Annual Environmental Report

2020

Waterford City

D0022-01

CONTENTS

1 EXECUTIVE SUMMARY AND INTRODUCTION TO THE 2020 AER

This Annual Environmental Report has been prepared for D0022-01, Waterford City, in Waterford in accordance with the requirements of the wastewater discharge licence for the agglomeration. Specified reports where relevant are included as an appendix to the AER.

1.1 ANNUAL STATEMENT OF MEASURES

A summary of any improvements undertaken is provided where applicable.

IW are currently undertaking a Drainage Area Plan for the Waterford Agglomeration. This DAP will identify deficiencies within the agglomeration and outline the timeframe for completion of same.

1.2 TREATMENT SUMMARY

The agglomeration is served by a wastewater treatment plant(s)

- WATERFORD CITY WWTP - 2020 with a Plant Capacity PE of 190600, the treatment type is 2 - Secondary treatment

1.3 ELV OVERVIEW

The overall compliance of the final effluent with the Emission Limit Values (ELVs) is shown below. More detailed information on the below ELV's can be found in Section 2.

Discharge Point Reference	Treatment Plant	Discharge Type	Compliance Status	Parameters failing if relevant
TPEFF3000D0022SW001	WATERFORD CITY WWTP - 2020	Treated	Compliant	N/A

1.4 LICENCE SPECIFIC REPORTING INCLUDED IN AER

Assessment / Report	Included in AER
There are no Licence Specific Reports included in the AER.	

2 TREATMENT PLANT PERFORMANCE AND IMPACT SUMMARY

2.1 WATERFORD CITY WWTP - 2020 - TREATED DISCHARGE

2.1.1 INFLUENT MONITORING SUMMARY - WATERFORD CITY WWTP - 2020

A summary of influent monitoring for the treatment plant is presented below. This monitoring is primarily undertaken in order to determine the overall efficiency of the plant in removing pollutants from the raw wastewater.

Parameters	Number of Samples	Annual Max	Annual Mean
Suspended Solids mg/l	26	648	177.23
Total Phosphorus (as P) mg/l	26	15.2	4.61
Total Nitrogen mg/l	26	50.6	26.55
BOD, 5 days with Inhibition (Carbonaceous BOD) mg/l	26	321	119.38
COD-Cr mg/l	26	940	309.5
Hydraulic Capacity	N/A	77378	36987

If other inputs in the form of sludge / leachate are added to the WWTP then these are included in Section 2.1.5 if applicable.

Significance of Results:

The annual mean hydraulic loading is less than the peak Treatment Plant Capacity. The annual maximum hydraulic loading is less than the peak Treatment Plant Capacity. Further details on the plant capacity and efficiency can be found under the sectional ‘Operational Performance Summary’. The design of the wastewater tretament plant allows for peak values and therefore the peak loads have not impacted on compliance with Emission Limit Values.

2.1.2 EFFLUENT MONITORING SUMMARY - TPEFF3000D0022SW001

Parameter	WWDL ELV (Schedule A)	ELV with Condition 2 Interpretation included Note 1	Interim % reduction from influent concentration	Number of sample results	Number of exceedances	Number of with Condition 2 Interpretation included	Annual Mean	Overall Compliance (Pass/Fail)
COD-Cr mg/l	125	250	N/A	26	N/A	N/A	27.22	Pass
Total Nitrogen mg/l	35	42	N/A	26	N/A	N/A	10.01	Pass
Total Oxidised Nitrogen (as N) mg/l	35	42	N/A	26	N/A	N/A	4.56	Pass
Suspended Solids mg/l	35	87.5	N/A	26	N/A	N/A	7.46	Pass
Ammonia-Total (as N) mg/l	25	30	N/A	26	N/A	N/A	4.41	Pass
BOD, 5 days with Inhibition (Carbonaceous BOD) mg/l	25	50	N/A	26	N/A	N/A	4.79	Pass
pH pH units	9	9	N/A	26	N/A	N/A	7.55	Pass
Fats, Oils & Greases mg/l	N/A	N/A	N/A	4	N/A	N/A	4.42	
ortho-Phosphate (as P) - unspecified mg/l	N/A	N/A	N/A	26	N/A	N/A	0.82	

Parameter	WWDL ELV (Schedule A)	ELV with Condition 2 Interpretation included Note 1	Interim % reduction from influent concentration	Number of sample results	Number of exceedances	Number of with Condition 2 Interpretation included	Annual Mean	Overall Compliance (Pass/Fail)
Conductivity @20°C µS/cm	N/A	N/A	N/A	26	N/A	N/A	1533.22	
Total Phosphorus (as P) mg/l	N/A	N/A	N/A	26	N/A	N/A	1.19	

Notes:
1 – This represents the Emission Limit Values after the Interpretation provided for under Condition 2 of the licence is applied

Cause of Exceedance(s):

Not applicable

Significance of Results:

The WWTP is compliant with the ELV's set in the Wastewater Discharge Licence.

2.1.3 AMBIENT MONITORING SUMMARY FOR THE TREATMENT PLANT DISCHARGE TPEFF3000D0022SW001

A summary of monitoring from ambient monitoring points associated with the wastewater discharge is provided in the sections below. For discharges to rivers upstream (U/S) and downstream (D/S) location data is provided. For other ambient points in lakes, coastal or transitional waters, monitoring data from the most appropriate monitoring station is selected.

The table below provides details of ambient monitoring locations and details of any designations as sensitive areas.

Ambient Monitoring Point from WWDL (or as agreed with EPA)	Irish Grid Reference	River Station Code	Bathing Water	Drinking Water	FWPM	Shellfish	WFD Status
Upstream	264720, 112043	TW30002102SR4002	No	No	No	Yes	Good
Downstream	266200, 113186	TW30002102SR4004	No	No	No	Yes	Good

The results for ambient results and / or additional monitoring data sets are included in the **Appendix 7.1 - Ambient monitoring summary**

Significance of Results:

The WWTP discharge was compliant with the ELV's set in the wastewater discharge licence.

The ambient monitoring results meet the required EQS. The EQS relates to the Oxygenation and Nutrient Conditions set out in the Surface Water Regulations 2009.

The discharge from the wastewater treatment plant does not have an observable impact on the water quality.

The discharge from the wastewater treatment plant does not have an observable negative impact on the Water Framework Directive status.

2.1.4 OPERATIONAL PERFORMANCE SUMMARY - WATERFORD CITY WWTP - 2020

2.1.4.1 Treatment Efficiency Report - WATERFORD CITY WWTP - 2020

Treatment efficiency is based on the removal of key pollutants from the influent wastewater by the treatment plant. In essence the calculation is based on the balance of load coming into the plant versus the load leaving the plant. The efficiency is presented as a percentage removal rate.

A summary presentation of the efficiency of the treatment process including information for all the parameters specified in the licence is included below:

Parameter	Influent mass loading (kg/year)	Effluent mass emission (kg/year)	Efficiency (% reduction of influent load)
SS	2471711	113244	95
COD	4316419	413309	90

Parameter	Influent mass loading (kg/year)	Effluent mass emission (kg/year)	Efficiency (% reduction of influent load)
TN	370230	151994	59
TP	64315	18052	72
cBOD	1664980	72672	96

Note: The above data is based on sample results for the number of dates reported

2.1.4.2 Treatment Capacity Report Summary - WATERFORD CITY WWTP - 2020

Treatment capacity is an assessment of the hydraulic (flow) and organic (the amount of pollutants) load a treatment plant is designed to treat versus the current loading of that plant.

WATERFORD CITY WWTP - 2020	
Peak Hydraulic Capacity (m^3/day) - As Constructed	82598
DWF to the Treatment Plant (m^3/day)	82598
Current Hydraulic Loading - annual max (m^3/day)	77378
Average Hydraulic loading to the Treatment Plant (m^3/day)	36987
Organic Capacity (PE) - As Constructed	190600
Organic Capacity (PE) - Collected Load (peak week)[Note1]	107254
Organic Capacity (PE) - Remaining	83346
Will the capacity be exceeded in the next three years? (Yes/No)	No

Nominal design capacities can be based on conservative design principles. In some cases assessment of existing plants has shown organic capacities significantly higher than the nominal design capacity. Accordingly plants that appear to be overloaded when comparing a collected peak load with the nominal design capacity can be fully compliant due to the safety factors in the original design.

2.1.5 SLUDGE / OTHER INPUTS - WATERFORD CITY WWTP - 2020

'Other inputs' to the waste water treatment plant are summarised in table below

Input type	Quantity	Unit	P.E.	% of load to WWTP	Included in Influent Monitoring (Y/N)?	Is there a leachate/sludge acceptance procedure for the WWTP?	Is there a dedicated leachate/sludge acceptance facility for the WWTP? (Y/N)
There is no Sludge and Other Input data for the Treatment Plant included in the AER.							

3 COMPLAINTS AND INCIDENTS

3.1 COMPLAINTS SUMMARY

A summary of complaints of an environmental nature is included below.

Number of Complaints	Nature of Complaint	Number Open Complaints	Number Closed Complaints
2	Blocked Sewer	0	2

3.2 REPORTED INCIDENTS SUMMARY

Environmental incidents that arise in an agglomeration are reported on an on-going basis in accordance with our waste water discharge licences. Where an incident occurs and it is reportable under the licence, it is reported to the Environmental Protection Agency through their Environmental Data Exchange Network, or in some instances by telephone. Some incidents which arise in the agglomeration are recorded by Irish Water but may not be reportable under our licence for example where the incident does not have an impact on environmental performance.

A summary of reported incidents is included below.

3.2.1 SUMMARY OF INCIDENTS

Incident Type	Cause	No. of incident occurrences	Recurring (Y/N)	Closed (Y/N)
Uncontrolled release	Adverse Weather	1	Yes	Yes
Spillage	Blocked Sewer	1	No	Yes
Spillage	Blocked Sewer	1	No	Yes

Incident Type	Cause	No. of incident occurrences	Recurring (Y/N)	Closed (Y/N)
Uncontrolled release	EO caused by power failure	1	No	No

3.2.2 SUMMARY OF OVERALL INCIDENTS

Question	Answer
Number of Incidents in 2020	4
Number of Incidents reported to the EPA via EDEN in 2020	4
Explanation of any discrepancies between the two numbers above	N/A

4 INFRASTRUCTURAL ASSESSMENTS AND PROGRAMME OF IMPROVEMENTS

4.1 STORM WATER OVERFLOW IDENTIFICATION AND INSPECTION REPORT

A summary of the operation of the storm water overflows and their significance where known is included below:

4.1.1 SWO IDENTIFICATION

WWDL Name / Code for Storm Water Overflow	Irish Grid Ref.	Included in Schedule A4 of the WWDL	Significance of the overflow(High / Medium / Low)	Assessed against DoEHLG Criteria	No. of times activated in 2020 (No. of events)	Total volume discharged in 2020 (m3)	Monitoring Status
SW026	260952, 112406	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
SW1	261619, 111853	Yes	Medium	Meeting	Unknown	Unknown	Monitored
SW11	262700, 111403	Yes	Medium	Meeting	Unknown	Unknown	Not Monitored
SW12	263259, 111766	Yes	Medium	Not yet Assessed	Unknown	Unknown	Monitored
SW19	264457, 110272	Yes	Medium	Meeting	Unknown	Unknown	Monitored
SW20	260329, 112787	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored

WWDL Name / Code for Storm Water Overflow	Irish Grid Ref.	Included in Schedule A4 of the WWDL	Significance of the overflow(High / Medium / Low)	Assessed against DoEHLG Criteria	No. of times activated in 2020 (No. of events)	Total volume discharged in 2020 (m3)	Monitoring Status
SW21	260379, 112742	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
SW22	260501, 112719	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
SW23	260589, 112698	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
SW24	260762, 112650	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
SW25	260886, 112571	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
SW26	260990, 112556	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
SW27	260154, 112820	Yes	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
SW4	261077, 112775	Yes	Medium	Meeting	Unknown	Unknown	Monitored
SW6	261499, 112575	Yes	Medium	Meeting	Unknown	Unknown	Monitored
SW7A	263551, 112256	No	Medium	Not Meeting	Unknown	Unknown	Not Monitored

WWDL Name / Code for Storm Water Overflow	Irish Grid Ref.	Included in Schedule A4 of the WWDL	Significance of the overflow(High / Medium / Low)	Assessed against DoEHLG Criteria	No. of times activated in 2020 (No. of events)	Total volume discharged in 2020 (m3)	Monitoring Status
SW8	263924, 112245	Yes	Medium	Not Meeting	Unknown	Unknown	Not Monitored
SW9	262238, 111332	Yes	Medium	Meeting	Unknown	Unknown	Not Monitored
TBC	261530, 111571	No	Unknown	Meeting	49	128044	Monitored
TBC	258982, 110907	No	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
TBC	260542, 111611	No	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
TBC	259928, 111072	No	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
TBC	259013, 111410	No	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
TBC	261506, 111785	No	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
TBC	261530, 111571	No	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
TBC	264457, 110272	No	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored

WWDL Name / Code for Storm Water Overflow	Irish Grid Ref.	Included in Schedule A4 of the WWDL	Significance of the overflow(High / Medium / Low)	Assessed against DoEHLG Criteria	No. of times activated in 2020 (No. of events)	Total volume discharged in 2020 (m3)	Monitoring Status
TBC	261750, 112656	No	Unknown	Not yet Assessed	Unknown	Unknown	Not Monitored
TBC	257803, 110079	No	Medium	Meeting	Unknown	Unknown	Not Monitored
TBC	260145, 109945	No	Unknown	Not yet Assessed	Unknown	Unknown	Unknown
TBC	264223, 110122	No	Unknown	Not yet Assessed	Unknown	Unknown	Unknown
TBC	322852, 246228	No	Unknown	Not yet Assessed	Unknown	Unknown	Unknown
TBC	263657, 110896	No	Unknown	Not yet Assessed	Unknown	Unknown	Unknown

SWO Summary	
How much sewage was discharged via SWOs in the agglomeration in the year (m3)?	Unknown
Is each SWO identified as not meeting DoEHLG Guidance included in the Programme of Improvements?	No
The SWO Assessment included the requirements of relevant of WWDL schedules?	Yes
Have the EPA been advised of any additional SWOs / changes to Schedule C3 and A4 under Condition 1.7?	No

4.2 REPORT ON PROGRESS MADE AND PROPOSALS BEING DEVELOPED TO MEET THE IMPROVEMENT PROGRAMME REQUIREMENTS.

4.2.1 SPECIFIED IMPROVEMENT PROGRAMME SUMMARY

A wastewater discharge licence may require a number of reports on specific subject areas to be prepared for the agglomeration in question. These reports are submitted to the EPA as part of the Annual Environmental Report. This section provides list of the various reports required for this agglomeration and a brief summary of their recommendations.

Specified Improvement Programmes (under Schedule A and C of WWDL)	Description	Licence Schedule	Licence Completion Date	Date Expired? (N/NA/Y)	Status of Works	Timeframe for Completing the Work	Comments
D0022-SIP:01	Waterford North West City Sewerage Scheme	C	31/12/2020	No	Not Started		Capital works not funded in RC3. Capital works funding post 2024 will be contingent on the project being included in the 2025-2029 investment period.

A summary of the status of any improvements identified by under Condition 5.2 is included below.

4.2.2 IMPROVEMENT PROGRAMME SUMMARY

Improvement Identifier	Improvement Description / or any Operational Improvements	Improvement Source	Expected Completion Date	Comments
There are no Improvements Programme for this Agglomeration.				

4.2.3 SEWER INTEGRITY RISK ASSESSMENT

The utilisation of multiple capital maintenance programmes and the outputs of the workshops with the Local Authority Operations Staff held under the programme can be used to satisfy the requirements of Condition 5 regarding network integrity. Improvement works identified by way of these programmes and workshops will be included in the Improvements Summary Table.

5 LICENCE SPECIFIC REPORTS

A wastewater discharge licence may require a number of reports on specific subject areas to be prepared for the agglomeration in question. These reports are submitted to the EPA as part of the Annual Environmental Report. This section provides list of the various reports required for this agglomeration and a brief summary of their recommendations.

5.a Licence Specific Reports Summary Table

Licence Specific Report	Required by licence	Year included in AER	Included in this AER	Reference to relevant section of AER
Shellfish Impact Assessment	Yes	Stage 4a - 2020	No	

6 CERTIFICATION AND SIGN OFF

6.1 SUMMARY OF AER CONTENTS

Parameter	Answer
Does the AER include an Executive Summary?	Yes
Does the AER include an assessment of the performance of the Waste Water Works (i.e. have the results of assessments been interpreted against WWDL requirements and or Environmental Quality Standards)?	Yes
Is there a need to advise the EPA for consideration of a Technical Amendment / Review of the licence?	Yes
List reason e.g. additional SWO identified	SWOs
Is there a need to request/advise the EPA of any modification to the existing WWDL with respect to condition 4 changes to monitoring location, frequency etc	No
List reason e.g. changes to monitoring requirements	N/A
Have these processes commenced?	No
Are all outstanding reports and assessments from previous AERs included as an appendix to this AER	n/a

I certify that the information given in this Annual Environmental Report is truthful, accurate and complete:

Signed: Date: 20/05/2021

This AER has been produced by Irish Water's Environmental Information System (EIMS) and has been electronically signed off in that system for and on behalf of ,

Katherine Walshe

Acting Head of Environmental Regulation.

7 APPENDIX

Appendix
Appendix 7.1 - Ambient monitoring summary
Appendix 7.2 - Shellfish Impact Assessment
Appendix 7.3 - Other

Appendix. 7.1 Ambient Monitoring

D0022 – Waterford

The WWTP discharges to the Lower Suir Estuary, this is designated as Transitional Water, the Environmental Protection Agency undertakes sampling of this water body. Data Source: https://www.catchments.ie/data/#/waterbody/IE_SE_100_0500?_k=7v110t

	Designations					
Ambient monitoring point/Coastal Monitoring Code	**Irish Grid Reference**	**Bathing Water**	**Drinking Water**	**FWPM**	**Shellfish**	**WFD Status**
TW30002102SR4002	264720.15,112043.12					Good
TW30002102SR4002	266200.35,113186.62	No	No	No	No	

Ambient Monitoring Results Summary

Monitoring point	Date	BOD - 5 days (Total)	Dissolved Oxygen %	ortho-Phosphate (as P)	pH	Total Oxidised Nitrogen (as N)
Upstream						
SR460 - Suir Estuary at Little Island **[U/S]**	20/01/2020	1.4	93	0.036	8	3.1
SR460 - Suir Estuary at Little Island **[U/S]**	08/07/2020	-	90	0.047	8	1.1
	Average	**1.4**	**91.5**	**0.0415**	**8**	**2.1**
Downstream						
SR480 - Suir Estuary at Glass House Quay **[D/S]**	20/01/2020	1	92	0.05	8	2.3
SR480 - Suir Estuary at Glass House Quay **[D/S]**	08/07/2020	-	92	0.028	8	0.58
	Average	**1**	**92**	**0.039**	**8**	**1.44**

			Receiving Waters Designation (Yes/No)					Mean (mg/l)	
Ambient Monitoring Point from WWDL (or as agreed with EPA)	**Irish National Grid Reference (Easting, Northing)**	**EPA Feature Coding Tool code**	**Bathing Water**	**Drinking Water**	**FWPM**	**Shellfish**	**Current WFD Status**	**cBOD**	**o-Phosphate (as P)**
Upstream Monitoring Point	TW30002102SR4002	264720.15, 112043.12					Good	1.4	0.042
Downstream Monitoring Point	TW30002102SR4004	266200.35, 113186.62	No	No	No	Yes	Good	1	0.04
Difference								*0.4*	*0.002*
EQS								4	0.04
% of EQS								25.00%	100.00%

WwTP Disinfection Programme

Waterford Shellfish Water – Stage 4 – Detailed Assessment of the Existing Primary Discharges

Employer:	**Irish Water**
Irish Water Project Number:	**10020264**
Project Supervisor Design Process (PSDP):	**Nicholas O'Dwyer Ltd.**
PSDP Project Number:	**20745**
Modelling Consultant:	**Intertek Energy and Water Consultancy Services**

Project Name: WwTP Disinfection Programme
Document: Waterford Shellfish Water - Baseline Assessment – Stage 4a – Detailed Assessment of the Existing Primary Discharges

Revision History

Revision	Reason for Revision	Prepared By	Reviewed By	Approved By	Issue Date
Rev 0	Initial Issue	MT	PAT	PAT	01/07/2020
A	Addressing comments from NOD	MT	PAT	PAT	02/07/2020
B	Addressing comments from IW	MT	PAT	PAT	16/07/2020
B.1	Inserting text from IW	MT	YW	YW	30/10/2020
C					
D					

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Abbreviations

BW	Bathing Water
CFU	Colony-forming unit
CTD	Conductivity, Temperature and Depth
DAP	Drainage Area Plan
EC/E. coli	Escherichia coli
EPA	Environment Protection Agency
Intertek	Intertek Energy and Water Consultancy Services
IW	Irish Water
MPN	Most Probable Number
NOD	Nicholas O’Dwyer
SWO	Surface Water Overflows
WQ	Water Quality
WwTP	Wastewater Treatment Plant

1. Background

As part of the Irish Water Wastewater Treatment Plant (WwTP) Disinfection Programme, Intertek Energy and Water Consultancy Services (Intertek) has been commissioned by Nicholas O'Dwyer (NOD) on behalf of Irish Water (IW) to undertake a modelling impact assessment of the main outfall discharges on the water quality of the Designated Shellfish Waters in Waterford Harbour.

The main objective of this modelling study was to assess whether discharges from agglomerations discharging directly to Waterford Harbour are impacting microbial water quality of the Designated Shellfish Waters, and identify the final effluent quality required in order to eliminate the impact of any discharges identified as impacting Designated Shellfish Water's microbial water quality.

1.1. Study Area

Waterford Harbour is situated on the coast of County Waterford in the South-Eastern River Basin District. The natural harbour is at the mouth of the three rivers; the River Nore, River Suir and River Barrow. It is bound by Creaden Head to the west and Hook Head to the east.

The Waterford Harbour shellfish waters were designated in 2009 under the European Communities (Quality of Shellfish Waters) (Amendment) Regulations 2009 (S.I. 55 of 2009). The total area of the Waterford Harbour designated shellfish area is circa 30 km^2 and extends from the confluence of the Suir and Barrow downstream to a line from Ardnamult Head across to Broomhill.

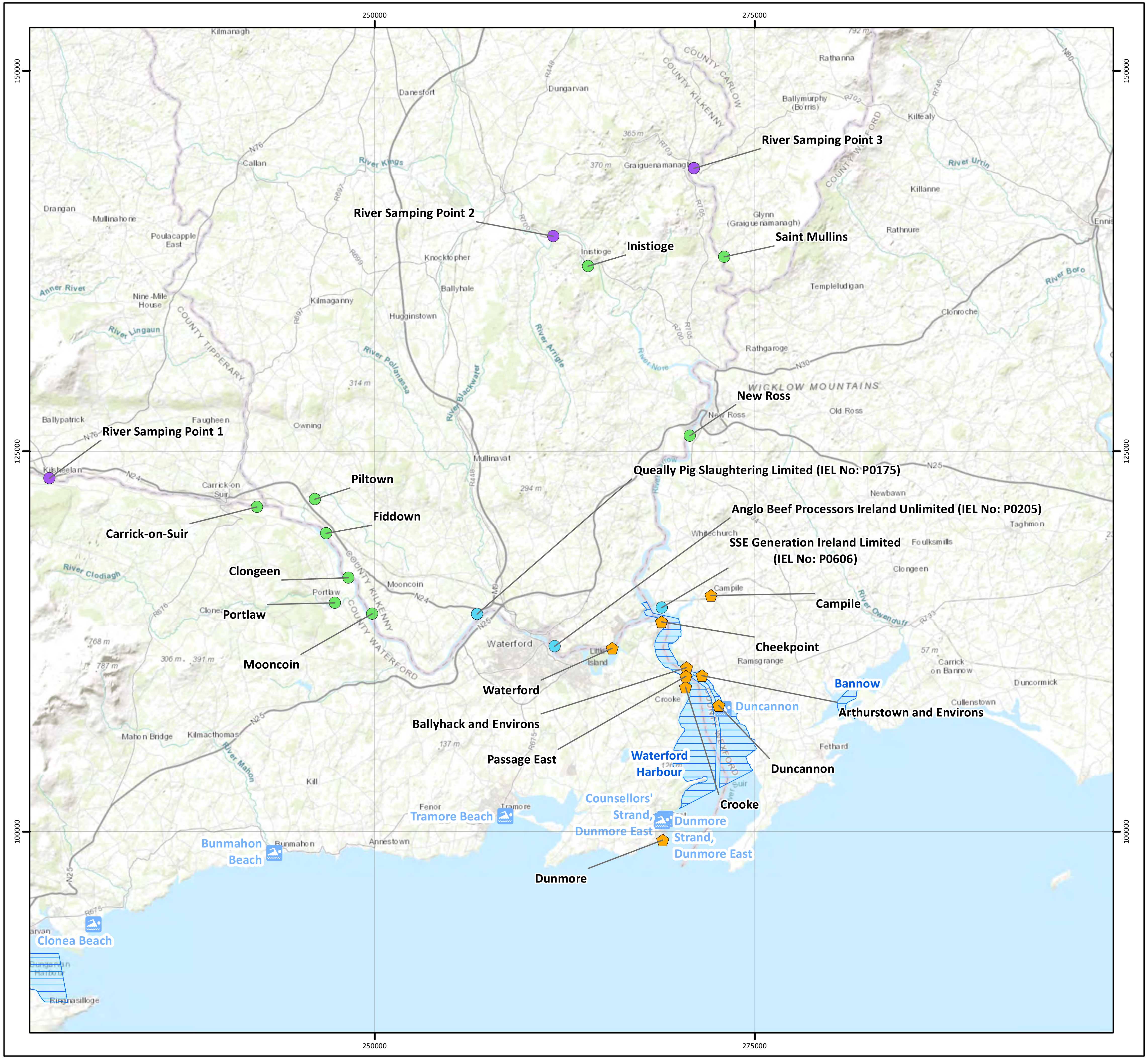
The assessment included modelling nine main WwTPs, which were the focus of the study. These were: Arthurstown and Environs, Ballyhack and Environs, Campile, Cheekpoint, Crooke, Duncannon, Dunmore East, Passage East and Waterford City. In addition, nine smaller works were also included. The diffuse or background load from the three main rivers that drain into the harbour were also included. Two slaughterhouses that also discharge a potentially large microbial load close to the shellfish water were also included. Finally, the flow from nine smaller rivers that drain into the tidal stretches of the three main rivers (i.e. downstream of the tidal limit) were also included, as well as the SSE power station cooling water discharge , to ensure any effect on the hydrodynamics was captured in the modelling, in particular on any stratification due to these fresh water inputs. It should be noted however that it was assumed that there was no bacterial load associated with these smaller rivers or the cooling water discharge. Therefore, there were 33 discharges included in the hydrodynamic model, but only 23 of these were modelled with a bacterial load in the water quality modelling.

Figure 1-1 presents a geographic overview of the area, including the main discharge locations and the Designated Shellfish Water.

COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL LOCATIONS
Discharge Locations

Drawing No: P2323-MOD-006 | A



Legend

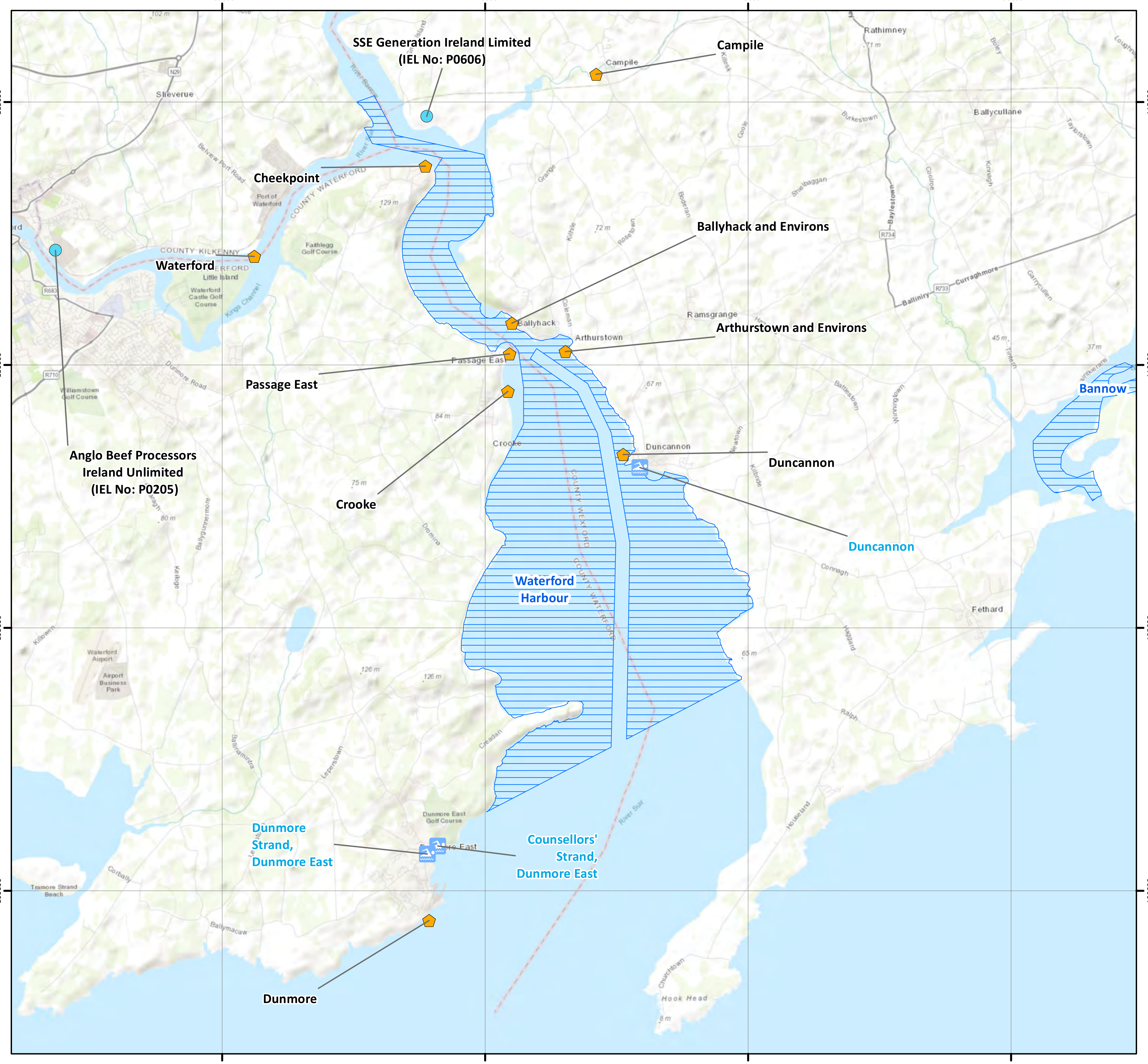
- Main WWTP
- Smaller WWTP
- Industrial Emission Licence (IEL)
- River
- Bathing Water Location
- Shellfish Water

NOTE: Not to be used for Navigation

Date	10 December 2019
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-006.mxd
Created By	Emma Langley
Reviewed By	Chris Goode
Approved By	Matthias Thomsen

0 2.5 5 7.5 10 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

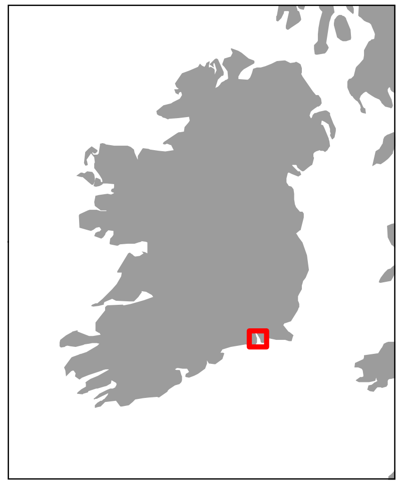
MODEL LOCATIONS
Discharge Locations - Waterford Harbour

Drawing No: P2323-MOD-013	A

Legend

- Main WWTP
- Industrial Emission Licence (IEL)
- Bathing Water Location
- Shellfish Water

N W E S



NOTE: Not to be used for Navigation

Date	28 April 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-013.mxd
Created By	Chris Dawe
Reviewed By	Emma Langley
Approved By	Matthias Thomsen

UISCE ÉIREANN : IRISH WATER

intertek

0 1 2 3 4 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;

2. Objectives

Three key specific objectives of the assessment are as follows;

1. Assess whether untreated, primary and secondary discharges from agglomerations discharging in the proximity of Waterford Harbour are impacting Escherichia coli (hereafter referred to as E. coli or EC) water quality of the Designated Shellfish Waters.
2. Identify the final effluent quality required in order to ensure discharges do not impact Designated Shellfish Water's microbial water quality.
3. Assess the impact of Surface Water Overflows (SWO) on the microbial water quality of the Designated Shellfish Waters.

   Separate to the Disinfection Programme, the Waterford City Drainage Area Plan (DAP) Study is currently ongoing which will provide detailed information on the volume, duration and frequency of discharges from SWOs. A Stage 4B SWO assessment will therefore be carried out in due course, once this information is available.

   This current assessment for the Disinfection Programme has therefore only considered discharges of final effluent from the WwTPs, as well as other continuous sources.

3. Approach

The assessment has followed a tiered approach, as outlined in IW's Technical Standard Marine Modelling Version 1.83 (TSMM 2019 – hereafter referred as the Technical Standards). Initially NOD undertook a scoping assessment and a series of desk-based analyses, including initial dilution studies. These initial assessments did not conclusively rule out the risk of impact on shellfish water quality from IW WwTPs discharging in the vicinity of Waterford Harbour, and it was concluded that the Waterford Harbour assessment required a Tier 3 approach, and therefore a fully dynamic hydrodynamic and water quality model was needed.

A three-dimensional (3D) hydrodynamic model has been developed and applied to assess the impact of 23 potential sources. These are the key continuous sources that potentially contribute to impacts at the Shellfish Water under normal, dry weather conditions.

The modelling approach is in line with IW's Technical Standards. The model was built using the best available bathymetry and boundary condition data, and calibrated and validated against site specific water levels, current velocities, salinity, temperature and EC concentration data collected through a bespoke survey commissioned by NOD. The model performance was assessed using industry standard criteria and the model is considered to be of a good standard and fit for the proposed use of assessing bacterial impacts at the Waterford Shellfish Water. A summary of model development and model performance is provided in Appendix B.

The 3D model has been used to simulate the Baseline scenario, to assess the impact from the 23 modelled sources. The total impacts throughout the model domain has been determined, and the proportional contribution from all sources has been calculated at six key locations. The Baseline scenario represents the likely microbial loads from the 23 sources identified under normal, dry weather conditions in winter. No intermittent discharges from SWOs or increased diffuse loads under wet weather conditions have been included.

The modelled loads for the WwTPs were based on a uniform flow for each asset, representative of current hydraulic loadings (or 1.25 x Dry Weather Flow (DWF) where this was not available) as provided by IW's asset planning team, and default concentrations, depending on the level of treatment, as follows:

- Untreated sewage — 1×10^7 EC/100ml
- Primary treated sewage — 1×10^6 EC/100ml
- Secondary treated sewage — 1×10^5 EC/100ml
- Tertiary treated (UV disinfected) sewage — 1×10^4 EC/100ml

For consistency throughout this document, bacteria concentrations (whether those from samples or from model predictions) are referred to simply as *number* EC/100ml (rather than using the terms Most Probable Number (MPN) or Colony Forming Unit (CFU).

It should be noted that although some sampling data of bacteria concentrations of the final effluent had been collected at some of the WwTPs, the datasets were generally quite small (<15 samples for each WwTP) and some of the sampled concentrations were capped at a maximum value due to an issue with how the samples had been analysed.

The datasets were therefore not considered to be robust enough for the purpose of this assessment, and it was agreed with IW to use the default concentrations above. These default values were provided by IW and are in line with default concentrations used throughout the water industry where adequate site specific data are lacking. They are also supported by the limited sampling data collected and are considered appropriate for the purpose of this assessment.

Regarding the modelled bacterial loading from Waterford WwTP, it should be noted that the hydraulic loading was determined from a detailed effluent flow monitoring dataset. Due to an absence of commensurate effluent bacterial quality data, literature values for E. coli concentrations were applied to the WwTP based on values commonly measured in typical municipal wastewater.

However, in the case of Waterford WwTP, this approach is considered conservative, due to the unusually high proportion of the influent to the WwTP which arises from trade effluent, which is not a major source of bacterial loads.

Accordingly, the Phase 4a assessment is considered conservative as it is based on a conservative estimate of the bacterial loading from Waterford WwTP.

The modelled loads for the three main rivers (the Suir, Nore and Barrow) and the two slaughterhouses were based on the best information available. The modelled flows applied for the three main rivers were the Q30% flow, based on the gauged data available for each of these three rivers. The gauges on the Nore and Barrow are close to the tidal limit, however the gauging station on the River Suir is approximately 60 km upstream of the tidal limit. In order to account for the increased catchment area between the gauge and the tidal limit, the gauged flows were increased by a factor of 1.7 – based on the ratio of the two catchment areas (upstream of the gauge ~ 1585 km^2, and upstream of the tidal limit ~ 2726 km^2). The upscaled Q30% flow for the Suir was then checked against the Q30% estimate from the Environment Protection Agency (EPA) HydroTool, and found to be consistent.

The estimated Q30% flows from the EPA HydroTool were used as the modelled flows for the other nine smaller rivers that drain into the tidal reaches of the three main rivers between their tidal limit and the shellfish water.

The modelled flow for the slaughterhouses and the power station were based on the consented discharge flow as per the Industrial Emissions Licence for each.

The modelled concentrations for the rivers were based on samples collected for the purpose of this assessment, and for the slaughterhouses were based on an estimate taken from literature. No bacterial load was applied to the nine smaller rivers or the power station cooling water discharge.

Full details of the modelled flows and concentrations applied are provided in Appendix C.

As this is a shellfish modelling assessment, the Baseline scenario was run for average winter conditions (January), as per IW's Technical Standards.

Specifically, this means winter bacterial discharge loads and winter decay rates were applied (T_{90} of 48 hours).

The model simulations were run for a sufficiently long 'warm-up' period to enable dynamic equilibrium of bacteria concentration in the environment to be reached (approximately one week). This provided the initial conditions for the simulation. The assessment period covered a spring-neap (15 day) cycle following the warm-up period, as outlined in IW's Technical Standards.

As the model is a 3D model with ten layers, the modelled sources were all discharged into the relevant layer in the model. For most of the main WwTPs, this is the bottom layer as the outfalls are fully submerged and on the seabed. Crooke WwTP discharges into an area of shallow water which dries out around low water, and therefore, this discharge was released into the surface layer. All of the smaller WwTPs, which are upstream on the tidal parts of the rivers, as well as the rivers themselves and the slaughterhouses were released at the surface layer.

The modelled impacts were calculated as the 95%ile concentration from the 15-day timeseries of impacts at each modelled grid cell, and a contour plot across the model domain has been generated. Contour plots have been generated for both the surface and bottom layers.

Impacts have been assessed against the Bathing Water 'Good' threshold of 500 EC/100ml at the 95%ile concentration, as per the interim criteria for assessing shellfish water impacts as outlined in IW's Technical Standards. Reference is also made the Bathing Water 'Excellent' standard of 250 EC/100ml.

4. Results

All results for the Baseline scenario are presented in Appendix A, and one key plot which summarises the main results is repeated as Figure 4-1. This is the contour plot of the 95%ile concentration in the bottom layer from all 23 modelled sources for the Waterford Harbour area, which shows the impacts within the shellfish water. This is also included in Appendix A as Figure A-4.

Results are shown for the surface layer in Figures A-1 and A-2 (Appendix A) and for the bottom layer in Figures A-3 and A-4 (Appendix A). These show contour plots of the 95%ile concentration resulting from combined impact from all 23 modelled sources. There are two plots – the first showing the whole model domain (including a zoom-in around Duncannon), and the second showing a detailed zoom-in on the Shellfish Water area of the Harbour. The same colour scheme is applied in all plots, as follows:

- <10 EC/100 ml = white;
- >10 and <250 EC/100ml = blue;
- >250 and <500 EC/100 ml = green;
- >500 and <1000 EC/100 ml = yellow, and;
- >1000 EC /100 ml = red.

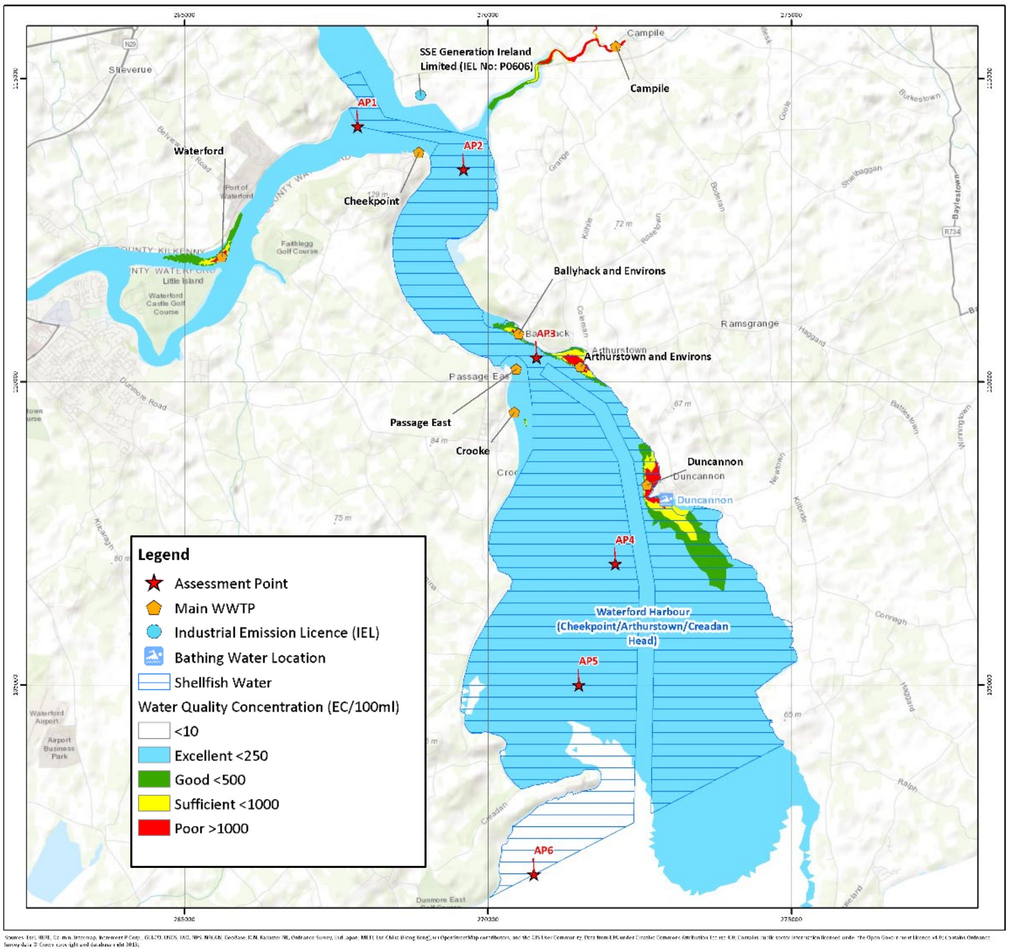
This means that areas shown in yellow or red exceed the assessment criteria of 500 EC/100 ml as a 95%ile, as described in IW's Technical Standards.

These plots show total impacts from all sources. It can be seen that impacts are generally greater in the bottom layer (except close to Crooke), and for the majority of the Shellfish Water the 95%ile concentration is <500 EC/100ml, and in fact for most of the Shellfish Water impacts are <250 EC/100ml.

However, there are some localised areas of high impact (>500 EC/100ml) within the Shellfish Water, which are observed around the Duncannon WwTP, the Arthurstown and Environs WwTP, and Ballyhack and Environs WwTP. Other areas of high impact within the estuary are observed close to the Waterford City and Campile WwTPs, but these are outside of the Shellfish Water. There is also an area of high impact in the River Suir (around Carrick-on-Suir, Piltown and Fiddown WwTPs), which is a long way upstream.

The largest impacts are centred around Arthurstown and Duncannon WwTPs, with peak concentrations exceeding 1,000 EC/100 ml (red contour), observed in the immediate vicinity of the discharge locations, as would be expected. However, concentrations reduce rapidly with distance, as the plume is advected and dispersed, as can be seen on the contour plots.

Figure 4-1 Contour plot of Waterford Harbour area showing 95%ile EC concentration in the bottom layer



In addition to the 95%ile concentration contour plots, Figure A-5 (Appendix A) provides timeseries of total impact for the surface and bottom layer at six assessment points (1 to 6) which were selected after discussion with IW. Assessment points 1 and 6 are on the northern and southern boundaries of the Shellfish Water, and the other four points are distributed throughout the Shellfish Water. The assessment point locations are presented in Figures A-1 to A-4 (Appendix A).

Furthermore, the proportional contribution to impacts from each individual source (source apportionment) has been calculated for the surface layer at each of the six assessment points (1 to 6). These are presented as pie charts in Figures A-6 to A-11, and summarised in Table 4.1.

The source apportionment analysis shows that Waterford City and Duncannon WwTPs dominate the contribution to EC concentrations at each of the six assessement points. However, the total impacts at these locations are very low (<100 EC/100ml in all cases) and therefore below the assessment threshold of 500 EC/100ml. The pie-charts therefore must be reviewed while taking into account the total impacts at these sites, and to facilitate this, the 95%ile concentration for both the surface and bottom layer is included with each pie-chart.

It should be noted that although Waterford City and Duncannon WwTPs are the largest contributors at all six assessment points, these are large contributions to very low impacts that are well below the assessment criteria.

The modelled impacts have been compared with the Bathing Water classifications at the three local Bathing Waters in Waterford Harbour (Duncannon and the two bathing waters at Dunmore East - Dunmore Strand and Counsellors Strand) and these classifications ('Good', 'Excellent' and 'Excellent', respectively) are in agreement with the modelled 95%ile concentrations.

Table 4-1. Total impacts and proportional contributions at the six assessment points

Assessment Points	AP1	AP2	AP3	AP4	AP5	AP6
95%ile concentration (EC/100ml)	90 (Surface)	48 (Surface)	50 (Surface)	42 (Surface)	27 (Surface)	17 (Surface)
	84 (Bottom)	45 (Bottom)	59 (Bottom)	23 (Bottom)	12 (Bottom)	1 (Bottom)
Pass / Fail criteria (500 EC/10 ml)	Pass	Pass	Pass	Pass	Pass	Pass
Source						
Waterford City	74.8 %	61.9 %	47.9 %	32.1 %	29.4 %	21.0 %
Duncannon	8.7 %	11.5 %	26.4 %	39.9 %	38.5 %	42.3 %
Ballyhack and Environs	5.4 % %	6.5 %	9.0 %	11.3 %	11.3 %	11.8 %
Arthurstown and Environs	5.1 %	5.7 %	12.4 %	13.0 %	13.6 %	15.3 %
New Ross	2.6 %	6.8 %	1.5 %	N.A	N.A	N.A
Campile	1.3 %	1.7 %	N.A	N.A	N.A	N.A
Passage East	N.A	N.A	N.A	1.0 %	1.9 %	1.1 %
Crooke	N.A	N.A	N.A	N.A	1.0 %	N.A
Dunmore East	N.A	N.A	N.A	N.A	2.4 %	N.A
River Nore	N.A	3.4 %	N.A	N.A	N.A	N.A
River Barrow	N.A	1.4 %	N.A	N.A	N.A	N.A
All Others	2.2 %	1.0 %	2.9 %	N.A	2.0 %	2.2 %
Total	**100** %	**100** %	**100** %	**100** %	**100** %	**100** %

5. Conclusion

The key conclusions taken from the Baseline scenario are as follows:

- The modelled 95%ile concentration across the majority of the Designated Shellfish Water is less than the 500 EC/100 ml threshold at both the surface and bottom layer.
- There are three localised areas within the Shellfish Water where the modelled 95%ile concentration exceeds the 500 EC/100 ml threshold. These are centred around the three main WwTPs that discharge directly into the shellfish water, namely: Arthurstown, Duncannon and Ballyhack. The area of impact that exceeds the 500 EC/100 ml within the Shellfish Water due to the Ballyhack discharge is very limited spatially.
- Impacts are generally higher in the bottom layer than in the surface layer in the areas of highest impact.
- The discharges from Waterford City WwTP, Campile and Dunmore East WwTP do not lead to a 95%ile concentration within the Shellfish Water that exceeds the 500 EC/100 ml assessment threshold (or even the 250 EC/100 ml threshold representative of the Excellent BW standard).
- The modelled impacts from Crooke and Passage East, which discharge close to, but not directly into, the Shellfish Water do not exceed the 500 EC/100 ml assessment threshold (or even the 250 EC/100 ml threshold representative of the Excellent BW standard).
- Local Bathing Water classifications in Waterford Harbour (Duncannon and the two bathing waters at Dunmore East - Dunmore Strand and Counsellors Strand) are in agreement with the modelled 95%ile concentrations ('Good', 'Excellent' and 'Excellent', respectively).
- Improvements in the levels of treatment at the three WwTPs that discharge directly into the Shellfish Water would reduce impacts.
- At Arthurstown and Duncannon, which currently discharge untreated sewage, and also at Ballyhack, which currently discharges primary treated effluent, improvement to secondary treatment is likely to be sufficient to reduce the resulting 95%ile concentration to below the 500 EC/100 ml threshold.

- Impacts at all of the six assessment points are always below 500 EC/100ml and in fact impacts only exceed the Excellent BW standard (250 EC/100ml) at one location (AP4) intermittently.

6. References

Nafarnda, W. D., Ajayi, I. E., Shawulu, J. C., Kawe, M. S., Omeiza, G. K., Sani, N. A., ... & Dantong, D. D. (2012). Bacteriological quality of abattoir effluents discharged into water bodies in Abuja, Nigeria. *ISRN veterinary science*.

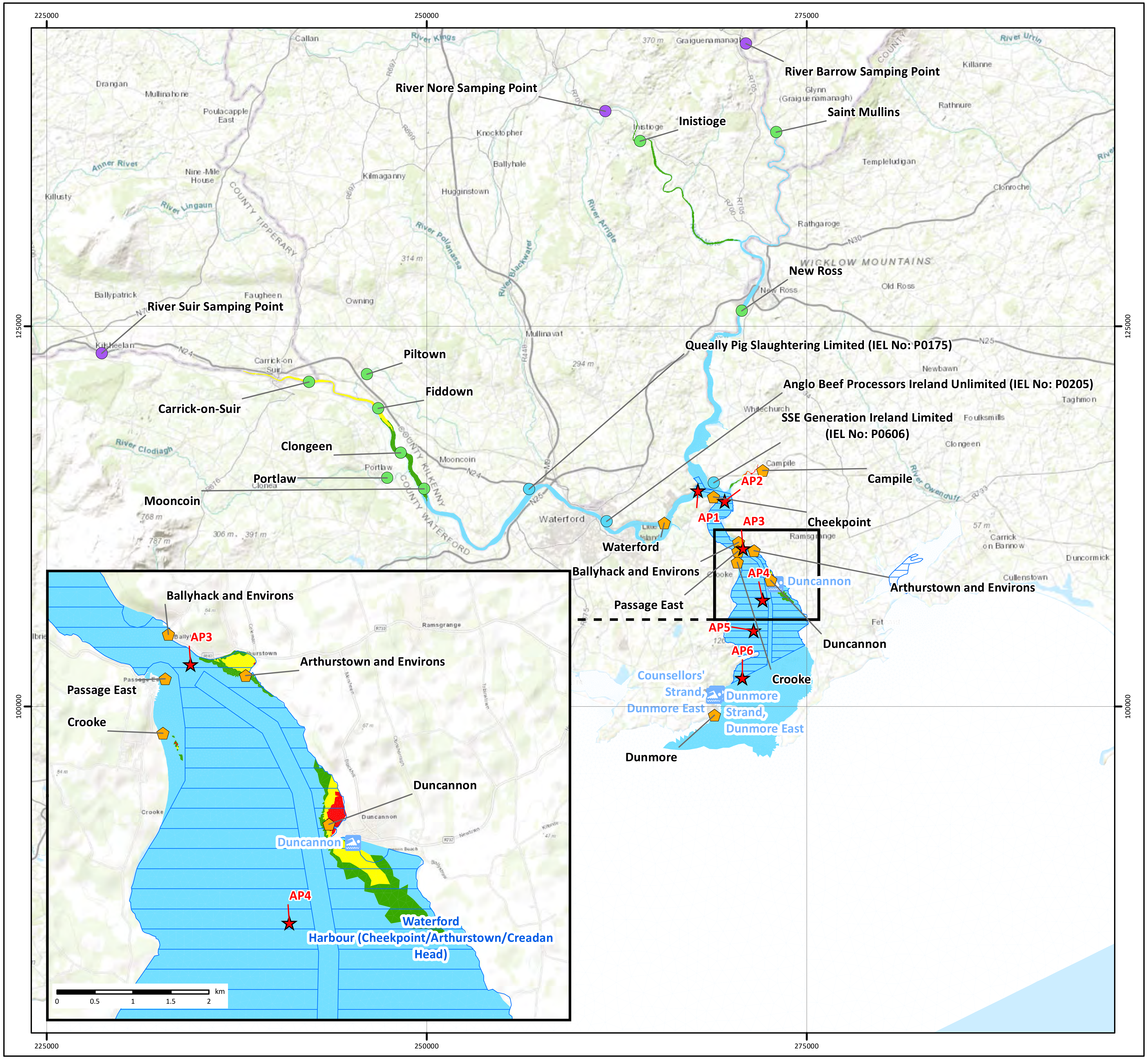
Shellfish Pollution Reduction Programme. Characterisation Report Number 35. Waterford Harbour Shellfish Area County Waterford.

TSMM (2019): Technical Standards – Marine Modelling Document No: IW-TEC-100-015, Revision: 1.83, printed date: 17/06/2019.

MSR (2019): WwTP Disinfection Programme, Stage 4 – Detailed Assessment of Discharges. Model Scoping Report – Waterford Harbour. Date: 16/10/2019. Ref: 20745.

Appendix A.

Summary result plots



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL RESULTS
Baseline Scenario: Surface Layer

Drawing No: P2323-MOD-015 | **A**

Legend

- Assessment Point
- Main WWTP
- Smaller WWTP
- Industrial Emission Licenced (IEL) Discharge
- River
- Bathing Water Location
- Shellfish Water

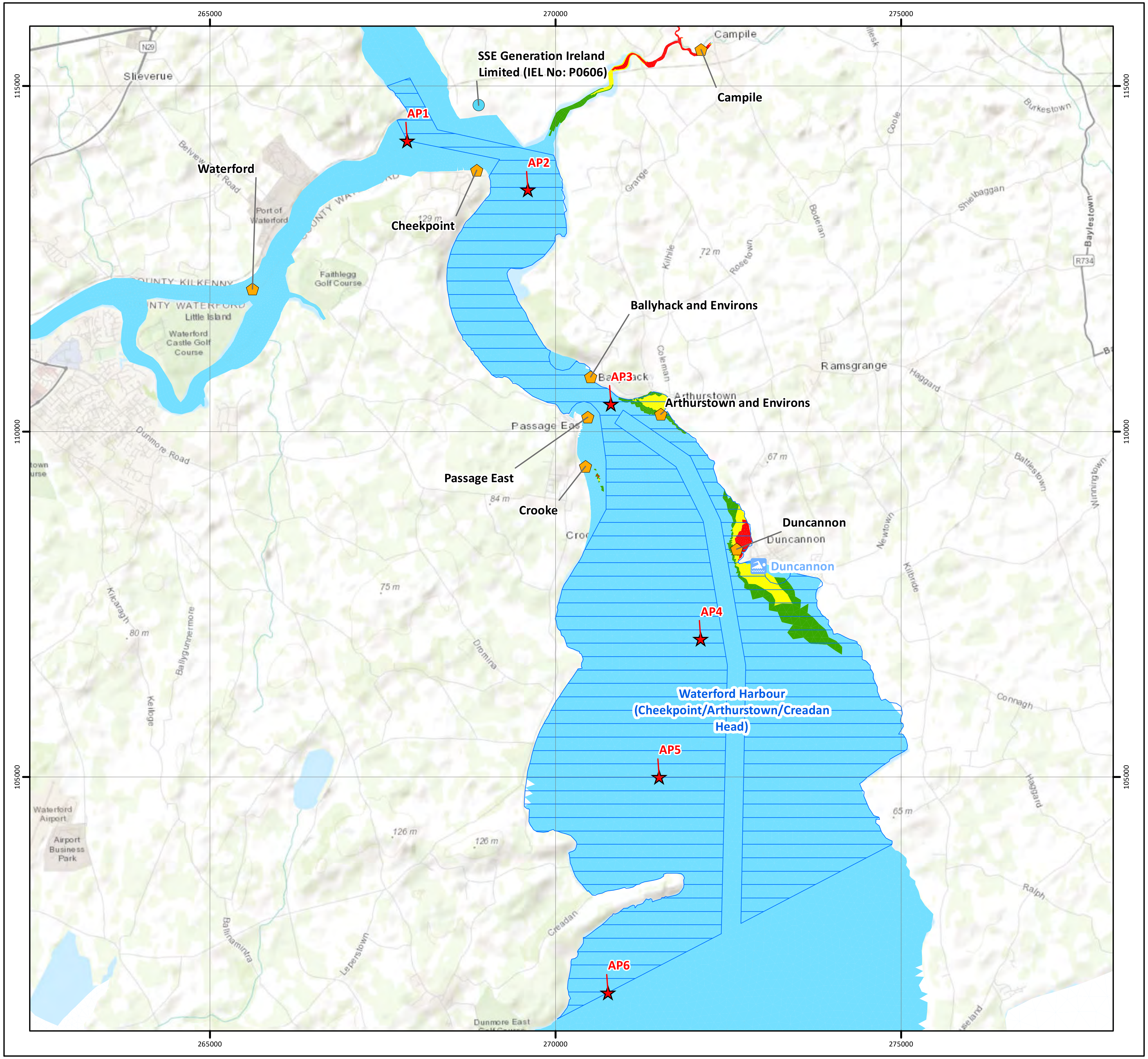
Water Quality Concentration (EC/100ml)

- <10
- Excellent <250
- Good <500
- Sufficient <1000
- Poor >1000

Date	29 June 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-015.mxd
Created By	Chris Dawe
Reviewed By	Emma Storey
Approved By	Matthias Thomsen

km 0 2.5 5 7.5 10

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL RESULTS
Baseline Scenario: Surface Layer
Waterford Harbour Area

Drawing No: P2323-MOD-015-1	A

Legend

- Assessment Point
- Main WWTP
- Industrial Emission Licence (IEL)
- Bathing Water Location
- Shellfish Water

Water Quality Concentration (EC/100ml)

- <10
- Excellent <250
- Good <500
- Sufficient <1000
- Poor >1000

NOTE: Not to be used for Navigation

Date	30 June 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
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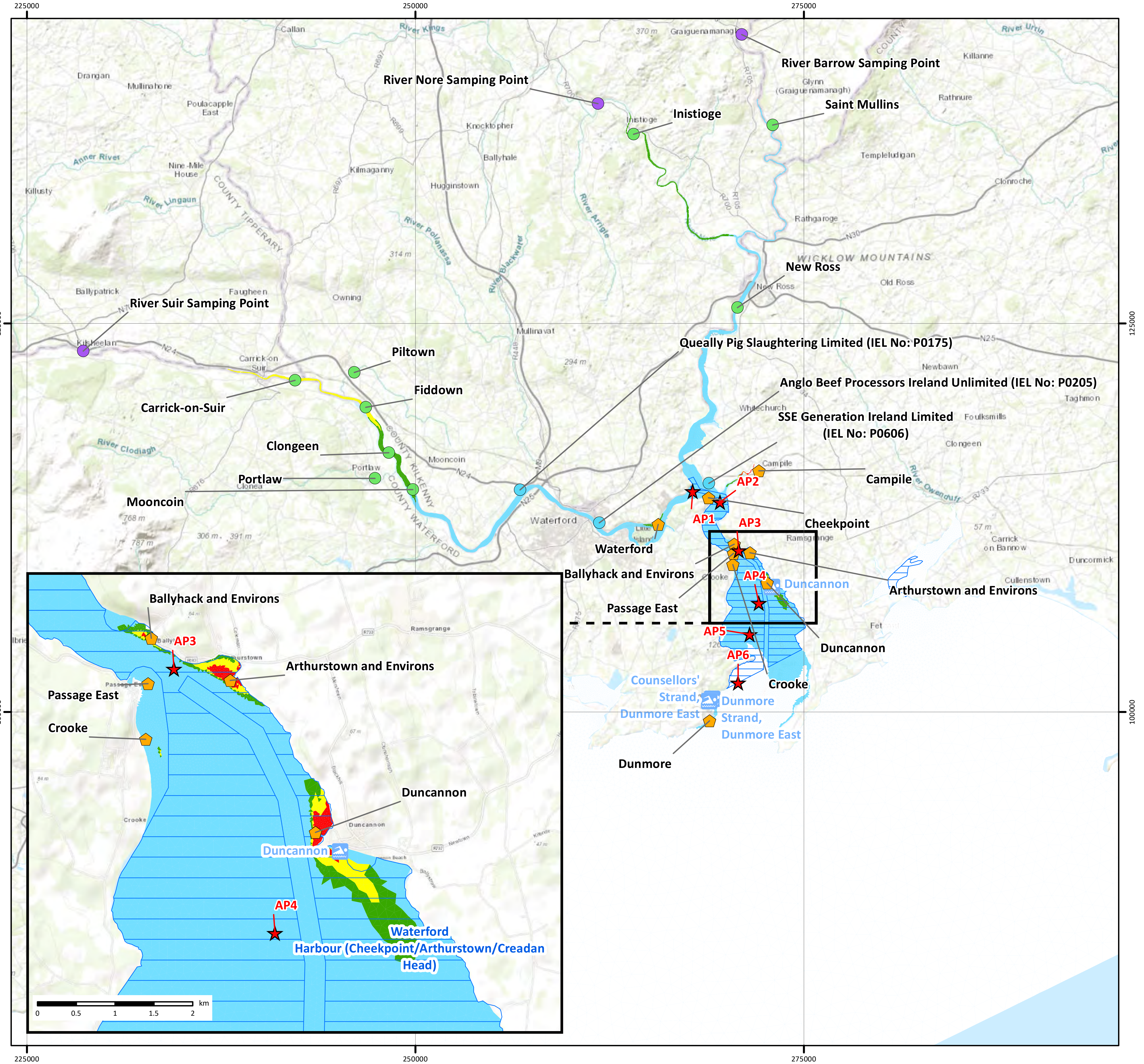
Created By	Chris Dawe
Reviewed By	Emma Storey
Approved By	Matthias Thomsen

0 0.5 1 1.5 2 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;

COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL RESULTS
Baseline Scenario: Bottom Layer

Drawing No: P2323-MOD-016	A

Legend

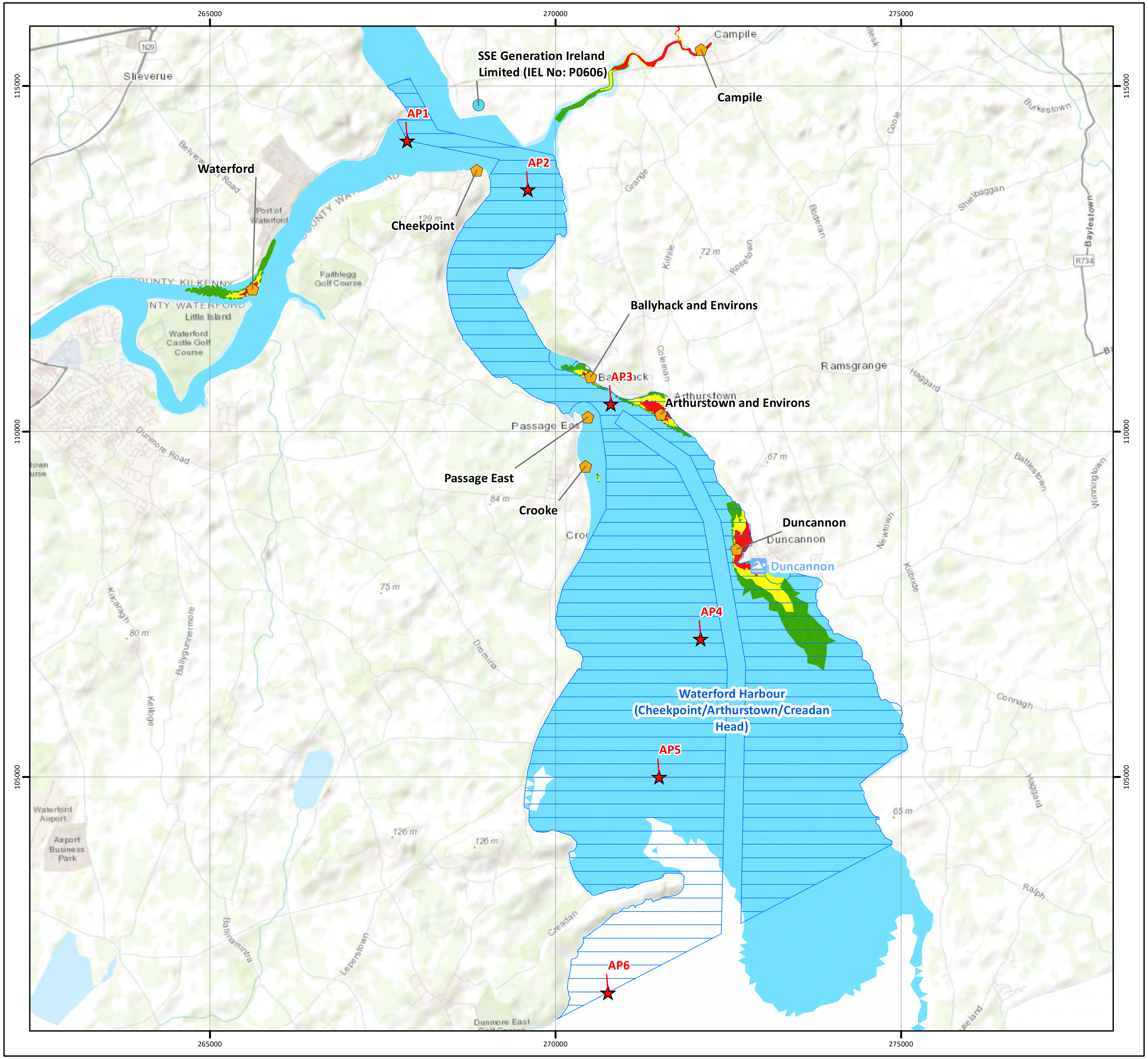
- Assessment Point
- Main WWTP
- Smaller WWTP
- Industrial Emission Licenced (IEL) Discharge
- River
- Bathing Water Location
- Shellfish Water

Water Quality Concentration (EC/100ml)

- <10
- Excellent <250
- Good <500
- Sufficient <1000
- Poor >1000

NOTE: Not to be used for Navigation

Date	29 June 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-016.mxd
Created By	Chris Dawe
Reviewed By	Emma Storey
Approved By	Matthias Thomsen



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;

COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL RESULTS
Baseline Scenario: Bottom Layer
Waterford Harbour Area

Drawing No: P2323-MOD-016-1	A

Legend

- Assessment Point
- Main WWTP
- Industrial Emission Licence (IEL)
- Bathing Water Location
- Shellfish Water

Water Quality Concentration (EC/100ml)

- <10
- Excellent <250
- Good <500
- Sufficient <1000
- Poor >1000

NOTE: Not to be used for Navigation

Date	29 June 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-016-1.mxd
Created By	Chris Dawe
Reviewed By	Emma Storey
Approved By	Matthias Thomsen

0 0.5 1 1.5 2 km

Figure A-5 Time series EC for the Baseline scenario for six assessment points

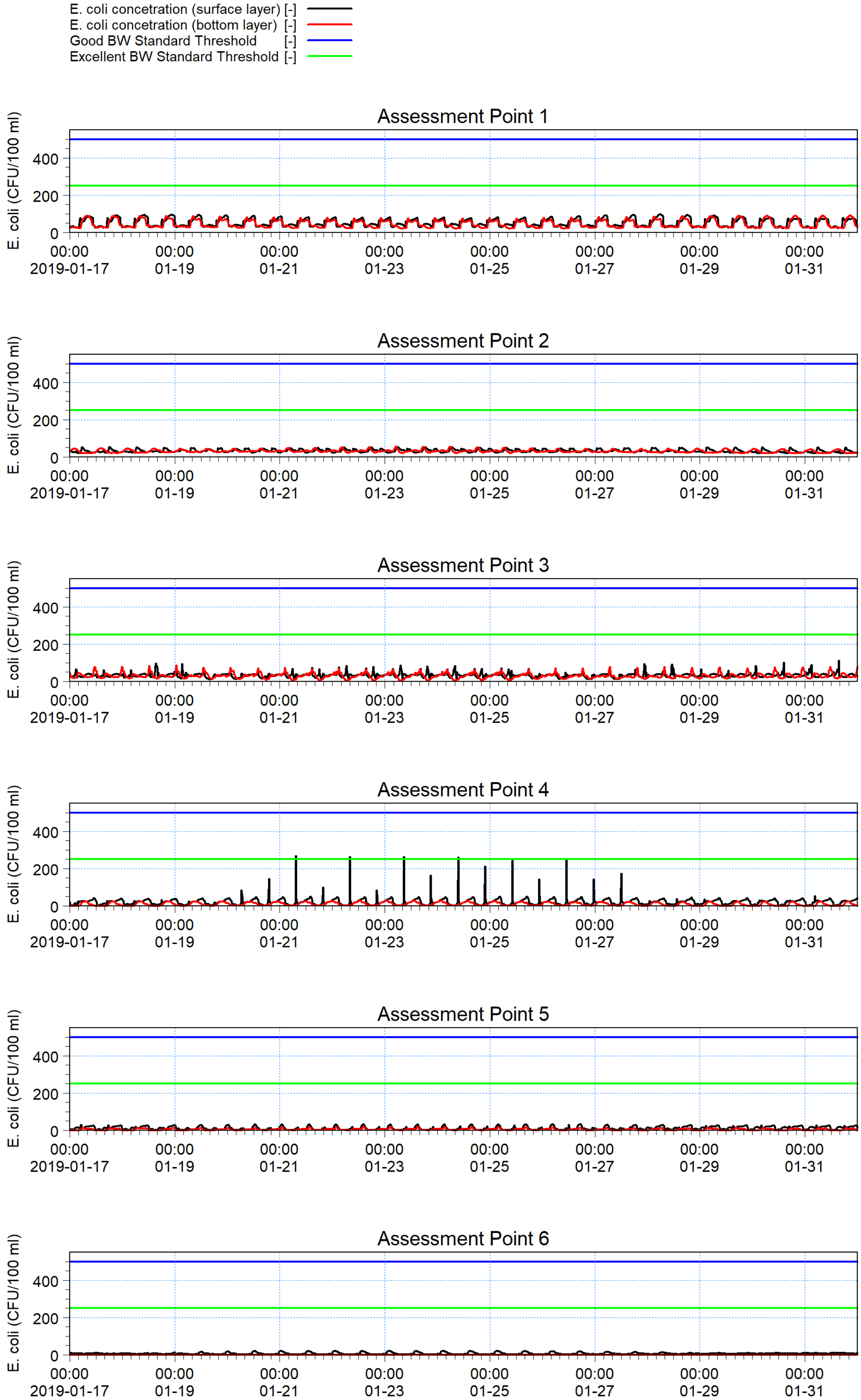


Figure A-6 Source apportionment: Assessment Point 1

Surface layer:
90 EC/100 ml

Bottom layer:
84 EC/100 ml

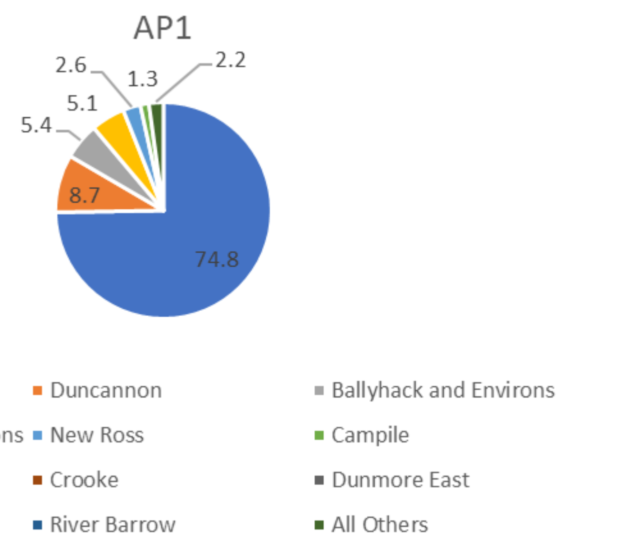


Figure A-7 Source apportionment: Assessment Point 2

Surface layer:
48 EC/100 ml

Bottom layer:
45 EC/100 ml

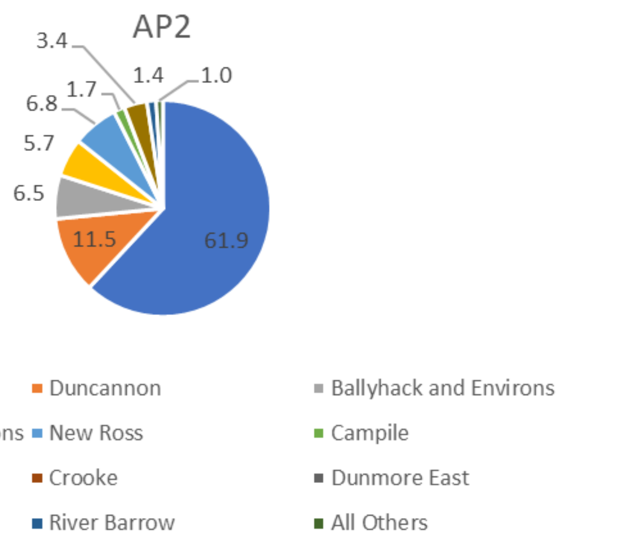


Figure A-8 Source apportionment: Assessment Point 3

Surface layer:
50 EC/100 ml

Bottom layer:
59 EC/100 ml

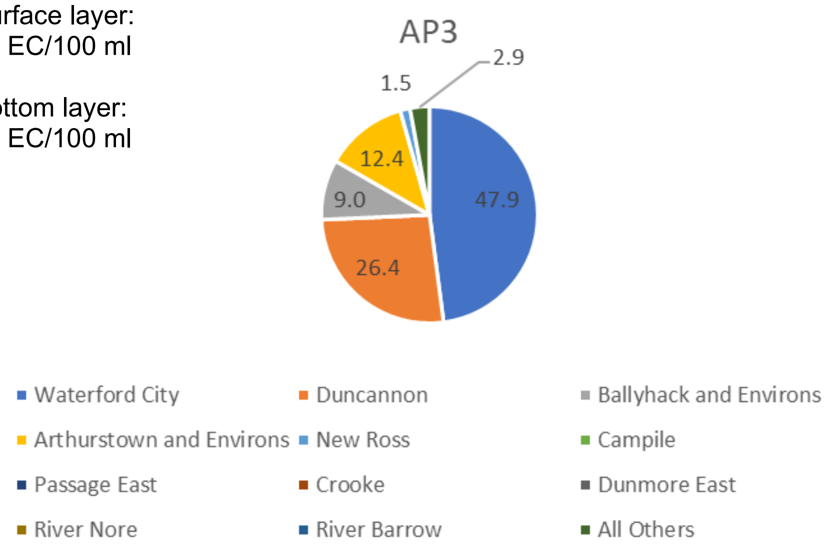


Figure A-9 Source apportionment: Assessment Point 4

Surface layer:
42 EC/100 ml

Bottom layer:
23 EC/100 ml

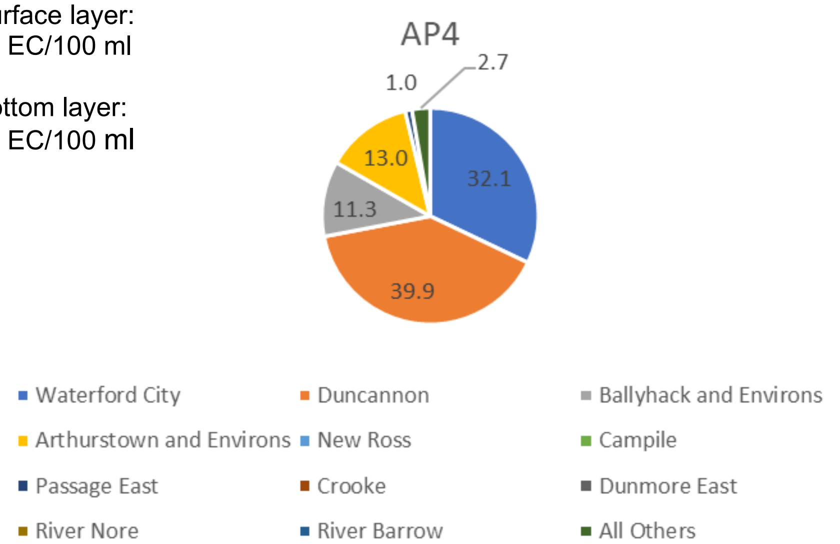


Figure A-10 Source apportionment: Assessment Point 5

Surface layer:
27 EC/100 ml

Bottom layer:
12 EC/100 ml

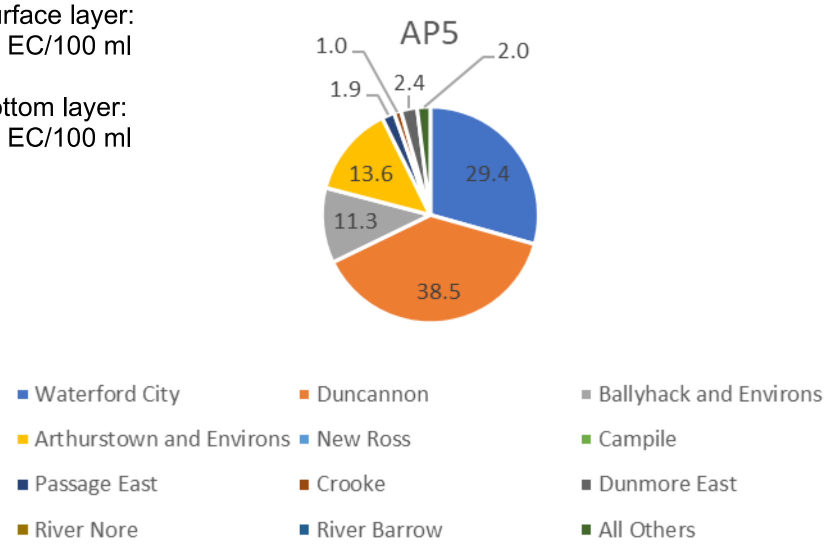
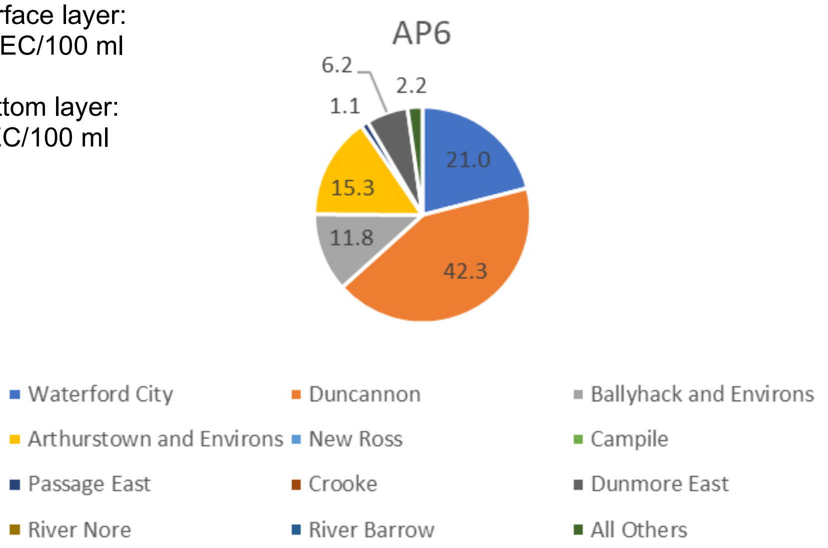


Figure A-11 Source apportionment: Assessment Point 6

Surface layer:
17 EC/100 ml

Bottom layer:
1 EC/100 ml



Appendix B.

Data and model calibration

Bathymetry

Four data sources were used for the model bathymetry, as follows:

- Duncannon survey data
- INFOMAR
- EMODnet
- Catchment-based Flood Risk Assessment and Management (CFRAM) Programme

These are shown in Figure B-1 and discussed below.

As detailed in the Model Scoping Report (MSR, 2019), the Duncannon survey was identified to infill the gap in the available data, and it was agreed that this survey data together with data from INFOMAR and EMODnet would be sufficient for the model development. However, during the model development phase, river channel cross-sections from the CFRAM Programme were also identified and provided for use in the model.

Duncannon survey data

The Duncannon survey data was a dedicated survey commissioned by NOD on behalf of IW in support of the Waterford Shellfish Water study to infill a gap in available bathymetry data that was identified in the MSR (2019), in the areas either side of the main channel around Duncannon. The survey obtained high resolution multibeam sonar data and was undertaken by Techworks Marine between the 2nd and the 8th of July 2019. The survey was undertaken in accordance with the UKHO 1A standard. The data quality was considered to be of good quality, with no data gaps or anomalies and suitable for the purpose of model development.

INFOMAR

The geographical extent of the INFOMAR data covers the entire south coast of Ireland at a spatial resolution of 10m. The data was collected from a number of surveys, as part of the ongoing INFOMAR project (formerly Irish National Seabed Survey), a joint seabed mapping project between the geological survey of Ireland and the Marine Institute. The INFOMAR dataset also includes non- INFOMAR data; Nephropsproject (2006 & 2013), Scallop surveys and Habmap 2005 projects. The dataset in its entirety has been collected from 2000 to 2016.

EMODnet

A harmonised EMODnet Digital Terrain Model (DTM) has been generated for the European sea regions from selected bathymetric survey data sets, composite DTMs, Satellite Derive Bathymetry (SDB) data products, while gaps with no data coverage are completed by integrating the GEBCO Digital Bathymetry.

The DTM with its information layers is made freely available for downloading from the EMODnet website (https://www.emodnet-bathymetry.eu/data-products). Survey data sets have been collated from an increasing number of data providers and activities have been undertaken for correcting identified anomalies, where possible.

The September 2018 version of the EMODnet DTM, which is the version that was used for the Waterford model, has an increased grid resolution of 1/16 x 1/16 arc minutes (circa 115 x 115 m).

CFRAM

River channel cross-section survey data, collected to support the CFRAM Programme, was obtained through IW from the Office of Public Works (OPW). The surveys included the three main rivers draining into Waterford Harbour, River Barrow, River Nore, and River Suir) and were undertaken for OPW during the period from 2012 to 2015. The surveyed river cross sections were used to inform the hydraulics report (The South-Eastern CFRAM Project, Suir CFRAM Study and North-Western CFRAM) and hydraulic models covering the Units of Management (UOM) for:

- Barrow (UoM14)
- Nore (UoM15)
- Suir (UoM16)

The purpose of the CFRAM Programme was to assess existing fluvial and coastal flood risk, and the potential increase in risk due to climate change, ongoing development and other pressures that may arise in the future, and to develop a Plan setting out a sustainable, long-term strategy to manage this risk. The OPW in conjunction with the CFRAM Study Consultants (RPS for the Barrow River Basin), are undertaking the National CFRAM Programme.

Water level and velocity

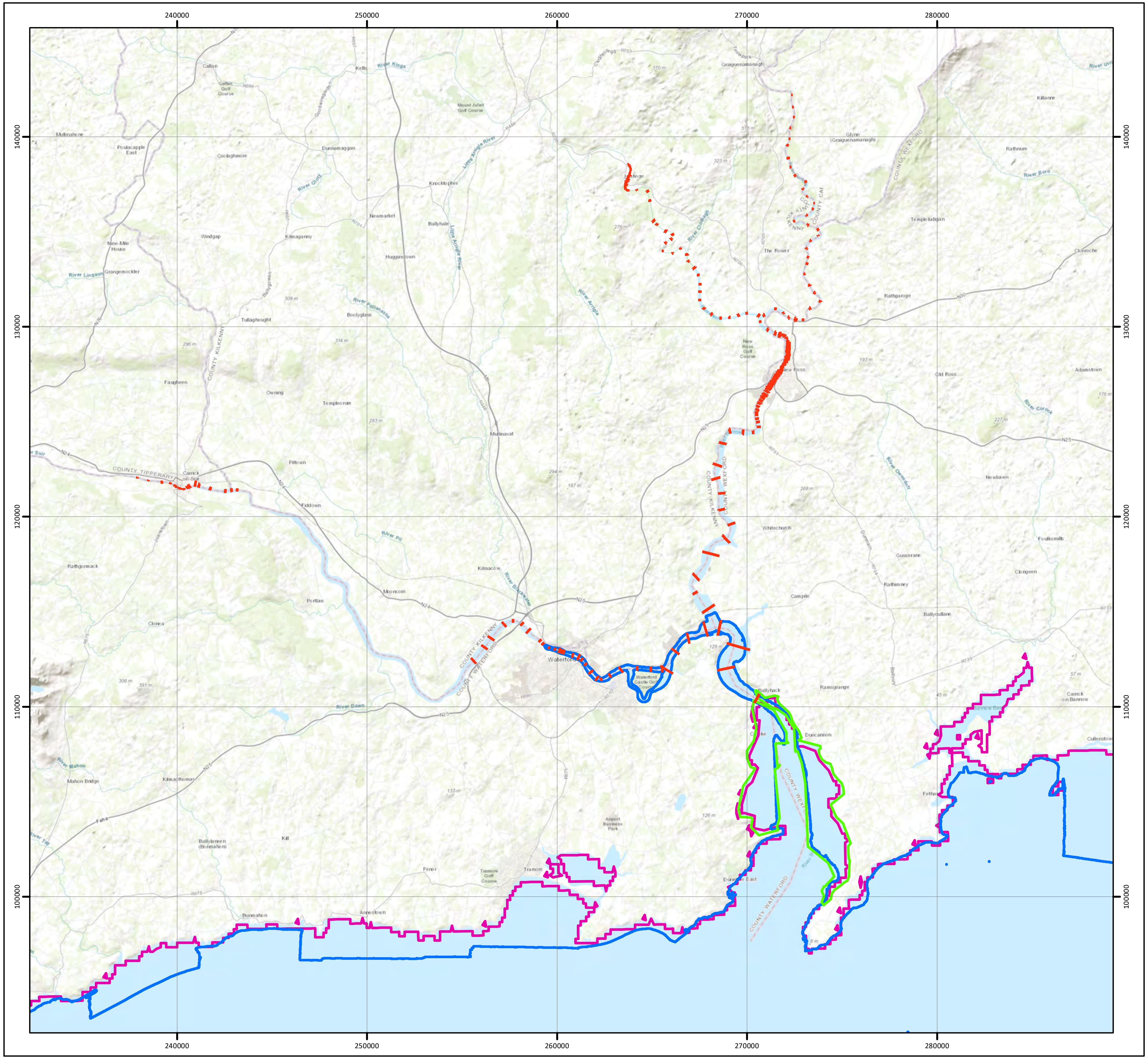
Water level data from Dunmore East Tidal Gauge was used for model calibration/validation.

Current velocities were collected from four ADCPs deployed at separate locations (see Figure B-2) within Waterford Harbour. ADCP1 and ADCP2 were deployed in the narrow northern section of Waterford Harbour. ADCP3 was deployed near the southern boundary of the shellfish water, and ADCP4 slightly further south near Dunmore East.

Current speed and direction were calculated from the measured current velocity components.

Salinity and Temperature

As part of the dedicated surveys commissioned by NOD on behalf of IW for the purpose of the Waterford modelling assessment, salinity and temperature data were collected from nine Conductivity-Temperature-Depth (CTD) sampling sites (see Figure B-5) within Waterford Harbour over two separate 13-hour periods covering a full semi-diurnal tidal cycle, the first on 8th August 2019 (Neap tide) and the second on 13th August (Spring tide).



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

BATHYMETRY
Data Sources - Waterford Harbour

Drawing No: P2323-MOD-002	B

Date	21 May 2020
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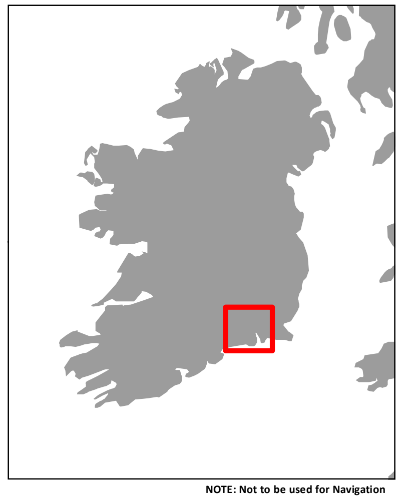
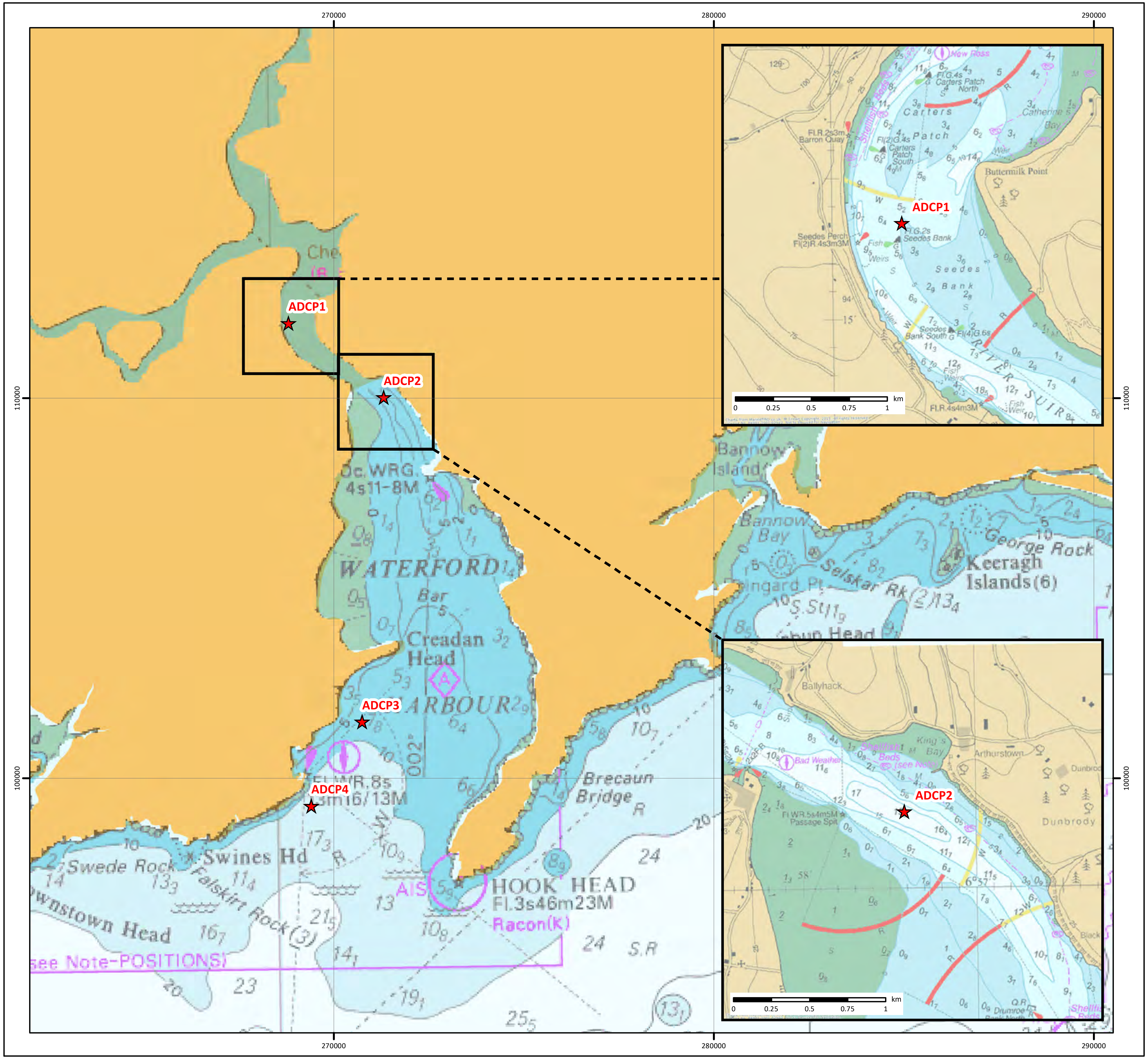
Projection	Transverse Mercator
Datum	TM65
Data Source	EMODnet; Infomar; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-002.mxd
Created By	Chris Dawe
Reviewed By	Emma Langley
Approved By	Matthias Thomsen



km 0 2.5 5 7.5 10



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL LOCATIONS
ADCP Locations

Drawing No: P2323-MOD-003 | **B**

Legend

★ ADCP Location

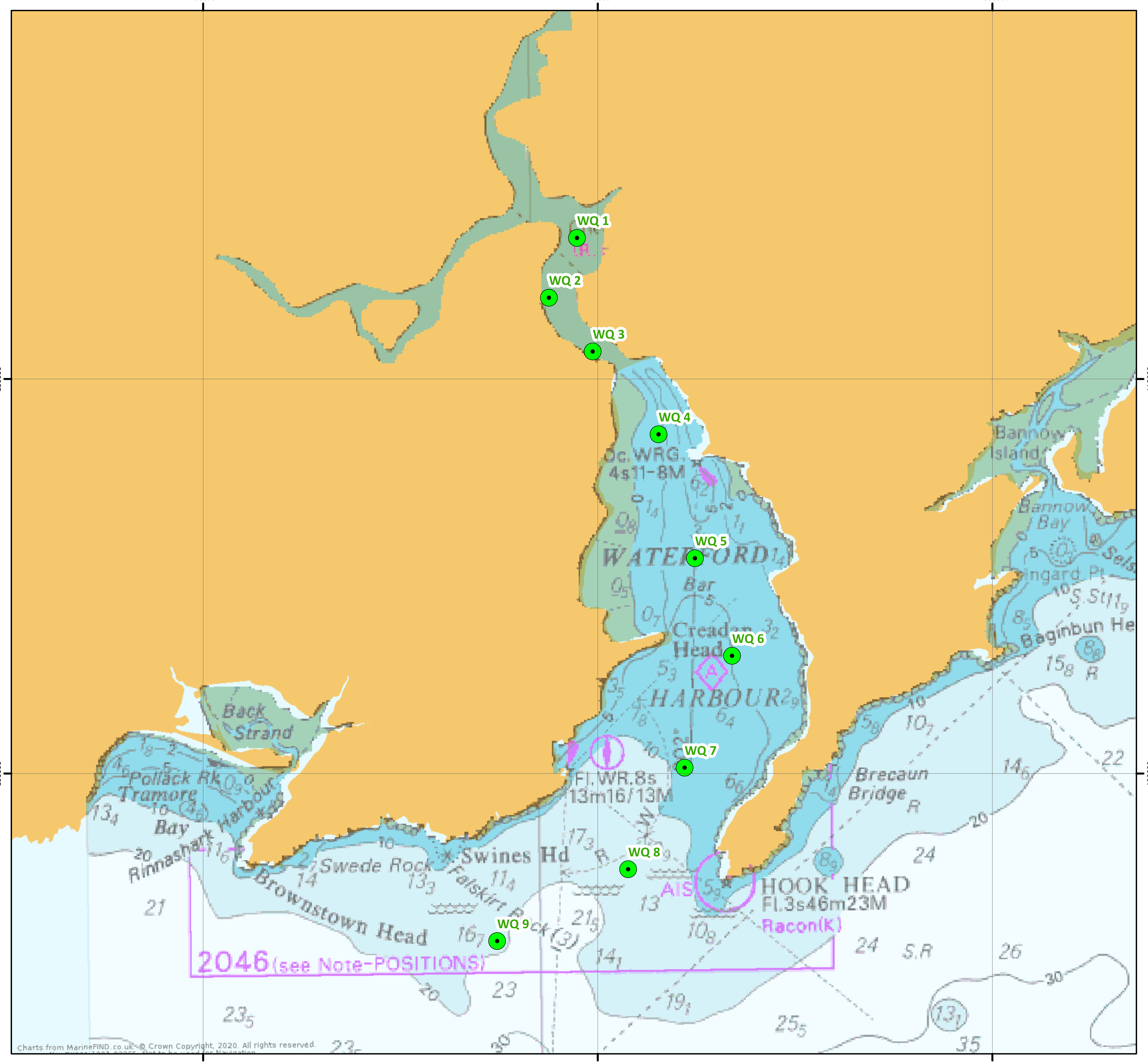
NOTE: Not to be used for Navigation

Date	28 April 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	MarineFind; OSI; ESRI
File Reference	J:\P2323\Mxd\02_MOD\P2323-MOD-003.mxd
Created By	Chris Dawe
Reviewed By	Emma Langley
Approved By	Matthias Thomsen

UISCE ÉIREANN : IRISH WATER

intertek

km 0 1.5 3 4.5 6



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL LOCATIONS
Water Quality Sampling Locations
Waterford Harbour

Drawing No: P2323-MOD-004	C

Legend

Water Quality Sampling Location

N E S W

Date	03 July 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	MarineFind; OSI; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-004.mxd
Created By	Chris Dawe
Reviewed By	Emma Langley
Approved By	Matthias Thomsen

UISCE ÉIREANN : IRISH WATER

intertek

0 1.5 3 4.5 6 km

Bacterial sampling

Sampling Data – ADCP

Water quality sampling of EC concentrations was conducted at each of the four ADCP locations (Figure B-2) subsequent to deployment on the 23/07/2019.

Sampling Data – Seawater

Seawater sampling for EC concentration was carried out for spring tides (13/08/2019 and 14/08/2019) and for neap tides (07/08/2019 and 08/08/2019). Sampling was carried out at sites WQ1-WQ9 (with four replicate samples collected near the surface at approximately 3-hour intervals; Figure B-3).

Sampling Data – Outfall locations

EC and faecal coliform samples were collected typically three times per day (morning, afternoon and evening) on eight separate days in August and September from each of the nine outfall locations. Unfortunately, some samples were incorrectly analysed in the laboratory, as a result some concentrations were capped at 10^6 EC/100ml (meaning that the actual concentration was at least 10^6 EC/100ml). The datasets for each WwTPs were very small (<15 samples per WwTP), and the data showed a very large range, with a number of unexpectedly low values. It was therefore agreed with IW that these data were not sufficiently robust to be used in the assessment.

Sampling Data – Rivers

The sampling data for the rivers is very limited (three samples taken on each river on the same day – 13th August - and within a short space of time). Such a small dataset does not provide a robust dataset from which to determine statistics (such as the arithmetic mean) with confidence.

Flow sources

Three main rivers; the River Suir, River Barrow and River Nore drain into Waterford Harbour as well as various smaller waterways.

Flow time-series data from the Office of Public Works (OPW) were used for the River Suir, the River Nore and the River Barrow.

3D Hydrodynamic model

A three-dimensional (3D) Hydrodynamic (HD) model was developed and applied in the modelling assessment. A 3D modelling approach was discussed and agreed with IW. Although initially it was assumed a 2D model could be utilised, following review of the survey data and on initial testing of a 2D and 3D model, it was concluded that a 3D model would improve the representation of the stratified hydrographic conditions and mixing processes of the freshwater inputs within Waterford Harbour through multiple layers.

The 3D model presented in the study has been calibrated against water levels, depth-averaged current velocities, salinity, temperature and EC.

The 3D model shows good performance across each of the model parameters and captures the environmental processes well although it is not perfect at all states of the tide. The model is considered to be fit for the intended use of undertaking the water quality assessment at Waterford Shellfish Water.

The data used in the calibration and validation of the HD model is outlined below:

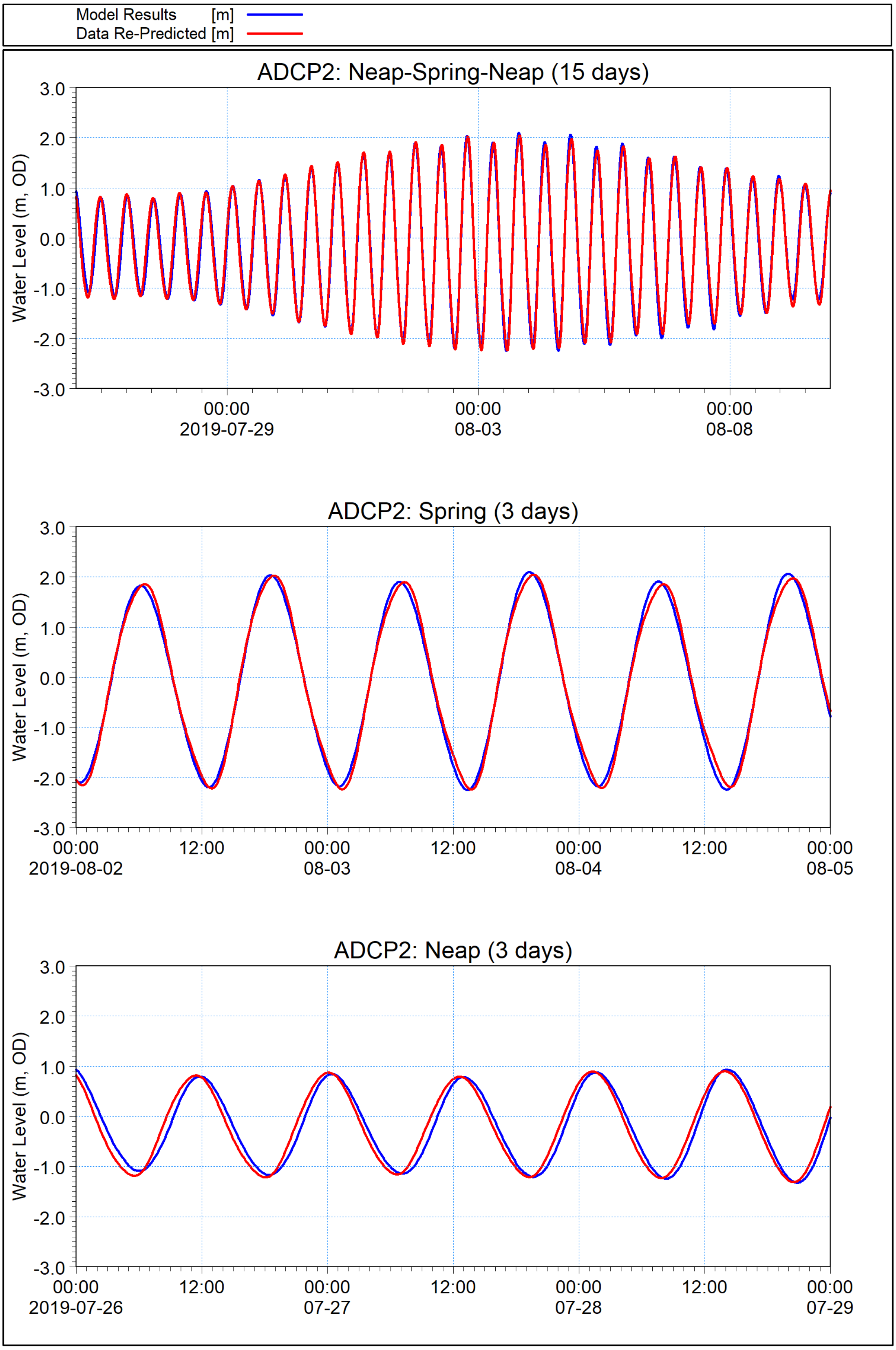
- Water Level (Tide Gauge and ADCPs)
- Current velocities and direction (ADCPs)
- Salinity (CTD profiles)
- Temperature (CTD profiles)
- Bacterial concentrations (sampling data)

Water level

The hydrodynamic 3D model has been calibrated against water level data, by undertaking sensitivity testing of the model bed roughness. The water level data used for model calibration was collected from the tide gauge at Dunmore East as well as from each of the four ADCP locations. Figure B-4 presents the model comparisons for water levels against the calibration from ADCP2 for a typical Neap-Spring tidal cycle (top plot), Spring tide only (middle plot) and the Neap tide only (bottom plot).

ADCP2 has been selected as it is within the Shellfish Water.

Figure B-4 Calibration against re-predicted water levels: ADCP2



Current speed and direction

Model calibration and validation of current speed and direction was undertaken against the observed data at the four ADCP sites, over three days under spring and neap tide, respectively. The observed data, instead of the re-predicted data, were selected for the calibration of current speed and direction as the density driven current, caused by the salinity gradient, can be significant in an estuary and may be removed from the harmonically re-predicted current. The fitness of the model was evaluated as a combination of depth-averaged velocity and velocity vertical profiles, over a period of three days under spring tide.

An example of the comparison plots of the model predicted depth-averaged velocity (east [U component] and north [V components]), current speed and direction with the observed data at ADCP2 are given in Figure B-5.

The 3D model performance in the vertical dimension is demonstrated by velocity vertical profiles at key tidal states, i.e. HW, mid-flood, LW, and mid-ebb. As an example, Figure B-6 shows the comparison of velocity vertical profiles against the observed profiles collected under spring tide at site ADCP2.

ADCP2 has been selected as it is within the Shellfish Water.

Figure B-5 Calibration against observed current speed and direction: ADCP2

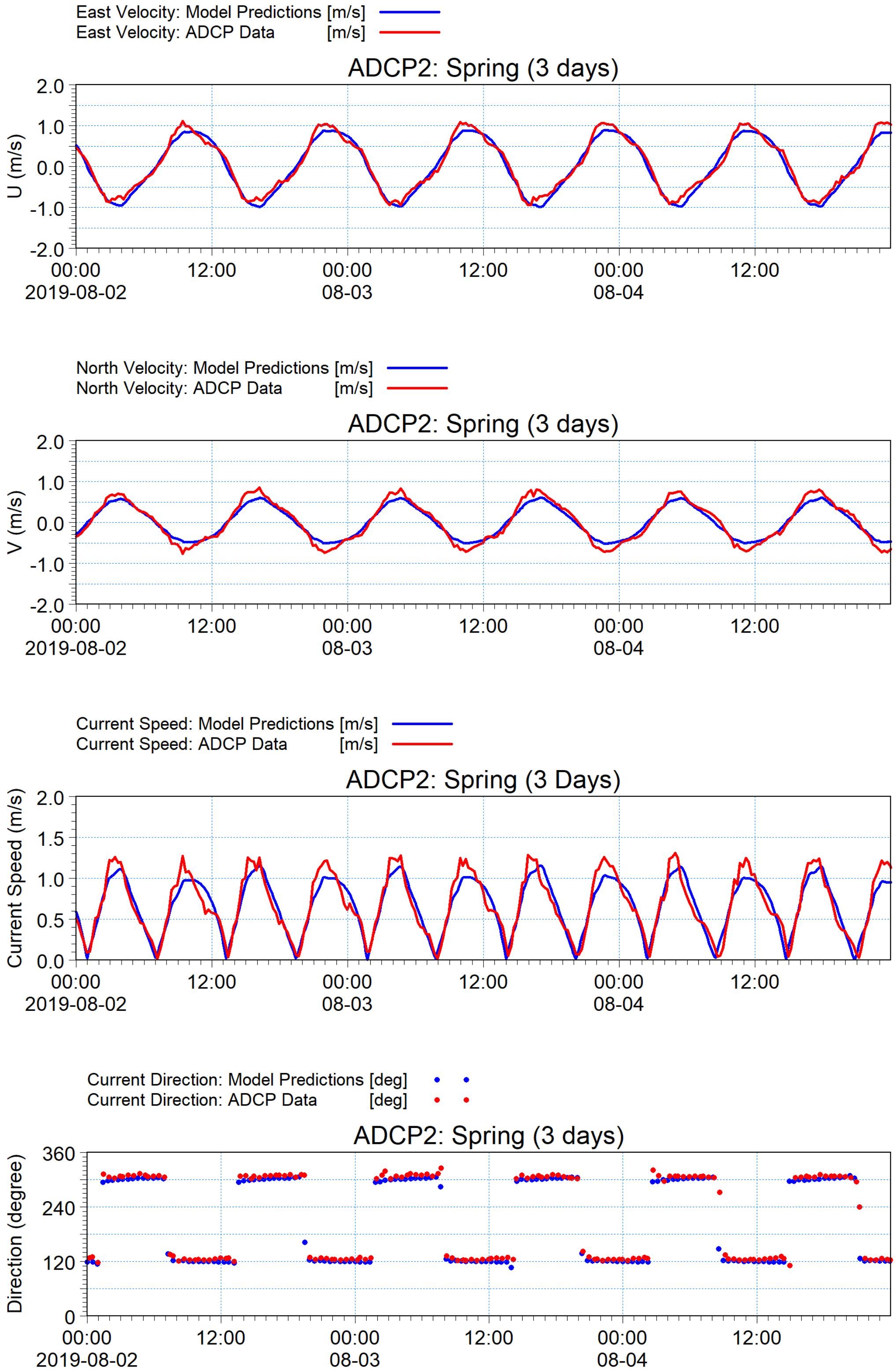
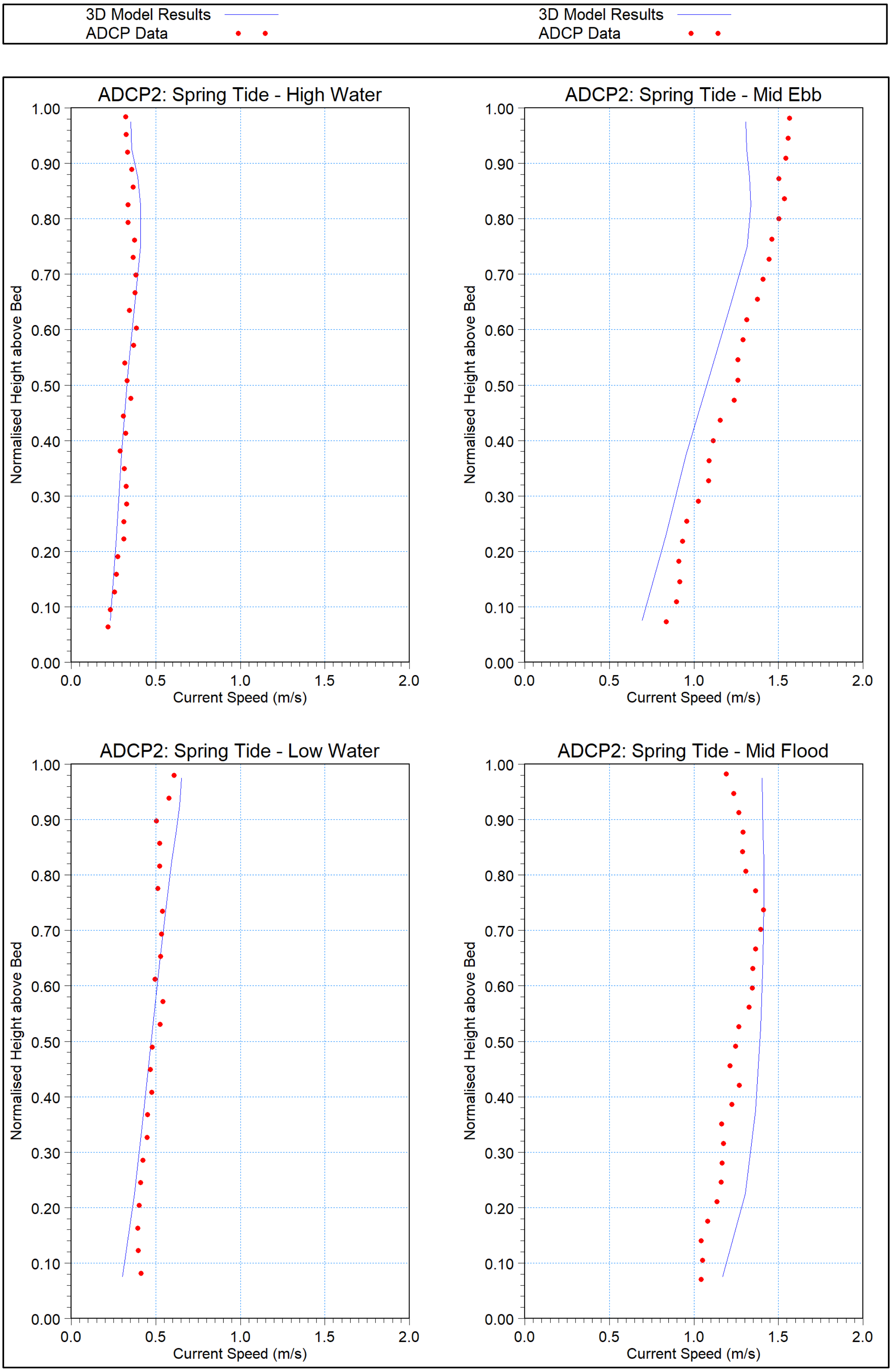


Figure B-6 Calibration against observed velocity vertical profiles: ADCP2



Salinity

Model calibration of salinity was undertaken against the observed data at the nine WQ sites, against four CTD casts under spring tide, whilst model validation of salinity was undertaken against the observed data at each of the nine WQ sites, against four CTD casts under neap tide.

Model calibration and validation was undertaken by comparing depth averaged salinity against observed data over two three-day periods over a spring tide (calibration) and neap tide (validation) at the nine WQ sites.

The 3D model performance was also assessed in the vertical dimension by comparing salinity vertical profiles against CTD profiles. As an example, Figure B-7 and Figure B-8 show the comparisons of salinity vertical profiles against the observed profiles collected under spring and neap tide, respectively at site WQ4, a site located within the shellfish water.

Overall comparisons of both depth-averaged salinity and salinity vertical profiles show that good agreement between the model predictions and CTD data are obtained most of the time, and in summary, the model performance is considered good, with no significant or unexplained anomalies identified in the model performance.

Figure B-7 Calibration against salinity vertical profiles: WQ4

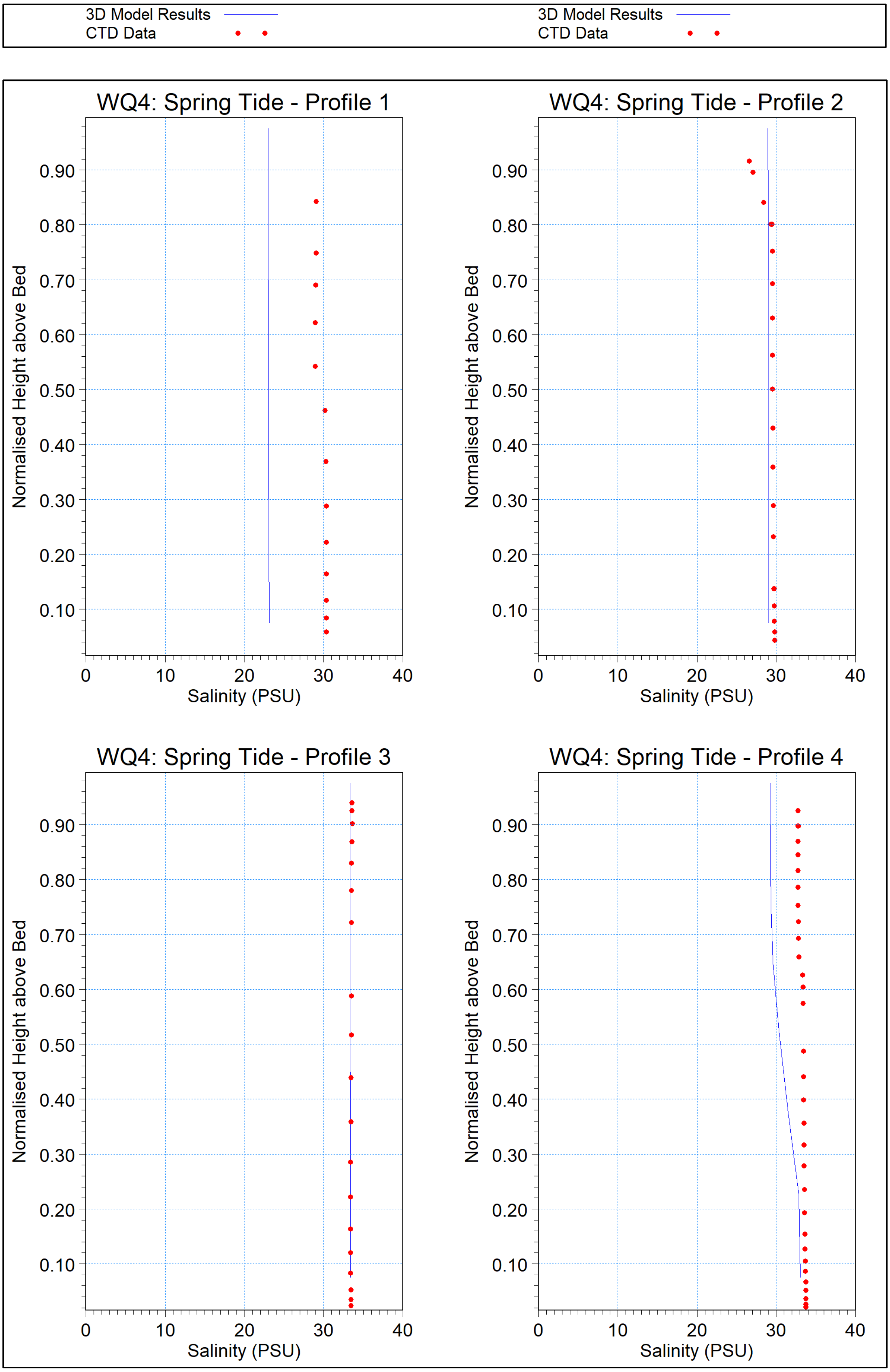
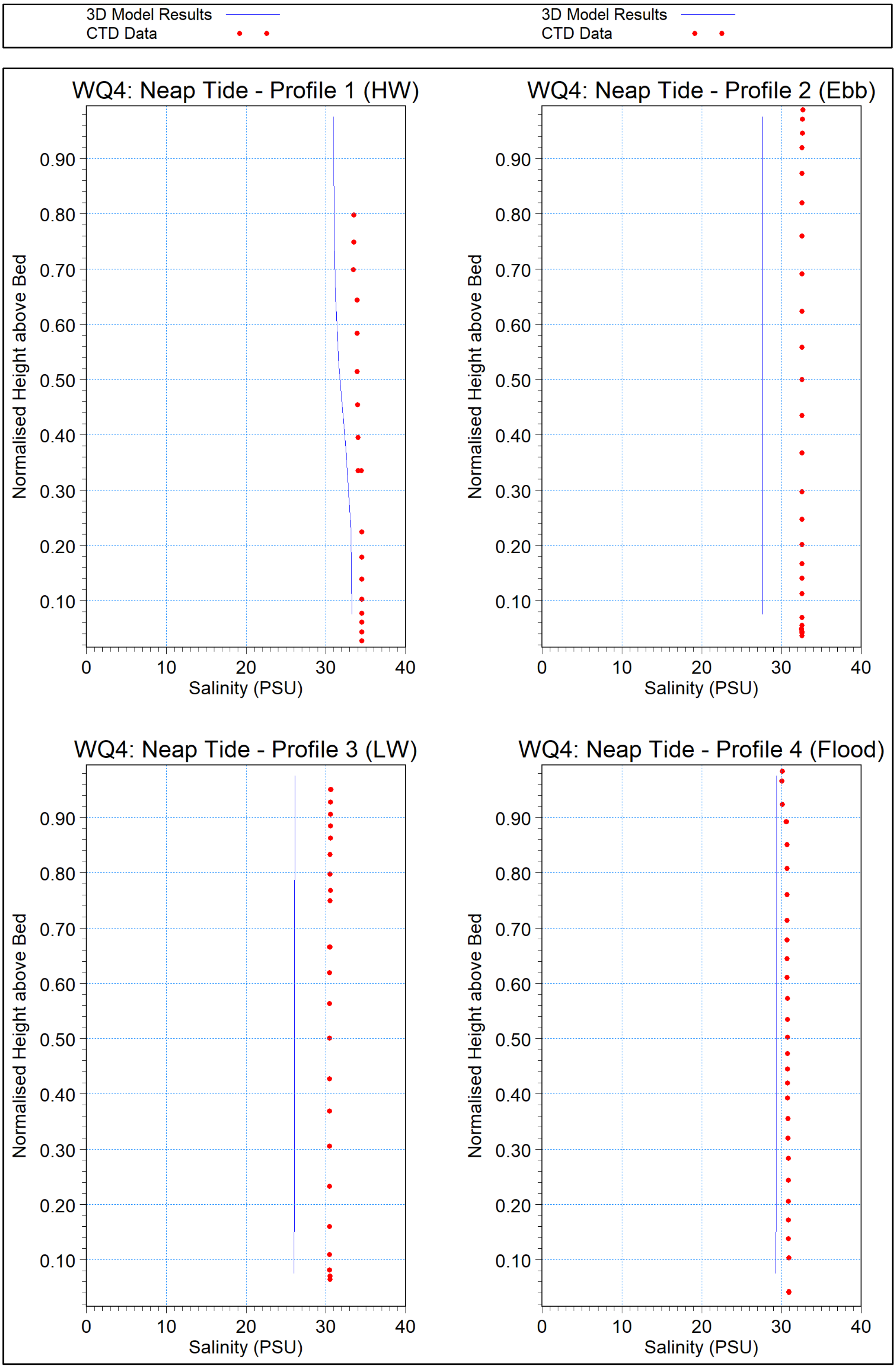


Figure B-8 Validation against salinity vertical profiles (neap tide): WQ4



Temperature

Model calibration and validation of water temperature was undertaken against the observed data at the nine WQ sites, against four CTD casts under spring and neap tide. The fitness of the model for temperature was evaluated in the same was as salinity – by comparing the time-series of depth-averaged temperature over a full spring tide and neap tide, and by assessing vertical profiles at four states of the tide.

The 3D model performance in the vertical dimension is assessed by comparing temperature vertical profiles against CTD profiles. As an example, Figure B-9 and Figure B-10 show the comparisons of temperature vertical profiles against the observed profiles collected under spring and neap tide, respectively, at site WQ4, a site located within the shellfish water.

Figure B-9 Calibration against temperature vertical profiles: WQ4

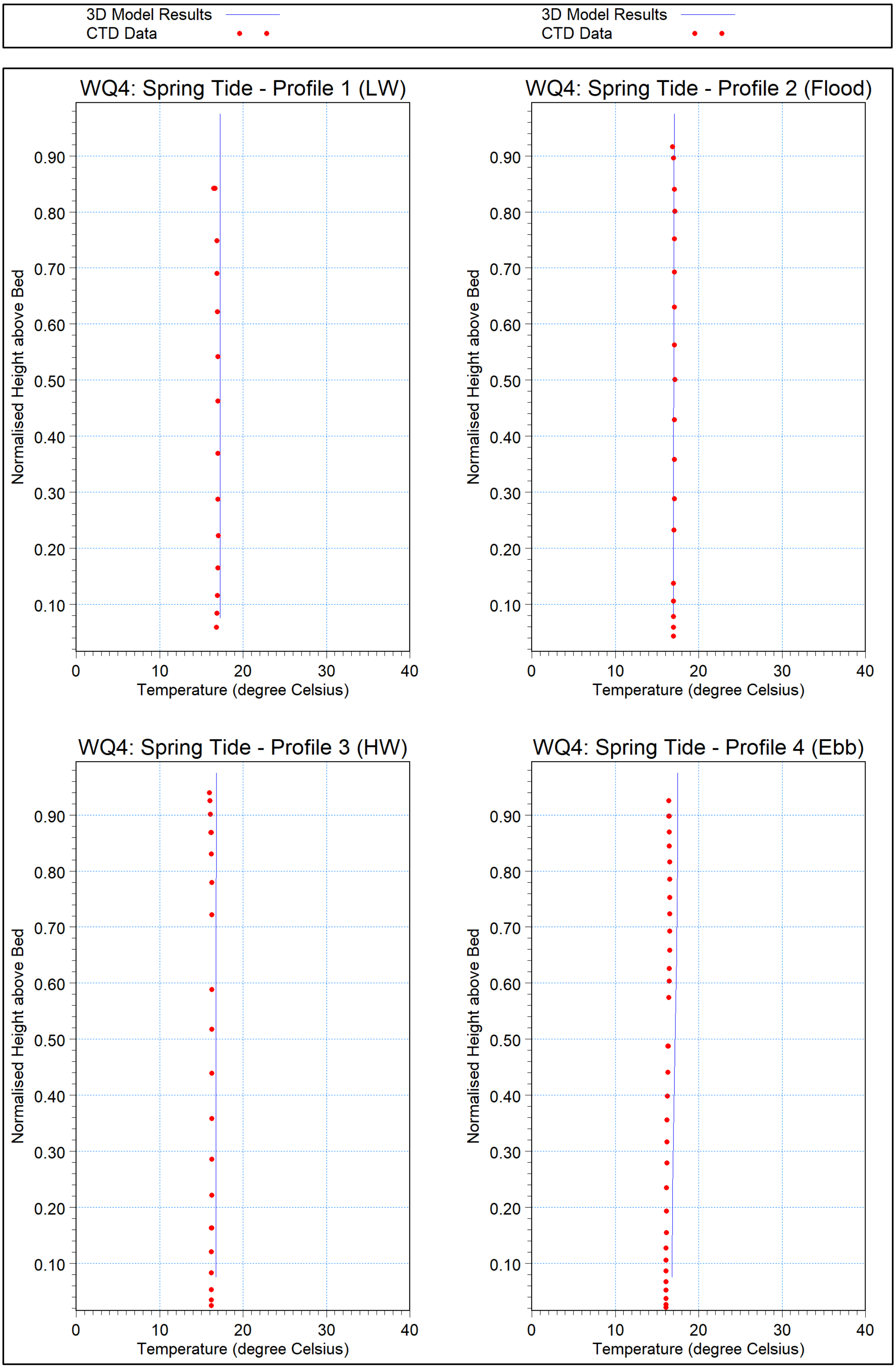
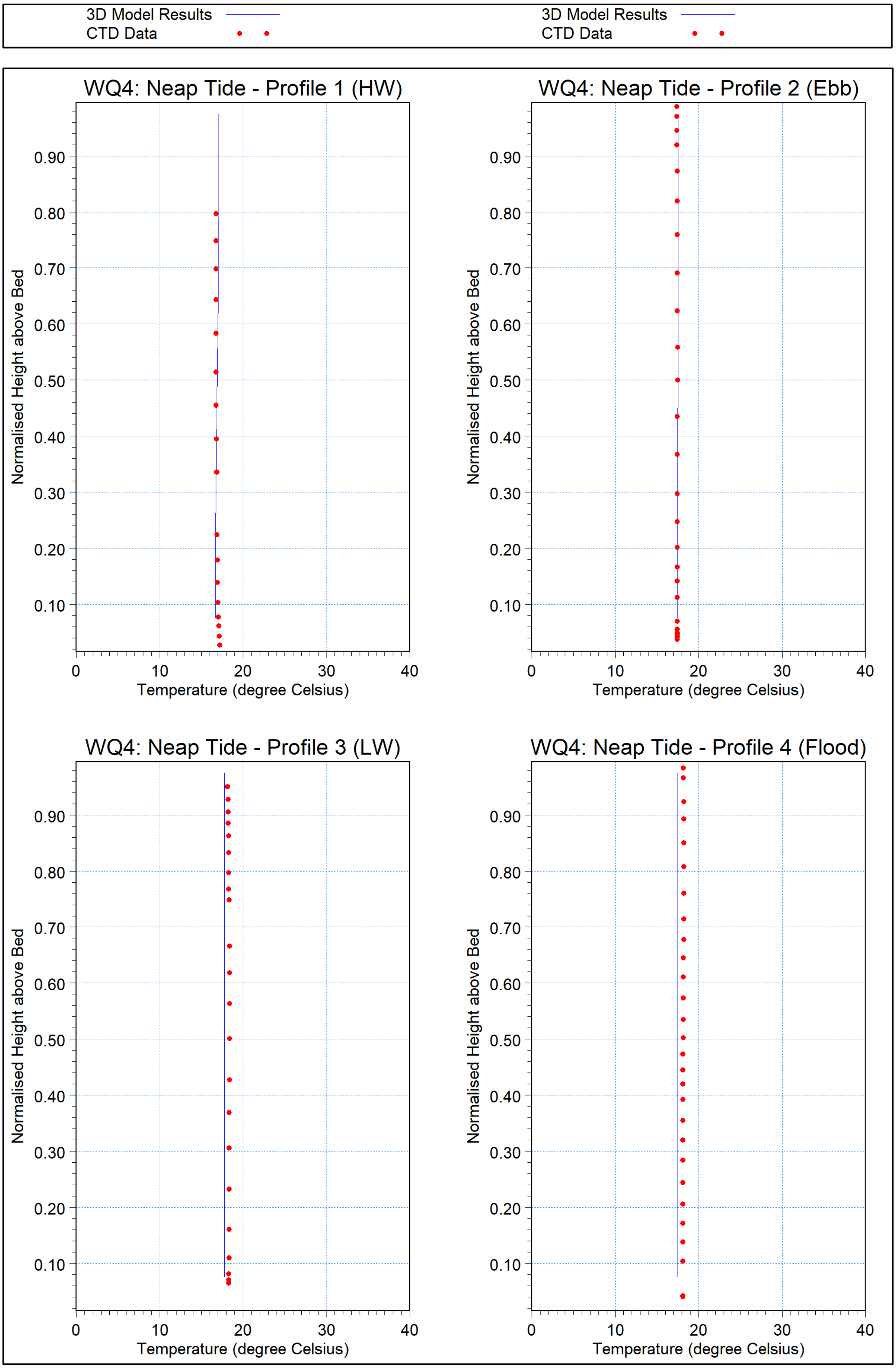


Figure B-10 Validation against temperature vertical profiles (neap tide): WQ4



Appendix C.

Modelled discharges

Discharges Modelled

As outlined in the Model Scoping Report (MSR, 2019), the modelling assessment has included a total of 24 individual discharges into Waterford Harbour or the main rivers draining into the Harbour. It should be noted however that one discharge (the SSE power station cooling water) was included to ensure any effect on hydrodynamics was captured, but it was assumed to carry no bacterial load. Therefore only 23 sources have been included in the water quality assessment. The discharges included are presented in Figure 1-1 and outlined below.

The nine main IW WwTPs, representing the main focus of the assessment include:

- Arthurstown and Environs
- Ballyhack and Environs
- Campile
- Cheekpoint
- Crooke
- Duncannon
- Dunmore East
- Passage East
- Waterford City

Nine smaller IW WwTPs which also contribute a bacterial load to the area of interest:

- Mooncoin
- Portlaw
- Clongeen
- Fiddown
- Piltown
- Carrick-on-Suir
- New Ross
- Inistioge
- Saint Mullins

Industrial Emission Licenced (IEL) sources

Three IEL licenced discharges, which include two slaughterhouses and the SSE power station:

- Queally Pig Slaughtering Limited (IEL licence No: P0175)
- Anglo Beef Processors Ireland Unlimited Company trading as ABP Waterford (IEL licence No: P0205)
- SSE Generation Ireland Limited (IEL licence No: P0606)

The slaughterhouse, Queally Pig Slaughtering limited (IEL licence No: P0175) discharge treated effluent into the River Suir, while the slaughterhouse, Anglo Beef Processors Ireland Unlimited Company trading as ABP Waterford (IEL licence No: P0205) and the power station (SSE Generation Ireland Limited; IEL license No: P0606) discharges into Waterford Harbour.

It should be noted that the SSE power station is not likely to contribute a bacterial load, but the cooling water and processes discharge may influence the local hydrodynamics, which is why it has been included. There are also two other slaughterhouses (IEL licence No: P0179 and P0040) which also discharge treated effluent to the rivers that drain to the harbour, but no discharge information is available for these, and these have been excluded as per the MSR (2019).

Diffuse river sources

The three main rivers that drain into Waterford Harbour:

- River Suir
- River Nore
- River Barrow

Each of the discharges outlined above were represented in the model by an EC concentration and discharge/river flow that is representative of winter loadings. These are detailed in Tables C-1 to C-4. A uniform load was applied for each source.

Modelled flows

Irish Water WwTPs

The modelled discharge flow for the main nine and smaller nine WwTPs were based on the current hydraulic loadings or 1.25 Dry Weather Flow (DWF) where hydraulic loadings information is not available for each works, as provided by IW Asset Planning team via Nicholas O'Dwyer (NOD).

River flows

The modelled river flow for the three main rivers is the Q30% flow, as per IW's Technical Standards. These have been calculated from the gauged flows for River Nore and River Barrow as they are gauged close to the tidal limit. For River Suir the most downstream gauging station is still too far from the tidal limit, and therefore the Q30% flow was obtained from the Environment Protection Agency (EPA) Hydro Tool.

IEL sources

The modelled discharge flow for the three IEL sources was based on the consented flow as provided in the MSR (2019).

Modelled concentrations

Irish Water WwTPs

The baseline scenario used uniform default concentrations provided by IW via NOD to represent the bacterial concentrations. The default concentrations applied are dependent on the level of treatment at each WwTPs as follows are;

- 1 x10^7 EC/100ml for untreated sewage;
- 1 x10^6 x EC/100ml for primary treatment;
- 1 x10^5 x EC/100ml for secondary treatment and;
- 1 x10^4 x EC/100ml for tertiary treatment.

The rationale for using default concentrations to represent bacterial concentrations was chosen due to lack a robust sampling data from the WwTPs.

Rivers

The sampling data for the rivers is very limited (three samples taken on each river on the same day – 13th August - and within a short space of time). Such a small dataset does not provide a robust dataset from which to determine statistics (such as the arithmetic mean) with confidence.

Furthermore, the data has been collected during the summer, and is not necessarily representative of winter loadings. However, these data have been used to represent the upstream diffuse river loads.

The main three rivers draining into Waterford Harbour have a total catchment area of 9,232 km^2. The overall catchment area has a total number of 1.37 livestock units per hectare (ha) of farmland (ref: Shellfish Pollution Reduction Programme). This equates to a total number of 1,264,784 livestock for the entire catchment, which includes pigs, cattle and sheep. Pigs and cattle are moved inside during winter while sheep are outside all year.

It is livestock that generate the majority of the diffuse bacterial load in rivers. Given that a proportion of livestock are moved inside in winter, it is likely that diffuse loads will be lower in winter than summer.

Furthermore, no slurry spreading is allowed between November and March, adding further weight to the theory that winter loads are likely to be lower than in summer.

The concentrations applied to the three river sources in the assessment are therefore considered to be conservative.

The mean of the river samples collected in each river was therefore applied.

IEL sources

The upper limit of the EC concentration range measured by Nafarnda et al. 2012 was applied for the slaughterhouses – 2 x 10^3 EC/100 ml.

Baseline scenario

Winter conditions

As this is a shellfish modelling assessment, the scenarios were run for average winter conditions (January), as per IW's Technical Standards. Specifically, this means winter bacterial discharge loads and winter decay rates were applied.

Modelled duration

The model simulations were run for a sufficiently long 'warm-up' period to enable dynamic equilibrium of bacteria concentration in the environment to be reached (approximately one week). This provided the initial conditions for the simulation. The assessment period covered a spring-neap (15 day) cycle following the warm-up period, as outlined in IW's Technical Standards.

Decay rate

The decay rate was represented by the T_{90} time (the time for 90% of the initial bacterial population to be reduced through mortality) For this assessment, the winter T_{90} value for EC in turbid estuaries (48 hours) as defined in IW's Technical Standards was applied.

Wind condition

No wind was applied in the assessment simulations.

Table C-1 Baseline scenario for the main nine WwTP for model discharge flow and for EC concentrations

WwTP	Treatment	Model discharge flow (m^3/d)	E. coli concentration (MPN/100 ml)
Arthurstown and Environs	Untreated	84.66	1 x 10^7
Ballyhack and Environs	Untreated	65.25	1 x 10^7
Campile	Primary	102	1 x 10^6
Cheekpoint	Secondary	42.75	1 x 10^5
Crooke	Secondary	158.91	1 x 10^5
Duncannon	Untreated	310.22	1 x 10^7
Dunmore East	Secondary	1,242	1 x 10^5
Passage East	Primary	51.19	1 x 10^6
Waterford City	Secondary	34,007	1 x 10^5

Table C-2 Baseline scenario for the smaller nine WwTP for model discharge flow and for EC concentrations

WwTP	Treatment	Model discharge flow (m^3/d)	E. coli concentration (MPN/100 ml)
Mooncoin	Secondary	270	1×10^5
Portlaw	Tertiary P	352	1×10^5
Clongeen	Secondary	75.94	1×10^5
Fiddown	Primary	137	1×10^6
Piltown	Secondary	525	1×10^5
Carrick-on-Suir	Tertiary N&P removal	2,591	1×10^5
New Ross	Tertiary N	4,352	1×10^5
Inistioge	Primary	118.13	1×10^6
Saint Mullins	Secondary	6.47	1×10^5
Note: It was agreed with IW to apply secondary default values (1×10^5) for tertiary treatment that only removed nutrients (i.e. N and/or P) and do not include bacterial (UV) treatment.			

Table C-3 Baseline scenario for the two abattoirs and the power station for model discharge flow and for EC concentrations

IEL discharge	Treatment	Model discharge flow (m^3/d)	E. coli concentration (MPN/100 ml)
Queally Pig Slaughtering Limited (MSR No: P0175)	Unknown	1,800	2,000
Anglo Beef Processors Ireland Unlimited Company trading as ABP Waterford (MSR No: P0205)	Unknown	2,000	2,000
SSE Generation Ireland Limited power station (P0606)	Not applicable	480,000	Not applicable
Note: EC concentrations from the abattoir effluent are based on observations published in the research article by Nafarnda et al. 2012.			

Table C-4 Baseline scenario for the three main rivers draining into Waterford Harbour for model discharge flow and for EC concentrations

River discharge	Model river flow (m^3/d; Q30 %)	E. coli concentration (MPN/100 ml)
River Suir	4,587,840	680
River Nore	3,741,120	400
River Barrow	3,965,760	150

Appendix. 7.1 Ambient Monitoring

D0022 – Waterford

The WWTP discharges to the Lower Suir Estuary, this is designated as Transitional Water, the Environmental Protection Agency undertakes sampling of this water body. Data Source: https://www.catchments.ie/data/#/waterbody/IE_SE_100_0500?_k=7v110t

	Designations					
Ambient monitoring point/Coastal Monitoring Code	Irish Grid Reference	Bathing Water	Drinking Water	FWPM	Shellfish	WFD Status
TW30002102SR4002	264720.15,112043.12					Good
TW30002102SR4002	266200.35,113186.62	No	No	No	No	

Ambient Monitoring Results Summary

Monitoring point	Date	BOD - 5 days (Total)	Dissolved Oxygen %	ortho-Phosphate (as P)	pH	Total Oxidised Nitrogen (as N)
Upstream						
SR460 - Suir Estuary at Little Island **[U/S]**	20/01/2020	1.4	93	0.036	8	3.1
SR460 - Suir Estuary at Little Island **[U/S]**	08/07/2020	-	90	0.047	8	1.1
	Average	**1.4**	**91.5**	**0.0415**	**8**	**2.1**
Downstream						
SR480 - Suir Estuary at Glass House Quay [**D/S**]	20/01/2020	1	92	0.05	8	2.3
SR480 - Suir Estuary at Glass House Quay [**D/S**]	08/07/2020	-	92	0.028	8	0.58
	Average	**1**	**92**	**0.039**	**8**	**1.44**

			Receiving Waters Designation (Yes/No)					Mean (mg/l)	
Ambient Monitoring Point from WWDL (or as agreed with EPA)	**Irish National Grid Reference (Easting, Northing)**	**EPA Feature Coding Tool code**	**Bathing Water**	**Drinking Water**	**FWPM**	**Shellfish**	**Current WFD Status**	**cBOD**	**o-Phosphate (as P)**
Upstream Monitoring Point	TW30002102SR4002	264720.15, 112043.12					Good	1.4	0.042
Downstream Monitoring Point	TW30002102SR4004	266200.35, 113186.62	No	No	No	Yes	Good	1	0.04
Difference								*0.4*	*0.002*
EQS								4	0.04
% of EQS								25.00%	100.00%

WwTP Disinfection Programme

Waterford Shellfish Water – Stage 4 – Detailed Assessment of the Existing Primary Discharges

Employer:	**Irish Water**
Irish Water Project Number:	**10020264**
Project Supervisor Design Process (PSDP):	**Nicholas O'Dwyer Ltd.**
PSDP Project Number:	**20745**
Modelling Consultant:	**Intertek Energy and Water Consultancy Services**

Project Name: WwTP Disinfection Programme

Document: Waterford Shellfish Water - Baseline Assessment – Stage 4a – Detailed Assessment of the Existing Primary Discharges

Revision History

Revision	Reason for Revision	Prepared By	Reviewed By	Approved By	Issue Date
Rev 0	Initial Issue	MT	PAT	PAT	01/07/2020
A	Addressing comments from NOD	MT	PAT	PAT	02/07/2020
B	Addressing comments from IW	MT	PAT	PAT	16/07/2020
B.1	Inserting text from IW	MT	YW	YW	30/10/2020
C					
D					

Contents

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Abbreviations

BW	Bathing Water
CFU	Colony-forming unit
CTD	Conductivity, Temperature and Depth
DAP	Drainage Area Plan
EC/E. coli	Escherichia coli
EPA	Environment Protection Agency
Intertek	Intertek Energy and Water Consultancy Services
IW	Irish Water
MPN	Most Probable Number
NOD	Nicholas O'Dwyer
SWO	Surface Water Overflows
WQ	Water Quality
WwTP	Wastewater Treatment Plant

1. Background

As part of the Irish Water Wastewater Treatment Plant (WwTP) Disinfection Programme, Intertek Energy and Water Consultancy Services (Intertek) has been commissioned by Nicholas O'Dwyer (NOD) on behalf of Irish Water (IW) to undertake a modelling impact assessment of the main outfall discharges on the water quality of the Designated Shellfish Waters in Waterford Harbour.

The main objective of this modelling study was to assess whether discharges from agglomerations discharging directly to Waterford Harbour are impacting microbial water quality of the Designated Shellfish Waters, and identify the final effluent quality required in order to eliminate the impact of any discharges identified as impacting Designated Shellfish Water's microbial water quality.

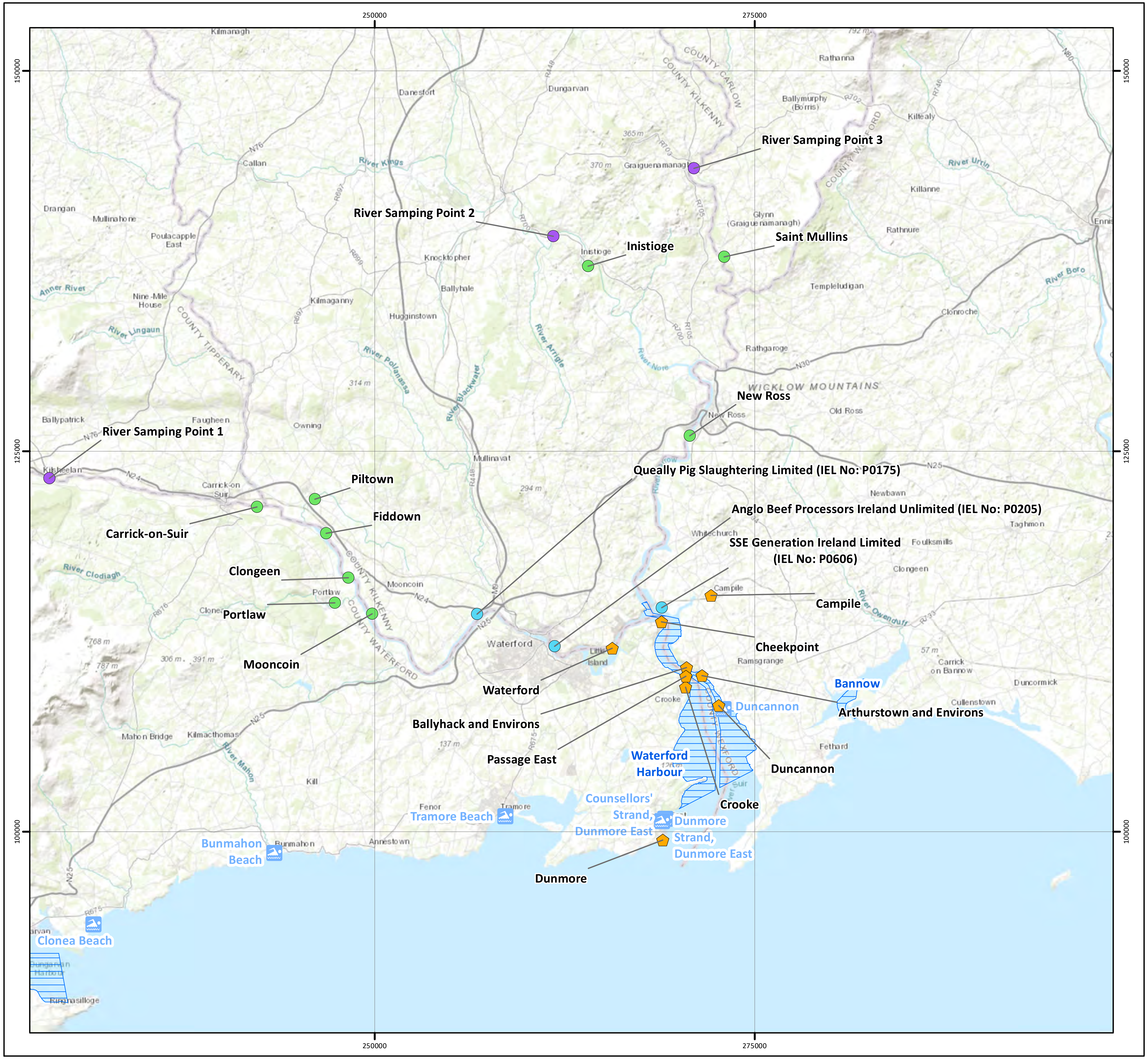
1.1. Study Area

Waterford Harbour is situated on the coast of County Waterford in the South-Eastern River Basin District. The natural harbour is at the mouth of the three rivers; the River Nore, River Suir and River Barrow. It is bound by Creaden Head to the west and Hook Head to the east.

The Waterford Harbour shellfish waters were designated in 2009 under the European Communities (Quality of Shellfish Waters) (Amendment) Regulations 2009 (S.I. 55 of 2009). The total area of the Waterford Harbour designated shellfish area is circa 30 km^2 and extends from the confluence of the Suir and Barrow downstream to a line from Ardnamult Head across to Broomhill.

The assessment included modelling nine main WwTPs, which were the focus of the study. These were: Arthurstown and Environs, Ballyhack and Environs, Campile, Cheekpoint, Crooke, Duncannon, Dunmore East, Passage East and Waterford City. In addition, nine smaller works were also included. The diffuse or background load from the three main rivers that drain into the harbour were also included. Two slaughterhouses that also discharge a potentially large microbial load close to the shellfish water were also included. Finally, the flow from nine smaller rivers that drain into the tidal stretches of the three main rivers (i.e. downstream of the tidal limit) were also included, as well as the SSE power station cooling water discharge , to ensure any effect on the hydrodynamics was captured in the modelling, in particular on any stratification due to these fresh water inputs. It should be noted however that it was assumed that there was no bacterial load associated with these smaller rivers or the cooling water discharge. Therefore, there were 33 discharges included in the hydrodynamic model, but only 23 of these were modelled with a bacterial load in the water quality modelling.

Figure 1-1 presents a geographic overview of the area, including the main discharge locations and the Designated Shellfish Water.



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL LOCATIONS
Discharge Locations

Drawing No: P2323-MOD-006	A

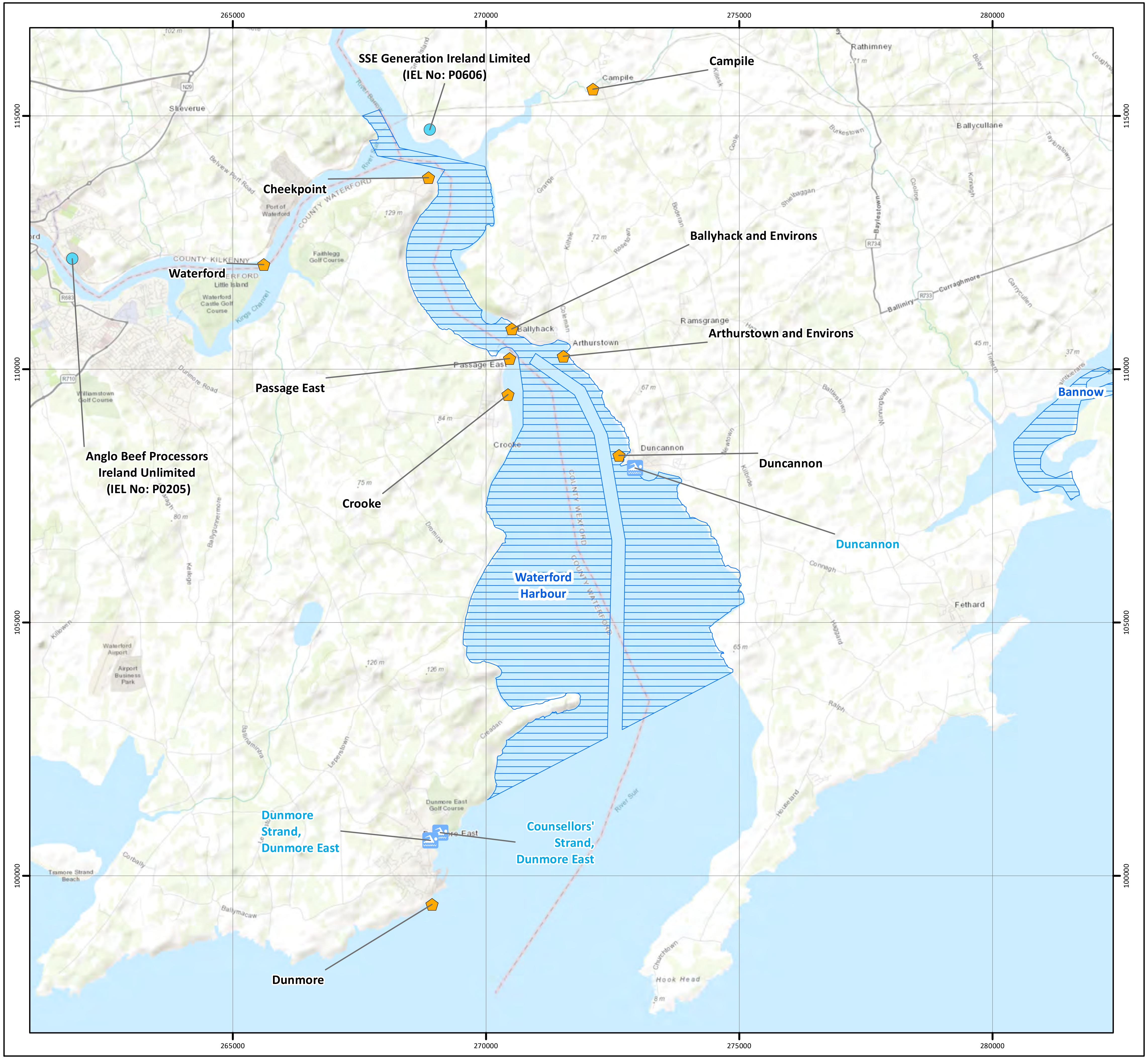
Legend

- Main WWTP
- Smaller WWTP
- Industrial Emission Licence (IEL)
- River
- Bathing Water Location
- Shellfish Water

Date	10 December 2019
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-006.mxd
Created By	Emma Langley
Reviewed By	Chris Goode
Approved By	Matthias Thomsen

0 2.5 5 7.5 10 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;

COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

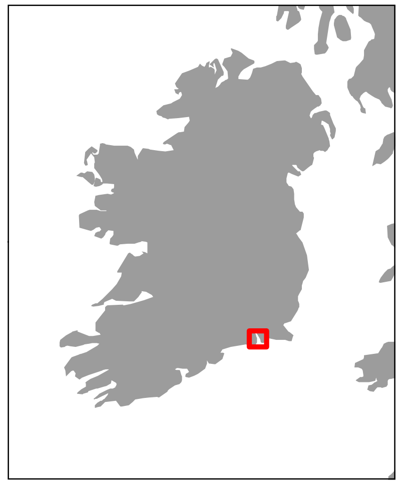
MODEL LOCATIONS
Discharge Locations - Waterford Harbour

Drawing No: P2323-MOD-013	A

Legend

- Main WWTP
- Industrial Emission Licence (IEL)
- Bathing Water Location
- Shellfish Water

N W E S



NOTE: Not to be used for Navigation

Date	28 April 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-013.mxd
Created By	Chris Dawe
Reviewed By	Emma Langley
Approved By	Matthias Thomsen

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intertek

0 1 2 3 4 km

2. Objectives

Three key specific objectives of the assessment are as follows;

1. Assess whether untreated, primary and secondary discharges from agglomerations discharging in the proximity of Waterford Harbour are impacting Escherichia coli (hereafter referred to as E. coli or EC) water quality of the Designated Shellfish Waters.
2. Identify the final effluent quality required in order to ensure discharges do not impact Designated Shellfish Water's microbial water quality.
3. Assess the impact of Surface Water Overflows (SWO) on the microbial water quality of the Designated Shellfish Waters.

   Separate to the Disinfection Programme, the Waterford City Drainage Area Plan (DAP) Study is currently ongoing which will provide detailed information on the volume, duration and frequency of discharges from SWOs. A Stage 4B SWO assessment will therefore be carried out in due course, once this information is available.

   This current assessment for the Disinfection Programme has therefore only considered discharges of final effluent from the WwTPs, as well as other continuous sources.

3. Approach

The assessment has followed a tiered approach, as outlined in IW's Technical Standard Marine Modelling Version 1.83 (TSMM 2019 – hereafter referred as the Technical Standards). Initially NOD undertook a scoping assessment and a series of desk-based analyses, including initial dilution studies. These initial assessments did not conclusively rule out the risk of impact on shellfish water quality from IW WwTPs discharging in the vicinity of Waterford Harbour, and it was concluded that the Waterford Harbour assessment required a Tier 3 approach, and therefore a fully dynamic hydrodynamic and water quality model was needed.

A three-dimensional (3D) hydrodynamic model has been developed and applied to assess the impact of 23 potential sources. These are the key continuous sources that potentially contribute to impacts at the Shellfish Water under normal, dry weather conditions.

The modelling approach is in line with IW's Technical Standards. The model was built using the best available bathymetry and boundary condition data, and calibrated and validated against site specific water levels, current velocities, salinity, temperature and EC concentration data collected through a bespoke survey commissioned by NOD. The model performance was assessed using industry standard criteria and the model is considered to be of a good standard and fit for the proposed use of assessing bacterial impacts at the Waterford Shellfish Water. A summary of model development and model performance is provided in Appendix B.

The 3D model has been used to simulate the Baseline scenario, to assess the impact from the 23 modelled sources. The total impacts throughout the model domain has been determined, and the proportional contribution from all sources has been calculated at six key locations. The Baseline scenario represents the likely microbial loads from the 23 sources identified under normal, dry weather conditions in winter. No intermittent discharges from SWOs or increased diffuse loads under wet weather conditions have been included.

The modelled loads for the WwTPs were based on a uniform flow for each asset, representative of current hydraulic loadings (or 1.25 x Dry Weather Flow (DWF) where this was not available) as provided by IW's asset planning team, and default concentrations, depending on the level of treatment, as follows:

- Untreated sewage — 1 x 10^7 EC/100ml
- Primary treated sewage — 1 x 10^6 EC/100ml
- Secondary treated sewage — 1 x 10^5 EC/100ml
- Tertiary treated (UV disinfected) sewage — 1 x 10^4 EC/100ml

For consistency throughout this document, bacteria concentrations (whether those from samples or from model predictions) are referred to simply as *number* EC/100ml (rather than using the terms Most Probable Number (MPN) or Colony Forming Unit (CFU).

It should be noted that although some sampling data of bacteria concentrations of the final effluent had been collected at some of the WwTPs, the datasets were generally quite small (<15 samples for each WwTP) and some of the sampled concentrations were capped at a maximum value due to an issue with how the samples had been analysed.

The datasets were therefore not considered to be robust enough for the purpose of this assessment, and it was agreed with IW to use the default concentrations above. These default values were provided by IW and are in line with default concentrations used throughout the water industry where adequate site specific data are lacking. They are also supported by the limited sampling data collected and are considered appropriate for the purpose of this assessment.

Regarding the modelled bacterial loading from Waterford WwTP, it should be noted that the hydraulic loading was determined from a detailed effluent flow monitoring dataset. Due to an absence of commensurate effluent bacterial quality data, literature values for E. coli concentrations were applied to the WwTP based on values commonly measured in typical municipal wastewater.

However, in the case of Waterford WwTP, this approach is considered conservative, due to the unusually high proportion of the influent to the WwTP which arises from trade effluent, which is not a major source of bacterial loads.

Accordingly, the Phase 4a assessment is considered conservative as it is based on a conservative estimate of the bacterial loading from Waterford WwTP.

The modelled loads for the three main rivers (the Suir, Nore and Barrow) and the two slaughterhouses were based on the best information available. The modelled flows applied for the three main rivers were the Q30% flow, based on the gauged data available for each of these three rivers. The gauges on the Nore and Barrow are close to the tidal limit, however the gauging station on the River Suir is approximately 60 km upstream of the tidal limit. In order to account for the increased catchment area between the gauge and the tidal limit, the gauged flows were increased by a factor of 1.7 – based on the ratio of the two catchment areas (upstream of the gauge ~ 1585 km^2, and upstream of the tidal limit ~ 2726 km^2). The upscaled Q30% flow for the Suir was then checked against the Q30% estimate from the Environment Protection Agency (EPA) HydroTool, and found to be consistent.

The estimated Q30% flows from the EPA HydroTool were used as the modelled flows for the other nine smaller rivers that drain into the tidal reaches of the three main rivers between their tidal limit and the shellfish water.

The modelled flow for the slaughterhouses and the power station were based on the consented discharge flow as per the Industrial Emissions Licence for each.

The modelled concentrations for the rivers were based on samples collected for the purpose of this assessment, and for the slaughterhouses were based on an estimate taken from literature. No bacterial load was applied to the nine smaller rivers or the power station cooling water discharge.

Full details of the modelled flows and concentrations applied are provided in Appendix C.

As this is a shellfish modelling assessment, the Baseline scenario was run for average winter conditions (January), as per IW's Technical Standards.

Specifically, this means winter bacterial discharge loads and winter decay rates were applied (T_{90} of 48 hours).

The model simulations were run for a sufficiently long 'warm-up' period to enable dynamic equilibrium of bacteria concentration in the environment to be reached (approximately one week). This provided the initial conditions for the simulation. The assessment period covered a spring-neap (15 day) cycle following the warm-up period, as outlined in IW's Technical Standards.

As the model is a 3D model with ten layers, the modelled sources were all discharged into the relevant layer in the model. For most of the main WwTPs, this is the bottom layer as the outfalls are fully submerged and on the seabed. Crooke WwTP discharges into an area of shallow water which dries out around low water, and therefore, this discharge was released into the surface layer. All of the smaller WwTPs, which are upstream on the tidal parts of the rivers, as well as the rivers themselves and the slaughterhouses were released at the surface layer.

The modelled impacts were calculated as the 95%ile concentration from the 15-day timeseries of impacts at each modelled grid cell, and a contour plot across the model domain has been generated. Contour plots have been generated for both the surface and bottom layers.

Impacts have been assessed against the Bathing Water 'Good' threshold of 500 EC/100ml at the 95%ile concentration, as per the interim criteria for assessing shellfish water impacts as outlined in IW's Technical Standards. Reference is also made the Bathing Water 'Excellent' standard of 250 EC/100ml.

4. Results

All results for the Baseline scenario are presented in Appendix A, and one key plot which summarises the main results is repeated as Figure 4-1. This is the contour plot of the 95%ile concentration in the bottom layer from all 23 modelled sources for the Waterford Harbour area, which shows the impacts within the shellfish water. This is also included in Appendix A as Figure A-4.

Results are shown for the surface layer in Figures A-1 and A-2 (Appendix A) and for the bottom layer in Figures A-3 and A-4 (Appendix A). These show contour plots of the 95%ile concentration resulting from combined impact from all 23 modelled sources. There are two plots – the first showing the whole model domain (including a zoom-in around Duncannon), and the second showing a detailed zoom-in on the Shellfish Water area of the Harbour. The same colour scheme is applied in all plots, as follows:

- <10 EC/100 ml = white;
- >10 and <250 EC/100ml = blue;
- >250 and <500 EC/100 ml = green;
- >500 and <1000 EC/100 ml = yellow, and;
- >1000 EC /100 ml = red.

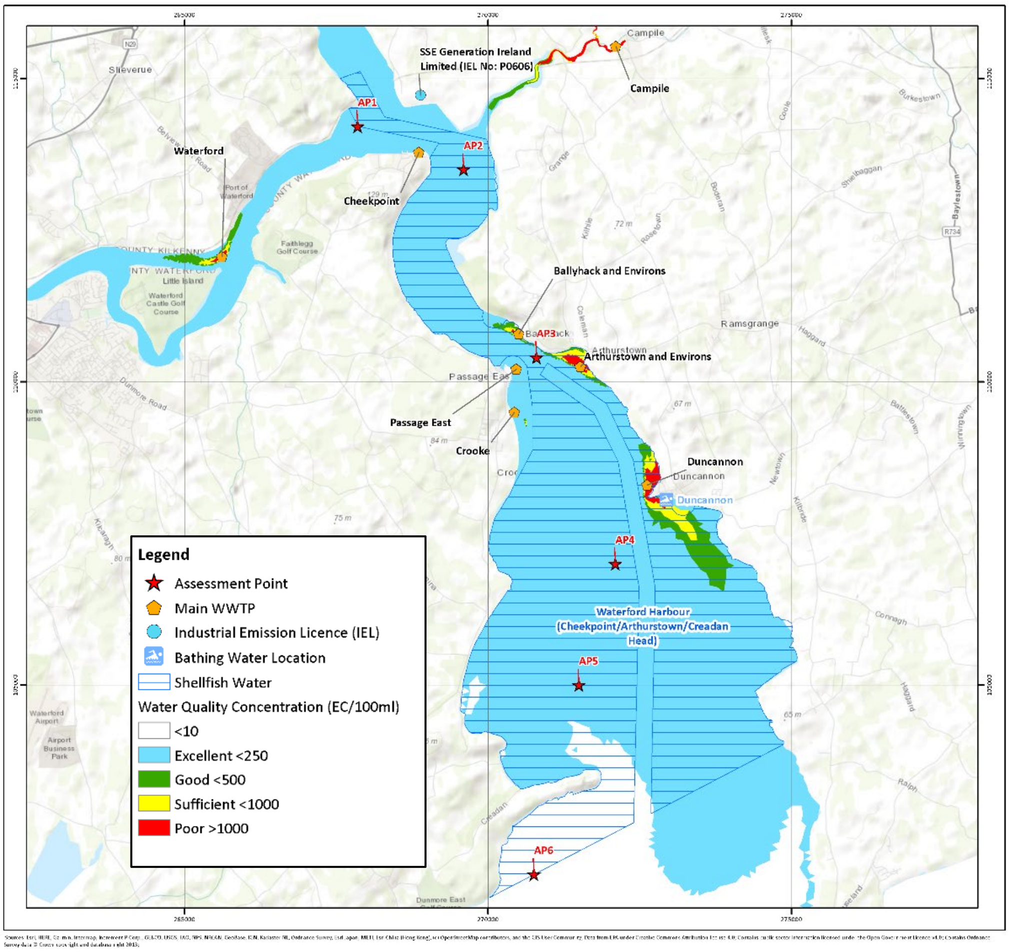
This means that areas shown in yellow or red exceed the assessment criteria of 500 EC/100 ml as a 95%ile, as described in IW's Technical Standards.

These plots show total impacts from all sources. It can be seen that impacts are generally greater in the bottom layer (except close to Crooke), and for the majority of the Shellfish Water the 95%ile concentration is <500 EC/100ml, and in fact for most of the Shellfish Water impacts are <250 EC/100ml.

However, there are some localised areas of high impact (>500 EC/100ml) within the Shellfish Water, which are observed around the Duncannon WwTP, the Arthurstown and Environs WwTP, and Ballyhack and Environs WwTP. Other areas of high impact within the estuary are observed close to the Waterford City and Campile WwTPs, but these are outside of the Shellfish Water. There is also an area of high impact in the River Suir (around Carrick-on-Suir, Piltown and Fiddown WwTPs), which is a long way upstream.

The largest impacts are centred around Arthurstown and Duncannon WwTPs, with peak concentrations exceeding 1,000 EC/100 ml (red contour), observed in the immediate vicinity of the discharge locations, as would be expected. However, concentrations reduce rapidly with distance, as the plume is advected and dispersed, as can be seen on the contour plots.

Figure 4-1 Contour plot of Waterford Harbour area showing 95%ile EC concentration in the bottom layer



In addition to the 95%ile concentration contour plots, Figure A-5 (Appendix A) provides timeseries of total impact for the surface and bottom layer at six assessment points (1 to 6) which were selected after discussion with IW. Assessment points 1 and 6 are on the northern and southern boundaries of the Shellfish Water, and the other four points are distributed throughout the Shellfish Water. The assessment point locations are presented in Figures A-1 to A-4 (Appendix A).

Furthermore, the proportional contribution to impacts from each individual source (source apportionment) has been calculated for the surface layer at each of the six assessment points (1 to 6). These are presented as pie charts in Figures A-6 to A-11, and summarised in Table 4.1.

The source apportionment analysis shows that Waterford City and Duncannon WwTPs dominate the contribution to EC concentrations at each of the six assessement points. However, the total impacts at these locations are very low (<100 EC/100ml in all cases) and therefore below the assessment threshold of 500 EC/100ml. The pie-charts therefore must be reviewed while taking into account the total impacts at these sites, and to facilitate this, the 95%ile concentration for both the surface and bottom layer is included with each pie-chart.

It should be noted that although Waterford City and Duncannon WwTPs are the largest contributors at all six assessment points, these are large contributions to very low impacts that are well below the assessment criteria.

The modelled impacts have been compared with the Bathing Water classifications at the three local Bathing Waters in Waterford Harbour (Duncannon and the two bathing waters at Dunmore East - Dunmore Strand and Counsellors Strand) and these classifications ('Good', 'Excellent' and 'Excellent', respectively) are in agreement with the modelled 95%ile concentrations.

Table 4-1. Total impacts and proportional contributions at the six assessment points

Assessment Points	AP1	AP2	AP3	AP4	AP5	AP6
95%ile concentration (EC/100ml)	90 (Surface)	48 (Surface)	50 (Surface)	42 (Surface)	27 (Surface)	17 (Surface)
	84 (Bottom)	45 (Bottom)	59 (Bottom)	23 (Bottom)	12 (Bottom)	1 (Bottom)
Pass / Fail criteria (500 EC/10 ml)	Pass	Pass	Pass	Pass	Pass	Pass
Source						
Waterford City	74.8 %	61.9 %	47.9 %	32.1 %	29.4 %	21.0 %
Duncannon	8.7 %	11.5 %	26.4 %	39.9 %	38.5 %	42.3 %
Ballyhack and Environs	5.4 % %	6.5 %	9.0 %	11.3 %	11.3 %	11.8 %
Arthurstown and Environs	5.1 %	5.7 %	12.4 %	13.0 %	13.6 %	15.3 %
New Ross	2.6 %	6.8 %	1.5 %	N.A	N.A	N.A
Campile	1.3 %	1.7 %	N.A	N.A	N.A	N.A
Passage East	N.A	N.A	N.A	1.0 %	1.9 %	1.1 %
Crooke	N.A	N.A	N.A	N.A	1.0 %	N.A
Dunmore East	N.A	N.A	N.A	N.A	2.4 %	N.A
River Nore	N.A	3.4 %	N.A	N.A	N.A	N.A
River Barrow	N.A	1.4 %	N.A	N.A	N.A	N.A
All Others	2.2 %	1.0 %	2.9 %	N.A	2.0 %	2.2 %
Total	**100** %	**100** %	**100** %	**100** %	**100** %	**100** %

5. Conclusion

The key conclusions taken from the Baseline scenario are as follows:

- The modelled 95%ile concentration across the majority of the Designated Shellfish Water is less than the 500 EC/100 ml threshold at both the surface and bottom layer.
- There are three localised areas within the Shellfish Water where the modelled 95%ile concentration exceeds the 500 EC/100 ml threshold. These are centred around the three main WwTPs that discharge directly into the shellfish water, namely: Arthurstown, Duncannon and Ballyhack. The area of impact that exceeds the 500 EC/100 ml within the Shellfish Water due to the Ballyhack discharge is very limited spatially.
- Impacts are generally higher in the bottom layer than in the surface layer in the areas of highest impact.
- The discharges from Waterford City WwTP, Campile and Dunmore East WwTP do not lead to a 95%ile concentration within the Shellfish Water that exceeds the 500 EC/100 ml assessment threshold (or even the 250 EC/100 ml threshold representative of the Excellent BW standard).
- The modelled impacts from Crooke and Passage East, which discharge close to, but not directly into, the Shellfish Water do not exceed the 500 EC/100 ml assessment threshold (or even the 250 EC/100 ml threshold representative of the Excellent BW standard).
- Local Bathing Water classifications in Waterford Harbour (Duncannon and the two bathing waters at Dunmore East - Dunmore Strand and Counsellors Strand) are in agreement with the modelled 95%ile concentrations ('Good', 'Excellent' and 'Excellent', respectively).
- Improvements in the levels of treatment at the three WwTPs that discharge directly into the Shellfish Water would reduce impacts.
- At Arthurstown and Duncannon, which currently discharge untreated sewage, and also at Ballyhack, which currently discharges primary treated effluent, improvement to secondary treatment is likely to be sufficient to reduce the resulting 95%ile concentration to below the 500 EC/100 ml threshold.

- Impacts at all of the six assessment points are always below 500 EC/100ml and in fact impacts only exceed the Excellent BW standard (250 EC/100ml) at one location (AP4) intermittently.

6. References

Nafarnda, W. D., Ajayi, I. E., Shawulu, J. C., Kawe, M. S., Omeiza, G. K., Sani, N. A., ... & Dantong, D. D. (2012). Bacteriological quality of abattoir effluents discharged into water bodies in Abuja, Nigeria. *ISRN veterinary science*.

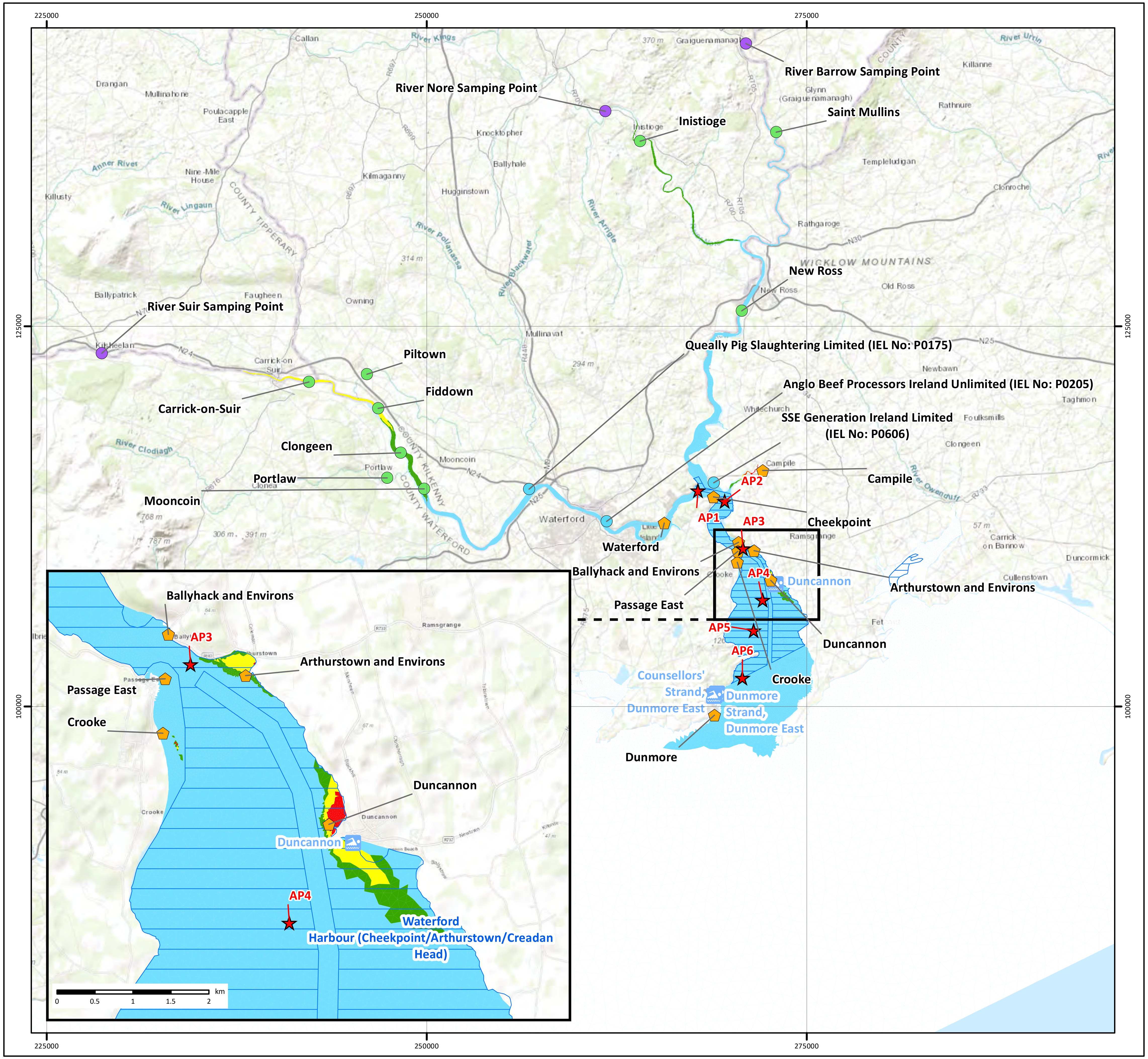
Shellfish Pollution Reduction Programme. Characterisation Report Number 35. Waterford Harbour Shellfish Area County Waterford.

TSMM (2019): Technical Standards – Marine Modelling Document No: IW-TEC-100-015, Revision: 1.83, printed date: 17/06/2019.

MSR (2019): WwTP Disinfection Programme, Stage 4 – Detailed Assessment of Discharges. Model Scoping Report – Waterford Harbour. Date: 16/10/2019. Ref: 20745.

Appendix A.

Summary result plots



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL RESULTS
Baseline Scenario: Surface Layer

Drawing No: P2323-MOD-015 | **A**

Legend

- Assessment Point
- Main WWTP
- Smaller WWTP
- Industrial Emission Licenced (IEL) Discharge
- River
- Bathing Water Location
- Shellfish Water

Water Quality Concentration (EC/100ml)

- <10
- Excellent <250
- Good <500
- Sufficient <1000
- Poor >1000

Date	29 June 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-015.mxd
Created By	Chris Dawe
Reviewed By	Emma Storey
Approved By	Matthias Thomsen

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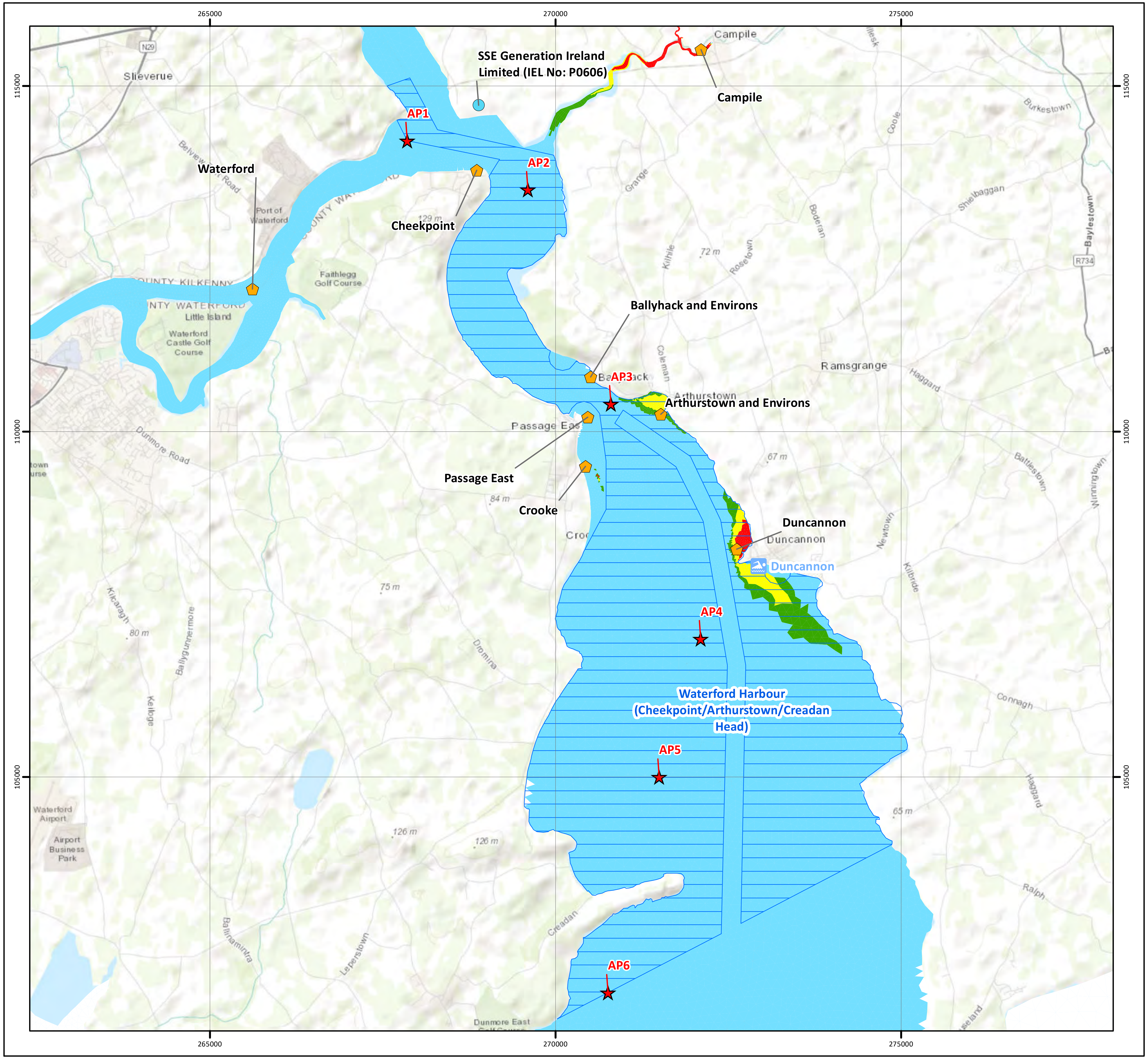
intertek

km 0 2.5 5 7.5 10

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;

COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL RESULTS
Baseline Scenario: Surface Layer
Waterford Harbour Area

Drawing No: P2323-MOD-015-1	A

Legend

- Assessment Point
- Main WWTP
- Industrial Emission Licence (IEL)
- Bathing Water Location
- Shellfish Water

Water Quality Concentration (EC/100ml)

- <10
- Excellent <250
- Good <500
- Sufficient <1000
- Poor >1000

NOTE: Not to be used for Navigation

Date	30 June 2020
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Projection	Transverse Mercator
Datum	TM65
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Created By	Chris Dawe
Reviewed By	Emma Storey
Approved By	Matthias Thomsen

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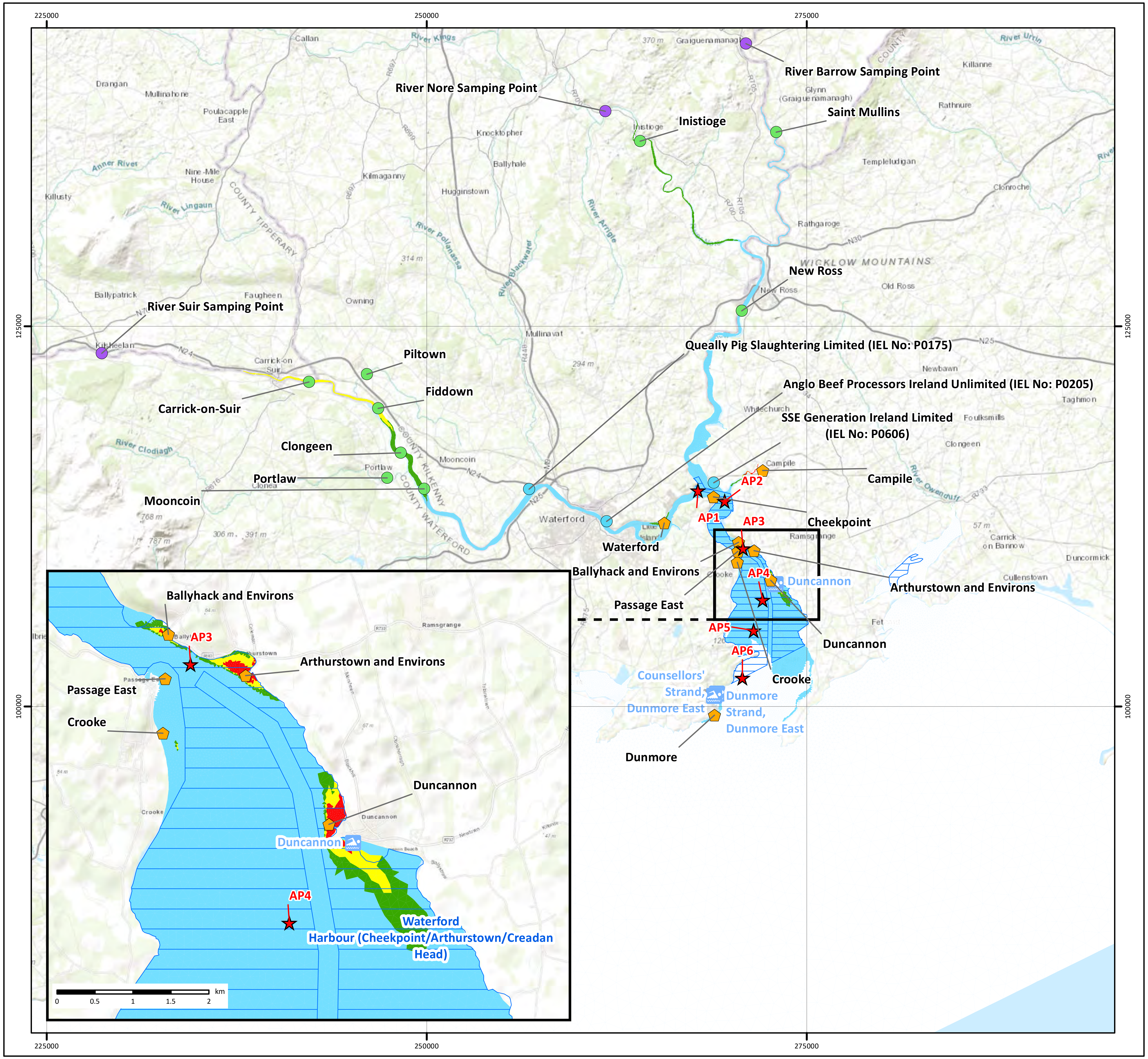


COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL RESULTS
Baseline Scenario: Bottom Layer

Drawing No: P2323-MOD-016 | **A**

Legend

- Assessment Point
- Main WWTP
- Smaller WWTP
- Industrial Emission Licenced (IEL) Discharge
- River
- Bathing Water Location
- Shellfish Water

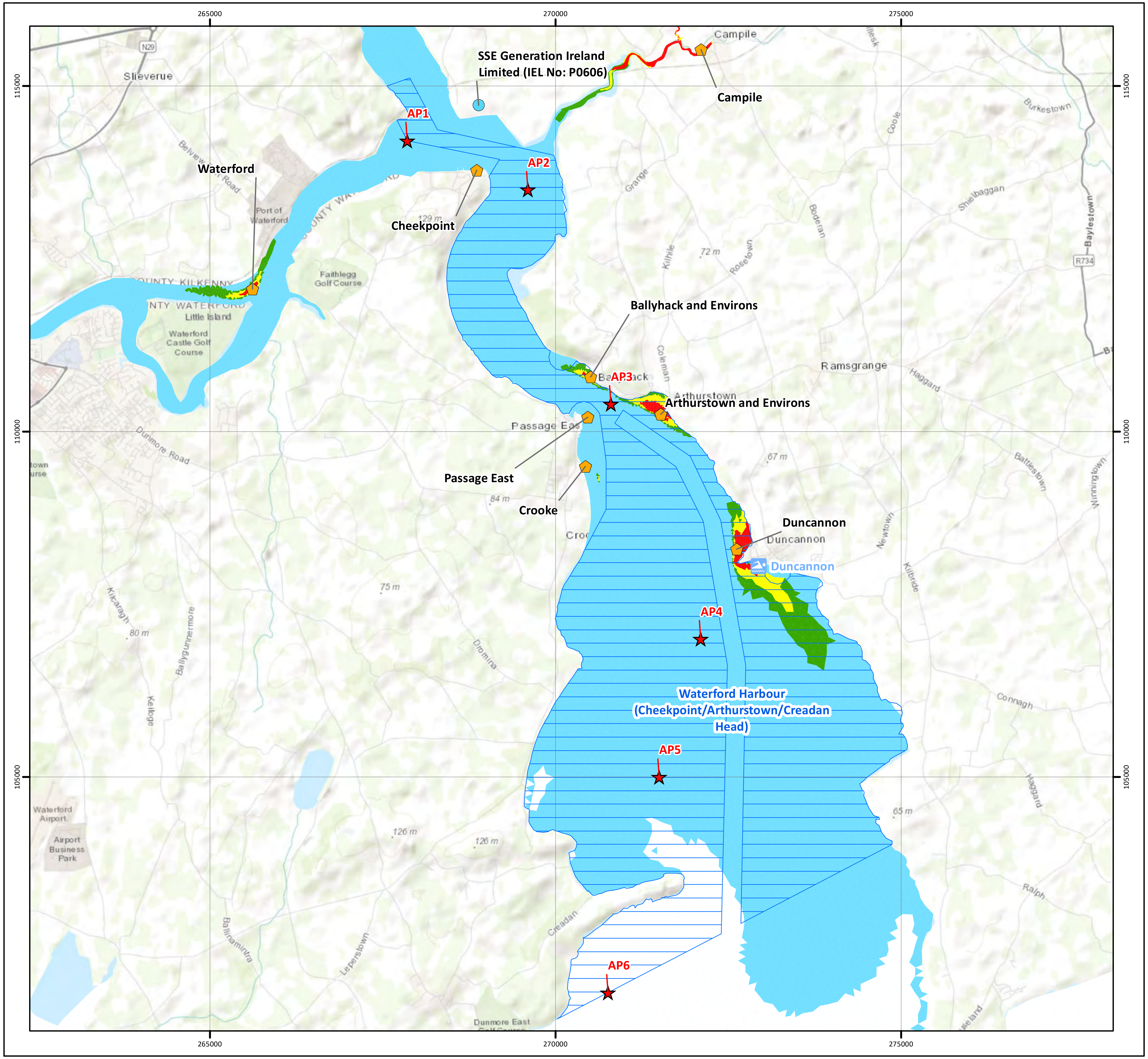
Water Quality Concentration (EC/100ml)

- <10
- Excellent <250
- Good <500
- Sufficient <1000
- Poor >1000

Date	29 June 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	DHPCLG; EPA; ESRI
File Reference	J:\P2323\Mxd\02_MOD\P2323-MOD-016.mxd
Created By	Chris Dawe
Reviewed By	Emma Storey
Approved By	Matthias Thomsen

0 2.5 5 7.5 10 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL RESULTS
Baseline Scenario: Bottom Layer
Waterford Harbour Area

Drawing No: P2323-MOD-016-1	A

Legend

- Assessment Point
- Main WWTP
- Industrial Emission Licence (IEL)
- Bathing Water Location
- Shellfish Water

Water Quality Concentration (EC/100ml)

- <10
- Excellent <250
- Good <500
- Sufficient <1000
- Poor >1000

NOTE: Not to be used for Navigation

Date	29 June 2020
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Projection	Transverse Mercator
Datum	TM65
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Reviewed By	Emma Storey
Approved By	Matthias Thomsen

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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; Data from EPA under Creative Commons Attribution license 4.0; Contains public sector information licensed under the Open Government Licence v4.0; Contains Ordnance Survey data © Crown copyright and database right 2013;

Figure A-5 Time series EC for the Baseline scenario for six assessment points

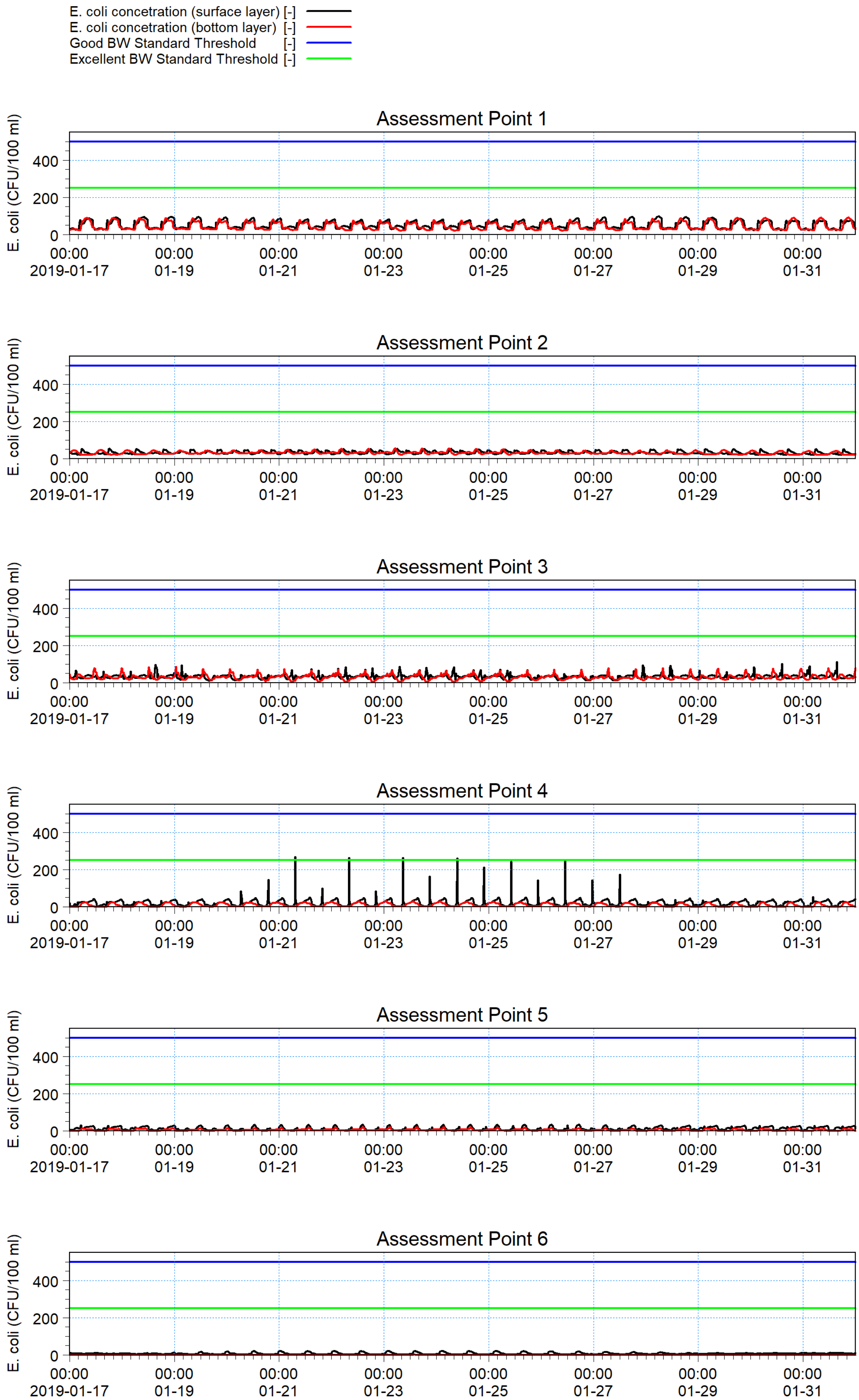


Figure A-6 Source apportionment: Assessment Point 1

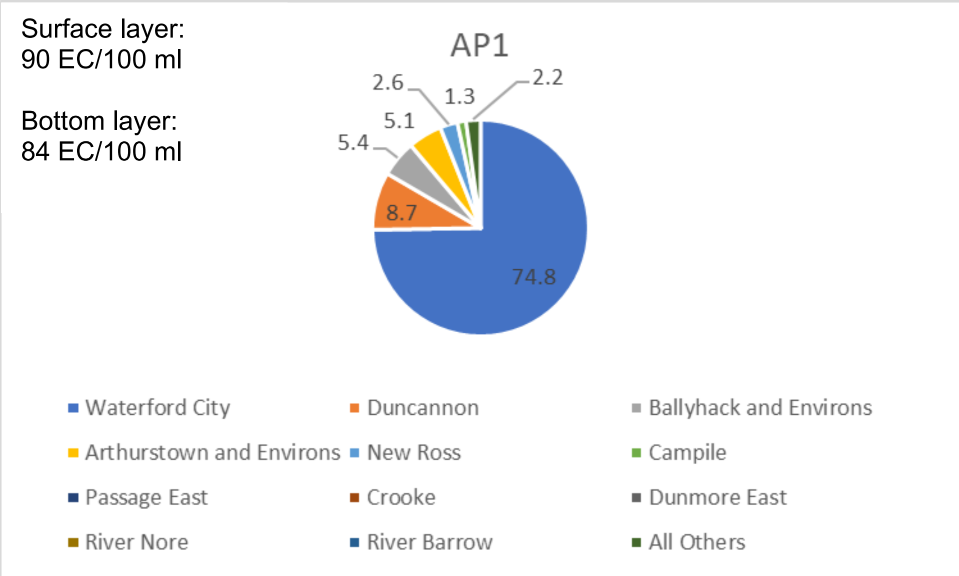


Figure A-7 Source apportionment: Assessment Point 2

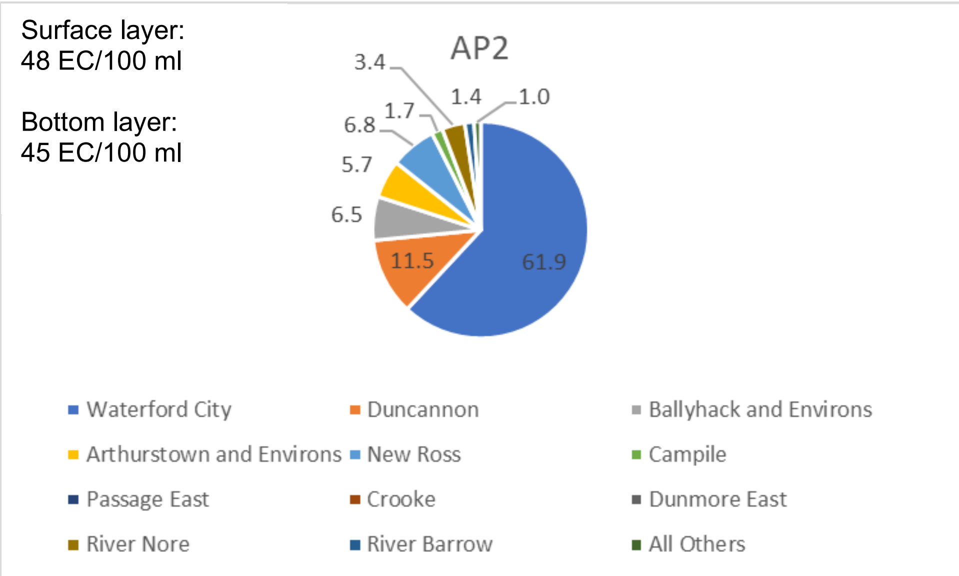


Figure A-8 Source apportionment: Assessment Point 3

Surface layer:
50 EC/100 ml

Bottom layer:
59 EC/100 ml

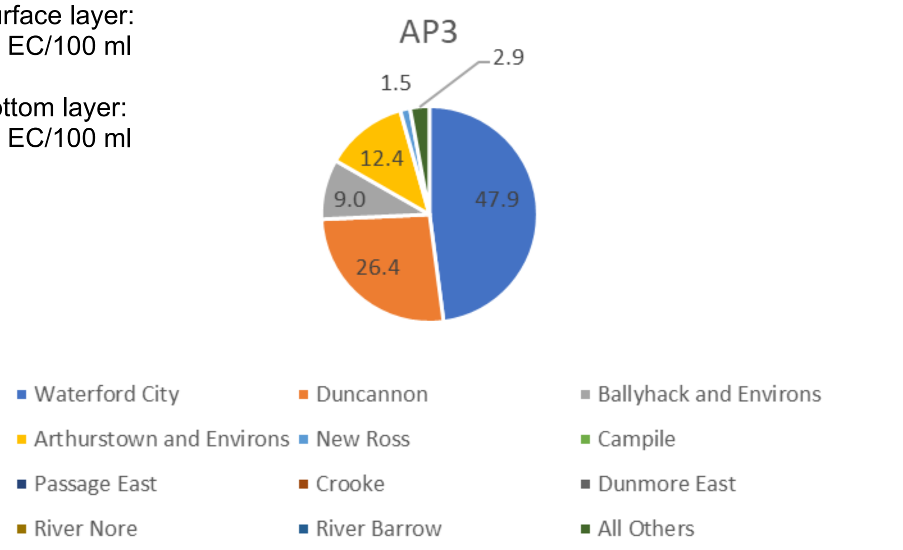


Figure A-9 Source apportionment: Assessment Point 4

Surface layer:
42 EC/100 ml

Bottom layer:
23 EC/100 ml

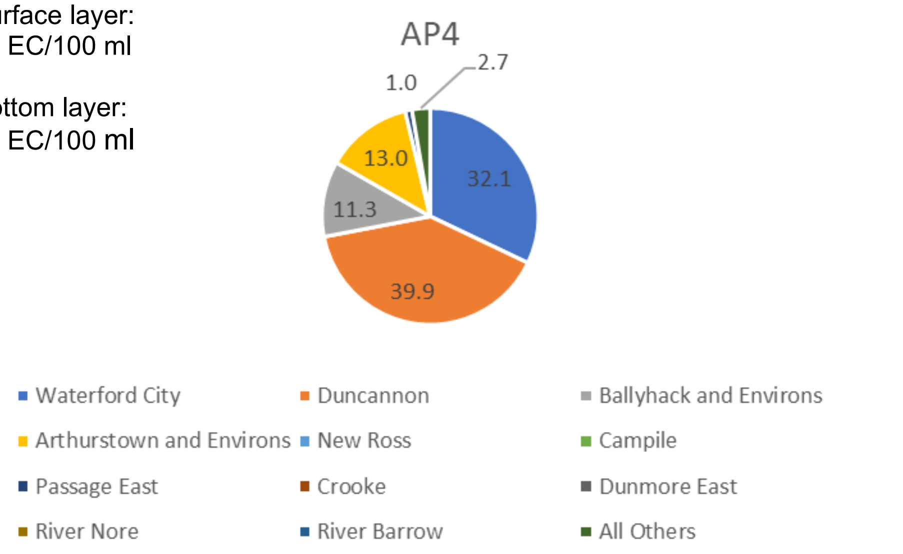


Figure A-10 Source apportionment: Assessment Point 5

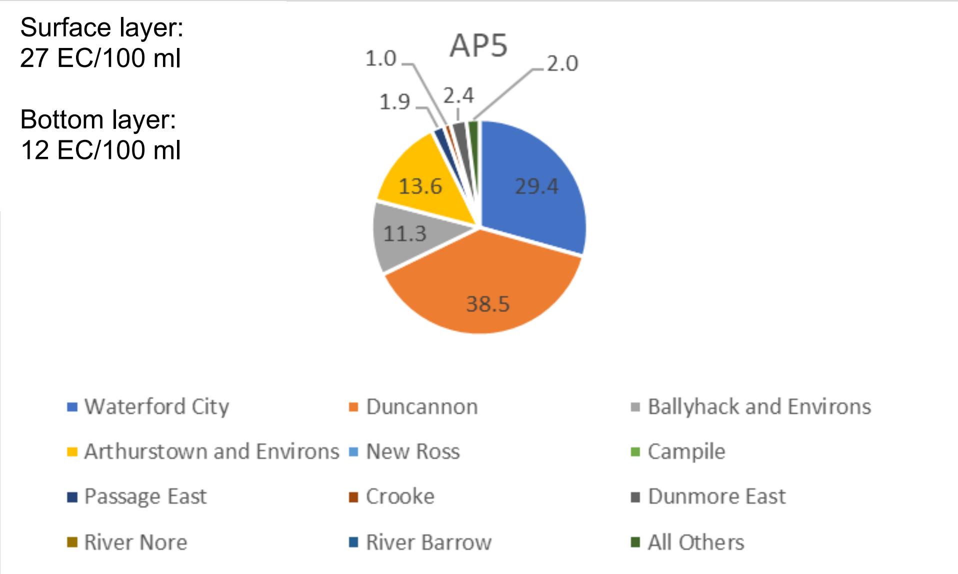
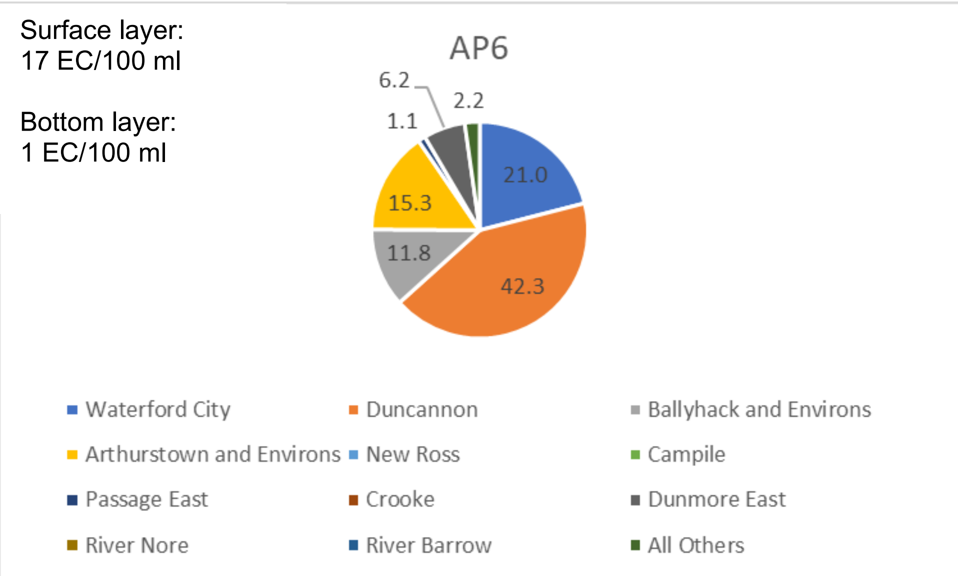


Figure A-11 Source apportionment: Assessment Point 6



Appendix B.

Data and model calibration

Bathymetry

Four data sources were used for the model bathymetry, as follows:

- Duncannon survey data
- INFOMAR
- EMODnet
- Catchment-based Flood Risk Assessment and Management (CFRAM) Programme

These are shown in Figure B-1 and discussed below.

As detailed in the Model Scoping Report (MSR, 2019), the Duncannon survey was identified to infill the gap in the available data, and it was agreed that this survey data together with data from INFOMAR and EMODnet would be sufficient for the model development. However, during the model development phase, river channel cross-sections from the CFRAM Programme were also identified and provided for use in the model.

Duncannon survey data

The Duncannon survey data was a dedicated survey commissioned by NOD on behalf of IW in support of the Waterford Shellfish Water study to infill a gap in available bathymetry data that was identified in the MSR (2019), in the areas either side of the main channel around Duncannon. The survey obtained high resolution multibeam sonar data and was undertaken by Techworks Marine between the 2nd and the 8th of July 2019. The survey was undertaken in accordance with the UKHO 1A standard. The data quality was considered to be of good quality, with no data gaps or anomalies and suitable for the purpose of model development.

INFOMAR

The geographical extent of the INFOMAR data covers the entire south coast of Ireland at a spatial resolution of 10m. The data was collected from a number of surveys, as part of the ongoing INFOMAR project (formerly Irish National Seabed Survey), a joint seabed mapping project between the geological survey of Ireland and the Marine Institute. The INFOMAR dataset also includes non- INFOMAR data; Nephropsproject (2006 & 2013), Scallop surveys and Habmap 2005 projects. The dataset in its entirety has been collected from 2000 to 2016.

EMODnet

A harmonised EMODnet Digital Terrain Model (DTM) has been generated for the European sea regions from selected bathymetric survey data sets, composite DTMs, Satellite Derive Bathymetry (SDB) data products, while gaps with no data coverage are completed by integrating the GEBCO Digital Bathymetry.

The DTM with its information layers is made freely available for downloading from the EMODnet website (https://www.emodnet-bathymetry.eu/data-products). Survey data sets have been collated from an increasing number of data providers and activities have been undertaken for correcting identified anomalies, where possible.

The September 2018 version of the EMODnet DTM, which is the version that was used for the Waterford model, has an increased grid resolution of 1/16 x 1/16 arc minutes (circa 115 x 115 m).

CFRAM

River channel cross-section survey data, collected to support the CFRAM Programme, was obtained through IW from the Office of Public Works (OPW). The surveys included the three main rivers draining into Waterford Harbour, River Barrow, River Nore, and River Suir) and were undertaken for OPW during the period from 2012 to 2015. The surveyed river cross sections were used to inform the hydraulics report (The South-Eastern CFRAM Project, Suir CFRAM Study and North-Western CFRAM) and hydraulic models covering the Units of Management (UOM) for:

- Barrow (UoM14)
- Nore (UoM15)
- Suir (UoM16)

The purpose of the CFRAM Programme was to assess existing fluvial and coastal flood risk, and the potential increase in risk due to climate change, ongoing development and other pressures that may arise in the future, and to develop a Plan setting out a sustainable, long-term strategy to manage this risk. The OPW in conjunction with the CFRAM Study Consultants (RPS for the Barrow River Basin), are undertaking the National CFRAM Programme.

Water level and velocity

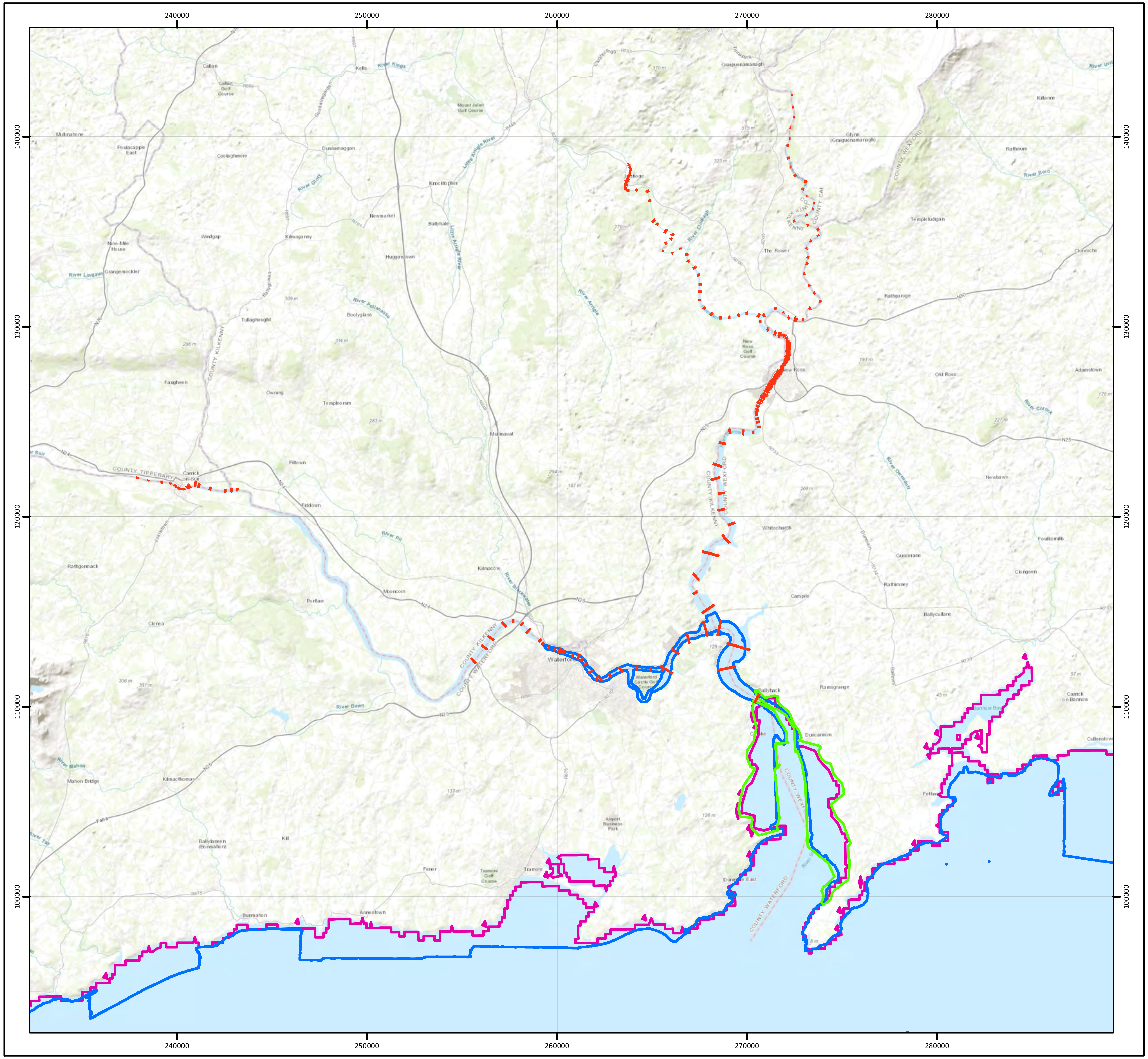
Water level data from Dunmore East Tidal Gauge was used for model calibration/validation.

Current velocities were collected from four ADCPs deployed at separate locations (see Figure B-2) within Waterford Harbour. ADCP1 and ADCP2 were deployed in the narrow northern section of Waterford Harbour. ADCP3 was deployed near the southern boundary of the shellfish water, and ADCP4 slightly further south near Dunmore East.

Current speed and direction were calculated from the measured current velocity components.

Salinity and Temperature

As part of the dedicated surveys commissioned by NOD on behalf of IW for the purpose of the Waterford modelling assessment, salinity and temperature data were collected from nine Conductivity-Temperature-Depth (CTD) sampling sites (see Figure B-5) within Waterford Harbour over two separate 13-hour periods covering a full semi-diurnal tidal cycle, the first on 8th August 2019 (Neap tide) and the second on 13th August (Spring tide).



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

BATHYMETRY
Data Sources - Waterford Harbour

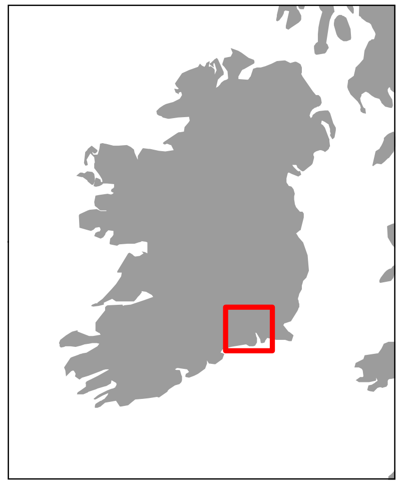
Drawing No: P2323-MOD-002	B

Legend

River Cross Sections

Bathymetry Extents

- Duncannon Bathymetry Survey Data
- INFOMAR 10m Bathymetry
- EMODnet 150m Bathymetry



NOTE: Not to be used for Navigation

Date	21 May 2020
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Datum	TM65
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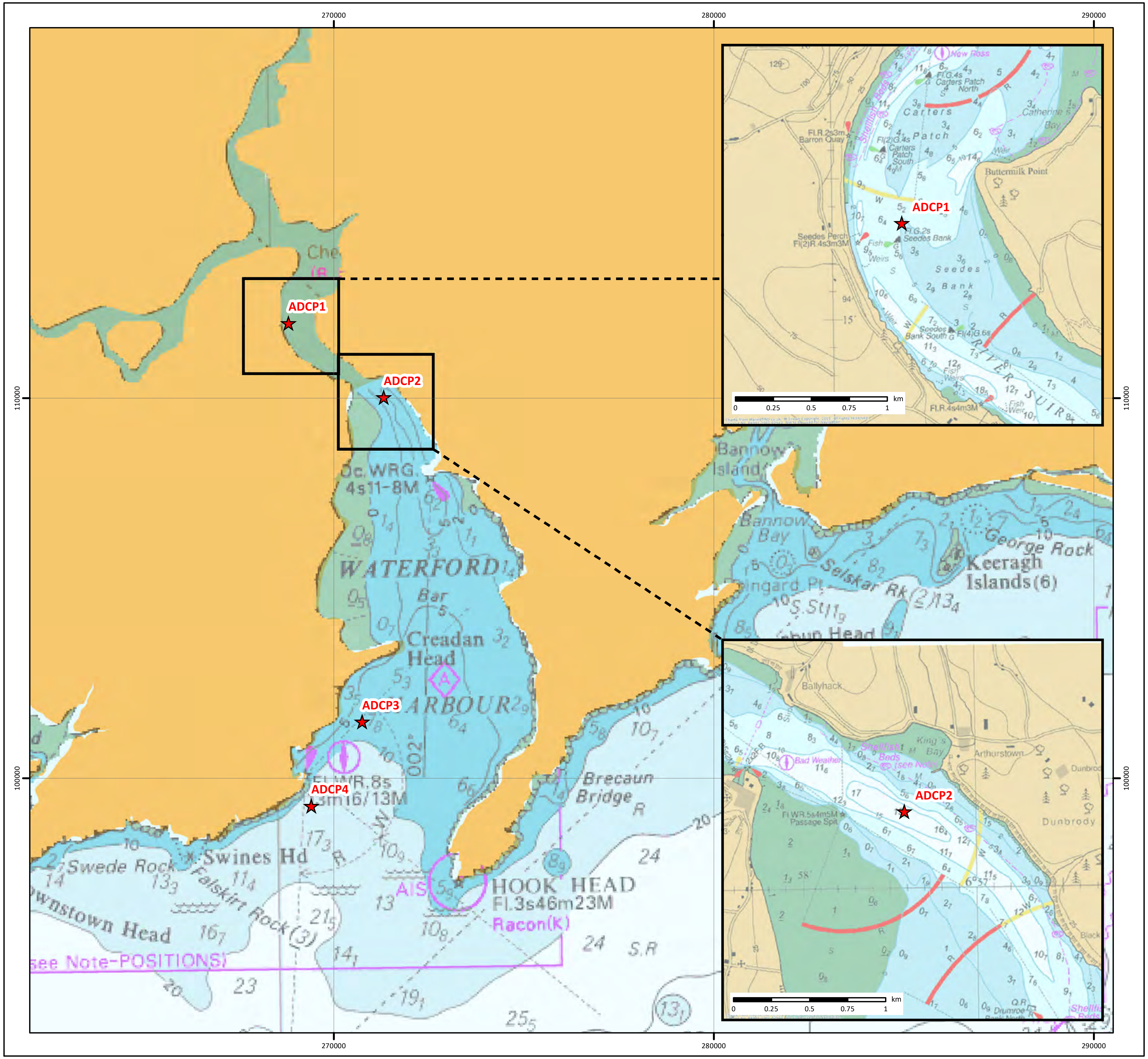
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-002.mxd
Created By	Chris Dawe
Reviewed By	Emma Langley
Approved By	Matthias Thomsen

0 2.5 5 7.5 10 km

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community; The bathymetric metadata and Digital Terrain Model data products have been derived from the EMODnet Bathymetry portal - http://www.emodnet-bathymetry.eu.; Contains Irish Public Sector Data (Geological Survey) licensed under a Creative Commons Attribution 4.0 International (CC BY 4.0) licence; ©Esri



Charts from MarineFIND.co.uk © British Crown and OceanWise, 2019. All rights reserved. License No. EK001-FN1001-02492 Not to be used for Navigation; Contains data published by Ordnance Survey Ireland licensed under Creative Commons Attribution 4.0; ©Esri

COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL LOCATIONS
ADCP Locations

Drawing No: P2323-MOD-003 | **B**

Legend

★ ADCP Location

N W E S

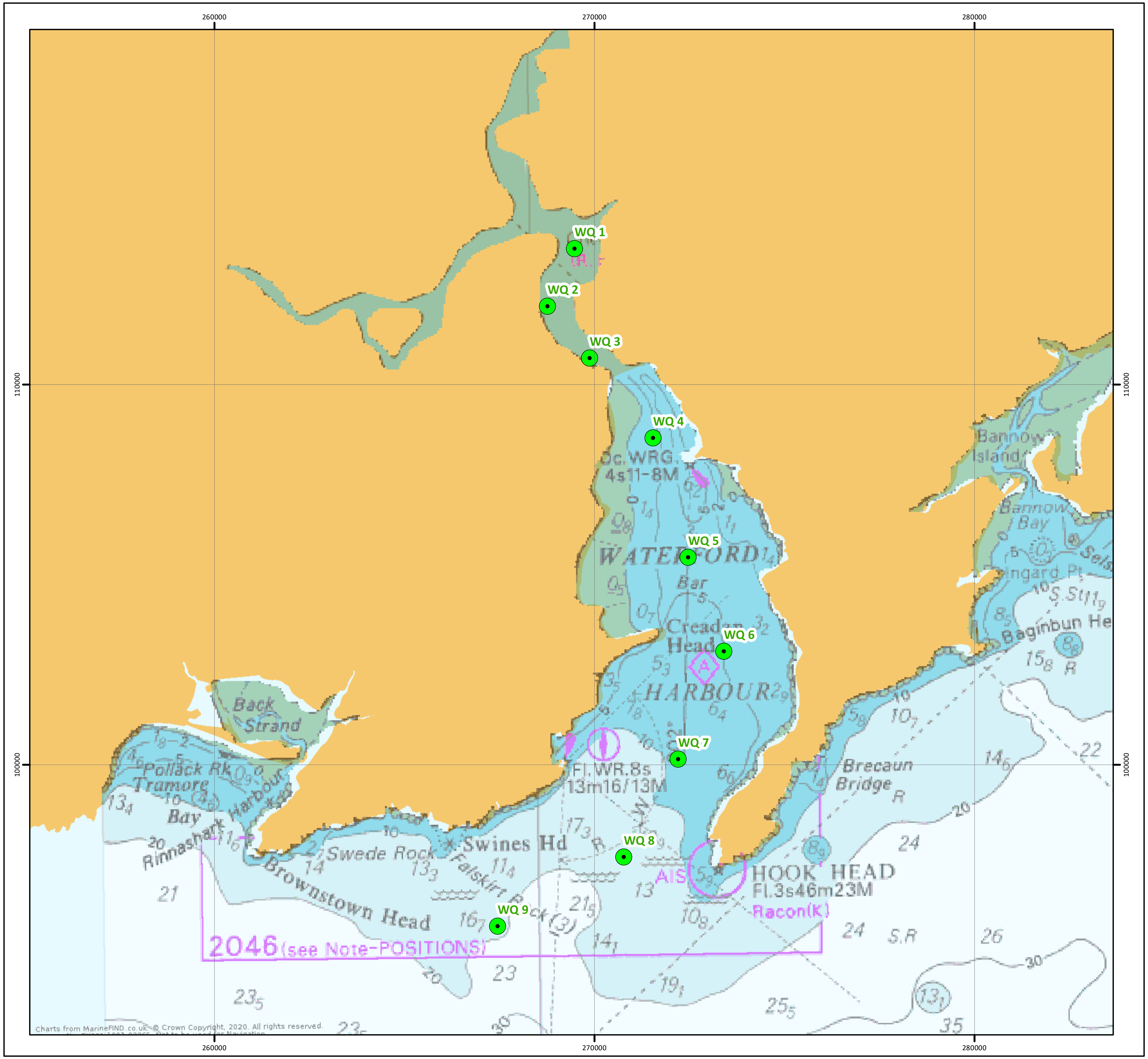
NOTE: Not to be used for Navigation

Date	28 April 2020
Coordinate System	TM65 Irish Grid
Projection	Transverse Mercator
Datum	TM65
Data Source	MarineFind; OSI; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-003.mxd
Created By	Chris Dawe
Reviewed By	Emma Langley
Approved By	Matthias Thomsen

UISCE ÉIREANN : IRISH WATER

intertek

0 1.5 3 4.5 6 km



COASTAL MODELLING FOR WATERFORD SHELLFISH WATERS

MODEL LOCATIONS
Water Quality Sampling Locations
Waterford Harbour

Drawing No: P2323-MOD-004 | **C**

Legend

Water Quality Sampling Location

NOTE: Not to be used for Navigation

Date	03 July 2020
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Projection	Transverse Mercator
Datum	TM65
Data Source	MarineFind; OSI; ESRI
File Reference	J:\P2323\Mxd\02_MOD\ P2323-MOD-004.mxd
Created By	Chris Dawe
Reviewed By	Emma Langley
Approved By	Matthias Thomsen

0 1.5 3 4.5 6 km

Bacterial sampling

Sampling Data – ADCP

Water quality sampling of EC concentrations was conducted at each of the four ADCP locations (Figure B-2) subsequent to deployment on the 23/07/2019.

Sampling Data – Seawater

Seawater sampling for EC concentration was carried out for spring tides (13/08/2019 and 14/08/2019) and for neap tides (07/08/2019 and 08/08/2019). Sampling was carried out at sites WQ1-WQ9 (with four replicate samples collected near the surface at approximately 3-hour intervals; Figure B-3).

Sampling Data – Outfall locations

EC and faecal coliform samples were collected typically three times per day (morning, afternoon and evening) on eight separate days in August and September from each of the nine outfall locations. Unfortunately, some samples were incorrectly analysed in the laboratory, as a result some concentrations were capped at 10^6 EC/100ml (meaning that the actual concentration was at least 10^6 EC/100ml). The datasets for each WwTPs were very small (<15 samples per WwTP), and the data showed a very large range, with a number of unexpectedly low values. It was therefore agreed with IW that these data were not sufficiently robust to be used in the assessment.

Sampling Data – Rivers

The sampling data for the rivers is very limited (three samples taken on each river on the same day – 13th August - and within a short space of time). Such a small dataset does not provide a robust dataset from which to determine statistics (such as the arithmetic mean) with confidence.

Flow sources

Three main rivers; the River Suir, River Barrow and River Nore drain into Waterford Harbour as well as various smaller waterways.

Flow time-series data from the Office of Public Works (OPW) were used for the River Suir, the River Nore and the River Barrow.

3D Hydrodynamic model

A three-dimensional (3D) Hydrodynamic (HD) model was developed and applied in the modelling assessment. A 3D modelling approach was discussed and agreed with IW. Although initially it was assumed a 2D model could be utilised, following review of the survey data and on initial testing of a 2D and 3D model, it was concluded that a 3D model would improve the representation of the stratified hydrographic conditions and mixing processes of the freshwater inputs within Waterford Harbour through multiple layers.

The 3D model presented in the study has been calibrated against water levels, depth-averaged current velocities, salinity, temperature and EC.

The 3D model shows good performance across each of the model parameters and captures the environmental processes well although it is not perfect at all states of the tide. The model is considered to be fit for the intended use of undertaking the water quality assessment at Waterford Shellfish Water.

The data used in the calibration and validation of the HD model is outlined below:

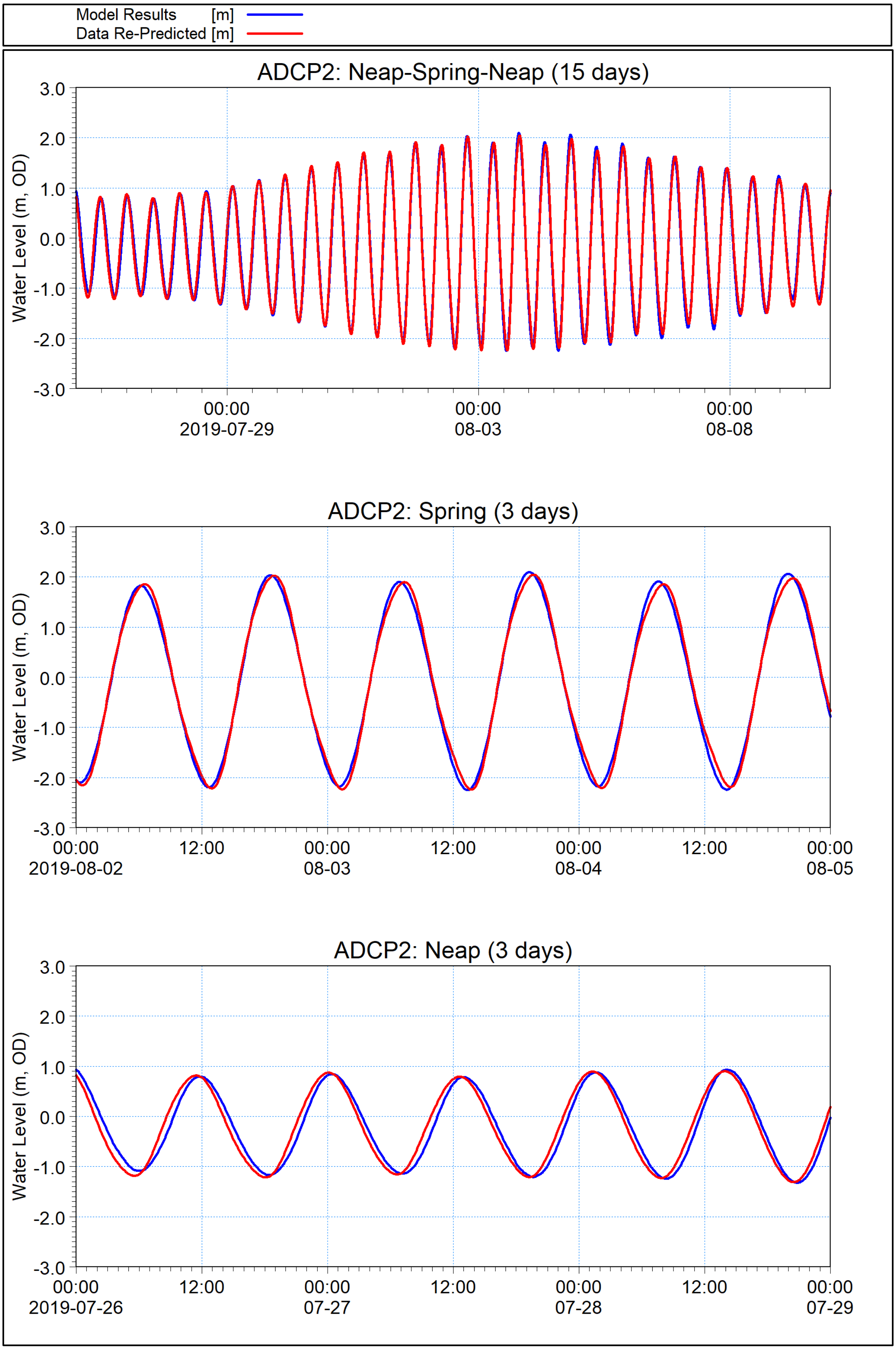
- Water Level (Tide Gauge and ADCPs)
- Current velocities and direction (ADCPs)
- Salinity (CTD profiles)
- Temperature (CTD profiles)
- Bacterial concentrations (sampling data)

Water level

The hydrodynamic 3D model has been calibrated against water level data, by undertaking sensitivity testing of the model bed roughness. The water level data used for model calibration was collected from the tide gauge at Dunmore East as well as from each of the four ADCP locations. Figure B-4 presents the model comparisons for water levels against the calibration from ADCP2 for a typical Neap-Spring tidal cycle (top plot), Spring tide only (middle plot) and the Neap tide only (bottom plot).

ADCP2 has been selected as it is within the Shellfish Water.

Figure B-4 Calibration against re-predicted water levels: ADCP2



Current speed and direction

Model calibration and validation of current speed and direction was undertaken against the observed data at the four ADCP sites, over three days under spring and neap tide, respectively. The observed data, instead of the re-predicted data, were selected for the calibration of current speed and direction as the density driven current, caused by the salinity gradient, can be significant in an estuary and may be removed from the harmonically re-predicted current. The fitness of the model was evaluated as a combination of depth-averaged velocity and velocity vertical profiles, over a period of three days under spring tide.

An example of the comparison plots of the model predicted depth-averaged velocity (east [U component] and north [V components]), current speed and direction with the observed data at ADCP2 are given in Figure B-5.

The 3D model performance in the vertical dimension is demonstrated by velocity vertical profiles at key tidal states, i.e. HW, mid-flood, LW, and mid-ebb. As an example, Figure B-6 shows the comparison of velocity vertical profiles against the observed profiles collected under spring tide at site ADCP2.

ADCP2 has been selected as it is within the Shellfish Water.

Figure B-5 Calibration against observed current speed and direction: ADCP2

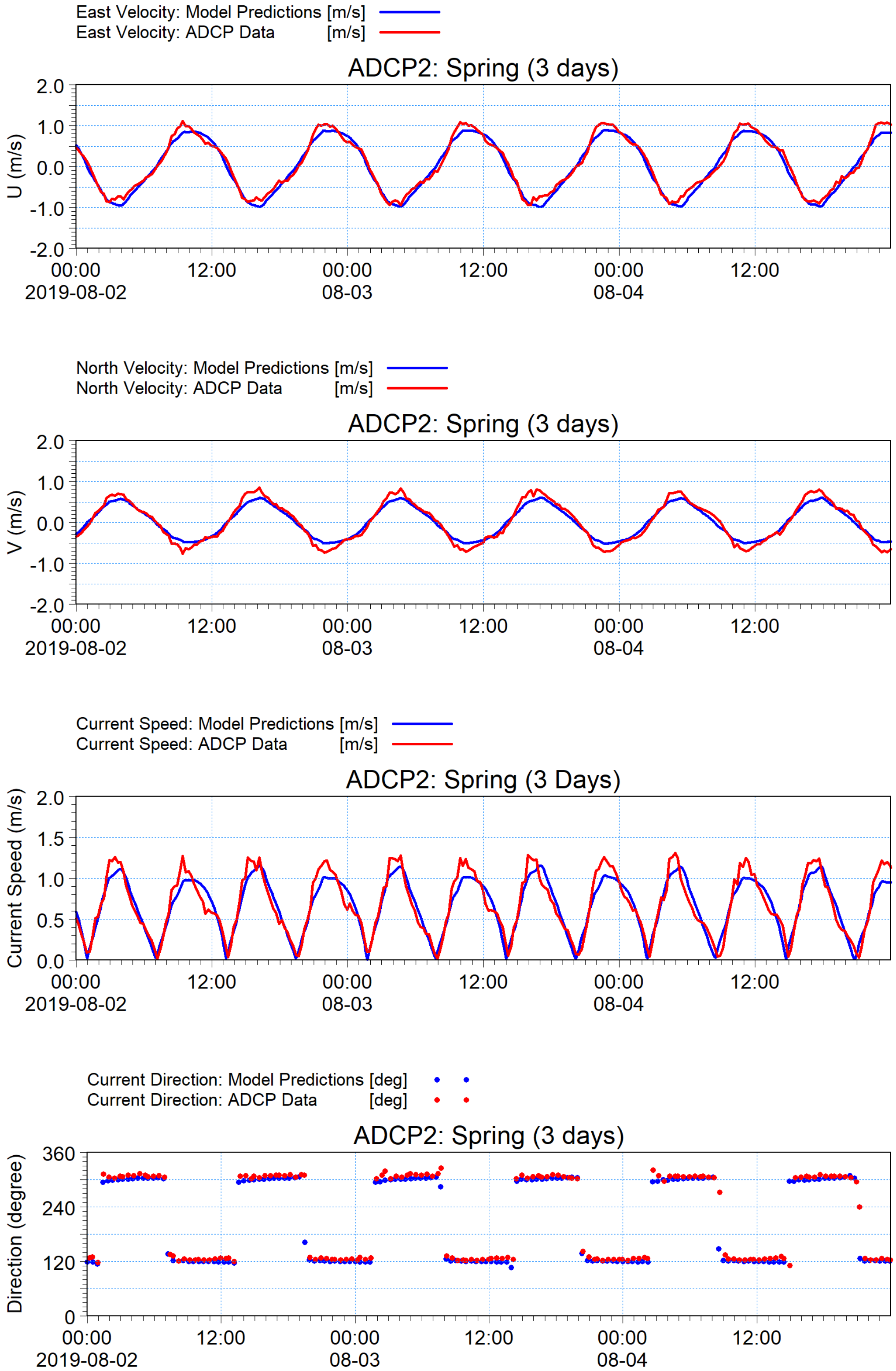
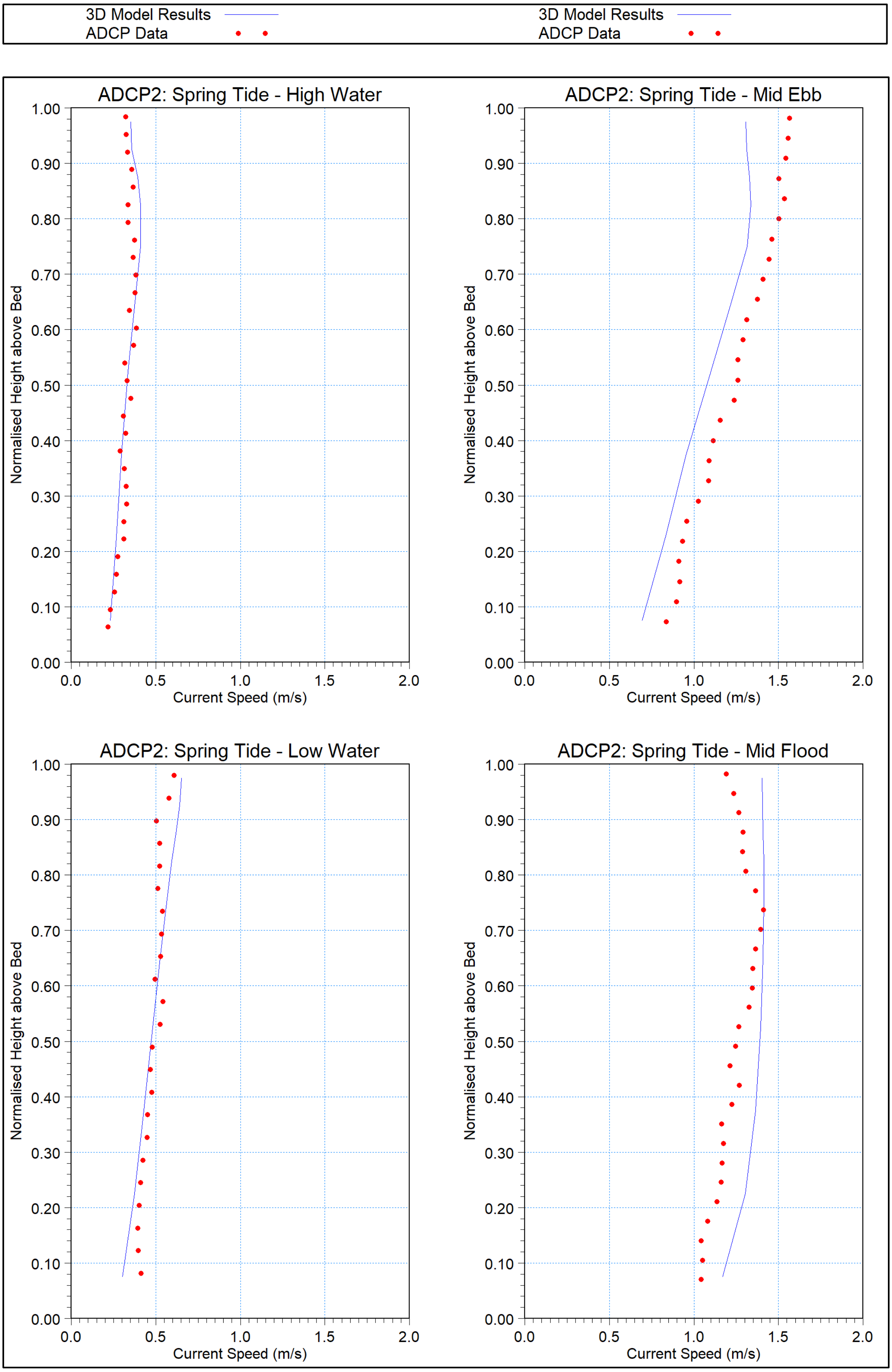


Figure B-6 Calibration against observed velocity vertical profiles: ADCP2



Salinity

Model calibration of salinity was undertaken against the observed data at the nine WQ sites, against four CTD casts under spring tide, whilst model validation of salinity was undertaken against the observed data at each of the nine WQ sites, against four CTD casts under neap tide.

Model calibration and validation was undertaken by comparing depth averaged salinity against observed data over two three-day periods over a spring tide (calibration) and neap tide (validation) at the nine WQ sites.

The 3D model performance was also assessed in the vertical dimension by comparing salinity vertical profiles against CTD profiles. As an example, Figure B-7 and Figure B-8 show the comparisons of salinity vertical profiles against the observed profiles collected under spring and neap tide, respectively at site WQ4, a site located within the shellfish water.

Overall comparisons of both depth-averaged salinity and salinity vertical profiles show that good agreement between the model predictions and CTD data are obtained most of the time, and in summary, the model performance is considered good, with no significant or unexplained anomalies identified in the model performance.

Figure B-7 Calibration against salinity vertical profiles: WQ4

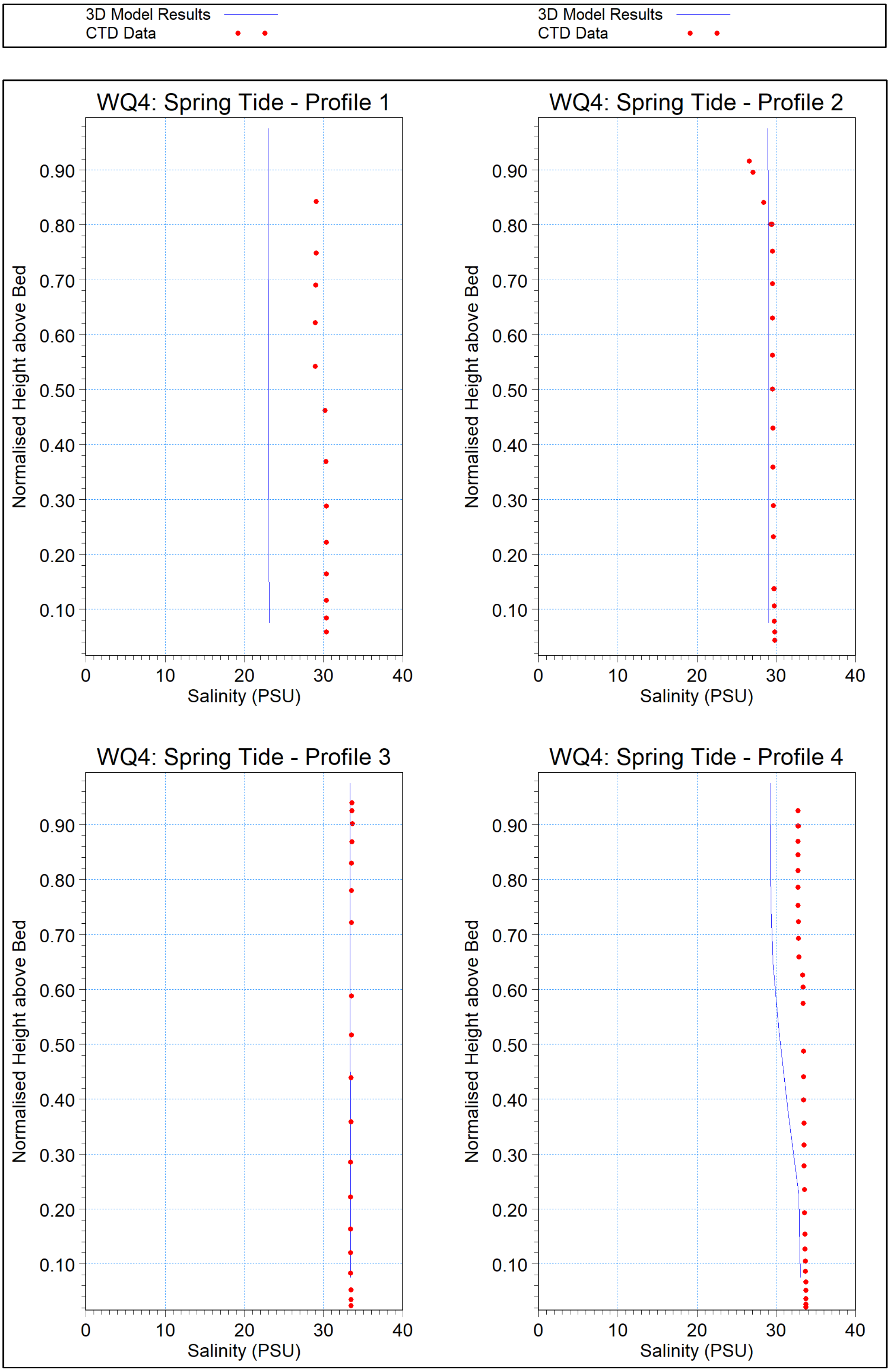
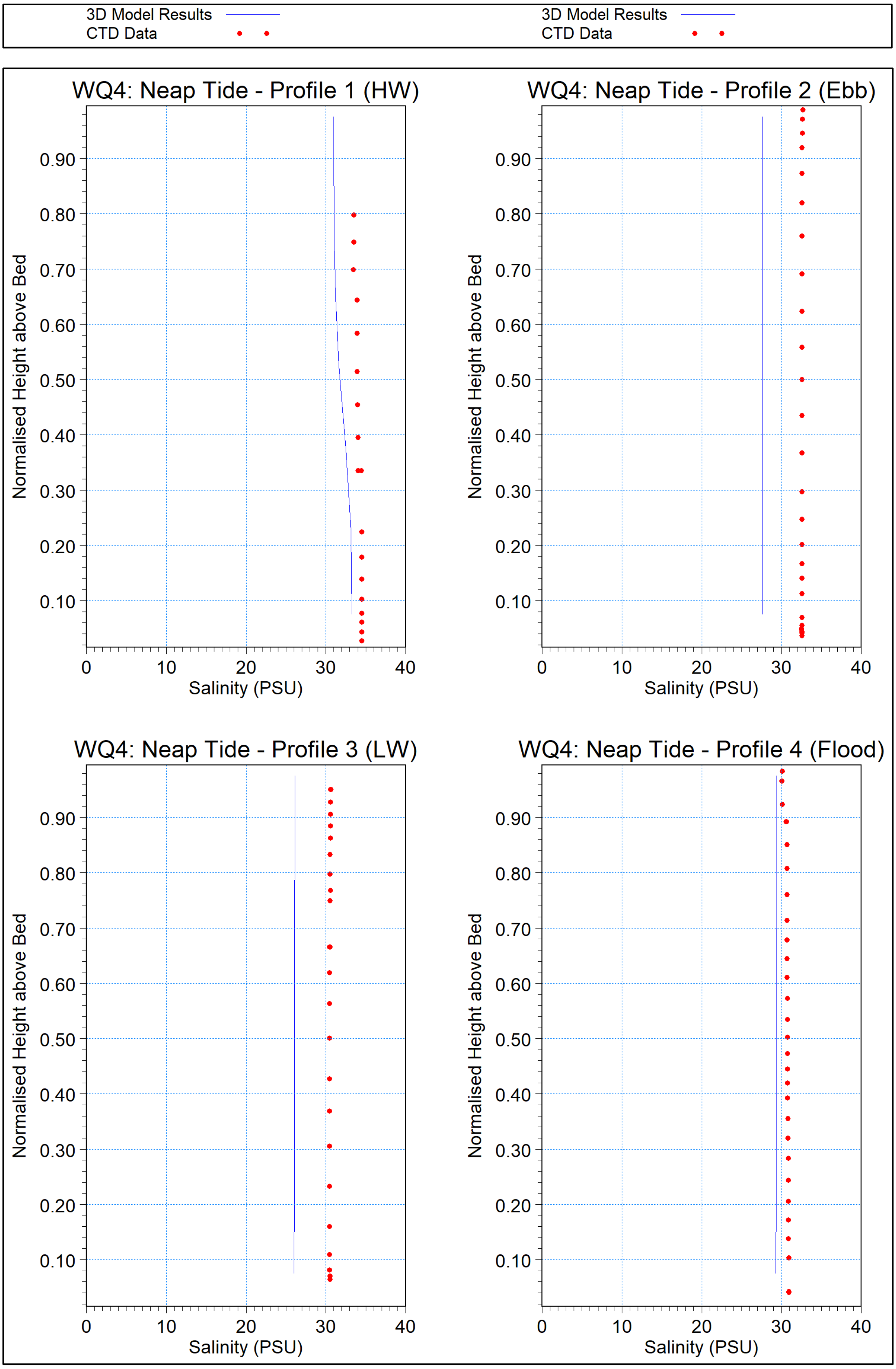


Figure B-8 Validation against salinity vertical profiles (neap tide): WQ4



Temperature

Model calibration and validation of water temperature was undertaken against the observed data at the nine WQ sites, against four CTD casts under spring and neap tide. The fitness of the model for temperature was evaluated in the same was as salinity – by comparing the time-series of depth-averaged temperature over a full spring tide and neap tide, and by assessing vertical profiles at four states of the tide.

The 3D model performance in the vertical dimension is assessed by comparing temperature vertical profiles against CTD profiles. As an example, Figure B-9 and Figure B-10 show the comparisons of temperature vertical profiles against the observed profiles collected under spring and neap tide, respectively, at site WQ4, a site located within the shellfish water.

Figure B-9 Calibration against temperature vertical profiles: WQ4

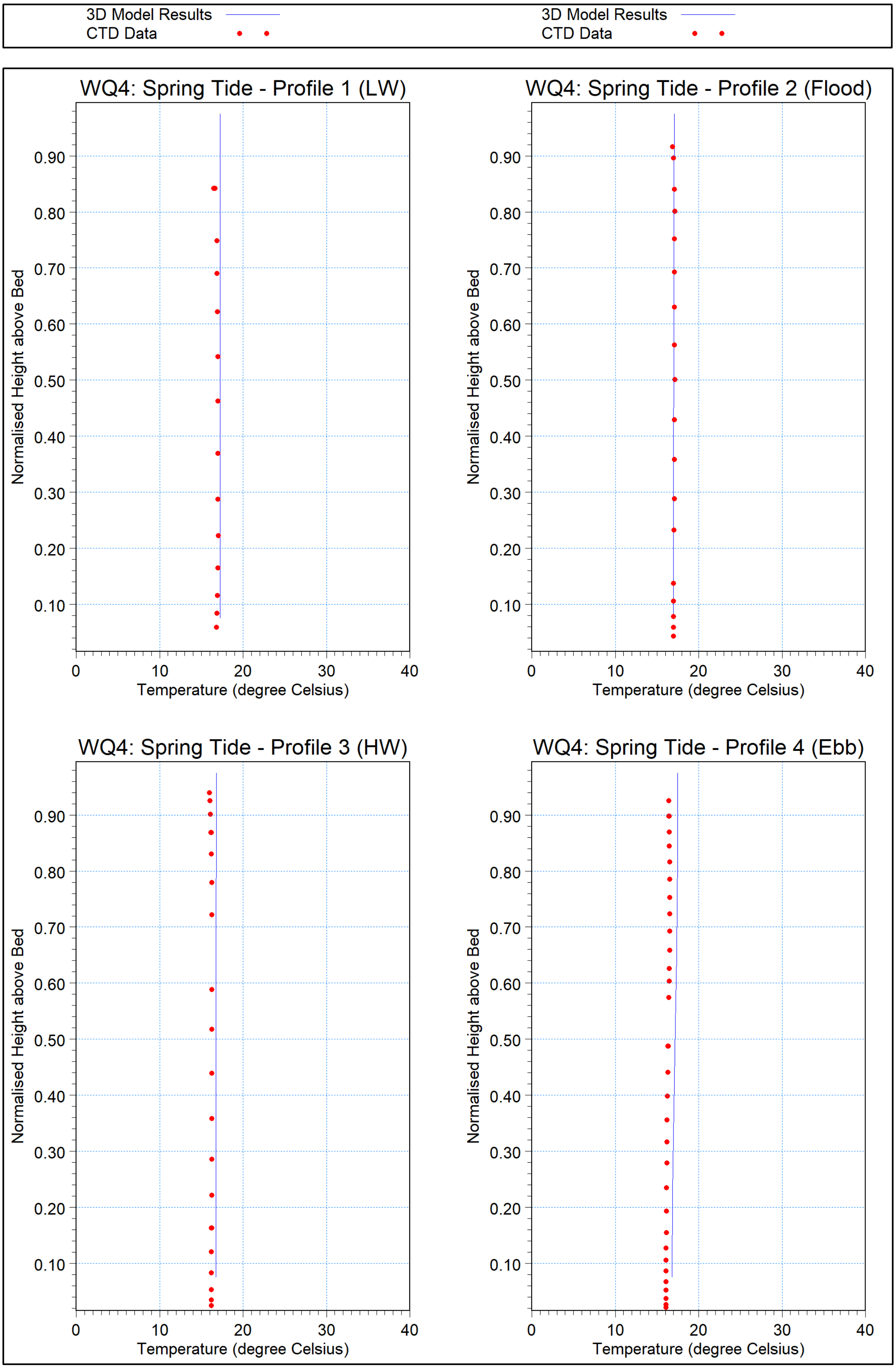
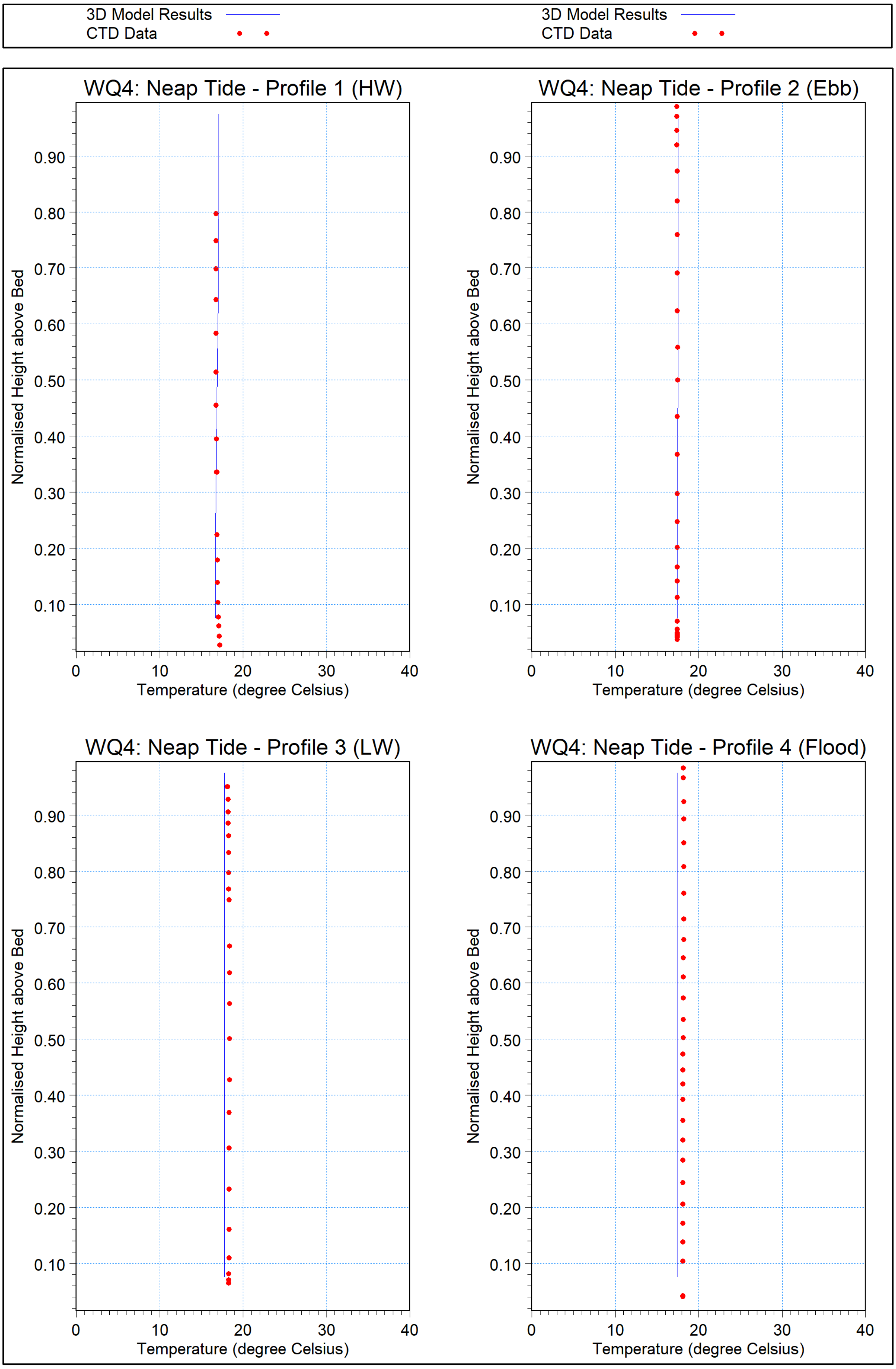


Figure B-10 Validation against temperature vertical profiles (neap tide): WQ4



Appendix C.

Modelled discharges

Discharges Modelled

As outlined in the Model Scoping Report (MSR, 2019), the modelling assessment has included a total of 24 individual discharges into Waterford Harbour or the main rivers draining into the Harbour. It should be noted however that one discharge (the SSE power station cooling water) was included to ensure any effect on hydrodynamics was captured, but it was assumed to carry no bacterial load. Therefore only 23 sources have been included in the water quality assessment. The discharges included are presented in Figure 1-1 and outlined below.

The nine main IW WwTPs, representing the main focus of the assessment include:

- Arthurstown and Environs
- Ballyhack and Environs
- Campile
- Cheekpoint
- Crooke
- Duncannon
- Dunmore East
- Passage East
- Waterford City

Nine smaller IW WwTPs which also contribute a bacterial load to the area of interest:

- Mooncoin
- Portlaw
- Clongeen
- Fiddown
- Piltown
- Carrick-on-Suir
- New Ross
- Inistioge
- Saint Mullins

Industrial Emission Licenced (IEL) sources

Three IEL licenced discharges, which include two slaughterhouses and the SSE power station:

- Queally Pig Slaughtering Limited (IEL licence No: P0175)
- Anglo Beef Processors Ireland Unlimited Company trading as ABP Waterford (IEL licence No: P0205)
- SSE Generation Ireland Limited (IEL licence No: P0606)

The slaughterhouse, Queally Pig Slaughtering limited (IEL licence No: P0175) discharge treated effluent into the River Suir, while the slaughterhouse, Anglo Beef Processors Ireland Unlimited Company trading as ABP Waterford (IEL licence No: P0205) and the power station (SSE Generation Ireland Limited; IEL license No: P0606) discharges into Waterford Harbour.

It should be noted that the SSE power station is not likely to contribute a bacterial load, but the cooling water and processes discharge may influence the local hydrodynamics, which is why it has been included. There are also two other slaughterhouses (IEL licence No: P0179 and P0040) which also discharge treated effluent to the rivers that drain to the harbour, but no discharge information is available for these, and these have been excluded as per the MSR (2019).

Diffuse river sources

The three main rivers that drain into Waterford Harbour:

- River Suir
- River Nore
- River Barrow

Each of the discharges outlined above were represented in the model by an EC concentration and discharge/river flow that is representative of winter loadings. These are detailed in Tables C-1 to C-4. A uniform load was applied for each source.

Modelled flows

Irish Water WwTPs

The modelled discharge flow for the main nine and smaller nine WwTPs were based on the current hydraulic loadings or 1.25 Dry Weather Flow (DWF) where hydraulic loadings information is not available for each works, as provided by IW Asset Planning team via Nicholas O'Dwyer (NOD).

River flows

The modelled river flow for the three main rivers is the Q30% flow, as per IW's Technical Standards. These have been calculated from the gauged flows for River Nore and River Barrow as they are gauged close to the tidal limit. For River Suir the most downstream gauging station is still too far from the tidal limit, and therefore the Q30% flow was obtained from the Environment Protection Agency (EPA) Hydro Tool.

IEL sources

The modelled discharge flow for the three IEL sources was based on the consented flow as provided in the MSR (2019).

Modelled concentrations

Irish Water WwTPs

The baseline scenario used uniform default concentrations provided by IW via NOD to represent the bacterial concentrations. The default concentrations applied are dependent on the level of treatment at each WwTPs as follows are;

- 1 x10^7 EC/100ml for untreated sewage;
- 1 x10^6 x EC/100ml for primary treatment;
- 1 x10^5 x EC/100ml for secondary treatment and;
- 1 x10^4 x EC/100ml for tertiary treatment.

The rationale for using default concentrations to represent bacterial concentrations was chosen due to lack a robust sampling data from the WwTPs.

Rivers

The sampling data for the rivers is very limited (three samples taken on each river on the same day – 13th August - and within a short space of time). Such a small dataset does not provide a robust dataset from which to determine statistics (such as the arithmetic mean) with confidence.

Furthermore, the data has been collected during the summer, and is not necessarily representative of winter loadings. However, these data have been used to represent the upstream diffuse river loads.

The main three rivers draining into Waterford Harbour have a total catchment area of 9,232 km^2. The overall catchment area has a total number of 1.37 livestock units per hectare (ha) of farmland (ref: Shellfish Pollution Reduction Programme). This equates to a total number of 1,264,784 livestock for the entire catchment, which includes pigs, cattle and sheep. Pigs and cattle are moved inside during winter while sheep are outside all year.

It is livestock that generate the majority of the diffuse bacterial load in rivers. Given that a proportion of livestock are moved inside in winter, it is likely that diffuse loads will be lower in winter than summer.

Furthermore, no slurry spreading is allowed between November and March, adding further weight to the theory that winter loads are likely to be lower than in summer.

The concentrations applied to the three river sources in the assessment are therefore considered to be conservative.

The mean of the river samples collected in each river was therefore applied.

IEL sources

The upper limit of the EC concentration range measured by Nafarnda et al. 2012 was applied for the slaughterhouses – 2 x 10^3 EC/100 ml.

Baseline scenario

Winter conditions

As this is a shellfish modelling assessment, the scenarios were run for average winter conditions (January), as per IW's Technical Standards. Specifically, this means winter bacterial discharge loads and winter decay rates were applied.

Modelled duration

The model simulations were run for a sufficiently long 'warm-up' period to enable dynamic equilibrium of bacteria concentration in the environment to be reached (approximately one week). This provided the initial conditions for the simulation. The assessment period covered a spring-neap (15 day) cycle following the warm-up period, as outlined in IW's Technical Standards.

Decay rate

The decay rate was represented by the T_{90} time (the time for 90% of the initial bacterial population to be reduced through mortality) For this assessment, the winter T_{90} value for EC in turbid estuaries (48 hours) as defined in IW's Technical Standards was applied.

Wind condition

No wind was applied in the assessment simulations.

Table C-1 Baseline scenario for the main nine WwTP for model discharge flow and for EC concentrations

WwTP	Treatment	Model discharge flow (m^3/d)	E. coli concentration (MPN/100 ml)
Arthurstown and Environs	Untreated	84.66	1 x 10^7
Ballyhack and Environs	Untreated	65.25	1 x 10^7
Campile	Primary	102	1 x 10^6
Cheekpoint	Secondary	42.75	1 x 10^5
Crooke	Secondary	158.91	1 x 10^5
Duncannon	Untreated	310.22	1 x 10^7
Dunmore East	Secondary	1,242	1 x 10^5
Passage East	Primary	51.19	1 x 10^6
Waterford City	Secondary	34,007	1 x 10^5

Table C-2 Baseline scenario for the smaller nine WwTP for model discharge flow and for EC concentrations

WwTP	Treatment	Model discharge flow (m^3/d)	E. coli concentration (MPN/100 ml)
Mooncoin	Secondary	270	1×10^5
Portlaw	Tertiary P	352	1×10^5
Clongeen	Secondary	75.94	1×10^5
Fiddown	Primary	137	1×10^6
Piltown	Secondary	525	1×10^5
Carrick-on-Suir	Tertiary N&P removal	2,591	1×10^5
New Ross	Tertiary N	4,352	1×10^5
Inistioge	Primary	118.13	1×10^6
Saint Mullins	Secondary	6.47	1×10^5
Note: It was agreed with IW to apply secondary default values (1 x 10^5) for tertiary treatment that only removed nutrients (i.e. N and/or P) and do not include bacterial (UV) treatment.			

Table C-3 Baseline scenario for the two abattoirs and the power station for model discharge flow and for EC concentrations

IEL discharge	Treatment	Model discharge flow (m^3/d)	E. coli concentration (MPN/100 ml)
Queally Pig Slaughtering Limited (MSR No: P0175)	Unknown	1,800	2,000
Anglo Beef Processors Ireland Unlimited Company trading as ABP Waterford (MSR No: P0205)	Unknown	2,000	2,000
SSE Generation Ireland Limited power station (P0606)	Not applicable	480,000	Not applicable
Note: EC concentrations from the abattoir effluent are based on observations published in the research article by Nafarnda et al. 2012.			

Table C-4 Baseline scenario for the three main rivers draining into Waterford Harbour for model discharge flow and for EC concentrations

River discharge	Model river flow (m^3/d; Q30 %)	E. coli concentration (MPN/100 ml)
River Suir	4,587,840	680
River Nore	3,741,120	400
River Barrow	3,965,760	150