	0.5	v10	0.2	0.060	235	208	14.0	9.6	5.8	24.5
W3-Q90-v10	Q90	0.2	W3	0.5	v10	0.2	0.020	211	189	13.8	10.9	6.2	22.5
W3-Q10-v50	Q10	0.2	W3	0.5	v50	0.6	0.060	781	544	14.8	8.3	4.9	120.5
W3-Q50-v50	Q50	0.6	W3	0.5	v50	0.6	0.180	553	423	14.6	8.7	5.4	102.5
W3-Q90-v50	Q90	0.2	W3	0.5	v50	0.6	0.060	488	383	14.6	9.1	5.6	96.5
W3-Q10-v90	Q10	0.2	W3	0.5	v90	0.2	0.020	1299	753	15.0	8.1	4.8	240.5
W3-Q50-v90	Q50	0.6	W3	0.5	v90	0.2	0.060	892	595	14.8	8.3	5.1	201.5
W3-Q90-v90	Q90	0.2	W3	0.5	v90	0.2	0.020	872	587	14.7	8.6	5.5	188.5
Emergency Bypass													
D4-Q10-v10	Q10	0.2	D4	0.5	v10	0.2	0.020	29	25	2.3	8.4	3.0	3
D4-Q50-v10	Q50	0.6	D4	0.5	v10	0.2	0.060	20	18	2.2	6.7	4.0	4
D4-Q90-v10	Q90	0.2	D4	0.5	v10	0.2	0.020	17	**16**	2.2	7.4	4.3	4
D4-Q10-v50	Q10	0.2	D4	0.5	v50	0.6	0.060	55	43	3.4	5.6	5.2	7
D4-Q50-v50	Q50	0.6	D4	0.5	v50	0.6	0.180	28	24	3.4	6.3	4.8	6
D4-Q90-v50	Q90	0.2	D4	0.5	v50	0.6	0.060	22	20	3.2	5.5	5.5	6
D4-Q10-v90	Q10	0.2	D4	0.5	v90	0.2	0.020	121	73	1.9	8.0	7.2	62
D4-Q50-v90	Q50	0.6	D4	0.5	v90	0.2	0.060	88	60	1.1	8.3	8.2	54
D4-Q90-v90	Q90	0.2	D4	0.5	v90	0.2	0.020	75	53	0.7	8.5	8.7	52
W4-Q10-v10	Q10	0.2	W4	0.5	v10	0.2	0.020	26	24	4.5	11.1	5.2	4
W4-Q50-v10	Q50	0.6	W4	0.5	v10	0.2	0.060	29	27	3.5	13.5	6.9	5
W4-Q90-v10	Q90	0.2	W4	0.5	v10	0.2	0.020	29	27	3.1	14.8	7.7	5
W4-Q10-v50	Q10	0.2	W4	0.5	v50	0.6	0.060	27	25	6.5	5.5	4.0	7
W4-Q50-v50	Q50	0.6	W4	0.5	v50	0.6	0.180	31	29	6.1	8.2	5.3	11
W4-Q90-v50	Q90	0.2	W4	0.5	v50	0.6	0.060	29	27	5.8	8.5	6.0	12
W4-Q10-v90	Q10	0.2	W4	0.5	v90	0.2	0.020	57	49	8.0	5.9	3.9	20
W4-Q50-v90	Q50	0.6	W4	0.5	v90	0.2	0.060	47	41	7.5	6.7	4.8	20
W4-Q90-v90	Q90	0.2	W4	0.5	v90	0.2	0.020	43	38	7.3	7.1	5.3	18

Note: 1. Values calculated by VISJET model. Bolded and shaded values indicated minimum initial dilution.
2. Initial dilution was corrected using the background buildup concentration predicted by the far field model for UDS. Bolded and shaded values indicated minimum initial dilution.

Table 4.3 Example of Background Build Up Correction

Outfall	Year	Minimum Initial Dilution[1]	Initial Tracer Concentration in Effluent[2] (mg/L)	Average Tracer Concentration[2] (mg/L)		Corrected Minimum Initial Dilution[5]
				Dry[3]	Wet[4]	
		(A)	(B)	(C)	(D)	(E)
Twin Submarine Outfalls (Pipeline A&B)	2012	204	1000	0.773	0.518	185

Note:
1. Minimum initial dilution predicted by VISJET model for 2012. This dilution occurred in the wet season (run ID W1-Q90-v10)
2. Effluent tracer concentration assumed in the far field modelling.
3. Average background buildup concentration for dry season predicted by the far field model for 2012.
4. Average background buildup concentration for wet season predicted by the far field model for 2012.
5. The average background buildup concentration for wet season was used for the correction in this case as the minimum dilution occurred under the wet season scenario. Corrected Initial Dilution, (E) = (B) ÷ {[1 x (B) + ((A) – 1) x (D)] ÷ (A)}

4.1.4 It is noted that all the predicted minimum dilution rates occurred under the scenario with the largest effluent flow (Q90) and the smallest ambient current (v10). **Table 4.4** summarizes the initial dilution factors.

Table 4.4 Summary of VISJET Initial Dilution Factors

	Normal Operations (Pipeline A&B)		Emergency Bypass	
	2012	**Ultimate Year**	**2012**	**Ultimate Year**
Minimum	185	158	9	16
5%ile	200	164	9	18
10%ile	241	176	15	19

4.2 Input to Far Field Model

4.2.1 The near field modelling results were used to determine the appropriate vertical and horizontal grid cell(s) into which the Project discharge would be allocated into the far field 3D model. Under each of the assessment years, two weighted averages of the plume depth were calculated for dry and wet seasons respectively based on their joint probabilities of occurrence as shown in **Table 3.1** and **Table 3.2**. Two weighted averages of the plume thicknesses were also calculated for dry and wet seasons respectively. The weighted average plume depths and plume thicknesses for dry and wet seasons were used to determine the appropriate vertical grid cell(s) into which the Project discharge would be allocated.

4.2.2 The number of horizontal grid cell(s) of the far field model to be used for loading input was based on the average dimensions of the ZID. Under each of the assessment years, the average of all the downstream distances predicted amongst the 18 model runs was used as the average width of the ZID. The average of all the plume width results predicted amongst the 18 model runs was used for calculating the average length of the ZID. It is assumed that the ZID would be the same in dry and wet seasons for far field modelling. **Table 4.5** illustrates the calculation.

Table 4.5 Summary of Dimension of ZID

Scenario		Weighted Average Plume Depth (m below surface)	Weighted Average Plume Thickness (m)	Average Half Plume Width (m) (A)	Average Downstream Distance (m) (B)	Average Dimension of ZID (m)
Twin Submarine Outfalls (Pipeline A&B)	2012	Dry: 12.0	Dry: 12.2	6	153	437[i] x 306[ii]
		Wet: 14.7	Wet: 8.5			
	UDS	Dry: 13.4	Dry: 9.9	6	126	437[i] x 252[ii]
		Wet: 14.6	Wet: 8.8			
Emergency Bypass	2012	Dry: 3.2	Dry: 7.0	5	15	60[i] x 30[ii]
		Wet: 6.5	Wet: 8.0			
	UDS	Dry: 2.7	Dry: 6.7	6	17	62[i] x 34[ii]
		Wet: 5.9	Wet: 8.6			

Notes:
i. Length of ZID = diffuser length + average half plume width x 2
ii. Width of ZID = average downstream distance x 2

4.2.3 The horizontal allocation of pollution load from the PPSTW was based on the predicted dimension of ZID. The pollution loading was evenly distributed to the grid cells of the water quality model covered by the ZID.

4.2.4 The vertical allocation of pollution load was based on the average plume depth and average plume thickness. As mentioned before, the hydrodynamic model consists of 10 vertical layers. Aggregation of the model grid was performed for water quality simulations to reduce the vertical resolution from 10 layers to 5 layers. The vertical distribution of the layers of water quality model was 10%, 20%, 20%, 30% and 20% of the hydrodynamic layers from surface to bottom. Given that the total water depth assumed in the VISJET modelling was 16 m at the twin submarine outfalls, the pollution loads for dry season was specified in the third to fifth layer from the surface for 2012; fourth to fifth layer from the surface for the UDS whilst for the wet season, the pollution loads were allocated in the fourth to fifth layer from the surface for both dry and wet seasons. **Table 4.6** summarizes the vertical allocation of pollution loads.

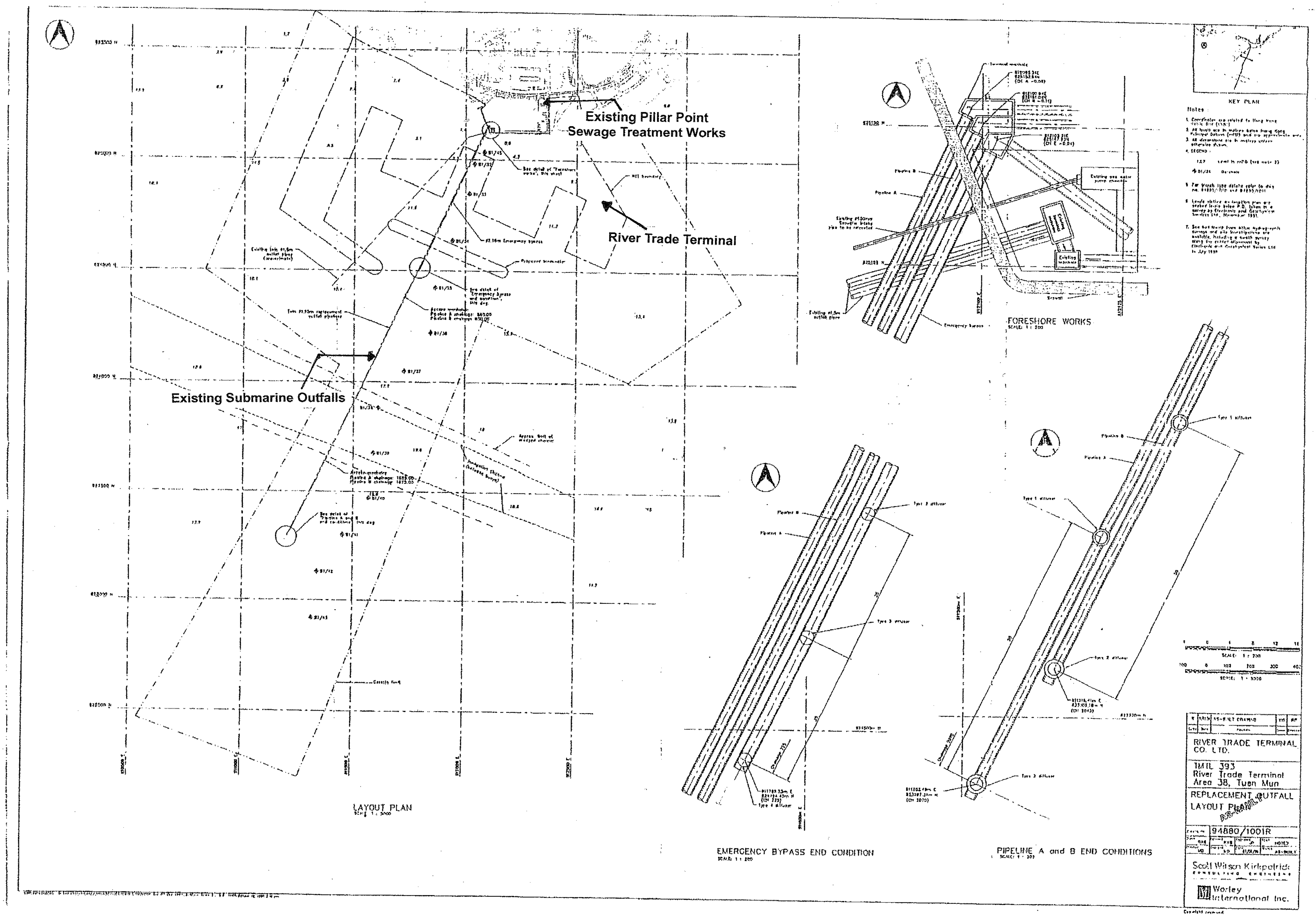
Table 4.6 Summary of Vertical Allocation of Pollution Loads

Scenario		Vertical layers of the water quality model into which the loading was allocated: Twin Submarine Outfalls	Emergency Bypass
2012	Dry	Layer 3 to Layer 5	Layer 1 to Layer 4
	Wet	Layer 4 to Layer 5	Layer 2 to Layer 5
UDS	Dry	Layer 4 to Layer 5	Layer 1 to Layer 4
	Wet	Layer 4 to Layer 5	Layer 2 to Layer 5

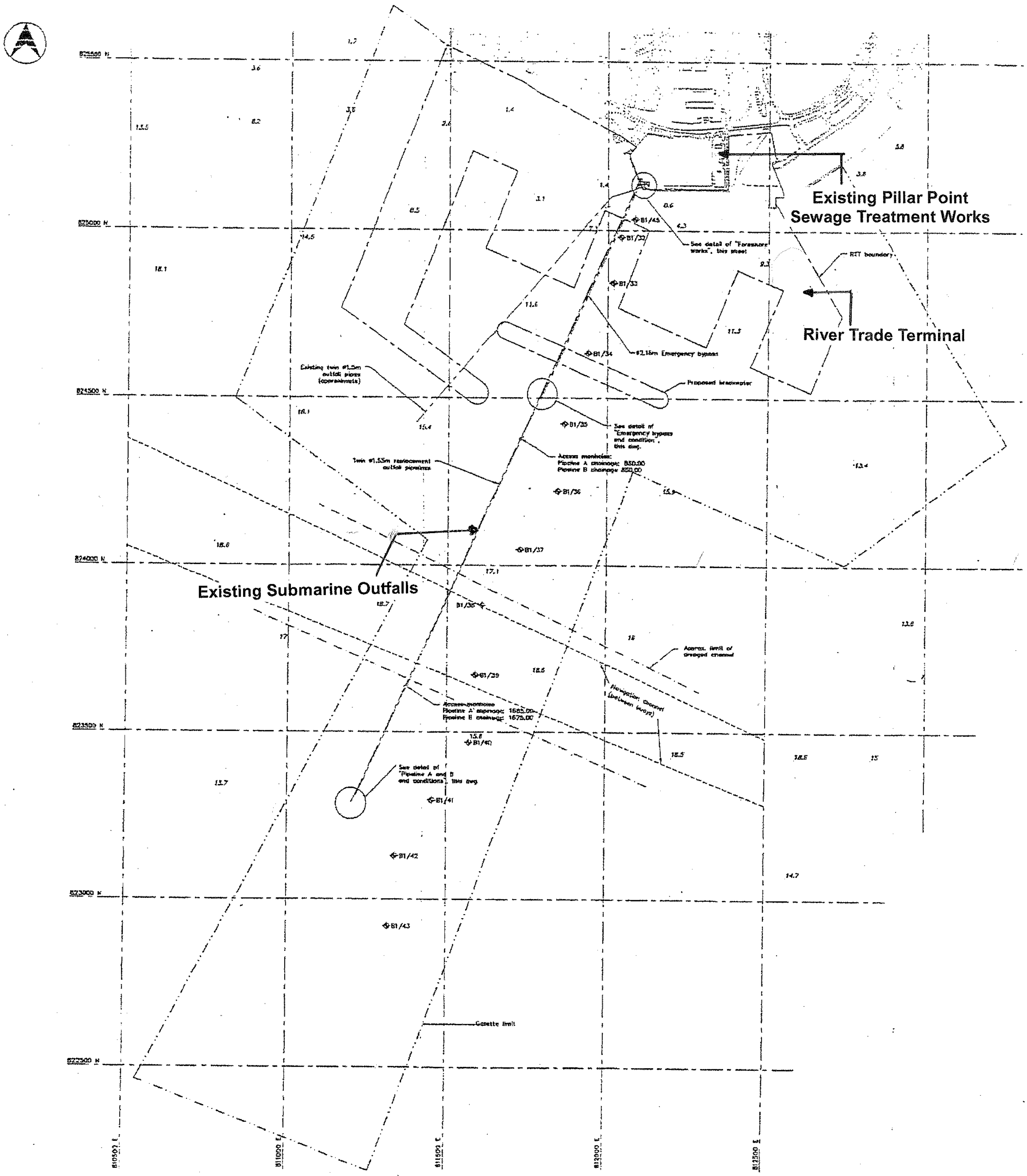
Notes: (a) The water depths at the twin submarine outfalls and emergency bypass were assumed to be 16 m and 11 m respectively.
(b) The layers are the aggregated layers in the water quality model.

4.2.5 As compared to the emergency bypass, the twin submarine outfalls were subject to a much stronger ambient current where the effluent plume could be transported farther away from the outfalls. The emergency bypass was situated nearer to the shore with relatively weaker ambient current where the buoyancy effect on the effluent plume would be relatively more significant. On the other hand, the effluent discharged via the twin submarine outfalls was subject to a much stronger effect from the water current than the buoyancy. Thus, the predicted plume depths of the effluent discharged via the emergency bypass were generally located nearer to the water surface as compared to those predicted for the twin submarine outfalls.

ATTACHMENT I
AS-BUILT DRAWING OF PPSTW OUTFALLS



Existing Pillar Point Sewage Treatment Works
River Trade Terminal
Existing Submarine Outfalls
LAYOUT PLAN
FORESHORE WORKS
KEY PLAN
EMERGENCY BYPASS END CONDITION
PIPELINE A and B END CONDITIONS
Pipeline A
Pipeline B
Emergency bypass
Existing sea water pump chamber
Existing manhole
RIVER TRADE TERMINAL CO. LTD.
TMTL 393
River Trade Terminal
Area 38, Tuen Mun
REPLACEMENT OUTFALL
LAYOUT PLAN
94880/1001R
Scott Wilson Kirkpatrick
Worley International Inc.


Existing Pillar Point
Sewage Treatment Works
River Trade Terminal
Existing Submarine Outfalls

LAYOUT PLAN