Sensitivity: General

Raglan Wastewater Options

Watercare Services Limited

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An Auckland Council Organisation

Raglan Wastewater Options

Prepared for Watercare Services Limited

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Wainui Stream

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Executive Summary

A previously calibrated Raglan Harbour model has been used to assess a number of potential future discharge options for the Raglan WWTP.

A draft report detailing the model setup, calibration and model results was peer reviewed by Metocean on behalf of the Waikato Regional Council.

That review process identified a number of points of clarification around some of the technical details of the various models used in the study.

As a results of the review process, the draft report was finalised to include a more detailed methodology section, clarification that data from a 1995 current meter deployment was at the existing outfall location (in a similar water depth to the current bathymetry), details of an additional calibration of the hydrodynamic model against observed water levels at Manu Bay, details of an additional validation of currents at a site within the main channel of the harbour (some 300 m from the existing outfall), clarification of how the near-field and far-field models are couple to provide conservative estimates of dilution in the immediate vicinity of the outfall and clarification on the purpose of the wave model.

The predicted level of dilution achieved by the existing outfall for the current day discharge regime is used to benchmark the future options.

These options include a discharge to Wainui Creek (with MBR and UV treatment) and discharges via a proposed new outfall located approximately 100 m to the east of the existing outfall, extending 85 m offshore in a minimum water depth of 2.5 m (compared to a minimum water depth of 0.3 m for the existing outfall).

For the new outfall options, two different levels of treatment were considered - the first being a combination of Pond plus Tertiary Membrane plus UV and the second being a combination of MBR and UV. A full discharge via the new outfall was considered as well as a combination of land disposal and discharge of residual treated wastewater via the new outfall were considered.

The timing of the proposed (and existing) discharges via the outfall have been optimised to maximise the dilution achieved at the outfall sites.

The most optimal discharge window is for a discharge to commence one hour after high water for a period of 4 hours.

Modelling of the dynamics of the treated wastewater plume in the immediate vicinity of the new outfall, show that for the majority of the discharge window the plume would sit in the top 50% of the water column.

The minimum dilution achieved over the existing outfall for the 2025 discharge scenario is 314. This is higher than the minimum level of dilution of 96 achieved for the existing outfall and the non-optimised current discharge regime. This indicates the clear benefit of the optimised discharge timing.

The minimum dilution achieved over the new outfall for the 2055 discharge scenario is 105 – on a par with the level of dilution for the existing outfall and the non-optimised current discharge regime. That is, the improved performance of the new outfall offsets the effects of the increased discharge volume that may occur through to 2055.

There are clear advantages associated with the partial disposal of the treated wastewater to land with reduced (or no) discharges via the new outfall from November through to April.

In addition to considering the level of dilution achieved for the various discharge options, the relative role of catchment and WWTP derived Total Nitrogen have been assessed.

Increases in mean annual Total Nitrogen near the outfall sites increase by less than 0.10 mg/L (compared to background levels of 0.14 mg/L).

For the Wainui Stream option an increase in mean annual Total Nitrogen of 0.12 mg/L is predicted to occur (compared to background levels of 1.01 mg/L).

Data from the calibrated model have been extracted at key sites as input to the Quantitative Microbial Risk Assessment of the future options.

1 Introduction

This report provides details of the use of a calibrated model of Raglan Harbour (DHI, 2019) to assess alternative discharge options for the Raglan wastewater treatment plant. All options are benchmarked against the discharge via the existing outfall located near the entrance to Raglan Harbour.

The options considered include a discharge to the Wainui Stream and discharges via a new outfall located just to the east of the existing outfall. The extended outfall option also considers the discharge of the residual treated wastewater from two land disposal options.

The report provides details of the optimisation of the timing of the outfall discharge (Section 2), modelling of the near-field performance of the new outfall (Section 4), an assessment of the relative roles of the input of nitrogen from the Raglan catchment and the discharge options (Section 7), an overview of the treated wastewater plume dynamics (Section 5) and a summary of the level of dilution achieved at a number of key sites in the Wainui Stream and Raglan Harbour (6).

The discharge scenarios and options considered are summarised in Table 1-1.

The current discharge rate for the existing outfall option is based on monitoring data from 2015-2019. Discharge rates for the other options are based on future population projections and the estimated volumes to land for the Public and Private land disposal options (detailed in Section 3).

As for the previous work (DHI, 2019) a combination of near-field modelling and far-field modelling has been used to assess the level of dilution achieved in the immediate vicinity of the discharges and in the wider harbour.

A draft report detailing the model setup, calibration and model results was peer reviewed by Metocean on behalf of the Waikato Regional Council.

That review process identified a number of points of clarification around some of the technical details of the various models used in the study.

As a results of the review process, the draft report was finalised to include a more detailed methodology section, clarification that data from a 1995 current meter deployment was at the existing outfall location (in a similar water depth to the current bathymetry), details of an additional calibration of the hydrodynamic model against observed water levels at Manu Bay, details of an additional validation of currents at a site within the main channel of the harbour (some 300 m from the existing outfall), clarification of how the near-field and far-field models are couple to provide conservative estimates of dilution in the immediate vicinity of the outfall and clarification on the purpose of the wave model.

The near-field modelling has been done using the industry standard CORMIX model (Doneker and Jirka, 2007). The far-field modelling has been carried out using the MIKE3 three-dimensional hydrodynamic and advection-dispersion models which have been coupled to the MIKE21 spectral-wave model to ensure the potential effects of waves on near-shore currents are adequately resolved (as detailed in DHI, 2019).The far-field model was run for the 2018 calendar year, since 2018 is very representative of the long-term distribution of winds, waves, water level variations and freshwater inflows that occur.

Table 1-1 Summary of discharge options considered.

Option	Level of Treatment	Discharge Location	Flows Considered
Existing	Pond + UV	Existing outfall	Current
M1	Pond + Tertiary membrane + UV	New outfall	2025 and 2055
M2	MBR + UV	New outfall	2025 and 2055
F1	MBR + UV	Wainui Stream	2025 and 2055
L1 – public land/outfall	Pond + Tertiary membrane + UV	New outfall	2025 and 2055
L3 – private land/outfall	Pond + Tertiary membrane + UV	New outfall	2025 and 2055
L4 – public land/outfall	MBR + UV	New outfall	2025 and 2055

2 Discharge Timing Optimisation

The current consent allows for a discharge to occur half an hour before high water for up to six hours. High water time is taken from the Wharf Tide Gauge (which is the LINZ reference site for Raglan). High tide at the outfall site occurs approximately 35 minutes prior to high water at Raglan Wharf.

Previous work (DHI, 2019) showed that the discharges via the existing outfall often occur prior to high water. When this occurs, the treated wastewater plume is initially transported into Raglan Harbour leading to elevated concentrations just inshore of the outfall.

Earlier modelling showed that maximum predicted concentrations inshore of the outfall are determined by the discharge start time and an analysis of three years of plant discharge data shows that the discharge starting before high water occurs for around 30% of the time.

Even though the public health risk at sites inshore of the outfall are considered to be below the no observable adverse effects level[1], it is recommended that optimising of the start time of the discharge should be carried out to bring about improvements to water quality in the harbour without leading to higher concentrations in areas offshore of the outfall.

To do this, six discharge timings have been considered. All timings refer to local high water at the outfall.

For all options a maximum discharge rate of 3000 m^3/day has been assumed, which is the maximum discharge rate being considered for the future options.

Option 1. Current discharge window for 6 hours. Starting half an hour before local high water. Constant discharge rate of 0.064 m^3/s.

Option 2. Five hour discharge window. Starting half an hour after local high water. Constant discharge rate of 0.076 m^3/s.

Option 3. Four hour discharge window. Starting one and a half hours after local high water. Constant discharge rate of 0.083 m^3/s.

Option 4. Three hour discharge window. Starting one and a half hours after local high water. Constant discharge rate of 0.119 m^3/s.

Option 5. Two hour discharge window. Starting two hours after local high water (timed to coincide with peak tidal currents). Constant discharge rate of 0.167 m^3/s.

Option 6. Four hour discharge window. Starting one hour after local high water. Constant discharge rate of 0.083 m^3/s.

An example of the timing of the discharge timing options relative to the tide at the outfall site is shown in Figure 2-1.

The previously calibrated harbour model was run for each of the timing options for a 7-day period (starting at a mean tide through to a spring tide). No winds or waves were considered.

A six-hour discharge starting half an hour before high water results in the plume initially being transported inshore of the discharge point. As the tide falls, the plume is transported away from the discharge along Ngarunui Beach (Figure 2-2).

A five-hour discharge starting half an hour after high water avoids the elevated concentrations inshore of the outfall. As the tide falls, the plume is transported away from the discharge along Ngarunui Beach and, because of the slightly higher discharge rate, concentrations along northern end of Ngarunui Beach are slightly higher than for the six-hour discharge (Figure 2-3)

A four-hour discharge starting one and a half hours after high water avoids the elevated concentrations inshore of the outfall. As the tide falls, the plume is transported away from the discharge along Ngarunui Beach. Because the discharge is happening more towards the peak of the tidal currents, the predicted concentrations along the northern end of Ngarunui Beach are slightly lower than for the six-hour or five-hour discharge options - despite the discharge rate being higher (Figure 2-4).

The three hour and two hour discharge options result in higher concentrations along northern end of Ngarunui Beach – the effect of the higher discharge rates for these options

[1] NIWA 2019. Human health risk assessment Raglan WWTP. NIWA Client Report 2019297HN prepared for Beca.

is not offset by the discharge occurring when tidal currents are at a maximum (Figure 2-5 and Figure 2-6).

Finally, the plume dynamics for the four hour discharge commencing at high water plus one hour (Figure 2-7) is very similar to those for the four hour discharge commencing one and a half hours after high water (Figure 2-4).

Based on this schematic discharge regime of 3000 m^3/day, the four hour discharge commencing at local high water plus one hour provides the best overall performance in terms of the predicted maximum concentrations immediately inshore of the outfall (Figure 2-8) and it does not lead to increases in concentrations offshore of the outfall and along Ngarunui Beach seen with shorter duration discharge options.

Compared to the current consented discharge window timing, this timing option provides more than a five times decrease in the maximum predicted concentration immediately inshore of the outfall and around a two times decrease in the maximum predicted concentration towards the northern end of Ngarunui Beach.

This timing option also avoids the discharge occurring towards local low water when a combination of shallow water depth and reduced tidal currents result in relatively low levels of dilution occurring in the immediate vicinity of the outfall and the highest visual impact from the discharge.

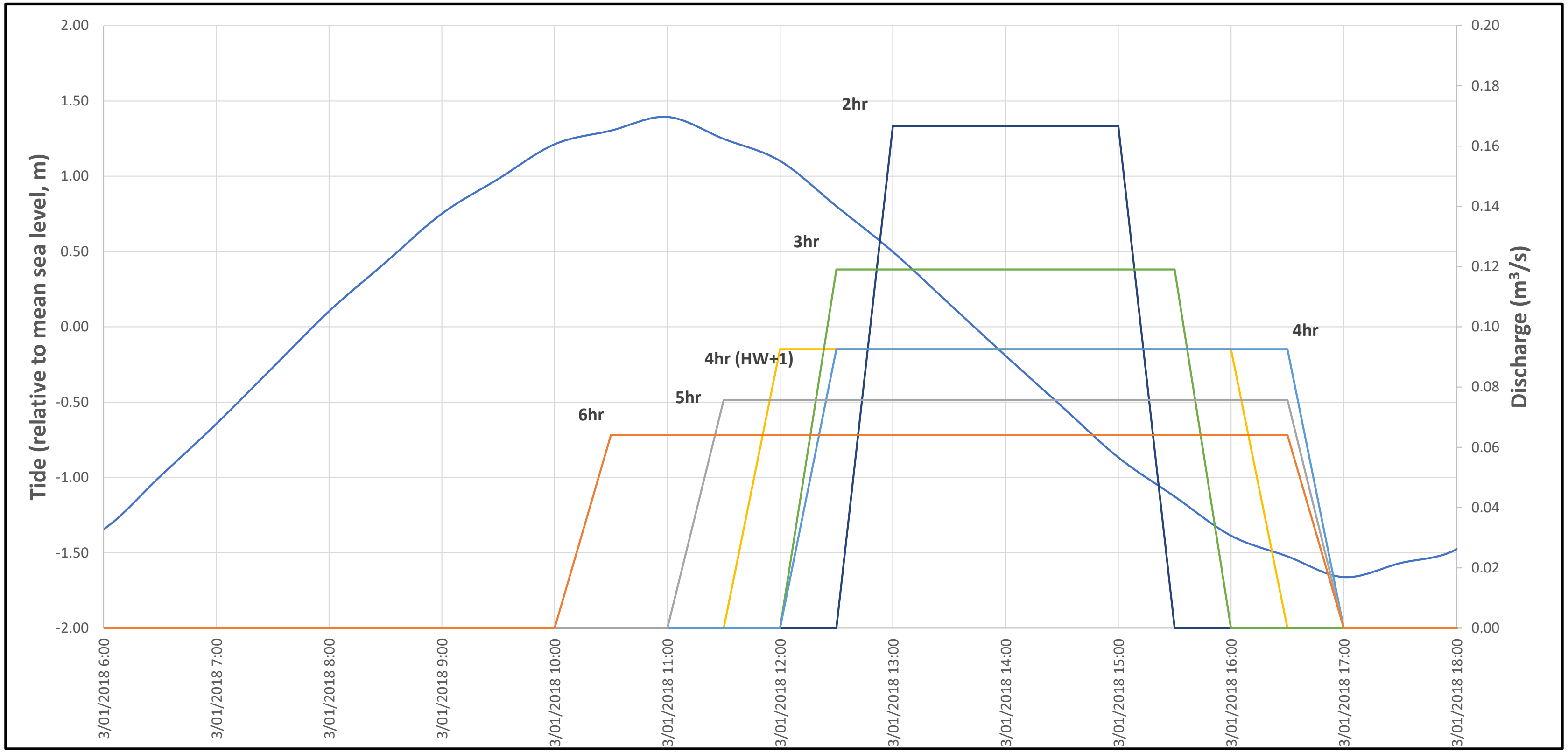

Figure 2-1. Example timings for the six timing options considered.

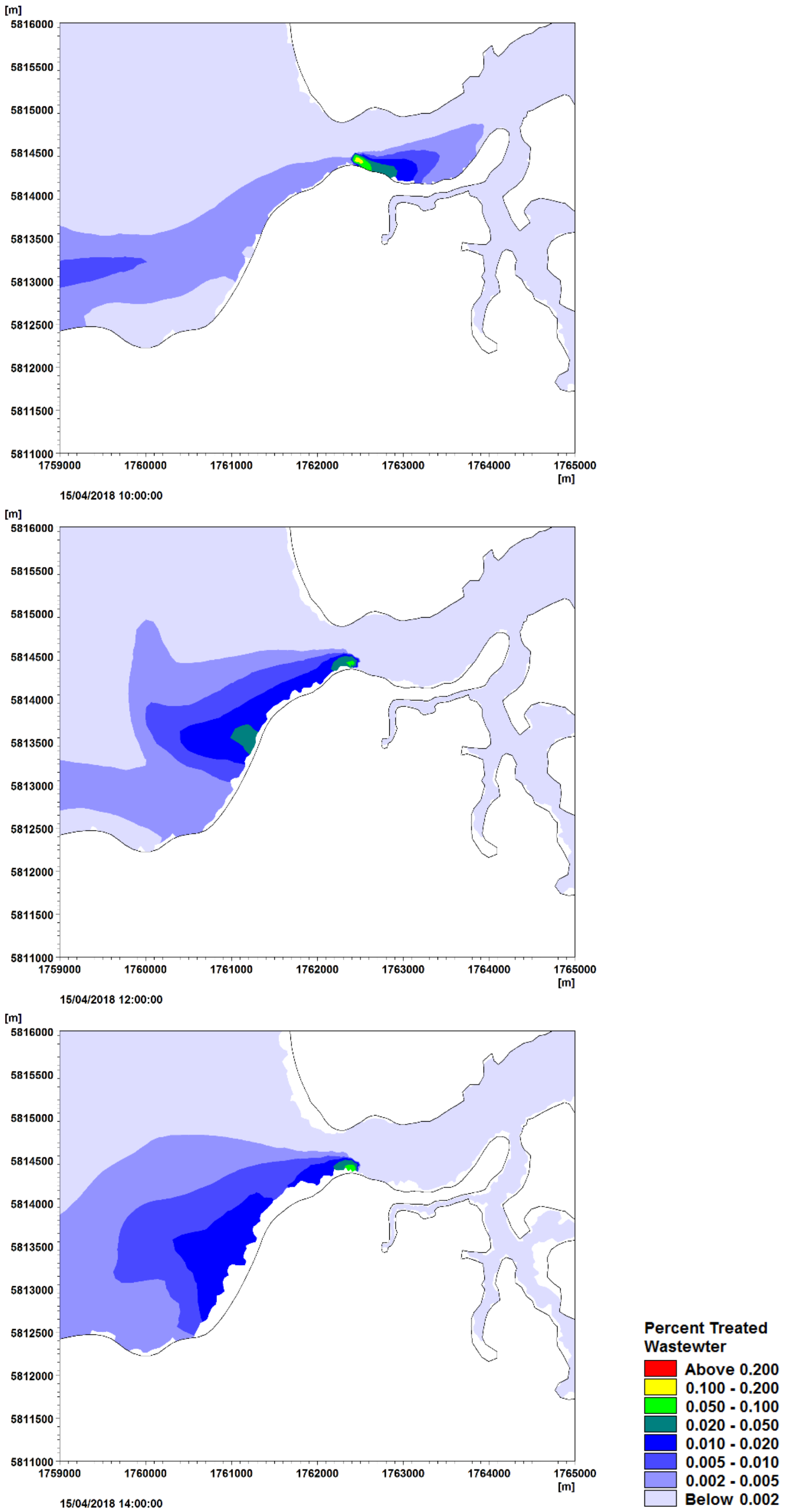

Figure 2-2. Six-hour discharge option commencing half an hour prior to high water (the current consent discharge window). Predicted concentration at the start of the discharge (half an hour prior to local high water), just prior to peak-ebb tide currents and just after peak ebb tide currents.

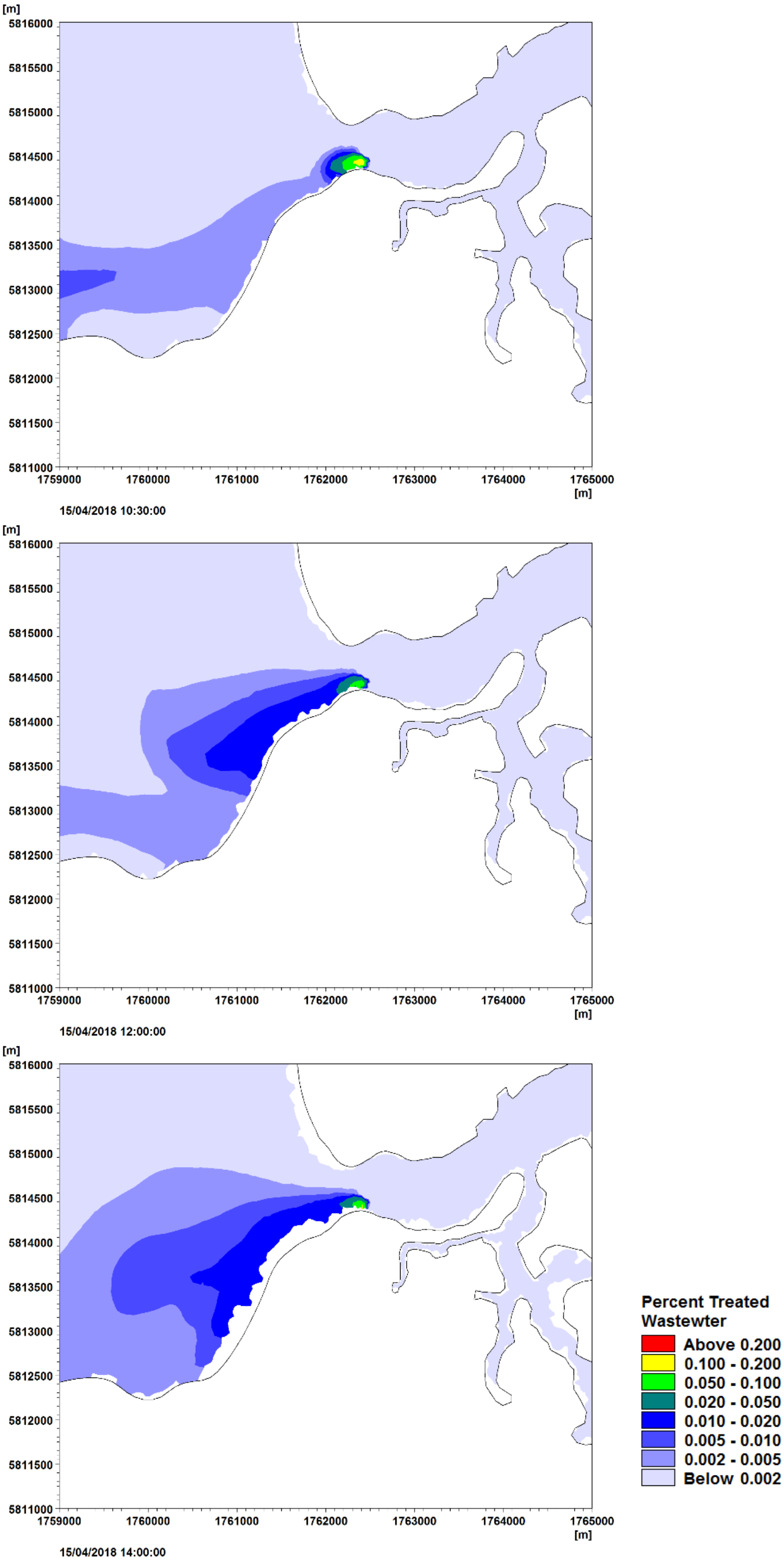

Figure 2-3. Five-hour discharge option commencing half an hour after high water. Predicted concentration at the start of the discharge (local high water plus half an hour), just prior to peak-ebb tide currents and just after peak ebb tide currents.

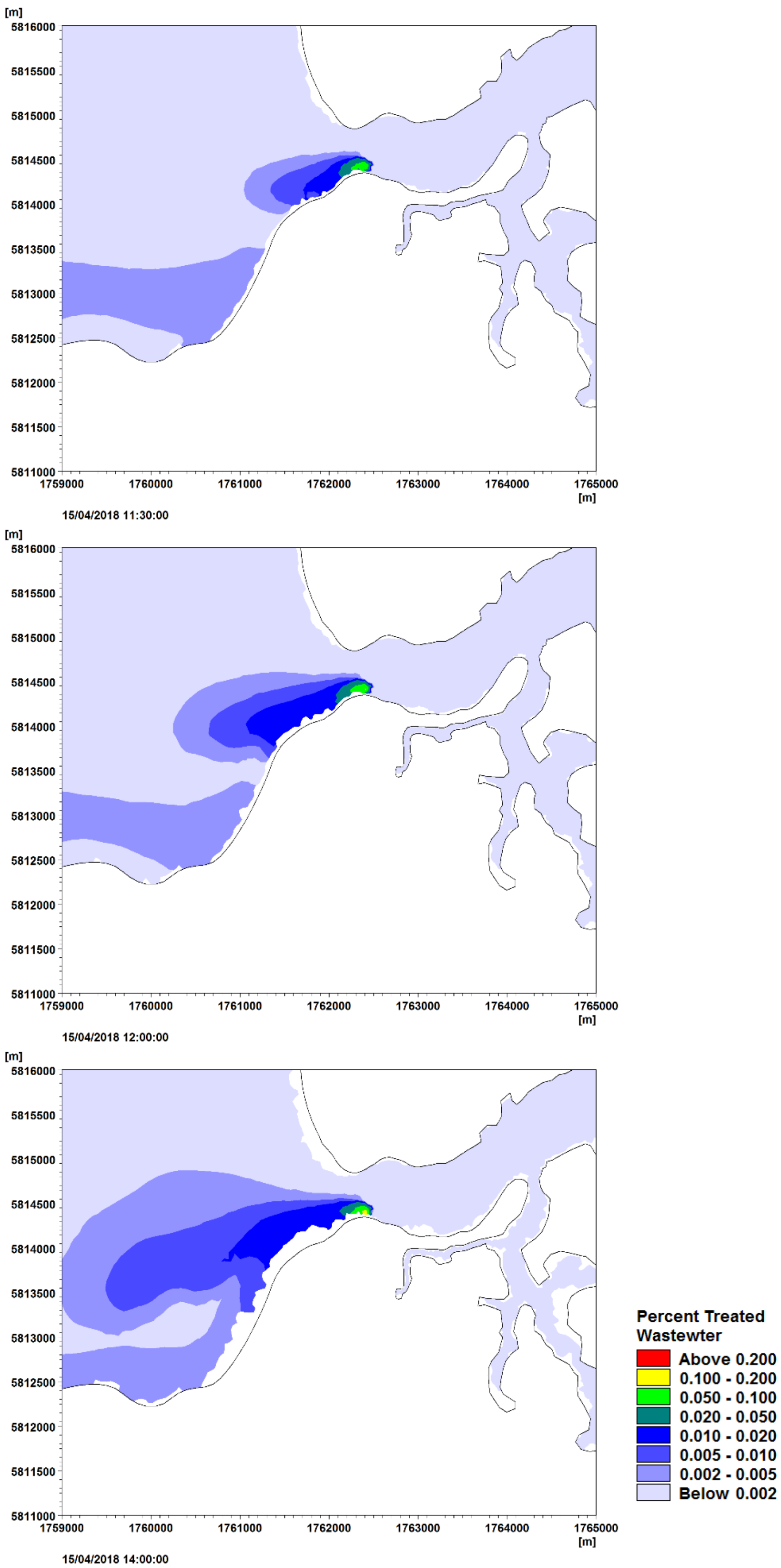

Figure 2-4. Four-hour discharge option commencing one and a half hours after high water. Predicted concentration at the start of the discharge (local high water plus one and a half hours), just prior to peak-ebb tide currents and just after peak ebb tide currents.

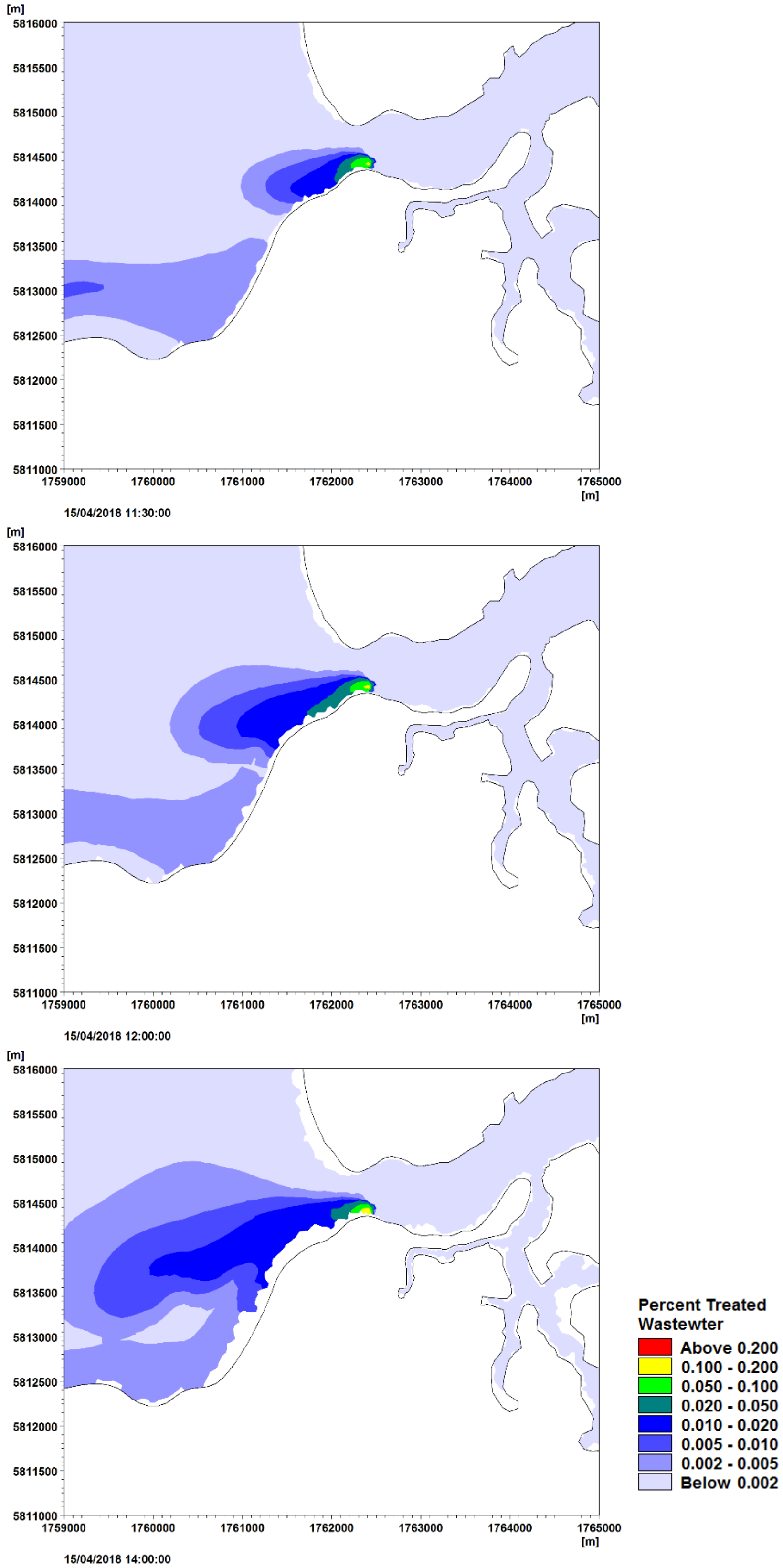

Figure 2-5. Three-hour discharge option commencing one and a half hours after high water. Predicted concentration at the start of the discharge (local high water plus one and a half hours), just prior to peak-ebb tide currents and just after peak ebb tide currents.

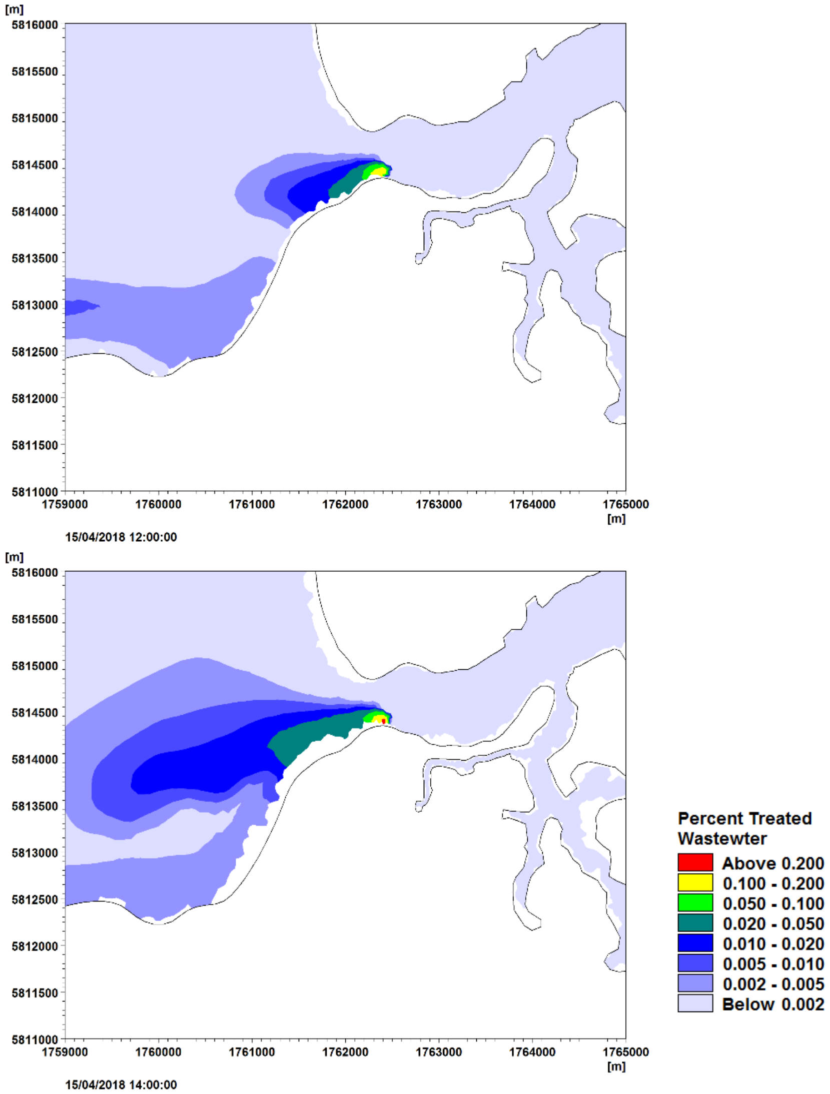

Figure 2-6. Two-hour discharge option commencing two hours after high water. Predicted concentration at the start of the discharge (local high water plus two hours - just prior to peak-ebb tide currents) and just after peak ebb tide currents.

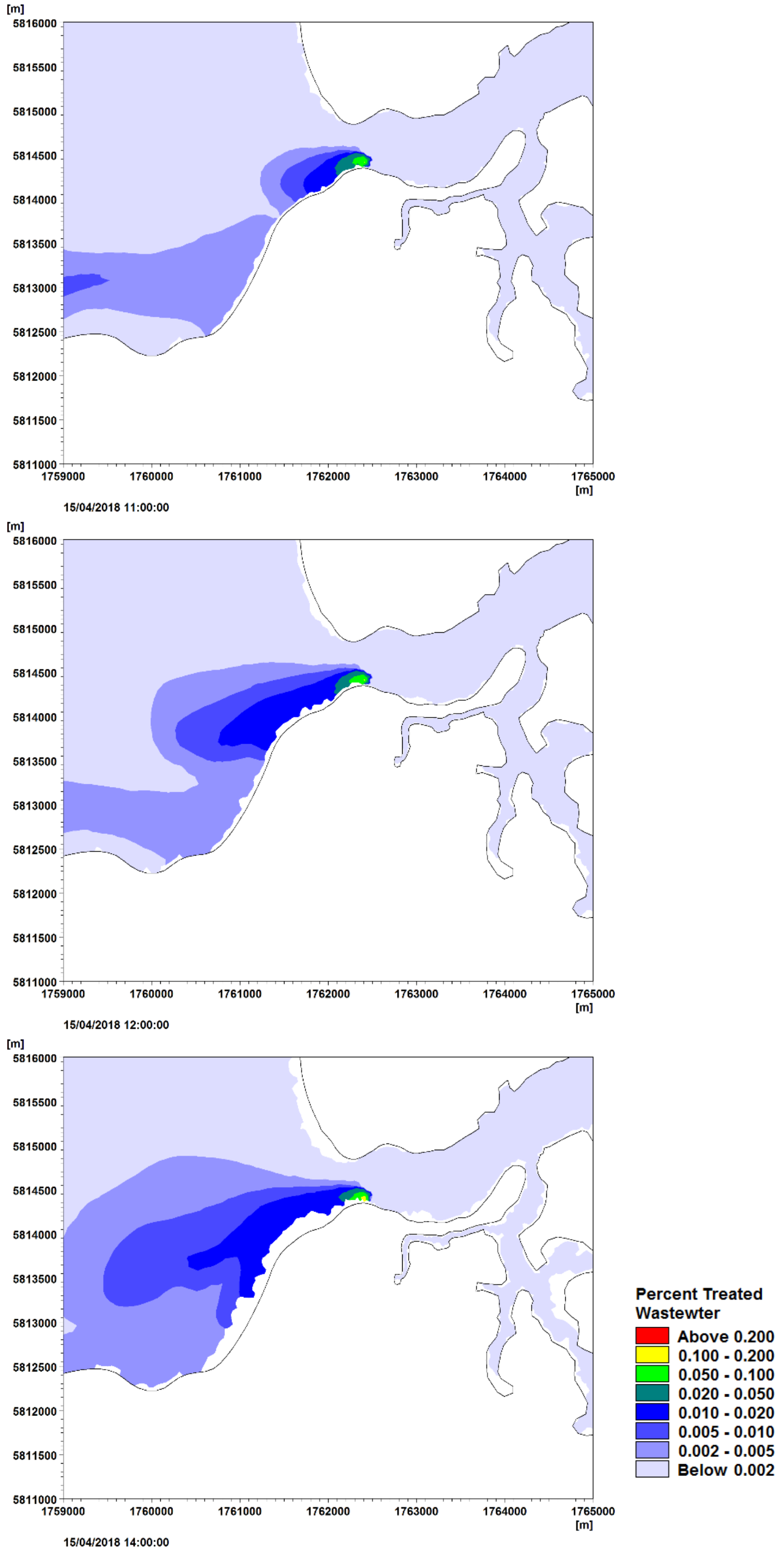

Figure 2-7. Four-hour discharge starting at local high water plus one hour. Predicted concentration at the start of the discharge (high water plus one hour), just prior to peak-ebb tide currents and just after peak ebb tide currents.

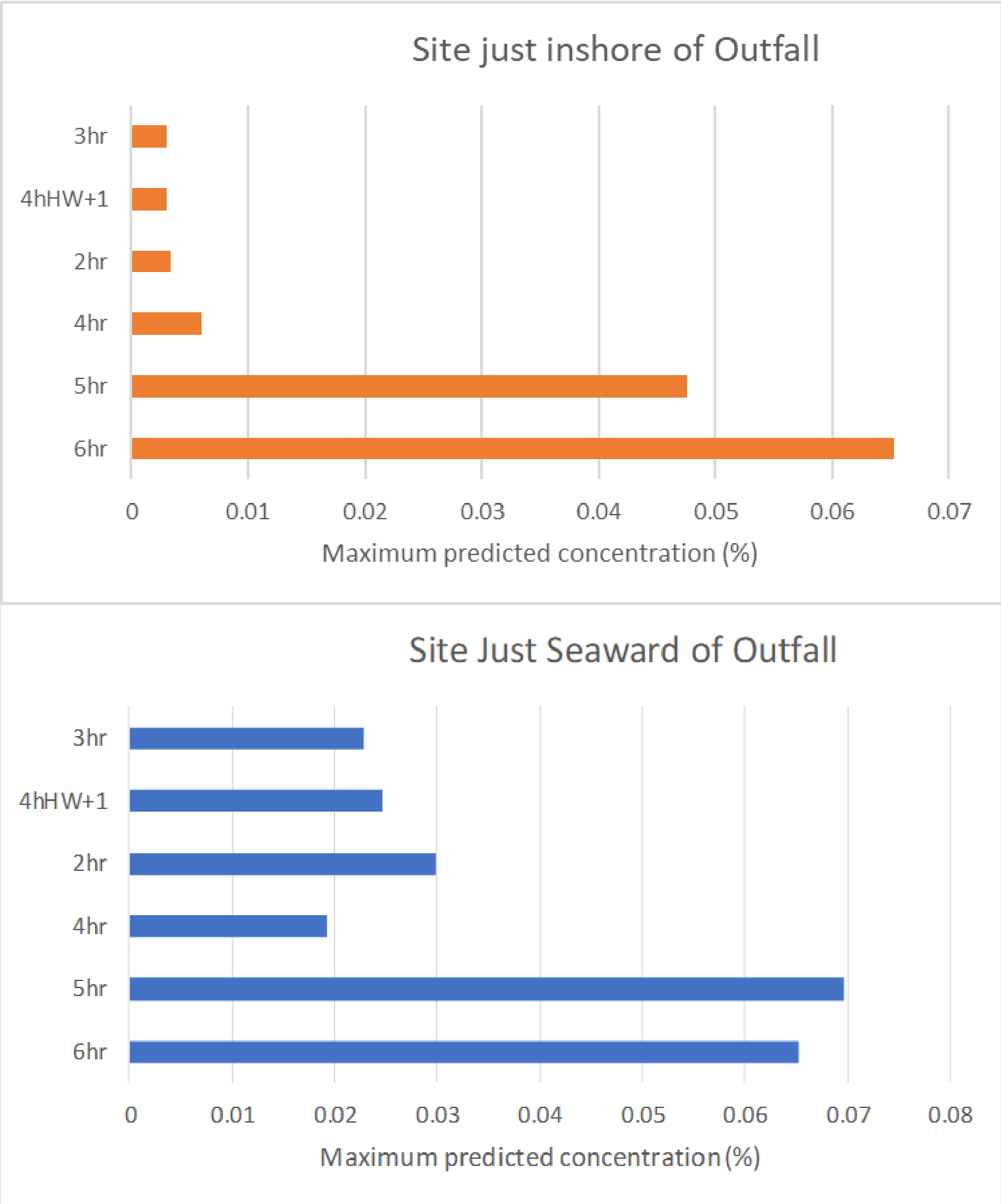

Figure 2-8. Predicted maximum concentrations just inshore of the outfall and at the very northern end of Ngarunui Beach for the timing options considered. Timing options are sorted by lowest predicted maximum concentration at the inshore site.

3 Discharge Scenarios

The following provides the assumptions used to derive the discharge rates for the four discharge options being considered for the Raglan Wastewater Treatment Plant.

These options are:

- A discharge via the exiting outfall for 2020 flow rates;
- A discharge via the new outfall for estimated flow rates in 2025 and 2055;
- A continuous discharge to the Wainui Stream for estimated flow rates in 2025 and 2055;
- A Public Land disposal option with partial discharge to a new outfall for estimated flow rates in 2025 and 2055; and
- A Private Land disposal option with partial discharge to a new outfall for estimated flow rates in 2025 and 2055

All options consider the predicted 2025 and 2055 Average Dry Weather discharges of 1372 and 1957 m^3/day respectively.

The average daily flow for the period from 2015 through to 2019 is 1025 m^3/day with the monthly variation as shown in Table 3-1. These volumes are used for the Existing scenario (Table 1-1) via the existing outfall.

This variability is used to define the mean monthly flows for the 2025 and 2055 discharge scenarios (Table 3-2).

These discharge volumes are used Options M1, M2 (via a new Outfall - Table 1-1) and F1 (via Wainui Stream - Table 1-1). For the outfall option the discharge occurs over four hours commencing one-hour after local high water.

PDP supplied estimates of the volumes that could be disposed of via both the Public and Private Land disposal options (Table 3-3 and Table 3-4). For these options, the residual volume would be discharged via an outfall (with the same 4 hour timing as for Options M1 and M2).

The volume to the new outfall for Options L1 and L4 (Public Land Disposal - Table 1-1) and L4 (Private Land Disposal -Table 1-1) and are shown in Table 3-5 and Table 3-6 respectively.

For the Public Land disposal options there is always some discharge to the outfall while for the Private Land disposal option there is no discharge to marine for 7 months (in 2025) and 5 months (in 2055).

An example of the timing of the discharges relative to the state of tide are shown in Figure 3-1.

Table 3-1. Mean daily discharge from the Raglan Wastewater Treatment Plant (2015-2019). These volumes are used for the discharge to the **Existing Outfall**.

Month	Mean Daily discharge (m^3/day)
January	900
February	790
March	668
April	992
May	1024
June	1104
July	1421
August	1337
September	1157
October	1131
November	935
December	834

Table 3-2. Assumed distribution of monthly mean daily discharge for the 2025 and 2055 discharge scenarios based on the current monthly distribution of discharges (Table 3-1). These volumes are used for the discharge scenarios to the **New Outfall** and **Wainui Stream**.

Month	Mean Volume to Outfall (m^3/day) for 2025	Mean Volume to Outfall (m^3/day) for 2055
January	1205	1719
February	1058	1509
March	895	1276
April	1328	1895
May	1372	1957
June	1478	2108
July	1903	2715
August	1791	2554
September	1550	2210
October	1515	2161
November	1252	1786
December	1117	1593
Mean Annual	1372	1957

Table 3-3. Assumed potential volumes irrigated to **Public Land** (with 50m Property Buffered Areas and Public Event Spaces Removed). Note that the volumes are all less than the assumed mean monthly discharge from the plant (Table 3-2) so that residual volumes are discharged via the outfall for all months.

Month	Mean Volume to Outfall (m^3/day) for 2025	Mean Volume to Outfall (m^3/day) for 2055
January	803	803
February	708	708
March	659	659
April	442	442
May	307	307
June	273	273
July	228	228
August	287	287
September	402	402
October	552	552
November	478	478
December	816	816

Table 3-4. Assumed potential volumes irrigated to **Private Land**. Note that these volumes are often more than the assumed mean monthly discharge from the plant (Table 3-2) so that for some months there will is no marine discharge component.

Month	Mean Volume to Outfall (m^3/day) for 2025	Mean Volume to Outfall (m^3/day) for 2055
January	1657	2168
February	1663	2123
March	1622	2015
April	1504	1603
May	856	856
June	732	732
July	625	625
August	821	821
September	1264	1264
October	1763	1809
November	1523	2003
December	1692	2131

Table 3-5. Assumed distribution of monthly mean daily discharge to **New Marine Outfall** for the 2025 and 2055 discharge scenarios with **Public Land Disposal.**

Month	Mean Volume to Outfall (m^3/day) for 2025	Mean Volume to Outfall (m^3/day) for 2055
January	402	916
February	350	801
March	236	618
April	886	1453
May	1064	1649
June	1205	1835
July	1675	2487
August	1503	2267
September	1147	1808
October	963	1609
November	775	1308
December	301	778

Table 3-6. Assumed distribution of monthly mean daily discharge to **New Marine Outfall** for the 2025 and 2055 discharge scenarios with **Private Land Disposal**.

Month	Mean Volume to Outfall (m^3/day) for 2025	Mean Volume to Outfall (m^3/day) for 2055
January	0	0
February	0	0
March	0	0
April	0	292
May	515	1100
June	746	1376
July	1278	2090
August	970	1733
September	286	947
October	0	352
November	0	0
December	0	0

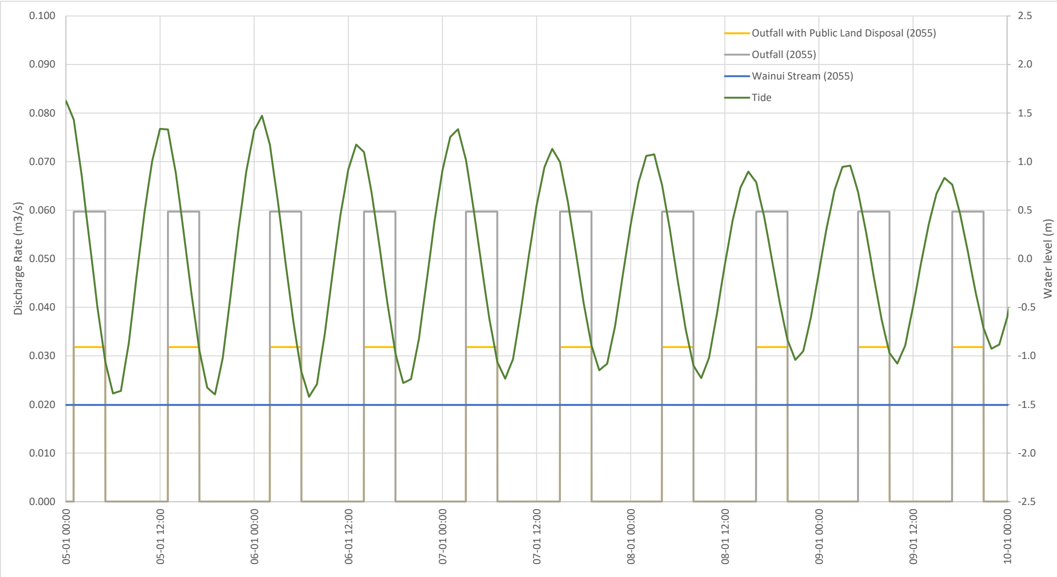

Figure 3-1. Example timing for the new outfall option for the 2055 discharge rate.

4 Near Field Modelling

The new outfall location (Figure 4-1) is approximately 100 m to the east of the existing outfall, 85 m offshore and would sit in a minimum water depth of 2.5 m (compared to a minimum water depth of 0.3 m for the existing outfall).

For the new outfall near-field modelling has been done using the industry standard CORMIX model (Doneker and Jirka, 2007). This model considers the configuration of the outfall structure, the discharge flow rate, the discharge characteristics, the bathymetry of the point of discharge and the range of currents and water depths that can occur over an outfall. Outputs from the CORMIX model are used to quantify the behaviour of the treated wastewater discharge plume within the first few hundred metres of the discharge point and to determine when the treated wastewater plume rapidly becomes fully mixed in the water.

Previous near-field modelling of the existing outfall (DHI, 2019) indicated that the lowest level of dilution occurs near high water when ambient currents are the lowest.

Under such conditions, the plume from the existing outfall occupies the top 10% of the water column and the 10-15 fold dilution is achieved at the edge of the near-field (i.e. 10-15 m from the existing outfall). At other phases of the tide, much higher levels of dilutions are achieved, and the plume becomes fully mixed through the water column within 225 metres of the outfall.

By avoiding a discharge near high-water the minimum dilution achieved over the existing outfall site will be much higher than previously modelled.

For this assessment the key outcome of the near-field modelling is to ensure that the plume dynamics within the near-field zone of the new outfall are adequately and conservatively represented in the far-field model. To do this a number of worst-case combinations of low ambient current conditions and minimal associated water depths over the outfall have been assessed using the CORMIX model.

For the new outfall location, the distribution of water depth and current speed over the outfall for the first three hours of the discharge are shown in Figures 4-2 through to 4-5. The plots also show the schematic CORMIX scenarios modelled (as summarised in Table 4-1).

The CORMIX schematic conditions are modelled for the maximum discharge rate being considered (2715 m^3/day - Table 3-2) and a single port with duck-bill valve.

Because a duck-bill valve is being fitted to the new outfall, the jet velocity will be relatively constant over the range of discharges being considered so that the jet momentum term (which is a key process in defining the near-field mixing) will be similar for the lower discharge rates being considered.

The CORMIX model results (Table 4-2) show that, with the exception of the extreme low current scenario of 0.1 m/s (which only occurs ~1% of the time - Figure 4-2), the dilution achieved over the outfall is 2-3 times higher than the minimum dilution achieved over the existing outfall.

The CORMIX model results also show that the treated wastewater discharge always occupies more than the top 20% of the water column and that the size of the near field region is relatively small (5-10 m) due to the strong tidal currents that occur during the discharge window.

Furthermore, the CORMIX modelling shows that, with the exception of the extreme low current scenario of 0.1 m/s the plume becomes fully vertically mixed within less than 275 m of the new outfall.

As for the earlier work (DHI, 2019), the treated wastewater discharge is conservatively added to just the top 20% of the water column of the far-field hydrodynamic model (i.e. the top layer of the MIKE3 model). This approach is conservative because for the majority of the time the discharge is occurring the plume will occupy more than the top 20% of the water column in the immediate vicinity of the outfalls and therefore concentrations near the surface will be less than those predicted by the far-field model (i.e. actual dilutions achieved over the new outfall are likely to be higher).

Beyond ~300m of the outfalls the plume is predicted to be fully mixed so any assumptions about the near-field behaviour incorporated into the far-field model do not affect the far-field model results.

Appendix A provides plots of predicted dilution versus distance from the new outfall for the schematic conditions modelled.

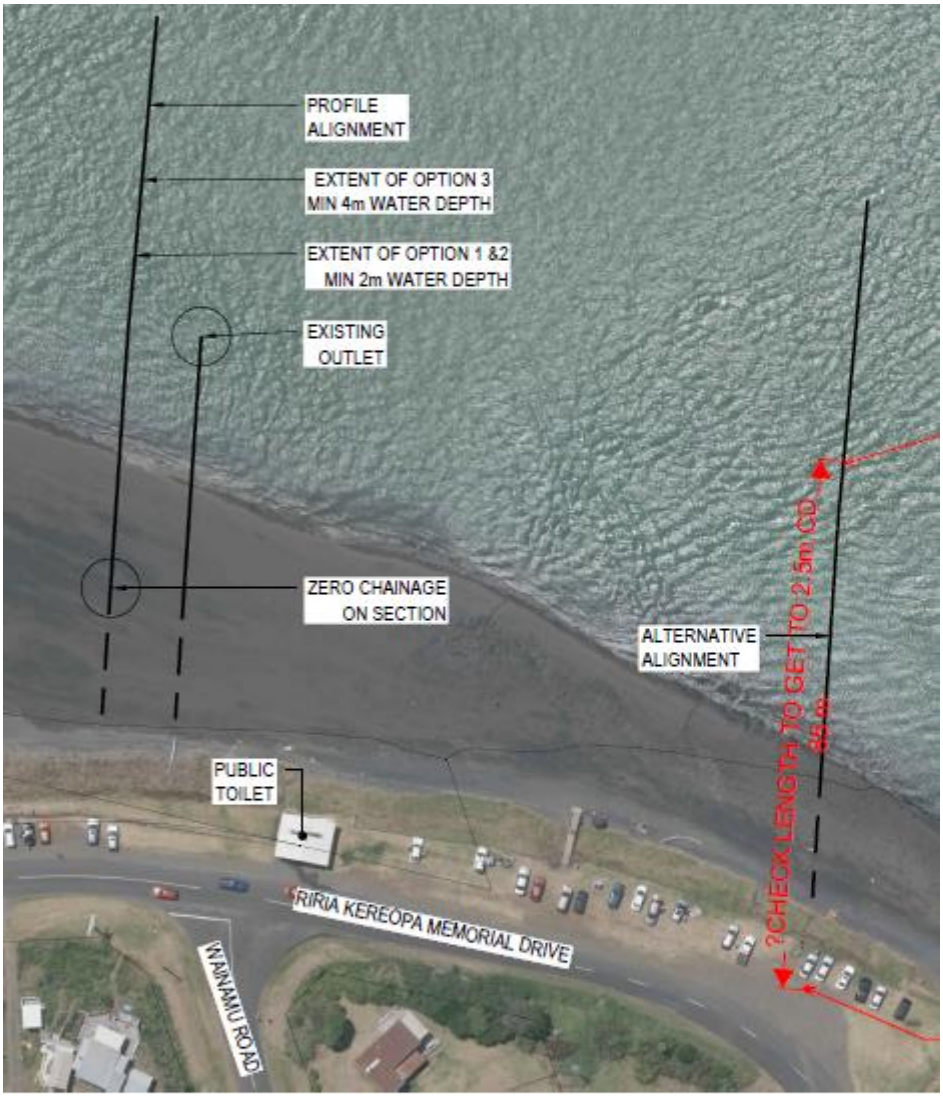

Figure 4-1. Existing and proposed new outfall location.

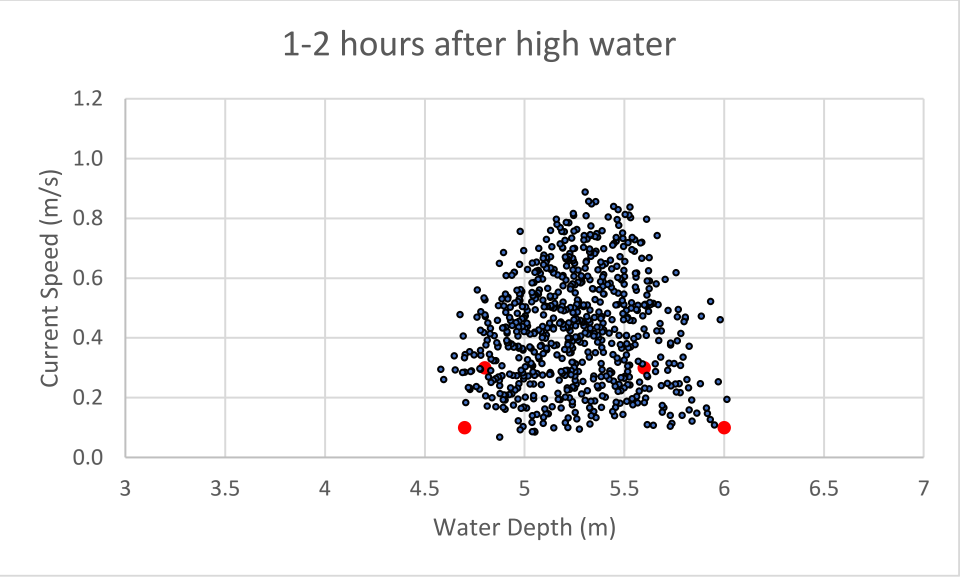

Figure 4-2. Distribution of predicted water depth and current speed over the new outfall during the first hour of the discharge window. The red symbols show the schematic CORMIX scenarios modelled.

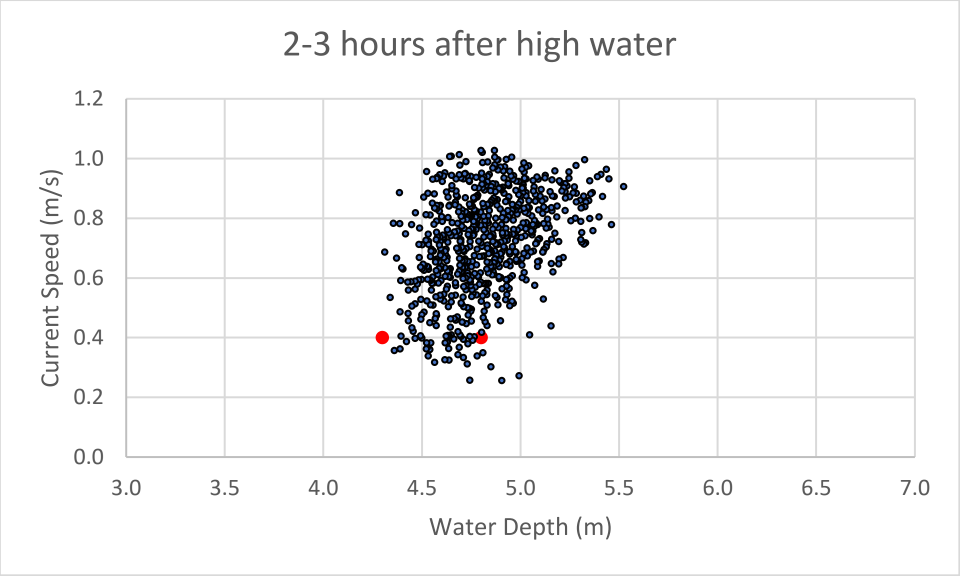

Figure 4-3. Distribution of predicted water depth and current speed over the new outfall during the second hour of the discharge window. The red symbols show the schematic CORMIX scenarios modelled.

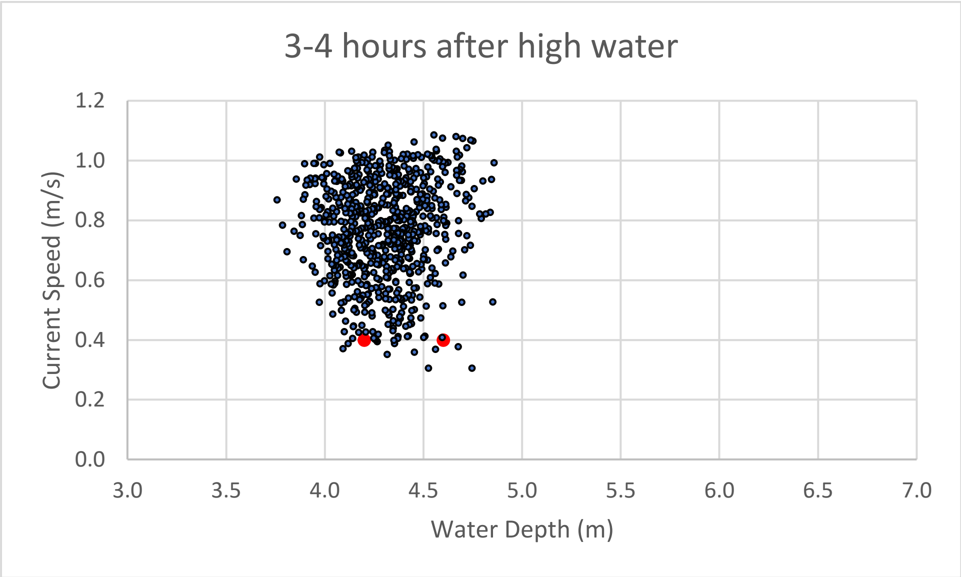

Figure 4-4. Distribution of predicted water depth and current speed over the new outfall during the third hour of the discharge window. The red symbols show the schematic CORMIX scenarios modelled.

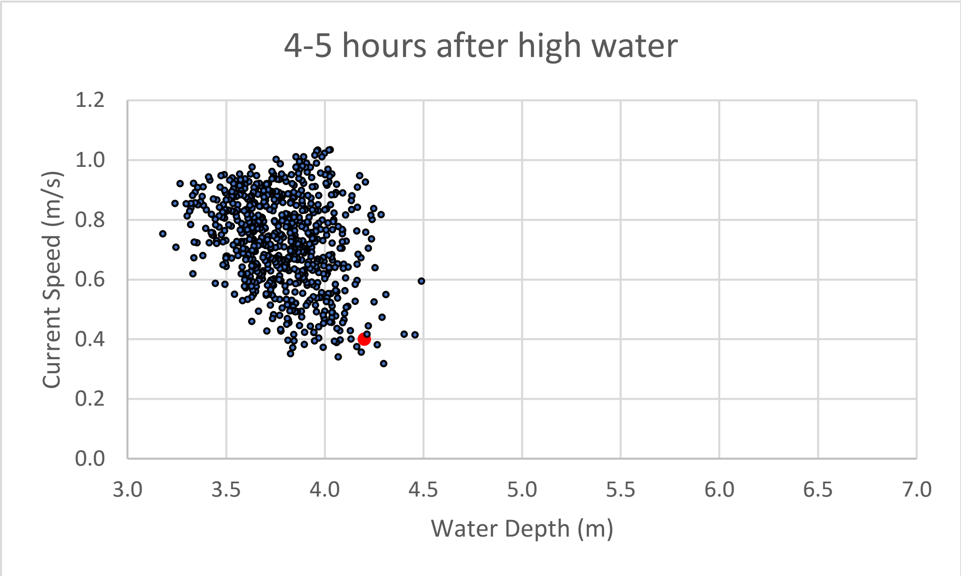

Figure 4-5. Distribution of predicted water depth and current speed over the new outfall during the fourth hour of the discharge window. The red symbols show the schematic CORMIX scenarios modelled.

Table 4-1 Summary of CORMIX scenarios modelled.

Scenario ID	Schematic condition	Schematic Current Speed (m/s)	Schematic Water Depth (m)
A	Neap (First hour of discharge), minimum current	0.10	4.70
B	Spring (First hour of discharge), minimum current	0.10	6.00
C	Neap (First hour of discharge), mean current	0.30	4.30
D	Spring (First hour of discharge), mean current	0.30	4.80
E	Neap (Second hour of discharge), minimum current	0.40	4.10
F	Spring (Second hour of discharge), minimum current	0.40	4.40
G	Neap (Third and fourth hour of discharge), minimum current	0.40	3.80
H	Spring (Third and fourth hour of discharge), minimum current	0.40	4.20

Table 4-2 CORMIX results for the schematic scenarios modelled.

Schematic condition	Schematic Current Speed (m/s)	Schematic Water Depth (m)	Distance to Edge of Near Field Region (m)	Sigma thickness	Plume Thickness at edge of Near Field Region (m)	Dilution at edge of Near Field Region	Dilution at 100m	Dilution at 100m	Distance when plume is fully vertically mixed (m)
Neap (First hour of discharge), minimum current	0.10	4.70	9.00	19%	0.88	11	32	85	-
Spring (First hour of discharge), minimum current	0.10	6.00	9.00	18%	1.08	15	35	84	-
Neap (First hour of discharge), mean current	0.30	4.30	5.00	43%	1.86	15	94	328	275
Spring (First hour of discharge), mean current	0.30	4.80	7.00	48%	2.28	31	205	521	172
Neap (Second hour of discharge), minimum current	0.40	4.10	9.00	50%	2.03	33	209	269	115
Spring (Second hour of discharge), minimum current	0.40	4.40	10.00	49%	2.16	37	206	290	133
Neap (Third and fourth hour of discharge), minimum current	0.40	3.80	8.00	50%	1.91	29	190	241	111
Spring (Third and fourth hour of discharge), minimum current	0.40	4.20	9.00	50%	2.08	35	208	275	124

5 Plume Dynamics

Figures 5-1 through to Figure 5-16 show the predicted 95th percentile plots for each of the scenarios considered.

Percentile plots for the period from January-March and July-September are provided for each scenario so that the influence of the reduced volumes to the outfall for the land disposal options can be visualised against the full discharge to marine options.

For the outfall options, the plots show the clear distinction between the January-March dilutions (when discharge volumes are lower) and those in July-September. The area where dilutions of less than 2000 are predicted to occur extends more offshore during the July-September period compared to in January-March. There is also an overall reduction in the level of dilution achieved in July-September period compared to in January-March.

The reduced volumes to the outfall with the Land Disposal options results in an overall increase in dilution.

For the Wainui Stream options, the zone where dilutions of less than 100 are achieved is very similar for the January-March period and the July-September period (extending slightly more into the Opotoru Arm in July-September).

The area where a dilution of less than 100 is achieved increases slightly between the 2025 scenario and the 2055 scenario from ~9.6 Ha to ~12.0 Ha.

In the wider harbour, as for the outfall options, there is an overall increase in the level of dilution achieved in July-September period compared to in January-March.

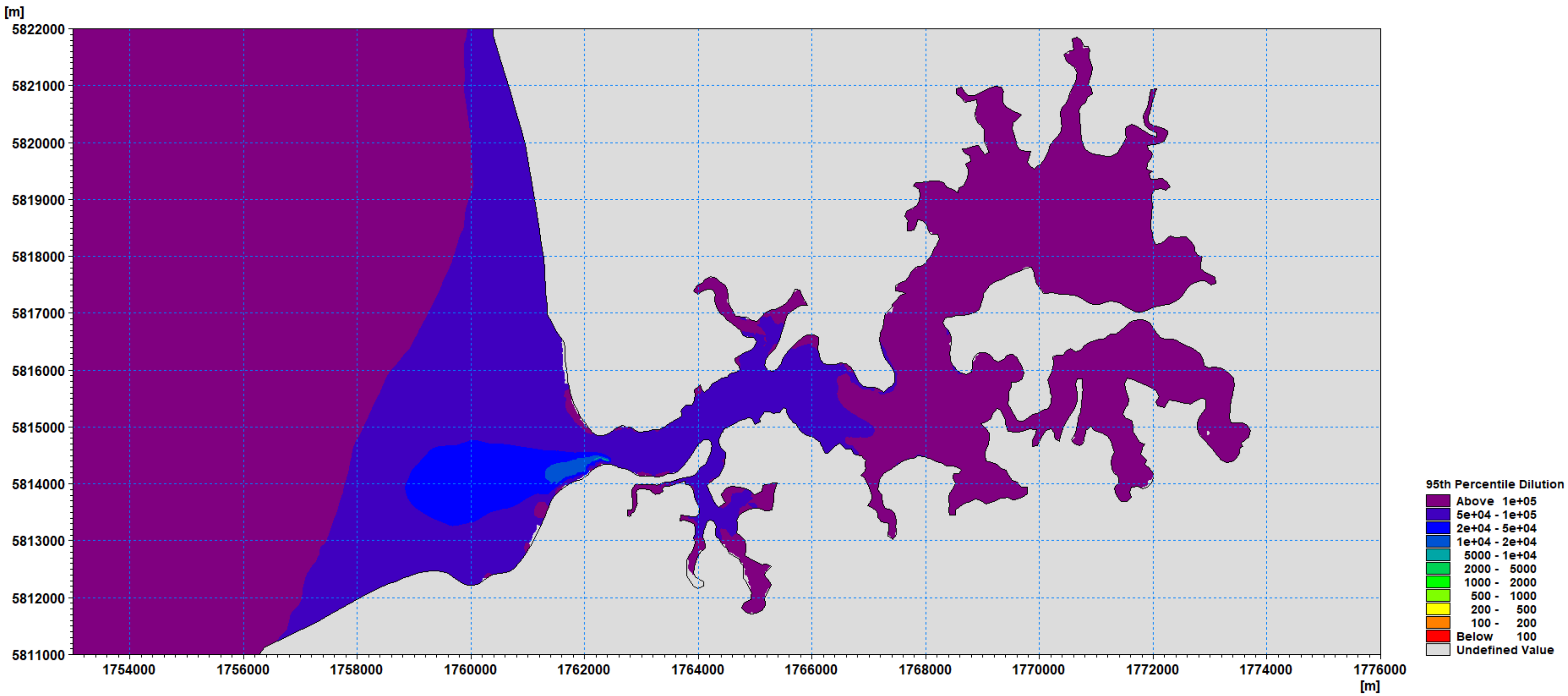

Figure 5-1. Predicted 95th percentile dilution for the January-March period for Existing Scenario (Existing Outfall, Current Discharge rate).

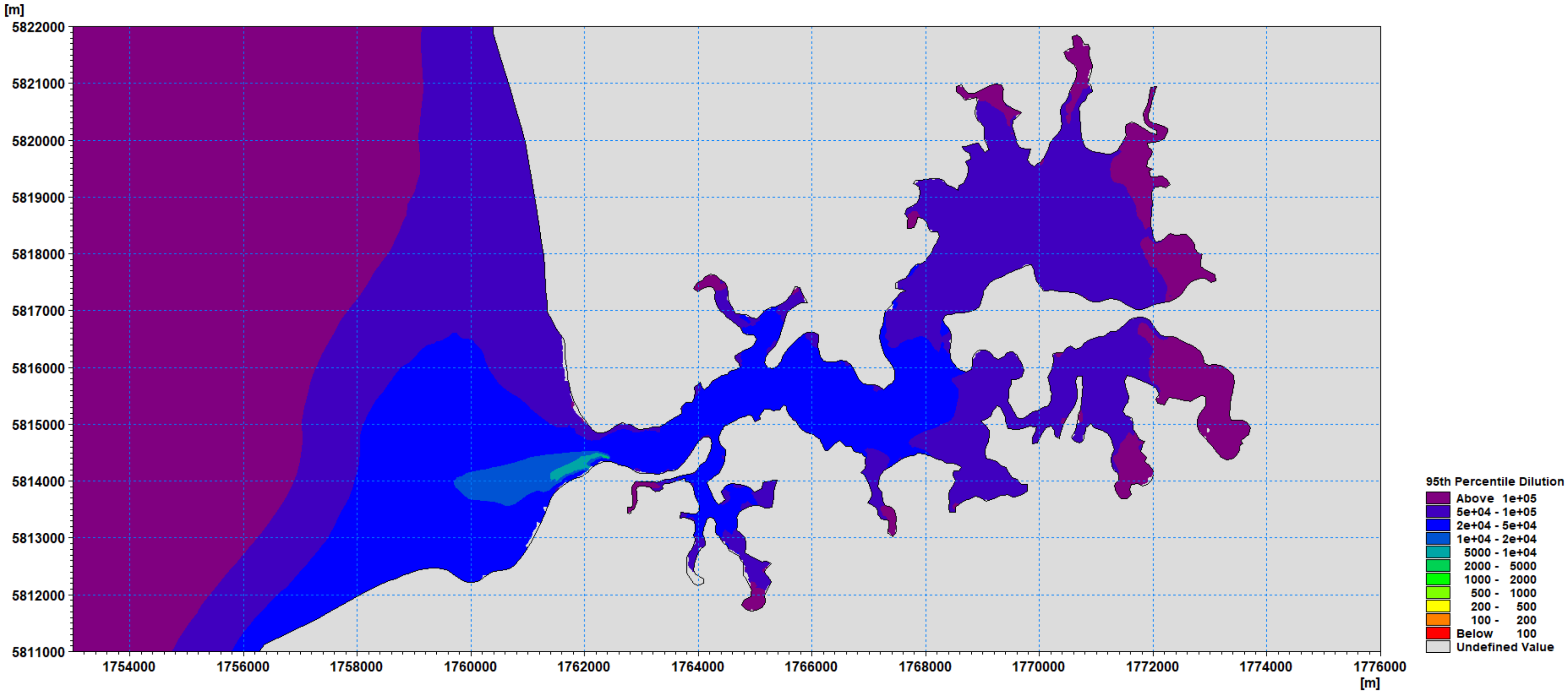

Figure 5-2. Predicted 95th percentile dilution for the July-September period for Existing Scenario (Existing Outfall, Current Discharge rate).

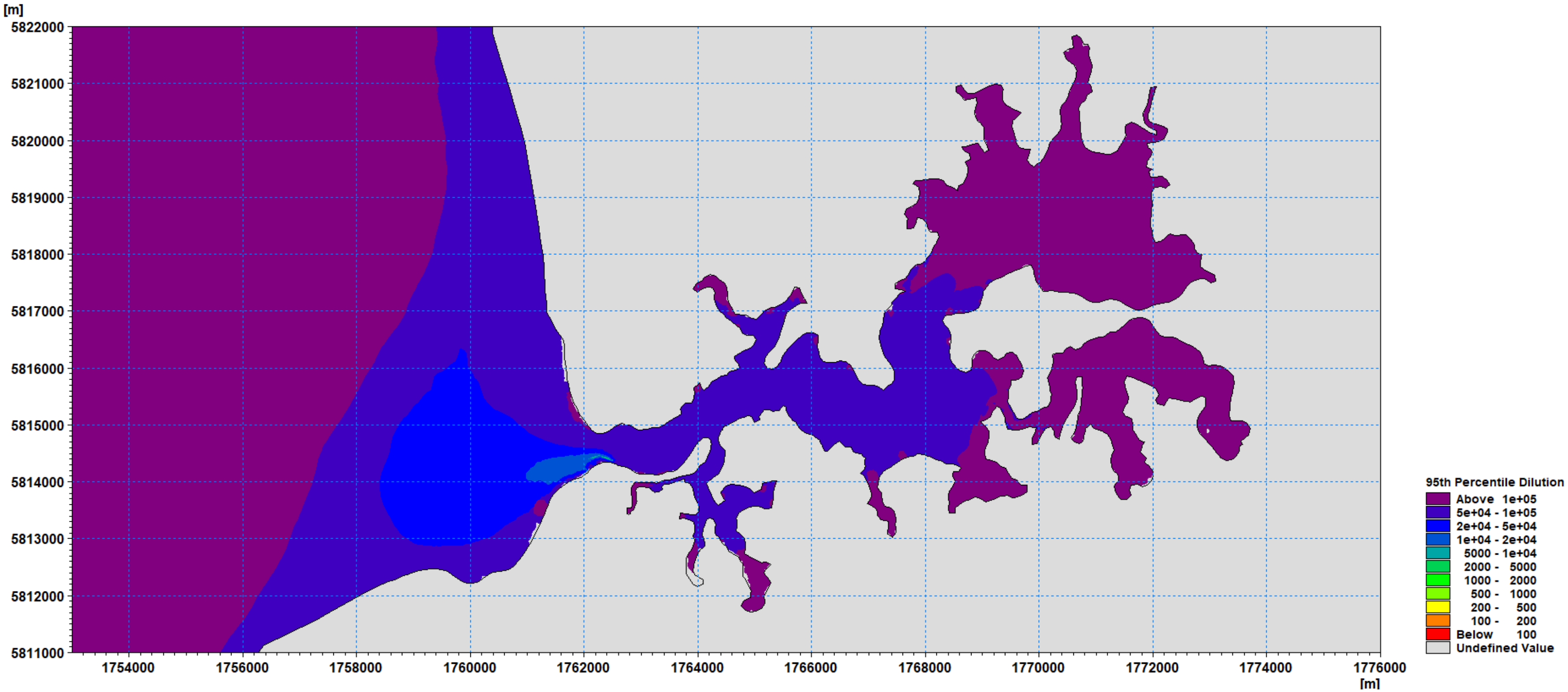

Figure 5-3. Predicted 95th percentile dilution for the January-March period for Scenario M1 (New Outfall, 2025 Discharge rate).

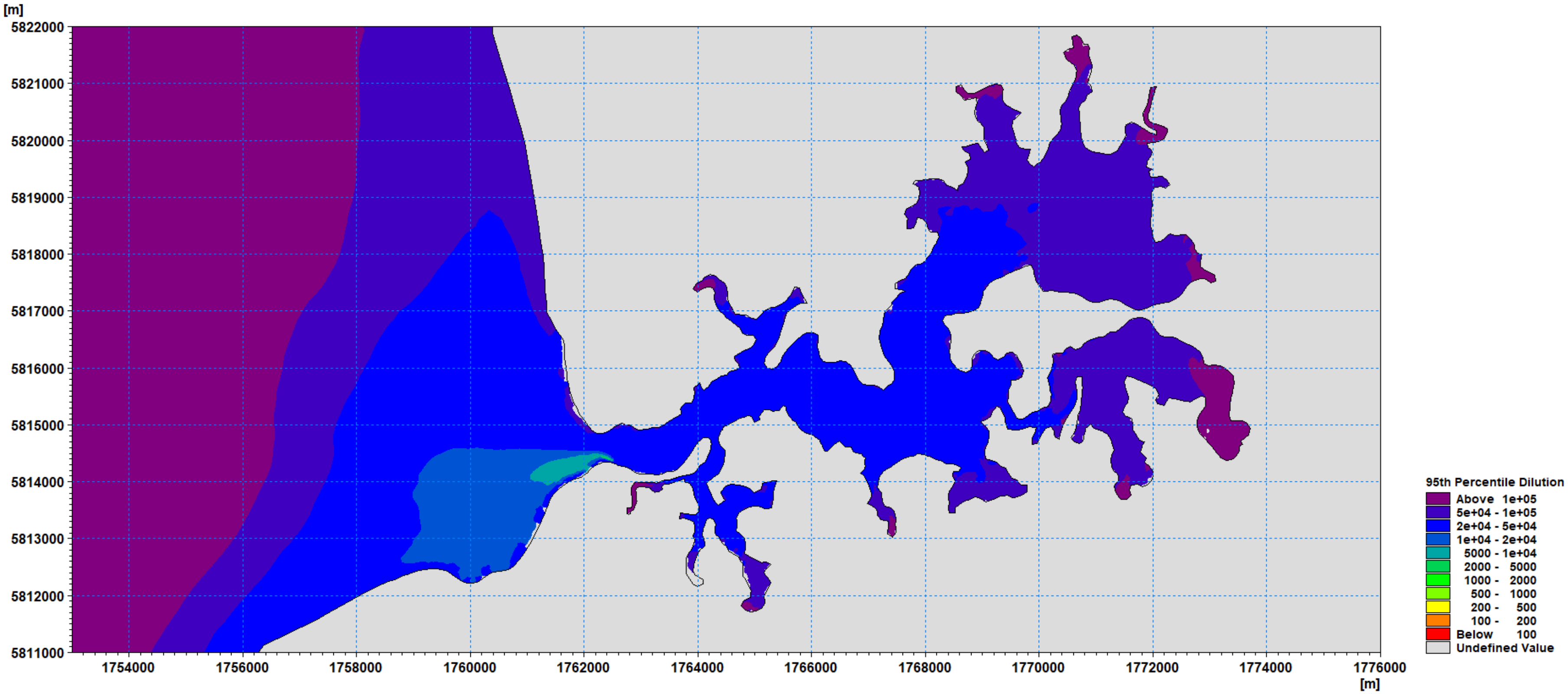

Figure 5-4. Predicted 95th percentile dilution for the July-September period for Scenario M1 (New Outfall, 2025 Discharge rate).

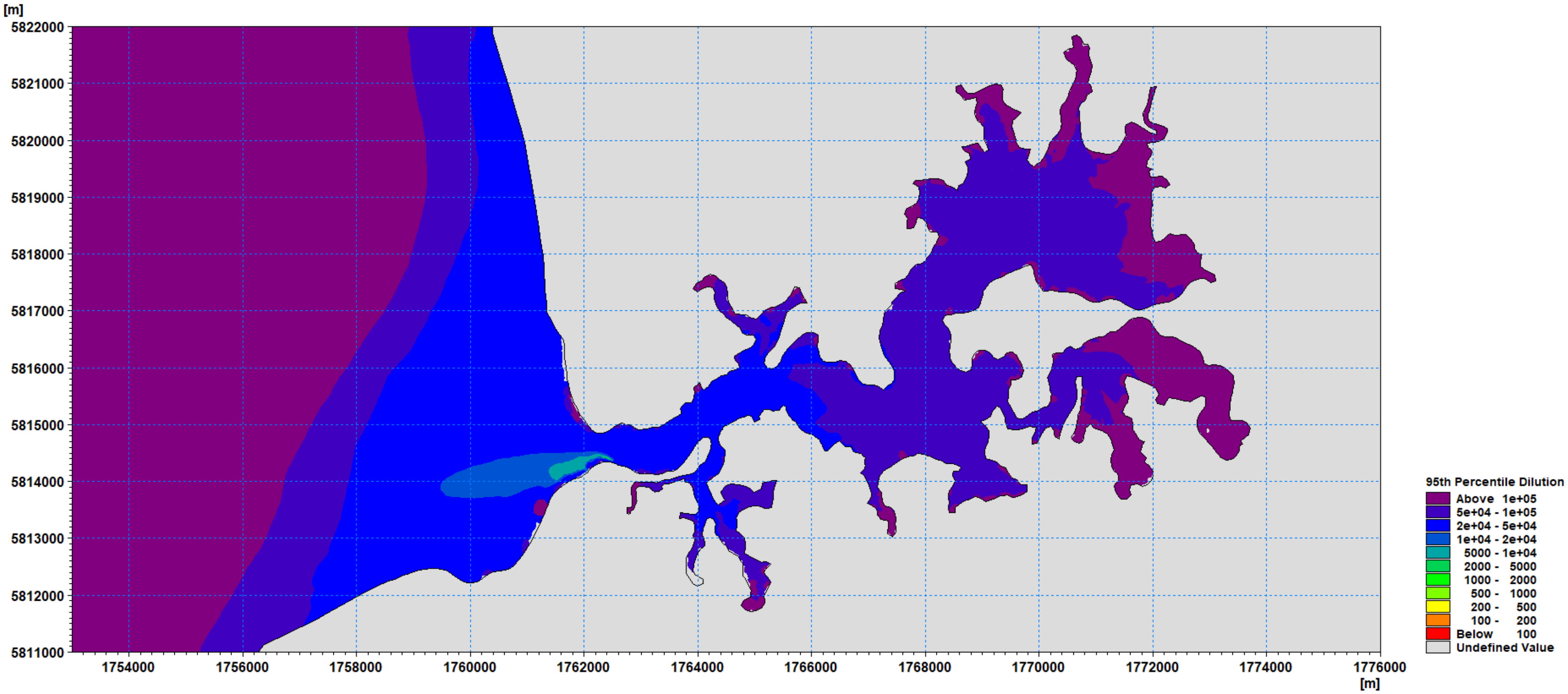

Figure 5-5. Predicted 95th percentile dilution for the January-March period form M1 (New Outfall, 2055 Discharge rate).

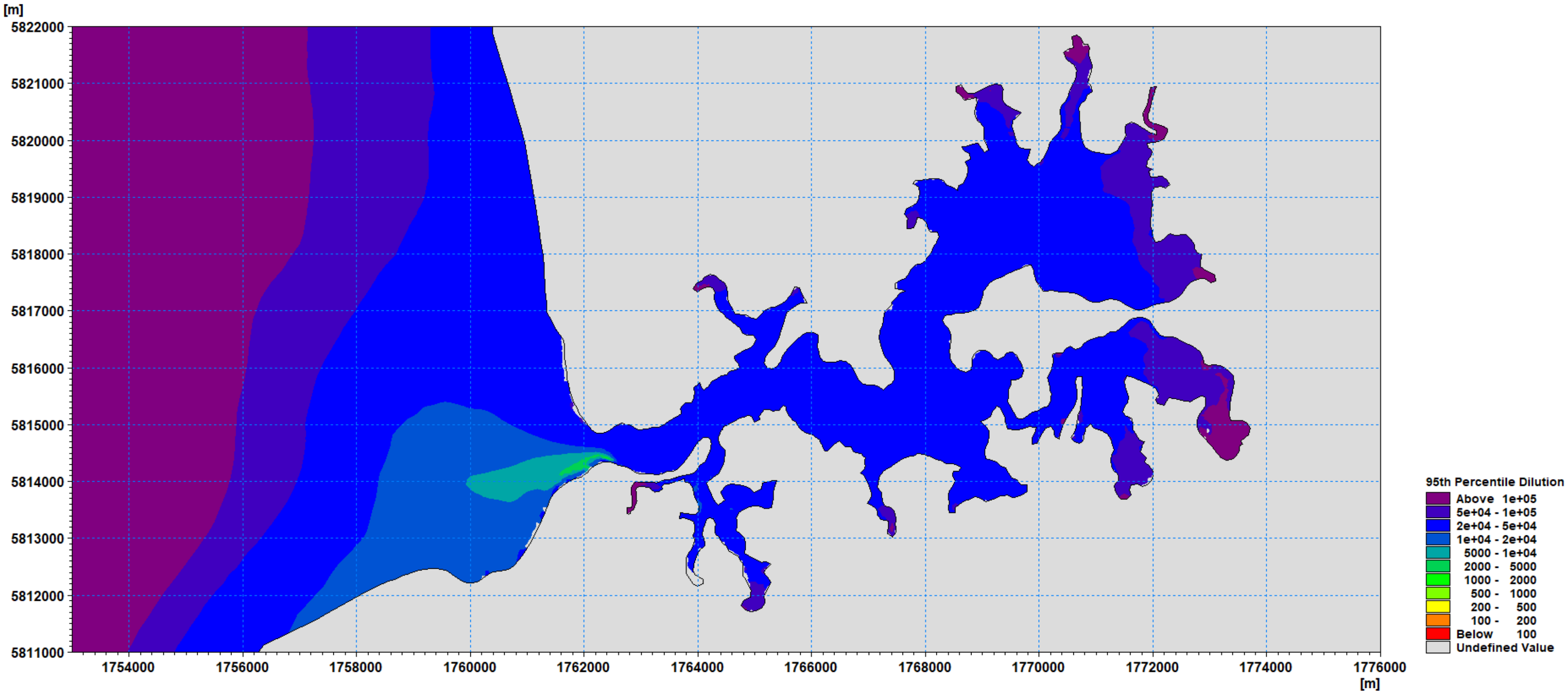

Figure 5-6. Predicted 95th percentile dilution for the July-September period form M1 (New Outfall, 2055 Discharge rate).

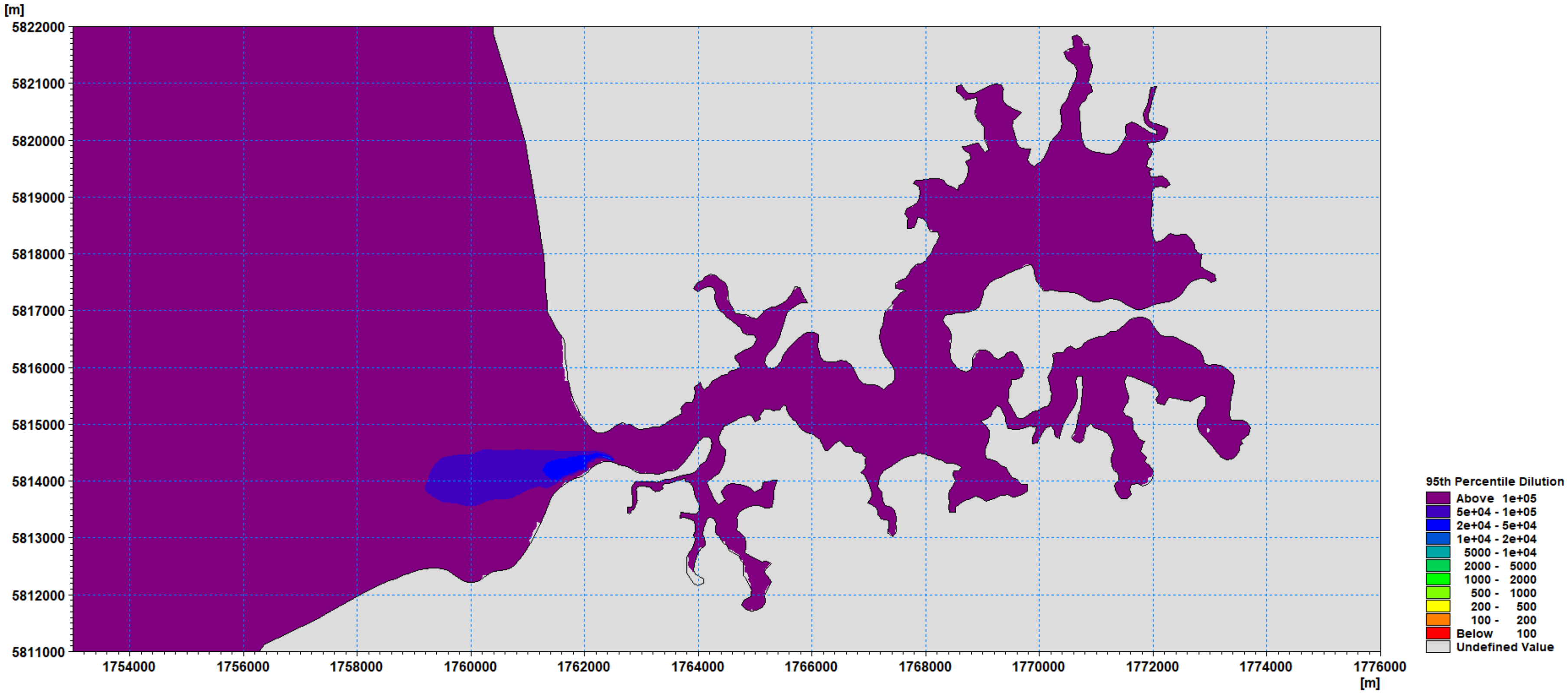

Figure 5-7. Predicted 95th percentile dilution for the January-March period for Scenario L1 (Public Land disposal plus New Outfall, 2025 Discharge rate).

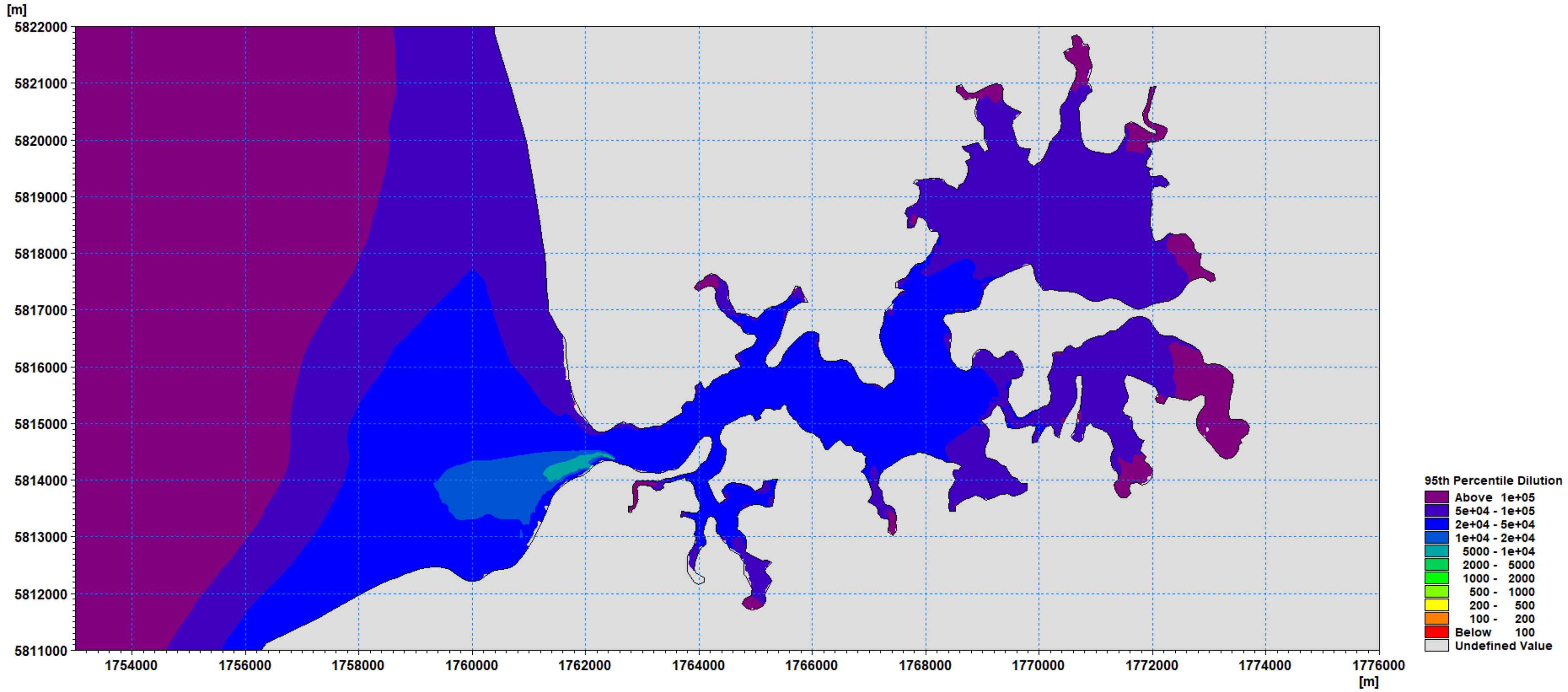

Figure 5-8. Predicted 95th percentile dilution for the July-September period form L1 (Public Land Disposal plus New Outfall, 2025 Discharge rate).

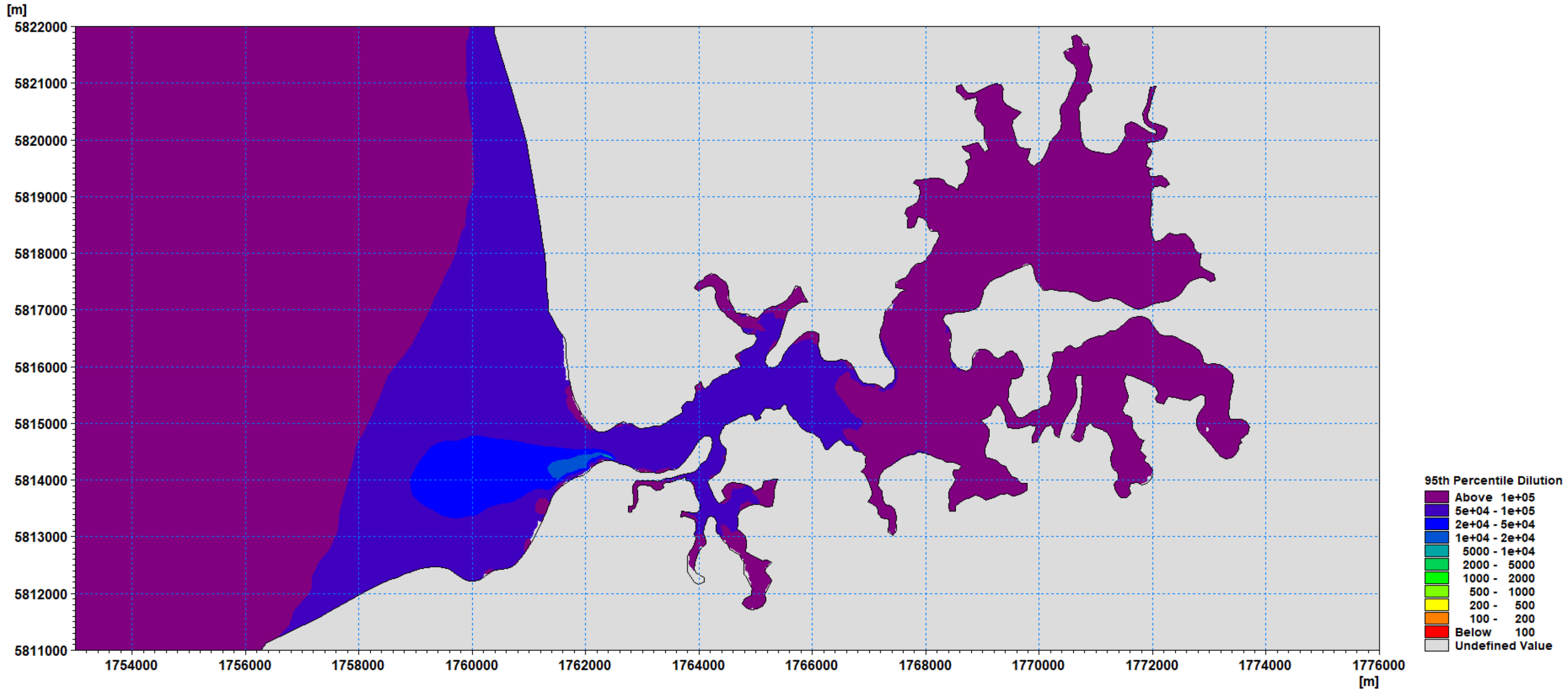

Figure 5-9. Predicted 95th percentile dilution for the January-March period for Scenario L3 (Public Land disposal plus New Outfall, 2055 Discharge rate).

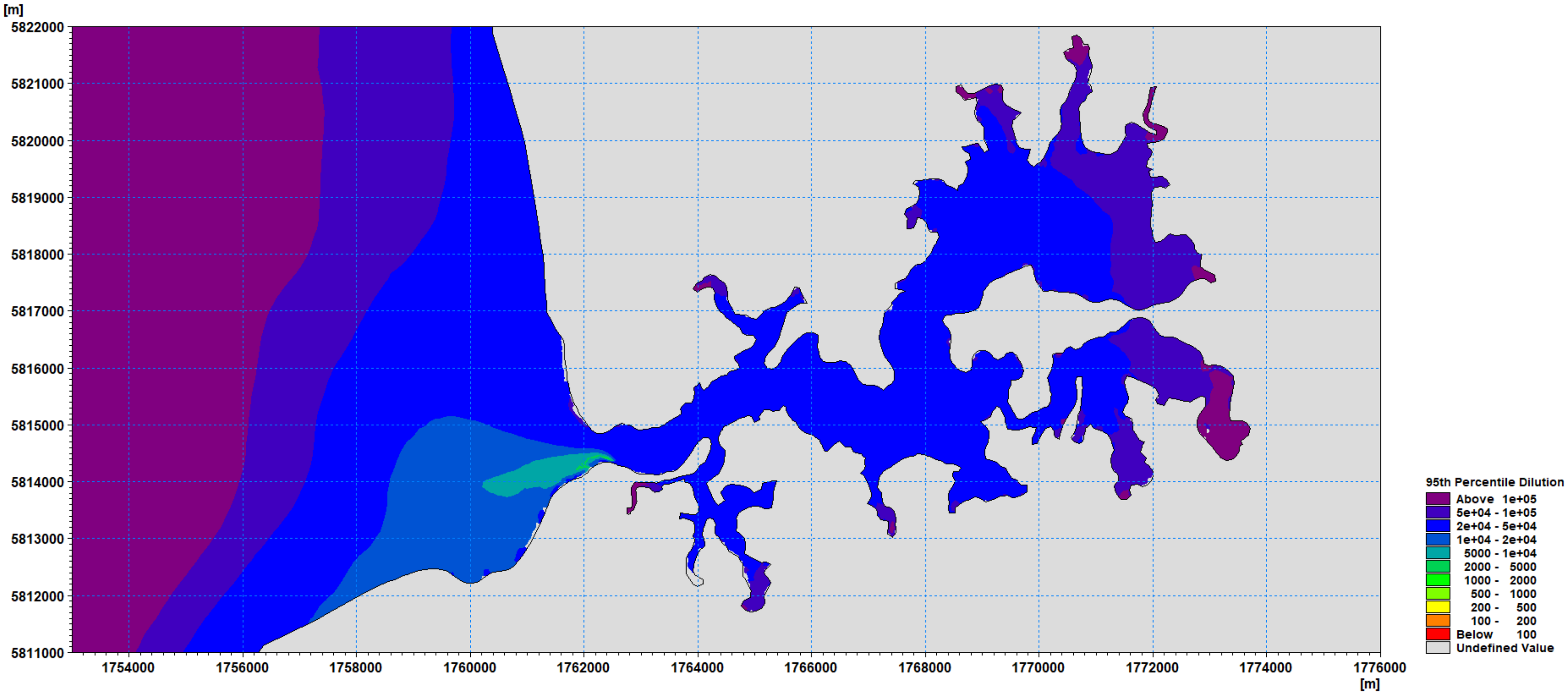

Figure 5-10. Predicted 95th percentile dilution for the July-September period form L3 (Public Land Disposal plus New Outfall, 2025 Discharge rate).

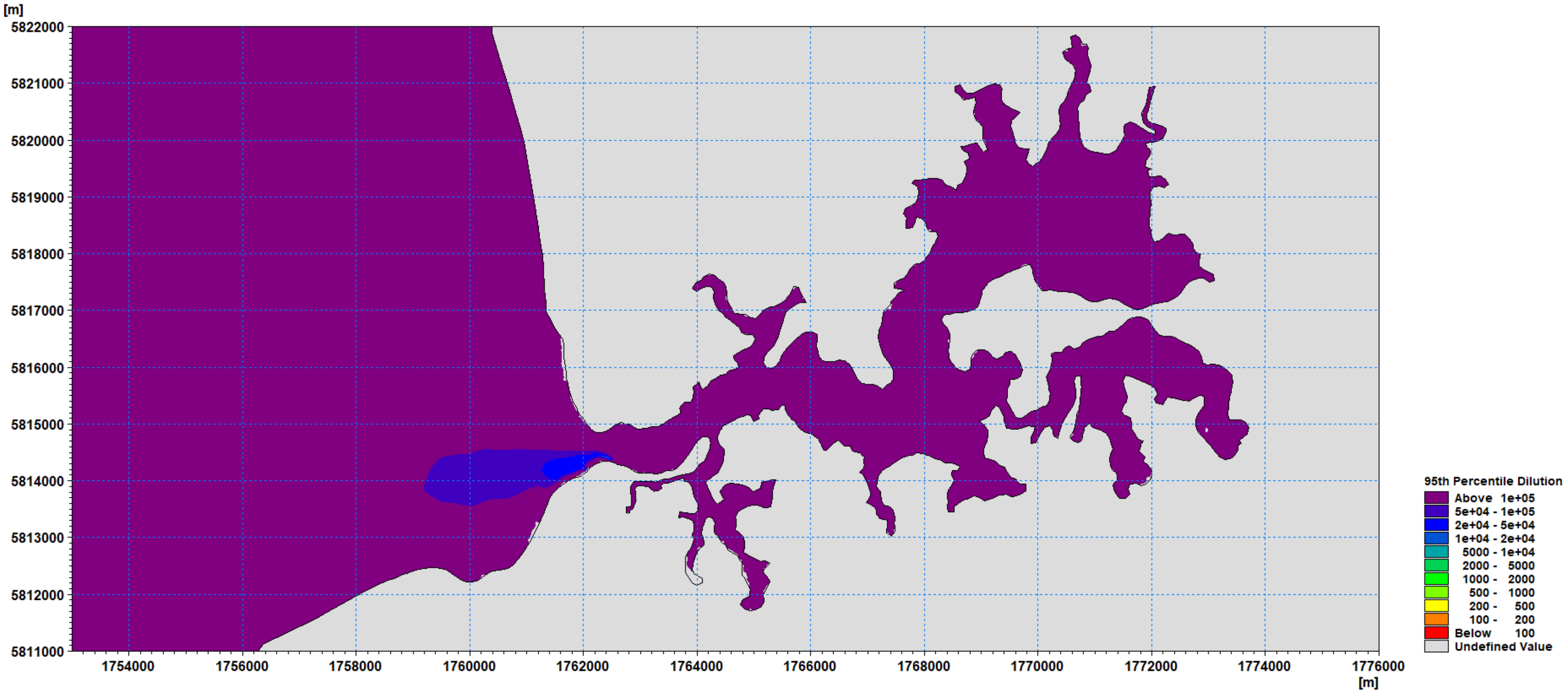

Figure 5-11. Predicted 95th percentile dilution for the July-September period form L3 (Private Land Disposal plus New Outfall, 2025 Discharge rate). Note there is no discharge in January-March for this discharge options.

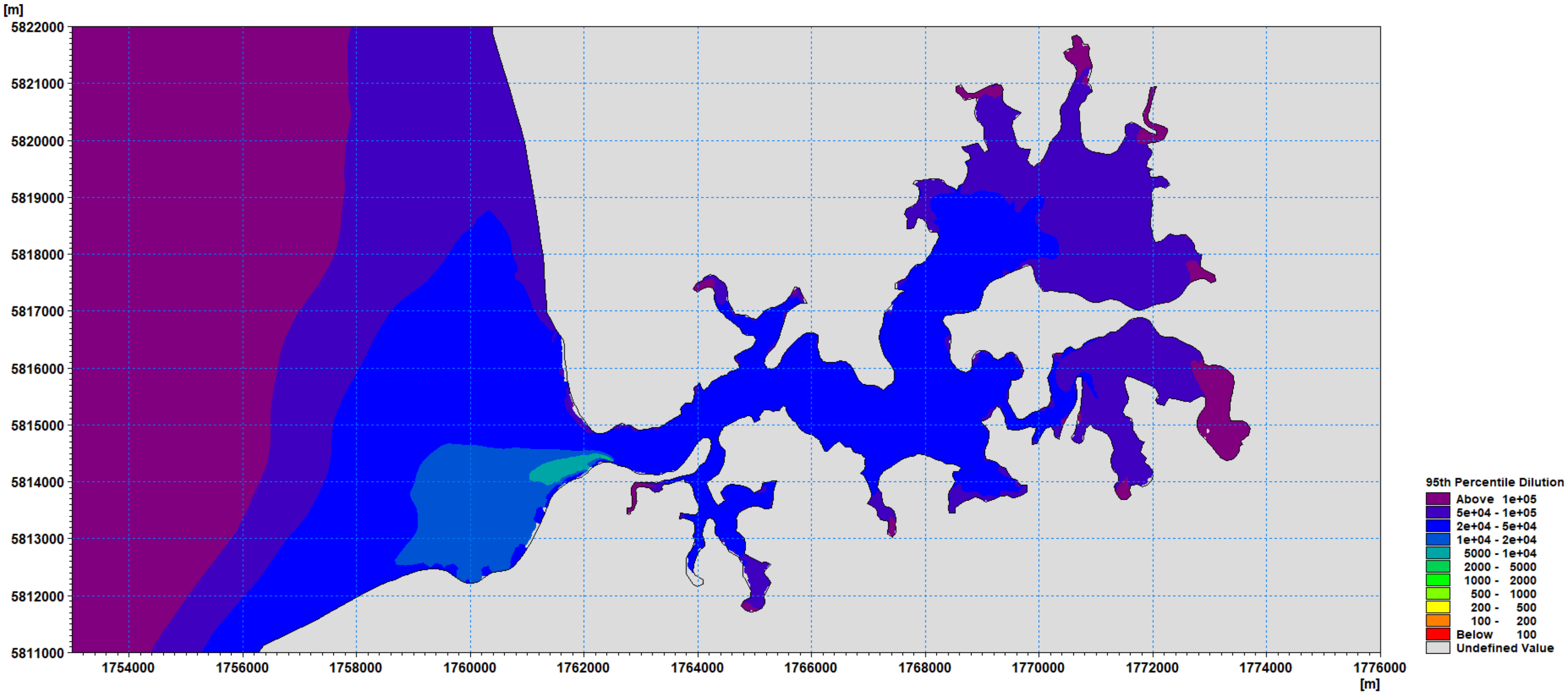

Figure 5-12. Predicted 95th percentile dilution for the July-September period form L3 (Private Land Disposal plus New Outfall, 2055 Discharge rate). Note there is no discharge in January-March for this discharge options.

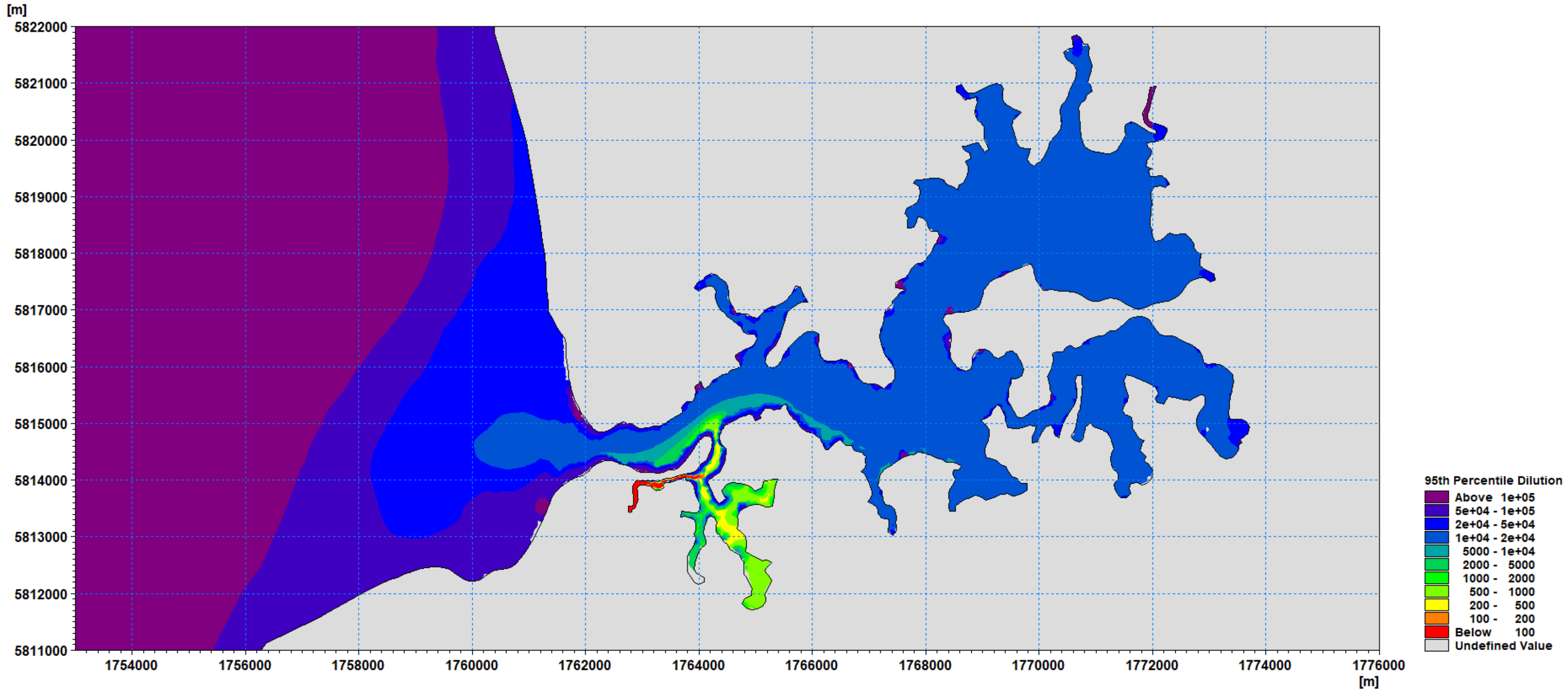

Figure 5-13. Predicted 95th percentile dilution for the January-March period for Scenario F1 (Wainui Stream, 2025 Discharge rate).

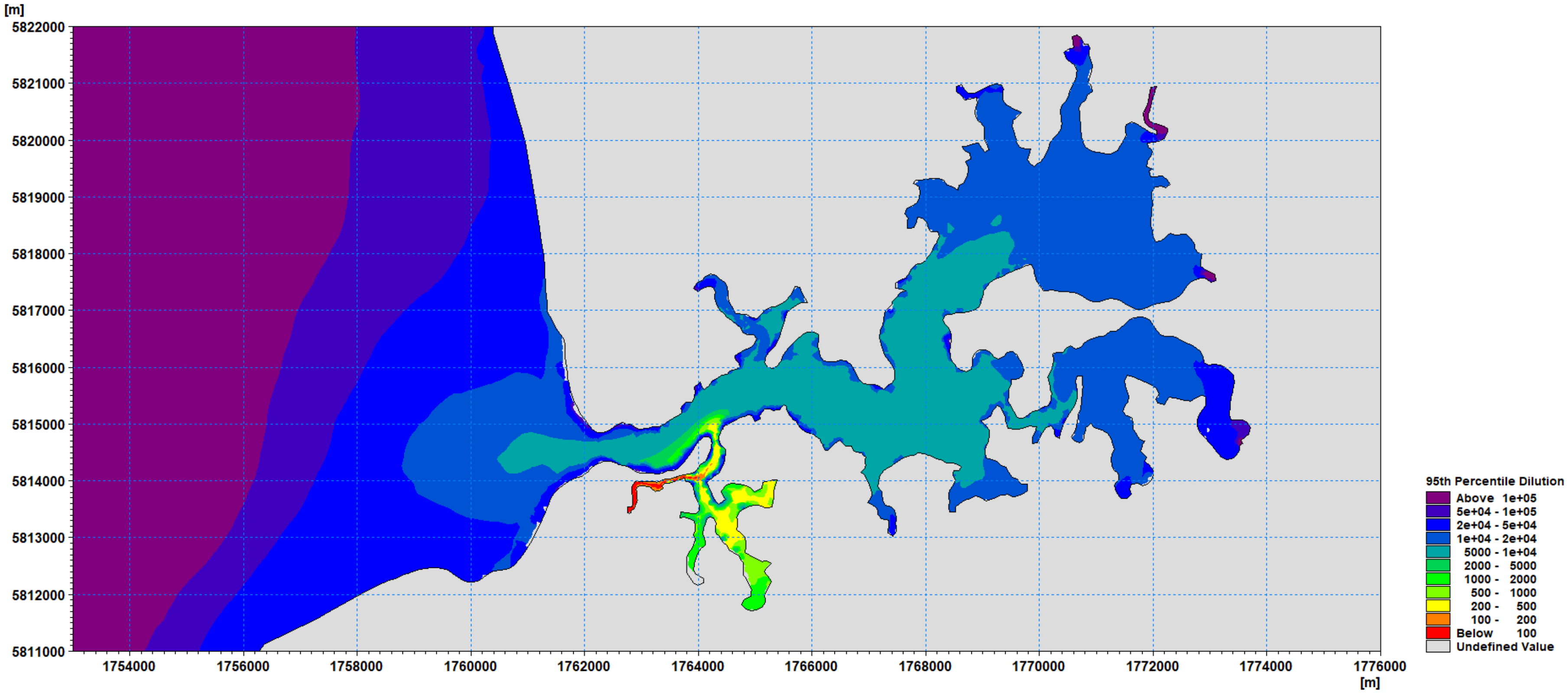

Figure 5-14. Predicted 95th percentile dilution for the July-September period for Scenario F1 (Wainui Stream, 2025 Discharge rate).

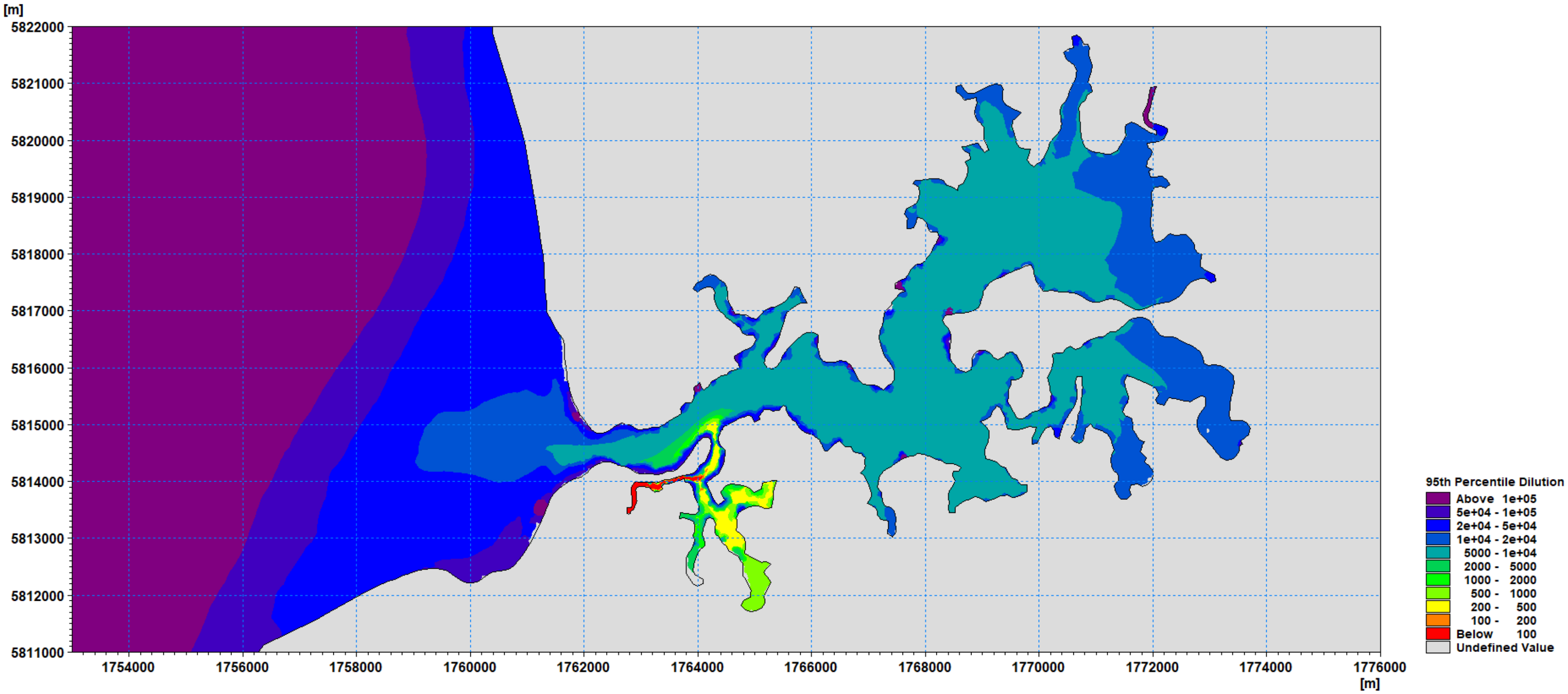

Figure 5-15. Predicted 95th percentile dilution for the January-March period for Scenario F1 (Wainui Stream, 2055 Discharge rate).

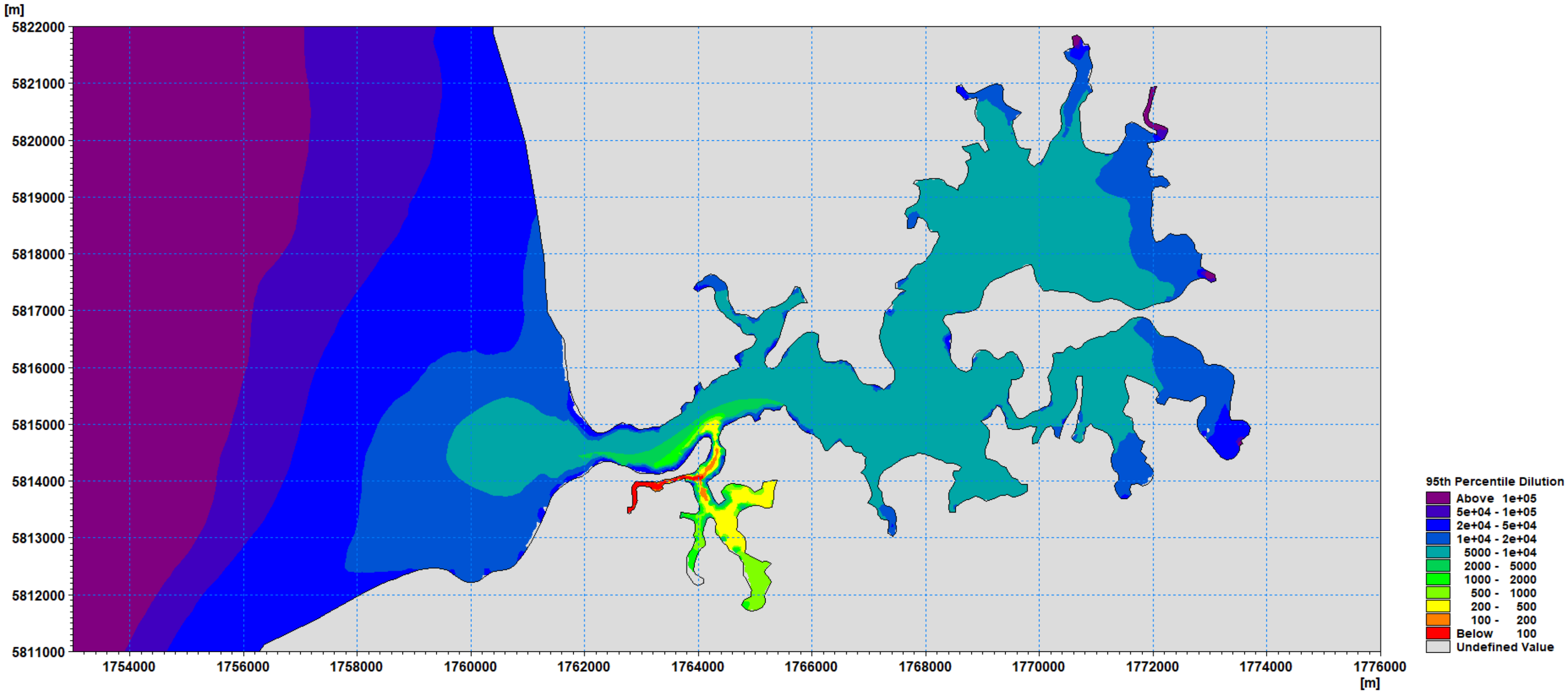

Figure 5-16. Predicted 95th percentile dilution for the July-September period for Scenario F1 (Wainui Stream, 2055 Discharge rate).

6 Dilutions at QMRA Sites

The following section provides a summary of the dilutions achieved at each of the QMRA sites (Figure 6-1) for each of the discharge options and discharges considered (Table 1-1).

The minimum dilution achieved over the existing outfall for the 2025 discharge scenario is 314 This is higher than the minimum level of dilution of 96 achieved for the existing outfall and the non-optimised current discharge regime (DHI, 2019) giving a clear indication of the benefit of the optimised discharge timing.

The minimum dilution achieved over the new outfall for the 2055 discharge scenario is 105 – on a par with the level of dilution for the existing outfall and the non-optimised current discharge regime. That is the improved performance of the new outfall (i.e. optimised timing, duck-bill valve and increased water depth) offsets the effects of the increased discharge volume through to 2055.

Taking into account the conservative nature of the assumption around the schematisation of the of the plume in the far-field model (i.e. it is only ever in the top 20% of the water column) actual minimum dilutions over the new outfall could be a factor of 2 times more than has been modelled.

Further improvements to water quality will also be achieved through the proposed higher level of treatment for the discharges from the new outfall (Table 1-1) but the overall risk of the future discharges will be assessed as part of the QMRA process.

At the nearest QMRA sites to the outfall an order of magnitude increase in the 99.9th percentile dilution is predicted to occur compared to the level of dilution achieved directly over the outfalls with significant increases in dilution at other QMRA sites (i.e. > 10,000).

For the Wainui Stream option, the 99.9th percentile dilution within the Wainui Stream and Opotoru Arm of the harbour range from 32 to 172 for the 2025 discharge scenario and decrease to between 23 and 120 under the 2055 discharge scenario. The minimum level of dilution achieved reflects the relative flow off the Wainui catchment compared to the treated wastewater discharge volumes being considered.

Within the main body of the harbour, the 99.9th percentile dilutions range from 300 (at Site S14) through to around 15,000 at Site S4 for the 2025 discharge and these decrease to 200 and 11,000 under the 2055 discharge.

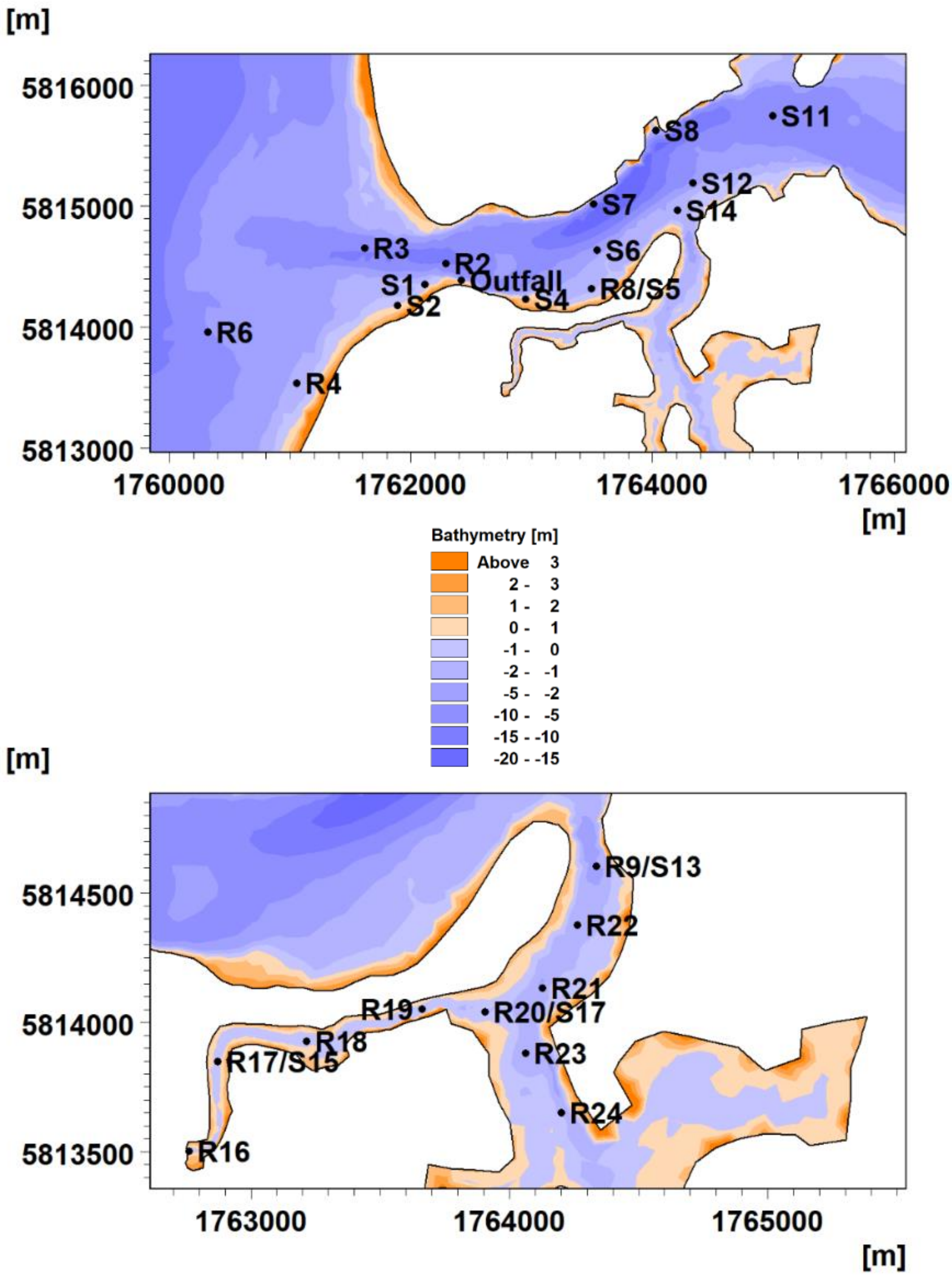

Figure 6-1. Sites where model data is extracted for the QMRA. S denotes a Shellfish site and R denotes a recreational site.

Table 6-1 QMRA sites. Confirm with Chris R vs S numbering

Option	Site ID for QMRA	NZTM (E)	NZTM (N)
Outfall (Existing)	Outfall (Existing)	1762416	5814388
Outfall (New)	Outfall (New)	1762521	5814386
Eastern end of tuatua	S1	1762113	5814351
Mid point of tuatua	S2	1761887	5814178
Inshore Kite surf	R2	1762288	5814525
Northern swimming	R4	1761054	5813536
Bar surf	R6	1760316	5813961
Entrance kite surf	R3	1761619	5814655
Western Cockle/Pipi (In Harbour)	S4	1762946	5814230
Western Swimming & Shellfish (In Harbour)	R8/S5	1763494	5814316
Western Shellfish (In Harbour A)	S6	1763538	5814637
Western Shellfish (In Harbour B)	S7	1763512	5815020
Mid Harbour Shellfish	S8	1764024	5815627
Inner Harbour (Shellfish C)	S11	1764996	5815749
Inner Harbour (Shellfish D)	S12	1764336	5815194
Inner Harbour (Shellfish)	S14	1764205	5814968
Wainui Stream (Recreational)	R16	1762760	5813501
Marae (Recreational/Shellfish)	R17/S15	1762872	5813849
Airstrip (Recreational)	R18	1763216	5813927
Airstrip Bridge (Recreational)	R19	1763662	5814053
Wainui/Opotoru (Recreational)	R20/S17	1763905	5814040
Domain North (Recreation/Shellfish)	R9/S13	1764335	5814604
Domain Boat Ramp (Recreational)	R21	1764127	5814134
Domain South (Recreation/Shellfish)	R22	1764264	5814377
Raglan Area School (Recreational)	R23	1764062	5813880
Upper Opotoru (Recreational)	R24	1764201	5813652

Table 6-2 Summary of dilutions for the Existing Scenario (Existing outfall and current discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (Existing)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	1210	8982	12665	13402	52401	29687	61190	66635	68742	73748	79469	79158	80288	76666	74741
99.0	736	5691	7136	6697	18502	14856	33624	38119	37848	40357	45363	45365	44632	42470	39575
99.5	671	5229	6546	5580	13992	13801	30623	35610	33871	36163	42004	41681	41189	38071	35958
99.9	531	4451	5688	3841	9488	12772	23197	30803	28869	30125	36485	36366	35499	32605	31289

Table 6-3. Summary of dilutions for the Existing Scenario (Existing outfall and current discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	11302941	810438	221388	119749	104088	76674	82589	79954	80040	81160
99.0	990241	236084	86628	45274	41619	39302	38948	39491	39058	39616
99.5	759659	204444	76622	38802	36719	35797	35728	36107	35705	35730
99.9	432894	169962	60002	32011	31618	31318	31350	31323	31457	31694

Table 6-4 Summary of dilutions for Scenario M1 (New outfall and 2025 discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (new)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	544	7006	9671	14283	39730	22710	46074	50211	51386	54856	59246	58991	59639	57083	55646
99.0	304	4474	5434	6700	14226	11428	25485	28831	28440	30143	33801	33825	33217	31616	29706
99.5	268	4128	5032	5678	10891	10640	23403	26893	25351	26978	31093	31041	30540	28436	26992
99.9	214	3374	4281	4377	7390	9834	18813	23255	21529	22184	26900	26822	26388	24355	23349

Table 6-5. Summary of dilutions for Scenario M1 (New outfall and 2025 discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	8545256	608255	164247	89027	77842	57146	61616	59578	59667	60217
99.0	757527	178109	64610	33779	30998	29560	29207	29600	29263	29539
99.5	576720	153801	57278	28917	27384	26880	26755	27126	26773	26745
99.9	321683	128044	44979	23786	23738	23545	23696	23540	23725	23860

Table 6-6 Summary of dilutions for Scenario M1 (New Outfall and 2055 discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (new)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	382	4910	6777	10001	27857	15913	32302	35194	35989	38469	41522	41348	41810	40020	39009
99.0	214	3136	3811	4684	9960	8013	17861	20235	19949	21137	23691	23713	23282	22170	20836
99.5	188	2893	3528	3965	7641	7462	16413	18850	17775	18922	21808	21770	21416	19941	18926
99.9	150	2366	2997	3041	5182	6898	13134	16309	15096	15545	18868	18815	18509	17068	16366

Table 6-7. Summary of dilutions for Scenario M1 (New Outfall and 2055 discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	6206618	429668	115703	62492	54595	40096	43177	41787	41841	42213
99.0	538081	125521	45399	23705	21737	20736	20473	20769	20506	20707
99.5	408516	108572	40269	20303	19185	18854	18764	19025	18767	18764
99.9	227350	90432	31534	16695	16637	16520	16617	16520	16633	16730

Table 6-8 Summary of dilutions for Scenario L1 (Outfall in combination with Public Land disposal and 2025 discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (New)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	758	9513	14154	19948	57013	32803	64573	72880	73060	78215	85017	85054	84886	80588	77874
99.0	388	5483	6598	9025	17503	13440	30354	34369	33755	35980	39313	39599	39010	37381	35159
99.5	344	5098	6068	7711	14181	12581	27769	32244	30254	32005	36434	36317	35744	33956	31918
99.9	277	4286	5123	5635	8767	11400	23789	27961	24973	26050	31555	31352	30781	28131	27122

Table 6-9. Summary of dilutions for Scenario L1 (Outfall in combination with Public Land disposal and 2025 discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	18825826	1331538	295696	149543	123614	79533	87651	83372	84152	84633
99.0	1739797	309050	97427	40730	37239	34827	34278	34865	34145	34599
99.5	1282393	260297	84449	33475	32343	31760	31567	32080	31412	31316
99.9	843534	206537	65300	27818	27899	27222	27557	27409	27750	27913

Table 6-10 Summary of dilutions for Scenario L1 (Outfall in combination with Public Land disposal and 2055 discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (New)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	482	6061	8903	12583	35387	20732	40991	45646	45770	48912	52982	52721	53235	50785	48883
99.0	253	3626	4363	5771	11633	9007	20174	22915	22563	23955	26417	26539	26127	25015	23373
99.5	224	3347	4058	4895	9180	8424	18495	21513	20281	21388	24405	24393	23994	22705	21313
99.9	181	2830	3396	3607	5839	7660	15376	18803	16679	17360	21007	20945	20623	18921	18146

Table 6-11. Summary of dilutions for Scenario L1 (Outfall in combination with Public Land disposal and 2055 discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	9796719	685832	167507	88058	75129	50144	55009	52914	52985	53158
99.0	890711	183833	61451	27138	24662	23099	22862	23218	22882	23103
99.5	670239	156433	53757	22477	21584	21231	21066	21390	21010	20906
99.9	397712	131419	41953	18604	18591	18223	18391	18354	18572	18677

Table 6-12 Summary of dilutions for Scenario L3 (Outfall in combination with Private Land disposal and 2025 discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (New)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	1187	14226	24875	30651	70047	46748	87695	88640	87104	93749	107073	103714	103319	98152	95916
99.0	553	7384	8874	13627	22567	17927	40687	45430	44506	47061	51667	51853	51016	48954	46047
99.5	489	6833	8078	11779	16965	16893	37228	42875	40175	42438	48765	48654	47911	45041	42371
99.9	387	5811	6710	8011	11619	14962	33158	39250	33071	34266	42755	42530	41688	37010	35707

Table 6-13. Summary of dilutions for Scenario L3 (Outfall in combination with Private Land disposal and 2025 discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	69126464270	12424669	695401	247303	191520	98956	116073	106786	104416	103402
99.0	14356916	518876	141842	50116	47817	45971	45455	46014	45121	45032
99.5	6304448	418276	119757	43581	42981	42632	42473	42834	42169	42183
99.9	3041450	296293	91885	37424	37451	36071	36350	36251	36821	37100

Table 6-14 Summary of dilutions for Scenario L3 (Outfall in combination with Private Land disposal and 2055 discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (New)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	669	8184	13076	17506	45872	27664	52959	58837	56112	59826	67482	66260	65810	62217	60019
99.0	325	4463	5333	7990	13879	10782	24213	27644	27049	28399	31343	31365	30994	29697	27738
99.5	291	4111	4910	6797	10835	10227	22493	25825	24054	25490	29289	29111	28681	27065	25600
99.9	234	3462	4129	4734	7106	9196	19818	23008	20122	20953	25513	25441	24817	22535	21842

Table 6-15. Summary of dilutions for Scenario L3 (Outfall in combination with Private Land disposal and 2055 discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	951644520	4028011	410848	147851	116819	62194	70568	66646	66135	64646
99.0	5176913	314636	85566	30636	28981	27553	27349	27764	27220	27346
99.5	3589889	242809	72595	26327	25484	25560	25540	25842	25259	25106
99.9	1819857	175973	54101	22657	22572	21898	22190	22067	22480	22556

Table 6-16 Summary of dilutions for Scenario F1 (Wainui Stream option and 2025 discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (new)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	8637	30634	54378	10602	53495	27429	14662	53514	3537	5823	13575	12558	11646	6284	658
99.0	4644	11006	19298	5813	14692	10222	8030	26702	1386	3521	8385	8344	8060	1258	398
99.5	4200	9117	16258	5311	11189	8833	7339	22695	1197	3255	7751	7715	7469	1036	364
99.9	3468	7331	12325	4475	6499	7581	6420	15599	928	2806	6577	6611	6417	770	307

Table 6-17. Summary of dilutions for Scenario F1 (Wainui Stream option and 2025 discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	40	45	51	56	62	425	190	313	436	621
99.0	33	34	34	36	39	250	105	156	152	213
99.5	33	33	34	35	36	223	95	142	141	195
99.9	32	32	33	34	35	179	80	126	122	172

Table 6-18 Summary of dilutions for Scenario F1 (Wainui Stream option and 2055 discharge volume) within the wider harbour.

Site Description	Outfall	Eastern end of tuatua	Mid point of tuatua	Inshore Kite surf	Northern swimming	Bar surf	Entrance kite surf	Western Cockle/Pipi (In Harbour)	Western Swimming & Shellfish (In Harbour)	Western Shellfish (In Harbour A)	Western Shellfish (In Harbour B)	Mid Harbour Shellfish	Inner Harbour (Shellfish C)	Inner Harbour (Shellfish D)	Inner Harbour (Shellfish)
Site ID	**Outfall (new)**	**S1**	**S2**	**R2**	**R4**	**R6**	**R3**	**S4**	**R8/S5**	**S6**	**S7**	**S8**	**S11**	**S12**	**S14**
Percentile	**Dilution**														
90.0	6063	21497	38142	7441	37526	19232	10285	37575	2477	4086	9523	8813	8172	4404	462
99.0	3260	7724	13539	4079	10294	7171	5636	18859	972	2472	5881	5853	5654	883	280
99.5	2948	6414	11411	3728	7851	6198	5150	15909	840	2285	5437	5413	5241	727	256
99.9	2434	5096	8644	3140	4561	5320	4503	11305	651	1970	4618	4636	4500	541	215

Table 6-19. Summary of dilutions for Scenario F1 (Wainui Stream option and 2055 discharge volume) within Wainui Stream and the Opotoru Arm.

Site Description	Wainui Stream (Recreational)	Marae (Shellfish)	Airstrip (Recreational)	Airstrip Bridge (Recreational/Shellfish)	Wainui/Opotoru (Recreational)	Domain North (Recreation/Shellfish)	Domain Boat Ramp (Recreational)	Domain South (Recreation/Shellfish)	Raglan Area School (Recreational)	Upper Opotoru (Recreational)
Site ID	**R16**	**R17/S15**	**R18**	**R19**	**R20/S17**	**R9/S13**	**R21**	**R22**	**R23**	**R24**
Percentile	**Dilution**									
90.0	28	32	36	39	44	298	133	219	306	435
99.0	24	24	24	25	27	175	74	109	106	150
99.5	23	24	24	25	26	156	66	100	99	137
99.9	23	23	23	24	24	125	56	89	85	120

7 Assessment of Water Column Total Nitrogen

This section of the report provides details of the methodology used and assumptions made to assess the relative roles of catchment derived Total Nitrogen (TN) and the loads from the proposed discharged options.

Catchment loads have been derived by mapping different land uses within the sub-catchments of Raglan Harbour (Figure 7-1) and applying minimum and maximum TN yields (Table 7-1) as tabulated in WRC (2018). The individual minimum and maximum TN loads for each of the catchments are shown in Table 7-2. Data from Zeldis et al. (2017) estimate a TN river load of 420 tonnes/yr. The average of the minimum and maximum loads in Table 7-2 have been scaled to achieve this mean annual catchment derived TN load of 420 tonnes/yr.

Based on the mean flow for each of the catchment sources in the Harbour model a mean concentration was initially set for each of the catchment sources so that a total TN load of 420 tonnes/yr was delivered during the 2018 model simulation. A number of iterations of the harbour model were then run to achieve a good match between the predicted mean annual concentrations from the model and the observed mean TN concentrations at the Waikato Regional Council monitoring sites (Figure 7-2). This was achieved by applying an attenuation factor of 85% for all the catchment loads except the Opotoru and Te Terata catchments which had attenuation factors of 43% and 64% applied respectively. An attenuation factor of 85% is within the broad scale range of calibrated attenuation factors applied for TN within the Waikato and Waipa River basin catchments (Semadeni-Davies et al., 2016). The calibration processes indicates that the predicted TN loads for the Opotoru and Te Terata catchments using the above methodology are likely to be too high.

No decay was applied to the TN within the marine receiving environment. This approach is justified because of the strong correlation between observed salinity and observed TN at the Waikato Regional Council monitoring sites. Salinity acts as a conservative tracer and can be used to define the level of dilution achieved for other conservative tracers at a particular site in the harbour. The calibration of predicted mean annual TN concentrations versus the observed mean values is given in Figure 7-4. The model tends to under predict the concentrations at the historic monitoring sites (except for the Mid Harbour site) but overall provides good estimates of the observed at the current monitoring sites (i.e. Slope of regression =1.10 and r^2 = 0.95).

The calibrated model loads for each of the catchments is shown in Table 7-3 with the total load of 324 tonnes/yr entering the system.

The spatial map of the predicted TN due to the attenuated TN catchment load is shown in Figure 7-5.

The calibrated TN model was then rerun with the inputs for the existing outfall (2020 discharge rate) and the 2055 discharge scenarios for the new outfall and the Wainui Stream. The assumed median TN concentrations and annual loads for these scenarios are shown in Table 7-4.

Spatial plots of the predicted mean annual TN footprint and percentage increase in mean annual TN (i.e. percentage increase above the background levels from the catchment derived sources) are shown in Figures 7-6 through to 7-9. Note that the concentration plot colour banding is 1) a semi-log scale and 2) at a different scale to the catchment derived plot.

For the outfall options there is a very small offshore zone where there are increases in TN of the order of 0.01 mg/L for the 2020 Existing and 2055, pond plus tertiary membrane plus UV level of treatment and less than this for the MBR plus UV level of treatment. Catchment derived mean annual TN directly over the outfall is around 0.14 mg/L so these increases equate to 9%, 11% and 4% in TN directly over the discharge location.

For the Wainui Stream option the maximum increase in TN (directly at the point of discharge) is of the order of 0.12 mg/L. The mean annual TN at the Wainui catchment outlet is 1.01 mg/L so the increase due to the 2055 discharge equates to a 12% increase in TN.

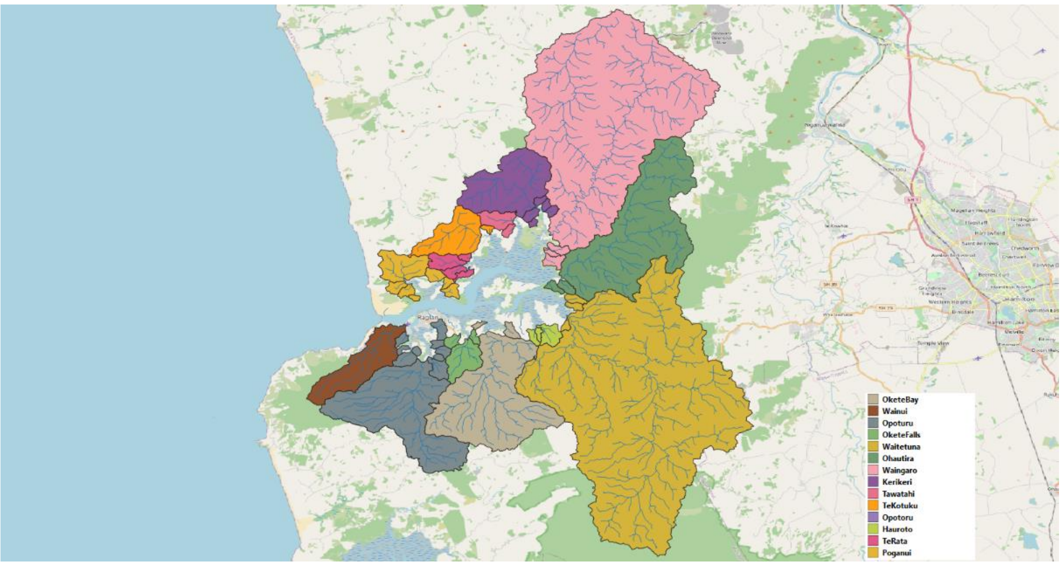

Figure 7-1. Raglan Harbour catchments.

Table 7-1 Summary of land use types within each of the Raglan catchments and estimated Total Nitrogen loads (WRC, 2018).

LUC land Use Class	WRC Land Use Class	Total Nitrogen Yield Minimum (kg/ha/yr)	Total Nitrogen Yield Mean (kg/ha/yr)	Total Nitrogen Yield Maximum (kg/ha/yr)	Hectares in Land Class
High Producing Exotic Grassland	Dairy	10.7	25.0	35.3	27563
Exotic Forest	Exotic	0.6	2.8	8.5	8371
Gorse and/or Broom					
Low Producing Grassland	Low Intensity Pasture	2.8	5.2	8.8	792
Short-rotation Cropland					
Herbaceous Saline Vegetation					
Indigenous Forest	Native	0.6	3.0	5.8	13041
Manuka and/or Kanuka					
Broadleaved Indigenous Hardwoods					
Deciduous Hardwoods					
Built-up Area (settlement)	Urban	2.5	3.3	4.0	111

Table 7-2 Catchment areas and estimated Total Nitrogen loads.

Catchment	Area (Ha)	Total Nitrogen (tonne/yr) Minimum Estimate	Total Nitrogen (tonne/yr) Mean Estimate	Total Nitrogen (tonne/yr) Maximum Estimate	Best Estimate of Mean Total Nitrogen (tonne/yr)[2]
Waitetuna	16866.2	89.1	221.1	335.0	123.1
Waingaro	12498.1	71.9	176.7	269.0	98.4
Okete Bay	4193.0	35.7	84.5	122.6	47.0
Opotoru	3699.2	34.2	80.7	114.9	44.9
Kerikeri	2128.2	17.0	40.6	59.8	22.6
Ohautira	5109.4	14.4	39.5	64.1	22.0
Te Kotuku	979.7	10.3	24.2	34.2	13.5
Wainui	1298.5	8.8	21.3	30.8	11.8
Poganui	978.0	8.4	19.9	28.5	11.1
Okete Falls	585.7	5.1	12.1	17.5	6.7
Hauroto Bay	419.2	4.5	10.4	14.7	5.8
Te Tarata	426.8	4.1	9.7	13.7	5.4
Tawatahi	287.5	3.0	7.1	10.0	3.9
Total	49469.5	306.7	754.2	1114.9	420.0

[2] The mean load estiamtes scaled to provide a total of 420 tonne/yr as reported in Zelids et al. 2017.

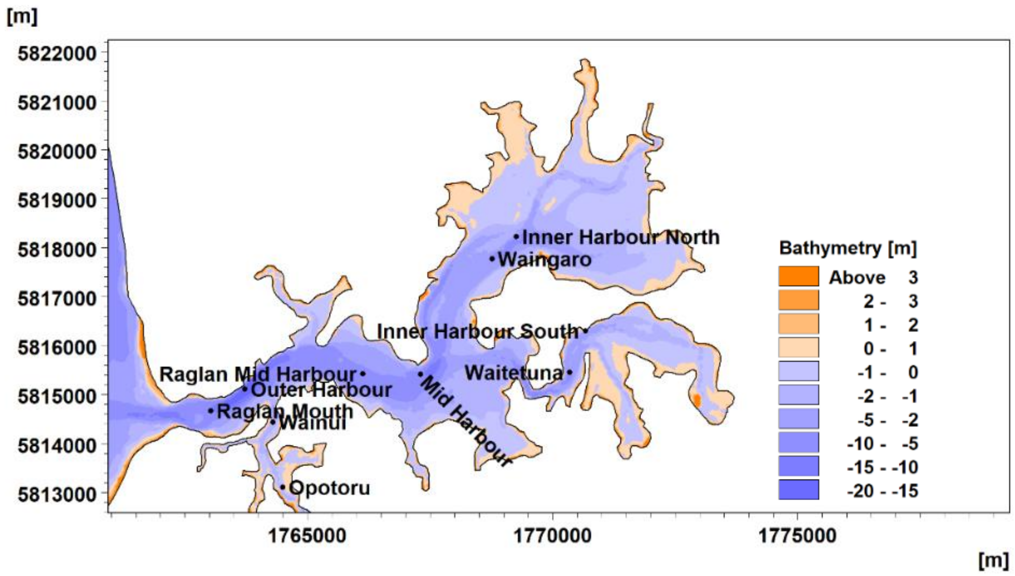

Figure 7-2. Waikato Regional Council monitoring sites.

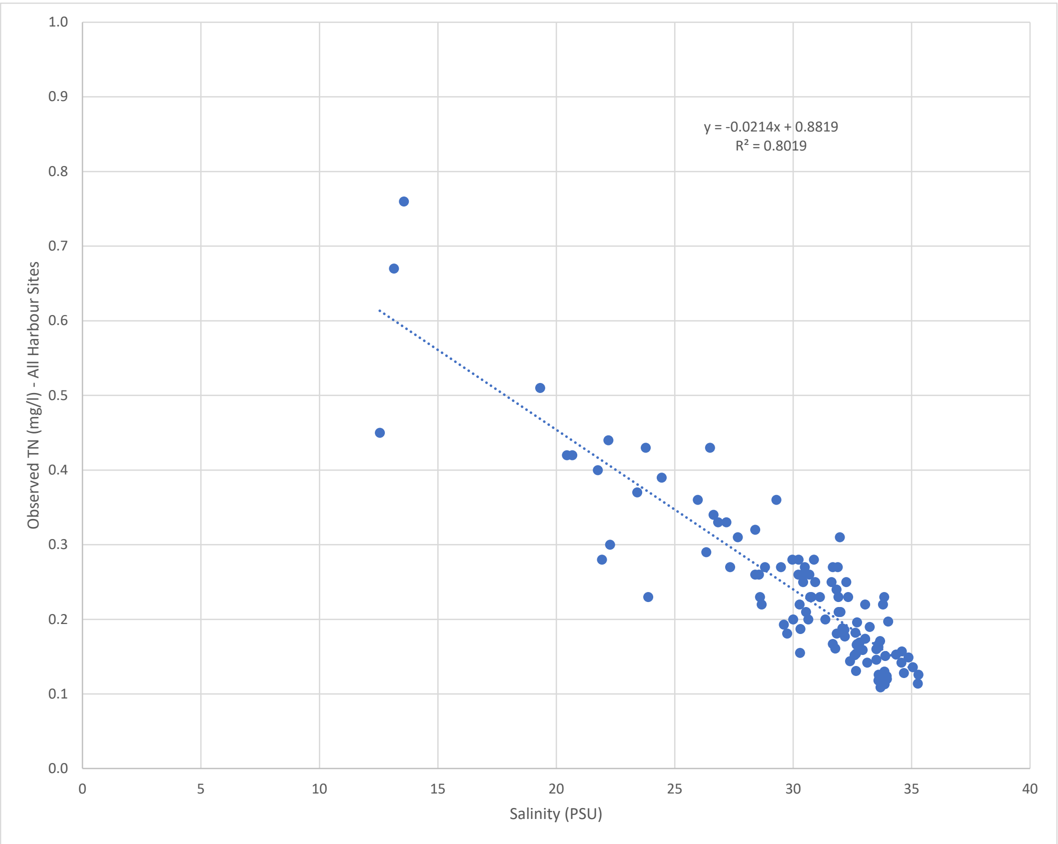

Figure 7-3. Observed Salinity and Total Nitrogen at all of the Waikato Regional Council monitoring sites (Figure 7-2).

Table 7-3 Total Nitrogen load modelled and attenuation factor based on a predicted overall load of 420 tonnes/yr.

Catchment	Total Nitrogen (tonne/yr)	Catchment Attenuation Factor
Waitetuna	104.4	85%
Waingaro	83.4	85%
Okete Bay	39.9	85%
Opotoru	19.5	43%
Kerikeri	19.2	85%
Ohautira	9.5	85%
Te Kotuku	11.4	85%
Wainui	10.0	85%
Poganui	9.4	85%
Okete Falls	5.7	85%
Hauroto Bay	4.9	85%
Te Tarata	3.4	64%
Tawatahi	3.3	85%
Total	333.9	80%

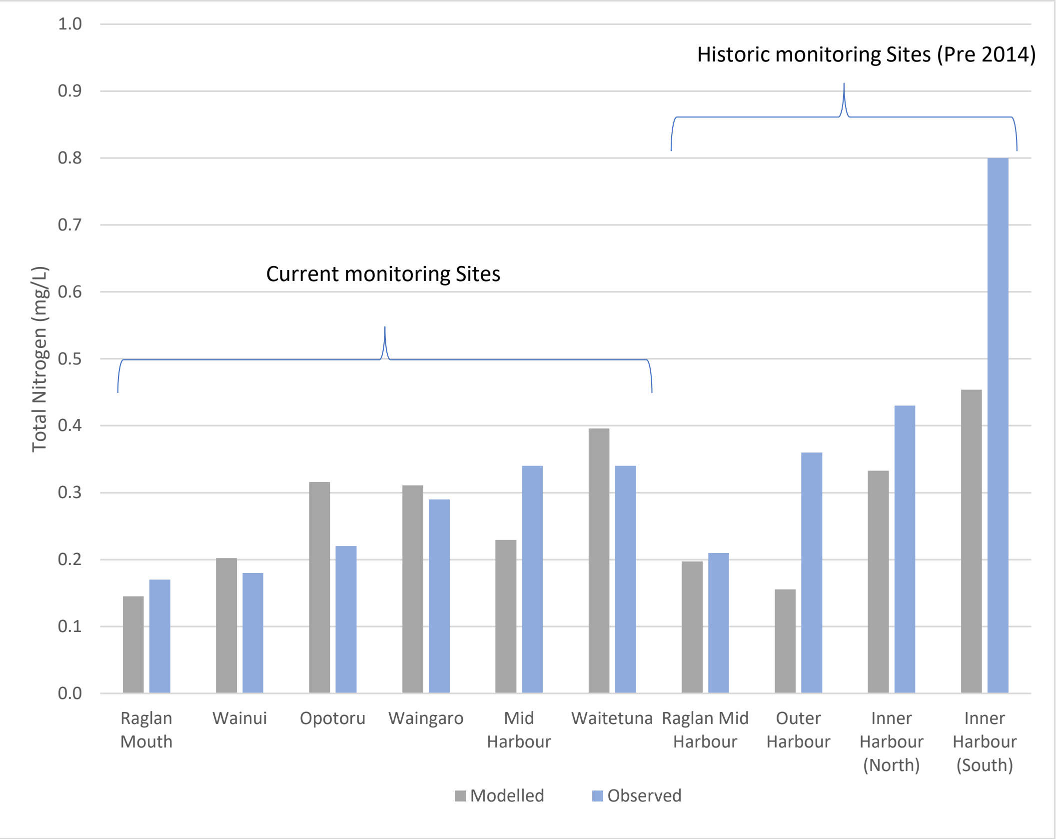

Figure 7-4. Predicted mean Total Nitrogen at each of the Waikato Regional Council sites (Figure 7-2) versus the mean of all observed data.

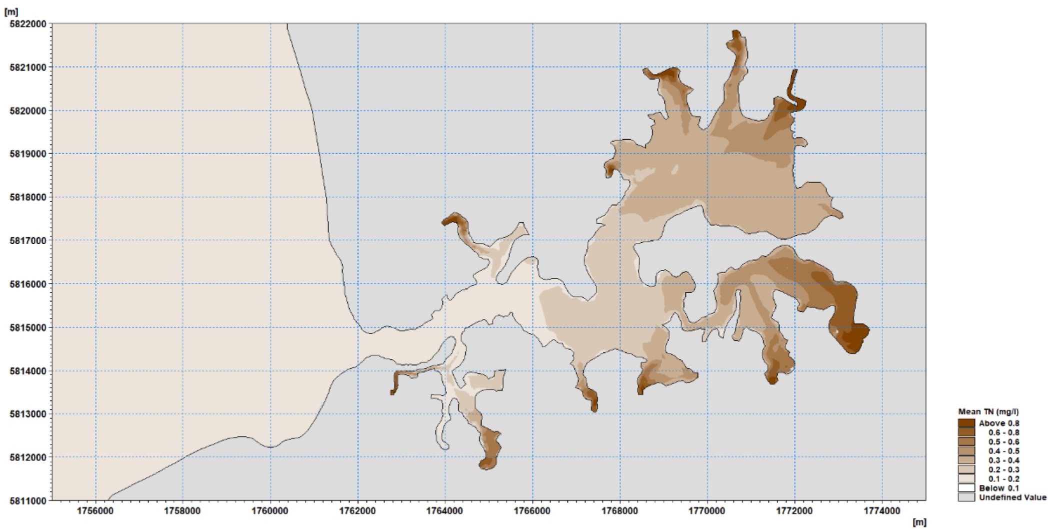

Figure 7-5. Mean annual Total Nitrogen (mg/l) for all Raglan harbour catchment sources.

Table 7-4 Assumed median Total Nitrogen concentrations (mg/l) for the options considered.

Scenario	Scenario Description	Median Total Nitrogen concentration (mg/l)	Total Nitrogen Load (tonnes/yr)
Existing	Existing Outfall Pond + UV (2020)	26	10.0
M1	New Outfall Pond + Tertiary membrane + UV (2055)	17	12.5
M2	New Outfall MBR + UV (2055)	6	4.4
F1	Wainui Stream MBR + UV (2055)	6	4.4

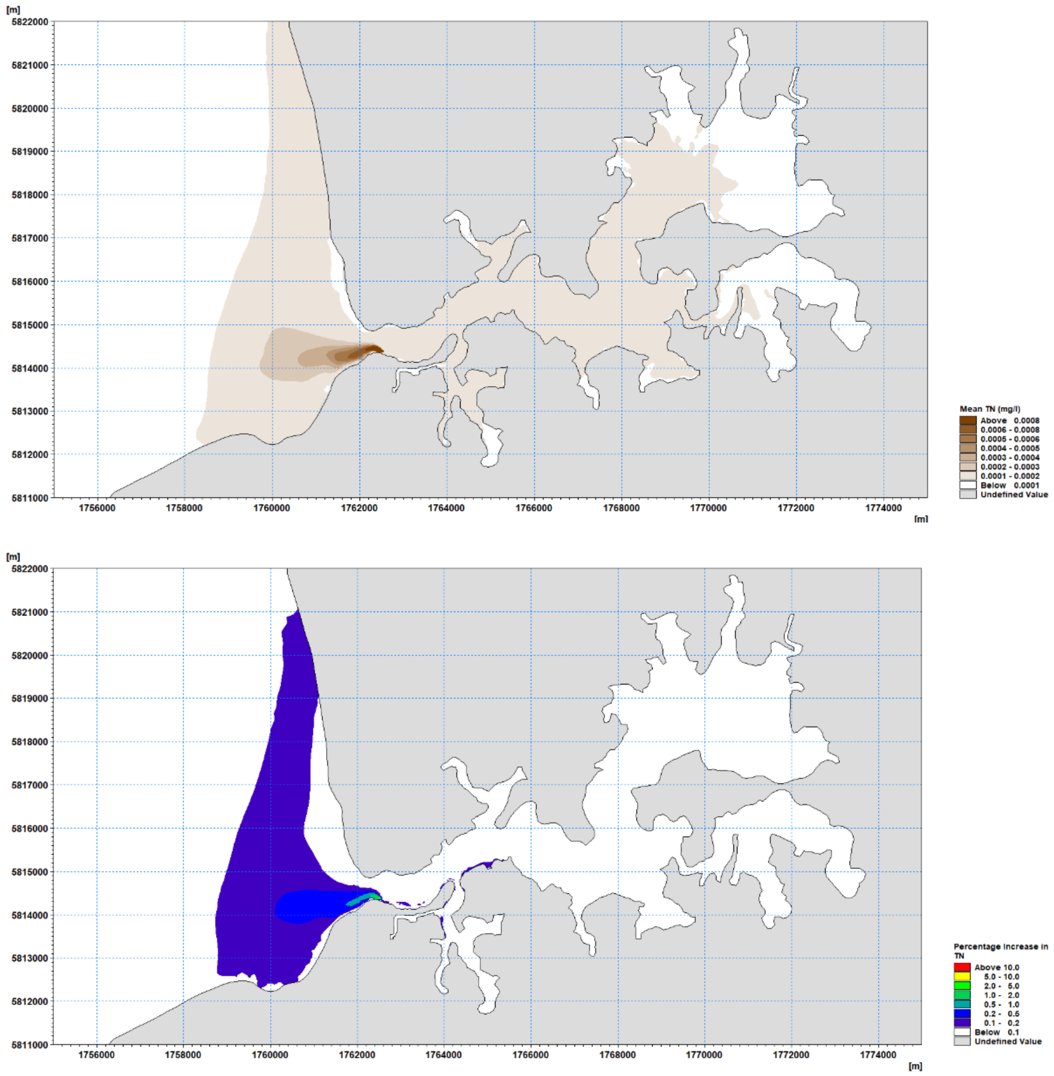

Figure 7-6. Mean annual Total Nitrogen footprint for the existing Outfall (2020) discharge scenario with Pond and UV treatment (top panel) and increase in Total Nitrogen (as a percentage of the catchment derive mean Total Nitrogen - Figure 5 5).

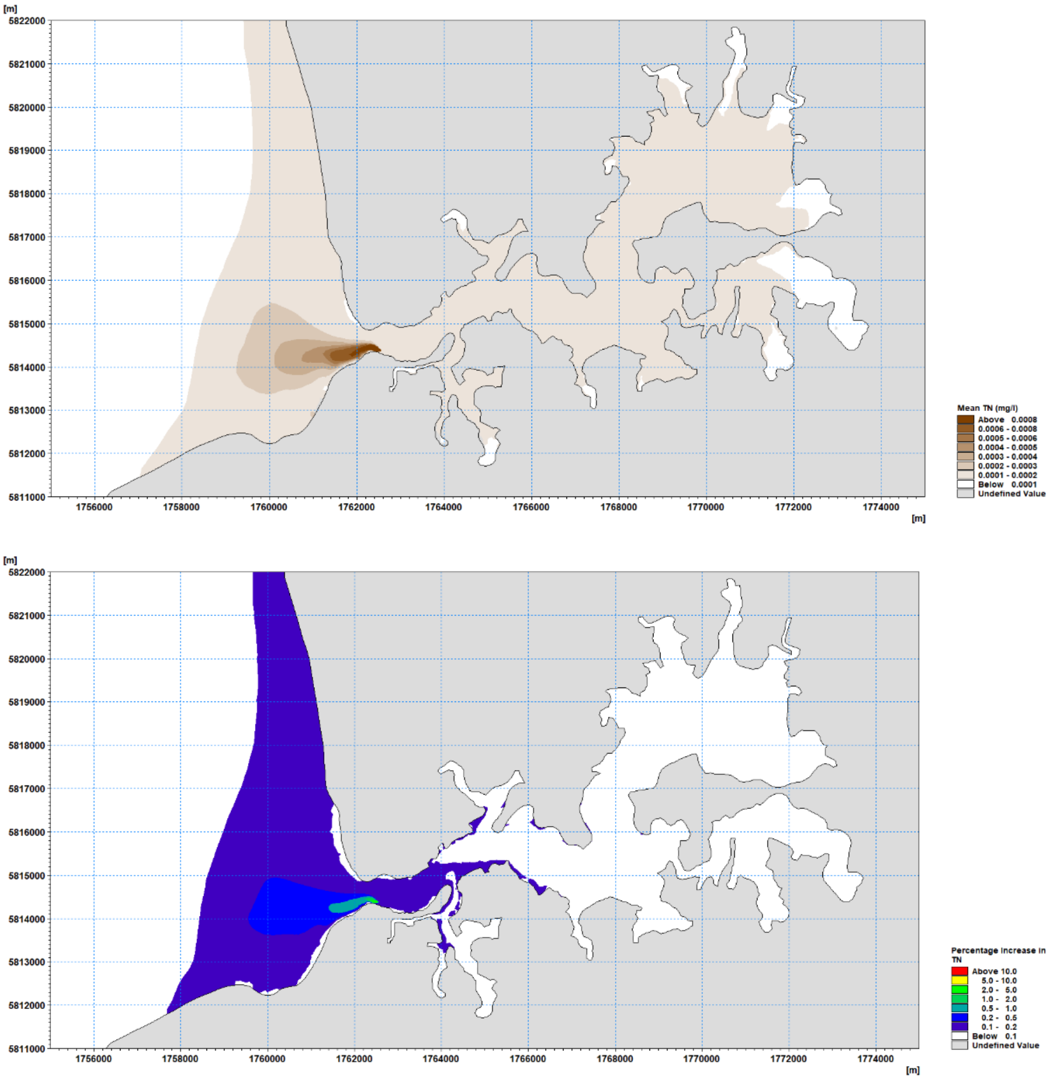

Figure 7-7. Mean annual Total Nitrogen footprint for the new Outfall (2055) discharge scenario with Pond, Tertiary and UV treatment (top panel) and increase in Total Nitrogen (as a percentage of the catchment derive mean Total Nitrogen - Figure 7-5).

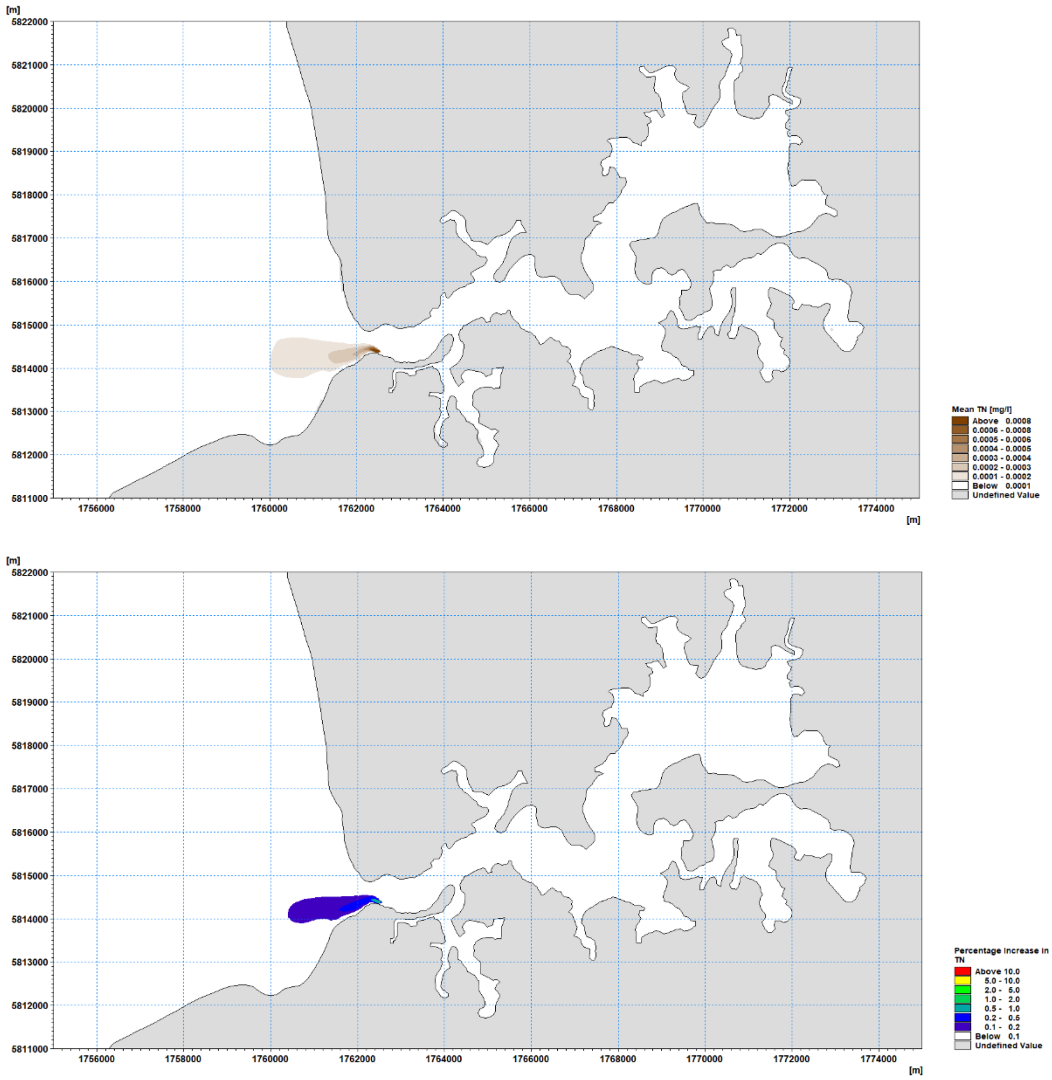

Figure 7-8. Mean annual Total Nitrogen footprint for the new Outfall (2055) discharge scenario with MBR and UV treatment (top panel) and increase in Total Nitrogen (as a percentage of the catchment derive mean Total Nitrogen - Figure 7-5).

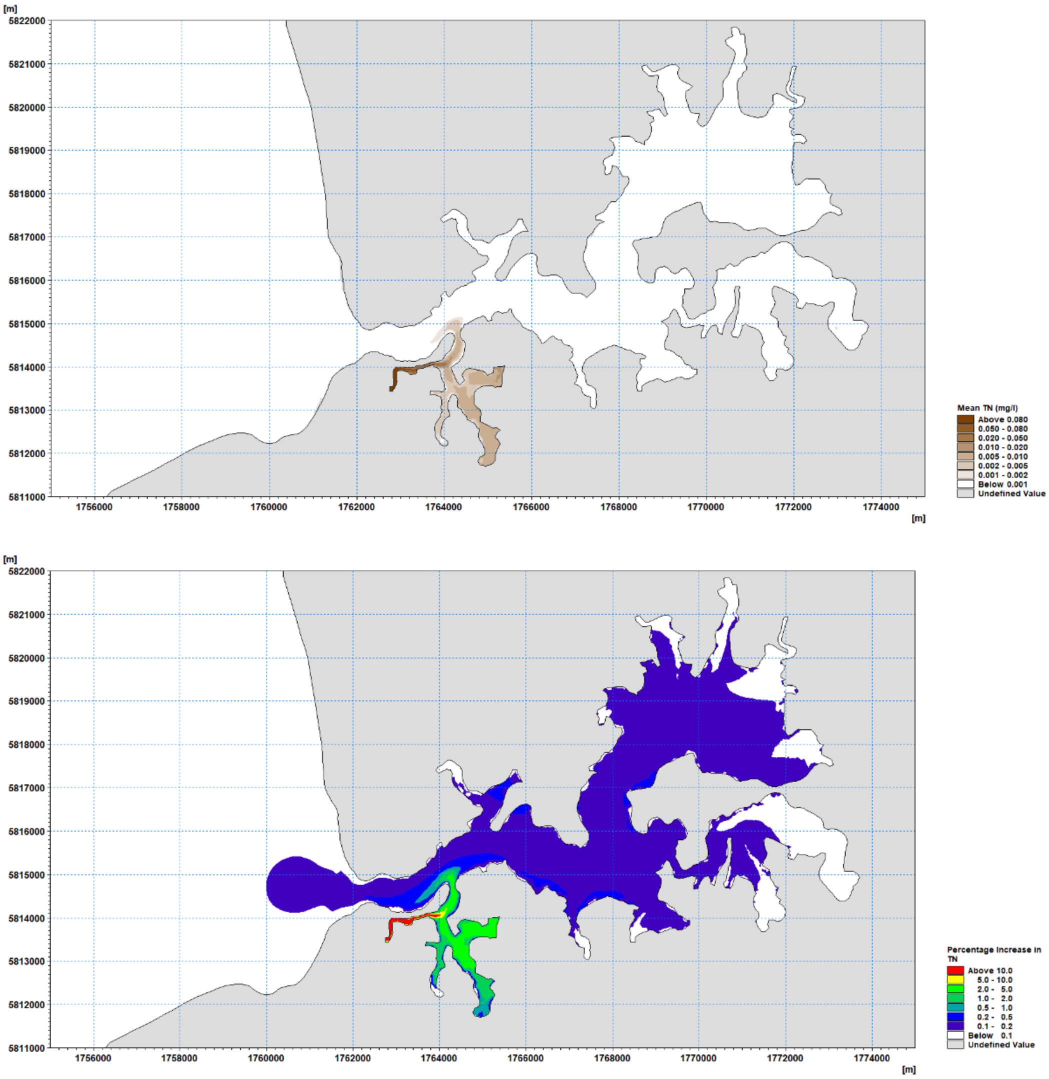

Figure 7-9. Mean annual Total Nitrogen footprint for the Wainui Stream (2055) discharge scenario with MBR and UV treatment (top panel) and increase in Total Nitrogen (as a percentage of the catchment derive mean Total Nitrogen - Figure 7-5).

References

Doneker, RL and Jirka GH 2007. CORMIX User Manual: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters. U.S. Environmental Protection Agency.

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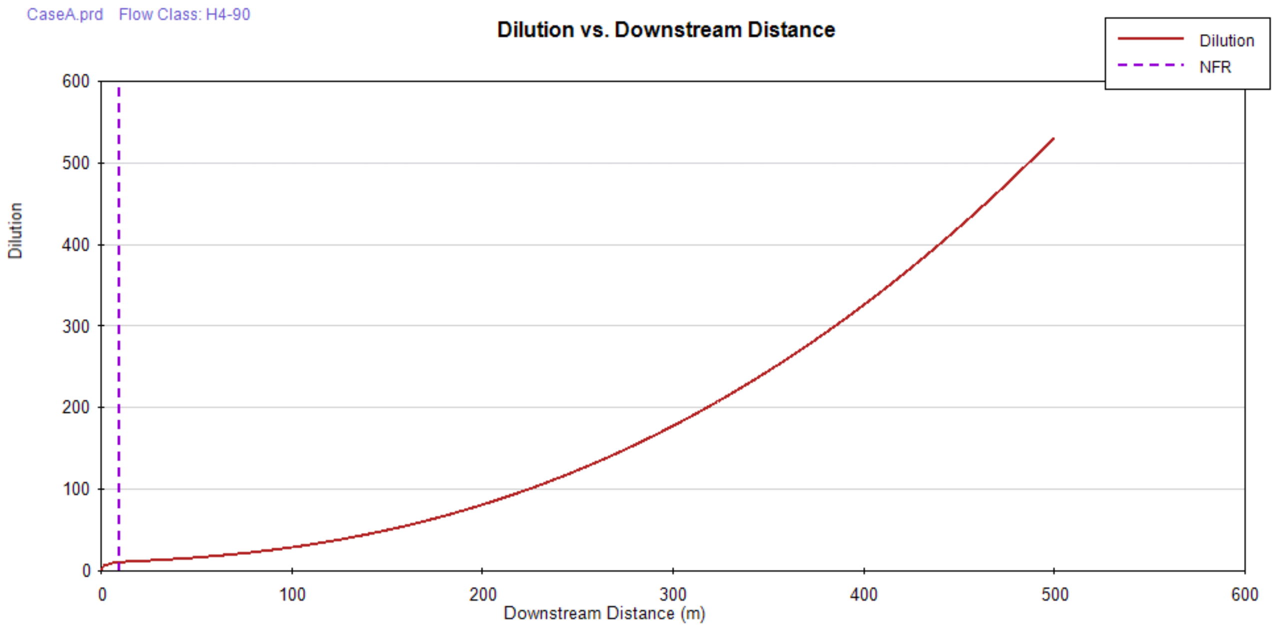
Zeldis, J., Plew, D., Whitehead, A., Madarasz-Smith, A., Oliver, M., Stevens, L., Robertson, B., Burge, O., Dudley, B. 2017. The New Zealand Estuary Trophic Index (ETI) Tools: Web Tool 1 - Determining Eutrophication Susceptibility using Physical and Nutrient Load Data. Ministry of Business, Innovation and Employment Envirolink Tools: C01X1420.

A Appendix A – CORMIX results



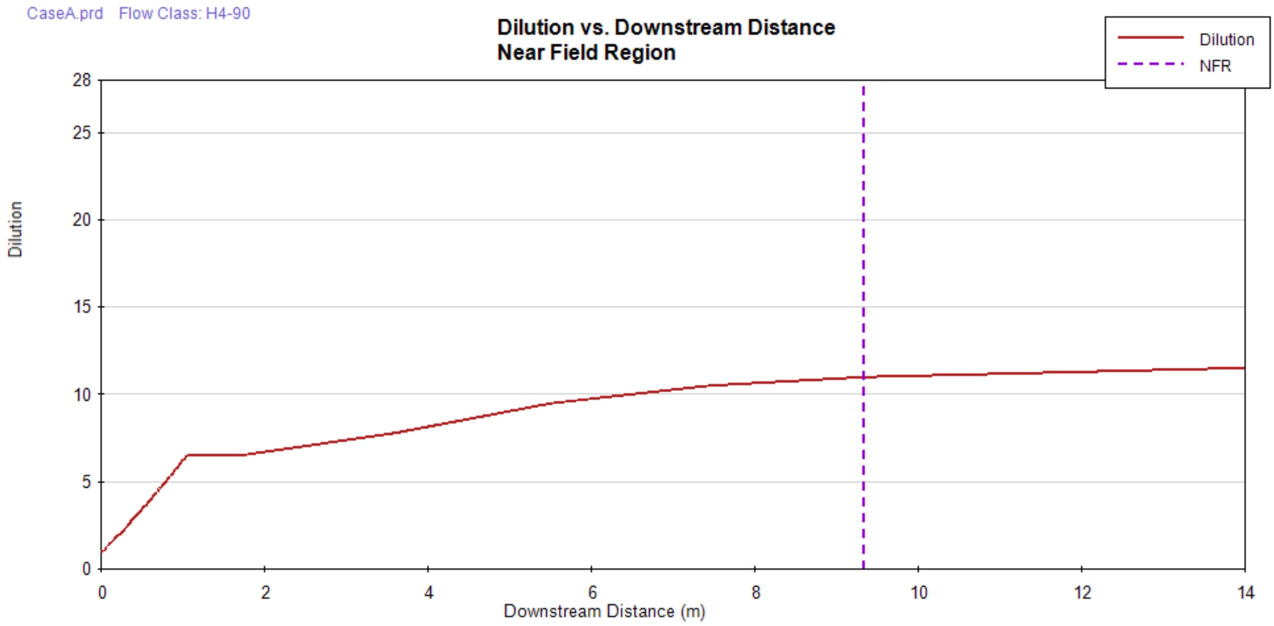
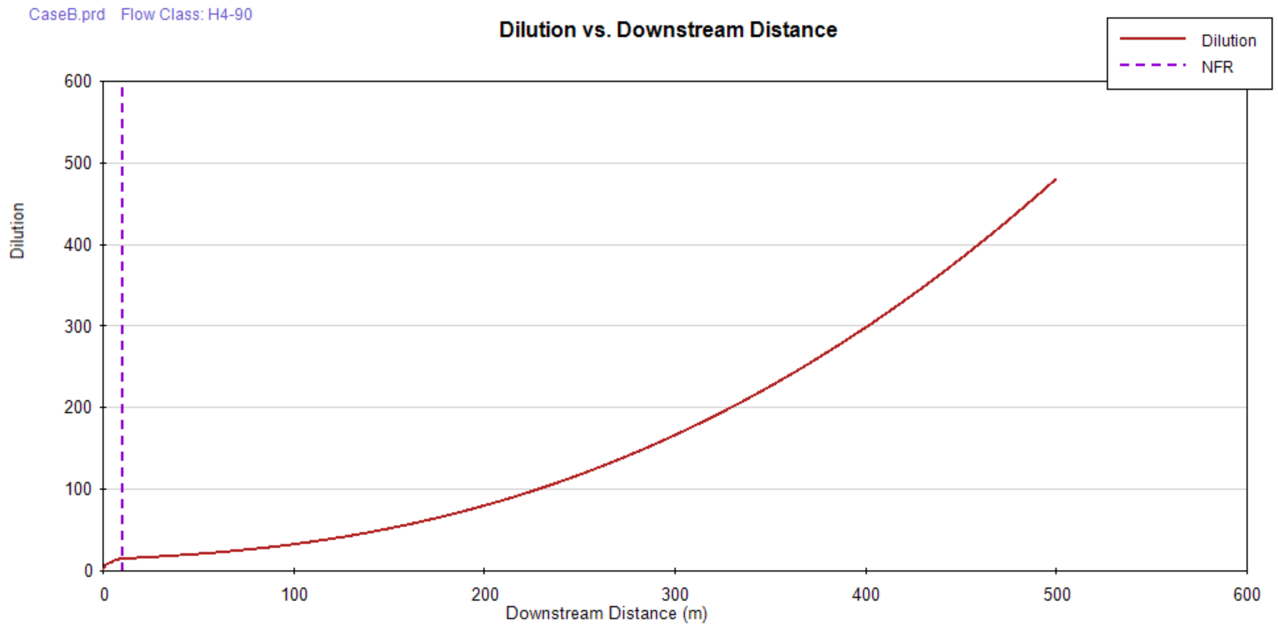


Figure A-1. Dilution versus downstream distance for Case A (Table 4-1). Dilution versus downstream distance for Case A (Table 4-1).



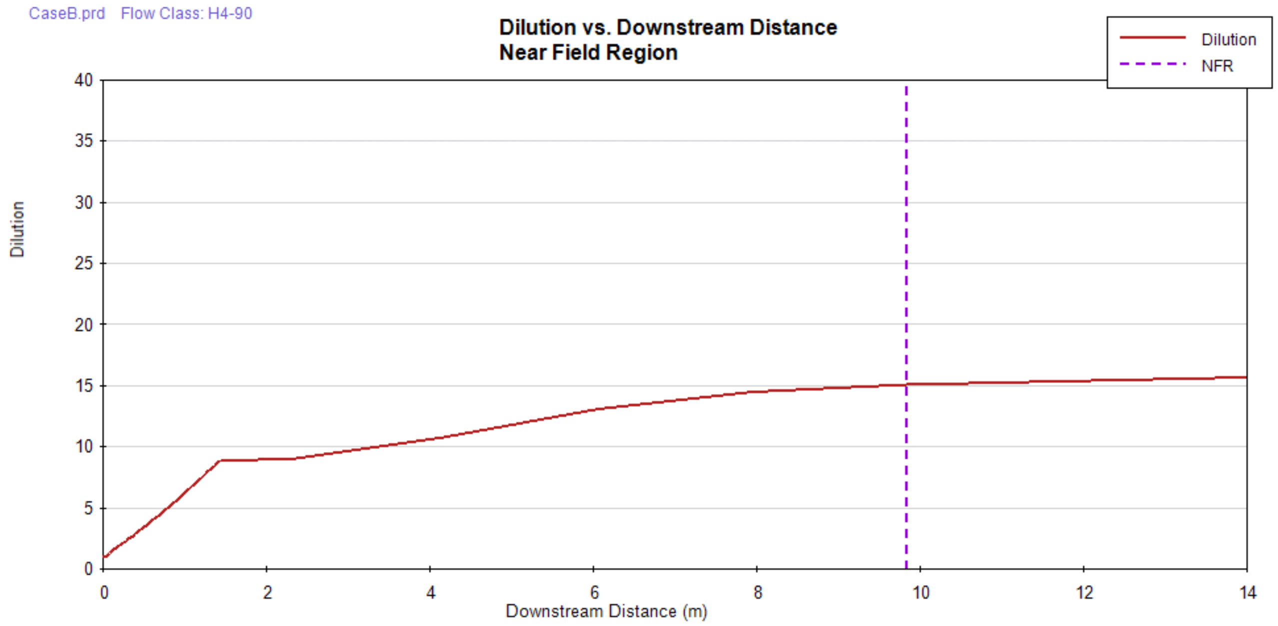


Figure A-2. Dilution versus downstream distance for Case A (Table 4-1). Dilution versus downstream distance for Case B (Table 4-1).

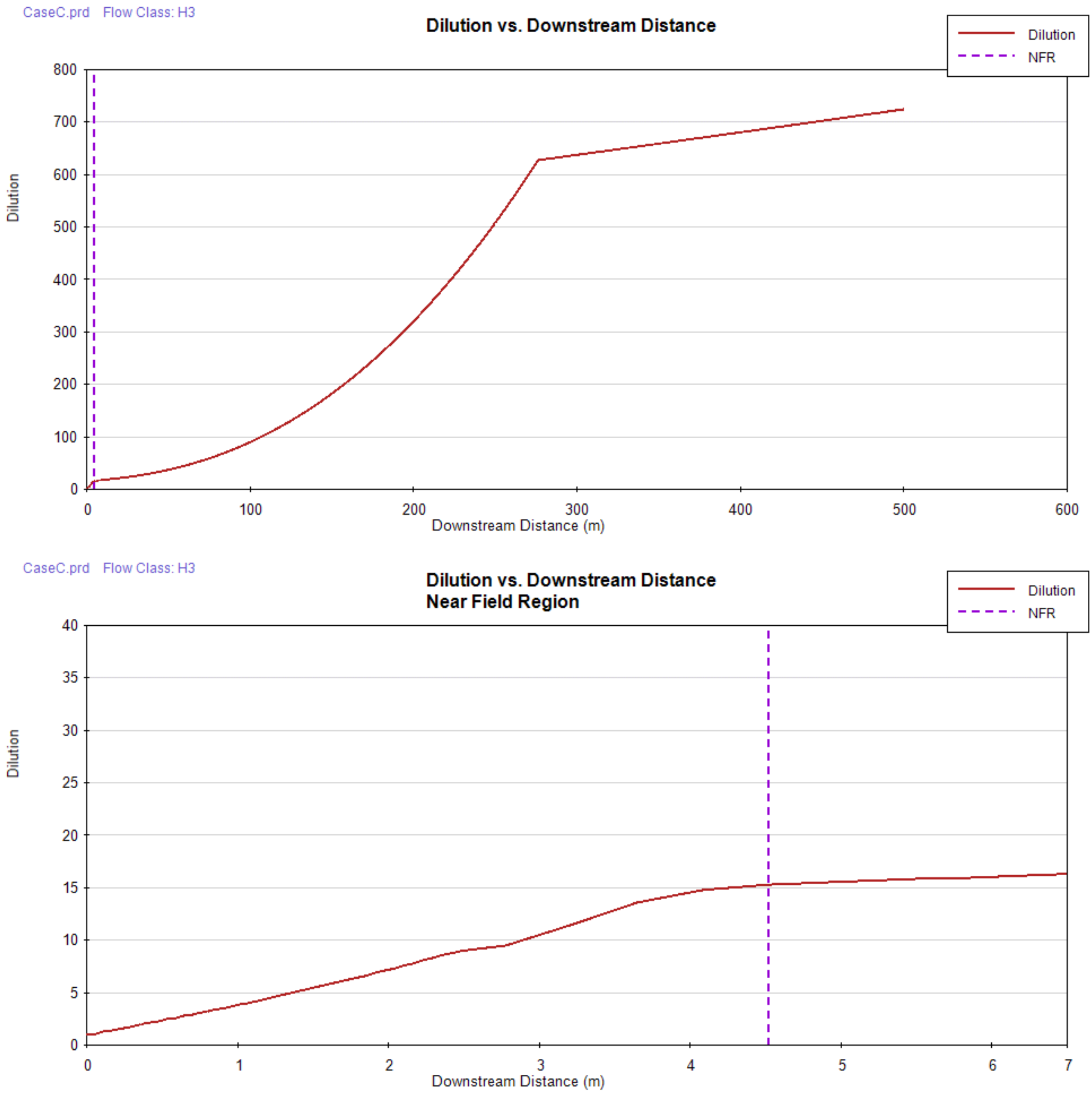


Figure A-3. Dilution versus downstream distance for Case C (Table 4-1).

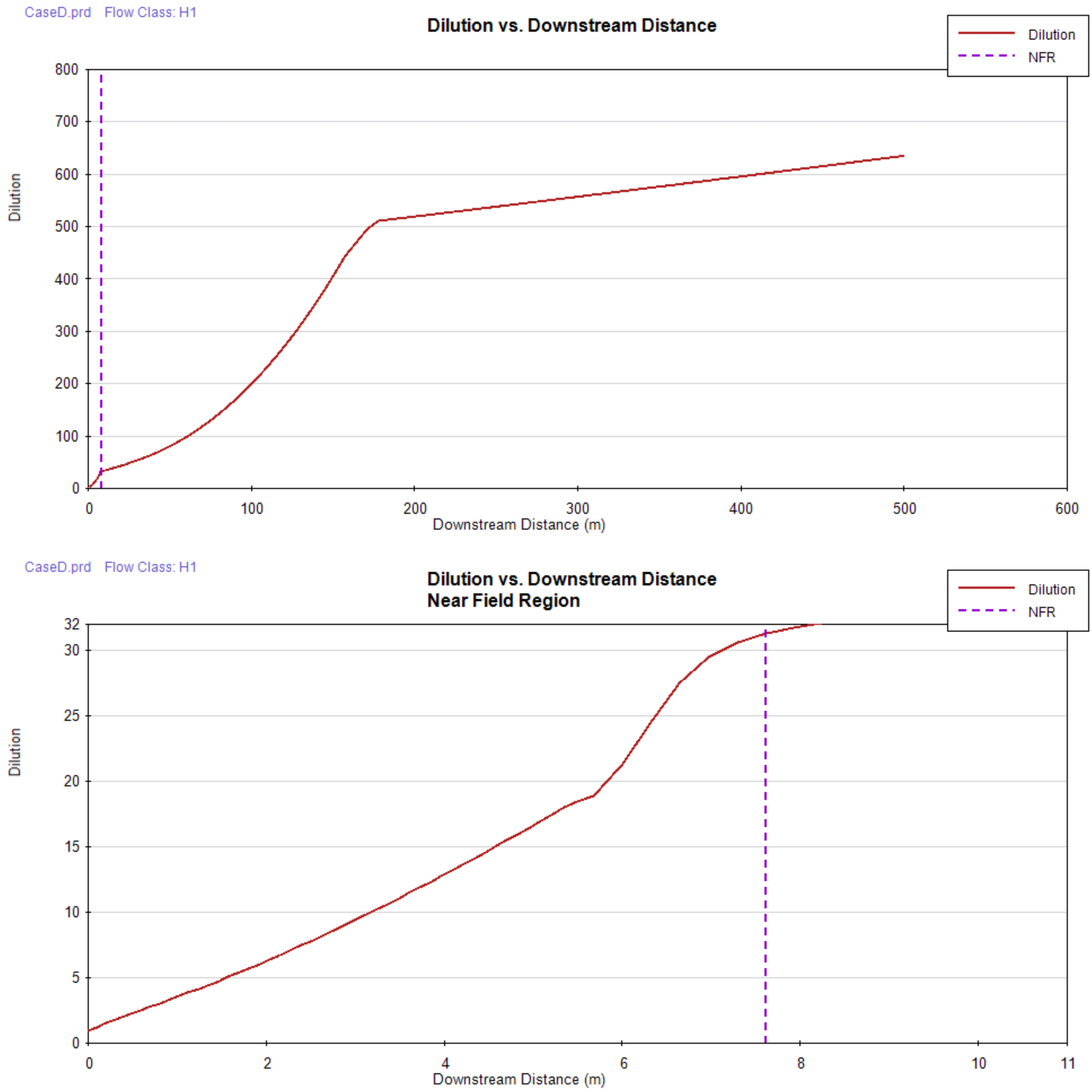
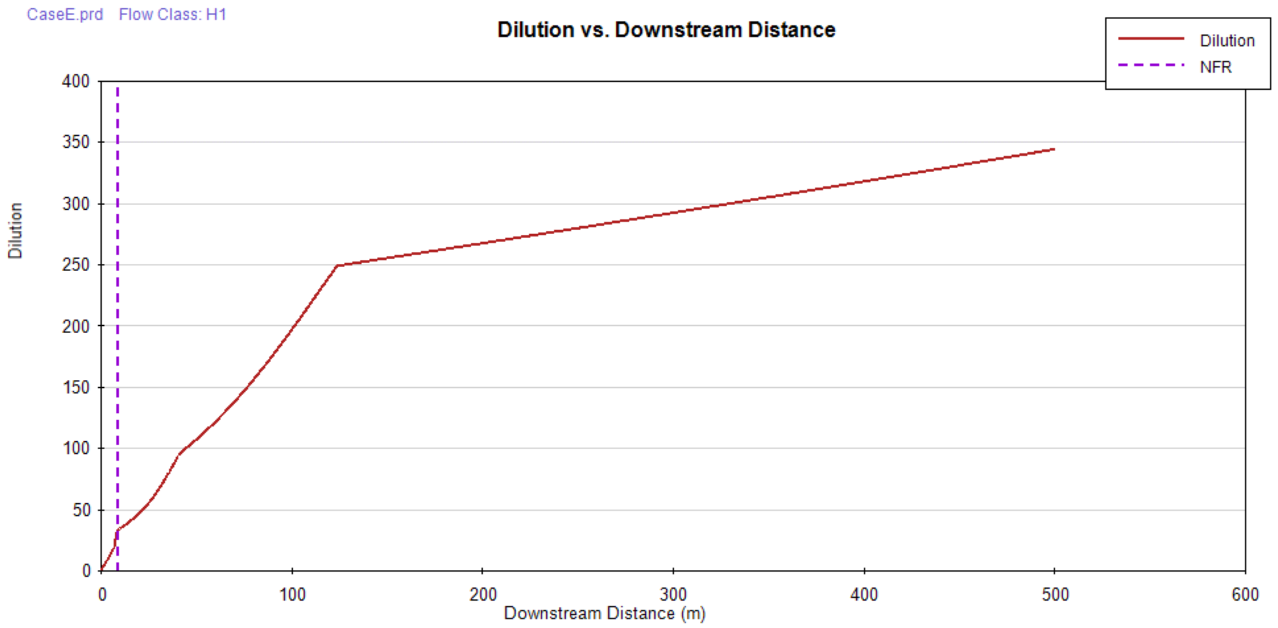


Figure A-4. Dilution versus downstream distance for Case D (Table 4-1).



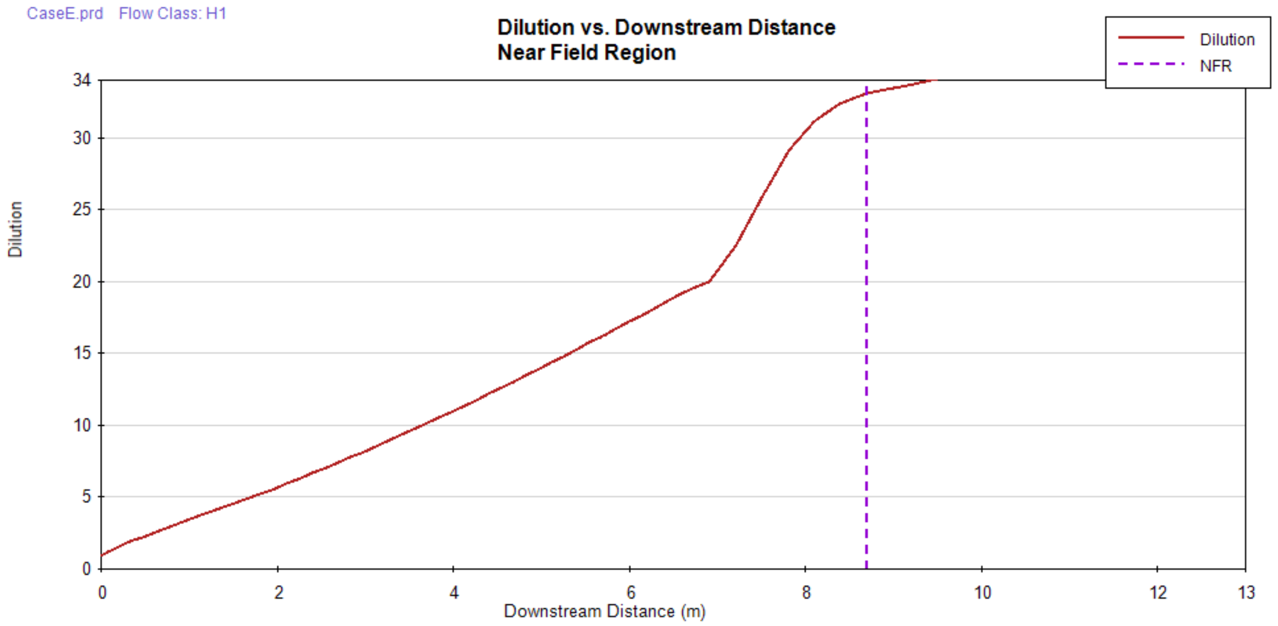
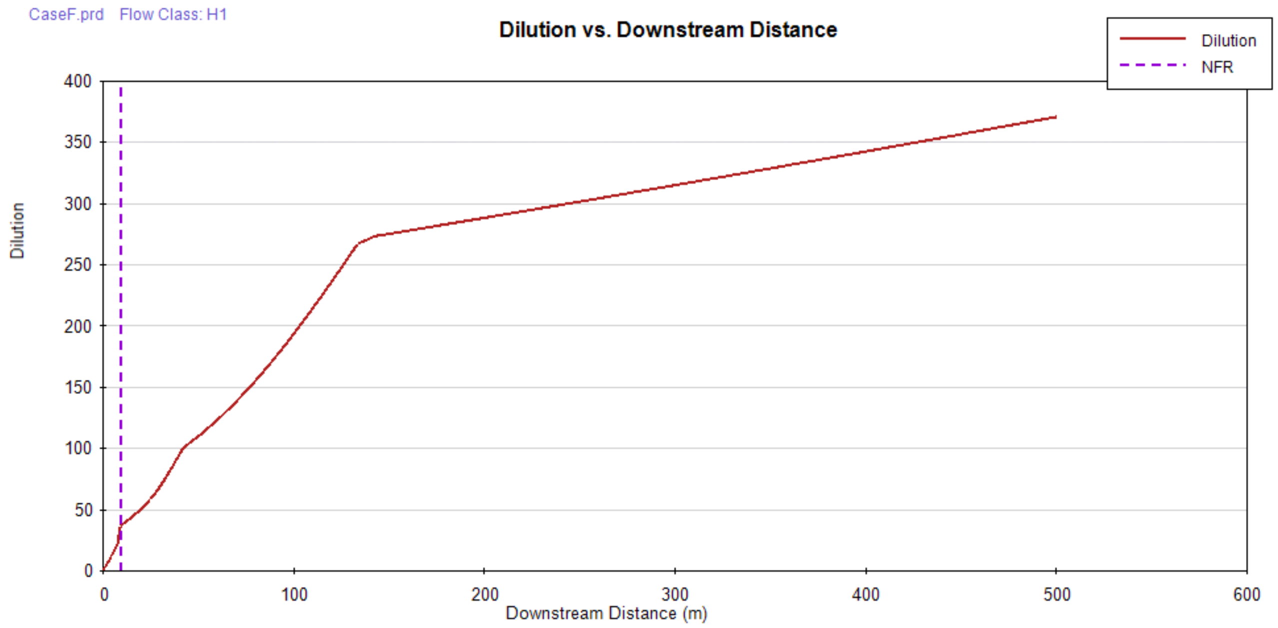


Figure A-5. Dilution versus downstream distance for Case E (Table 4-1).



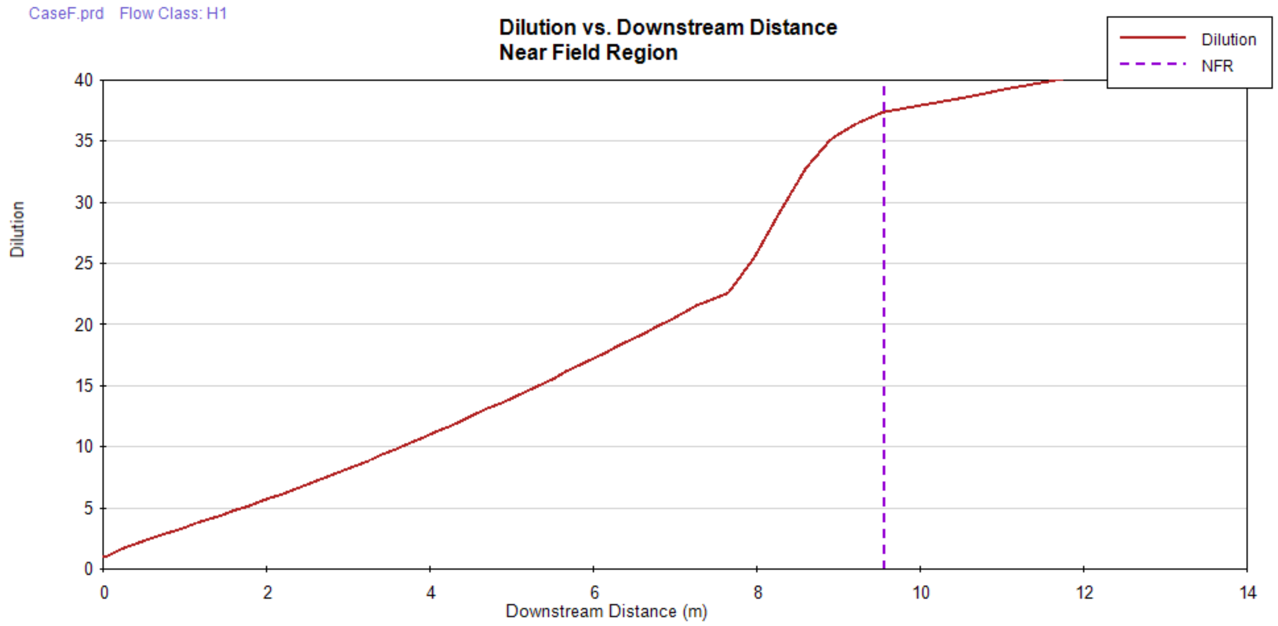
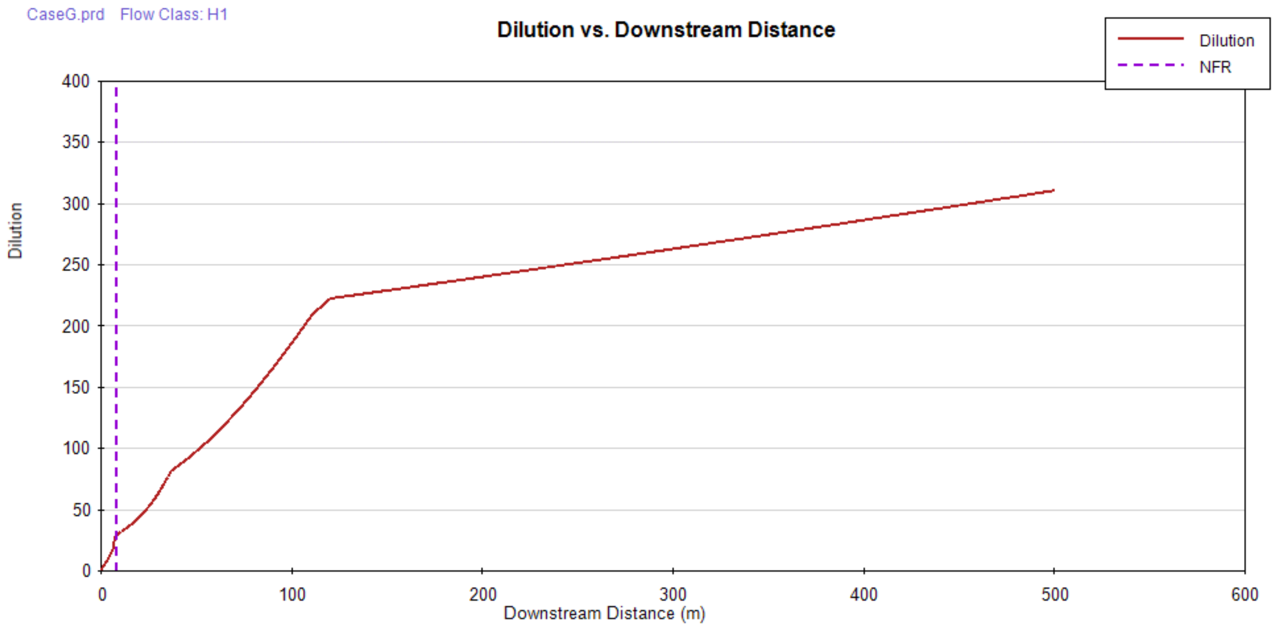


Figure A-6. Dilution versus downstream distance for Case F (Table 4-1).



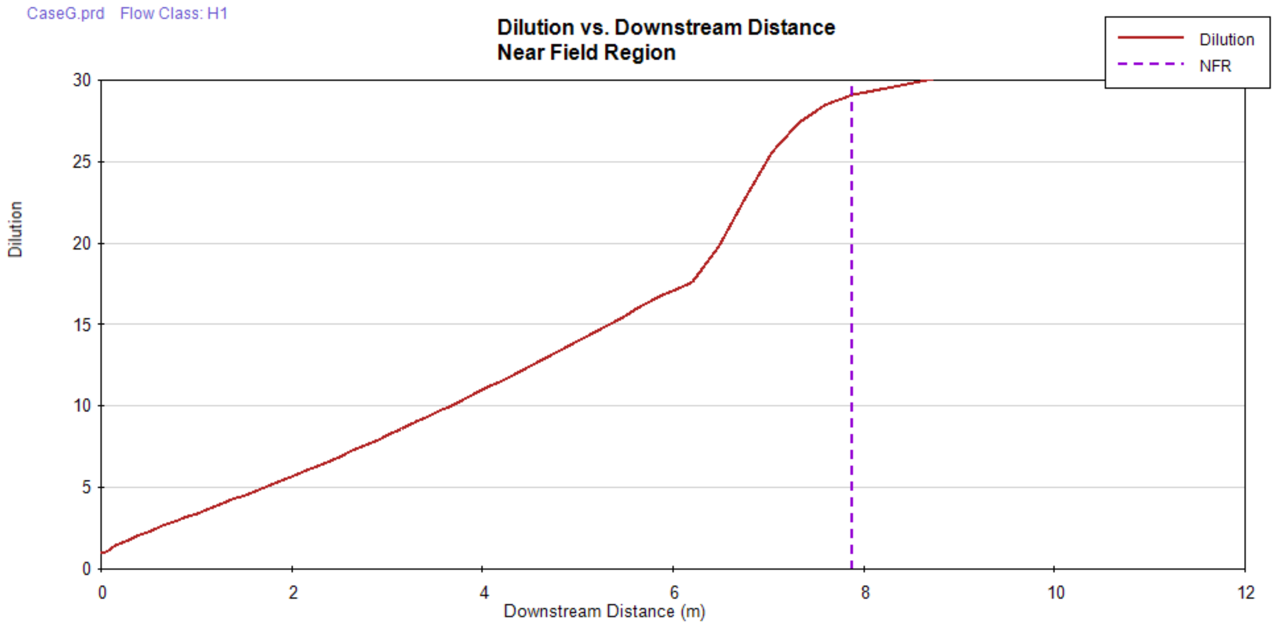


Figure A-7. Dilution versus downstream distance for Case G (Table 4-1).

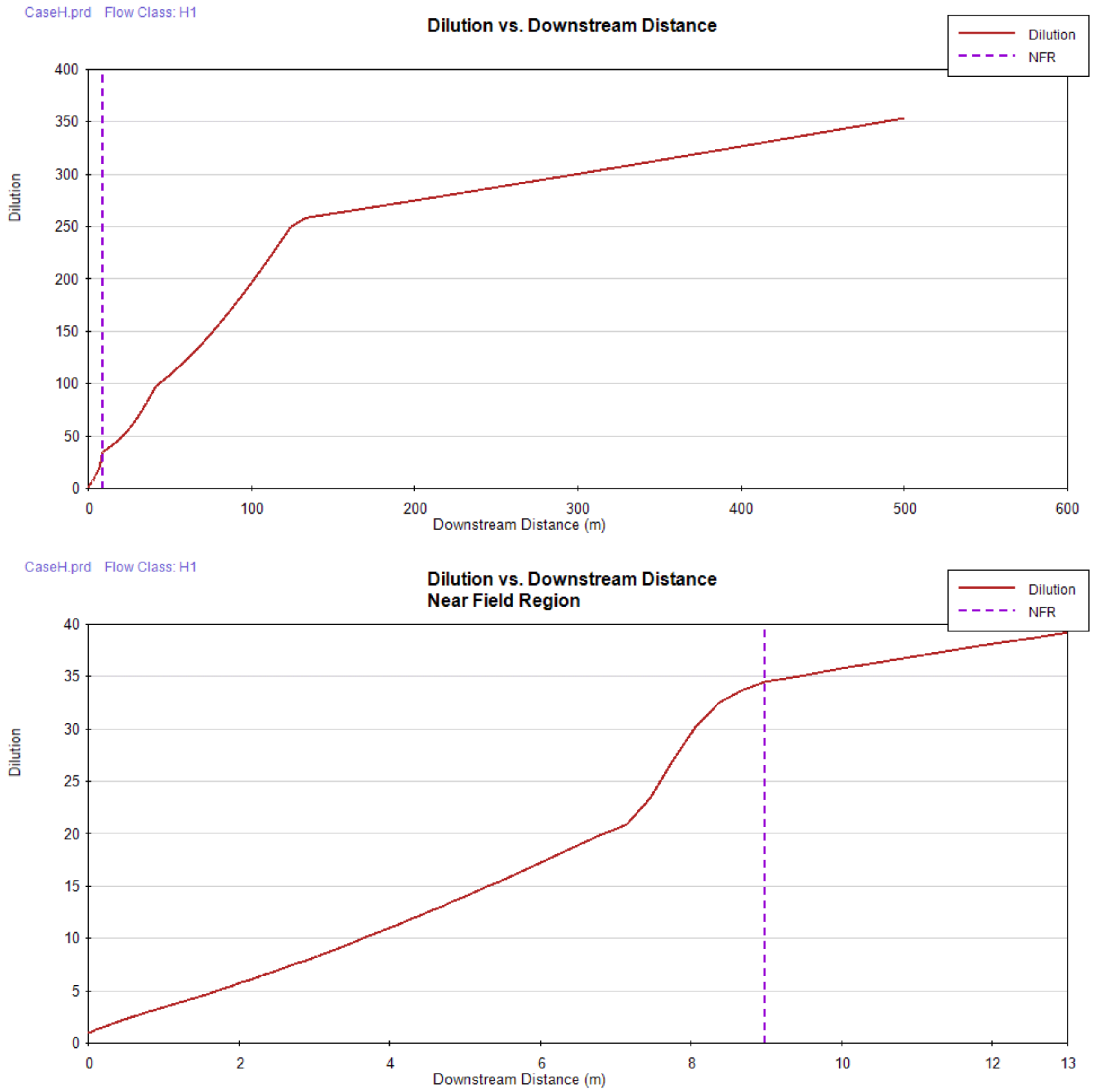


Figure A-8. Dilution versus downstream distance for Case H (Table 4-1).