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Sent: Friday 21 July 2023 15:45
To: Licensing Staff
Cc: Eve O'Sullivan; Peter Keegan
Subject: D0056-02 Midleton Licence Review Application
Attachments: Marine Modelling Report.pdf

Good Afternoon Eve & Licensing Team

Further to UÉ Licence Review Application for D0056-02, please find attached a copy of the Marine Modelling Report, which will support the application.

Would you please acknowledge receipt of this email and attachment.

Kind Regards

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Midleton / Carrigtwohill Licence Review

Water Quality Modelling Report

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Uisce Éireann

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Midleton / Carrigtwohill Licence Review

Water Quality Modelling Report

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Rev 2	21/07/2023	Addressing final Uisce Éireann comments and inclusion of Baseline Results at Appendix A.	NB	PAT	PAT

SUMMARY

Uisce Éireann required a strategic numerical water quality model to undertake the assessments as required for planning and Wastewater Discharge Authorisation (WWDA) licensing purposes and to assist Uisce Éireann in identifying necessary asset improvements that would lead to a significant improvement in the water quality in Cork Harbour.

The calibrated and validated Cork Harbour model (Intertek, 2023b; 2023c) has been used to deliver a number of assessments to establish the impact of the existing Uisce Éireann continuous discharges on key receptors in the harbour. These investigations include:

- Deterministic assessments of the mixing zone of Uisce Éireann discharges in terms of key WFD parameters of biochemical oxygen demand (BOD), dissolved inorganic nitrogen (DIN) and orthophosphate (as molybdate reactive phosphorus (MRP)) against Environmental Quality Standard (EQS) and Water Framework Directive (WFD) criteria. In addition, while it is noted there is no WFD EQS for ammonia, the un-ionised ammonia mixing plume has also been assessed to provide additional information with respect to potential for ecotoxic effects in the vicinity of Uisce Éireann discharges.
- Trophic assessments of the impact of DIN and MRP over the wider Cork Harbour Waterbody, particularly Nutrient Sensitive Waters, against relevant WFD standards in each WFD Waterbody within Cork Harbour.
- Microbiological impacts on Bathing Waters (BW) and Designated Shellfish Waters (SFW) in Cork Harbour.

The results of a Future Scenario and Future 'Notionally Clean' River applications scenarios are presented in this report. In both scenarios, the input loads have been modified to represent the proposed future characteristics of Uisce Éireann's discharges and maximum permitted flow and ELV concentration for industrial discharges.

In the Future 'Notionally Clean' River scenario the rivers have been represented as 'notionally clean' (i.e. upstream sources from human activity, including farming and septic tanks, are removed) . For the Future scenario rivers have been characterised using available gauging and Environmental Protection Agency (EPA) data.

The Future scenario represents a worst-case condition with all discharges operating at their maximum permitted emission limit values at the same time. The key model predictions from this scenario are:

- **BOD** concentrations in summer and winter around Cork Harbour are generally <1 mg/l with most areas having an indicative quality of High.

  There is a clearly defined BOD mixing zone of ca. 200m in length and ca. 100m in width in the immediate vicinity of the Carrigtwohill Wastewater Treatment Plant (WwTP) outfall. Outside of this mixing zone Good indicative quality is achieved.

  At Midleton WwTP, there is no mixing zone as the EQS value is met immediately at the surface with concentrations (~1 mg/l) around the secondary treated discharge point. Generally this area has an indicative quality of High.

- **DIN** concentrations in the transitional waters within the Harbour are typically between 0.5 mg/l and 1.5 mg/l, with winter conditions having slightly higher concentrations. Elevated DIN concentrations (up to 5.0 mg/l) are predicted in the upper reaches of the Lee Estuary, Glashaboy Estuary and Owenacurra Estuary due to riverine inputs of DIN. Overall indicative quality in the transitional waters is Moderate, except in the North Channel Great Island WB where Good or High is predicted. However, there is no WFD EQS for DIN in transitional waters and the elevated DIN in these areas is insufficient to have any significant influence on the Coastal WFD waterbodies where a DIN WFD target is applicable.

  Elevated concentrations are also predicted in the Lough Mahon (Harper's Island) WB around the Carrigtwohill WwTP discharge. Peak concentrations (5 mg/l in winter) occur within the discharge plume (2.0 mg/l and 2.5 mg/l over approximately 200m wide along the main tidal channel, and extending further eastward).

At Midleton WwTP, there is no predicted elevation in DIN concentrations around the discharge; modelled concentrations are <0.5 mg/l.

- **MRP** concentrations in the transitional waters of Cork Harbour are generally <0.04 mg/l in summer, with most areas in Cork Harbour having an indicative quality of High and Good in Lough Mahon. MRP concentrations are slightly elevated in winter, with a larger area of Moderate indicative quality in Lough Mahon and Moderate areas in the Owenacurra Estuary and Lower Lee Estuary.

  Elevated MRP concentrations are predicted around Carrigtwohill WwTP discharge. The shallow bathymetry and enclosed nature of the WB at Carrigtwohill gives rise to a mixing zone around the outfall (outside which Good status is simulated). In summer the mixing zone extends approximately 700m downstream (width approximately 100m wide) and approximately 1000m long and 200m wide upstream, in winter the mixing zone extends across the channel width approximately 1000m upstream and downstream of the discharge location. Indicative MRP quality of Moderate prevails locally and upstream of the outfall.

  At Midleton WwTP, there is a small area of slightly elevated MRP concentration around the discharge point, but this remains below the EQS threshold and indicative quality is High (summer) Good (winter).

- ***E. coli* (EC)** concentrations are generally low in Cork Harbour with most areas falling below the geomean SFW target of 110 EC/100 ml or the 95th percentile concentration for Excellent BW Quality of 250 EC/100 ml. There are some local elevated EC concentrations predicted in the immediate vicinity of the Carrigtwohill WwTP however there is no bacterial standard applicable at this location and impacts do not influence bacterial concentrations at any SFW or BW. Modelled EC concentrations around Midleton WwTP were below limit of detection levels with concentrations of <5 EC/100 ml predicted at both the geomean and 95th percentile concentrations.

  Modelled EC concentrations in the Designated SFWs do not exceed the 110 EC/100 ml geomean target. Modelled EC concentrations at Fountainstown Designated BW suggest an indicative quality of Excellent.

- **Intestinal enterococci (IE)** 95th percentile concentrations around Cork Harbour are generally <100 IE/100 ml with most areas having an indicative quality of Excellent. There are some local elevated IE concentrations predicted in the immediate vicinity of the Carrigtwohill WwTP however there is no bacterial standard applicable at this location and impacts do not influence bacterial concentrations at any SFW or BW. Modelled 95th percentile IE concentrations of <5 IE/100 ml are predicted around Midleton WwTP, equivalent to an indicative bathing water quality of Excellent. Modelled IE concentrations at Fountainstown Designated BW suggest an indicative quality of Excellent.

- **Un-ionised ammonia,** while not a WFD standard, has been assessed using historical (pre WFD) standards (0.021 mg/l in coastal and transitional waters) to assess potential for ecotoxic effects in the vicinity of Uisce Éireann discharges. Unionised ammonia concentrations around Cork Harbour are generally <0.005 mg/l in summer and winter. Concentrations are elevated around Carrigtwohill WwTP (< 0.03 mg/l) and at Midleton WwTP (<0.005 mg/l), but are not considered significant.

The predictions of the Future scenario indicate that the water quality impacts from Midleton WwTP are minimal. Local impacts for all parameters assessed in this study are observed around the Carrigtwohill WwTP discharge where dilution characteristics are less favourable than Midelton and the discharge plume and mixing zones (where applicable) have been assessed as part of this study.

The Future 'Notionally Clean' River scenario provides an assessment of the maximum potential impact of Carrigtwohill WwTP on the trophic status in Lough Mahon and the area around Harper's Island. The key model predictions from this scenario are:

- **DIN** concentrations around Carrigtwohill WwTP discharge predict Good status outside of a Moderate discharge plume that extends along the tidal channel (width 50m, length 250m) downstream of the discharge. An area (600m x 200m) of elevated concentrations is also seen at the top of the WB.. At Midleton WwTP discharge, modelled concentrations are low and the indicative quality is High in the surrounding area in summer and winter.
- **MRP** concentrations around Carrigtwohill WwTP are predicted to have an indicative quality of Good except for small areas associated with the outfall mixing zone. In the mixing zone Moderate indicative quality is predicted over an area extending 700m downstream of the discharge (mixing zone width 100m), and in the shallow waters upstream of the discharge (approx. 1000m long and 200m wide at the head of the transitional water). In winter, elevated MRP concentrations are also seen locally around Carrigtwohill WwTP, but an indicative quality of Good is predicted. At Midleton WwTP, there is a small area of elevated MRP concentrations (~ 0.04 mg/l) around the discharge, the concentration is below EQS and in summer indicative quality in the area of the discharge plume is High and in winter Good.

The predictions of the Future 'Notionally Clean' River scenario indicate that the rivers are significant contributors to water quality impacts as the indicative quality across Cork Harbour significantly improves as compared to the Future scenario. The impacts from Midleton WwTP are minimal. However, concentrations for DIN and MRP are elevated around the plume from Carrigtwohill WwTP discharge.

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GLOSSARY

3D
3-dimensional

BW
Bathing Water

BWD
Bathing Water Directive

BOD
Biochemical Oxygen Demand

CCC
Cork City Council

DHI
Danish Hydraulic Institute

DIN
Dissolved Inorganic Nitrogen

EC
Escherichia coli (*E. coli*)

ELV
Emission Limit Value

EPA
Environmental Protection Agency

EQS
Environmental Quality Standard

ESR
Environmental Scoping Report

FM
Flexible Mesh

HEP
Hydro Electric Power

IE
Intestinal Enterococci

IEL
Industrial Emissions Licence

IPC
Integrated Pollution Control

LCHD
Lower Cork Harbour Drainage

LSO
Long Sea Outfall

MRP
Molybdate Reactive Phosphorus

NOD
Nicholas O'Dwyer

OPW
Office of Public Works

PE
Population Equivalent

psu
Practical Salinity Units

SFW
Shellfish Water

SWO
Storm Water Overflows

TON
Total Oxidised Nitrogen

TSAS
Tropic Status Assessment Scheme

TSMM
Technical Standards Marine Modelling

TWM
Techworks Marine

VMADCP
Vessel-mounted Acoustic Doppler Current Profiler

WB
Water Body (WFD)

WFD
Water Framework Directive

WWDA

The Wastewater Discharge Authorisation

WwTP

Wastewater Treatment Plant

1. INTRODUCTION

Uisce Éireann has responsibility for more than 150 continuous and intermittent discharges to Cork Harbour – either direct to the Harbour or via watercourses that discharge to the Harbour. There are presently multiple separate coastal models of the harbour that have been developed for different wastewater projects and at different points in time over the past 15 years.

Uisce Éireann now requires an up-to-date, strategic numerical water quality model of the Harbour that can be used as a singular point of reference to undertake the assessments as required for planning and The Wastewater Discharge Authorisation (WWDA) licensing purposes, and to assist Uisce Éireann in identifying necessary asset improvements that would lead to a significant improvement in the water quality in Cork Harbour.

1.1 Overview

In April 2021 Nicholas O'Dwyer Ltd. (NOD) was appointed by Uisce Éireann to act as Engineering Service Provider for the Cork Harbour Strategic Modelling Study. The aim of the study is to establish a strategic water quality model which is suitable to support the assessment of all Uisce Éireann discharges in Cork Harbour against various criteria for a range of environmental legislation and Uisce Éireann policies and targets. The model shall be capable of assessing the cumulative impact of all pollutant sources to the study area system, including riverine and other licensed discharges.

The study is composed of a number of Work Packages related either directly to model development and delivery or related to the execution of analyses on specific receptors, agglomerations or future projects. A list of the key Work Packages is presented below;

Work Package 1 – Model Scoping (NOD, 2022a)

Work Package 2 – Surveys (NOD, 2022b)

Work Package 3 – Model Build, Calibration and Validation (Intertek, 2023a; Intertek, 2023b; Intertek 2023c; Intertek, 2023d)

Work Package 4 – Scenario Analyses and Reporting

- 4.1 Deterministic Existing Scenario Runs
- 4.2 Development of a Unit Impact Database
- 4.3 Existing Microbiological Impact Assessment
- 4.4 Trophic Status Assessment
- 4.5 Midleton WWDA Licence Review
- 4.6 Carrigtwohill / Midleton Upgrade Analyses
- 4.7 Wastewater Network Improvement Analyses
- 4.8 Final Modelling Report

The required model and supporting survey was scoped and specified, following a review of available data, in the project Environmental Scoping Report (ESR) (NOD, 2022a). This forms the foundation upon which all subsequent project activities are based and provides a comprehensive review of data and modelling approaches undertaken, and the rationale for the resulting proposed actions and methodologies are clearly documented.

The aim of the ESR was to clearly establish and justify the approaches proposed for subsequent surveying, model build, calibration, validation and assessment exercises. This included a desktop review of all available physical, hydrometric, hydrodynamic, meteorological, bathymetric, water

quality, Uisce Éireann assets and third-party wastewater discharge data to establish a conceptual understanding of the hydrodynamic and water quality processes operating in Cork Harbour.

Following completion of the ESR, site specific surveys were undertaken to gather data for hydrodynamic model calibration and validation. The Cork Harbour model comprises three key elements: a hydrodynamic model to simulate water levels, current flows, dispersion, salinity and temperature; a water quality model, driven by the hydrodynamic model, to simulate the transport and fate of water quality determinands; and a microbiological model, similar to the water quality model but focused specifically on microbiological parameters.

The Cork Harbour hydrodynamic model was constructed, calibrated and validated using approaches set out in Uisce Éireann's Technical Standards for Marine Modelling Version 3.00 (Uisce Éireann, 2022 – hereafter referred as the TSMM) for hydrodynamics, temperature and salinity (Intertek, 2023a). This model development was supported by bespoke surveys undertaken in February 2022 (Techworks Marine (TWM), 2022; NOD, 2022b).

The Cork Harbour water quality model has been calibrated and validated using long term Environmental Protection Agency (EPA), third party and project specific monitoring datasets (Intertek, 2023c). Calibration has been undertaken for a winter condition for Biochemical Oxygen Demand (BOD), ammonia, Total Oxidised Nitrogen (TON), dissolved inorganic nitrogen (DIN), orthophosphate (as molybdate reactive phosphorus (MRP)) and dissolved oxygen (as % saturation). Validation has been undertaken for the same parameters during the summer period.

The Cork Harbour microbiological model has been validated using bacteria data collected from estuarine sampling points and Vessel-mounted Acoustic Doppler Current Profiler (VMADCP) surveys, which formed part of bespoke surveys undertaken in summer 2021 and winter 2022 (Intertek, 2023b). Validation has been undertaken for a winter and summer condition for *Escherichia coli* (EC) and intestinal enterococci (IE).

1.2 Objectives

This report fulfils the requirements of Work Package 4 undertaken for the Midleton WWDA Licence Review and Carrigtwohill / Midleton Upgrade Analyses under items 4.5 and 4.6, which includes deterministic, trophic and microbiological assessments to establish the impact from the Midleton and Carrigtwohill Wastewater Treatment Plant (WwTP) discharges on key receptors in the harbour.

These investigations include:

- Deterministic assessments of the mixing zone of Uisce Éireann discharges in terms of key parameters of BOD, un-ionised ammonia, DIN and MRP against Environmental Quality Standards (EQS) and Water Framework Directive (WFD) standards.
- Trophic assessments of the impact of DIN and MRP over the wider Cork Harbour Waterbody, particularly Nutrient Sensitive Waters, against relevant WFD standards in each WFD Waterbody within Cork Harbour.
- Microbiological impacts on Bathing Waters (BW) and Designated Shellfish Waters (SFW) in Cork Harbour.

The deterministic and trophic assessments were undertaken within the Cork Harbour water quality model while the microbiological impact assessment was undertaken within the microbiological model.

The calibrated and validated water quality and microbiological models were applied to the following scenarios:

- A **Future Scenario** representing proposed future discharges from Uisce Éireann WwTPs discharging the maximum permitted ELV concentration of BOD, ammonia, TON and MRP under the current licence at a discharge average daily flow based on an estimated population

equivalent (PE) up to a design horizon of 2028. This scenario also includes the proposed diversion of wastewater from the Midleton WwTP to the Carrigtwohill WwTP and includes the addition of a number of proposed new housing developments in the Carrigtwohill catchment as well as the addition of new industrial discharges. The Midleton discharge from the tidal tank at Rathcoursey includes the industrial load from Dairygold Co-Operative Society Ltd and TINE Ireland Ltd. (P1103-01) and Irish Distillers Limited (P0442) at the maximum permitted flow and ELV concentrations.

It is noted that a number of smaller discharges (Minane Bridge, Cloyne, Saleen Village) are currently operating above design capacity, or will be operating above design capacity under the future scenario. While these discharges are on the Uisce Éireann investment programme they have been modelled based on current performance as a precautionary approach as the impact from these sources would be reduced as a result of future investment. The Future Scenario therefore provides an assessment of the maximum potential impact under future operating conditions. Bacteria discharges were modelled using predicted future flows from WwTPs and concentrations based on existing monitoring data where available, or typical default concentrations for the treatment level where not.

- A **Future 'Notionally Clean' River** scenario representing the discharges from Uisce Éireann WwTPs discharging at the same concentrations as in the Future Scenario, with the riverine inputs for ammonia, DIN, nitrate and MRP given 'notionally clean' values. This scenario provides an assessment of the maximum potential impact of Carrigtwohill WwTP on the trophic status in Lough Mahon and the mixing zone around Harper's Island. The notionally clean scenario assumes that upstream sources of pollutants to the water body shall be mitigated by the respective pressure owners such that ambient water quality upstream of the tidal limits of rivers is equal to 1/5th of the High/Good EQS boundary, in line with EPA practices for notionally clean assessment.

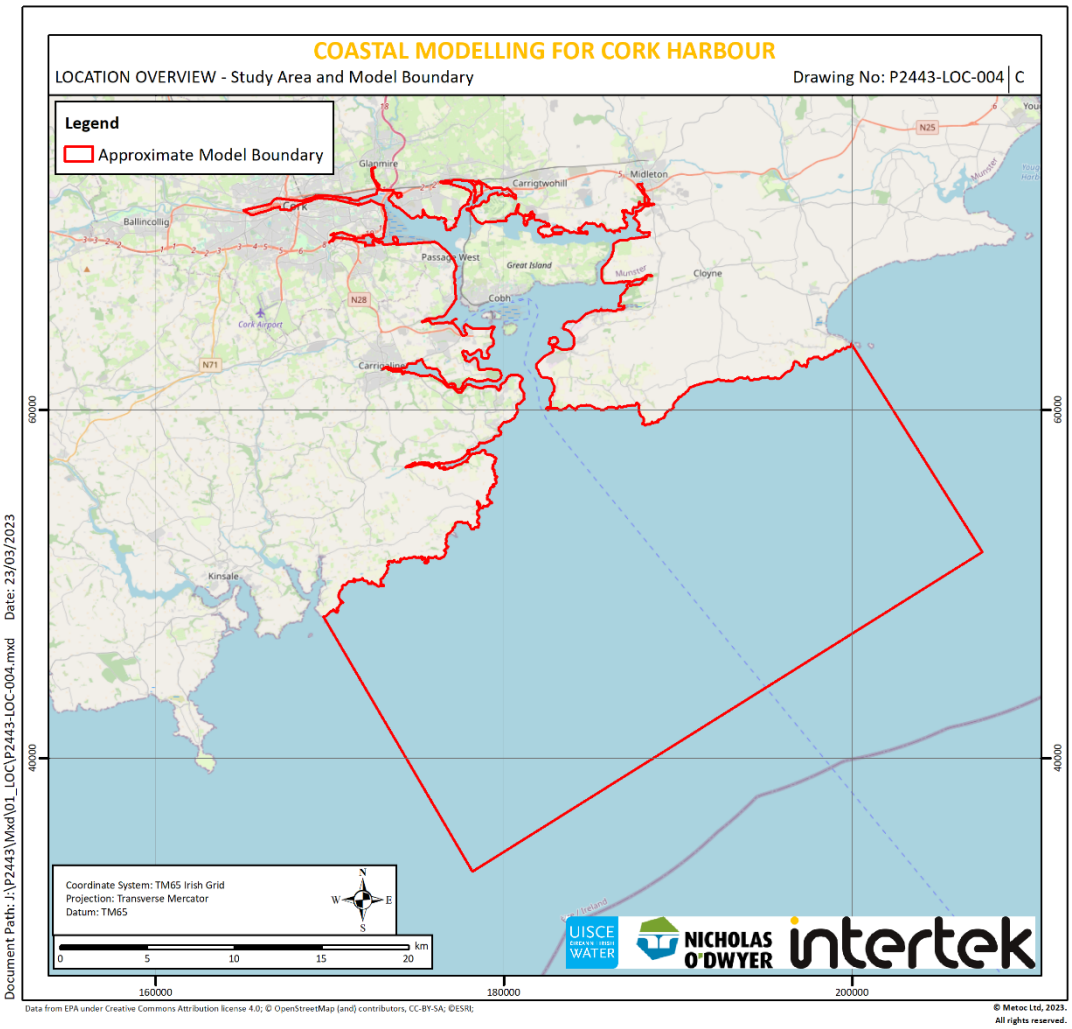
1.3 Study Area

Cork Harbour is situated on the coast of County Cork in the South-Western River Basin District. The upper Harbour is characterised by a complex network of interconnected transitional waters, fed by a number of rivers and streams, with the primary riverine inputs being from the Lee, Glashaboy, Owenacurra, Minane and Owenboy rivers.

In addition, there are a number of smaller rivers discharging to the Harbour. The discharge from the River Lee includes releases from the Inniscarra Hydro Electric Power (HEP) scheme. These discharges correspond to periods of electricity generation and the effects of spillway discharges under high flow conditions, which can lead to significant increases in flow entering Cork Harbour from the River Lee.

The study area is shown in Figure 1-1 (Drawing No: P2443-LOC-004-C) and consists of the entirety of Cork Harbour and the downstream (tidal) reaches of the river networks draining to the harbour. The model domain covers the entire area of Cork Harbour, including all major rivers to the normal tidal limit and a large offshore area. The model resolution varies from 1000 m in the offshore area to less than 25 m in the complex intertidal areas, main channel and areas around WwTP outfalls.

Figure 1-1 Cork Harbour Model Domain



2. APPROACH

The assessment presented in the following sections is based on a bespoke water quality model of Cork Harbour developed specifically for this project. The model is composed of three primary components:

- a three-dimensional (3D) hydrodynamic (HD) model that represents tidal and non-tidal flow, circulation and mixing within Cork Harbour (Intertek 2023a),
- a bacteria water quality model (Intertek 2003b), driven by the HD model, that describes the decay of bacteria (E-Coli and Intestinal Enterococci),
- a water quality (WQ) model (Intertek 2023c), driven by the HD model, that represents the physico-chemical processes that define the decay of BOD in the water column and uptake of soluble nitrogen and phosphorous by plants and phytoplankton.

The modelling software applied (MIKE3) is one of the most advanced available for coastal and estuarine modelling and uses a fine three-dimensional mesh to best represent horizontal and spatial gradients.

The HD model has undergone calibration and validation (Intertek 2023a), against bespoke survey data (January to February 2022) at sites throughout Cork Harbour. Calibration was undertaken in accordance with Uisce Éireann's Technical Standards for Marine Modelling (TSMM) Version 3 (UE 2022). The model provides a good fit against observed datasets for water level, current velocity, salinity and temperature, and is considered fit for use.

The bacteria water quality model was calibrated against sample data collected in the Cork Harbour shellfish waters during summer 2021 and winter 2021 / 2022.

The WQ model was calibrated and validated against EPA WFD National Water Monitoring sampling data. This data provides good coverage throughout Cork Harbour but is subject to the practical limits of any sampling programme, e.g. sample location / spread, depth, timing (e.g. dry, wet weather, tidal state), sampling frequency and limits of detection. The period of sample data used must recognise the potential effects of changes within the receiving water catchment, e.g. large-scale sewerage upgrade programmes, that can affect sample concentrations pre- and post-change. These practicalities also apply to the description of chemical loads input to the model, which are based on spot sampling of rivers and WwTP.

WQ model calibration and validation was undertaken using sample data over the period 2019 to 2021. Data was pooled into sub-sets for winter (November to February) and summer (May to September) conditions and statistically analysed to determine mean, median and quartile values. The WQ model was run to represent typical summer and winter conditions and output compared with the summer and winter sample statistics. Typical conditions were defined on the model boundaries as seasonal time series of typical tide and meteorology and average (steady state) river and WwTP loading, and ambient water temperature and salinity. Industrial loads are represented using permit ELV flow and concentrations, except where measured data are available. WQ model calibration is described in Intertek (2023b), Intertek (2023d) provides detail of the analysis of sample data sets to derive model inputs.

The model does not include the effects of short-term episodic events, e.g. storms, that would be expected to increase loads from rivers, WwTP and Storm Water Overflows (SWOs). These effects will be short term and localised and unlikely to significantly affect the longer-term trends in water quality and WFD chemical and trophic classification.

The WQ model provided a good fit against the available sample data with calibration coefficients and parameters within the normal range applied in studies of similar water bodies, i.e. good fit with the mean observed concentration and was within typical seasonal range for each chemical parameter. The

spatial and temporal trends in chemical concentrations was predicted at sample sites throughout Cork Harbour. The model also represented the seasonal variation between summer and winter periods well, showing the model responded to effects of changes in load, temperature, and biochemical processes. The model is considered fit for purpose.

For the model applications a precautionary approach is adopted. Uisce Éireann discharge loads are modelled as maximum ELV concentration under a continuous mean discharge flow. All industrial discharges are at maximum ELV flow and concentration. Model output is derived from the surface layer in the model, as most chemical inputs are buoyant freshwater, which will tend to produce the highest concentrations at the surface of the water column: this trend is supported by EPA sample data (Intertek 2023b).

As discussed in Section 3.1 model output is produced as concentrations and as indicative quality based on the WFD EQS for the water body. It is noted that indicative quality derived from the model output will differ from that derived from observed data due to differences in the spatial and temporal coverage between sampled and model-derived concentrations and the use of a WFD water body median salinity to determine the DIN and MRP EQS. However, the indicative water quality derived from the model applications is considered suitable to determine the contribution of Uisce Éireann discharges to WFD performance and goals in Cork Harbour.

2.1 Model Set-Up

2.1.1 Input Loads

The model applications use the calibrated and validated Cork Harbour Models described in Section 2 above. The model validation was undertaken for winter and summer conditions under a steady state mean input load from rivers and direct anthropogenic sources (including Uisce Éireann WwTPs, industrial discharges and Section 4 Licensed discharges that discharge directly to the tidal waters of Cork Harbour).

The calibrated and validated model provides a baseline condition representing typical winter / summer conditions validated against EPA routine WFD water quality sampling.

Baseline input loads were derived from an analysis of available data to determine average flow and concentration from each source during summer and winter conditions. The derivation of these inputs is described in the Cork Harbour Water Quality Modelling Appendix (Intertek 2023d). For future application scenarios the baseline model has been modified by changing input loads to represent future changes in discharge flow and / or concentration, resulting from increase in population equivalent (PE) or transfer of flows to alternative discharge locations. In summary:

- **River** discharges are based on available flow gauging data and EPA routine sample data derived from National Water Quality Monitoring Stations. These data have been analysed to determine typical (mean) flow and concentration during summer and winter periods. These river loads are applied in the Future Scenario. For the 'Notionally Clean' River scenario, MRP, nitrate, ammonia and DIN are given 'notionally clean' values; suitable concentrations were provided by NOD and are applied to rivers using 1/5th of the High-Good boundary in line with EPA practices for notionally clean assessment.

- **Uisce Éireann** discharge flows and concentrations under present operating conditions were calculated as seasonal mean values determined from current measured discharge flow and concentration data collected during routine monitoring undertaken by Uisce Éireann and Cork City Council (CCC). These loads were used to develop the baseline model scenario used for calibration and validation. For future scenarios, baseline flow is scaled by the ratio of present mean flow to projected future mean flow (to a specific design horizon) for each agglomeration. Future concentrations are modified to reflect the current or proposed maximum licenced ELV for a WwTP. Where the licence ELV is specified as total nitrogen the ratio of DIN:TN and ammonia:TON is calculated from a ratio derived from the available sample data.
- **Industrial** discharges are based on available data where possible to derive the baseline condition for model calibration and validation. Where no data are available the permit limits for flow and concentration are used. Where the permit does not specify a limit for a specific modelled parameter it is assumed that the discharge concentration is small, and the discharge concentration is set to zero for that parameter. For future applications the maximum permitted flow and concentration is used for all industrial discharges to represent a worst-case condition. This includes the industrial sources that discharge via Uisce Éireann outfalls at Midleton and Shanbally.

2.1.2 Environmental Conditions

Model applications were undertaken for a winter and summer condition to represent seasonal effects on input flow and concentration from rivers and anthropogenic sources and the effects of water temperature on physico-chemical processes in Cork Harbour.

Water temperatures were based on seasonal averages taken from available data, being 8°C in winter and 15°C in summer. Salinity at the model boundary was set to 35 psu in winter and summer; all river, WwTP and industrial discharges have zero salinity.

During each run meteorological conditions (wind and heat flux) are described using a typical seasonal pattern derived from local meteorological observations as used for the model calibration and validation.

Model application scenarios are run from an initial condition for a 30-day spin up period, to ensure dynamic equilibrium is achieved, and a further of 30-day period (two spring-neap tidal cycles). Results are extracted from the latter 30-day period.

2.1.3 Model Applications

The approach adopted for future scenarios is considered a more conservative (precautionary) approach for the assessment of mixing zones and trophic impacts against EQSs. Three model applications are undertaken for each scenario, in each season, to assess a range of potential impacts, as described below and summarised in Table 2-1:

- A **Trophic Model** based on mean seasonal inputs from all sources is used to assess impacts on nutrient concentrations (nitrogen and phosphorus) against WFD standards and classification. Trophic assessments use the mean summer and mean winter flow from rivers to provide an assessment of the longer-term dispersion and take-up of nutrients in the waters of Cork Harbour during summer and winter.
- A **Deterministic (Mixing Zone) Model** is used to assess more localised areas around discharge mixing zones, particularly for parameters such as BOD and ammonia[1]. This model is the same as the trophic model but uses a more conservative (precautionary) approach of a low river flow condition (annual 95th percentile for summer, annual 30th percentile for winter) to reduce the effects of dilution from river flow. A low flow scenario would not be appropriate for a trophic study as such conditions are not sustained over long periods but can be applied for mixing zone assessments where dispersion is rapid and parameters such as BOD and ammonia decay rapidly compared to nutrients.
- A **Microbiological Model** which uses the hydrodynamic model to drive an advection-dispersion model is used to simulate the fate of bacteria discharged from rivers and Uisce Éireann assets under summer and winter flow conditions and typical bacteria decay rates. Summer and winter flows are as described for the deterministic model, to represent a dry weather condition. Decay rates are derived from an initial base rate, which are modified through a validation process to achieve best fit against observed bacteria concentrations at specific monitoring sites.

[1] There is currently no EQS standard under WFD for ammonia in transitional and coastal waters. A value of 0.021 mg/l as a mean annual concentration for un-ionised ammonia has been adopted. This value originates from 1) the 95%ile standard in the repealed EU Freshwater Fish Directive (78/659/EEC), and 2) the annual average EQS under the repealed Dangerous Substances Directive (76/464/EEC) for the protection of saltwater fish and shellfish. In the UK the 0.021 mg/l standard as an annual average concentration has been recommended by WFD Technical Advisory Group (UKTAG) for transitional and coastal waters.

Table 2-1 Definition of Environmental Conditions for Model Applications

Scenario	Summer		Winter	
	Ambient Temperature (°C)	River Flows	Ambient Temperature (°C)	River Flows
Trophic (Nutrients)	15	Seasonal Mean	8	Seasonal Mean
Deterministic (Mixing Zone)	15	Annual Q_{95}	8	Annual Q_{30}
Microbiological	15	Annual Q_{95}	8	Annual Q_{30}

2.2 Scenarios

For the purpose of this report, the Future Scenario and Future 'Notionally Clean' River scenarios are presented (see Section 1.2). Baseline Scenario outputs are presented in Appendix A. Figure 2-1 (Drawing No: P2443C-LOC-017-C) shows the locations of Uisce Éireann's continuous discharges, the significant industrial sources and the riverine sources.

2.2.1 Baseline Scenario

A baseline scenario, reflecting current discharge flow and summer / winter mean discharge concentration from Uisce Éireann WwTP discharges was run for the calibration and validation of the coastal water quality model (Intertek 2023c and 2023d). While the subject of this assessment is the future case Appendix A presents a comparison of Baseline and Future Scenario plots for DIN and MRP around the Carrigtwohill WwTP primary discharge. For the baseline condition Uisce Éireann continuous discharges are set at present discharge rates (January 2019 to June 2022) and future permit maximum ELV concentrations. Future plots are presented for a condition as described in Section 2.2.2.

2.2.2 Future Scenario

Discharge loads are defined as follows:

- **Uisce Éireann discharge** loads are based on operation at proposed ELV concentrations under a future discharge flow representing predicted growth (PE) to a 2028 design horizon. Different discharge flows are used for summer and winter scenarios, based on current discharge measurements (mean discharge), to reflect the seasonal variation in flow due to e.g. higher infiltration and more frequent rainfall in winter. This scenario includes the proposed diversion of wastewater from the Midleton WwTP to the Carrigtwohill WwTP and the addition of a number of proposed new housing developments in the Carrigtwohill catchment. The Midleton discharge also includes the industrial loads from Irish Distillers Limited, which discharges to the sewer network, and from Dairygold / TINE Limited which discharges via the Midleton WwTP outfall at Rathcoursey. These industrial discharges are assumed to operate at maximum permitted flow and ELV concentration.
- **Industrial and trade discharges** are represented as a maximum flow and maximum ELV concentration based on available information from Section 4 trade effluent, Integrated Pollution Control (IPC) and Industrial Emissions Licences (IEL).
- **River discharges** loads are represented by flows and concentrations which have been derived from an analysis of available river gauging records and EPA routine sampling.

This scenario provides an assessment of the maximum potential impact under future operating conditions of Uisce Éireann continuous discharges and industrial discharges. Table 2-3 and Table 2-4 summarise Uisce Éireann's continuous discharges and their modelled flows and concentrations. 0 summarises the discharge flow and concentration from significant industrial sources.

2.2.3 Future 'Notionally Clean' River Scenario

Discharge loads are defined as follows:

- **Uisce Éireann discharge** loads are represented as in the Future Scenario.
- **Industrial and trade discharges** are represented as in the Future Scenario.
- **River discharges** are represented as in the Future Scenario for BOD. Table 2-2 shows the 'notionally clean' concentrations used for ammonia, DIN, nitrate and MRP. The same values were applied for summer and winter.

Table 2-2 Riverine Concentrations for Future 'Notionally Clean' River Scenario

Parameter	Riverine Concentrations	Comments
DIN	0.008 mg/L – Ammonia 0.32 mg/L – DIN 0.312 mg/L – Nitrate	20% difference between the Good / High thresholds From river supporting element thresholds From transitional water guidance at 0 psu salinity
MRP	0.006 mg/L	20% difference between Good/High thresholds (from transitional water guidance at 0 psu salinity; this is 0.001 mg/L higher than the value for riverine systems, and is regarded as a conservative in this analysis)

Figure 2-1 Cork Harbour Model Discharges

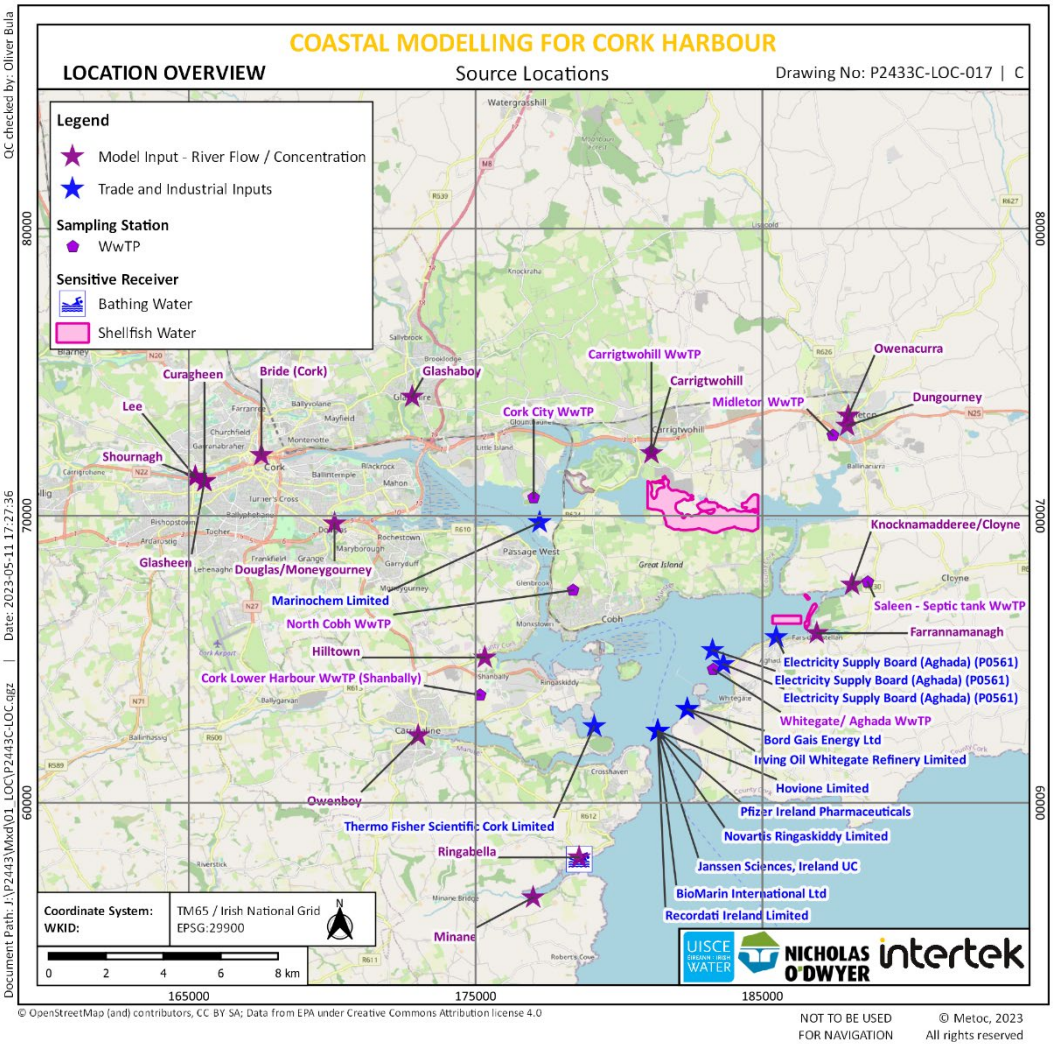


Table 2-3 Summary of Uisce Éireann's Continuous Discharges

Uisce Éireann Discharge	Current Mean Annual Flow (m^3/s)	Future (2028) Mean Annual Flow (m^3/s)	Change (%)	Model Current Summer Flow (m^3/s)	Model current Winter Flow (m^3/s)	Model Future Summer Flow (m^3/s)	Model Future Winter Flow (m^3/s)
Shanbally (Cork Lower Harbour)	0.112	0.182	63	0.094	0.150	0.153	0.244
North Cobh	0.008	0.008	8	0.006	0.010	0.006	0.011
Cork / Carrigrennan	1.468	1.587	8	1.185	1.597	1.281	1.727
Midleton	0.097	0.095	-2	0.086	0.112	0.084	0.109
Carrigtwohill	0.057	0.092	61	0.048	0.066	0.077	0.106
Whitegate-Aghada	0.006	0.007	6	0.008	0.008	0.008	0.008
Saleen Village	0.002	0.002	14	0.002	0.002	0.002	0.002
Cloyne	0.006	0.007	23	0.006	0.006	0.007	0.007
Minane Bridge	0.0003	0.0004	42	0.001	0.001	0.001	0.001

Table 2-4 Summary of Uisce Éireann's Modelled Future Discharge Concentrations

Summer

Uisce Éireann Discharge	BOD (mg/l)	Ammonia (mg/l)	TON (mg/l)	DIN (mg/l)	MRP (µg/l)
Cork	25.0	16.1	3.3	19.4	1.5
Shanbally	25.0	20.7	24.3	45.0	12.0
Carrigtwohill	25.0	5.0	20.0	25.0	0.58
Midleton	25.0	1.3	5.60	6.9	2.0
North Cobh	25.0	9.9	1.74	11.6	1.04
Whitegate	267.0	55	5.0	60.0	14.0
Cloyne	10.0	19.6	3.3	22.87	1.6
Saleen	113.7	26	3.1	29.13	1.9
Minane	1.9	9.2	1.5	10.7	0.5

Winter

Uisce Éireann Discharge	BOD (mg/l)	Ammonia (mg/l)	TON (mg/l)	DIN (mg/l)	MRP (µg/l)
Cork	25.0	12.9	3.7	16.6	1.3
Shanbally	25.0	20.44	24.6	45.0	12.0
Carrigtwohill	25.0	5.0	20.0	25.0	0.58
Midleton	25.0	1.1	8.76	9.90	2.0
North Cobh	25.0	7.1	2.6	9.7	0.8
Whitegate	267.0	55.0	5.0	60.0	14.0
Cloyne	10.0	11.1	4.5	15.7	1.48
Saleen	113.7	27.9	6.2	34.1	2.3
Minane	2.2	5.2	2.1	7.4	0.4

Table 2-5 Summary of Industrial Discharge Permitted Flow and ELV

Discharge	Flow (m^3/s)	BOD (mg/l)	Ammonia (mg/l)	TON (mg/l)	DIN (mg/l)	MRP (mg/l)
Thermo Fisher Scientific Cork Limited (P0004)	0.090	300.0	10.0	25.0		2.0
Hovione Limited (P0010) [1]	0.021	2000.0	50.0	50.0	100.0	200.0
Recordati Ireland Limited (P0476) [1]	0.001	300.0	0.0	100.0	100.0	200.0
Novartis Ringaskiddy Limited (P0006) [1]	0.010	250.0	10.0	30.0	40.0	11.1
Janssen Sciences, Ireland UC (P0778) [1]	0.009	40.0	0.0	80.0	80.0	20.0
Pfizer Ireland Pharmaceuticals (Ringaskiddy) (P0013) [1]	0.034	887.6	75.0	390.7	465.7	55.2
BioMarin International Ltd (P0864) [1]	0.002	1334.0	0.0	110.0	110.0	0.0
Marinochem Limited (P0034)	0.017	20.0	10.0	15.0		

Discharge	Flow (m^3/s)	BOD (mg/l)	Ammonia (mg/l)	TON (mg/l)	DIN (mg/l)	MRP (mg/l)
Irish Distillers Limited (P0442)	0.058	25.0	2.5	12.5	15.0	2.0
Dairygold/ TINE Ltd	0.046	25.0	5.0	10.0	15.0	1.2
Electricity Supply Board (Aghada) (P0561)	8.889	-	-	-		-
Electricity Supply Board (Aghada) (P0561)	9.167	-	-	-		-
Irving Oil Whitegate Refinery Limited (P0266)	0.139	30.0	3.0	25.0		0.4
Bord Gais Energy Ltd (P0830)	0.014	20.0	5.0			5.0

1 Discharges via the Uisce Éireann Shanbally Outfall

2.3 Representation of Midleton Tidal Tank Discharge

The Midleton WwTP discharges to sea via a long sea outfall (LSO) to the deep channel of Passage East near Rathcoursey. To reduce the impact of the discharge on the shallow intertidal areas of the North Channel and Owenacurra estuary effluent is released on the ebb tide only, from high water to low water. To achieve this the discharge from the WwTP is stored in a tidal tank during the period from low water to high water and then released via a penstock at high water.

The tidal tank also receives effluent from two industrial sources, Irish Distillers Ltd. and Dairygold / TINE Ltd. Irish Distillers discharges to sewer where the effluent is combined with the treated effluent from Midleton WwTP and pumped to the tidal tank. Dairygold effluent is discharged direct to the tidal tank via a separate rising main. Effluent is stored at the Dairygold site such that the discharge to the tidal tank only occurs when the penstock is open and there is a discharge via the LSO. This ensures the Dairygold discharge is not stored in the tidal tank. When the penstock is open any additional (continuous) flow received from Midleton WwTP and Irish Distillers will discharge freely until the penstock is closed.

Storage capacity for the Midleton tidal tank is 2012.5 m^3 with a further 163 m^3 of online storage, therefore total effective storage is 2175.5 m^3.

The rate of discharge from the tidal tank through the penstock has not been measured. The rate of discharge from the tank was estimated using typical design criteria for a marine outfall. The outfall is a 750 mm diameter pipe; assuming a normal design operating discharge velocity of 1 m/s (to avoid sedimentation and saltwater intrusion) gives a typical operating flow of 0.44 m^3/s. This figure is considered a reasonable average for the discharge.

The model input representing the Midleton discharge is derived as follows:

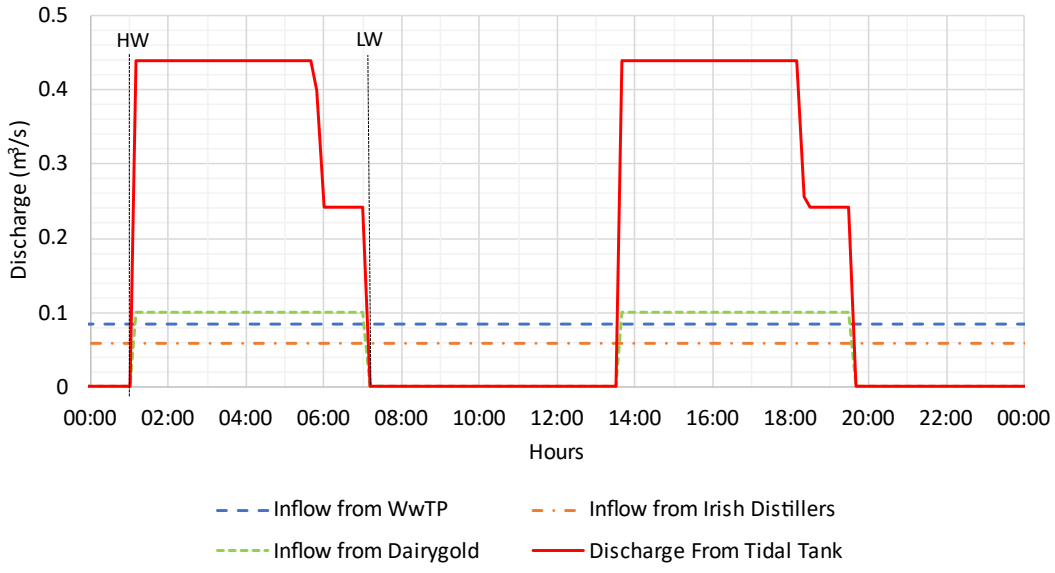
- Flow to the tank is based on average future discharge from the WwTP and daily permitted discharge volume for the industrial sources. Flow is assumed to be constant. In the case of the Dairygold discharge the permitted daily volume is divided by the discharge period (approx. 12 hours total per day) to derive a mean flow.
- The stored volume during the period the penstock is closed is calculated from the daily average flow from the WwTP plus daily permitted flow from Irish Distillers multiplied by the period the penstock is closed.

- When the penstock is open the stored volume is released, together with the continuous average flow from the WwTP and Irish Distillers and the average flow from the Dairygold storage tank. The total discharge is maintained at 0.44 m^3/s until the tank is drained. At this point flow is reduced to the sum of the continuous flows from the WwTP, Irish Distillers and the flow from the Dairygold storage tank. When the penstock closes flow stops.
- This cycle is repeated on each tide with the discharge time from the tank adjusted to the high-water time for each tide in the model.
- The discharge concentration in the tidal tank is derived by calculating the load (flow and concentration) from each source to determine a total discharge load. This is divided by the discharge flow to derive a combined concentration. It is assumed there is no decay within the tank during the short storage period. The concentration of the continuous discharges through the tank when the penstock is open is derived in a similar way as the total load from the three sources divided by the total flow.

A discharge timeseries for the Midleton tidal tank over a 24-hour period is presented in Figure 2-2. Dotted lines represent the inflows to the tank from the WwTP, Irish Distillers and Dairygold; the solid line represents the discharge from the tidal tank.

The plot shows that maximum discharge flow is maintained over the majority of the discharge period (0 to 5 hours after the penstock opens at high water) at which point the tank empties and the combined flow from the three sources passes through the tank to the outfall (5 to 6 hours after high water). Flow then falls to zero as the penstock closes at low water.

Figure 2-2 Midleton Tidal Tank Discharge Profile



3. RESULTS

Results from each model application were extracted from the output files and post-processed to calculate relevant statistical concentrations for comparison against the EQS thresholds presented in Table 3-1. EQSs are taken from the Surface Water Regulations Ireland (amended 2019). Under the Surface Water Regulations Ireland (amended 2019) there is no standard for ammonia in transitional and coastal waters.

To provide an indication of the mixing zone for ammonia, un-ionised ammonia has been used. The concentration of un-ionised ammonia is determined by the concentration of ammonia, ambient salinity, temperature and pH. The proportion of un-ionised ammonia increases with increasing temperature and pH, but decreases with increasing salinity.

The un-ionised ammonia concentration was calculated from the modelled salinity, temperature and ammonia concentration in each model cell assuming a pH of 8.0. Analysis of EPA sample data indicates pH is typically between 7.7 and 8.1 in Cork Harbour. Lower pH tends to occur in the estuarine waters. The use of a pH of 8.0 is therefore considered conservative as un-ionised ammonia tends to increase rapidly with pH. Use of the maximum observed pH of 8.1 was considered overly conservative. At a pH of 8.0 approximately 5% to 10% of ammonia will be present as un-ionised ammonia.

Table 3-1 EQS Thresholds Applied

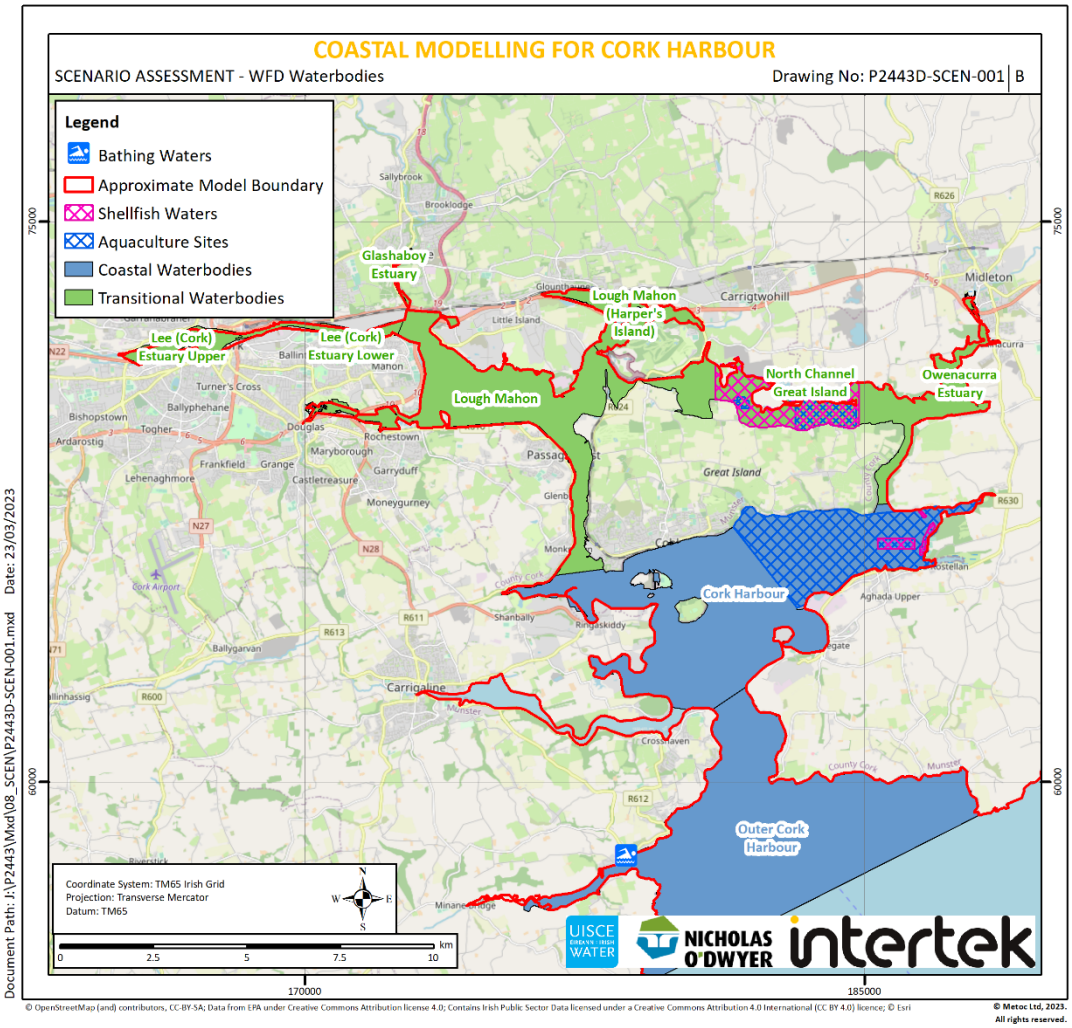
EQS	Transitional Waterbody		Coastal Waterbody	
BOD (mg/ O_2/l)	High status ≤ 3.0 (95th percentile)	Good status ≤ 4.0 (95th percentile)		
DIN (mg N/l)[1]			High status 0 psu[1] ≤ 1.0 mg N/l (median) 34.5 psu[1] ≤0.17 mg N/l (median)	Good Status 0 psu[1] ≤2.6 mg N/l (median) 34.5 psu[1] ≤0.25 mg N/l (median)
MRP (mg P/l)[1]	High Status 0-17 psu[1] ≤ 0.030 (median) >17-35 psu[1] ≤ 0.030-0.025 (median)	Good Status 0-17 psu[1] ≤ 0.060 (median) >17-35 psu[1] ≤ 0.060-0.040 (median)		

[1] Linear interpolation used to establish the limit value for waterbodies between these salinity levels based on the median salinity of the waterbody being assessed.

A median salinity for summer and winter has been determined based on the latest WFD sampling undertaken by the EPA for the 2021 WFD assessment. This sampling covers the period 2019 to 2021. The sampling covers all waterbodies except North Lough Mahon (Harper's Island) where Lough Mahon data are used.

The seven transitional (Lee Upper, Lee Lower, Glashaboy Estuary, Lough Mahon, Lough Mahon (Harper's Island), North Channel Great Island and Owenacurra Estuary) and two coastal (Cork Harbour and Outer Cork Harbour) WFD waterbodies included in this study are shown in Figure 3-1 (Drawing No: P2443D-SCEN-001-B).

Figure 3-1 Cork Harbour Study WFD Waterbodies



3.1 Presentation of Results

Results are presented for the future and Future 'Notionally Clean River' Scenarios in the following sections.

Additional water quality plots of the Carrigtwohill WwTP primary discharge, representative of baseline dissolved inorganic nitrogen (DIN) and orthophosphate (as molybdate reactive phosphorous MRP), were prepared from the model calibration and validation runs and are provided in Appendix A to provide additional context on the net impact of the future scenario.

For consistency with EPA monitoring, and to provide a conservative assessment, model results are presented for the surface layer. Highest concentrations typically occur in the surface layer, particularly in the mixing zone around outfall discharges and where rivers discharge to estuaries as these discharges tend to be buoyant and stratification may reduce vertical mixing.

Results are presented as contoured map plots or in terms of source apportionment:

- **Concentration Plots** – present the concentration from each model grid cell contoured as concentrations in mg/l or cfu/100 ml as appropriate over the model domain. The concentration represents the relevant statistical measure required under the specific parameter EQS, e.g. 95th percentile for BOD, mean for un-ionised ammonia, median for DIN and MRP. Plots are presented for winter and summer conditions. These plots provide an overview of the distribution of concentration of each parameter in Cork Harbour.
- **Indicative Quality Plots** – present contours of the indicative WFD class in each model cell. Indicative quality is determined by comparing the modelled concentration with the relevant statistical EQS threshold (Table 3-1) to determine a reference number based on class (e.g. 1=High, 2=Good, 3=Moderate). The reference numbers are then contoured to delineate class boundary as High, Good, Moderate. These plots provide an indication of the WFD class achieved through each Waterbody within Cork Harbour. In preparing indicative class plots the following are noted:
    a. In the case of DIN and MRP the class thresholds are referenced against a Waterbody median salinity determined from EPA sampling from 2019 to 2021. This provides a single reference threshold for the Waterbody for consistency with EPA WFD assessment.
    b. The EQSs published in the Surface Water Regulations Ireland (amended 2019) provide thresholds for High and Good indicative quality only. Class in the plots is therefore labelled as High (blue), Good (green) and Moderate (yellow).
    c. In the case of EC, geomean concentrations in the range 10 EC/100 ml – 110 EC/100 ml are coloured yellow and geomean concentrations that exceed the 110 EC/100 ml threshold are coloured red.
    d. In the case of EC and IE, in accordance with BW classifications, 95%ile concentrations are presented as Excellent (blue), Good (green), Sufficient (yellow) and Poor (orange) BW quality.

For each parameter plots are presented for summer and winter conditions for:

- **Cork Harbour** – an overview plot showing concentration and indicative quality throughout Cork Harbour.
- **Waterbody** – a smaller area focussing on a specific Waterbody(ies) of interest. For this study the key area of interest is the north east area of Cork Harbour which is most impacted by the Midleton and Carrigtwohill discharges, i.e. Lough Mahon, North Channel Great Island and Owenacurra Estuary waterbodies.
- **Mixing Zones** – a plot covering the area immediately adjacent to the Midleton and Carrigtwohill discharges to allow delineation of the mixing zones, where applicable, around each discharge.

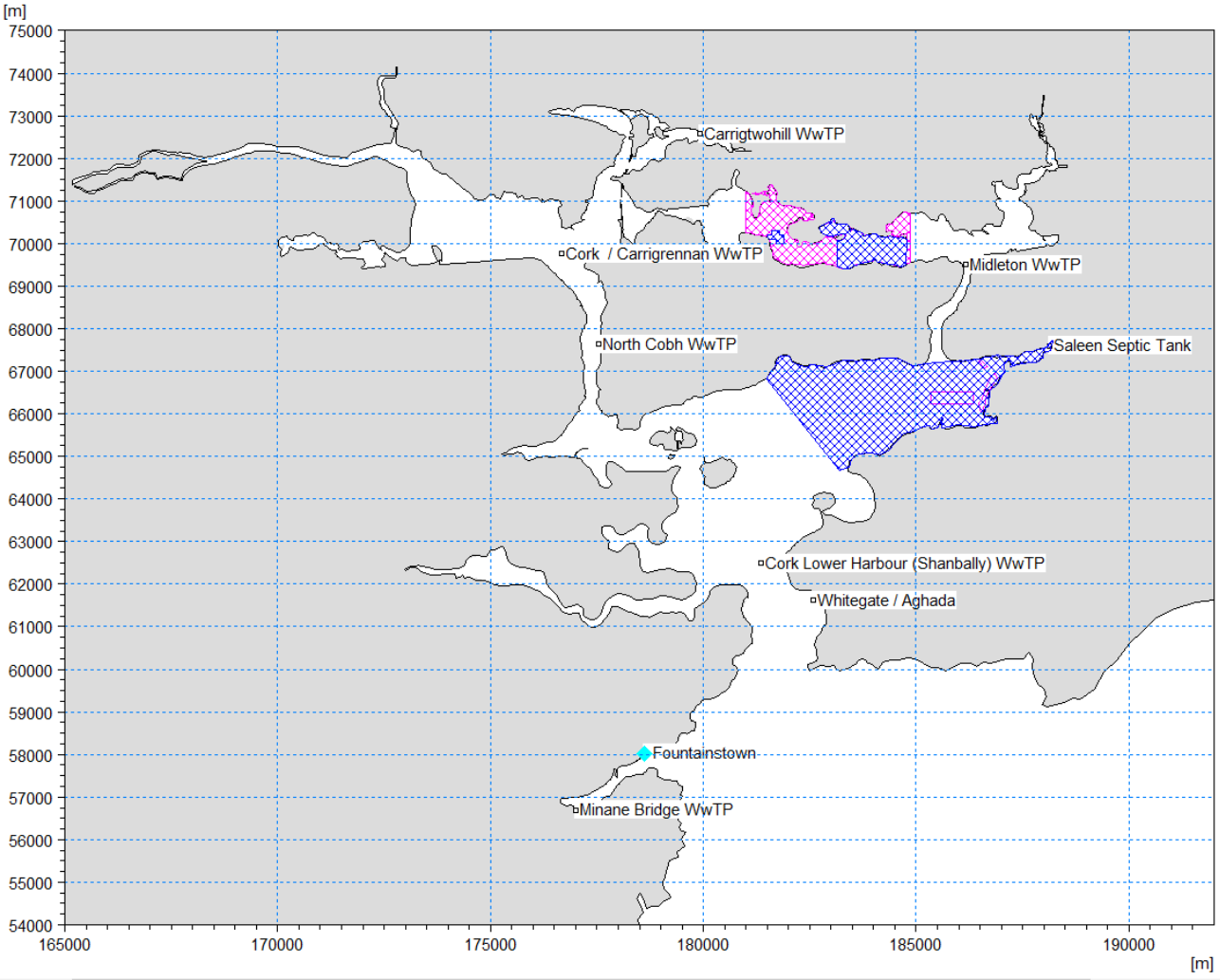
- **Mass Load Pie Charts** present the input loads for BOD, DIN and MRP for summer and winter. The top ten contributors plus Midleton WwTP, Carrigtwohill WwTP and the Owenacurra River are represented. These pie charts are shown alongside with the waterbody plots.
- **Source Apportionment** – presents tables and pie charts of the proportional contribution to impacts from each individual source for EC and IE at the six assessment locations in Cork Harbour. Source apportionment is shown at two assessment thresholds (95th percentile for EC and IE, and geomean for EC only).

Table 3-2 List of Results Presentations

Model	Parameter	Season	Area	Figure
Deterministic	BOD – 95th percentile	Summer	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone – Carrigtwohill	Figure 3-3 Figure 3-4 Figure 3-5 Figure 3-6
Deterministic	BOD – 95th percentile	Winter	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone – Carrigtwohill	Figure 3-7 Figure 3-8 Figure 3-9 Figure 3-10
Deterministic	Un-ionised Ammonia	Summer	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone – Carrigtwohill	Figure 3-11 Figure 3-12 Figure 3-13 Figure 3-14
Deterministic	Un-ionised Ammonia	Winter	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone - Carrigtwohill	Figure 3-15 Figure 3-16 Figure 3-17 Figure 3-18
Trophic (Nutrient)	DIN – median	Summer	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone – Carrigtwohill	Figure 3-19 Figure 3-20 Figure 3-21 Figure 3-22
Trophic (Nutrient)	DIN – median	Winter	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone – Carrigtwohill	Figure 3-23 Figure 3-24 Figure 3-25 Figure 3-26
Trophic (Nutrient)	MRP – median	Summer	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone – Carrigtwohill	Figure 3-35 Figure 3-36 Figure 3-37 Figure 3-38
Trophic (Nutrient)	MRP – median	Winter	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone – Carrigtwohill	Figure 3-39 Figure 3-40 Figure 3-41 Figure 3-42
Microbiological	EC – geomean	Summer	Cork Harbour Waterbody Mixing Zone – Midleton Mixing Zone – Carrigtwohill	Figure 3-52 Figure 3-53 Figure 3-54 Figure 3-55
Microbiological	EC – geomean	Winter	Cork Harbour	Figure 3-56

Model	Parameter	Season	Area	Figure
			Waterbody	Figure 3-57
			Mixing Zone – Midleton	Figure 3-58
			Mixing Zone – Carrigtwohill	Figure 3-59
Microbiological	EC – 95th percentile	Summer	Cork Harbour	Figure 3-60
			Waterbody	Figure 3-61
			Mixing Zone – Midleton	Figure 3-62
			Mixing Zone – Carrigtwohill	Figure 3-63
Microbiological	EC – 95th percentile	Winter	Cork Harbour	Figure 3-64
			Waterbody	Figure 3-65
			Mixing Zone – Midleton	Figure 3-66
			Mixing Zone – Carrigtwohill	Figure 3-67
Microbiological	IE – 95th percentile	Summer	Cork Harbour	Figure 3-68
			Waterbody	Figure 3-69
			Mixing Zone – Midleton	Figure 3-70
			Mixing Zone – Carrigtwohill	Figure 3-71
Microbiological	IE – 95th percentile	Winter	Cork Harbour	Figure 3-72
			Waterbody	Figure 3-73
			Mixing Zone – Midleton	Figure 3-74
			Mixing Zone – Carrigtwohill	Figure 3-75

Figure 3-2 Cork Harbour Overview Plot highlighting WwTP, Aquaculture Area (Blue Hash) and Designated BW (Blue Diamond) and SFW (Pink Hash) Locations



3.2 Deterministic (Mixing Zone) Assessment

3.2.1 BOD

Modelled BOD concentration and indicative quality plots are shown from Figure 3-3 to Figure 3-5 for summer, and from Figure 3-6 to Figure 3-9 for winter. The WwTP locations are shown in Figure 3-2.

In summer, BOD concentrations around Cork Harbour are generally <1 mg/l with most areas having an indicative quality of High (see Figure 3-2).

BOD concentrations above 1 mg/l are predicted in the Upper Lee Estuary in summer (up to 10 mg/l) due to inputs from the Lee river, with this area having an indicative quality of Moderate (Figure 3-2), and in Lough Beg (10 mg/l) due to the local industrial discharge from Thermo Fisher Scientific Cork Limited.

Mixing zones with modelled BOD concentrations in excess of EQS targets (up to 10 mg/l) were observed in the immediate vicinity of outfalls from

- Cork/Carrigrennan WwTP (see Figure 3-2), where the mixing zone extends approximately 100m to the north west and south east of the discharge location.
- Carrigtwohill WwTP (see Figure 3-5), where the mixing zone extends approximately 120m to the north west and south east of the discharge location

The transitional waters downstream of Saleen Septic Tank[2] (Figure 3-3) have a mixing zone that extends approximately 200m into the coastal water, where peak concentrations reach approximately 6 mg/l.

At these locations an indicative quality of Moderate is observed, which becomes High beyond of the mixing zone.

A very localised area of elevated summer BOD concentrations were modelled around the IDA outfall pipe which includes discharges from Cork Lower Harbour WwTP (Shanbally), however the area is too small to be seen on the indicative quality plot – Figure 3-2. At Midleton WwTP outfall, there is no discernible mixing zone with the whole area having an indicative quality of High.

Similar overall patterns in modelled BOD concentrations are seen in winter (Figure 3-6). In winter, modelled BOD mixing zones are visible at Cork/Carrigrennan WwTP (Figure 3-7) and Carrigtwohill WwTP (Figure 3-9). The area of the mixing zone at Cork/Carrigrennan WwTP has a similar size and concentration (>10 mg/l) when compared to summer. At Carrigtwohill WwTP the size of the mixing zone is smaller than in summer, 10 m upstream and downstream, and the peak concentration is lower (8 mg/l).

The area around the IDA outfall pipe Cork Lower Harbour WwTP (Shanbally) also shows a very local area of elevated BOD concentrations, although again, the area is too small to be seen – Figure 3-6.

In winter, the area around Saleen Septic Tank shows a mixing zone where the discharge enters the coastal water (see Figure 3-7). However, modelled concentrations around Saleen Septic Tank are lower in winter compared to the summer. Consequently, this area has an indicative quality of High in winter. At Midleton WwTP, there is a small patch of slightly elevated BOD concentration around the discharge, as shown in Figure 3-8. The area of elevated concentration around this discharge is larger in winter compared to the summer. However, the concentration is below the EQS and the whole area around Midleton WwTP discharge has an indicative quality of High.

[2] It should be noted that Saleen Septic Tank is on the Uisce Éireann investment plan and the results produced in this report are conservative since they are based on current performance and future loads.

The pie charts in Figure 3-3 and Figure 3-7 show the proportion of BOD discharge loads from all sources including the WwTPs. In summer and winter, a high proportion of BOD is shown to be from the Cork/Carrigrennan WwTP, Hovione Ltd. and industrial inputs that enter the area at the IDA outfall pipe. The rivers have a greater proportion of BOD input in winter, especially the River Lee.

Figure 3-3 Concentration and Indicative Quality Plots for BOD (95th percentile) – Summer, Cork Harbour

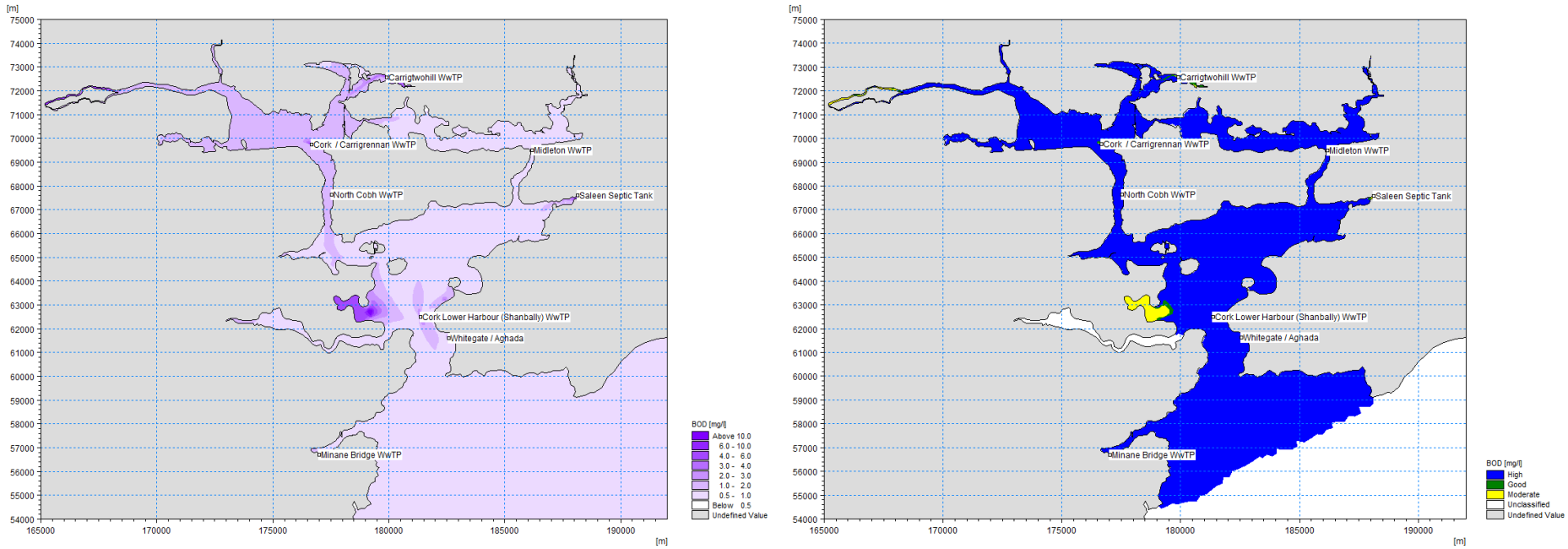


Figure 3-4 Concentration and Indicative Quality Plots for BOD (95th percentile) – Summer, Lough Mahon and North Channel Great Island, and BOD Mass Load Pie Chart

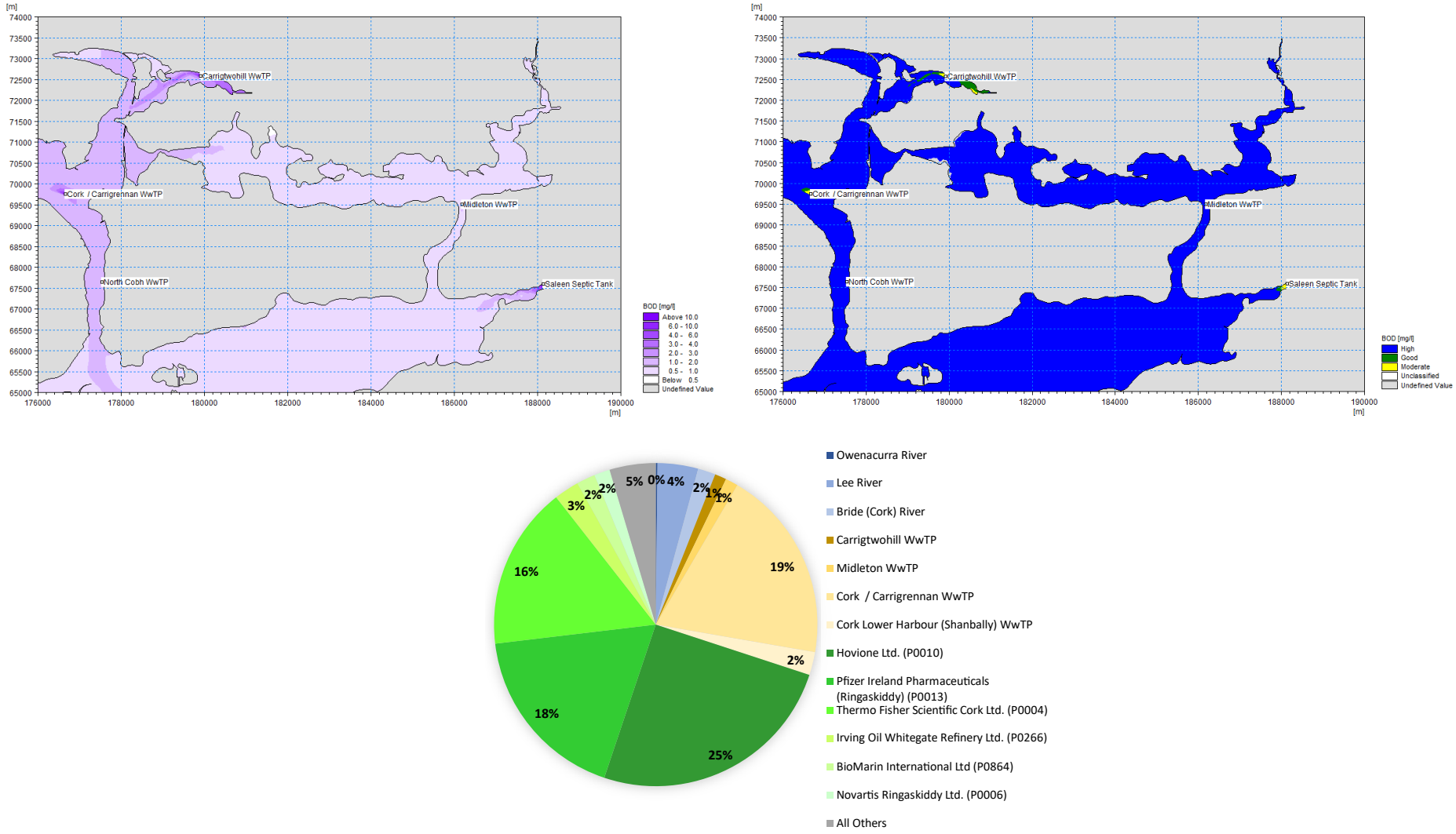


Figure 3-5 Concentration and Indicative Quality Plots for BOD (95th percentile) – Summer, Mixing Zone Midleton Discharge

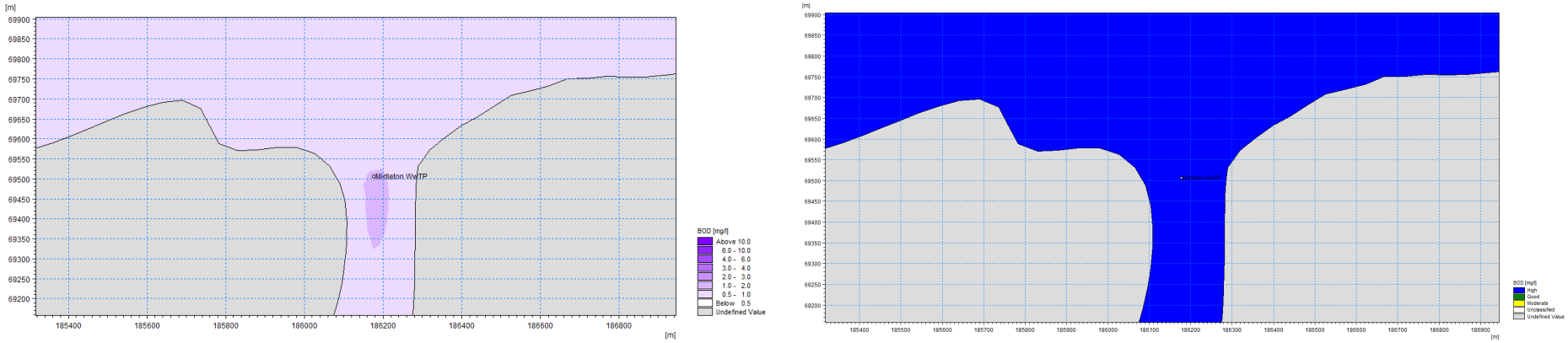


Figure 3-6 Concentration and Indicative Quality Plots for BOD (95th percentile) – Summer, Mixing Zone Carrigtwohill Discharge

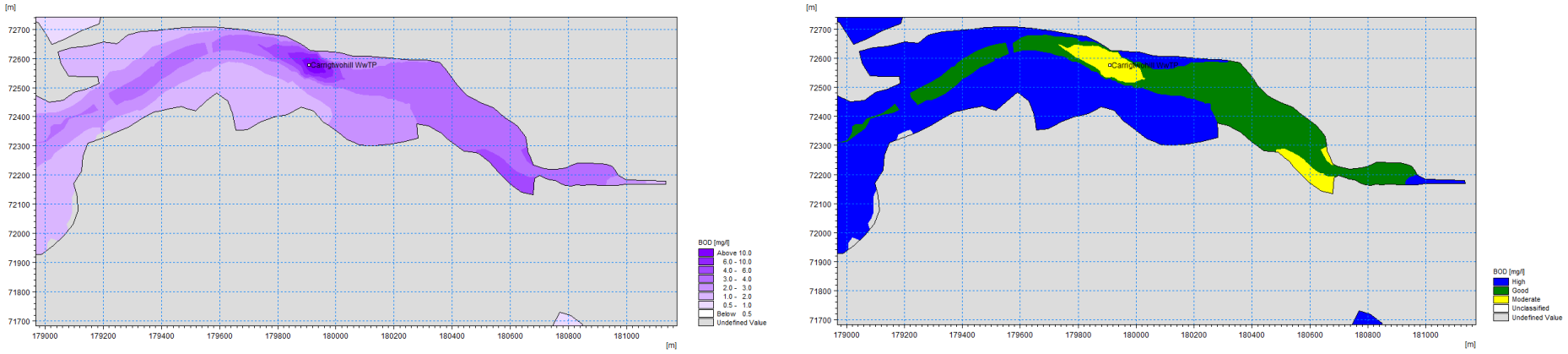


Figure 3-7 Concentration and Indicative Quality Plots for BOD (95th percentile) – Winter, Cork Harbour

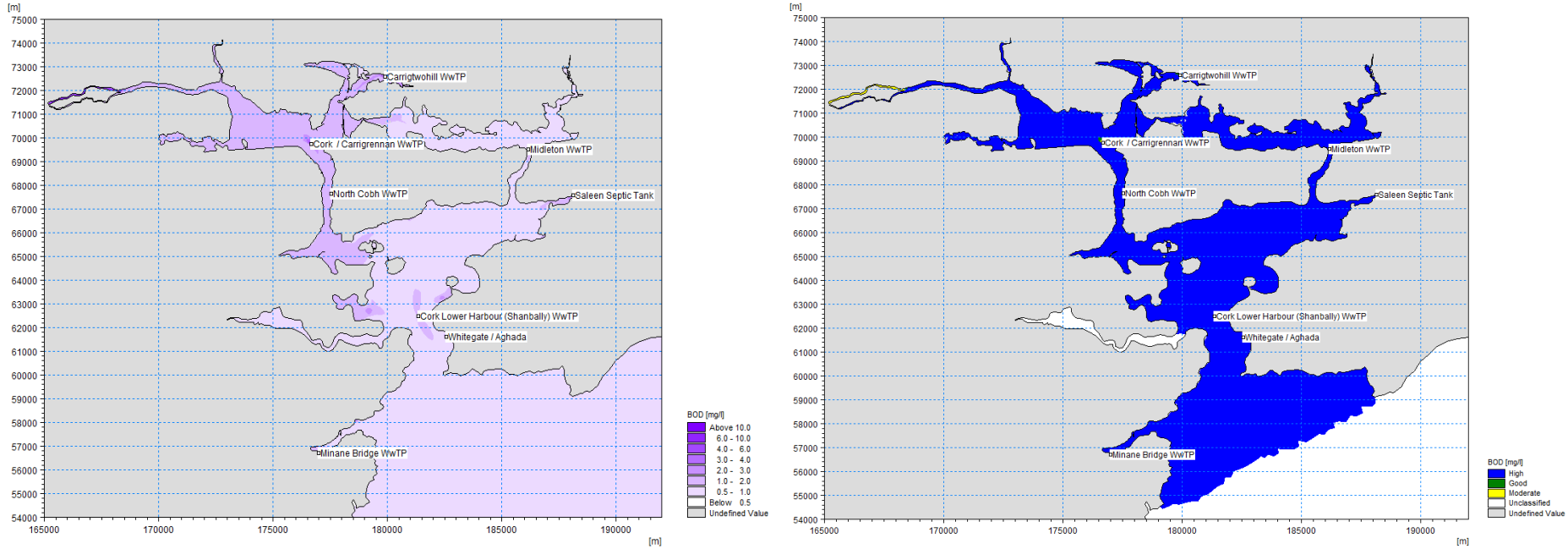
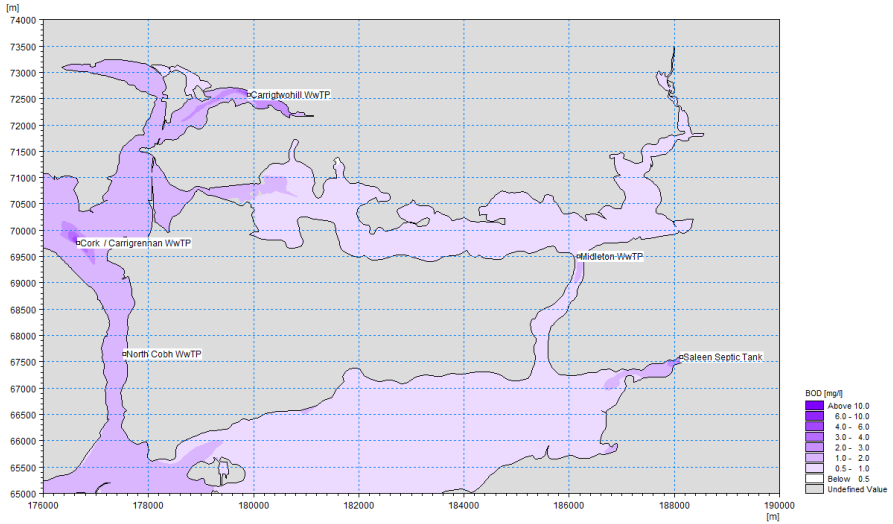
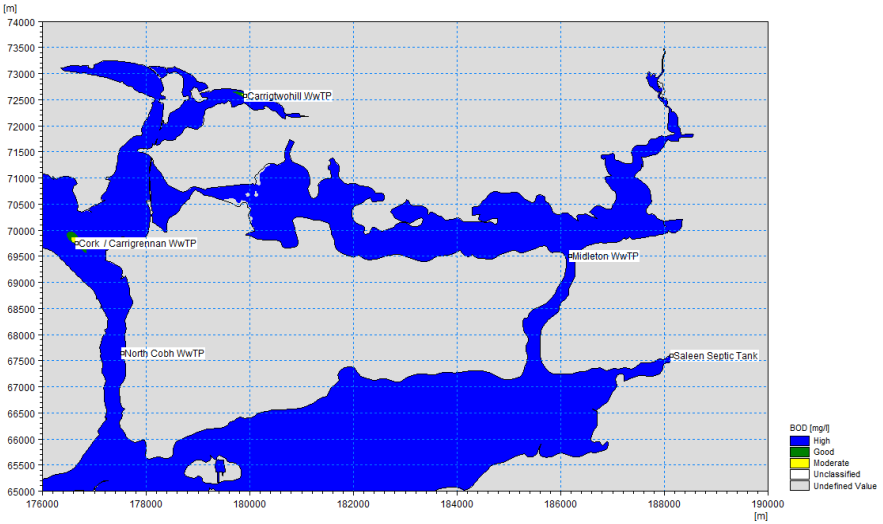


Figure 3-8 Concentration and Indicative Quality Plots for BOD (95th percentile) – Winter, Lough Mahon and North Channel Great Island, and BOD Mass Load Pie Chart





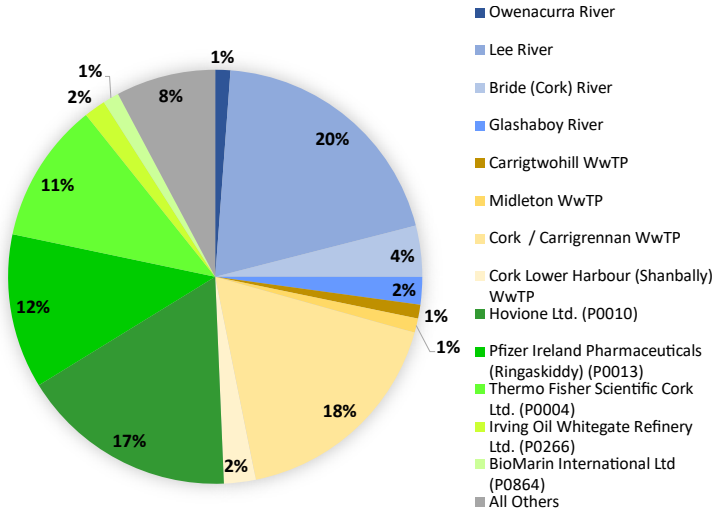


Figure 3-9 Concentration and Indicative Quality Plots for BOD (95th percentile) – Winter, Mixing Zone Midleton Discharge

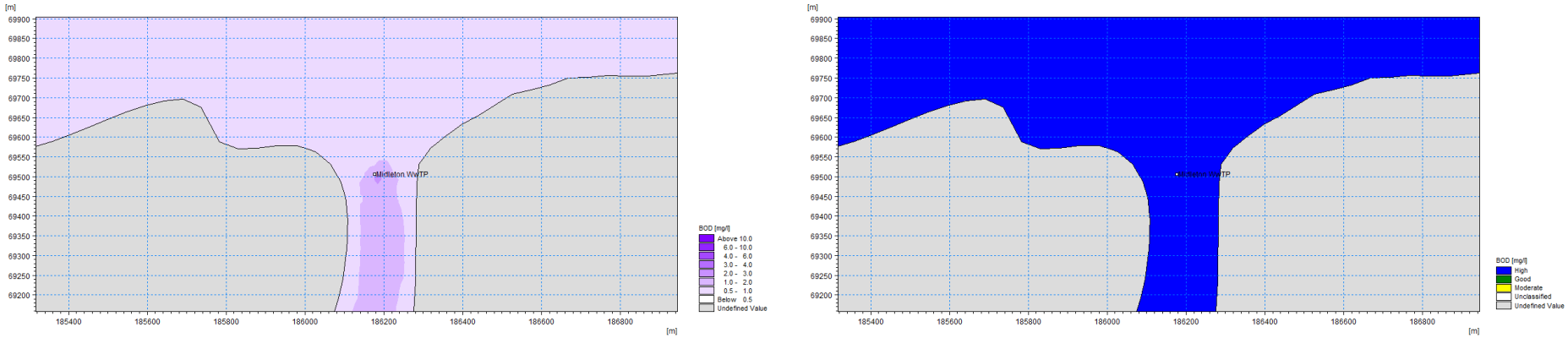
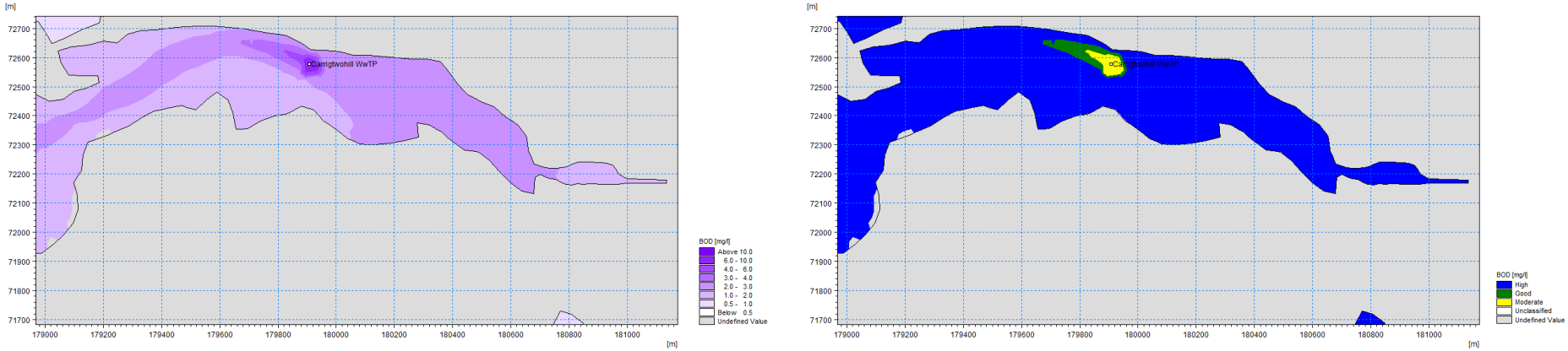


Figure 3-10 Concentration and Indicative Quality Plots for BOD (95th percentile) – Winter, Mixing Zone Carrigtwohill Discharge



3.2.2 Un-Ionised Ammonia

Modelled un-ionised ammonia (NH_3) concentration plots are shown from Figure 3-10 to Figure 3-13 for summer, and from Figure 3-14 to Figure 3-17 for winter. There are no indicative quality plots for un-ionised ammonia as there is currently no EQS for ammonia in transitional and coastal waters. The mixing plume has been estimated based on a guideline concentration of 0.021mg/l adopted for the study (Section 2.1.3).

In summer, un-ionised ammonia concentrations around Cork Harbour are generally <0.005 mg/l (Figure 3-10). An area of slightly elevated concentrations (< 0.01 mg/l) can be seen in the north-west region of Cork Harbour (around the Cork/Carrigrennan WwTP discharge), however these concentrations are below the guideline concentration of 0.021mg/l . Elevated modelled un-ionised ammonia concentrations are also seen around Saleen Septic Tank discharge where it enters the coastal waterbody, reaching concentrations >0.05 mg/l (Figure 3-11).

Concentrations are also elevated around Carrigtwohill WwTP, as shown in Figure 3-13, where concentrations exceed 0.020 mg/l approximately 30m upstream and downstream of the discharge location.

At Midleton WwTP, the un-ionised ammonia concentrations around the discharge are low at <0.005 mg/l (Figure 3-12).

Modelled un-ionised ammonia concentrations in winter show lower overall concentrations than in summer. Small areas of elevated un-ionised ammonia concentrations can be seen in the vicinity of Cork/Carrigrennan WwTP and Saleen Septic Tank, as shown in Figure 3-15, and in the vicinity of Carrigtwohill WwTP, as shown in Figure 3-17. In all these areas peak concentrations are below 0.015 mg/l.

Figure 3-11 Concentration Plot for NH_3 (Mean) – Summer, Cork Harbour

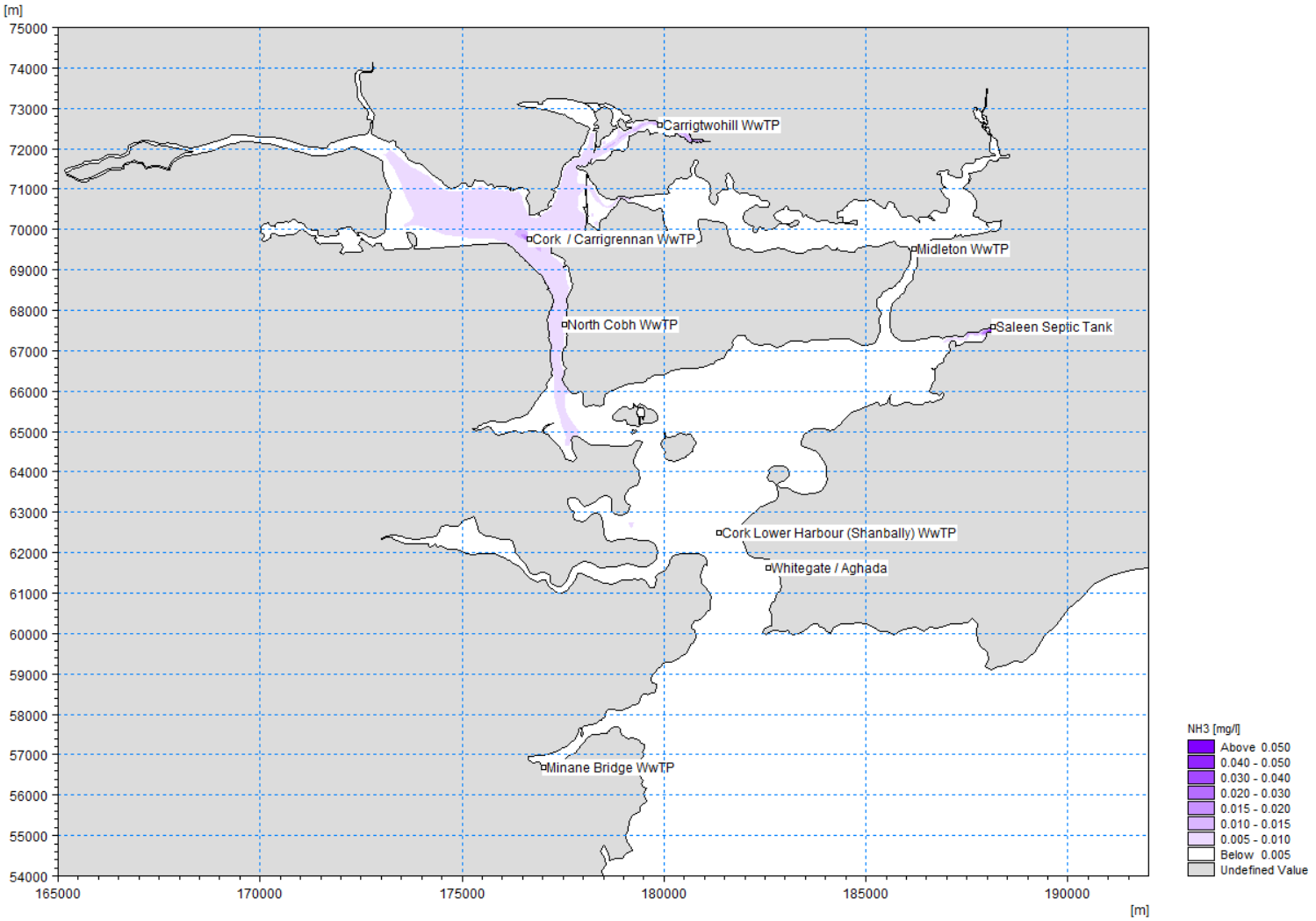


Figure 3-12 Concentration Plot for NH_3 (Mean) – Summer, Lough Mahon and North Channel Great Island

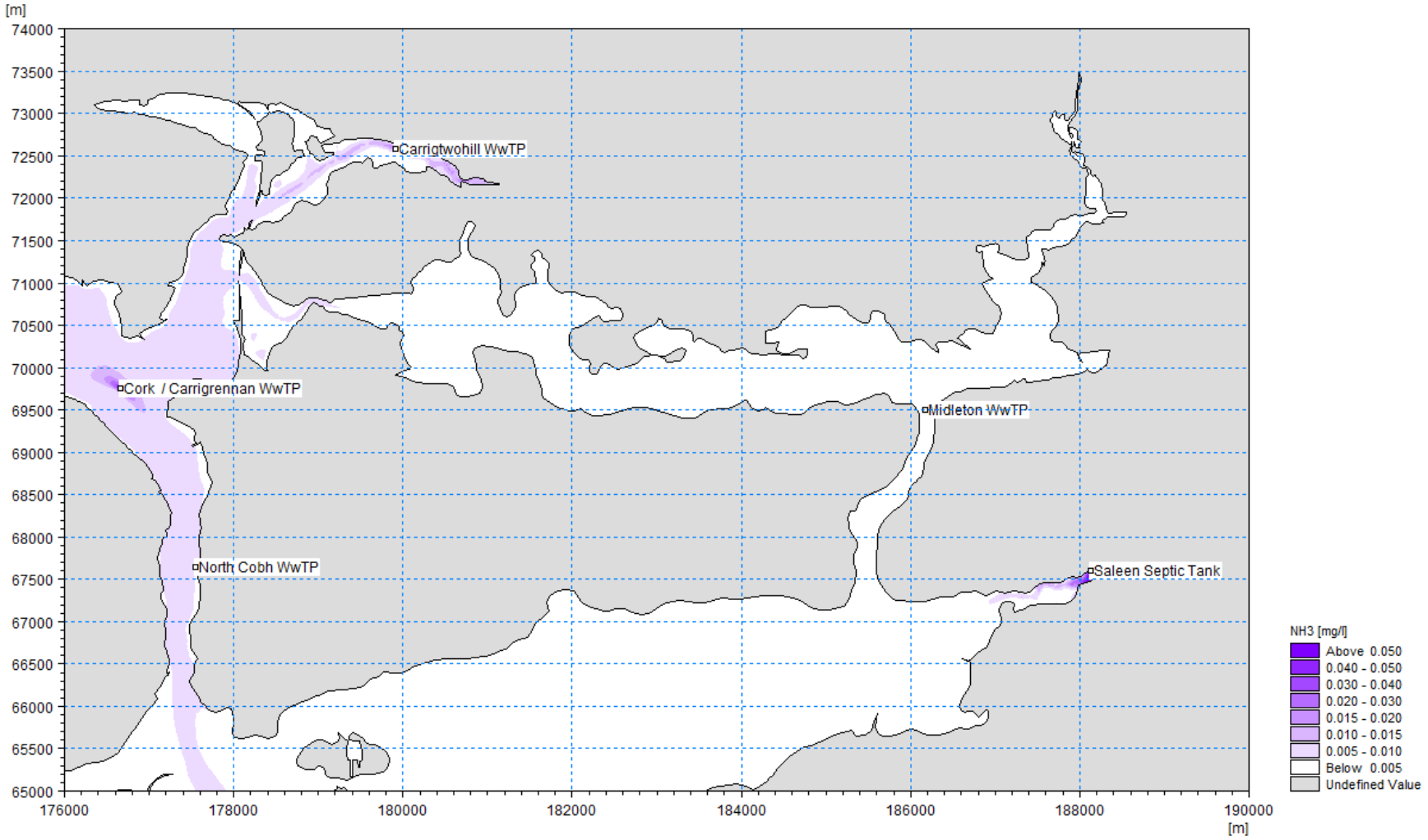


Figure 3-13 Concentration Plot for NH_3 (Mean) – Summer, Mixing Zone Midleton Discharge

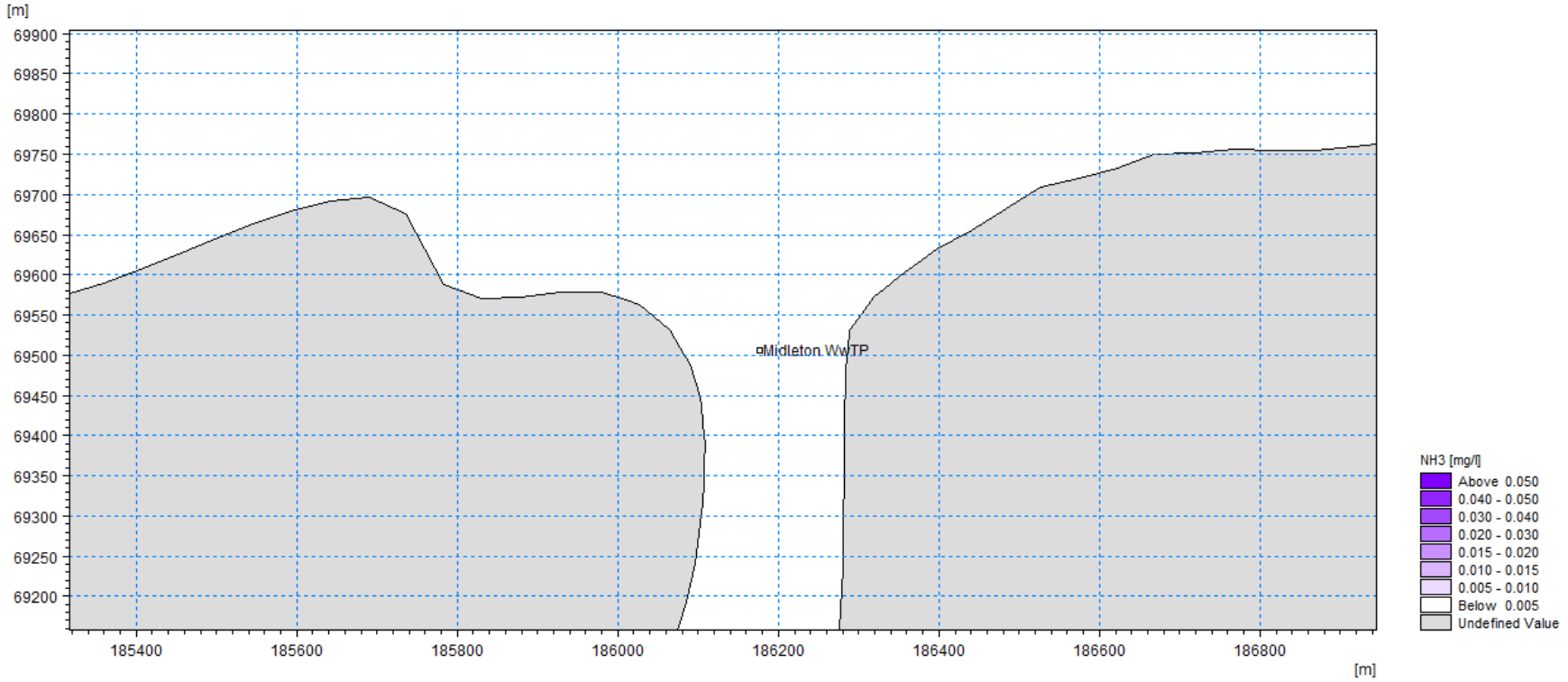


Figure 3-14 Concentration Plot for NH_3 (Mean) – Summer, Mixing Zone Carrigtwohill Discharge

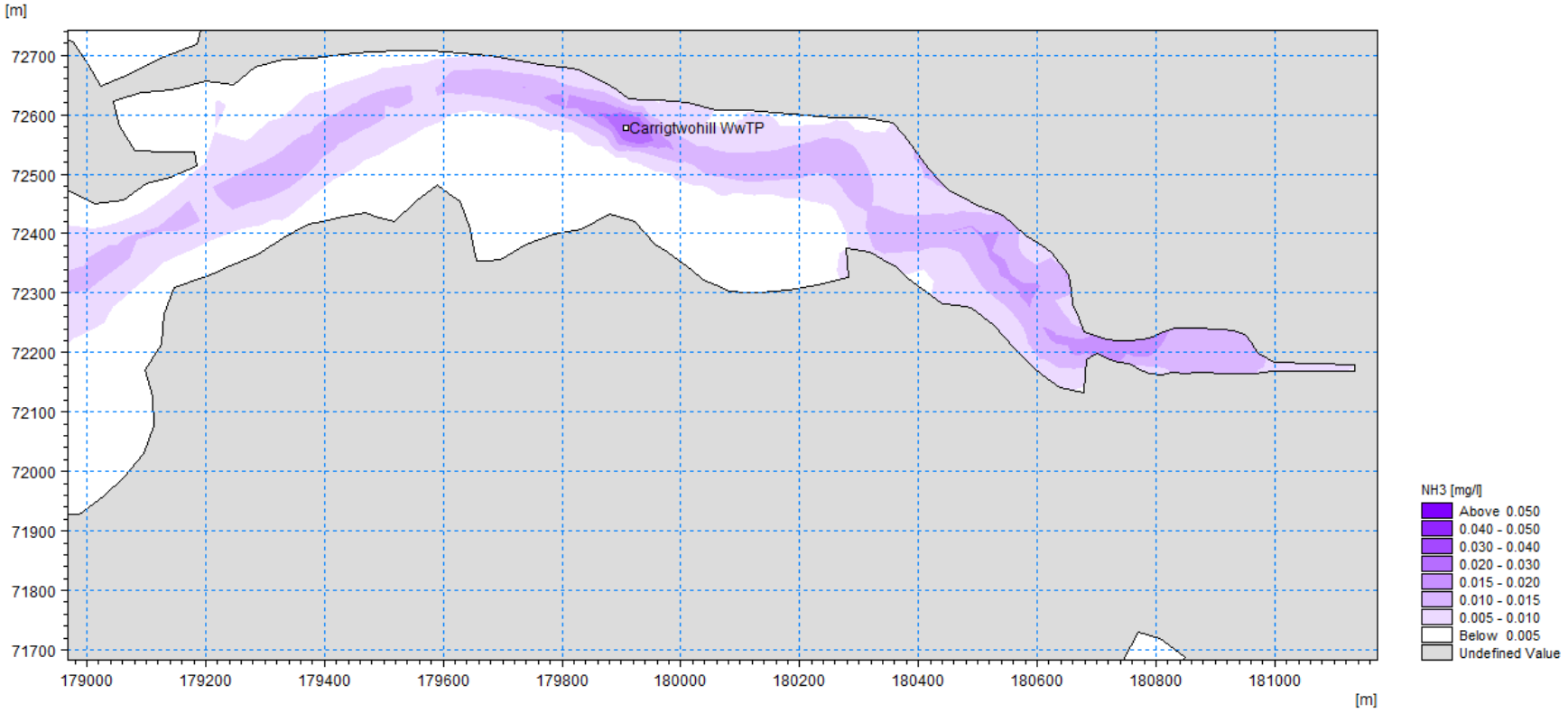


Figure 3-15 Concentration Plot for NH_3 (Mean) – Winter, Cork Harbour

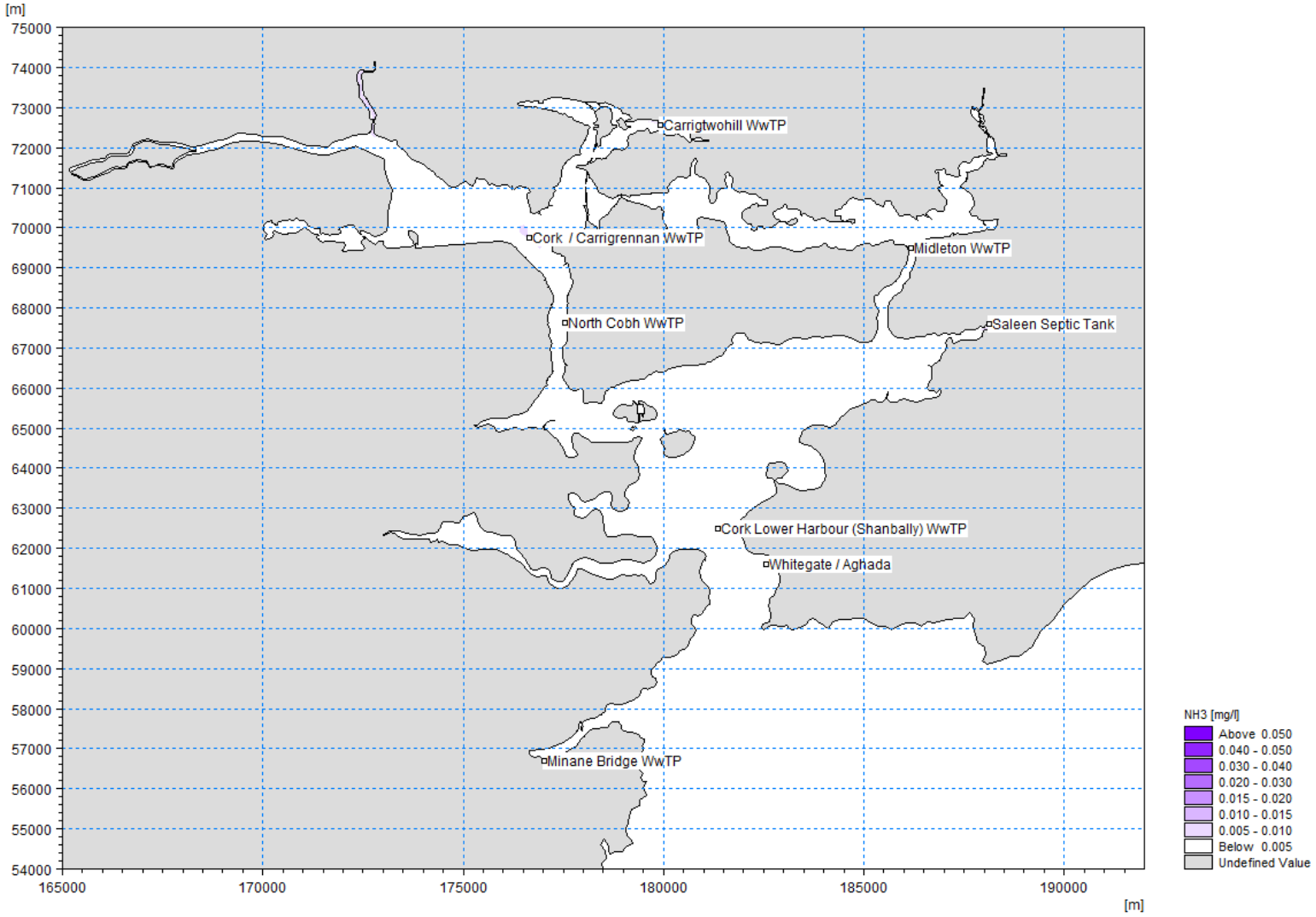


Figure 3-16 Concentration Plot for NH_3 (Mean) – Winter, Lough Mahon and North Channel Great Island

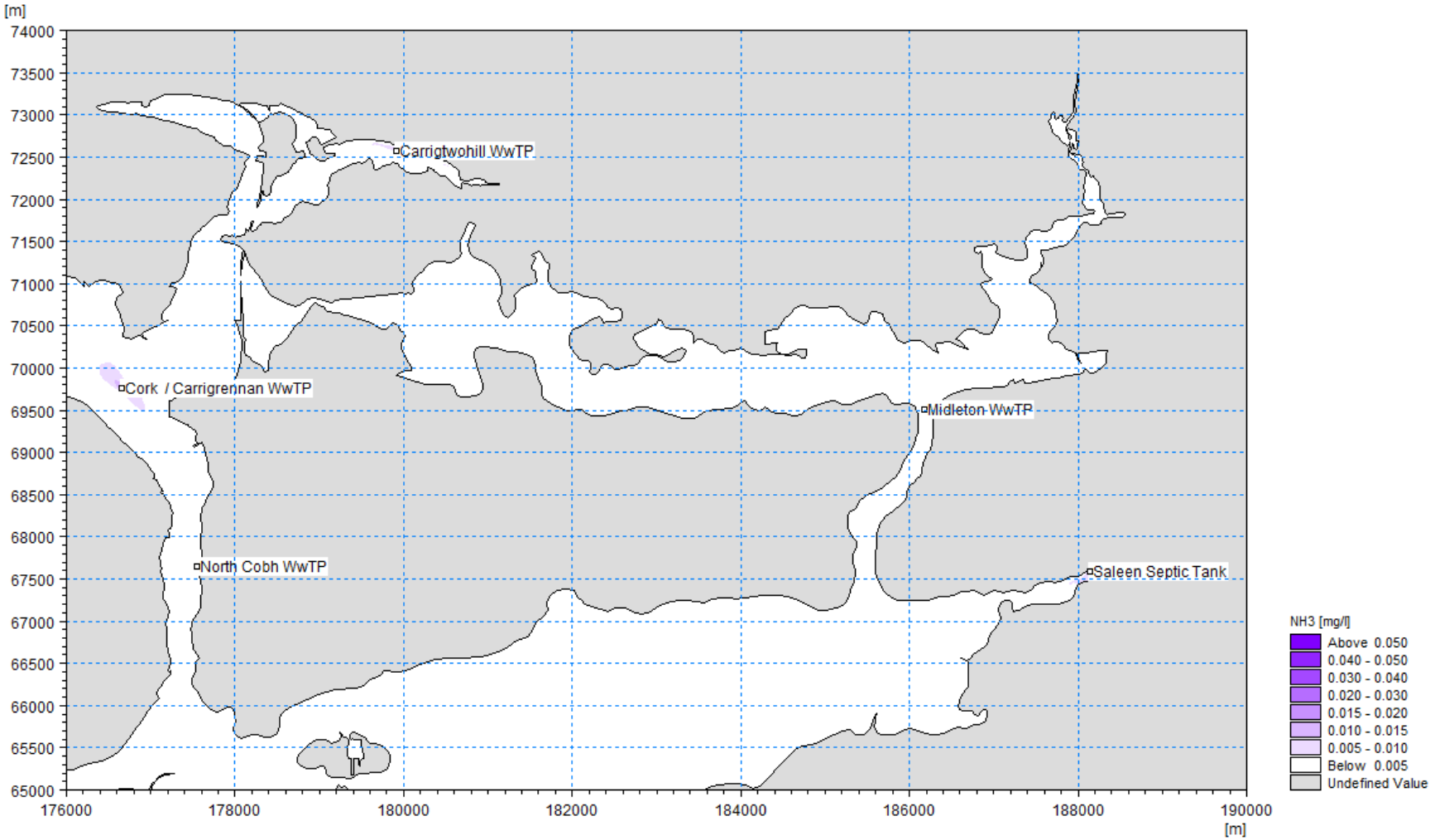


Figure 3-17 Concentration and Indicative Quality Plots for NH_3 (Mean) – Winter, Mixing Zone Midleton Discharge

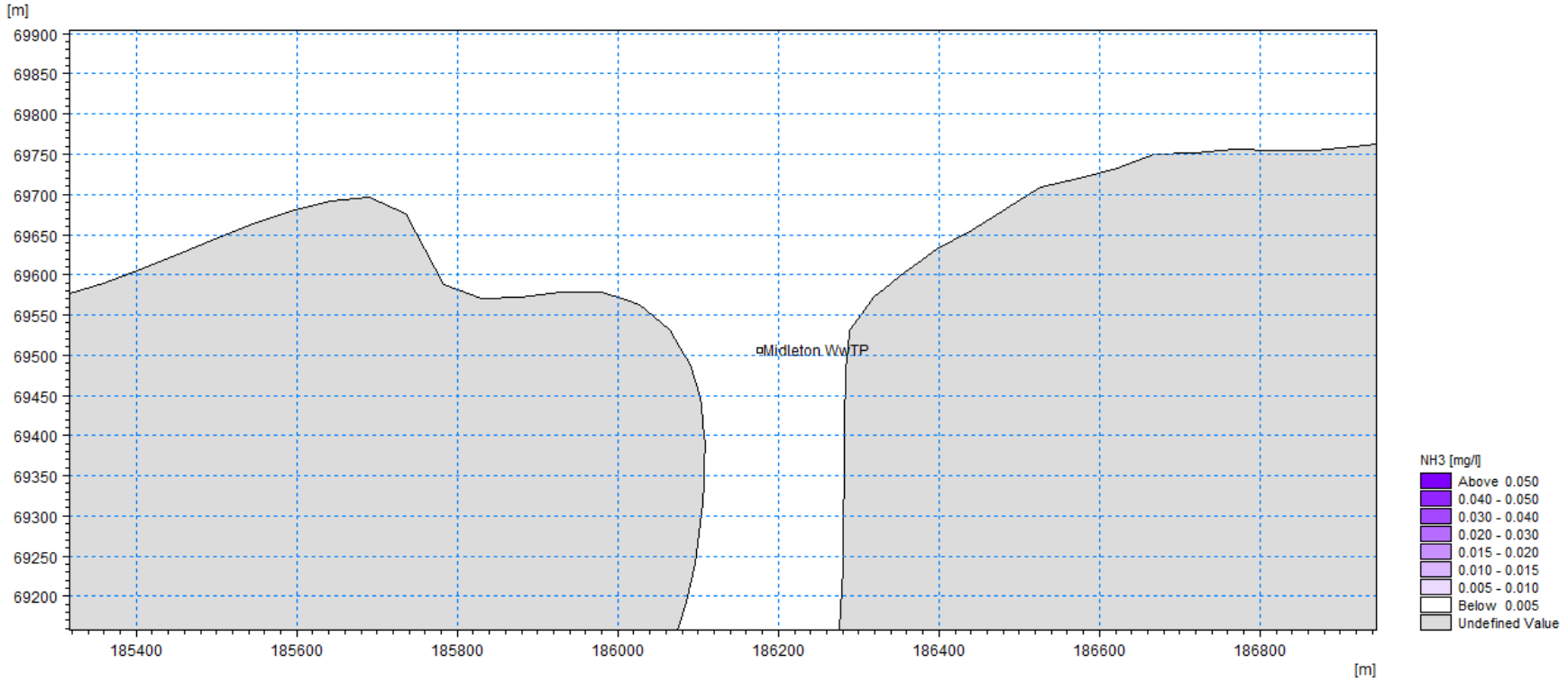
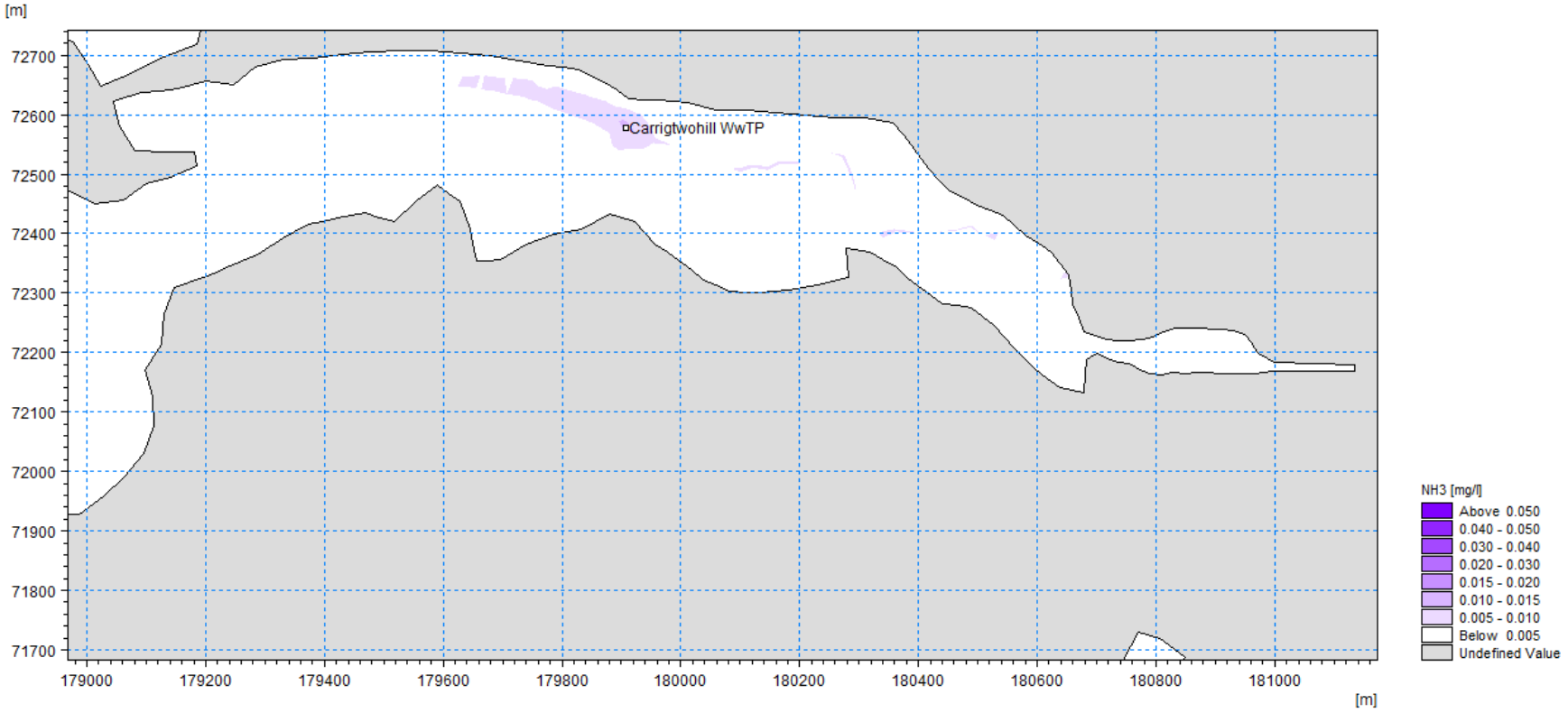


Figure 3-18 Concentration and Indicative Quality Plots for NH_3 (Mean) – Winter, Mixing Zone Carrigtwohill Discharge



3.3 Trophic (Nutrient) Assessment

3.3.1 DIN

3.3.1.1 Future Scenario

Modelled DIN concentration and indicative quality plots for the Future Scenario are shown from Figure 3-18 to Figure 3-21 for summer, and from Figure 3-22 to Figure 3-25 for winter. The WwTP locations are shown in Figure 3-2.

As EQS varies with salinity for DIN, mixing zones are estimated based on the relevant EQS within each water body using median salinity defined in the latest (2022) EPA TSAS assessment. It is noted that there is no DIN EQS for transitional waters, in this case the EQS for coastal waters is used as a proxy to delineate a mixing plume (in this instance referred to as the discharge plume) and provide an indicative water quality in terms of WFD classification.

In summer, DIN concentrations in the Cork Harbour and Outer Cork Harbour coastal WBs are less than 0.5 mg/l indicating High class (Figure 3-18 and Figure 3-19). Good class is indicated where the Cork Harbour Water WB meets the Lough Mahon transitional WB, where concentrations are elevated due to the discharge plume from the Lee Estuary.

Small localised areas of higher concentrations, typically 200m to 400m in length, are also seen in a number of areas where rivers enter Cork Harbour, e.g. Minane, and Rostellan and where the Saleen Septic Tank discharges to the harbour (Figure 3-18). In these areas indicative water quality is Moderate to Good.

In the upper parts of transitional waters of the Lee Estuary, Glashaboy Estuary and Owenacurra Estuary DIN concentrations are typically between 0.5 mg/l and 5.0 mg/l, due to the DIN loads from local rivers, and decrease to 0.5 mg/l in the downstream areas adjacent to the Lough Mahon and North Channel Great Island WBs.

At Midleton WwTP (North Channel Great Island transitional WB), there is no discernible increase in DIN concentrations around the discharge. Modelled concentrations are <0.5 mg/l (Figure 3-20).

In the Lough Mahon (Harper's Island) transitional water DIN concentrations are typically 0.5 mg/l or less (Figure 3-20) except in the area around the Carrigtwohill WwTP discharge (Figure 3-22). Peak concentrations (3.5 mg/l) occur within the Carrigtwohill WwTP discharge plume, over a small area (20m x 20m along the plume axis) and a discharge plume, approximately 100m wide, can be seen along the main tidal channel where concentrations range between 0.5 mg/l and 2.0 mg/l. There is an area of elevated concentration (1.5 mg/l to 3.5 mg/l) in the upper part of the water body where the shallow channel is bounded by the estuary banks and mud flats, which limit dispersion of the discharge plume on the flood tide.

Overall the indicative quality in the transitional WBs is Good, or High (North Channel Great Island WB), except in the estuarine areas where DIN loads from the rivers (Lee Estuary, Owenacurra Estuary, Lough Mahon) and DIN loads from Cork / Carrigrennan WwTP (Lough Mahon) and Carrigtwohill WwTP (Lough Mahon (Harper's Island)) produce an initiative quality of Moderate. However, as noted above DIN does not have an EQS in transitional waters.

In winter predicted DIN concentrations are higher than in summer, in response to increased loads from rivers and WwTP and less uptake by plants and phytoplankton.

The coastal water bodies of Cork Harbour have predicted concentrations of <1.0 mg/l, except in areas close to transitional waters and rivers (Lough Mahon, Saleen) and a small area around the Shanbally WwTP discharge (Figure 3-22). In these areas local inputs increase DIN concentrations to 1.5 mg/l and up to 3.0 mg/l in localised areas of approximately 400m x 400m around Saleen. Predicted indicative quality is Good except in those areas close to inputs where Moderate is predicted (Figure 3-22).

In the transitional waters a similar pattern to summer is seen except concentrations are typically 0.5 mg/l to 1.0 mg/l higher than in summer.

In the upper parts of transitional waters of the Lee Estuary, Glashaboy Estuary and Owenacurra Estuary DIN concentrations are typically between 1.5 mg/l and 5.0 mg/l, due to the DIN loads from local rivers, and decrease to 1.0 mg/l in the downstream areas adjacent to the North Channel Great Island WB and 2.0 mg/l in the Lough Mahon WB (Figure 3-22 and Figure 3-23).

Around the Midleton discharge concentrations are typically <1.0 mg/l and no discernible plume can be seen from the discharge (Figure 3-24).

In the Lough Mahon (Harper's Island) transitional water DIN concentrations are typically 1.5 mg/l to 2.0 mg/l (Figure 3-23) except in the area around the Carrigtwohill WwTP discharge (Figure 3-24). Peak concentrations (5 mg/l) occur within the Carrigtwohill WwTP discharge plume, over a small area (50m x 100m along the plume axis) and a discharge plume, approximately 200m wide, can be seen along the main tidal channel where concentrations range between 2.0 mg/l and 2.5 mg/l. There is an area of high concentration (1.5 mg/l to 5 mg/l) in the upper part of the water body where the shallow channel is bounded by the estuary banks and mud flats, which limit dispersion of the discharge plume on the flood tide.

Overall the indicative quality in the transitional WBs is Moderate, except in the North Channel Great island WB where indicative quality is High or Good. As noted above DIN does not have an EQS in transitional waters.

The pie charts in Figure 3-19 and Figure 3-23 show the proportion of DIN loads from all sources including the WwTPs. In summer, highest proportions of DIN are shown to be from the WwTPs and river inputs, with the highest at Cork/Carrigrennan WwTP and the River Lee. The rivers have a much greater proportion of DIN input in winter, making up nearly 75% of inputs. The highest DIN load is discharged from the River Lee.

Figure 3-19 Future Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Summer, Cork Harbour

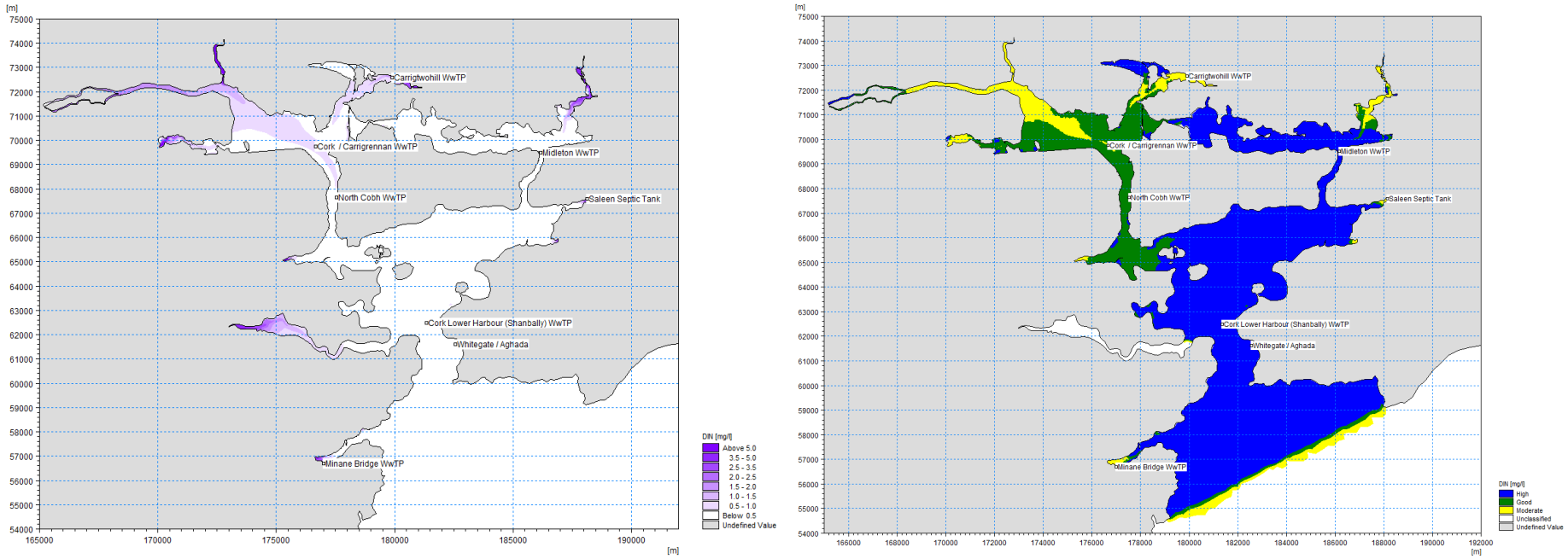
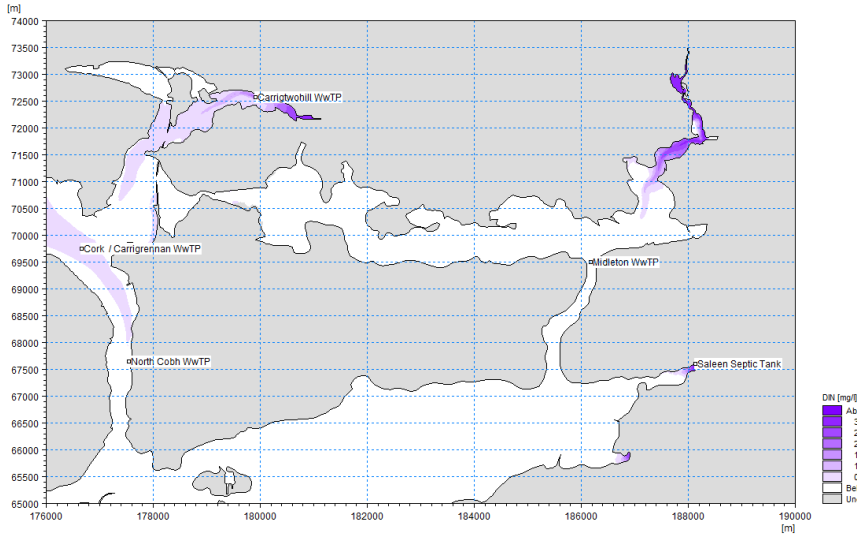
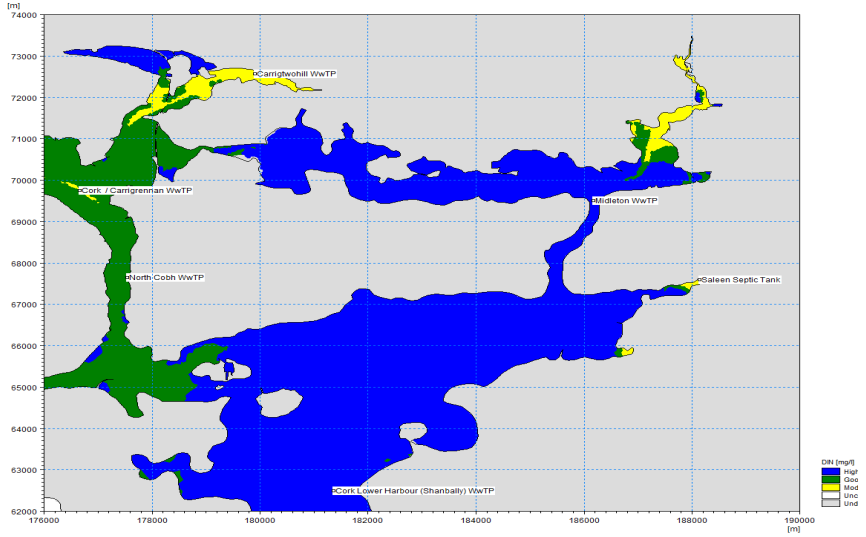


Figure 3-20 Future Maximum ELV: Concentration and Indicative Quality Plots for DIN (Median) – Summer, Lough Mahon and North Channel Great Island, and DIN Mass Load Pie Chart





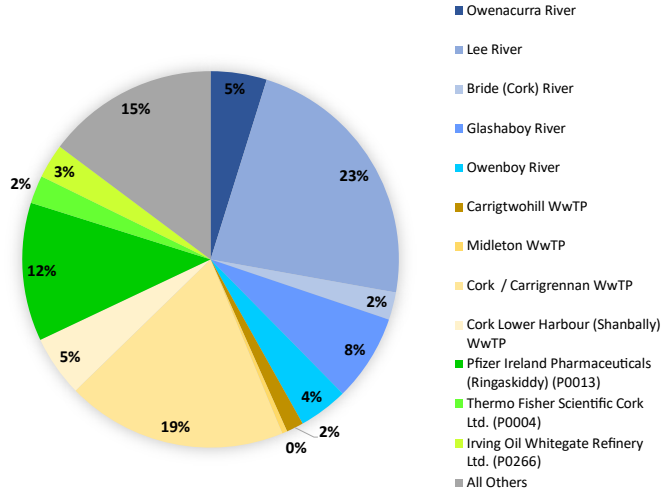


Figure 3-21 Future Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Summer, Midleton Discharge Plume

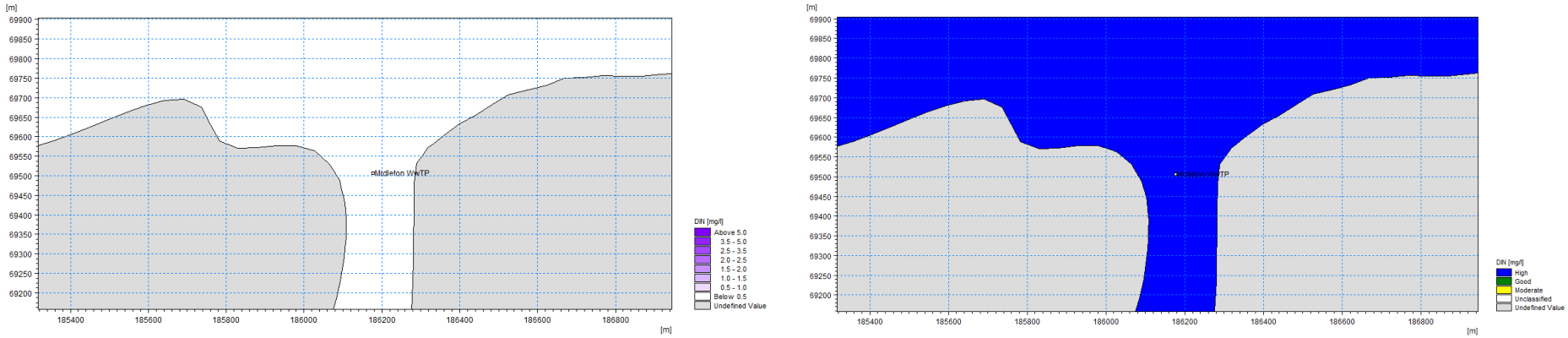


Figure 3-22 Future Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Summer, Carrigtwohill Discharge Plume

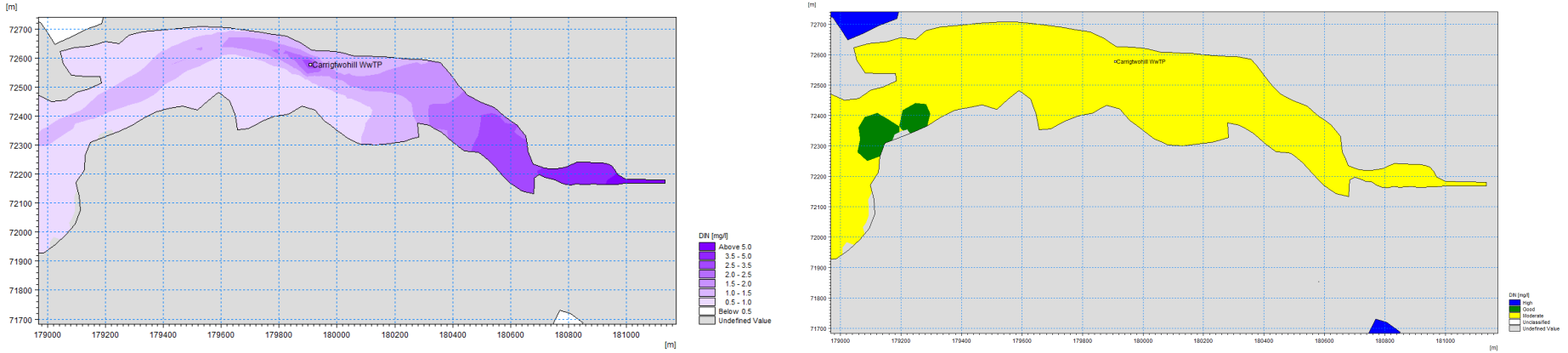


Figure 3-23 Future Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Winter, Cork Harbour

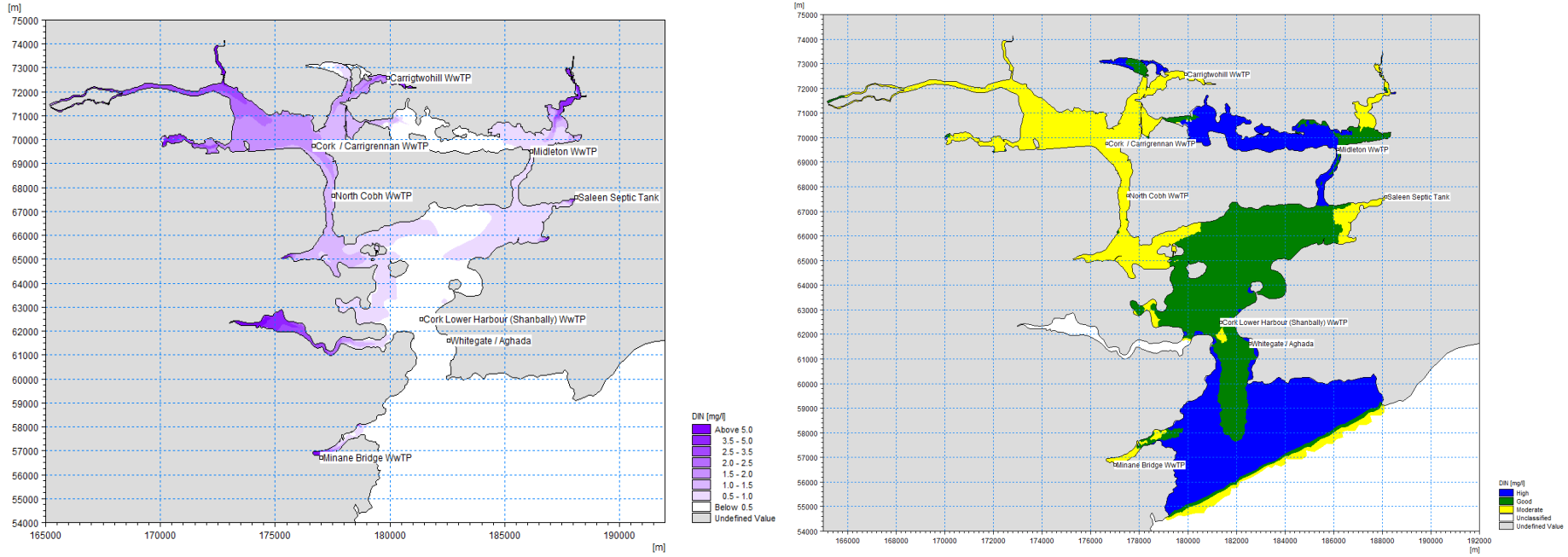
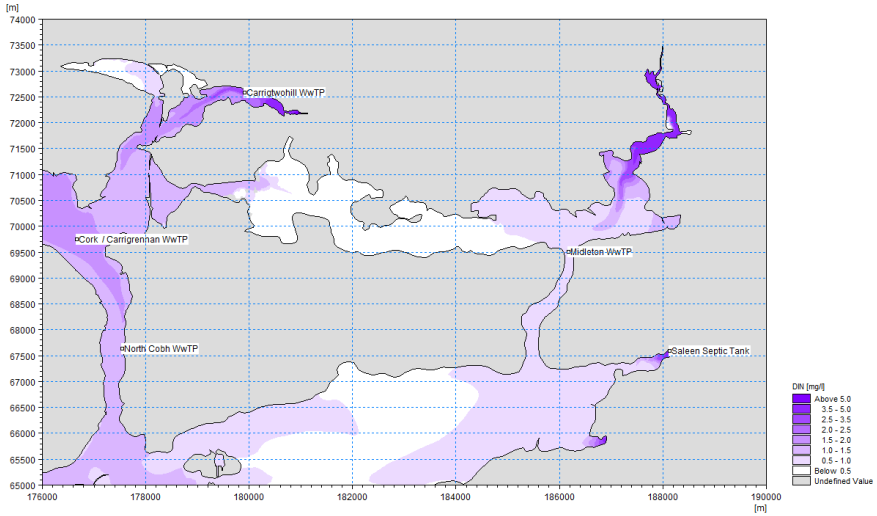
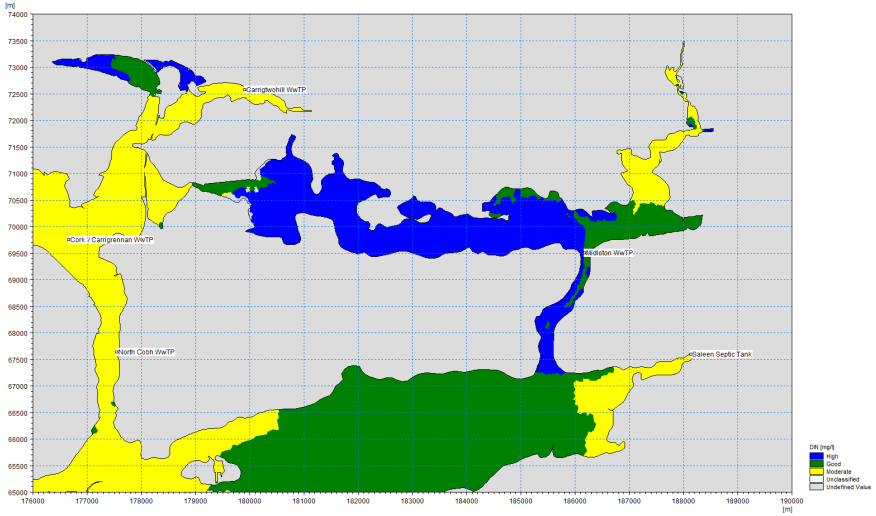


Figure 3-24 Future Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Winter, Lough Mahon and North Channel Great Island, and DIN Mass Load Pie Chart





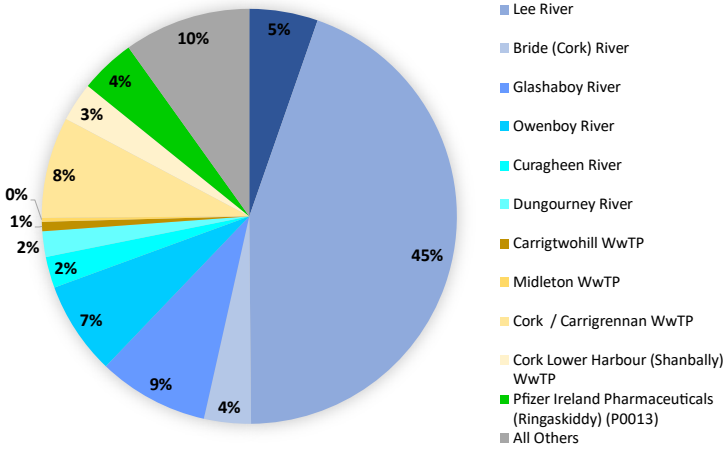


Figure 3-25 Future Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Winter, Midleton Discharge Plume

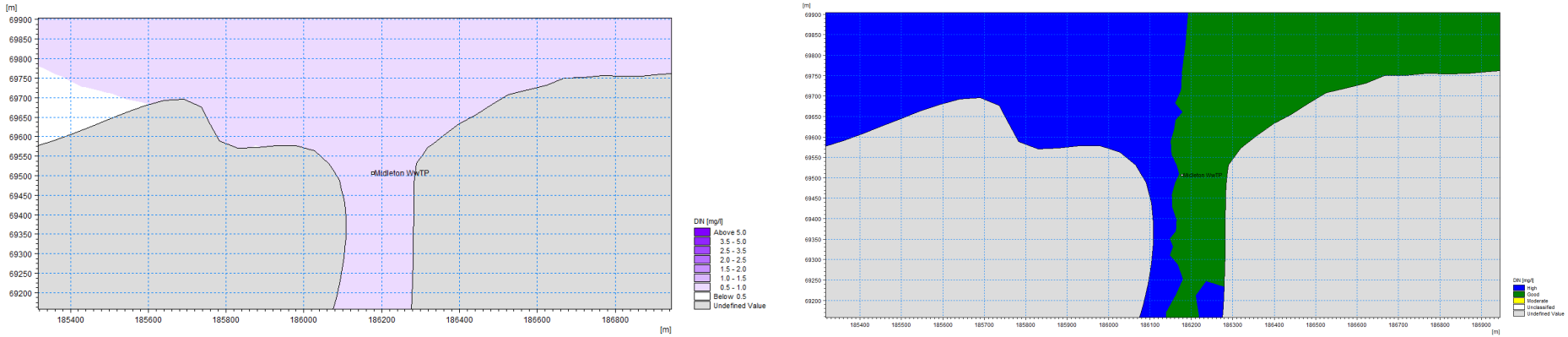
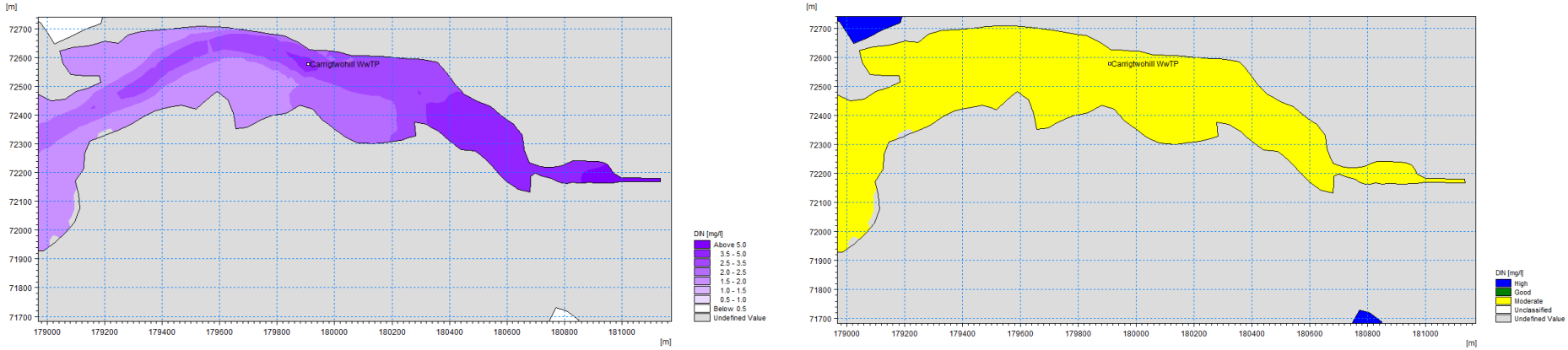


Figure 3-26 Future Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Winter, Carrigtwohill Discharge Plume



3.3.1.2 Future 'Notionally Clean' River Scenario

Modelled DIN concentration and indicative quality plots for the 'Notionally Clean' River scenario are shown from Figure 3-26 to Figure 3-29 for summer, and from Figure 3-30 to Figure 3-33 for winter. The WwTP locations are shown in Figure 3-2.

In summer, DIN concentrations around Cork Harbour are generally <0.5 mg/l (Figure 3-26), with most having an indicative quality of High, except a small area (100m x 100m) close to the Saleen Septic Tank and Minane Bridge Saleen discharges where indicative quality is Good.

In the transitional waters concentrations of DIN are generally <0.5 mg/l, and indicative quality is High (Figure 3-26 and Figure 3-27), except as noted below.

At Midleton WwTP, modelled concentrations are <0.5 mg/l and with no discernible discharge plume (Figure 3-28).

Around the discharge from the Carrigtwohill WwTP in the Laugh Mahon (Harper's Island) WB (Figure 3-29) there is a discharge plume (where concentrations are between 1.0 mg/l and 1.5 mg/l) that extends along the tidal channel (width 50m, length 250m) downstream of the discharge. An area (600m x 200m) of elevated concentrations (1.0 mg/l and 1.5 mg/l) is also seen at the top of the WB. In these areas of the Lough Mahon (Harper's Island) WB, the predicted indicative quality is Moderate, while in the remainder of the WB indicative quality is Good or High.

In winter a similar pattern to summer is predicted. In the coastal WBs of Cork Harbour concentrations of DIN are <0.5 mg/l with indicative quality High (Figure 3-30). In transitional waters concentrations are <0.5 mg/l (indicative quality of High) (Figure 3-30, Figure 3-31 and Figure 3-32). At Midleton WwTP, modelled concentrations are <0.5 mg/l with no discernible discharge plume (indicative quality of High) (Figure 3-32 and Figure 3-32). In the Lough Mahon (Harper's Island) in vicinity of the Carrigtwohill WwTP discharge (Figure 3-33) a similar pattern is seen to the summer with elevated DIN concentrations (1.0 mg/l and 1.5 mg/l) in the discharge plume and at the upper reach of the WB, where indicative quality is Moderate, elsewhere in the water body indicative quality is Good or High (Figure 3-32).

Figure 3-27 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Summer, Cork Harbour

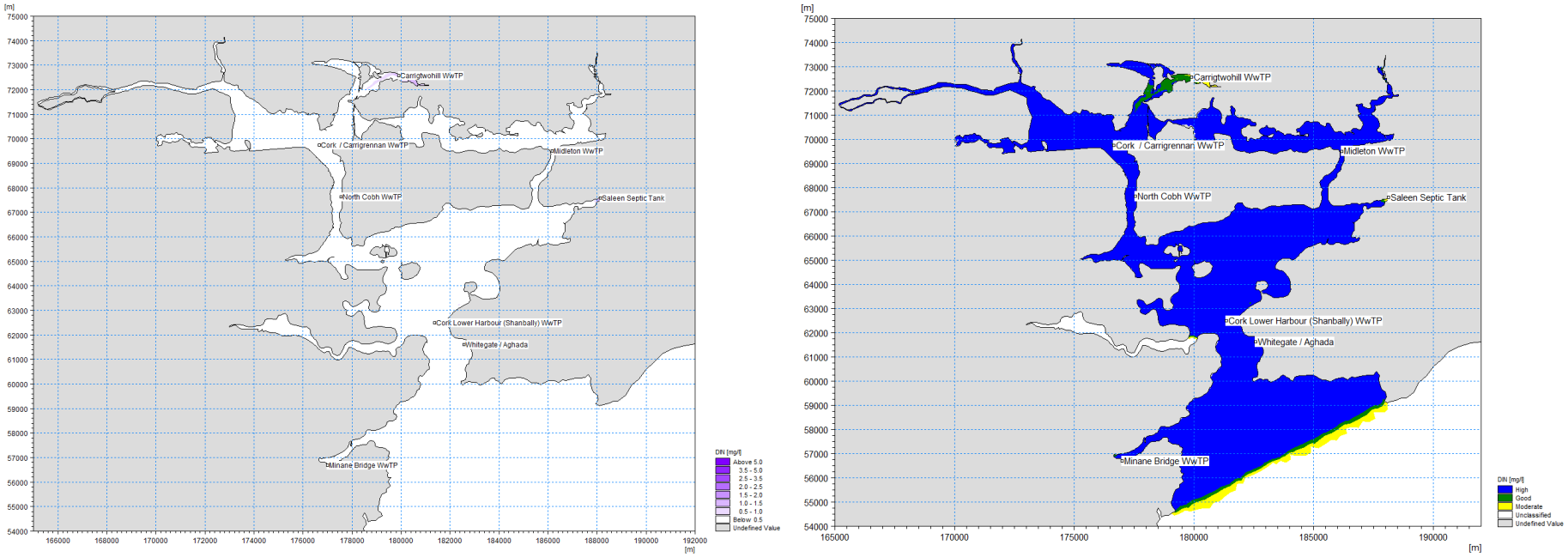


Figure 3-28 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Summer, Lough Mahon and North Channel Great Island

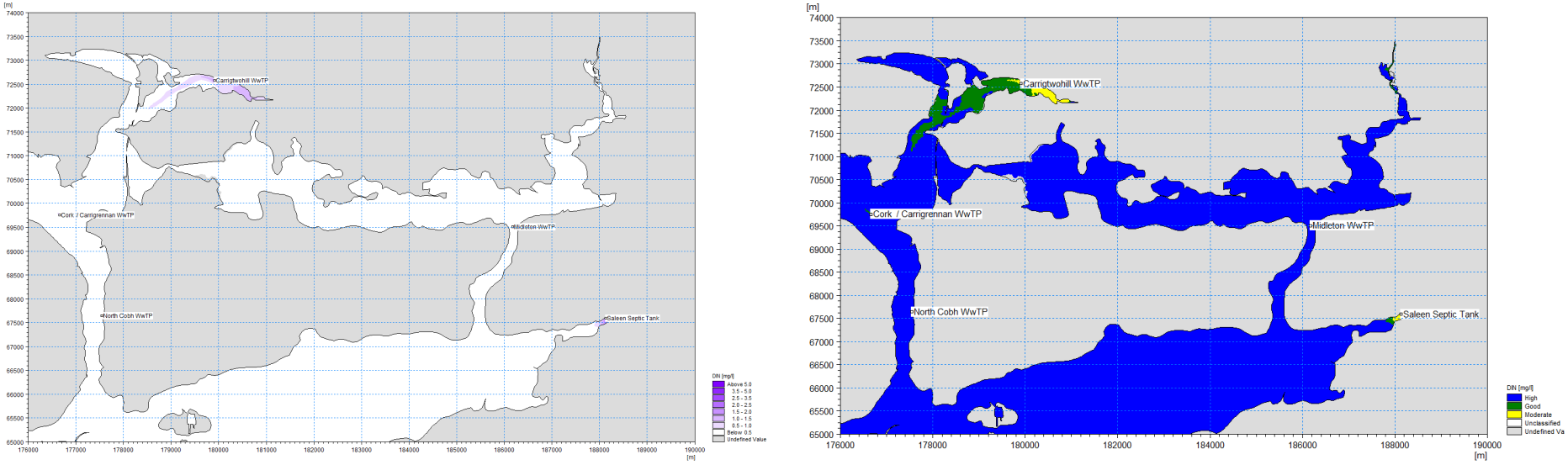


Figure 3-29 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Summer, Midleton Discharge Plume

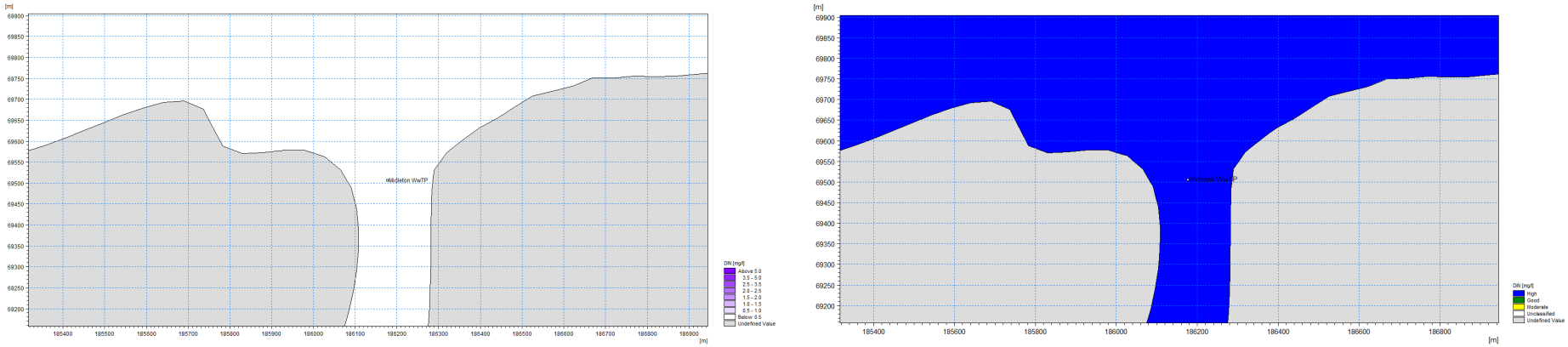


Figure 3-30 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Summer, Carrigtwohill Discharge Plume

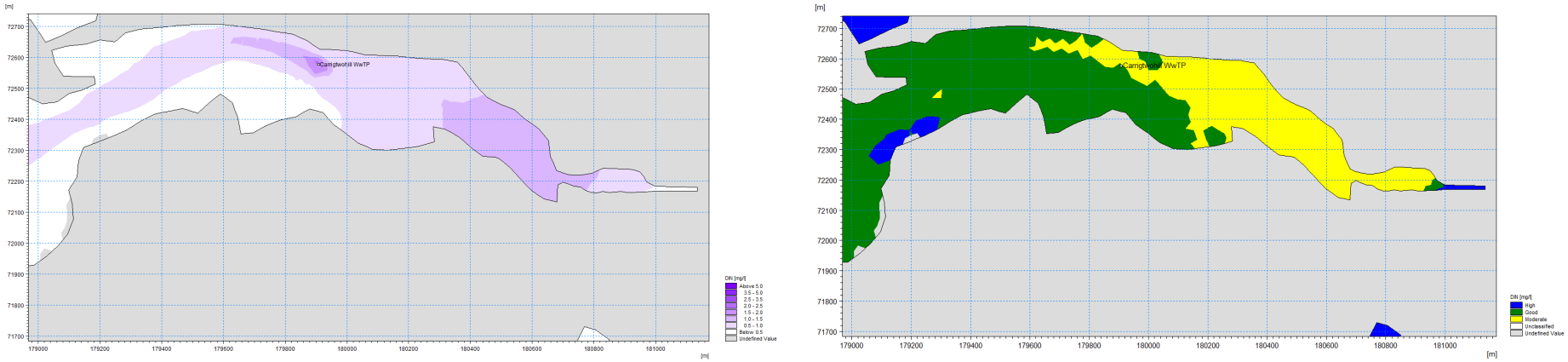
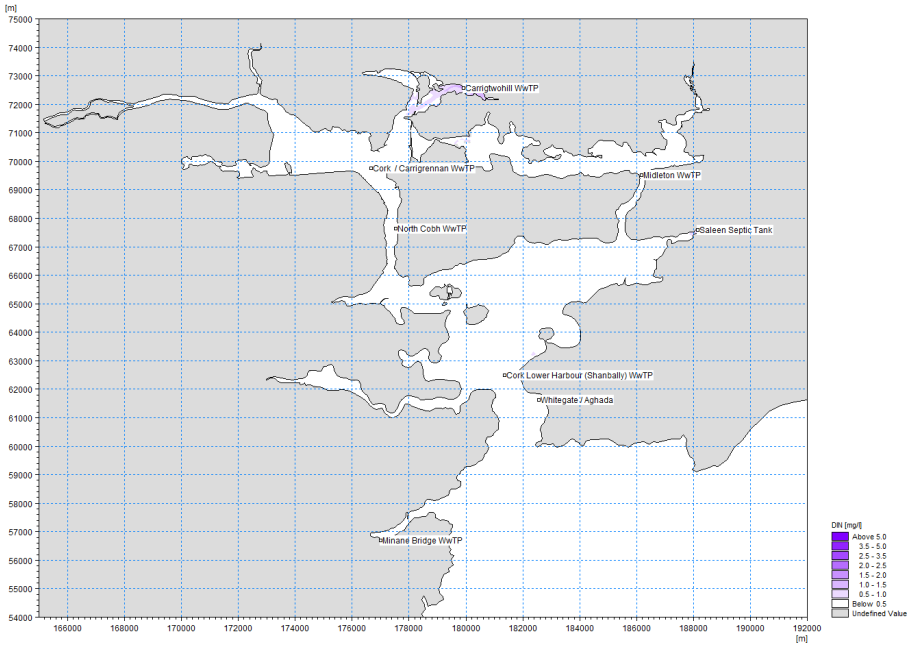


Figure 3-31 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Winter, Cork Harbour



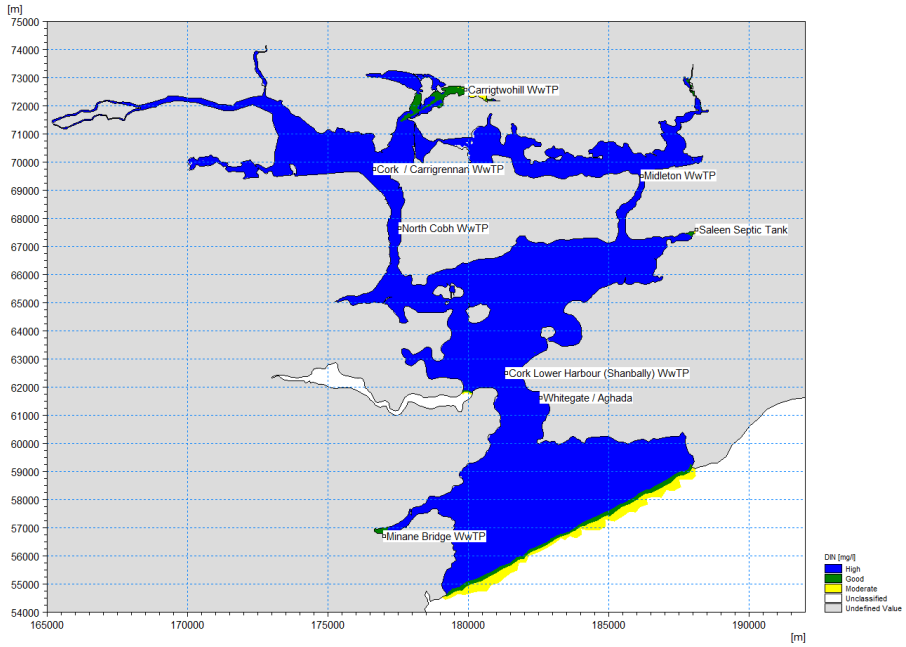
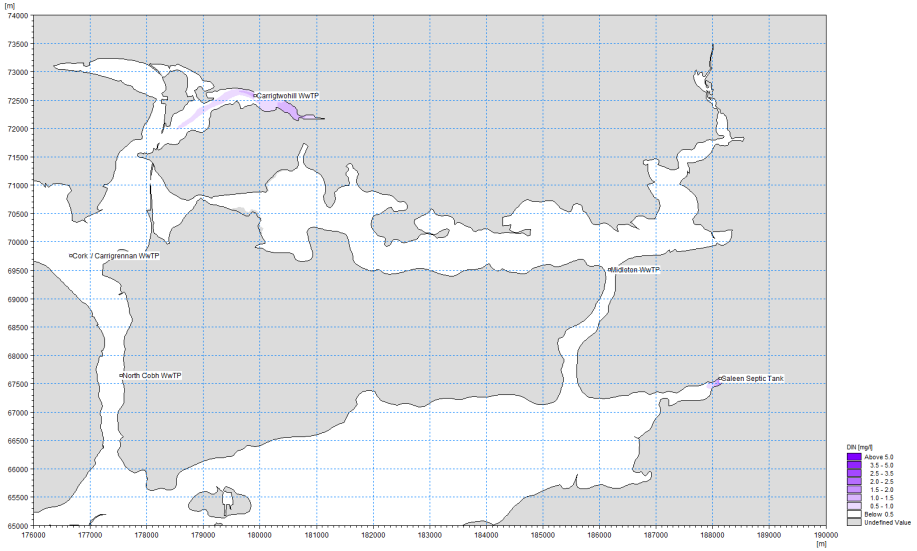


Figure 3-32 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Winter, Lough Mahon and North Channel Great Island



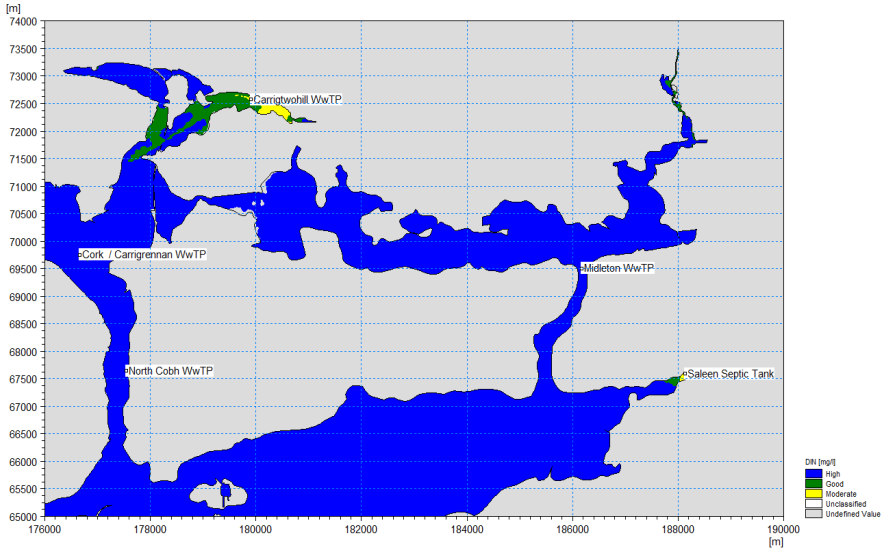


Figure 3-33 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Winter, Midleton Discharge Plume

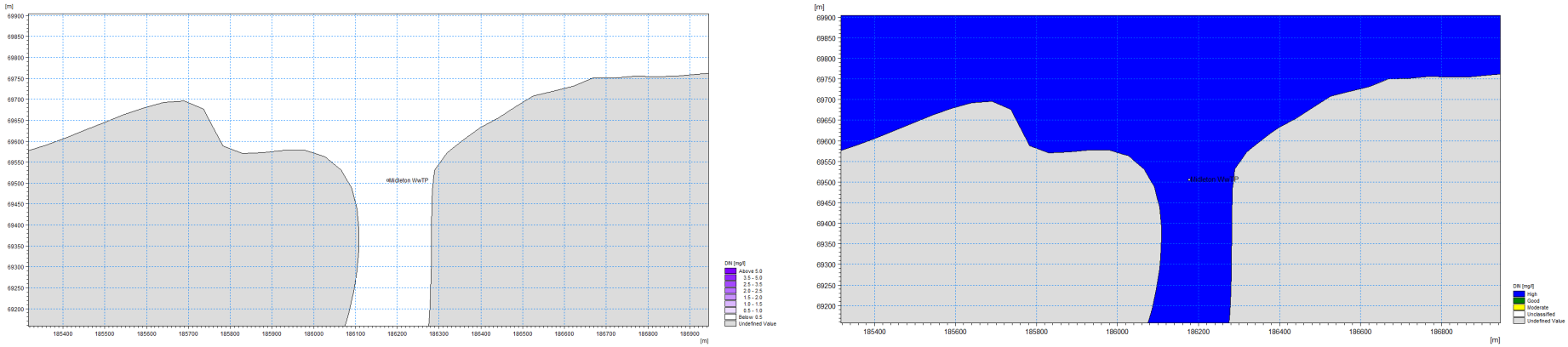
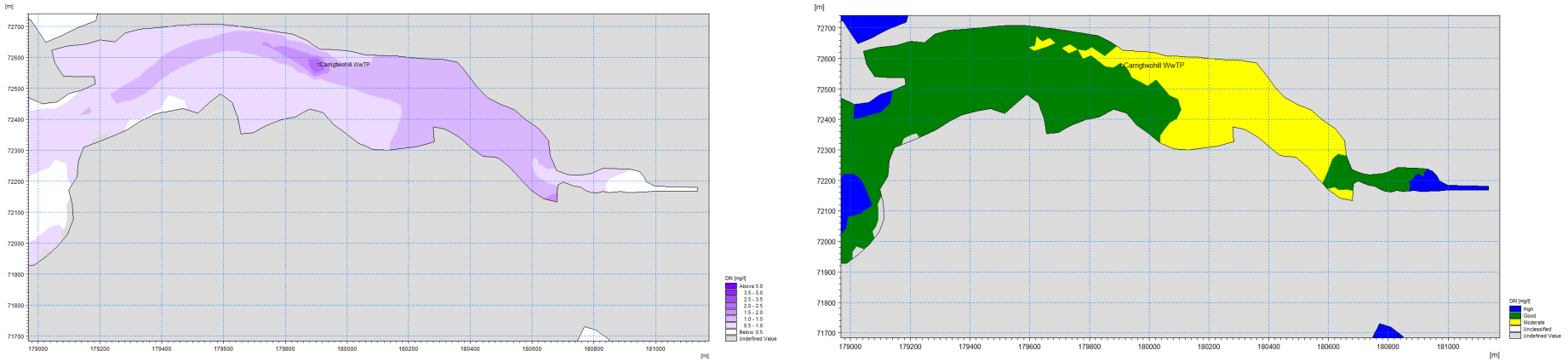


Figure 3-34 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for DIN (Median) – Winter, Carrigtwohill Discharge Plume



3.3.2 MRP

3.3.2.1 Future Scenario

Modelled MRP concentration and indicative quality plots are shown for the Future Scenario for the MRP WFD standard. Results are presented for transitional waters, where the WFD EQS is applicable, and also in coastal waters for reference.

Figure 3-34 to Figure 3-37 for summer, and from Figure 3-38 to Figure 3-41 for winter. The WwTP locations are shown in Figure 3-2.

In summer, predicted MRP concentrations around Cork Harbour are generally <0.02 mg/l, with slightly lower concentrations (<0.01 mg/l) in the outer regions of Cork Harbour. The coastal waters of Cork Harbour and Outer Cork Harbour have a predicted indicative quality of High (Figure 3-34), except for a small area of indicative Good around the Hovione discharge in Lough Beg on the western side of Cork Harbour and an area (Good / Moderate) in the shallow tidal waters around the Saleen Septic Tank discharge: noting the EQS is not applicable in these coastal waters.

The transitional waters of the North Channel Great Island have a predicted indicative quality of High (Figure 3-35).

MRP concentrations are elevated in the north-west of Cork Harbour, e.g. Lough Mahon WB and the Upper Lee Estuary (Figure 3-34 and Figure 3-35). Highest concentrations are seen in the Lough Mahon (Harper's Island) WB. These elevated MRP concentrations are in response to the relatively large river and WwTP loads that discharge into narrow, shallow channels, particularly in the Harper's Island area. While concentrations are elevated in these areas the indicative quality is Good over the majority of the WBs (Figure 3-34 and Figure 3-35).

At Midleton WwTP, there is a small patch of slightly elevated MRP concentration around the discharge point, but this remains below the EQS threshold indicating mixing is achieved within one model cell (<25m) of the discharge point. The indicative quality in this area is High (Figure 3-36).

Highest summer MRP concentrations are found in the Upper Lee Estuary, Glashaboy Estuary and around Carrigtwohill WwTP. Carrigtwohill WwTW discharge lies within the relatively small Harper's Island (Lough Mahon) WB, a largely intertidal area with shallow tidal channels. The Carrigtwohill outfall discharges to a shallow tidal channel close to the upstream limit of the tidal area. The shallow bathymetry gives rise to a relatively large mixing zone (concentrations above 0.05 mg/l) around the outfall (Figure 3-37). On the ebb tide the mixing zone follows the main channel, extending approximately 700m downstream of the discharge (width approximately 100m wide at the discharge point), towards Lough Mahon. On the flood tide the area available for plume dispersion is significantly constrained, by the estuary banks and intertidal area, to a relatively small area upstream of the discharge location (maximum 0.25km^2 at HW). The mixing zone extends over much of the upper estuary occupying an area of approximately 1000m long and 200m wide (0.2 km^2) where the indicative quality is Moderate.

In the coastal waterbodies elevated concentrations are predicted around the eastern and western margins of Cork Harbour and in the northern area where Inner Cork Harbour WB meets the Lough Mahon transitional WB (Figure 3-38). However, these areas all meet the Good class threshold, as applied to transitional waters, except in a small area around the Saleen Septic tank as noted for summer.

Highest MRP concentrations are seen in the Upper Lee Estuary WB and Glashaboy Estuary WB where concentrations are sufficiently high to give an indicative quality of Moderate (Figure 3-38). Elevated concentrations, compared to summer, are also seen in the Owenacurra transitional WB where the indicative quality is reduced from predominantly High in summer to Good in winter (Figure 3-39). Elevated concentrations are also predicted in the transitional waters of Lough Mahon, near the confluence of the Tramore River in the Lough Mahon WB (Figure 3-38) and in the Harper's Island (Lough Mahon) transitional WB around Carrigtwohill WwTP (Figure 3-39). In these areas the indicative water quality is predicted as Moderate, compared to Good over the rest of the WB.

An area of elevated concentration associated with WwTP discharge plume is seen at Midleton (Figure 3-40. This area is larger than in summer, but maximum concentrations are low (<0.04 mg/l) and are below the EQS Good threshold.

At Carrigtwohill WwTP discharge (Figure 3-41) MRP concentrations are approximately 0.01 mg/l higher than in summer, giving rise to a larger mixing zone. In winter the mixing zone extends across the whole WB area upstream of the discharge point on the ebb tide. On the flood tide the mixing zone (MRP >0.05 mg/l) extends over the width of the channel for approximately 300m west of the discharge after which it is confined to a narrower (50m) width along the axis of the main channel for a further 400m downstream.

The pie charts in Figure 3-35 and Figure 3-39 show the proportion of MRP loads from all sources including the WwTPs. In summer and winter, highest proportions of MRP are shown to be from the industrial discharges and WwTPs, with the highest from Hovione Ltd., Cork/Carrigrennan WwTP and Cork Lower Harbour (Shanbally) WwTP. The proportion of riverine input increases in winter.

Figure 3-35 Future Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Summer, Cork Harbour

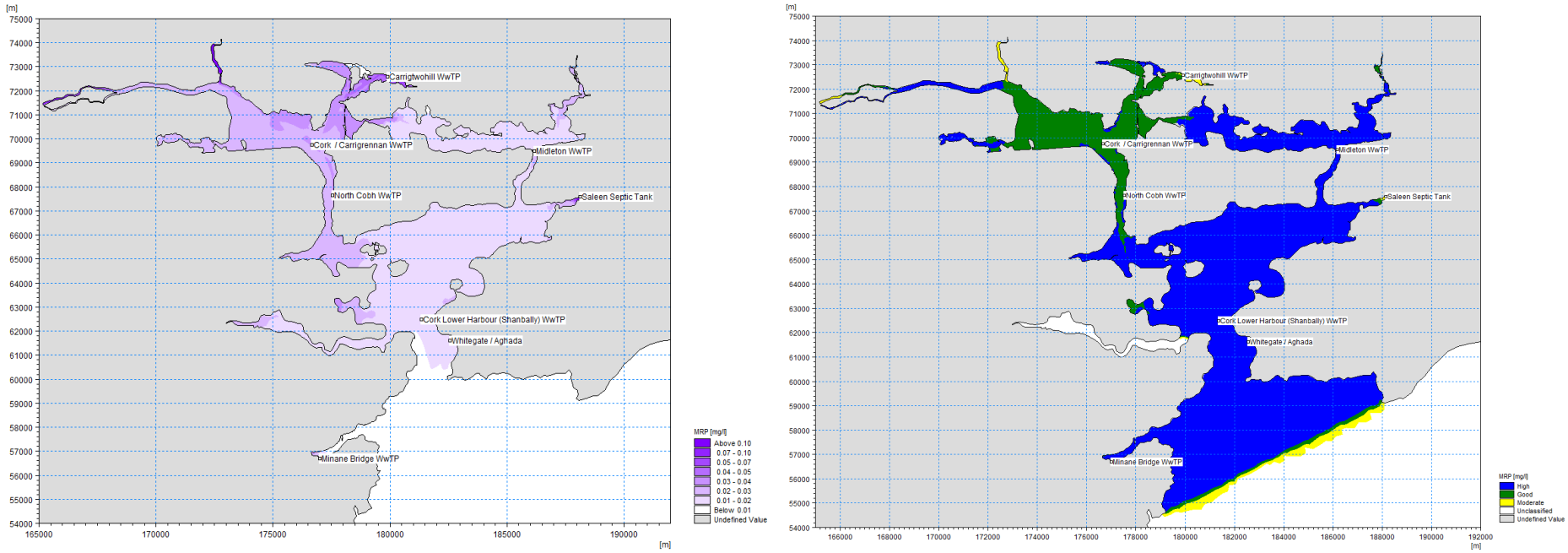
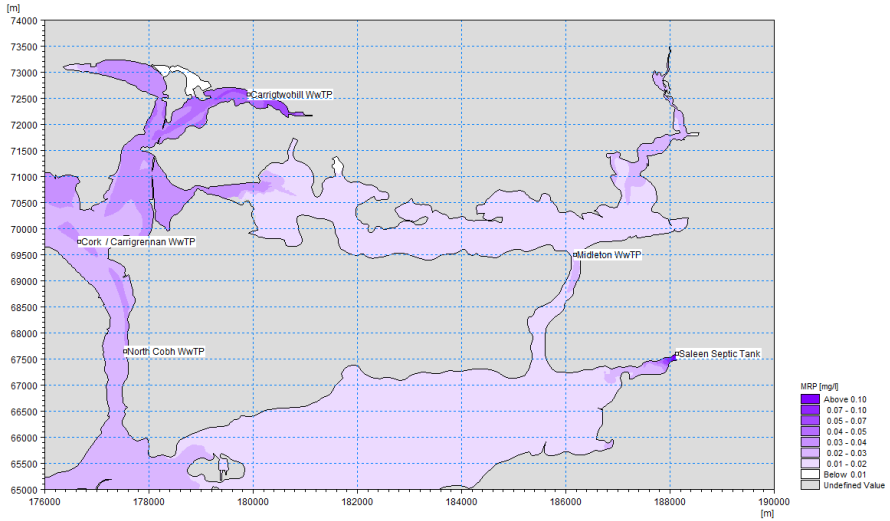
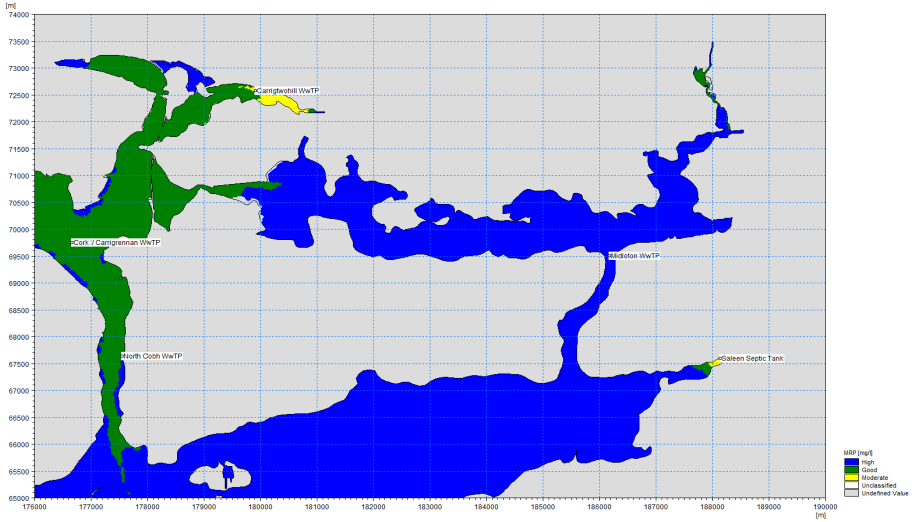


Figure 3-36 Future Maximum ELV: Concentration and Indicative Quality Plots for MRP (Median) – Summer, Lough Mahon and North Channel Great Island, and MRP Mass Load Pie Chart





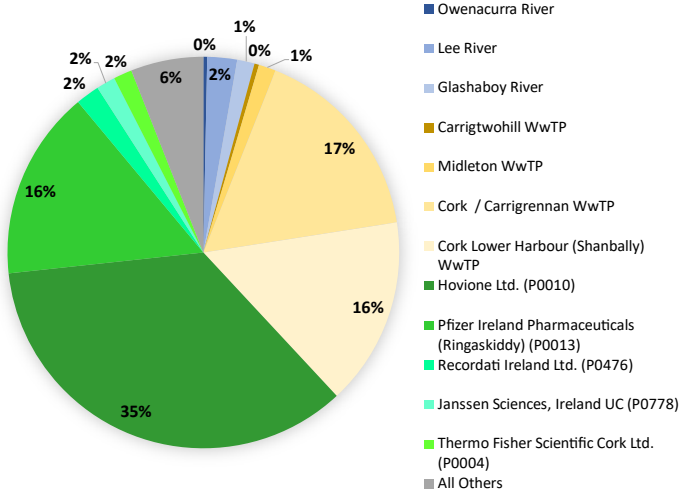


Figure 3-37 Future Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Summer, Mixing Zone Midleton Discharge

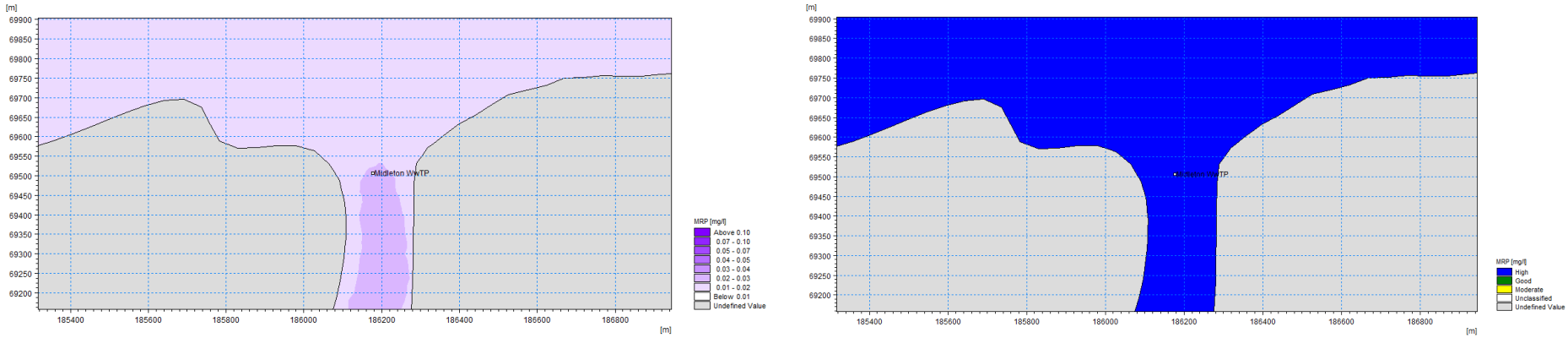


Figure 3-38 Future Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Summer, Mixing Zone Carrigtwohill Discharge

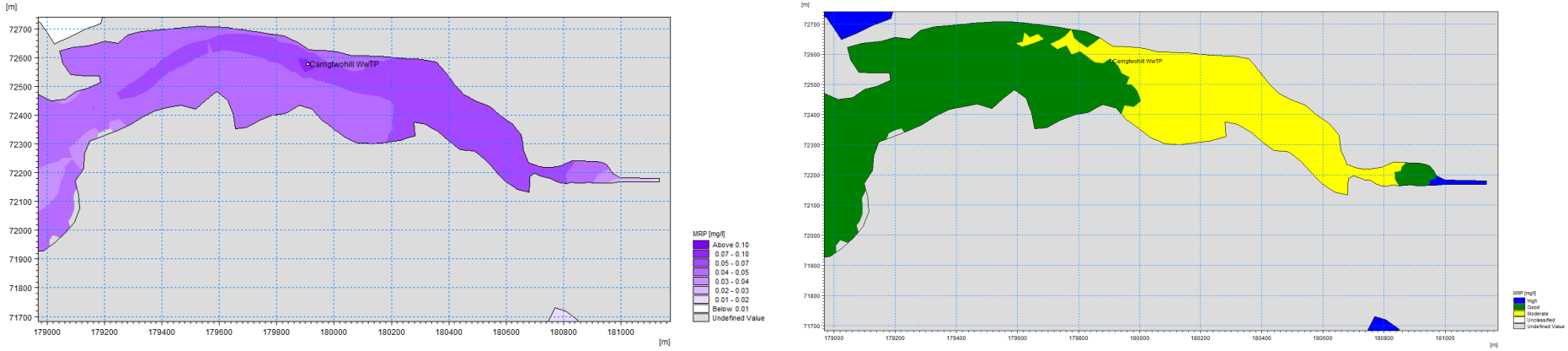


Figure 3-39 Future Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Winter, Cork Harbour

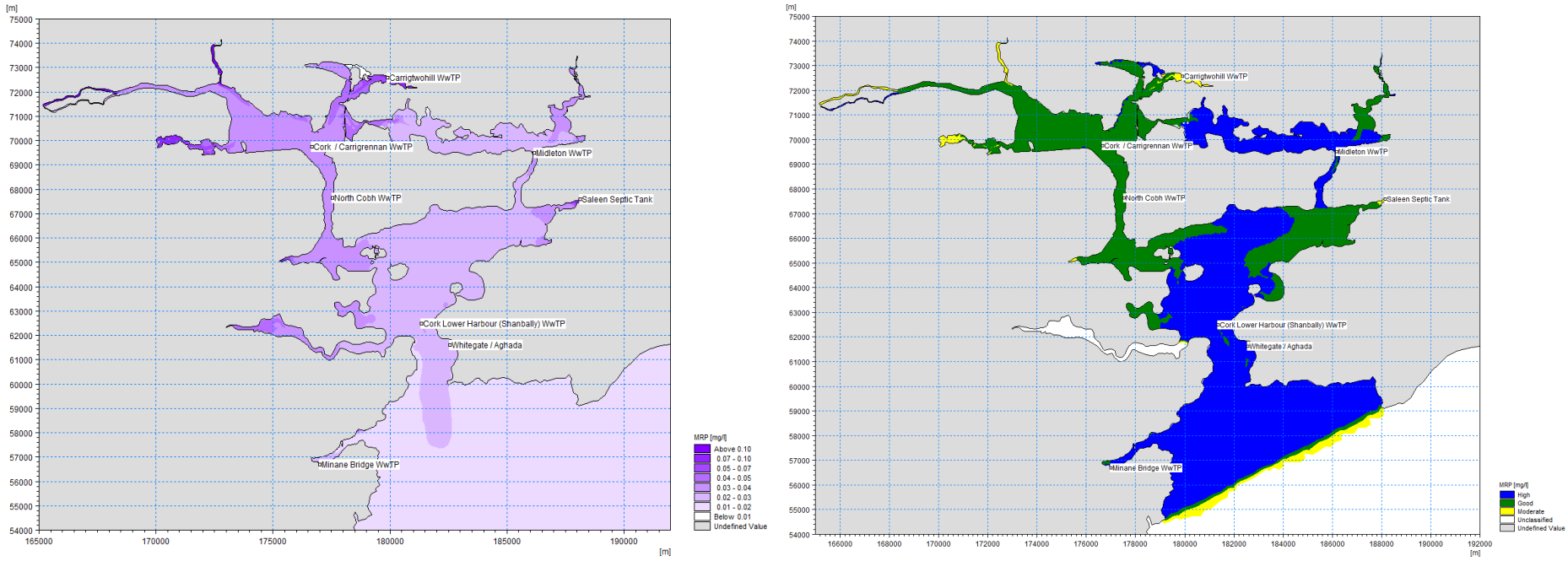
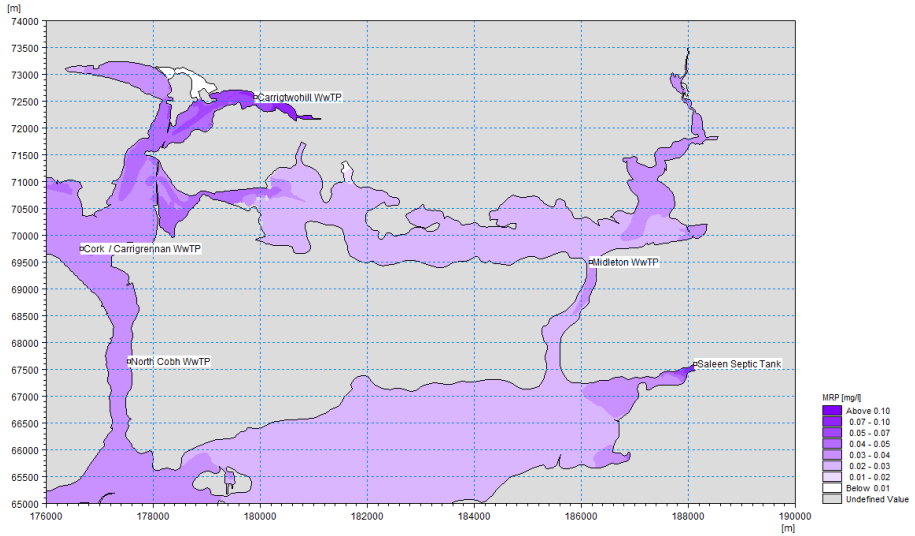
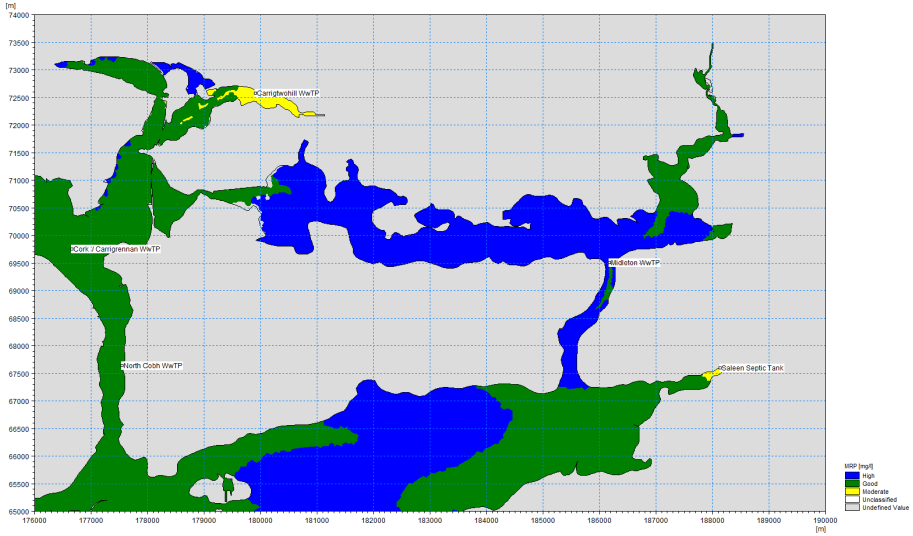


Figure 3-40 Future Maximum ELV: Concentration and Indicative Quality Plots for MRP (Median) – Winter, Lough Mahon and North Channel Great Island and MRP Mass Load Pie Chart





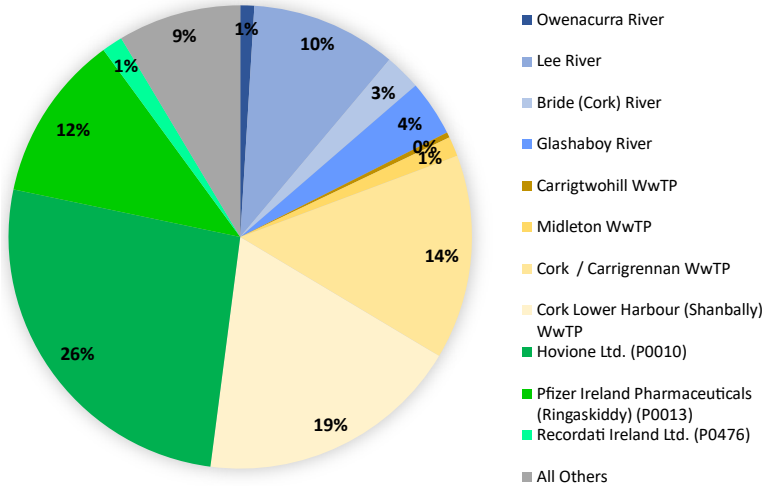


Figure 3-41 Future Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Winter, Mixing Zone Midleton Discharge

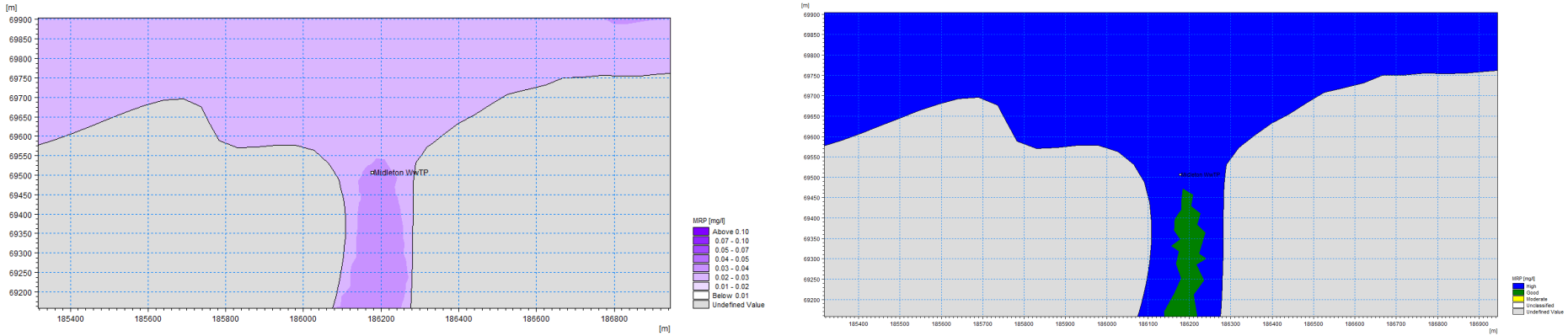
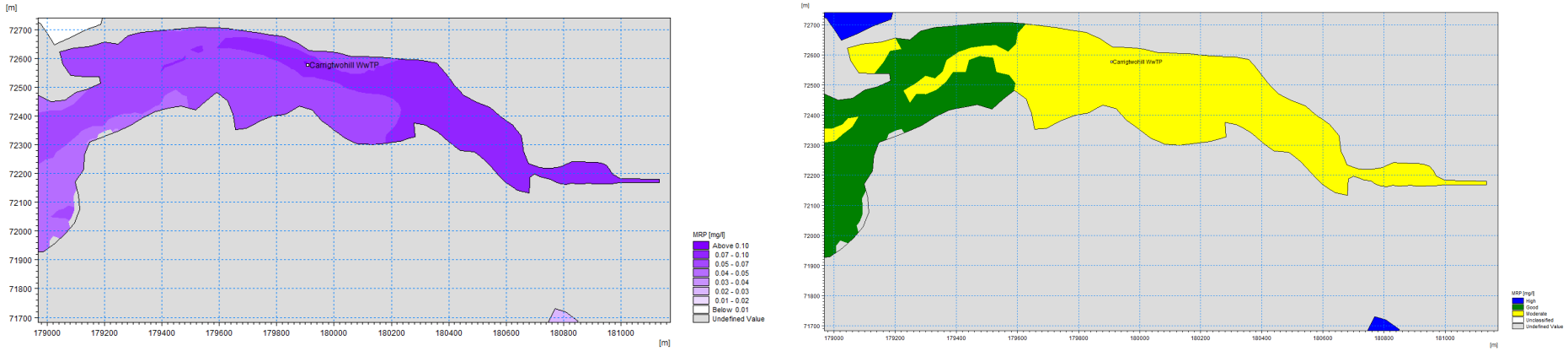


Figure 3-42 Future Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Winter, Mixing Zone Carrigtwohill Discharge



3.3.2.2 Future 'Notionally Clean' River Scenario

Modelled MRP concentration and indicative quality plots are shown for the Future 'Notionally Clean' River scenario from Figure 3-42 to Figure 3-45 for summer, and from Figure 3-46 to Figure 3-49 for winter. The WwTP locations are shown in Figure 3-2.

In summer, MRP concentrations in the coastal waterbodies of Cork Harbour are <0.02 mg/l, with slightly higher concentrations (<0.03 mg/l) in the area close to the Lough Mahon transitional WB, a small area adjacent to the Saleen discharge and in Lough Beg adjacent to the Hovione Ltd. industrial discharge (Figure 3-42). The majority of coastal WBs are predicted to have an indicative quality of High, noting the MRP EQS does not apply to coastal waters.

In the transitional waters MRP concentrations are generally <0.02 mg/l except in Lough Mahon where concentrations reach 0.03 mg/l due to the discharge from Cork / Carrigrennan WwTP. Concentrations of up to 0.04 mg/l are seen in a small area in the west of the North Channel Great Island WB (Figure 3-43). Elevated concentrations (0.04 mg/l) can be seen in the Midleton WwTP discharge plume over an area of approximately 500m x 200m (Figure 3-44) but the concentrations remain below the EQS. Elevated concentrations are also seen around the Carrigtwohill discharge in Lough Mahon (Harper's Island) WB where a small mixing zone (MRP> 0.07 mg/l, area approximately 20m x 20m) can be seen (Figure 3-45). An area of elevated concentration (0.06 mg/l) is also seen in the upper part of the WB.

Indicative quality is predicted to be High in all transitional WBs except the western part of the North Channel Great Island WB (Good indicative quality) and parts of Lough Mahon (Harper's Island) where Good is predicted. There are areas of elevated concentration, with indicative quality of Moderate, around the Carrigtwohill WwTP discharge as noted above.

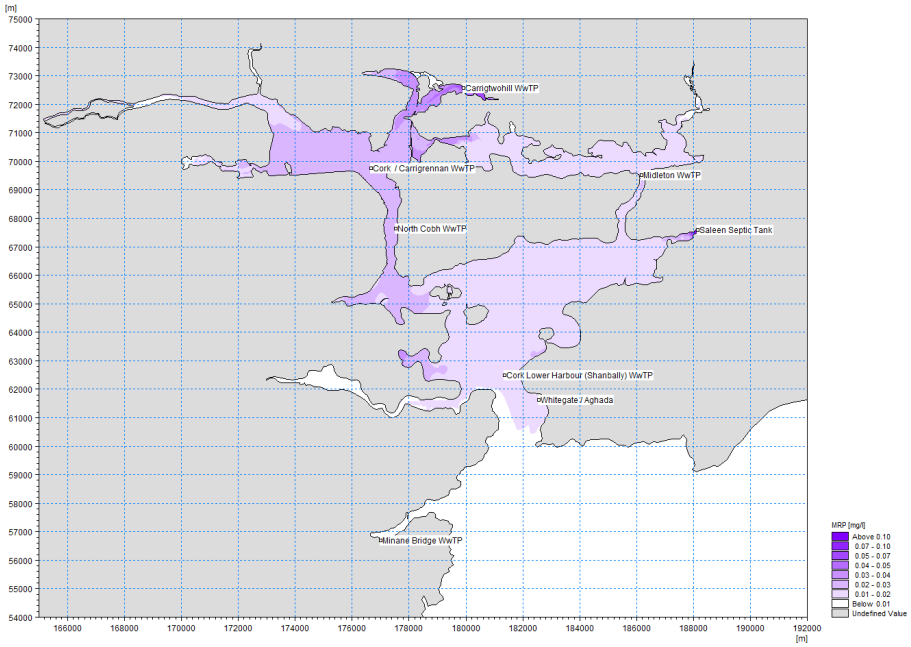
In winter a similar pattern is observed. MRP concentrations in the coastal waters of Inner Cork Harbour are generally <0.03 mg/l, with slightly lower concentrations (<0.02 mg/l) in Cork Harbour (Figure 3-46). A discharge plume from Shanbally WwTP can be seen but concentrations in the plume (<0.03 mg/l) remain within the EQS.

In the transitional waters concentrations are marginally lower than in summer in Lough Mahon ranging from <0.01 mg/l to 0.03 mg/l (Figure 3-46 and Figure 3-47). In the North Channel Great Island WB elevated concentrations (<0.03 mg/l) can be seen in the west of the WB around Belvelly and in the east as the discharge plume from Midleton WwTP (Figure 3-47 and Figure 3-48) however concentrations remain within EQS.

Highest MRP concentrations are seen around Carrigtwohill WwTP in Lough Mahon (Harper's Island) WB where a small mixing zone (MRP> 0.07 mg/l, area approximately 50m x 200m) can be seen (Figure 3-49). Elevated concentrations (0.06 mg/l) is also seen in the upper part of the WB although the EQS is not exceeded in these areas in winter.

In winter the predicted indicative water quality is High in the transitional (and coastal) waterbodies in Cork Harbour with the exception of parts of Lough Mahon (Harper's Island) where indicative quality is Good.

Figure 3-43 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Summer, Cork Harbour



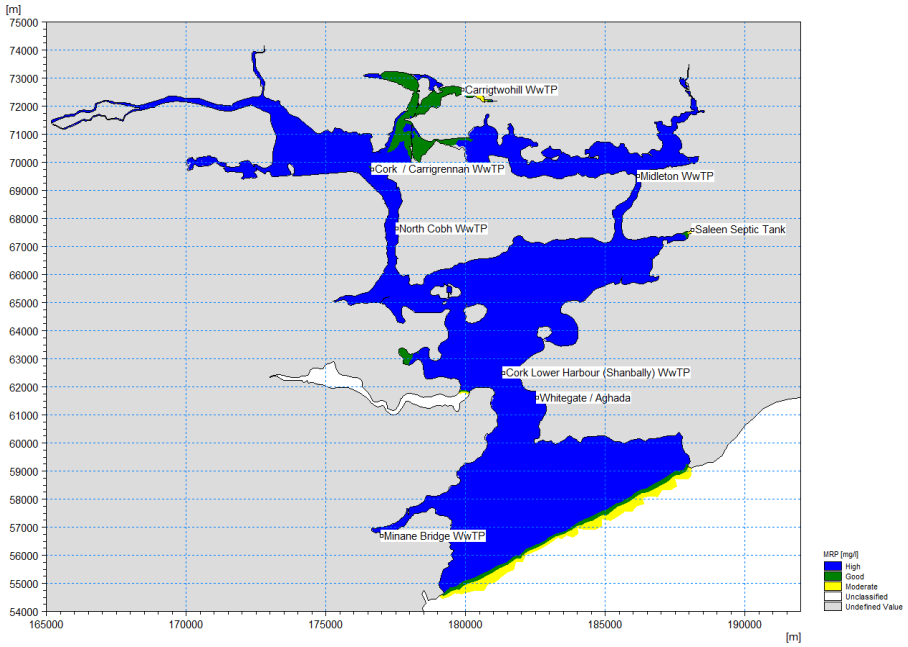


Figure 3-44 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Summer, Lough Mahon and North Channel Great Island

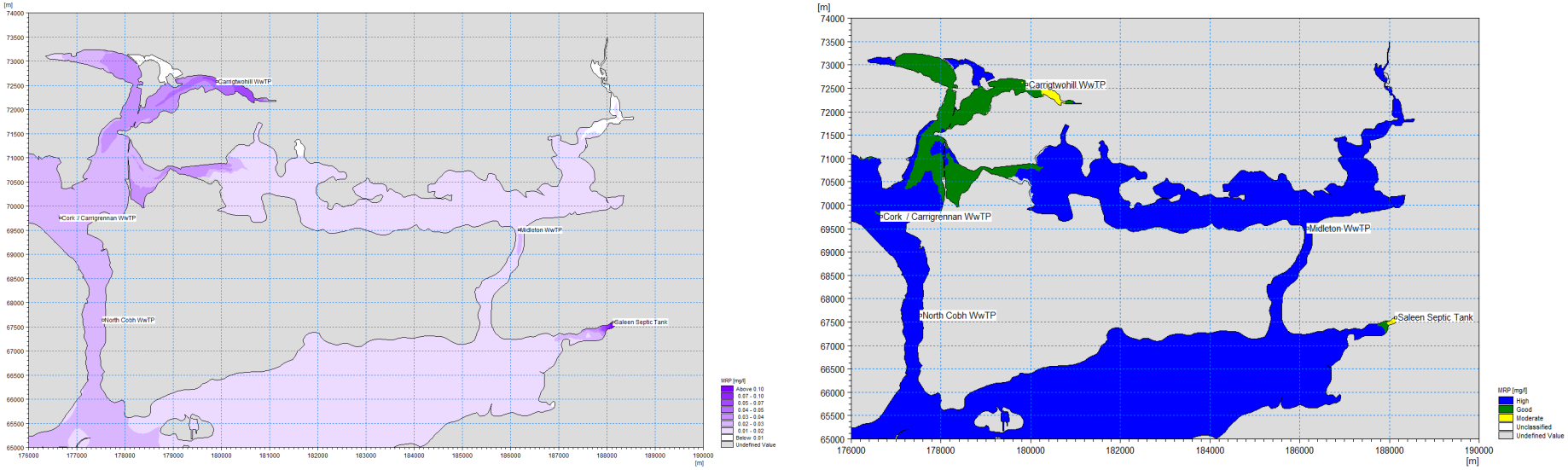


Figure 3-45 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Summer, Mixing Zone Midleton Discharge

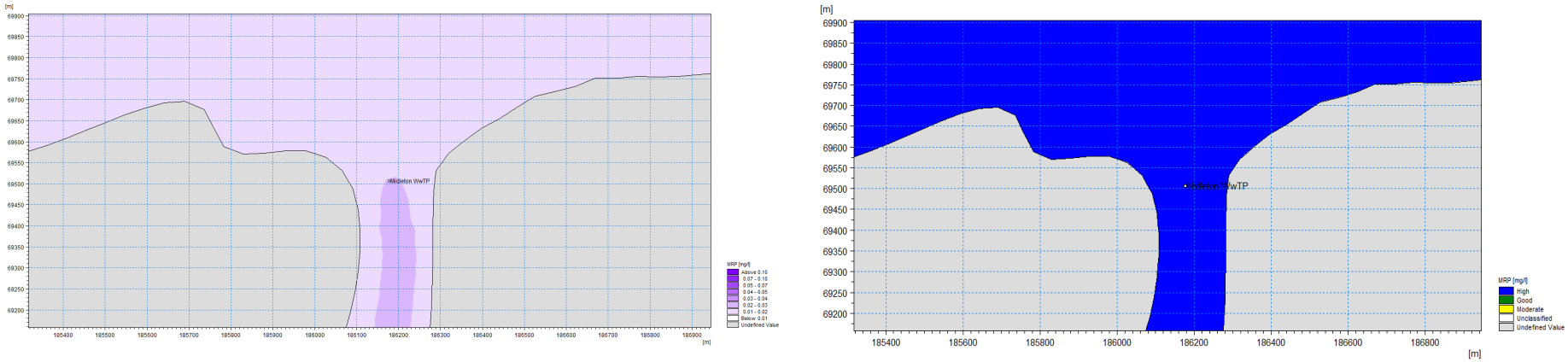


Figure 3-46 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Summer, Mixing Zone Carrigtwohill Discharge

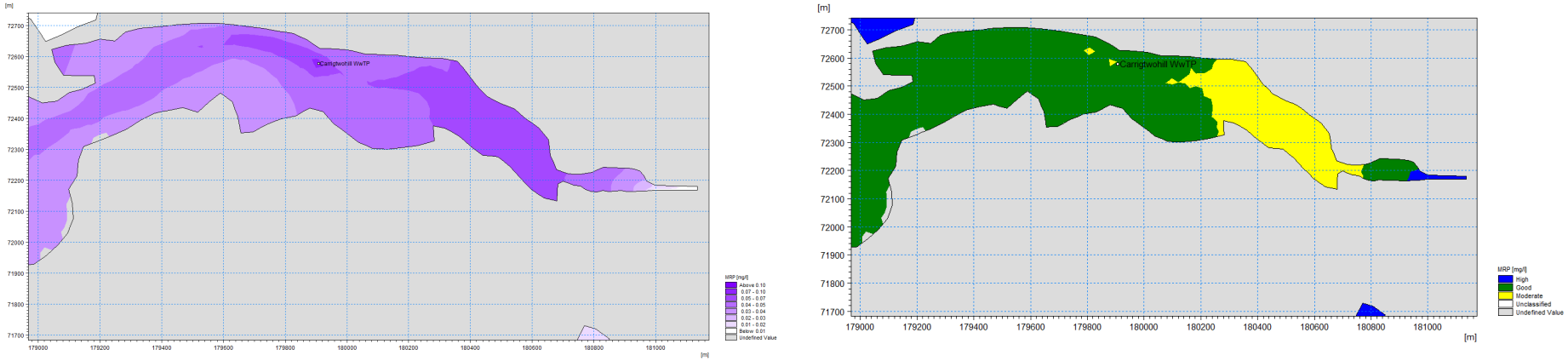


Figure 3-47 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Winter, Cork Harbour

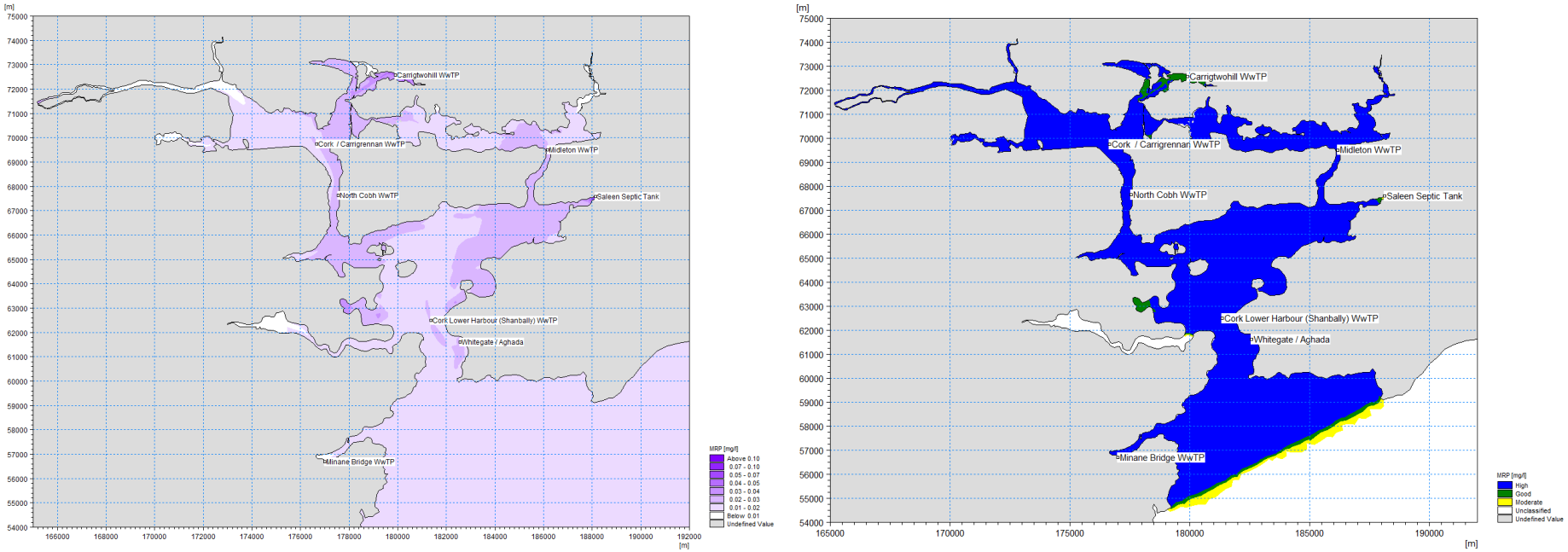


Figure 3-48 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Winter, Lough Mahon and North Channel Great Island

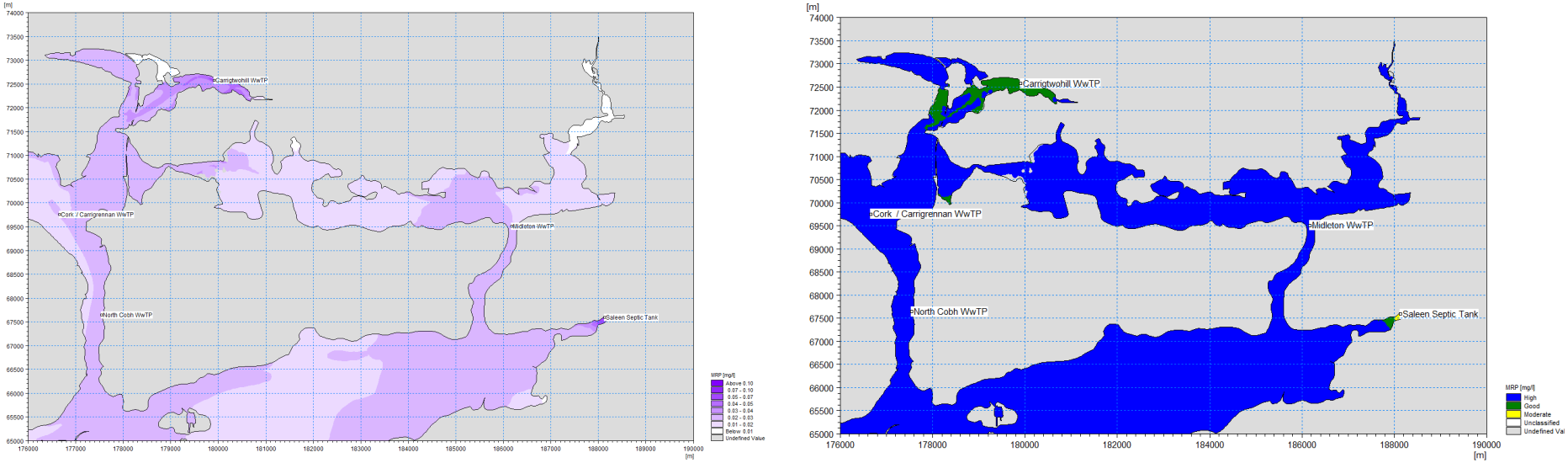


Figure 3-49 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Winter, Mixing Zone Midleton Discharge

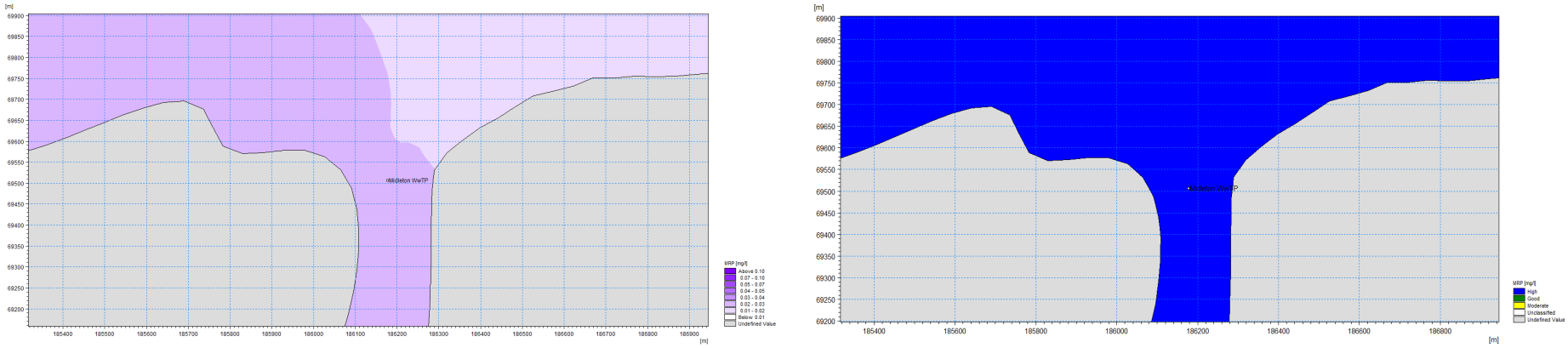
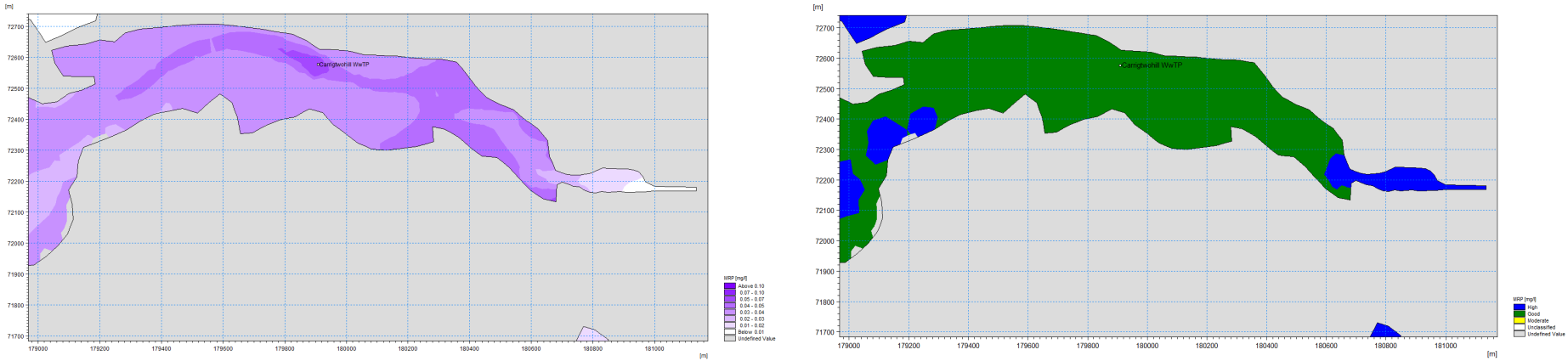


Figure 3-50 Future 'Notionally Clean' River Scenario: Concentration and Indicative Quality Plots for MRP (Median) – Winter, Mixing Zone Carrigtwohill Discharge



3.4 Microbiological Assessment

One of the objectives of this modelling study is to assess whether discharges from WwTP agglomerations discharging directly to Cork Harbour are impacting microbial water quality of the Designated SFWs, licensed aquaculture areas and BWs. These are:

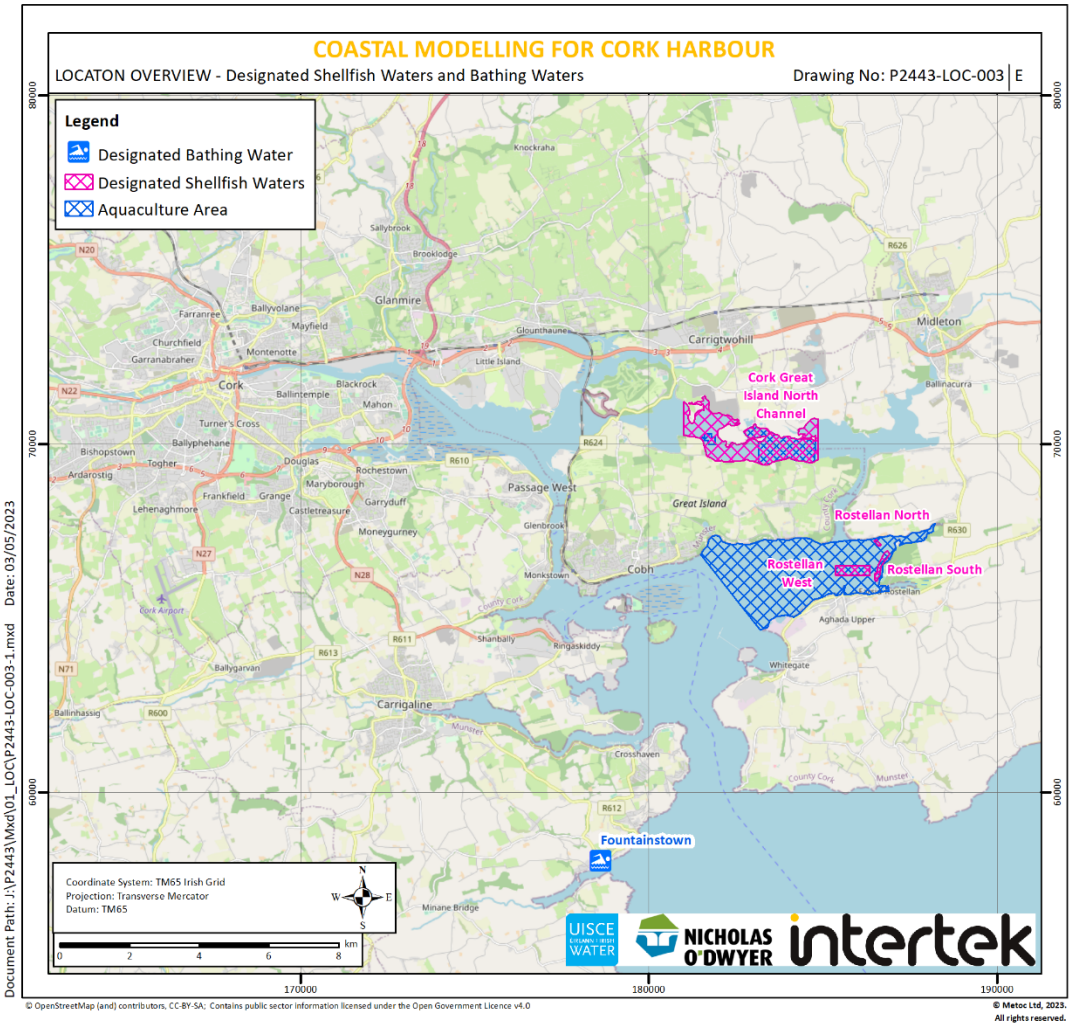
- Cork Great Island North Channel SFW
- Rostellan West SFW
- Rostellan South SFW
- Rostellan North SFW
- Fountainstown BW

The Designated SFW and BW locations are shown in Figure 3-50 (Drawing No: P2443-LOC-003-E).

The Cork Harbour 3D microbiological water quality model has been validated using the criteria as outlined in Uisce Éireann's TSMM (2022). The findings of this validation study are outlined in the Cork Harbour Microbiological Validation Report (Intertek, 2023b).

This section presents the geomean concentration results for EC (relevant to the SFW standard) and 95th percentile concentration results for EC and IE (relevant to the BW standards) for the summer and winter Future discharge scenario.

Figure 3-51 Designated Shellfish and Bathing Waters



3.4.1 EC (Geomean)

Modelled EC concentrations and indicative quality plots at the geomean concentration are shown in Figure 3-51 to Figure 3-54 for summer, and Figure 3-55 to Figure 3-58 for winter. The WwTP, Designated SFW (pink) and aquaculture area (blue) locations are shown in Figure 3-2 and in the plots in Section 3.4.1. There are no shellfish waters or aquaculture sites in the vicinity of the Carrigtwohill WwTP discharge, bacteria concentration and indicative plots are presented for this area for completeness and consistency with other assessments.

In summer, EC concentrations around Cork Harbour are generally <10 EC/100 ml with most areas falling below a geomean of 110 EC/100 ml (Figure 3-51). Slightly elevated concentrations (between 10 – 110 EC/100 ml) are mainly observed in Lough Mahon where the Carrigtwohill and Cork/Carrigrennan WwTPs discharge, and in the River Lee channel.

High modelled summer EC concentrations that exceed a geomean of 110 EC/100 ml can be seen in the immediate vicinity of rivers Lee, Owenboy and Owenacurra, and the continuous discharges of Minane Bridge WwTP, Cork/Carrigrennan WwTP, Saleen Septic Tank, and Whitegate / Aghada. The modelled EC concentrations in the channel around the Carrigtwohill WwTP discharge plume (Figure 3-54) is between 100 EC/100ml and 2000 EC/100ml, while in the deeper waters around Midleton WwTP the modelled geomean EC concentration is <5 EC/100 ml (Figure 3-53).

Modelled summer EC concentrations in the Designated SFWs do not exceed the 110 EC/100 ml geomean target. However, high EC concentrations (> 110 EC/100 ml) around the Saleen Septic Tank are predicted in the most easterly part of the Cork Harbour aquaculture area.

In winter, predicted EC concentrations around Cork Harbour are generally higher than in summer. However, there are parts of the North Channel Great Island and Outer Cork Harbour that have an EC concentration of <10 EC/100 ml (Figure 3-55). Elevated concentrations (between 10 – 110 EC/100 ml) are mainly observed in Cork Harbour where the plumes from Cork/Carrigrennan and Carrigtwohill WwTPs extend.

Highest modelled winter EC concentrations can be seen in the rivers Lee, Owenboy and Owenacurra, and around the continuous discharges from Minane Bridge WwTP, Cork/Carrigrennan WwTP, Saleen Septic Tank, Whitegate / Aghada and Carrigtwohill WwTP. The plumes from these discharges are noticeably larger than during the summer. A winter geomean EC concentration <10 EC/100 ml is predicted around the Midleton WwTP discharge (Figure 3-57).

Modelled winter EC concentrations in the Designated SFWs do not exceed a geomean of 110 EC/100 ml. However, high EC concentrations (> 110 EC/100 ml) from Saleen Septic Tank are predicted in the most easterly part of the Cork Harbour aquaculture area.

Figure 3-52 Concentration and Indicative Quality Plots for EC (Geomean) – Summer, Cork Harbour

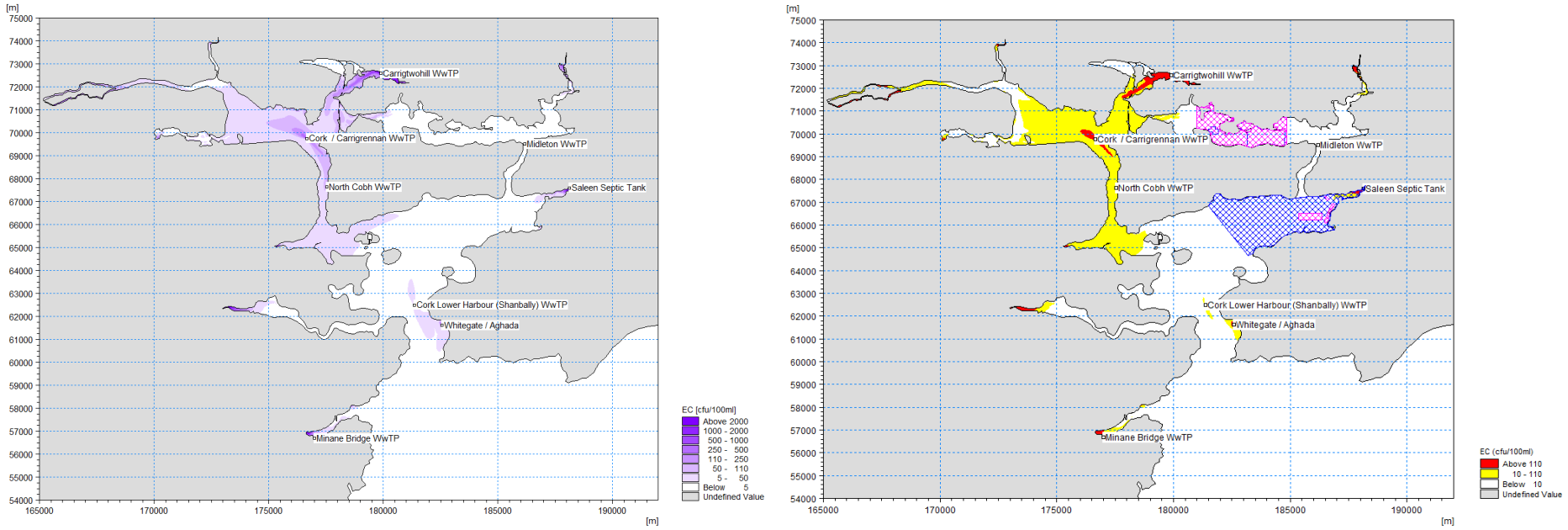


Figure 3-53 Concentration and Indicative Quality Plots for EC (Geomean) – Summer, Lough Mahon and North Channel Great Island

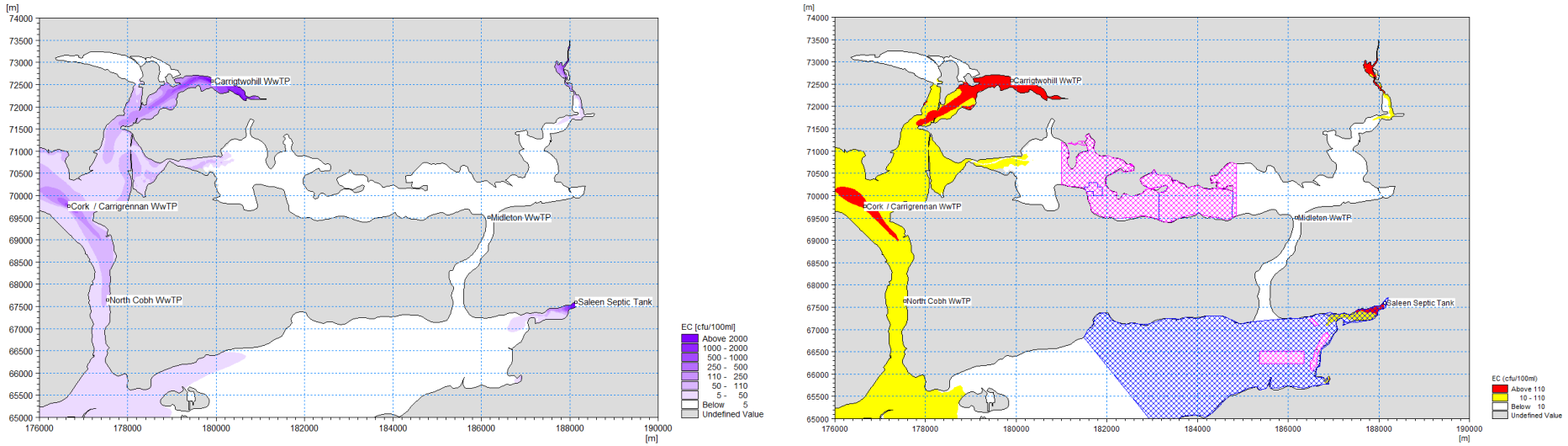


Figure 3-54 Concentration and Indicative Quality Plots for EC (Geomean) – Summer, Midleton Discharge Plume

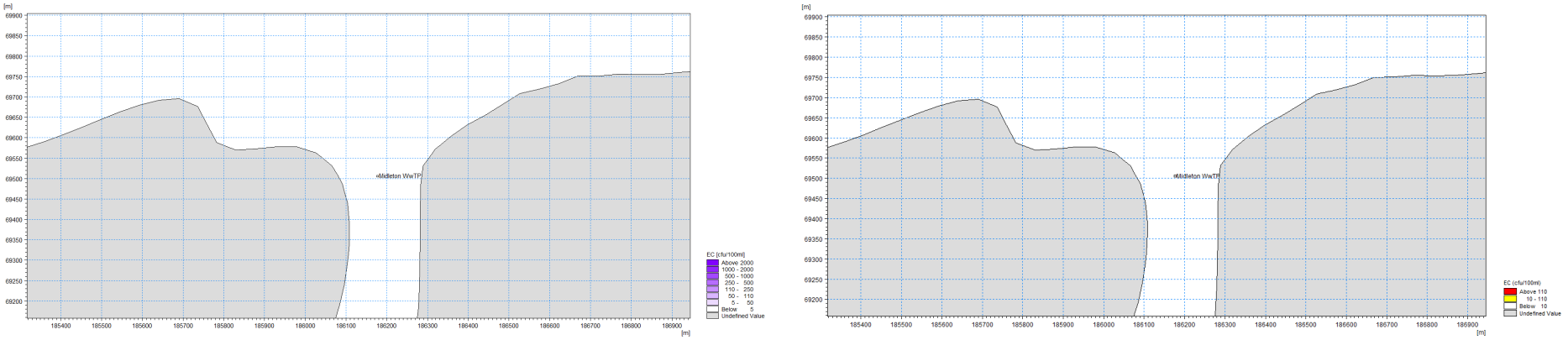


Figure 3-55 Concentration and Indicative Quality Plots for EC (Geomean) – Summer, Carrigtwohill Discharge Plume

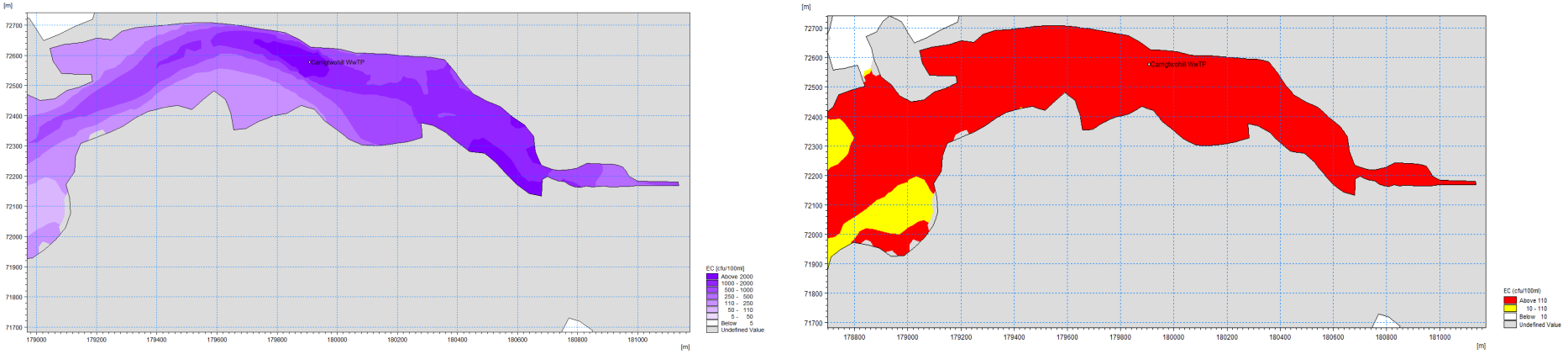


Figure 3-56 Concentration and Indicative Quality Plots for EC (Geomean) – Winter, Cork Harbour

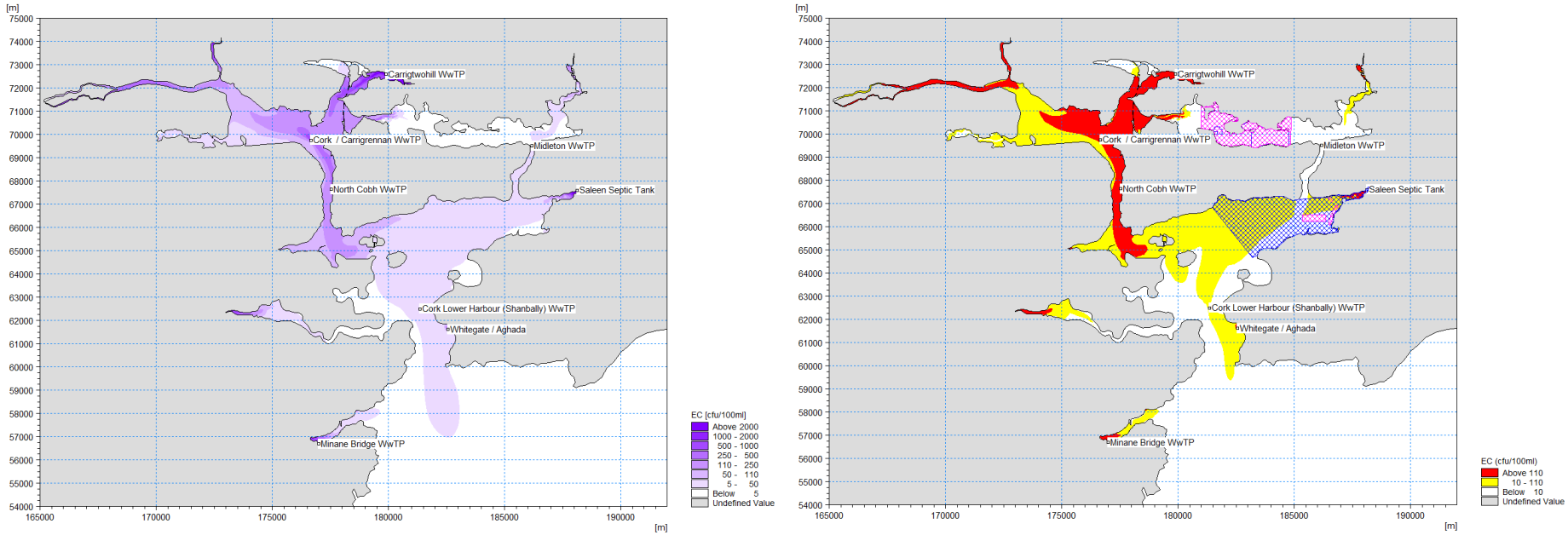


Figure 3-57 Concentration and Indicative Quality Plots for EC (Geomean) – Winter, Lough Mahon and North Channel Great Island

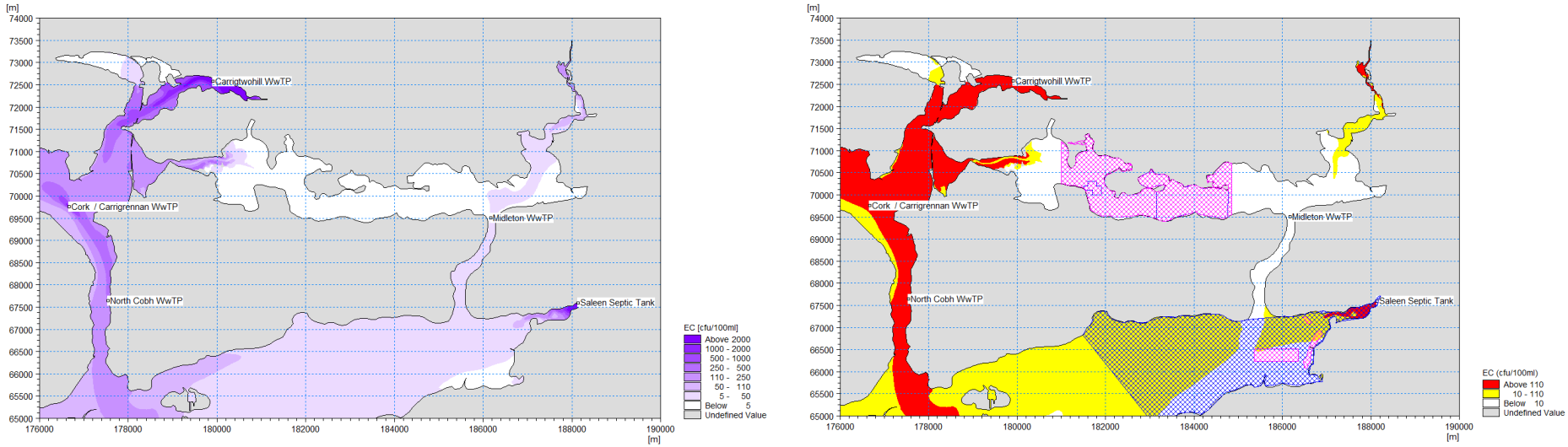


Figure 3-58 Concentration and Indicative Quality Plots for EC (Geomean) – Winter, Midleton Discharge Plume

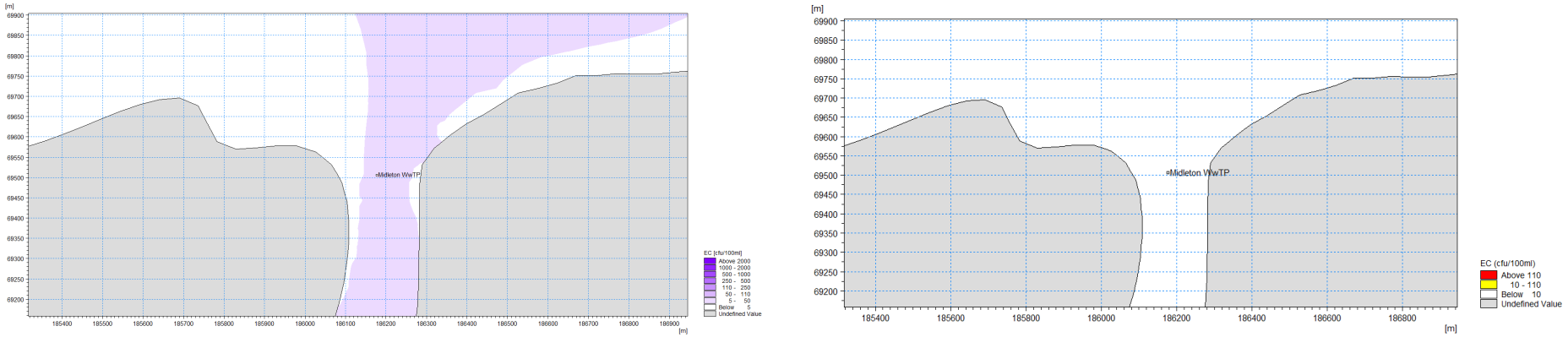
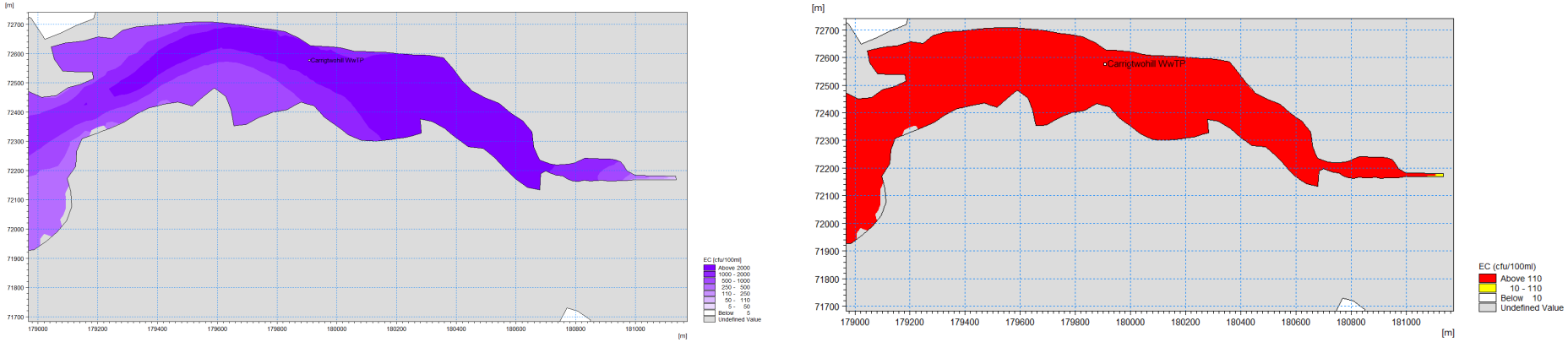


Figure 3-59 Concentration and Indicative Quality Plots for EC (Geomean) – Winter, Carrigtwohill Discharge Plume



3.4.2 EC (95th percentile)

Modelled EC concentrations and indicative quality plots at the 95th percentile concentration are shown in Figure 3-59 to Figure 3-62 for summer, and Figure 3-63 to Figure 3-66 for winter. The WwTP and Designated BW (blue diamond) locations are shown in Figure 3-2 and in the plots in Section 3.4.2.

For ease of reference, the plots and the discussion below relate the predicted 95th percentile concentrations to the standards of the 2006 Bathing Water Directive (BWD), although it should be noted that these standards only apply at Fountainstown Designated BW. The BW standards would also apply only in the summer (bathing season), but winter results are shown for reference too.

In summer, 95th percentile EC concentrations around Cork Harbour are generally <250 EC/100 ml where the indicative BW quality is Excellent in most areas (Figure 3-59). Elevated 95th percentile concentrations (< 500 EC/100 ml) are predicted in Lough Mahon around the Cork/Carrigrennan WwTP discharge, where indicative water quality is equivalent to Good BW quality.

High summer EC concentrations are also predicted in the immediate vicinity of the continuous discharges from Minane Bridge WwTP, Cork/Carrigrennan WwTP, Saleen Septic Tank, Whitegate / Aghada and Carrigtwohill WwTP. The indicative water quality in these areas is Sufficient / Poor, as would be expected within a discharge plume in the near vicinity of an outfall. Low EC concentrations are predicted around Midleton WwTP, equivalent to Excellent BW quality (Figure 3-61).

Modelled summer EC concentrations at Fountainstown Designated BW indicate Excellent water quality, consistent with BW classification since 2019.

Similar overall patterns in modelled EC concentrations are seen in winter. In winter, 95th percentile EC concentrations around Cork Harbour are generally <250 EC/100 ml where the indicative BW quality is Excellent in most areas (Figure 3-63). Elevated concentrations (< 500 EC/100 ml) are predicted in Lough Mahon around the Cork/Carrigrennan WwTP discharge, where water quality equivalent to the Good BW quality.

High modelled winter EC concentrations can be seen in the immediate vicinity the continuous discharges of Minane Bridge WwTP, Cork/Carrigrennan WwTP, Saleen Septic Tank and Carrigtwohill WwTP. These areas would be classified as Sufficient / Poor under the BWD standards. Modelled 95th percentile EC concentrations of <5 EC/100 ml are shown around Midleton WwTP, which indicate Excellent BW quality (Figure 3-65).

Modelled winter EC concentrations at Fountainstown Designated BW indicate Excellent BW quality.

Figure 3-60 Concentration and Indicative Quality Plots for EC (95th percentile) – Summer, Cork Harbour

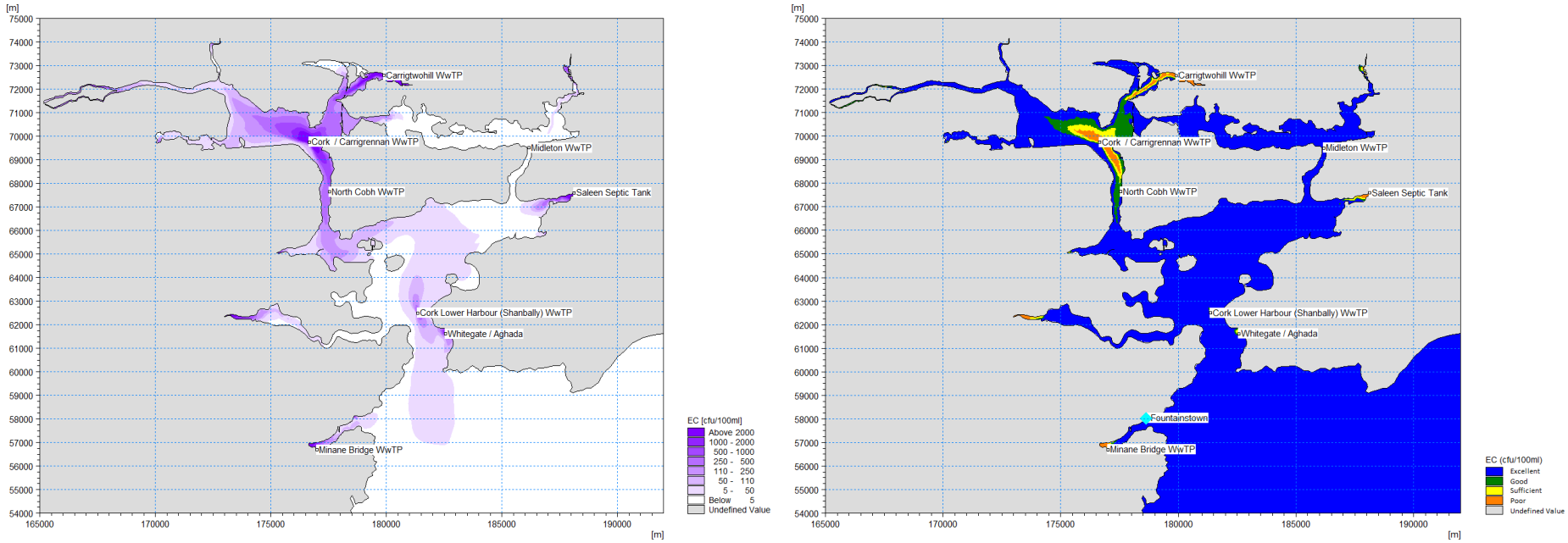


Figure 3-61 Concentration and Indicative Quality Plots for EC (95th percentile) – Summer, Lough Mahon and North Channel Great Island

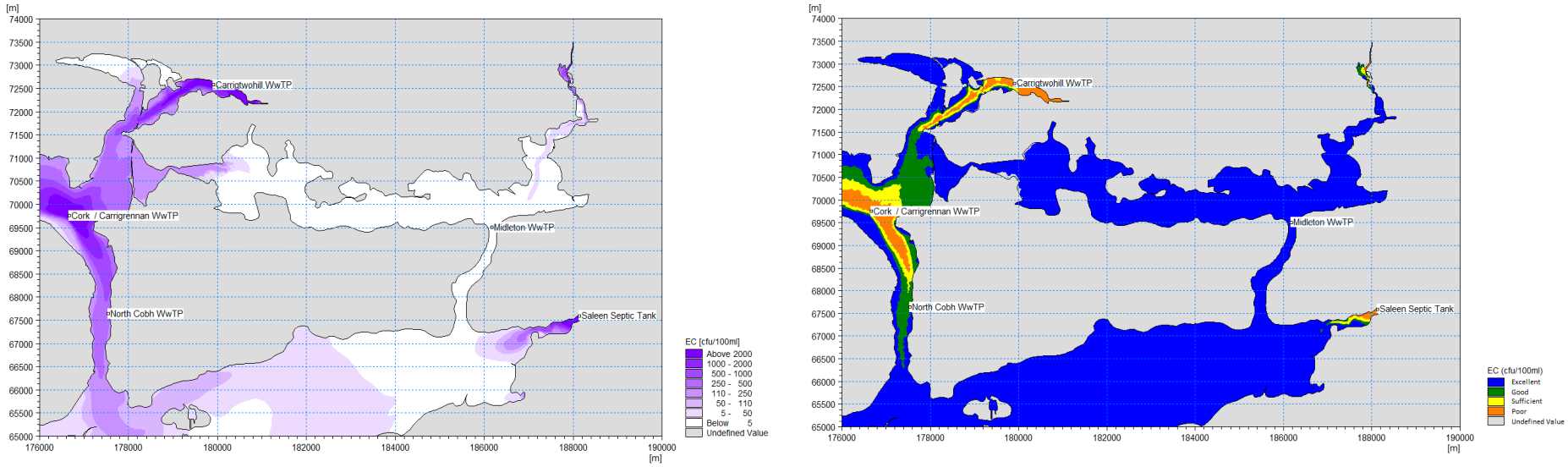


Figure 3-62 Concentration and Indicative Quality Plots for EC (95th percentile) – Summer, Midleton Discharge Plume

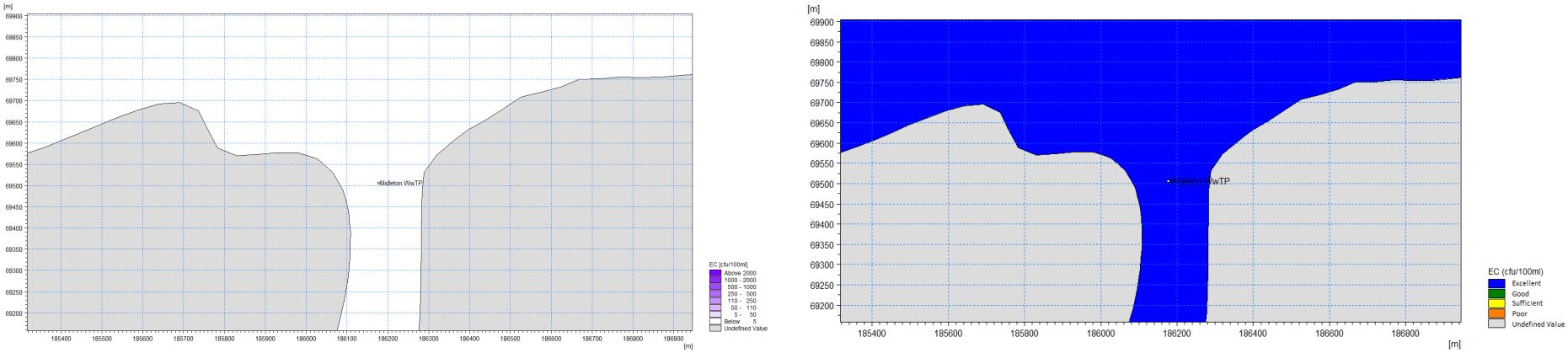


Figure 3-63 Concentration and Indicative Quality Plots for EC (95th percentile) – Summer, Carrigtwohill Discharge Plume

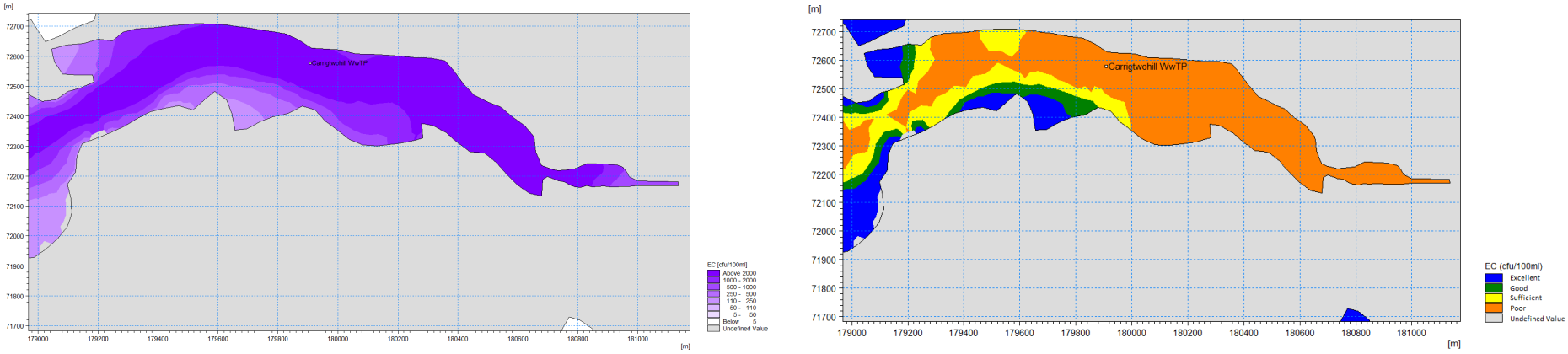


Figure 3-64 Concentration and Indicative Quality Plots for EC (95th percentile) – Winter, Cork Harbour

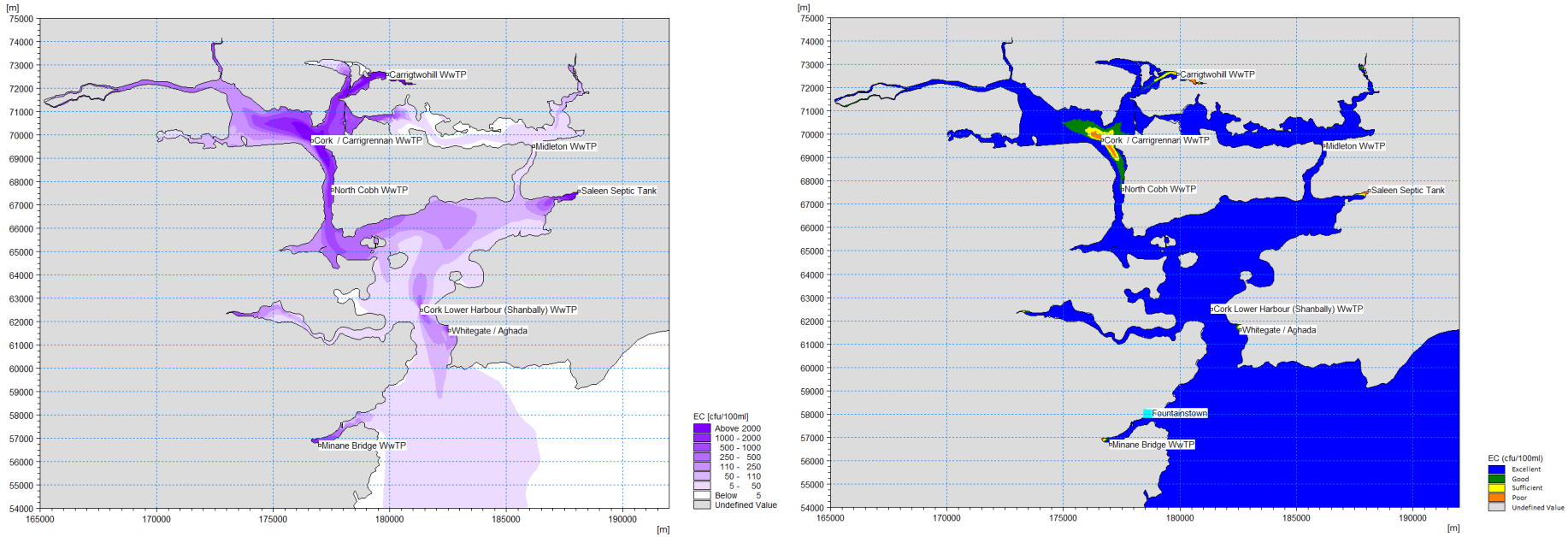


Figure 3-65 Concentration and Indicative Quality Plots for EC (95th percentile) – Winter, Lough Mahon and North Channel Great Island

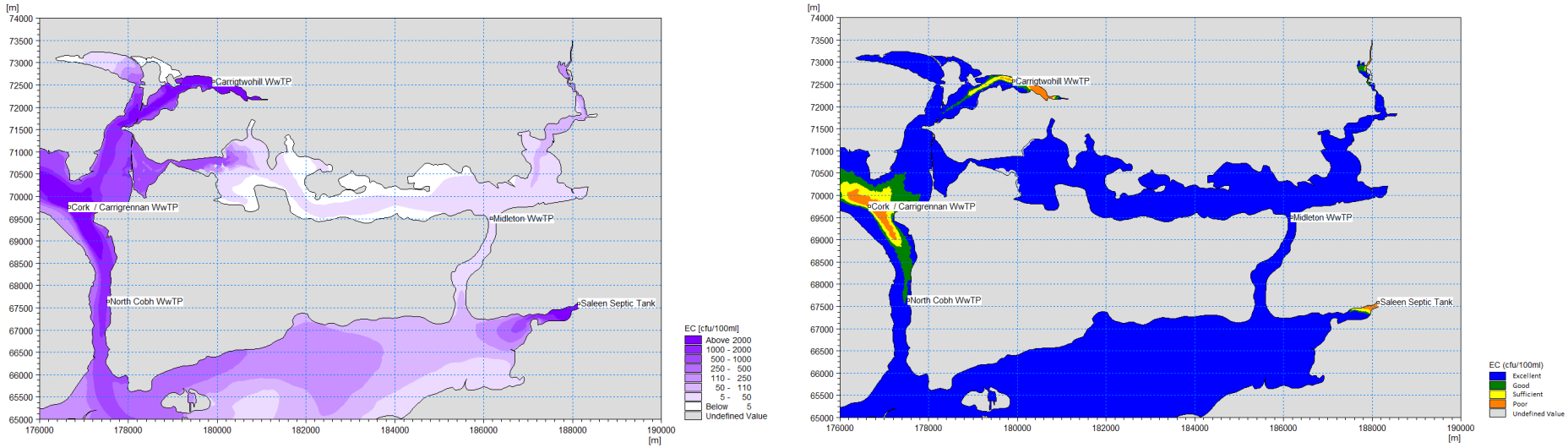


Figure 3-66 Concentration and Indicative Quality Plots for EC (95th percentile) – Winter, Midleton Discharge Plume

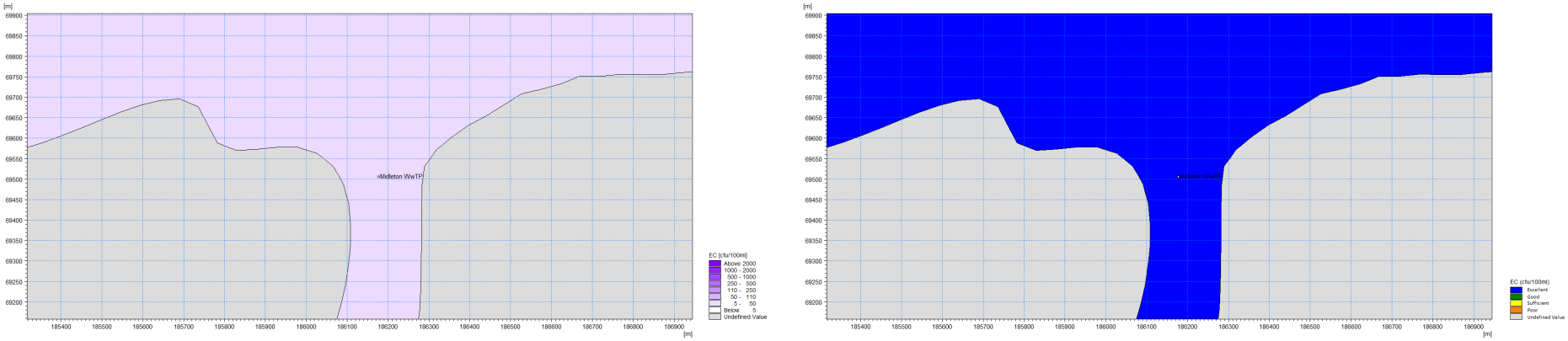
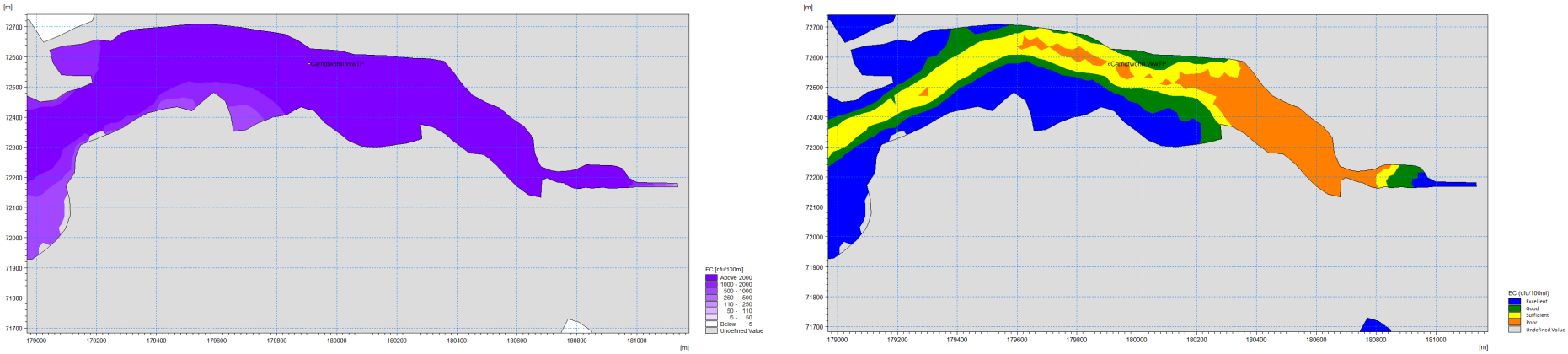


Figure 3-67 Concentration and Indicative Quality Plots for EC (95th percentile) – Winter, Carrigtwohill Discharge Plume



3.4.3 IE (95th percentile)

Modelled IE concentrations and indicative quality plots at the 95th percentile concentration are shown in Figure 3-67 to Figure 3-70 for summer, and Figure 3-71 to Figure 3-74 for winter. The WwTP and Designated BW (blue diamond) locations are shown in Figure 3-2 and in the plots in Section 3.4.3.

As with EC, for ease of reference, the plots and the discussion below relate the predicted 95th percentile concentrations to the standards of the 2006 BWD.

In summer, 95th percentile IE concentrations around Cork Harbour are generally <100 IE/100 ml where the indicative BW quality is Excellent in most areas (Figure 3-67). Elevated concentrations (<200 IE/100 ml) are predicted in Lough Mahon around the Cork/Carrigrennan WwTP discharge, where indicative water quality equivalent to Good.

High predicted summer IE concentrations can be seen in the immediate vicinity of the continuous discharges of Minane Bridge WwTP, Cork/Carrigrennan WwTP, Saleen Septic Tank and Carrigtwohill WwTP. The indicative water quality in these areas is Sufficient / Poor. Modelled 95th percentile IE concentrations of <5 IE/100 ml are shown around Midleton WwTP, indicative of Excellent BW quality (Figure 3-69).

Modelled IE concentrations at Fountainstown Designated BW indicate Excellent BW quality, consistent with BW classification since 2019.

Similar overall patterns in modelled IE concentrations are seen in winter, 95th percentile IE concentrations around the study area are generally <100 IE/100 ml, indicative BW quality is Excellent in most areas (Figure 3-71). Elevated concentrations (< 200 IE/100 ml) are predicted in Lough Mahon around the Cork/Carrigrennan and Carrigtwohill WwTP discharges and in the River Lee, where water quality indicative of Good BW quality (Figure 3-72).

High modelled winter IE concentrations can be seen in the immediate vicinity of the continuous discharges of Minane Bridge WwTP, Cork/Carrigrennan WwTP, Saleen Septic Tank and Carrigtwohill WwTP. The indicative water quality in these areas is Sufficient / Poor. 95th percentile IE concentrations of <20 IE/100 ml are predicted around Midleton WwTP, indicative of Excellent BW quality (Figure 3-73).

Modelled IE concentrations at Fountainstown Designated BW indicative of Excellent BW quality.

Figure 3-68 Concentration and Indicative Quality Plots for IE (95th percentile) – Summer, Cork Harbour

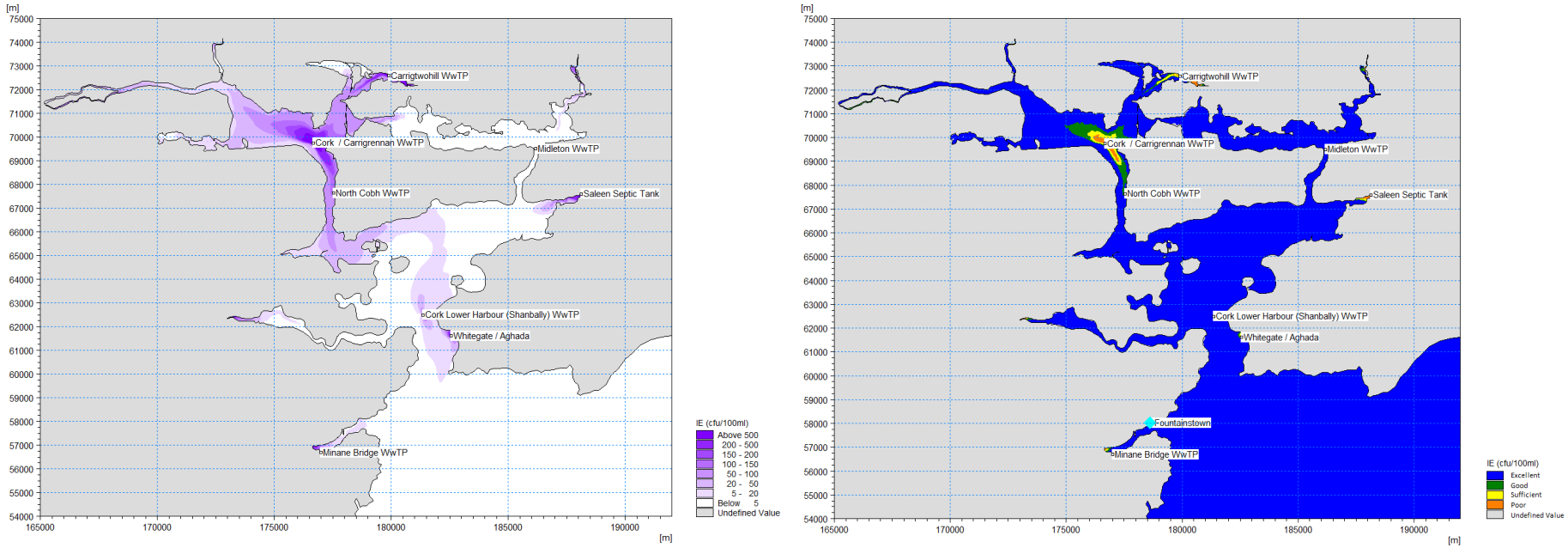
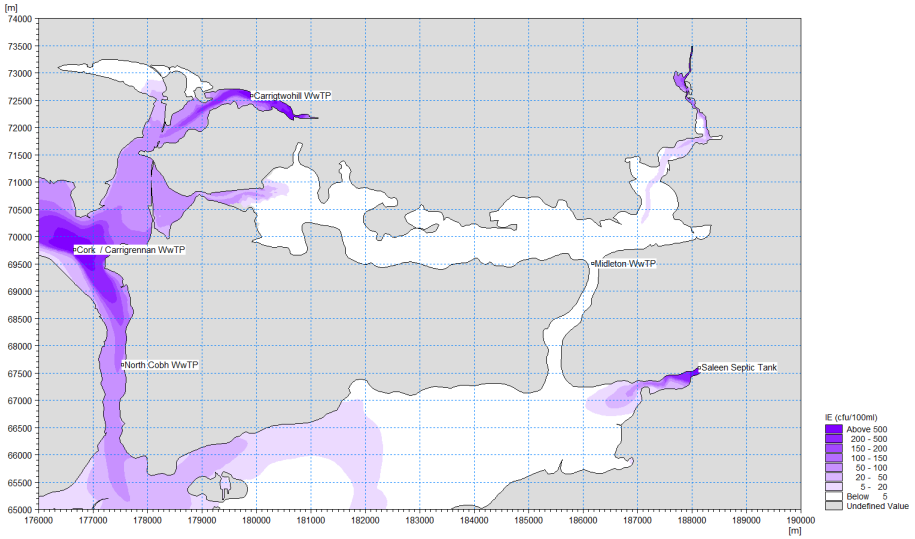


Figure 3-69 Concentration and Indicative Quality Plots for IE (95th percentile) – Summer, Lough Mahon and North Channel Great Island



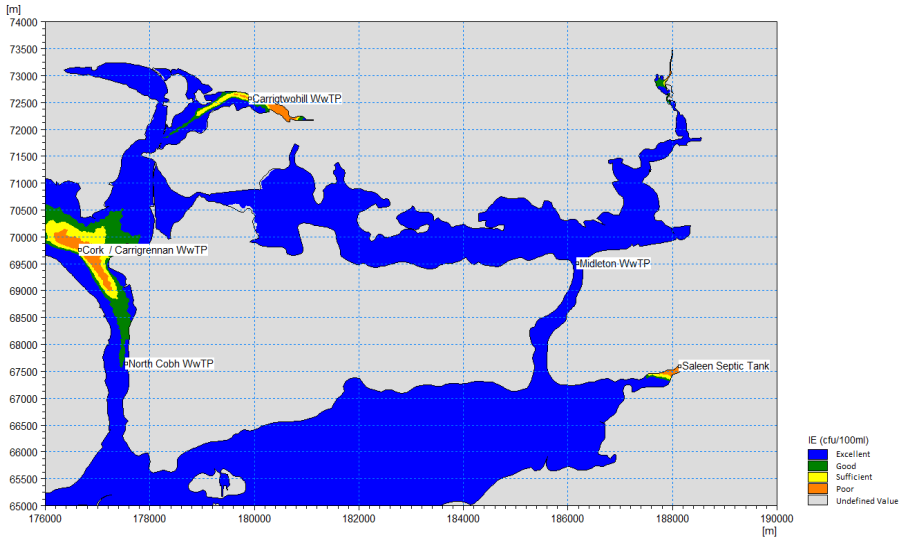


Figure 3-70 Concentration and Indicative Quality Plots for IE (95th percentile) – Summer, Midleton Discharge Plume

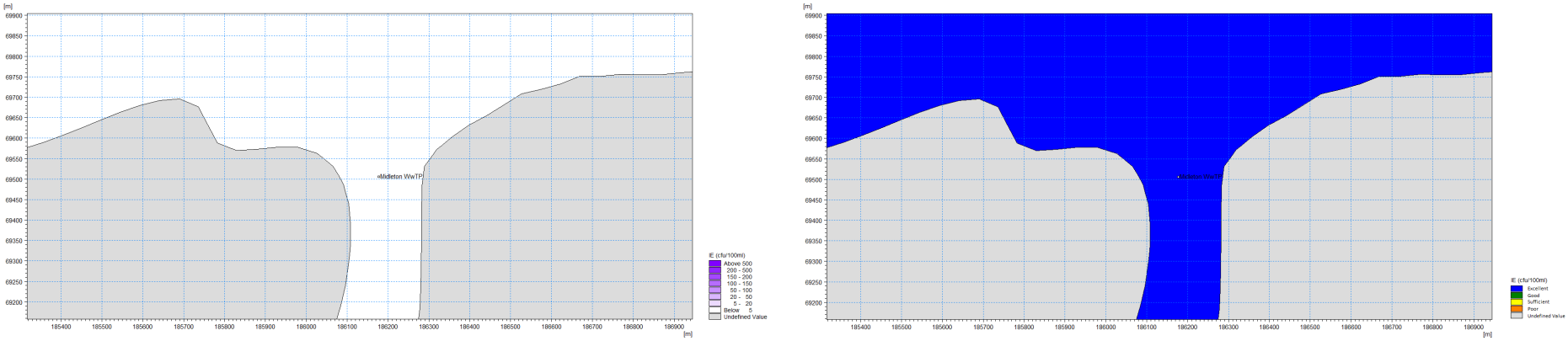


Figure 3-71 Concentration and Indicative Quality Plots for IE (95th percentile) – Summer, Carrigtwohill Discharge Plume

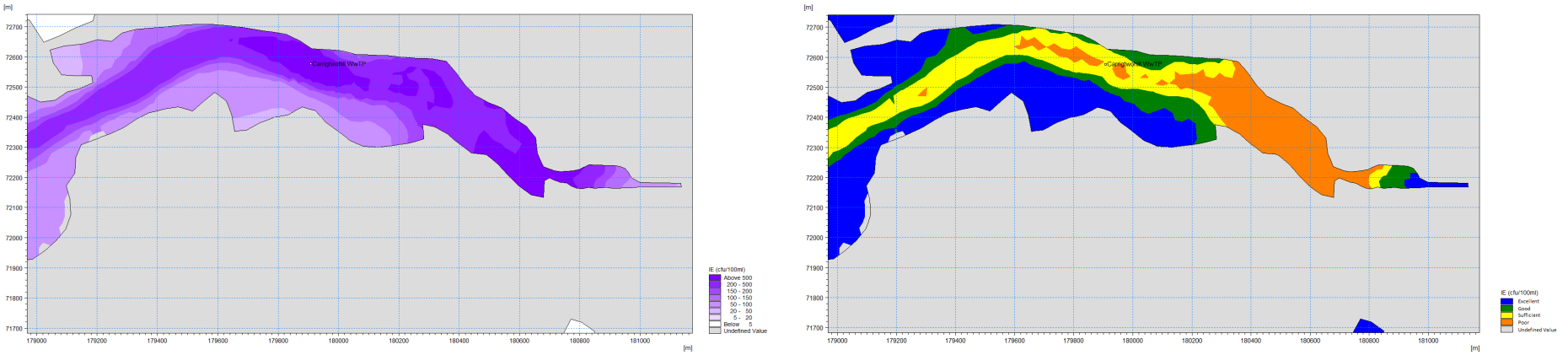


Figure 3-72 Concentration and Indicative Quality Plots for IE (95th percentile) – Winter, Cork Harbour

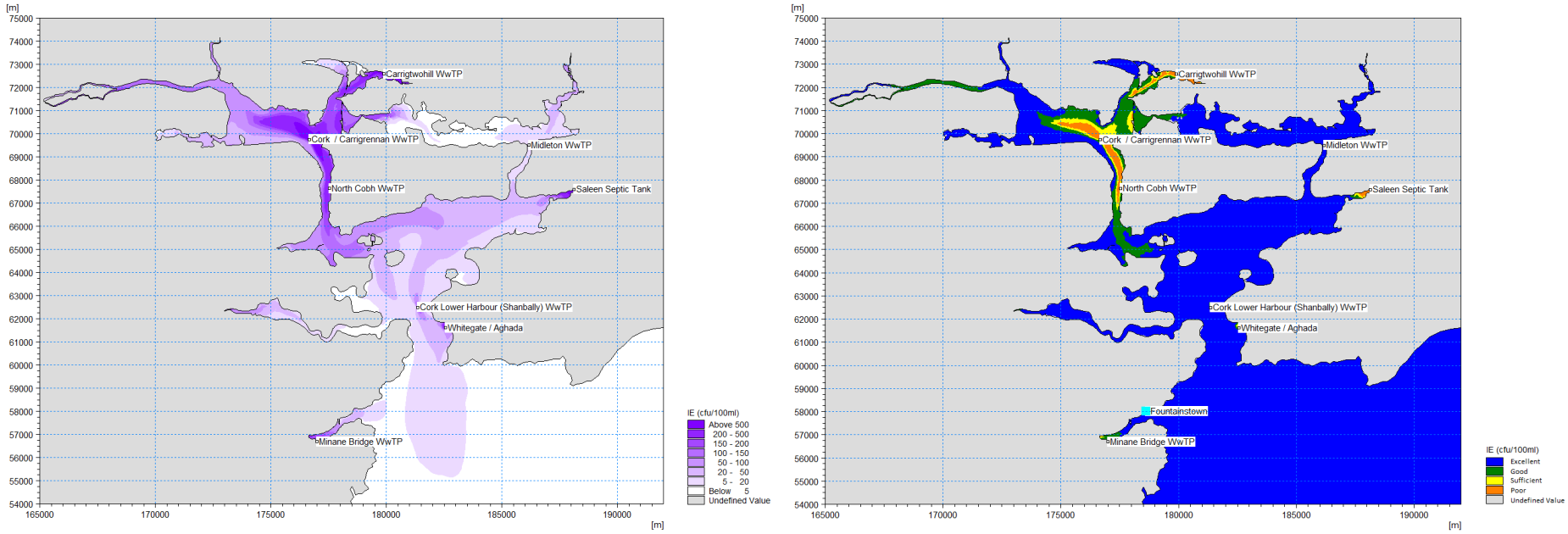


Figure 3-73 Concentration and Indicative Quality Plots for IE (95th percentile) – Winter, Lough Mahon and North Channel Great Island

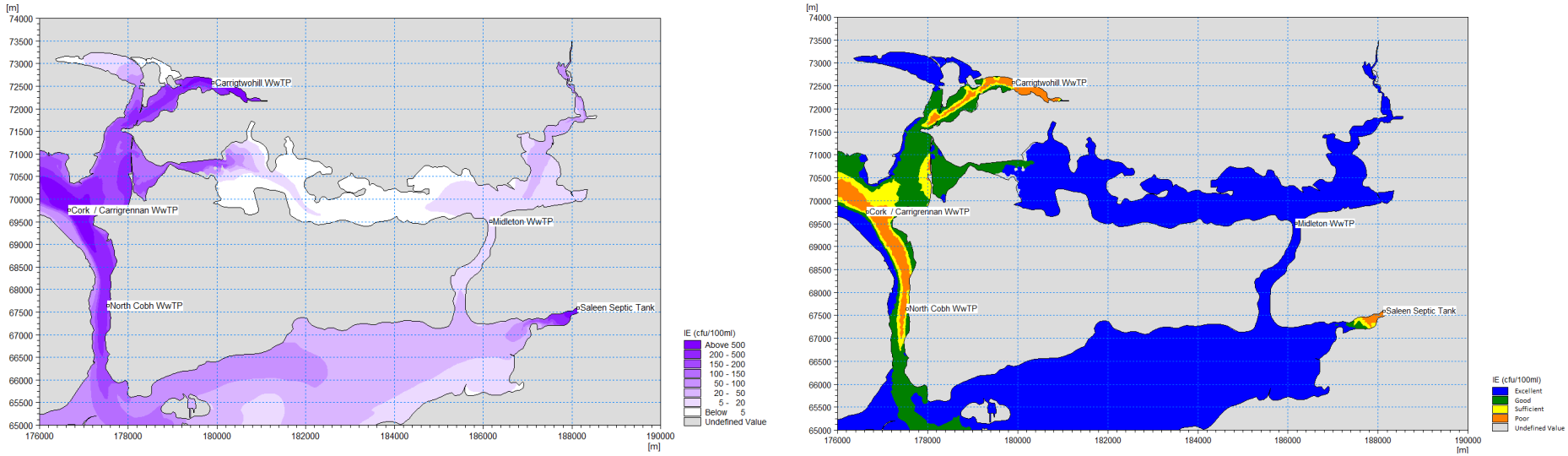


Figure 3-74 Concentration and Indicative Quality Plots for IE (95th percentile) – Winter, Midleton Discharge Plume

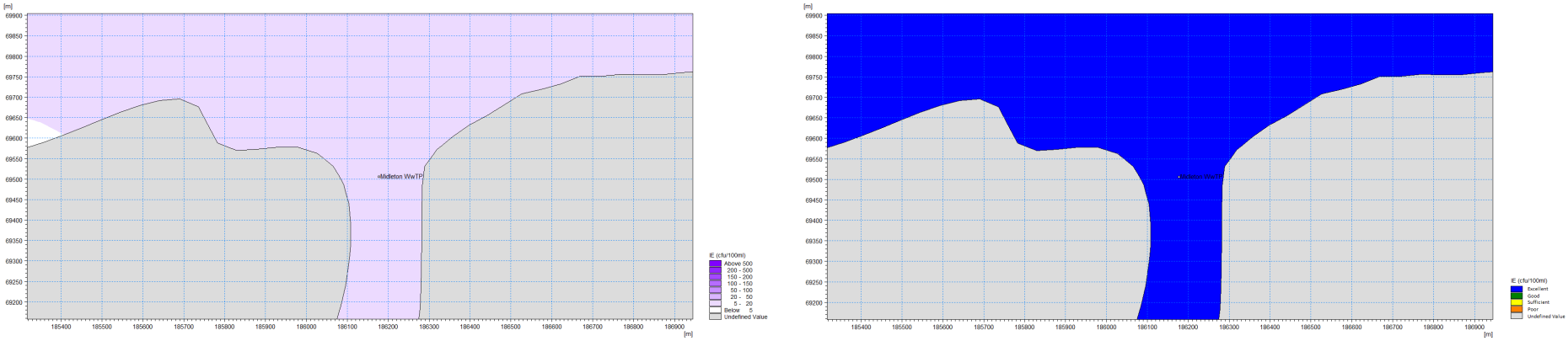
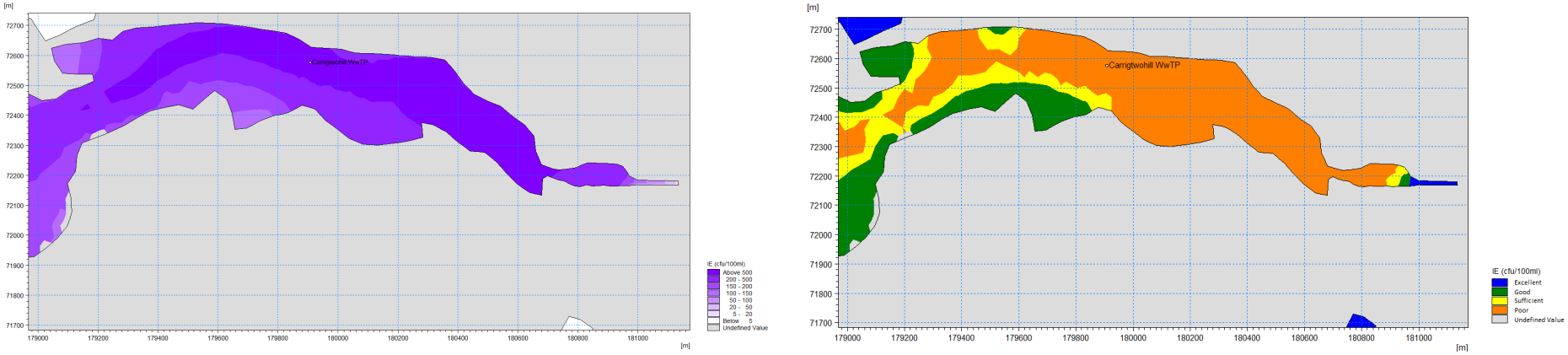


Figure 3-75 Concentration and Indicative Quality Plots for IE (95th percentile) – Winter, Carrigtwohill Discharge Plume



3.4.4 Source Apportionment

This section presents the source apportionment results for EC and IE for the summer and winter Future scenario. This scenario is based on continuous discharges only. A total of six assessment locations have been chosen in Cork Harbour as shown in Figure 3-75 (Drawing No: P2443D-SCEN-002-B). These locations were selected to represent water quality in the Designated SFWs and BW.

The proportional contribution to impacts from each individual source (source apportionment) has been calculated at the six assessment locations for summer and winter at two assessment thresholds (95th percentile and geomean). Note that source apportionment for EC and IE are presented at the 95th percentile concentration (relating to the BW standards), but only source apportionment for EC is presented at the geomean concentration (relating to the SFW standard).

Source apportionment results for the 95th percentile concentrations are summarised in Table 3-3 to Table 3-5 and in Figure 3-76. Source apportionment for the geomean concentration is shown in Table 3-6 to Table 3-7 and Figure 3-77 to Figure 3-78.

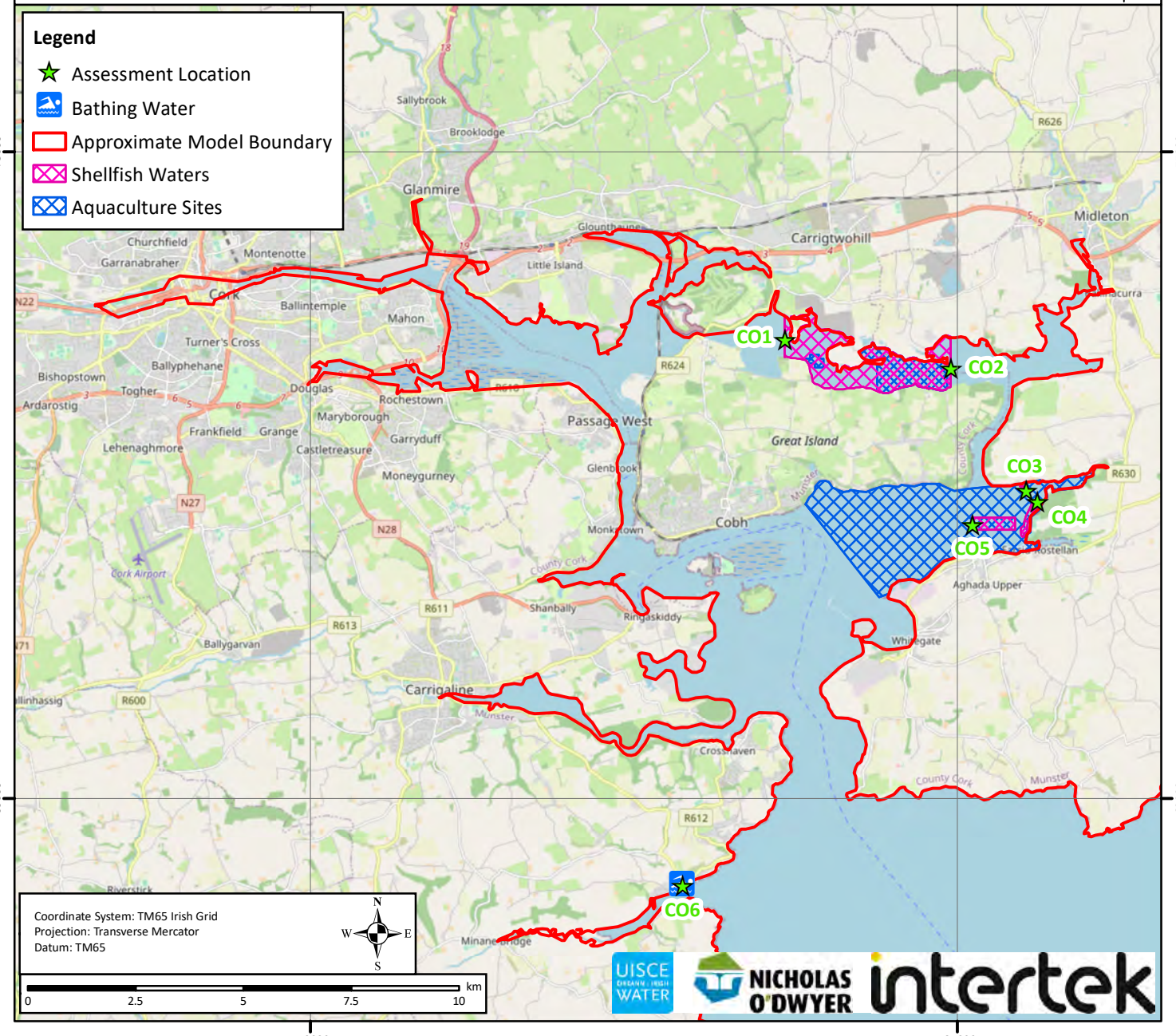
The source apportionment tables and pie charts should be viewed together when taking into account the total impact (concentration) at these sites; for example, a source may be a significant contributor but to a low impact (concentration). To facilitate this, the relevant 95th percentile or geomean concentrations for each assessment location are included in the pie charts and in the tables.

It should be noted that source apportionment is not provided for the assessment locations that never exceed the target thresholds of 110 EC/100 ml (target geomean) or either 250 EC/100 ml or 100 IE/100 ml (indicative Excellent BW threshold).

COASTAL MODELLING FOR CORK HARBOUR

SCENARIO ASSESSMENT - Cork Harbour Assessment Locations

Drawing No: P2443D-SCEN-002 | B



Document Path: J:\P2443\Mxd\08_SCEN\P2443D-SCEN-002.mxd Date: 23/03/2023

3.4.4.1 95th percentile Concentration

No source apportionment is presented at the 95th percentile concentration for the summer EC, summer IE or winter IE scenarios as these never exceed the 250 EC/100 ml or 100 IE/100 ml thresholds. The 95th percentile concentrations are presented for these scenarios in Table 3-3 and Table 3-4. The pass/fail criteria are based on the Excellent standards of the BWD although in reality these only apply (for summer) at the Fountainstown Designated BW (C06), and not at the five other locations which are within a SFW.

Table 3-3 95th percentile Concentrations for the Six Assessment Locations – Summer

Assessment Location	CO1	CO2	CO3	CO4	CO5	CO6
95th percentile (EC/100 ml)	1	1	89	29	3	45
95th percentile (IE/100ml)	1	1	17	7	1	6
Pass / Fail Criteria?	Pass	Pass	Pass	Pass	Pass	Pass

Table 3-4 95th percentile Concentrations for the Six Assessment Locations – Winter

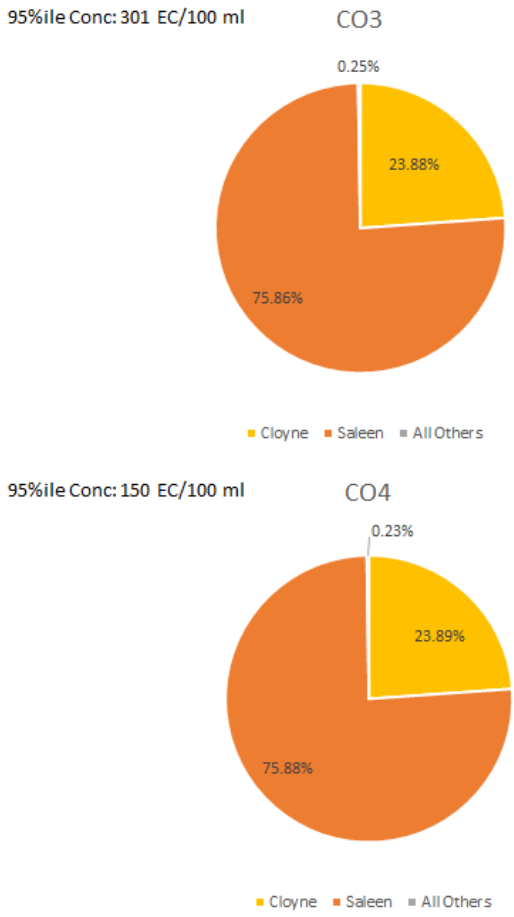
Assessment Location	CO1	CO2	CO3	CO4	CO5	CO6
95th percentile (EC/100 ml)	7	8	301	150	59	106
95th percentile (IE/100 ml)	5	5	36	21	19	24
Pass / Fail Criteria?	Pass	Pass	Fail	Pass	Pass	Pass

Source apportionment at the 95th percentile concentration is presented for the winter EC scenario in Table 3-5 and Figure 3-76. Source apportionment is only presented for CO3 and CO4, as all other sites never exceed the 250 EC/100 ml threshold. The source apportionment results indicate that Saleen Septic Tank and Cloyne WwTP are the biggest contributors at CO3 and CO4, contributing 76% and 24% respectively at both assessment locations.

Table 3-5 Source Apportionment for the Six Assessment Locations at the 95th Percentile Threshold – Winter EC

Assessment Location	CO1	CO2	CO3	CO4	CO5	CO6
95th percentile (EC/100 ml)	7	8	301	150	59	106
Pass / Fail Criteria?	Pass	Pass	Fail	Pass	Pass	Pass
Source						
Cloyne WwTP			24%	24%		
Saleen Septic Tank			76%	76%		
All Others						
Total			100%	100%		

Figure 3-77 Source Apportionment for the Assessment Locations at the 95th percentile Concentration – Winter EC



3.4.4.2 Geomean Concentration

Source apportionment results at the geomean concentration are presented in Table 3-6 and Figure 3-77 for summer and Table 3-7 and Figure 3-78 for winter. Source apportionment for the geomean concentration is only presented for EC since this is the only bacterial determinand relevant to the geomean SFW standard. Note that site C06 (Fountainstown Designated BW) does not lie within a SFW so the standard does not apply here, but results are presented anyway for completeness.

For summer, source apportionment results are presented for CO3 and CO6, as all other sites never exceed the 110 EC/100 ml concentration. The source apportionment results show that during the summer, Saleen Septic Tank is the largest contributor at CO3 accounting for 76% of total impact. The largest contributer at CO6 is Ringabella River, accounting for 88% of total impact.

For winter, source apportionment results are presented for all sites excluding CO2, as this site does not exceed the 110 EC/100 ml concentration. Source apportionment indicates that the largest contributor at CO1 and CO5 is Cork / Carrigrennan WwTP, contributing 65% and 58%, respectively. The largest contributor at CO3 and CO4 is Saleen Septic Tank, contributing 76% at both assessment locations. At CO6, the largest contributor is Ringabella River, contributing 68% of total impacts.

Table 3-6 Source Apportionment for the Six Assessment Locations at the Geomean – Summer

Assessment Location	CO1	CO2	CO3	CO4	CO5	CO6
Geomean (EC/100 ml)	1	1	3	2	1	6
Pass / Fail Criteria?	Pass	Pass	Pass	Pass	Pass	Pass
Source						
Cloyne WwTP			24%			
Minane River						10%
Minane Bridge WwTP						2%
Ringabella River						88%
Saleen Septic Tank			76%			
Total			100%			100%

Figure 3-78 Source Apportionment at the Geomean Concentration – Summer

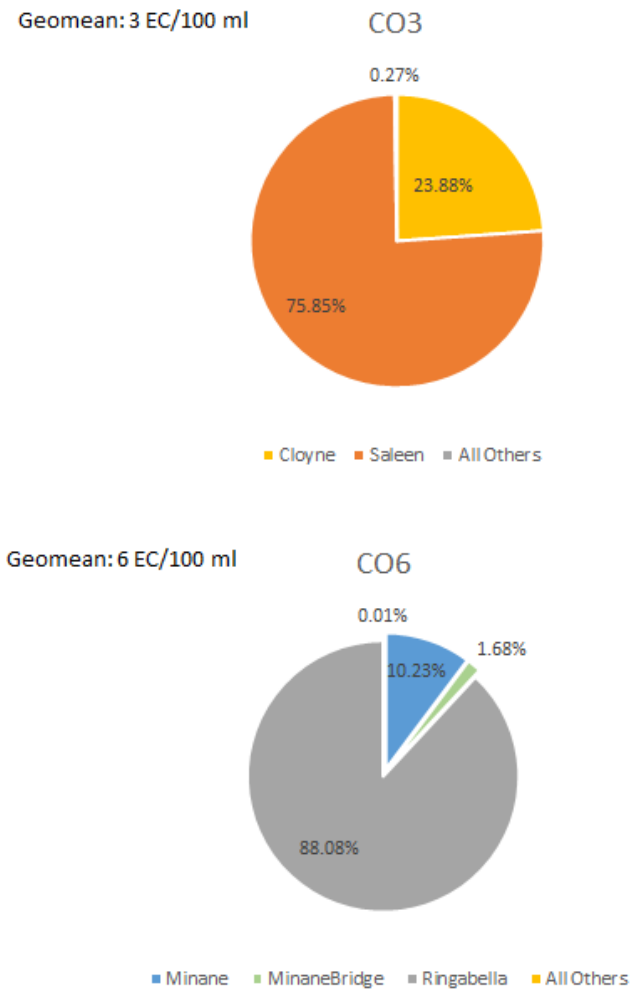
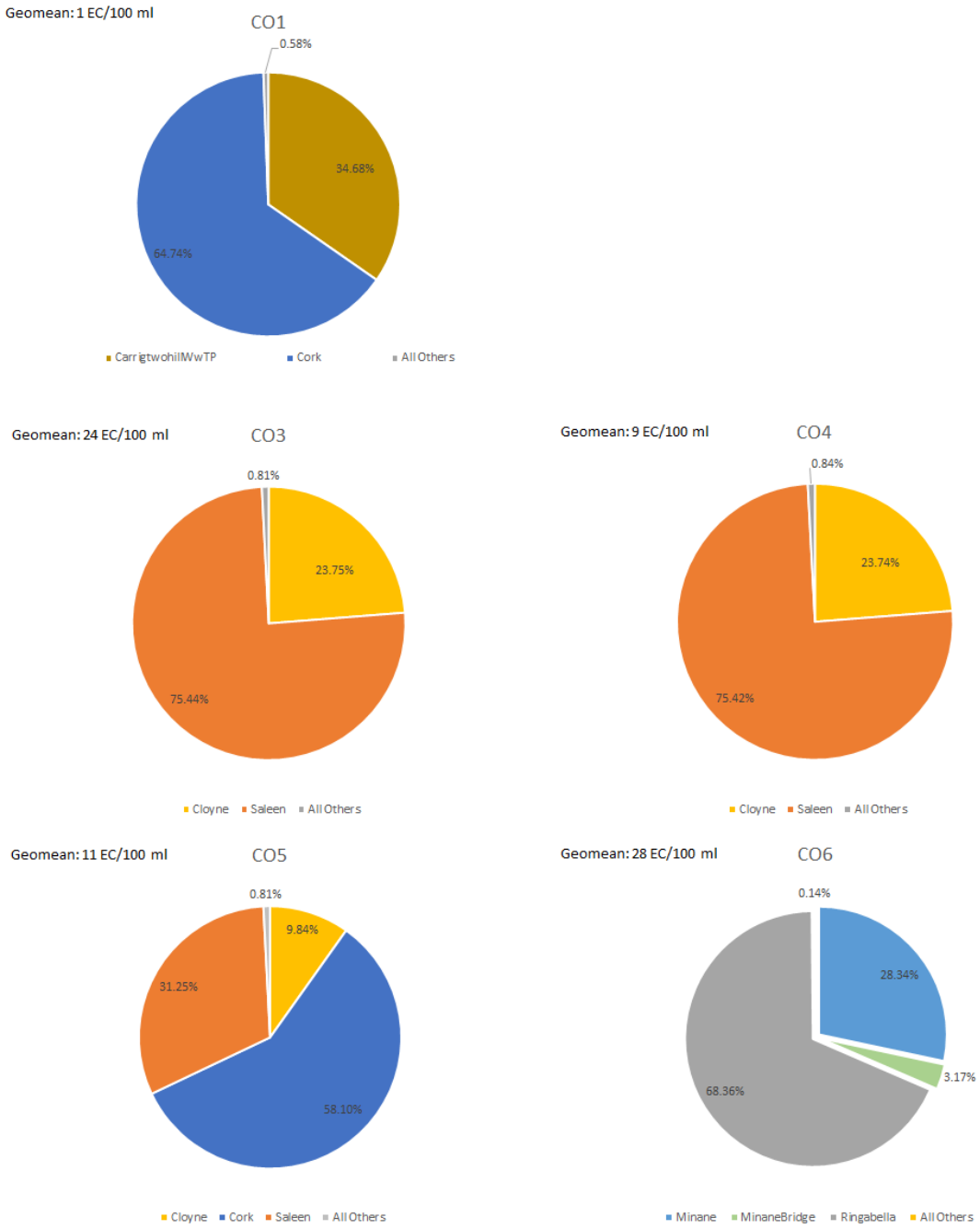


Table 3-7 Source Apportionment for the Six Assessment Locations at the Geomean – Winter

Assessment Location	CO1	CO2	CO3	CO4	CO5	CO6
Geomean (EC/100 ml)	1	2	24	9	11	28
Pass / Fail Criteria?	Pass	Pass	Pass	Pass	Pass	Pass
Source						
Carrigtwohill WwTP	35%					
Cloyne WwTP			24%	24%	10%	
Cork / Carrigrennan WwTP	65%				58%	
Minane River						28%
Minane Bridge WwTP						3%
Ringabella River						68%
Saleen Septic Tank			75%	75%	31%	
All Others			1%	1%	1%	1%
Total	100%		100%	100%	100%	100%

Figure 3-79 Source Apportionment at the Geomean Concentration – Winter



4. CONCLUSIONS

Uisce Éireann required a strategic numerical water quality model to undertake the assessments as required for planning and Wastewater Discharge Authorisation (WWDA) licensing purposes and to assist Uisce Éireann in identifying necessary asset improvements that would lead to a significant improvement in the water quality in Cork Harbour.

The calibrated and validated Cork Harbour model (Intertek, 2023b; 2023c) has been used to deliver a number of assessments to establish the impact of the existing Uisce Éireann continuous discharges on key receptors in the harbour. These investigations include:

- Deterministic assessments of the mixing zone of Uisce Éireann discharges in terms of key WFD parameters of biochemical oxygen demand (BOD), dissolved inorganic nitrogen (DIN) and orthophosphate (as molybdate reactive phosphorus (MRP)) against Environmental Quality Standard (EQS) and Water Framework Directive (WFD) criteria. In addition, the un-ionised ammonia mixing plume has also been assessed to provide additional information with respect to potential for ecotoxic effects in the vicinity of Uisce Éireann discharges.
- Trophic assessments of the impact of DIN and MRP over the wider Cork Harbour Waterbody, particularly Nutrient Sensitive Waters, against relevant WFD standards in each WFD Waterbody within Cork Harbour.
- Microbiological impacts on Bathing Waters (BW) and Designated Shellfish Waters (SFW) in Cork Harbour.

The results of the Future and Future 'Notionally Clean' River applications scenarios are presented in this report. In both scenarios, the input loads have been modified to represent the proposed future characteristics of Uisce Éireann discharges and maximum permitted flow and concentration for industrial discharges.

In the Future 'Notionally Clean' River scenario the rivers have been represented as 'notionally clean' (i.e. upstream sources from human activity, including farming and septic tanks, are removed) . For the Future scenario rivers have been characterised using available gauging and Environmental Protection Agency (EPA) data.

The Future scenario represents a worst-case condition with all discharges operating at their maximum permitted emission limit values at the same time. The key model predictions from this scenario are:

- **BOD** concentrations in summer and winter around Cork Harbour are generally <1 mg/l with most areas having an indicative quality of High.

  There is a clearly defined BOD mixing zone of ca. 200m in length and ca. 100m in width in the immediate vicinity of the Carrigtwohill Wastewater Treatment Plant (WwTP) outfall. Outside of this mixing zone Good indicative quality is achieved.

  At Midleton WwTP, there is no discernible mixing zone as the EQS value is met immediately at the surface with concentrations (~1 mg/l) around the discharge. Generally this area has an indicative quality of High.

- **DIN** concentrations around Cork Harbour are generally <0.5 mg/l in summer, with most areas having an indicative quality of High.

  Elevated DIN concentrations are predicted around Carrigtwohill WwTP, with an indicative quality of Moderate, however these are not sufficient to have any significant influence on the Coastal WFD waterbodies where a DIN WFD target is applicable.

  At Midleton WwTP, there is no predicted elevation in DIN concentrations around the discharge; modelled concentrations are <0.5 mg/l with an indicative quality of High.

  DIN concentrations are generally higher in winter with the majority of areas across Cork Harbour having an indicative quality of Good or Moderate.

- **MRP** concentrations around Cork Harbour are generally <0.02 mg/l in summer, with most areas in Cork Harbour having an indicative quality of High.

  Elevated MRP concentrations are predicted around Carrigtwohill WwTP discharge. The shallow bathymetry and enclosed nature of the WB at Carrigtwohill gives rise to a mixing zone around the outfall. In summer the mixing zone extends approximately 700m downstream (width approximately 100m wide) and approximately 1000m long and 200m wide upstream, in winter the mixing zone extends across the channel width approximately 1000m upstream and downstream of the discharge location. Indicative MRP quality of Moderate prevails locally and upstream of the outfall.

  At Midleton WwTP, the whole area has an indicative quality of High, with no discernible mixing zone. MRP concentrations around Cork Harbour are generally higher in winter, with large regions of Cork Harbour having an indicative quality of Good.

- ***E. coli*** **(EC)** concentrations are generally low in Cork Harbour with most areas falling below the geomean SFW target of 110 EC/100 ml or the 95th percentile concentration for Excellent BW Quality of 250 EC/100 ml. There are some local elevated EC concentrations predicted in the immediate vicinity of the Carrigtwohill WwTP however there is no bacterial standard applicable at this location and impacts do not influence bacterial concentrations at any SFW or BW. Modelled EC concentrations around Midleton WwTP were below limit of detection levels with concentrations of <5 EC/100 ml predicted at both the geomean and 95th percentile concentrations.

  Modelled EC concentrations in the Designated SFWs do not exceed the 110 EC/100 ml geomean target. Modelled EC concentrations at Fountainstown Designated BW suggest an indicative quality of Excellent.

- **Intestinal enterococci (IE)** 95th percentile concentrations around Cork Harbour are generally <100 IE/100 ml with most areas having an indicative quality of Excellent. There are some local elevated IE concentrations predicted in the immediate vicinity of the Carrigtwohill WwTP however there is no bacterial standard applicable at this location and impacts do not influence bacterial concentrations at any SFW or BW. Modelled 95th percentile IE concentrations of <5 IE/100 ml are predicted around Midleton WwTP, equivalent to an indicative bathing water quality of Excellent. Modelled IE concentrations at Fountainstown Designated BW suggest an indicative quality of Excellent.

- **Un-ionised ammonia** concentrations around Cork Harbour are generally <0.005 mg/l in summer and winter. Concentrations are elevated around Carrigtwohill WwTP (< 0.03 mg/l). At Midleton WwTP, the un-ionised ammonia concentrations around the discharge are low at <0.005 mg/l.

The predictions of the Future scenario indicate that the water quality impacts from Midleton WwTP are minimal. Local impacts for all parameters assessed in this study are observed around the Carrigtwohill WwTP discharge where dilution characteristics are less favourable than Midelton and the mixing zones (where applicable) have been assessed as part of this study.

Bacteria concentrations in Cork Harbour are generally low and predicted impacts from Uisce Éireann assets do not significantly impact water quality in the Designated SFWs and BW, nor preclude the achievement of WFD objectives for protected areas.

The Future 'Notionally Clean' River scenario provides an assessment of the maximum potential impact of Carrigtwohill WwTP on the trophic status in Lough Mahon and the mixing zone around Harper's Island. The key model predictions from this scenario are:

- **DIN** concentrations around Carrigtwohill WwTP outfall are elevated in summer and winter, where the indicative quality is Moderate and Good. At Midleton WwTP outfall, modelled concentrations are low and the indicative quality is High in the surrounding area in summer and winter.
- **MRP** concentrations around Carrigtwohill WwTP outfall are elevated in summer, where an indicative quality of Good is predicted except for an area of Moderate within the discharge mixing zone, which extends over an area 700m downstream of the discharge (width 100m), and in the shallow waters upstream of the discharge (approx. 1000m long and 200m wide at the head of the transitional water). In winter, elevated MRP concentrations are also seen locally around Carrigtwohill WwTP, but an indicative quality of Good is predicted. This is an improvement on summer conditions. At Midleton WwTP outfall, there is a small area of elevated MRP concentrations (~ 0.04 mg/l) around the discharge in summer and winter but the concentration is below the EQS and the surrounding area has an indicative quality of High.

The predictions of the Future 'Notionally Clean' River scenario indicate that the rivers are significant contributors to water quality impacts as the indicative quality across Cork Harbour significantly improves as compared to the Future scenario. The impacts from Midleton WwTP are minimal. However, concentrations for DIN and MRP are elevated around the Carrigtwohill WwTP discharge. The mixing zone for each of these parameters has been assessed as part of this study under notionally clean conditions.

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2 Intertek (2023b). Cork Harbour Calibration and Validation Report: Volume 2, Microbiological Validation Report. Report No. P2443_R6021_Rev1, August 2023.

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5 Nicholas O'Dwyer (2022a). Cork Harbour Strategic Modelling Study: Environmental Scoping Report. Rev2, October 2022.

6 Nicholas O'Dwyer. (2022b). Survey Interpretive Report for Cork Harbour. Rev0, April 2022.

7 Techworks Marine (TWM) (2022). IW NOD – Cork Harbour Survey – TWM Final Report. Rev1, April 2022.

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APPENDIX A

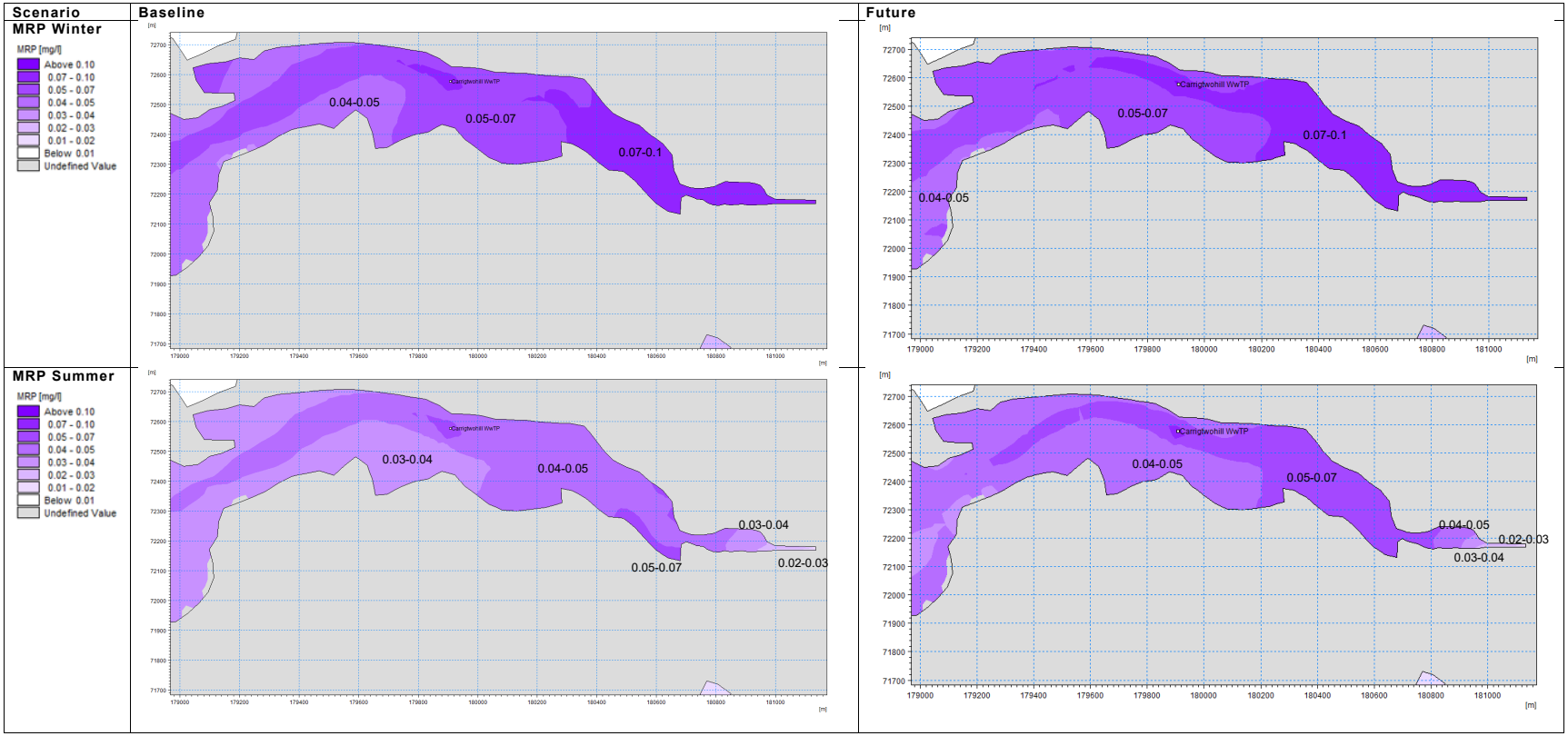
Supplemental Water Quality Modelling Plots

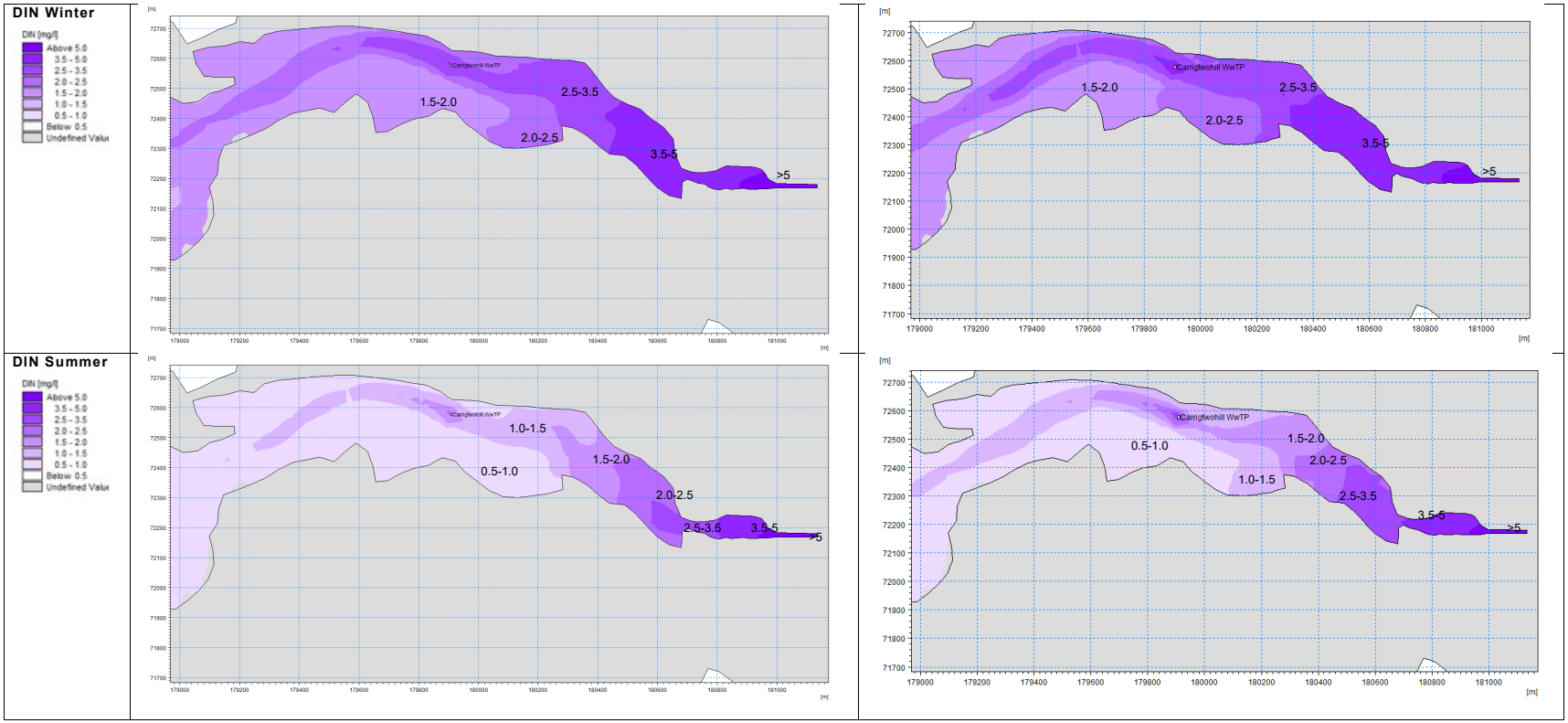
This appendix document has been prepared to present supplemental water quality modelling plots not presented in the **Water Quality Modelling Report, May 2023.** Additional water quality plots of the Carrigtwohill WwTP primary discharge, representative of baseline dissolved inorganic nitrogen (DIN) and molybdate reactive phosphorous (MRP), were prepared to provide additional context on the net impact of the future scenario. This additional context has been presented to support the assessment of impacts undertaken in **Attachment D.2.2** AA Screening and NIS (June 2023) and **Attachment B.5** Environmental Impact Assessment Report (June 2023).

The following table presents concentration plots of DIN and MRP around the Carrigtwohill WwTP primary discharge under baseline and future conditions (note future conditions are as presented in the Water Quality Modelling Report Section 3.3). The summer and winter plots of each parameter are presented to allow direct comparison between the baseline and future scenario.

The detailed hydrodynamic water quality model of Cork Harbour as presented in the Water Quality Modelling Report was used to establish the plots presented in the following table. All model inputs for these baseline model runs were identical to the future scenario with the exception of the Uisce Éireann's Continuous Discharges flow rates. The discharge rates utilised in the baseline scenario) were set to the mean measured flows from each WwTP between January 2019 and June 2022. Concentrations were set to the maximum ELV permitted for each WwTP. For further details on the hydrodynamic water quality, please refer to the Water Quality Modelling Report.

Table 1 Summer and Winter DIN and MRP Absolute Concentrations Surrounding the Carrigtwohill WwTP Primary Discharge; Baseline and Future Condition




DIN Winter
DIN [mg/l]
Above 5.0
3.5 - 5.0
2.5 - 3.5
2.0 - 2.5
1.5 - 2.0
1.0 - 1.5
0.5 - 1.0
Below 0.5
Undefined Value
1.5-2.0
2.5-3.5
2.0-2.5
3.5-5
>5
DIN Summer
1.0-1.5
0.5-1.0
1.5-2.0
2.0-2.5
2.5-3.5
3.5-5
>5