Merimbula Sewage Treatment Plant Upgrade and Ocean Outfall
Environmental Impact Statement
Bega Valley Shire Council
May 2021

# Merimbula Sewage Treatment Plant Upgrade and Ocean Outfall

# Appendix Q

## Dispersion Modelling Report

# Appendix Q

Dispersion Modelling Report

Client: Bega Valley Shire Council (BVSC)

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May 2021

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## Nomenclature

| Symbol/Units | Definition |
|---|---|
| %ile | Percentile |
| 2D | Two-dimensional |
| 3D | Three-dimensional |
| deg C | Degrees Celsius |
| kg/m$^3$ | Kilogram per cubic metre |
| km | Kilometre |
| m | Metre |
| m/s | Metre per second |
| ML | Megalitre |
| **Abbreviation** | **Definition** |
| AECOM | AECOM Australia Pty Ltd |
| BVSC | Bega Valley Shire Council |
| EIS | Environmental Impact Statement |
| EPA | Environment Protection Authority |
| EPL | Environment Protection Licence |
| IDEA | Intermittently decanted extended aeration |
| MHL | Manly Hydraulics Laboratory (NSW Government) |
| NOx | Oxides of nitrogen |
| NSW | New South Wales |
| PRP | Pollution Reduction Program |
| STP | Sewage treatment plant |
| TEWQ | Treated effluent water quality |

# Executive Summary

AECOM was commissioned by the Bega Valley Shire Council to provide engineering services for the Merimbula Sewage Treatment Plant Upgrade and Ocean Outfall Concept Design and Environmental Assessment. This report summarises the treated wastewater dispersion modelling for the proposed ocean outfall concepts.

Numerical modelling was used to assess the water quality impacts and risk of treated wastewater discharges within the bay and further offshore. The numerical modelling looked at both near-field and far-field mixing behaviours as part of the assessment. All four proposed outfall locations were initially modelled. In addition, four existing conditions (e.g. shore-based discharge) scenarios were modelled for a baseline comparison to the proposed outfalls.

During the dispersion modelling phase, outfall location 1 (also referred to as the “north-short” outfall) was selected as the preferred outfall location during the concept design process. Therefore, the remaining runs focused on location 1. The results of the numerical modelling provided input to the outfall concept design and outfall location selection. The modelling results also informed the Environmental Impact Statement (EIS).

The dispersion modelling study showed that the proposed ocean outfall treated wastewater discharges offer a significant improvement over the existing shore-based outfall and would meet the required dilution targets within 200 m of the outfall location. Near-field modelling focused on the plume behaviour near the discharge location where dispersion is dominated by momentum and turbulent mixing. Far-field modelling accounted for larger-scale mixing associated with the ambient conditions and hydrodynamics of the discharge environment. The key summaries were as follows:

- Near-field modelling (CORMIX):
  - For the median treated effluent water quality (TEWQ) which was used to define the mixing zone extent in the EIS, the required dilution factor of 237 was achieved within 25 m of the diffuser for all conditions modelled. For currents greater than 0.34 m/s, the required dilution was achieved within 5m.
  - The 90$^{th}$ percentile TEWQ values were included as a sensitivity test. The required dilution factor of 2,496 was achieved in less than 50 m for currents above 0.34 m/s. For the lower currents modelled (0.05 and 0.15 m/s), the required dilution was not met within the near-field calculations of CORMIX. Therefore, the far-field model was used to assess the dilution extents for these scenarios.
- Far-field modelling (Delft3D):
  - For the assessed outfall model runs, the only dilution contours visible are between the 1,000 to 100,000 dilution factor range because dilution is achieved within a short distance of the outfall location which is consistent with the near-field results. These dilution contours are well above the required water quality dilution target of 237 for median TEWQ which indicated the water quality objectives were met within a short distance of the outfall. These higher dilution contours are only shown for reference on the greater plume trajectory. The high dilution factor results were expected after seeing the results of the near-field model predictions that showed a high dilution factor.
    - For the lower current conditions (less than 0.15 m/s) that showed higher distances to dilution in the CORMIX modelling for the 90$^{th}$ percentile TEWQ, the far-field model showed the 2,496 times dilution contour was reached in approximately 200 m from the preferred outfall location.
  - By comparison, the existing conditions model runs had dilution factor contours visible that were less than 100 times dilution, which is below the required dilution requirements needed to meet the water quality objectives. The shore-based discharge remains within the bay and even extends into the nearby estuaries under some model runs.

The near-field and far-field dispersion modelling provided valuable insight into the potential treated wastewater plume behaviours. When applying these model results, it should be remembered that such

models are not an exact science and they represent simplified versions of very complex processes. The limitations and uncertainties of modelling need to be reflected in how the results are utilised for design activities. However, the modelling showed that all the off-shore outfall locations provide a high level of dilution due in part to the relatively low rate of treated wastewater discharge into an approximately 30 m-deep ocean location. The required dilution rates are met quickly for the conditions modelled herein. For the preferred outfall location, the water quality objectives are met within 200 m of the outfall location.

# 1.0 Introduction

AECOM was commissioned by the Bega Valley Shire Council (BVSC) to perform dispersion modelling as part of the Merimbula Sewage Treatment Plant (STP) Upgrade and Ocean Outfall Concept Design and Environmental Assessment project (hereafter referred to as “the project”). This report summarises the treated wastewater dispersion modelling for the proposed ocean outfall concepts (hereafter referred to as “the study”).

## 1.1 Project Description

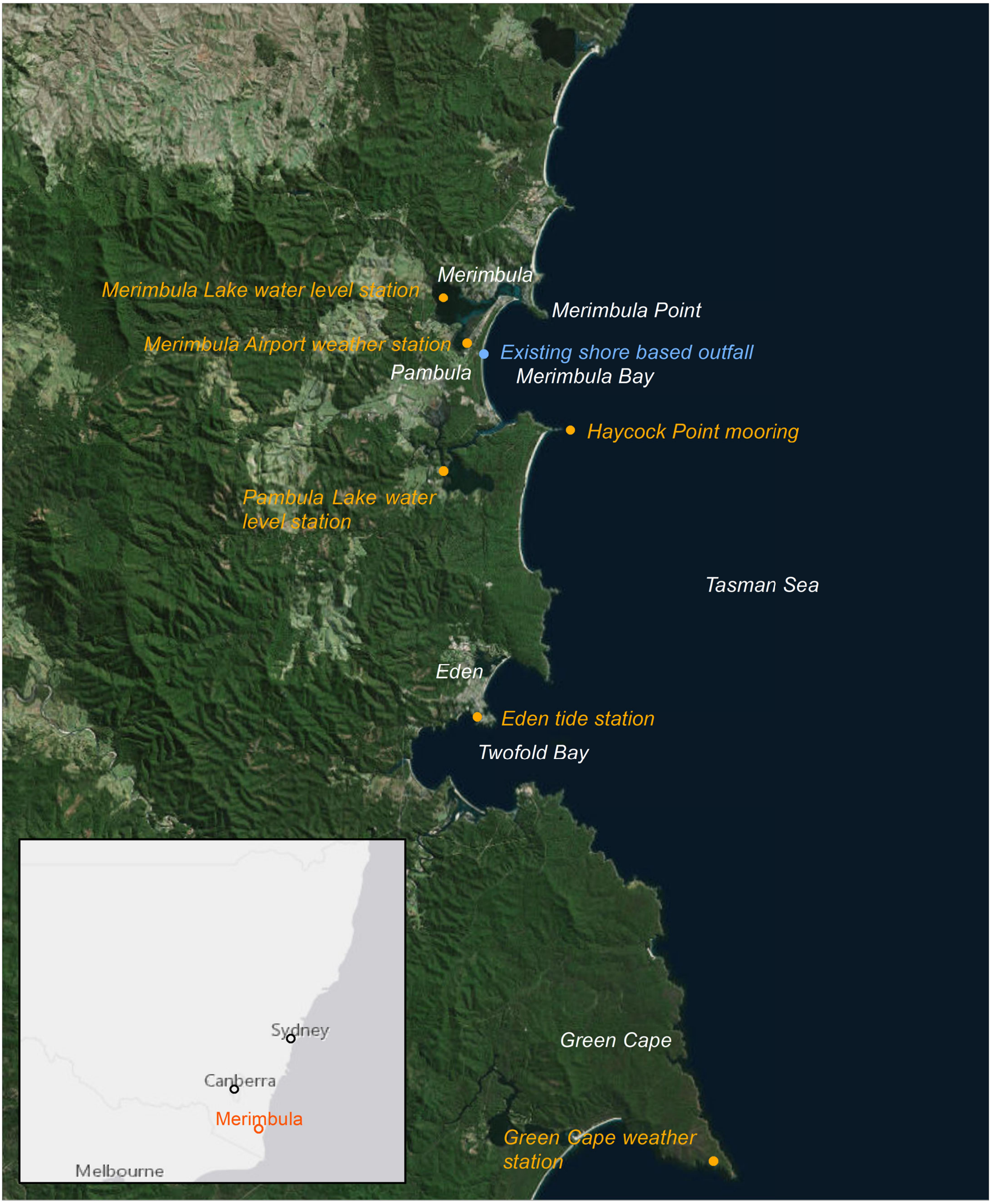
Merimbula STP is located between the regional coastal townships of Merimbula to the north and Pambula to the south. It is an intermittently decanted extended aeration (IDEA) activated sludge plant that treats sewage from Merimbula, Pambula, South Pambula, and Pambula Beach to an advanced secondary standard. The STP treats approximately 700 megalitres (ML) of sewage per year. The current strategy for managing treated wastewater from the Merimbula STP comprises a combination of beneficial reuse (approximately 20 to 25%) and treated wastewater disposal (approximately 75 to 80%) with up to 50% of disposal going to the beach-face outfall at Merimbula beach positioned above high-tide. **Figure 1** shows the location of the existing shore-based outfall.

The current treated wastewater disposal via the beach-face outfall is vulnerable to coastal processes (erosion) and not sustainable or acceptable in the long-term. Merimbula STP is licenced by the New South Wales (NSW) Environment Protection Authority (EPA) under the *Protection of the Environment Operations Act 1997*. The treated wastewater produced at the Merimbula STP must comply with the requirements outlined in Environment Protection Licence (EPL), Number 1741. The licence defines discharge points, monitoring points, pollutant load limits, pollutant concentration limits and volume limits for the treated wastewater discharged. In 2008, the EPA modified the EPL with the addition of a Pollution Reduction Program (PRP), requiring BVSC to investigate and assess reasonable and feasible options for disposal and reuse of treated wastewater from the STP and to nominate a preferred strategy. In 2013, the EPA amended BVSC’s EPL for the STP to include a requirement to upgrade the STP and construct an ocean outfall.

The proposed ocean outfall is to be a new treated wastewater disposal outlet for the Merimbula STP, to allow disposal of treated wastewater offshore at a location that takes advantage of greater dilution by ocean currents and mixing.

## 1.2 Study Objective

Numerical modelling was used to assess the water quality impacts and risk of treated wastewater discharges within the bay and further offshore. The numerical modelling looked at both near-field and far-field mixing behaviours as part of the assessment. The results of the numerical modelling provided input to the outfall concept design and outfall location selection. The modelling results also informed the Environmental Impact Statement (EIS).




MERIMBULA HYDRODYNAMIC MODELLING

**Figure 1. Project location**

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## 1.3 Dispersion Modelling Methodology

The dispersion modelling was focused on four prospective outfall discharge locations, shown on **Figure 2**, which were determined during the options assessment phase. The dispersion modelling methodology involved a combination of near-field modelling and far-field modelling.

Near-field modelling focuses on the plume behaviour near the discharge location where it is typically dominated by momentum and turbulent mixing. The discharge geometry (i.e. the diffuser) and the ambient conditions near the discharge location determine the near-field mixing behaviour. Based on guidance from the EPA, the water quality objectives should be achieved within the near-field mixing region.

Far-field modelling accounts for larger-scale mixing associated with the ambient conditions and hydrodynamics of the discharge environment. For this project, a hydrodynamic model was developed and calibrated for use in the far-field dispersion modelling.

The detailed model inputs, methodologies, and results for the near-field and far-field models are discussed in **Section 2** and **Section 3**, respectively.

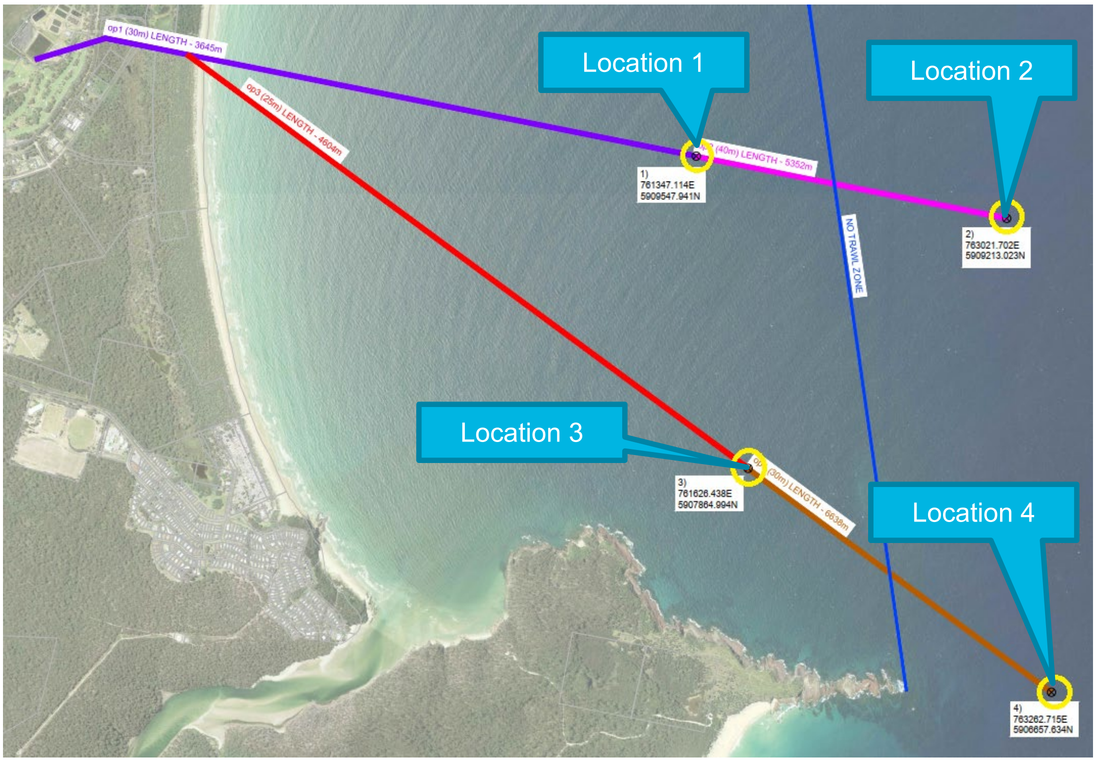


**Figure 2 Outfall locations under consideration**

## 1.4 Water Quality Assessment and Dilution Required

Prior to initiating any dispersion modelling, an assessment was conducted to determine the dilution required to meet water quality objectives, considering:

a. what comes out of the outfall, described as the treated effluent water quality (TEWQ);

b. the ambient or receiving water quality (monitoring); and

c. what we need to achieve in the environment, described by water quality guidelines.

The details of the water quality assessment can be found in the separate memorandum[1] which is included in **Appendix A**, however the key outcomes are summarised below:

[1] AECOM, 2019a. *Merimbula Ocean Outfall – Preliminary Water Quality Assessment*, dated 17 July 2019.

- A maximum dilution factor of 237 is needed to achieve all water quality objectives for the median TEWQ. This dilution factor is required to achieve the target concentrations of the oxides of nitrogen (NOx). All other pollutants require a dilution factor less than 237 to meet their target concentrations. Therefore, if the dilution factor of 237 is achieved, water quality objectives are met for all pollutants.
- A maximum dilution factor of 2,496 is needed to achieve all water quality objectives for the 90th percentile TEWQ. This dilution factor is required to achieve the target concentrations of ammonia. Similarly, if the dilution of 2,496 is achieved, then the water quality objectives are met for all pollutants.

The focus of the dispersion modelling was to determine a mixing zone extent for the median TEWQ conditions, however the 90th percentile TEWQ dilution value is also referenced in this report in the model results section.

## 1.5 Current Statistics from Haycock Point Mooring

The ambient currents used in the dispersion models were based on Haycock Point mooring statistics derived from approximately 15 months of mooring data collected by Manly Hydraulics Laboratory (MHL) during 31 March 2015 to 26 October 2016.[2] The mooring location was selected as it was originally believed to be the preferred outfall location from a preliminary modelling study[3]. The mooring data represented a long-term hydrodynamic data set for an offshore outfall location which was representative of the four proposed outfall locations. The data was used to inform the modelling activities. The current data was isolated into directional components (i.e. north, south, east, west) for the statistical analysis.

Upon a review of the mooring data, the predominant flow direction was parallel to the coast, therefore only north and south currents were considered for the dispersion modelling scenarios. Currents flow towards the south approximately 88% of the time and are stronger than currents flowing to the north. **Table 1** summarises the statistical analysis of the mooring current data used in the near-field and far-field dispersion modelling. A more detailed assessment of the mooring data was also presented in the dispersion modelling methodology memorandum included as **Appendix C**.[4]

**Table 1 Haycock Point mooring current statistics**

| Statistic | Northward Current Speed (m/s) | Southward Current Speed (m/s) |
|---|---|---|
| 10th percentile | 0.03 | 0.15 |
| 50th percentile | 0.15 | 0.40 |
| 90th percentile | 0.34 | 0.56 |
| 99th percentile | 0.51 | 0.78 |
| Maximum | 0.53 | 0.96 |
| Mean | 0.17 | 0.38 |

[2] MHL, 2017. *Merimbula Deep Ocean Outfall, Oceanographic Mooring Data Collection, Report MHL2374*, dated 25 April 2017
[3] MHL, 2015. *Proposed Merimbula Deep Outfall, Relative Hydrodynamic Merits of Different Outfall Locations (Report MHL2418)*. Manly Hydraulics Laboratory, dated 18 November 2015.
[4] AECOM, 2019b. *Merimbula STP Upgrade and Ocean Outfall Concept Design & Environmental Assessment – Dispersion Modelling Methodology Memorandum*, dated 09 December 2019.

# 2.0 Near-Field Dispersion Modelling (CORMIX)

The near-field modelling for this study was conducted using CORMIX and its multi-port discharge module (referred to as CORMIX2). CORMIX is an internationally accepted analysis tool for various treated wastewater discharges in the near-field. CORMIX employs a data driven approach to plume simulation by selecting the appropriate hydrodynamic model to simulate the mixing processes for the specified discharge characteristics and ambient conditions.[5]

Preliminary CORMIX modelling had been completed throughout the project for all four proposed locations and a variety of diffuser configurations. However, for clarity, only the inputs and results of the preferred location (Location 1) and diffuser concept design are presented herein.

As discussed in the far-field model calibration report[6], in the absence of suitable non-prescriptive boundary conditions, it was decided that the two-dimensional far-field model would not be extended to three-dimensions. Three-dimensional plume behaviour would instead be evaluated with the steady-state model CORMIX and used to determine if the plume may be trapped beneath the pycnocline during stratified conditions.

## 2.1 Near-Field Model Inputs

**Table 2** summarises the main inputs used in the CORMIX model runs. **Figure 3** illustrates the diffuser geometry used in the CORMIX model as determined during the concept design.

**Table 2 CORMIX model inputs**

| Parameter | Value |
|---|---|
| Ambient current speed | Varied from 0.05 m/s to 0.78 m/s (see **Section 2.2**) |
| Ambient current direction | 90 degrees to diffuser (see “UA” arrow in **Figure 3**) |
| Treated wastewater flow rate | 80 L/s (typical dry weather flow rate) |
| Treated wastewater density | 1,000 kg/m$^3$ (is fresh water and more buoyant than the receiving saltwater environment) |
| Average water depth | 30 m |
| Depth at discharge | 30 m (representative of outfall Location 1 on **Figure 2**) |
| Wind speed | 2 m/s (CORMIX recommends using this value for conservative design conditions) |
| Manning’s n roughness | 0.025 |
| Ambient water density | Uniform conditions (i.e. non-stratified): 1,020 kg/m$^3$<br>Stratified conditions: 20 deg C surface, 14 deg C bottom with the pycnocline height at 15 m (mid-depth) |
| Diffuser length | 50 m (25 m between risers) |
| Risers/Ports | Three risers with two ports per riser (facing opposite directions) |
| Port Diameter | 0.225 m (area = 0.04 m$^2$) |
| Port height off bed | 1 m |

[5] CORMIX, 2007. *CORMIX User Manual: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharged into Surface Waters*. U.S. Environmental Protection Agency, December 2007.
[6] AECOM, 2019c. *Merimbula Ocean Outfall: Hydrodynamic Modelling – Coastal Model Calibration Report.* AECOM, dated 13 June 2019.

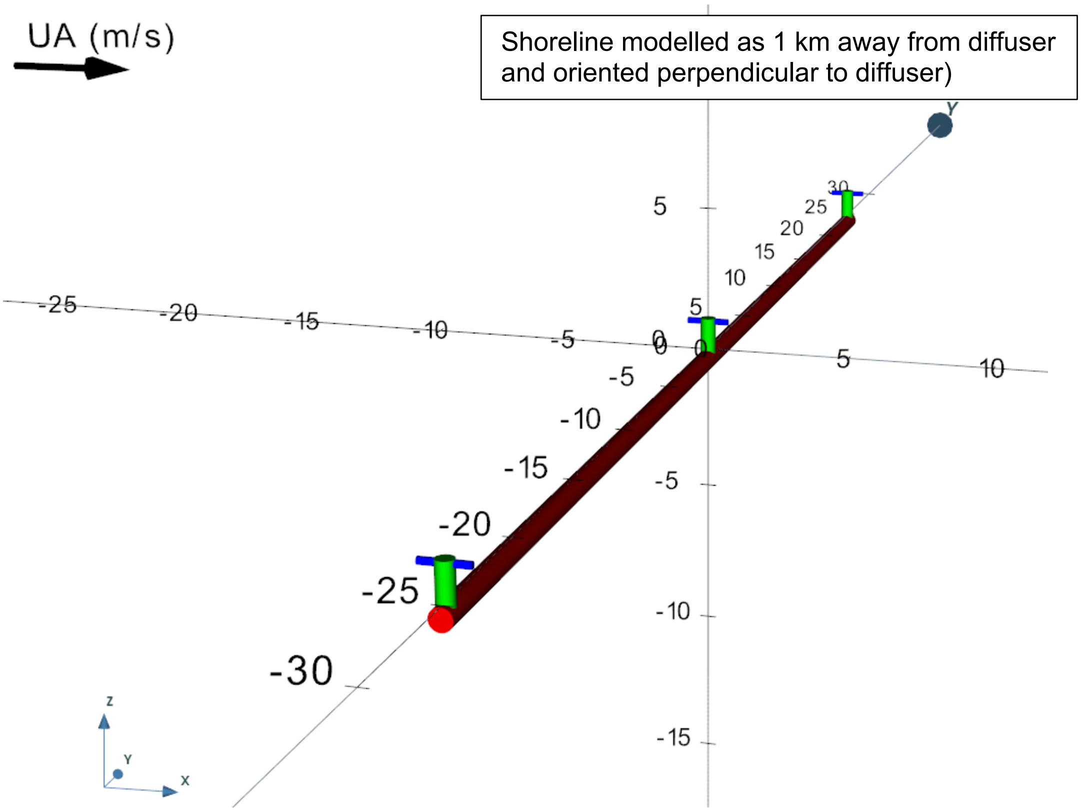


**Figure 3 Diffuser arrangement modelled in CORMIX (northward scenario shown)**

## 2.2 Near-Field Model Scenarios

The CORMIX model was run for a variety of current speeds for both uniform and stratified ambient conditions. The current speeds were varied from 0.05 m/s to 0.78 m/s representing the 10th percentile to 99th percentile range of currents from the Haycock Point mooring data. The stratified condition was adapted from a stratified scenario measured during the mooring deployment. For the stratified cases, the ambient temperature differential was six degrees between the surface and bottom temperatures with the pycnocline height at mid-depth. **Table 3** summarises the conditions analysed in CORMIX.

**Table 3 Near-field model scenarios**

| Scenario | Current Speed (m/s) |
|---|---|
| 10$^{th}$ percentile northward current | 0.05 |
| 10$^{th}$ percentile southward current | 0.15 |
| 90$^{th}$ percentile northward current | 0.34 |
| 50$^{th}$ percentile southward current | 0.40 |
| 90$^{th}$ percentile southward current | 0.56 |
| 99$^{th}$ percentile southward current | 0.78 |
| Notes: Both uniform and stratified conditions were run for each current speed. CORMIX does not differentiate between northward and southward current directions, so a range of current speeds were selected to encompass the current speeds measured at the mooring. | |

## 2.3 Near-Field Model Results

CORMIX provides visual plume results as illustrated by the example of dilution contours shown in **Figure 4** and contained in **Appendix B**. However, the key model output desired from the CORMIX model is the distance to achieve the required dilution targets which would help define the mixing zone extent for the EIS. The distances required to meet the dilution targets are summarised in **Table 4**.

For the median TEWQ which would be used to define the mixing zone extent in the EIS, the required dilution factor of 237 was achieved within 25 m of the diffuser for all conditions modelled. For the currents greater than 0.34 m/s, the required dilution was achieved within 5m.

The 90th percentile TEWQ values are shown as a sensitivity test. The required dilution factor of 2,496 is achieved in less than 50m for currents above 0.34 m/s. For the lower current speeds modelled (0.05 and 0.15 m/s), distances greater than 690 m are required, indicating that the required dilution would need to be achieved in the far-field extent.

**Figure 5** shows the dilution as a function of distance from the diffuser for uniform ambient conditions. **Figure 6** is a similar plot for the stratified conditions modelled. The 99th percentile southward current (0.78 m/s) has been omitted for clarity on these plots since it is virtually a straight vertical line on both plots.

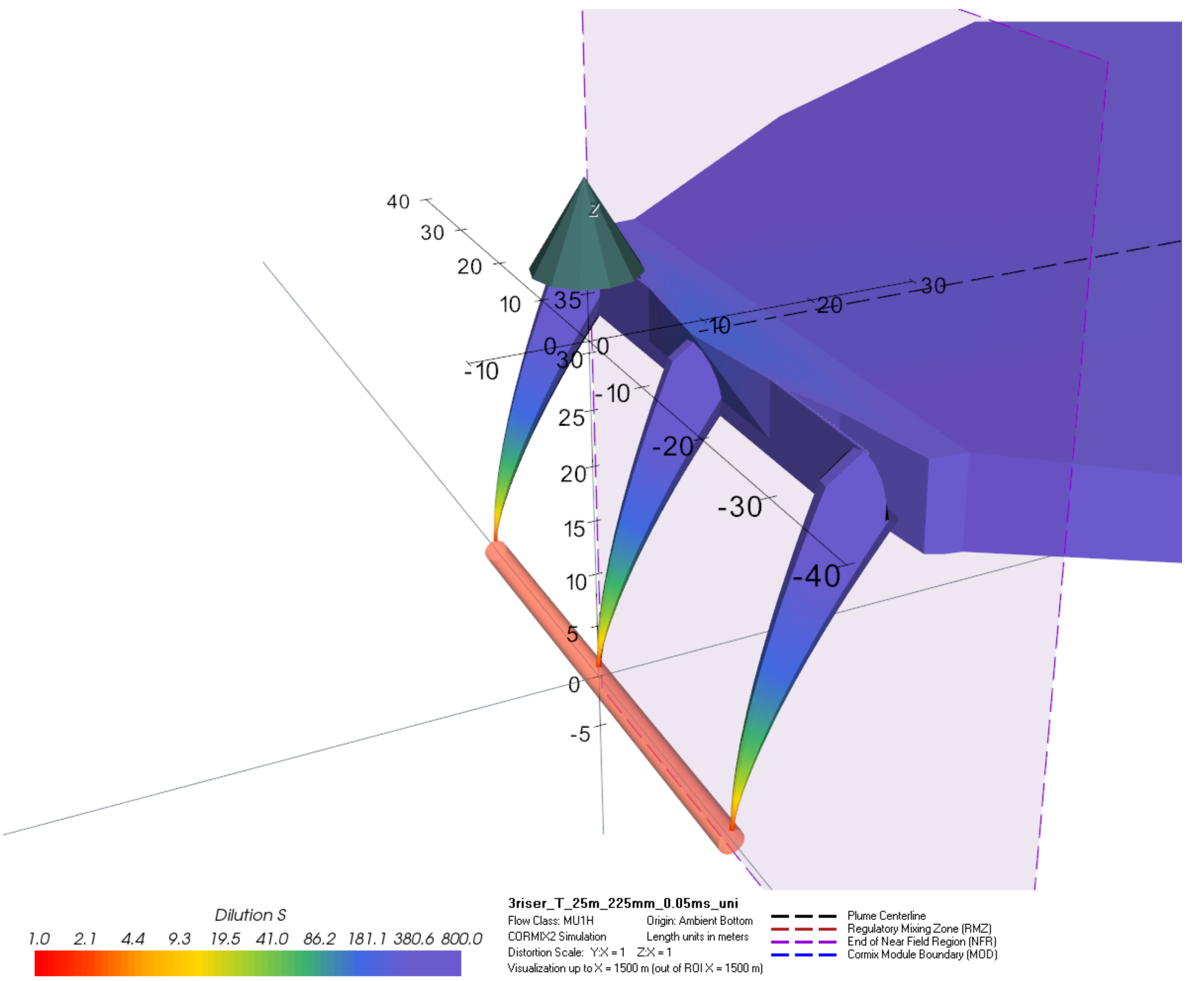


**Figure 4 Example of visual plume output from CORMIX (0.05 m/s current shown)**

**Table 4 Near-field model results**

| Scenario | Current Speed (m/s) | Distance to Required Dilution (m)[A] | | | |
|---|---|---|---|---|---|
| | | Uniform Conditions | | Stratified Conditions | |
| | | Median TEWQ | 90th %ile TEWQ | Median TEWQ | 90th %ile TEWQ |
| 10th percentile northward current | 0.05 | 15 | N/A[B] | 20 | N/A[B] |
| 10th percentile southward current | 0.15 | 25 | N/A[B] | <5 | N/A[B] |
| 90th percentile northward current | 0.34 | <5 | 25 | <5 | 50 |
| 50th percentile southward current | 0.40 | <5 | 20 | <5 | 35 |
| 90th percentile southward current | 0.56 | <5 | 15 | <5 | 20 |
| 99th percentile southward current | 0.78 | <5 | 10 | <5 | 10 |

Notes:

A) Distances rounded to the nearest 5m.

B) Distance marked "N/A" did not reach the required dilution within CORMIX's near-field calculations. Distances for required dilution would be based off of far-field model results for these scenarios.

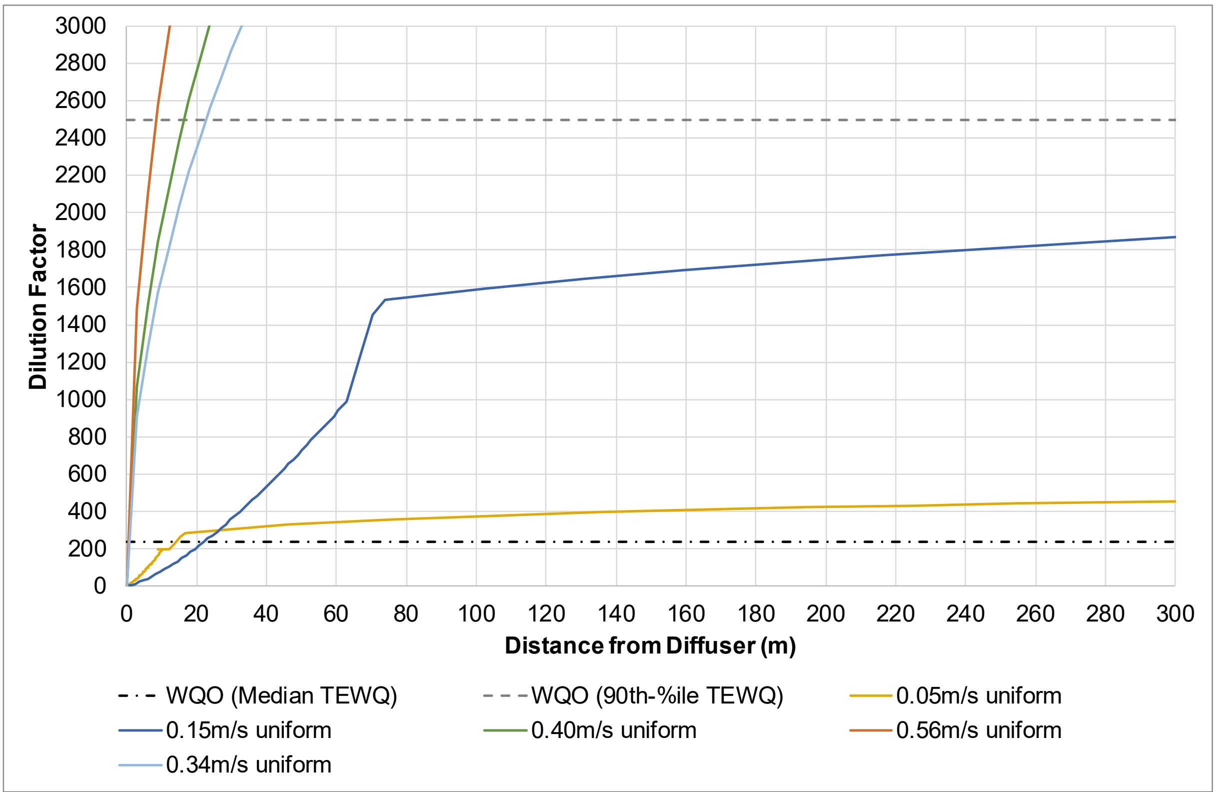


**Figure 5 Near-field dilution achieved during uniform ambient conditions for various currents**

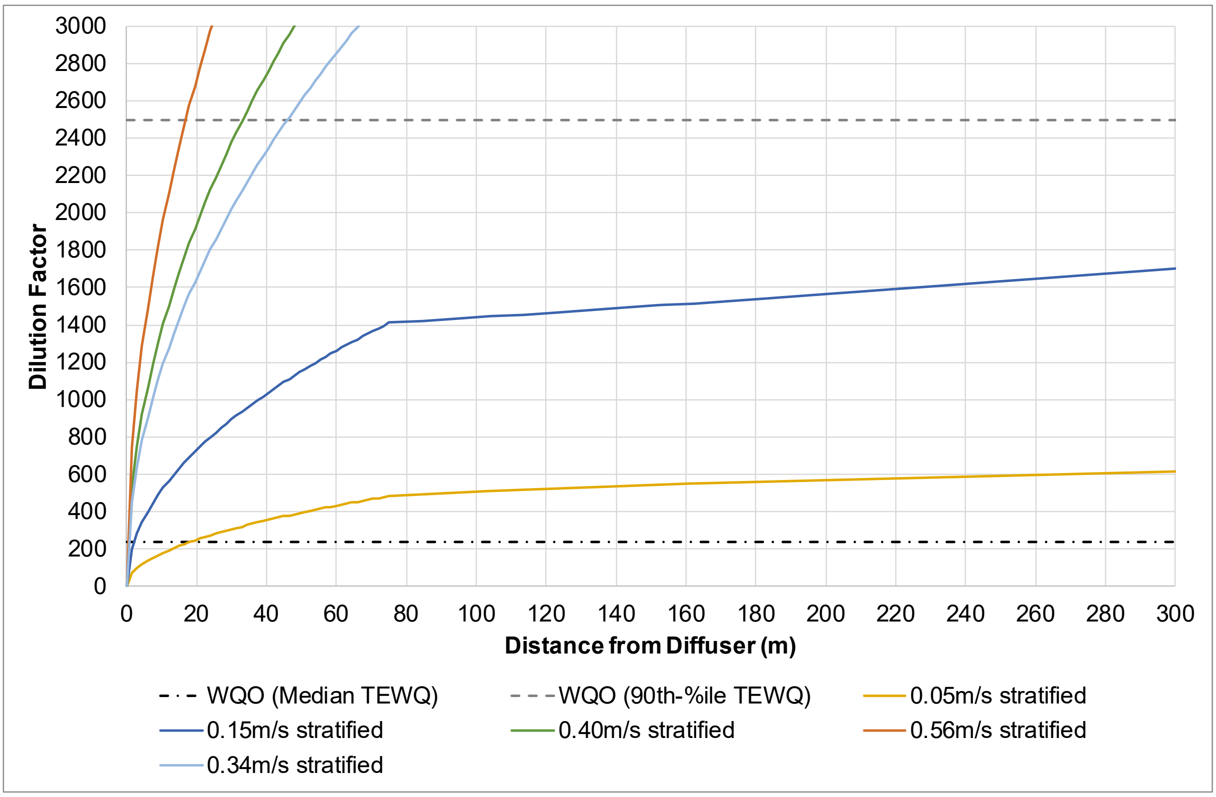


**Figure 6 Near-field dilution achieved during stratified ambient conditions for various currents**

# 3.0 Far-Field Dispersion Modelling (Delft3D)

The far-field dispersion modelling was conducted in Delft3D using the FLOW module for hydrodynamics and the PART module (particle tracking) for water quality modelling. The following sections summarise each module.

## 3.1 Delft3D-FLOW Model Description

Delft3D is an integrated flow, transport and water quality modelling system developed by Deltares, an independent institute for applied research based in Delft and Utrecht, the Netherlands. The flow module of the system, Delft3D-FLOW, provides hydrodynamics for other Delft3D modules simulating wind waves, bed morphology changes, estimation of various water quality parameters and particle tracking.[7]

The hydrodynamic module Delft3D-FLOW simulates two-dimensional (2D) depth averaged or three-dimensional (3D) unsteady flow and transport phenomena resulting from tidal and/or meteorological forcing, including the effect of density differences due to a non-uniform temperature and salinity distribution (density-driven flow). The flow model can be used to predict the flow in shallow seas, coastal areas, estuaries, lagoons, rivers and lakes. It aims to model flow phenomena of which the horizontal length and time scales are significantly larger than the vertical scales.

Flow can be forced by a combination of tide and ocean currents at the open boundaries, wind stress at the free surface, pressure gradients due to free surface gradients (barotropic) or density gradients (baroclinic). Source and sink terms are included in the equations to model the discharge and withdrawal of water. The wetting and drying algorithms implemented in the model allow the simulation of flood inundation and recession in coastal areas.

## 3.2 Delft3D-PART Model Description

The PART module of Delft3D simulates transport and water quality processes through a particle tracking method using flow data from the Delft3D-FLOW module. Particle tracking allows water quality processes to be described in a detailed spatial extent by resolving sub-grid concentration distributions. Delft3D-PART is best suited for studies over the mid-field range (200m to 15km) of instantaneous or continuous releases.[8] The PART tracer module with a conservative, non-decaying tracer was used in this analysis to model the plume.

## 3.3 Far-Field Model Development and Calibration

The development and calibration of the far-field Delft3D-FLOW model has been described in detail in the model calibration report[9]. For reference, **Figure 7** shows the far-field model extent and grid resolution, **Figure 8** shows the bathymetry used in the model domain, and **Figure 9** shows the bathymetry within the bay.

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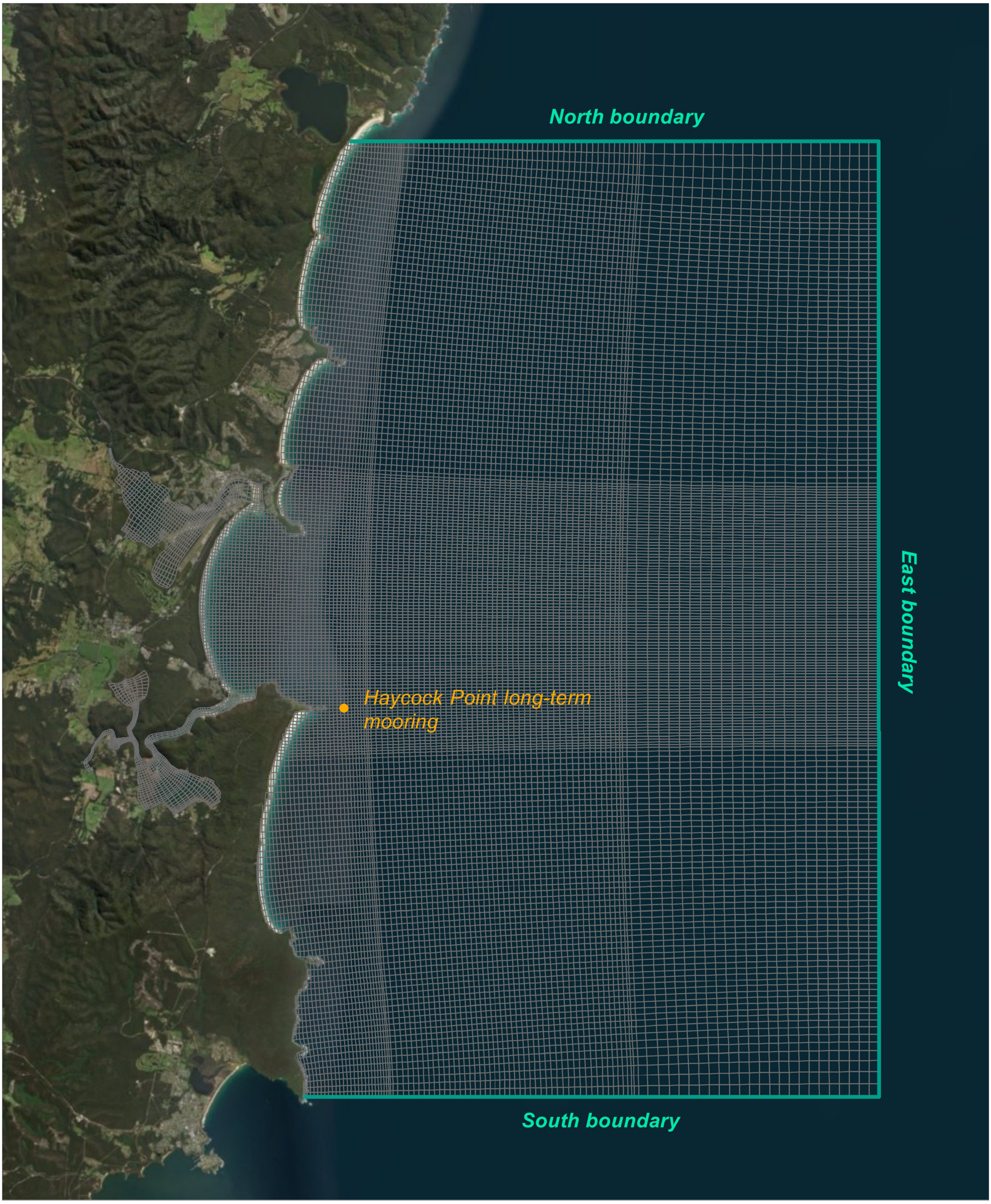
[7] Deltares, 2011a. *Delft3D-FLOW, Simulation of multi-dimensional hydrodynamic flows and transport phenomena, including sediments, User Manual*. 7 September 2011.
[8] Deltares, 2011b. *Delft3D-PART, Simulation of mid-field water quality and oil spills, using particle tracking, User Manual*. 18 May 2011.
[9] AECOM, 2019c. *Merimbula Ocean Outfall: Hydrodynamic Modelling – Coastal Model Calibration Report.* AECOM, dated 13 June 2019.




MERIMBULA HYDRODYNAMIC MODELLING

**Figure 7. Hydrodynamic model grid and open boundaries**

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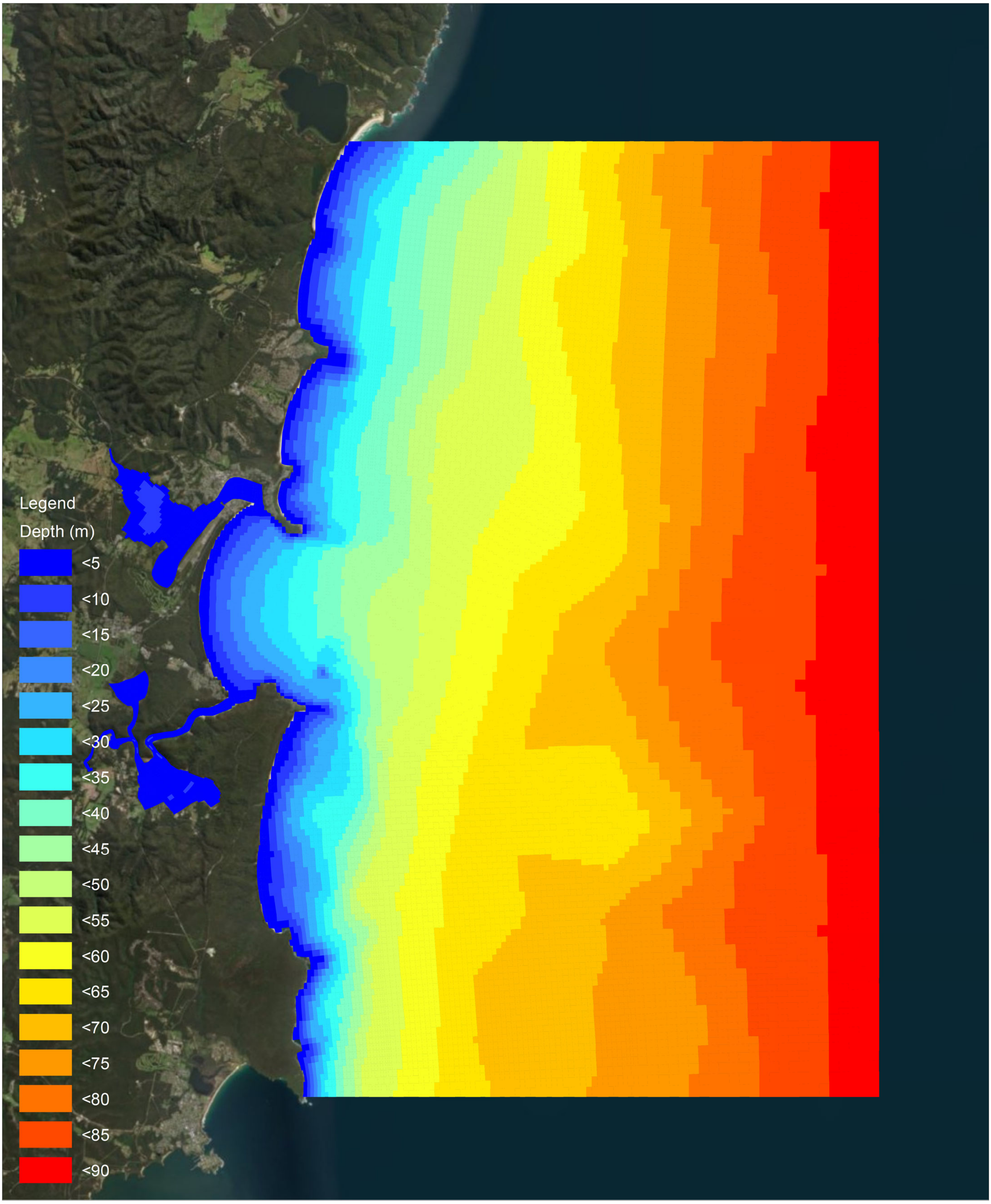
N

0 5 10 km




MERIMBULA HYDRODYNAMIC MODELLING

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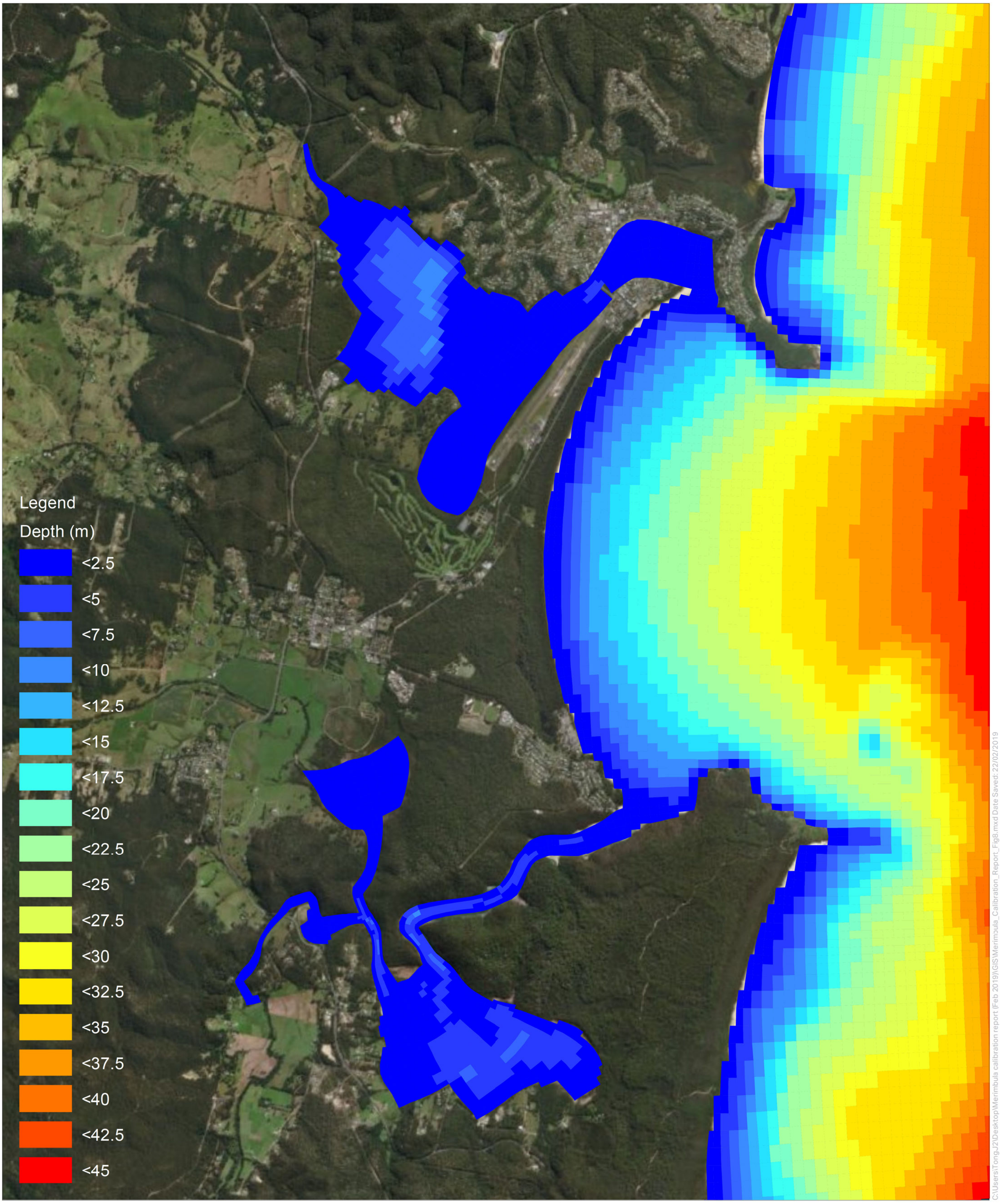
**Figure 8. Hydrodynamic model bathymetry for entire model domain**

N

0 5 10 km



*Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community*




MERIMBULA HYDRODYNAMIC MODELLING

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**Figure 9. Hydrodynamic model bathymetry within Merimbula Bay**

0 1 2 km



*Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community*

## 3.4 Far-Field Dispersion Modelling Scenarios

During the far-field model development, a preliminary list of dispersion model runs was presented and were primarily based on different current strengths and directions.[10] The general modelling scenarios selected for the dispersion modelling task were outlined in a previous memorandum on the dispersion modelling methodology[11] which is included in **Appendix C**. The 44 dispersion model runs are included in **Table 5**. The 44 model runs were chosen to be representative of a variety of hydrodynamic and ambient conditions for each outfall location, including modelling the existing shore-based discharge for comparison. By modelling a variety of conditions, the modelling assessed the dilution performance's sensitivity to various parameters.

The overall approach of the dispersion modelling scenarios was to include the range of possible hydrodynamic and ambient conditions that could impact the transport of the plume. Based on an analysis of the Haycock Point mooring current data, the currents are predominantly in the north-south direction at Haycock Point. The current data was analysed to develop the 10th, 50th and 90th percentile values for currents in both the northward and southward direction. In addition, the maximum northward and southward currents recorded during the mooring deployments were also included in the modelling approach. A zero current condition was also modelled as a sensitivity test. These currents were applied to the model boundary to drive the hydrodynamic conditions within the bay.

Non-stratified and stratified conditions were also included in the model runs. For non-stratified conditions, the treated wastewater tracer was released in the PART model from the bottom of the grid cell containing the outfall location. For stratified conditions, the tracer was released in the far-field model at mid-depth to simulate a reduced water column depth. However, it should be noted that the near-field modelling was the primary focus for plume behaviour under stratified conditions.

The hydrodynamic models were run for two weeks with a constant velocity applied at the model boundaries. The PART tracer models were run over multiple days of simulated treated wastewater discharge operation. In general, after three days of treated wastewater discharge, the plume would start to escape the bay and/or exit through the model boundaries depending on what outfall location was being modelled.

A treated wastewater discharge of 80 L/s was modelled for all runs. This corresponds to the design dry weather flow rate which is the design flow condition. The treated wastewater discharge was released between the hours of 10:00 PM and 6:00 AM as per the proposed operation of the STP.

All four proposed outfall locations were initially modelled. In addition, four existing conditions (e.g. shore-based discharge) scenarios were modelled for a baseline comparison to the proposed outfalls.

During the dispersion modelling phase, outfall Location 1 (also referred to as the "north-short" outfall) was selected as the preferred outfall location during the concept design process. Therefore, the remaining runs focused on Location 1 and the model runs for the extreme current conditions (i.e. zero current and max currents) replaced some of the proposed runs that were originally planned at the Haycock Point outfall locations.

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[10] AECOM, 2018. *Merimbula Sewage Treatment Plant and Deep Ocean Outfall Concept Design and Environmental Assessment: Model Development and Boundary Conditions Selection (Revision B).* AECOM, dated 31 January 2018.
[11] AECOM, 2019b. *Merimbula STP Upgrade and Ocean Outfall Concept Design & Environmental Assessment – Dispersion Modelling Methodology Memorandum*, dated 09 December 2019.

**Table 5 Far-field dispersion model scenarios**

| Model Run No. | Modelled Current Scenario | Current Speed (m/s) | Stratified Condition | Outfall Location |
|---|---|---|---|---|
| 1 | 10th percentile southward current | 0.15 | No | Location 1 |
| 2 | 10th percentile southward current | 0.15 | No | Location 2 |
| 3 | 10th percentile southward current | 0.15 | No | Location 3 |
| 4 | 10th percentile southward current | 0.15 | No | Location 4 |
| 5 | 10th percentile southward current | 0.15 | No | Existing |
| 6 | 10th percentile northward current | 0.05 | No | Location 1 |
| 7 | 10th percentile northward current | 0.05 | No | Location 2 |
| 8 | 10th percentile northward current | 0.05 | No | Location 3 |
| 9 | 10th percentile northward current | 0.05 | No | Location 4 |
| 10 | 10th percentile northward current | 0.05 | No | Existing |
| 11 | 50th percentile southward current | 0.40 | No | Location 1 |
| 12 | 50th percentile southward current | 0.40 | No | Location 2 |
| 13 | 50th percentile southward current | 0.40 | No | Location 3 |
| 14 | 50th percentile southward current | 0.40 | No | Location 4 |
| 15 | 50th percentile southward current | 0.40 | No | Existing |
| 16 | 50th percentile northward current | 0.15 | No | Location 1 |
| 17 | 50th percentile northward current | 0.15 | No | Location 2 |
| 18 | 50th percentile northward current | 0.15 | No | Location 3 |
| 19 | 50th percentile northward current | 0.15 | No | Location 4 |
| 20 | 50th percentile northward current | 0.15 | No | Existing |
| 21 | 90th percentile southward current | 0.56 | No | Location 1 |
| 22 | 90th percentile southward current | 0.56 | No | Location 2 |
| 23 | 90th percentile southward current | 0.56 | No | Location 3 |
| 24 | 90th percentile southward current | 0.56 | No | Location 4 |
| 25 | 90th percentile northward current | 0.34 | No | Location 1 |
| 26 | 90th percentile northward current | 0.34 | No | Location 2 |
| 27 | 90th percentile northward current | 0.34 | No | Location 3 |
| 28 | 90th percentile northward current | 0.34 | No | Location 4 |
| 29 | 10th percentile southward current | 0.15 | Yes | Location 1 |
| 30 | 10th percentile southward current | 0.15 | Yes | Location 2 |
| 31 | 10th percentile southward current | 0.15 | Yes | Location 4 |
| 32 | 10th percentile northward current | 0.05 | Yes | Location 1 |
| 33 | 10th percentile northward current | 0.05 | Yes | Location 2 |
| 34 | 10th percentile northward current | 0.05 | Yes | Location 4 |

| Model Run No. | Modelled Current Scenario | Current Speed (m/s) | Stratified Condition | Outfall Location |
|---|---|---|---|---|
| 35 | 90$^{th}$ percentile southward current | 0.56 | Yes | Location 1 |
| 36 | 90$^{th}$ percentile southward current | 0.56 | Yes | Location 2 |
| 37 | 90$^{th}$ percentile northward current | 0.34 | Yes | Location 1 |
| 38 | 90$^{th}$ percentile northward current | 0.34 | Yes | Location 2 |
| 39 | Zero current | 0.00 | No | Location 1 |
| 40 | Maximum northward current | 0.53 | No | Location 1 |
| 41 | Maximum southward current | 0.96 | No | Location 1 |
| 42 | Zero current | 0.00 | Yes | Location 1 |
| 43 | Maximum northward current | 0.53 | Yes | Location 1 |
| 44 | Maximum southward current | 0.96 | Yes | Location 1 |

## 3.5 Far-Field Model Results

Visual plots of the treated wastewater plume dilution contours are included for each run in **Appendix D**. For each model run, four plume images are shown: one image just after the initial plume release to show the outfall location, and then three additional plots showing the plume extent in 24-hour increments.

For the proposed outfall model runs, the only dilution contours visible are between the 1,000 to 100,000 dilution factor range as dilution factors less than 1,000 are achieved close to the outfall location and are hard to visualise. These dilution contours are well above the required water quality target discussed earlier in this report (237 for median TEWQ). These higher dilution contours are only shown for reference on the greater plume trajectory as plots of the 237 dilution factor contours would result in a small dot on a map of the model results. The high dilution factor results were expected following analysis of the results of the near-field model predictions that showed a high dilution factor was achieved within 25m of the outfall for most conditions assessed.

By comparison, the existing conditions model runs do have dilution factor contours visible that are less than 100 times dilution, which is below the required dilution requirements because the shore-based discharge offers poorer dilution performance to the ocean-based discharges. The shore-based discharge remains within the bay and even extends into the nearby estuaries under some model runs. The shore-based discharge's poor dilution and entrapment of the plume within the bay illustrated the potential benefits of providing an ocean-based outfall option.

To summarise the far-field results for the preferred outfall location (Location 1), the plume extent required to achieve the 90$^{th}$ percentile TEWQ values (i.e. a required dilution factor of 2,496) is shown on **Figure 10** as a green circle. The required dilution is achieved within 200m of the outfall location for all scenarios modelled.


**Figure 10 Hydrodynamic model bathymetry within Merimbula Bay**

*Note: The green circle represents the plume extent required to achieve the 90th percentile TEWQ values*

# 4.0 Summary of Dispersion Modelling Results

The dispersion modelling study shows that the proposed ocean outfall treated wastewater discharges offer a significant improvement over the existing shore-based outfall and would meet the required dilution targets within 200m of the outfall location. The key summaries are as follows:

- Near-field modelling (CORMIX):
  - For the TEWQ which was used to define the mixing zone extent in the EIS, the required dilution factor of 237 was achieved within 25 m of the diffuser for all conditions modelled. For currents greater than 0.34 m/s, the required dilution was achieved within 5m.
  - The 90th percentile TEWQ values were included as a sensitivity test. The required dilution factor of 2,496 was achieved in less than 50 m for currents above 0.34 m/s. For the lower currents modelled (0.05 and 0.15 m/s), the required dilution was not met within the near-field calculations of CORMIX. Therefore, the far-field model was used to assess the dilution extents for these scenarios.
- Far-field modelling (Delft3D):
  - For the assessed outfall model runs, the only dilution contours visible are between the 1,000 to 100,000 dilution factor range because dilution is achieved within a short distance of the outfall location which is consistent with the near-field results. These dilution contours are well above the required water quality dilution target of 237 for median TEWQ which indicated the water quality objectives were met within a short distance of the outfall. These higher dilution contours are only shown for reference on the greater plume trajectory. The high dilution factor results were expected after seeing the results of the near-field model predictions that showed a high dilution factor.
    - For the lower current conditions (less than 0.15 m/s) that showed higher distances to dilution in the CORMIX modelling for the 90th percentile TEWQ, the far-field model showed the 2,496 times dilution contour was reached in approximately 200m from the preferred outfall (Location 1).
  - By comparison, the existing conditions model runs had dilution factor contours visible that were less than 100 times dilution, which is below the required dilution requirements needed to meet the water quality objectives. The shore-based discharge remains within the bay and even extends into the nearby estuaries under some model runs.

The near-field and far-field dispersion modelling provided valuable insight into the potential treated wastewater plume behaviours. When applying these model results, it should be remembered that such models are not an exact science and they represent simplified versions of very complex processes. The limitations and uncertainties of modelling need to be reflected in how the results are used for design activities. However, the modelling showed that all the off-shore outfall locations provide a high level of dilution due in part to the relatively low rate of treated wastewater discharge into an approximately 30 m-deep ocean location. The required dilution rates are met quickly for the conditions modelled herein. For the preferred outfall location, the water quality objectives are met within 200m of the outfall location.

# 5.0 References


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MHL, 2015. *Proposed Merimbula Deep Outfall, Relative Hydrodynamic Merits of Different Outfall Locations (Report MHL2418).* Manly Hydraulics Laboratory, dated 18 November 2015.

# 6.0 Standard Limitations

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# Appendix A

## Dilution Required Calculations and Water Quality Assessment

# Appendices

## Appendix A: Dilution Required Calculations and Water Quality Assessment

## Merimbula: Dilution Required Calculation

Using Table 7 from the Merimbula Ocean Outfall - Preliminary Water Quality Assessment Memo (AECOM, 12 Mar 2019)

### Table 1: Using TEWQ values from Table 10 of the WQ memo (Discharge criteria 90th and 100th percentile limits, 90th percentile of historical monitoring data)

| | | | | Using Ambient Water Quality (AWQ) = Median | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Analyte** | **Units** | **Treated Effluent Water Quality (TEWQ)** | **MWQO trigger level** | **Ambient Water Quality (AWQ) - Median** | **Condition (from WQ memo)** | **Use CORMIX?** | **WQ criteria = MWQO** | **Dilution Required $[D=(C_e-C_b)/(C_o-C_b)]$** | **WQ criteria = AWQ** | **Dilution Required $[D=(C_e-C_b)/(C_o-C_b)]$** |
| | | $C_e$ | | $C_b$ | | | $C_o$ | | | |
| pH | pH units | 6.5-8.5 | 8.0-8.4 | 8.17 | | | | | | |
| pseudo pH (for calculation purposes, rel. to amb.) | pH units | 9.84 | 8.2 | 8.17 | Further assessment. | Yes | 8.2 | 55.7 | 8.17 | |
| Suspended solids | mg/L | 30 | 10 | 12 | Further assessment. | | | | 12 | |
| Electrical Conductivity | µS/cm | 874 | NA | 53,408 | NA - No assessment | | | | | |
| Dissolved Oxygen | mg/L | 12.9 | >5 | 7.6 | No assessment | | | | | |
| Total Nitrogen (TN) | mg/L | 15 | 0.12 | 0.12 | Further assessment. | | | | 0.12 | |
| Oxides of Nitrogen (NOx) | mg/L | 8.06 | 0.025 | 0.017 | Further assessment. | Yes | 0.025 | 1005.4 | 0.017 | |
| Ammonia | mg/L | 5 | 0.01 | 0.008 | Further assessment. | Yes | 0.01 | 2496.0 | 0.008 | Can't calculate |
| Total Phosphorus (TP) | mg/L | 13 | 0.025 | 0.007 | Further assessment. | Yes | 0.025 | 721.8 | 0.007 | dilution factor |
| Orthophosphate | mg/L | 11 | 0.01 | 0.004 | Further assessment. | Yes | 0.01 | 1832.7 | 0.004 | (infinite) |
| Chlorophyll a | µg/L | 68.8 | 1 | 1.2 | Further assessment. | | | | 1.2 | |
| Faecal coliforms | cfu/100 ml | 200 | 150 | 0.5 | Further assessment. | Yes | 150 | 1.3 | 0.5 | Where does plume |
| Enterococci | cfu/100 ml | 188 | 35 | 0.5 | Further assessment. | Yes | 35 | 5.4 | 0.5 | reach background? |
| Aluminium | µg/L | 74.6 | 10 | 4.5 | Further assessment. | Yes | 10 | 12.7 | 4.5 | |
| Antimony | µg/L | 1.5 | 270 | 0.25 | Further assessment. Section 3.4.2 => No assessment | | | | 0.25 | |
| Arsenic | µg/L | 3 | 2.3 | 1.8 | Further assessment. | Yes | 2.3 | 2.4 | 1.8 | |
| Barium | µg/L | 10.2 | 1000 | 5.9 | Further assessment. Section 3.4.2 => No assessment | | | | 5.9 | |
| Boron | µg/L | 80 | 1000 | 4295 | No assessment | | | | | |
| Cadmium | µg/L | 0.025 | 0.7 | 0.1 | No assessment | | | | | |
| Chromium | µg/L | 1 | 20 | 0.25 | Further assessment. Section 3.4.2 => No assessment | | | | 0.25 | |
| Cobalt | µg/L | 0.5 | 1 | 0.025 | Further assessment. | | | | 0.025 | |
| Copper | µg/L | 272 | 1.3 | 0.2 | Further assessment. | Yes | 1.3 | 247.1 | 0.2 | |
| Iron | µg/L | 706 | 300 | 5 | Further assessment. | Yes | 300 | 2.4 | 5 | |
| Lead | µg/L | 5.6 | 4.4 | 0.1 | Further assessment. | Yes | 4.4 | 1.3 | 0.1 | |
| Manganese | µg/L | 54.2 | 100 | 0.25 | Further assessment. | | | | 0.25 | |
| Mercury | µg/L | 0.05 | 0.1 | 0.05 | No assessment | | | | | |
| Nickel | µg/L | 3 | 7 | 0.25 | Further assessment. | | | | 0.25 | |
| Selenium | µg/L | 7.8 | 3 | 1 | Further assessment. | Yes | 3 | 3.4 | 1 | |
| Silver | µg/L | 0.5 | 1.4 | 0.35 | Further assessment. | | | | 0.35 | |
| Zinc | µg/L | 140.4 | 5 | 2.5 | Further assessment. | Yes | 5 | 55.2 | 2.5 | |

### Table 2: Using Discharge Criteria 50th percentile limit and median of historical monitoring data

| | | | | Using Ambient Water Quality (AWQ) = Median | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Analyte** | **Units** | **Treated Effluent Water Quality (TEWQ) [b]** | **MWQO trigger level** | **Ambient Water Quality (AWQ) - Median** | **Condition** | **Use CORMIX?** | **WQ criteria = MWQO** | **Dilution Required $[D=(C_e-C_b)/(C_o-C_b)]$** | **WQ criteria = AWQ** | **Dilution Required $[D=(C_e-C_b)/(C_o-C_b)]$** |
| | | $C_e$ | | $C_b$ | | | $C_o$ | | | |
| pH | pH units | 7.8 | 8.0-8.4 | 8.17 | | | | | | |
| pseudo pH (for calculation purposes, rel. to amb.) | pH units | 8.54 | 8.2 | 8.17 | Further assessment. | Yes | 8.2 | 12.3 | 8.17 | |
| Suspended solids | mg/L | 5 | 10 | 12 | No assessment | | | | | |
| Electrical Conductivity | µS/cm | 730 | NA | 53,408 | NA - No assessment | | | | | |
| Dissolved Oxygen | mg/L | 9.7 | >5 | 7.6 | No assessment | | | | | |
| Total Nitrogen (TN) | mg/L | 4.29 | 0.12 | 0.12 | Further assessment. | | | | 0.12 | Can't calculate |
| Oxides of Nitrogen (NOx) | mg/L | 1.915 | 0.025 | 0.017 | Further assessment. | Yes | 0.025 | 237.3 | 0.017 | dilution factor |
| Ammonia | mg/L | 0.335 | 0.01 | 0.008 | Further assessment. | Yes | 0.01 | 163.5 | 0.008 | (infinite) |
| Total Phosphorus (TP) | mg/L | 1 | 0.025 | 0.007 | Further assessment. | Yes | 0.025 | 55.2 | 0.007 | |
| Orthophosphate | mg/L | 0.8 | 0.01 | 0.004 | Further assessment. | Yes | 0.01 | 132.7 | 0.004 | Where does plume |
| Chlorophyll a | µg/L | 5.2 | 1 | 1.2 | Further assessment. | | | | 1.2 | reach background? |
| Faecal coliforms [c] | cfu/100 ml | 50 | 150 | 0.5 | Further assessment. | | | | 0.5 | |
| Enterococci | cfu/100 ml | 1 | 35 | 0.5 | Further assessment. | | | | 0.5 | |
| Aluminium | µg/L | 40 | 10 | 4.5 | Further assessment. | Yes | 10 | 6.5 | 4.5 | |
| Antimony | µg/L | 1.5 | 270 | 0.25 | Further assessment. | | | | 0.25 | |
| Arsenic | µg/L | 2 | 2.3 | 1.8 | Further assessment. | | | | 1.8 | |
| Barium | µg/L | 6 | 1000 | 5.9 | Further assessment. | | | | 5.9 | |
| Boron | µg/L | 60 | 1000 | 4295 | No assessment | | | | | |
| Cadmium | µg/L | 0.025 | 0.7 | 0.1 | No assessment | | | | | |
| Chromium | µg/L | 1 | 20 | 0.25 | Further assessment. | | | | 0.25 | |
| Cobalt | µg/L | 0.3 | 1 | 0.025 | Further assessment. | | | | 0.025 | |
| Copper | µg/L | 21 | 1.3 | 0.2 | Further assessment. | Yes | 1.3 | 18.9 | 0.2 | |
| Iron | µg/L | 150 | 300 | 5 | Further assessment. | | | | 5 | |
| Lead | µg/L | 0.2 | 4.4 | 0.1 | Further assessment. | | | | 0.1 | |
| Manganese | µg/L | 33.8 | 100 | 0.25 | Further assessment. | | | | 0.25 | |
| Mercury | µg/L | 0.05 | 0.1 | 0.05 | No assessment | | | | | |
| Nickel | µg/L | 2 | 7 | 0.25 | Further assessment. | | | | 0.25 | |
| Selenium | µg/L | 3 | 3 | 1 | Further assessment. | Yes | 3 | 1.0 | 1 | |
| Silver | µg/L | 0.5 | 1.4 | 0.35 | Further assessment. | | | | 0.35 | |
| Zinc | µg/L | 50 | 5 | 2.5 | Further assessment. | Yes | 5 | 19.0 | 2.5 | |

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# Memorandum

| To | Ross Bailey (NSW PWA) | Page | 1 of 39 |
|---|---|---|---|
| CC | Toby Browne (BVSC), Jim Collins (BVSC), Ed Couriel (MHL) | | |
| Subject | Merimbula Ocean Outfall - Preliminary Water Quality Assessment | | |
| From | Will Legg, Dr. Judith Herold | | |
| File/Ref No. | 60541653 | Date | 17 July 2019 |

## 1.0 Introduction

AECOM has been commissioned by the Bega Valley Shire Council (BVSC) to provide engineering services for the Merimbula Sewage Treatment Plant Upgrade and Deep Ocean Outfall Concept Design and Environmental Assessment (hereafter, the Project). This preliminary water quality assessment memorandum presents the water quality considerations relevant to effluent disposal as part of the Project.

Central to the water quality considerations are the definitions of the treated effluent water quality, the water quality objectives (trigger levels) and the ambient water quality to which the proposed outfall discharges. An understanding of the indicator concentrations for these three groups is essential for undertaking the modelling (near-field and far-field modelling). In addition, this memorandum presents the water quality framework for disposal and based on a preliminary water quality assessment, identifies those indicators which require further assessment.

The purposes of this memorandum are two-fold as follows:

1. To provide statistics on the water quality monitoring data. Specifically, to separate the water quality monitoring data (undertaken between October 2014 and April 2017 by Elgin Associates Pty Ltd) into different sites and offshore events and to observe any correlations.

   The water quality monitoring was conducted to allow determination of a representative ambient water quality for the Project. Water quality monitoring was conducted at a total of six locations (the sites) in Merimbula Bay and further south of the bay as illustrated in Figure 1.

2. To provide a foundation to allow consultation with NSW EPA, specifically to discuss the water quality considerations, the water quality framework and the outcomes of a preliminary water quality assessment.

The technical objectives of this memorandum are to:

- Document the process and findings of a water quality data review to determine the indicators and relevant ambient water quality conditions to be used during the hydrodynamic modelling;
- Define the marine water quality objectives and set out an approach for how the marine water quality objectives are to be considered as part of the Project which aligns with relevant guidance; and
- Document the process and findings of a preliminary water quality assessment undertaken to determine the indicators of interest which require further assessment (i.e. to be assessed as part of the hydrodynamic modelling).

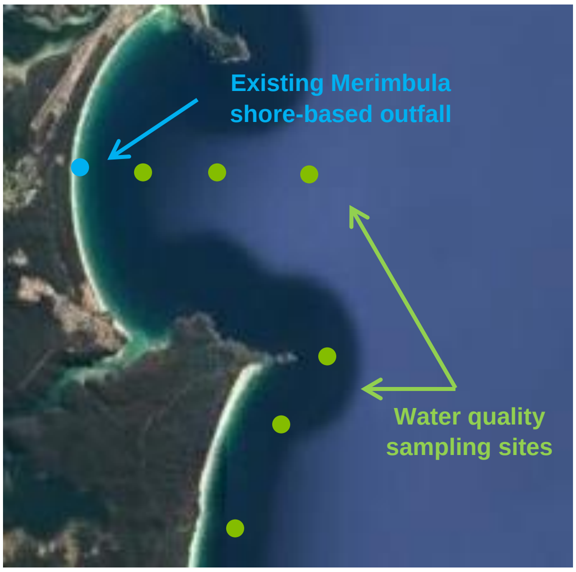


**Figure 1 Water quality monitoring sites in Merimbula Bay and surrounds**

The memorandum is set out as follows:

- Section 1.0 – provides the background, purpose and layout of this memorandum
- Section 2.0 – discusses the adopted marine water quality objectives and defines the indicators of potential interest and associated trigger levels
- Section 3.0 – defines the ambient water quality and treated effluent water quality for assessment purposes and presents the approach and findings of a preliminary water quality assessment to identify key indicators (pollutants) which require further assessment through modelling
- Section 4.0 – outlines the next steps to be undertaken in terms of water quality assessment including modelling and risk evaluation
- Section 5.0 – provides the conclusions of this assessment
- Section 6.0 – provides a list of references
- Section 7.0 – lists the attachments to this memorandum

## 2.0 Marine Water Quality Objectives

### 2.1 Background

In 1999, water quality objectives for NSW rivers and estuaries were introduced in 31 catchments. To complement these, the Government developed a set of Marine Water Quality Objectives (MWQOs) for NSW ocean waters. This was a key initiative under the Government's Coastal Protection Package announced in June 2001. The aim of the MWQOs is to simplify and streamline the consideration of water quality in coastal planning and management. This will ensure that the values and uses that the community places on ocean waters are recognised and protected, now and into the future (DEC, 2005).

The process for setting MWQOs was based on the national framework outlined in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC, 2000), part of the *National Water Quality Management Strategy* (ANZECC & ARMCANZ, 1994). The ANZECC (2000) guidelines advocate an ‘issues-based’ approach to assessing ambient water quality, rather than the application of rigid numerical criteria with no appreciation of context (DEC, 2006). They are not regulatory or mandatory and are just intended as a tool for strategic planning and development assessment processes influencing coastal water quality (DEC, 2005).

The MWQOs apply to those ocean waters that adjoin the NSW coast and extend three nautical miles from the shore (DEC, 2005). The MWQOs consist of three parts, the environmental values, their indicators and guideline criteria for assessing the risk of impact to water quality (trigger levels). The adopted MWQOs are based on the *Marine Water Quality Objectives for NSW Ocean Waters, South Coast* (DEC, 2005).

The key considerations for applying the MWQOs to the Project are:

- The MWQOs do not apply as an end-of pipe effluent discharge criteria.
- The MWQOs apply as a strategic objective for ambient waters at the outer extent of a nominated zone of influence (100 m radius, hereby referred to as the mixing zone) from the outlet.
- Achievement of the MWQOs at the outer extent of the mixing zone is affected by multiple diffuse sources (e.g. stormwater, agricultural runoff) as well as the proposed effluent discharge from the Merimbula ocean outfall.
- The MWQOs are to be used as a tool only by the project decision makers rather than as fixed criteria.

### 2.2 Environmental values

The environmental values and associated objectives that apply to the South Coast of NSW are listed in Table 1.

**Table 1 Environmental values and marine water quality objectives**

| Environmental Value | Marine Water Quality Objective |
|---|---|
| Aquatic ecosystem health | To maintain or improve the ecological condition of ocean waters |
| Primary contact recreation | To maintain or improve the ocean water quality so that it is suitable for activities such as swimming and other direct water contact sports. |
| Secondary contact recreation | To maintain or improve ocean water quality so it is suitable for activities such as boating and fishing where there is less bodily contact with the waters. |
| Visual amenity | To maintain or improve ocean water quality so that it looks clean and is free of surface films and debris. |
| Aquatic foods | To maintain or improve ocean water quality for the production of aquatic foods for human consumption (where derived from aquaculture or recreational, commercial or indigenous fishing). |

## 2.3 Indicators and trigger levels

The ANZECC (2000) guidelines provide trigger levels for a wide range of indicators which vary for each environmental value. Ambient water quality monitoring results can be compared with the trigger levels to assess whether the environmental values are at risk. DEC (2006) states that indicators should be selected based on the key issues in the waterway and main pollutants that might be generated by the activity under consideration, in this instance an effluent discharge.

A preliminary list of potential indicators for consideration and respective marine trigger levels for the various environmental values based on the ANZECC (2000) guidelines is provided in Table 2 with the source of the trigger levels listed in Table 3. The preliminary list was developed based on indicators monitored historically in effluent at the Merimbula sewage treatment plant and within coastal waters as part of the water quality monitoring as part of this Project.

**Table 2 Marine Water Quality Objective trigger levels**

| Indicator | Units | MWQO Trigger Levels | | | |
|---|---|---|---|---|---|
| | | Aquatic ecosystem health | Primary and secondary recreation and visual amenity [4] | Aquatic foods [5] | Adopted WQO trigger level |
| pH | pH units | 8.0 - 8.4 [1] | 5.0-9.0 | 6.0 - 9.0 | 8.0 - 8.4 |
| Suspended solids | mg/L | | | 10 | 10 |
| Turbidity | NTU | 0.5-10[1] | | | 0.5 [8] |
| Electrical Conductivity | µS/cm | | | | NA |
| Secchi depth | m | | >1.6 | | >1.6 |
| Dissolved Oxygen | Varies | 90-110% sat.[1] | | >5 mg/L | >5 mg/L |
| Total Nitrogen (TN) | mg/L | 0.12 [1] | | | 0.12 |
| Oxides of Nitrogen (NOx) | mg/L | 0.025 [1] | | | 0.025 |
| Nitrate | mg/L | 0.7 [6] | 10 | 100 | 0.7 |
| Ammonia | mg/L | 0.91 [2] | 0.01 | 0.1 | 0.01 |
| Ammonium | mg/L | 0.02 [1] | | | 0.02 |
| Total Phosphorus | mg/L | 0.025 [1] | | | 0.025 |
| Orthophosphate | mg/L | 0.01 [1, 7] | | | 0.01 |
| Chlorophyll a | µg/L | 1 [1] | | | 1 |
| Faecal coliforms | cfu/100 ml | | 150 | | 150 |
| Enterococci | cfu/100 ml | | 35 | | 35 |
| Aluminium | µg/L | | 200 | 10 | 10 |
| Antimony | µg/L | 270 [6] | | | 270 |
| Arsenic (III) | µg/L | 2.3 [6] | | | 2.3 |
| Arsenic (V) | µg/L | 4.5 [6] | | | 4.5 |
| Barium | µg/L | | 1000 | | 1000 |
| Boron | µg/L | | 1000 | | 1000 |
| Cadmium | µg/L | 0.7 [3] | 5 | <0.5-5 | 0.7 |
| Chromium (total) | µg/L | | 50 | 20 | 20 |
| Chromium (III) | µg/L | 27.4 [2] | | | 27.4 |
| Cobalt | µg/L | 1 [2] | | | 1 |
| Copper | µg/L | 1.3 [2] | 1000 | 5 | 1.3 |
| Iron | µg/L | | 300 | | 300 |
| Lead | µg/L | 4.4 [2] | 50 | <1-7 | 4.4 |
| Manganese | µg/L | | 100 | | 100 |
| Mercury (inorganic) | µg/L | 0.1 [3] | 1 | 1 | 0.1 |
| Nickel | µg/L | 7 [3] | 100 | 100 | 7 |

| Indicator | Units | MWQO Trigger Levels | | | |
|---|---|---|---|---|---|
| | | Aquatic ecosystem health | Primary and secondary recreation and visual amenity [4] | Aquatic foods [5] | Adopted WQO trigger level |
| Selenium | µg/L | 3 [6] | 10 | 10 | 3 |
| Silver | µg/L | 1.4 [2] | 50 | 3 | 1.4 |
| Zinc | µg/L | 15 [2] | 5000 | 5 | 5 |

[1] Protection of marine aquatic ecosystems in South East Australia (Table 3.3.2 and Table 3.3.3 of ANZECC, 2000)
[2] Marine water trigger values for 95% species protection (Table 3.4.1 of ANZECC, 2000)
[3] Marine water trigger values for 99% species protection (Table 3.4.1 of ANZECC, 2000)
[4] Water quality guidelines for recreational purposes (Table 5.2.2 and Table 5.2.3 of ANZECC, 2000)
[5] Physico-chemical stressor and toxicant guidelines for the protection of saltwater aquaculture species (Table 4.4.2 and Table 4.4.3 of ANZECC, 2000)
[6] Interim Working level (Volume 2, ANZECC, 2000)
[7] Filterable reactive phosphate (FRP) is generally considered to be chemically indicative of orthophosphate
[8] Low turbidity value normally found in offshore waters (Table 3.3.3 of ANZECC, 2000)

**Table 3 Source of trigger levels**

| Environmental value / type of indicator | Trigger level reference (unless otherwise stated) |
|---|---|
| Aquatic ecosystem health – physical and chemical stressors | Protection of marine aquatic ecosystems in South East Australia as defined in Table 3.3.2, ANZECC (2000) |
| Aquatic ecosystem health – toxicants | Default trigger values for slightly to moderately disturbed systems as defined by grey shaded values in Table 3.4.1, ANZECC (2000) |
| Primary, secondary recreation and visual amenity | Summary of water quality guidelines for recreation purposes, Table 5.2.2 and Table 5.2.3, ANZECC (2000) |
| Aquatic foods | Physico-chemical stressor and toxicant guidelines for the protection of saltwater aquaculture species, Table 4.4.2 and Table 4.4.3, ANZECC (2000) |

To understand which of these indicators warrants further assessment (i.e. modelling), a preliminary screening assessment was then undertaken to identify which indicators present a risk to the environmental values and warrant being modelled. This required ambient water quality and treated effluent water quality assumptions to be derived to inform the screening assessment and for use as required during future modelling. The method and findings of this process are described in section 3.0.

## 3.0 Water Quality Data Review and Preliminary Assessment

### 3.1 Risk based approach

A risk based approach is required to assess and manage water quality with respect to the MWQOs. The proposed approach is summarised in Figure 2.The approach generally aligns with the following guidelines:

- *Marine Water Quality Objectives for NSW Ocean Waters, South Coast (DEC, 2005)*
- *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000)*
- *Using the ANZECC Guidelines and Water Quality Objectives in NSW (DEC, 2006)*
- *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning (Dela-Cruz et al., 2017)*

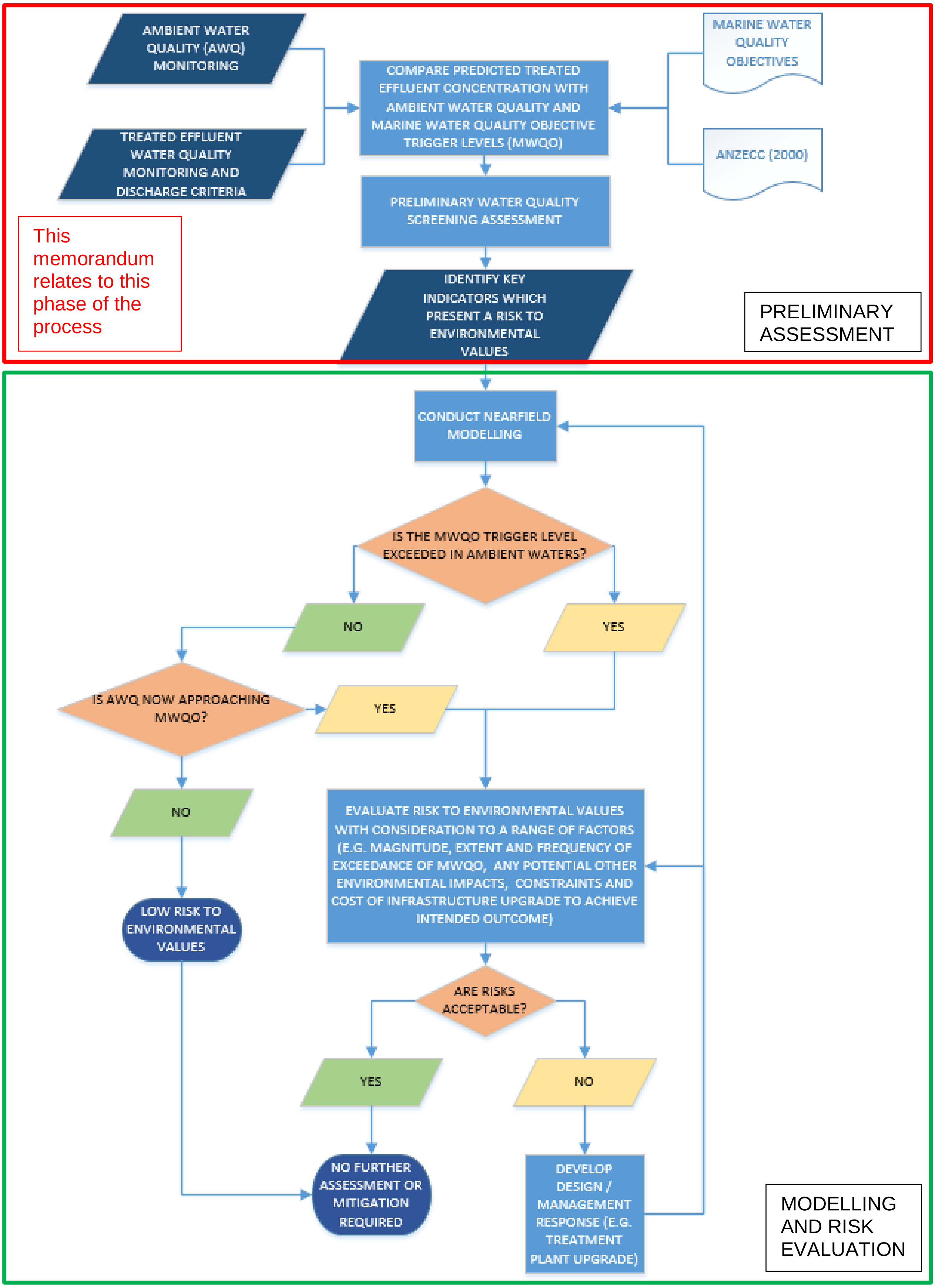


**Figure 2 Risk based process for assessing and managing water quality for the Project**

Section 3.4 outlines the first phase of the risk based approach (preliminary assessment). The process and assumptions adopted for ambient water quality and treated effluent water quality which informed this assessment is described in section 3.2 and 3.3 respectively.

### 3.2 Ambient Water Quality

Water quality monitoring has been conducted by Elgin Associates Pty Ltd as part of the Project off the coast of Merimbula between October 2014 and April 2017. Three sets of data were obtained by Elgin as follows:

1. Ambient water quality monitoring in Merimbula Bay (at sites MBWQ20, MBWQ30 and MBWQ40) during the period October 2014 to October 2015
2. Three post event (significant rain) estuary sampling (inside Merimbula and Pambula lakes) on 9 April 2015, 31 January 2016 and 5 to 6 June 2016. The purpose of this data set was to gain an understanding of what indicator concentrations may discharge to Merimbula Bay following major rainfall events. As this sampling data is not from the bay and specifically post event, this data set has not been used in the analysis as part of this memorandum.
3. Ambient water quality monitoring in Merimbula Bay (at sites MBWQ20 and MBWQ40 only) and at Reference sites further south (sites HAY20, HAYSTH20 and QUON20) during the period April 2016 to April 2017

The locations of the water quality monitoring sites are shown below in Figure 3.

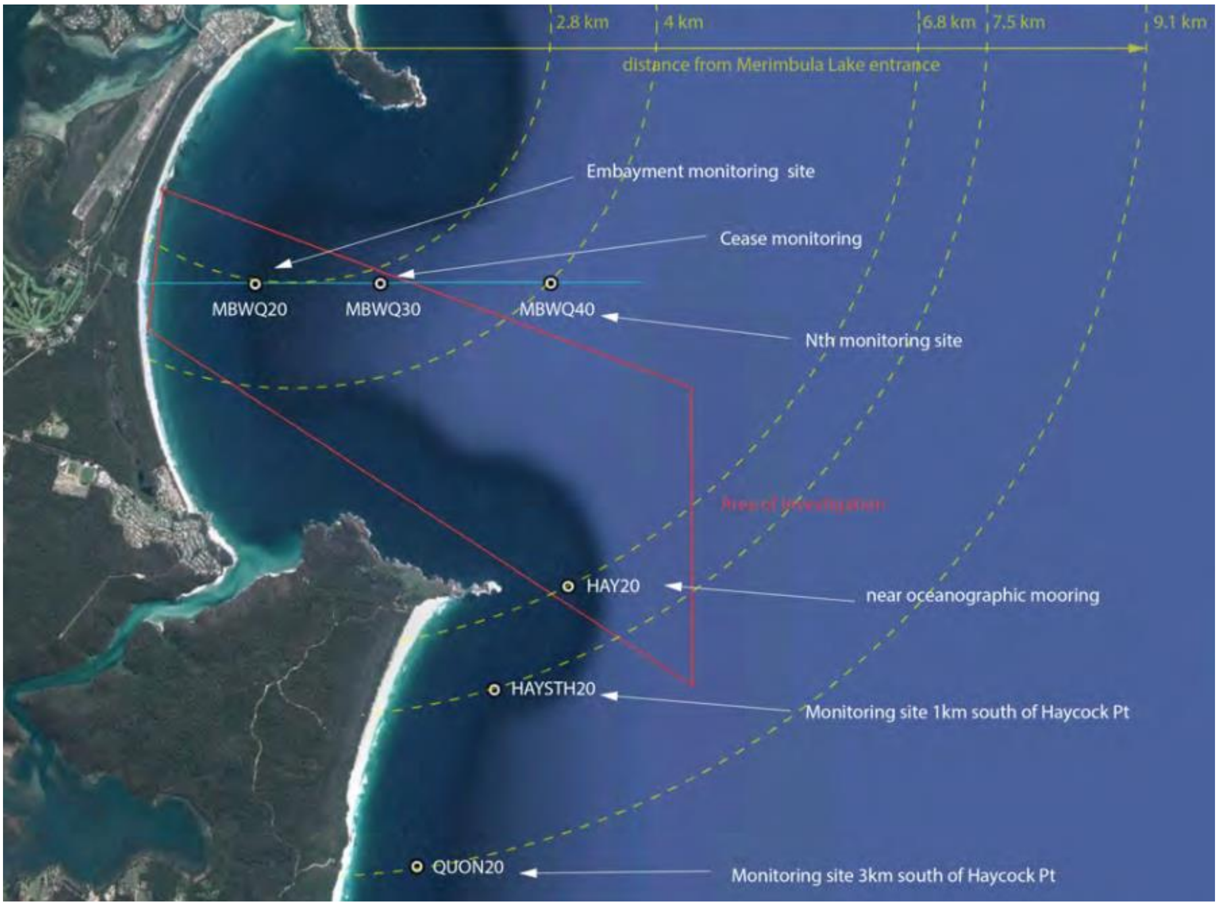


**Figure 3 Locations of the water quality monitoring sites (Source: Elgin, 2016)**

A statistical analysis of the water quality data was undertaken which compared monitoring results for various datasets including:

- All data
- Individual monitoring sites
- Sites within Merimbula Bay (sites MBWQ20, MBWQ30 and MBWQ40)
- Reference sites (i.e. monitoring conducted outside the assumed zone of influence of the current outfall)
- Coastal process events such as upwelling, weak current, south current and north current events
- Monitoring at different depths within the water column (surface, middle and bottom)

Graphs summarising the statistics for the various indicators are provided in Attachment 1. It is noted that where results were below the limit of reporting, a value equal to half the limit of reporting was adopted for statistical analysis.

The data and statistics were reviewed and an assumed ambient concentration was selected for each indicator. The adopted ambient water quality concentrations (AWQ) and the assumptions for their adoption are provided in Table 9 in Attachment 2.

Generally the median concentration of the bay sites was adopted as ambient water quality. For some indicators (including total nitrogen, chlorophyll a, suspended solids, nitrate, NOx, total phosphorus, orthophosphate, faecal coliforms and enterococci), concentrations were observed to be statistically higher during upwelling events. As these events are relatively infrequent, to be conservative, the median concentration was calculated without inclusion of upwelling event data. This enabled the median concentration to be more representative of typical ambient water quality conditions.

For comparison purposes only, Table 4 presents adopted ambient water quality values for those indicators in which upwelling events were excluded and with the inclusion of upwelling events. The indicators NOx, Nitrate and Orthophosphate show a very slight increase in median concentration where all data is included.

**Table 4 Comparison of ambient water quality medians excluding and including upwelling**

| **Indicator** | **Units** | **Adopted Ambient Water Quality (AWQ)**<br><br>**Median of Bay sites excluding upwelling event samples** | **Ambient Water Quality (AWQ) - *for comparison***<br><br>**Median of Bay sites (including upwelling event samples)** |
|---|---|---|---|
| Suspended solids | mg/L | 12 | 12 |
| Total Nitrogen (TN) | mg/L | 0.12 | 0.12 |
| Oxides of Nitrogen (NOx) | mg/L | 0.017 | 0.018 |
| Nitrate | mg/L | 0.017 | 0.018 |
| Total Phosphorus | mg/L | 0.007 | 0.007 |
| Orthophosphate | mg/L | 0.004 | 0.005 |
| Chlorophyll a | µg/L | 1.2 | 1.2 |
| Faecal coliforms | cfu/100 ml | 0.5 | 0.5 |
| Enterococci | cfu/100 ml | 0.5 | 0.5 |

It is not uncommon during water quality studies to find ambient water quality concentration for some indicators to be at or exceeding the water quality objective. In Advisian (2018), the baseline water quality assessment conducted for the Eden Breakwater Wharf Extension Project is presented. For this project, eight rounds of water quality monitoring was undertaken at six sites in Snug Cove and Twofold Bay (the reference sites) over a short four month period (September 2016 to January 2017) in order to describe ambient water quality conditions. It found that the ambient water quality median for both Chlorophyll a and total nitrogen exceeded the water quality objective trigger levels at the bay reference sites. Chlorophyll a ranged between 1-6 µg/L (ANZECC guideline of 1 µg/L) and total nitrogen generally exceeded the ANZECC guideline (<0.12 mg/L) with median values ranging between 0.13-0.145 mg/L. Possible contributors to the elevated concentrations may be a bloom of the toxic dinoflagellate Alexandrium fundyense that occurred during the monitoring program and a moderate upwelling detected from water temperature differential data from one round of monitoring. The post-event (wind and ocean swell event) sampling demonstrated disturbance on colour and clarity with all other parameters relatively unaffected by the event.

It is well-known that upwelling events that occur off the south-east coast of Australia are a natural oceanic source of nutrients and although only episodic, they have the ability to overwhelm anthropogenic nutrient loads off Sydney (Pritchard & Lee, 2001). In Dela-Cruz et al. (2002), the temporal abundance patterns of the red tide Noctiluca scintillans along the southeast coast of Australia were investigated. It is one of the most common red tide forming species along the south-east coast. Samples were collected approximately weekly from two coastal stations off Port Hacking between March 1997 to March 1998. During the monitoring period, three main uplifting events were observed during the Spring and Summer months. Results suggest that naturally occurring nutrient enrichment processes promote the species population growth, with peaks observed at the same time or subsequent to diatom blooms caused by episodic uplifting of nutrient-rich slope water. The single most important variable related to the species abundance was the Ammonia content of surface waters. It is important to acknowledge this backdrop of natural upwelling events and associated elevations in nutrient concentrations in water quality assessment studies.

To illustrate elevated indicator concentrations during upwelling events, Table 5 presents AWQ concentrations during potential upwelling events as recorded by Elgin Associates Pty Ltd during water quality monitoring between October 2014 and April 2017. From observation of IMOS (Integrated Marine Observing System) regional current and sea surface temperature (SST) charts, one monitoring event was classified as an upwelling event (21 March 2017). If an upwelling event is defined by elevated Nitrate levels in conjunction with a temperature differential between surface and bottom waters of approximately 3-4 °C or greater, a further two monitoring events could potentially be classified as an upwelling (15 December 2014 and 19 February 2015) (email correspondence with Elgin, 24 Jan 2019). In Table 5, the AWQ concentrations have been determined from averages of the data for both the single upwelling event and also for the three upwelling events, for both all sites and bay only sites. Due to the limited data, average concentration is more appropriate to report. Metal sampling data was only reported from the middle of the water column for the 21 March 2017 upwelling event, hence the non-varying values in Table 5. As can be seen (highlighted orange), numerous indicators exceed the MWQOs during the defined upwelling events.

**Table 5 Ambient water quality concentrations during recorded upwelling events**

| Indicator | Units | Adopted MWQO | Adopted AWQ | AWQ (all sites, 1 upwelling event) | AWQ (all sites, 3 upwelling events) | AWQ (bay sites, 1 upwelling event) | AWQ (bay sites, 3 upwelling events) |
|---|---|---|---|---|---|---|---|
| pH | pH units | 8.0 - 8.4 | 8.17 | 8.06 | 8.12 | 8.04 | 8.13 |
| Suspended solids | mg/L | 10 | 12 | 20 | 14 | 15 | 12 |
| Turbidity | NTU | 0.5 | 0.3 | 0.3 | 0.4 | 0.1 | 0.5 |
| Electrical Conductivity | µS/cm | NA | 53408 | 53665 | 53289 | 53715 | 53114 |
| Secchi depth | m | >1.6 | 8.9 | 5.9 | 6.8 | 5.6 | 7.0 |

| Indicator | Units | Adopted MWQO | Adopted AWQ | AWQ (all sites, 1 upwelling event) | AWQ (all sites, 3 upwelling events) | AWQ (bay sites, 1 upwelling event) | AWQ (bay sites, 3 upwelling events) |
|---|---|---|---|---|---|---|---|
| Dissolved Oxygen | mg/L | >5 | 7.6 | 7.6 | 7.4 | 7.8 | 7.4 |
| Total Nitrogen (TN) | mg/L | 0.12 | 0.12 | 0.15 | 0.14 | 0.17 | 0.13 |
| Oxides of Nitrogen (NOx) | mg/L | 0.025 | 0.017 | 0.052 | 0.045 | 0.076 | 0.048 |
| Nitrate | mg/L | 0.7 | 0.017 | 0.052 | 0.045 | 0.076 | 0.047 |
| Ammonia | mg/L | 0.01 | 0.008 | 0.014 | 0.008 | 0.015 | 0.007 |
| Ammonium | mg/L | 0.02 | 0.008 | 0.013 | 0.008 | 0.014 | 0.007 |
| Total Phosphorus | mg/L | 0.025 | 0.007 | 0.011 | 0.010 | 0.012 | 0.010 |
| Orthophosphate | mg/L | 0.01 | 0.004 | 0.009 | 0.008 | 0.012 | 0.008 |
| Chlorophyll a | µg/L | 1 | 1.2 | 5.4 | 2.9 | 3.8 | 1.7 |
| Faecal coliforms | cfu/100 ml | 150 | 0.5 | 117.5 | 42.3 | 254.8 | 46.7 |
| Enterococci | cfu/100 ml | 35 | 0.5 | 23.7 | 9.1 | 53.0 | 10.5 |
| Aluminium | µg/L | 10 | 4.5 | 48.2 | 48.2 | 13.5 | 13.5 |
| Antimony | µg/L | 270 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Arsenic (III) | µg/L | 2.3 | 1.8 | 2.0 | 2.0 | 2.1 | 2.1 |
| Arsenic (V) | µg/L | 4.5 | NA | NA | NA | NA | NA |
| Barium | µg/L | 1000 | 5.9 | No data | No data | No data | No data |
| Boron | µg/L | 1000 | 4295 | 3894 | 3894 | 4005 | 4005 |
| Cadmium | µg/L | 0.7 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Chromium (total) | µg/L | 20 | 0.25 | 0.25 | 0.25 | 0.25 | 0.25 |
| Chromium (III) | µg/L | 27.4 | NA | NA | NA | NA | NA |
| Cobalt | µg/L | 1 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 |
| Copper | µg/L | 1.3 | 0.2 | 0.5 | 0.5 | 0.1 | 0.1 |
| Iron | µg/L | 300 | 5 | 13 | 13 | 10 | 10 |
| Lead | µg/L | 4.4 | 0.1 | 0.2 | 0.2 | 0.1 | 0.1 |
| Manganese | µg/L | 100 | 0.25 | 0.32 | 0.32 | 0.25 | 0.25 |
| Mercury (inorganic) | µg/L | 0.1 | 0.05 | 0.02 | 0.02 | 0.02 | 0.02 |
| Nickel | µg/L | 7 | 0.25 | 0.34 | 0.34 | 0.25 | 0.25 |
| Selenium | µg/L | 3 | 1 | 1 | 1 | 1 | 1 |
| Silver | µg/L | 1.4 | 0.35 | 0.08 | 0.08 | 0.13 | 0.13 |
| Zinc | µg/L | 5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |

Notes:
1. Orange highlighted cells indicate exceedance of the MWQOs
2. For AWQ data, indicator recorded as Arsenic and Chromium.

### 3.3 Treated Effluent Water Quality

Treated effluent water quality is monitored at the Merimbula sewage treatment plant outfall. Monitoring data for EPA monitoring point 4 and treated effluent discharge criteria stated within the design criteria for the project (AECOM, 2018), were used to establish treated effluent concentrations for the various indicators. For the purposes of this assessment, the assumed effluent quality was established based on the following:

- Where an effluent discharge criteria has been set for the indicator, the maximum criteria (whether that be the 100$^{th}$ percentile or the 90$^{th}$ percentile criteria depending on indicator) was adopted
- Where no discharge criteria were set, the 90$^{th}$ percentile historical effluent quality was adopted for the purposes of this preliminary screening assessment. Further assessment through modelling will also consider median water quality concentrations.

The adopted treated effluent water quality concentration (TEWQ) and assumptions are listed in Table 10 in Attachment 3.

### 3.4 Preliminary Water Quality Assessment

#### 3.4.1 Preliminary screening

A preliminary water quality impact assessment was undertaken to select indicators which could potentially present a risk to the environmental values and warrant a more detailed quantitative assessment. There are six different cases where the relative concentrations of TEWQ, AWQ and MWQO trigger levels vary in each case as shown in Figure 4.

The adopted treated effluent water quality concentration, ambient water quality concentration and MWQO trigger level were compared for each indicator and the risk to the environment was assessed based on the conditions set out in Table 6. The results of the assessment are provided in Table 7.

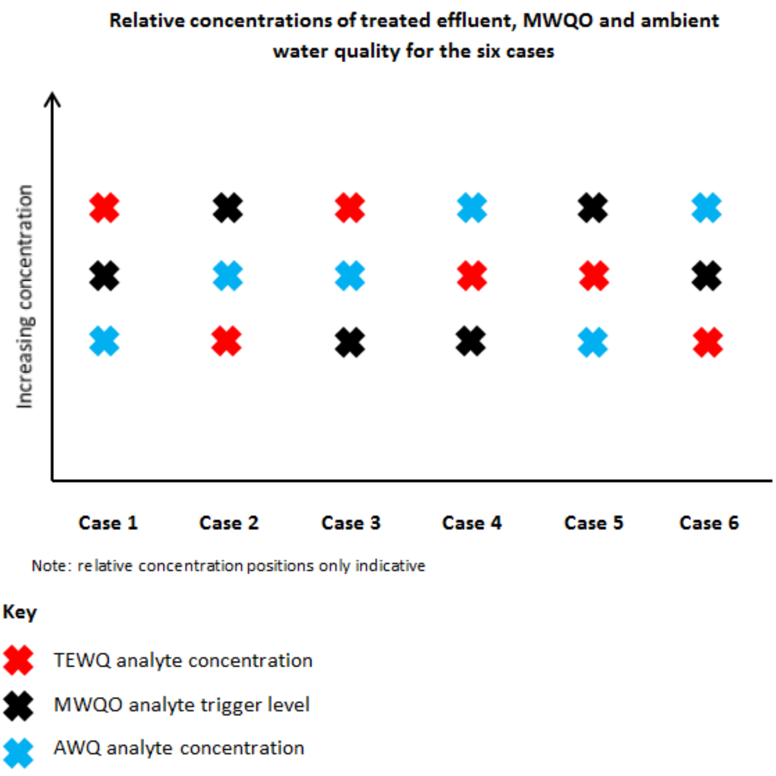


**Figure 4 Varying cases of relative concentrations**

**Table 6 Criteria for preliminary water quality screening assessment**

| Case | Condition | Preliminary Assessment | Conclusion |
|---|---|---|---|
| 1 | TEWQ > MWQO<br>TEWQ > AWQ<br>AWQ < MWQO | Discharge could potentially increase AWQ to above MWQO. | Presents a potential risk, further assessment of indicator required. |
| 2 | TEWQ < MWQO<br>TEWQ < AWQ<br>AWQ < MWQO | As the TEWQ is less than AWQ, the discharge could improve the AWQ. As AWQ already below the MWQO, no risk of MWQO being exceeded. The increased load within the receiving waters is unlikely to present a risk due to mixing. | Low risk to environment with potential for some improvement. No further assessment of indicator required. |
| 3 | TEWQ > MWQO<br>TEWQ > AWQ<br>AWQ > MWQO | AWQ already exceeds MWQO. Discharge could potentially increase AWQ further above the MWQO. | Presents a potential risk, further assessment of indicator required. |
| 4 | TEWQ > MWQO<br>TEWQ < AWQ | As the TEWQ is less than AWQ, the AWQ could potentially be improved. The increased load within the receiving waters is not considered to present a risk due to adequate mixing within ocean waters. | Low risk to environment with potential for some improvement, no further assessment of indicator required. |
| 5 | TEWQ < MWQO<br>TEWQ > AWQ | Potential to increase AWQ but due to dilution, the AWQ will continue to remain below the MWQO. The increased load within the receiving waters is unlikely to present a risk due to adequate mixing within ocean waters. | Compare magnitude of TEWQ with MWQO trigger level to assess risk of raising ambient water to close to MWQO (refer section 3.4.2). Where potential for AWQ to approach MWQO, further assessment of indicator required. |
| 6 | TEWQ < MWQO<br>TEWQ < AWQ<br>AWQ > MWQO | As the TEWQ is less than AWQ, the discharge could improve the AWQ. The increased load within the receiving waters is unlikely to present a risk due to mixing however given the MWQO may still be exceeded, this should be considered further. | Low risk to environment with potential for some improvement. No further assessment of indicator required. |

TEWQ – Adopted Treated Effluent Water Quality
AWQ – Adopted Ambient Water Quality
MWQO – Adopted Marine Water Quality Objective Trigger Level

Only indicators with a MWQO trigger level, ambient water quality monitoring data and treated effluent monitoring data were assessed. On this basis, the following indicators were excluded:

- Turbidity, nitrate, ammonium and secchi depth as no treated effluent water quality concentration was available.
- BOD, COD, Total Oil and Grease, E-Coli, total calcium, total potassium and total magnesium as no ambient water quality samples were collected and no marine water trigger level was available.
- Beryllium as no marine water trigger level is available.

The following indicators exceeded the MWQO trigger level in the TEWQ:

- Physical and chemical stressors – pH, suspended solids, total nitrogen, oxides of nitrogen, ammonia, total phosphorus, orthophosphate, chlorophyll a
- Microbiological - Faecal coliforms and enterococci
- Metals – aluminium, arsenic, copper, iron, lead, selenium and zinc

The following indicators exceeded the MWQO trigger level in the AWQ:

- Physical and chemical stressors – suspended solids, chlorophyll A and boron, noting the AWQ for total nitrogen was equal to the MWQO

**Table 7 Preliminary Water Quality Assessment**

| Indicator | Units | Current Treated Effluent Water Quality (TEWQ) | MWQO trigger level | Ambient Water Quality (AWQ) | Condition |
|---|---|---|---|---|---|
| pH | pH units | **6.5-8.5** | 8.0 - 8.4[1] | 8.17 | TEWQ range outside MWQO range and different to AWQ<br>AWQ within MWQO range |
| Suspended solids | mg/L | **30** | 10[4] | **12** | TEWQ > WQO,<br>TEWQ > AWQ<br>AWQ > WQO |
| Electrical Conductivity | µS/cm | 874 | NA | 53,408 | Not applicable - EC to be modelled for information purposes only |
| Dissolved Oxygen | mg/L | 12.9 | >5[4] | 7.6 | TEWQ < MWQO,<br>TEWQ < AWQ<br>AWQ < MWQO<br>(noting low risk trigger level is high value not low value) |
| Total Nitrogen (TN) | mg/L | **15** | 0.12[1] | 0.12 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ = MWQO |
| Oxides of Nitrogen (NOx) | mg/L | **8.06** | 0.025[1] | 0.017 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Ammonia | mg/L | **5** | 0.01[5] | 0.008 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Total Phosphorus | mg/L | **13** | 0.025[1] | 0.007 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Orthophosphate | mg/L | **11** | 0.01[1] | 0.004 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Chlorophyll a | µg/L | **68.8** | 1[1] | **1.2** | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ > MWQO |
| Faecal coliforms | cfu/100 ml | **200** | 150[5] | 0.5 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ<MWQO |
| Enterococci | cfu/100 ml | **188** | 35[5] | 0.5 | TEWQ > MWQO,<br>TEWQ > AWQ |

| Indicator | Units | Current Treated Effluent Water Quality (TEWQ) | MWQO trigger level | Ambient Water Quality (AWQ) | Condition |
|---|---|---|---|---|---|
| | | | | | AWQ < MWQO |
| Aluminium | µg/L | **74.6** | 10[4] | 4.5 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Antimony | µg/L | 1.5 | 270[6] | 0.25 | TEWQ < MWQO,<br>TEWQ > AWQ |
| Arsenic | µg/L | **3** | 2.3[6,7] | 1.8 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Barium | µg/L | 10.2 | 1000[5] | 5.9 | TEWQ < MWQO,<br>TEWQ > AWQ |
| Boron | µg/L | 80 | 1000[5] | **4295** | TEWQ < MWQO,<br>TEWQ < AWQ<br>AWQ > MWQO |
| Cadmium | µg/L | 0.025 | 0.7[3] | 0.1 | TEWQ < MWQO,<br>TEWQ < AWQ<br>AWQ < MWQO |
| Chromium | µg/L | 1 | 20[4] | 0.25 | TEWQ < MWQO,<br>TEWQ > AWQ |
| Cobalt | µg/L | 0.5 | 1[2] | 0.025 | TEWQ < MWQO,<br>TEWQ > AWQ |
| Copper | µg/L | **272** | 1.3[2] | 0.20 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Iron | µg/L | **706** | 300[5] | 5 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Lead | µg/L | **5.6** | 4.4[2] | 0.1 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Manganese | µg/L | 54.2 | 100[5] | 0.25 | TEWQ < MWQO,<br>TEWQ > AWQ |
| Mercury | µg/L | 0.05 | 0.1[3] | 0.05 | TEWQ < MWQO,<br>TEWQ = AWQ<br>AWQ < MWQO |
| Nickel | µg/L | 3 | 7[3] | 0.25 | TEWQ < MWQO,<br>TEWQ > AWQ |
| Selenium | µg/L | **7.8** | 3[6] | 1 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |
| Silver | µg/L | 0.5 | 1.4[2] | 0.35 | TEWQ < MWQO,<br>TEWQ > AWQ |
| Zinc | µg/L | **140.4** | 5[4] | 2.50 | TEWQ > MWQO,<br>TEWQ > AWQ<br>AWQ < MWQO |

**Bold** values indicate exceedance of MWQO trigger level

[1] Protection of marine aquatic ecosystems in South East Australia (Table 3.3.2 and Table 3.3.3 of ANZECC, 2000)

[2] Marine water trigger values for 95% species protection (Table 3.4.1 of ANZECC, 2000)

[3] Marine water trigger values for 99% species protection (Table 3.4.1 of ANZECC, 2000)

[4] Physico-chemical stressor and toxicant guidelines for the protection of saltwater aquaculture species (Table 4.4.2 and Table 4.4.3 of ANZECC, 2000)

[5] Water quality guidelines for recreational purposes (Table 5.2.2 and Table 5.2.3 of ANZECC, 2000)

[6] Interim Working level (Volume 2, ANZECC, 2000)

[7] Based on Arsenic (III)

### 3.4.2 Assessment of indicators with potential to approach WQO trigger level

Dela-Cruz (2017) states that allowing waterways to be affected up to the numerical criterion (i.e. MWQO trigger level) should be avoided to reserve the maximum opportunity for other present and future uses of the waterway and allow adoption of a precautionary approach where there is uncertainty about the environmental outcomes of the land-use activity.

With consideration to the mixing and dilution effects of release to the ocean, the treated effluent loading is unlikely to raise ambient water quality to a concentration greater than the TEWQ. Therefore by comparing the magnitude of the TEWQ with the MWQO it is possible to assess whether there is a risk of effluent raising the AWQ to a concentration approaching the MWQO. An assessment of the indicators where TEWQ < MWQO but > AWQ and recommendation where further assessment would be required is provided below:

- Antimony - MWQO is over 100 times greater than the TEWQ, therefore discharge presents a low risk and no further assessment required
- Barium – MWQO is over approximately 100 times greater than the TEWQ, therefore discharge presents a low risk and no further assessment required
- Chromium – MWQO is 20 times greater than the TEWQ, therefore discharge presents a low risk and no further assessment required
- Cobalt - MWQO is only slightly (2 times) higher than the TEWQ, therefore there is potential risk of discharge causing the AWQ to approach the WQO, further assessment required
- Manganese – MWQO is slightly (less than 2 times) higher than the TEWQ, therefore there is potential risk of discharge causing the AWQ to approach the MWQO, further assessment required
- Nickel - MWQO is slightly (less than 3 times) higher than the TEWQ, therefore there is potential risk of discharge causing the AWQ to approach the MWQO, further assessment required
- Silver - MWQO is slightly (less than 3 times) higher than the TEWQ, therefore there is potential risk of discharge causing the AWQ to approach the MWQO, further assessment required.

### 3.5 Indicators which present a potential risk to environmental values

Based on the assessment above, the following indicators are considered to warrant a more detailed quantitative assessment through modelling:

- **Physical and chemical stressors** – pH, suspended solids, total nitrogen, oxides of nitrogen, ammonia, total phosphorus, orthophosphate, chlorophyll-a, faecal coliforms and enterococci
- **Metals** - aluminium, arsenic, cobalt, copper, iron, lead, manganese, nickel, selenium, silver and zinc

The purpose of this assessment is not to identify the reasons contributing to potential risk nor propose mitigation measures. These will be addressed during the concept design and environmental assessment process.

## 4.0 Quantitative assessment and risk evaluation

Further assessment (modelling) of the indicators identified in section 3.5 is required to better define the potential change in ambient water quality conditions within the receiving waters.

As presented in Figure 2, where modelling indicates that ambient water quality is neither exceeding or approaching (refer section 3.4.2) the MWQO, the proposed discharge is considered to present a low risk to the environmental values and as such, no risk evaluation is considered to be required. Where the MWQO is exceeded or being approached, risk evaluation will be undertaken.

The adopted TEWQ should be used for modelling purposes in the first instance, but where modelling indicates ambient waters will exceed the MWQO, expected median TEWQ should also be considered for the purpose of informing the risk evaluation phase.

The risk evaluation process may include (but is not limited to) consideration of:

- Magnitude, extent and frequency of exceedance of the MWQO and change in ambient water quality.
- Likely environmental outcomes of the change in water quality conditions.
- Constraints and practicalities of implementing a design/management response to achieve an improved water quality outcome (e.g. improved treatment infrastructure, altering the proposed discharge criteria). This may include some form of cost-effectiveness analysis and/or cost vs benefit analysis. Potential improvements in effluent concentrations should be modelled as required.

Where risks are deemed to be unacceptable, a design (e.g potentially increasing treatment) or management response will need to be developed and where required, further evaluation (and modelling as required) undertaken until all risks are deemed to be acceptable or as otherwise agreed with the relevant authorities.

## 5.0 Conclusions

This memorandum has identified:

- Ambient water quality concentrations for the Merimbula ocean outfall receiving waters for assessment and modelling purposes.
- Treated effluent water quality concentrations for the purpose of this preliminary assessment. Other concentrations (i.e. median concentrations) may be used for modelling and risk evaluation purposes as required.
- Marine water quality objective trigger levels to support the environmental values identified by the Marine Water Quality Objectives.
- Indicators (i.e. pollutants) within the treated effluent which present a potential risk to the environmental values of the receiving waters and require further assessment and risk evaluation.

The assumed ambient water quality, marine water quality objectives and treated effluent concentrations will form the basis of future modelling and risk evaluation. It is therefore recommended that this memorandum and its assumptions and approach are reviewed and approved by relevant stakeholders and authorities prior to modelling and risk evaluation phases being undertaken.

## 6.0 References

Advisian, 2018, Water Quality CEMP Sub-plan (Eden Breakwater Wharf Extension - Stage 2)

AECOM, 2018, Merimbula STP upgrade and ocean outfall concept design and environmental assessment, prepared for Bega Valley Shire Council

Dela-Cruz J, Pik A & Wearne P, 2017, Risk-based framework for considering waterway health outcomes in strategic land-use planning decisions, Office of Environment and Heritage and Environment Protection Authority, Sydney

Dela-Cruz et al, 2002, Temporal abundance patterns of the red tide dinoflagellate Noctiluca scintillans along the southeast coast of Australia, Marine Ecology Progress Series, Vol. 236: 75-88

Department of Environment and Conservation NSW (DEC), 2005, Marine Water Quality Objectives for NSW Ocean Waters, South Coast

Department of Environment and Conservation NSW (DEC), 2006, Using the ANZECC Guidelines and Water Quality Objectives in NSW

Elgin, 2016, Water quality and marine ecology - Summary of knowledge and understanding PowerPoint

Pritchard T, Lee R, 2001, How do ocean outfalls affect nutrient patterns in coastal waters of New South Wales, Australia?, Aust J Coast Res 34:87-95

## 7.0 Attachments

Attachment 1 – Statistical Analysis of Water Quality Monitoring Results

Attachment 2 – Ambient Water Quality Review

Attachment 3 – Treated Effluent Water Quality Assumptions

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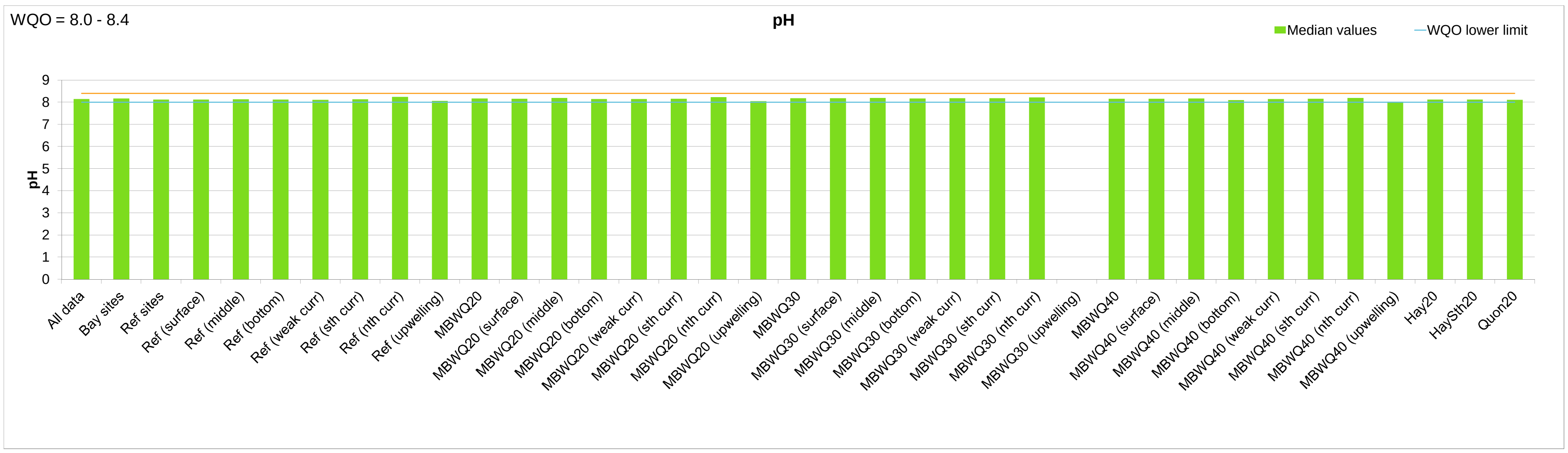
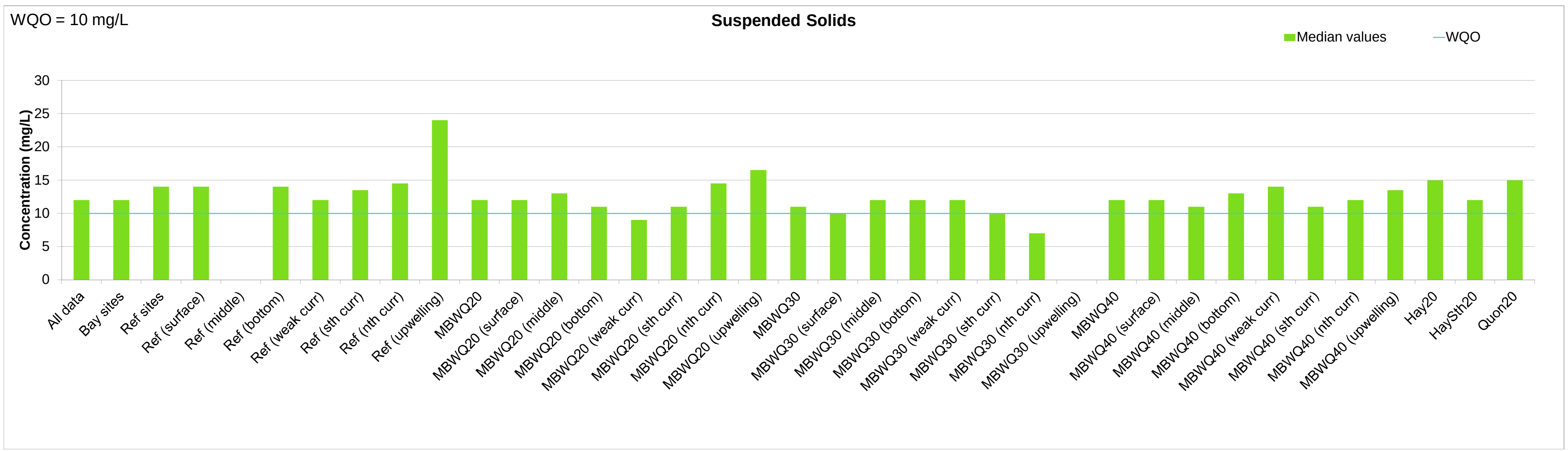
# Attachment 1 – Statistical Analysis of Water Quality Monitoring Results

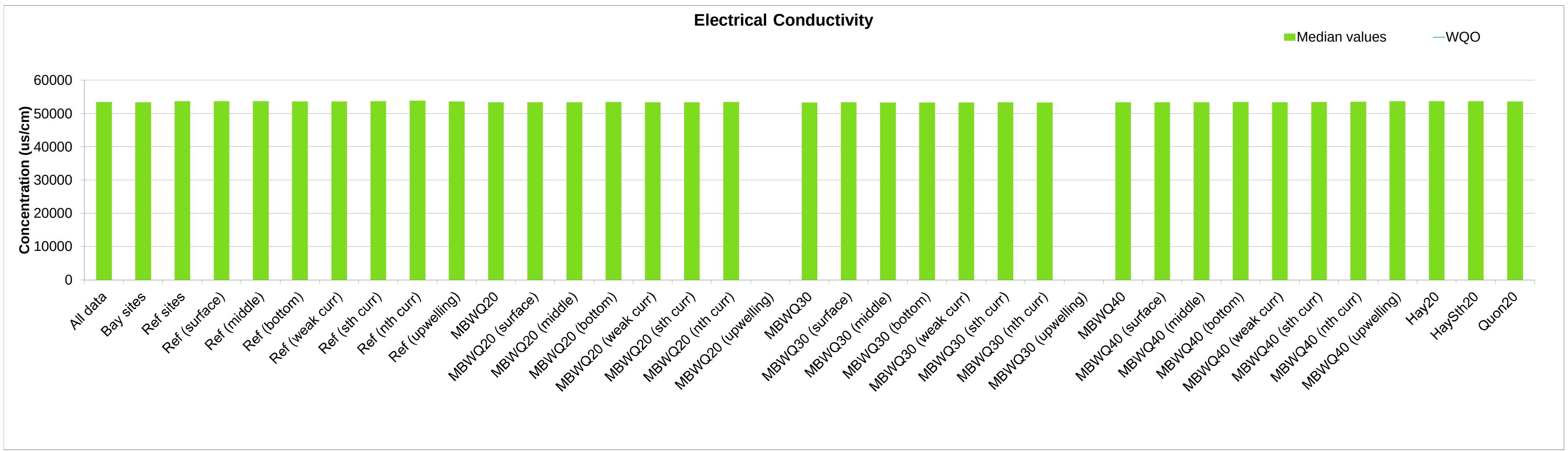
**Table 8 Explanation of categories for statistical analysis**

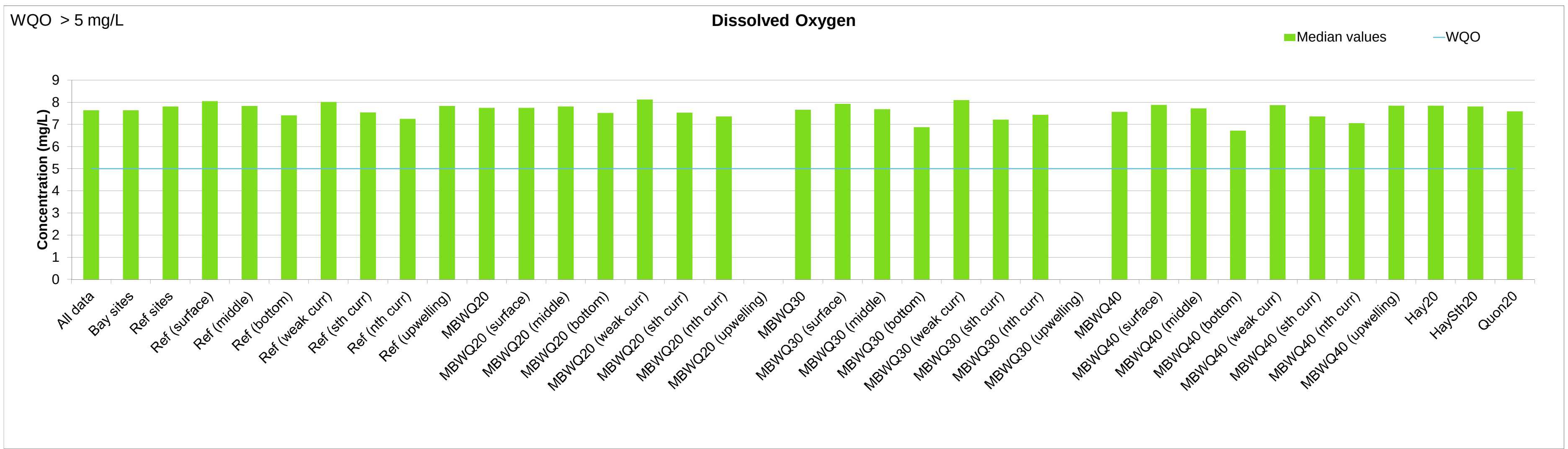
| No. | Category | Site | Subset of data used |
|---|---|---|---|
| 1 | All data | All sites | All data |
| 2 | Bay sites | Bay sites only | All data |
| 3 | Ref sites | Reference sites only (Hay20, HaySth20, Quon20) | All data |
| 4 | Ref (surface) | Reference sites only (Hay20, HaySth20, Quon20) | Top of water column sample data |
| 5 | Ref (middle) | Reference sites only (Hay20, HaySth20, Quon20) | Mid-depth of water column sample data |
| 6 | Ref (bottom) | Reference sites only (Hay20, HaySth20, Quon20) | Bottom of water column sample data |
| 7 | Ref (weak curr) | Reference sites only (Hay20, HaySth20, Quon20) | Weak N or S offshore current, not apparent |
| 8 | Ref (sth curr) | Reference sites only (Hay20, HaySth20, Quon20) | Strong South flowing offshore current |
| 9 | Ref (nth curr) | Reference sites only (Hay20, HaySth20, Quon20) | Strong North flowing offshore current |
| 10 | Ref (upwelling) | Reference sites only (Hay20, HaySth20, Quon20) | Upwelling event occurring |
| 11 | MBWQ20 | Merimbula bay 20 m depth | All data |
| 12 | MBWQ20 (surface) | Merimbula bay 20 m depth | Top of water column sample data |
| 13 | MBWQ20 (middle) | Merimbula bay 20 m depth | Mid-depth of water column sample data |
| 14 | MBWQ20 (bottom) | Merimbula bay 20 m depth | Bottom of water column sample data |
| 15 | MBWQ20 (weak curr) | Merimbula bay 20 m depth | Weak N or S offshore current, not apparent |
| 16 | MBWQ20 (sth curr) | Merimbula bay 20 m depth | Strong South flowing offshore current |
| 17 | MBWQ20 (nth curr) | Merimbula bay 20 m depth | Strong North flowing offshore current |
| 18 | MBWQ20 (upwelling) | Merimbula bay 20 m depth | Upwelling event occurring |
| 19 | MBWQ30 | Merimbula bay 30 m depth | All data |
| 20 | MBWQ30 (surface) | Merimbula bay 30 m depth | Top of water column sample data |
| 21 | MBWQ30 (middle) | Merimbula bay 30 m depth | Mid-depth of water column sample data |
| 22 | MBWQ30 (bottom) | Merimbula bay 30 m depth | Bottom of water column sample data |
| 23 | MBWQ30 (weak curr) | Merimbula bay 30 m depth | Weak N or S offshore current, not apparent |
| 24 | MBWQ30 (sth curr) | Merimbula bay 30 m depth | Strong South flowing offshore current |
| 25 | MBWQ30 (nth curr) | Merimbula bay 30 m depth | Strong North flowing offshore current |
| 26 | MBWQ30 (upwelling) | Merimbula bay 30 m depth | Upwelling event occurring |
| 27 | MBWQ40 | Merimbula bay 40 m depth | All data |

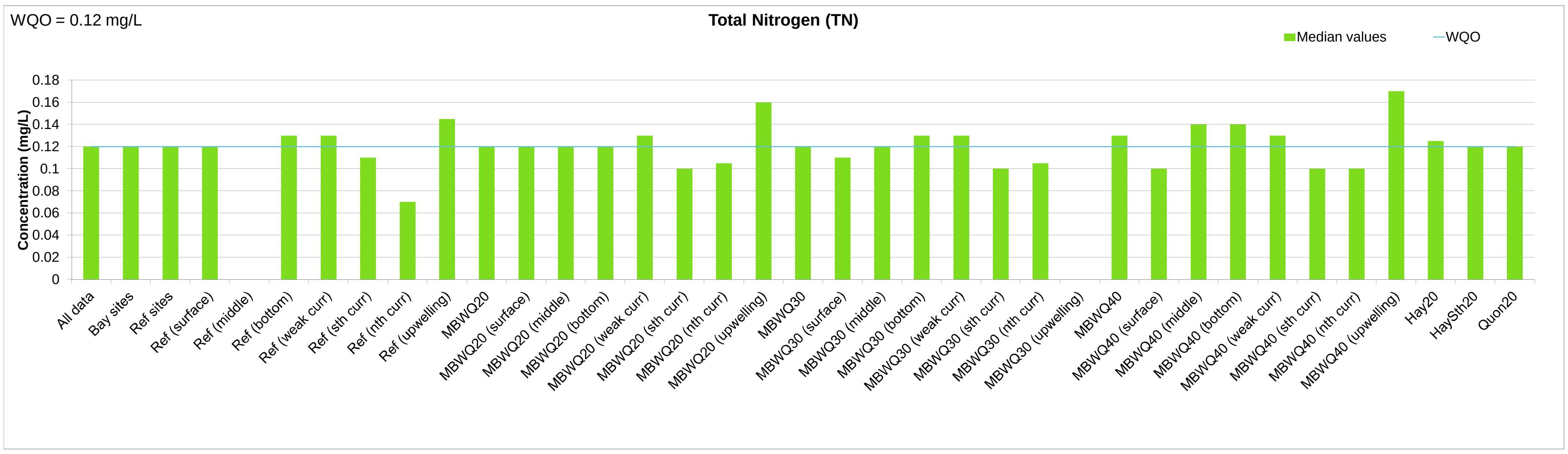
| No. | Category | Site | Subset of data used |
|---|---|---|---|
| 28 | MBWQ40 (surface) | Merimbula bay 40 m depth | Top of water column sample data |
| 29 | MBWQ40 (middle) | Merimbula bay 40 m depth | Mid-depth of water column sample data |
| 30 | MBWQ40 (bottom) | Merimbula bay 40 m depth | Bottom of water column sample data |
| 31 | MBWQ40 (weak curr) | Merimbula bay 40 m depth | Weak N or S offshore current, not apparent |
| 32 | MBWQ40 (sth curr) | Merimbula bay 40 m depth | Strong South flowing offshore current |
| 33 | MBWQ40 (nth curr) | Merimbula bay 40 m depth | Strong North flowing offshore current |
| 34 | MBWQ40 (upwelling) | Merimbula bay 40 m depth | Upwelling event occurring |
| 35 | Hay20 | Off Haycock Point 20 m depth | All data |
| 36 | HaySth20 | South of Haycock Point 20 m depth | All data |
| 37 | Quon20 | Off Quondolo Point 20 m depth | All data |

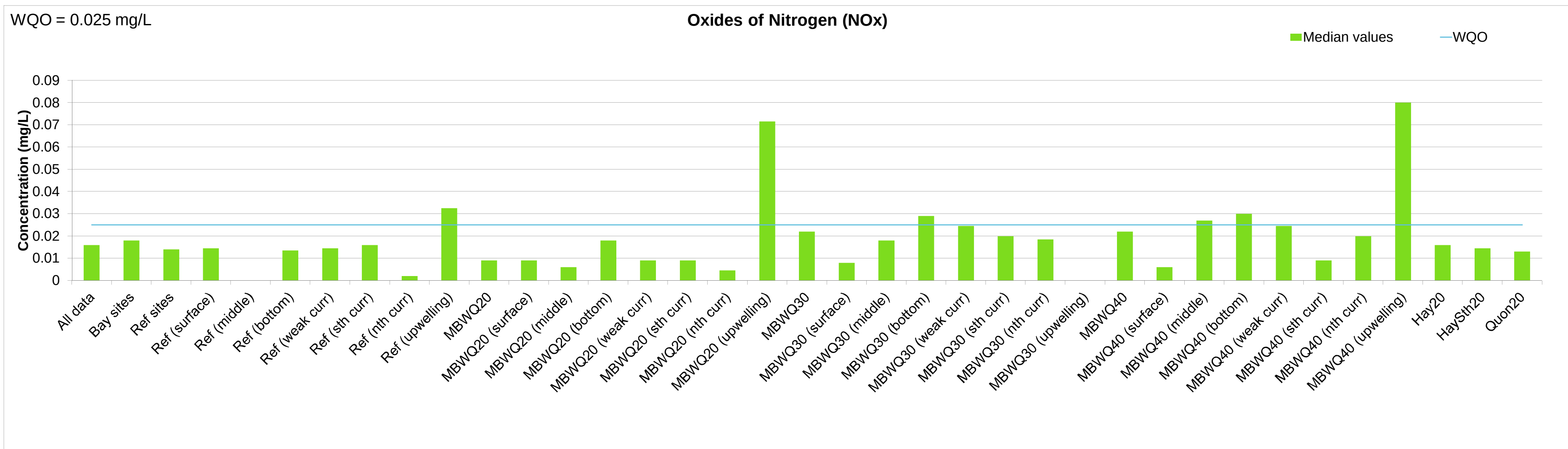

WQO = 8.0 - 8.4
pH
Median values
WQO lower limit
pH

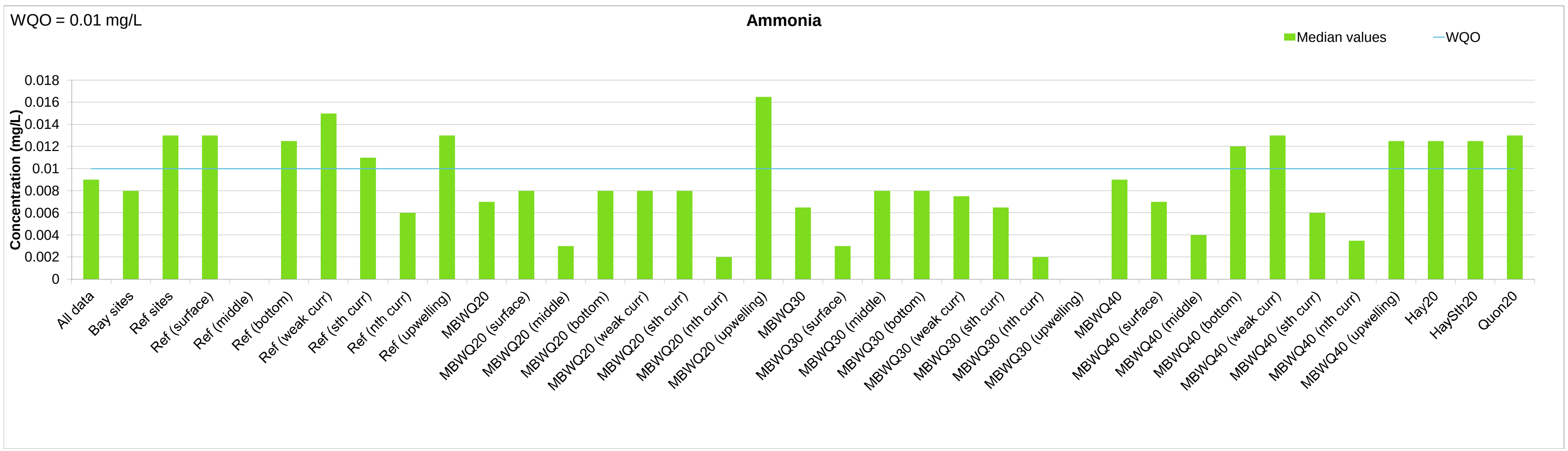

WQO = 10 mg/L
Suspended Solids
Median values
WQO
Concentration (mg/L)

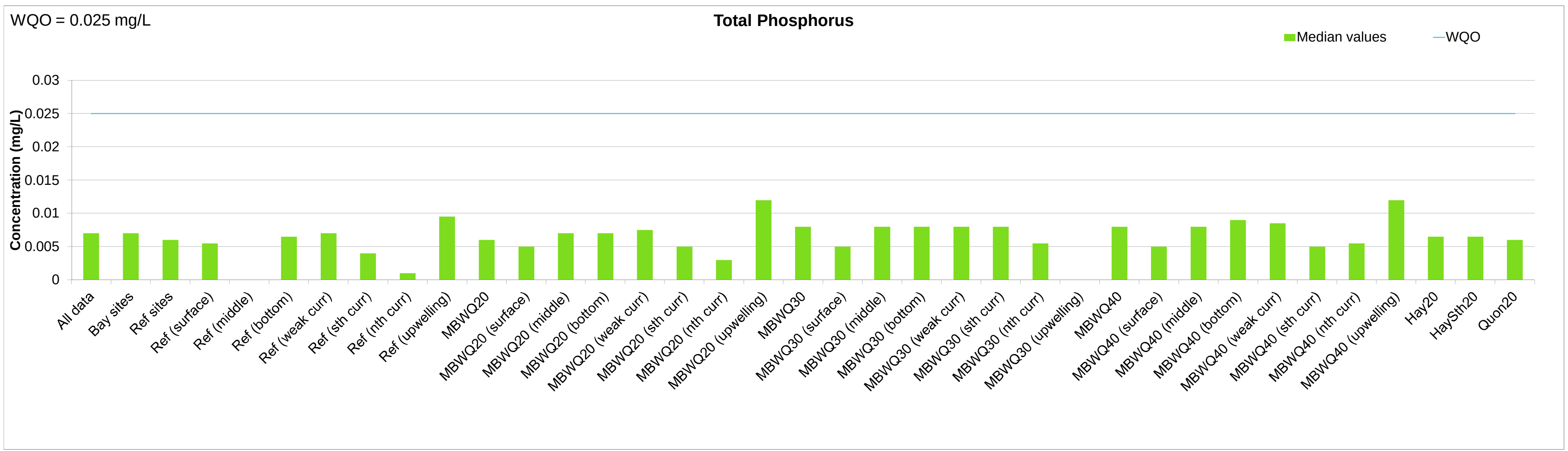

Electrical Conductivity
Median values
WQO
Concentration (us/cm)

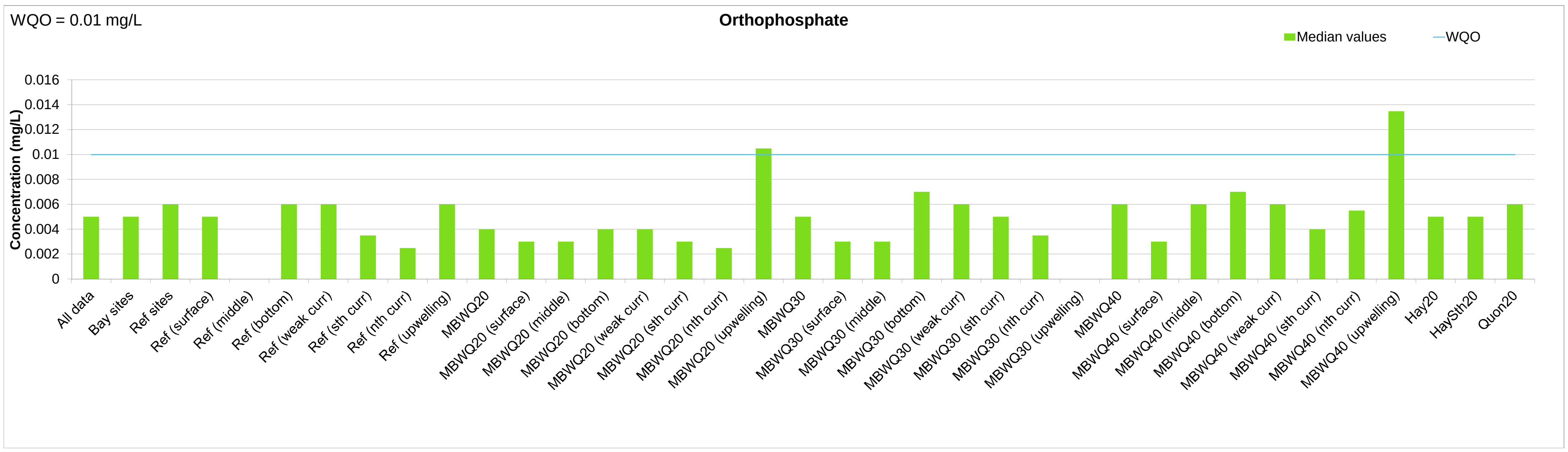

WQO > 5 mg/L
Dissolved Oxygen
Median values
WQO
Concentration (mg/L)

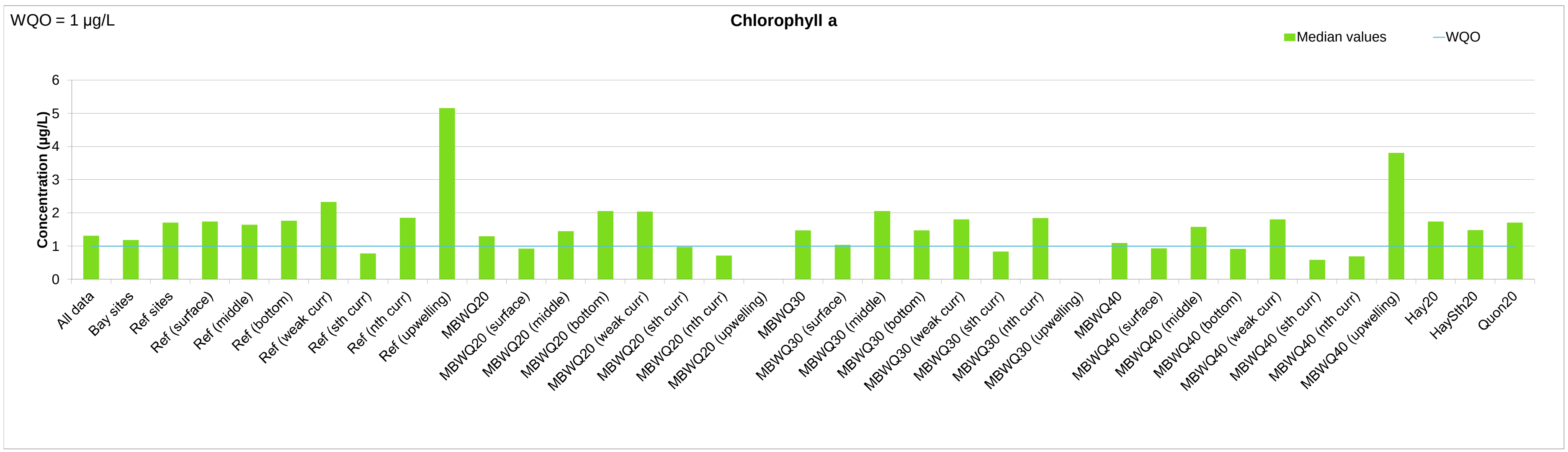

WQO = 0.12 mg/L
Total Nitrogen (TN)
Median values
WQO
Concentration (mg/L)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

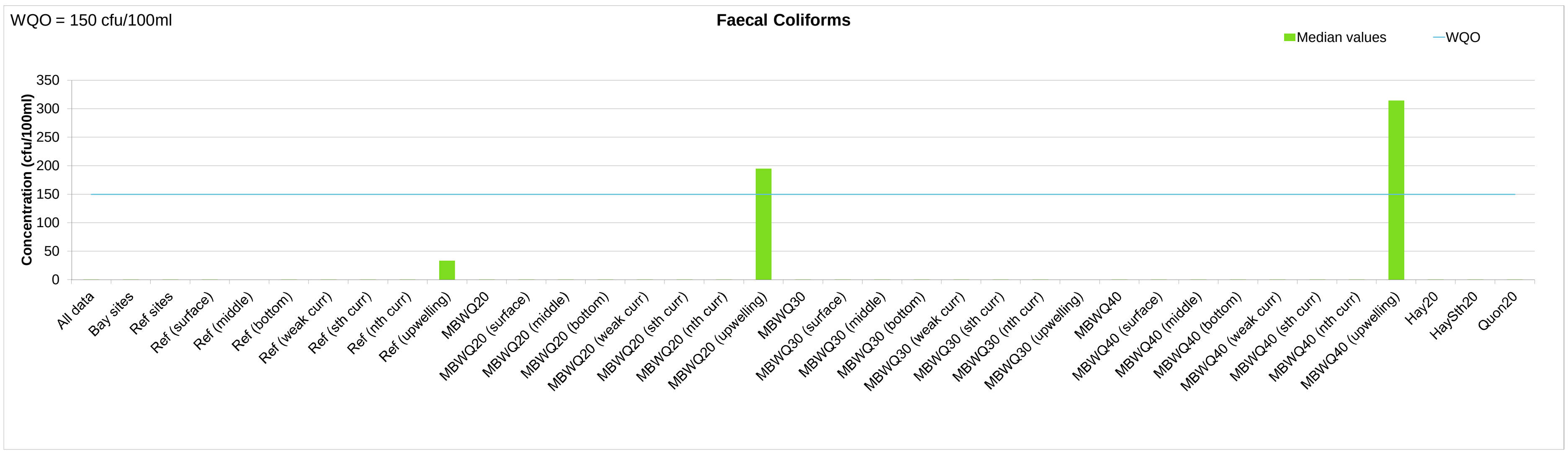

WQO = 0.025 mg/L
Oxides of Nitrogen (NOx)
Median values
WQO
Concentration (mg/L)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

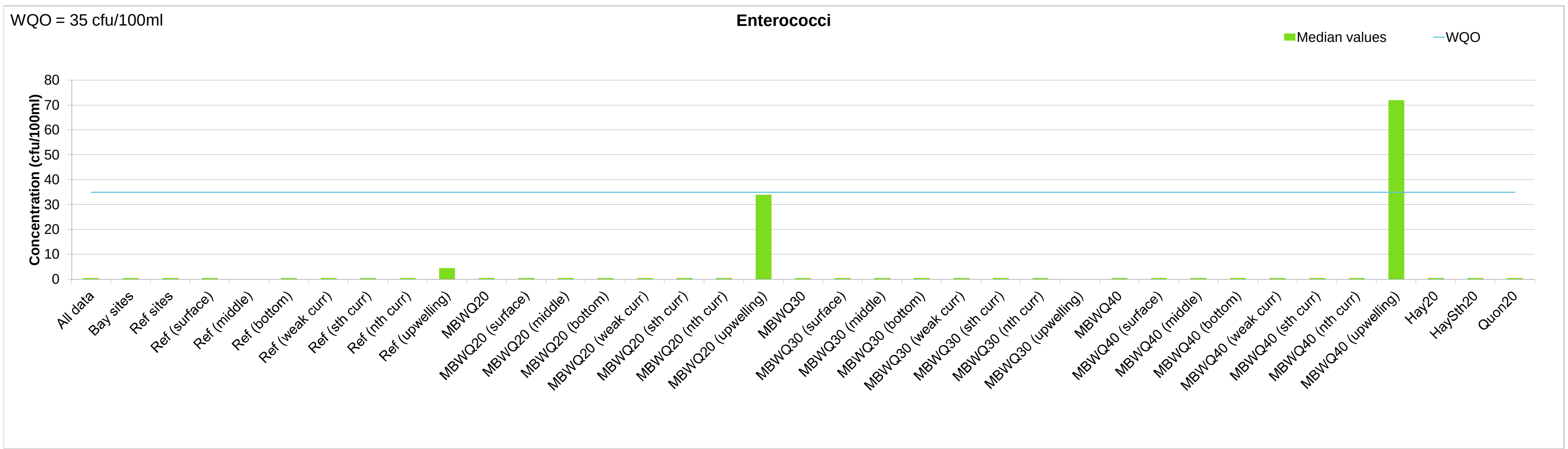

WQO = 0.01 mg/L
Ammonia
Median values
WQO
Concentration (mg/L)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

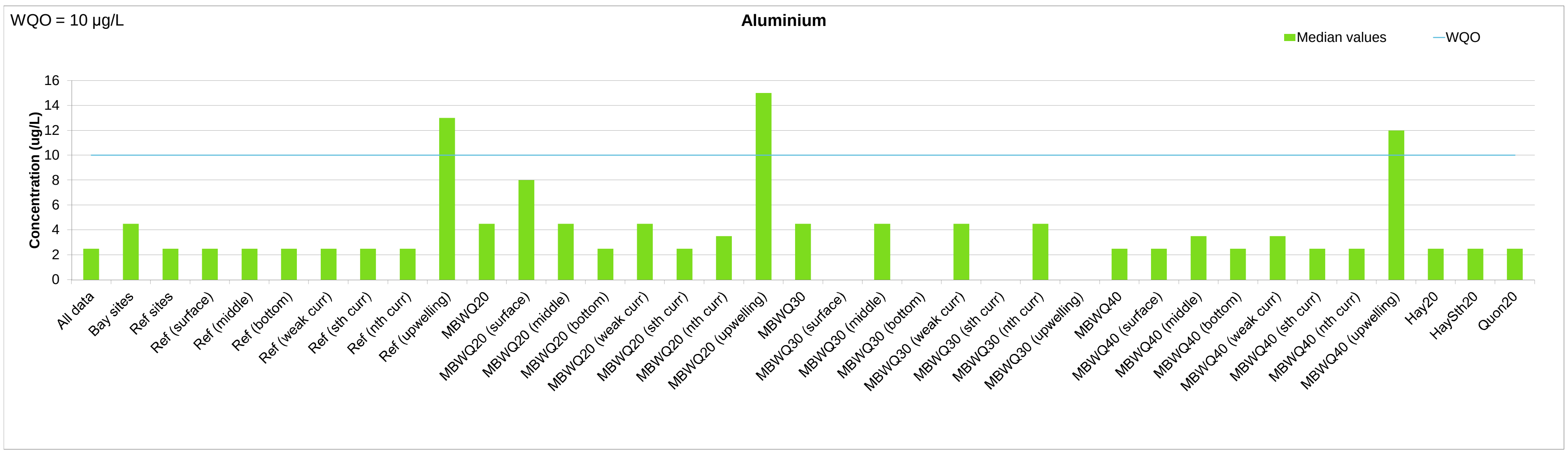

WQO = 0.025 mg/L
Total Phosphorus
Median values
WQO
Concentration (mg/L)
0.03
0.025
0.02
0.015
0.01
0.005
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

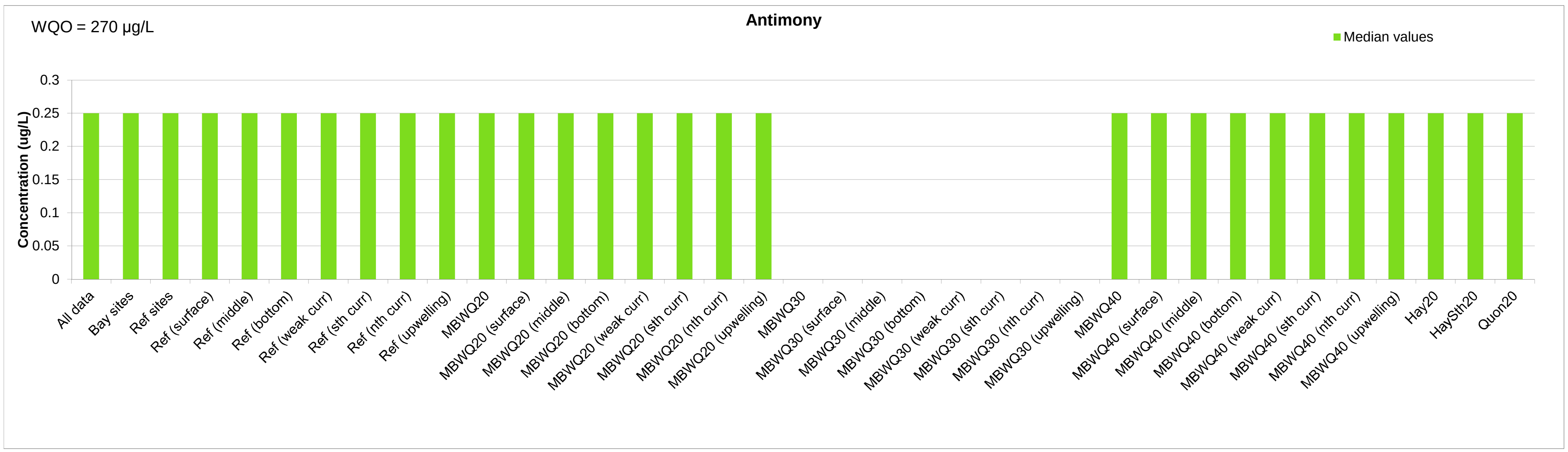

WQO = 0.01 mg/L
Orthophosphate
Median values
WQO
Concentration (mg/L)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

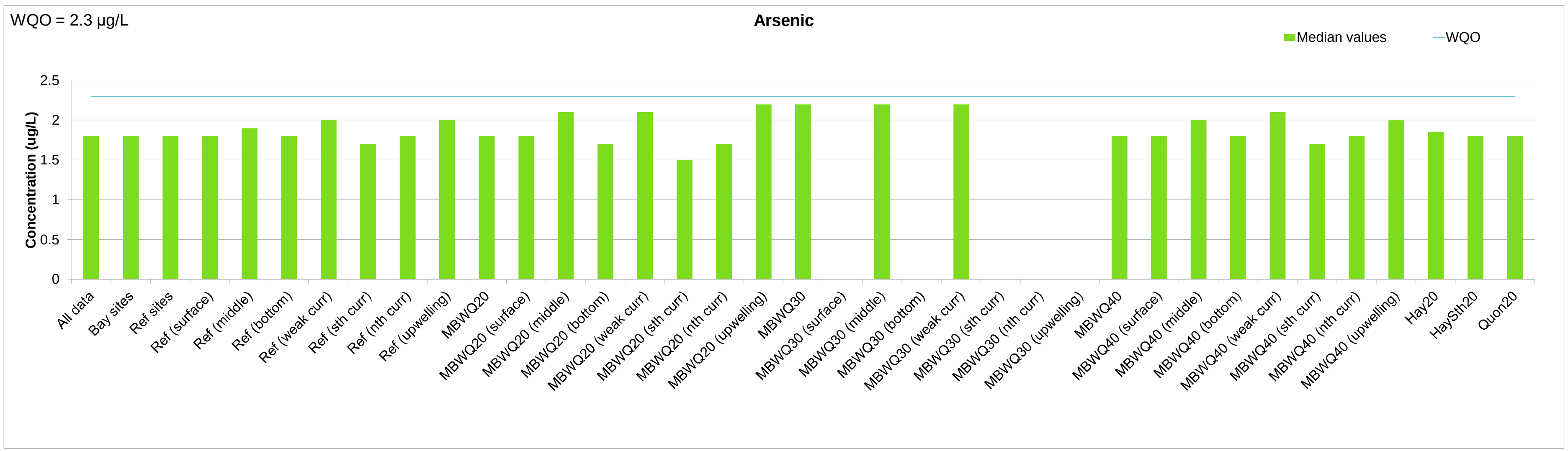

WQO = 1 µg/L
Chlorophyll a
Median values
WQO
Concentration (µg/L)
6
5
4
3
2
1
0

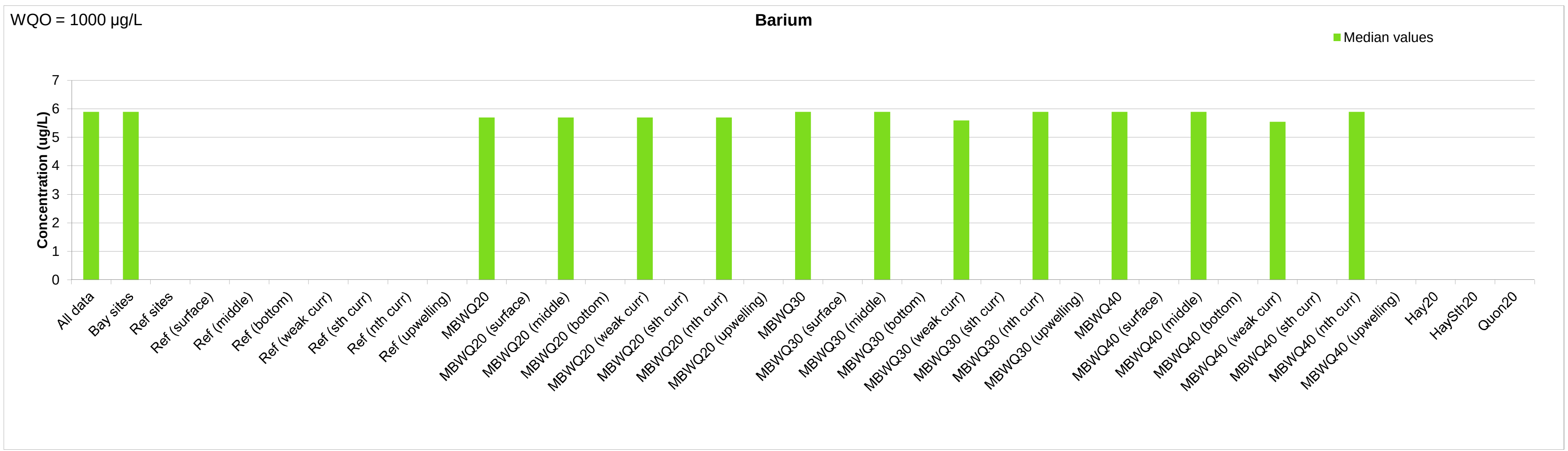

WQO = 150 cfu/100ml
Faecal Coliforms
Median values
WQO
Concentration (cfu/100ml)
350
300
250
200
150
100
50
0

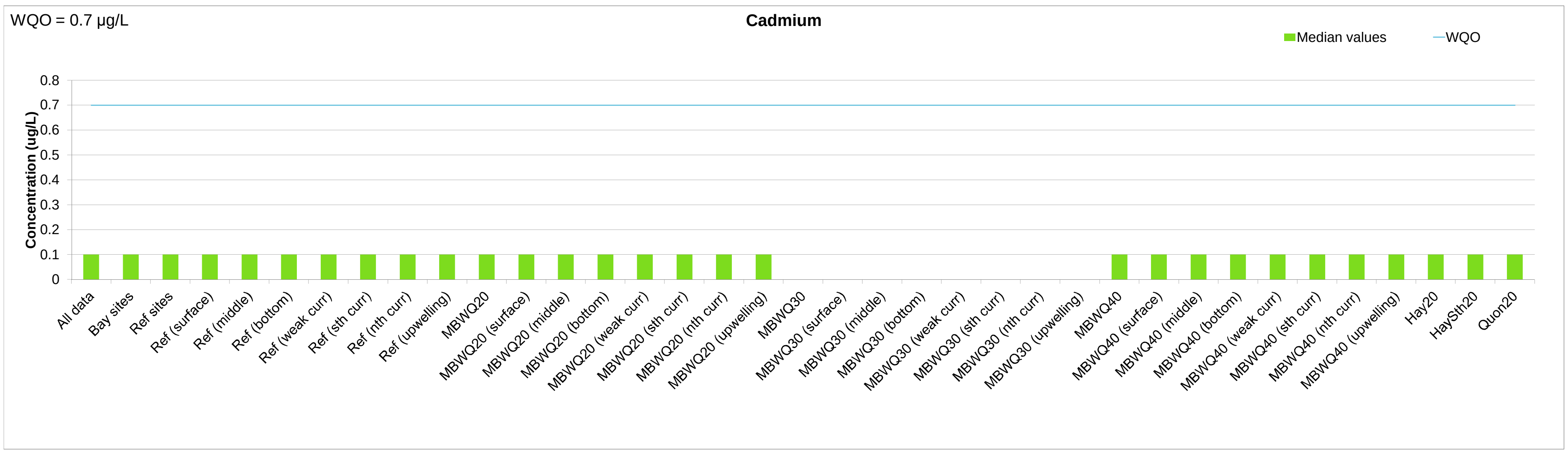

WQO = 35 cfu/100ml
Enterococci
Median values
WQO
Concentration (cfu/100ml)
80
70
60
50
40
30
20
10
0

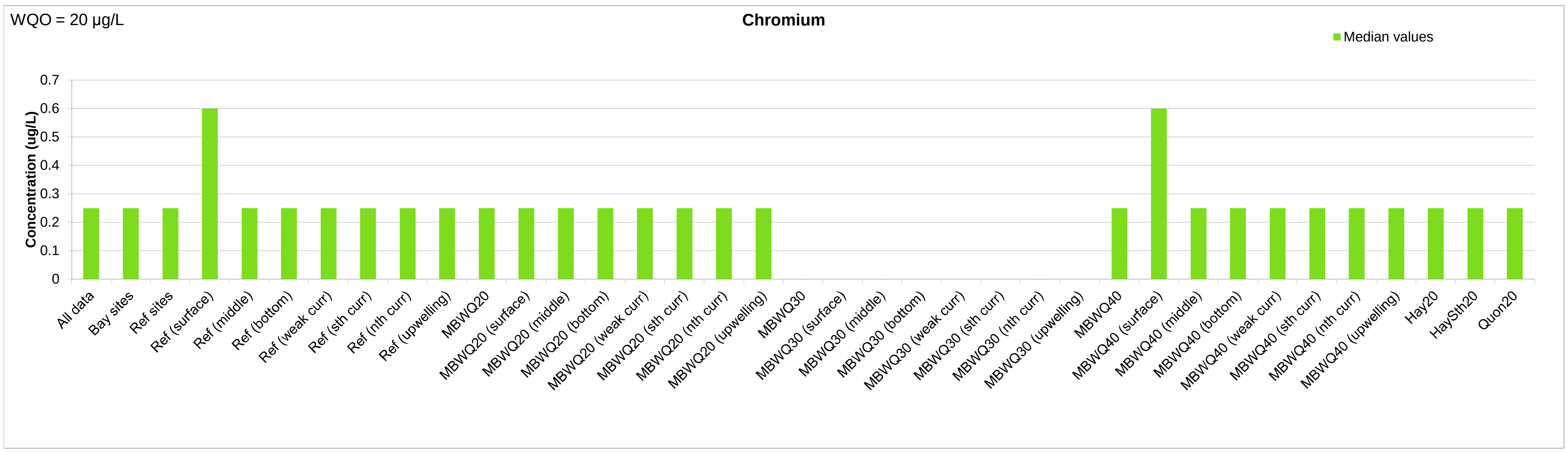

WQO = 10 µg/L
Aluminium
Median values
WQO
Concentration (ug/L)

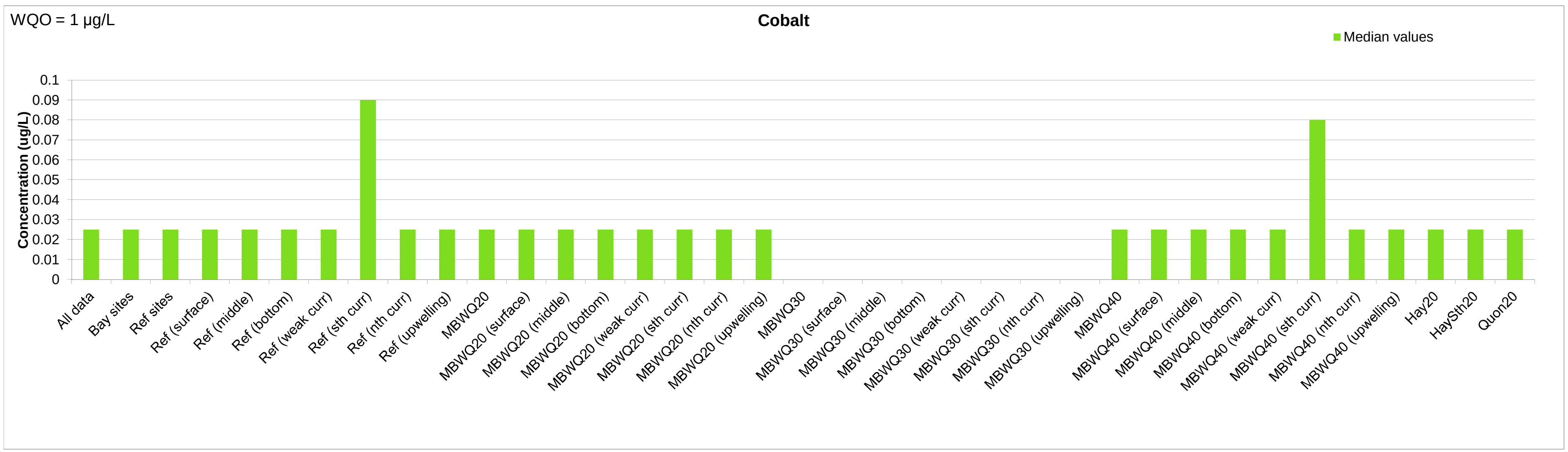

WQO = 270 µg/L
Antimony
Median values
Concentration (ug/L)

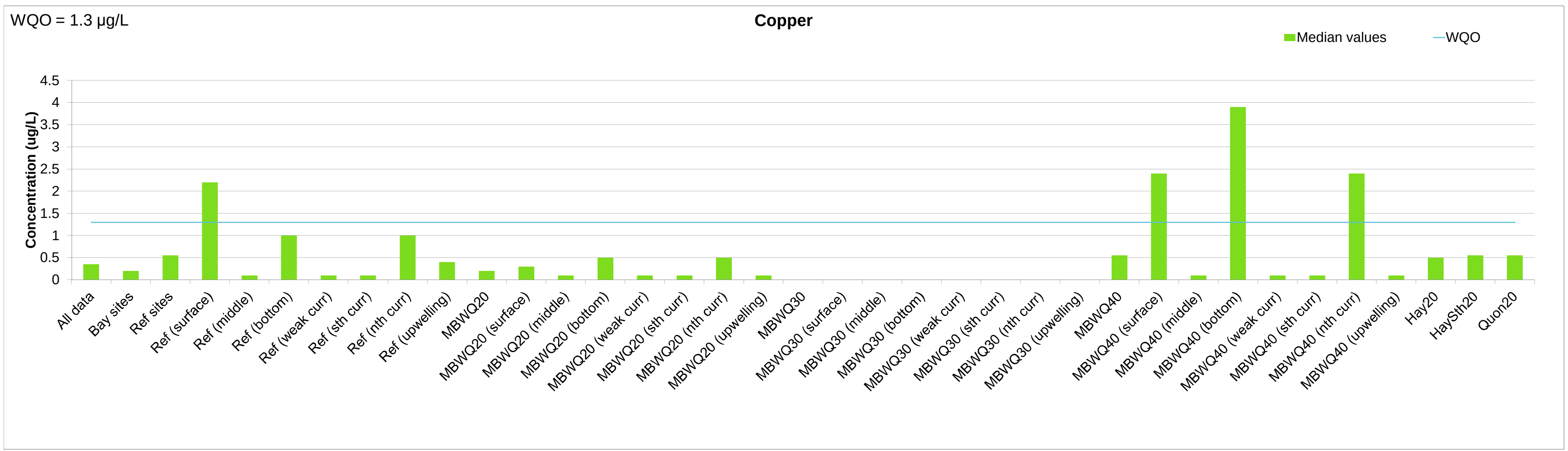

WQO = 2.3 µg/L
Arsenic
Median values
WQO
Concentration (ug/L)

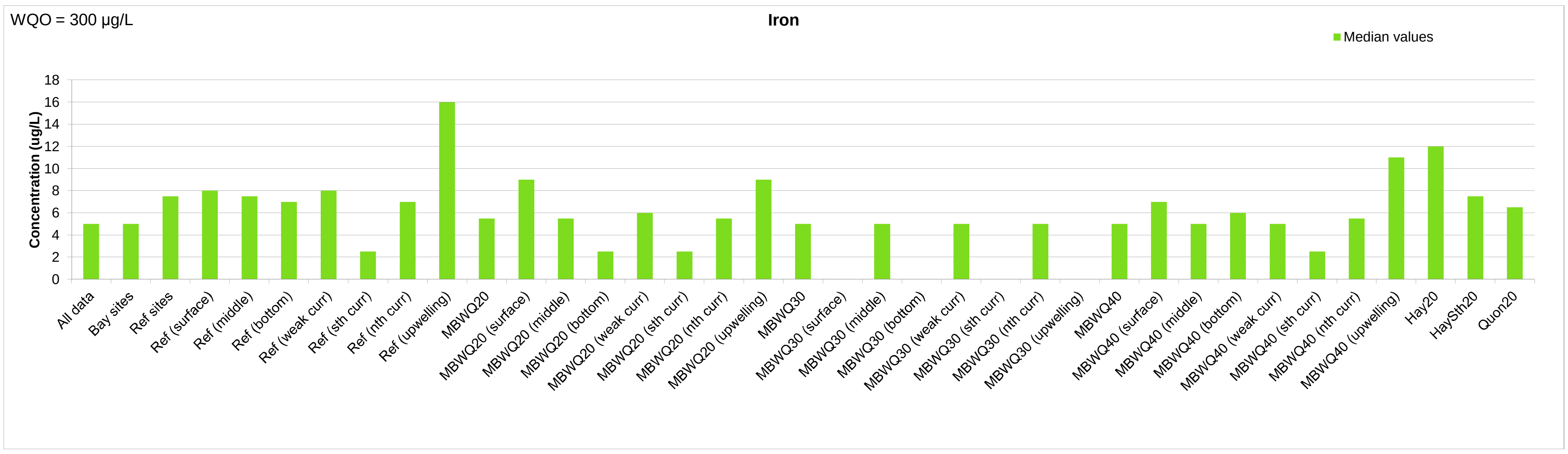

WQO = 1000 µg/L
Barium
Median values
Concentration (ug/L)

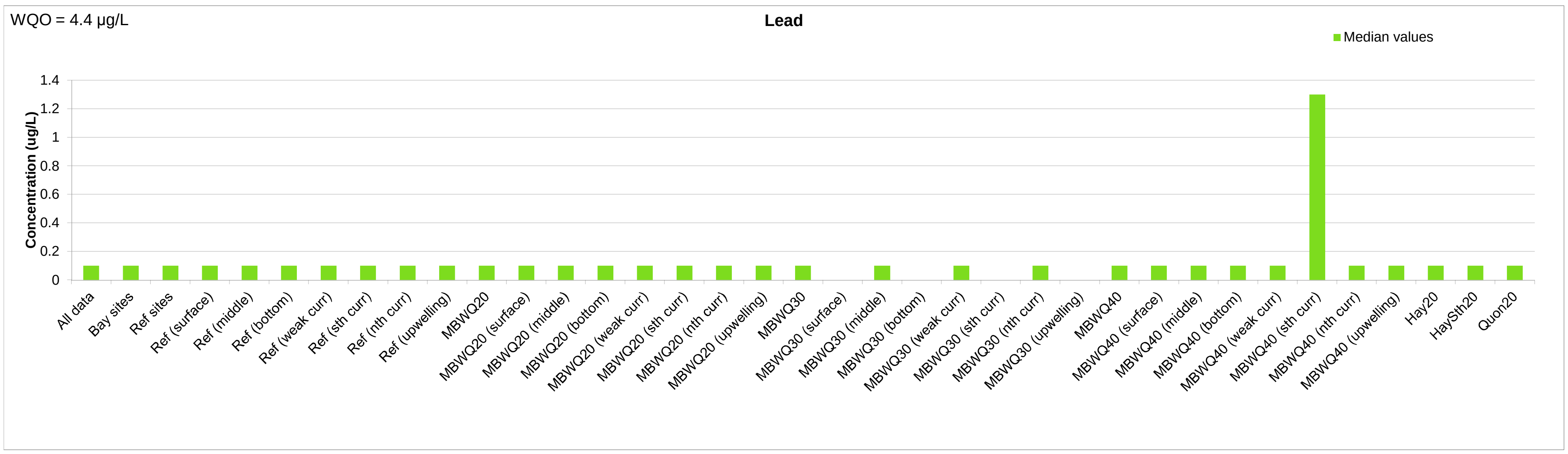

WQO = 0.7 µg/L
Cadmium
Median values
WQO
Concentration (ug/L)
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

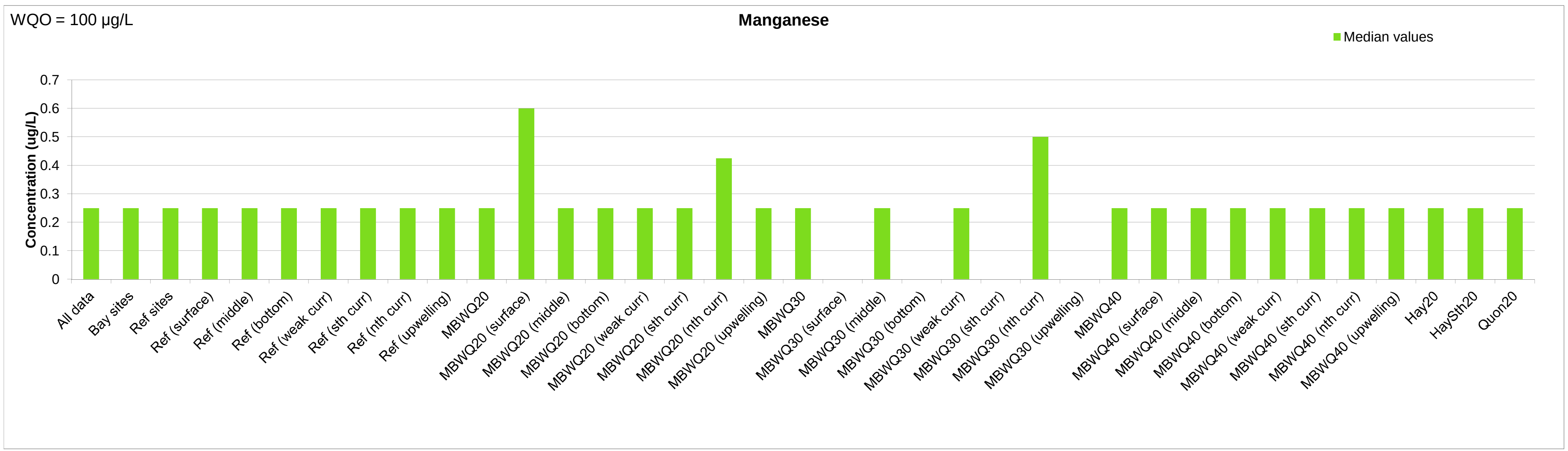

WQO = 20 µg/L
Chromium
Median values
Concentration (ug/L)

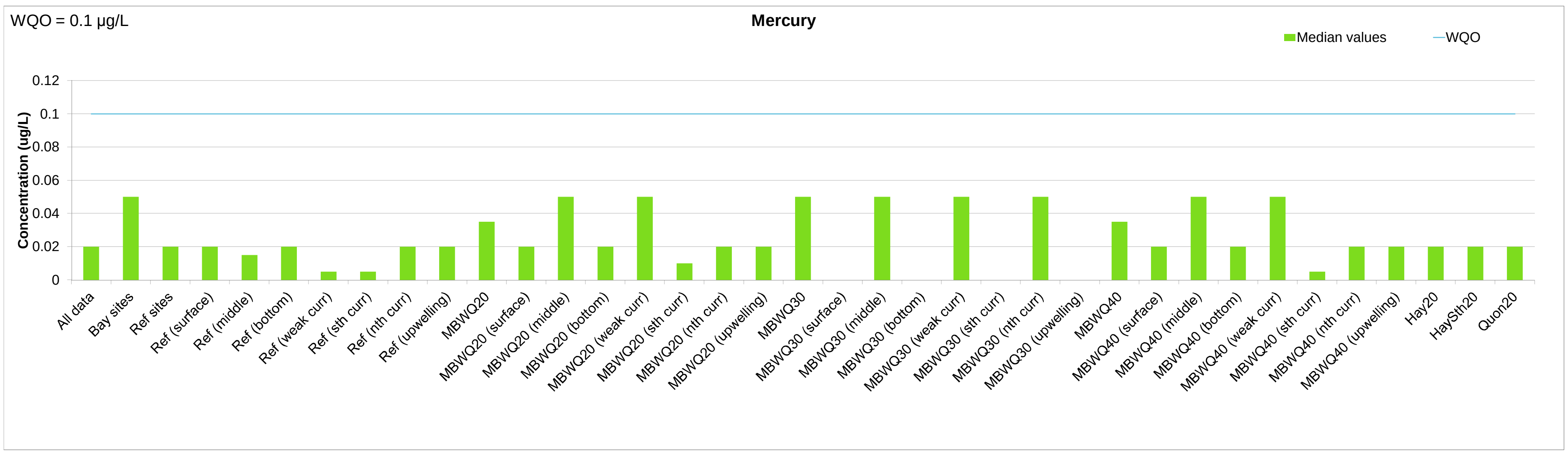

WQO = 1 µg/L
Cobalt
Median values
Concentration (ug/L)

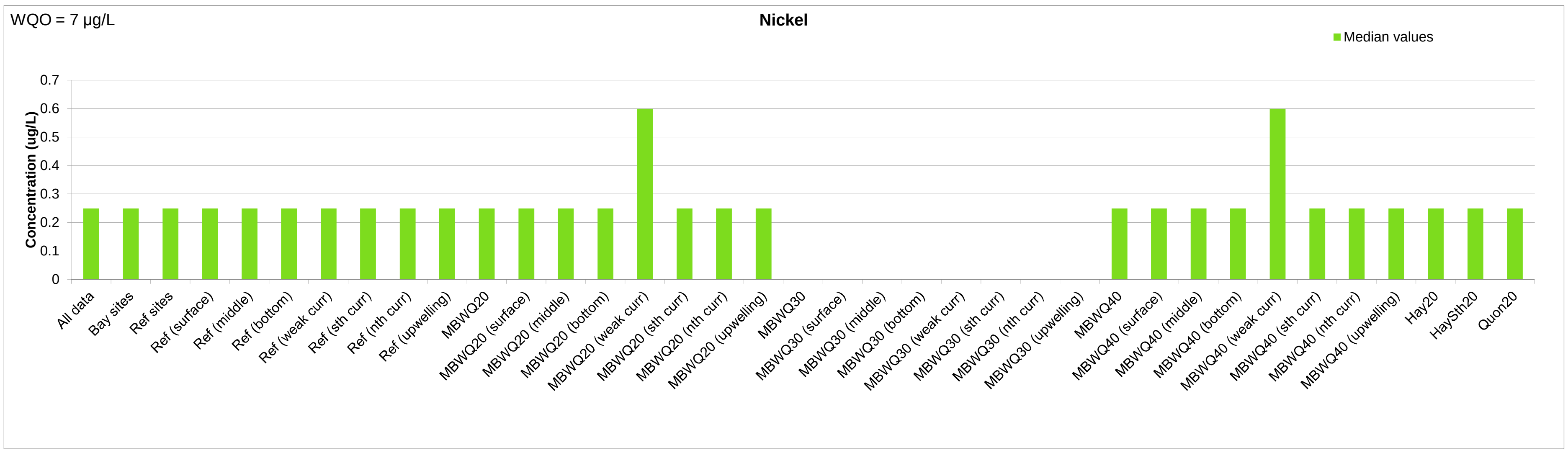

WQO = 1.3 µg/L
Copper
Median values
WQO
Concentration (ug/L)

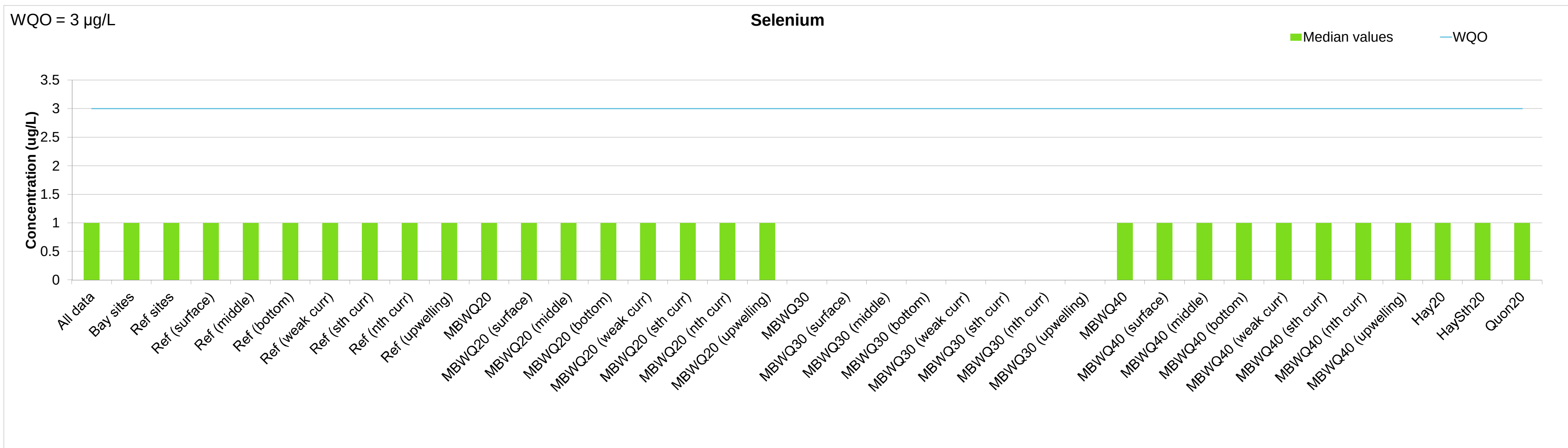

WQO = 300 µg/L
Iron
Median values
Concentration (ug/L)
18
16
14
12
10
8
6
4
2
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

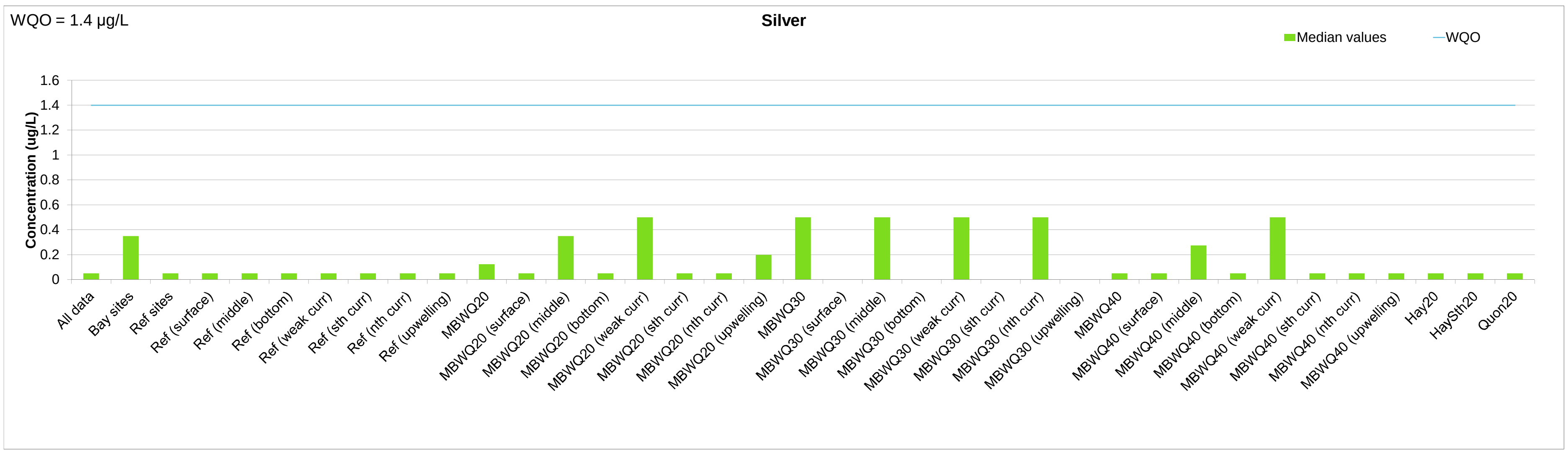

WQO = 4.4 µg/L
Lead
Median values
Concentration (ug/L)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

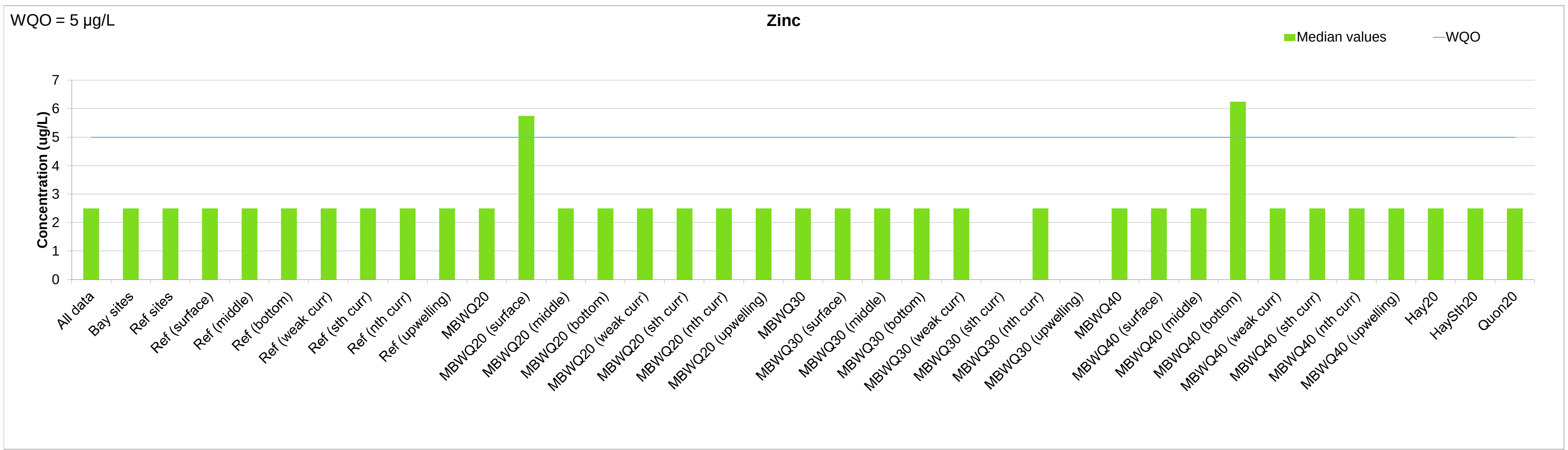

WQO = 100 µg/L
Manganese
Median values
Concentration (ug/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

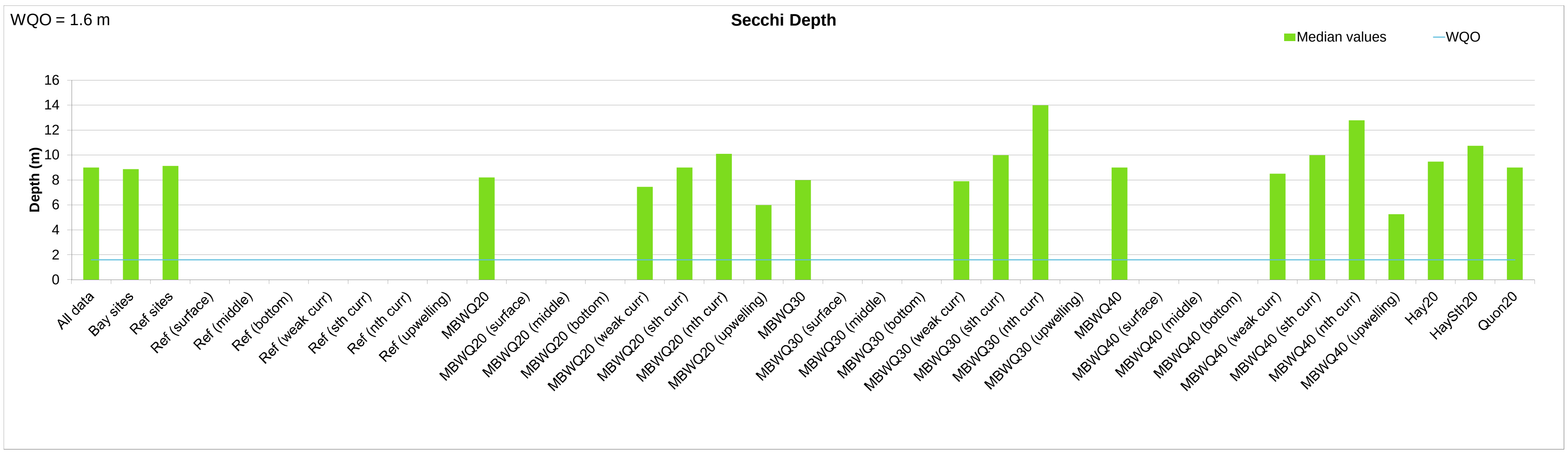

WQO = 0.1 µg/L
Mercury
Median values
WQO
Concentration (ug/L)
0.12
0.1
0.08
0.06
0.04
0.02
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

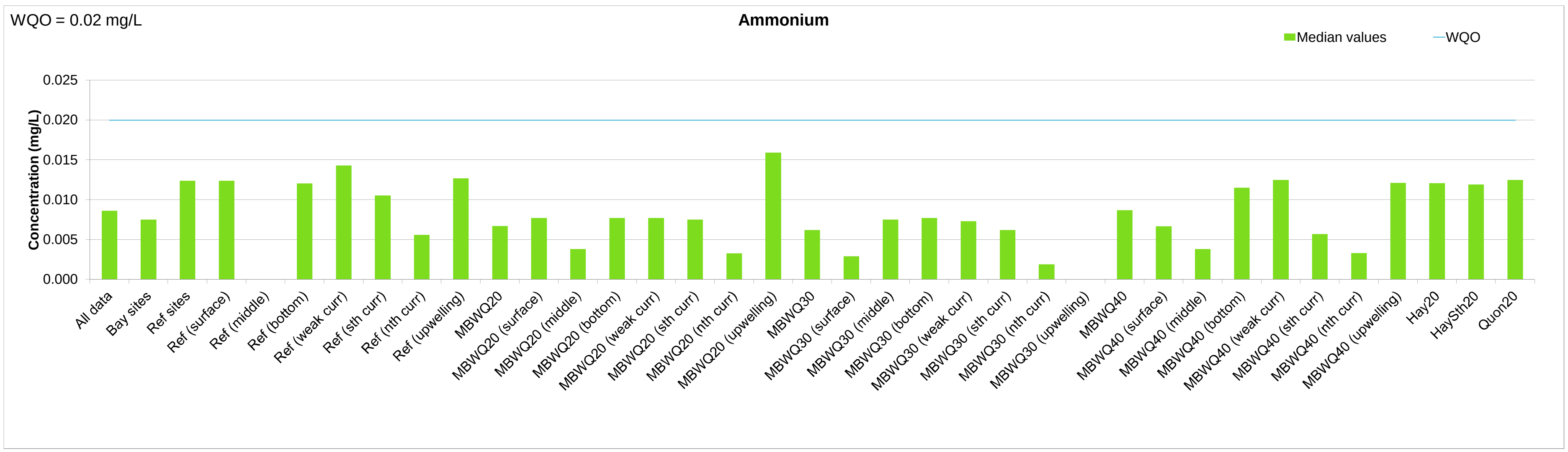

WQO = 7 µg/L
Nickel
Median values
Concentration (ug/L)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

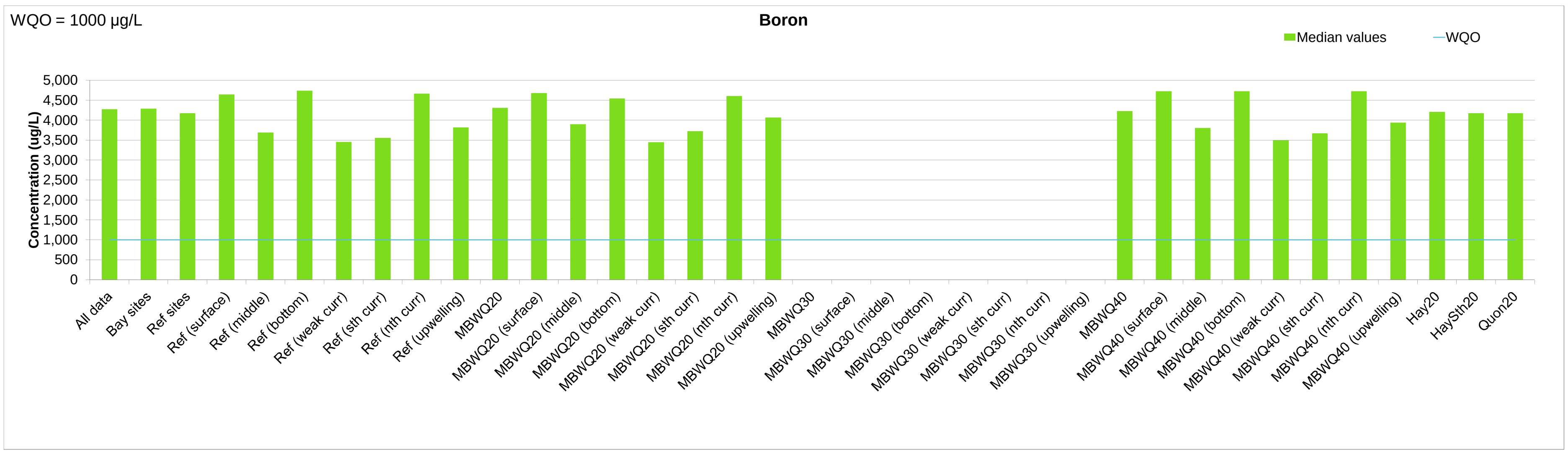

WQO = 3 µg/L
Selenium
Median values
WQO
Concentration (ug/L)
0 0.5 1 1.5 2 2.5 3 3.5

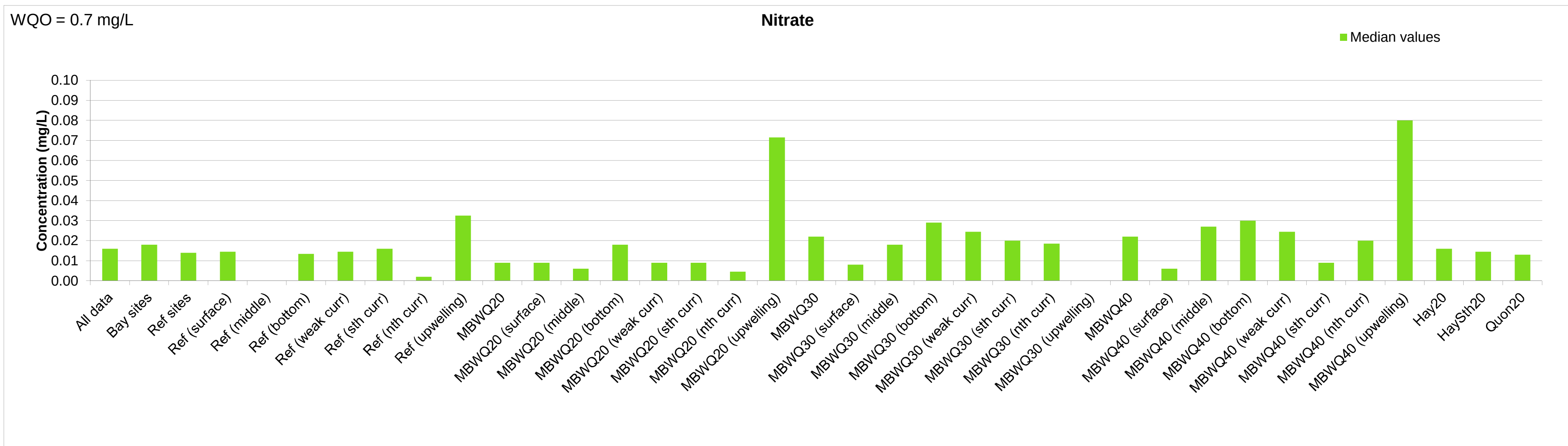

WQO = 1.4 µg/L
Silver
Median values
WQO
Concentration (ug/L)
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6

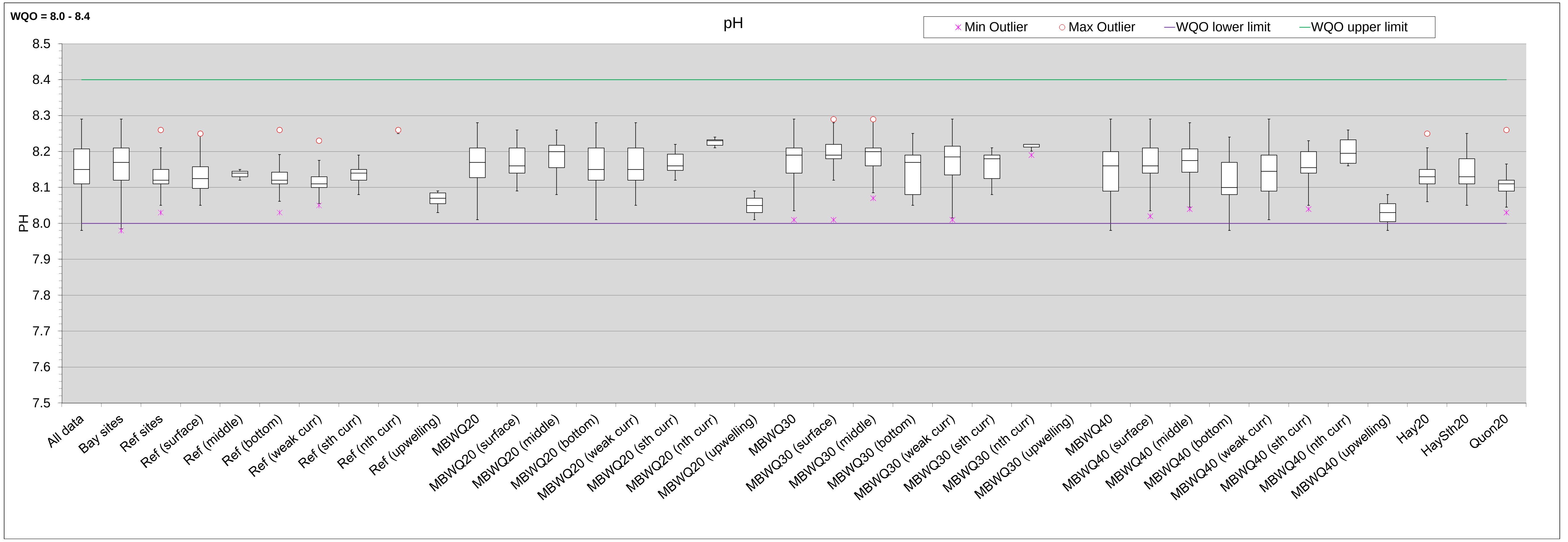

WQO = 5 µg/L
Zinc
Median values
WQO
Concentration (ug/L)
0 1 2 3 4 5 6 7

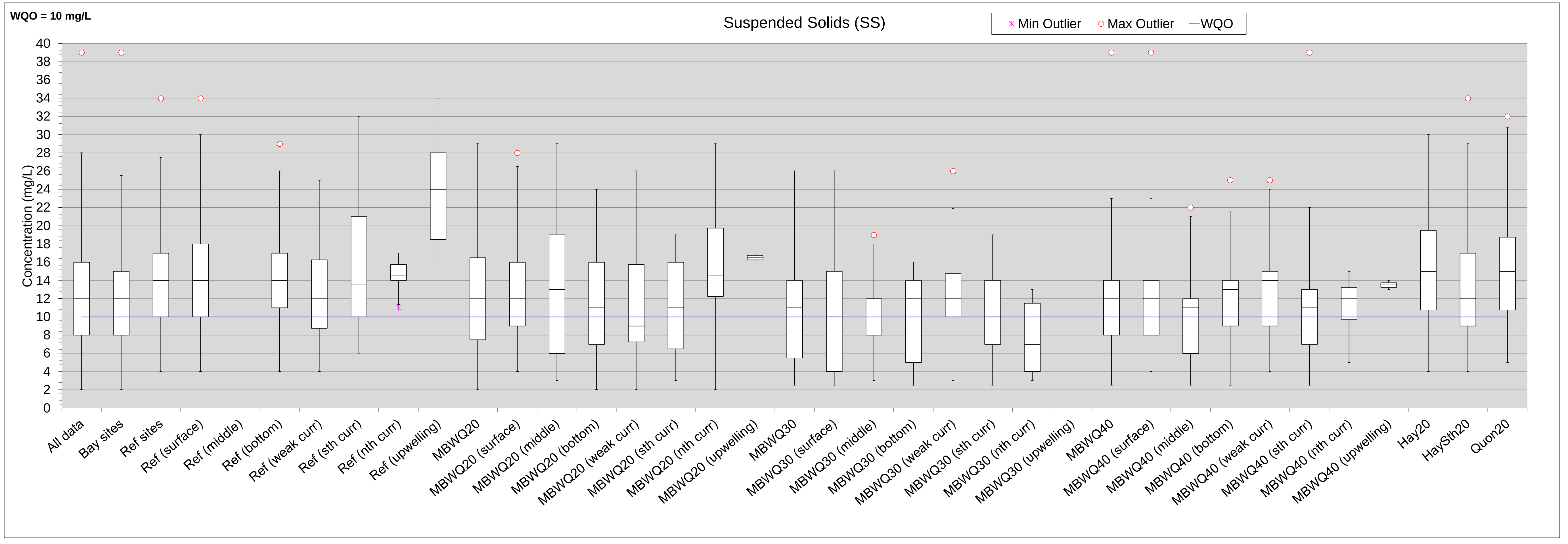

WQO = 1.6 m
Secchi Depth
Median values
WQO
Depth (m)
0
2
4
6
8
10
12
14
16
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

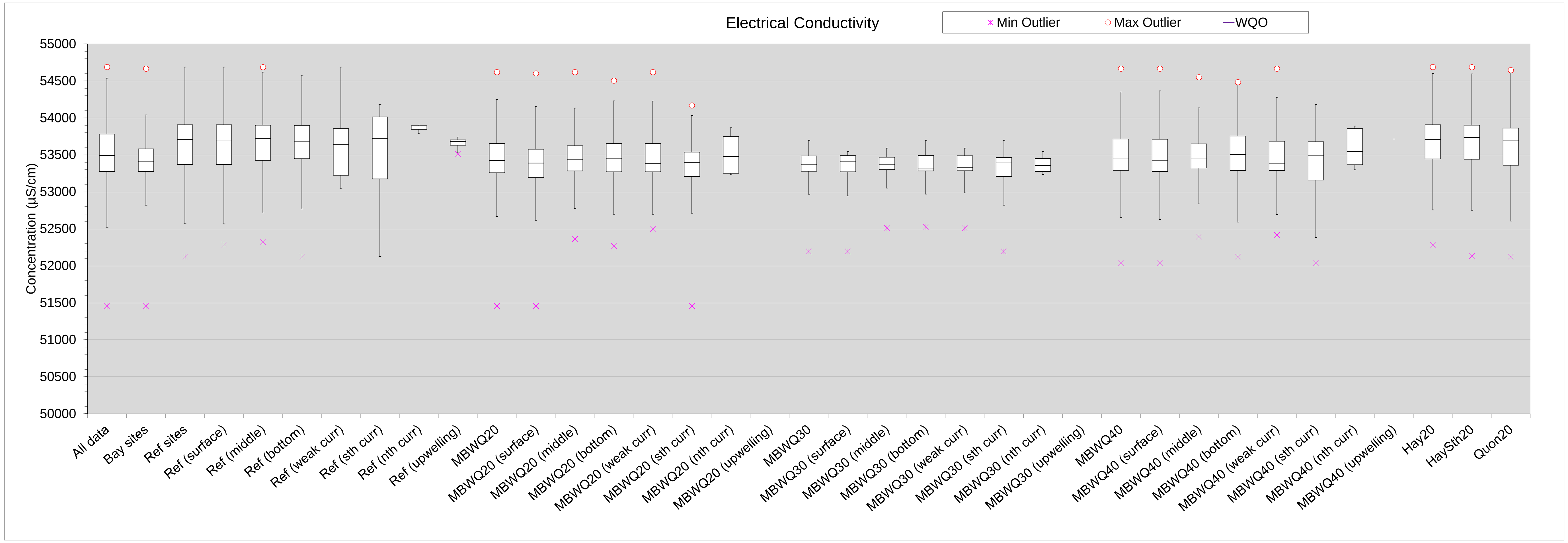

WQO = 0.02 mg/L
Ammonium
Median values
WQO
Concentration (mg/L)
0.000
0.005
0.010
0.015
0.020
0.025

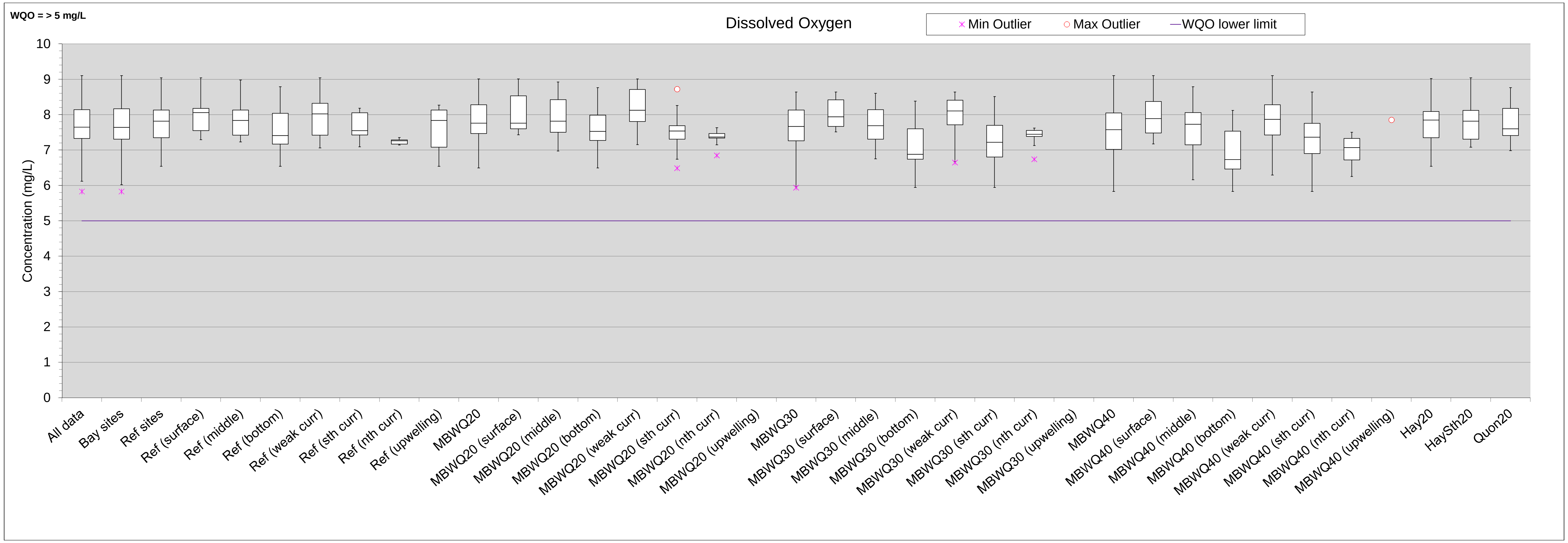

WQO = 1000 µg/L
Boron
Median values
WQO
Concentration (ug/L)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000

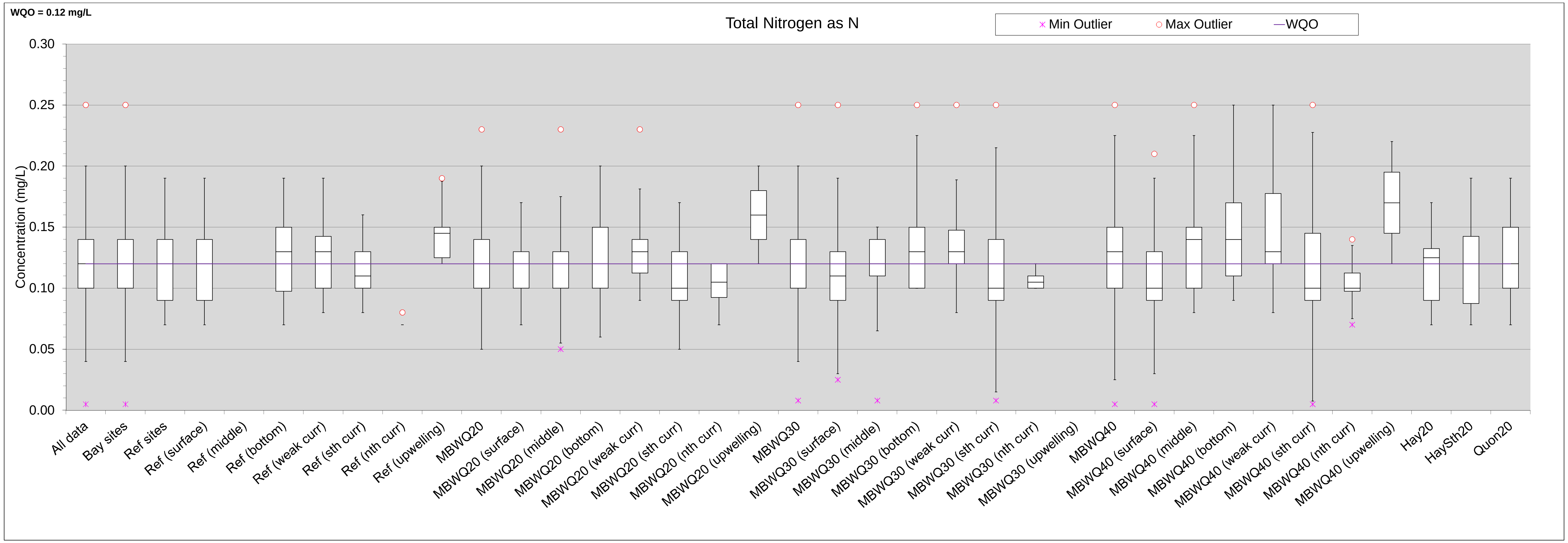

WQO = 0.7 mg/L
Nitrate
Median values
Concentration (mg/L)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.10

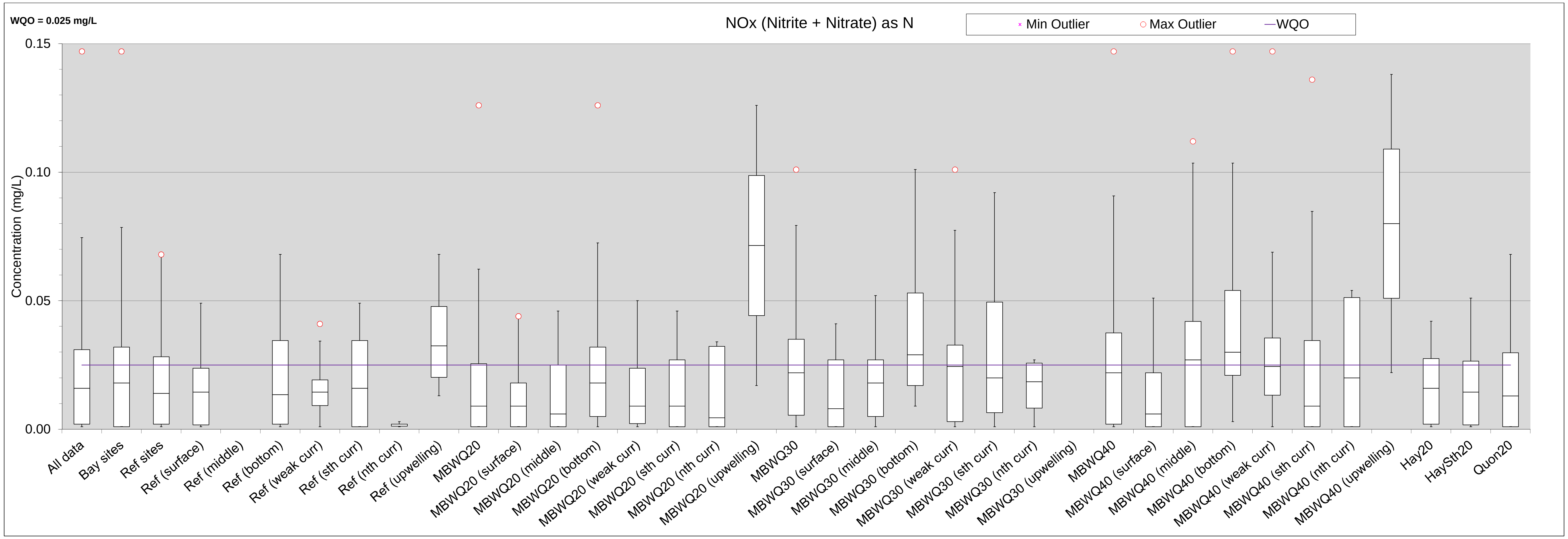

WQO = 8.0 - 8.4
pH
Min Outlier
Max Outlier
WQO lower limit
WQO upper limit
PH
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

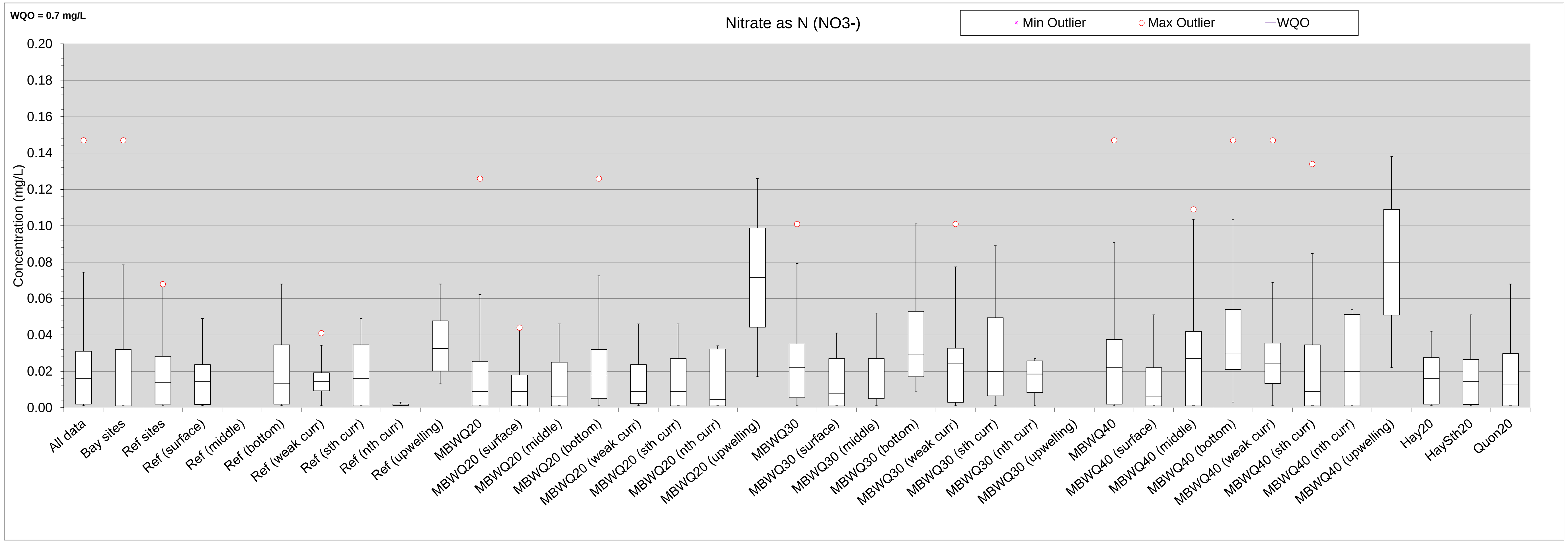

WQO = 10 mg/L
Suspended Solids (SS)
Min Outlier
Max Outlier
WQO
Concentration (mg/L)
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

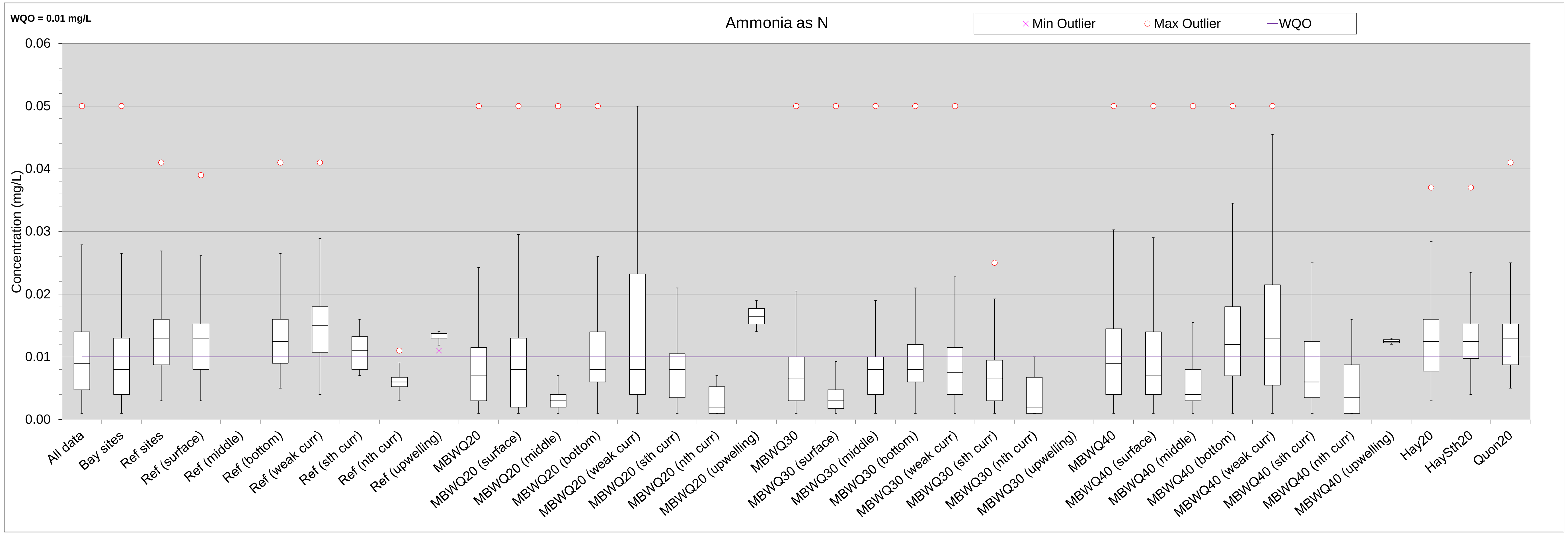

Electrical Conductivity
Min Outlier
Max Outlier
WQO
Concentration (µS/cm)
55000
54500
54000
53500
53000
52500
52000
51500
51000
50500
50000
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

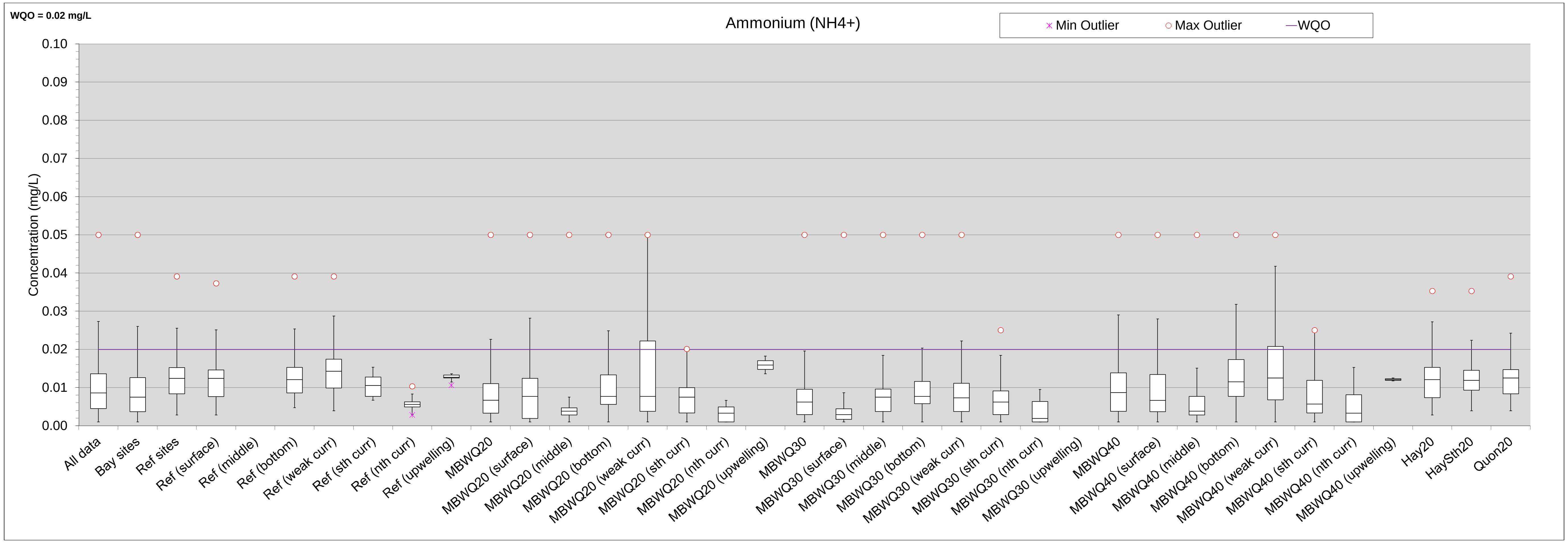

WQO = > 5 mg/L
Dissolved Oxygen
Min Outlier
Max Outlier
WQO lower limit
Concentration (mg/L)
10
9
8
7
6
5
4
3
2
1
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

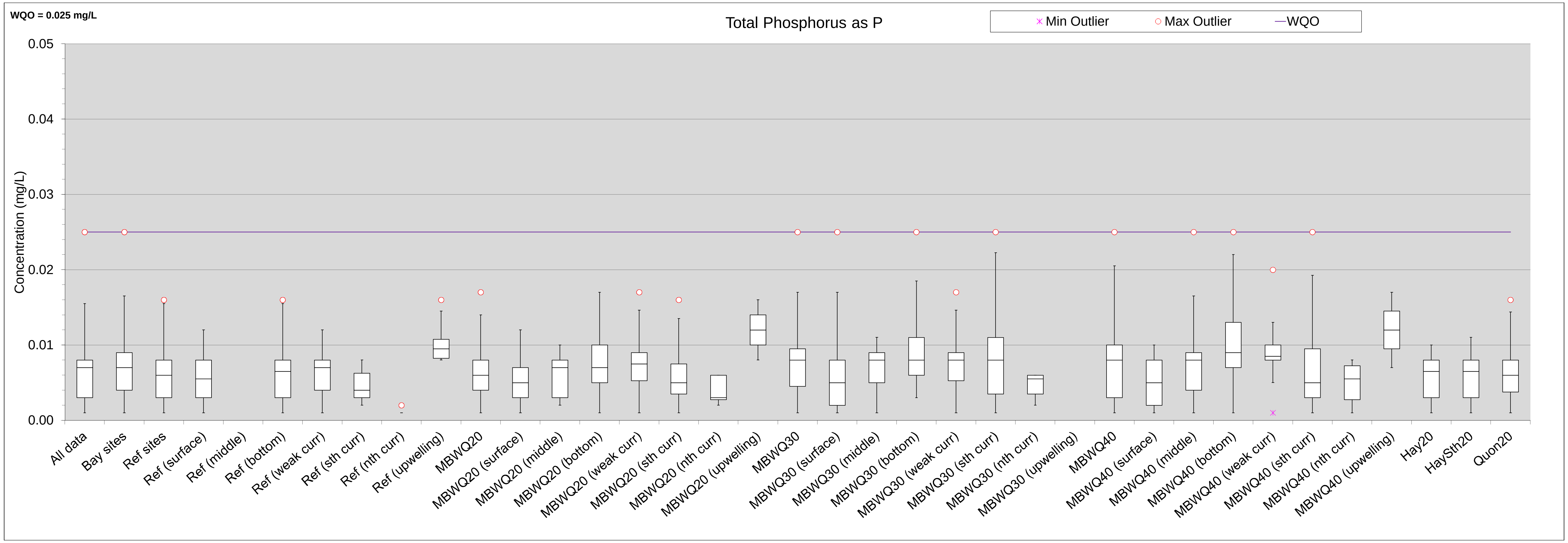

WQO = 0.12 mg/L
Total Nitrogen as N
Min Outlier
Max Outlier
WQO
Concentration (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

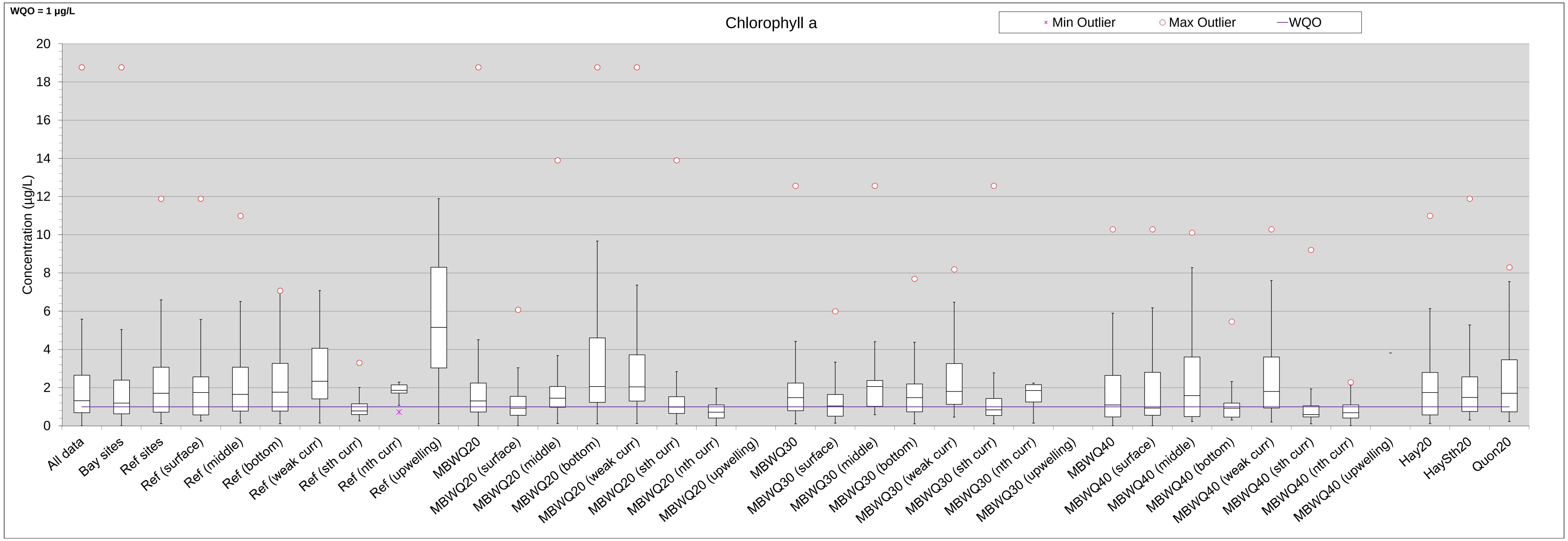

WQO = 0.025 mg/L
NOx (Nitrite + Nitrate) as N
Min Outlier
Max Outlier
WQO
Concentration (mg/L)
0.15
0.10
0.05
0.00
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

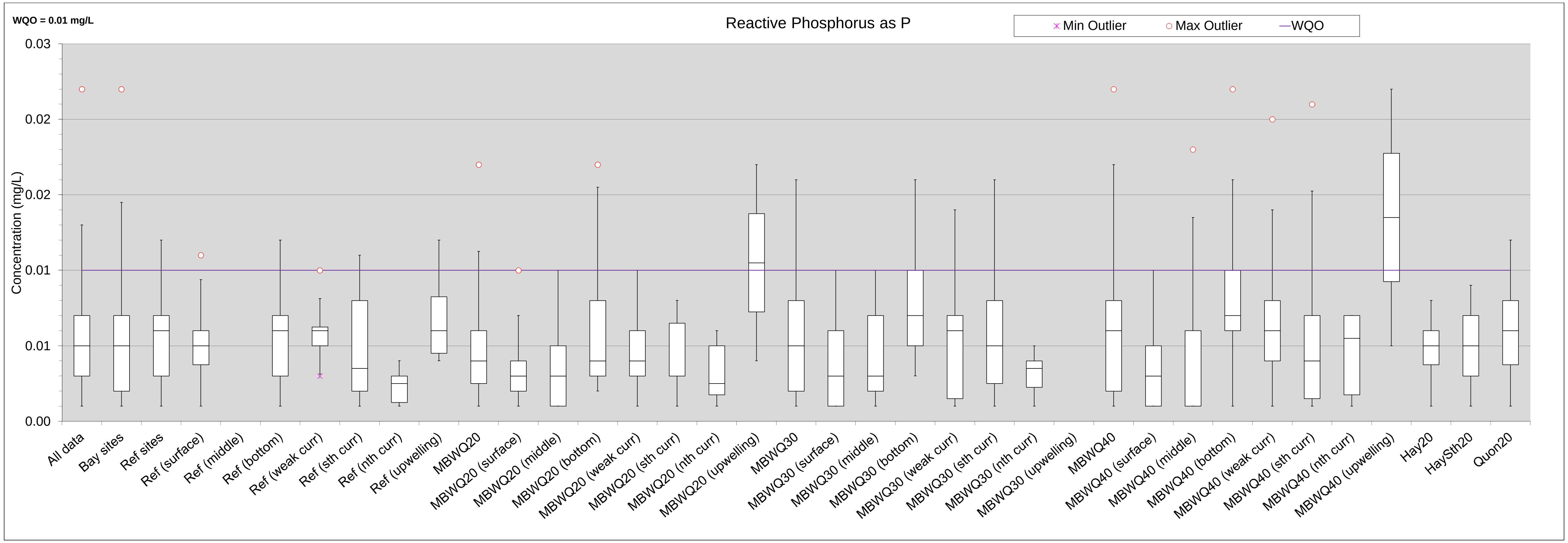

WQO = 0.7 mg/L
Nitrate as N (NO3-)
Min Outlier
Max Outlier
WQO
Concentration (mg/L)
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

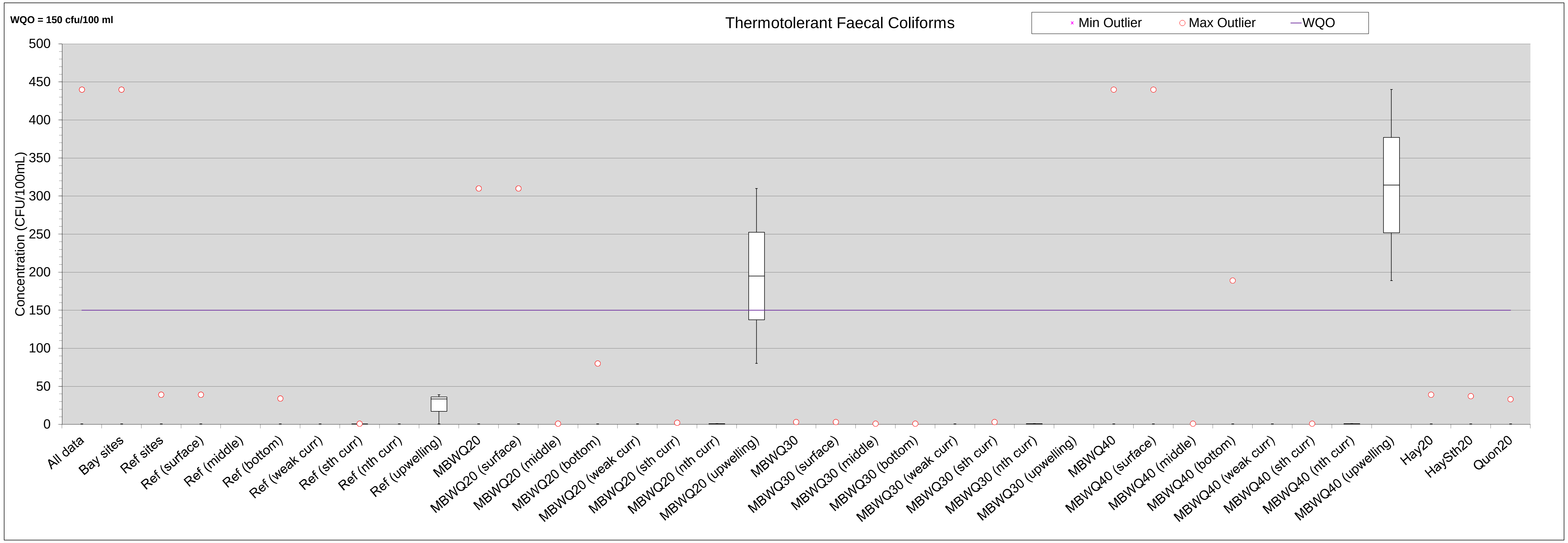

WQO = 0.01 mg/L
Ammonia as N
Min Outlier
Max Outlier
WQO
Concentration (mg/L)
0.06
0.05
0.04
0.03
0.02
0.01
0.00
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

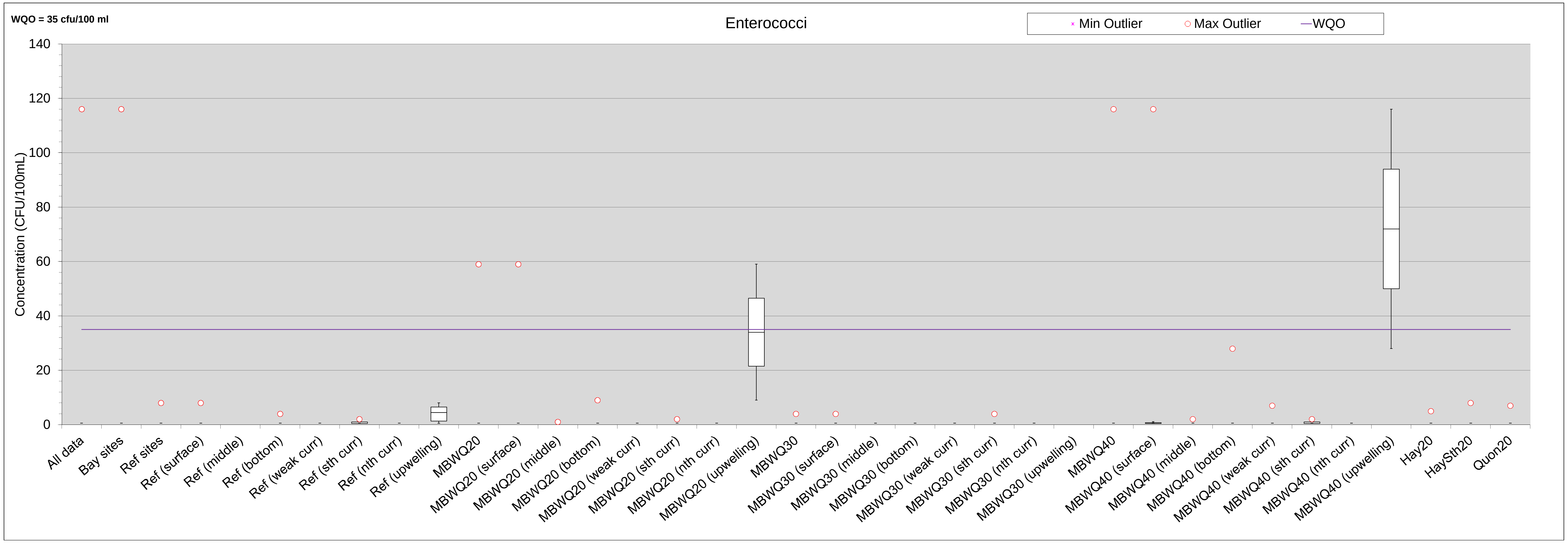

WQO = 0.02 mg/L
Ammonium (NH4+)
Min Outlier
Max Outlier
WQO
Concentration (mg/L)
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20


WQO = 0.025 mg/L
Total Phosphorus as P
Min Outlier
Max Outlier
WQO
Concentration (mg/L)
0.05
0.04
0.03
0.02
0.01
0.00
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20


WQO = 1 µg/L
Chlorophyll a
Min Outlier
Max Outlier
WQO
Concentration (µg/L)
0
2
4
6
8
10
12
14
16
18
20
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20


WQO = 0.01 mg/L
Reactive Phosphorus as P
Min Outlier
Max Outlier
WQO
Concentration (mg/L)
0.00
0.01
0.01
0.02
0.02
0.03
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20


WQO = 150 cfu/100 ml
Thermotolerant Faecal Coliforms
Min Outlier
Max Outlier
WQO
Concentration (CFU/100mL)
500
450
400
350
300
250
200
150
100
50
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20


WQO = 35 cfu/100 ml
Enterococci
Min Outlier
Max Outlier
WQO
Concentration (CFU/100mL)
140
120
100
80
60
40
20
0
All data
Bay sites
Ref sites
Ref (surface)
Ref (middle)
Ref (bottom)
Ref (weak curr)
Ref (sth curr)
Ref (nth curr)
Ref (upwelling)
MBWQ20
MBWQ20 (surface)
MBWQ20 (middle)
MBWQ20 (bottom)
MBWQ20 (weak curr)
MBWQ20 (sth curr)
MBWQ20 (nth curr)
MBWQ20 (upwelling)
MBWQ30
MBWQ30 (surface)
MBWQ30 (middle)
MBWQ30 (bottom)
MBWQ30 (weak curr)
MBWQ30 (sth curr)
MBWQ30 (nth curr)
MBWQ30 (upwelling)
MBWQ40
MBWQ40 (surface)
MBWQ40 (middle)
MBWQ40 (bottom)
MBWQ40 (weak curr)
MBWQ40 (sth curr)
MBWQ40 (nth curr)
MBWQ40 (upwelling)
Hay20
HaySth20
Quon20

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# Attachment 2 – Ambient Water Quality Review

**Table 9 Summary of ambient water quality analysis**

| Indicator | Units | Adopted Ambient Water Quality (AWQ) | Assumption | Number of samples AWQ based on | Observations |
|---|---|---|---|---|---|
| pH | pH units | 8.17 | Median of Bay sites | 163 | Median values were slightly higher for north current events but not a significant trend. Results generally within the bounds of the WQO lower and upper limits |
| Suspended solids | mg/L | 12 | Median of Bay sites excluding upwelling event samples | 161 | Median values were higher for the reference site and MBWQ20 upwelling events. Limited upwelling data available. Median values generally exceeded WQO |
| Turbidity | NTU | 0.3 | Median of Bay sites | 184 | Median values were higher in bottom waters at sites MBWQ20 and MBWQ30 |
| Electrical Conductivity | µS/cm | 53,408 | Median of Bay sites | 184 | No obvious trend, relatively consistent |
| Dissolved Oxygen | mg/L | 7.6 | Median of Bay sites | 178 | Median values slightly higher for weak current events but trend not significant. All values were above and therefore did not exceed the WQO |
| Secchi depth | m | 8.9 | Median of Bay sites | 58 | Median values slightly higher for north current events. Trend was not significant |
| Total Nitrogen (TN) | mg/L | 0.12 | Median of Bay sites excluding upwelling event samples | 161 | Was equal to or exceeded WQO with exception of Reference sites (middle), MBWQ20 north and MBWQ30 north.<br>Median highest for upwelling events |
| Oxides of Nitrogen (NOx) | mg/L | 0.017 | Median of Bay sites excluding upwelling event samples | 161 | Obvious trend showing increases in concentration for upwelling event. Limited upwelling data available. Some median values above the WQO |
| Nitrate | mg/L | 0.017 | Median of Bay sites excluding upwelling event samples | 161 | Obvious trend showing increases in concentration for upwelling event. Limited upwelling data available. All |

| Indicator | Units | Adopted Ambient Water Quality (AWQ) | Assumption | Number of samples AWQ based on | Observations |
|---|---|---|---|---|---|
| | | | | | values below WQO |
| Ammonia | mg/L | 0.008 | Median of Bay sites | 164 | Weak current events tended to show slightly higher concentrations but median values showed no obvious trend. Some median values were above the WQO |
| Ammonium | mg/L | 0.008 | Median of Bay sites | 164 | No obvious trend, median values below WQO |
| Total Phosphorus | mg/L | 0.007 | Median of Bay sites excluding upwelling event samples | 161 | Median values higher for upwelling events. Concentrations typically below the WQO |
| Orthophosphate | mg/L | 0.004 | Median of Bay sites excluding upwelling event samples | 161 | Median values were higher for the MBWQ20 and MBWQ40 upwelling events although reference site upwelling events aligned with other events. Concentrations mostly below the WQO |
| Chlorophyll a | µg/L | 1.2 | Median of Bay sites excluding upwelling event samples | 183 | Upwelling monitoring only undertaken at reference site. Data typically above the WQO for all areas with the reference upwelling median being the most significant exceedance |
| Faecal coliforms | cfu/100 ml | 0.5 | Median of Bay sites excluding upwelling event samples | 161 | Limited data above LOR with the exception of upwelling events |
| Enterococci | cfu/100 ml | 0.5 | Median of Bay sites excluding upwelling event samples | 143 | Limited data above LOR with the exception of upwelling events |
| Aluminium | µg/L | 4.5 | Median of Bay sites | 30 | Median values were higher for the upwelling events but limited data available to confirm trend. No impact on median value if upwelling events excluded |
| Antimony | µg/L | 0.25 | Median of Bay sites | 12 | Limited data available to detect trends, all below the LOR and WQO |
| Arsenic | µg/L | 1.8 | Median of Bay sites | 15 | Limited data available to detect trends, median values below the WQO, no obvious trend |
| Barium | µg/L | 5.9 | Median of Bay sites | 15 | Limited data available to detect trends, median values below the WQO, no obvious trend |
| Boron | µg/L | 4295 | Median of Bay sites | 12 | Limited data available to detect trends, median values generally above the WQO. Only recreational WQO available for Boron, which does not consider higher values typically in the marine environment. |
| Cadmium | µg/L | 0.1 | Median of Bay sites | 12 | Limited data available to detect trends, all below LOR |

| Indicator | Units | Adopted Ambient Water Quality (AWQ) | Assumption | Number of samples AWQ based on | Observations |
|---|---|---|---|---|---|
| | | | | | and well below WQO |
| Chromium | µg/L | 0.25 | Median of Bay sites | 15 | Limited data available to detect trends, mostly below LOR and well below WQO |
| Cobalt | µg/L | 0.025 | Median of Bay sites | 12 | Limited data available to detect trends, mostly below LOR and well below WQO |
| Copper | µg/L | 0.20 | Median of Bay sites | 36 | Limited data available to detect trends. Some median values above WQO |
| Iron | µg/L | 5 | Median of Bay sites | 30 | Median values were slightly higher for upwelling events were slightly higher but limited data available to confirm trend. No impact on median value if upwelling events excluded. |
| Lead | µg/L | 0.1 | Median of Bay sites | 30 | Limited data available to detect trends, mostly below LOR and all below WQO |
| Manganese | µg/L | 0.25 | Median of Bay sites | 30 | Limited data available to detect trends, all below WQO |
| Mercury | µg/L | 0.05 | Median of Bay sites | 30 | Limited data available to detect trends, all below WQO |
| Nickel | µg/L | 0.25 | Median of Bay sites | 12 | Limited data available to detect trends, all below WQO |
| Selenium | µg/L | 1 | Median of Bay sites | 12 | Limited data available to detect trends, all below LOR and WQO |
| Silver | µg/L | 0.35 | Median of Bay sites | 30 | Limited data available to detect trends, typically below WQO |
| Zinc | µg/L | 2.50 | Median of Bay sites | 36 | Limited data available to detect trends, mostly below LOR and generally below WQO |

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# Attachment 3 - Treated effluent water quality assumptions

**Table 10 Treated effluent water quality assumptions**

| Indicator | Units | Treated effluent | Assumption |
|---|---|---|---|
| pH | pH units | 6.5-8.5 | Discharge criteria - 100$^{th}$ percentile limit (AECOM, 2018) |
| Suspended solids | mg/L | 30 | Discharge criteria - 100$^{th}$ percentile limit (AECOM, 2018) |
| Electrical Conductivity | µS/cm | 874 | 90$^{th}$ percentile of historical monitoring data |
| Dissolved Oxygen | mg/L | 12.9 | 90$^{th}$ percentile of historical monitoring data |
| Total Nitrogen | mg/L | 15 | Discharge criteria - 100$^{th}$ percentile limit (AECOM, 2018) |
| Oxides of Nitrogen (NOx) | mg/L | 8.06 | 90$^{th}$ percentile of historical monitoring data |
| Ammonia | mg/L | 5 | Discharge criteria - 100$^{th}$ percentile limit (AECOM, 2018) |
| Total Phosphorus | mg/L | 13 | Discharge criteria - 90$^{th}$ percentile limit (AECOM, 2018) |
| Orthophosphate | mg/L | 11 | 90$^{th}$ percentile of historical monitoring data |
| Chlorophyll a | µg/L | 68.8 | 90$^{th}$ percentile of historical monitoring data |
| Faecal coliforms | cfu/100 ml | 200 | Discharge criteria - 90$^{th}$ percentile limit (AECOM, 2018) |
| Enterococci | cfu/100 ml | 188 | 90$^{th}$ percentile of historical monitoring data |
| Aluminium | µg/L | 74.6 | 90$^{th}$ percentile of historical monitoring data |
| Antimony | µg/L | 1.5 | 90$^{th}$ percentile of historical monitoring data |
| Arsenic | µg/L | 3 | 90$^{th}$ percentile of historical monitoring data |
| Barium | µg/L | 10.2 | 90$^{th}$ percentile of historical monitoring data |
| Boron | µg/L | 80 | 90$^{th}$ percentile of historical monitoring data |
| Cadmium | µg/L | 0.025 | 90$^{th}$ percentile of historical monitoring data |
| Chromium (Total) | µg/L | 1 | 90$^{th}$ percentile of historical monitoring data |
| Cobalt | µg/L | 0.5 | 90$^{th}$ percentile of historical monitoring data |
| Copper | µg/L | 272.2 | 90$^{th}$ percentile of historical monitoring data |
| Iron | µg/L | 706 | 90$^{th}$ percentile of historical monitoring data |
| Lead | µg/L | 5.6 | 90$^{th}$ percentile of historical monitoring data |
| Manganese | µg/L | 54.2 | 90$^{th}$ percentile of historical monitoring data |

| Indicator | Units | Treated effluent | Assumption |
|---|---|---|---|
| Mercury | µg/L | 0.05 | $90^{th}$ percentile of historical monitoring data |
| Nickel | µg/L | 3 | $90^{th}$ percentile of historical monitoring data |
| Selenium | µg/L | 7.8 | $90^{th}$ percentile of historical monitoring data |
| Silver | µg/L | 0.5 | $90^{th}$ percentile of historical monitoring data |
| Zinc | µg/L | 140.4 | $90^{th}$ percentile of historical monitoring data |

# Appendix B

## Near-Field Modelling Plots (CORMIX)

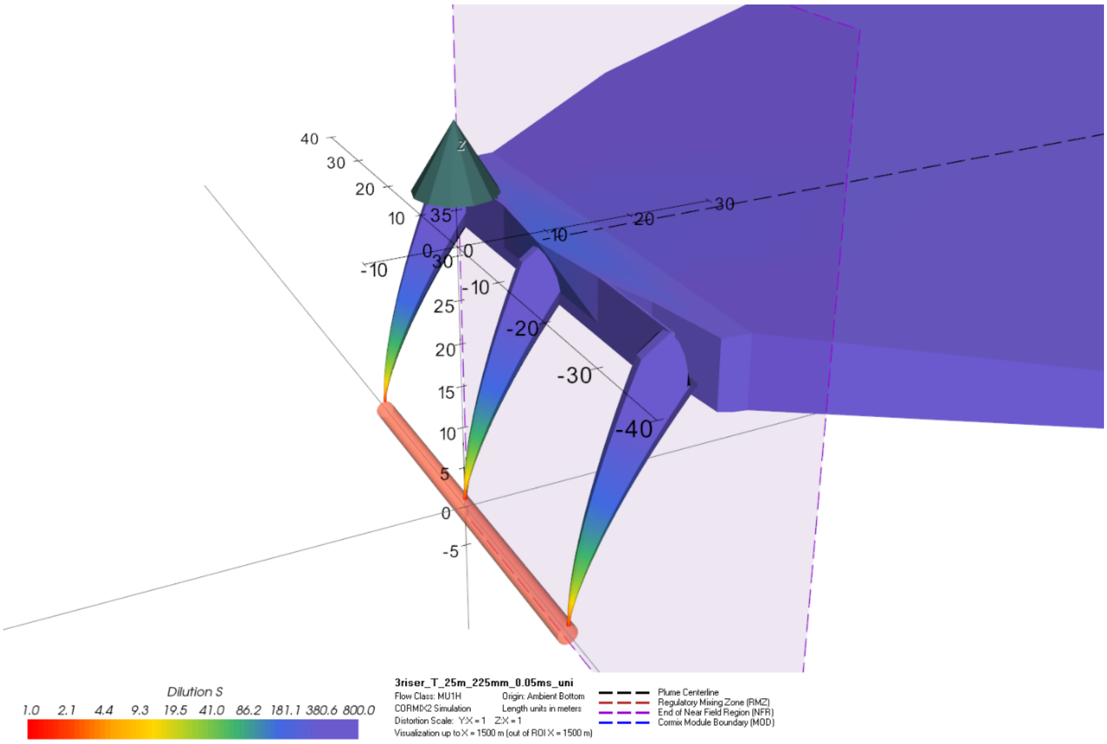


**Figure 11. Near-field dilution contours: uniform conditions, 0.05 m/s current**

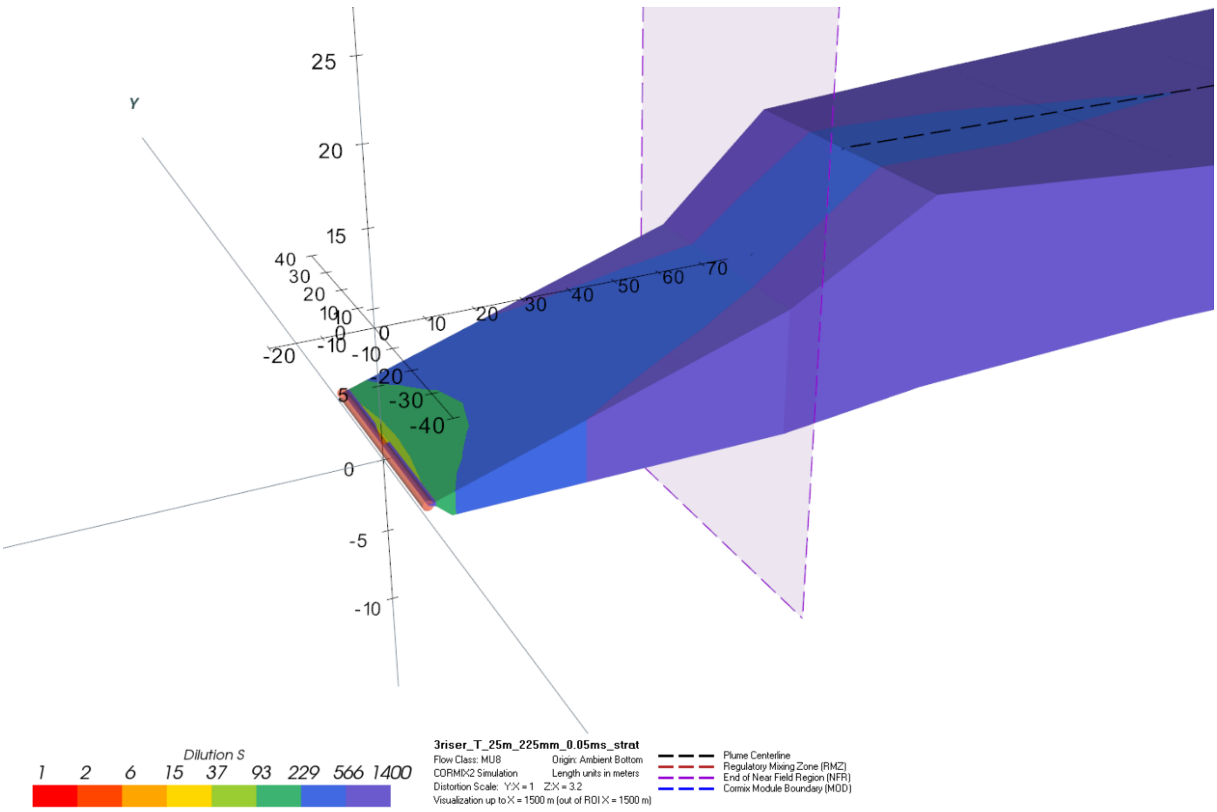


**Figure 12. Near-field dilution contours: stratified conditions, 0.05 m/s current**

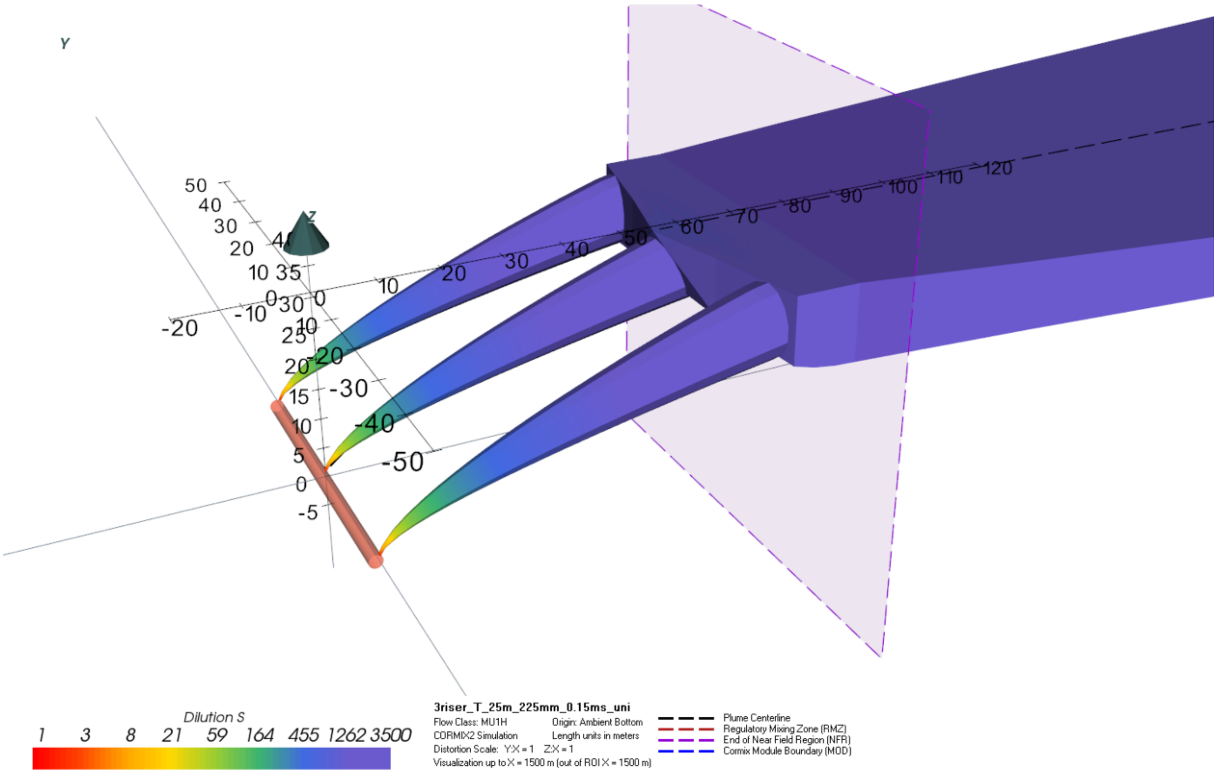


**Figure 13. Near-field dilution contours: uniform conditions, 0.15 m/s current**

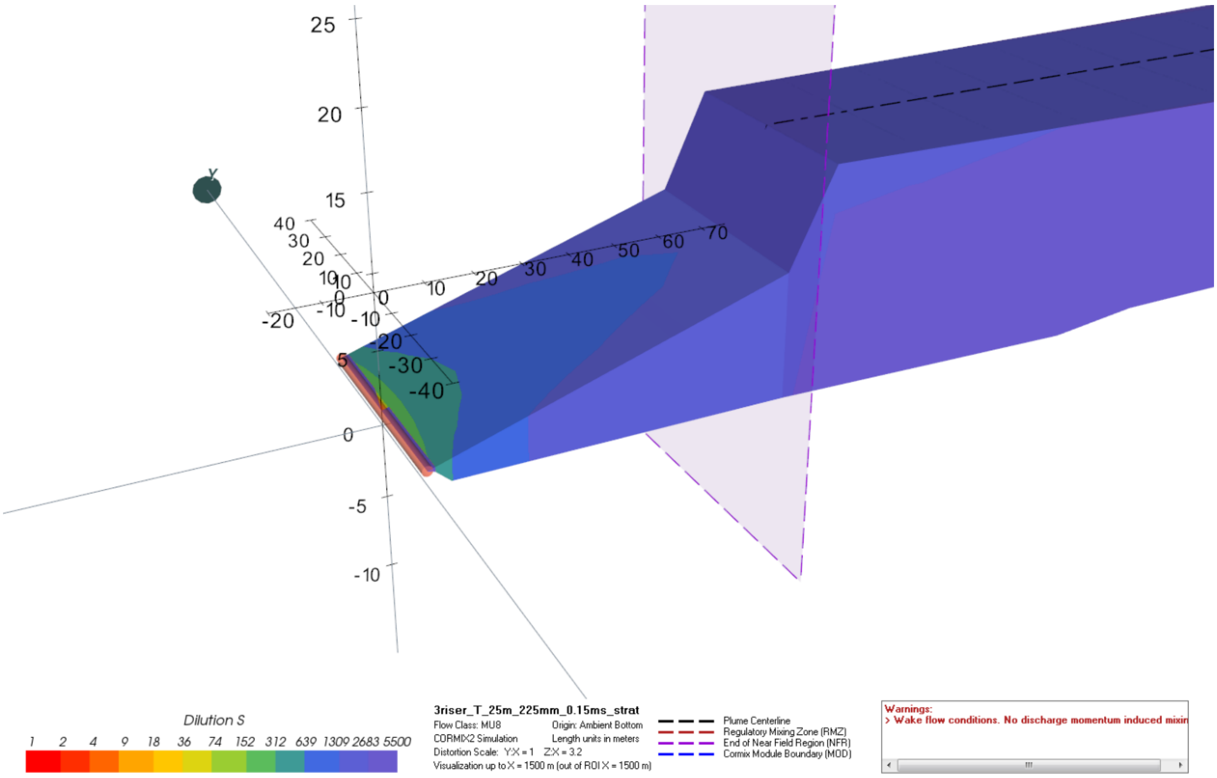


**Figure 14. Near-field dilution contours: stratified conditions, 0.15 m/s current**

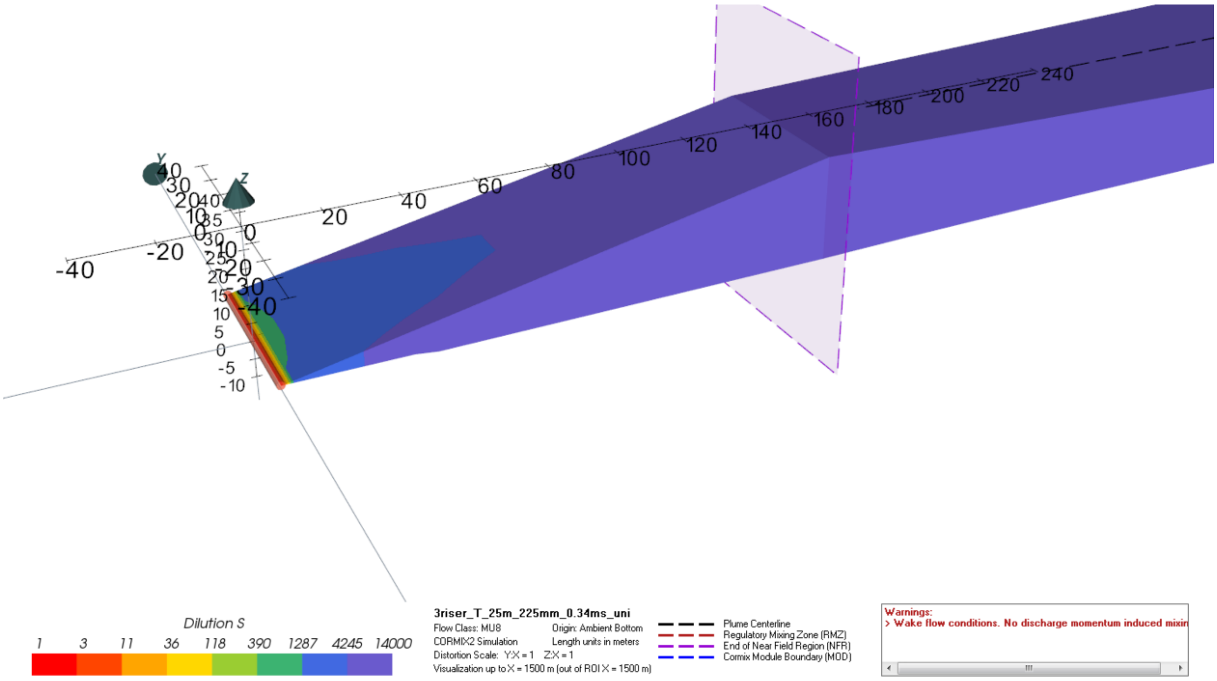


**Figure 15. Near-field dilution contours: uniform conditions, 0.34 m/s current**

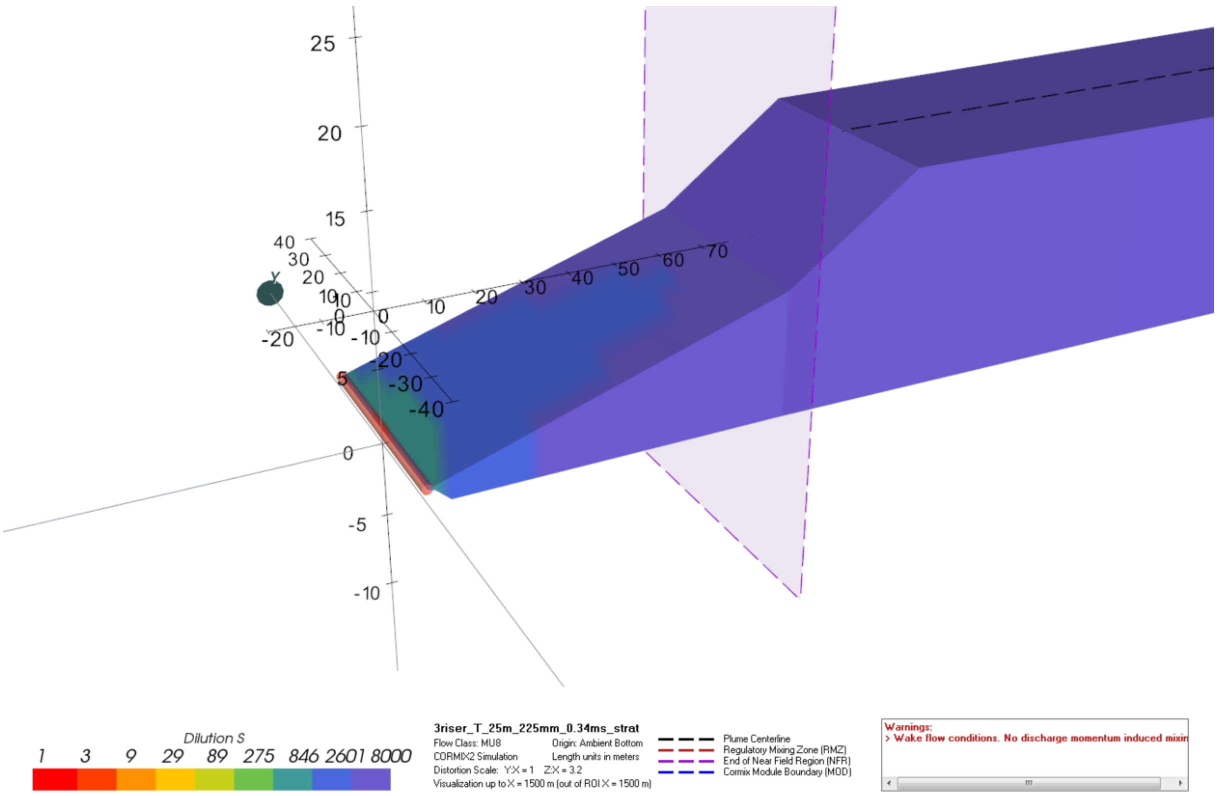


**Figure 16. Near-field dilution contours: stratified conditions, 0.34 m/s current**

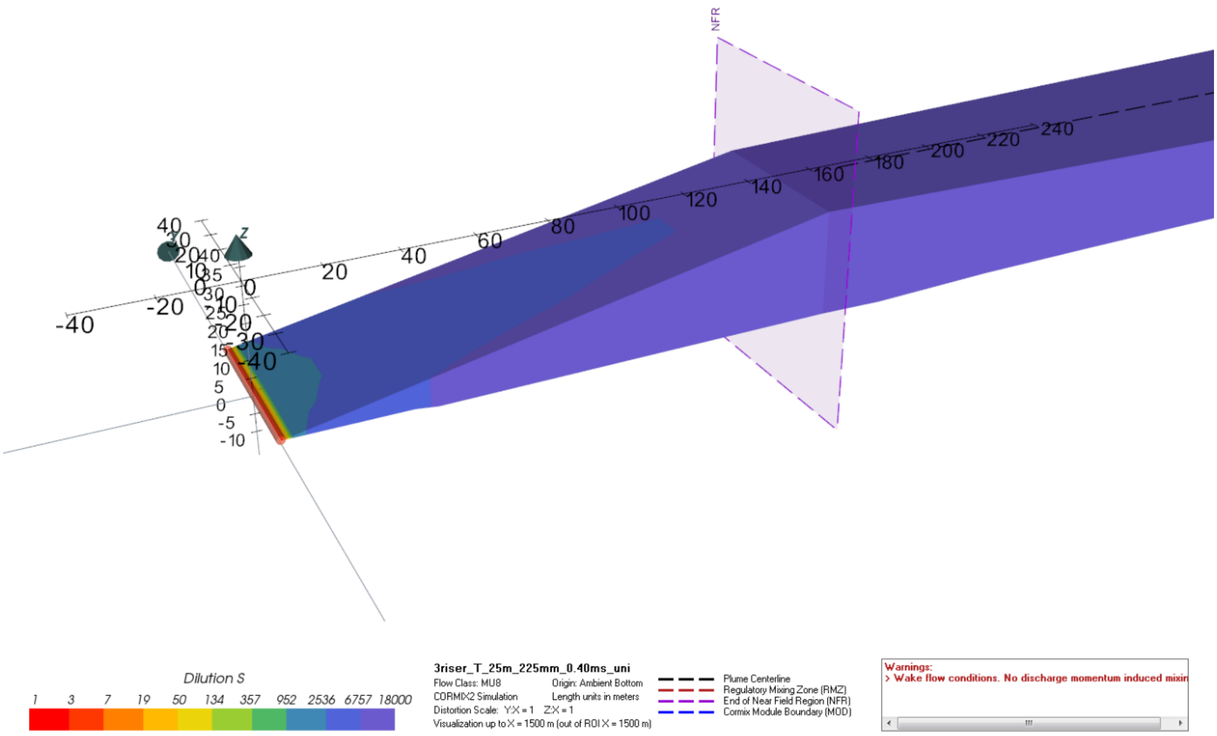


**Figure 17. Near-field dilution contours: uniform conditions, 0.40 m/s current**

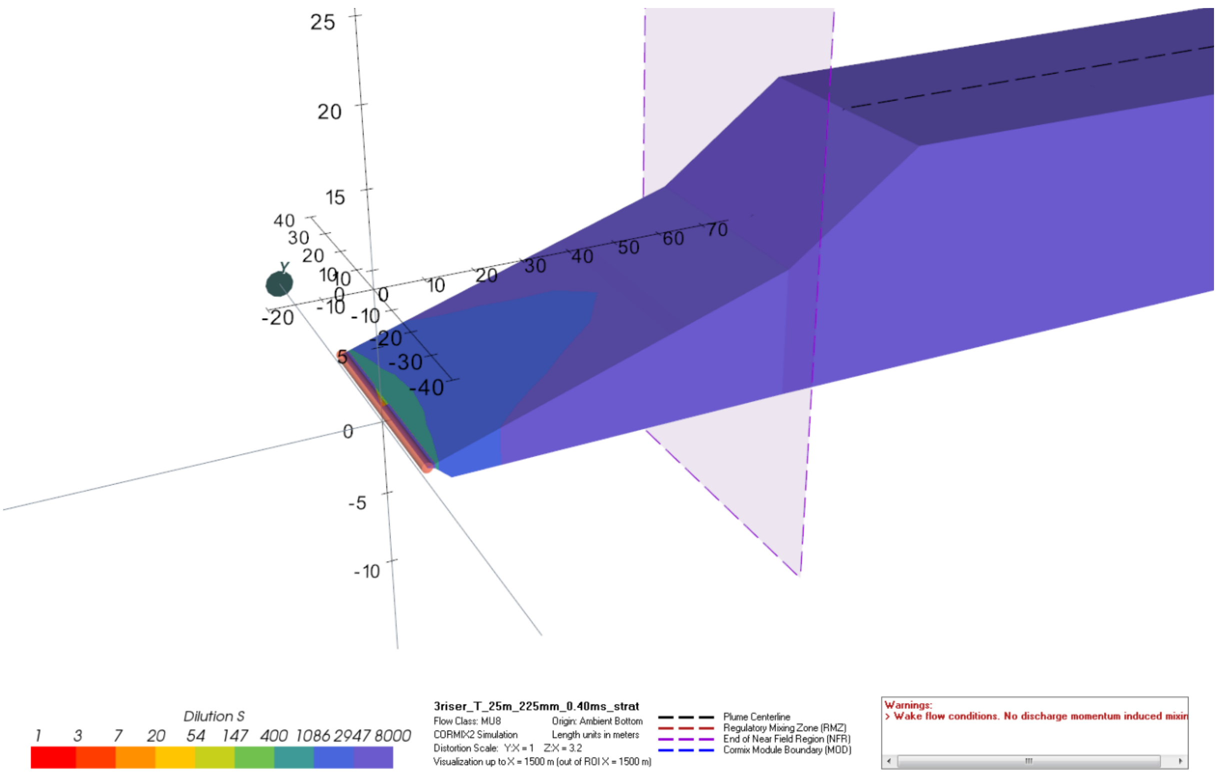


**Figure 18. Near-field dilution contours: stratified conditions, 0.40 m/s current**

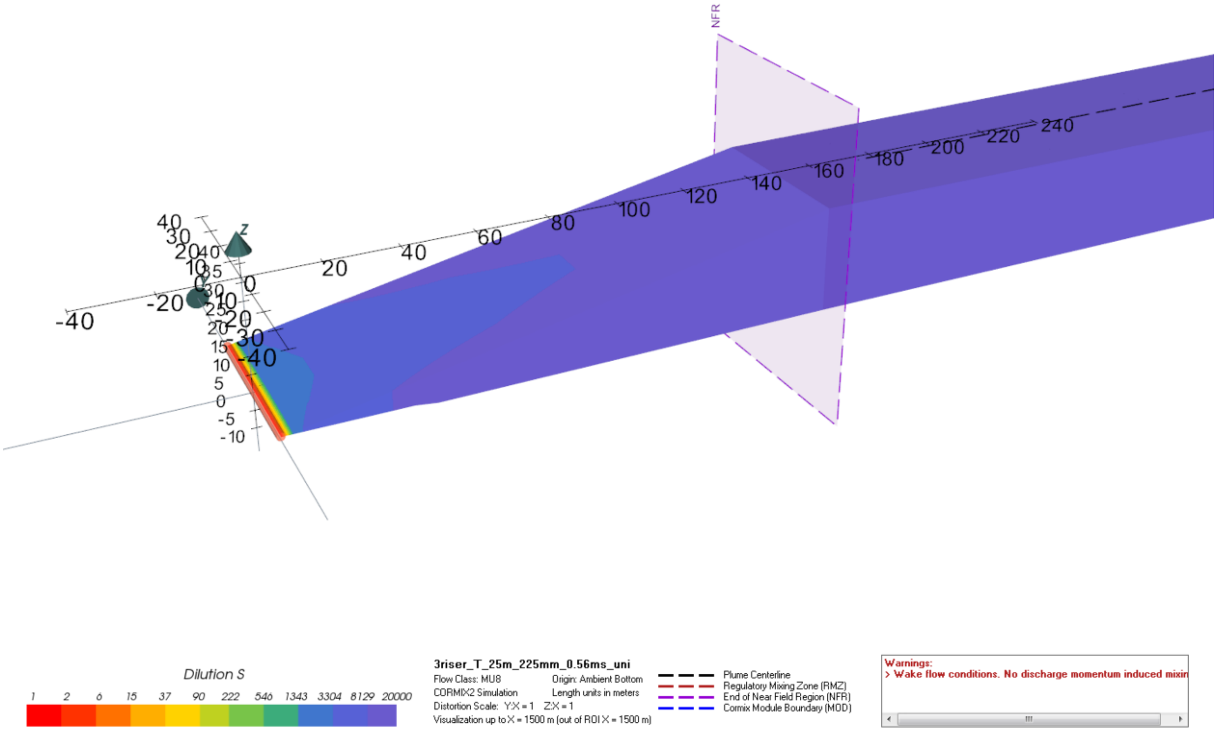


**Figure 19. Near-field dilution contours: uniform conditions, 0.56 m/s current**

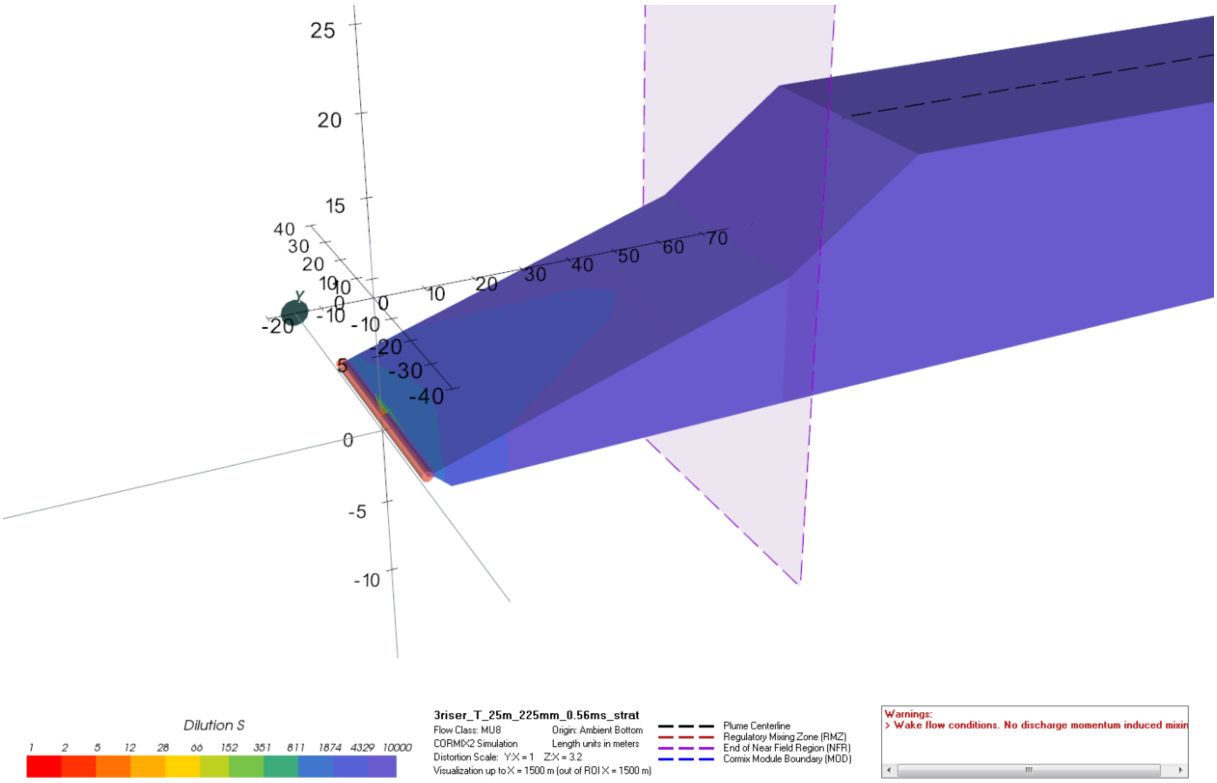


**Figure 20. Near-field dilution contours: stratified conditions, 0.56 m/s current**

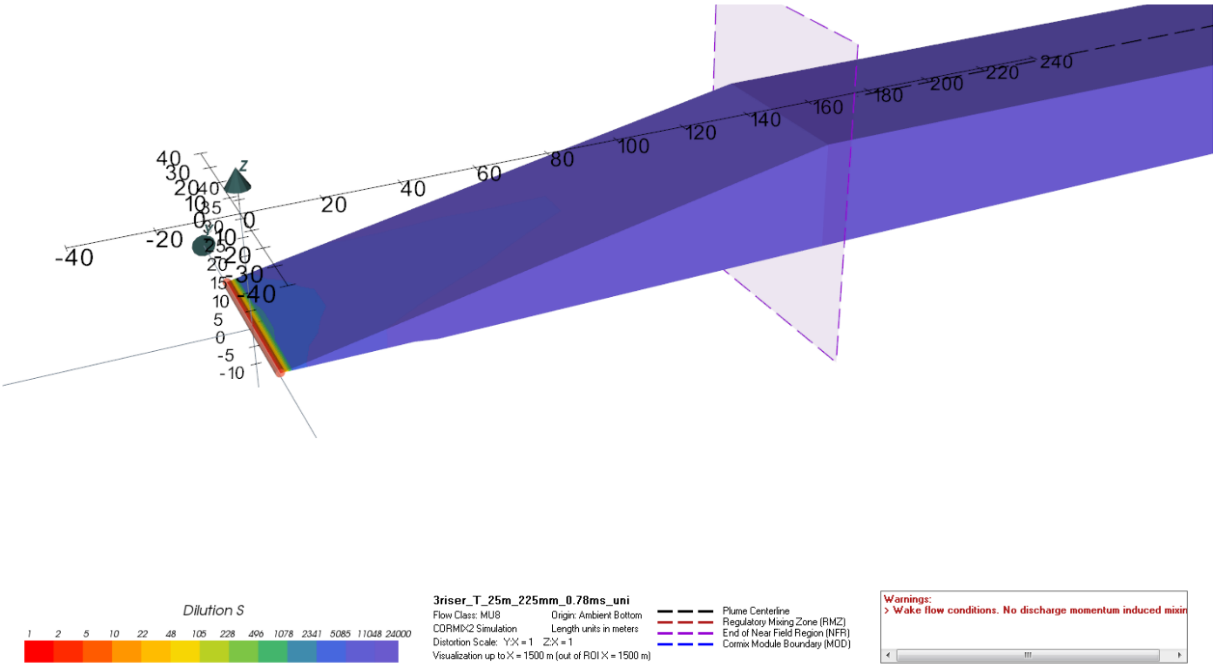


**Figure 21. Near-field dilution contours: uniform conditions, 0.78 m/s current**

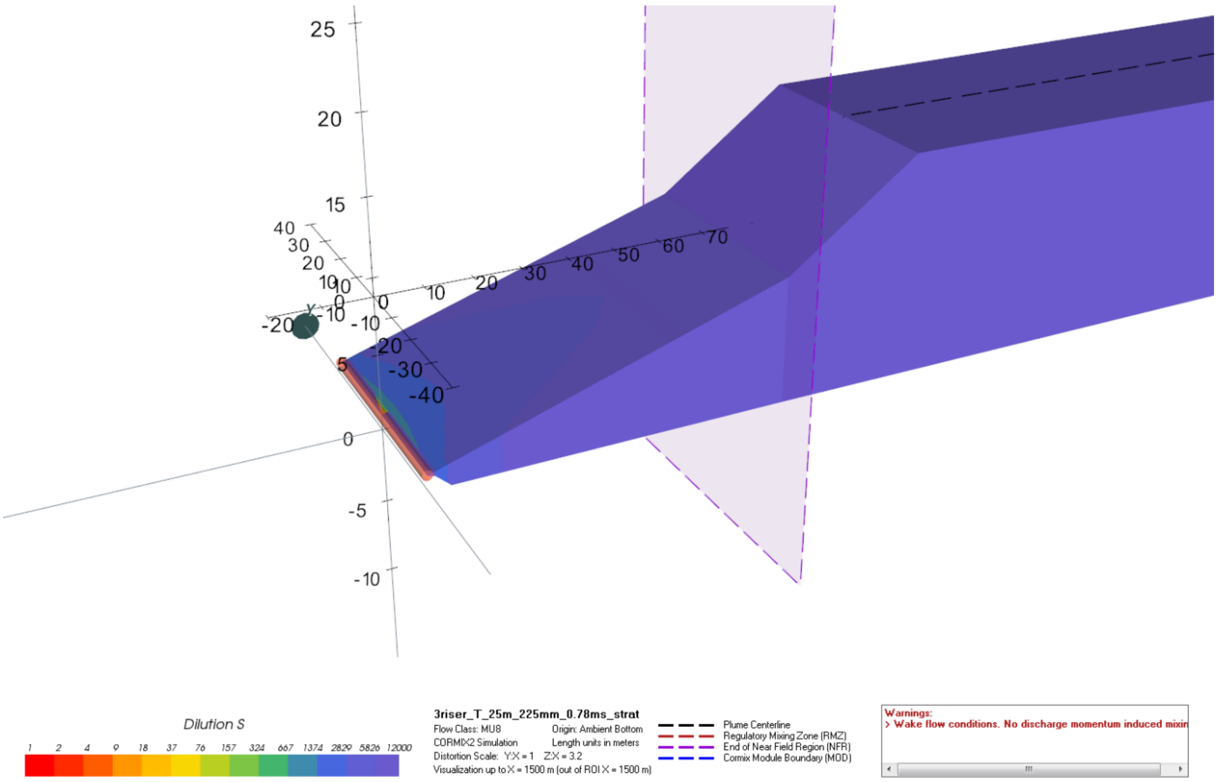


**Figure 22. Near-field dilution contours: stratified conditions, 0.78 m/s current**

# Appendix C

## Dispersion Methodology Memorandum

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# Memorandum

| | | | |
|---|---|---|---|
| To | Toby Browne (BVSC), Ross Bailey (NSWPWA) | Page | Page 1 of 15 |
| CC | Ed Couriel (MHL) | | |
| Subject | Merimbula STP Upgrade and Ocean Outfall Concept Design & Environmental Assessment – Dispersion Modelling Methodology Memorandum | | |
| From | Stuart Bettington, Eric Lemont | | |
| File/Ref No. | 60541653 | Date | 09-Dec-2019 |

## 1.0 Introduction

This memorandum summarises the dispersion modelling methodology proposed to support the Merimbula Sewage Treatment Plant (STP) Upgrade and Ocean Outfall Concept Design and Environmental Assessment.

AECOM's modelling scope accounts for 40 dispersion modelling scenarios which are outlined herein. An additional four model runs were added during the project to represent existing shore-based outfall discharges, bringing the total number of dispersion runs to 44. The proposed dispersion modelling methodology includes a variety of ambient and operating conditions in an effort to encompass the range of treated effluent plume behaviour.

The dispersion modelling will account for both a near-field mixing analysis (e.g., CORMIX) in conjunction with the far-field modelling using the Delft3D model. This memorandum outlines the proposed list of 44 dispersion modelling runs and the rationale behind the pertinent model input parameters selected for the model runs.

## 2.0 Dispersion Modelling Scenarios

During the far-field model development, a preliminary list of dispersion model runs was presented and were primarily based on different current strengths and directions (AECOM, 2018). Building on that overall methodology, Table 1 summarises the general modelling scenarios selected for the dispersion modelling task. The detailed list of the 44 dispersion runs is included in Appendix A.

The previous modelling studies conducted by AECOM in 2010 and MHL in 2015 did not include modelling of the near-field outfall plume behaviour, which is of great importance for estimating the initial mixing characteristics and plume height of rise for different current speed and stratification levels. Each scenario presented in Table 1 will include CORMIX near-field simulations which will be translated as inputs to the far-field modelling.

There are currently four outfall locations currently under consideration for the treated effluent outfall location as shown on Figure 1. Each model scenario presented in Table 1 will be repeated for each potential outfall location, unless otherwise noted in Appendix A. If an outfall location is eliminated from consideration during the dispersion modelling task, its respective dispersion model runs may be replaced by other scenarios discussed in Section 4.

The statistical analysis of the Haycock Point mooring data used to determine the currents is discussed further in the following section (Section 3).

All dispersion model runs will consider a typical tide condition derived from the nearby Eden tide station. To simplify the modelling approach, wind will not be modelled and the specified currents will be the main driver of plume behaviour. For the stratified model runs, the temperature profile will be determined from a review of the available data and a literature review. These will be discussed with MHL prior to selecting the final temperature inputs to use in the models.

**Table 1. Proposed Sets of Dispersion Modelling Runs**

| Set ID | Set Name | Treated Effluent Flow (L/s) | Current Direction | Current Speed[A] (m/s) | Stratified Ambient Conditions |
|---|---|---|---|---|---|
| 1 | $10^{th}$ %ile southward current without stratification | 80 | Southward | 0.15 | No |
| 2 | $10^{th}$ %ile northward current without stratification | 80 | Northward | 0.05 | No |
| 3 | $50^{th}$ %ile southward current without stratification | 80 | Southward | 0.40 | No |
| 4 | $50^{th}$ %ile northward current without stratification | 80 | Northward | 0.15 | No |
| 5 | $90^{th}$ %ile southward current without stratification | 80 | Southward | 0.56 | No |
| 6 | $90^{th}$ %ile northward current without stratification | 80 | Northward | 0.34 | No |
| 7 | $10^{th}$ %ile southward current with stratification | 80 | Southward | 0.15 | Yes |
| 8 | $10^{th}$ %ile northward current with stratification | 80 | Northward | 0.05 | Yes |
| 9 | $90^{th}$ %ile southward current with stratification | 80 | Southward | 0.56 | Yes |
| 10 | $90^{th}$ %ile northward current with stratification | 80 | Northward | 0.34 | Yes |
| 11 | Extreme currents without stratification | 80 | N/A<br>Northward<br>Southward | 0.00<br>0.53<br>0.96 | No |
| 12 | Extreme currents with stratification | 80 | N/A<br>Northward<br>Southward | 0.00<br>0.53<br>0.96 | Yes |
| Notes : Currents were based on Haycock Point mooring statistics for approximately 15 months of mooring data collected by MHL during 31 March 2015 to 26 October 2016 (MHL, 2017). The current data was isolated into directional components (i.e., North, South, East, West) for the statistical analysis. | | | | | |

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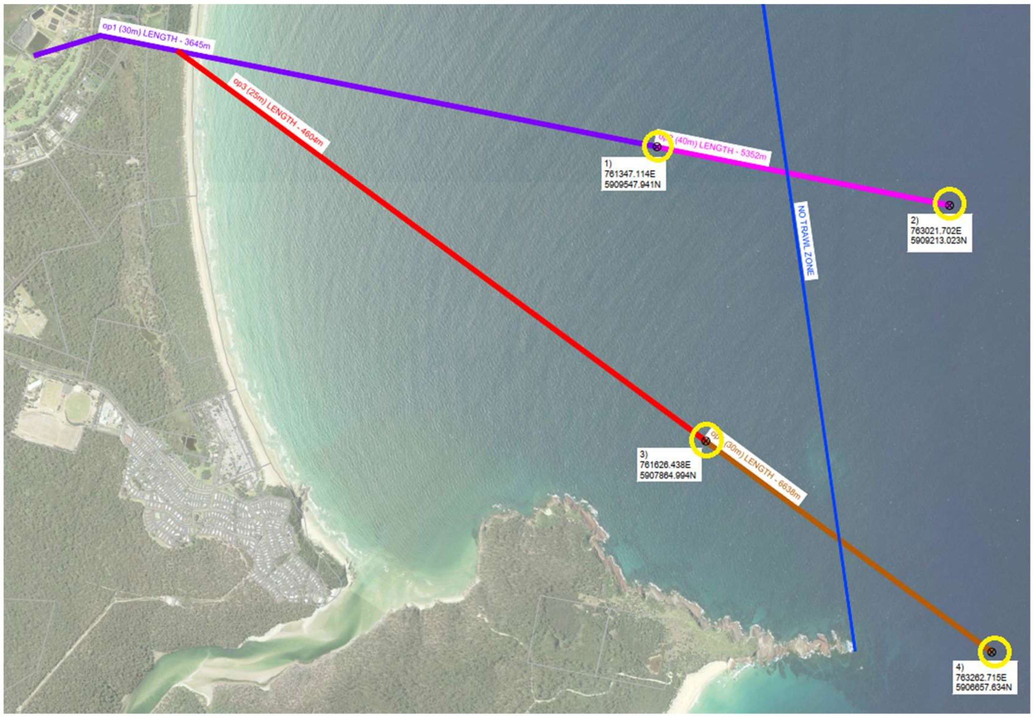


**Figure 1. Outfall Locations Under Consideration**

## 3.0 Haycock Point Current Statistics

The currents shown in Table 1 were based on Haycock Point mooring statistics for approximately 15 months of mooring data collected by MHL during 31 March 2015 to 26 October 2016 (MHL, 2017). The current data was isolated into directional components (i.e., North, South, East, West) for the statistical analysis. Since the predominant flow direction is parallel to the coast, only north and south currents were considered for the dispersion modelling scenarios. Appendix B contains a detailed summary of the statistics.

The proposed currents are based on the 10$^{th}$, 50$^{th}$ and 90$^{th}$ percentile value for the northern and southern components of the measured current data. This is meant to be representative of weak, typical and strong current conditions. As a sensitivity test, runs for a zero current condition and the maximum northward and maximum southward currents have also been included.

The non-stratified currents (Set Nos. 1 to 6) presented in Table 1, represent the range of currents that typically impact the area and will describe the range of plume behaviours. Stratified conditions (Set Nos. 7 to 10) are described for the weaker (10$^{th}$ percentile) and stronger (90$^{th}$ percentile) current speeds to encompass a range of observed current behaviour.

The adopted current conditions describe the bulk of hydrodynamic conditions that the effluent plume will encounter. As discussed later the option of including additional conditions (e.g. a flow reversal run or a 50% percentile stratified flow scenario) could be added if the number of outfall scenarios were reduced (e.g. if the near shore or offshore or southern options were examined for 50% flow and found to be not preferred).


**Figure 2. Haycock Point Mooring Location**

## 4.0 Other Considerations for Dispersion Modelling Scenarios

The 44 dispersion runs contained in Appendix A consist of repeat runs for the various outfall locations being considered. If any of the outfall locations are ruled out of consideration during the dispersion modelling exercise, its remaining model runs will not be performed.

In this potential scenario, additional dispersion modelling scenarios will be considered in place of the omitted outfall locations. These revised scenarios will be discussed with the client and MHL prior to selecting a replacement model run.

## 5.0 Three-Dimensional Dispersion Modelling Considerations

As discussed in the model calibration report, in the absence of suitable non-prescriptive boundary conditions, it was decided that the two-dimensional far-field model would not be extended to three-dimensions (AECOM, 2019).

When modelling plumes in Delft3D, the depth-averaged modelling tool assumes simplified flow behaviours based on parabolic flow profiles. This modelling is acceptable for situations where surface plumes are driven by oceanic currents. The far-field three-dimensional modelling tool was primarily intended to include depth varying factors such as stratification or strong surface currents influenced by wind.

Three-dimensional plume behaviour will instead be evaluated with the steady-state model CORMIX and used to determine if the plume may be trapped beneath the pycnocline during stratified conditions.

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Based on guidance from the EPA, the water quality objectives should be achieved within the near-field mixing region (i.e., using the CORMIX model results).

## 6.0 Dispersion Modelling Status

As listed in Table 1, two of the dispersion modelling scenarios have been completed at the time of this memorandum. The results of the dispersion modelling for Set Nos. 1 and No. 4 were previewed on 30 August 2019 at a meeting with the EPA. The remainder of the dispersion modelling runs are in progress and due to be completed by the end of December 2019.

## 7.0 Dispersion Modelling Summary

The proposed dispersion modelling scenarios consist of a mix of near-field and far-field model runs for various ambient conditions. Using a mix of ambient current strengths and directions, the proposed modelling approach encompasses a variety of potential treated effluent plume behaviours expected at the proposed outfall locations. It is anticipated that the proposed modelling approach will provide a reasonable representation of the treated effluent plume dilution and trajectory under these conditions.

When applying the dispersion model results, it should be remembered that such models are not an exact science and they represent simplified versions of very complex processes. The limitations and uncertainties of modelling need to be reflected in how the results are utilised for design activities.

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## References

AECOM, 2018. *Merimbula Sewage Treatment Plant and Deep Ocean Outfall Concept Design and Environmental Assessment: Model Development and Boundary Conditions Selection (Revision B).* AECOM, dated 31 January 2018.

AECOM, 2019. *Merimbula Ocean Outfall: Hydrodynamic Modelling – Coastal Model Calibration Report.* AECOM, dated 13 June 2019.

MHL, 2015. *Proposed Merimbula Deep Outfall, Relative Hydrodynamic Merits of Different Outfall Locations (Report MHL2418).* Manly Hydraulics Laboratory, dated 18 November 2015.

MHL, 2017. *Merimbula Deep Ocean Outfall, Oceanographic Mooring Data Collection (Report MHL2374).* Manly Hydraulics Laboratory, dated April 2017.

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# Appendix A: Matrix of Dispersion Modelling Scenarios

| Run Count | Run Title | Ambient Conditions | | | | | Discharge Details | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Tide Conditions | Ambient Current Speed | Ambient Current Direction | Ambient Analyte Conc. | Stratified Condition | Outfall Location/Depth | Wastewater Flow | Wastewater Density | Release Mode, Time/Duration |
| | | | m/s | | mg/L | | site, m deep | $m^3/s$ | kg/m3 | |
| **Set #1** | **Future WW flow, typical tide and south current (10th percentile S current only), no stratification** | | | | | | | | | |
| 1 | Future WW flow, typical tide and south current (10th percentile S current only), no stratification | typical | 0.15 | southward | median | none | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 2 | Future WW flow, typical tide and south current (10th percentile S current only), no stratification | typical | 0.15 | southward | median | none | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 3 | Future WW flow, typical tide and south current (10th percentile S current only), no stratification | typical | 0.15 | southward | median | none | Location 3 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 4 | Future WW flow, typical tide and south current (10th percentile S current only), no stratification | typical | 0.15 | southward | median | none | Location 4 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 5 | Future WW flow, typical tide and south current (10th percentile S current only), no stratification | typical | 0.15 | southward | median | none | Existing (shore) | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #2** | **Future WW flow, typical tide and north current (10th percentile N current only), no stratification** | | | | | | | | | |
| 6 | Future WW flow, typical tide and north current (10th percentile N current only), no stratification | typical | 0.05 | northward | median | none | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 7 | Future WW flow, typical tide and north current (10th percentile N current only), no stratification | typical | 0.05 | northward | median | none | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 8 | Future WW flow, typical tide and north current (10th percentile N current only), no stratification | typical | 0.05 | northward | median | none | Location 3 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 9 | Future WW flow, typical tide and north current (10th percentile N current only), no stratification | typical | 0.05 | northward | median | none | Location 4 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 10 | Future WW flow, typical tide and north current (10th percentile N current only), no stratification | typical | 0.05 | northward | median | none | Existing (shore) | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #3** | **Future WW flow, typical tide and south current (50th percentile S current only), no stratification** | | | | | | | | | |
| 11 | Future WW flow, typical tide and south current (50th percentile S current only), no stratification | typical | 0.40 | southward | median | none | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 12 | Future WW flow, typical tide and south current (50th percentile S current only), no stratification | typical | 0.40 | southward | median | none | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 13 | Future WW flow, typical tide and south current (50th percentile S current only), no stratification | typical | 0.40 | southward | median | none | Location 3 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 14 | Future WW flow, typical tide and south current (50th percentile S current only), no stratification | typical | 0.40 | southward | median | none | Location 4 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 15 | Future WW flow, typical tide and south current (50th percentile S current only), no stratification | typical | 0.40 | southward | median | none | Existing (shore) | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #4** | **Future WW flow, typical tide and north current (50th percentile N current only), no stratification** | | | | | | | | | |
| 16 | Future WW flow, typical tide and north current (50th percentile N current only), no stratification | typical | 0.15 | northward | median | none | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 17 | Future WW flow, typical tide and north current (50th percentile N current only), no stratification | typical | 0.15 | northward | median | none | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 18 | Future WW flow, typical tide and north current (50th percentile N current only), no stratification | typical | 0.15 | northward | median | none | Location 3 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 19 | Future WW flow, typical tide and north current (50th percentile N current only), no stratification | typical | 0.15 | northward | median | none | Location 4 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 20 | Future WW flow, typical tide and north current (50th percentile N current only), no stratification | typical | 0.15 | northward | median | none | Existing (shore) | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #5** | **Future WW flow, typical tide and south current (90th percentile S current only), no stratification** | | | | | | | | | |
| 21 | Future WW flow, typical tide and south current (90th percentile S current only), no stratification | typical | 0.56 | southward | median | none | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 22 | Future WW flow, typical tide and south current (90th percentile S current only), no stratification | typical | 0.56 | southward | median | none | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 23 | Future WW flow, typical tide and south current (90th percentile S current only), no stratification | typical | 0.56 | southward | median | none | Location 3 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 24 | Future WW flow, typical tide and south current (90th percentile S current only), no stratification | typical | 0.56 | southward | median | none | Location 4 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |

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| Run Count | Run Title | Ambient Conditions | | | | | Discharge Details | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Tide Conditions | Ambient Current Speed | Ambient Current Direction | Ambient Analyte Conc. | Stratified Condition | Outfall Location/Depth | Wastewater Flow | Wastewater Density | Release Mode, Time/Duration |
| | | | *m/s* | | mg/L | | *site, m deep* | *$m^3/s$* | *kg/m3* | |
| **Set #6** | **Future WW flow, typical tide and north current (90th percentile N current only), no stratification** | | | | | | | | | |
| 25 | Future WW flow, typical tide and north current (90th percentile N current only), no stratification | typical | 0.34 | northward | median | none | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 26 | Future WW flow, typical tide and north current (90th percentile N current only), no stratification | typical | 0.34 | northward | median | none | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 27 | Future WW flow, typical tide and north current (90th percentile N current only), no stratification | typical | 0.34 | northward | median | none | Location 3 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 28 | Future WW flow, typical tide and north current (90th percentile N current only), no stratification | typical | 0.34 | northward | median | none | Location 4 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #7** | **Future WW flow, typical tide and south current (10th percentile S current only), with stratification** | | | | | | | | | |
| 29 | Future WW flow, typical tide and south current (10th percentile S current only), with stratification | typical | 0.15 | southward | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 30 | Future WW flow, typical tide and south current (10th percentile S current only), with stratification | typical | 0.15 | southward | median | particle release at depth | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 31 | Future WW flow, typical tide and south current (10th percentile S current only), with stratification | typical | 0.15 | southward | median | particle release at depth | Location 4 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #8** | **Future WW flow, typical tide and north current (10th percentile N current only), with stratification** | | | | | | | | | |
| 32 | Future WW flow, typical tide and north current (10th percentile N current only), with stratification | typical | 0.05 | northward | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 33 | Future WW flow, typical tide and north current (10th percentile N current only), with stratification | typical | 0.05 | northward | median | particle release at depth | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 34 | Future WW flow, typical tide and north current (10th percentile N current only), with stratification | typical | 0.05 | northward | median | particle release at depth | Location 4 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #9** | **Future WW flow, typical tide and south current (90th percentile S current only), with stratification** | | | | | | | | | |
| 35 | Future WW flow, typical tide and north current (90th percentile S current only), with stratification | typical | 0.56 | northward | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 36 | Future WW flow, typical tide and north current (90th percentile S current only), with stratification | typical | 0.56 | northward | median | particle release at depth | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #10** | **Future WW flow, typical tide and north current (90th percentile N current only), with stratification** | | | | | | | | | |
| 37 | Future WW flow, typical tide and north current (90th percentile N current only), with stratification | typical | 0.34 | northward | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 38 | Future WW flow, typical tide and north current (90th percentile N current only), with stratification | typical | 0.34 | northward | median | particle release at depth | Location 2 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #11** | **Future WW flow, typical tide and extreme currents, no stratification** | | | | | | | | | |
| 39 | Future WW flow, typical tide and zero current, no stratification | typical | 0.00 | N/A | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 40 | Future WW flow, typical tide and maximum north current, no stratification | typical | 0.53 | northward | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 41 | Future WW flow, typical tide and maximum south current, no stratification | typical | 0.96 | southward | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| **Set #12** | **Future WW flow, typical tide and extreme currents, with stratification** | | | | | | | | | |
| 42 | Future WW flow, typical tide and zero current, with stratification | typical | 0.00 | N/A | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 43 | Future WW flow, typical tide and maximum north current, with stratification | typical | 0.53 | northward | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |
| 44 | Future WW flow, typical tide and maximum south current, with stratification | typical | 0.96 | southward | median | particle release at depth | Location 1 | DWF (0.08 $m^3/s$) | 1000 | Between 22:00 & 6:00 daily |

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# Appendix B: Haycock Point Statistics

**Statistics Comparison (ROMS model output vs Haycock Point observational data)**

For the statistics comparison, the following were compared:

- Statistics provided by MetOcean Solutions on 23 years (1 Jan 1994 to 30 Sep 2016) of the ROMS hind cast model output. Surface current velocities considered over the entire time period. (Source: MOS, 2017, *Merimbula Outfall, Current and water temperature climate at hydrodynamical model boundaries*, dated 19 February 2018).
- Statistics provided by AECOM on approximately 15 months of mooring data collected by MHL (during 31 March 2015 to 26 October 2016). For the statistics, daily averaged data was considered, both surface and depth averaged currents and both the North-South and East-West current components.

The locations of the model output and the data used to calculate statistics are shown in Figure A-1.

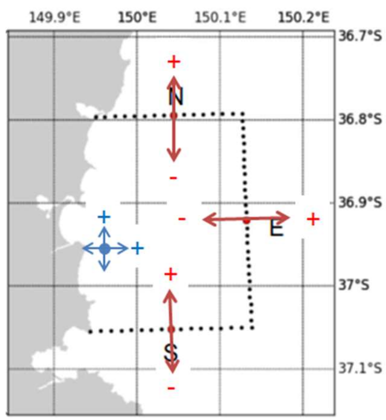


**Figure A-3. Locations for the statistics comparison (red = ROMS site N, E and S, blue = Haycock Point)**

The statistics comparison is provided in Table A-1. Also provided in Table A-1 are the statistics for Haycock Point directional currents. Haycock Point currents were isolated into northward, southward, eastward and westward current components and statistics were conducted on the current magnitudes.

Graphical comparison of currents in the N-S direction and the E-W direction are provided in Figures A-2 and A-3 respectively. Graphical representations of Haycock Point northward, southward, eastward and westward current components are provided in Figures A-4 and A-5.

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## Table A-2. Statistics comparison (between ROMS data and Haycock Point observations) and statistics for Haycock Point directional currents (N, S, E, W)

| | Statistics Comparison (ROMS vs Haycock Point Obs) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Data set** | **min** | **max** | **mean** | **std** | **p1** | **p5** | **p10** | **p50** | **p80** | **p90** | **p95** | **p98** | **p99** | **Notes** |
| **Currents in N-S direction** | ROMS, Site N (surface current) | -1.47 | 0.59 | -0.15 | 0.28 | -0.98 | -0.68 | -0.52 | -0.11 | 0.07 | 0.16 | 0.22 | 0.30 | 0.35 | ROMS statistics, surface current, all data |
| | ROMS, Site S (surface current) | -1.85 | 0.62 | -0.21 | 0.32 | -1.17 | -0.81 | -0.62 | -0.17 | 0.05 | 0.15 | 0.23 | 0.32 | 0.36 | ROMS statistics, surface current, all data |
| | Haycock Pt Obs (N-S comp, surface current) | -0.96 | 0.53 | -0.32 | 0.24 | -0.78 | -0.62 | -0.56 | -0.37 | -0.15 | 0.03 | 0.16 | 0.27 | 0.36 | Haycock Pt statistics, surface current |
| | Haycock Pt Obs (N-S comp, depth avg current) | -0.50 | 0.33 | -0.13 | 0.11 | -0.41 | -0.29 | -0.24 | -0.14 | -0.06 | 0.00 | 0.06 | 0.10 | 0.15 | Haycock Pt statistics, depth avg current |
| **Currents in E-W direction** | ROMS, Site E (surface current) | -0.41 | 0.88 | 0.08 | 0.14 | -0.19 | -0.11 | -0.07 | 0.07 | 0.18 | 0.26 | 0.33 | 0.43 | 0.51 | ROMS statistics, surface current, all data |
| | Haycock Pt Obs (E-W comp, surface current) | -0.67 | 0.69 | 0.27 | 0.24 | -0.41 | -0.19 | -0.03 | 0.30 | 0.50 | 0.55 | 0.59 | 0.64 | 0.66 | Haycock Pt statistics, surface current |
| | Haycock Pt Obs (E-W comp, depth avg current) | -0.36 | 0.46 | 0.12 | 0.10 | -0.13 | -0.04 | -0.01 | 0.12 | 0.20 | 0.25 | 0.27 | 0.32 | 0.35 | Haycock Pt statistics, depth avg current |
| **N** | Haycock Pt Obs (N surface current) | 0.01 | 0.53 | 0.17 | 0.13 | 0.01 | 0.01 | 0.03 | 0.15 | 0.25 | 0.34 | 0.43 | 0.49 | 0.51 | Haycock Pt statistics, northward surface current |
| **S** | Haycock Pt Obs (S surface current) | 0.00 | 0.96 | 0.38 | 0.16 | 0.03 | 0.07 | 0.15 | 0.40 | 0.51 | 0.56 | 0.63 | 0.72 | 0.78 | Haycock Pt statistics, southward surface current |
| **N** | Haycock Pt Obs (N depth avg current) | 0.00 | 0.33 | 0.07 | 0.07 | 0.00 | 0.01 | 0.01 | 0.06 | 0.10 | 0.15 | 0.19 | 0.25 | 0.29 | Haycock Pt statistics, northward depth avg current |
| **S** | Haycock Pt Obs (S depth avg current) | 0.00 | 0.50 | 0.16 | 0.08 | 0.01 | 0.04 | 0.05 | 0.15 | 0.21 | 0.25 | 0.30 | 0.38 | 0.41 | Haycock Pt statistics, southward depth avg current |
| **E** | Haycock Pt Obs (E surface current) | 0.00 | 0.69 | 0.33 | 0.18 | 0.01 | 0.03 | 0.07 | 0.33 | 0.51 | 0.56 | 0.59 | 0.64 | 0.67 | Haycock Pt statistics, eastward surface current |
| **W** | Haycock Pt Obs (W surface current) | 0.00 | 0.67 | 0.19 | 0.15 | 0.00 | 0.01 | 0.02 | 0.16 | 0.33 | 0.40 | 0.44 | 0.48 | 0.57 | Haycock Pt statistics, westward surface current |
| **E** | Haycock Pt Obs (E depth avg current) | 0.00 | 0.46 | 0.14 | 0.09 | 0.00 | 0.01 | 0.03 | 0.13 | 0.22 | 0.25 | 0.28 | 0.32 | 0.37 | Haycock Pt statistics, eastward depth avg current |
| **W** | Haycock Pt Obs (W depth avg current) | 0.00 | 0.36 | 0.05 | 0.06 | 0.00 | 0.01 | 0.01 | 0.04 | 0.08 | 0.12 | 0.15 | 0.17 | 0.27 | Haycock Pt statistics, westward depth avg current |

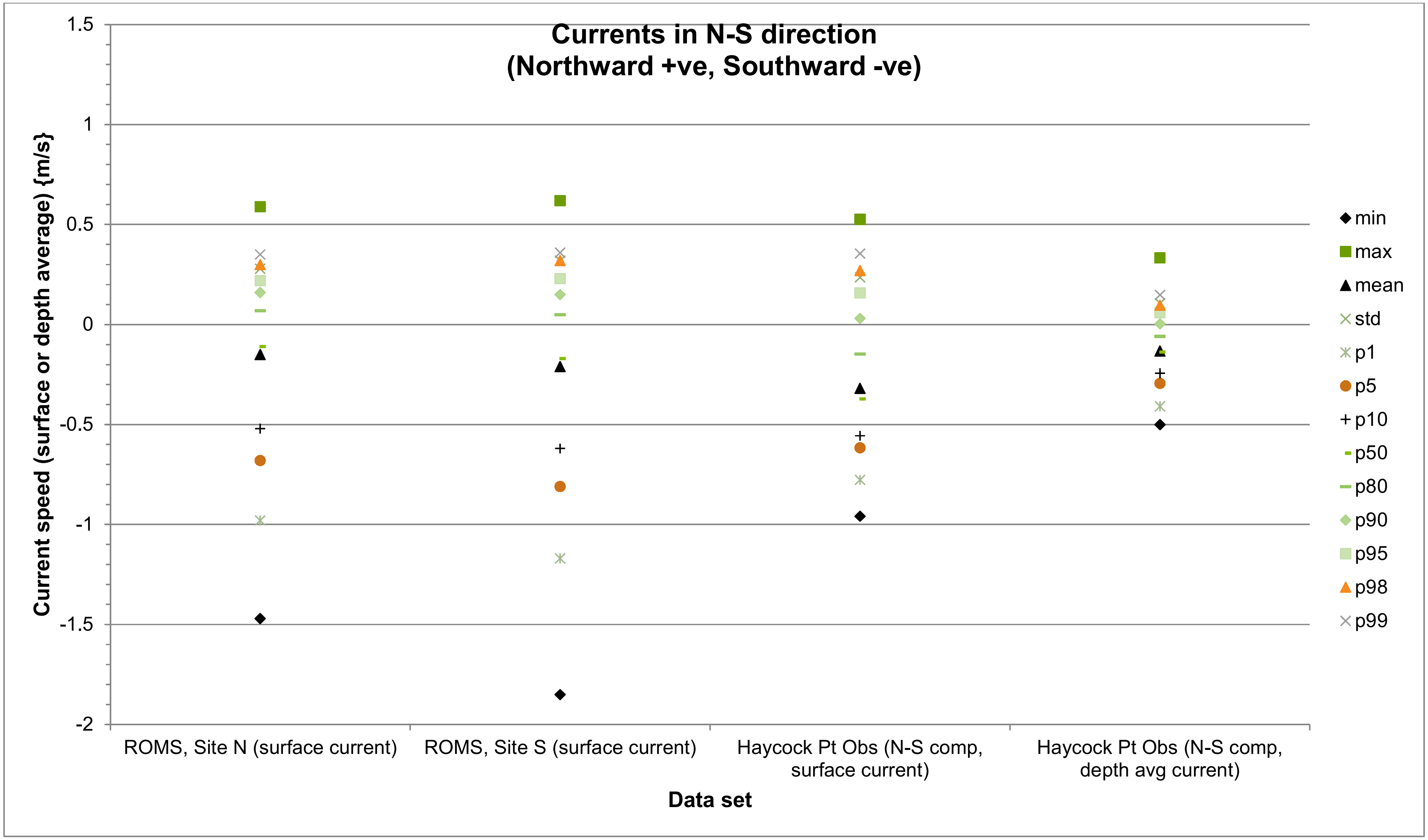


**Figure A-4. Comparison of currents in the N-S direction**

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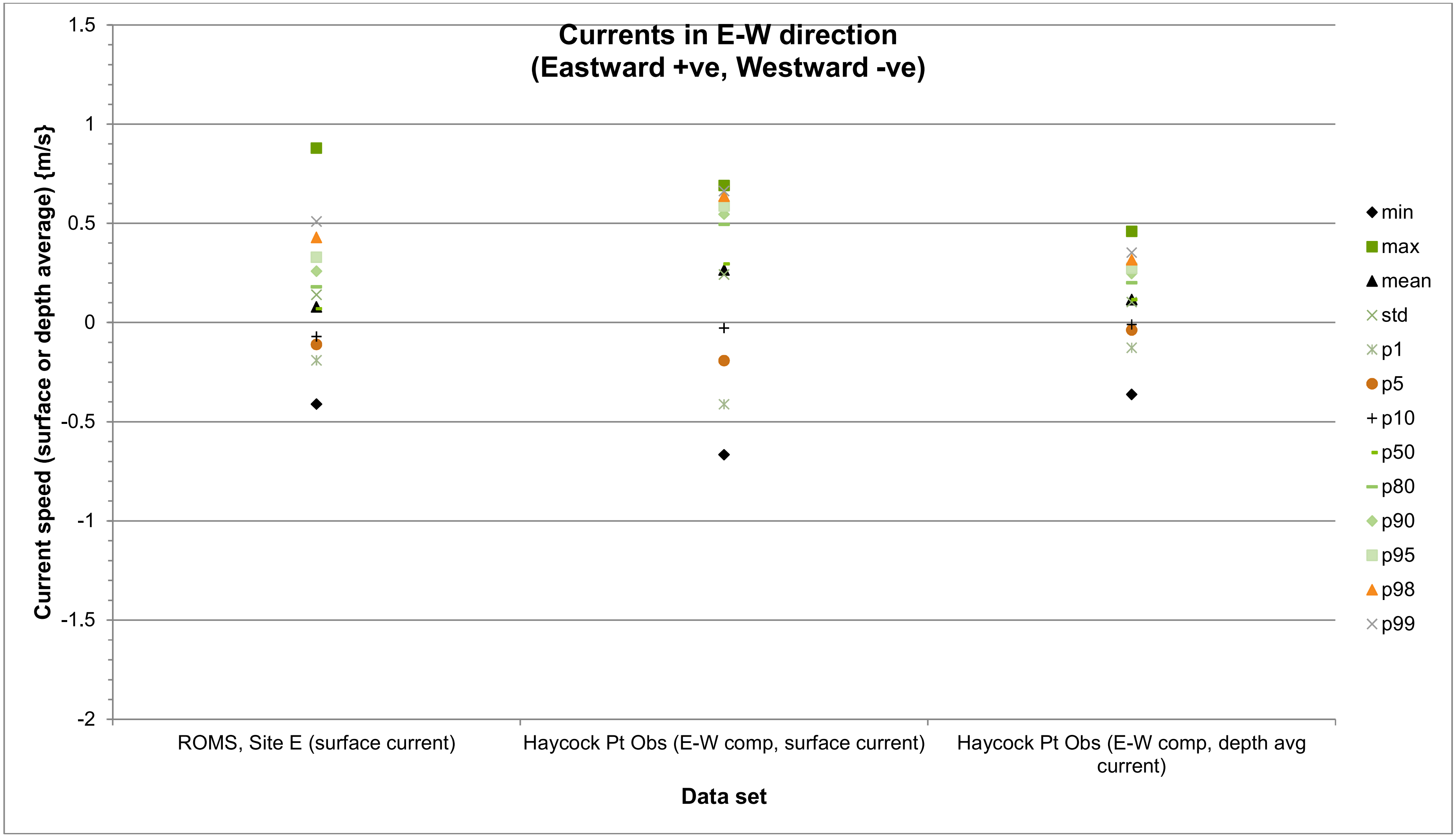


**Figure A-5. Comparison of currents in the E-W direction**

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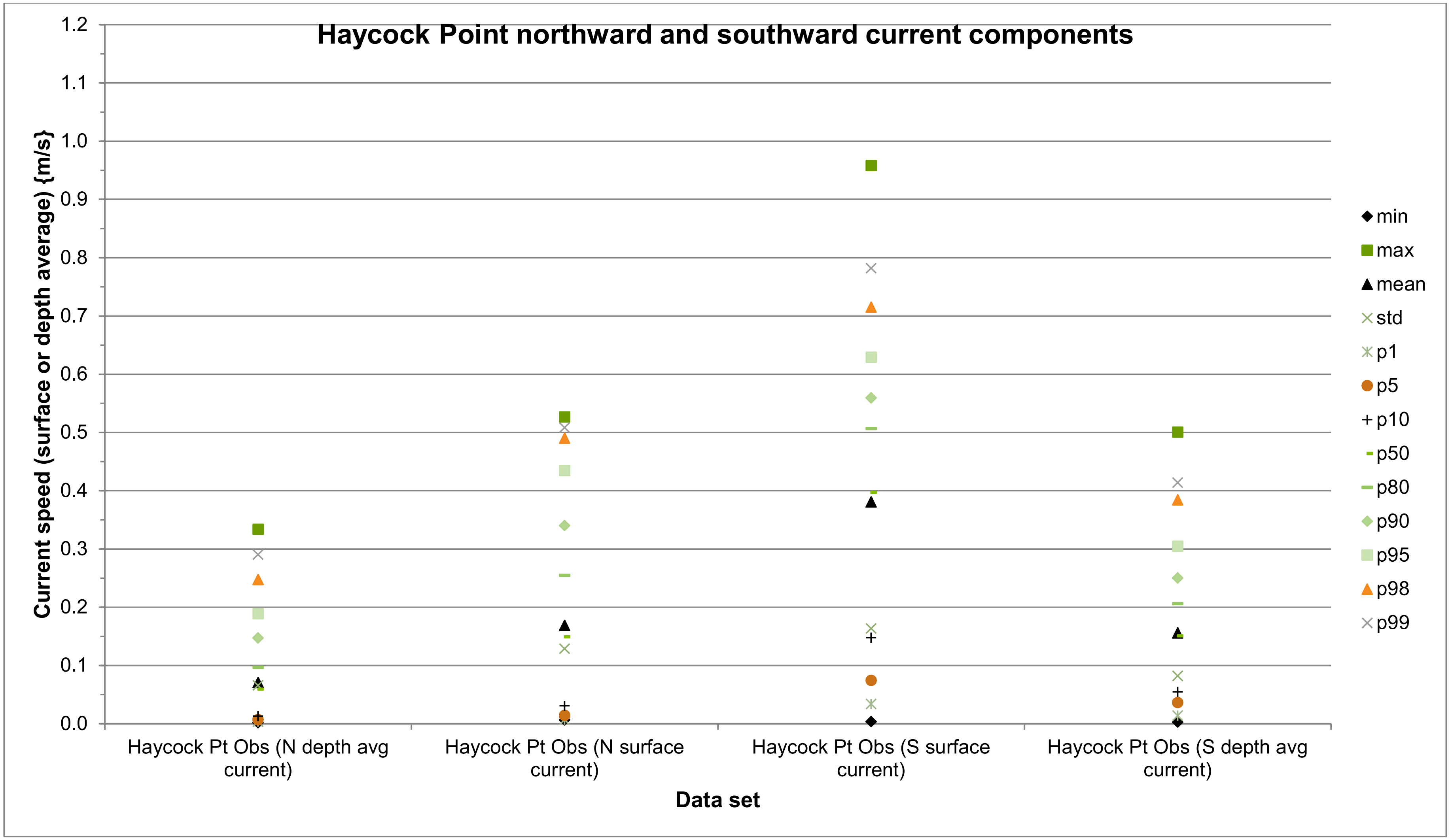


**Figure A-6. Haycock Point northward and southward current components**

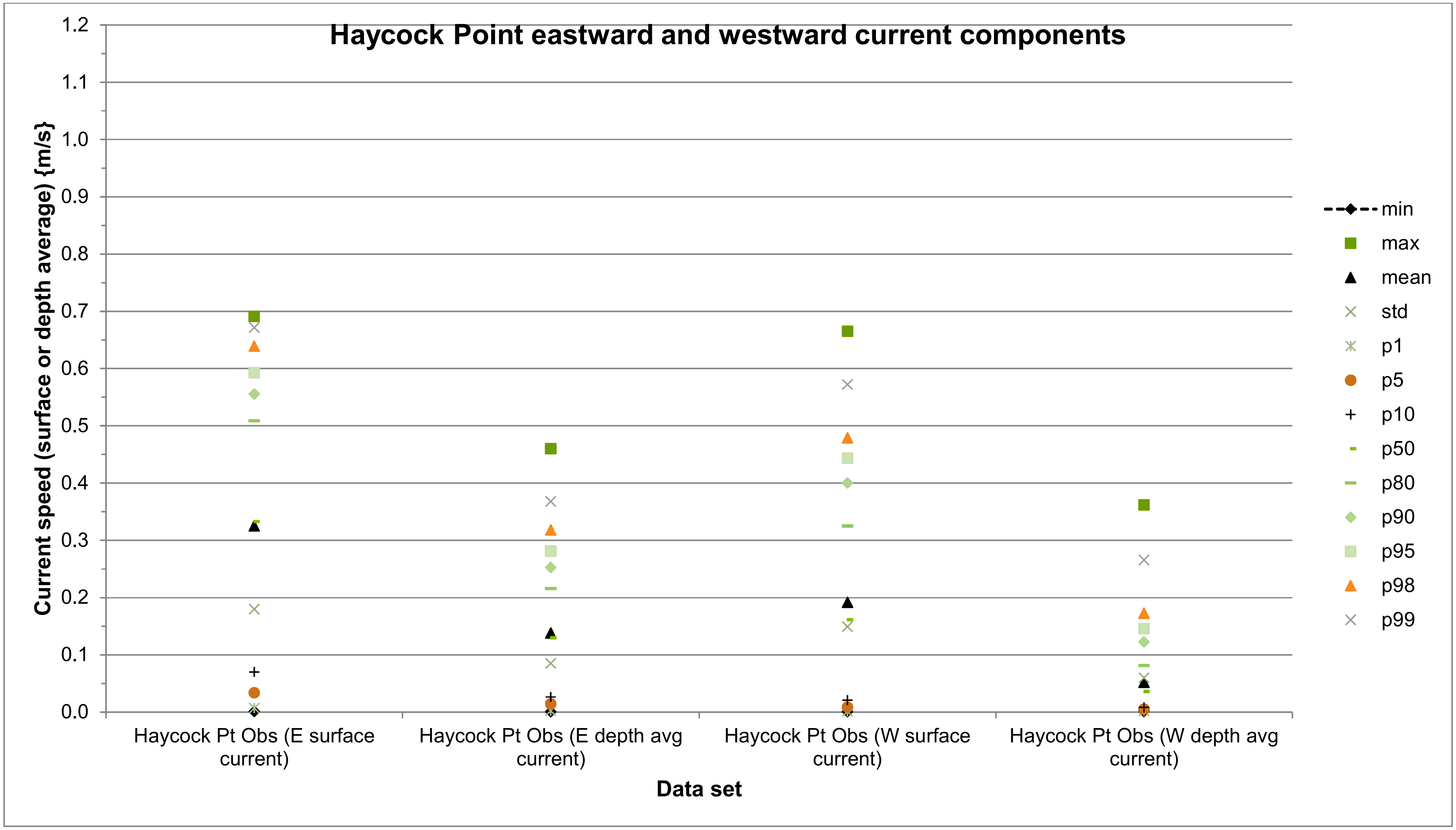


**Figure A-7. Haycock Point eastward and westward current components**

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During model calibration, design current boundary conditions were derived from depth averaged ADCP data and applied on the North and South boundary. Focusing on the yellow highlighted cells in Table 1, we could use the following currents for the dispersion runs.

Considering the currents in the North-South direction and averaging:

- For median (p50) - Use current **-0.14 m/s** (southward), ignoring Haycock Point surface current
- For 10th percentile (p10) - Use current **-0.57 m/s** (southward), ignoring Haycock Point depth averaged current
- For 90th percentile (p90) - Use current **+0.16 m/s** (northward), ignoring Haycock Point data (which is low current)
- Additionally assess a no current or low alternating current scenario as discussed in last modelling meeting (29/4/19)

Note: the values ignored in the above fall within the **-0.57 m/s to +0.16 m/s** range.

Considering the current components at Haycock Point split into northward and southward currents:

- For northward current

| | **p10 (m/s)** | **p50 (m/s)** | **p90 (m/s)** | **Adopted p10 (m/s)** | **Adopted p50 (m/s)** | **Adopted p90 (m/s)** |
|---|---|---|---|---|---|---|
| **N surface current** | 0.03 | 0.15 | 0.34 | **0.05** | **0.15** | **0.34** |
| **N depth avg current** | 0.01 | 0.06 | 0.15 | | | |
| **Comment** | | | | This could be adapted to be the low alternating current scenario. | Using surface current. This can also be considered the p90 N-S current scenario from above. | Using surface current. |

- For southward current

| | **p10 (m/s)** | **p50 (m/s)** | **p90 (m/s)** | **Adopted p10 (m/s)** | **Adopted p50 (m/s)** | **Adopted p90 (m/s)** |
|---|---|---|---|---|---|---|
| **S surface current** | 0.15 | 0.40 | 0.56 | **0.15** | **0.40** | **0.56** |
| **S depth avg current** | 0.05 | 0.15 | 0.25 | | | |
| **Comment** | | | | Using surface current. This can also be considered the typical p50 N-S current scenario from above. | Using surface current. | Using surface current. This can also be considered the p10 N-S current scenario from above. |

# Appendix D

## Far-Field Modelling Plots (Delft3D-PART)

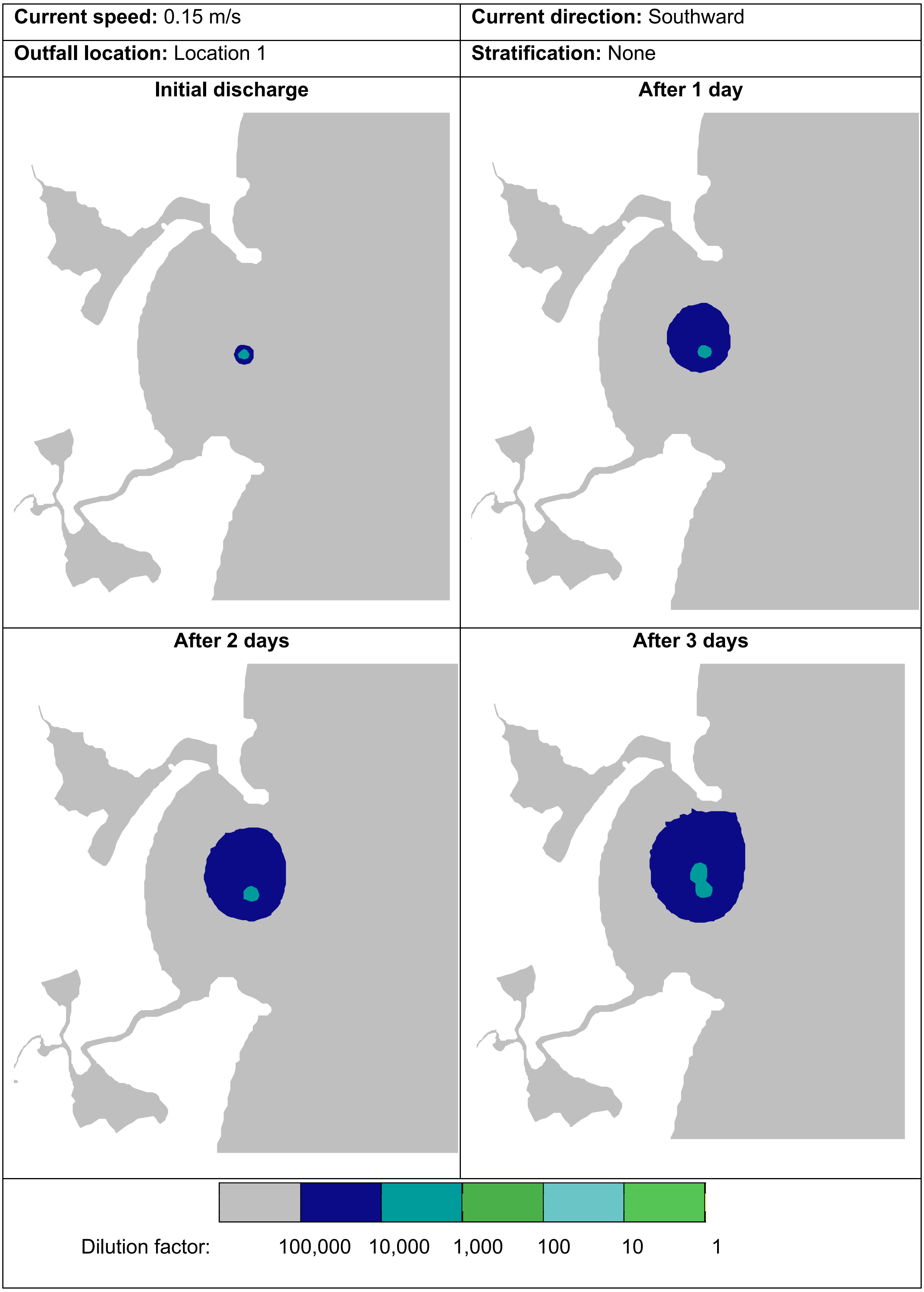



**Figure 23. Model run #1: 0.15 m/s southward current, no stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Southward |
| **Outfall location:** Location 2 | **Stratification:** None |

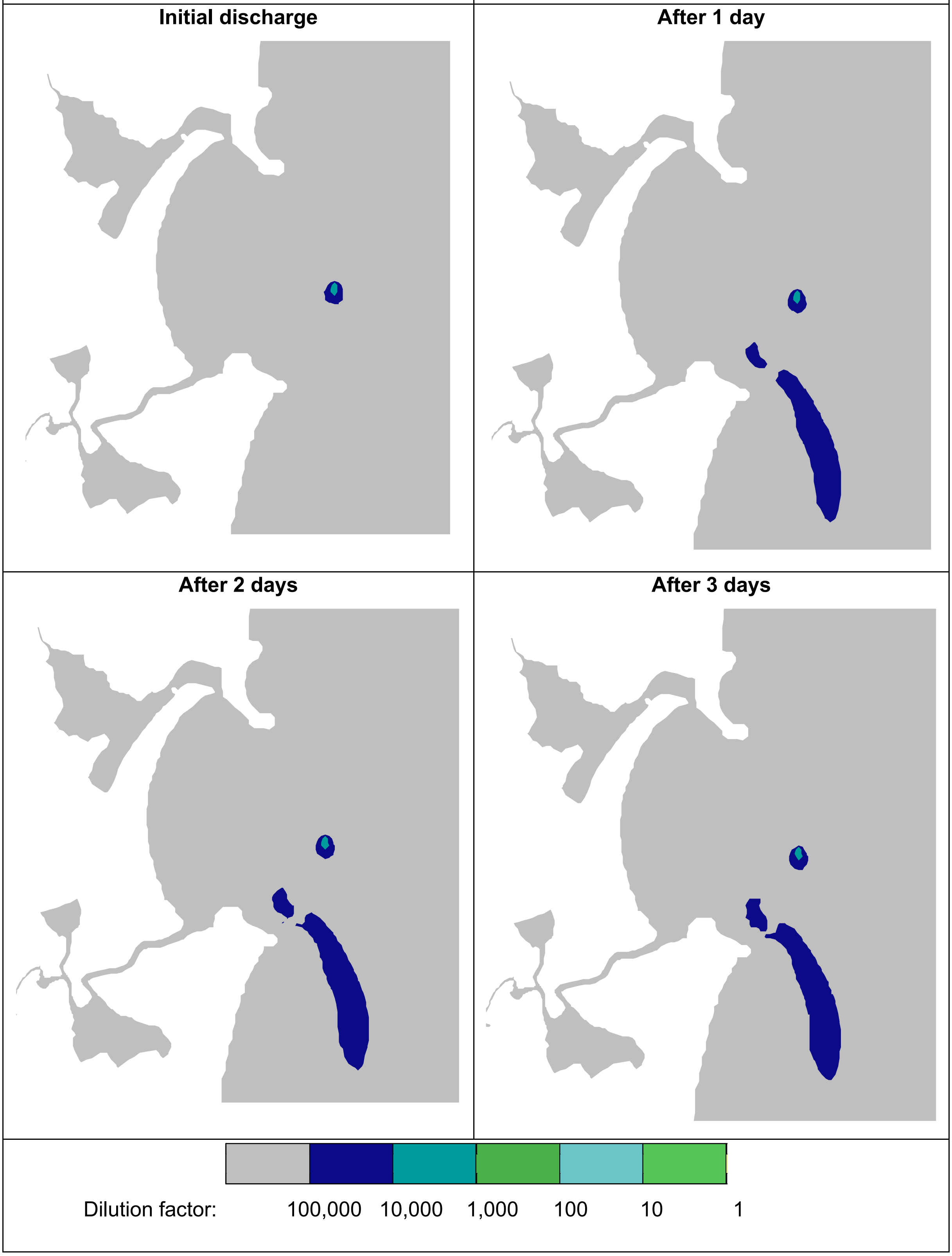



**Figure 24. Model run #2: 0.15 m/s southward current, no stratification, outfall location 2**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Southward |
| **Outfall location:** Location 3 | **Stratification:** None |

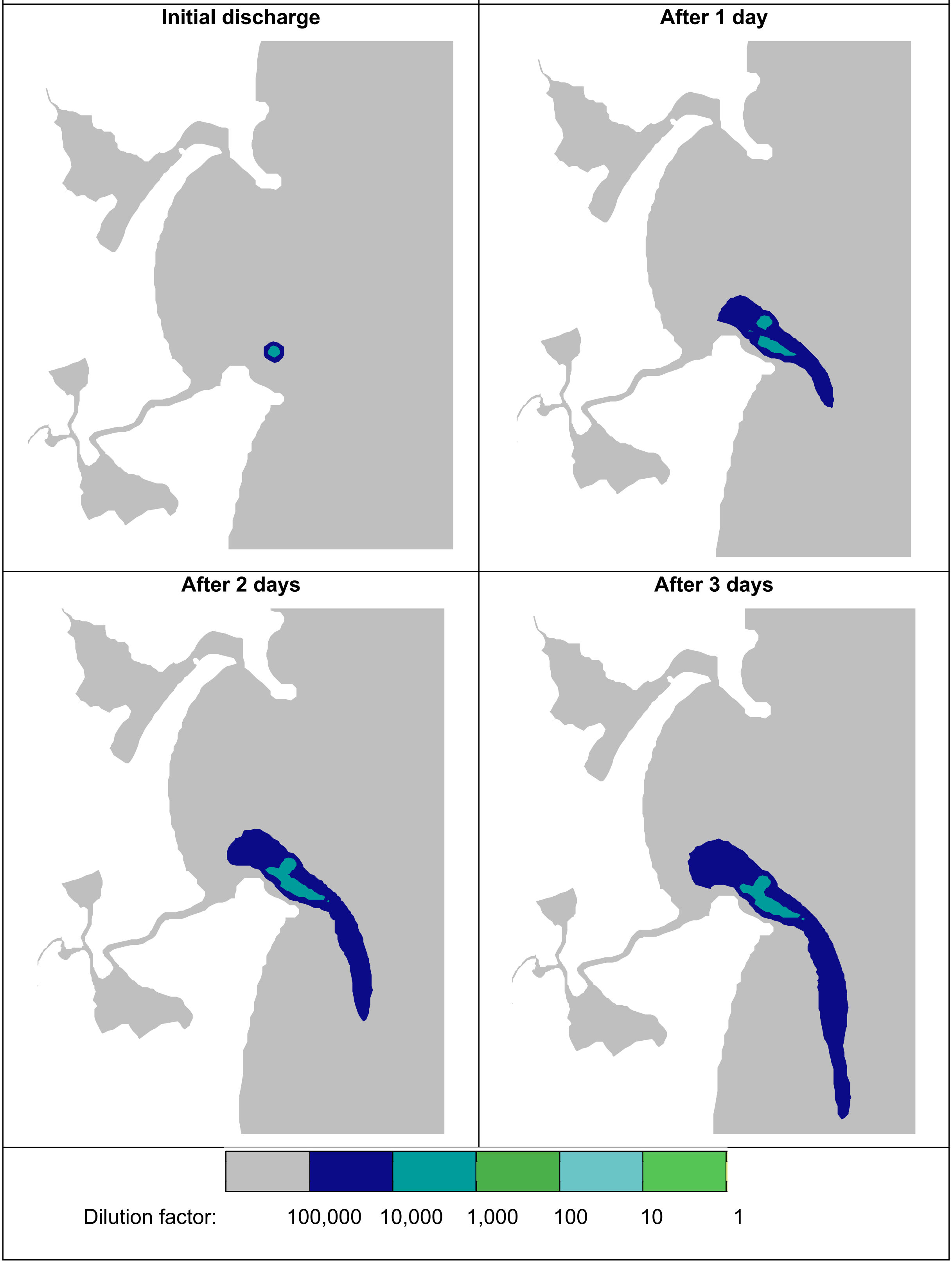
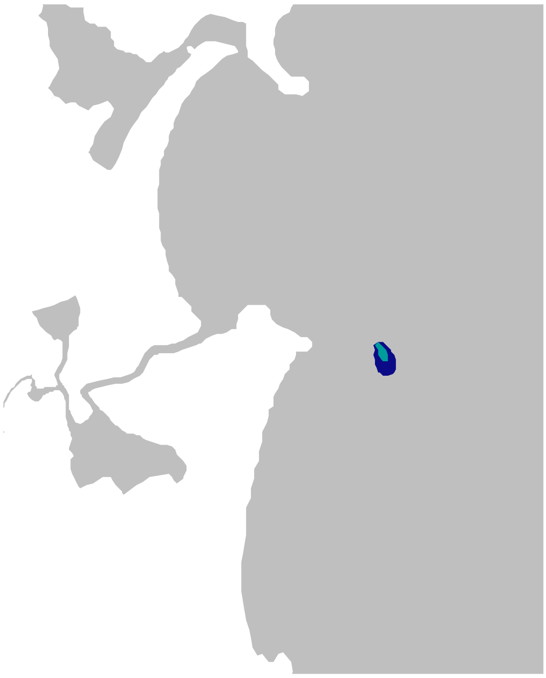
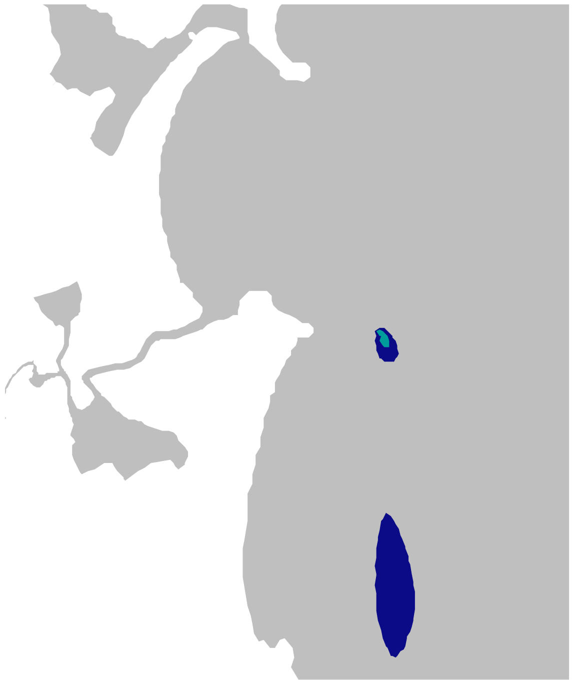
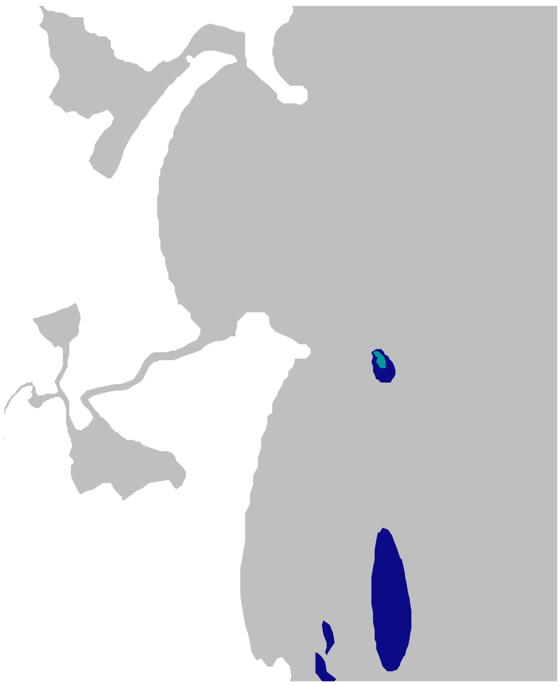
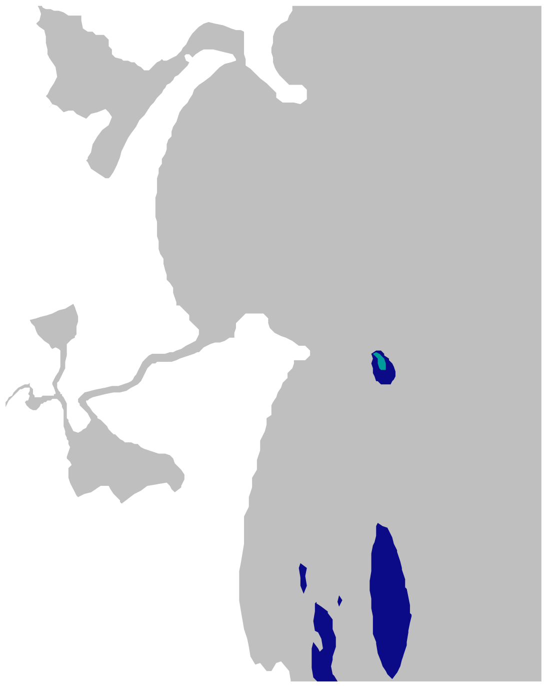



**Figure 25. Model run #3: 0.15 m/s southward current, no stratification, outfall location 3**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Southward |
| **Outfall location:** Location 4 | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |

Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 26. Model run #4: 0.15 m/s southward current, no stratification, outfall location 4**

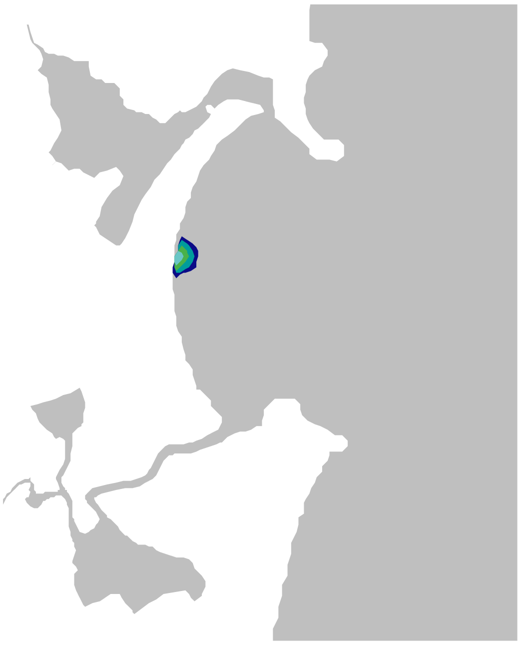
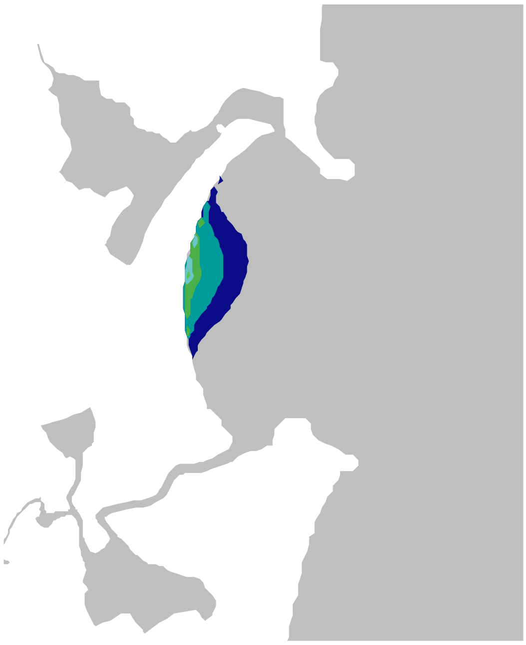
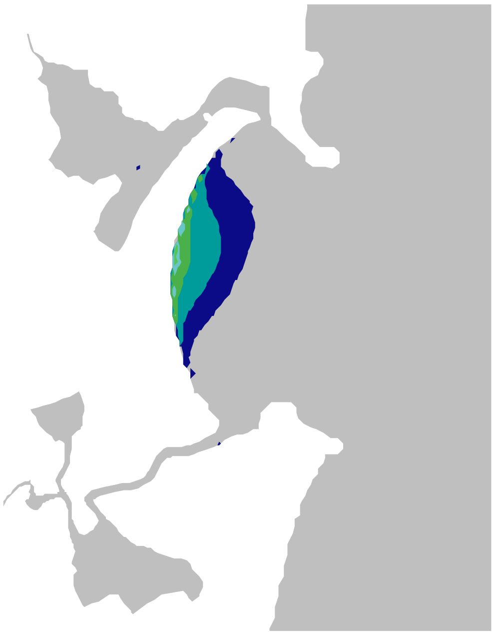
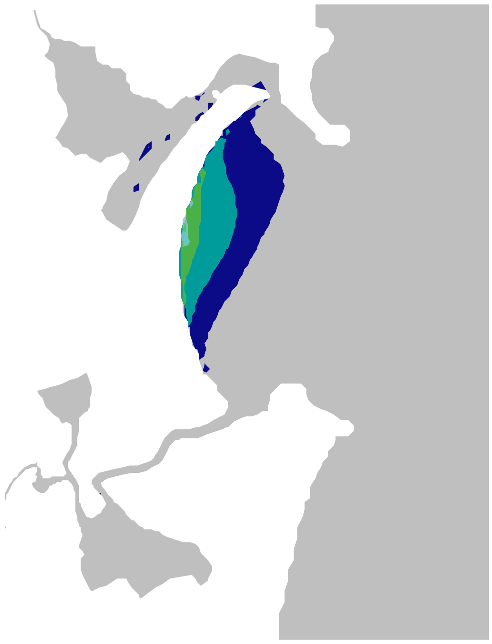
| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Southward |
| **Outfall location:** Existing | **Stratification:** None |
| **Initial discharge**<br> | **After 1 day**<br> |
| **After 2 days**<br> | **After 3 days**<br> |
| <br>Dilution factor: 100,000 10,000 1,000 100 10 1 | |

**Figure 27. Model run #5: 0.15 m/s southward current, no stratification, existing outfall**

| | |
|---|---|
| **Current speed:** 0.05 m/s | **Current direction:** Northward |
| **Outfall location:** Location 1 | **Stratification:** None |

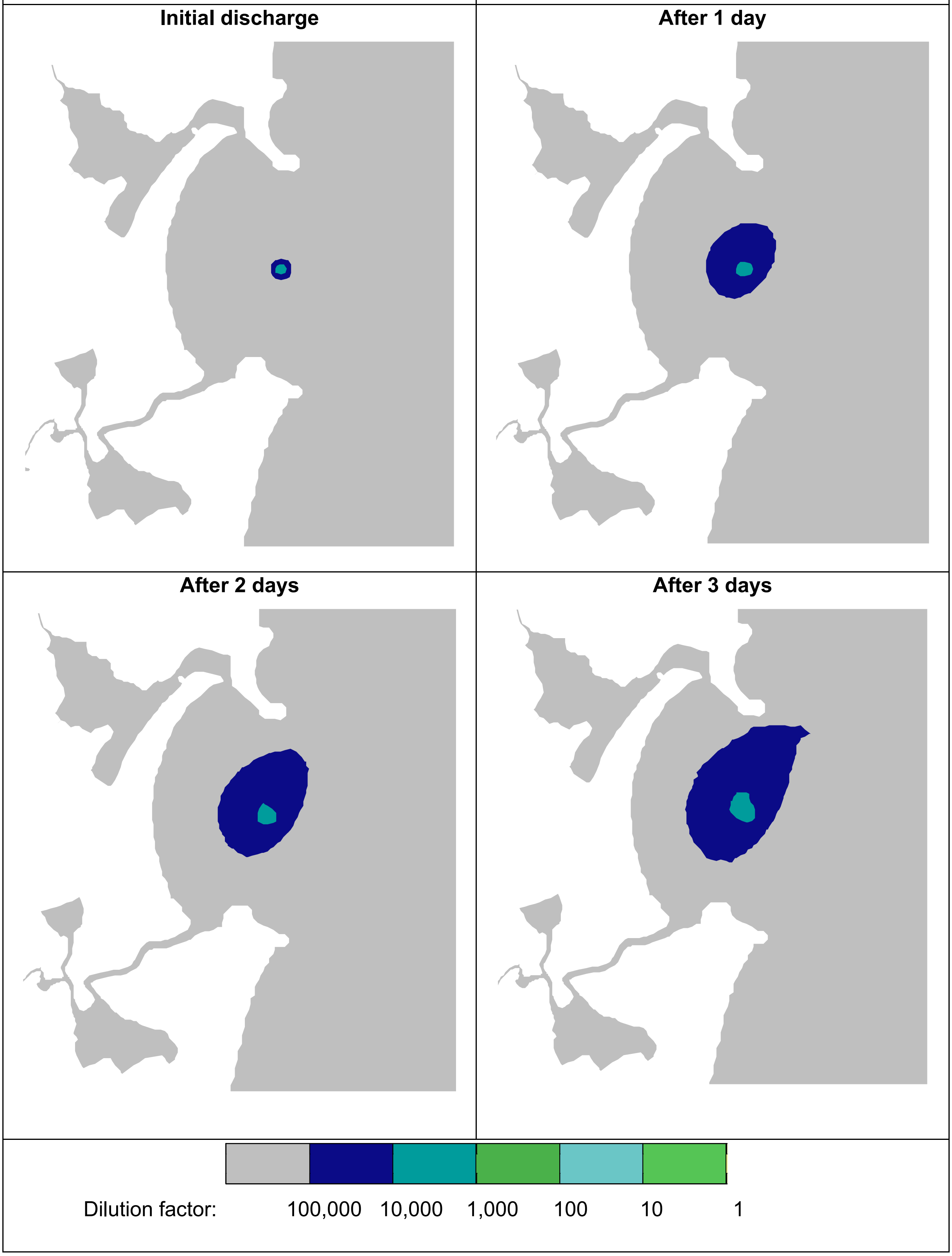
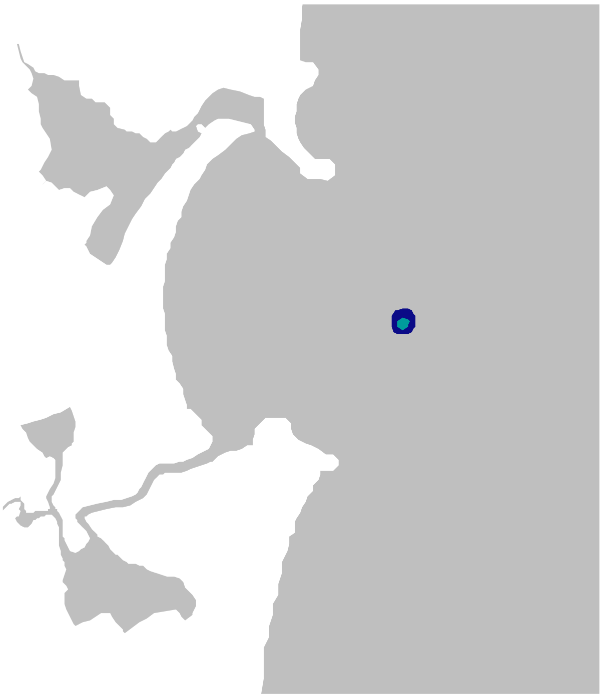
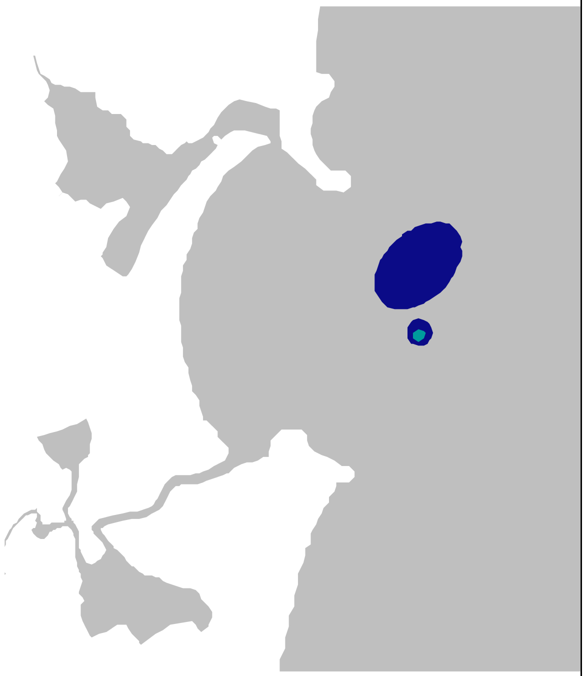
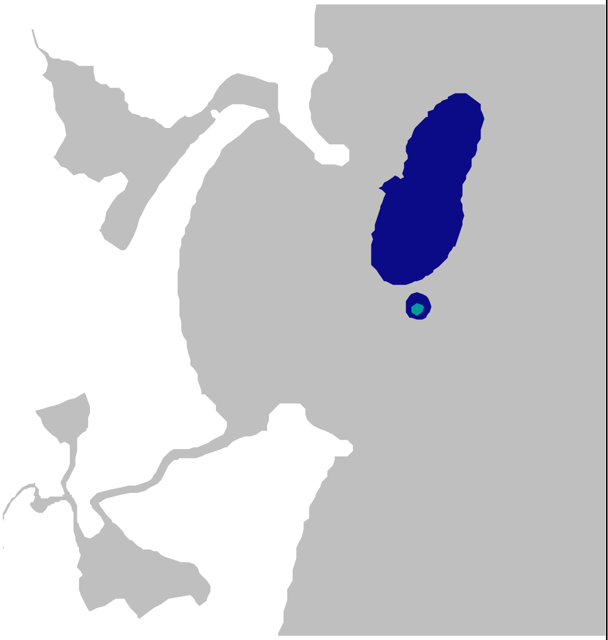
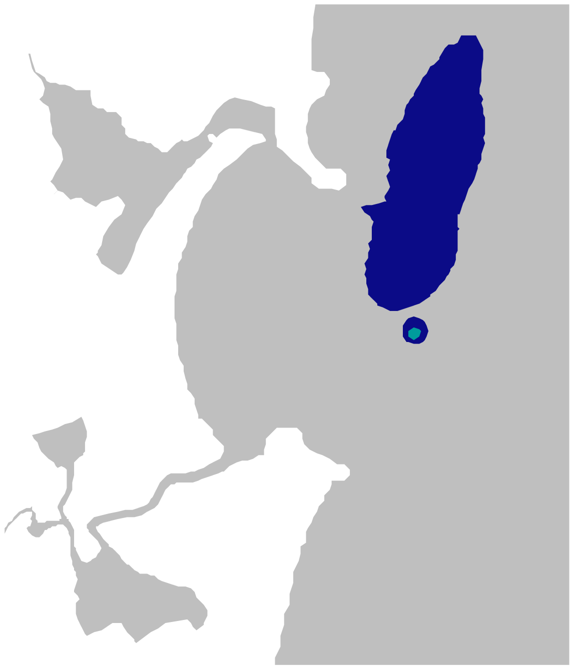
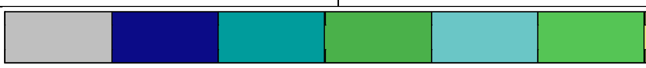


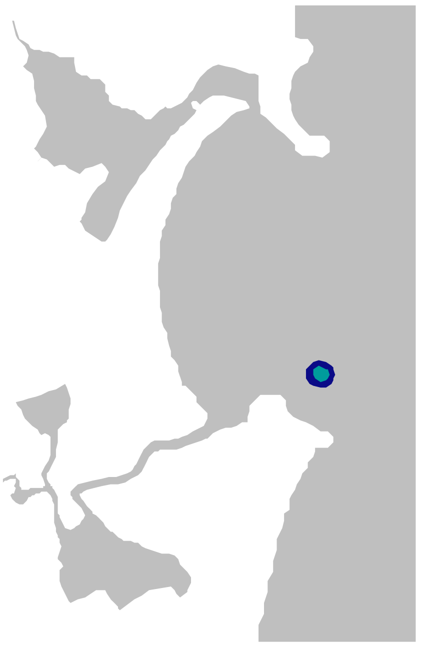
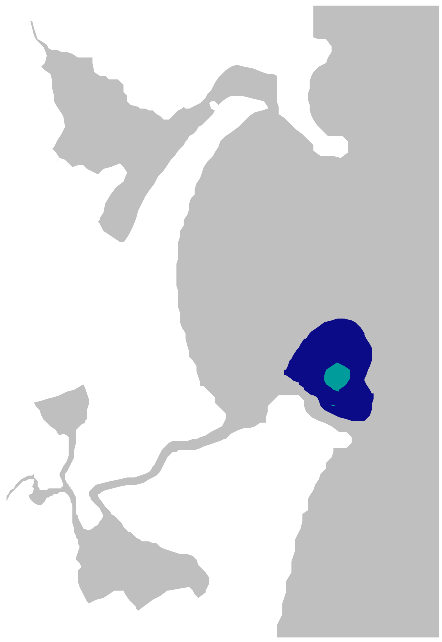
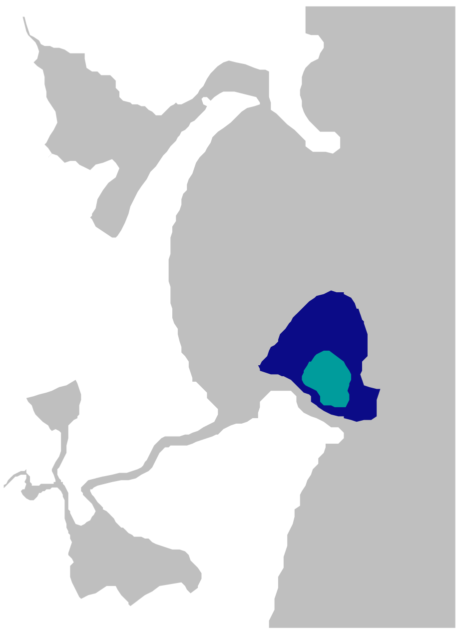
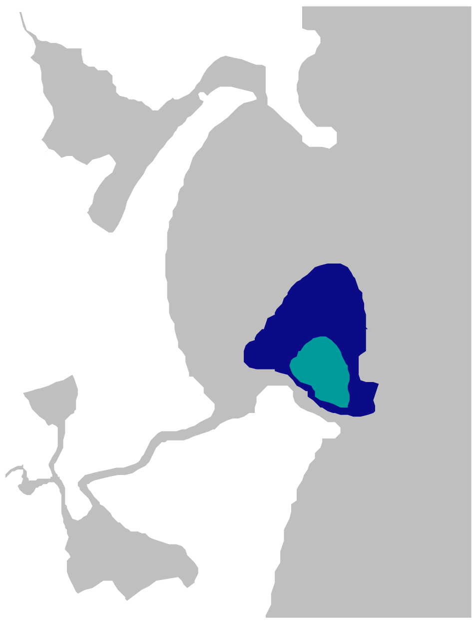

**Figure 28. Model run #6: 0.05 m/s northward current, no stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.05 m/s | **Current direction:** Northward |
| **Outfall location:** Location 2 | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |



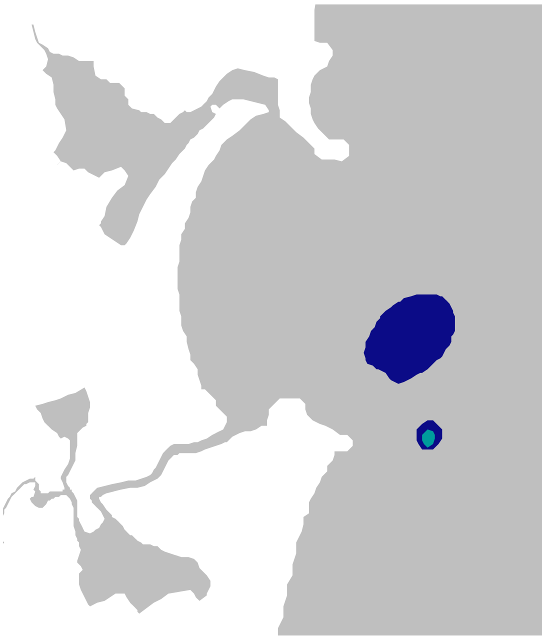
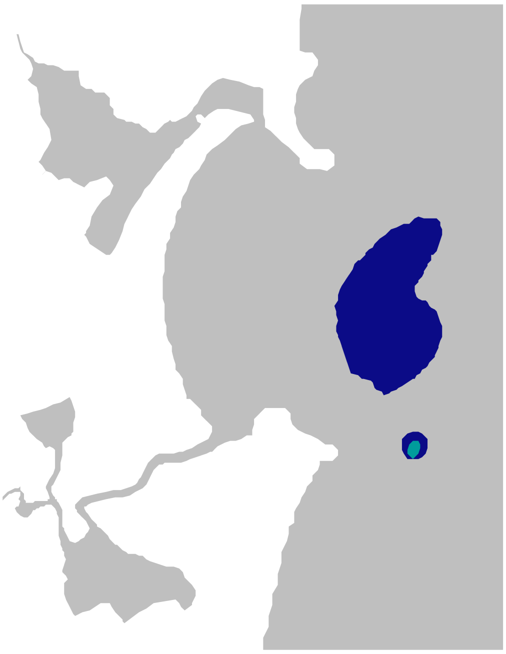
Dilution factor: 100,000 10,000 1,000 100 10 1

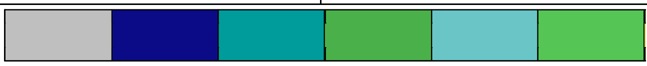
**Figure 29. Model run #7: 0.05 m/s northward current, no stratification, outfall location 2**

| | |
|---|---|
| **Current speed:** 0.05 m/s | **Current direction:** Northward |
| **Outfall location:** Location 3 | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |

Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 30. Model run #8: 0.05 m/s northward current, no stratification, outfall location 3**

| | |
|---|---|
| **Current speed:** 0.05 m/s | **Current direction:** Northward |
| **Outfall location:** Location 4 | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |



Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 31. Model run #9: 0.05 m/s northward current, no stratification, outfall location 4**

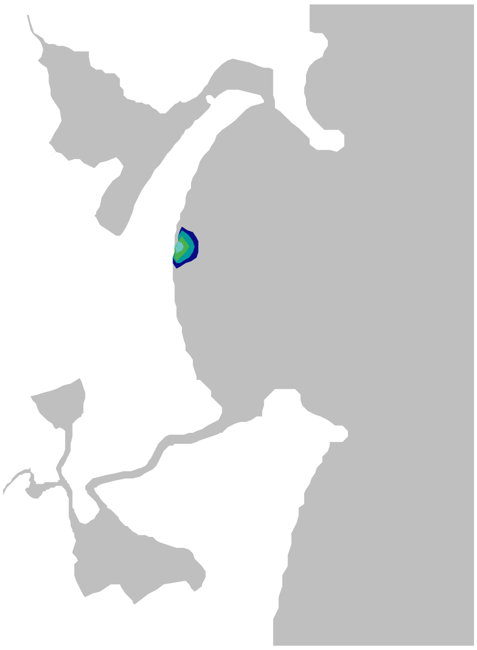
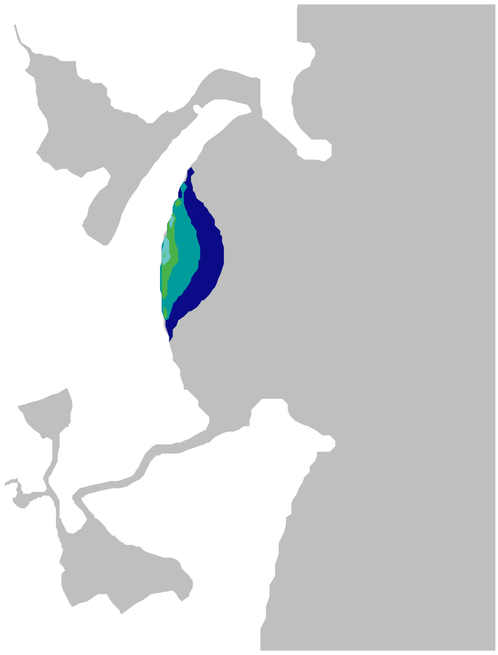
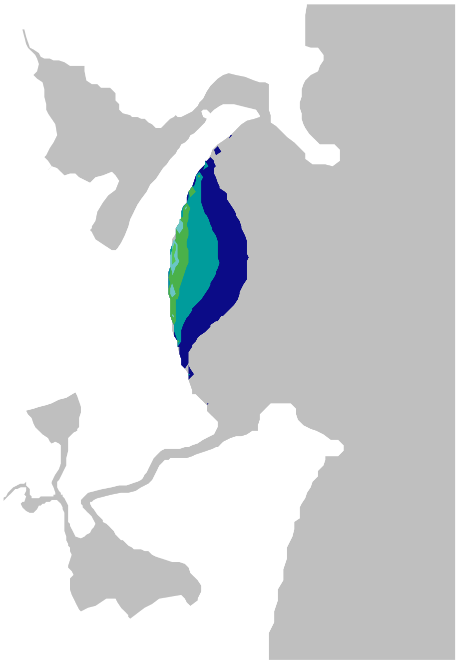
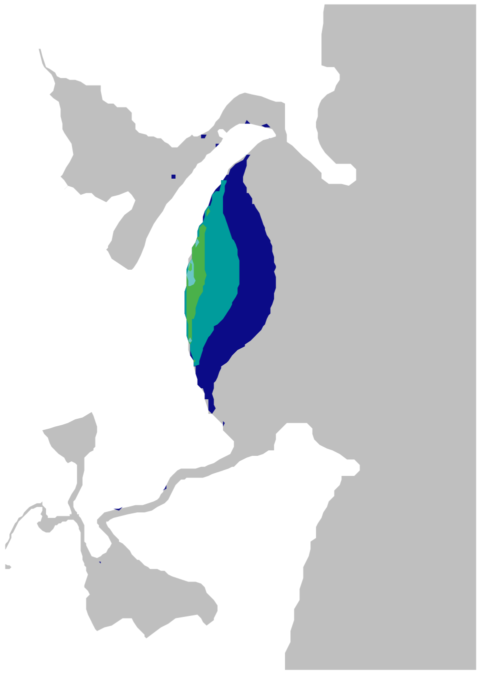
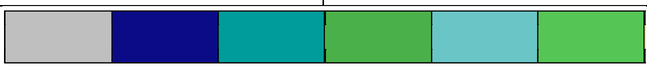
| | |
|---|---|
| **Current speed:** 0.05 m/s | **Current direction:** Northward |
| **Outfall location:** Existing | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |
|   | |

**Figure 32. Model run #10: 0.05 m/s northward current, no stratification, existing outfall**

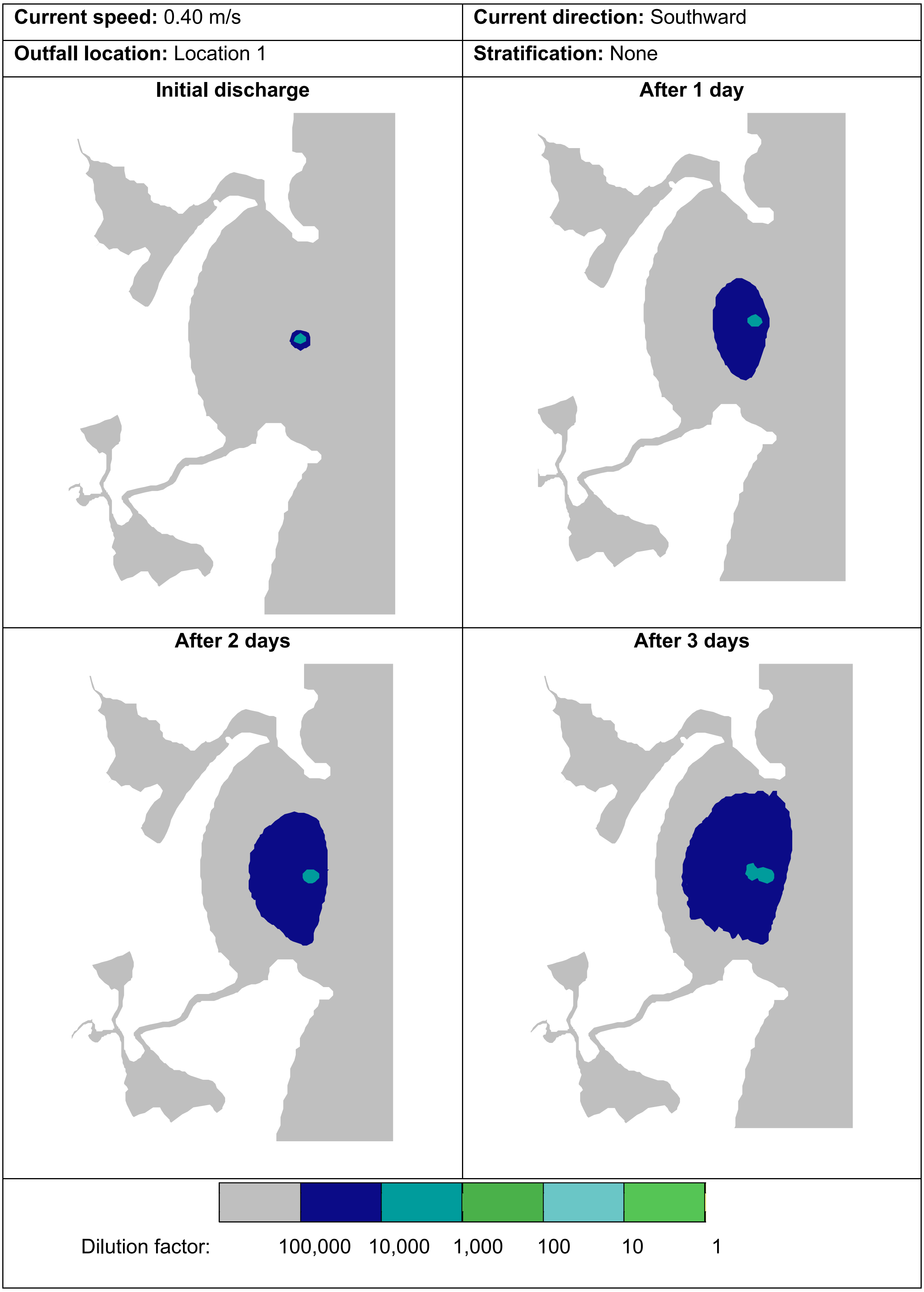



**Figure 33. Model run #11: 0.40 m/s southward current, no stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.40 m/s | **Current direction:** Southward |
| **Outfall location:** Location 2 | **Stratification:** None |

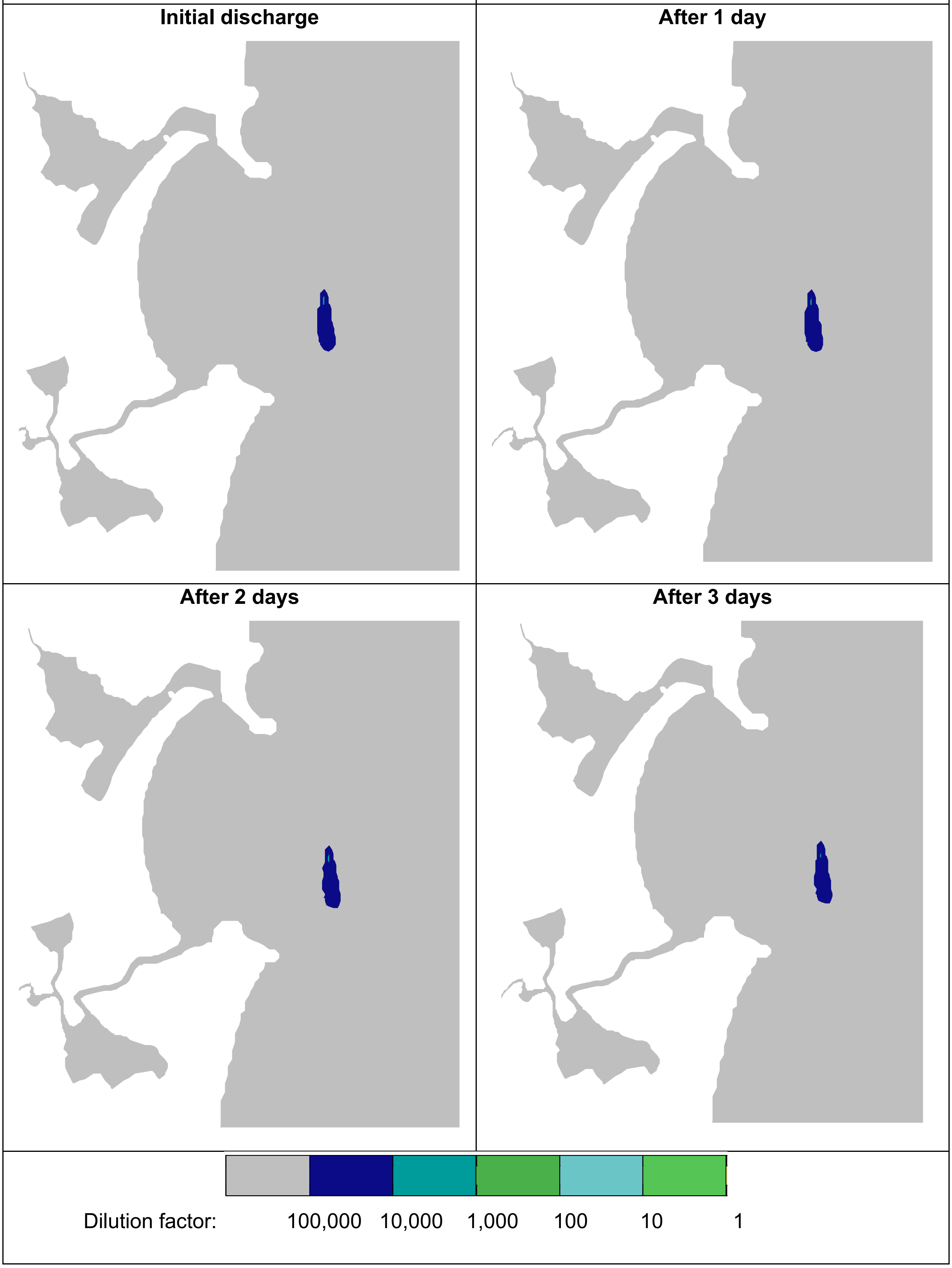



**Figure 34. Model run #12: 0.40 m/s southward current, no stratification, outfall location 2**

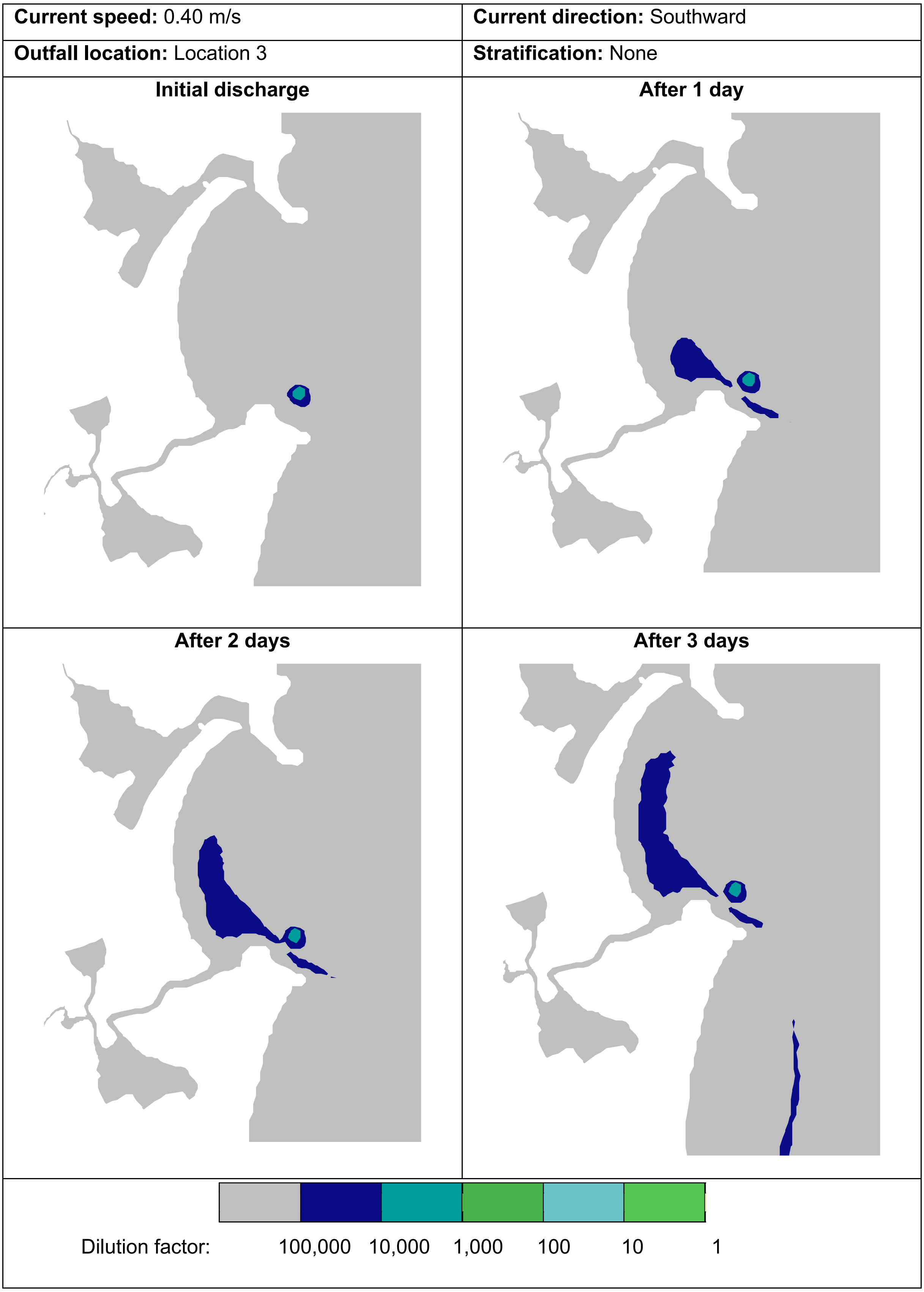



**Figure 35. Model run #13: 0.40 m/s southward current, no stratification, outfall location 3**

| | |
|---|---|
| **Current speed:** 0.40 m/s | **Current direction:** Southward |
| **Outfall location:** Location 4 | **Stratification:** None |

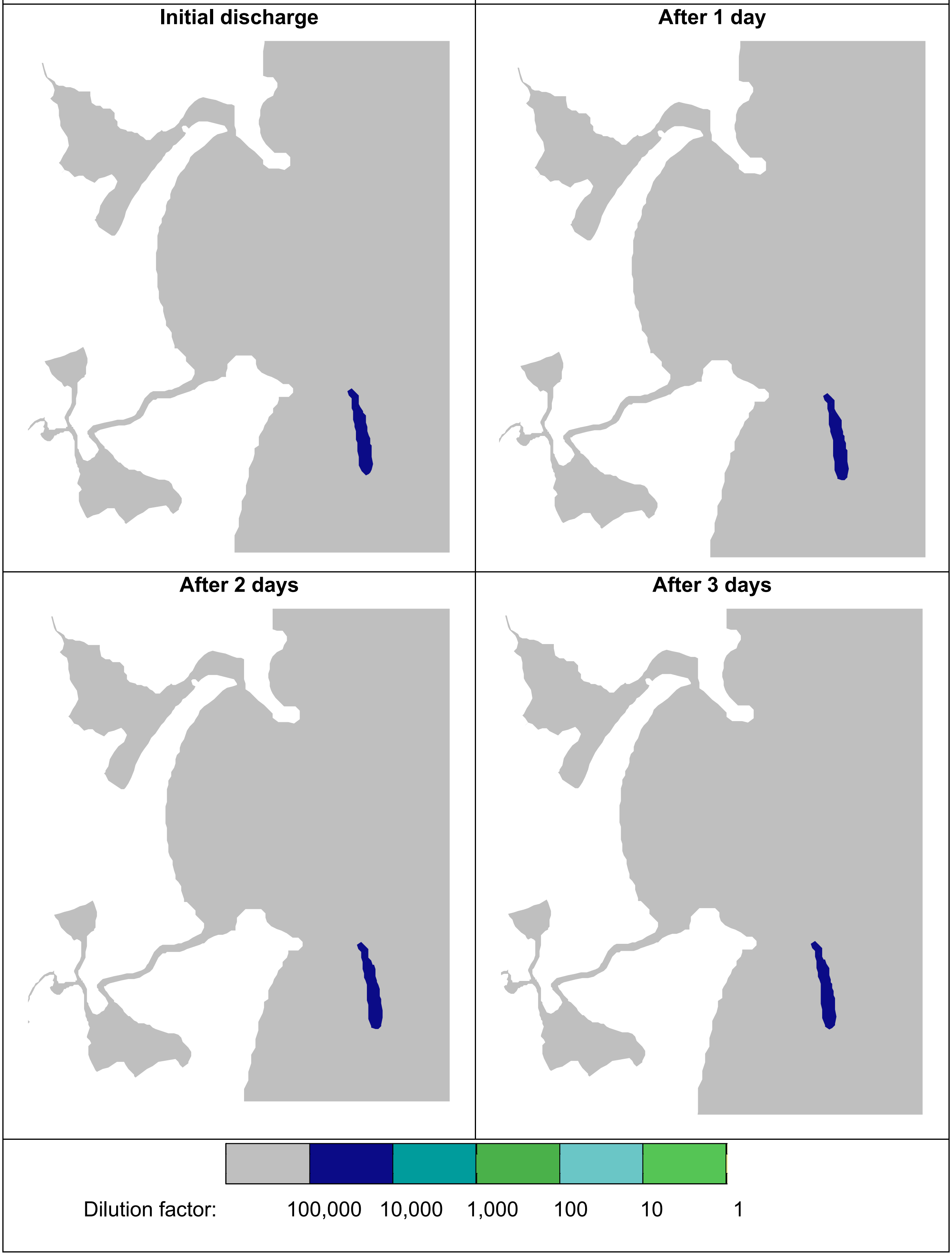



**Figure 36. Model run #14: 0.40 m/s southward current, no stratification, outfall location 4**

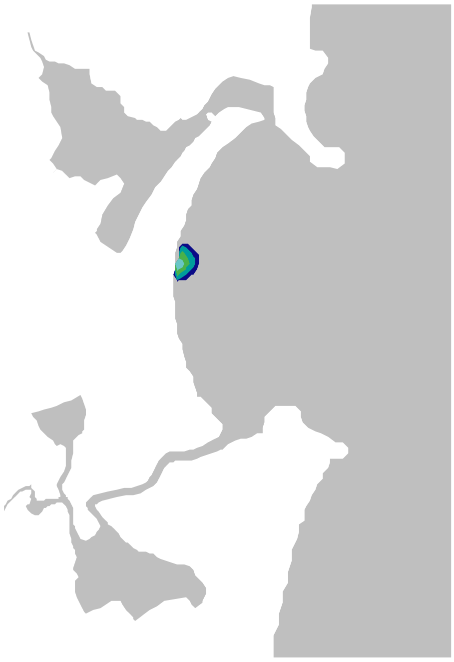
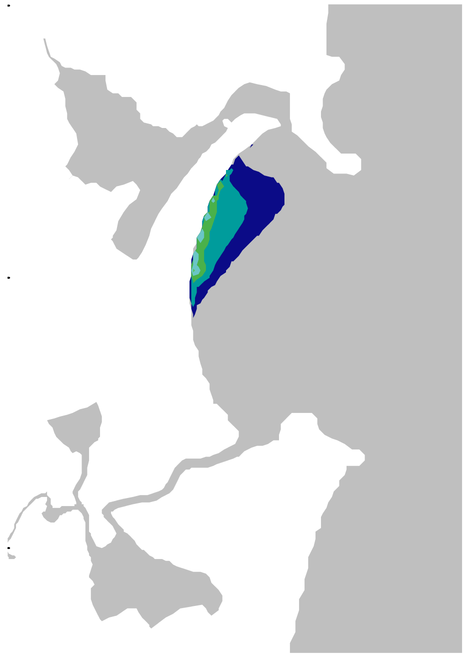
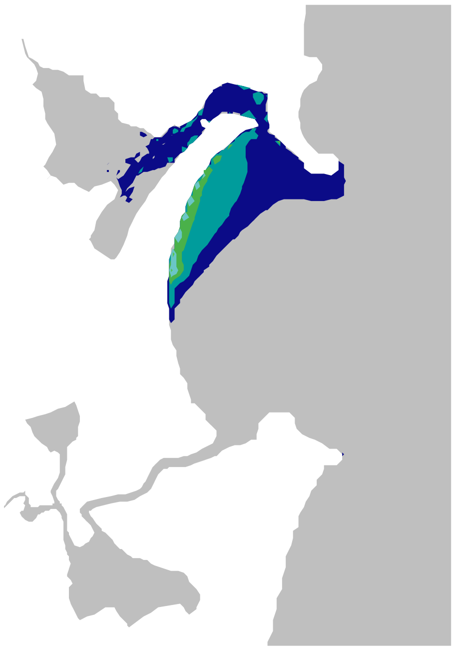
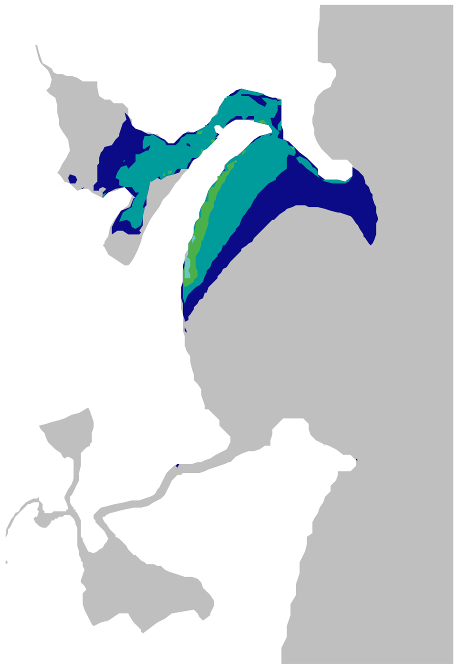
| | |
|---|---|
| **Current speed:** 0.40 m/s | **Current direction:** Southward |
| **Outfall location:** Existing | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |


**Figure 37. Model run #15: 0.40 m/s southward current, no stratification, existing outfall**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Northward |
| **Outfall location:** Location 1 | **Stratification:** None |

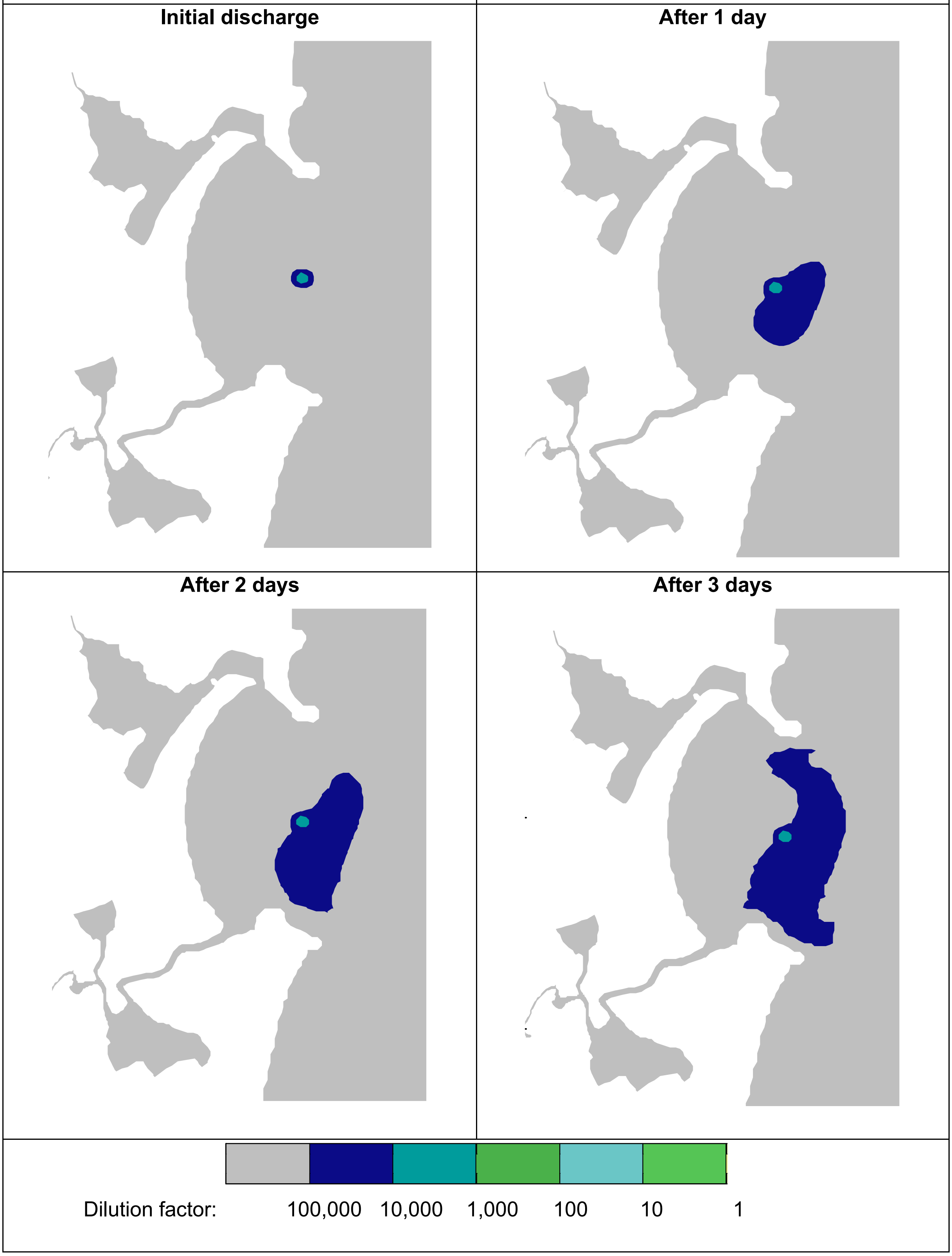



**Figure 38. Model run #16: 0.15 m/s northward current, no stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Northward |
| **Outfall location:** Location 2 | **Stratification:** None |


**Figure 39. Model run #17: 0.15 m/s northward current, no stratification, outfall location 2**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Northward |
| **Outfall location:** Location 3 | **Stratification:** None |

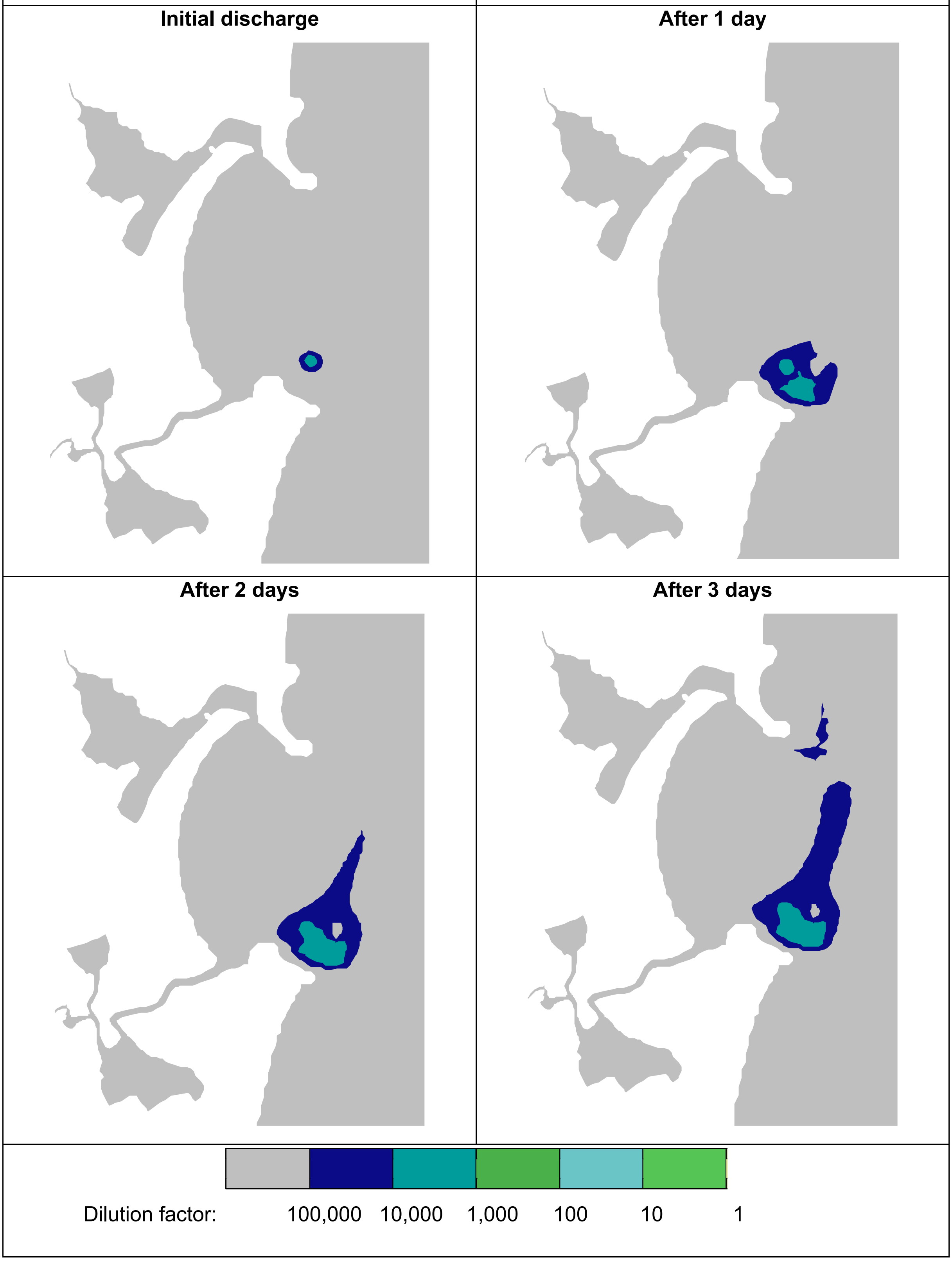
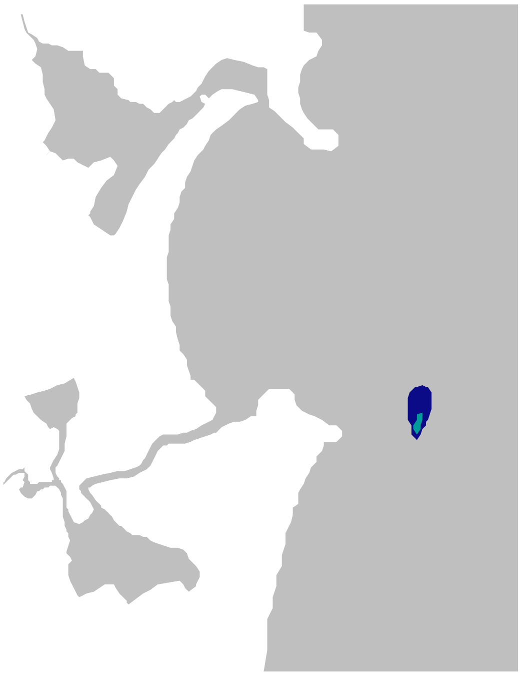


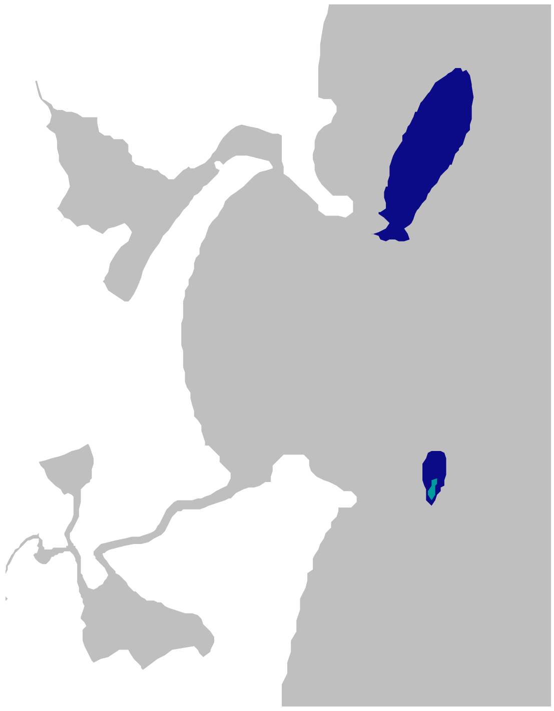

**Figure 40. Model run #18: 0.15 m/s northward current, no stratification, outfall location 3**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Northward |
| **Outfall location:** Location 4 | **Stratification:** None |

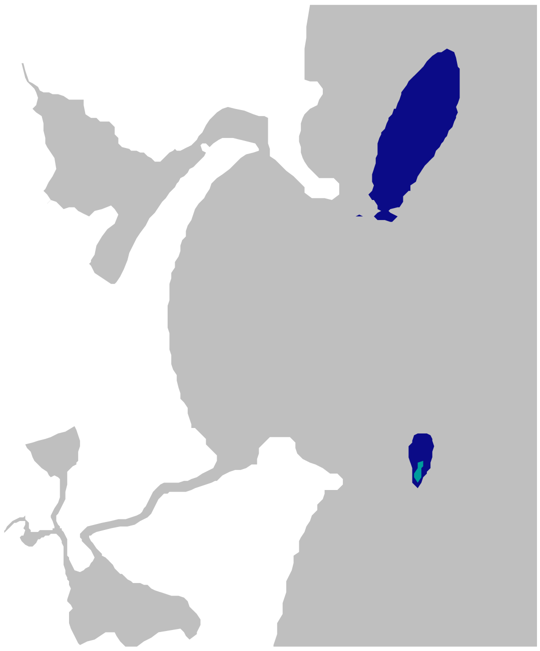
**Initial discharge**



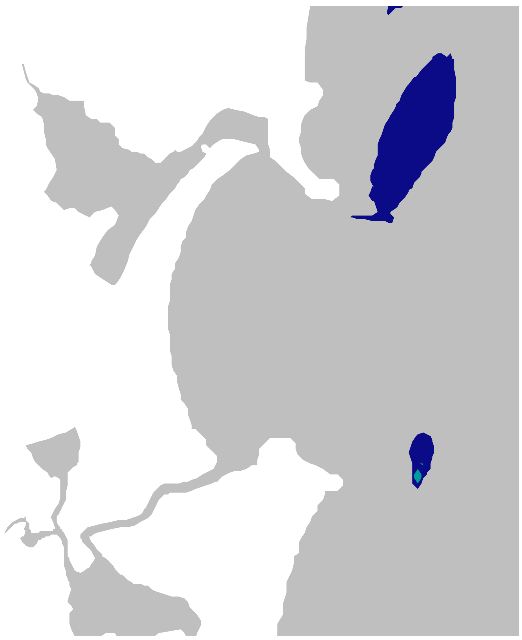
**After 1 day**



**After 2 days**

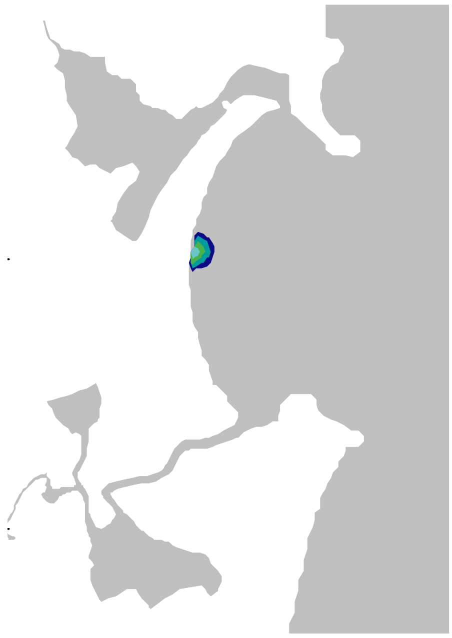
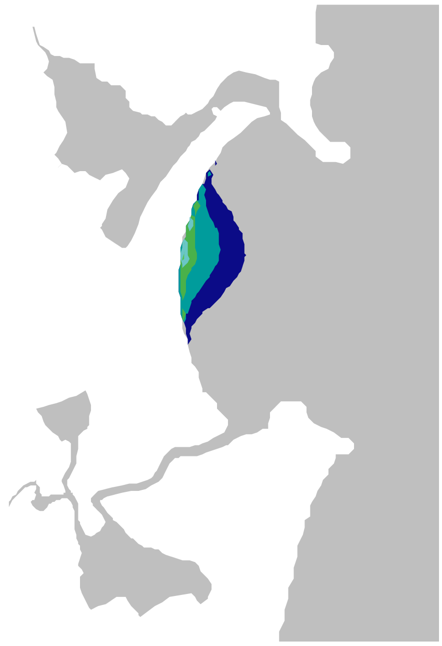
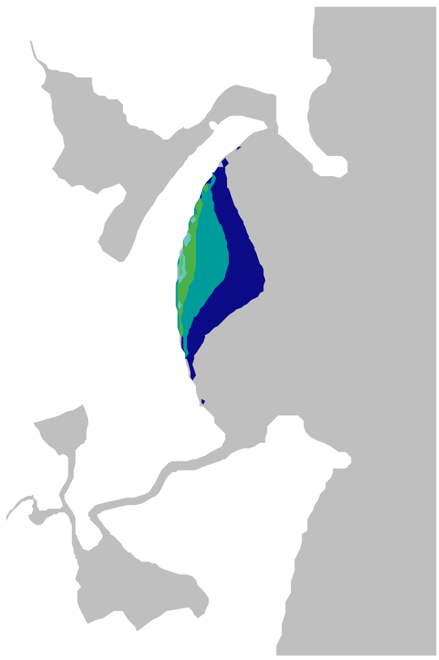
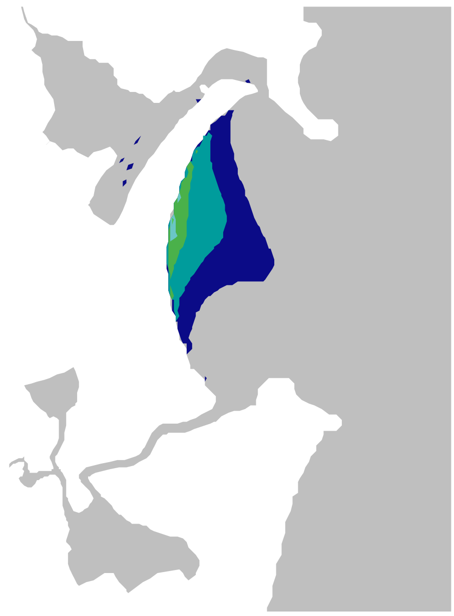


**After 3 days**



Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 41. Model run #19: 0.15 m/s northward current, no stratification, outfall location 4**

| **Current speed:** 0.15 m/s | **Current direction:** Northward |
| --- | --- |
| **Outfall location:** Existing | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |

Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 42. Model run #20: 0.15 m/s northward current, no stratification, existing outfall**

| | |
|---|---|
| **Current speed:** 0.56 m/s | **Current direction:** Southward |
| **Outfall location:** Location 1 | **Stratification:** None |

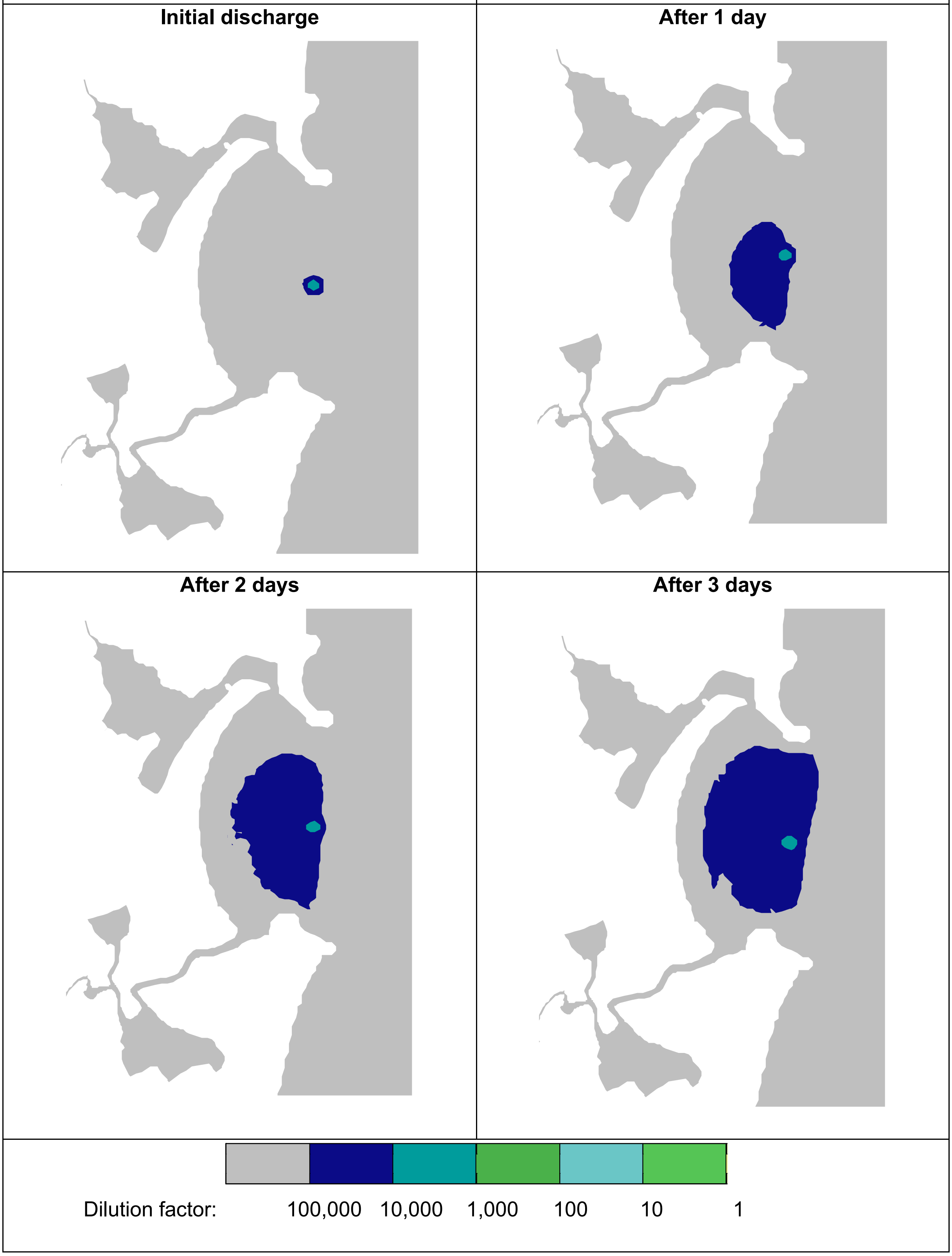



**Figure 43. Model run #21: 0.56 m/s southward current, no stratification, outfall location 1**

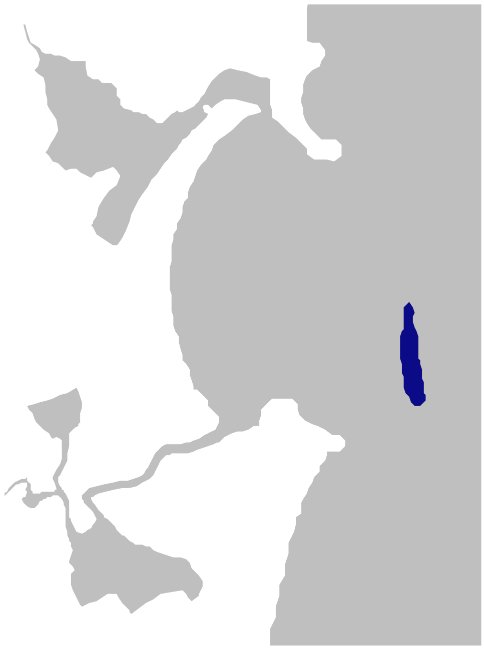
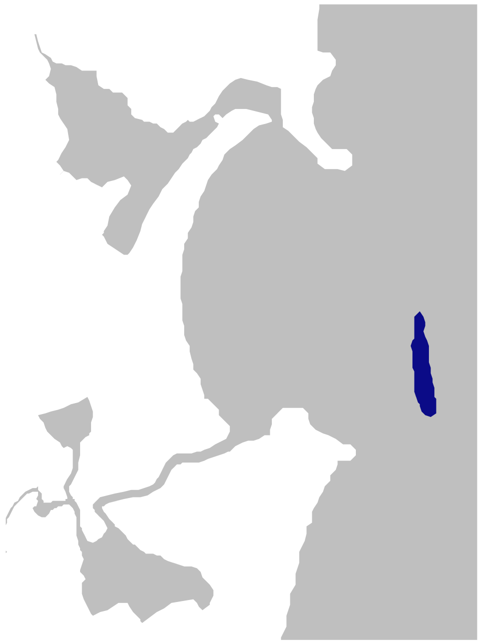
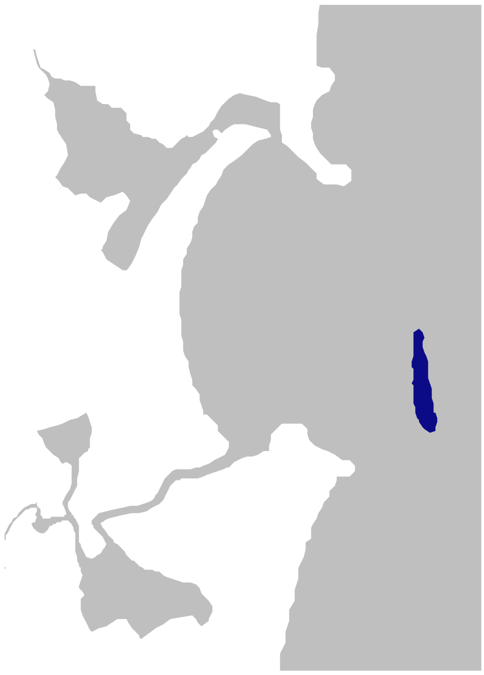
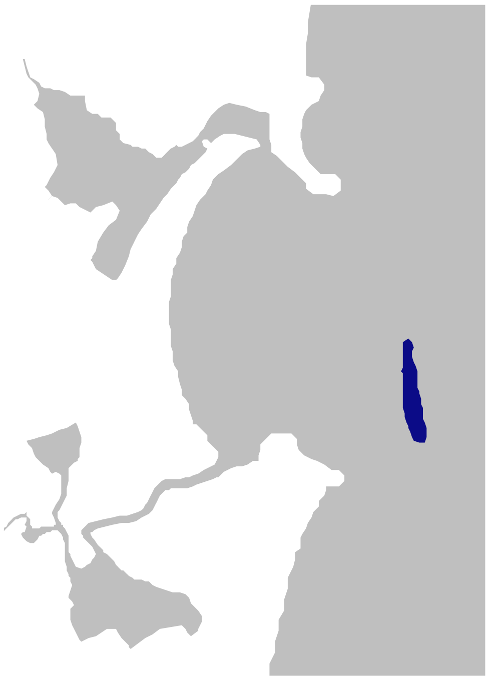
| | |
|---|---|
| **Current speed:** 0.56 m/s | **Current direction:** Southward |
| **Outfall location:** Location 2 | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |


**Figure 44. Model run #22: 0.56 m/s southward current, no stratification, outfall location 2**

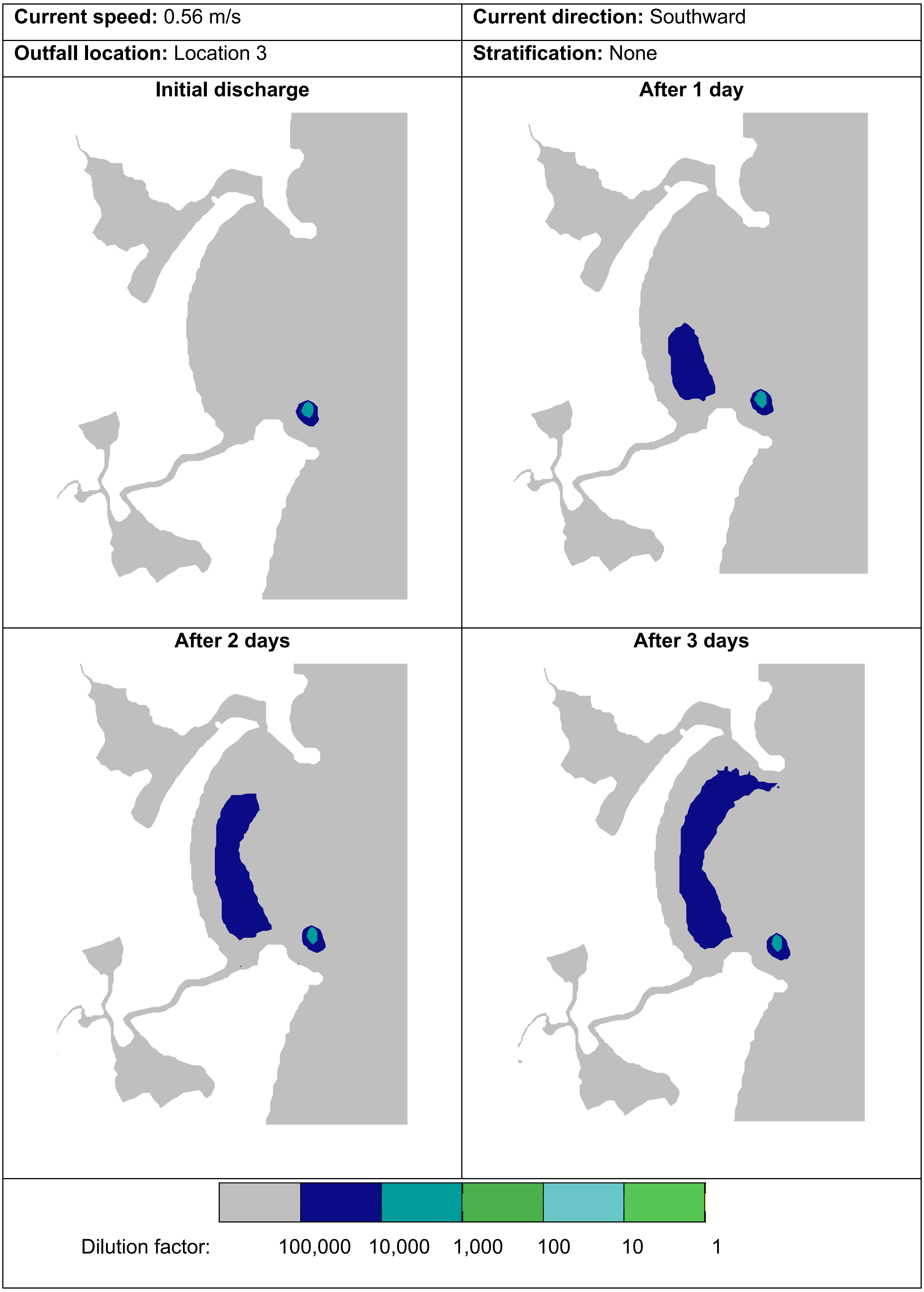



**Figure 45. Model run #23: 0.56 m/s southward current, no stratification, outfall location 3**

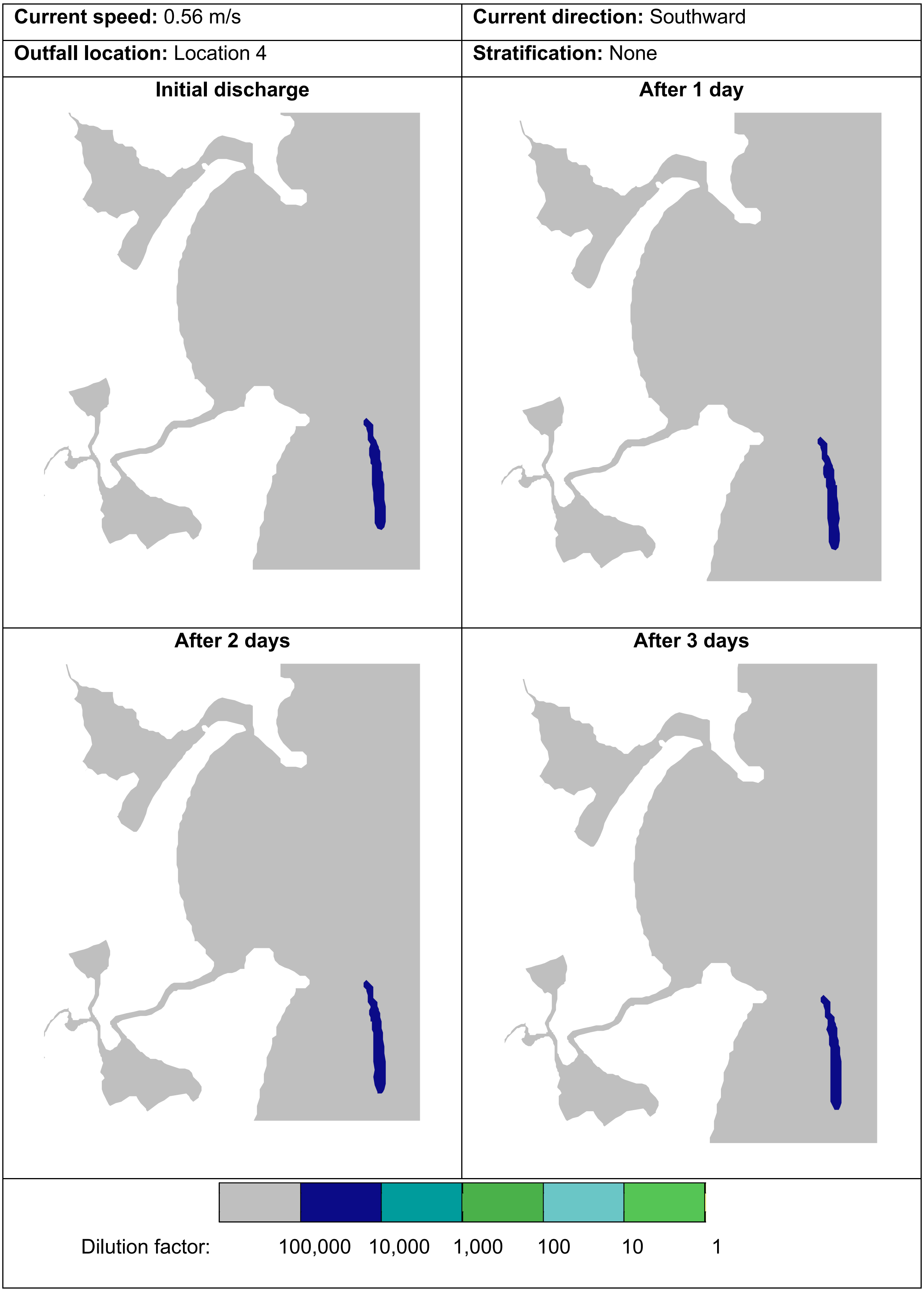
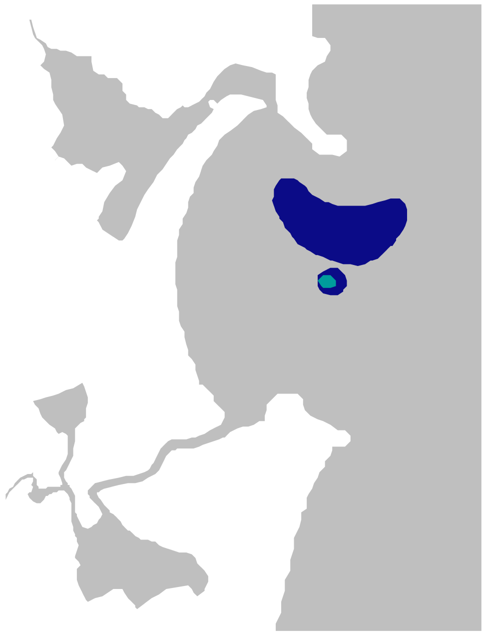
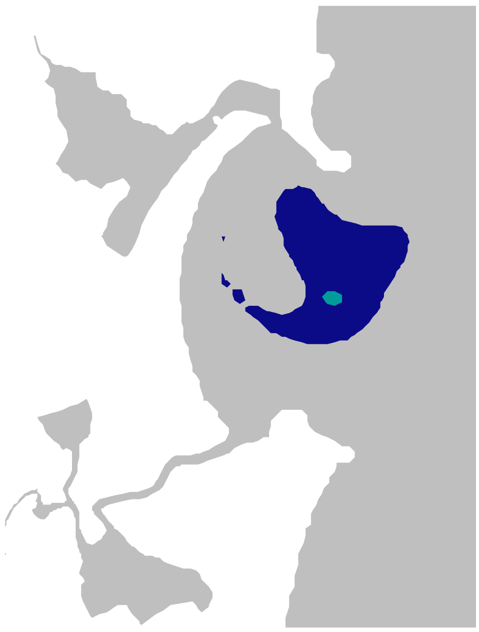
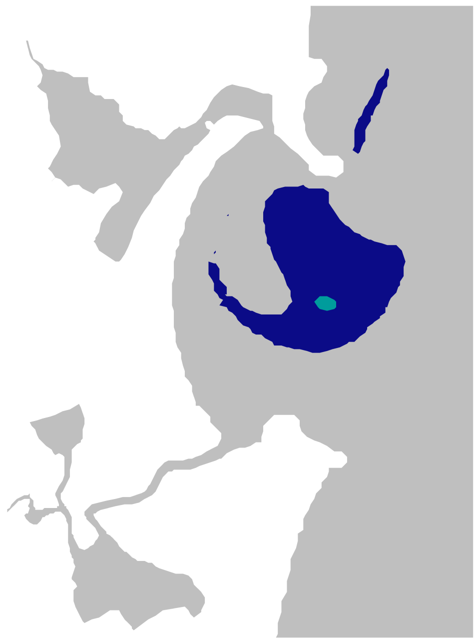



**Figure 46. Model run #24: 0.56 m/s southward current, no stratification, outfall location 4**

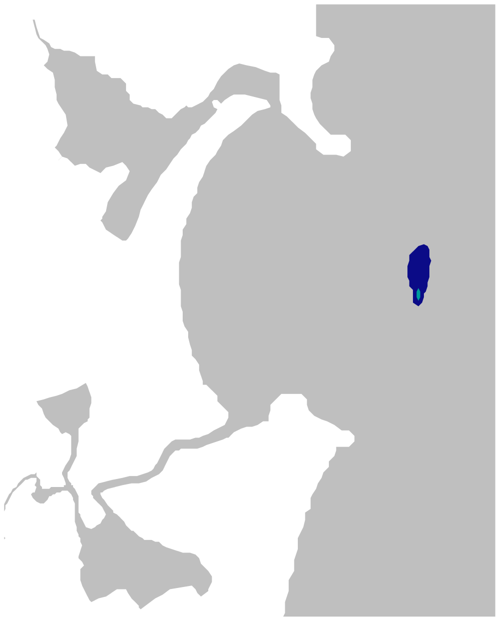
| | |
|---|---|
| **Current speed:** 0.34 m/s | **Current direction:** Northward |
| **Outfall location:** Location 1 | **Stratification:** None |
| **Initial discharge** | **After 1 day** |
|  |  |
| **After 2 days** | **After 3 days** |
|  |  |

Dilution factor: 100,000 10,000 1,000 100 10 1

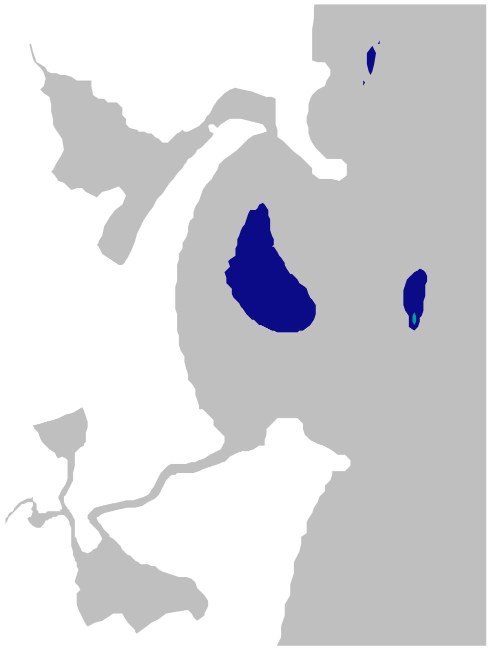
**Figure 47. Model run #25: 0.34 m/s northward current, no stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.34 m/s | **Current direction:** Northward |
| **Outfall location:** Location 2 | **Stratification:** None |

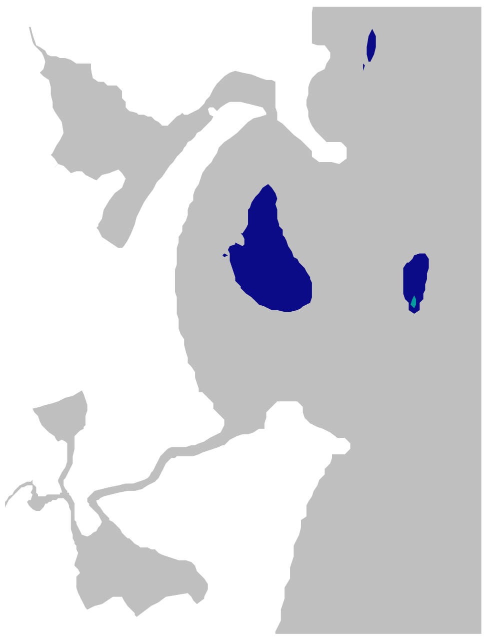
**Initial discharge**



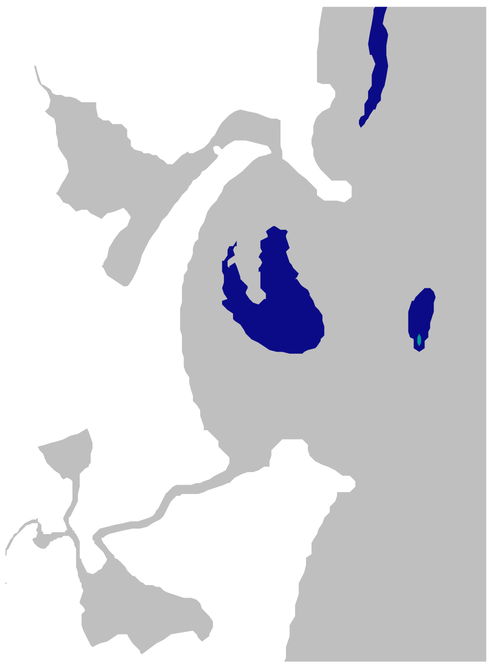
**After 1 day**



**After 2 days**



**After 3 days**



Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 48. Model run #26: 0.34 m/s northward current, no stratification, outfall location 2**

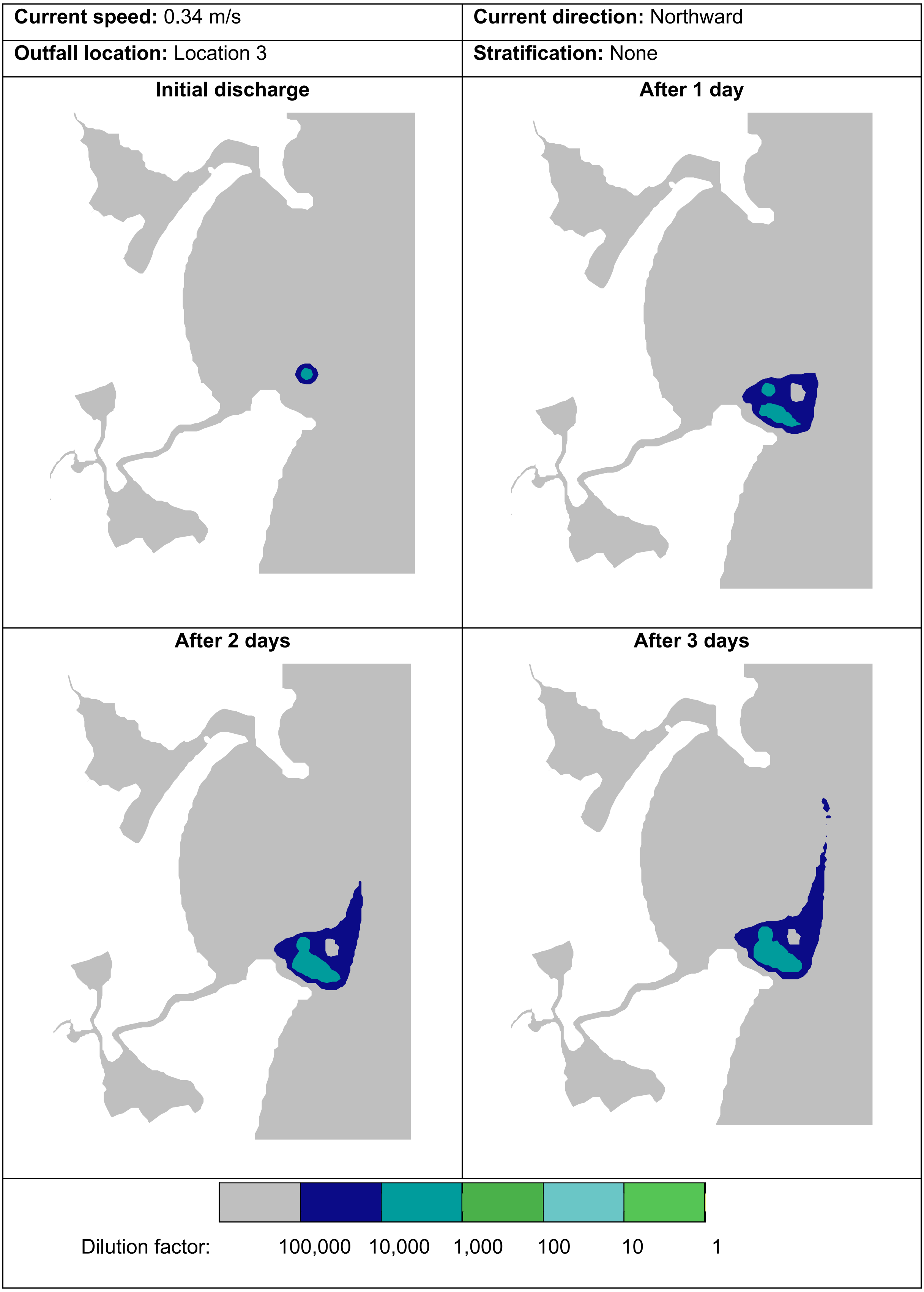
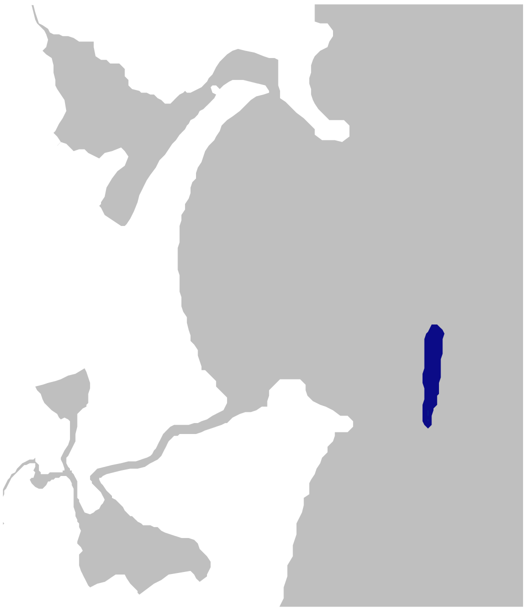
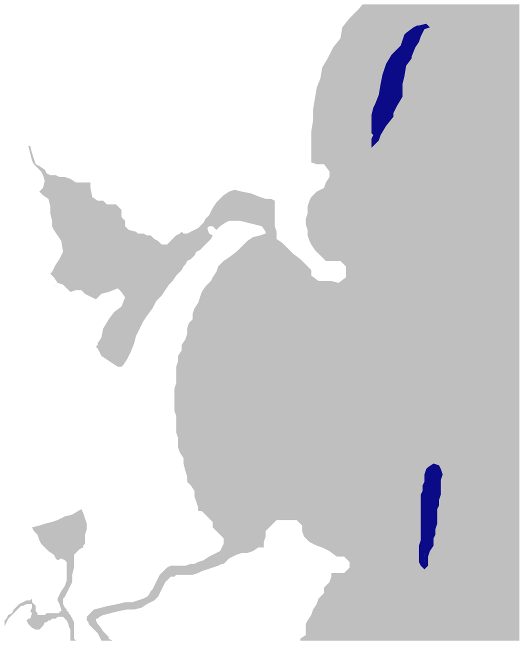
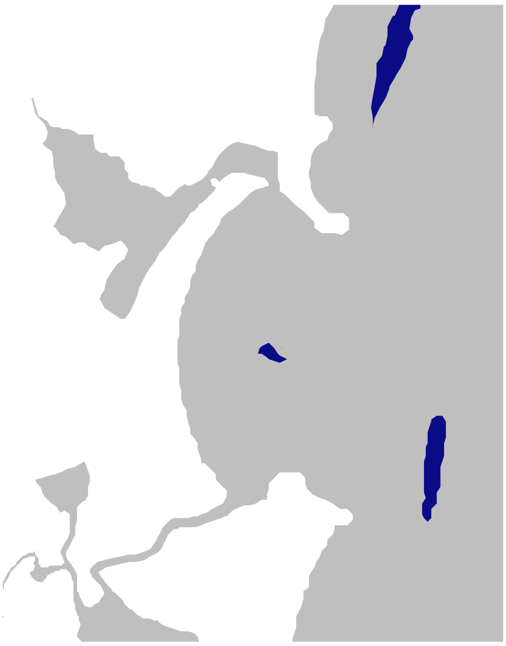
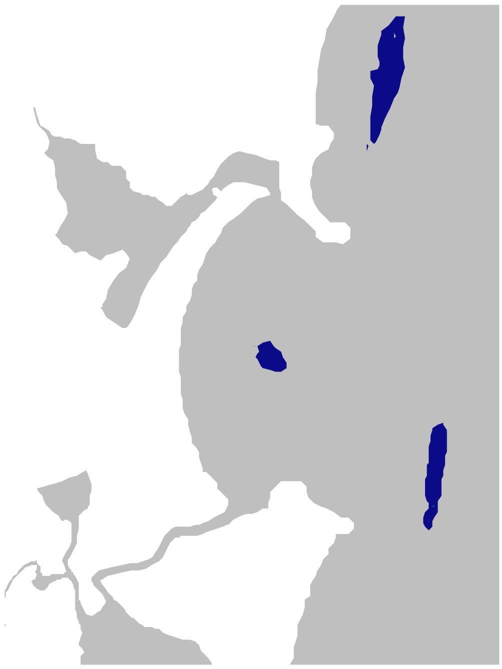



**Figure 49. Model run #27: 0.34 m/s northward current, no stratification, outfall location 3**

| | |
|---|---|
| **Current speed:** 0.34 m/s | **Current direction:** Northward |
| **Outfall location:** Location 4 | **Stratification:** None |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |

Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 50. Model run #28: 0.34 m/s northward current, no stratification, outfall location 4**

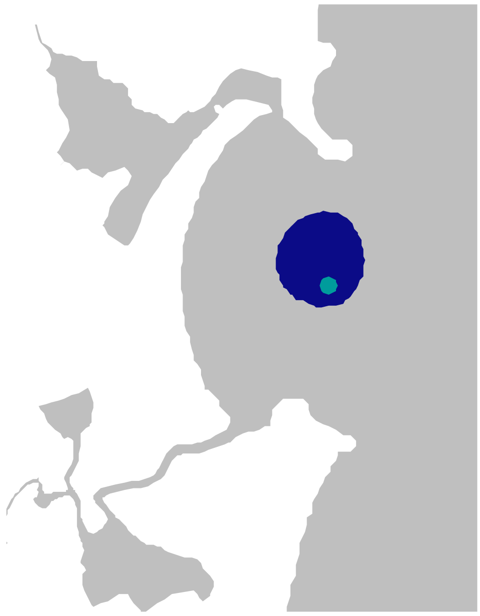
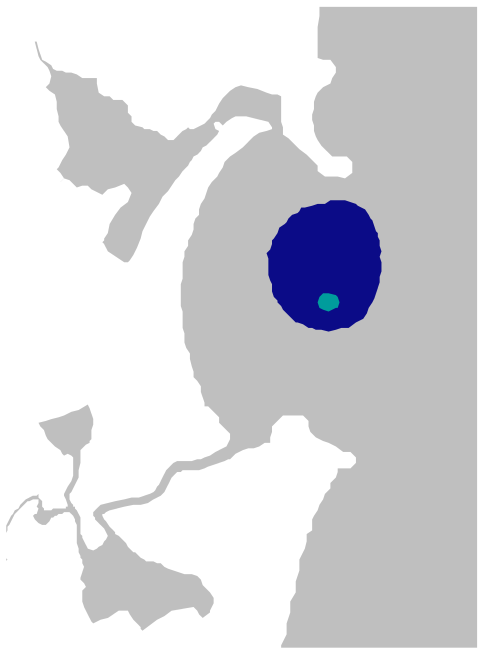
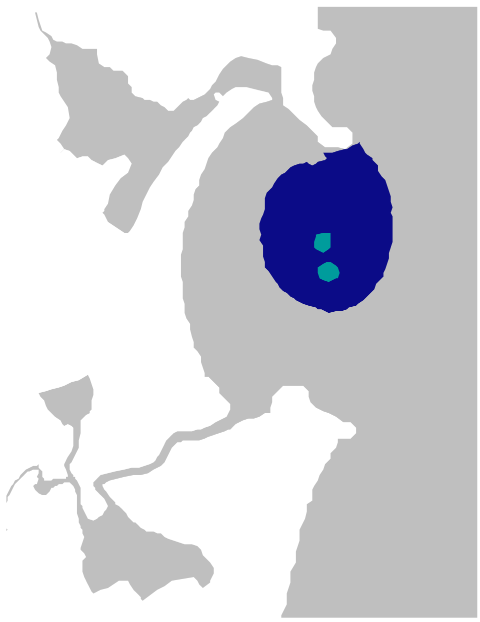
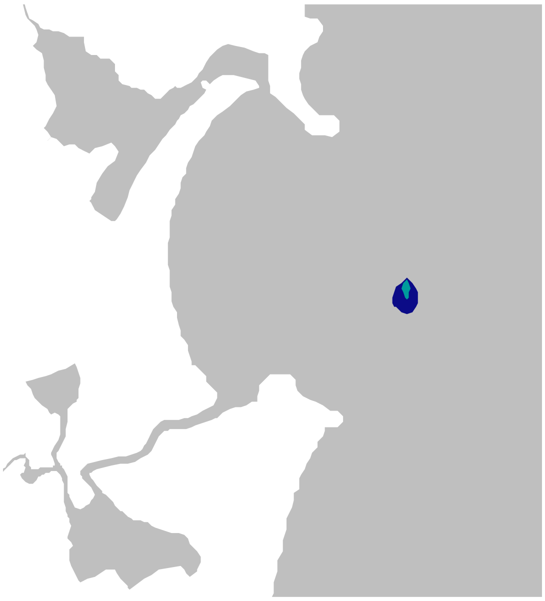
| **Current speed:** 0.15 m/s | **Current direction:** Southward |
|---|---|
| **Outfall location:** Location 1 | **Stratification:** Mid-depth stratification |
| **Initial discharge**<br> | **After 1 day**<br> |
| **After 2 days**<br> | **After 3 days**<br> |
| <br>Dilution factor: 100,000 10,000 1,000 100 10 1 | |

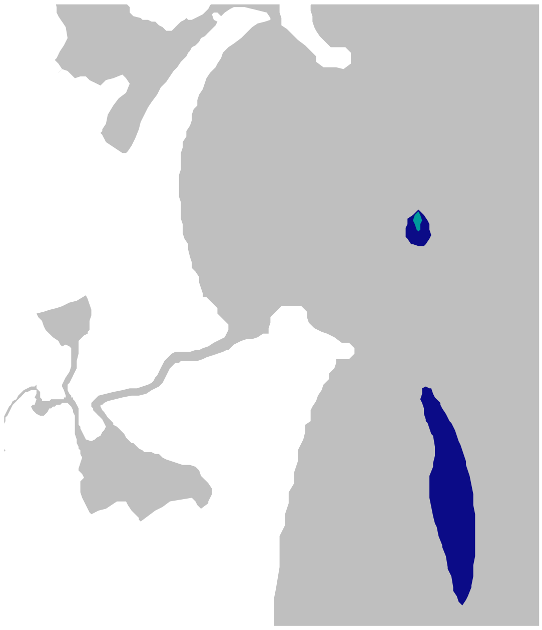
**Figure 51. Model run #29: 0.15 m/s southward current, with stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Southward |
| **Outfall location:** Location 2 | **Stratification:** Mid-depth stratification |

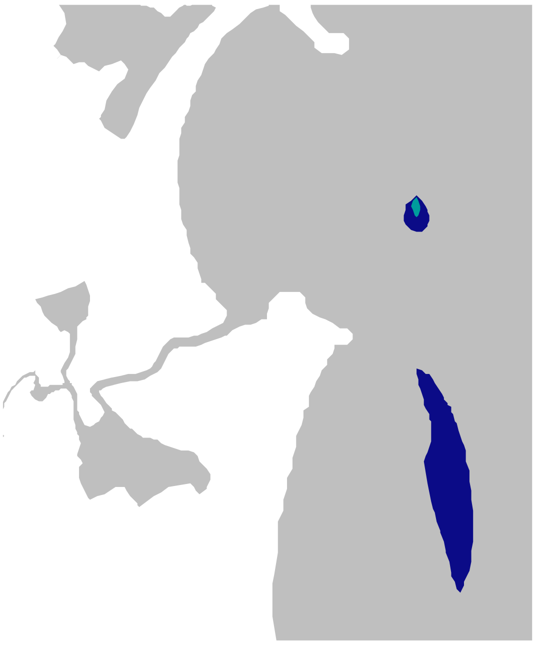
**Initial discharge**



**After 1 day**



**After 2 days**



**After 3 days**

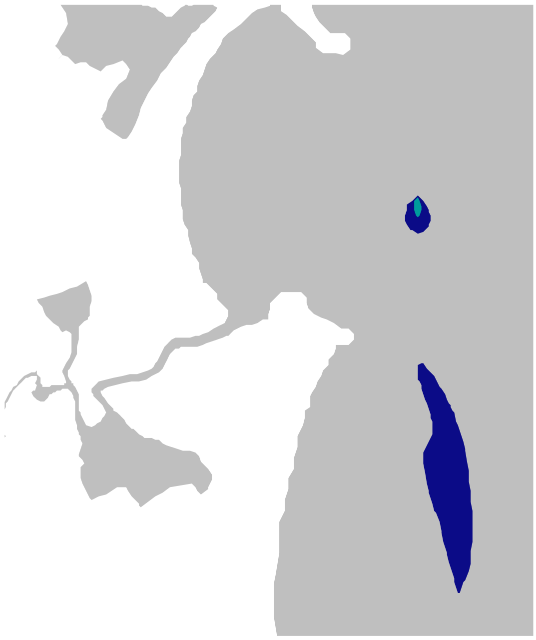



**Figure 52. Model run #30: 0.15 m/s southward current, with stratification, outfall location 2**

| | |
|---|---|
| **Current speed:** 0.15 m/s | **Current direction:** Southward |
| **Outfall location:** Location 4 | **Stratification:** Mid-depth stratification |

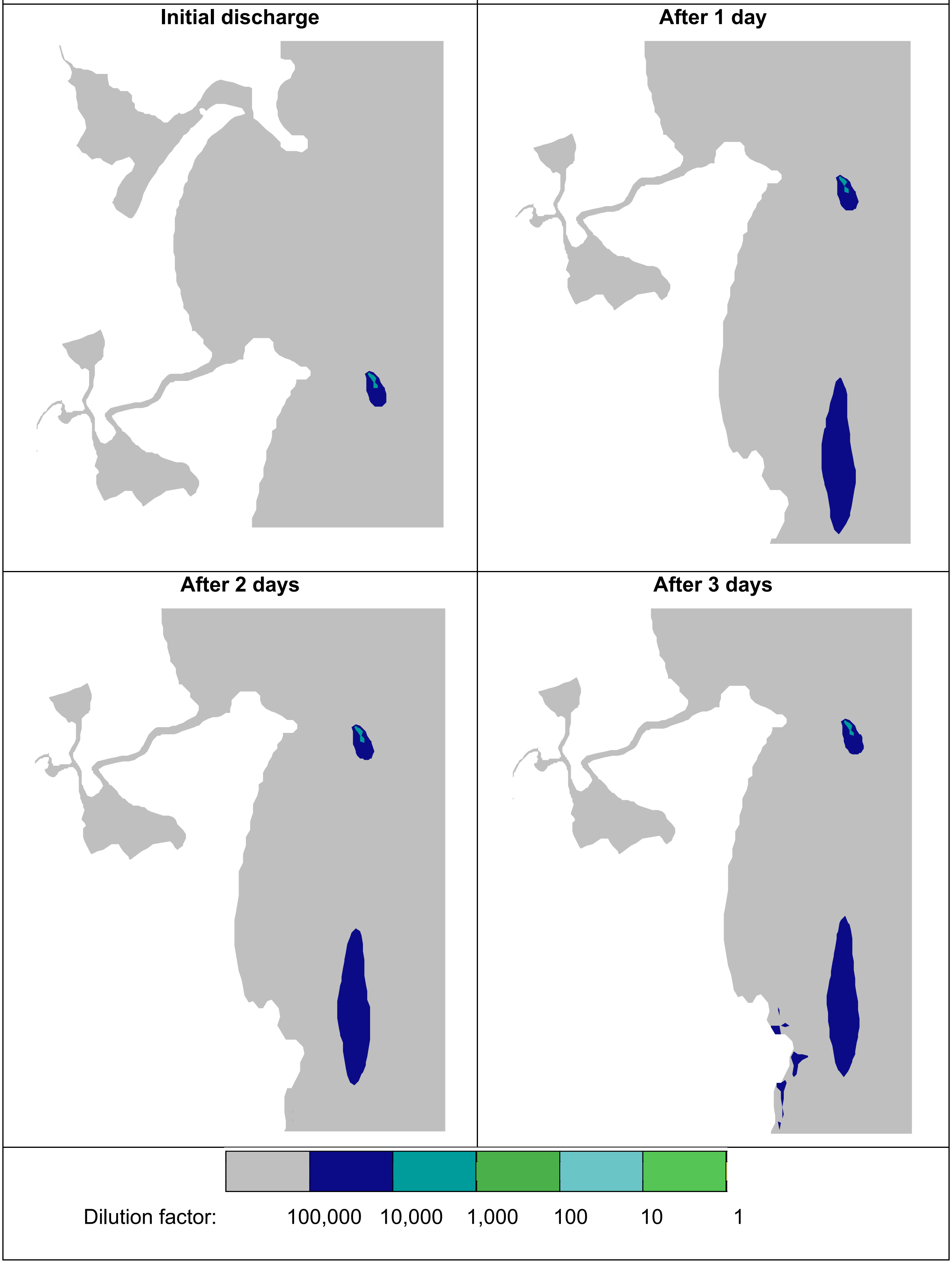



**Figure 53. Model run #31: 0.15 m/s southward current, with stratification, outfall location 4**

| | |
|---|---|
| **Current speed:** 0.05 m/s | **Current direction:** Northward |
| **Outfall location:** Location 1 | **Stratification:** Mid-depth stratification |

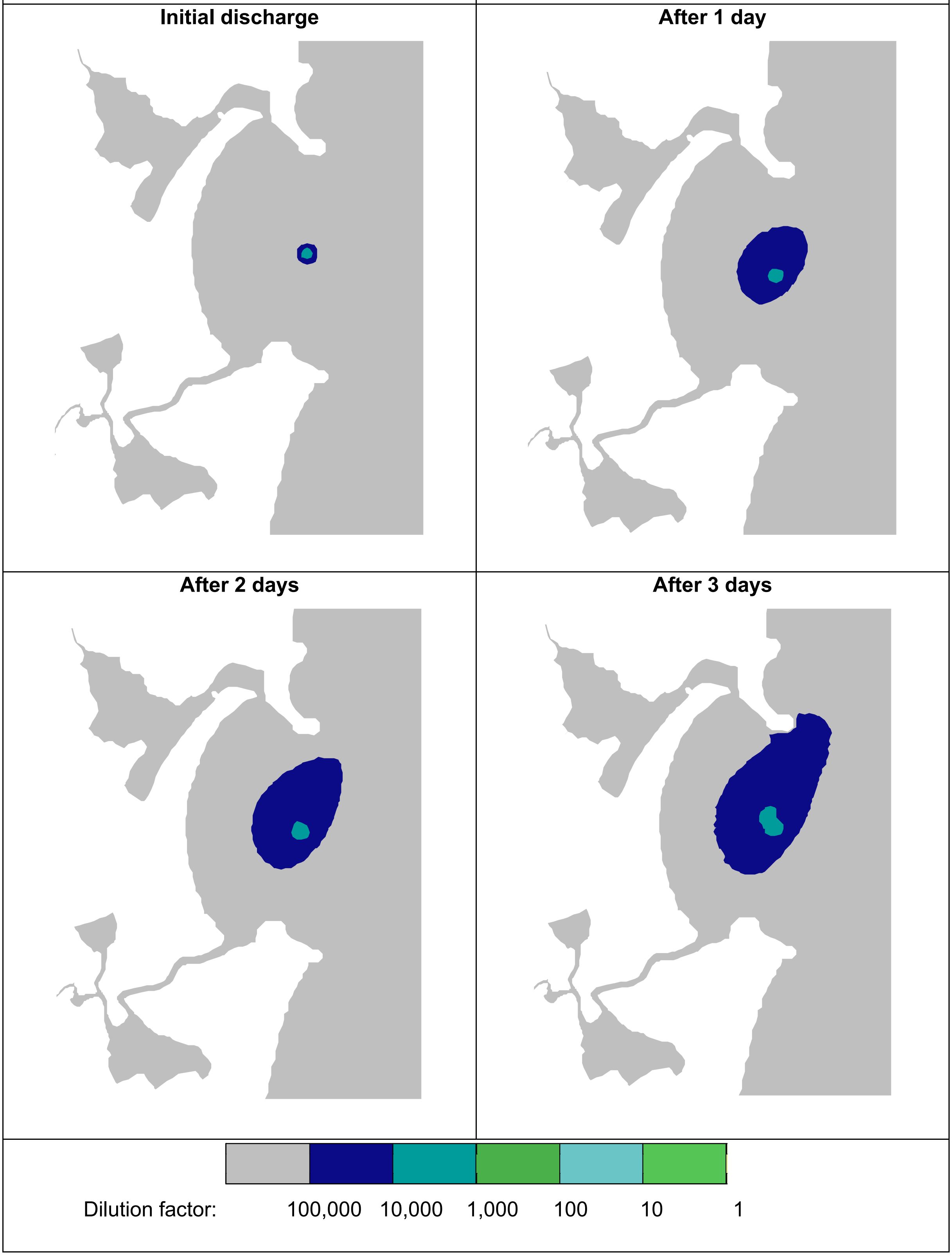



**Figure 54. Model run #32: 0.05 m/s northward current, with stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.05 m/s | **Current direction:** Northward |
| **Outfall location:** Location 2 | **Stratification:** Mid-depth stratification |

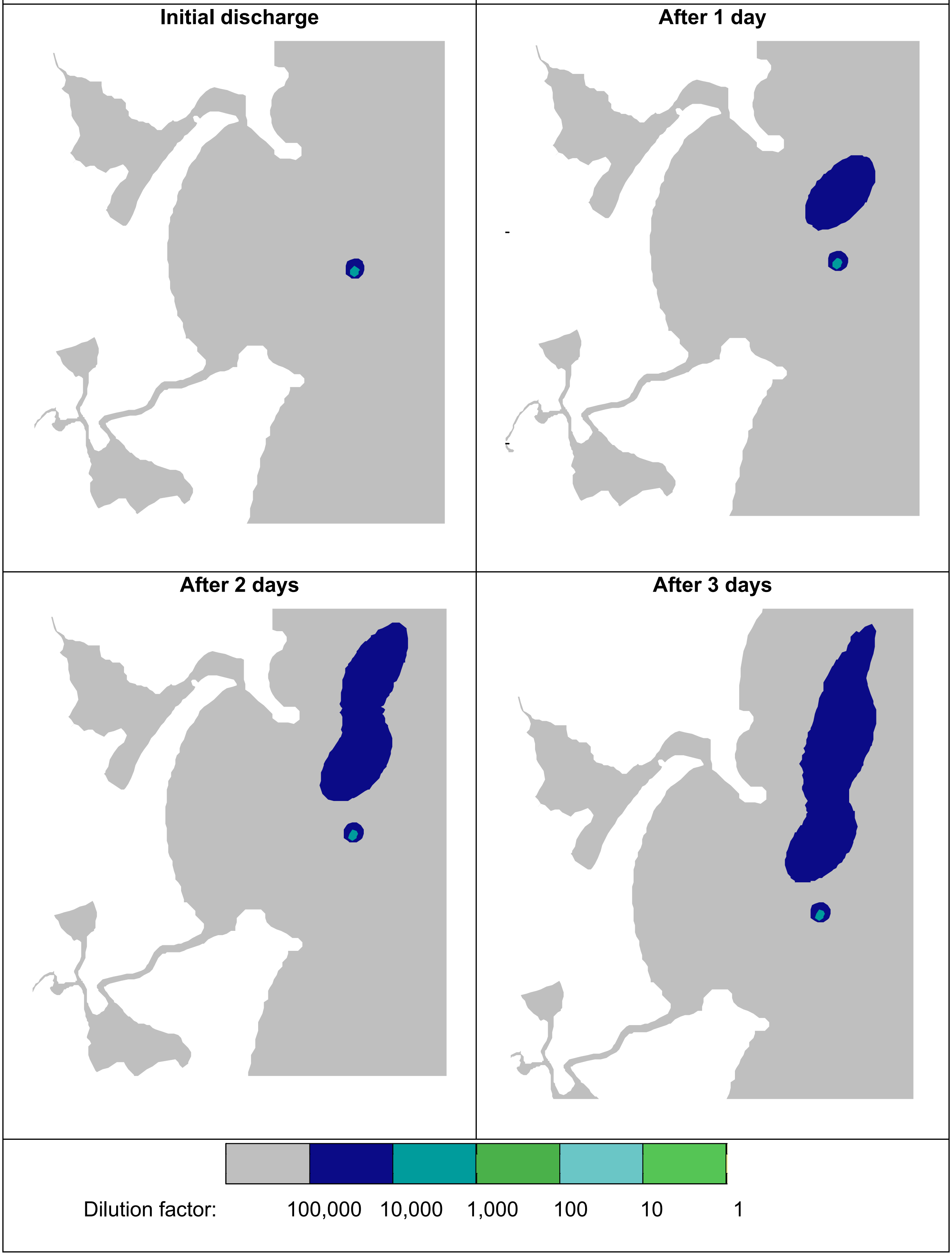



**Figure 55. Model run #33: 0.05 m/s northward current, with stratification, outfall location 2**

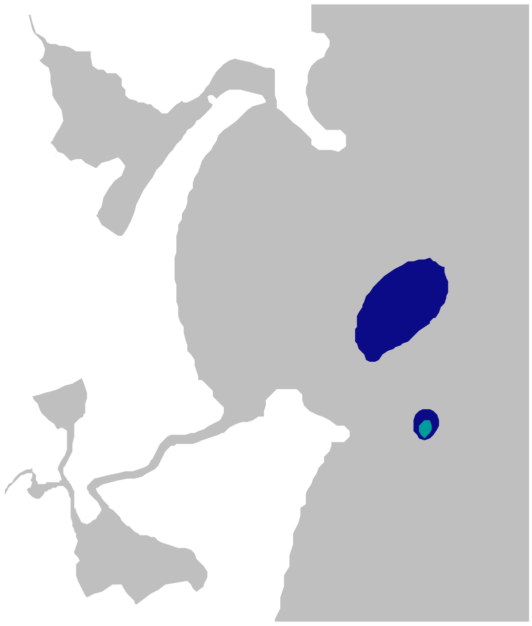
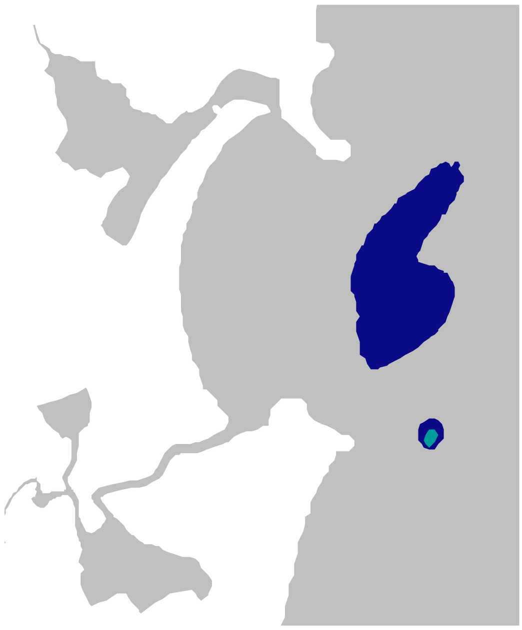
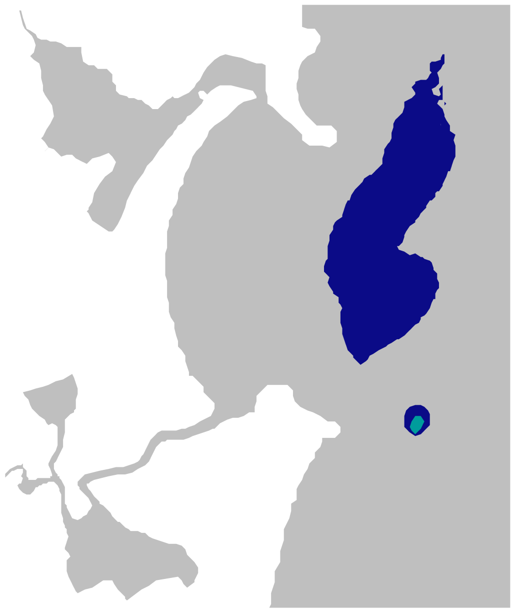
| **Current speed:** 0.05 m/s | **Current direction:** Northward |
|---|---|
| **Outfall location:** Location 4 | **Stratification:** Mid-depth stratification |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |


**Figure 56. Model run #34: 0.05 m/s northward current, with stratification, outfall location 4**

| | |
|---|---|
| **Current speed:** 0.56 m/s | **Current direction:** Southward |
| **Outfall location:** Location 1 | **Stratification:** Mid-depth stratification |

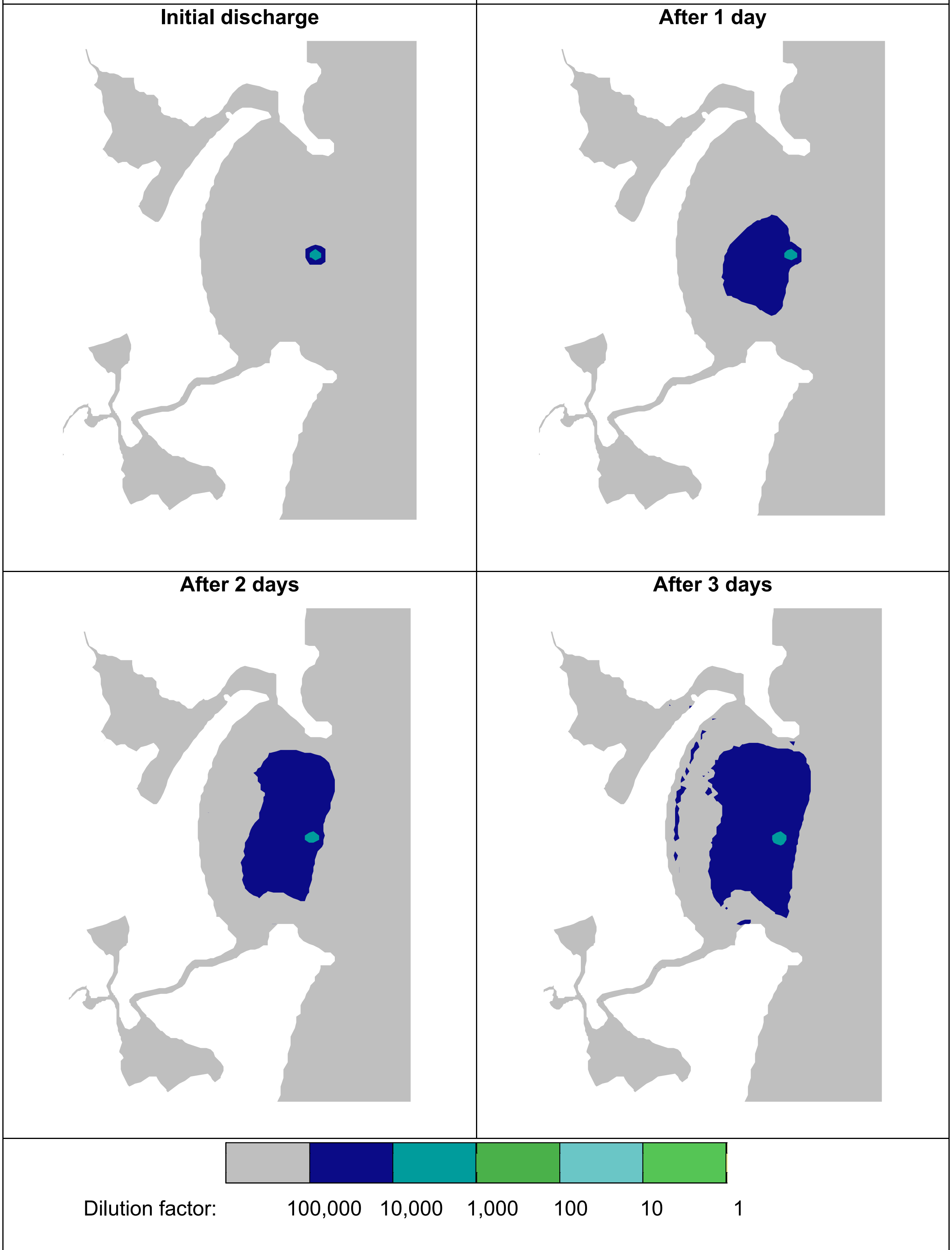



**Figure 57. Model run #35: 0.56 m/s southward current, with stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.56 m/s | **Current direction:** Southward |
| **Outfall location:** Location 2 | **Stratification:** Mid-depth stratification |

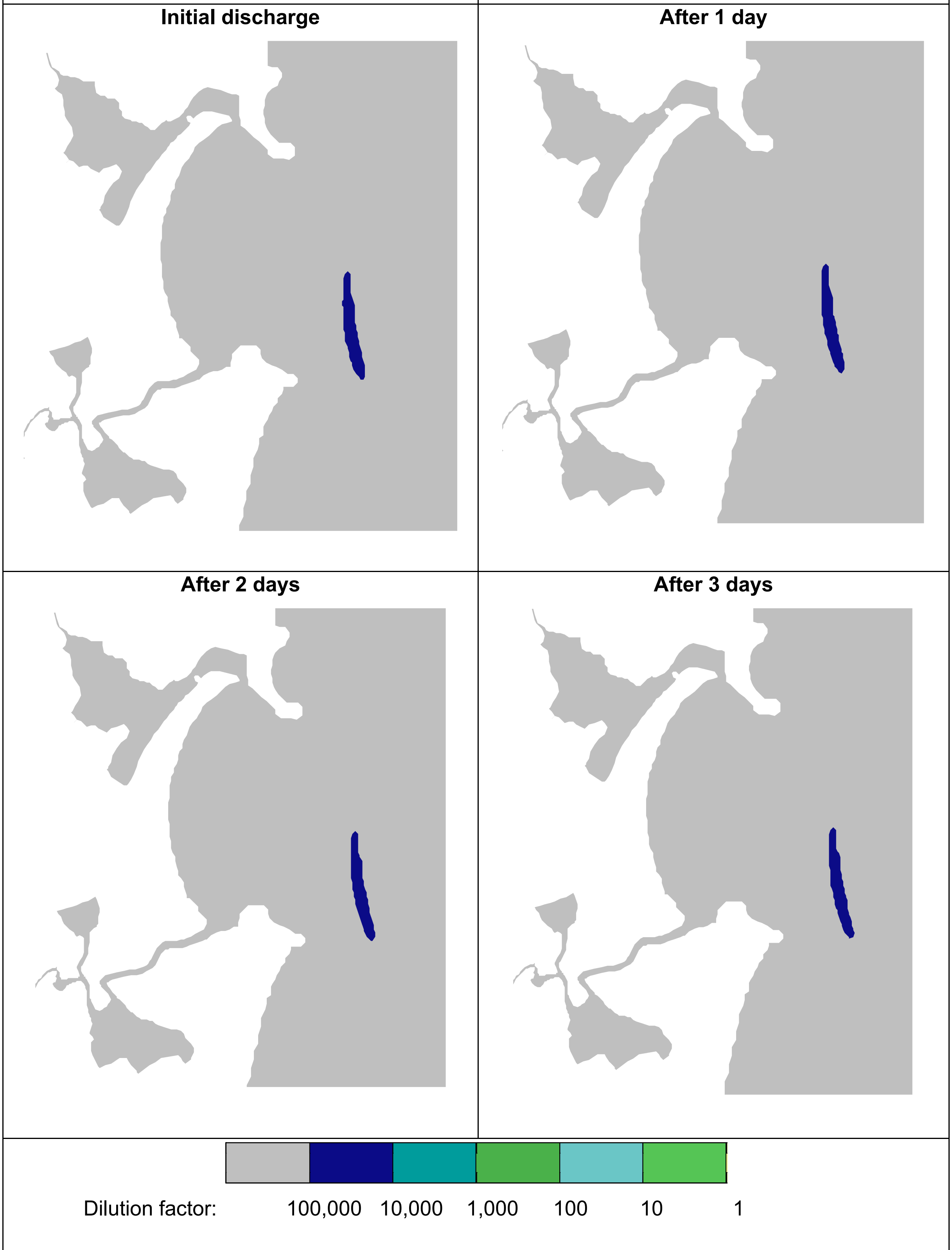



**Figure 58. Model run #36: 0.56 m/s southward current, with stratification, outfall location 2**

| | |
|---|---|
| **Current speed:** 0.34 m/s | **Current direction:** Northward |
| **Outfall location:** Location 1 | **Stratification:** Mid-depth stratification |

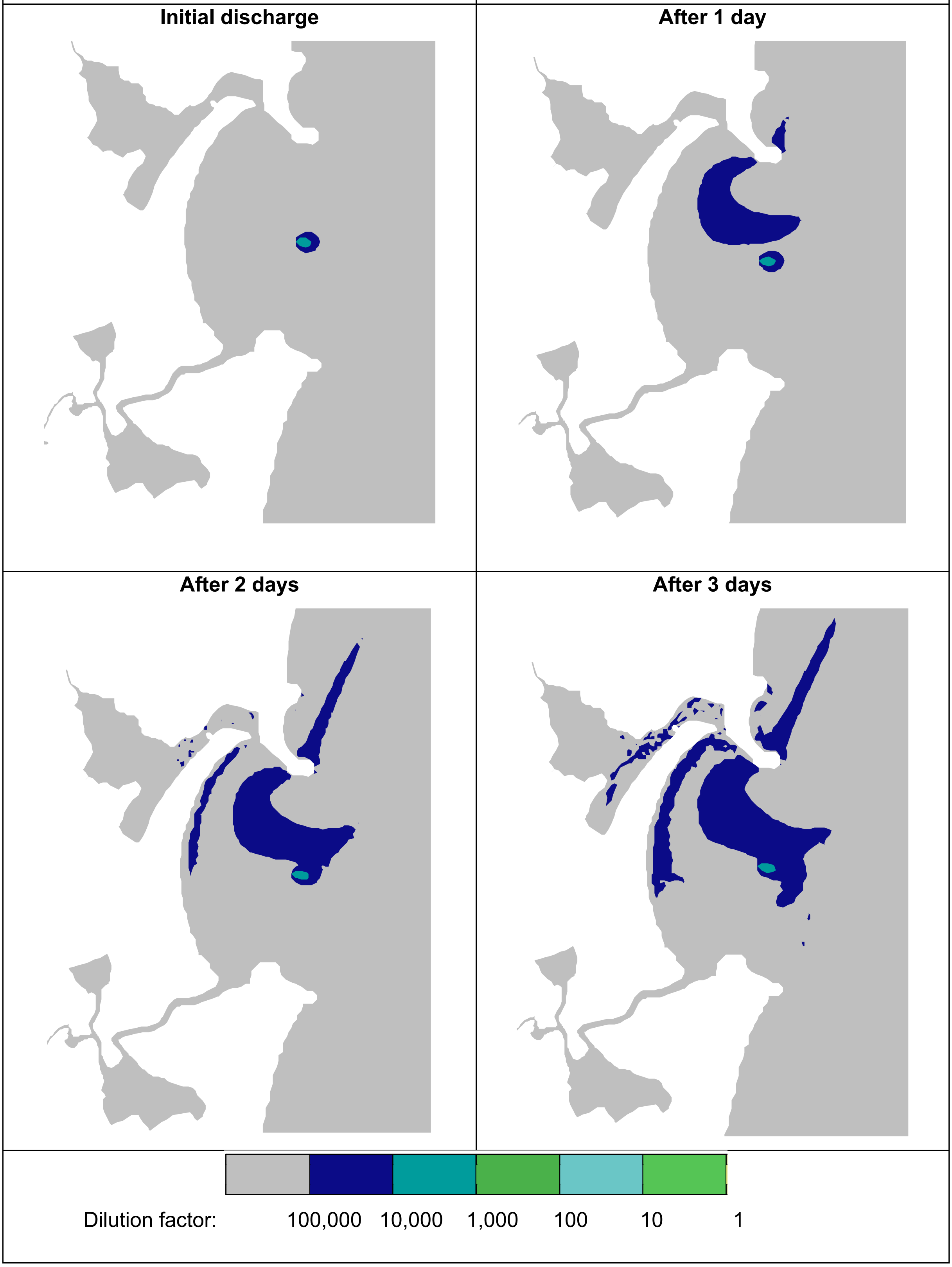
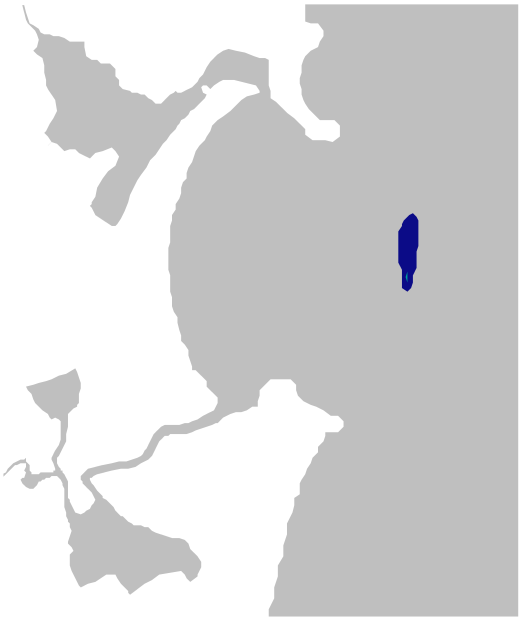
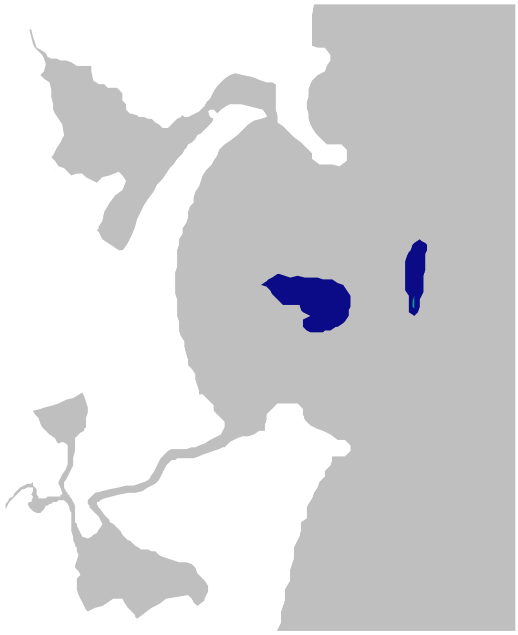
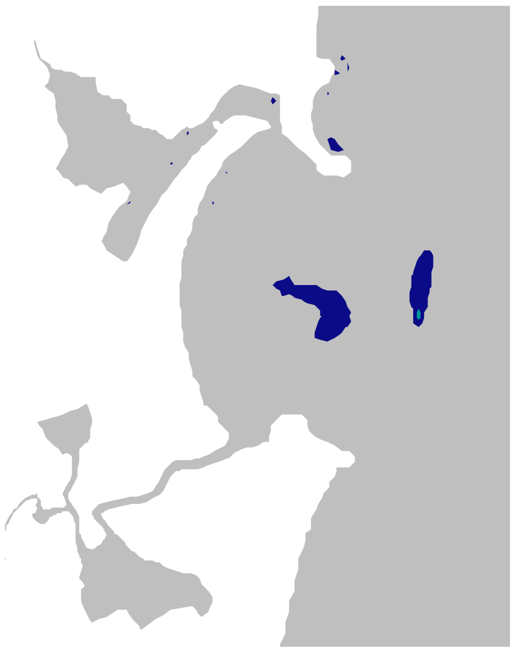



**Figure 59. Model run #37: 0.34 m/s northward current, with stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.34 m/s | **Current direction:** Northward |
| **Outfall location:** Location 2 | **Stratification:** Mid-depth stratification |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |

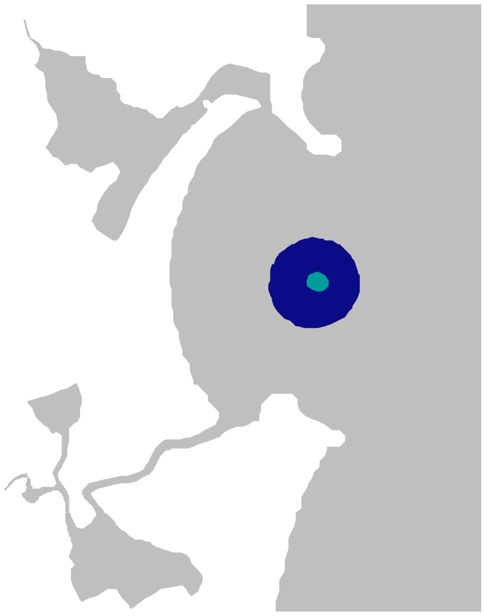
Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 60. Model run #38: 0.34 m/s northward current, with stratification, outfall location 2**

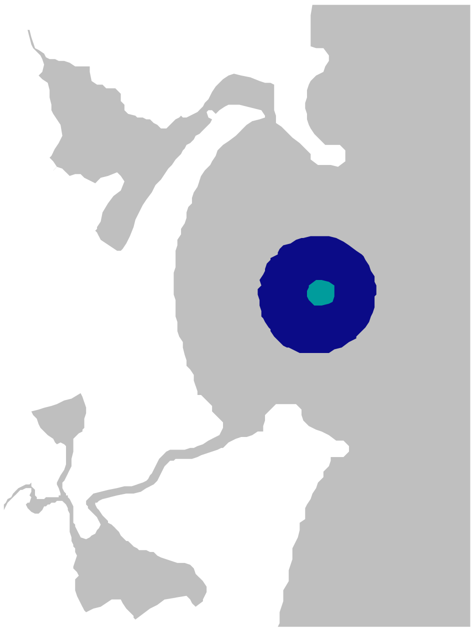
| | |
|---|---|
| **Current speed:** None | **Current direction:** N/A |
| **Outfall location:** Location 1 | **Stratification:** None |

**Initial discharge**

**After 1 day**



**After 2 days**



**After 3 days**

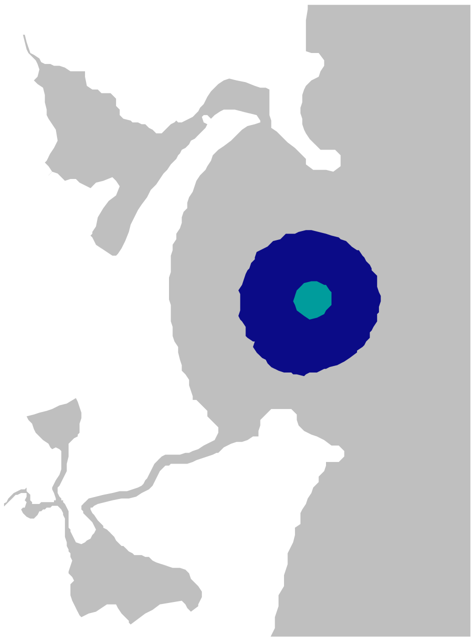
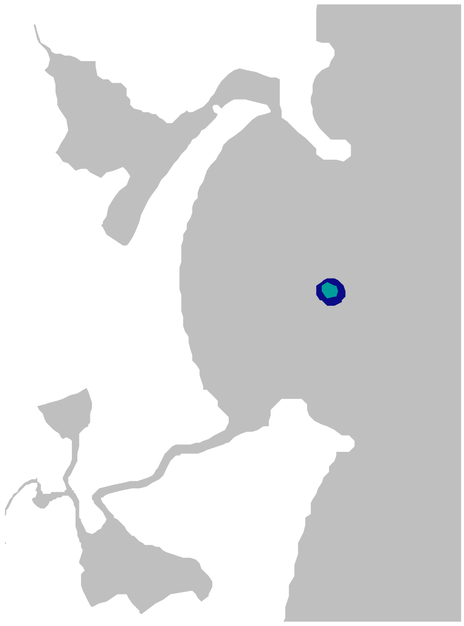


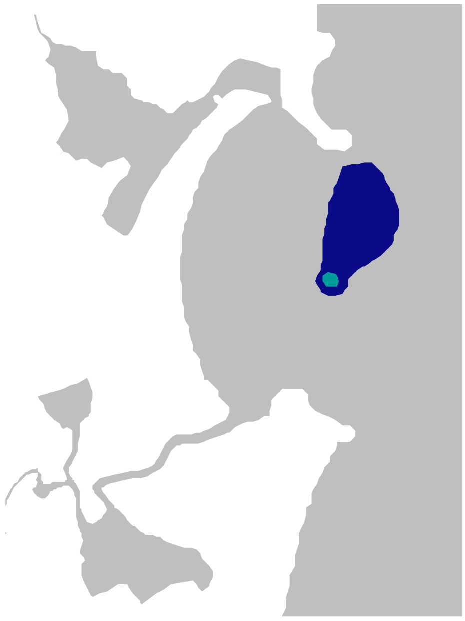

**Figure 61. Model run #39: Zero current, no stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.53 m/s | **Current direction:** Northward |
| **Outfall location:** Location 1 | **Stratification:** None |

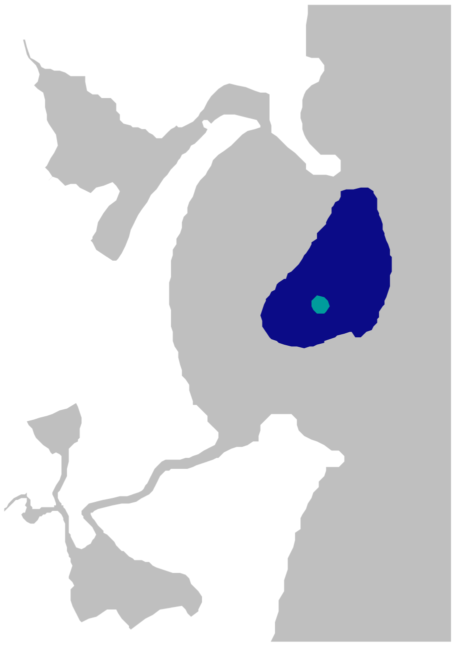
**Initial discharge**



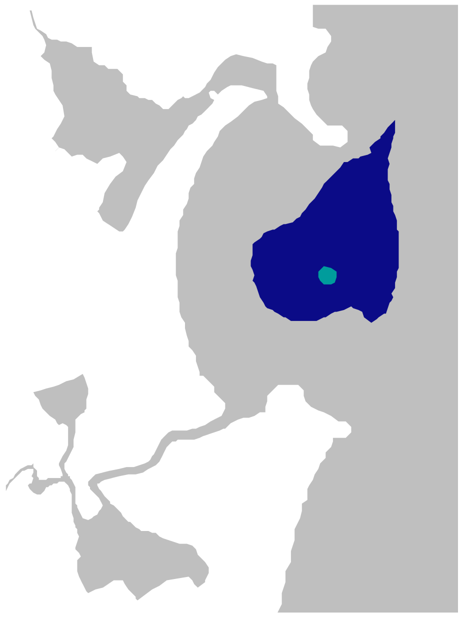
**After 1 day**



**After 2 days**



**After 3 days**



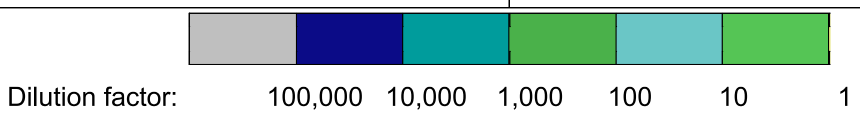



**Figure 62. Model run #40: 0.53 m/s northward current, no stratification, outfall location 1**

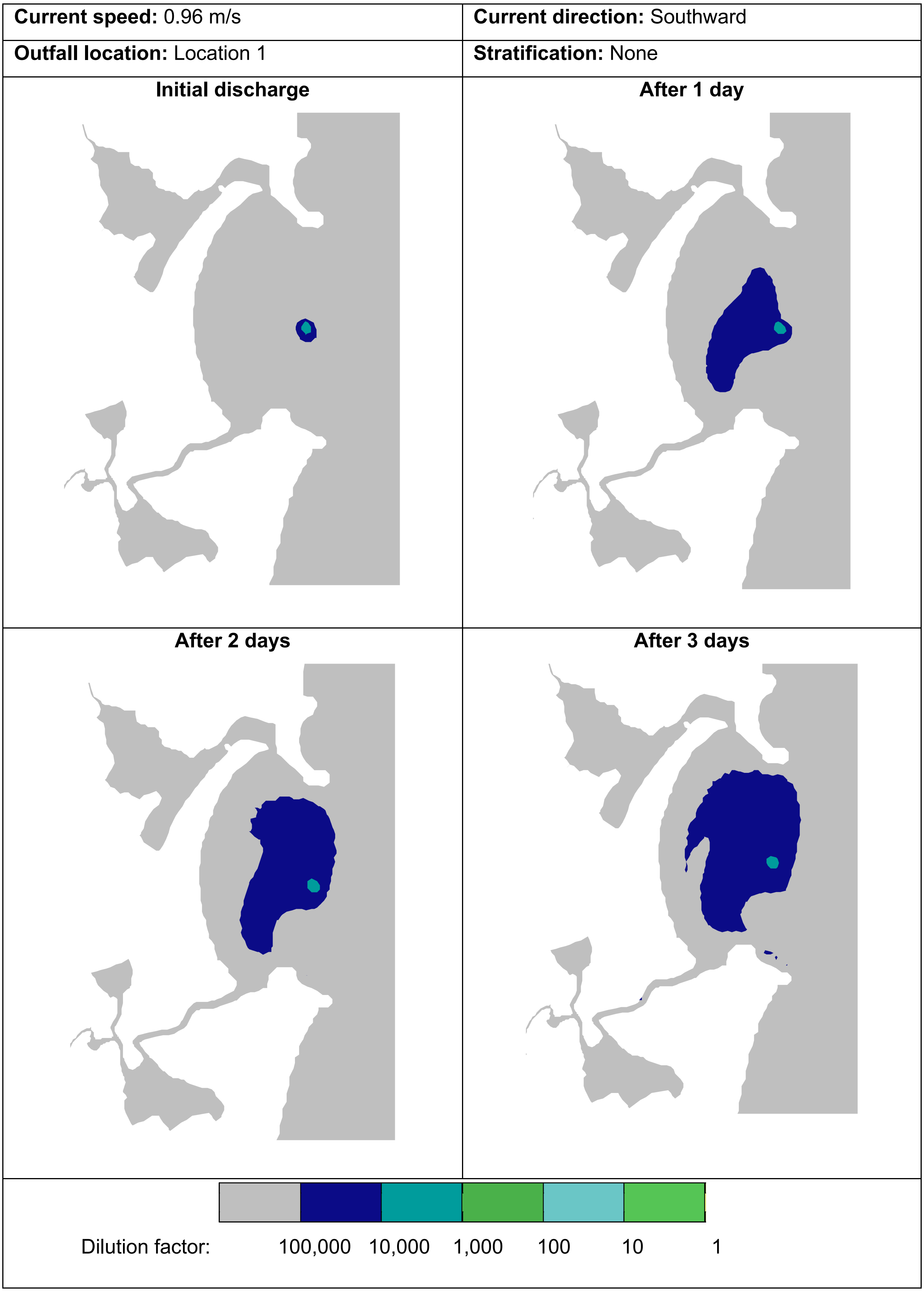



**Figure 63. Model run #41: 0.96 m/s southward current, no stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** None | **Current direction:** N/A |
| **Outfall location:** Location 1 | **Stratification:** Mid-depth stratification |

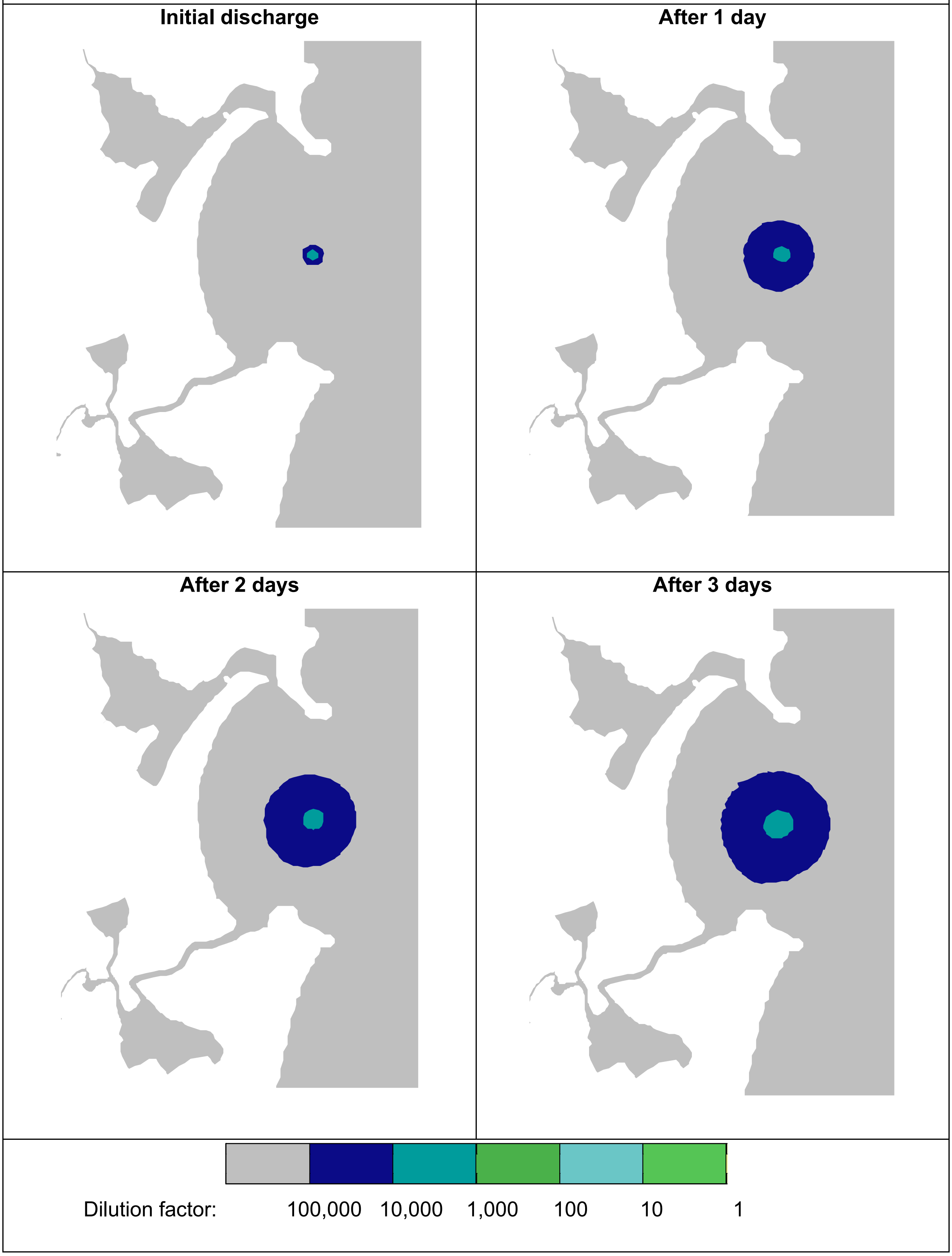
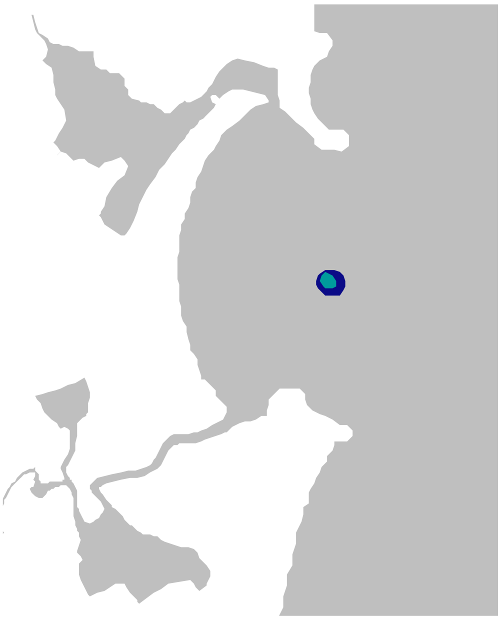
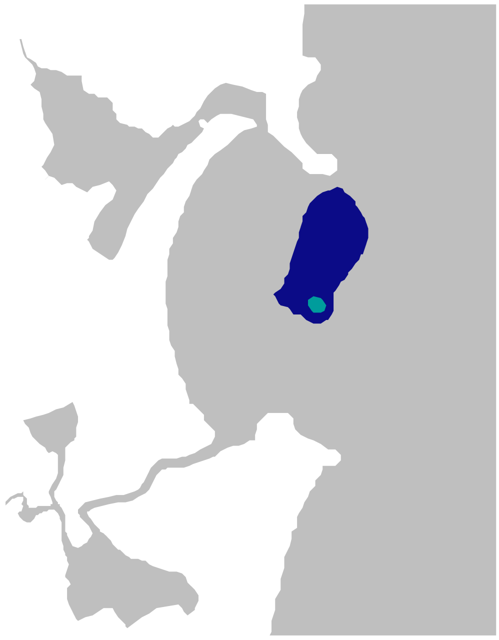



**Figure 64. Model run #42: Zero current, with stratification, outfall location 1**

| | |
|---|---|
| **Current speed:** 0.53 m/s | **Current direction:** Northward |
| **Outfall location:** Location 1 | **Stratification:** Mid-depth stratification |
| **Initial discharge**  | **After 1 day**  |
| **After 2 days**  | **After 3 days**  |

Dilution factor: 100,000 10,000 1,000 100 10 1

**Figure 65. Model run #43: 0.53 m/s northward current, with stratification, outfall location 1**

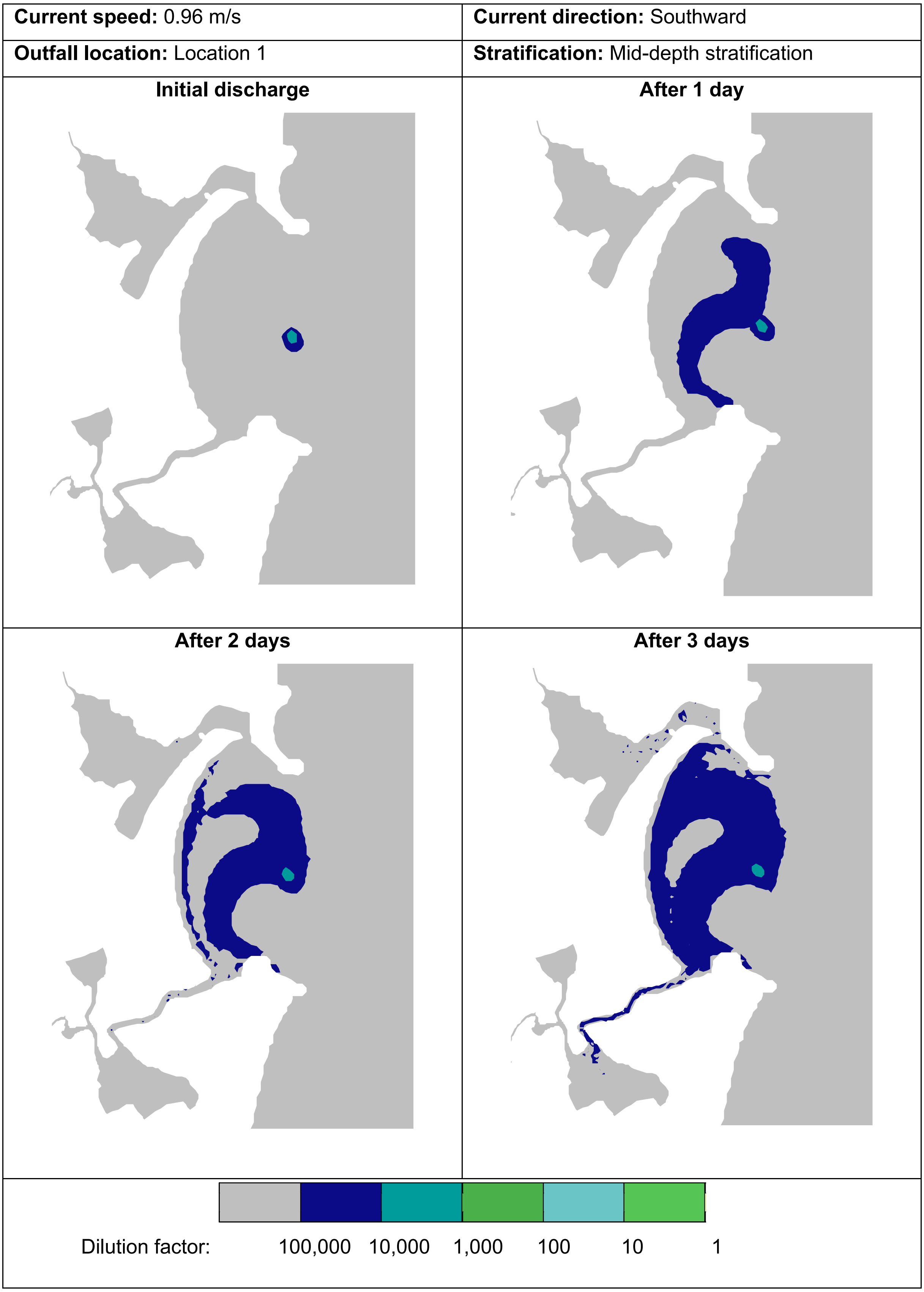



**Figure 66. Model run #44: 0.96 m/s southward current, with stratification, outfall location 1**