SECTION D – EXISTING ENVIRONMENT & IMPACT OF THE DISCHARGE(S)

Attachment D1: Marine Modelling Study Report

- **Attachment D.1a: Phase 1 Model Scoping report**
- **Attachment D.1b: Phase 2 Survey Interpretative report**
- **Attachment D.1c: Phase 3 Model Calibration report**
- **Attachment D.1d: Phase 4 Modelling report**

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Youghal Marine Modelling Study

Modelling Report

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Quality information

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Revision History

Revision	Revision date	Details	Authorized	Name	Position
1	23/09/2020	Draft	RS	Rob Stevens	Project Manager
2	30/09/2020	Final	RS	Rob Stevens	Project Manager
3	23/10/2020	Revised Final	RS	Rob Stevens	Project Manager

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Glossary

1D, 2D, 3D	1-, 2- or 3-dimensions, assumed to be spatial dimensions when referring to a model.
AA	Annual Average
AD	Advection-Dispersion
ADCP	Acoustic Doppler Current Profiler
AER	Annual Environmental Report
BOD	Biochemical Oxygen Demand
BW	Bathing Water
BWD	Bathing Water Directive (EU, 2006).
CD	Chart datum
CFRAMS	Catchment Flood Risk Assessment & Management Studies
CIS	European Commission Common Implementation Strategy
DAP	Drainage Area Plan
Data Manual	A structured data repository kept 'live' throughout the Marine Modelling Study and maintained by the Consultant for duration of appointment.
dfsX/ dfs0/ dfs1/ dfs2/ dfsu	A DHI proprietary file of dfs0, dfs1, dfs2 or dfsu format.
DHI	Danish Hydraulics Institute, vendor for MIKE by DHI modelling suite
DIN	Dissolved Inorganic Nitrogen
DO	Dissolved Oxygen
EC	Escherichia Coli European Commission
ELV	Emission Limit Value
EPA	Environmental Protection Agency
EQS	Environmental Quality Standard
EU	European Union
Exceedance Plot	Plot detailing modelled concentration at each model element for a specified statistical metric (e.g. 95%ile, Median)
FC	Faecal Coliforms
FIB	Faecal Indicator Bacteria
FSU	Flood Studies Update
GSI	Geological Survey of Ireland
GUI	Graphical User Interface
HAB	Harmful Algal Bloom
HAT	Highest Astronomical Tide
HD	Hydrodynamic
ICPSS	Irish Coastal Protection Strategy Study
ID	Initial Dilution
IE	Intestinal Enterococci
IPPC	Integrated Pollution Prevention and Control
IW	Irish Water
IWDDS	Interactive Web Data Delivery System
L/h/Day	Litres per Head per Day
LAT	Lowest Astronomical Tide
LiDAR	Light Detection and And Ranging
LOD	Limit of Detection
MAC	Maximum Allowable Concentration
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs

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MIKE	MIKE Powered by DHI, a DHI Marine Modelling Software Suite of modelling software for modelling hydrodynamics, water quality and sediment transport in a wide range of aquatic environments.
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MMS	Marine Modelling Study
mOD	Metres above Ordnance Datum (Mean sea level at Malin Head)
MRP	Molybdate-Reactive Phosphorous
MSL	Mean Sea Level
MSR	Model Scoping Report
OPW	Office of Public Works
Parameter	A specific parameter of interest. To be used in preference to other expressions such as “state parameter” or “contaminant of interest”.
PE	Population Equivalent
PSU	Practical Salinity Units
Q	Discharge rate, normally in m3/s or litres/s
QA	Quality Assurance
RMSE	Root Mean Squared Error
SAC	Special Area of Conservation
SFW	Shellfish Water
SPA	Special Protection Area
Study	Marine Modelling Study
TOR	Terms of Reference describing the scope of work, tasks and objectives for the Study
TSAS	EPA Trophic Status Assessment Scheme
WFD	Water Framework Directive
WWTP	Wastewater Treatment Plant

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1. Introduction

1.1 Background

AECOM has been commissioned to complete a Marine Modelling Study to help in the assessment of discharges of treated wastewater from Youghal Wastewater Treatment Plant (WwTP) to the tidal River Blackwater Estuary.

A Licence Review of the existing Licence, which has been granted under the Wastewater Discharge Authorisation Regulations, is to be submitted to the Environmental Protection Agency (EPA) which must be supported with an assessment of the potential impacts on environmental water quality. This report provides the details of the modelling work completed to assess the significance of the discharges to support the determination of the environmental impact (if any) of the discharges and to inform the Licence Review.

The Marine Modelling Study is undertaken in four phases and this report is the deliverable for Phase 4: Modelling Report. The previous phases of the project have produced the deliverables listed below. Where appropriate relevant key information has been copied from them to this report.

- Phase 1: Model Scoping Report (MSR) (AECOM, 2020a)[1].
- Phase 2: Survey Interpretive Report (SIR) (AECOM, 2020b)[1].
- Phase 3: Calibration and validation Report (CR) (AECOM, 2020c)[1]

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1.2 Objective

The purpose of this report is to investigate the dispersion of effluent from the primary discharge from the Youghal WwTP in the receiving waters of Youghal Harbour, the Blackwater Estuary and wider area. The assessments of the resulting concentrations of BOD, DIN, MRP, ammonia (and inferred unionised ammonia), EC and IE have been undertaken using both absolute and relative methods.

The locations of the existing primary discharge point, Dunnes Park outfall and the proposed outfall are shown in Figure 1-1. The key sensitive receptors of the public beaches and the shellfish harvesting areas are also shown.

[1] The abbreviations MSR, SIR and CR are used in this report without further reference to the AECOM, 2020 documents.

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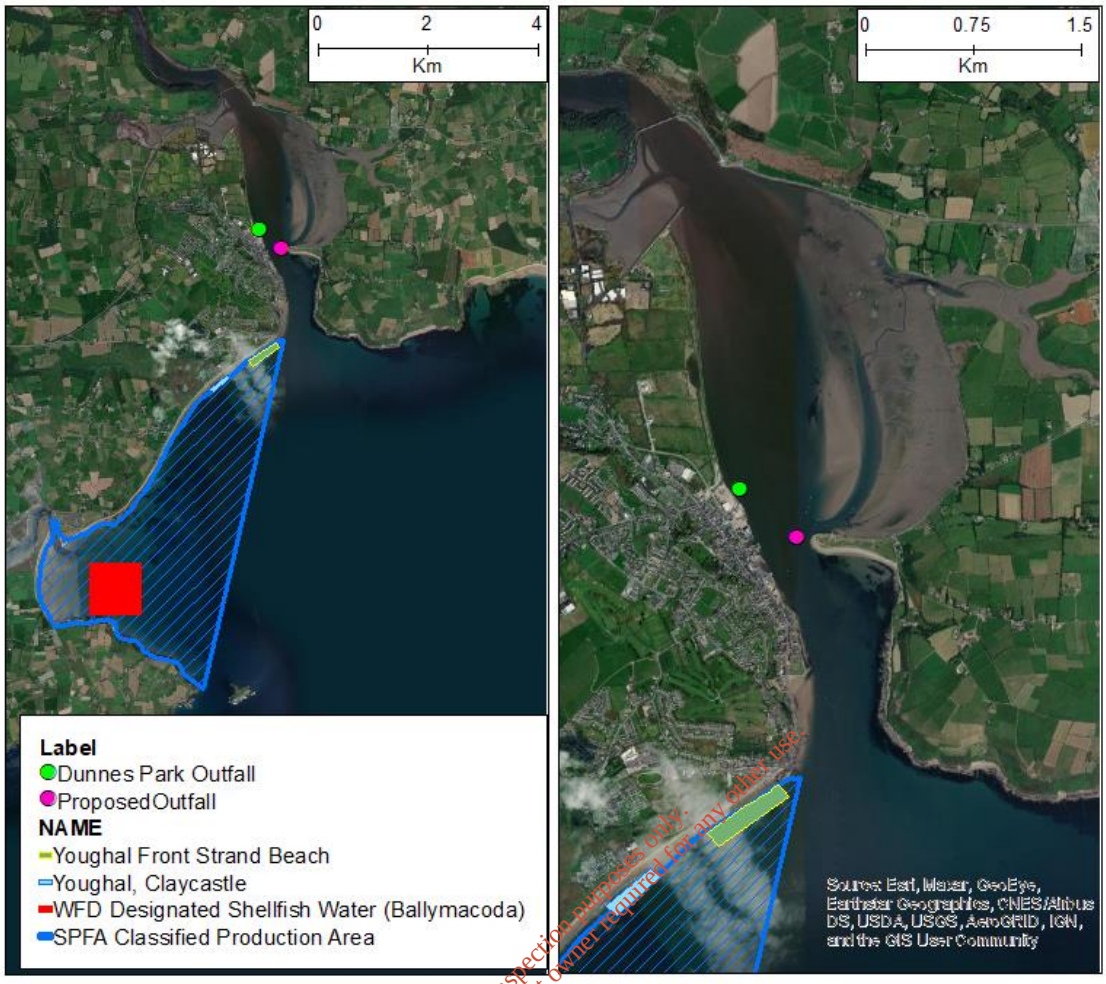

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Figure 1-1. Map of the study area showing the locations of the existing and proposed outfalls and key sensitive receptors.

1.3 Scenarios

The calibrated hydrodynamic and water quality model presented in the CR has been used to evaluate five different scenarios. Each of the scenarios is numbered as shown below (Scenarios 1 and 2 were used in model development and calibration):

3. Existing (Baseline 11 168 PE) Summer
4. Existing (Baseline 11 168 PE) Winter
5. Future (16 000PE Loading) Summer
6. Future (16 000PE Loading) Winter
7. Future (16 000PE Loading) Summer + New outfall location
8. Future (16 000PE Loading) Winter + New outfall location

Each scenario utilises a specific hydrodynamic model that simulates different environmental and/or discharge conditions to investigate the dispersion of the water quality parameters. A water quality model is then run for each water quality parameter. To identify a specific model run a unique identifier was allocated of the format XX.YY where XX represents the underlying hydrodynamic (HD) model and is the same as the scenario number. The YY provides a two-digit reference of 01 to 06 representing each of the parameters (BOD, EC, IE, DIN, MRP, ammonia). A full list of the run codes used is provided in Table 1.1.

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The table also shows the Irish Water code that includes the above ground asset and influent loading codes as summarised in Table 1.2 and correspond to the approach proposed in the technical standard (Irish Water, 2020). The effluent discharge and concentrations for each scenario are summarised in Table 1.3 and provided in the Model Log in Appendix A. The concentration used for the future scenarios correspond to the ELV values for DIN, BOD and ammonia. The values for EC and IE are accepted values for the type of treatment at the Youghal WwTP and account for the use of UV treatment during the summer. A conservative value of 10mg/l has been used for MRP as provided by Irish Water.

The purpose of the different hydrodynamic scenarios is to provide “typical” environmental conditions and are not meant to represent any specific calendar dates. Similarly, the water quality models simulate specific concentrations of each parameter in the environment and are representative rather than for a specific set of dates.

For the purposes of the underlying hydrodynamics however, the periods of August 2019 and January 2020 have been used for the summer and winter scenarios.

Further description of the model set-up is provided in Section 1.5.

Table 1.1. Scenario descriptions and run codes

Run code	IW Code	Season	Parameter	Discharge Location
3	**A01s**	**Summer**	**HD**	**Dunnes Park**
3.01	A01s_BOD	Summer	BOD	Dunnes Park
3.02	A01s_EC	Summer	EC	Dunnes Park
3.03	A01s_IE	Summer	IE	Dunnes Park
3.04	A01s_DIN	Summer	DIN	Dunnes Park
3.05	A01s_MRP	Summer	MRP	Dunnes Park
3.06	A01s_Amm	Summer	Ammonia	Dunnes Park
4	**B01w**	**Winter**	**HD**	**Dunnes Park**
4.01	B01w_BOD	Winter	BOD	Dunnes Park
4.02	B01w_EC	Winter	EC	Dunnes Park
4.03	B01w_IE	Winter	IE	Dunnes Park
4.04	B01w_DIN	Winter	DIN	Dunnes Park
4.05	B01w_MRP	Winter	MRP	Dunnes Park
4.06	B01w_Amm	Winter	Ammonia	Dunnes Park
5	**A03s**	**Summer**	**HD**	**Dunnes Park**
5.01	A03s_BOD	Summer	BOD	Dunnes Park
5.02	A03s_EC	Summer	EC	Dunnes Park
5.03	A03s_IE	Summer	IE	Dunnes Park
5.04	A03s_DIN	Summer	DIN	Dunnes Park
5.05	A03s_MRP	Summer	MRP	Dunnes Park
5.06	A03s_Amm	Summer	Ammonia	Dunnes Park
6	**B03w**	**Winter**	**HD**	**Dunnes Park**
6.01	B03w_BOD	Winter	BOD	Dunnes Park
6.02	B03w_EC	Winter	EC	Dunnes Park
6.03	B03w_IE	Winter	IE	Dunnes Park
6.04	B03w_DIN	Winter	DIN	Dunnes Park
6.05	B03w_MRP	Winter	MRP	Dunnes Park
6.06	B03w_Amm	Winter	Ammonia	Dunnes Park

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Run code	IW Code	Season	Parameter	Discharge Location
7	**C03s**	**Summer**	**HD**	**Proposed Outfall**
7.01	C03s_BOD	Summer	BOD	Proposed Outfall
7.02	C03s_EC	Summer	EC	Proposed Outfall
7.03	C03s_IE	Summer	IE	Proposed Outfall
7.04	C03s_DIN	Summer	DIN	Proposed Outfall
7.05	C03s_MRP	Summer	MRP	Proposed Outfall
7.06	C03s_Amm	Summer	Ammonia	Proposed Outfall
8	**C03w**	**Winter**	**HD**	**Proposed Outfall**
8.01	C03w_BOD	Winter	BOD	Proposed Outfall
8.02	C03w_EC	Winter	EC	Proposed Outfall
8.03	C03w_IE	Winter	IE	Proposed Outfall
8.04	C03w_DIN	Winter	DIN	Proposed Outfall
8.05	C03w_MRP	Winter	MRP	Proposed Outfall
8.06	C03w_Amm	Winter	Ammonia	Proposed Outfall

Table 1.2. Irish Water run codes (above ground assets and influent loading)

Above Ground Assets		Influent Loading	
Code	**Description**	**Code**	**Description**
A	Dunnes Park with UV	1	Existing
B	Dunnes Park without UV	2	Current Design
C	New Outfall with UV	3	Future (16 000PE)
D	New Outfall without UV		

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Table 1.3. List of scenarios and effluent discharge rates and concentrations

Scenario	Discharge [m^3/s]	BOD [mg/l]	EC [cfu/ 100ml]	IE [cfu/ 100ml]	DIN [mg/l]	MRP [mg/l]	Amm [mg/l]
3	0.027	5.0	60	15	2.2	1.4	1.3
4	0.047	5.0	38 730	9683	2.2	1.4	1.3
5	0.043	25.0	10 000	2500	15.0	10.0	10.0
6	0.063	25.0	100 000	25000	15.0	10.0	10.0
7	0.043	25.0	10 000	2500	15.0	10.0	10.0
8	0.063	25.000	100 000	25000	15.0	10.0	10.0

1.4 Current water quality classifications

The MSR reviewed the sensitive receptors that could be at risk due to the effluent from the Youghal WwTP. The report identified the following principle potential impacts:

- Risk of reduced water quality and increased potential for eutrophication within the nutrient sensitive SPA and SAC waters within the Blackwater Estuary and connected waterbodies due to nutrient loading from the discharged effluent;

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- Risk of increased bacterial contamination of bathing water beaches; and
- Risk of increased bacterial contamination and reduced oxygen saturation in designated shellfish waters.

The waterbodies in the wider study are shown in Figure 1-2 with nutrient sensitive waters identified in Figure 1-3. The bathing beaches and designated shellfish harvesting areas are shown in Figure 1-4 and Figure 1-5 and respectively. Table 1.4 lists the waterbodies of interest and identifies specifically the reason that the area is of interest to this study.

Table 1.4. Summary of the WFD waterbodies and their status

Waterbody	Type	Comments	Status (2013-2018)
Lower Blackwater	Transitional	Nutrient sensitive tidal waterbody	Moderate
Youghal Bay	Transitional	Contains both Designated Shellfish Water and SFPA Classified Production Area in the western part of the bay. Three designated bathing beaches.	Moderate

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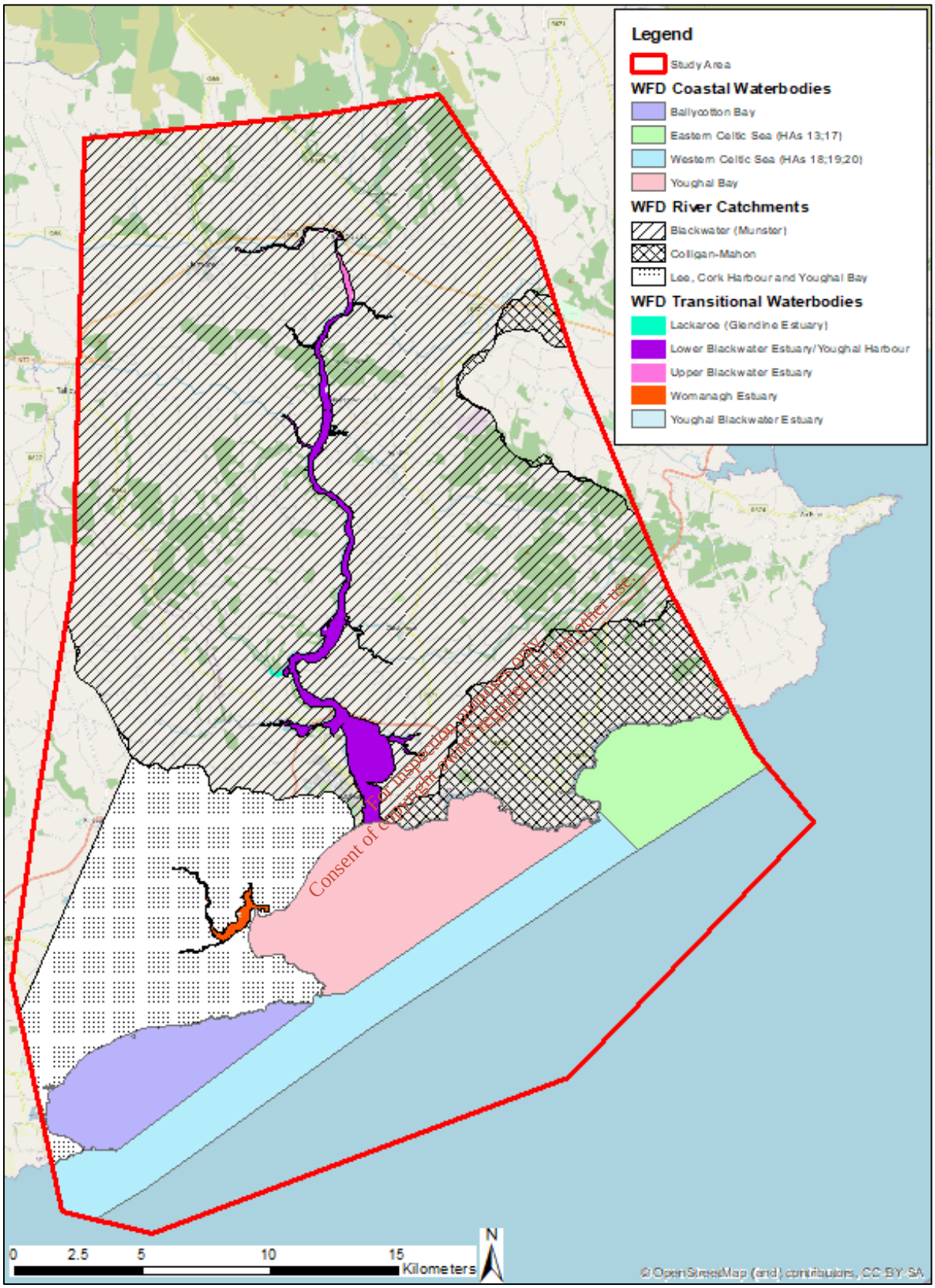

Figure 1-2. WFD River Catchments, Coastal Waterbodies and Transitional Waterbodies

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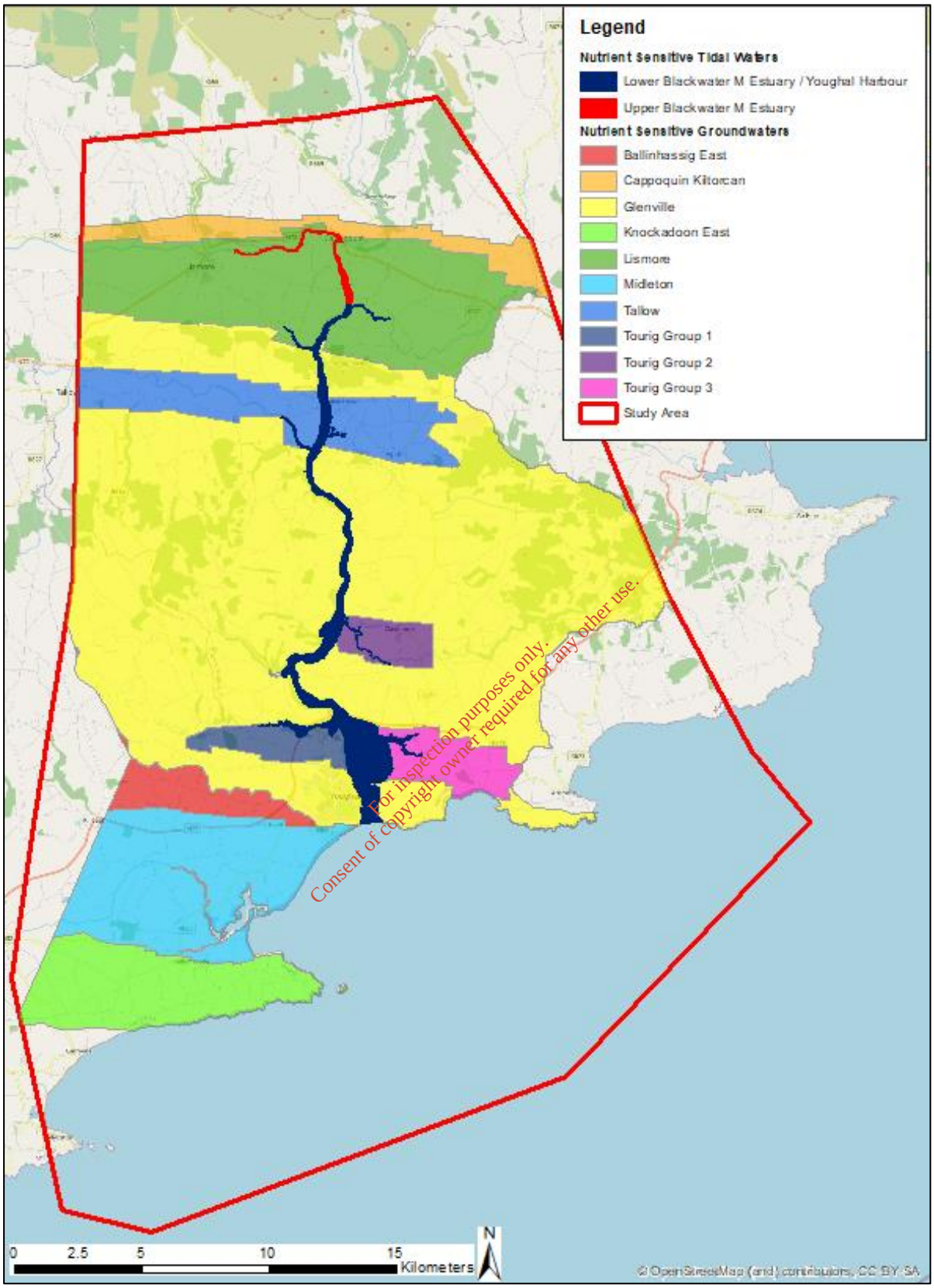

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Figure 1-3. Nutrient Sensitive Tidal Waterbodies and Groundwaters

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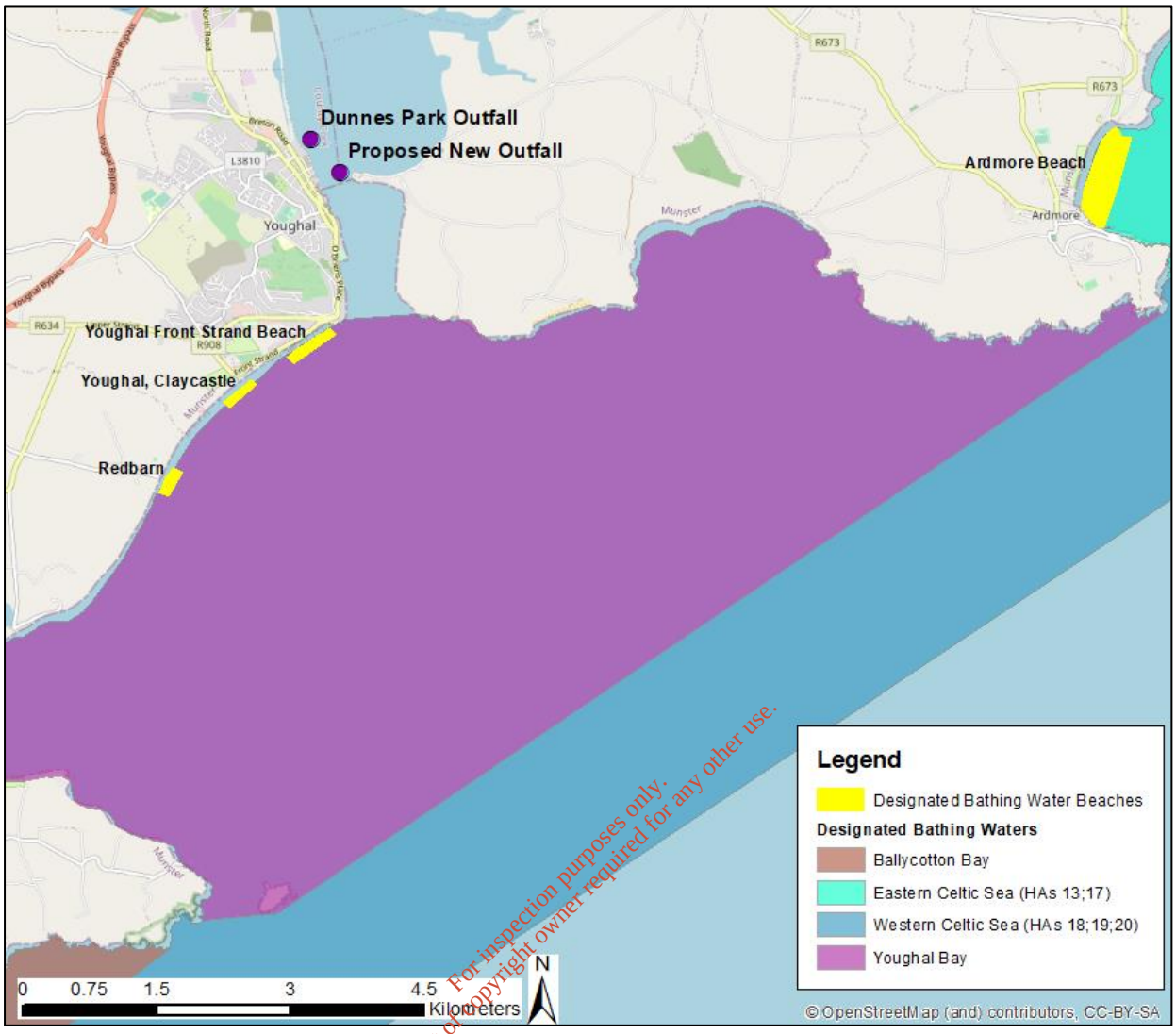

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Figure 1-4. Designated Bathing Waters and Beaches at Youghal

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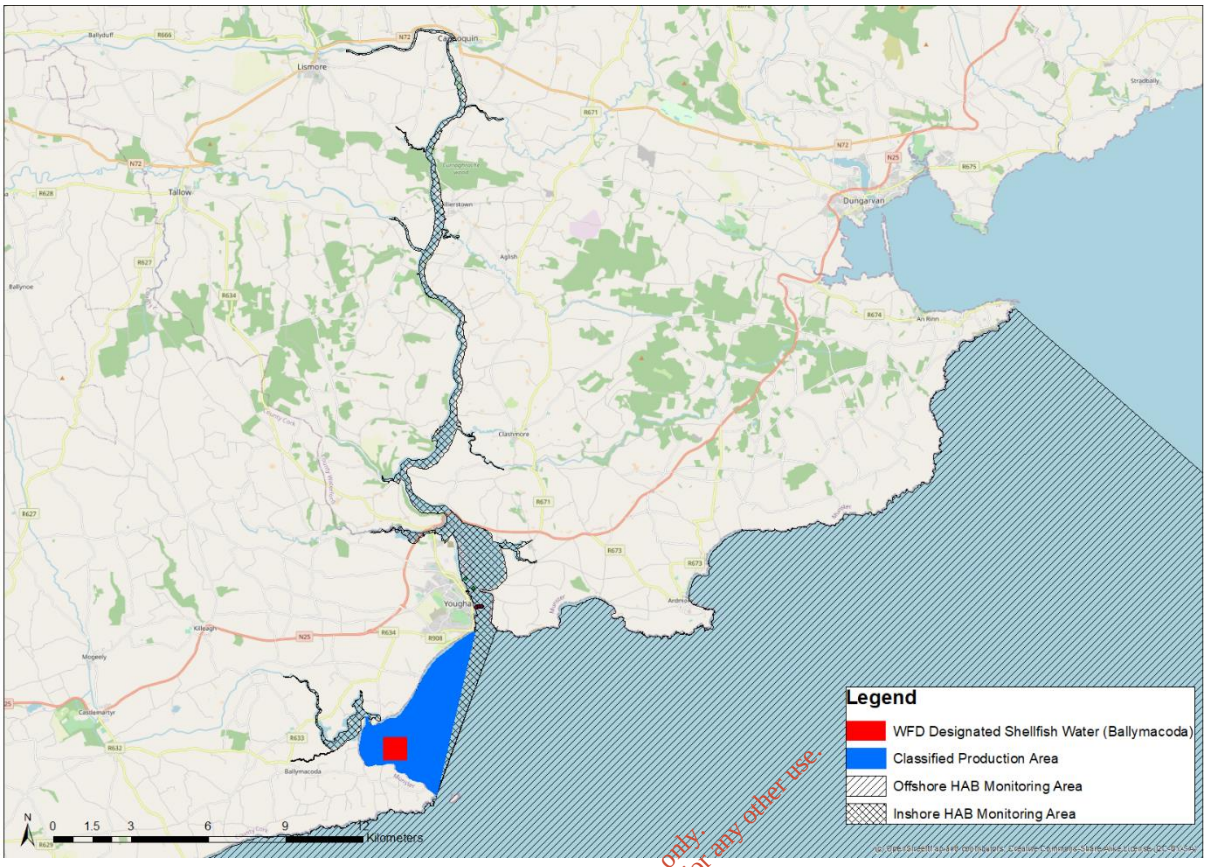

Figure 1-5. Designated Shellfish Waters and HAB Monitoring Areas at Youghal

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1.5 Model set-up

1.5.1 Introduction

The model utilised for this study was developed using the MIKE by DHI suite of models. The model is a 3-dimensional model (MIKE3) and uses the advection-dispersion module to simulate the transport and decay of the different parameters.

The model calibration process was undertaken in two key stages. The hydrodynamic model was initially developed and calibrated against the observed data for January 2020, including water levels, current speed, current direction, temperature and salinity throughout the estuary up to the tidal limit near Lismore. The model was tested to demonstrate the impact of changes to inputs such as river flows and bed resistance. The model was also validated against the observed water level data at Youghal for August 2019.

The water quality model was then calibrated against the long-term EPA monitoring data for August 2019 and January 2020 and the observed data for January 2020.

A summary of the hydrodynamic and water quality model set-ups is provided in the following sections.

1.5.2 Hydrodynamic model

The bathymetry has been developed using a range of sources including a bathymetric survey of Youghal Harbour in January 2020 and cross-sections from an OPW river model. Plots of the bathymetry are provided in Appendix B.

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The model has 10 vertical layers: five sigma-layers and five z-layers (Figure 1-6). The sigma-layers were evenly distributed between the water surface and -15 mOD. The five z-layers were each 5, 10, 15, 15 and 15 m deep. This represents the area of the model in which most mixing will take place (Youghal Harbour) with at least five sigma layers.

The Dunnes Park outfall discharges close to the low water mark and therefore at low tide discharges to the surface water and at high tide to the bottom layer. During calibration it was found that always discharging to the surface layer provided the best calibration and therefore this is the approach that was applied to the water quality modelling.

The open sea boundaries of the model are identified as the west, south and east, as shown in Figure 1-7. The boundary data has been obtained from the Marine Institute's Northeast Atlantic Regional Ocean Modelling System (ROMS) model. The MI model uses 40 sigma layers. The data provided by the MI is in a standard MATLAB® format data file and includes the following data for each boundary:

- Bed level;
- Surface elevation time series along the boundary and predefined points;
- A time series of the absolute elevation (m MSL) of each of the sigma layers and the mid-point of each sigma layer (as this is the location of the other data provided);
- Orthogonal current components (U and V) for each point along the boundary and each of the 40 vertical layers; and
- Temperature and salinity data for each of the 40 vertical layers within the MI model.

The model was calibrated against observed data (water levels, currents, temperature and salinity) for January 2020 and water levels for August 2019. Sensitivity tests on the horizontal and vertical dispersion concluded that a scaled Smagorinsky formulation using scaling factors of 2 and 1 for the horizontal and vertical dispersion provided the best overall calibration.

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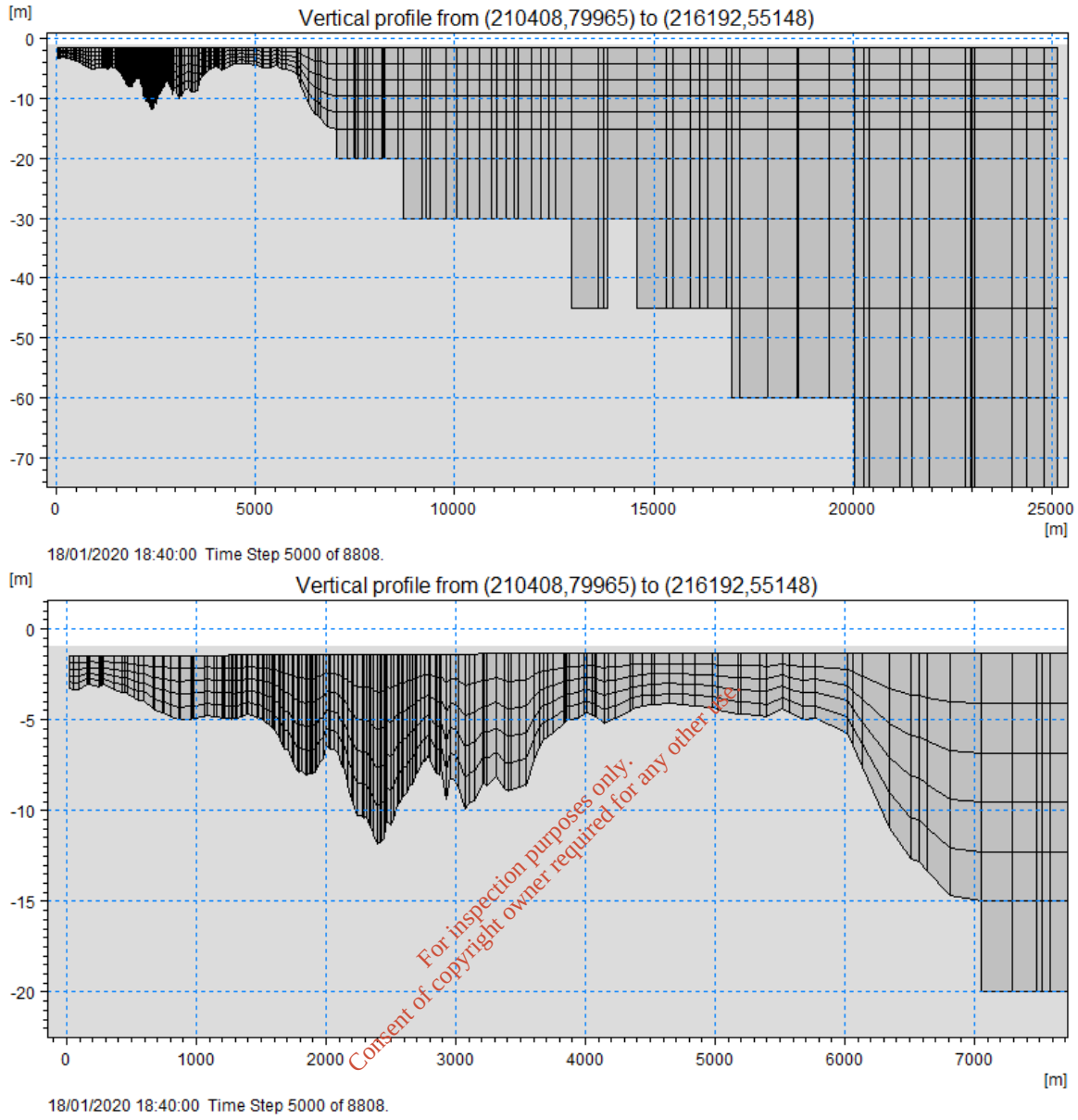

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Figure 1-6. Section through the estuary and out to the south boundary of the model (top) and landward end of the section (bottom). Both show the top five (sigma) layers. The top plot also shows the bottom five (z) layers.

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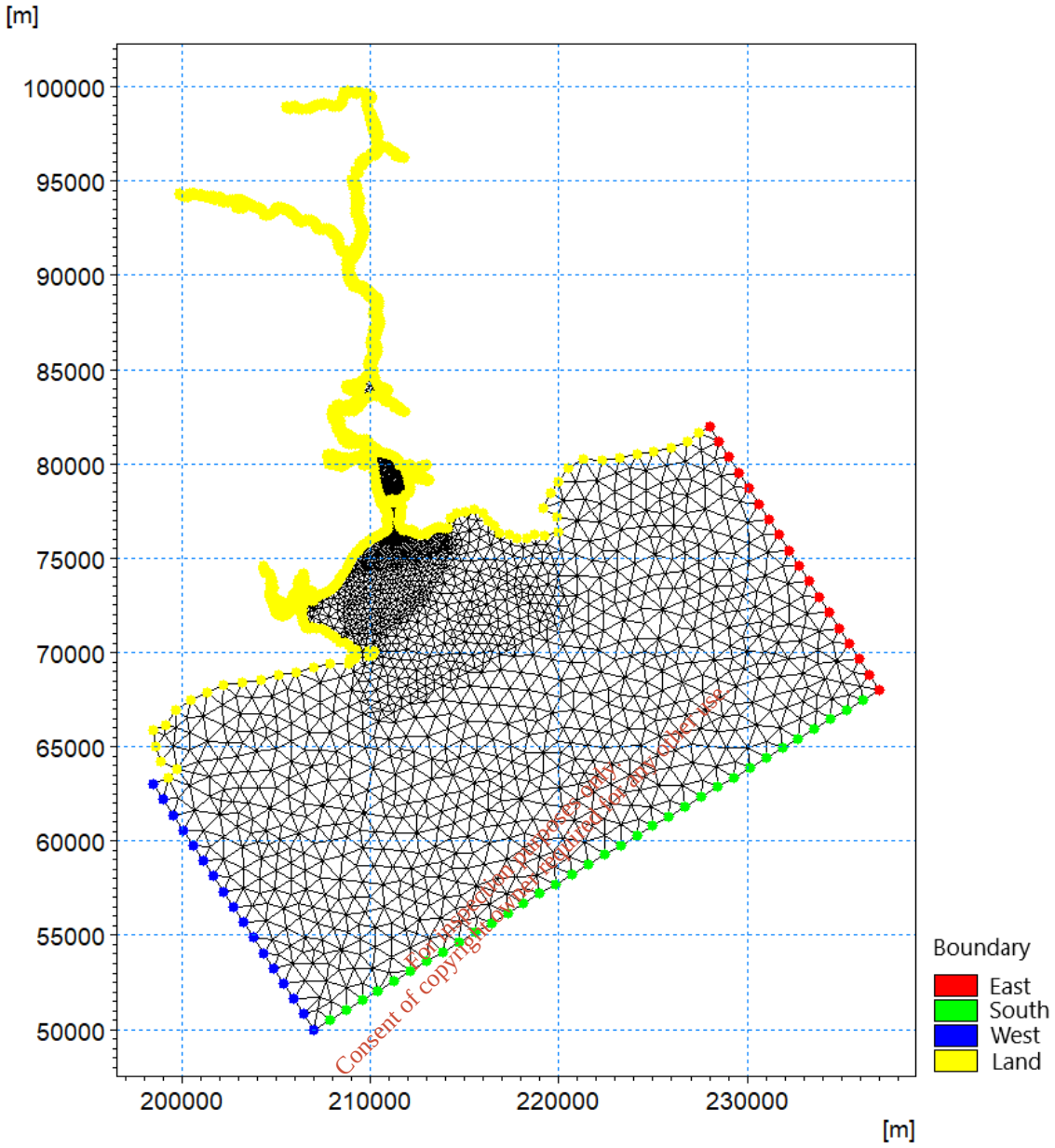

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Figure 1-7. Plot of the model domain showing the locations of all open boundaries.

River data was downloaded from WaterLevel.ie and identified that the River Blackwater was the primary source contributing 60-70% of the freshwater flow in the estuary. The River Bride is the next largest source contributing approximately 15% and 18 other sources contributed the remaining freshwater flow. The Q30 and Q95 values were estimated from the downloaded data and have been used for the winter and summer scenarios respectively.

The calibration identified that the lower estuary is flushed by the freshwater flows, particularly during and after large rainstorm events. The twice daily flushing of the estuary by tidal waters does affect the distribution of the flow through the day. The estuary may be stratified with saline water underlying freshwater during high fluvial flow events occurring at the same time as a flood tide. However, at other times the estuary may be fully mixed vertically with no density gradient between the bed and the surface at periods of low fluvial flows. The net flow is out of the estuary due to the river flows, and this is more evident on the surface than near the bed.

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1.5.3 Water Quality Model

The water quality parameters for the WwTP are based on samples taken over the past three years by Irish Water and during the site survey in January 2020. The water quality parameters for the receiving waters are based on the EPA WFD and Bathing Water compliance monitoring data. River concentrations have been estimated from the available data and the smaller tributaries assumed to be similar to the tributaries for which data is available. Details of the analyses are provided in the CR and MSR.

It should be noted that WwTPs are designed to manage the impact on the receiving waters. This means that the effluent is treated in the WwTP to change the parameters that are considered harmful to the environment. For example, the Youghal WwTP has UV treatment fitted to reduce the bacterial concentrations during the summer.

The size of model cells around the discharge are smaller than those out in the open sea. This ensures that there are more detailed calculations in the areas of most rapid change. The discharge from the Dunnes Park outfall is into a single model element with a length scale of approximately 30 m and an area of approximately 950 m^2. This means that as soon as the effluent enters the model cell there is an initial dilution depending on the depth of the layer. If the cell is approximately 1 m deep (over high water), then the initial dilution is of the order 1000 times. If the depth of the surface layer is smaller, such as approximately 0.2 m over low water, the initial dilution in the cell is of the order 200 times. This means that the effluent is assumed to spread over the area approximately 15 m in all directions as soon as it enters the water. The analyses then determine a concentration for the appropriate percentile of time. This means that whilst a plume may be present in the model during low water, for example, it may not be present at high water or during periods of high current speeds. This means that a discernible plume may not be present for sufficient time to be visible in the percentile plots.

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The size of the cells has been selected based on an understanding of the hydrodynamics within the estuary. The Blackwater estuary has a semi-diurnal tide and a strong fluvial influence. This means that there is a continuous change in current speed and direction with the net flow out of the estuary. This serves to flush the estuary of any effluent discharged into it. The initial dilution is also affected by the rate of exchange of water with adjacent cells. During periods of high current speed, the entire volume may be replaced; however, for periods of low current speed there may be minimal exchange.[2] This means that the initial dilution of the effluent in the model may not raise the average concentration significantly, resulting in a limited plume in the model. This is demonstrating that the effluent has been treated to manage the potential impact on the receiving waters.

The water quality model was run for 15 days to allow the model to stabilise and the results were then extracted for the following 15 days. The calibration process identified that the 15-day warm-up period was sufficient to achieve a dynamically stable concentration. This was achieved by starting the model with different initial conditions and comparing the results.

The decay rates and concentration of each of the water quality parameters in the rivers and the open sea boundary conditions for each season are set out in Table 1.5. The effluent flow rates and concentrations vary for each scenario; these are identified at the start of each section presenting the results of the scenario.

[2] Note that MIKE21 uses an adaptive timestep to ensure that the rate of change within a cell is not too large such that instabilities in the calculation can occur. The maximum CFL criterion is set to 0.8 for both the HD and AD calculations. The CFL number is a measure of the speed of the water moving compared to the spatial and temporal scale of the model. It is intended that water cannot "bypass" a cell due to high current speeds. If the speed increases, then the timestep of the calculation must decrease for a specific cell. A full description of the CFL number can be found here: https://en.wikipedia.org/wiki/Courant%E2%80%93Friedrichs%E2%80%93Lewy_condition.

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Table 1.5. Summary of the key model parameters for summer and winter.

Parameter	Initial Conditions [mg/l]	Open Sea Boundary concentration	Rivers Concentration	T_{90} [hours]
Summer				
BOD	1.0 mg/l	1.0 mg/l	0.5 to 1.3 mg/l	550
EC	100 cfu/100ml	100 cfu/100ml	650 cfu/100ml	24
IE	50 cfu/100ml	50 cfu/100ml	150 cfu/100ml	48
DIN	0.24 mg/l	0.24 mg/l	0.03 to 5.21 mg/l	800
MRP	0.24 mg/l	0.24 mg/l	0.01 to 0.03 mg/l	1600
Ammonia	0.01 mg/l	0.01 mg/l	0.01 to 0.02 mg/l	275
Winter				
BOD	1.0 mg/l	1.0 mg/l	0.5 to 1.0 mg/l	550
EC	100 cfu/100ml	100 cfu/100ml	650 cfu/100ml	48
IE	50 cfu/100ml	50 cfu/100ml	150 cfu/100ml	96
DIN	0.24 mg/l	0.24 mg/l	2.71 to 4.71 mg/l	800
MRP	0.24 mg/l	0.24 mg/l	0.01 to 0.03 mg/l	1600
Ammonia	0.01 mg/l	0.01 mg/l	0.01 to 0.03 mg/l	275

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1.6 Assessments undertaken

A range of assessments have been undertaken that include the actual modelled concentration, the estimation of the indicative quality and change from a baseline for scenarios in the future. All assessments are made on the concentration in the surface layer of the model. The percentiles for summer and winter are calculated separately over a full spring-neap cycle (15 days).

The indicative quality assessments are summarised in Table 1.6. For all plots the indicative quality of High, Good and Moderate for EQS assessment and Excellent, Good and Sufficient for Bathing Water assessments are used unless noted otherwise. These are shaded Blue, Green and Yellow respectively. For the purposes of assessing the quality of the water in the designated Shellfish Waters, the indicative quality of Good bathing waters has been used[3].

No specific legislation applies to the concentrations of ammonia and unionised ammonia in transitional and coastal waters and therefore the 95%ile concentration of ammonia has been plotted. A 95%ile concentration of unionised ammonia of 0.021 mg/l has been applied as an EQS in other jurisdictions[4] in marine environments, and while not applicable in Ireland, this provides some context with regards to the modelled concentrations of unionised ammonia from the Youghal WWTP.

[3] In line with the Section 11.5 of the Irish Water Technical Standard (Irish Water, 2020) bathing water quality is used as a proxy for shellfish water quality assessments.
[4] SEPA, 2020, "Supporting Guidance (WAT-SG-53), Environmental Quality Standards and Standards for Discharges to Surface Waters" https://www.sepa.org.uk/media/152957/wat-sg-53-environmental-quality-standards-for-discharges-to-surface-waters.pdf

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Unionised ammonia can be estimated using a function of the concentration of ammonia, pH and temperature (EPA, 2012). In practical terms the function estimates unionised ammonia as being approximately 0.2% to 3.2% of the ammonia concentration for the range of pH and temperatures that can be expected in the estuary (7 to 8 for pH and 5 to 15°C for temperature). The factor for the median pH and temperature would be approximately 1% for the winter and 1.5% for the summer. For the purposes of information, a factor of 2% has been assumed for both summer and winter.

For the non-baseline scenarios (5, 6 and 7) the estimated change in concentration from the appropriate baseline scenario of 3 or 4 are also provided as delta plots.

For each Scenario the size of the mixing zone for each modelled parameter is presented. For Scenario 7, which involves the assessment of impact of a new outfall, the mixing zone is also evaluated against additional criteria as set out in the Irish Water Technical Standard[5]:

The edge of the mixing zone is defined as the point at which the indicative quality of the water around the outfall is worse than the EQS of the receiving water. The waterbody status presented in Table 1.4 were determined by the EPA and are not based only on the statistics of the EPA physio-chemical and nutrient sampling but also consider other sampling elements such as ecological and biological supporting quality elements which are outside the scope of this modelling exercise. For IE and EC there is no formal definition of a mixing zone, however, the indicative mixing zone is assumed to occur where the concentration falls below the criteria for Good bathing water standard.

The spatial extent of the plume has been assessed in terms of the width of the estuary on the surface and not the cross-sectional area. The estuary is approximately 1800 m wide at the location of the Dunnes Park outfall and 375 m at the location of the proposed outfall.

The plots of concentration throughout the report have selected a colour ramp that has key values in the determination of the indicative quality. For example, the MRP scale includes 0.025 mg/l as this is a threshold for High/Good boundary at 34.5 psu.

For the purposes of visual assessment of the plots, the Classified Production Areas are shown as shaded blue areas and the Designated Shellfish Waters (Ballymacoda) is shown as a shaded red area. The locations of the Designated Bathing beaches (Clay Castle and Front Strand) are shown as point markers. The plots also include the location of the Dunnes Park outfall and for Scenario 7, the location of the proposed outfall.

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[5] Table 8-1 Technical Standard (Irish Water, 2020) as based on European Commission, 2010 and CIS-WFD, 2010.

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Table 1.6. Indicative quality assessments undertaken on all scenarios

Parameter	Description	Categories	
BOD	Surface Water regulations[6] 95%ile calculated over 15 days for summer and winter separately.	High <3 mg/l Good <4 mg/l Moderate >= 4 mg/l	
DIN	Surface Water Regulations[6] 50%ile DIN combined with 50%ile salinity calculated over 15 days for summer and winter separately	Interpolate based on salinity High: < Interpolate from 1.0 mg/l at 0 psu to 0.17 mg/l at 34.5 psu Good:< Interpolate from 2.6 at at 0 psu to 0.25 mg/l at 34.5 psu See Figure 1-8	
MRP	Surface Water Regulations[6] 50%ile MRP combined with 50%ile salinity calculated over 15 days for summer and winter separately	Interpolate based on salinity High: Salinity ≤ 17 psu ≤ 0.03 mg/l Salinity >17 interpolate from 0.03 mg/l at 17 psu to 0.025 mg/l at 34.5 psu Good:< Salinity ≤ 17 psu < 0.06 mg/l Salinity >17 interpolate from 0.06 mg/l at 17 psu to 0.04 mg/l at 34.5 psu See Figure 1-9	
IE	Bathing Water Directive[7] and as a proxy for Shellfish water[3] for summer and winter separately.	Excellent	95%ile ≤ 100 cfu/100ml
		Good	95%ile ≤ 200 cfu/100ml
		Sufficient	90%ile ≤ 185 cfu/100ml
		Poor	90%ile >185 cfu/100ml
EC	Bathing Water Directive[7] and as a proxy for Shellfish water[3] for summer and winter separately.	Excellent	95%ile ≤ 250 cfu/100ml
		Good	95%ile ≤ 500 cfu/100ml
		Sufficient	90%ile ≤ 500 cfu/100ml
		Poor	90%ile > 500 cfu/100ml

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[6] Surface Water Regulations Statutory Instruments SI No 272 of 2009 European Communities Environmental Objectives (Surface Waters) Regulations 2009 http://www.irishstatutebook.ie/eli/2009/si/272/made/en/pdf, updated 2015 and 2019, http://www.irishstatutebook.ie/eli/2015/si/386/made/en/pdf, accessed 15th July 2020

[7] EU, 2006: Directive 2006/7/EC and Irish Statutory Instruments, 2008

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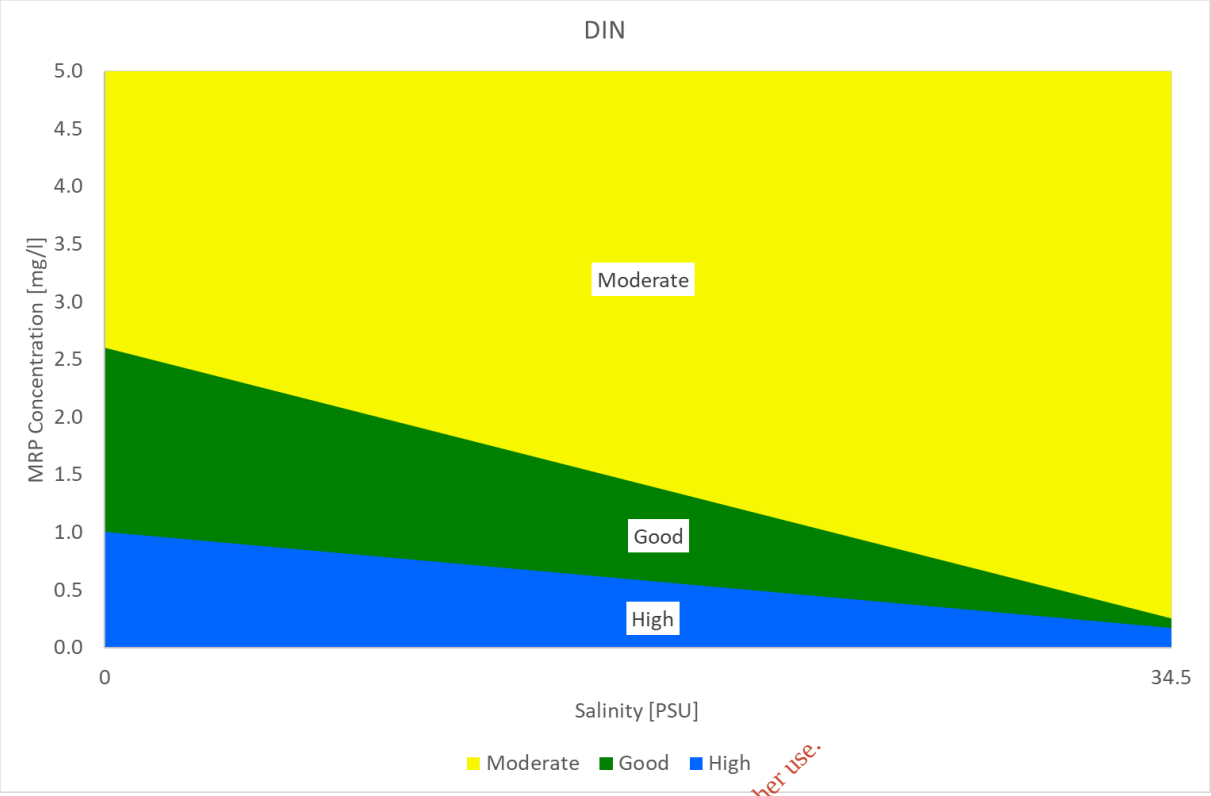

Figure 1-8. Assessment criteria and categories for DIN (50%ile) as a function of salinity (50%ile).

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Figure 1-9. Assessment criteria and categories for MRP (50%ile) as a function of salinity (50%ile).

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2. Scenario 3: Existing (Baseline) Summer

The Youghal WwTP discharge for the existing situation in the summer is 0.027 m^3/s (2 306 m^3/day, median of all measured flows for summer 2018 to 2020) and the water quality parameters as set out in Table 2.1. General model parameters are set out in Table 1.5.

Table 2.1. Effluent discharge rate and concentrations for each parameter for Scenario 3

Discharge [m^3/s]	BOD [mg/l]	EC [cfu/ 100ml]	IE [cfu/ 100ml]	DIN [mg/l]	MRP [mg/l]	Amm [mg/l]
0.027	5.0	60	15	2.2	1.4	1.3

The modelled concentrations of EC, IE, BOD, DIN, MRP and ammonia are plotted in Figure 2-1 to Figure 2-6. The indicative quality for each parameter is shown in Figure 2-7.

The plots of concentration show that there are small areas of higher concentrations present where river sources enter the model. These are flushed by both the tide and fluvial flows from the rivers in the same way as the whole estuary is flushed and described in section 1.5.2. These contribute to the "background" concentration of the receiving waters.

The primary discharge of the WwTP at Dunnes Park is assumed to be operating using UV treatment during the summer and therefore the bacterial concentration being released is significantly lower than the winter (see Scenario 4).

For DIN it is not possible to identify the plume as the concentration of the receiving water is almost unaffected by the discharge with concentrations being between 0.1 and 0.17 mg/l (the threshold for the indicative quality of High and Good in water of salinity of 34.5 psu). The reason for this is that the initial dilution of the discharge is between 200 and 1000, as described in section 1.5.3. The effluent will therefore increase the concentration in the model by approximately 0.002 to 0.01 mg/l in the first cell.

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Similarly, the concentration of MRP around the outfall is not significantly different to the receiving waters (between 0.01 and 0.025 mg/l). Ammonia concentrations are below 0.05 mg/l and therefore unionised ammonia is estimated to be below 0.001 mg/l and no plot provided.

The modelled indicative quality for BOD, DIN and MRP is High and for EC and IE is Excellent.

The concentration of ammonia is less than 0.05 mg/l (Figure 2-6). If unionised ammonia is assumed to be approximately 2% of the ammonia concentration (as described in section 1.6), then the concentration of unionised ammonia is less than 0.001 mg/l.

The mixing zones for all modelled parameters are less than 50m.

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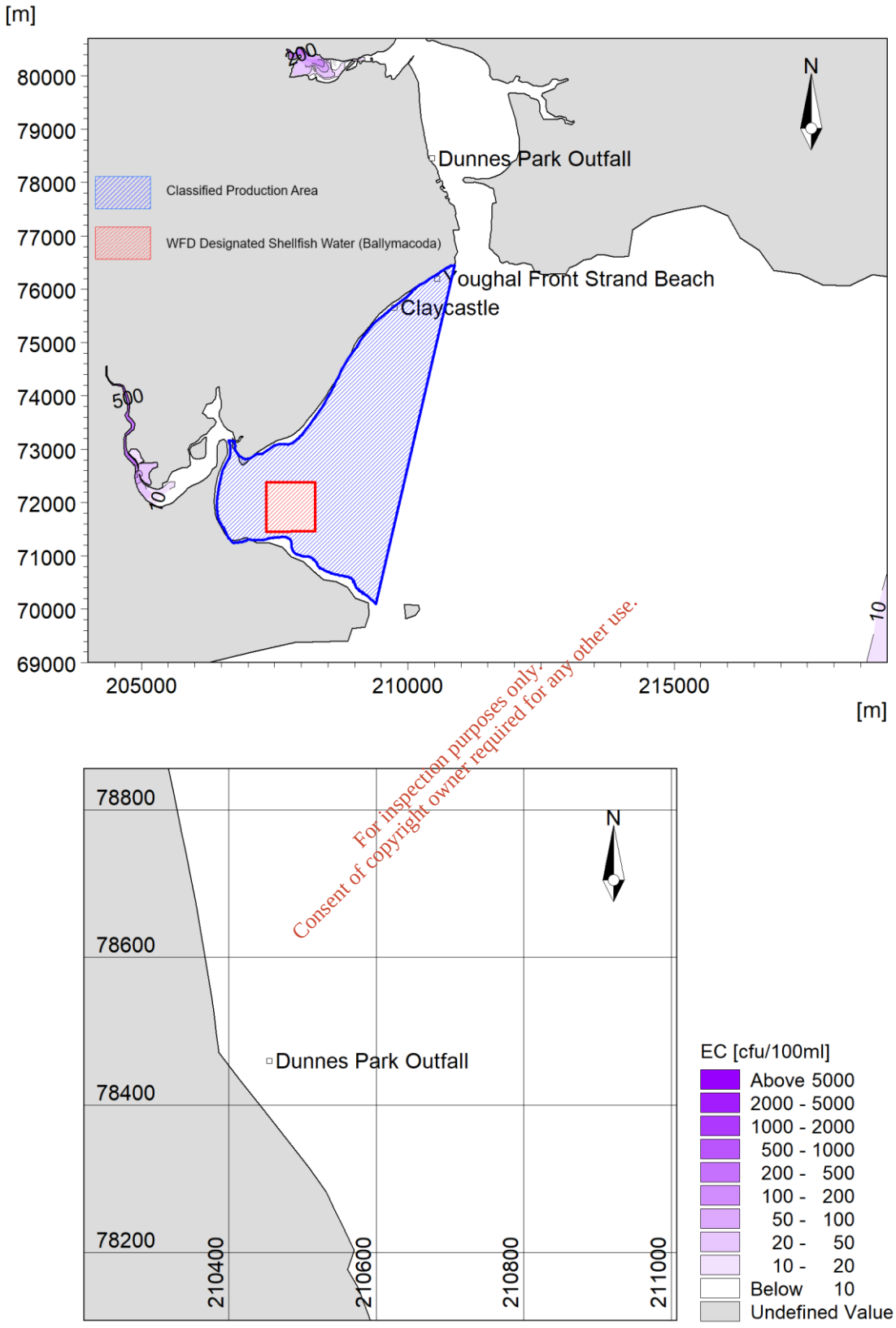

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Figure 2-1. Scenario 3: EC 95%ile concentration [cfu/100ml]

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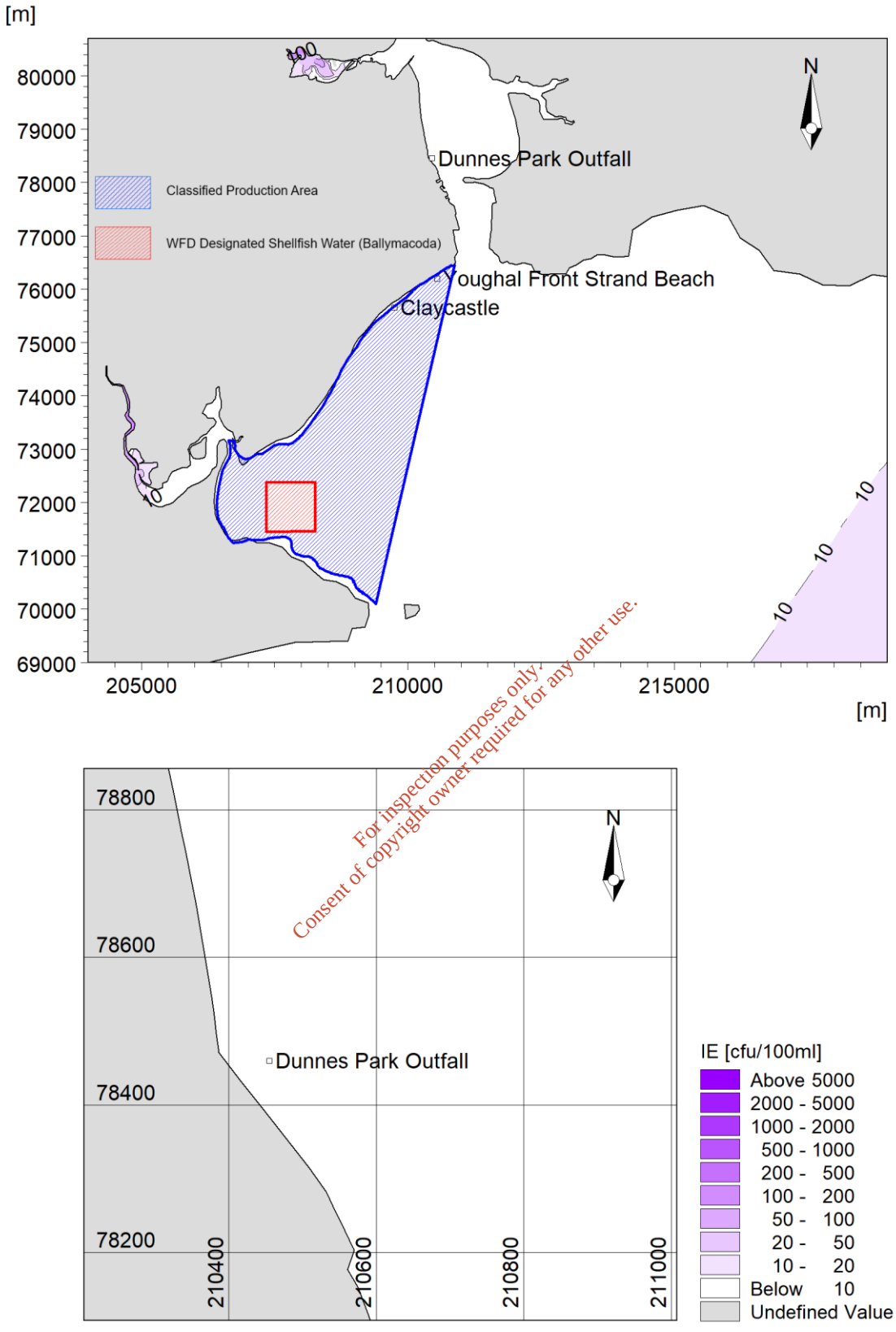

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Figure 2-2. Scenario 3: IE 95%ile concentration [cfu/100ml]

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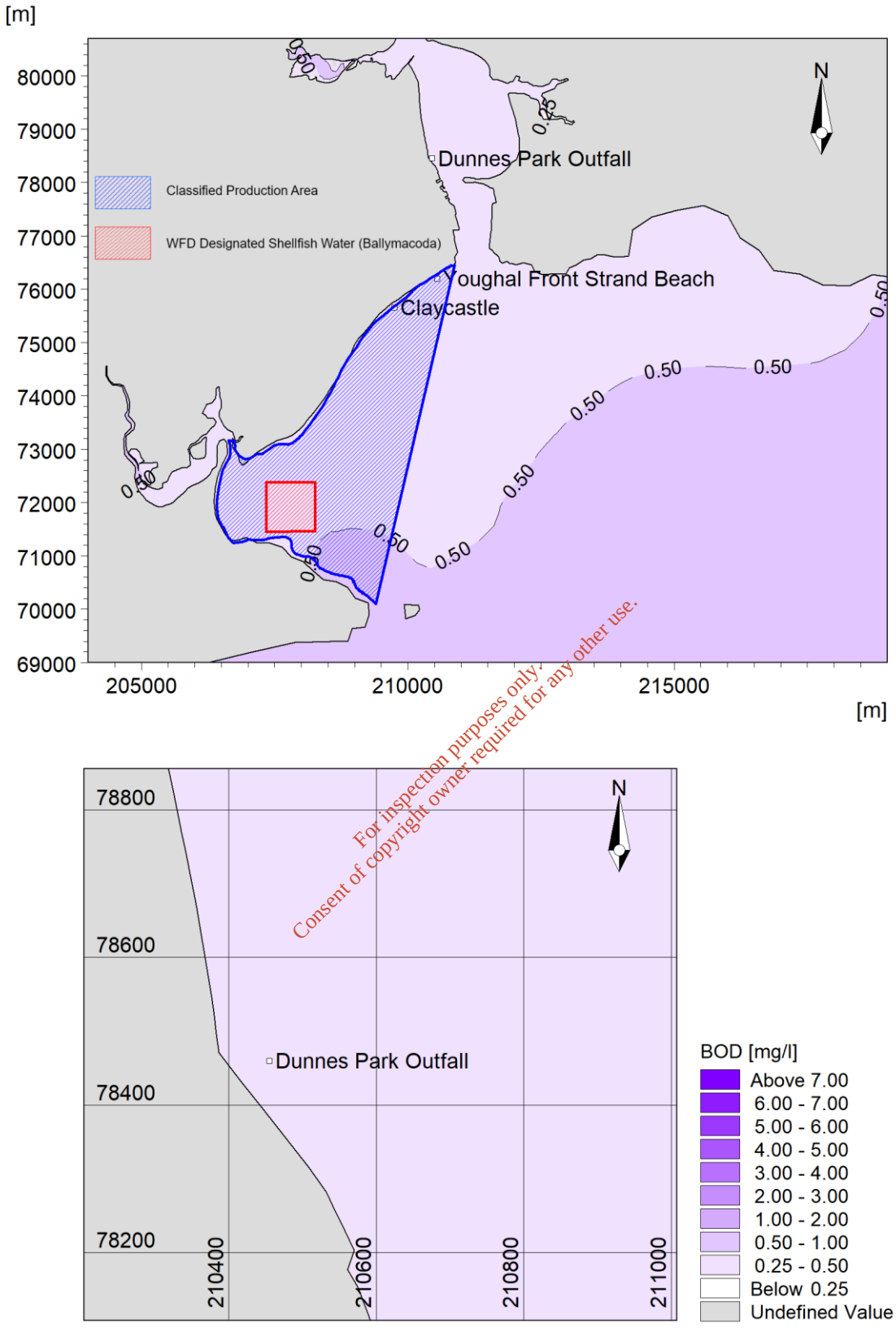

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Figure 2-3. Scenario 3: BOD 95%ile concentration [mg/l]

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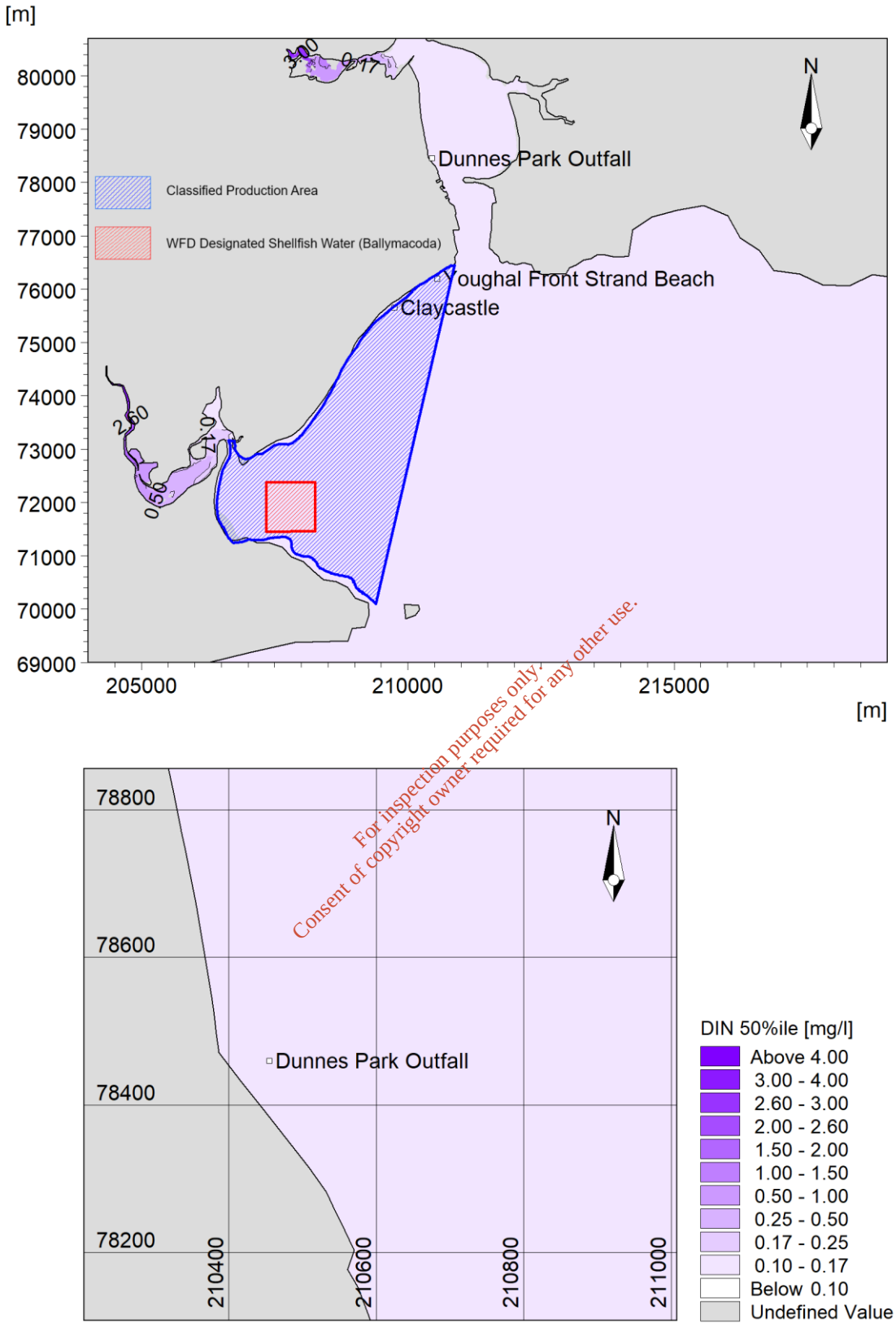

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Figure 2-4. Scenario 3: DIN 50%ile concentration [mg/l]

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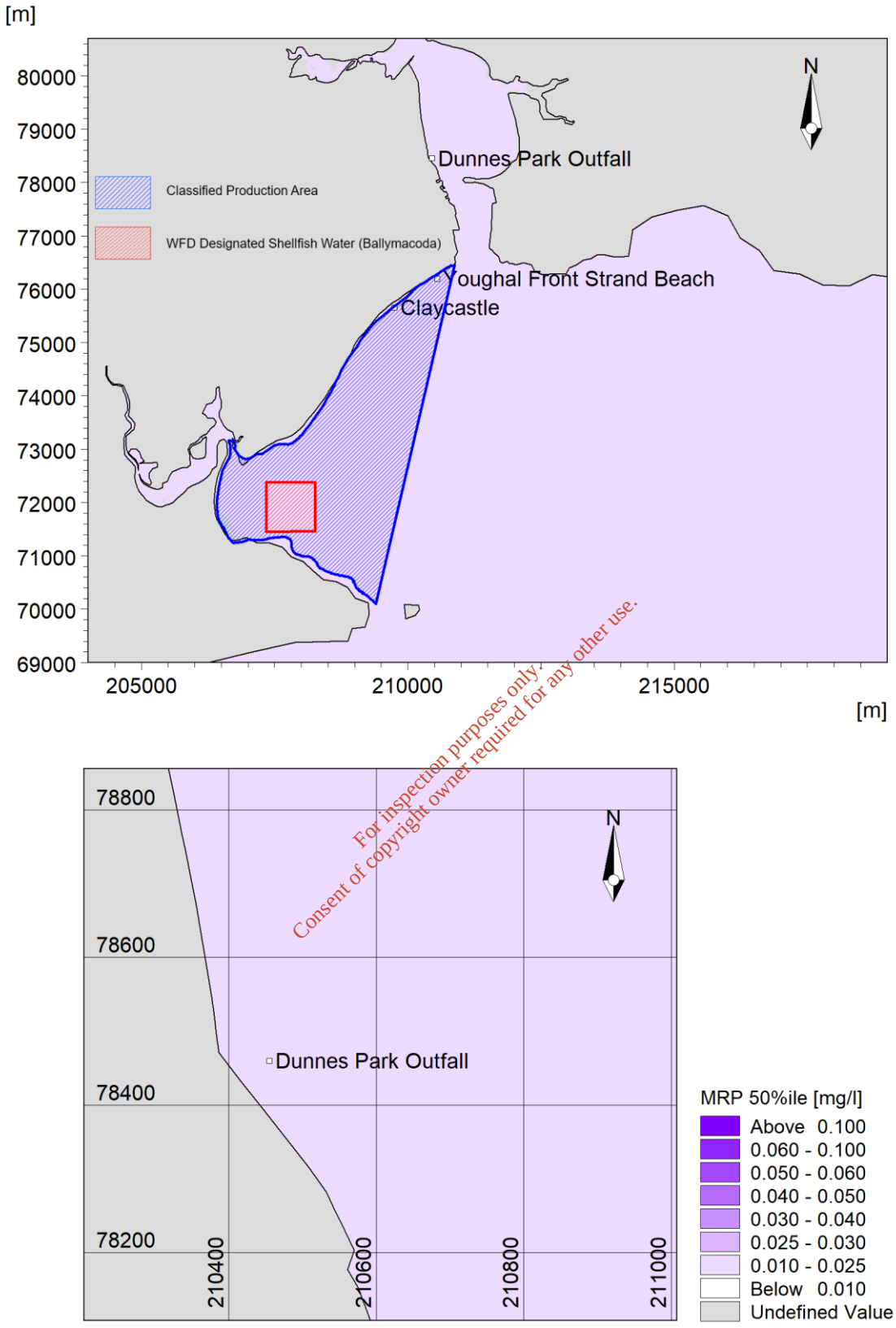

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Figure 2-5. Scenario 3: MRP 50%ile concentration [mg/l] (the concentrations are all between 0.01 and 0.025 mg/l).

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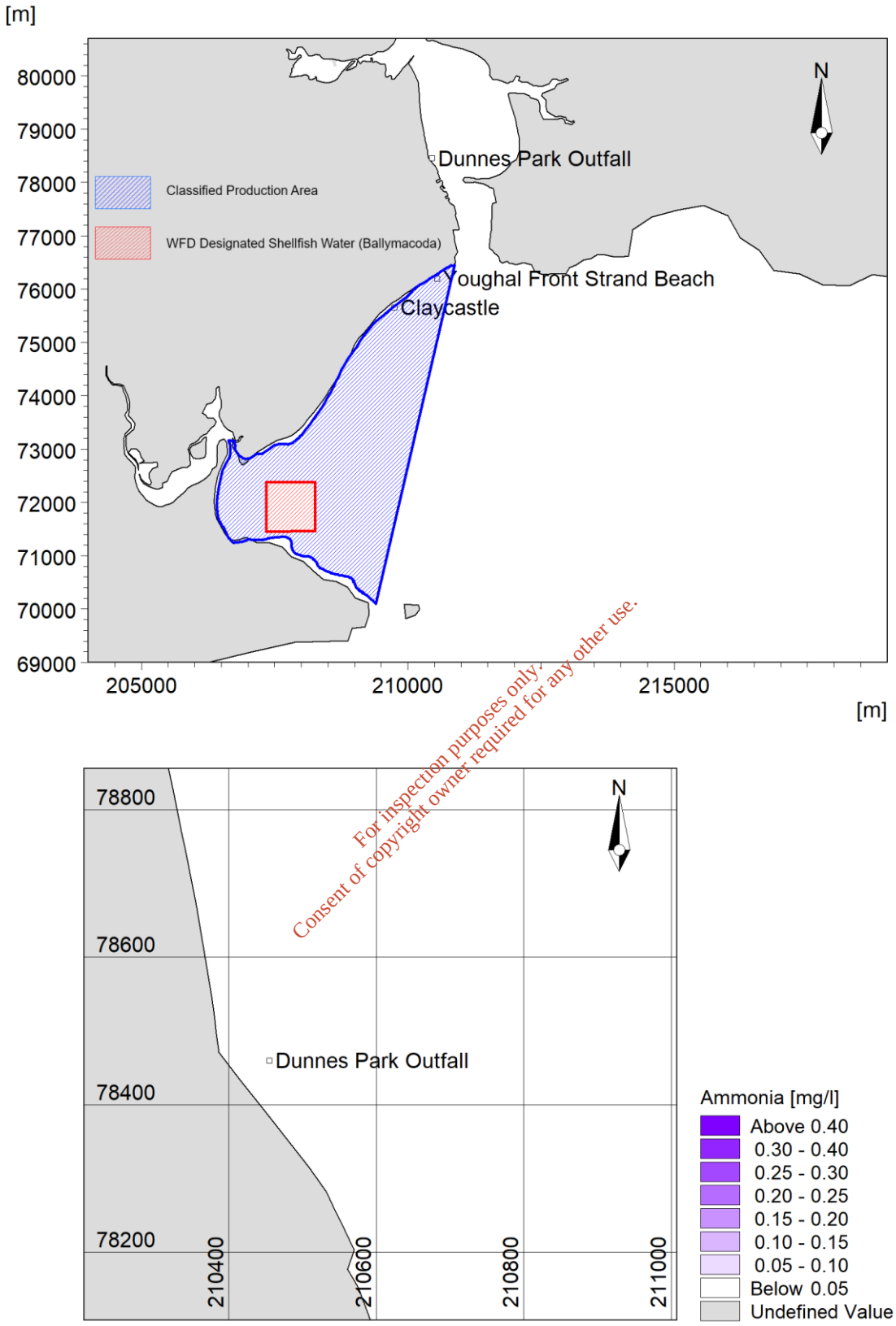

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Figure 2-6. Scenario 3: Ammonia 95%ile concentration [mg/l] all concentrations are below 0.05 mg/l.

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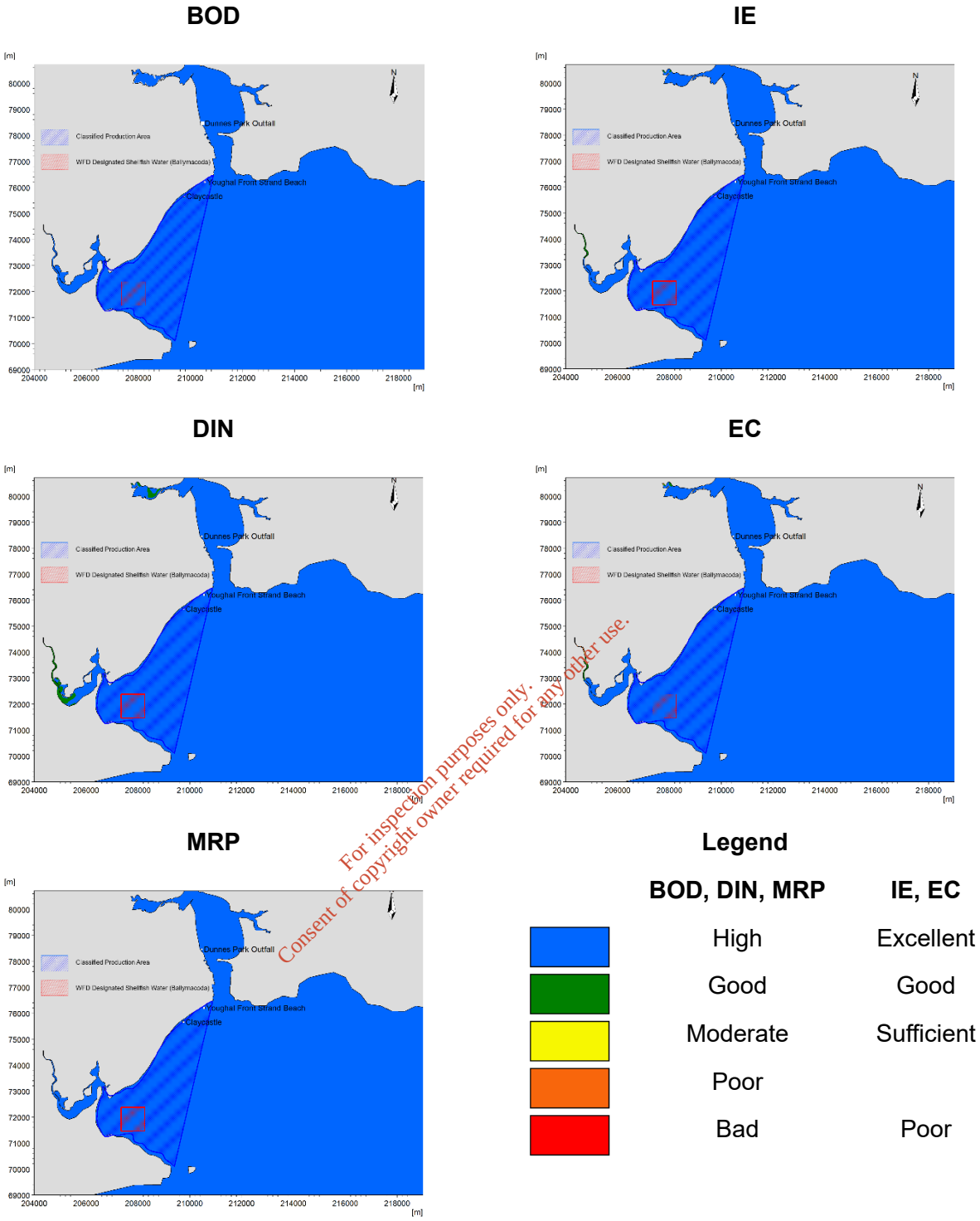

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Figure 2-7. Scenario 3: Indicative quality BOD, DIN, MRP, IE and EC

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3. Scenario 4: Existing (Baseline) Winter

The Youghal WwTP discharge for the existing situation in the summer is 0.047 m^3/s (4 089 m^3/day, median of all measured flows for summer 2018 to 2020) and the water quality parameters as set out in Table 3.1. General model parameters are set out in Table 1.5.

Table 3.1. Effluent discharge rate and concentrations for each parameter for Scenario 4

Discharge [m^3/s]	BOD [mg/l]	EC [cfu/ 100ml]	IE [cfu/ 100ml]	DIN [mg/l]	MRP [mg/l]	Amm [mg/l]
0.047	5.0	38 730	9683	2.2	1.4	1.3

The modelled concentrations of EC, IE, BOD, DIN, MRP and ammonia are plotted in Figure 3-1 to Figure 3-7. The indicative quality for each parameter is shown in Figure 3-8.

The plots of bacterial concentration show elevated concentrations around the outfall and the plume up and downstream within the estuary (Figure 3-1 and Figure 3-2). For context, a notional[8] mixing zone for EC, based on achievement of Excellent Bathing Water Quality (<250cfu/100ml), measures as approximately 100 m wide and 150 m long. Additional plots showing the concentration through a tidal cycle are presented for EC in Figure 3-3 showing the mixing of the plume vertically and horizontally. The long-section through the outfall extends approximately 250 m upstream and 250 m downstream.

The EC plume from the Youghal WWTP does not reach the Designated Shellfish Waters.

The concentration is higher during the winter as the UV treatment is not being used outside of the bathing season. The plume does not extend to the beach areas, where concentrations of EC are less than 10 cfu/100 ml. Concentrations of this magnitude meet Excellent Bathing Water Quality thresholds and are close to laboratory limits of detection for EC.

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The concentrations of DIN are also higher in the winter than the summer (Figure 3-5). The indicative quality for DIN also shows that whilst the parts of the estuary and Youghal Bay have an indicative quality of High, parts are also Good (Figure 3-8 and Figure 3-9). The indicative quality for all other parameters is High (BOD, MRP) or excellent (EC and IE).

The plots of concentration for Scenario 4 show the increase in concentration from the river sources and that this affects the concentration within the study area. Note specifically the potential influence of the Womanagh river on bacterial concentrations in the Classified Production Area (Figure 3-1); although the concentrations of EC are still very low, below 10 cfu/100ml and close to laboratory limits of detection, except in the northwest corner.

The concentration of ammonia is less than 0.05 mg/l (Figure 3-7). If unionised ammonia is assumed to be approximately 2% of the ammonia concentration (as described in section 1.6), then the concentration of unionised ammonia is less than 0.001 mg/l.

[8] This is not a statutory mixing zone, as there is no regulatory EQS for bacteria in the vicinity of the outfall.

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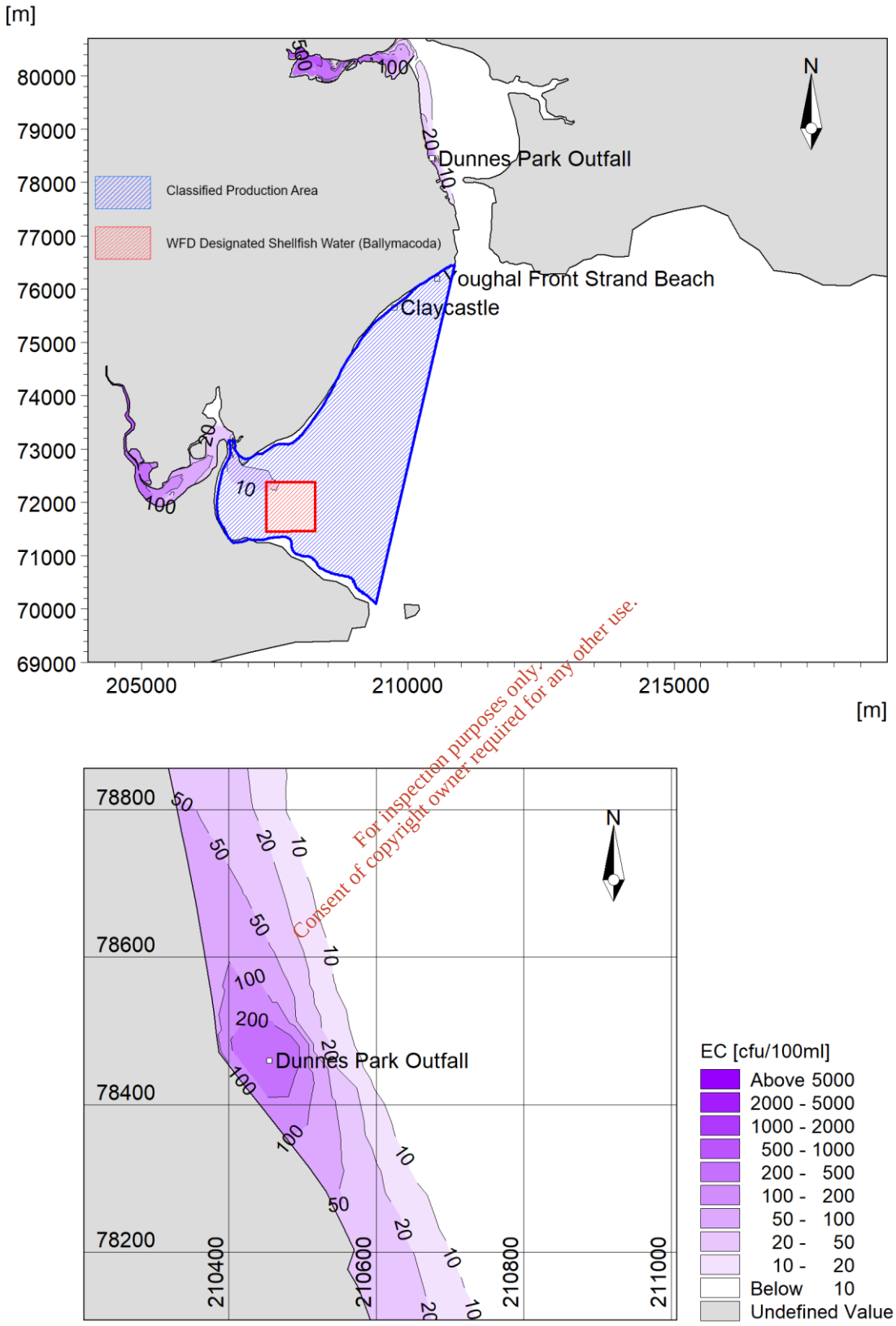

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Figure 3-1. Scenario 4: EC 95%ile concentration [cfu/100ml] – note concentrations at key receptors are below limits for Excellent Bathing Quality [<250cfu/100ml]

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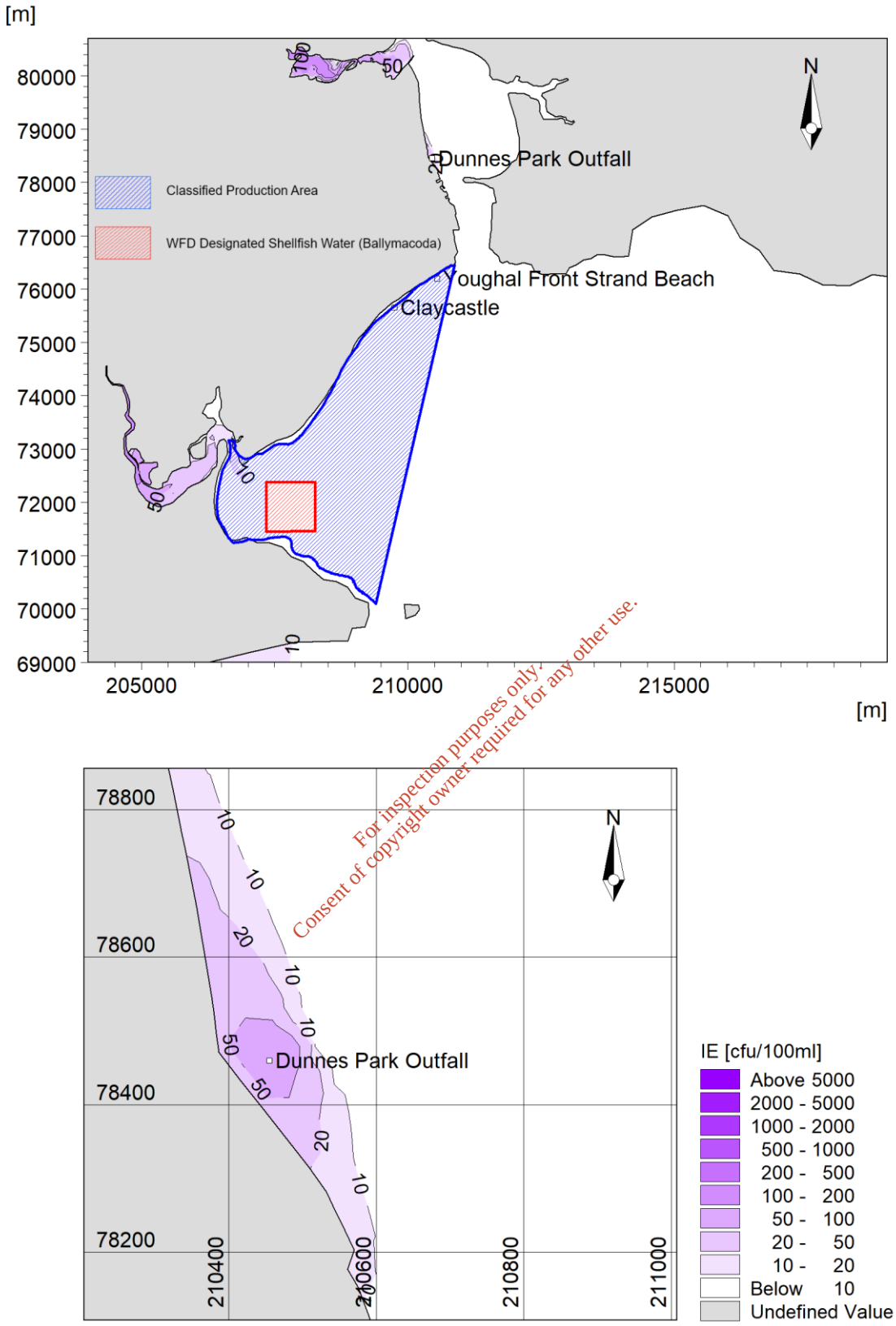

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Figure 3-2. Scenario 4: IE 95%ile concentration [cfu/100ml] – note concentrations at key receptors are below limits for Excellent Bathing Quality [<100cfu/100ml]

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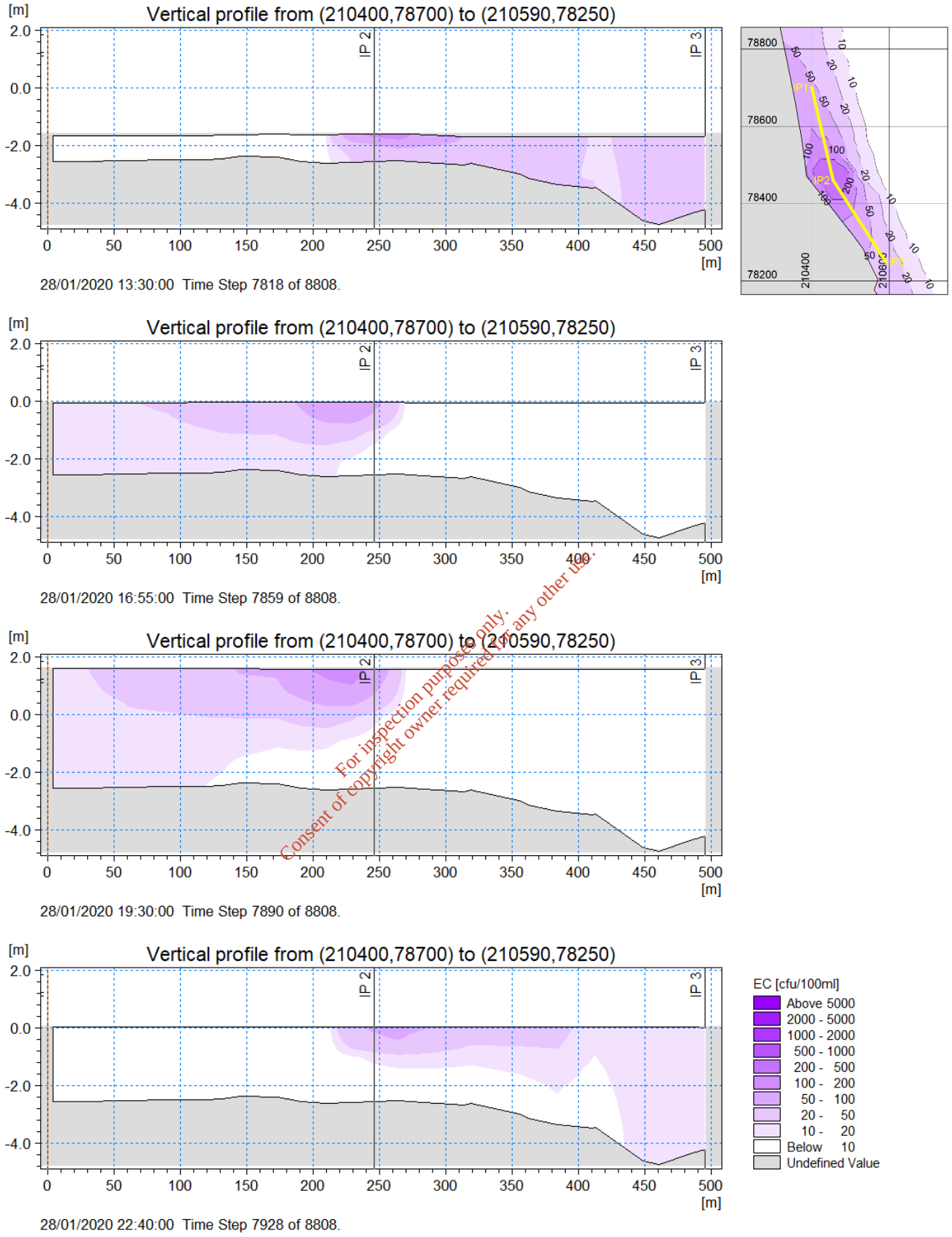

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Figure 3-3. Scenario 4: A long-section of EC concentration [cfu/100ml] through a tidal cycle (top to bottom: low tide, mid flood, high tide, mid ebb). Location of the long-section shown on top right figure.

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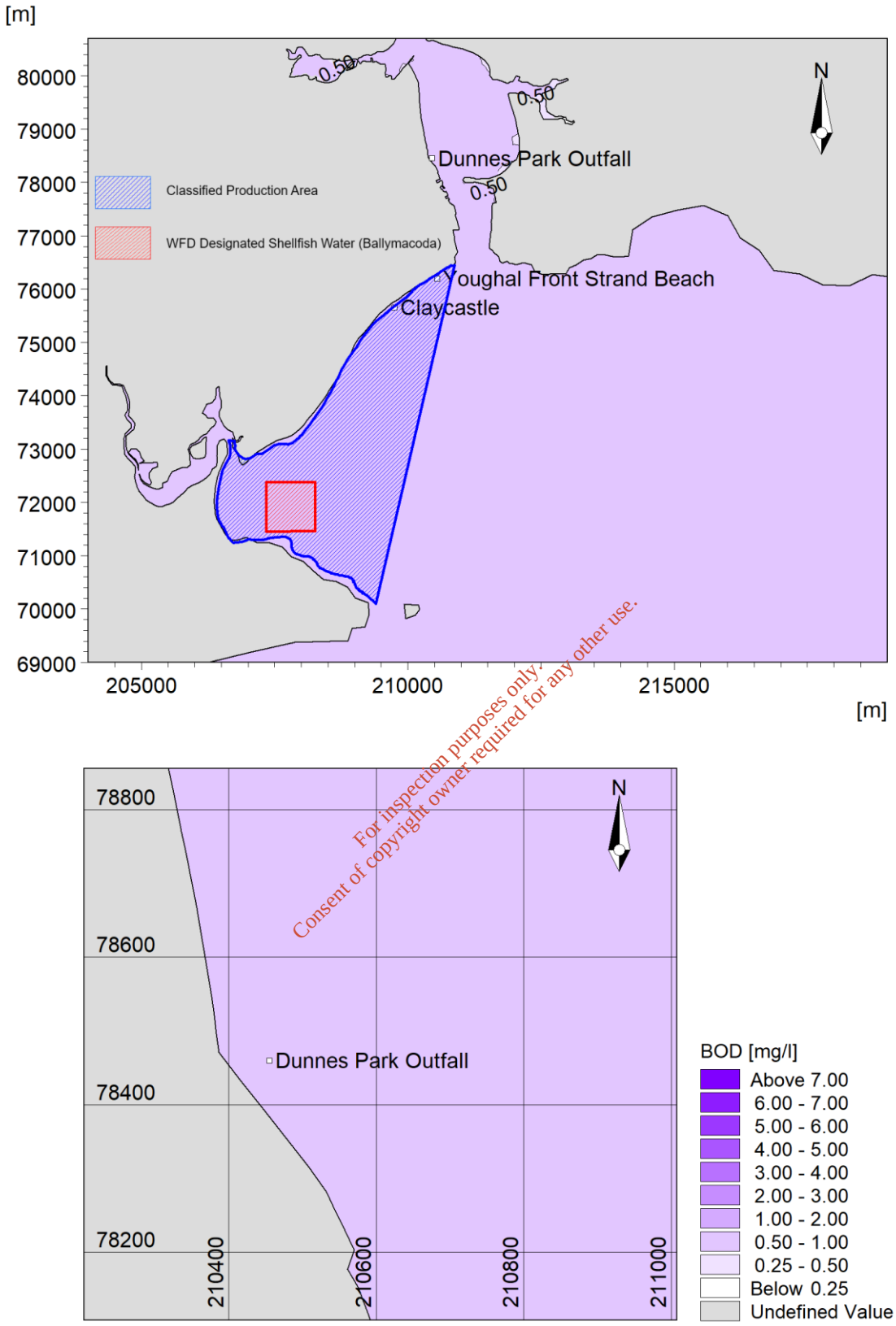

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Figure 3-4. Scenario 4: BOD 95%ile concentration [mg/l] (the concentrations are all between 0.5 and 1.0 mg/l)

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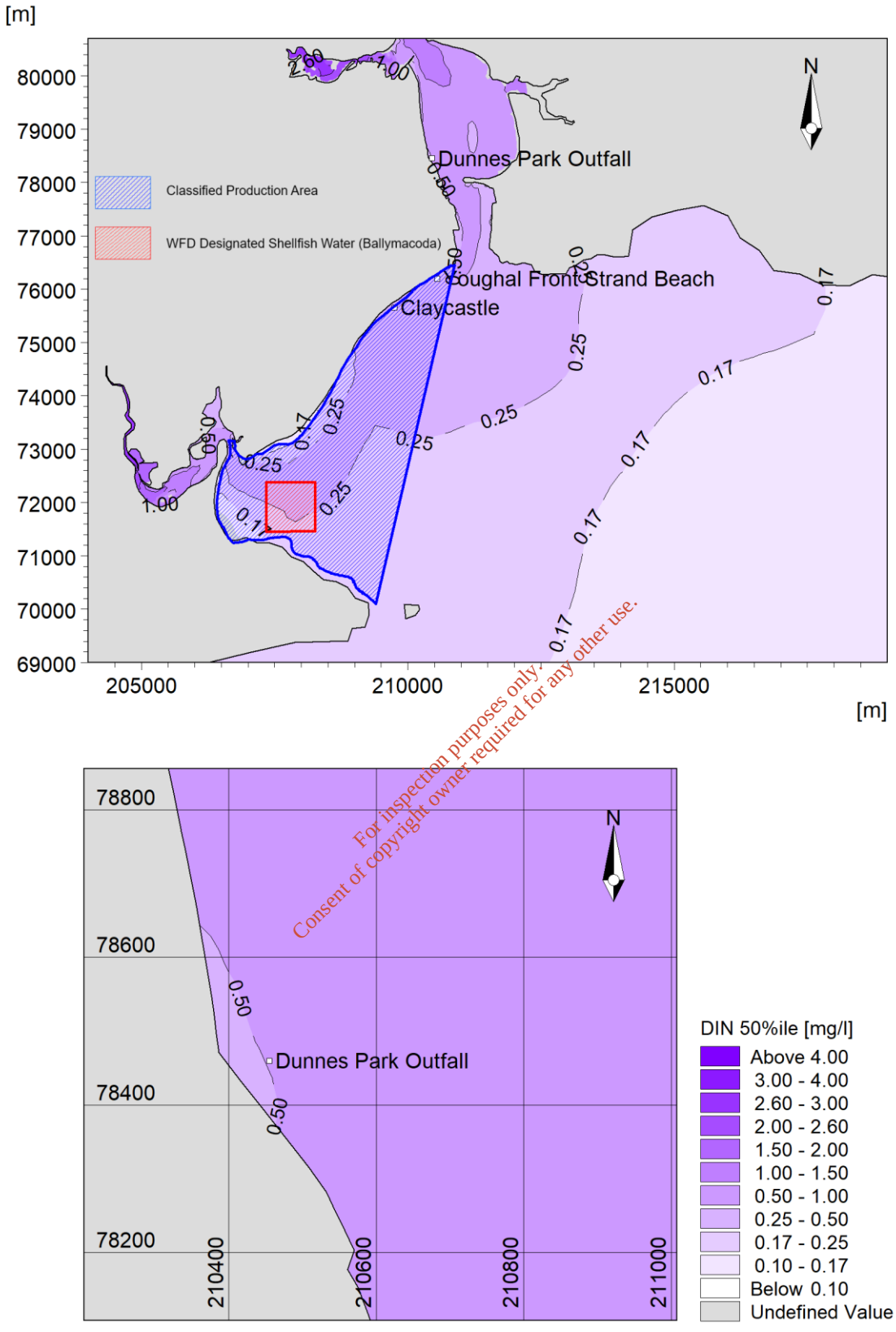

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Figure 3-5. Scenario 4: DIN 50%ile concentration [mg/l]

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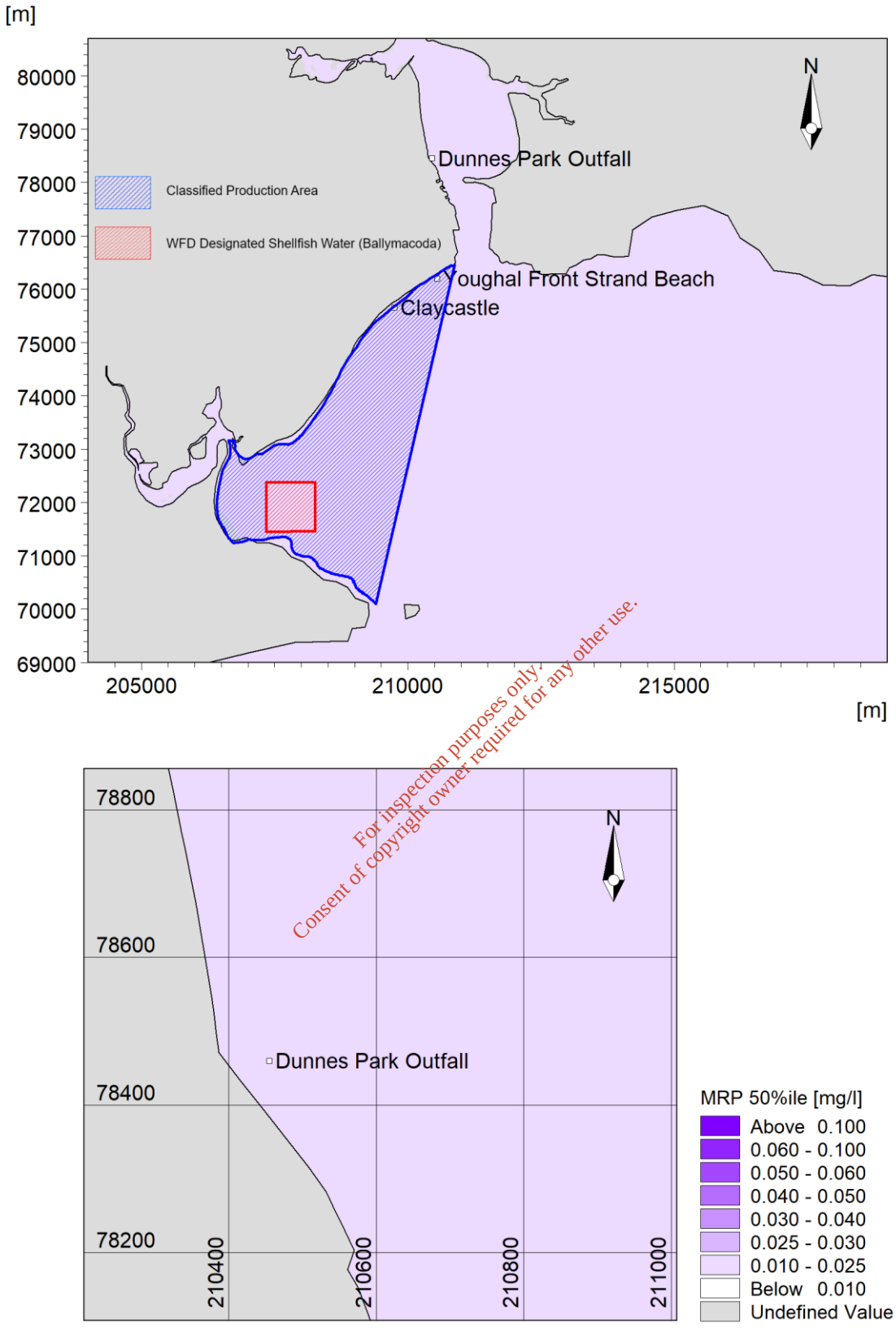

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Figure 3-6. Scenario 4: MRP 50%ile concentration [mg/l]

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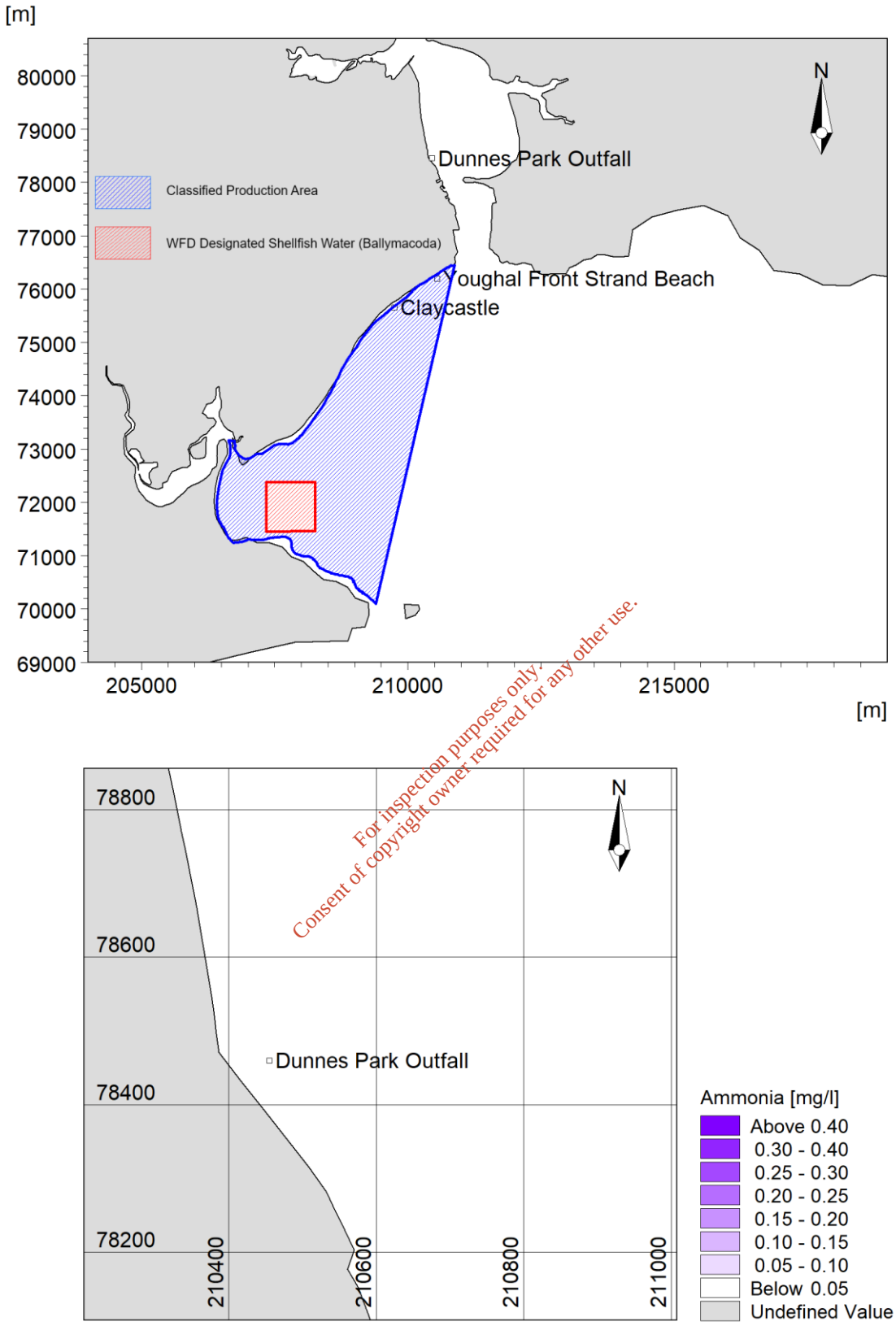

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Figure 3-7. Scenario 4: Ammonia 95%ile concentration [mg/l] all concentrations are below 0.05 mg/l.

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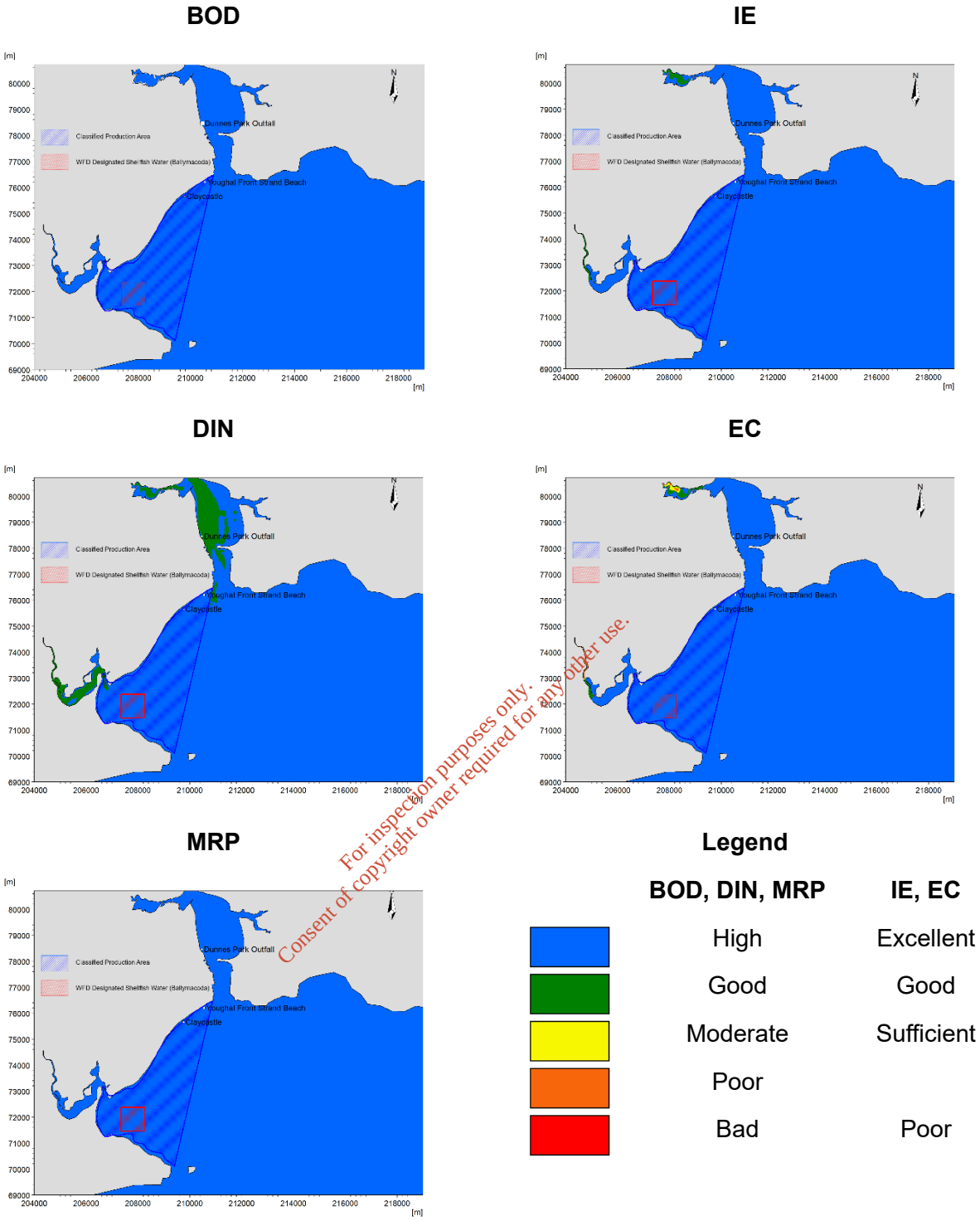

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Figure 3-8. Scenario 4: Indicative quality BOD, DIN, MRP, IE and EC

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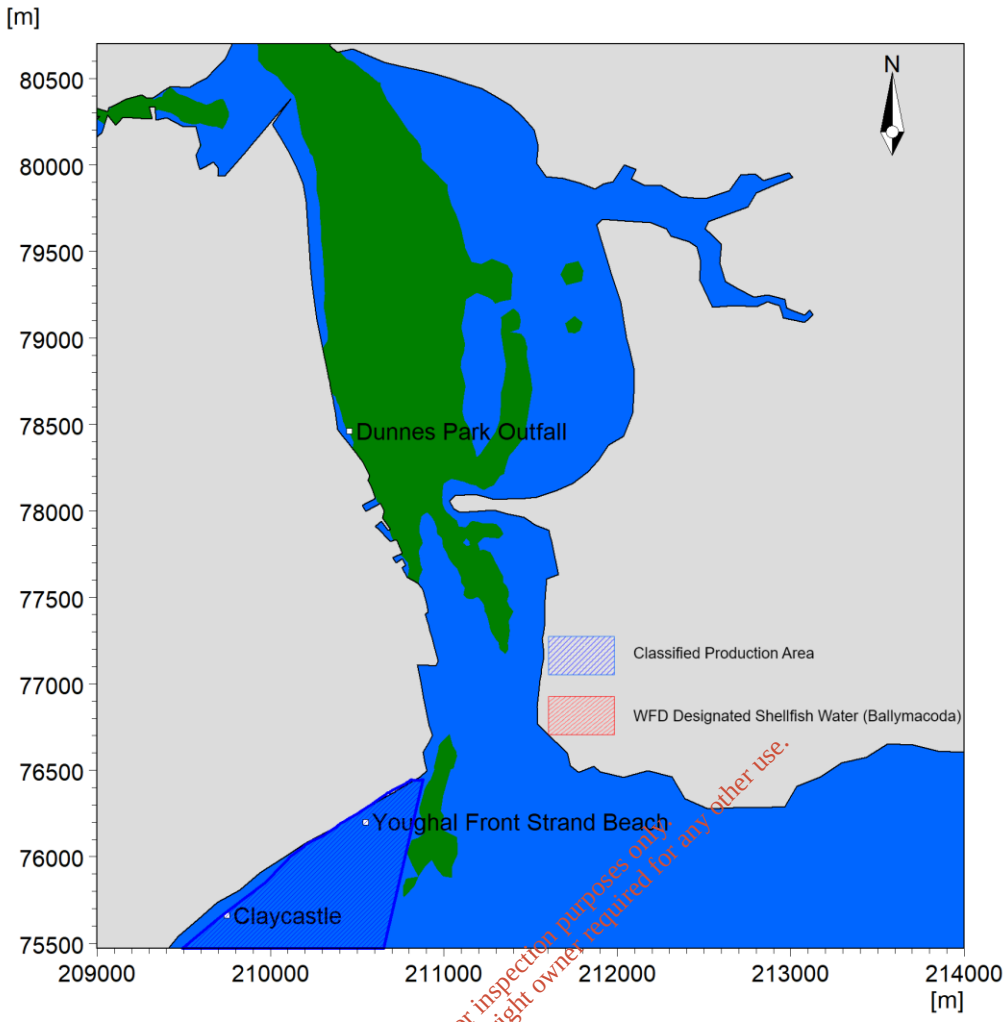

Figure 3-9. Scenario 4: Indicative quality DIN within Youghal Harbour

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4. Scenario 5: Future (16,000PE Capacity) Summer

The Youghal WwTP discharge for the future situation in the summer is 0.043 m^3/s (3 673 m^3/day, median of all measured flows for summer 2018 to 2020 plus additional flow for the increase in PE over present day loading) and the water quality parameters as set out in Table 4.1. General model parameters are set out in Table 1.5.

Table 4.1. Effluent discharge rate and concentrations for each parameter for Scenario 5

Discharge [m^3/s]	BOD [mg/l]	EC [cfu/ 100ml]	IE [cfu/ 100ml]	DIN [mg/l]	MRP [mg/l]	Amm [mg/l]
0.043	25.0	10 000	2500	15.0	10.0	10.0

The modelled concentrations of EC, IE, BOD, DIN, MRP and ammonia are plotted in Figure 4-1 to Figure 4-6. The indicative quality for each parameter is shown in Figure 4-7. Delta plots showing the change in concentration of each bacterial parameter from the baseline of Scenario 3 are shown in Figure 4-8.

The difference between Scenario 3 and 5 is the increase in the discharge rate from the primary discharge of Youghal WwTP (0.027 m^3/s to 0.043 m^3/s) and a significant increase in the concentration (60 cfu/100ml to 10 000 cfu/100ml). This is evident with the increase in the 95%ile concentration of EC around the outfall; however, it still achieves a notional[9] mixing zone extent (<250 cfu/100ml) of less than 50 m.

The changes in EC and IE concentrations are only apparent immediately (less than 50m) around the outfall and magnitude of these are less than 50 cfu/100 ml.

The indicative quality for all parameters is unchanged: High for BOD, DIN and MRP and Excellent for EC and IE.

The concentration of ammonia is between 0.05-0.1 mg/l in a localised area around the outfall. Elsewhere the concentration is less than 0.05 mg/l (Figure 4-6). If unionised ammonia is assumed to be approximately 2% of the ammonia concentration (as described in section 1.6), then the concentration of unionised ammonia is less than 0.001 mg/l, other than within 50 m of the outfall.

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[9] This is not a statutory mixing zone, as there is no regulatory EQS for bacteria in the vicinity of the outfall

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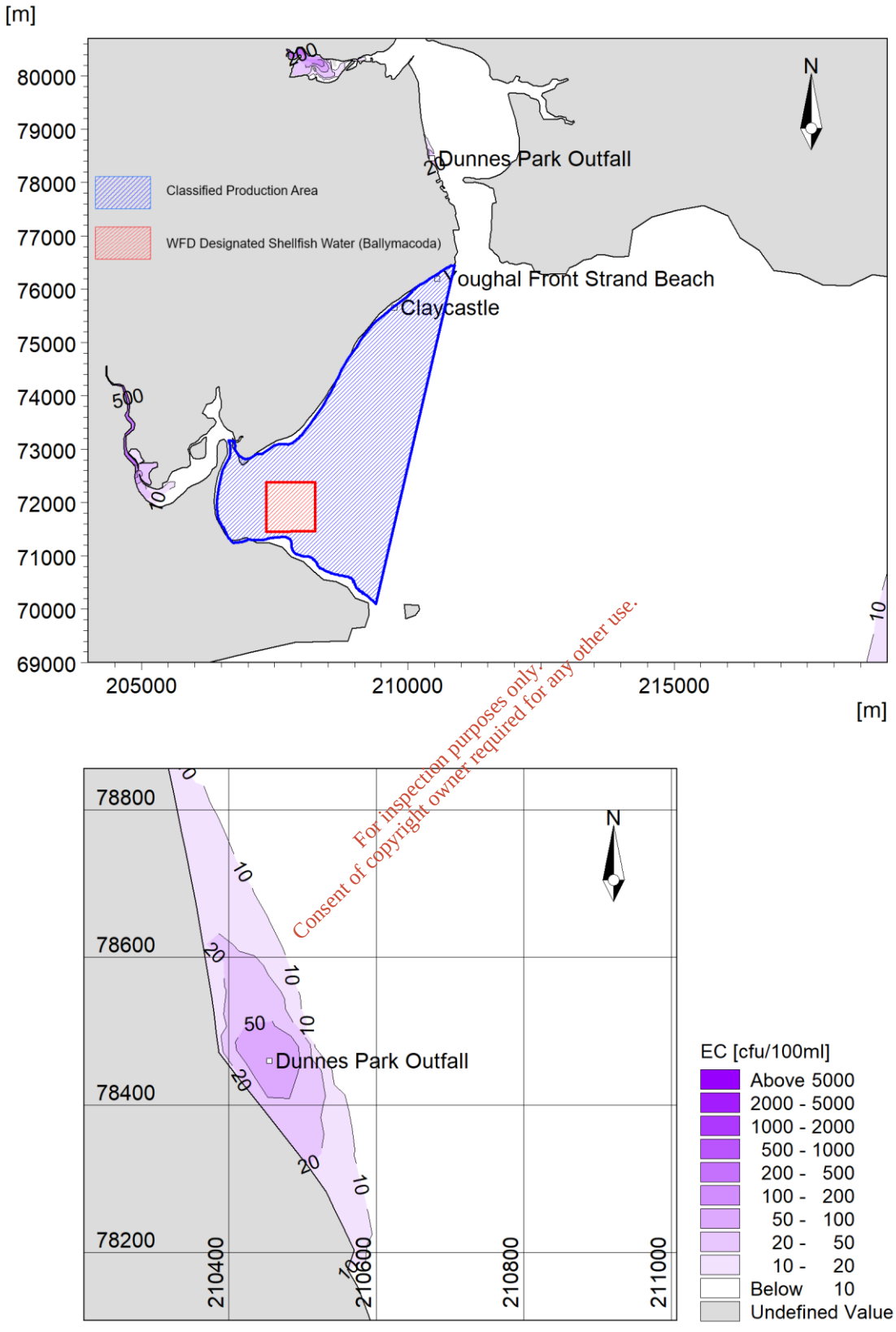

Figure 4-1. Scenario 5: EC 95%ile concentration [cfu/100ml]

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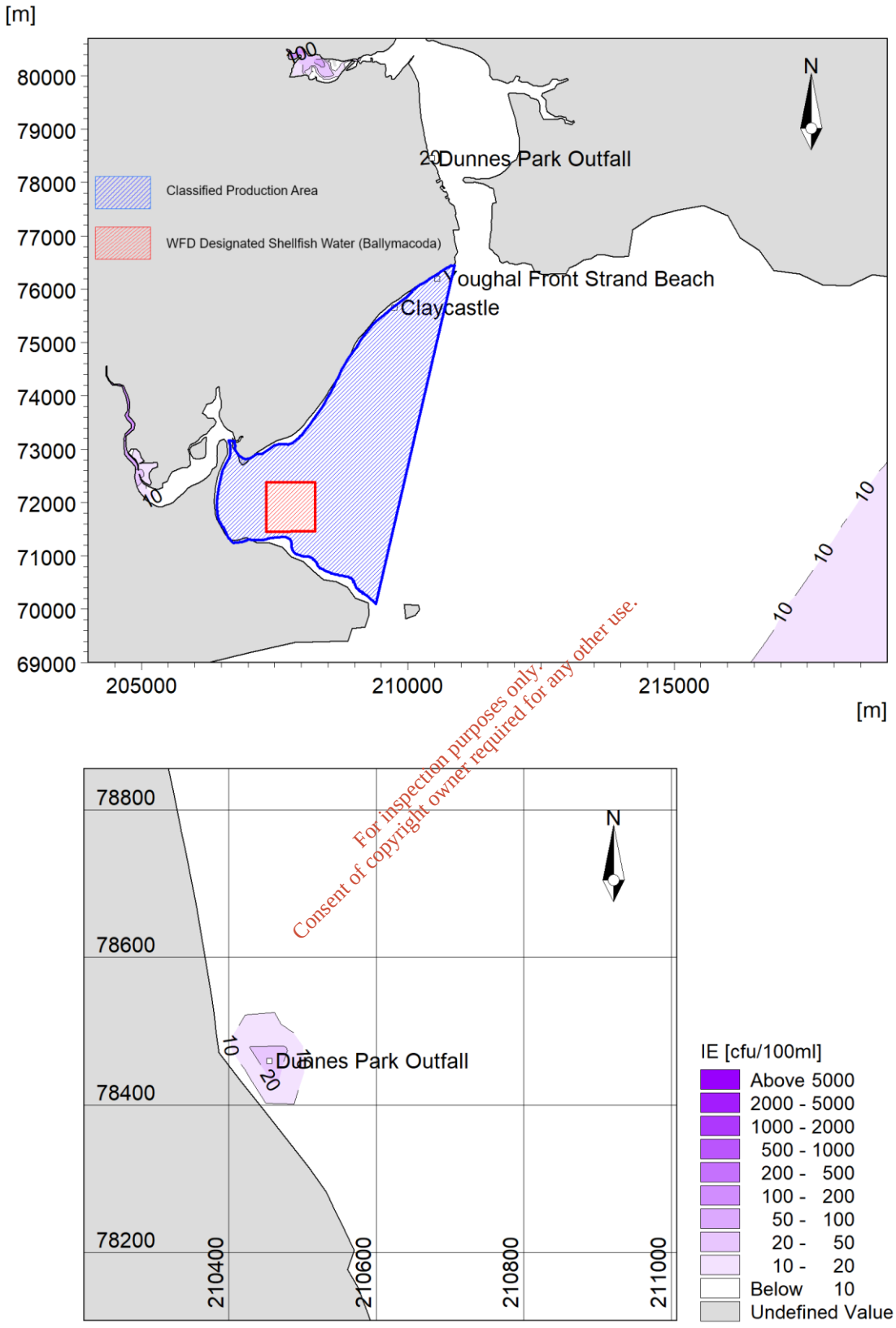

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Figure 4-2. Scenario 5: IE 95%ile concentration [cfu/100ml]

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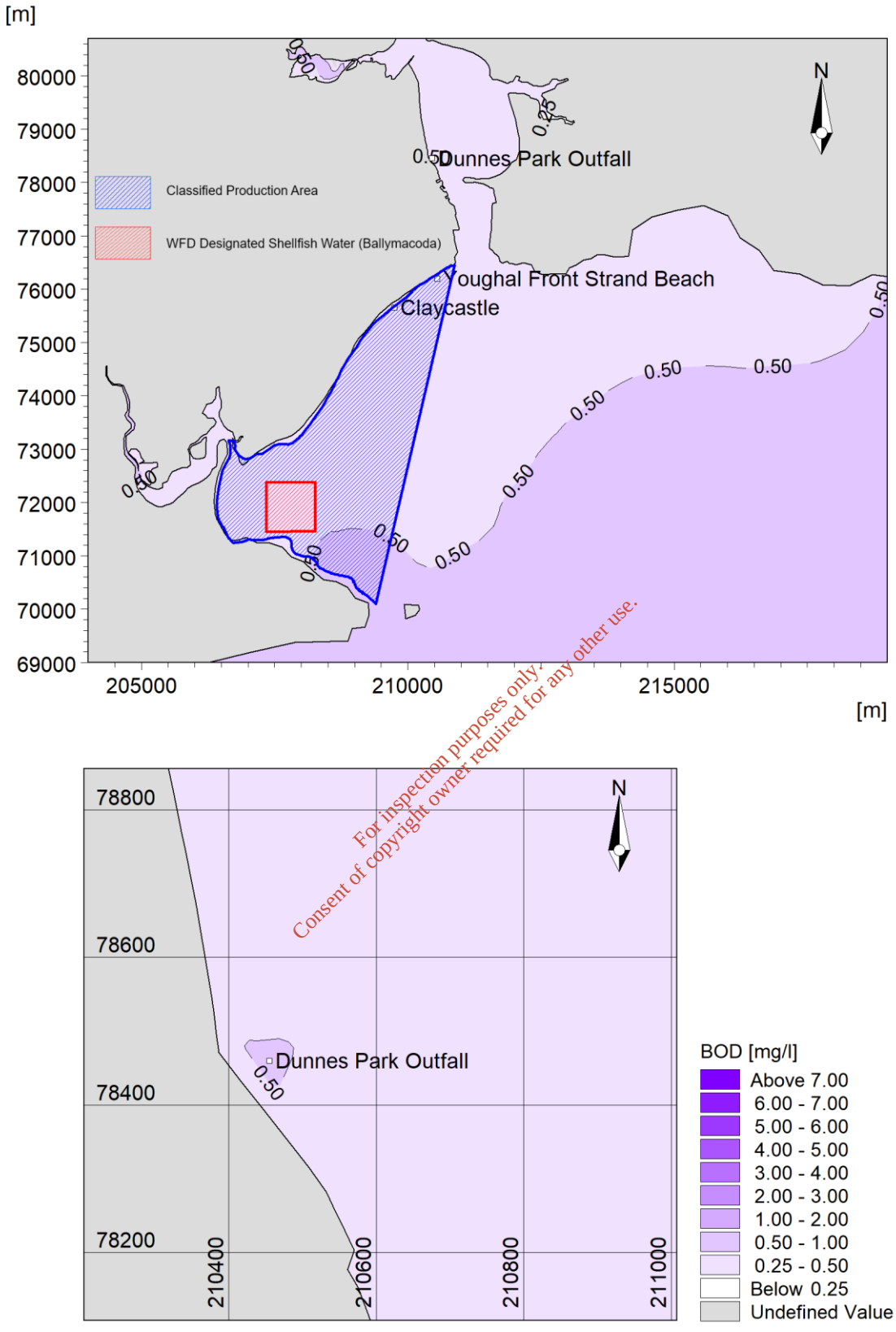

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Figure 4-3. Scenario 5: BOD 95%ile concentration [mg/l]

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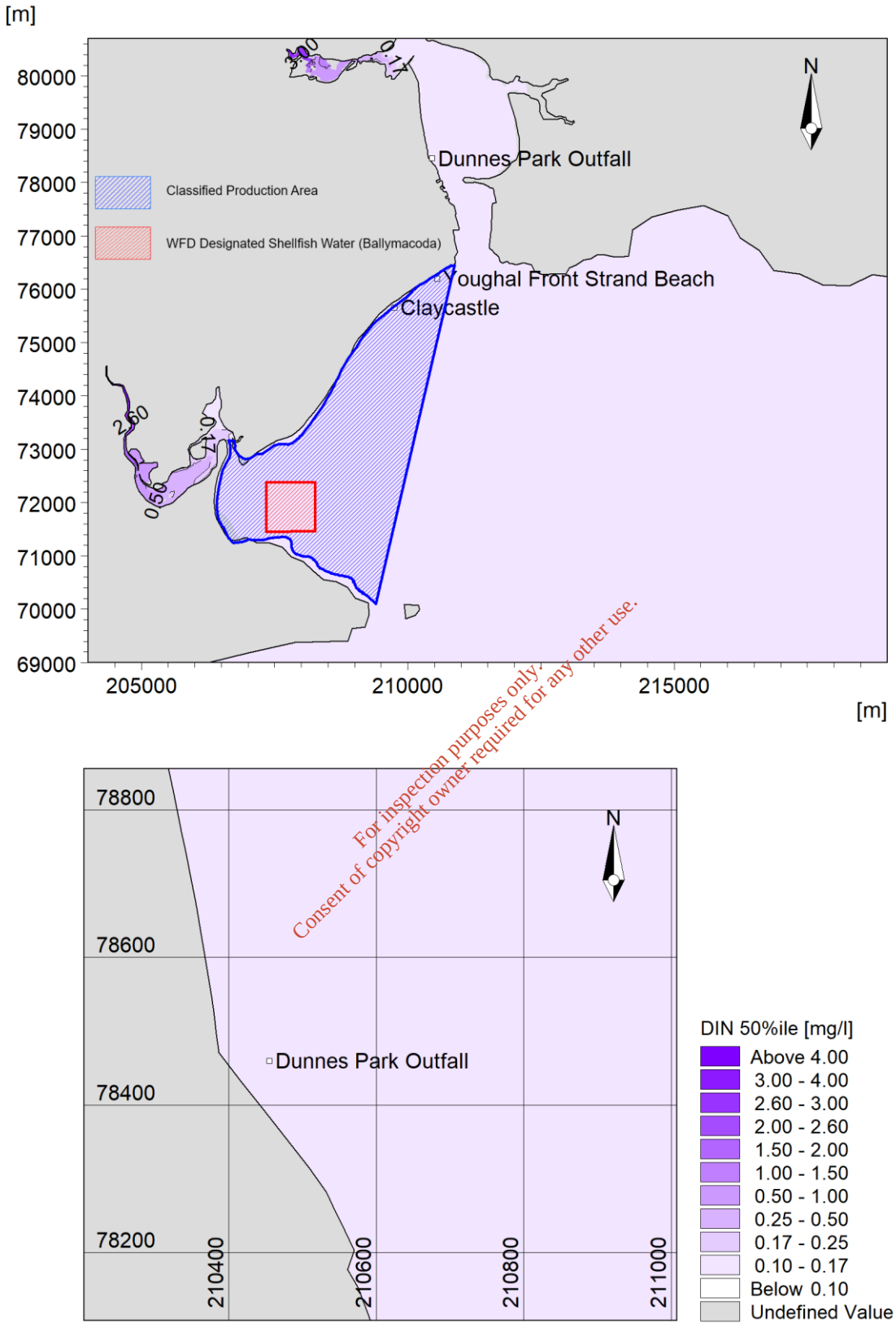

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Figure 4-4. Scenario 5: DIN 50%ile concentration [mg/l]

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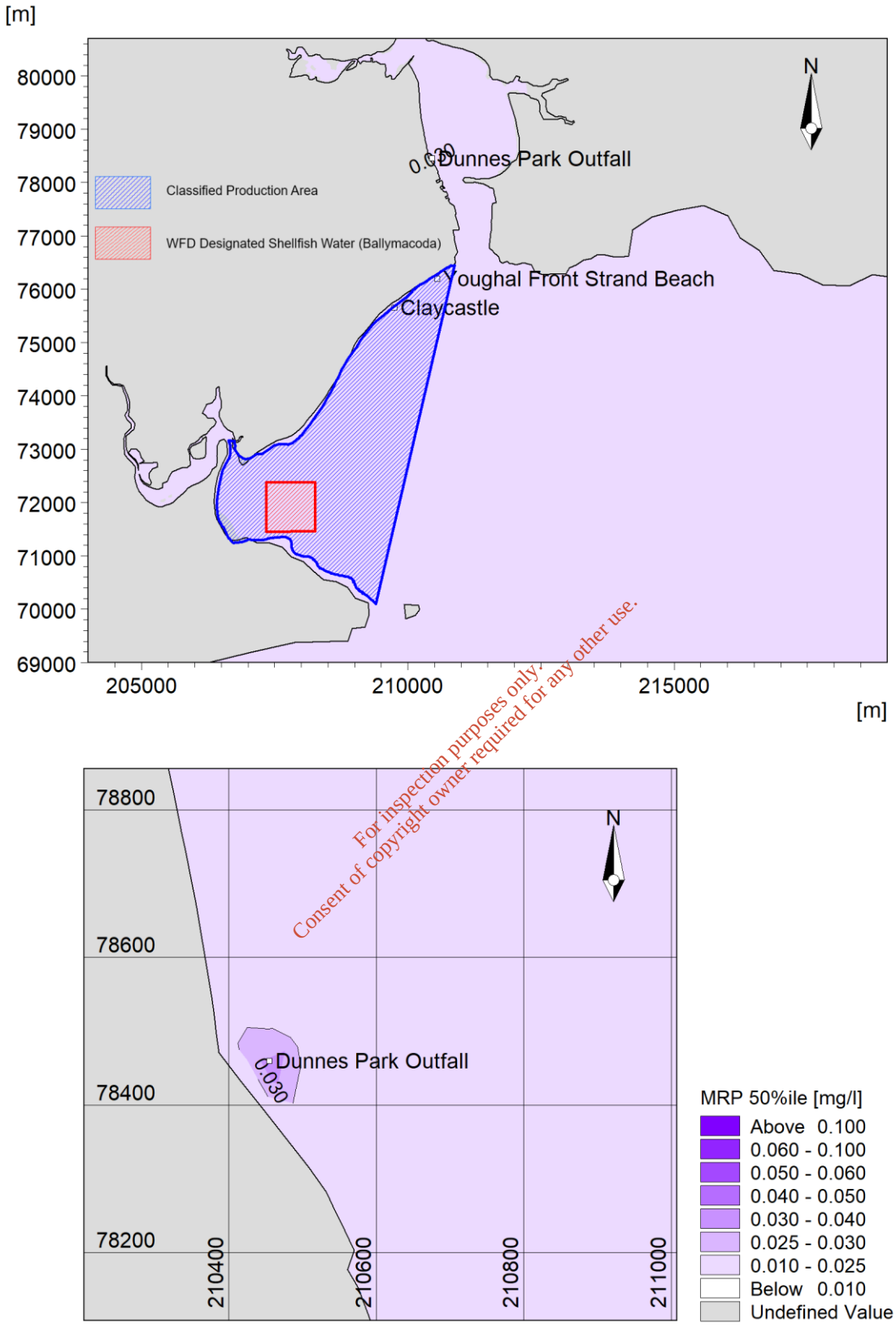

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Figure 4-5. Scenario 5: MRP 50%ile concentration [mg/l]

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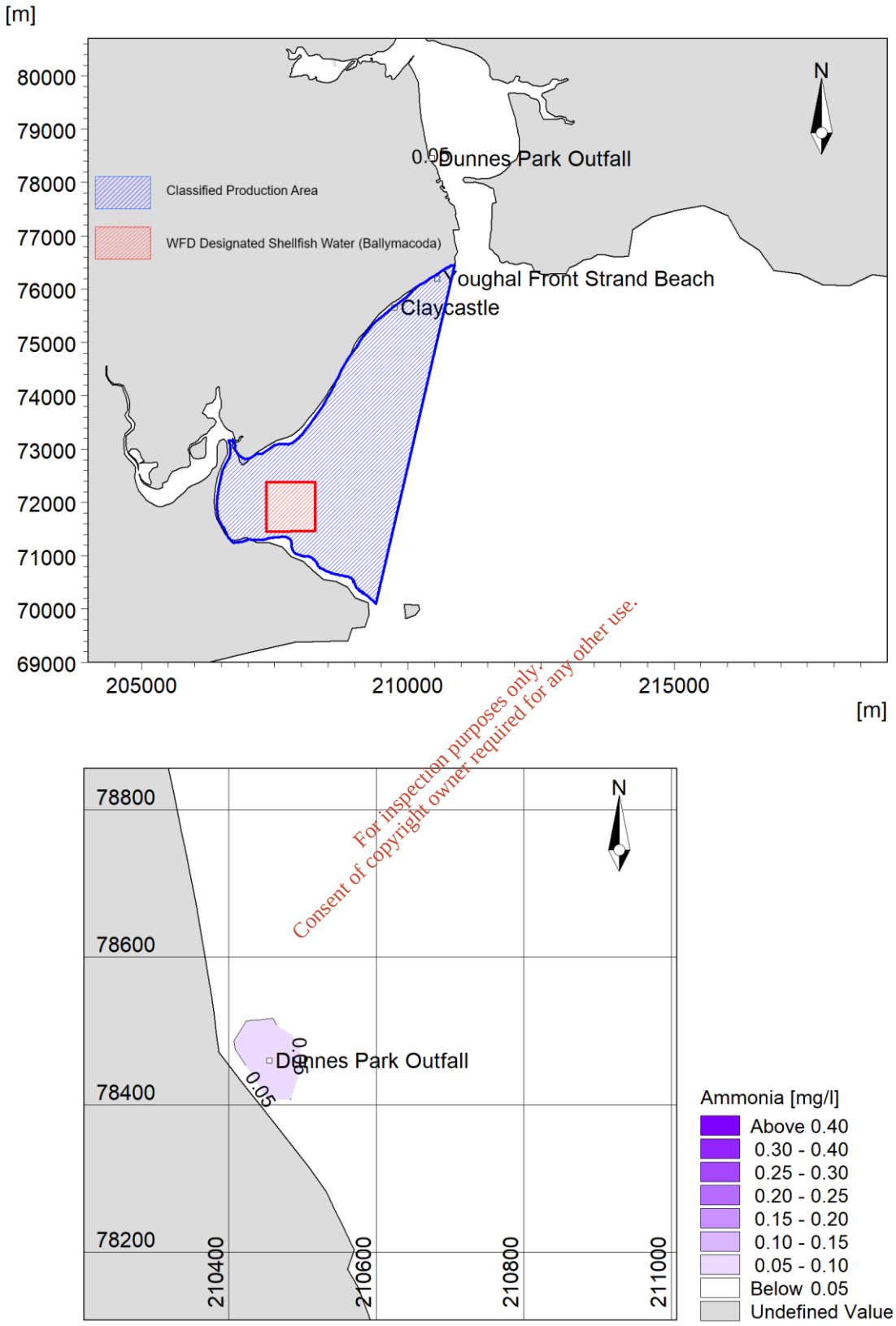

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Figure 4-6. Scenario 5: Ammonia 95%ile concentration [mg/l]

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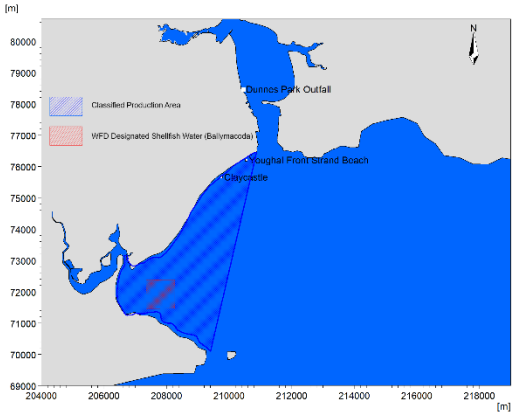
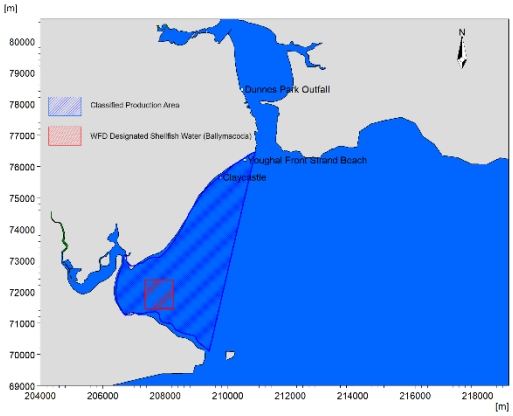
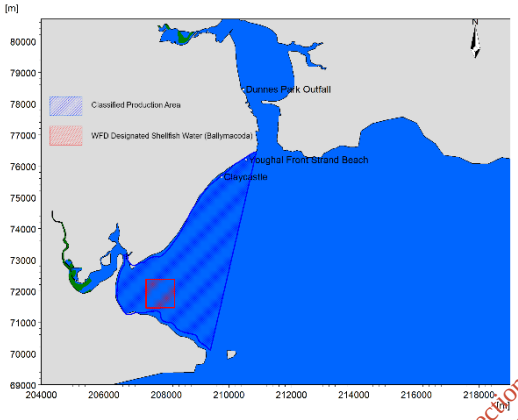
BOD



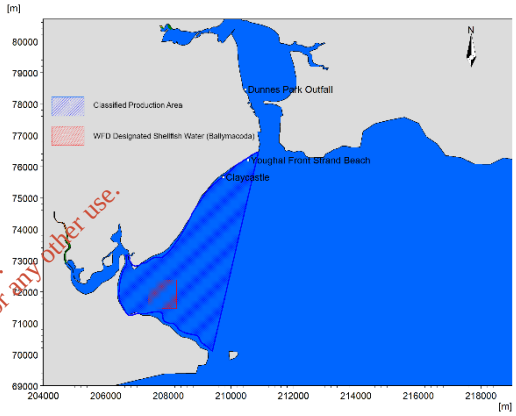
IE



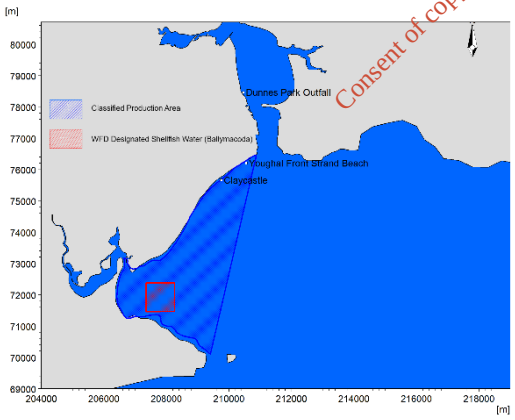
DIN



EC



MRP



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Legend

	BOD, DIN, MRP	IE, EC
	High	Excellent
	Good	Good
	Moderate	Sufficient
	Poor	
	Bad	Poor

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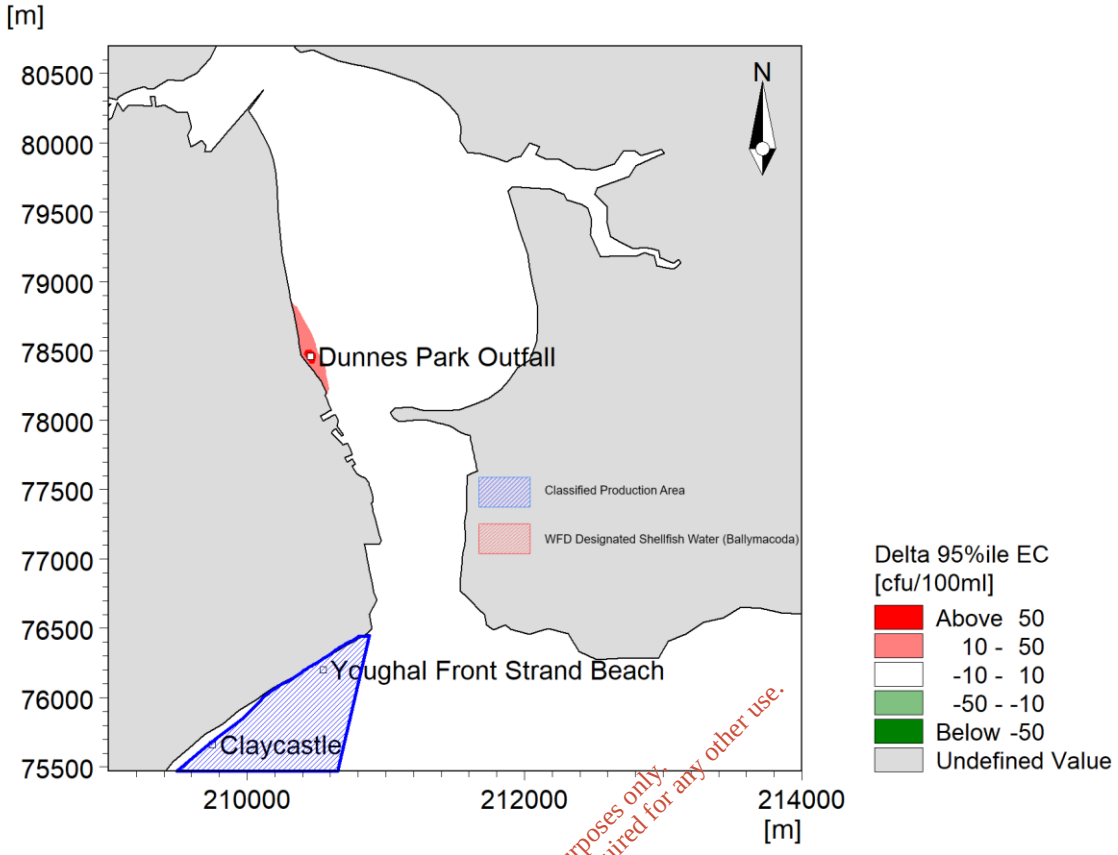
Figure 4-7. Scenario 5: Indicative quality BOD, DIN, MRP, IE and EC



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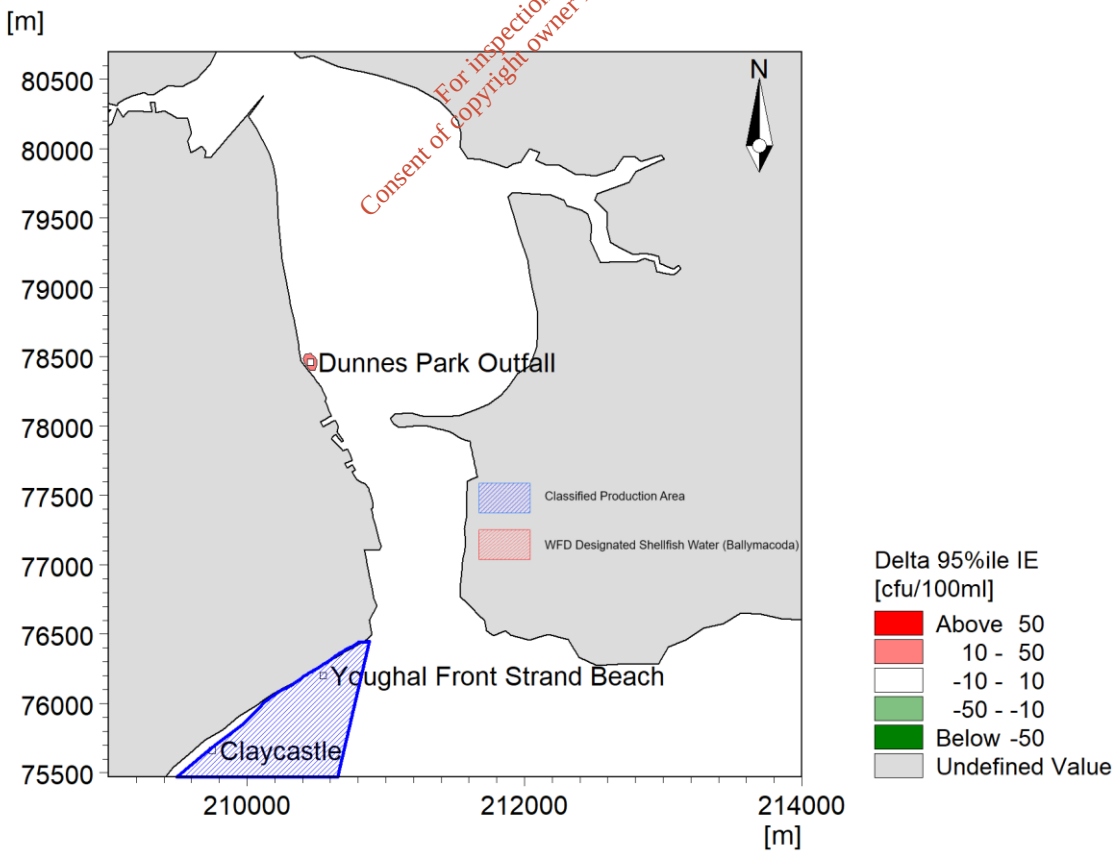

Figure 4-8. Scenario 5: Changes in concentration between Scenario 3 and 5 for EC (top) and IE (bottom)

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5. Scenario 6: Future (16,000PE Capacity) Winter

The Youghal WwTP discharge for the future situation in the winter is 0.063 m^3/s (5 456 m^3/day, median of all measured flows for summer 2018 to 2020 plus additional flow for the increase in PE over present day loading) and the water quality parameters as set out in Table 5.1. General model parameters are set out in Table 1.5.

Table 5.1. Effluent discharge rate and concentrations for each parameter for Scenario 6

Discharge [m^3/s]	BOD [mg/l]	EC [cfu/ 100ml]	IE [cfu/ 100ml]	DIN [mg/l]	MRP [mg/l]	Amm [mg/l]
0.063	25.0	100 000	25000	15.0	10.0	10.0

The modelled concentrations of EC, IE, BOD, DIN, MRP and ammonia are plotted in Figure 5-1 to Figure 5-6. The indicative quality for each parameter is shown in Figure 5-7. Delta plots showing the change in concentration of each bacterial parameter from the baseline of Scenario 4 are shown in Figure 4-8.

The modelled concentration of EC immediately around the Dunnes Park outfall is higher for Scenario 6 than Scenario 4 due to the increased loading from the WwTP.

For context, a notional[10] mixing zone, based on achievement of Excellent Bathing Water Quality (<250cfu/100ml), measures approximately 100m width across the estuary and extends up and down the estuary by approximately 200-300m each way (Figure 5-1).

The plume is evident in low concentrations (less than 10 cfu/100ml) at the beaches and the northern edge of the Classified Production Area. However, the indicative quality of the water remains Excellent at these locations (Figure 5-8).

The EC plume does not reach the Designated Shellfish Water.

The pattern is similar for IE with the notional mixing zone to achieve Excellent Bathing Water Quality (<100cfu/100ml) being smaller than that of EC, measuring approximately 100m in width and extending 100m both upstream and downstream from the outfall.

The concentration of ammonia is less than 0.05 mg/l (Figure 5-6). If unionised ammonia is assumed to be approximately 2% of the ammonia concentration (as described in section 1.6), then the concentration of unionised ammonia is less than 0.001 mg/l.

For all other parameters there are no significant changes compared to Scenario 4.

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[10] This is not a statutory mixing zone, as there is no regulatory EQS for bacteria in the vicinity of the outfall.

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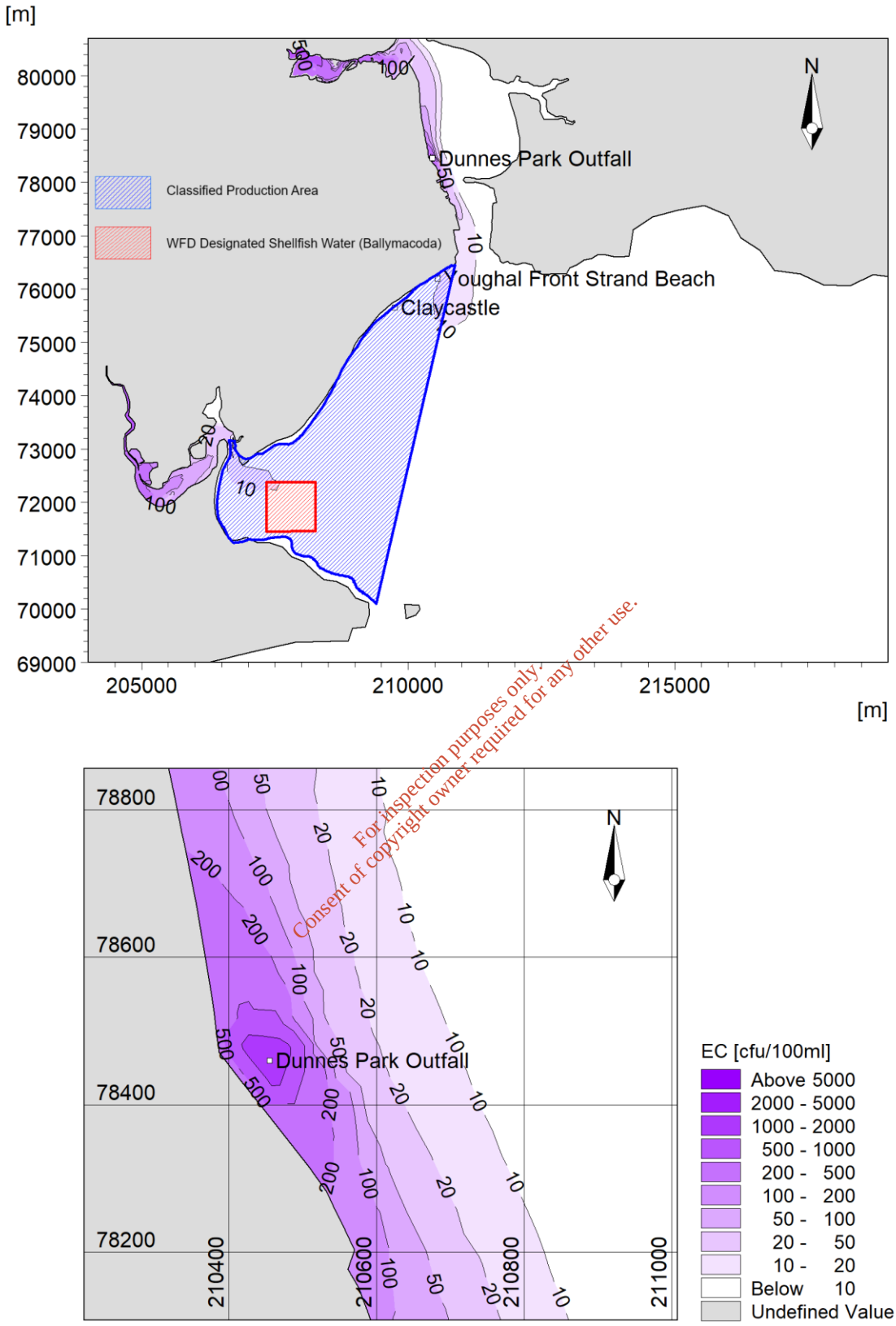

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Figure 5-1. Scenario 6: EC 95%ile concentration [cfu/100ml] - note concentrations at key receptors are below limits for Excellent Bathing Quality [<250cfu/100ml]

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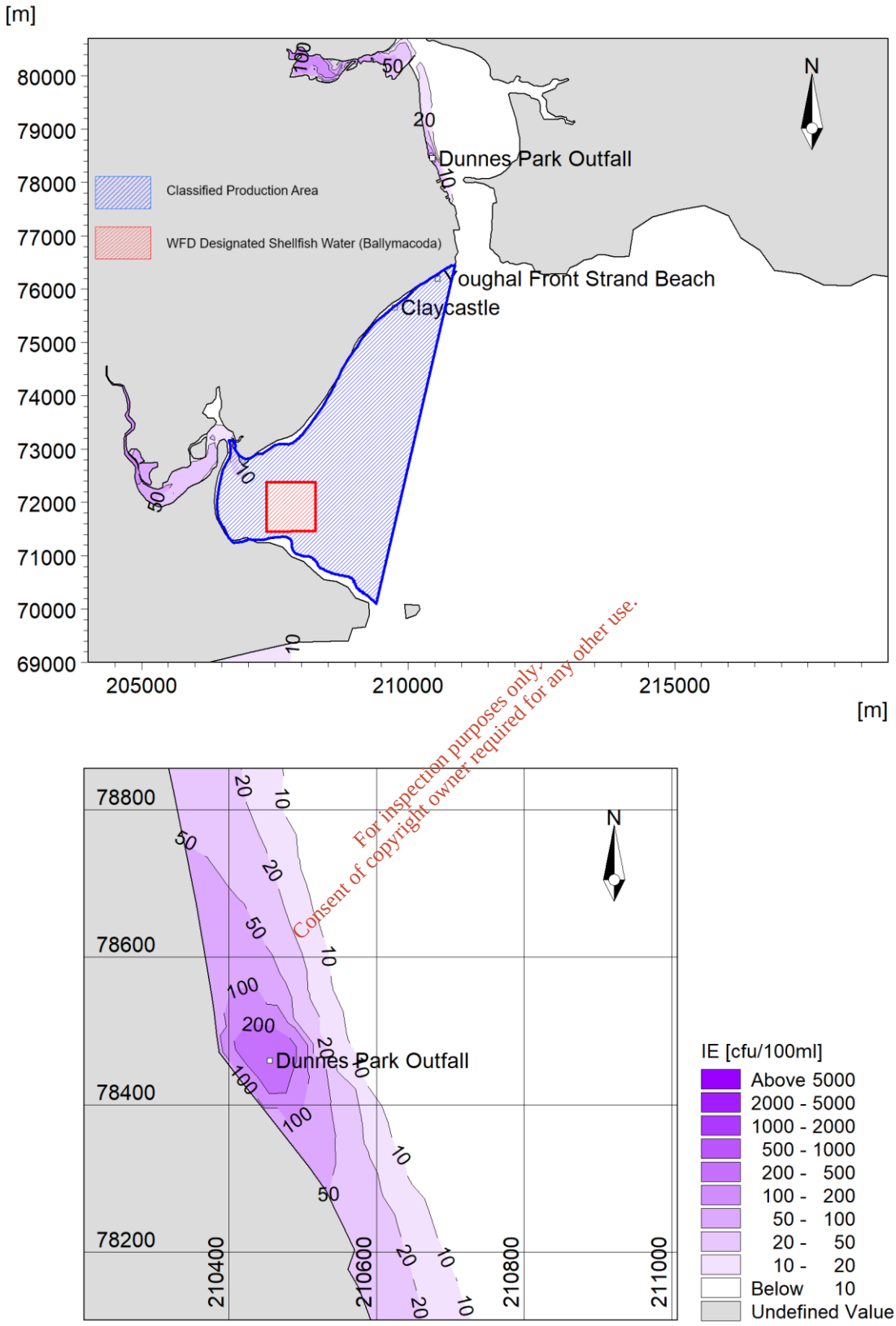

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Figure 5-2. Scenario 6: IE 95%ile concentration [cfu/100ml] - note concentrations at key receptors are below limits for Excellent Bathing Quality [<100cfu/100ml]

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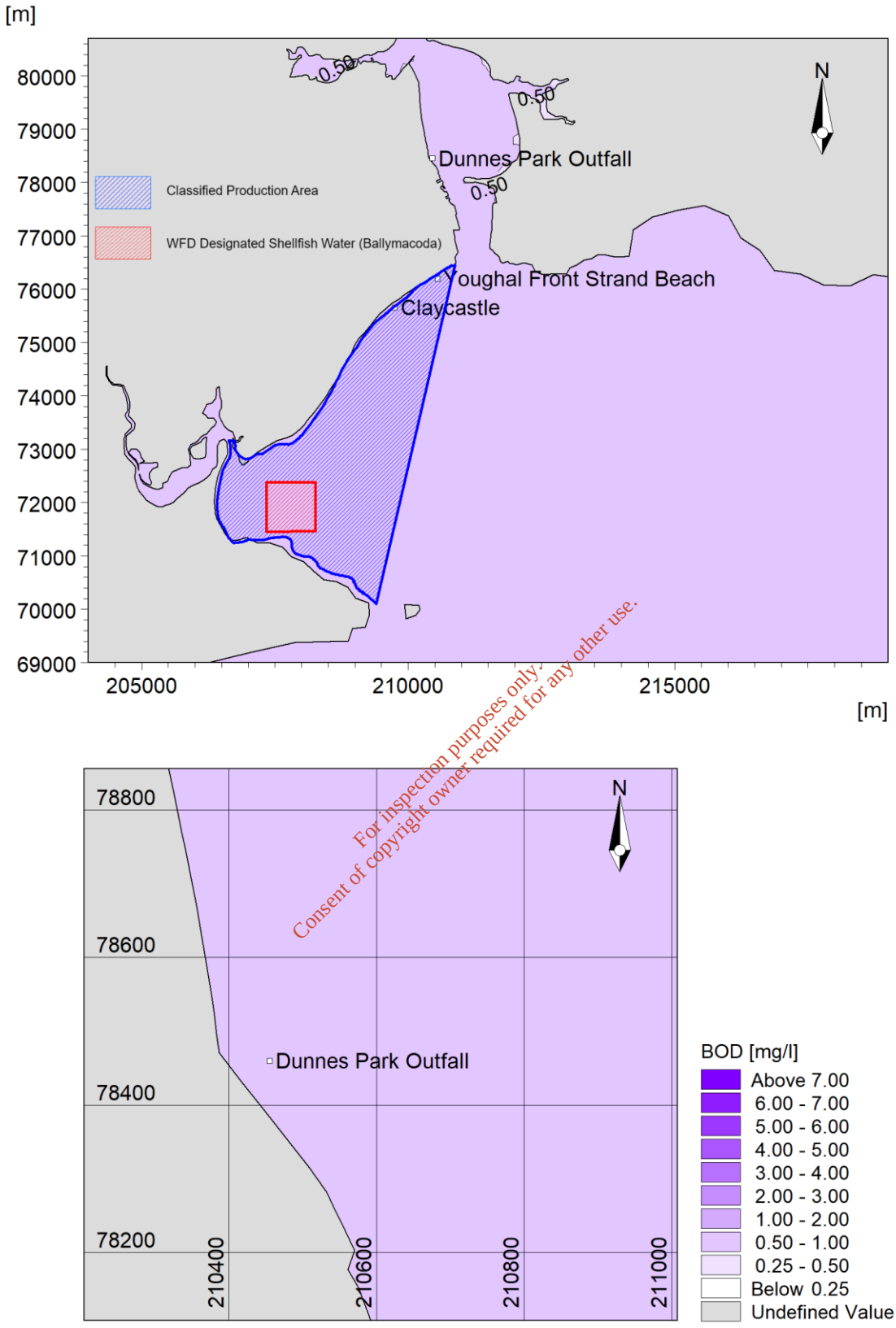

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Figure 5-3. Scenario 6: BOD 95%ile concentration [mg/l]

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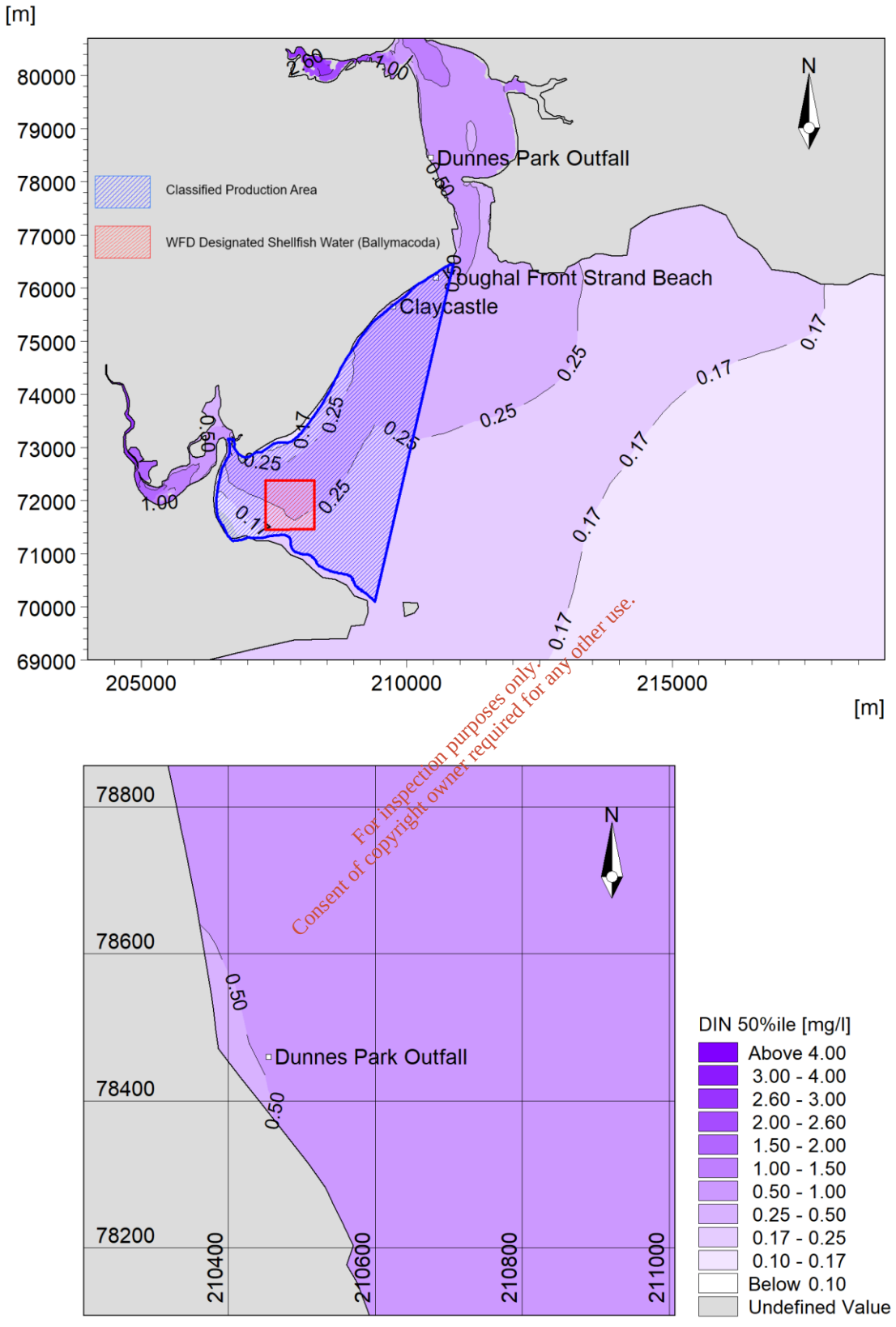

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Figure 5-4. Scenario 6: DIN 50%ile concentration [mg/l]

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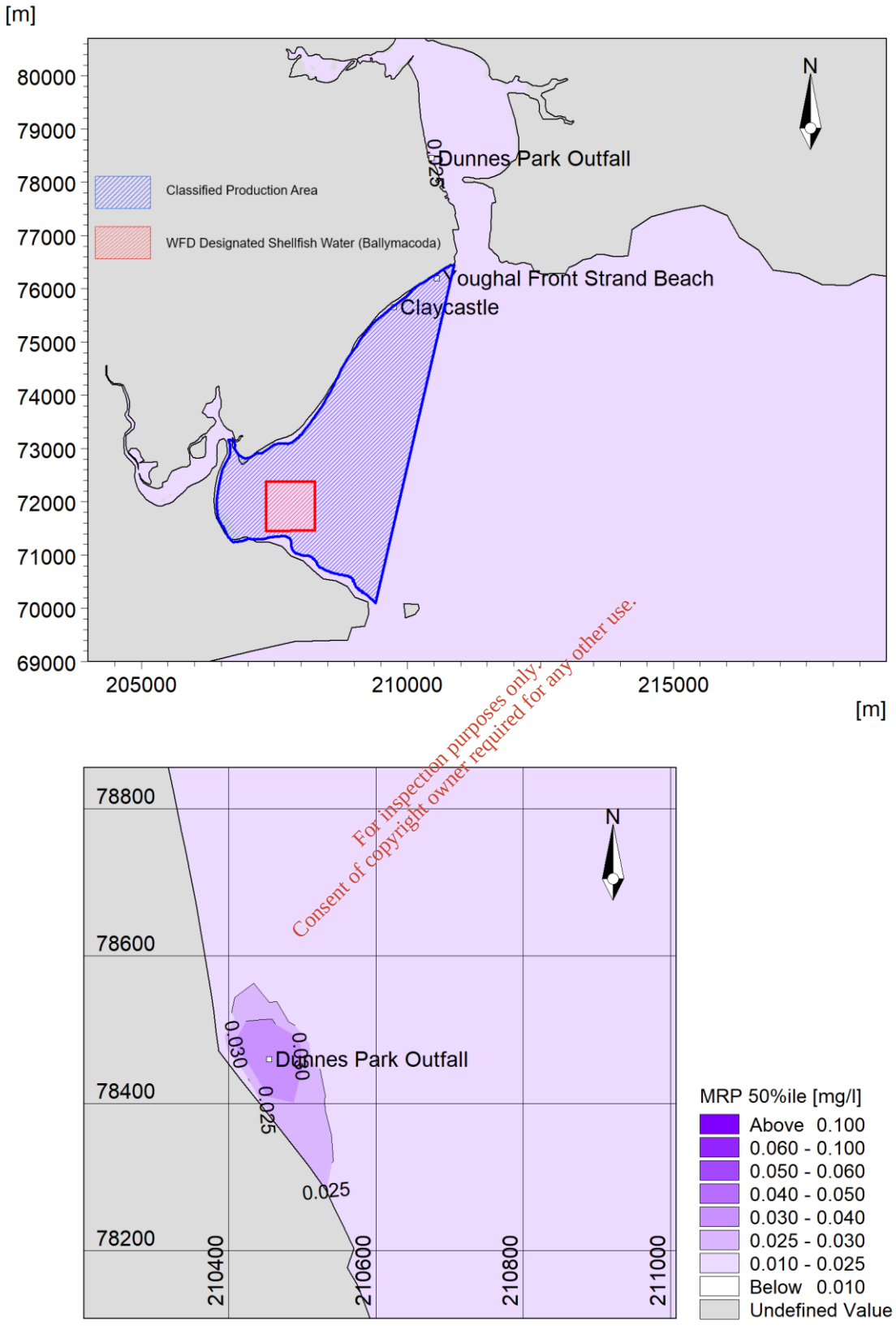

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Figure 5-5. Scenario 6: MRP 50%ile concentration [mg/l]

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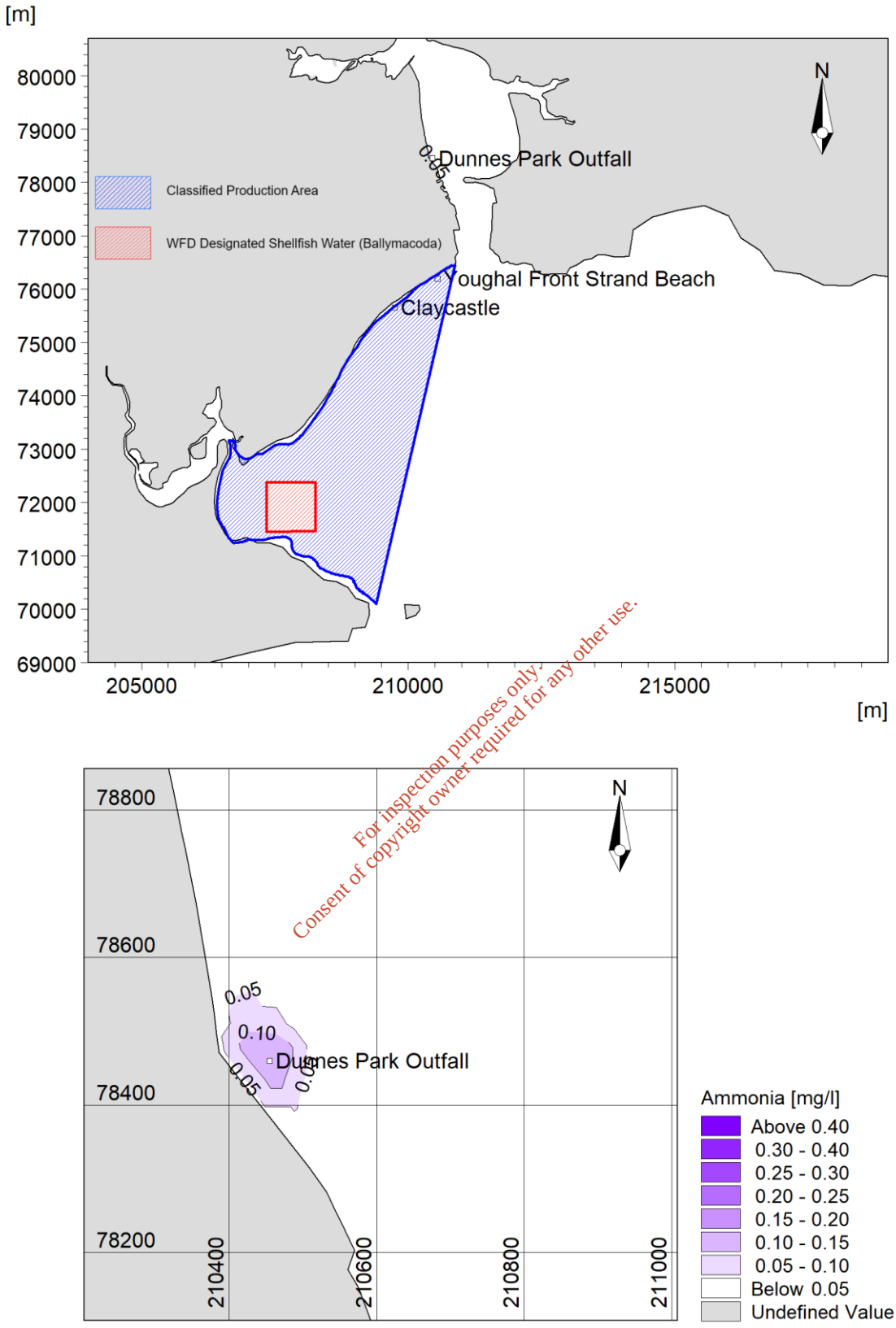

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Figure 5-6. Scenario 6: Ammonia 95%ile concentration [mg/l] all concentrations are below 0.05 mg/l.

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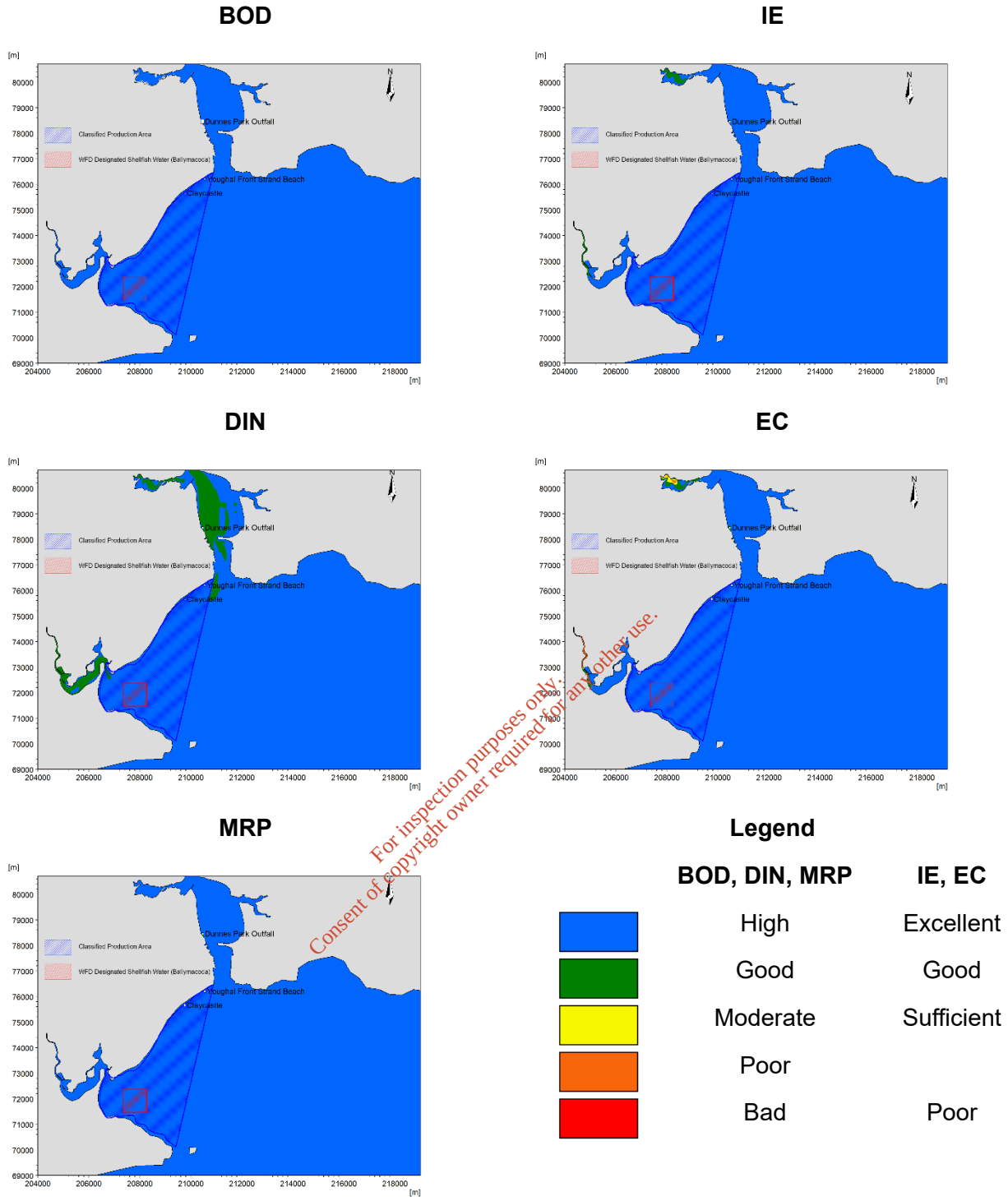

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Figure 5-7. Scenario 6: Indicative quality for BOD, DIN, MRP, IE and EC

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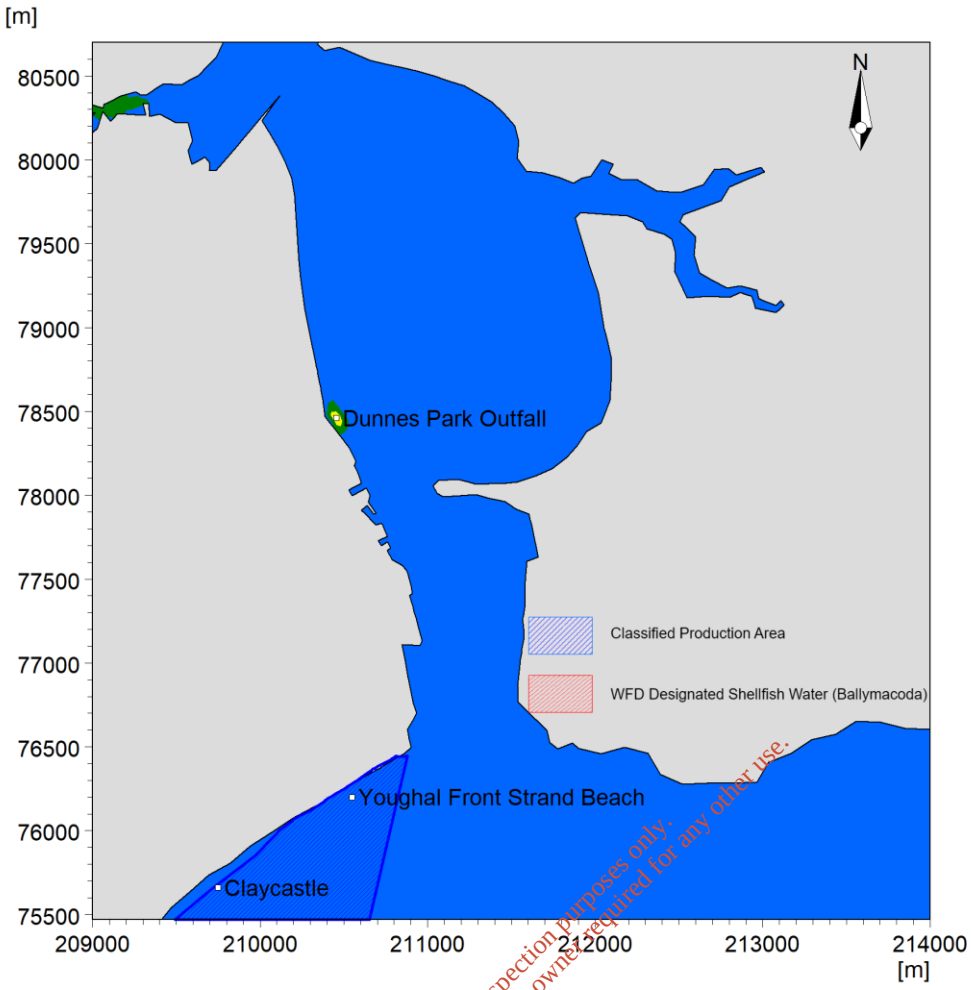

Figure 5-8. Scenario 6: Indicative quality for EC within Youghal Harbour

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