Napier City Wastewater Ocean Outfall

Napier Outfall Assessment

Report prepared for Napier District Council

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MetOcean SOLUTIONS

Document History

Versions

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0.1	1/10/2020	Initial Document	Goward Brown
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1.Introduction

Napier City Council (NCC) operates the Napier City Wastewater Ocean Outfall, located to the south of the City of Napier. The outfall extends some 1540 m offshore and has 32 diffuser ports discharging in approximately 10-12 m of water depth (Figure 1.1, Table 1.1).

The consented treated discharge from the outfall should not exceed 32,000 m^3 day^{-1} with a maximum flow rate of 1,400 L s^{-1}.

Previous hydrodynamic and diffusion modelling of the outfall was commissioned by NCC in 2011(MOS 2011). The report explored the hydrodynamic transport and diffusion of virus content within the discharged effluent.

In this present report, the impact of a break in the outfall 700 m from the shore on the dispersion of the discharge is compared with a “normal” discharge scenario. In addition, the influence of an extension of the outfall diffuser to a location 2.5 km offshore on effluent dispersion is also examined and compared with the current diffuser location. The rate of effluent release is kept constant between each scenario modelled to facilitate comparison.

The three proposed scenarios are listed below:

- Scenario 1: Particle release for the current diffuser location (“Normal Operation”, the control).
- Scenario 2: Particle release from a pipe break 700 m from the shore.
- Scenario 3: Particle release from a prospective new diffuser location 2.5 km offshore.

The report is organised as follows: Section 2 provides a summary of the existing model data and a description of the particle-tracking model and its application to the plume dispersal scenarios simulated. Section 3 provides the results of the plume simulations. Section 4 gives a concise summary of the results. Finally, the references cited in this report are listed in Section 5.

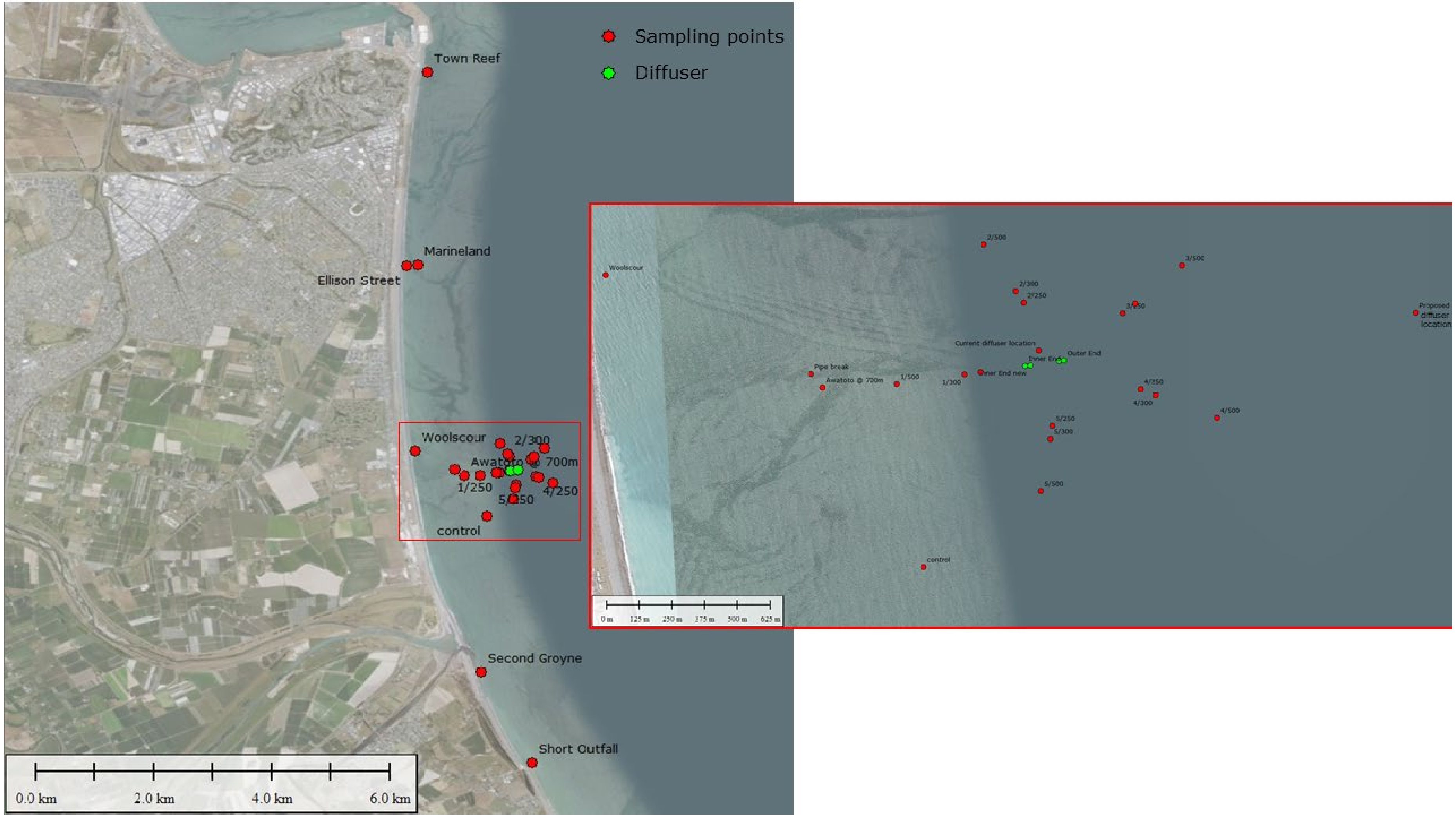

Figure 1.1 *Location of the Napier City Wastewater Ocean Outfall. Green points indicate the current diffuser locations. The red circles show the locations where time series were extracted and give the locations of the scenarios modelled, given in Table 1.1.*

Table 1.1 Description of the sites from which time series are extracted within the model domain (Figure 1.1).

	Site description and location		
	Latitude (° N)	**Longitude (° E)**	**Water Depth (m, MSL)**
Town Reef	176.92	-39.48	1.79
Marineland	176.92	-39.51	4.76
Ellison Street	176.92	-39.51	1.62
Woolscour	176.92	-39.54	1.97
Awatoto @ 700m	176.93	-39.54	10.0
Second Groyne	176.93	-39.57	-1.01
Short Outfall	176.94	-39.59	1.11
1/250	176.93	-39.54	10.0
1/300	176.92	-39.27	14.98
1/500	176.93	-39.54	10.0
2/250	176.94	-39.54	10.0
2/300	176.94	-39.54	10.0
2/500	176.93	-39.54	10.0
3/250	176.94	-39.54	10.0
3/300	176.94	-39.44	15.45
3/500	176.94	-39.54	10.0
4/250	176.94	-39.54	10.0
4/300	176.94	-39.54	10.0
4/500	176.94	-39.54	10.77
5/250	176.94	-39.54	10.0
5/300	176.94	-39.54	10.0
5/500	176.94	-39.55	10.0
control	176.93	-39.55	10.0

2. Methods

A full description of the 3D hydrodynamic model, SELFE/SCHISM, used to provide the 3-dimensional current and wind conditions for the Lagrangian particle tracking model are given in the previous MOS report (MOS 2011).

The transport and dispersion results from the previous MOS reports (MOS 2011; 2012) showed similar results for both modelled El Niño and La Niña years. El Niño conditions tend to impose a west-southwest anomaly on the 'normal' wind conditions. For La Niña events, the opposite is generally true, and this results in an east-north-easterly wind field anomaly. The results from MOS (2011) suggested that whilst directional distribution is not significantly altered between modelled scenarios, the El Niño year sees an increase in mean and median current speeds compared to the La Niña year, suggesting that El Niño will enable greater particle dispersion. For conservatism (in terms of potential spreading), the hydrodynamic model data used for these simulations was for June – July 2002 (an El Niño climatic regime).

2.1 Wastewater Plume Dispersion Modelling

2.1.1 OpenDrift Model description

The transport and dispersion of a conservative tracer was simulated using the ocean trajectory modelling framework OpenDrift[1] (Dagestad et al. 2018). OpenDrift is an open-source Python-based framework for Lagrangian particle tracking developed by the Norwegian Meteorological Institute, where it is notably used operationally as an emergency response tool for oil spill and search and rescue events. The framework is highly modular and can be used for any type of drift calculations in the ocean or atmosphere. Several modules have already been developed, including an oil drift module (see Röhrs et al., 2019), a stochastic search-and-rescue module, a pelagic egg module, and a plastic drift module. The dispersion simulations described in the study were undertaken using the generic OceanDrift3D [2] module. The wastewater dispersion

[1] https://github.com/OpenDrift/opendrift7

[2] https://github.com/OpenDrift/opendrift/blob/master/opendrift/models/oceandrift3D.py

modelling consists of a trajectory tracking scheme applied to discrete particles in time and space-varying 3D oceanic currents (2.1):

$$\frac{dx_p}{dt} = \tilde{u}(x,y,z,t) + u_t \quad (2.1a)$$

$$\frac{dy_p}{dt} = \tilde{v}(x,y,z,t) + v_t \quad (2.1\ b)$$

$$\frac{dz_p}{dt} = w_t \quad (2.1c)$$

where (xp, yp, zp) are particle 3D coordinates, $\tilde{u}(x,y,z,t), \tilde{v}(x,y,z,t)$ are horizontal ocean currents, u_t, v_t, w_t are the diffusion components representing turbulent motions.

In the horizontal plane, particles were advected by ocean currents using a 4th-order Runge-Kutta tracking scheme, and subject to additional displacement by horizontal diffusion. In the OpenDrift framework, the horizontal diffusion is included by applying an uncertainty to the horizontal current magnitudes. The magnitude of the current uncertainty was estimated using the general diffusion equation):

$$\int_t^{t+\Delta t} u_t \cdot d_t = \sqrt{6K_{u,v} \cdot \Delta t} \cdot \theta(-1,1) \quad (2.2)$$

where $\theta(-1,1)$ is a random number from a uniform distribution between -1 and 1, Δt is the time-step of the model in seconds and $K_{u,v}$ is the horizontal eddy diffusivity coefficient in $m^2\ s^{-1}$.

In the vertical plane, particles are subject to diffusive displacement (w_t) due to vertical turbulent motion through the water column. In OpenDrift, the vertical mixing process is parameterised using a numerical scheme described in Visser (1997) which is similar to equation 2.2 when using a constant vertical diffusion coefficient, Kz (as employed here).

Horizontal and vertical diffusion are included in the dispersion modelling to account for the mixing and diffusion caused by sub-grid scale turbulent processes, such as eddies, which are not explicitly resolved by the hydrodynamic models.

For dispersion at oceanic scales, Okubo (1974,1971) proposed that $K_{u,v}$ varies approximately as Equation 2.3a, close to the general 4/3 power law often considered for atmospheric (Richardson, L.F 1962) and oceanic diffusions (Batchelor, 1952; Stommel, 1949; Equation 2.3b):

$$k_{u,v} = 0.103 \cdot L^{1.15} \quad (2.3)$$

$$k_{u,v} = \alpha \cdot L^{\frac{4}{3}} \quad (2.4)$$

where L is the horizontal scale of the mixing phenomena and α indicates proportionality.

These equations relate the magnitude of the eddy diffusivity ($K_{u,v}$) to the length scale of the phenomena and this 4/3 power relationship was found to be applicable over a large range of scales (10 m to 1000 km) (Okubo 1974; Okubo, A. 1971). A similar relationship was found by List et al. (1990) in coastal waters.

In the present study, since high resolution flows are resolved, the amount of added diffusion should be limited. A generic horizontal coefficient of 0.01 $m^2\ s^{-1}$ was applied which is consistent with a length scale of the order 20 - 40 m. The spatial scales of the vertical turbulent motions within the water column are one or several orders of magnitude smaller than horizontal turbulence. The vertical diffusion coefficient was set to a value of 1 $cm^2\ s^{-1}$.

The particle tracking simulation is run for 30-days whereby particles are released continuously over a 15-day period and are given a further 15-days to disperse after the final release. In addition, the particles are each given a maximum age of 15-days which prevents a build-up of particles towards the end of the simulation and skew in the results.

The particles are assumed to be passive (neutrally buoyant with no decay and to facilitate comparison between each three release locations) and are released randomly over the full depth of the water column. In terms of dispersion within the nearfield, the jet trajectory is assumed to be dominated by the momentum of the discharge from the pipe (Zhao, Chen, and Lee 2011). Distributing the particles randomly across the water column enables further spread of the particles and reduces the possibility that the particles will become trapped on the seabed next to the release location.

For scenarios 1 and 3: The 'normal' and proposed operation scenarios, particles are given additional randomness to their starting positions through horizontal distribution over a radius of 400 m. This simulates the additional, and initial, dispersion provided by the diffusers at the end of the outflow. For the pipe break scenario (scenario 2), the particles are released over a 20 m radius.

Time series of the concentrations are extracted from the model every half an hour over a month, to capture tidal variation in the signal.

Statistical maps of dilution are produced from the particle distribution at each output timestep of the particle tracking model; the dilution fields can be scaled to any reference nearfield concentration (e.g. mg L^{-1}, cfu L^{-1}, pfu L^{-1}) to obtain absolute results. The particle distribution is obtained by generating a grid with the smallest grid size as is computationally practical, in this case, grid cells were 50 m by 50 m.

The normalized depth-averaged tracer concentration is obtained by a) computing the particle concentration at each cell (numbers of particles divided by cell volume), and b) normalizing by the nearfield particle concentration at the discharge location. This normalized tracer concentration quantifies the spatial relative dilution of the concentration near the discharge location (nearfield concentration).

A nominated nearfield concentration of 1 mg L^{-1} was assumed to enable specific contaminant levels to be determined using concentration ratios. Based on this, a concentration of 0.001 mg L^{-1} is equivalent to a dilution factor of 1000, while a concentration level of 0.01 mg L^{-1} is equivalent to a dilution factor of 100.

In order to compare between the three scenarios, the outflow remains constant. Using the plume footprints, it will be possible to assess the impact of a breach closer to the nearshore region compared to normal operation and how an extension of the outflow further offshore will change the dispersion patterns from those expected currently.

2.1.2 Modelling Scenarios

To identify the impact of a pipe break 700 m from the shore and the extension of the outfall to relocate the diffuser further offshore against the expected impact from the outfall operating normally with wastewater exiting the diffuser in its present location, three scenarios were simulated:

- Scenario 1: Particle release for the current diffuser location ("Normal Operation", the control).
- Scenario 2: Particle release from a pipe break 700 m from the shore.
- Scenario 3: Particle release from a prospective new diffuser location 2.5 km offshore.

The three scenarios simulated are described in Table 2.1 and the results are presented in the form of time series of concentrations at a number of locations (see Table 1.1), and as statistical maps.

Table 2.1 Summary of scenarios

Scenarios	Longitude [°E WGS84]	Latitude [°N WGS84]	Release Radius [m]	Number of particles released per day
Current diffuser location	176.9365	-39.5411	400	9600
Pipe break (~ 700 m from the shore)	176.9287	-39.5419	20	9600
Proposed diffuser location ~2.5km offshore	176.9494	-39.5398	400	9600

3. Results

This section of the report presents results from a month-long particle tracking simulation (June-July 2002). The dispersion modelling results presented below show the expected dilution and concentration of tracers for the three scenarios listed in Section 2.1.2. The flow rate was kept constant to facilitate comparison between the scenarios.

All dilution results should be interpreted in terms of relative concentration, where a dilution factor of 1000 is the equivalent of $1e^{-3}$ X L^{-1}, while a dilution factor of 100 is equivalent to a concentration level of $1e^{-2}$ X L^{-1} (where X is represents an arbitrary unit of concentration measurement).

Time-series of tracer concentration (assuming a concentration of 1 mg L^{-1}) were extracted at several sites within the model domain (Figure 1.1). These sites cover the edge of nearfield region, shellfish sites, contact, fishing and boating recreation sites (see Table 1.1). Statistical analysis of the time series comparing each of the three scenarios is presented for each of the extraction locations in Table 3.1 to Table 3.23. Presented are the maximum and mean values and the time taken for concentrations to reach or exceed these values, calculated from the start of the simulation.

From the extracted time-series histograms displaying the number of events which occur for different dilution thresholds (between 1 and 50000, split into 100 bins) are generated for each site and presented in Figure 3.1-Figure 3.22. In the present application, several sites are in shallow water (< 10 m) and can even be dry at times. Division by the water depth in the volume calculation can therefore result in artificial tracer spikes during periods of low water levels. Therefore, caution is advised during interpretation of tracer concentration at the shallowest sites.

The dilution maps in Figure 3.23-Figure 3.24 are given on a logarithmic scale (base 10) due to the localised nature of the peaks in the data (scale value of 1:10e4 means 1:100,000 or a dilution factor of 100,000). Enlarged versions of Figure 3.23 and Figure 3.24 are given in Appendix A (Figure A. 1 to Figure A. 6). As with the time series results, care should be taken when considering the particle counts in shallow water regions in Figure 3.23 and Figure 3.24, as elevated particle accounts can occur in shallow water regions.

Resident times of particles can be relatively long due to comparatively quiescent conditions resulting in higher concentrations when averaged over time. Furthermore, small fluctuations within the intertidal areas may maintain elevated levels of tracer due to the inability of the areas to effectively flush.

The process of converting the particle distributions to a volume will result in apparent elevation of concentrations in shallow water. To counter this, water depths shallower than 1 m are masked out.

Table 3.1 Statistics derived from the time series extracted at Town Reef for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.23E-05	2.26E-05	6.77E-05
Time taken to reach maximum [days]	16.00	16.63	18.44
Mean [mg L^{-1}]	6.86E-07	7.10E-07	1.28E-06
Time taken to reach mean [days]	16.00	16.63	16.75

Table 3.2 Statistics derived from the time series extracted at Marineland for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	1.68E-05	1.67E-05	2.52E-05
Time taken to reach maximum [days]	18.06	20.17	21.54
Mean [mg L^{-1}]	3.36E-07	4.12E-07	3.51E-07
Time taken to reach mean [days]	15.21	14.88	14.52

Table 3.3 Statistics derived from the time series extracted at Ellison Street for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.46E-05	2.59E-05	7.51E-05
Time taken to reach maximum [days]	16.08	16.06	19.29
Mean [mg L^{-1}]	8.62E-07	3.88E-07	1.64E-06
Time taken to reach mean [days]	16.08	16.06	15.71

Table 3.4 Statistics derived from the time series extracted at Woolscour for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	6.06E-05	8.21E-05	9.02E-05
Time taken to reach maximum [days]	14.88	26.46	21.25
Mean [mg L^{-1}]	2.37E-06	2.45E-06	1.70E-06
Time taken to reach mean [days]	0.52	14.33	18.58

Table 3.5 Statistics derived from the time series extracted at Awatoto – 700 m for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.80E-05	0.000704	1.80E-05
Time taken to reach maximum [days]	8.79	3.60	16.17
Mean [mg L^{-1}]	1.69E-06	3.39E-05	3.73E-07
Time taken to reach mean [days]	0.06	0.02	12.73

Table 3.6 Statistics derived from the time series extracted at Second Groyne for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	0	0	0
Time taken to reach maximum [days]	0	0	0
Mean [mg L^{-1}]	0	0	0
Time taken to reach mean [days]	0	0	0

Table 3.7 Statistics derived from the time series extracted at Short Outfall for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	0.000216255	0.000685731	0.000100285
Time taken to reach maximum [days]	14.10	14.10	21.13
Mean [mg L^{-1}]	1.12E-05	6.07E-05	1.36E-06
Time taken to reach mean [days]	1.52	1.04	9.90

Table 3.8 Statistics derived from the time series extracted at 1/250 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.80E-05	4.00E-06	1.80E-05
Time taken to reach maximum [days]	6.58	12.69	15.04
Mean [mg L^{-1}]	2.70E-06	1.14E-07	3.00E-07
Time taken to reach mean [days]	0.10	12.69	0.79

Table 3.9 Statistics derived from the time series extracted at 1/300 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	8.01E-06	5.34E-06	1.60E-05
Time taken to reach maximum [days]	15.67	15.04	15.92
Mean [mg L^{-1}]	2.00E-07	1.83E-07	2.72E-07
Time taken to reach mean [days]	13.38	13.35	13.65

Table 3.10 Statistics derived from the time series extracted at 1/500 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.40E-05	8.00E-06	1.20E-05
Time taken to reach maximum [days]	9.19	19.44	13.15
Mean [mg L^{-1}]	2.37E-06	1.94E-07	3.21E-07
Time taken to reach mean [days]	0.04	9.06	0.29

Table 3.11 Statistics derived from the time series extracted at 2/250 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.40E-05	8.00E-06	1.20E-05
Time taken to reach maximum [days]	0.42	13.73	13.42
Mean [mg L^{-1}]	1.76E-06	1.31E-07	2.61E-07
Time taken to reach mean [days]	0.10	9.77	5.00

Table 3.12 Statistics derived from the time series extracted at 2/300 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	1.60E-05	8.00E-06	1.80E-05
Time taken to reach maximum [days]	0.60	25.33	13.96
Mean [mg L^{-1}]	1.56E-06	1.54E-07	2.83E-07
Time taken to reach mean [days]	0.04	10.94	0.29

Table 3.13 Statistics derived from the time series extracted at 2/500 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	1.20E-05	8.00E-06	1.20E-05
Time taken to reach maximum [days]	0.33	13.79	13.48
Mean [mg L^{-1}]	1.08E-06	1.89E-07	3.09E-07
Time taken to reach mean [days]	0.02	9.88	3.54

Table 3.14 Statistics derived from the time series extracted at 3/250 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.00E-05	8.00E-06	1.80E-05
Time taken to reach maximum [days]	3.83	13.90	12.15
Mean [mg L^{-1}]	1.65E-06	1.71E-07	5.27E-07
Time taken to reach mean [days]	0.02	10.23	0.02

Table 3.15 Statistics derived from the time series extracted at 3/300 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	5.18E-06	7.75E-06	1.16E-05
Time taken to reach maximum [days]	12.98	26.83	19.40
Mean [mg L^{-1}]	1.50E-07	1.57E-07	1.97E-07
Time taken to reach mean [days]	12.42	12.98	11.79

Table 3.16 Statistics derived from the time series extracted at 3/500 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	1.20E-05	1.20E-05	3.00E-05
Time taken to reach maximum [days]	10.25	13.27	13.23
Mean [mg L^{-1}]	7.26E-07	2.14E-07	7.71E-07
Time taken to reach mean [days]	0.10	6.27	0.02

Table 3.17 Statistics derived from the time series extracted at 4/250 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.80E-05	1.20E-05	3.00E-05
Time taken to reach maximum [days]	0.29	25.63	14.90
Mean [mg L^{-1}]	2.41E-06	1.74E-07	7.80E-07
Time taken to reach mean [days]	0.02	9.92	0.04

Table 3.18 Statistics derived from the time series extracted at 4/300 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.40E-05	8.00E-06	1.80E-05
Time taken to reach maximum [days]	9.46	14.77	10.60
Mean [mg L^{-1}]	2.12E-06	1.37E-07	9.21E-07
Time taken to reach mean [days]	0.08	10.15	0.17

Table 3.19 Statistics derived from the time series extracted at 4/500 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.23E-05	7.41E-06	2.23E-05
Time taken to reach maximum [days]	9.00	14.71	8.69
Mean [mg L^{-1}]	1.48E-06	1.46E-07	1.76E-06
Time taken to reach mean [days]	0.02	6.29	0.08

Table 3.20 Statistics derived from the time series extracted at 5/250 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	2.80E-05	1.20E-05	1.80E-05
Time taken to reach maximum [days]	3.54	20.21	12.50
Mean [mg L^{-1}]	3.41E-06	1.66E-07	3.69E-07
Time taken to reach mean [days]	0.02	11.15	1.13

Table 3.21 Statistics derived from the time series extracted at 5/300 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	3.60E-05	8.00E-06	1.20E-05
Time taken to reach maximum [days]	14.50	14.54	11.94
Mean [mg L^{-1}]	3.73E-06	1.66E-07	3.56E-07
Time taken to reach mean [days]	0.04	12.00	0.48

Table 3.22 Statistics derived from the time series extracted at 5/500 for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	3.20E-05	8.00E-06	1.20E-05
Time taken to reach maximum [days]	0.40	14.94	8.81
Mean [mg L^{-1}]	3.98E-06	1.74E-07	3.94E-07
Time taken to reach mean [days]	0.04	11.88	0.25

Table 3.23 Statistics derived from the time series extracted at the Control site for each of the three scenarios.

Statistics	Current Outfall	700 m pipe break	Future Outfall
Maximum [mg L^{-1}]	3.20E-05	0.000276	1.80E-05
Time taken to reach maximum [days]	9.25	3.75	14.13
Mean [mg L^{-1}]	3.30E-06	2.53E-06	3.30E-07
Time taken to reach mean [days]	0.06	0.17	5.02

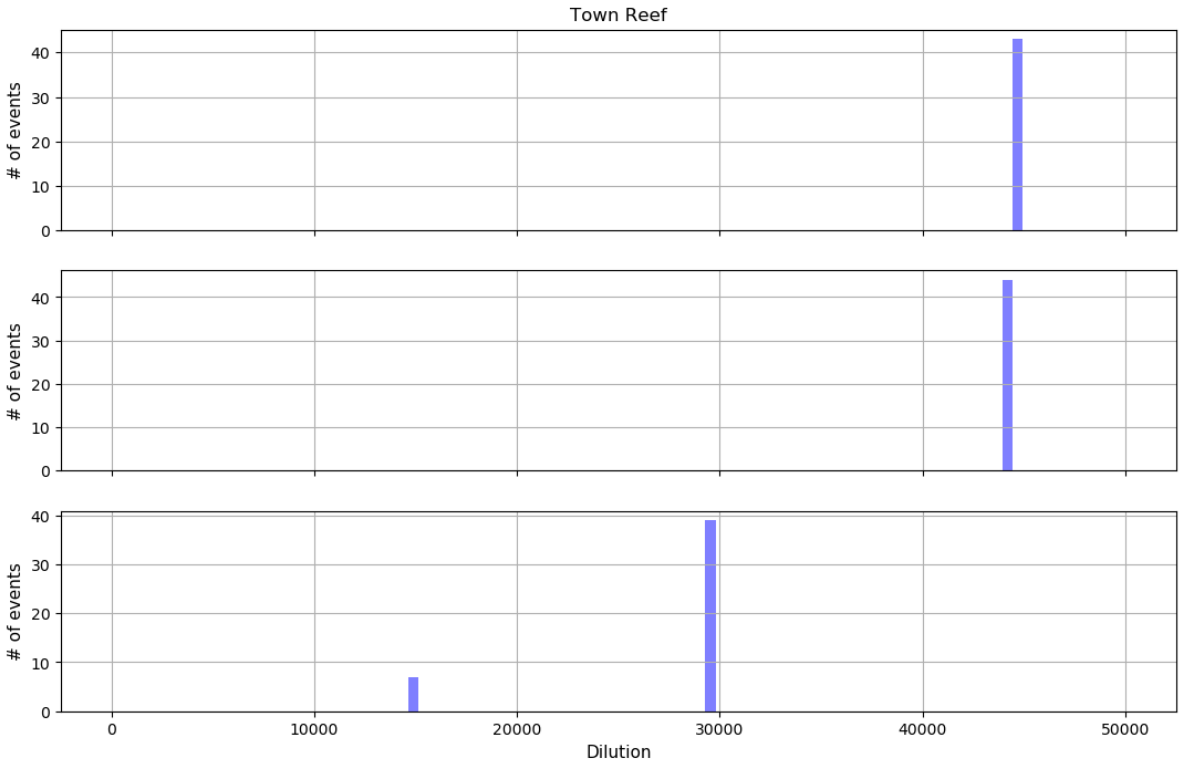

Figure 3.1 *Histograms of predicted dilution factors at Town Reef for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

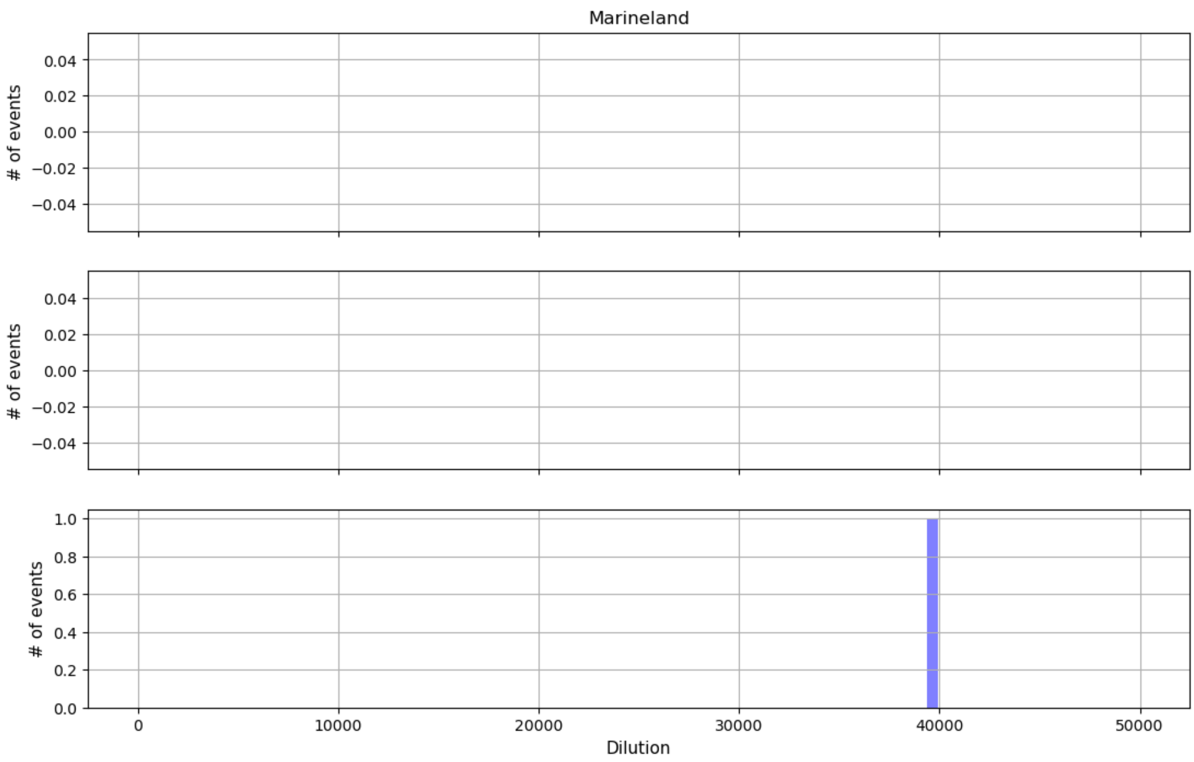

Figure 3.2 *Histograms of predicted dilution factors at Marine land for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

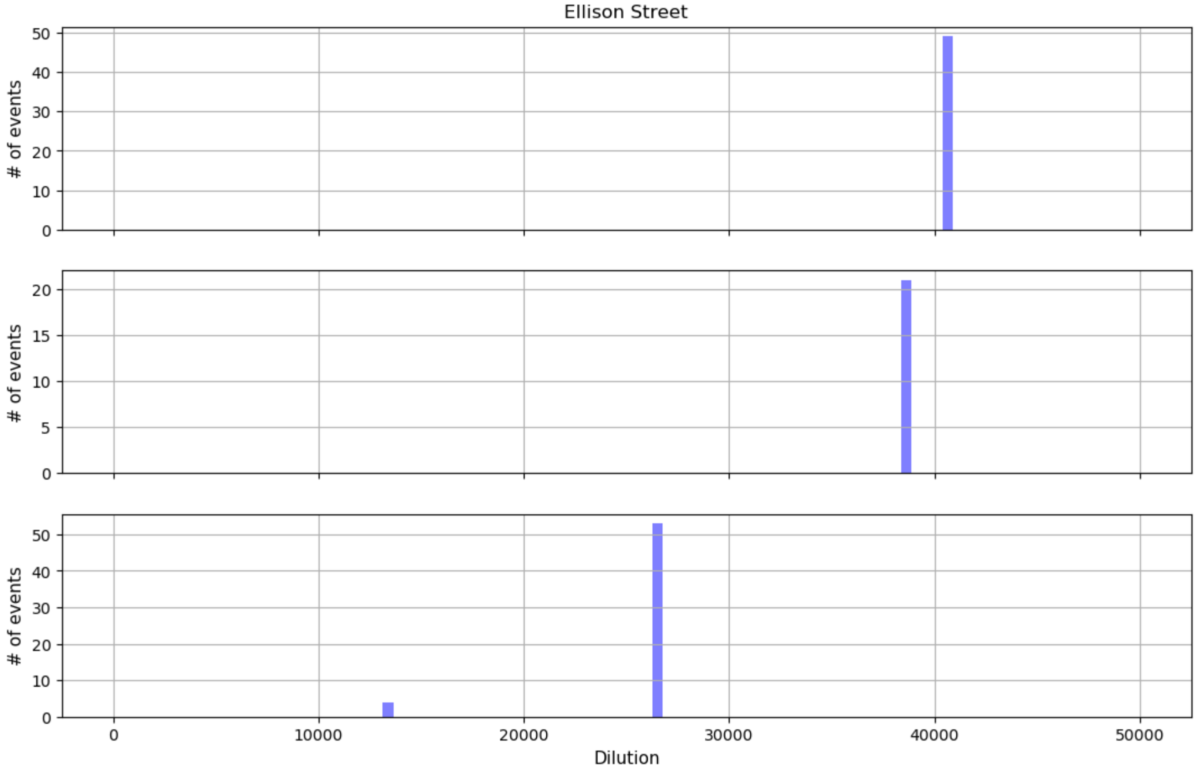

Figure 3.3 Histograms of predicted dilution factors at Ellison Street for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

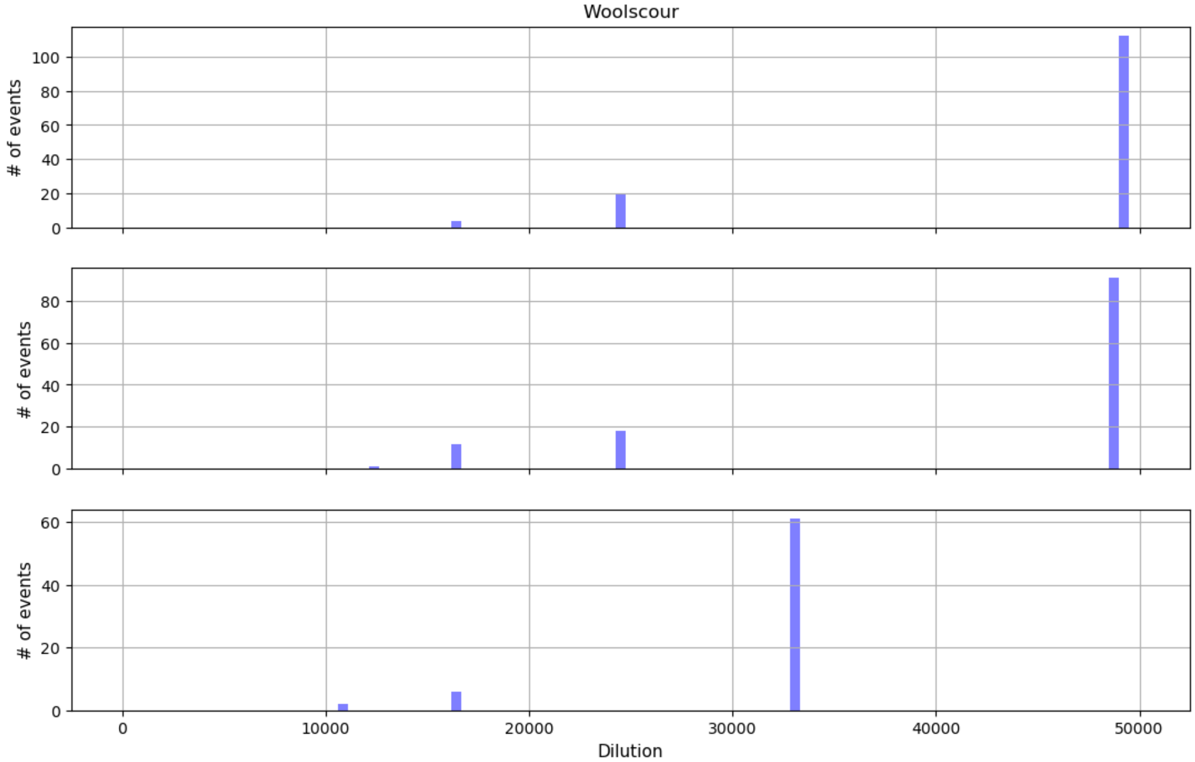

Figure 3.4 Histograms of predicted dilution factors at Woolscour for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

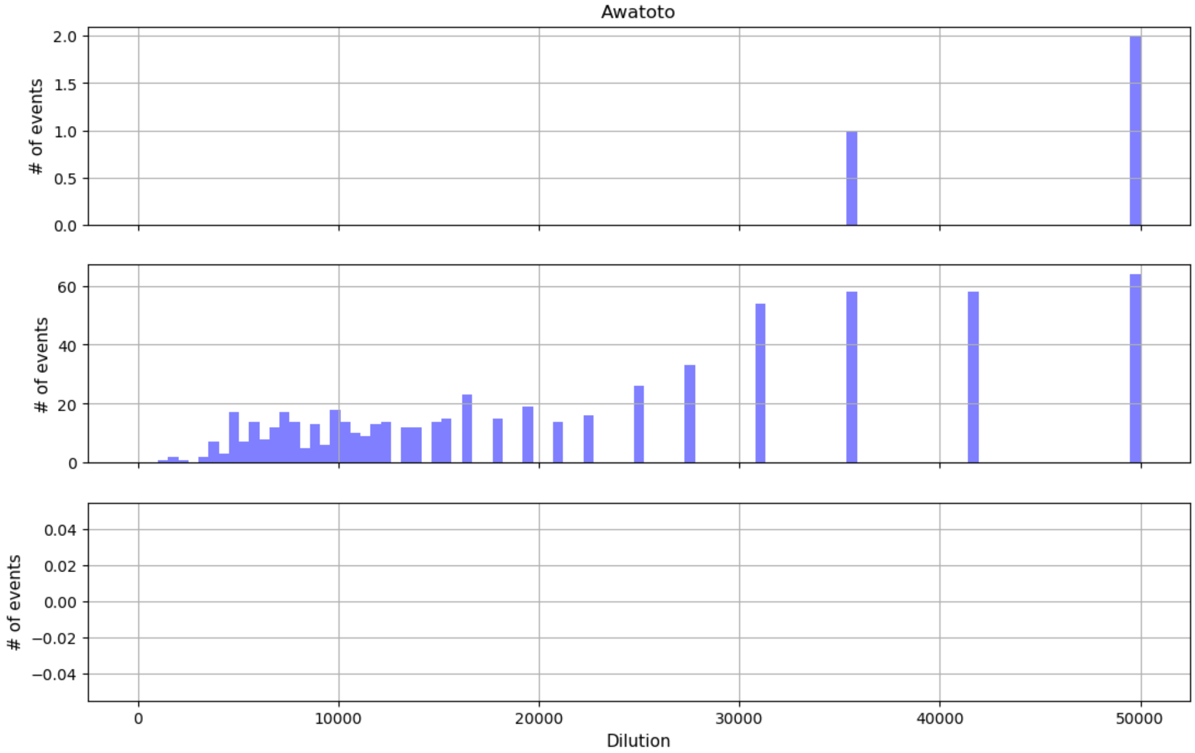

Figure 3.5 *Histograms of predicted dilution factors at Awatoto – 700 m for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

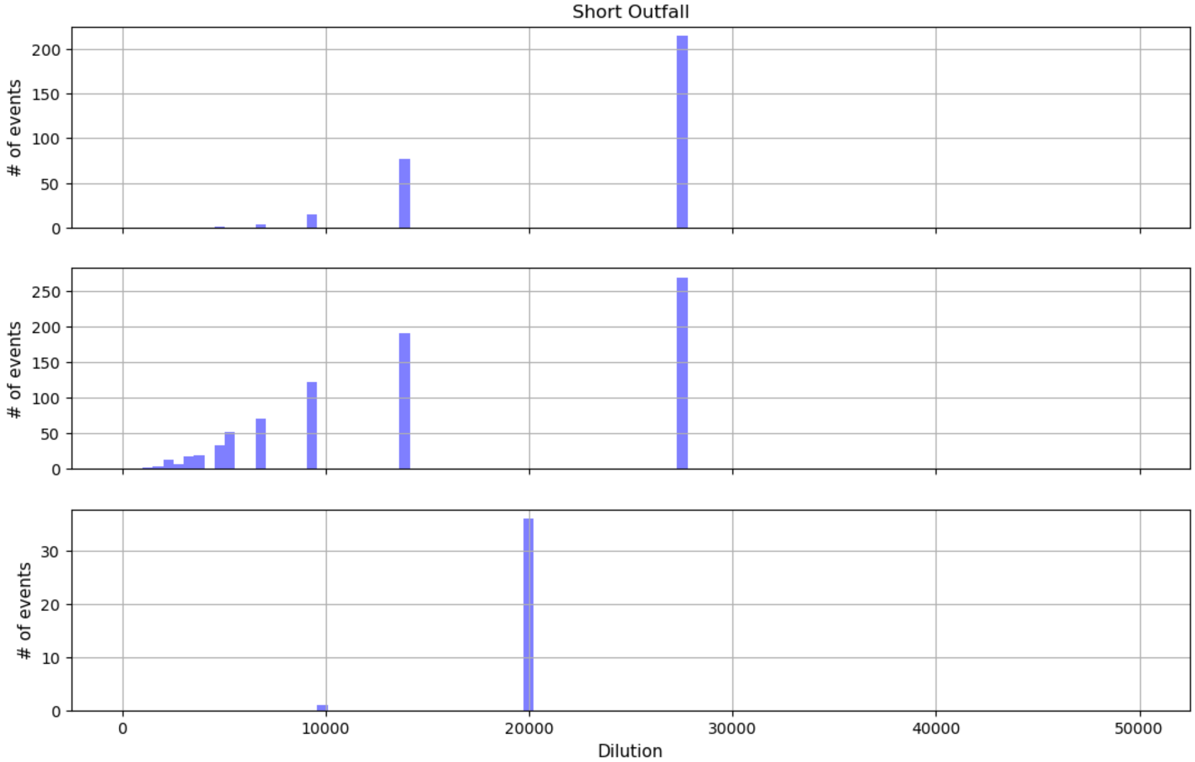

Figure 3.6 *Histograms of predicted dilution factors at Short Outfall for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

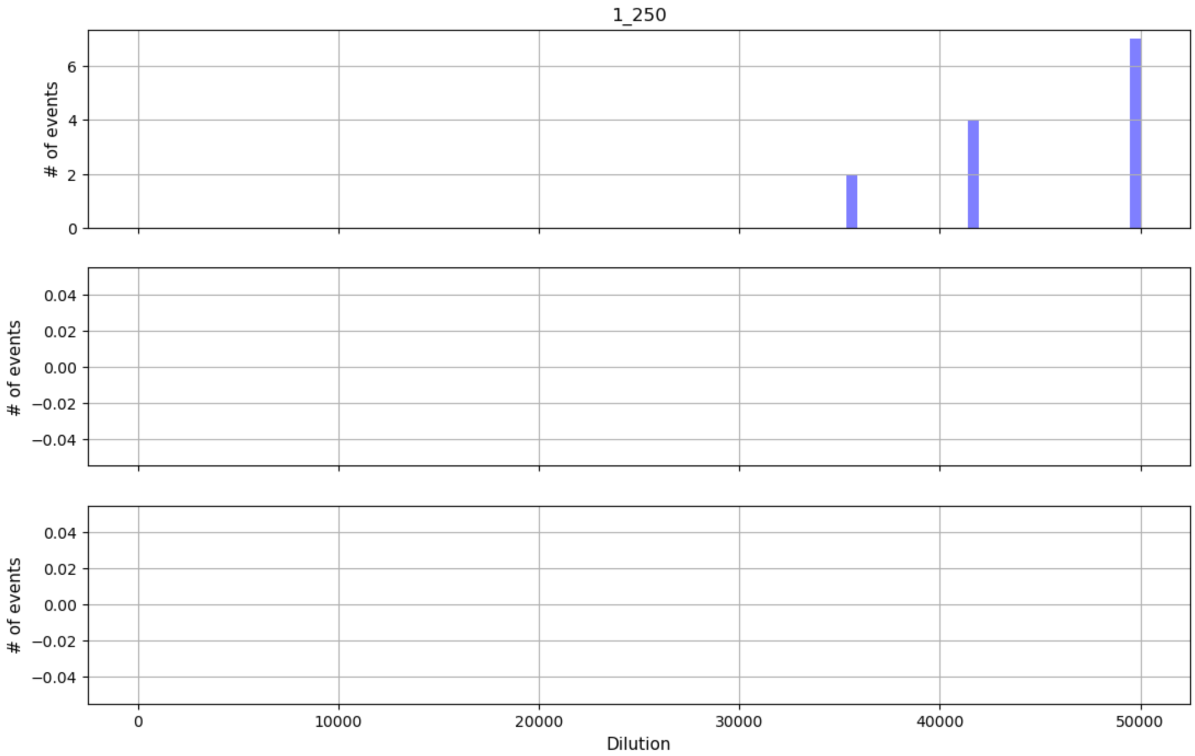

Figure 3.7 *Histograms of predicted dilution factors at 1/250 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

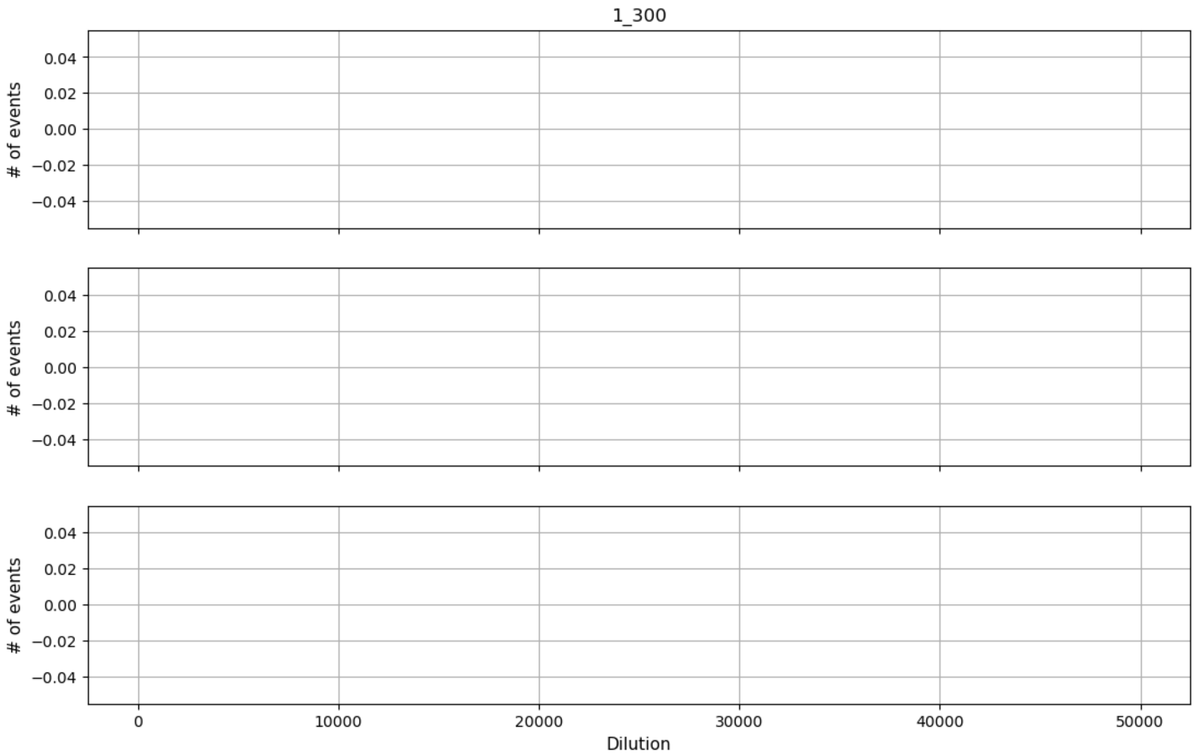

Figure 3.8 *Histograms of predicted dilution factors at 1/300 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

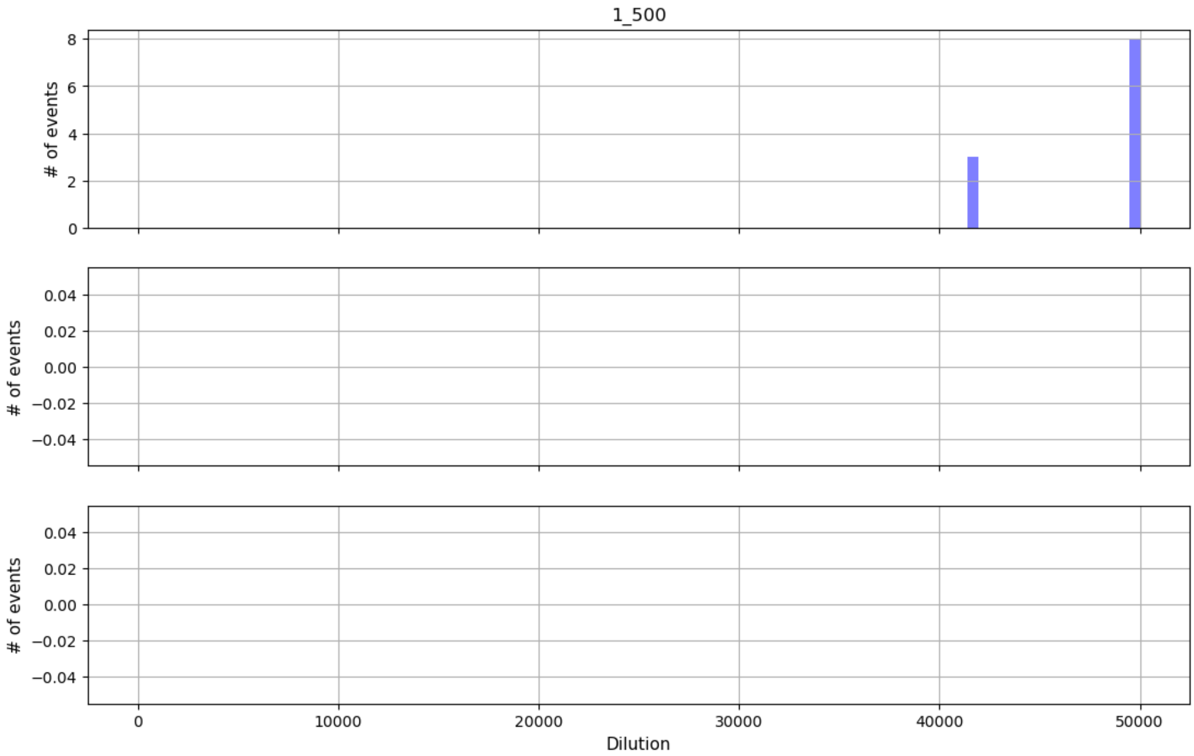

Figure 3.9 Histograms of predicted dilution factors at 1/500 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

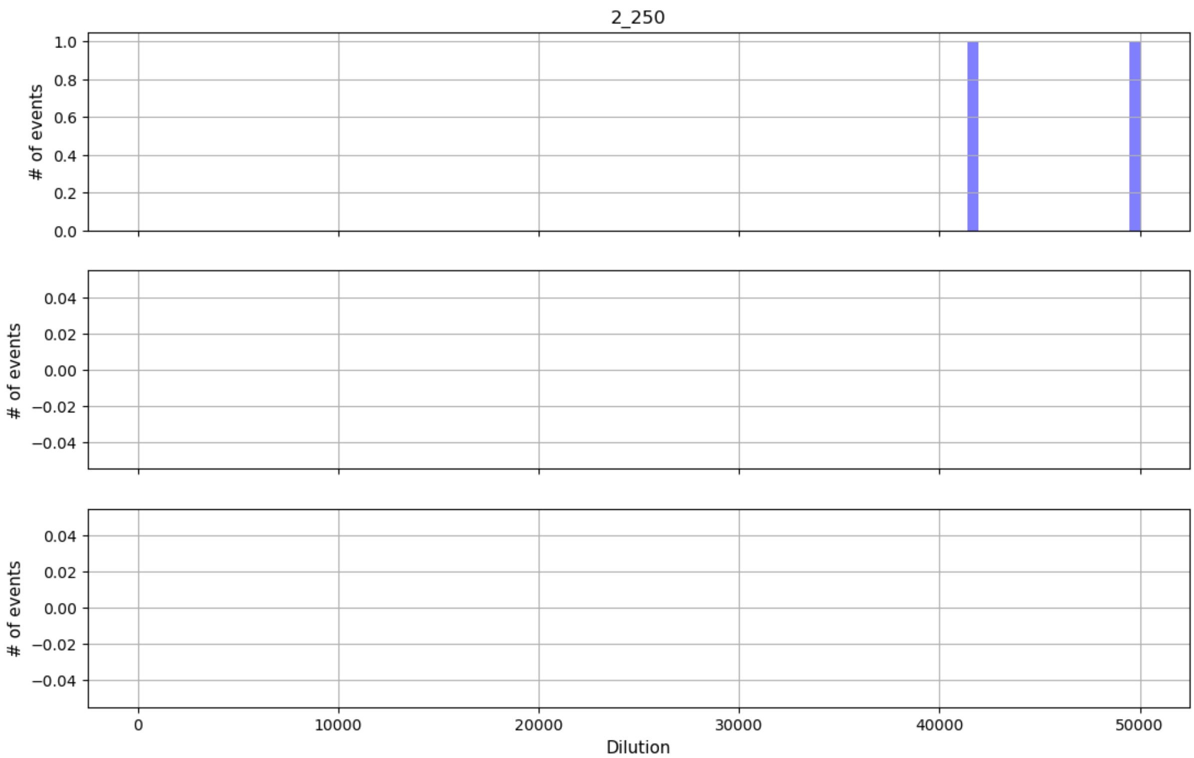

Figure 3.10 Histograms of predicted dilution factors at 2/250 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

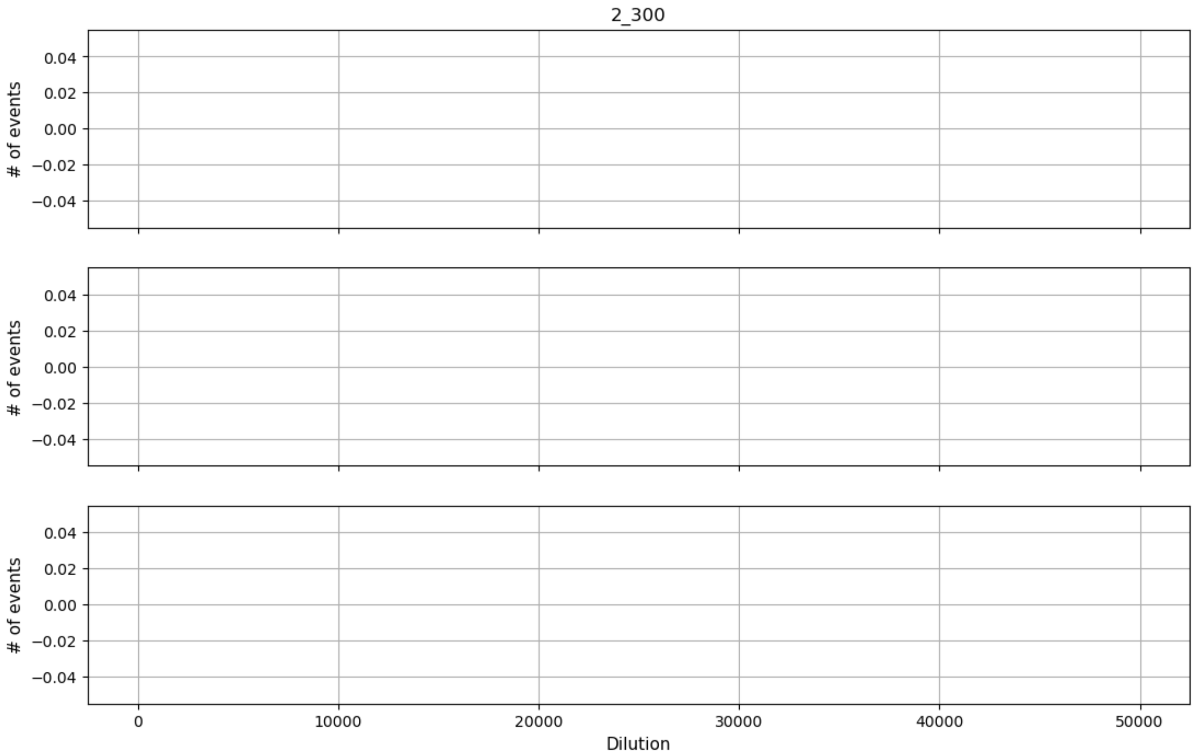

Figure 3.11 Histograms of predicted dilution factors at 2/300 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

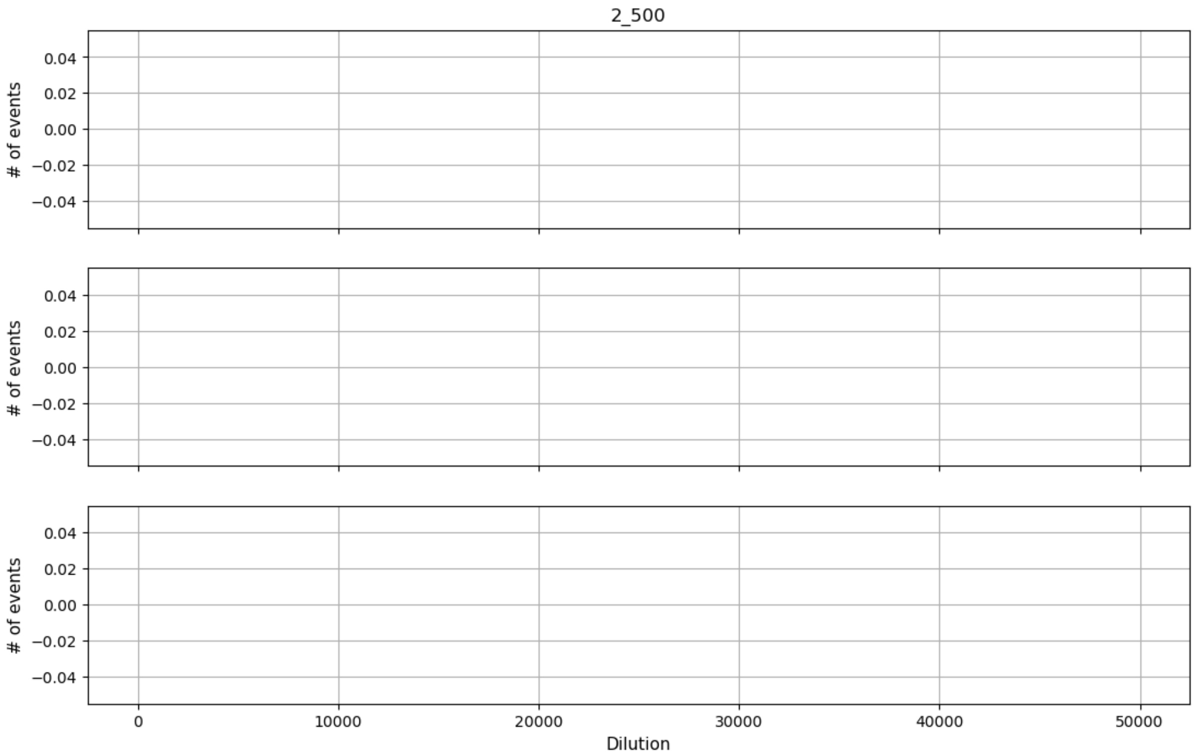

Figure 3.12 Histograms of predicted dilution factors at 2/500 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

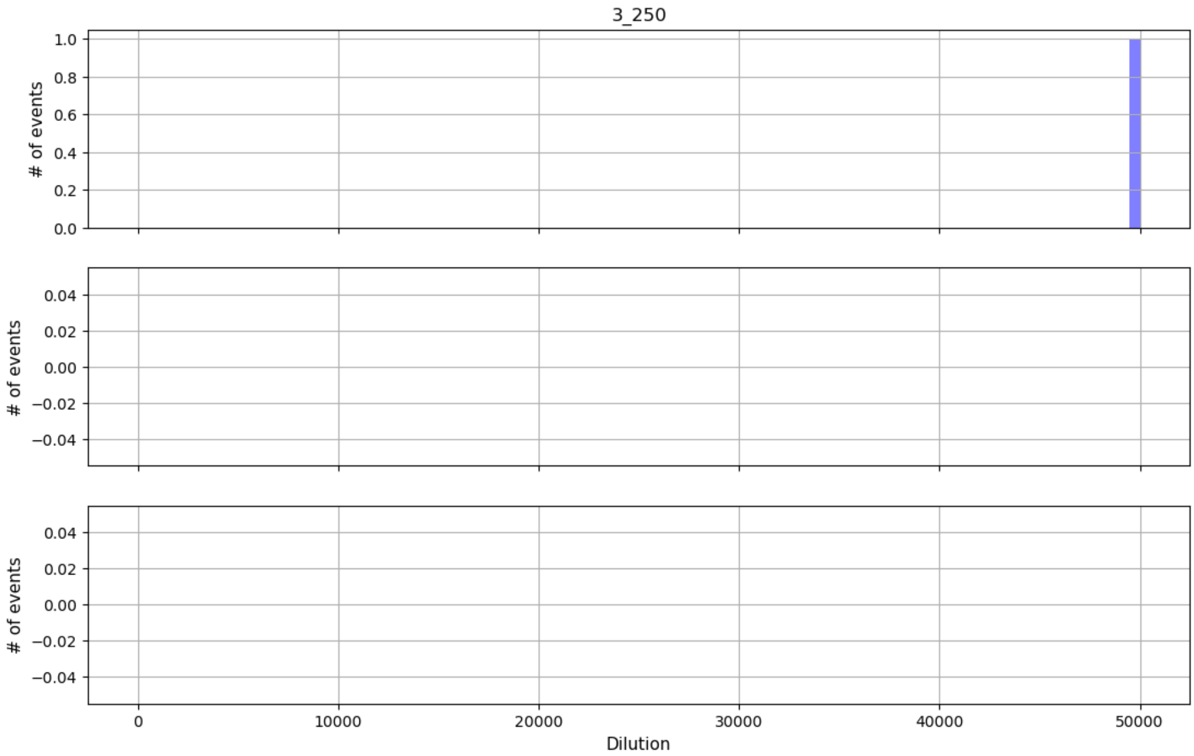

Figure 3.13 *Histograms of predicted dilution factors at 3/250 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

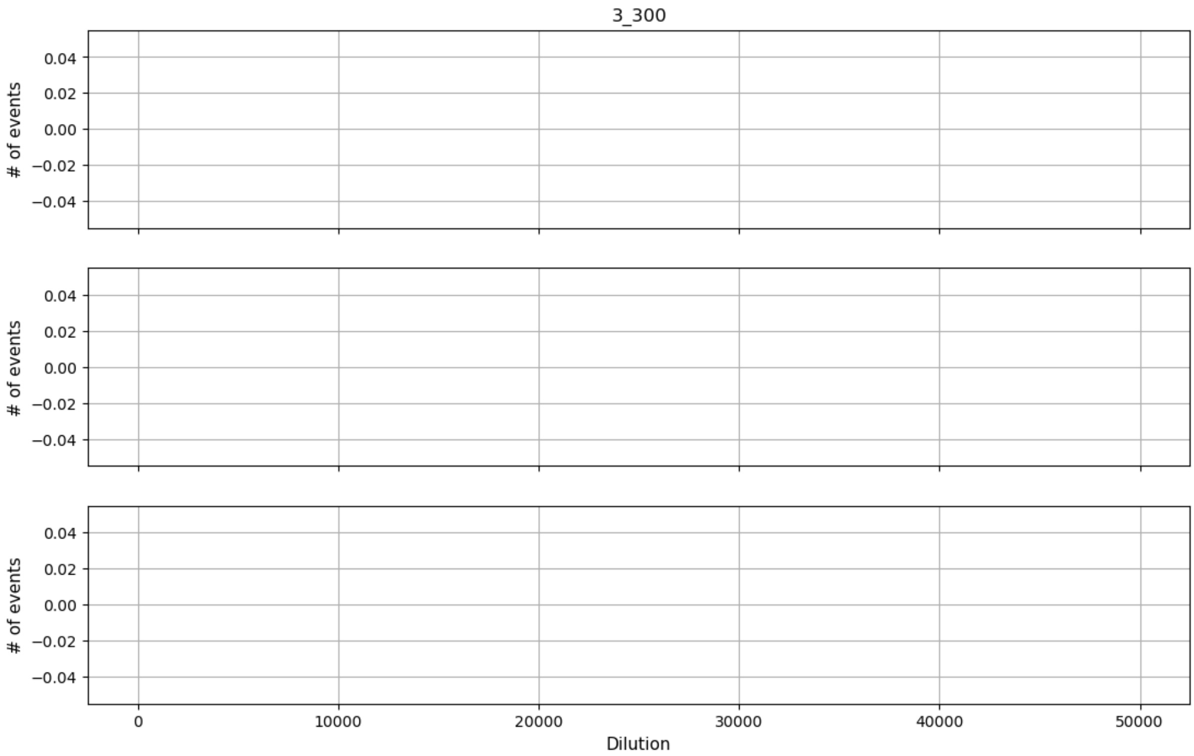

Figure 3.14 *Histograms of predicted dilution factors at 3/300 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

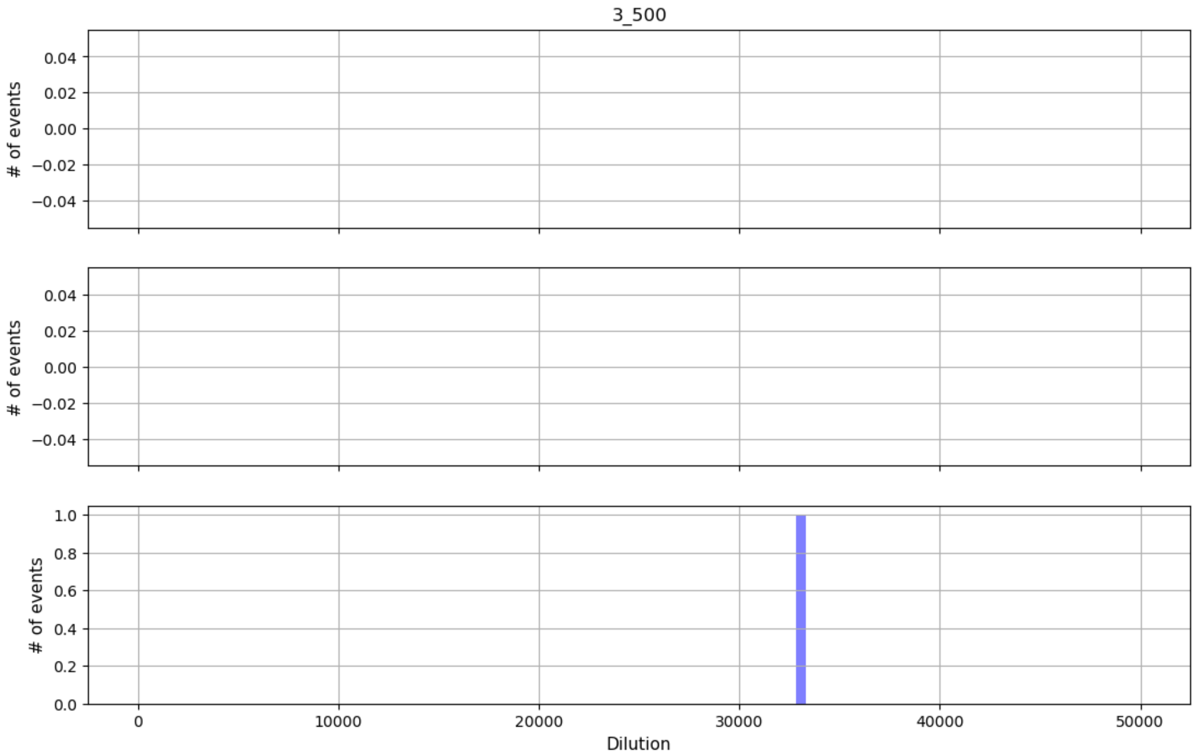

Figure 3.15 Histograms of predicted dilution factors at 3/500 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

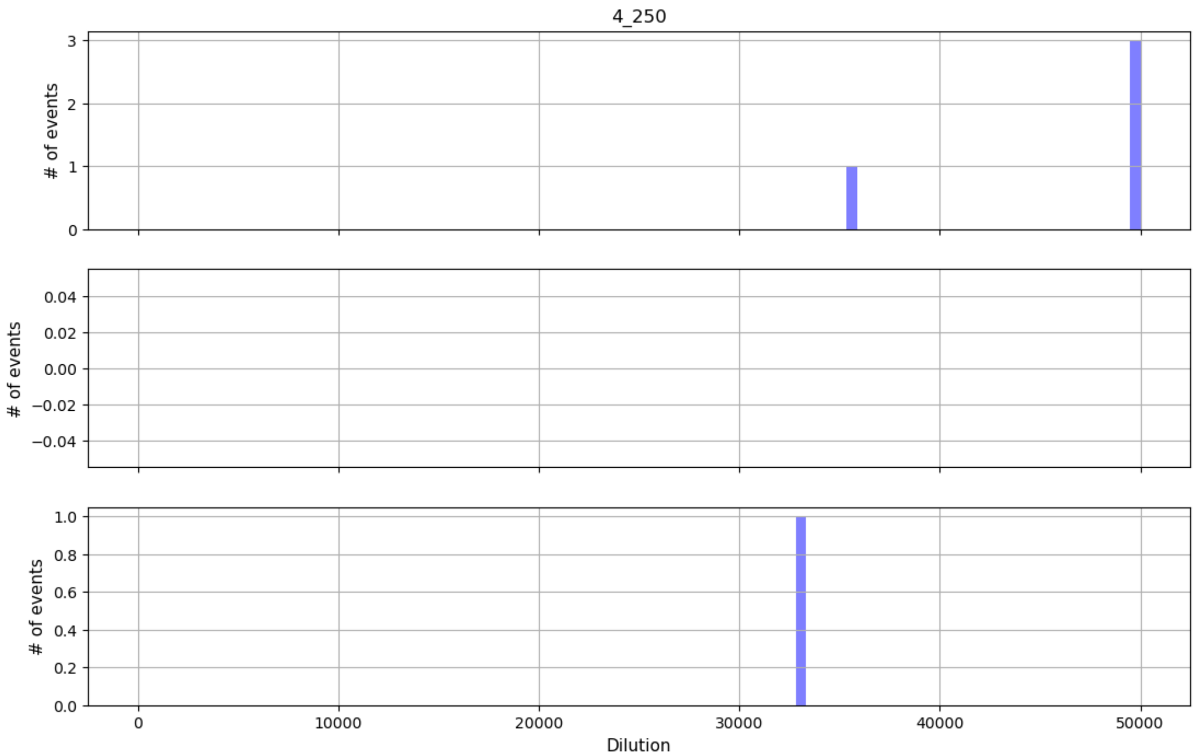

Figure 3.16 Histograms of predicted dilution factors at 4/250 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

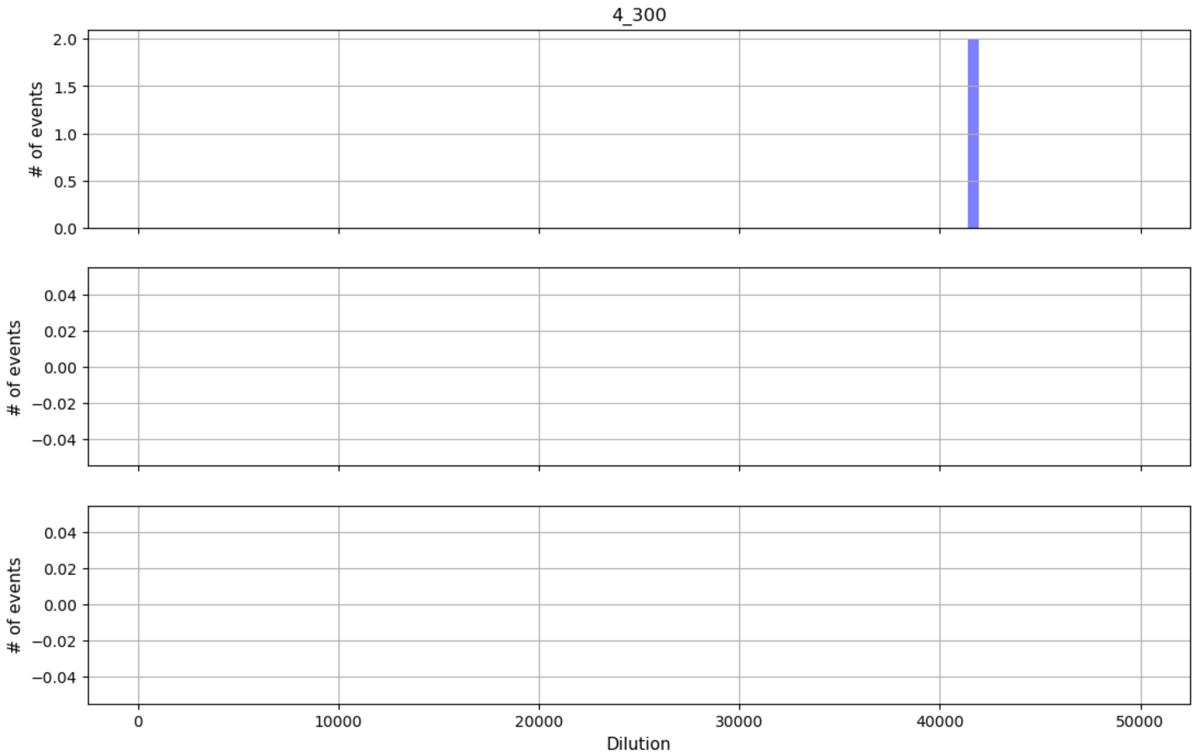

Figure 3.17 Histograms of predicted dilution factors at 4/300 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

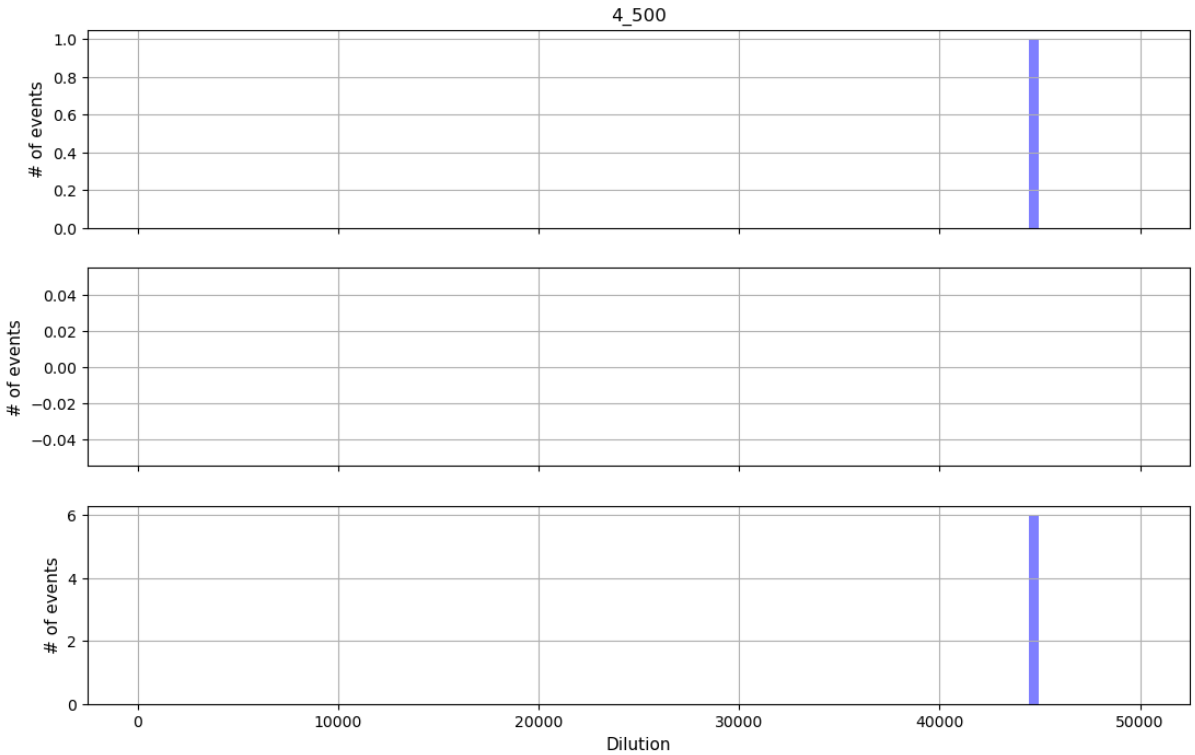

Figure 3.18 Histograms of predicted dilution factors at 4/500 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

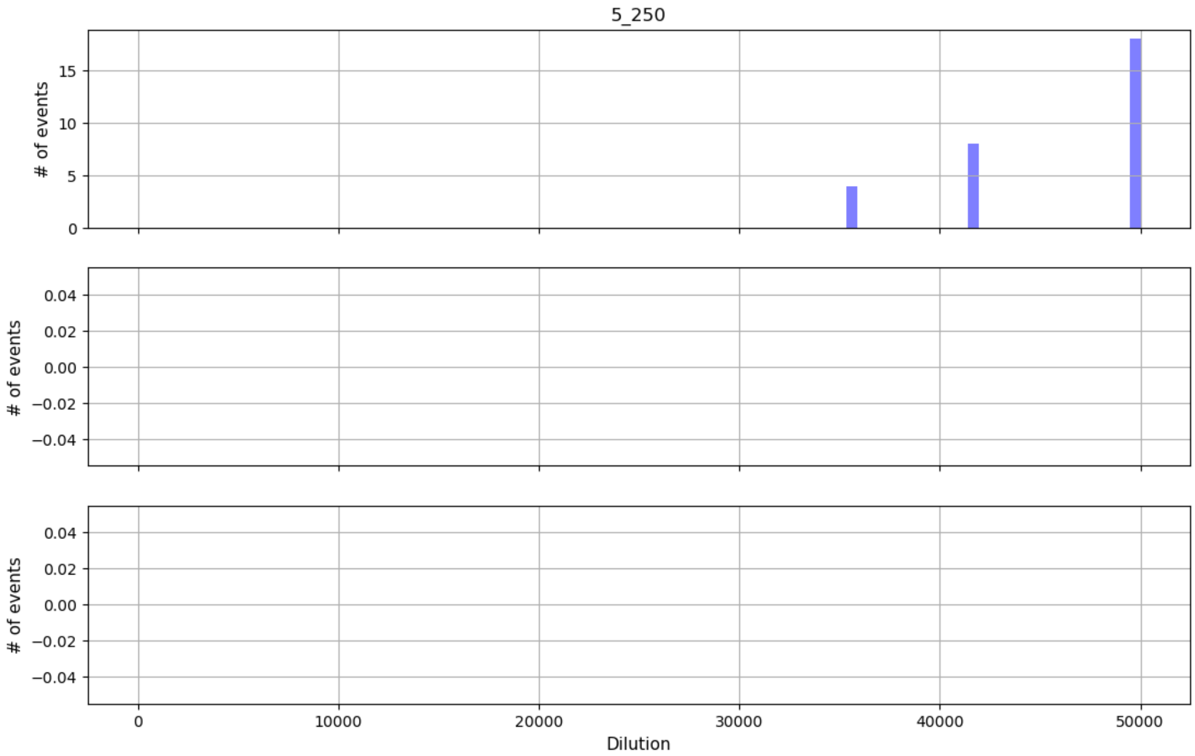

Figure 3.19 *Histograms of predicted dilution factors at 5/250 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

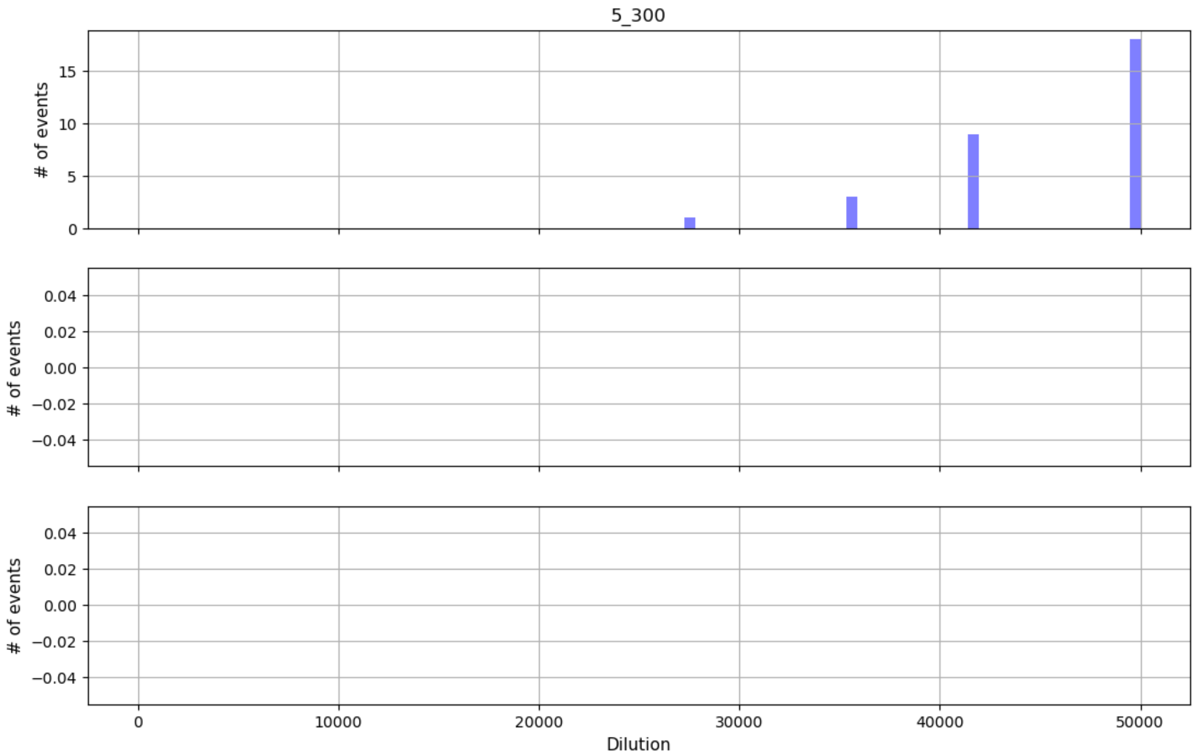

Figure 3.20 *Histograms of predicted dilution factors at 5/300 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).*

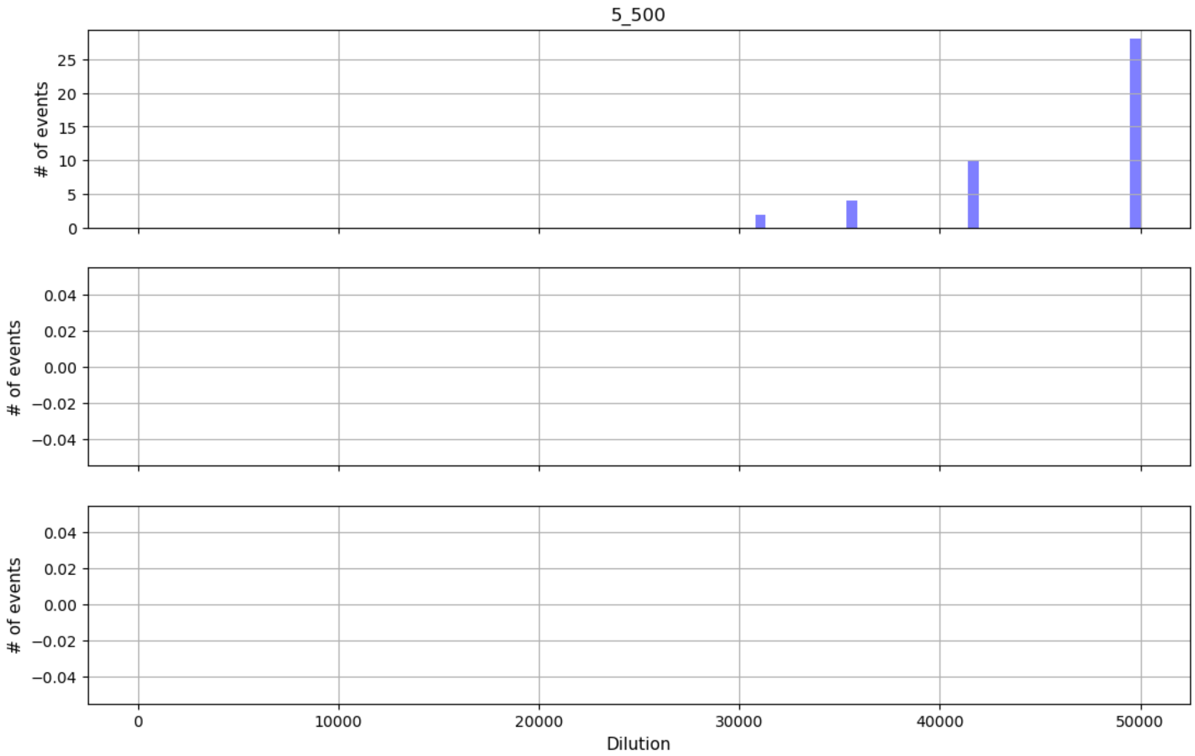

Figure 3.21 Histograms of predicted dilution factors at 5/500 for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

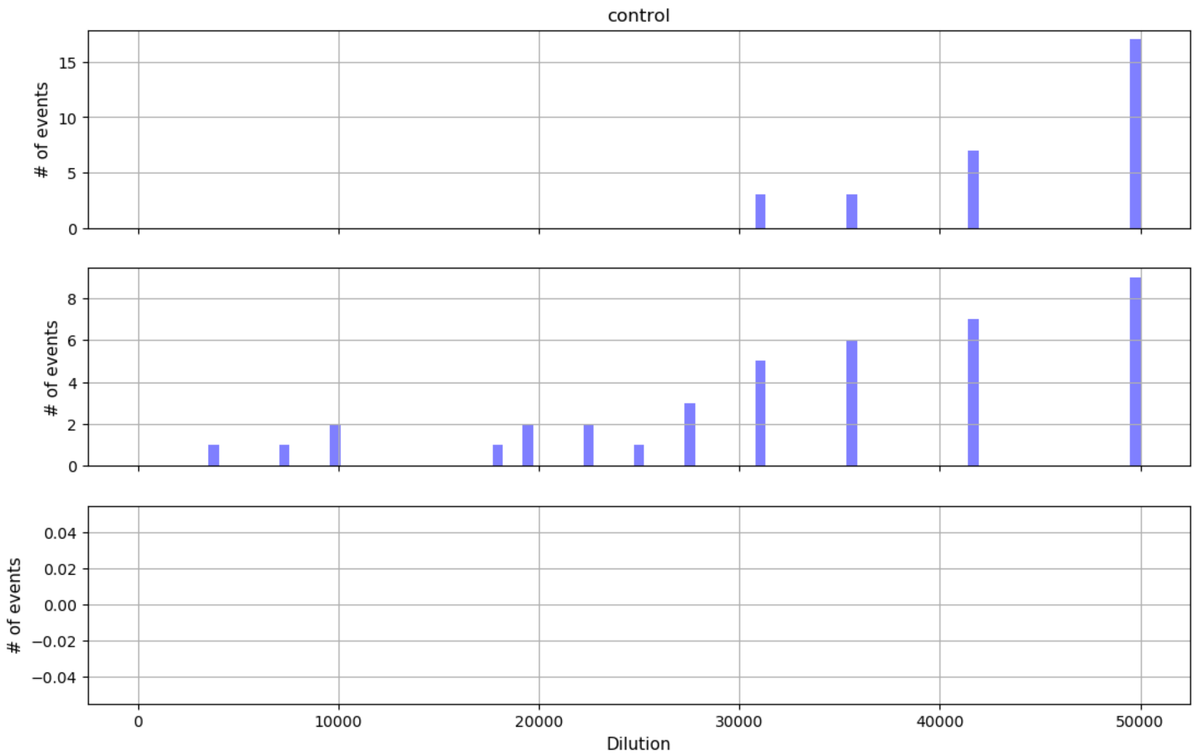

Figure 3.22 Histograms of predicted dilution factors at the control site for the 'Normal' scenario (top), the 700 m pipe breach scenario (middle) and the future outflow dispersion scenario (bottom).

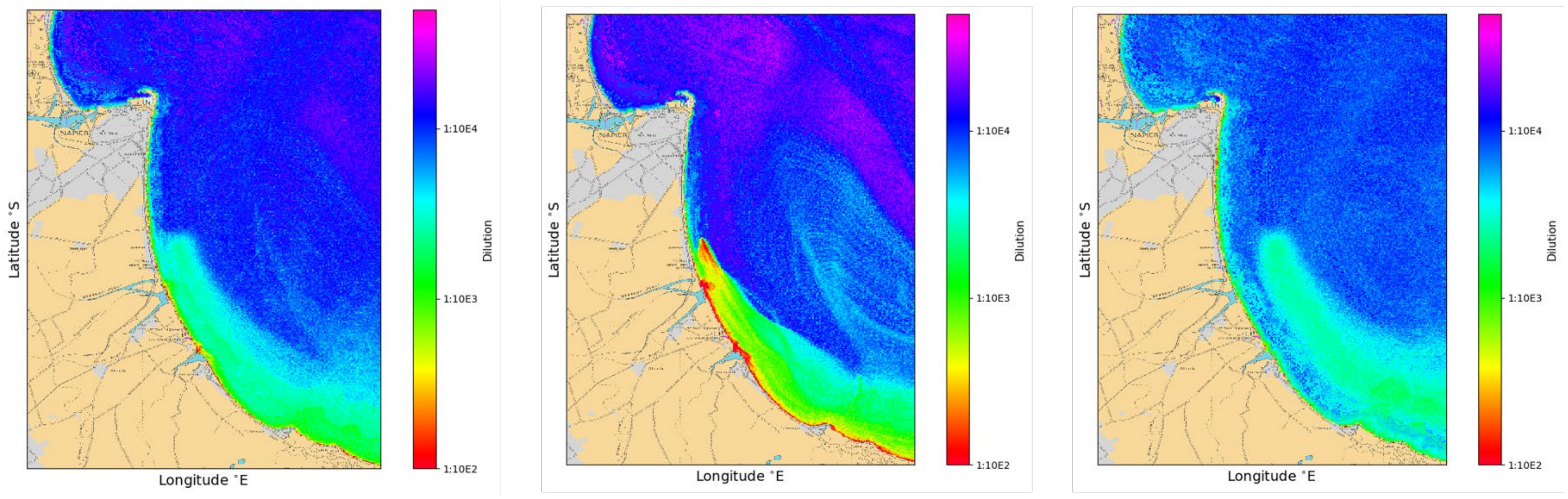

Figure 3.23 Maximum dilution factor during a month-long release for the 'normal' operation scenario (left), 700 m pipe breach scenario (centre) and 2.5 km future outfall scenario (right). Dilution factors above 5.10E4 (i.e. 500,000) have been masked.

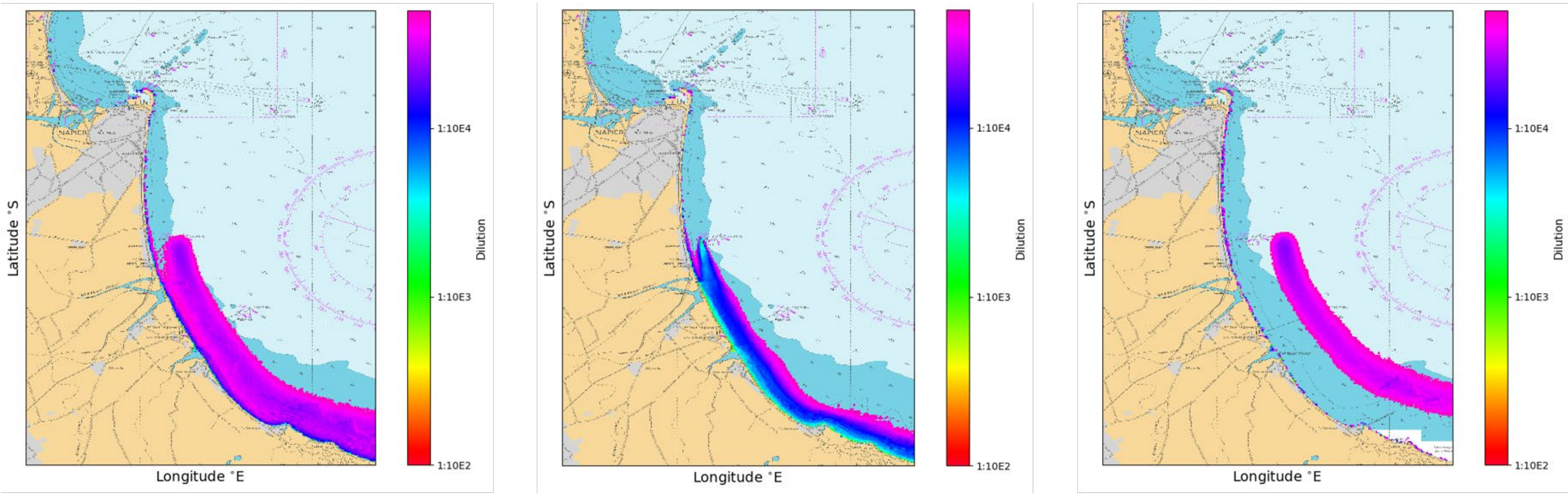

Figure 3.24 Mean dilution factor during a month-long release for the 'normal' operation scenario (left), 700 m pipe breach scenario (centre) and 2.5 km future outfall scenario (right). Dilution factors above 5.10E4 (i.e. 500,000) have been masked.

4. Summary

Lagrangian tracer simulations have been undertaken to investigate the dispersion of water discharged from the Napier City Wastewater Ocean Outfall, from both normal operation and discharge due to a pipeline leak at 700 m from the shore. Three different scenarios were considered: 'Normal Outflow Operation', a breach at 700 m along the length of the pipe and a proposed 2.5 km outfall extension. Results were postprocessed in terms of dilution factors, giving flexibility to the user to apply a reference concentration.

The maximum dilution maps show the peak pollutant accumulation during 30 days of particle release and tracking for each location. The pipe break scenario has the greatest impact within the coastal area. Although the values in the shallow water regions should be considered with caution, there are accumulations of particles around the river mouths and along the coast, compared to existing (scenario 1) and future (scenario 3) flow through the diffusers. Extending the outfall offshore shows a reduction in particle accumulation along the coast. The plume generally tracks south-west within 2 km of the coast, following the curvature of the bay. Recirculating currents within the bay cause some return of the particles, but these are at much lower concentrations and disperse further offshore.

The mean dilution maps illustrate how the plume footprint typically spreads south-west from the discharge location, consistent with MOS (2011). Dilution factors can be converted into concentrations and the particles scaled to link to the consent.

The concentration timeseries, assuming a concentration of 1 mg L^{-1} per particle, reflect the results shown in the spatial distribution statistical maps, with more sites receiving higher concentrations of the tracer during scenario 2, the breach nearshore. The offshore sites are situated around the normal outflow dispersion region, as a result, more particles released during scenario 1 are found at these locations (i.e. 1/250 – 1/500 to 5/250 – 5/500).

It takes nearly 16 days for sites to the north of the outfall to receive pollutants. Most coastal sites to the north of the outfall are reached by the particles from the outfall extension due to the offshore recirculation. Sites to the south of the outfall are affected by higher concentrations of pollutants released from the nearshore breach than for the other scenarios.

5. References

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Appendix A:

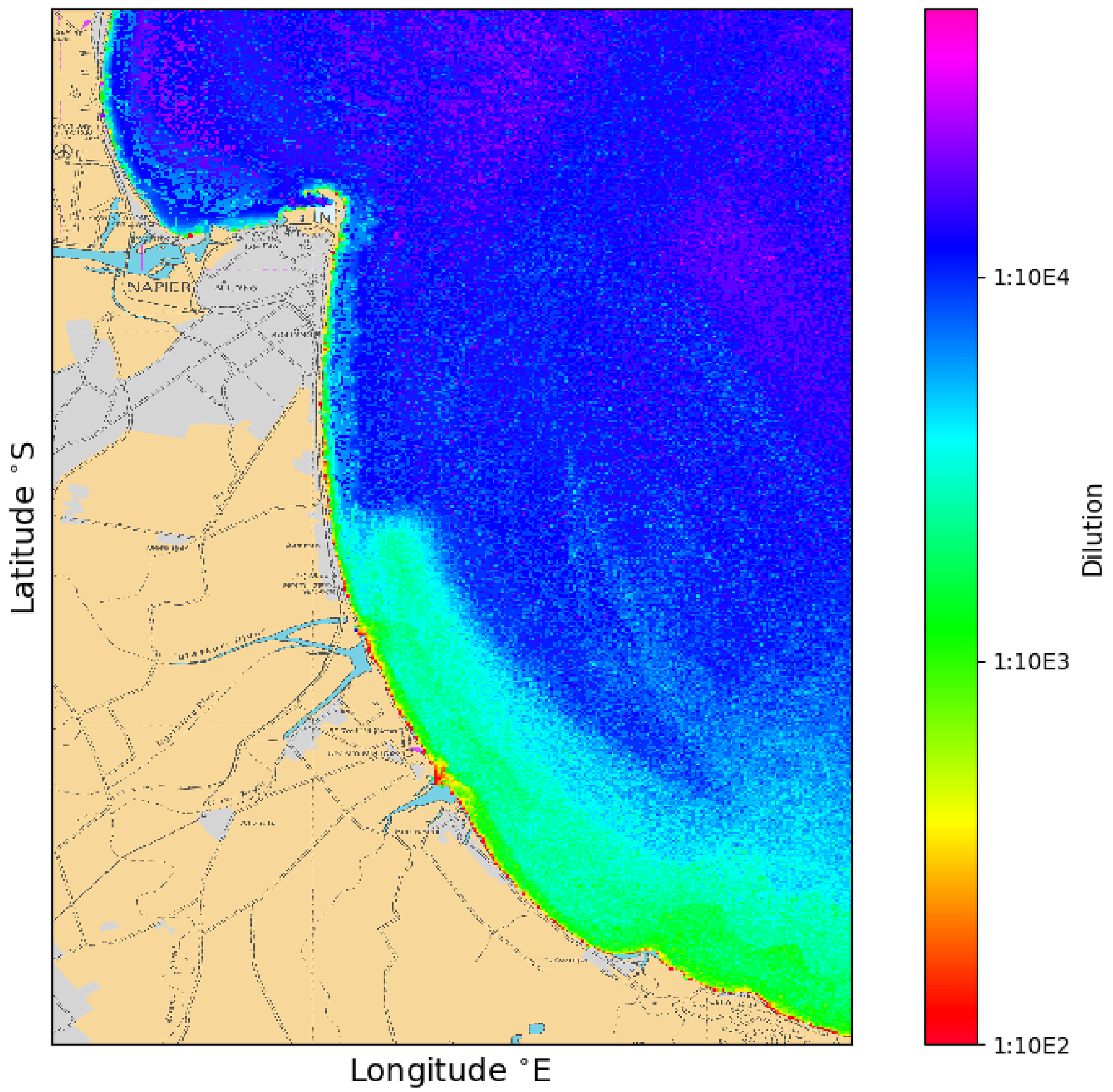

Figure A. 1 Maximum dilution factor during a month-long release the 'normal' operation scenario. Dilution factors above 5.10E4 (i.e. 500,000) have been masked.

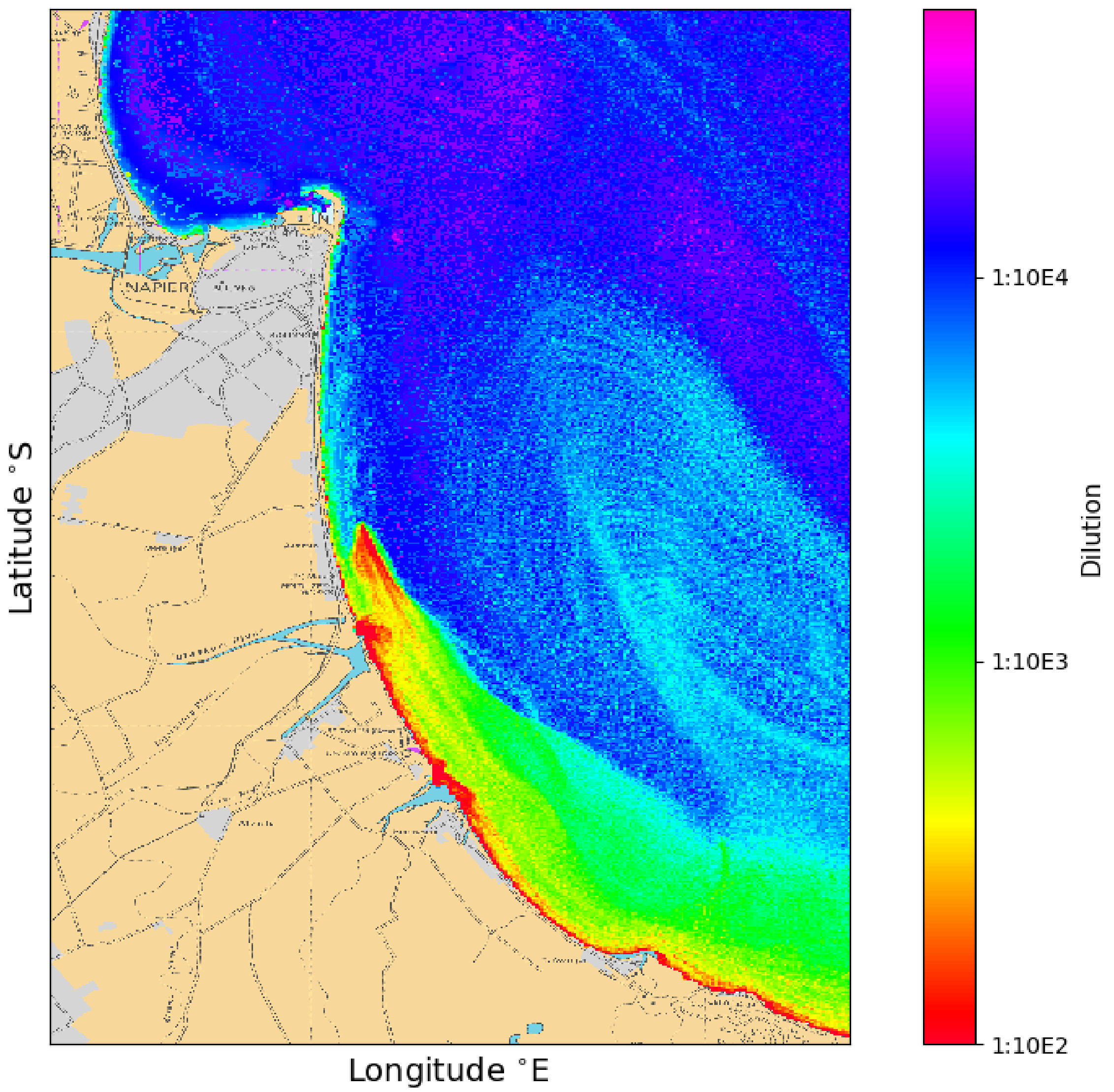

Figure A. 2 Maximum dilution factor during a month-long release for the 700 m pipe break scenario. Dilution factors above 5.10E4 (i.e. 500,000) have been masked.

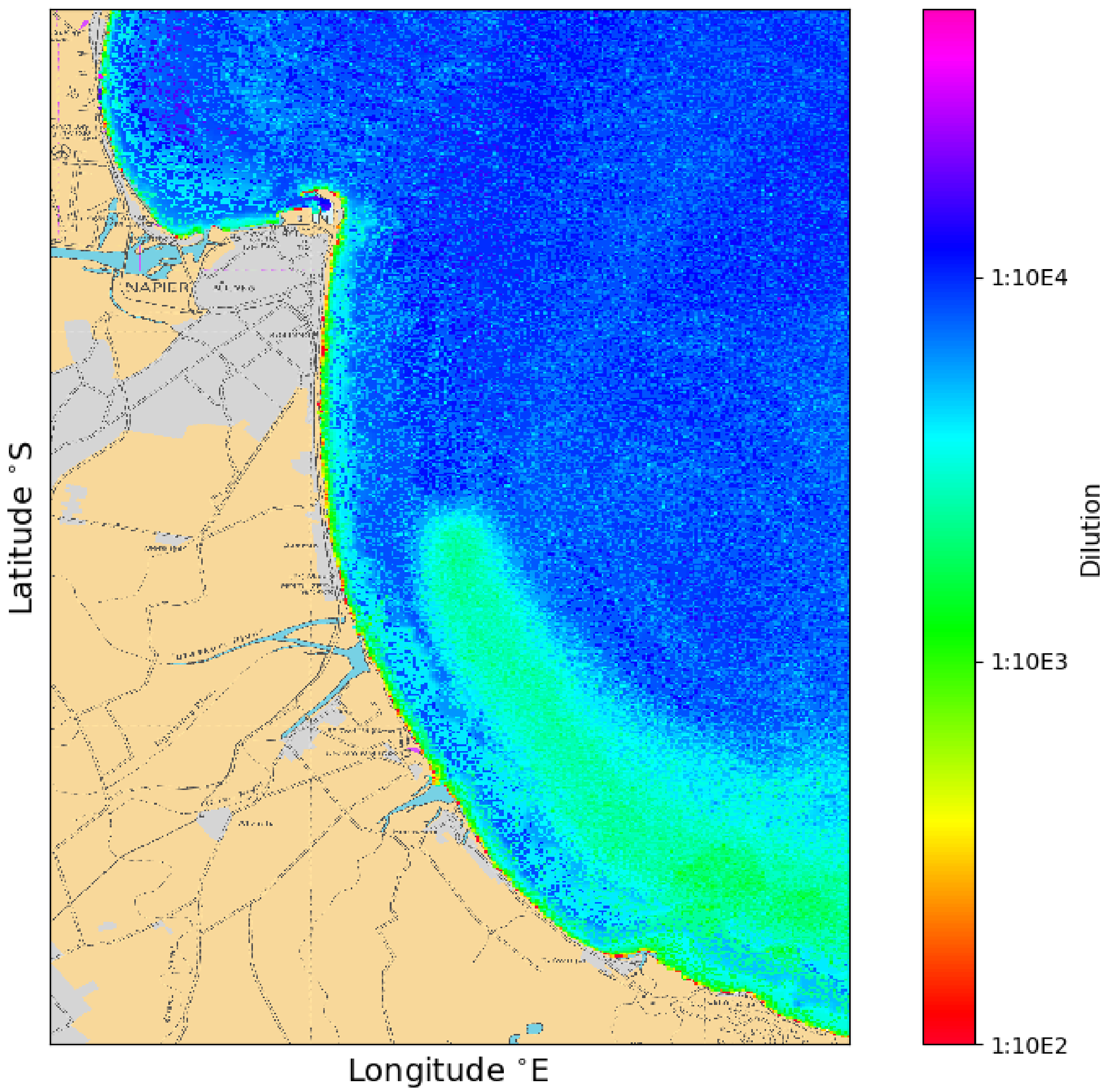

Figure A. 3 Maximum dilution factor during a month-long release for the 2.5 km offshore future diffuser scenario. Dilution factors above 5.10E4 (i.e. 500,000) have been masked.

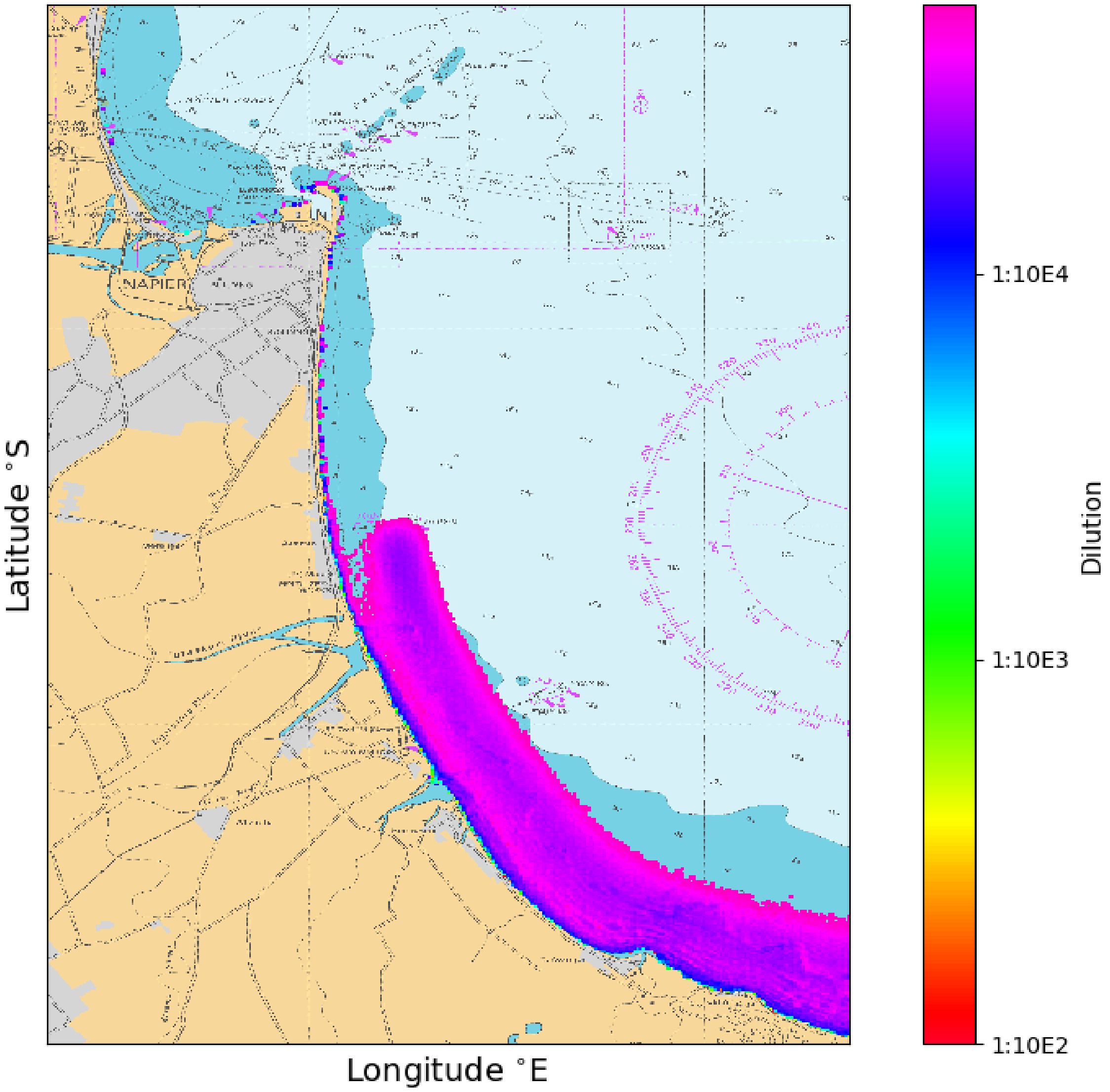

Figure A. 4 *Mean dilution factor during a month-long release the 'normal' operation scenario. Dilution factors above 5.10E4 (i.e. 500,000) have been masked.*

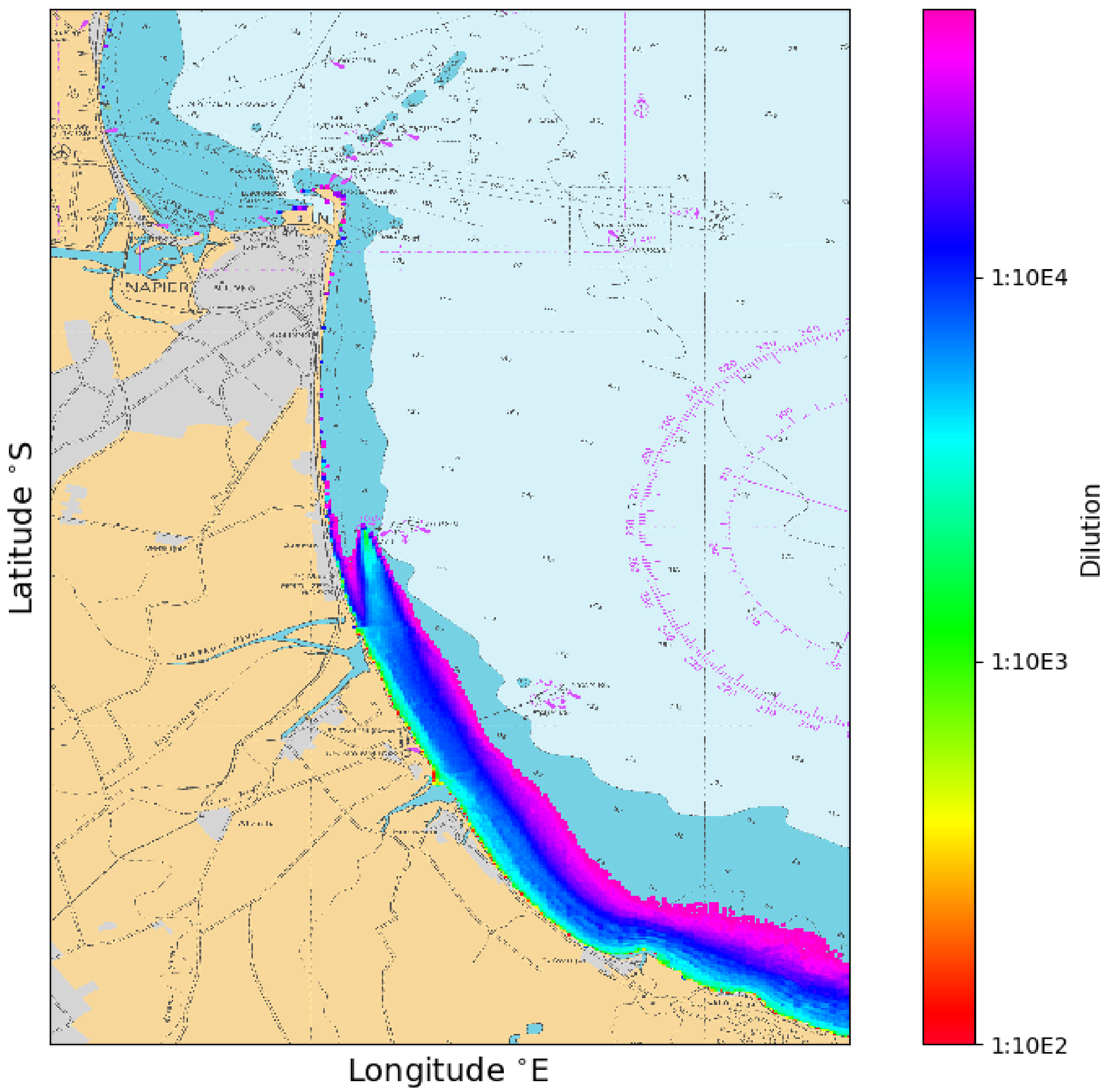

Figure A. 5 Mean dilution factor during a month-long release for the 700 m pipe break scenario. Dilution factors above 5.10E4 (i.e. 500,000) have been masked.

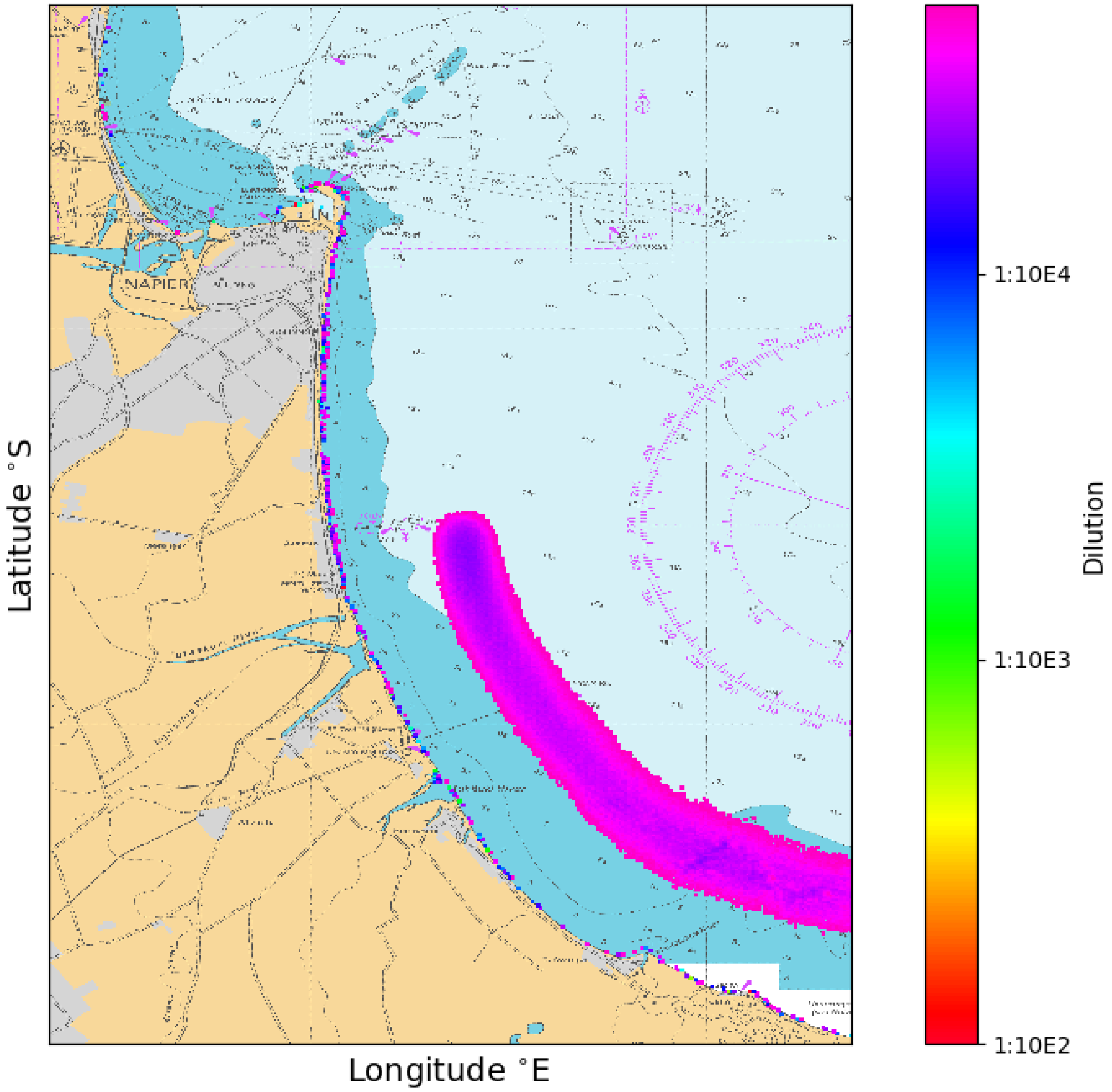

Figure A. 6 Mean dilution factor during a month-long release for the 2.5 km offshore future diffuser scenario. Dilution factors above 5.10E4 (i.e. 500,000) have been masked.