DRAFT HYDRODYNAMIC MODELLING RESULTS

MARCON COMPUTATIONS INTERNATIONAL
Advanced Engineering and Environmental Solutions

Project Title: Castletownbere Sewage Scheme and Regional Water Supply

Project No: MC058

Project Client: Tobin Consulting Engineers

Final Modelling Report (revision 1)

MarCon Computations International Ltd.
No. 10, NUIG Business Innovation Centre,
Upper Newcastle,
Galway,
Ireland.

Tel / Fax: +353 91 583543
Email: info@marcon.ie
Web: www.marcon.ie

MC058 Document Register

Document No.	Title	Issue	Revision	Date
doc001	Castletownbere Marine Survey Gannt Chart	1	0	11 May 2009
doc002	Progress report: 20th July 2009	1	0	20 July 2009
doc003	Progress report: 21st July 2009	1	0	21 July 2009
doc004	Progress report: 22nd July 2009	1	0	22/07/09
doc005	Progress report: 24nd July 2009	1	0	24/07/09
doc006	Progress report: 28th July 2009	1	0	28/07/09
doc007	Draft Modelling Report	1	0	10/08/09
doc008	Final Modelling Report	1	0	13/08/09
doc009	Revised Run 8 figures	1	0	10/09/09
doc009_1	Revised Run 8 figures	1	1	14/09/09
doc010	Final Modelling Report (revision 1)	1	1	07/10/09

Quality Control: MC058_doc010

Control	Signature	Name	Position	Date
Authored by:		AlanBerry	Project Director	
Approved by:	Alan Berry	Alan Berry	Project Director	7th Oct 2009

Table of Contents

List of Figures 4
List of Tables 7

1. Introduction 8

2. Model Study 11
2.1 Model Background 11
2.2 Model Development 12

3. Model Calibration 17
3.1 Introduction 17
3.2 Hydrodynamic model calibration 17
3.3 Hydrodynamic model calibration: Tide Gauge 18
3.4 Hydrodynamic model calibration: ADCP 20
3.5 Hydrodynamic model calibration: June Spot Current Metering 25
3.6 Hydrodynamic model calibration: July Spot Current Metering 32
3.7 Hydrodynamic model calibration: Drogue Releases 39
3.8 Hydrodynamic model current vectors 44
3.9 Calibration Discussion. 49

4. Model Scenarios 50
4.1 Introduction 50
4.2 Water Quality Standards. 51
4.3 Scenario 1 52
4.4 Scenario 2 54
4.5 Scenario 3 60
4.6 Scenario 4 61
4.7 Scenario 5 68
4.8 Scenario 6 74
4.9 Scenario 7 80
4.10 Scenario 8 86
4.11 Scenario 8b 89
4.12 Scenario 9 91
4.13 Scenario 10 99
4.14 Scenario 11 102
4.15 Scenario 12 105
4.16 Summary of Results 107

5. Discussion 115
5.1 Decay rates 115
5.2 Water quality predictions 116
5.3 Storm overflows 119
5.4 Outfall location 119
5.5 Other 120

6. Conclusion 121

7. Recommendations 122

List of Figures

Figure 1: Mathematical Model Domain 12
Figure 2: Location of existing and proposed outfalls 12
Figure 3: Moore Marine Services bathymetric survey coverage 15
Figure 4: Moore Marine Services interpolated bathymetry 15
Figure 5: Admiralty Chart interpolated bathymetry 16
Figure 6: Differences between Admiralty Chart and bathymetric survey 17
Figure 7: Histogram distribution of differences between datasets. 17
Figure 8: Water surface elevation calibration (26/06/09 - 29/06/09) 20
Figure 9: Water surface elevation calibration (29/06/09 - 02/07/09) 21
Figure 10: Water surface elevation calibration (02/07/09 - 05/07/09) 21
Figure 11: Current speed calibration (25/06/09 - 28/06/09) 23
Figure 12: Current speed calibration (28/06/09 - 01/07/09) 23
Figure 13: Current speed calibration (01/07/09 - 04/07/09) 24
Figure 14: Current speed calibration (04/07/09 - 07/07/09) 24
Figure 15: Current direction calibration (35/06/09 - 28/06/09) 25
Figure 16: Current direction calibration (28/06/09 - 01/07/09) 25
Figure 17: Current direction calibration (01/07/09 - 04/07/09) 26
Figure 18: Current direction calibration (04/07/09 - 07/07/09) 26
Figure 19: Locations of spot current metering 27
Figure 20: Current speed calibration at location A (29/06/09) 28
Figure 21: Current speed calibration at location B (29/06/09) 29
Figure 22: Current speed calibration at location C (29/06/09) 29
Figure 23: Current speed calibration at location D (30/06/09) 30
Figure 24: Current speed calibration at location E (30/06/09) 30
Figure 25: Current speed calibration at location F (30/06/09) 31
Figure 26: Current direction calibration at location A (29/06/09) 31
Figure 27: Current direction calibration at location B (29/06/09) 32
Figure 28: Current direction calibration at location C (29/06/09) 32
Figure 29: Current direction calibration at location D (30/06/09) 33
Figure 30: Current direction calibration at location E (30/06/09) 33
Figure 31: Current direction calibration at location F (30/06/09) 34
Figure 32: Current speed calibration at location A (07/07/09) 35
Figure 33: Current speed calibration at location B (08/07/09) 36
Figure 34: Current speed calibration at location C (08/07/09) 36
Figure 35: Current speed calibration at location D (07/07/09) 37
Figure 36: Current speed calibration at location E (07/07/09) 37
Figure 37: Current speed calibration at location F (07/07/09) 38
Figure 38: Current direction calibration at location A (07/07/09) 38
Figure 39: Current direction calibration at location B (08/07/09) 39
Figure 40: Current direction calibration at location C (08/07/09) 39
Figure 41: Current direction calibration at location D (07/07/09) 40
Figure 42: Current direction calibration at location E (07/07/09) 40
Figure 43: Current direction calibration at location F (07/07/09) 41
Figure 44: Drogue calibration 29/06/2009 42
Figure 45: Drogue calibration 30/06/2009 43
Figure 46: Drogue calibration 07/07/2009 44
Figure 47: Drogue calibration 08/07/2009 46

Figure 48: Current vectors mid ebb neap tide. ... 47
Figure 49: Current vectors low water neap tide. ... 47
Figure 50: Current vectors mid flood neap tide. ... 48
Figure 51: Current vectors high water neap tide. ... 48
Figure 52: Current vectors mid ebb spring tide. ... 49
Figure 53: Current vectors low water spring tide. ... 49
Figure 54: Current vectors mid flood spring tide. ... 50
Figure 55: Current vectors high water spring tide. ... 50
Figure 56: Scenario 1 predicted FCL concentrations ... 55
Figure 57: Scenario 2 predicted FCL concentrations ... 57
Figure 58: Scenario 2 faecal coliform concentrations neap tide low water ... 58
Figure 59: Scenario 2 faecal coliform concentrations neap tide mid flood ... 58
Figure 60: Scenario 2 faecal coliform concentrations neap tide high water ... 59
Figure 61: Scenario 2 faecal coliform concentrations neap tide mid ebb ... 59
Figure 62: Scenario 2 faecal coliform concentrations spring tide low water ... 60
Figure 63: Scenario 2 faecal coliform concentrations spring tide mid flood ... 60
Figure 64: Scenario 2 faecal coliform concentrations spring tide high water ... 61
Figure 65: Scenario 2 faecal coliform concentrations spring tide mid ebb ... 61
Figure 66: Scenario 3 predicted FCL concentrations ... 63
Figure 67: Scenario 4 predicted FCL concentrations ... 65
Figure 68: Scenario 4 faecal coliform concentrations neap tide low water ... 66
Figure 69: Scenario 4 faecal coliform concentrations neap tide mid flood ... 66
Figure 70: Scenario 4 faecal coliform concentrations neap tide high water ... 67
Figure 71: Scenario 4 faecal coliform concentrations neap tide mid ebb ... 67
Figure 72: Scenario 4 faecal coliform concentrations spring tide low water ... 68
Figure 73: Scenario 4 faecal coliform concentrations spring tide mid flood ... 68
Figure 74: Scenario 4 faecal coliform concentrations spring tide high water ... 69
Figure 75: Scenario 4 faecal coliform concentrations spring tide mid ebb ... 69
Figure 76: Scenario 5 predicted FCL concentrations ... 71
Figure 77: Scenario 5 faecal coliform concentrations neap tide low water ... 72
Figure 78: Scenario 5 faecal coliform concentrations neap tide mid flood ... 72
Figure 79: Scenario 5 faecal coliform concentrations neap tide high water ... 73
Figure 80: Scenario 5 faecal coliform concentrations neap tide mid ebb ... 73
Figure 81: Scenario 5 faecal coliform concentrations spring tide low water ... 74
Figure 82: Scenario 5 faecal coliform concentrations spring tide mid flood ... 74
Figure 83: Scenario 5 faecal coliform concentrations spring tide high water ... 75
Figure 84: Scenario 5 faecal coliform concentrations spring tide mid ebb ... 75
Figure 85: Scenario 6 predicted FCL concentrations ... 77
Figure 86: Scenario 6 faecal coliform concentrations neap tide low water ... 78
Figure 87: Scenario 6 faecal coliform concentrations neap tide mid flood ... 78
Figure 88: Scenario 6 faecal coliform concentrations neap tide high water ... 79
Figure 89: Scenario 6 faecal coliform concentrations neap tide mid ebb ... 79
Figure 90: Scenario 6 faecal coliform concentrations spring tide low water ... 80
Figure 91: Scenario 6 faecal coliform concentrations spring tide mid flood ... 80
Figure 92: Scenario 6 faecal coliform concentrations spring tide high water ... 81
Figure 93: Scenario 6 faecal coliform concentrations spring tide mid ebb ... 81
Figure 94: Scenario 7 predicted FCL concentrations ... 83
Figure 95: Scenario 7 faecal coliform concentrations neap tide low water ... 84
Figure 96: Scenario 7 faecal coliform concentrations neap tide mid flood ... 84

Figure 97: Scenario 7 faecal coliform concentrations neap tide high water 85
Figure 98: Scenario 7 faecal coliform concentrations neap tide mid ebb 85
Figure 99: Scenario 7 faecal coliform concentrations spring tide low water 86
Figure 100: Scenario 7 faecal coliform concentrations spring tide mid flood 86
Figure 101: Scenario 7 faecal coliform concentrations spring tide high water........................ 87
Figure 102: Scenario 7 faecal coliform concentrations spring tide mid ebb............................ 87
Figure 103: Scenario 8 predicted FCL & TCL concentrations 89
Figure 104: Scenario 8 predicted BOD & COD concentrations... 89
Figure 105: Scenario 8 predicted DIN & P concentrations 90
Figure 106: Scenario 8 predicted Suspended Solids concentration.. 90
Figure 107: Scenario 8b predicted FCL concentration. 92
Figure 108: Scenario 9 predicted FCL & TCL concentration 94
Figure 109: Scenario 9 predicted BOD & COD concentrations... 95
Figure 110: Scenario 9 predicted DIN & P concentrations 95
Figure 111: Scenario 9 predicted suspended solids concentration 96
Figure 112: Scenario 9 faecal coliform concentrations neap tide low water............................ 97
Figure 113: Scenario 9 faecal coliform concentrations neap tide mid flood 97
Figure 114: Scenario 9 faecal coliform concentrations neap tide high water 98
Figure 115: Scenario 9 faecal coliform concentrations neap tide mid ebb 98
Figure 116: Scenario 9 faecal coliform concentrations spring tide low water 99
Figure 117: Scenario 9 faecal coliform concentrations spring tide mid flood 99
Figure 118: Scenario 9 faecal coliform concentrations spring tide high water...................... 100
Figure 119: Scenario 9 faecal coliform concentrations spring tide mid ebb.......................... 100
Figure 120: Scenario 10 predicted FCL concentrations 102
Figure 121: Scenario 10 predicted BOD & COD concentrations... 102
Figure 122: Scenario 10 predicted DIN & P concentrations 103
Figure 123: Scenario 10 predicted suspended solids concentration 103
Figure 124: Scenario 11 predicted FCL & TCL concentrations 105
Figure 125: Scenario 11 predicted BOD & COD concentrations... 106
Figure 126: Scenario 11 predicted DIN & P concentrations 106
Figure 127: Scenario 11 predicted suspended solids concentration 107
Figure 128: Scenario 12 predicted FCL concentrations 109

List of Tables

Table 1: Model Scenarios 52
Table 2: EPA Eutrophic Assessment Criteria 54
Table 3: Details for Scenario 1 54
Table 4: Summary of Scenario 1 predicted FCL concentrations 56
Table 5: Details for Scenario 2 56
Table 6: Summary of Scenario 2 predicted FCL concentrations 57
Table 7: Details for Scenario 3 62
Table 8: Summary of Scenario 3 predicted FCL concentrations 63
Table 9: Details for Scenario 4 64
Table 10: Summary of Scenario 4 predicted FCL concentrations 65
Table 11: Details for Scenario 5 70
Table 12: Summary of Scenario 5 predicted FCL concentrations 71
Table 13: Details for Scenario 6 76
Table 14: Summary of Scenario 6 predicted FCL concentrations 77
Table 15: Details for Scenario 7 82
Table 16: Summary of Scenario 7 predicted FCL concentrations 83
Table 17: Details for Scenario 8 88
Table 18: Summary of results for Scenario 8 91
Table 19: Details for Scenario 8b 91
Table 20: Summary of results for Scenario 8b 92
Table 21: Details for Scenario 9 93
Table 22: Summary of results for Scenario 9 96
Table 23: Details for Scenario 10 101
Table 24: Summary of results for Scenario 10 104
Table 25: Details for Scenario 11 105
Table 26: Summary of results for Scenario 11 107
Table 27: Details for Scenario 12 108
Table 28: Summary of results for Scenario 12 108
Table 29: Summary of results from Scenarios 1, 2 & 3 for outfall location B1 109
Table 30: Summary of results from Scenarios 1, 2 & 3 for outfall location E 110
Table 31: Summary of results from Scenarios 4, 5 & 6 111
Table 32: Summary of results from Scenarios 4, 5 & 6 112
Table 33: Summary of results from Scenarios 4 & 7 for outfall locations B1 113
Table 34: Summary of results for Scenario 8 114
Table 35: Summary of results for Scenario 9 114
Table 36: Summary of results for Scenario 8b 114
Table 37: Summary of results for Scenario 10 115
Table 38: Summary of results for Scenario 11 116
Table 39: Summary of results for Scenario 12 116

1. Introduction

1.1 MarCon Computations International Ltd., were commissioned by Tobin Consulting Engineers to undertake a detailed mathematical modelling study of Castletownbere in order to determine the optimum location(s), appropriate discharge standards and possible impacts on the receiving waters of discharging effluent from the proposed Castletownbere Sewage Scheme and Regional Water Supply Scheme outfalls.

1.2 The study was undertaken with particular emphasis on the possible adverse impacts on the shellfish designated waters within the harbour.

1.3 As part of this study, a computer based hydrodynamic and water quality model DIVAST, (Depth Integrated Velocity and Solute Transport) was used to predict the relative changes in the water quality in Castletownbere due to discharges of foul effluent containing total & faecal coliforms, BOD, COD, total nitrogen, phosphorus and suspended solids from the outfalls.

1.4 The entire extent of the mathematical model study domain showing the locations of the proposed outfalls and the shellfish designated waters is presented in Figure 1. The area of interest is presented in more detail in Figure 2.

1.5 The results of the modelling study presented in this report identify the preferred location for the proposed outfall and portray the dispersion patterns and concentrations of the various effluent discharges from the outfall.

1.6 In total 6No. proposed outfall locations, as presented in Figure 2 were assessed to determine the location of the preferred outfall.

1.7 Based on the results of the modeling study and engineering and financial considerations, Outfall B1-70m was chosen as the preferred location.

1.8 The results from the modelling study were further used to determine if the regulatory requirements specified in national and international legislation were satisfied.

1.9 A description of the numerical model development is presented in Chapters 2, with details of model calibration presented in Chapter 3.

1.10 The results of the solute transport model for each of the model scenarios executed are presented in Chapter 4.

1.11 These results are discussed in relation to relevant water quality standards in Chapter 5.

Figure 1: Mathematical Model Domain

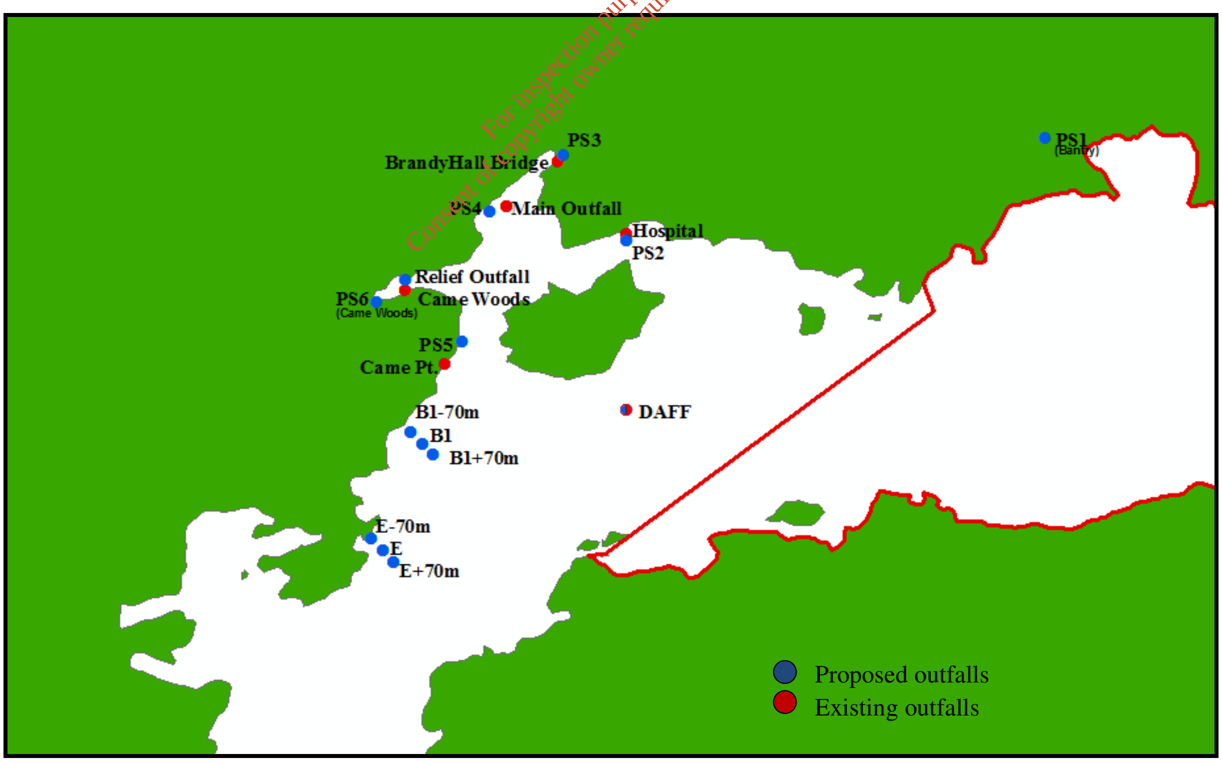

Figure 2: Location of existing and proposed outfalls

2. Model Study

2.1 Model Background

2.1.1 The DIVAST model used in this study is amongst the best tools available for the modelling of hydrodynamic conditions and solute transport within a coastal environment.

2.1.2 The mathematical formulation of the model is based on the well-validated Navier-Stokes equations that describe variations in current speeds and directions at discrete intervals of time.

2.1.3 These equations have been well validated on many hydraulic engineering studies and are widely used for the type of problem considered in this study.

2.1.4 DIVAST uses an implicit finite difference scheme to solve the Navier-Stokes equations for unsteady flow conditions. The finite difference technique is the most common method employed to solve these equations and is ideally suited for total water quality management of a water body as well as evaluating individual problems.

2.1.5 The model DIVAST was developed by Professor Roger Falconer at the University of Bradford about 20 years ago and is extended and upgraded on an ongoing basis.

2.1.6 The model is widely used in Ireland and the U.K. for many different types of hydro-environmental studies in coastal waters such as sewage effluent discharges, oil spill modelling, aquaculture assessment and water quality management planning.

2.1.7 The model has been used to date on more than 300 such studies throughout Ireland and the U.K. and has proven it to be a reliable tool for such analyses.

2.1.8 DIVAST is an industry standard package for water quality model studies.

2.2 Model Development

2.2.1 The mathematical modelling study was carried out by developing a numerical model to simulate both the water circulation throughout the model domain and the transport and degradation of material from the proposed outfall discharges.

2.2.2 This was performed, as typical in all such model studies, in three interactive stages.

2.2.3 The first stage consisted of developing a water circulation model of the Castletownbere area to compute the hydrodynamic patterns and tidal elevations within the region for prescribed environmental conditions.

2.2.4 The second stage in the study was the calibration of this hydrodynamic model against field data.

2.2.5 The third stage of the study consisted of the development of a solute transport model capable of computing concentrations of a contaminant throughout the water body.

2.2.6 As the spread and fate of a solute in water is dependent on the local water circulation patterns, the solute transport model developed in this study uses the output from the hydrodynamic model to compute concentrations of the various parameters in the water.

2.2.7 The finite difference model of Castletownbere was developed using information obtained from both the United Kingdom Hydrographic Office Admiralty Chart No. 1840 "Bantry Bay: Blackball Head to Shot Head", and the bathymetric survey undertaken by Moore Marine Services Ltd., under contract to MarCon Computations International Ltd.

2.2.8 Details of the bathymetric survey undertaken by Moore Marine Services Ltd., can be found in Appendix I accompanying this report, with the coverage from the bathymetric survey presented in Figure 3.

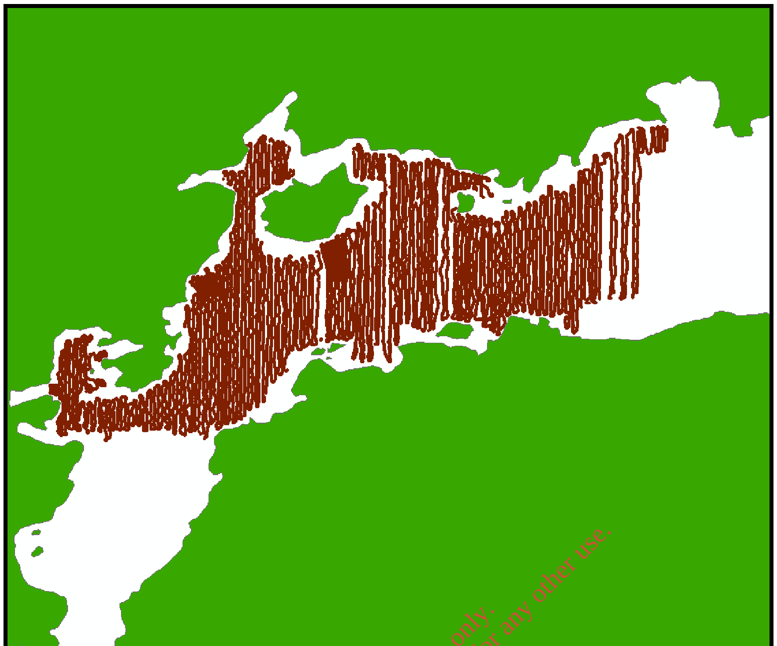

Figure 3: Moore Marine Services bathymetric survey coverage

2.2.9 The bathymetric survey data was also interpolated and gridded at 25m intervals to produce a finite difference bathymetric survey grid and is presented in Figure 4.

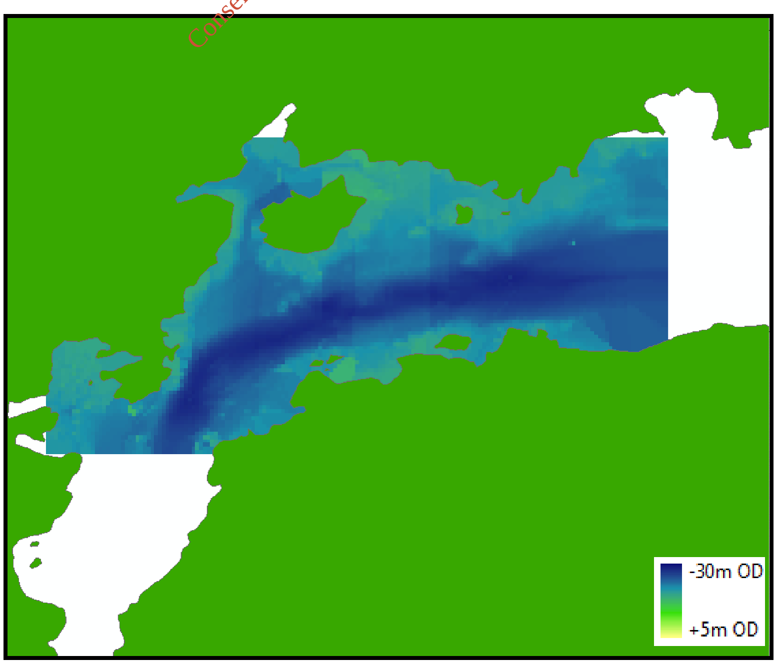

Figure 4: Moore Marine Services interpolated bathymetry

2.2.10 The Admiralty Chart data was digitised and georeferenced to Irish National Grid coordinates and reduced to Ordnance Datum Malin Head using ESRI ArcMap geographical information system, (GIS), and is presented in Figure 5.

2.2.11 The majority of bathymetric points digitised from Admiralty Chart 1840 consist of points representing the contour lines on the chart, with those contours generated from the original survey soundings undertaken between 1895 and 1914.

2.2.12 The Admiralty Chart data was interpolated and gridded at 25m intervals to produce a finite difference Admiralty Chart bathymetry grid and is presented in Figure 5.

2.2.13 The 25m finite difference bathymetric survey grid was compared geospatially with the 25m finite difference Admiralty Chart bathymetry grid to determine any differences between the two bathymetric datasets, the results of which are presented in Figure 6.

2.2.14 A histogram displaying the distribution of the differences between both datasets is presented in Figure 7.

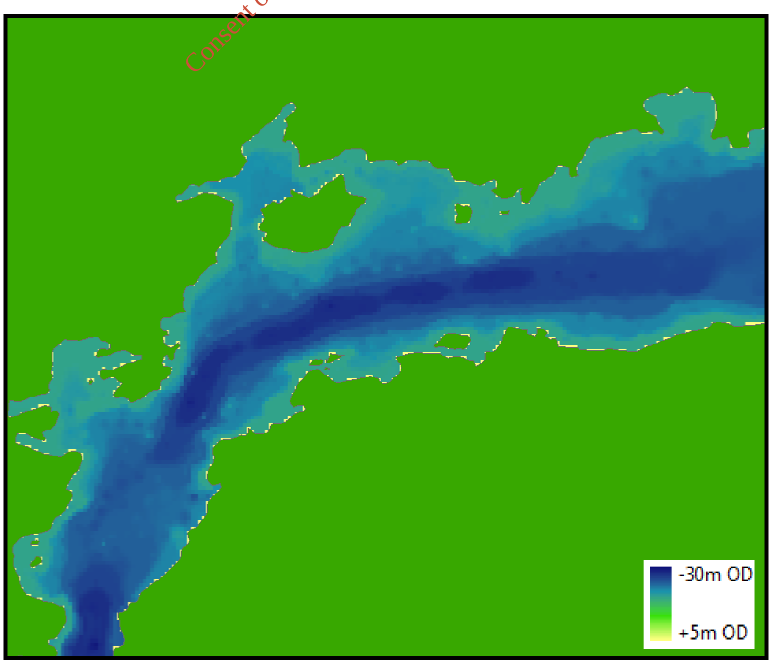

Figure 5: Admiralty Chart interpolated bathymetry

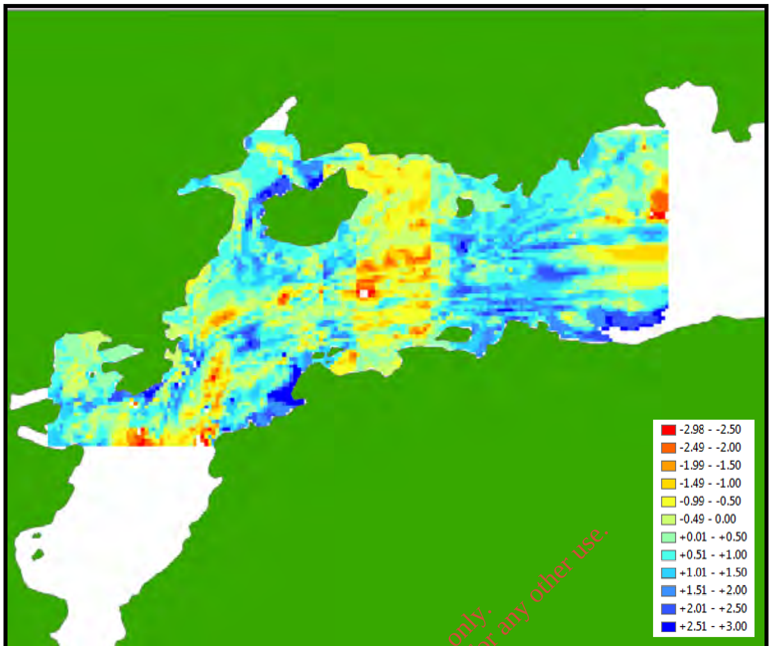

Figure 6: Differences between Admiralty Chart and bathymetric survey

2.2.15 Given the age of the survey data as digitised from Admiralty Chart 1840, the bathymetric survey data from Moore Marine Services Ltd., was used to replace the Admiralty Chart bathymetry in the finite difference bathymetry grid defined to the numerical model.

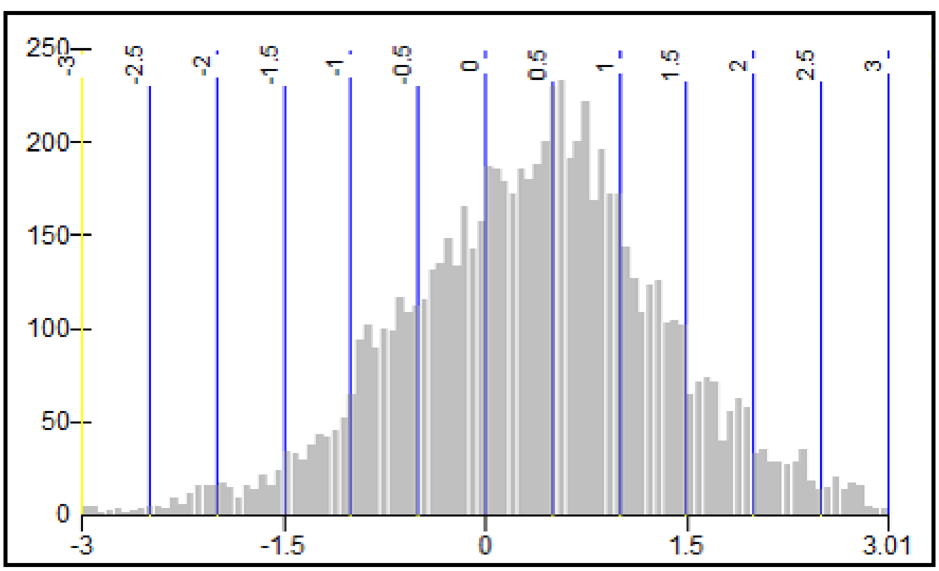

Figure 7: Histogram distribution of differences between datasets.

2.2.16 In total 84,000 grid points were used to define the finite difference bathymetry grid to the numerical model consisting of 200 x 420 computational cells at a resolution of 25m.

2.2.17 The topography of the area is defined by specifying land boundaries to delineate the extent of the water body with a water elevation boundary specified at the southern and eastern limits of the model domain.

2.2.18 The following significant forcing functions were incorporated into all simulation runs of the hydrodynamic model: tidal elevations, prevailing wind and Coriolis force.

2.2.19 The Coriolis force induces water currents due to the fact that the water body is on the surface of a rotating globe and is a function of the latitude of the water body and the rotational velocity of the earth, in this case considered to be 51^{o} 38.5' and 400 m/s respectively.

3. Model Calibration

3.1 Introduction

3.1.1 Calibration involves the adjustment of model parameters and forcing functions within the bounds of modelling uncertainties, to obtain the best possible approximation of the physical phenomena being simulated.

3.1.2 In the current study, the model was calibrated from recorded field survey data collected by Moore Marine Services Ltd., under contract to MarCon Computations International Ltd.

3.1.3 Details of the field surveys undertaken by Moore Marine Services Ltd., can be found in Appendix I accompanying this report.

3.1.4 Moore Marine Services Ltd., deployed a recording tide gauge to the south of Castletownbere, an Acoustic Doppler Current Profiler (ADCP) at outfall location B to record current speeds and directions, undertook spot current metering at 5No. locations throughout the area of interest on both spring and neap tides, undertook dye release surveys at 2No. locations on both spring and neap tides, undertook drogue release surveys at 2No. locations on both spring and neap tides and recorded wind speeds and directions over the course of the surveys.

3.1.5 The hydrodynamic and solute transport models were calibrated against all available recorded data collected by Moore Marine Services Ltd.

3.2 Hydrodynamic model calibration

3.2.1 The hydrodynamic model was calibrated by comparing model predictions against field measurements of water surface elevations and current speeds for given environmental conditions.

3.2.2 When running the model, tidal elevations were specified at the southern and eastern open sea boundaries commensurate with measured tidal dynamics. For the calibration simulations the tidal elevations as measured on the day when the hydrographic survey was carried out were specified to the model.

3.2.3 During the simulation the prevailing wind conditions were defined to the hydrodynamic model as wind blowing over the surface of a large body of water will transmit some of its energy to the water, thereby, inducing currents.

3.3 Hydrodynamic model calibration: Tide Gauge

3.3.1 Figure 8 through Figure 10 present the comparison of the water elevation as predicted by the numerical model against the recorded water elevations at the national tide gauge network location in Castletownbere Harbour from 26/06/2009 through to 05/07/2009.

3.3.2 From these figures it can be seen that the numerical model is very accurately predicting the phase and amplitude of the tidal signal at the national tide gauge network location in Castletownbere Harbour over both spring and neap tides.

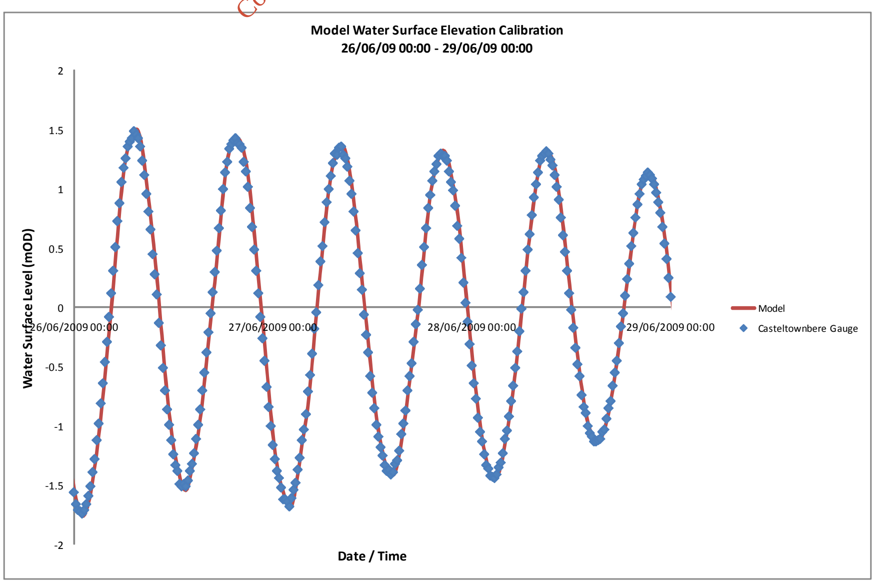

Figure 8: Water surface elevation calibration (26/06/09 - 29/06/09)

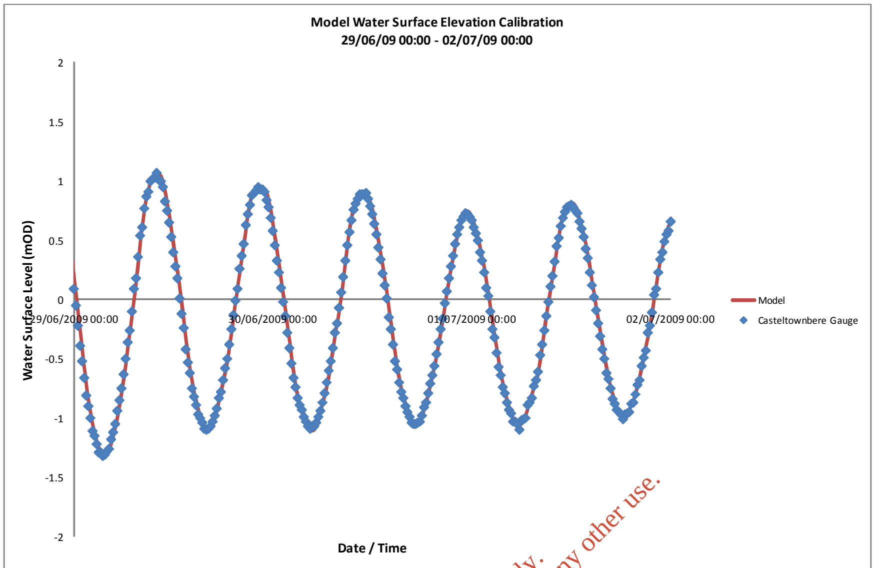

Figure 9: Water surface elevation calibration (29/06/09 - 02/07/09)

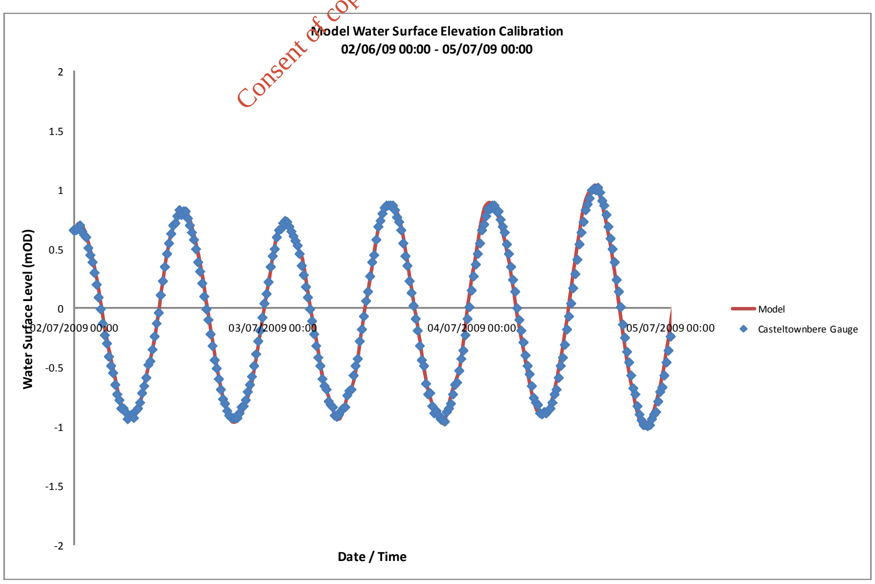

Figure 10: Water surface elevation calibration (02/07/09 - 05/07/09)

3.4 Hydrodynamic model calibration: ADCP

3.4.1 Figure 11 through Figure 14 present the comparison of the depth averaged current speed as predicted by the numerical model against the ADCP recorded depth averaged current speeds at proposed outfall location B in Castletownbere Harbour from 25/06/2009 through to 07/07/2009.

3.4.2 The calibration requirement was for model predicted current speeds to be within +/- 0.10m/s of recorded values, with the +/-0.10m/s of recorded values represented in the figures by the light grey shaded area.

3.4.3 Figure 15 through Figure 18 present the comparison of the depth averaged current direction as predicted by the numerical model against the ADCP recorded depth averaged current direction at proposed outfall location B in Castletownbere Harbour from 25/06/2009 through to 07/07/2009.

3.4.4 The calibration requirement was for model predicted current directions to be within +/- 10^{o} of recorded values, with the +/-10^{o} of recorded values represented in the figures by the light grey shaded area.

3.4.5 From these figures it can be seen that the numerical model is consistent in accurately predicting the current speeds at the proposed outfall location B in Castletownbere Harbour over both spring and neap tides.

3.4.6 While the model is not as accurately predicting the current directions consistently within the required +/-10^{o} range as stipulated, the model does predict values very close to this range and simulates the correct magnitude of change in direction at commensurate time periods.

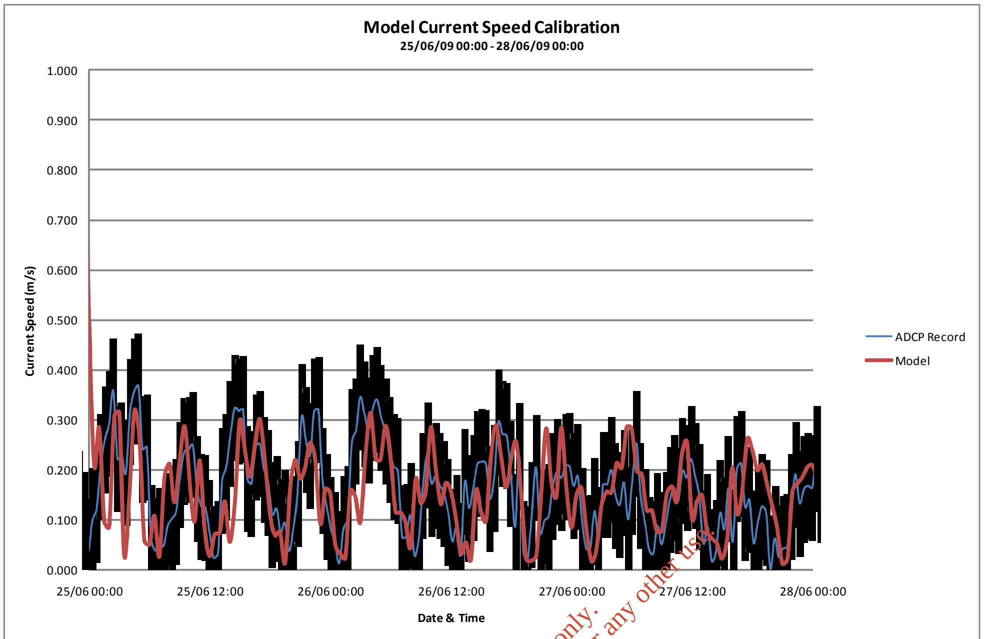

Figure 11: Current speed calibration (25/06/09 - 28/06/09)

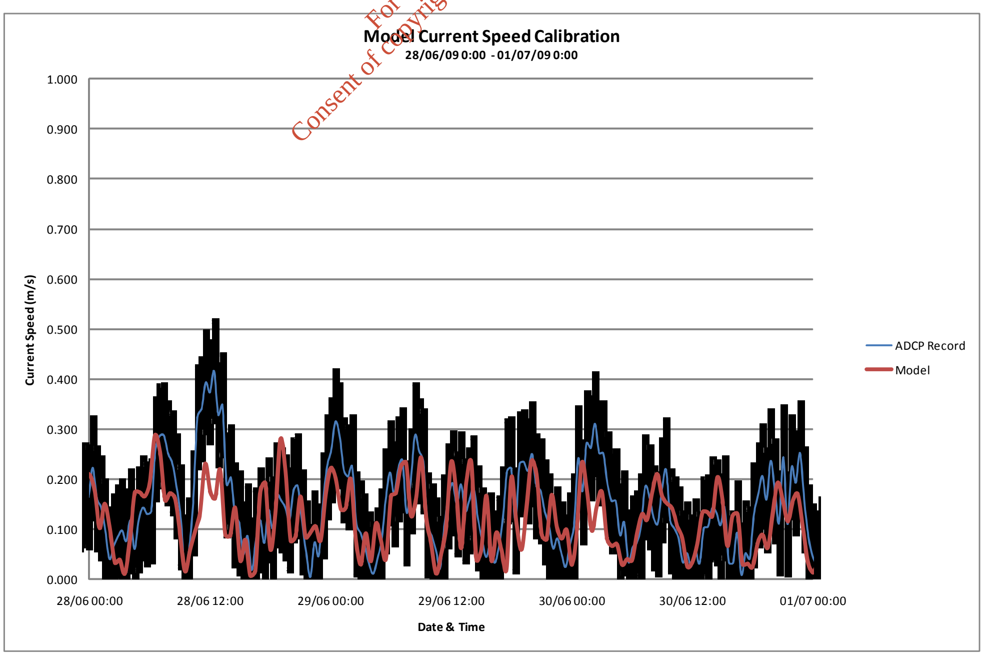

Figure 12: Current speed calibration (28/06/09 - 01/07/09)

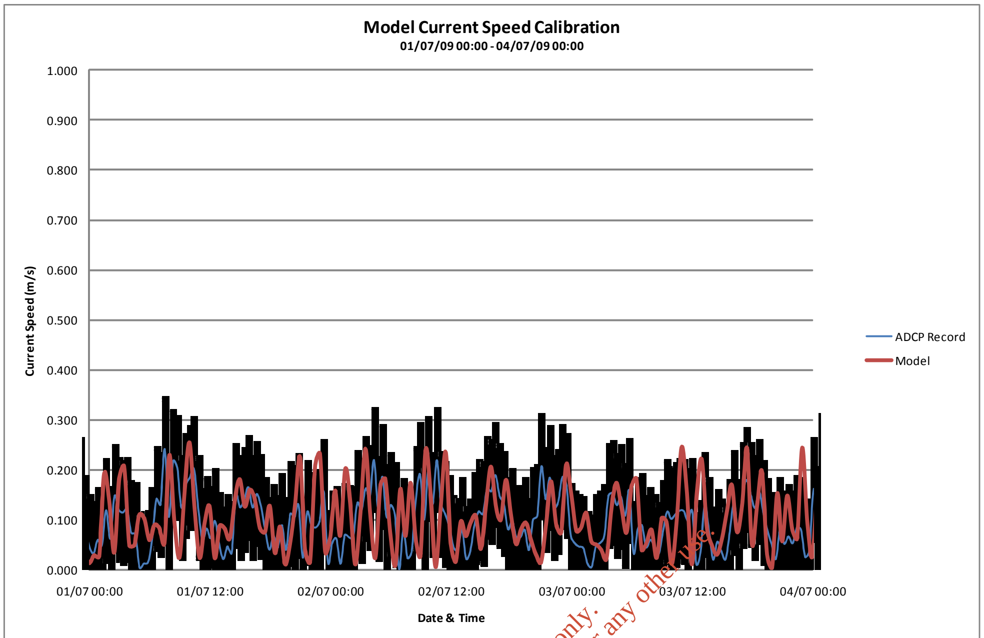

Figure 13: Current speed calibration (01/07/09 - 04/07/09)

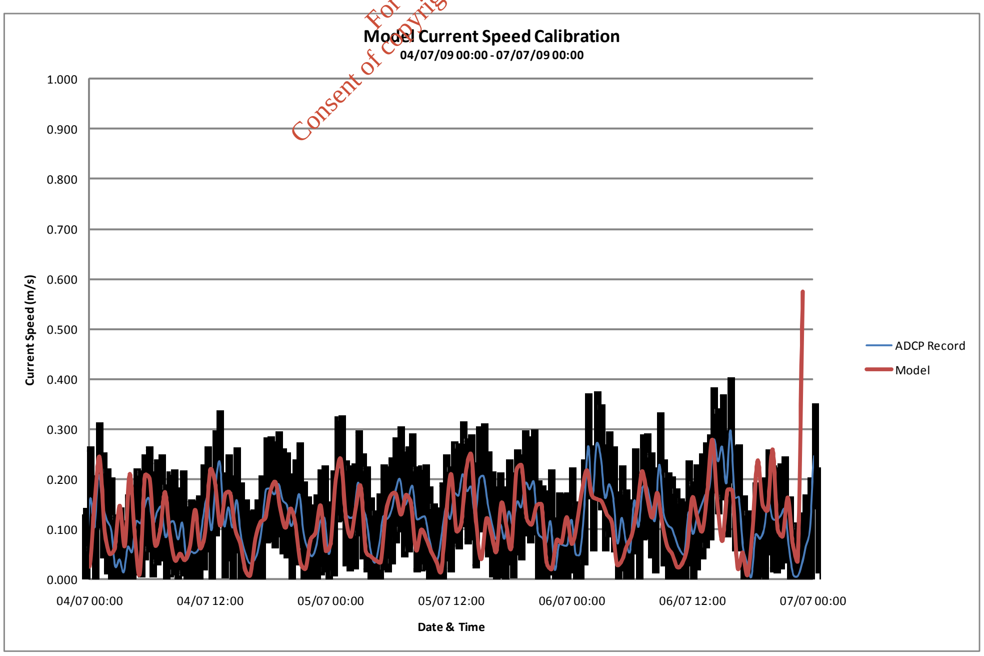

Figure 14: Current speed calibration (04/07/09 - 07/07/09)

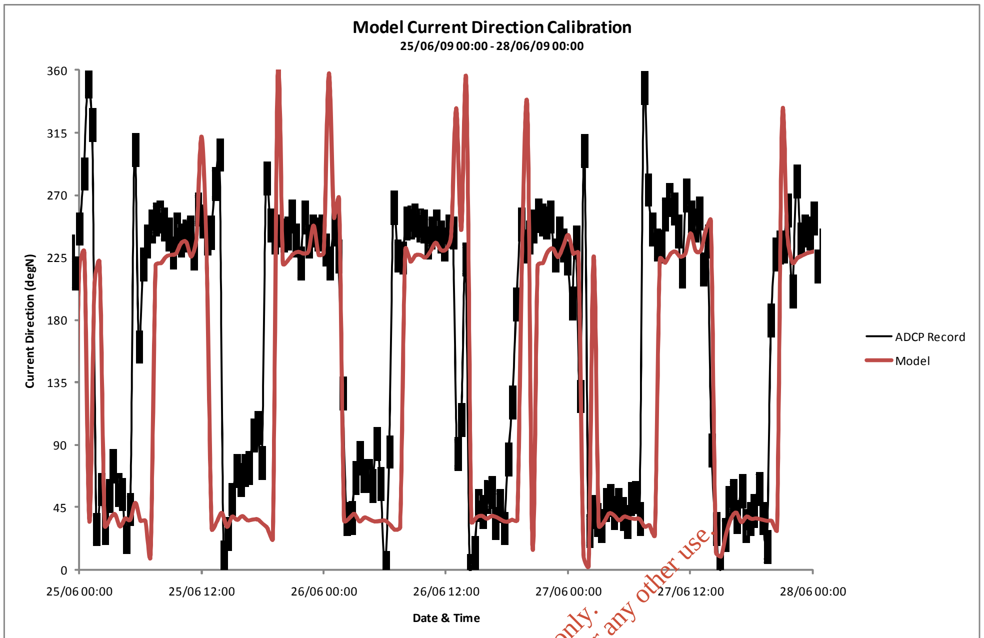

Figure 15: Current direction calibration (35/06/09 - 28/06/09)

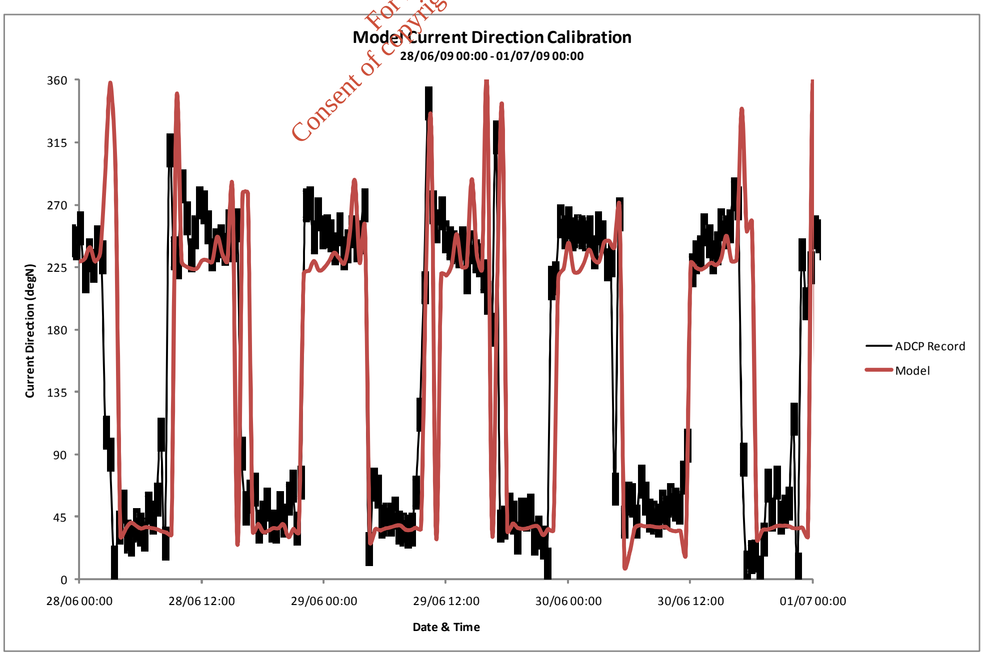

Figure 16: Current direction calibration (28/06/09 - 01/07/09)

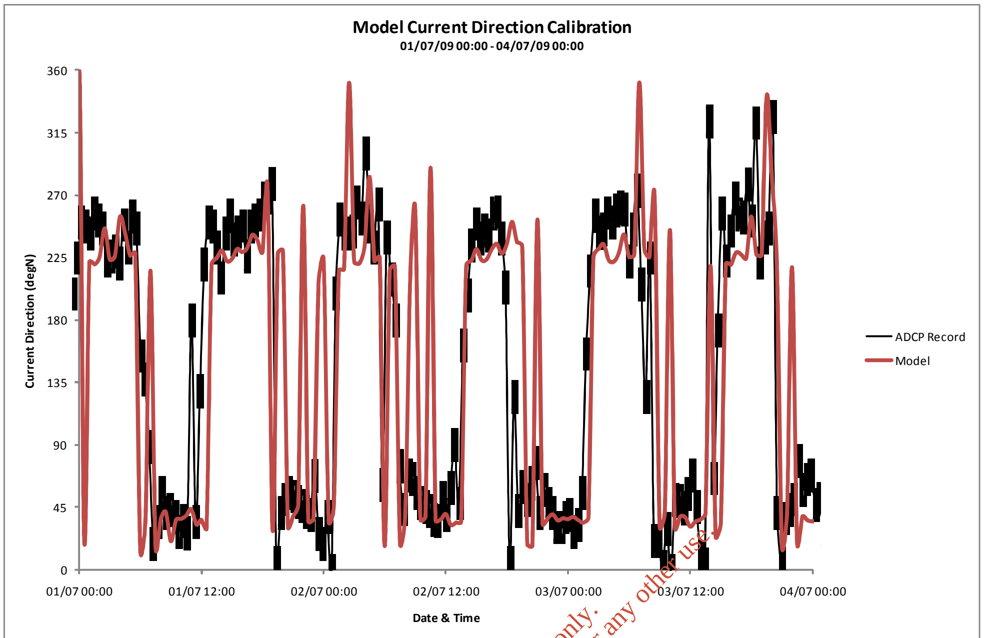

Figure 17: Current direction calibration (01/07/09 - 04/07/09)

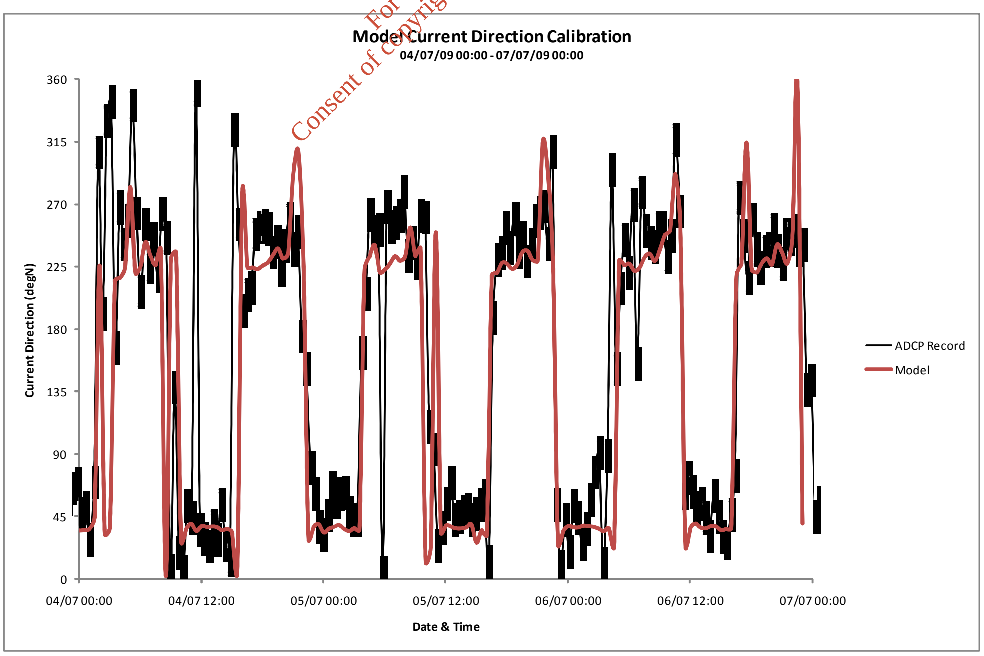

Figure 18: Current direction calibration (04/07/09 - 07/07/09)

3.5 Hydrodynamic model calibration: June Spot Current Metering

3.5.1 The locations at which the spot current metering were undertaken for both the June and July survey campaigns is presented in Figure 19.

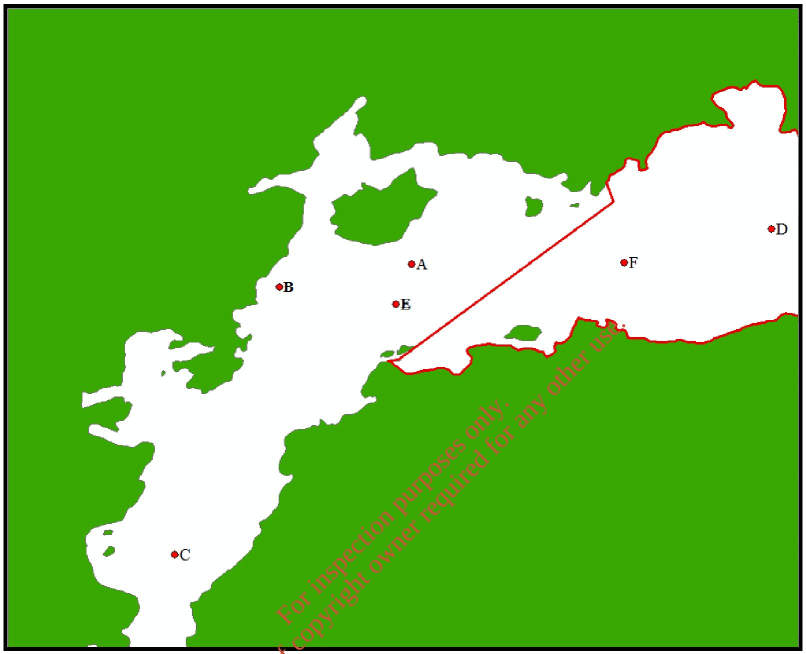

Figure 19: Locations of spot current metering

3.5.2 Figure 20 through Figure 25 present the comparison of the current speed as predicted by the numerical model against the spot recorded current speeds at locations A - F in Castletownbere Harbour on 29/06/2009 & 30/06/2009

3.5.3 As the spot current metering is not continuous, the readings are presented as individual points in each figure with the required calibration level +/-0.10m/s of recorded values represented by the vertical errors bars.

3.5.4 From these figures it can be seen that the numerical model is consistent in accurately predicting the current speed at the spot metering locations in Castletownbere Harbour for the dates in question.

3.5.5 Figure 26 through Figure 31 present the comparison of the current direction as predicted by the numerical model against the spot recorded current speeds at locations A - F in Castletownbere Harbour on 29/06/2009 & 30/06/2009.

3.5.6 As the spot current metering is not continuous, the readings are presented as individual points in each figure, however given the variation in readings, the points have been joined by line to facilitate interpretation.

3.5.7 With the exception of Figure 29, Location D, it can be seen that the numerical model is consistent in predicting the current direction relatively accurately at the spot metering locations in Castletownbere Harbour for the dates in question.

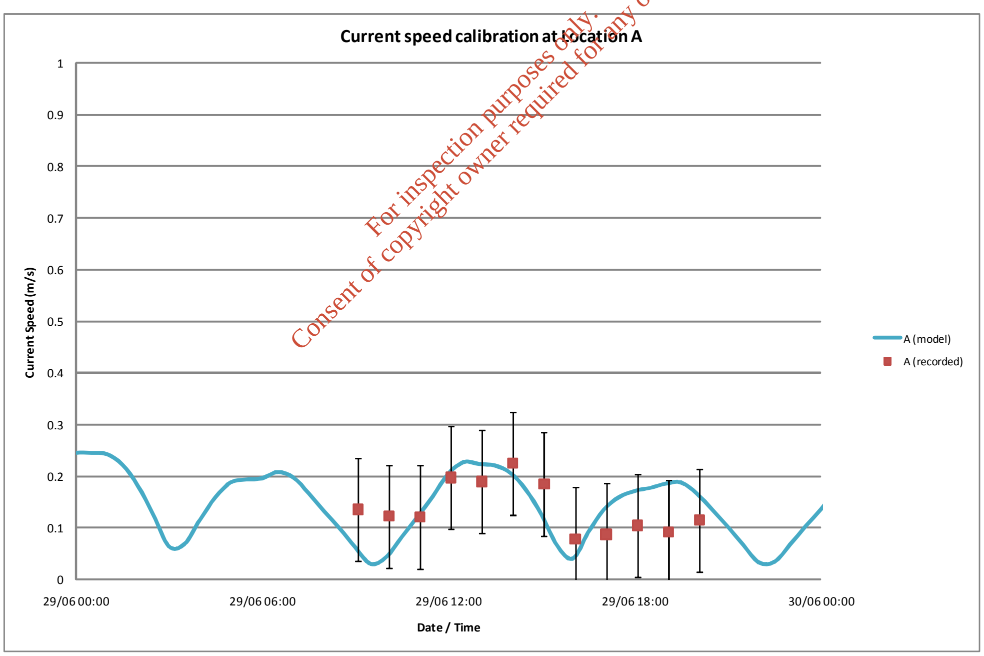

Figure 20: Current speed calibration at location A (29/06/09)

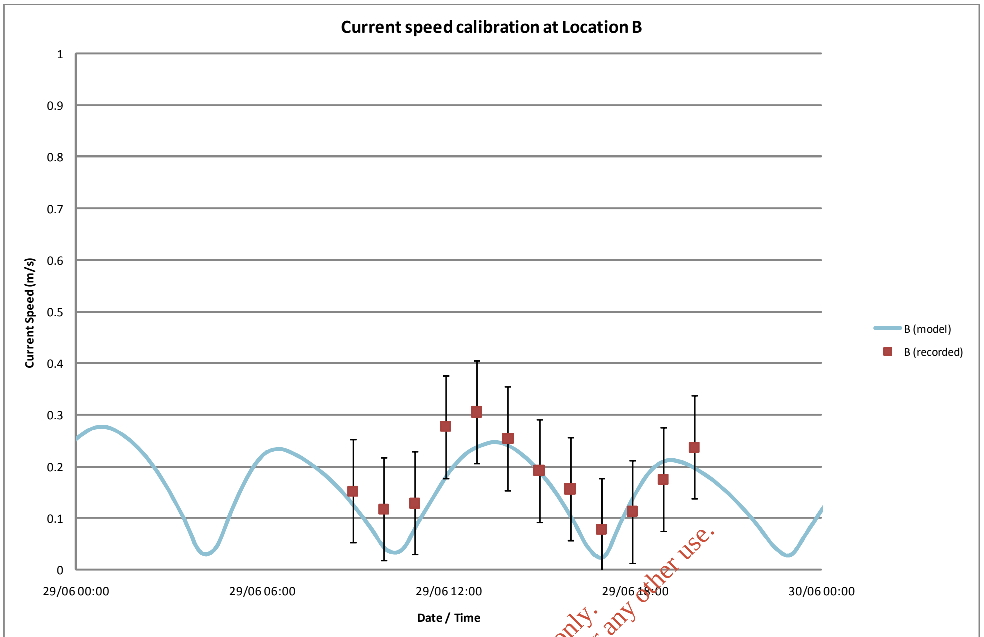

Figure 21: Current speed calibration at location B (29/06/09)

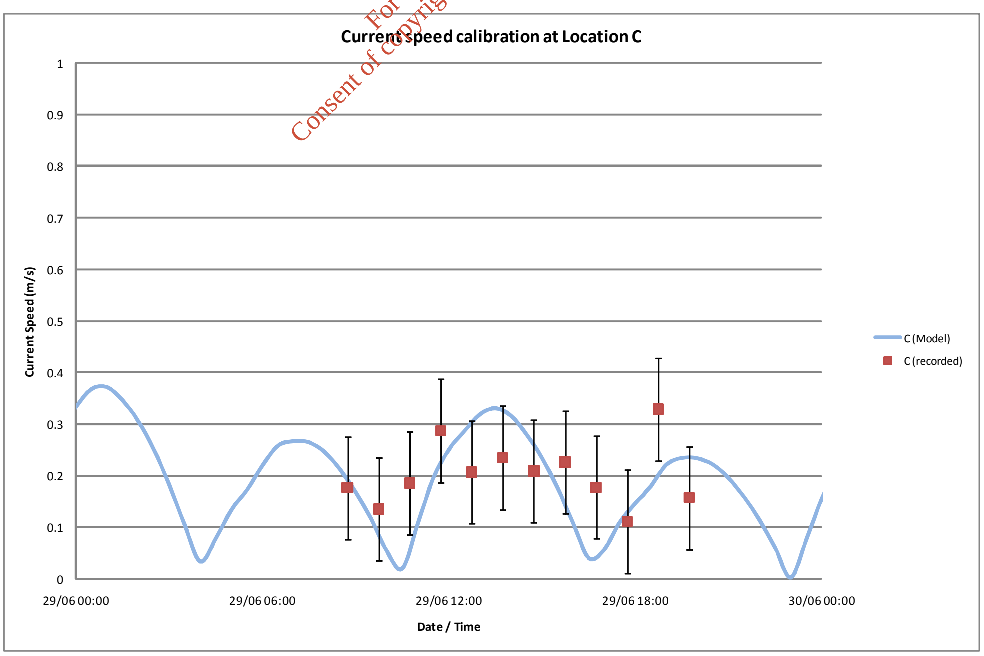

Figure 22: Current speed calibration at location C (29/06/09)

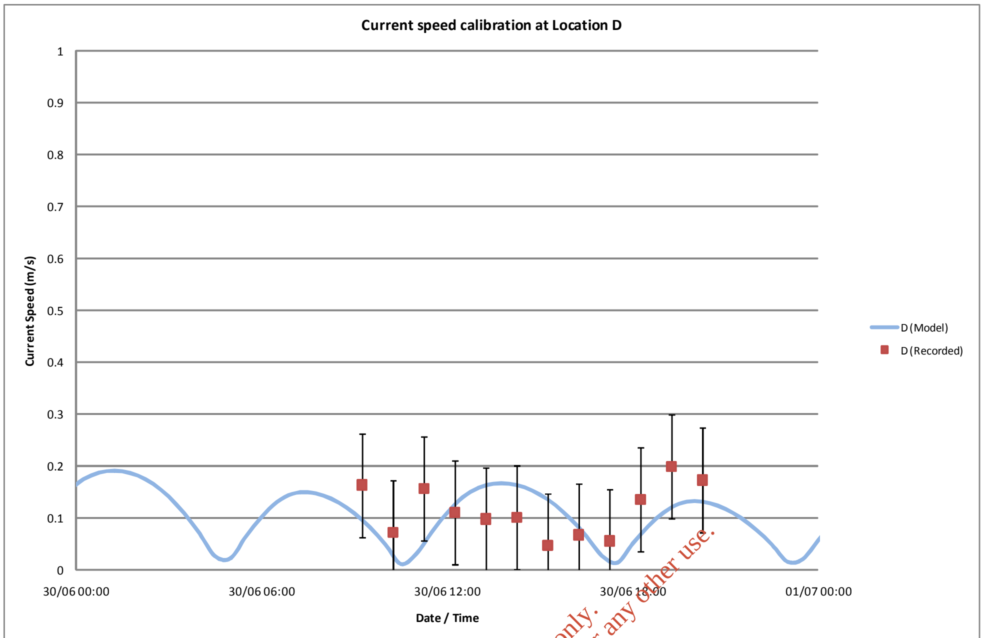

Figure 23: Current speed calibration at location D (30/06/09)

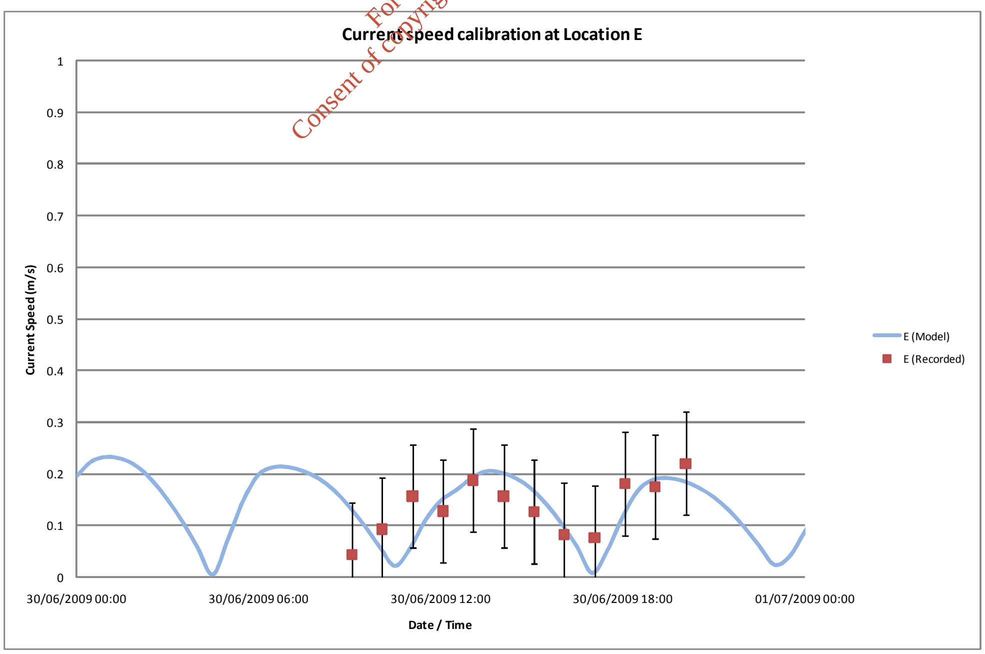

Figure 24: Current speed calibration at location E (30/06/09)

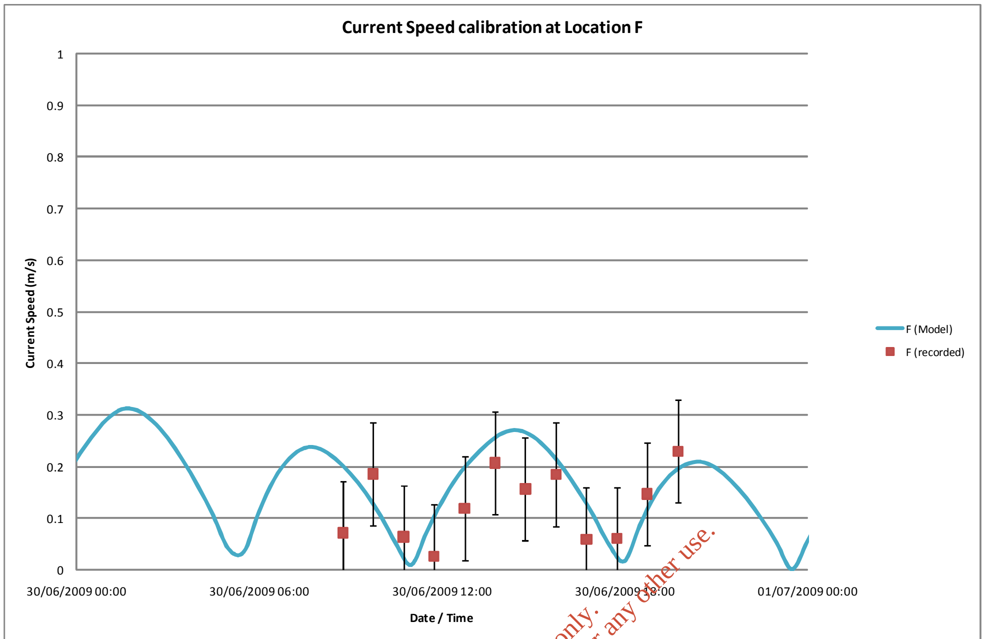

Figure 25: Current speed calibration at location F (30/06/09)

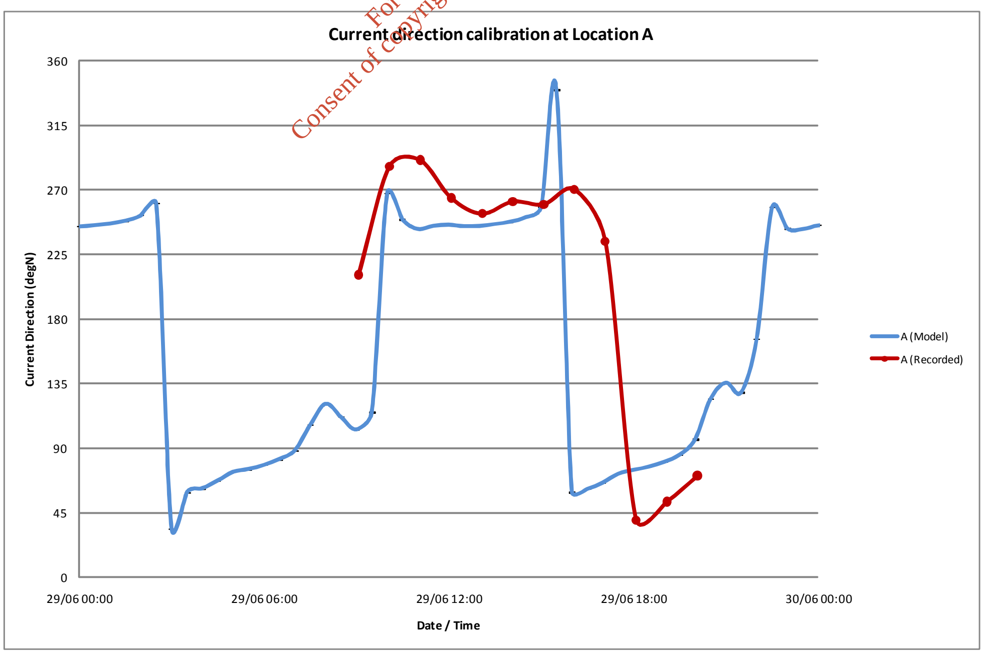

Figure 26: Current direction calibration at location A (29/06/09)

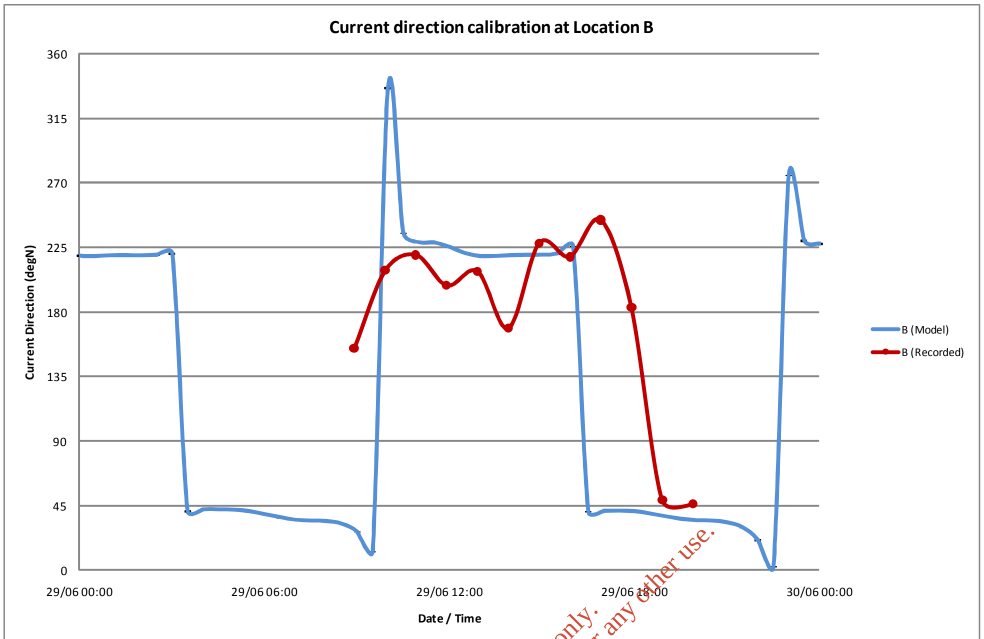

Figure 27: Current direction calibration at location B (29/06/09)

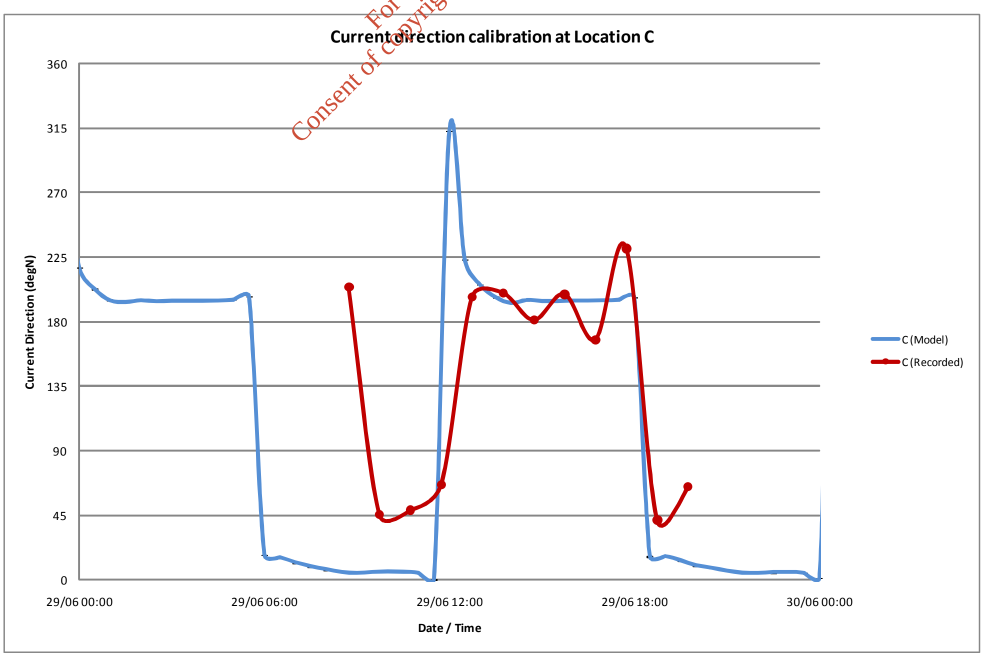

Figure 28: Current direction calibration at location C (29/06/09)

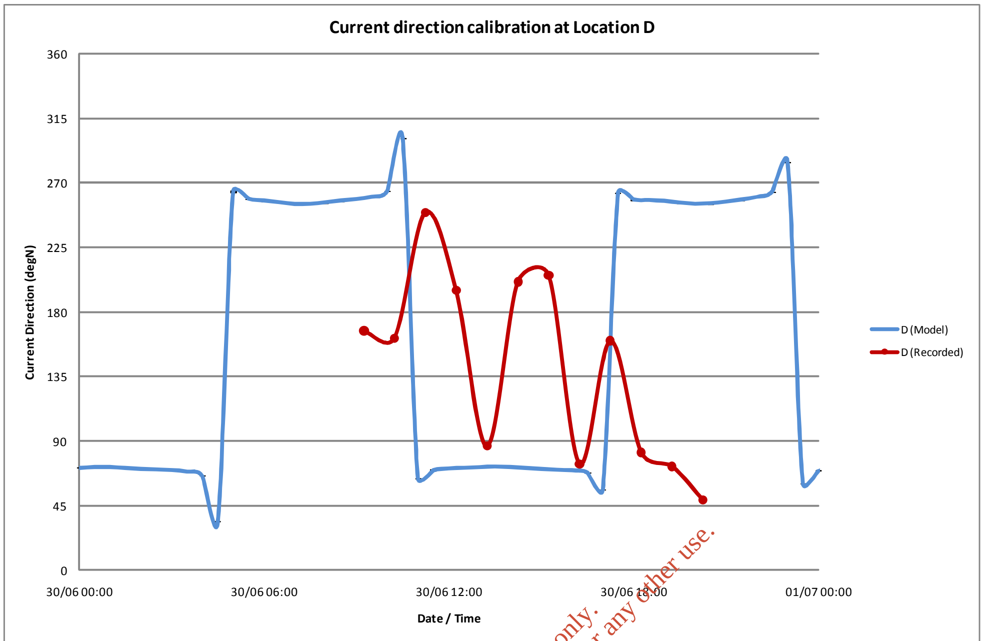

Figure 29: Current direction calibration at location D (30/06/09)

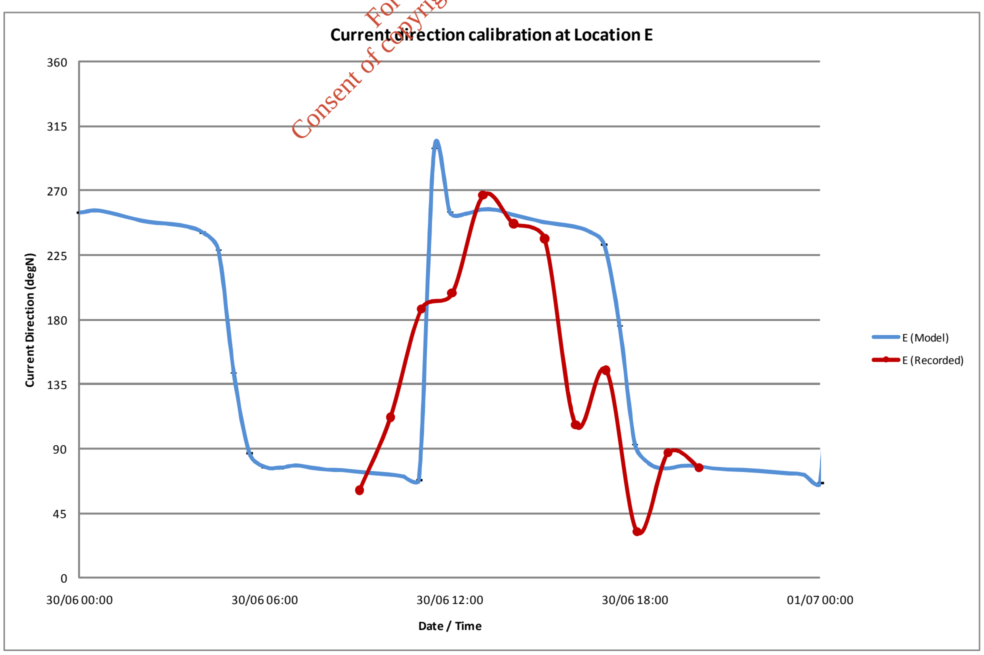

Figure 30: Current direction calibration at location E (30/06/09)

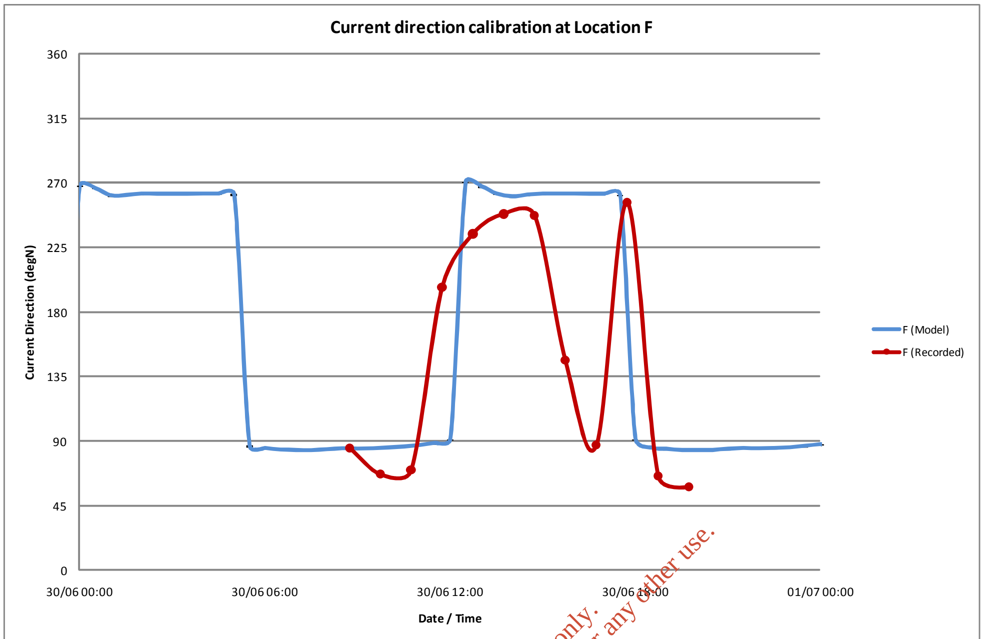

Figure 31: Current direction calibration at location F (30/06/09)

3.6 Hydrodynamic model calibration: July Spot Current Metering

3.6.1 Figure 32 through Figure 37 present the comparison of the current speed as predicted by the numerical model against the spot recorded current speeds at locations A - F in Castletownbere Harbour on 07/07/2009 & 08/07/2009.

3.6.2 Figure 38 through Figure 43 present the comparison of the current direction as predicted by the numerical model against the spot recorded current speeds at locations A - F in Castletownbere Harbour on 07/07/2009 & 08/07/2009.

3.6.3 From these figures it can be seen that the numerical model predicts both the current speed and current direction relatively accurately at locations A, C, & F, but that there is disagreement at locations B, D & E for both the magnitude of the current speed and variation in current direction.

3.6.4 As the model shows good agreement at C, A & F for the magnitude and phase of current direction, it could be assumed that the spot meter records at locations B & E may have been influenced by some localised or temporal effects not adequately captured within the resolution of the model.

3.6.5 The disagreement between model predictions and spot metering at location D cannot be accounted for, though it must be noted that the recorded data shows that the tide turned direction for only one hour which would not encourage confidence in the readings at that location.

3.6.6 From these figures it can be seen that the numerical model is consistent in accurately predicting the current direction at the proposed outfall location B in Castletownbere Harbour over both spring and neap tides.

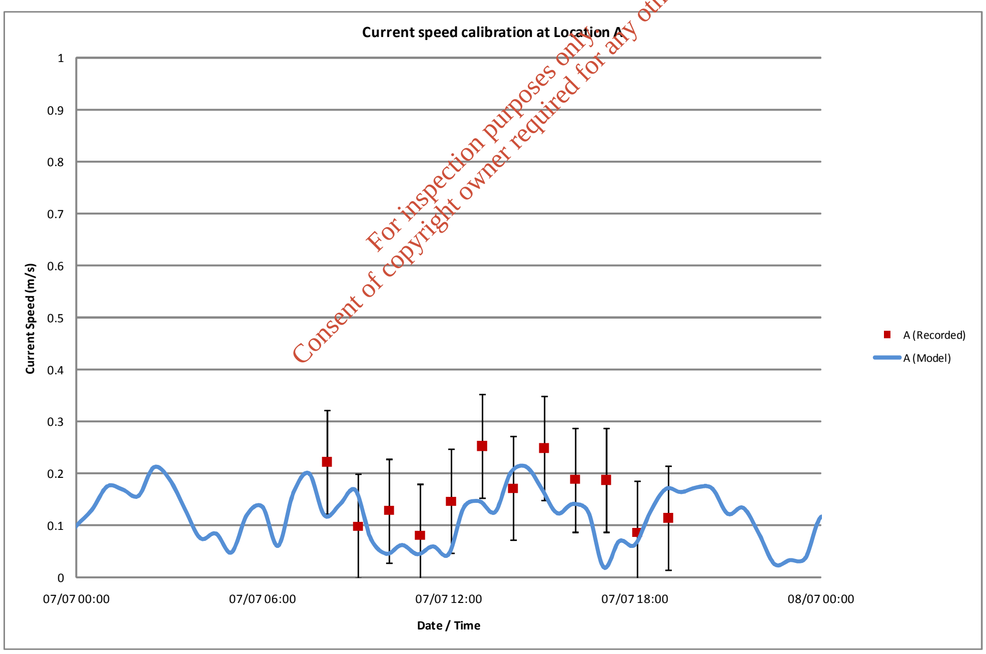

Figure 32: Current speed calibration at location A (07/07/09)

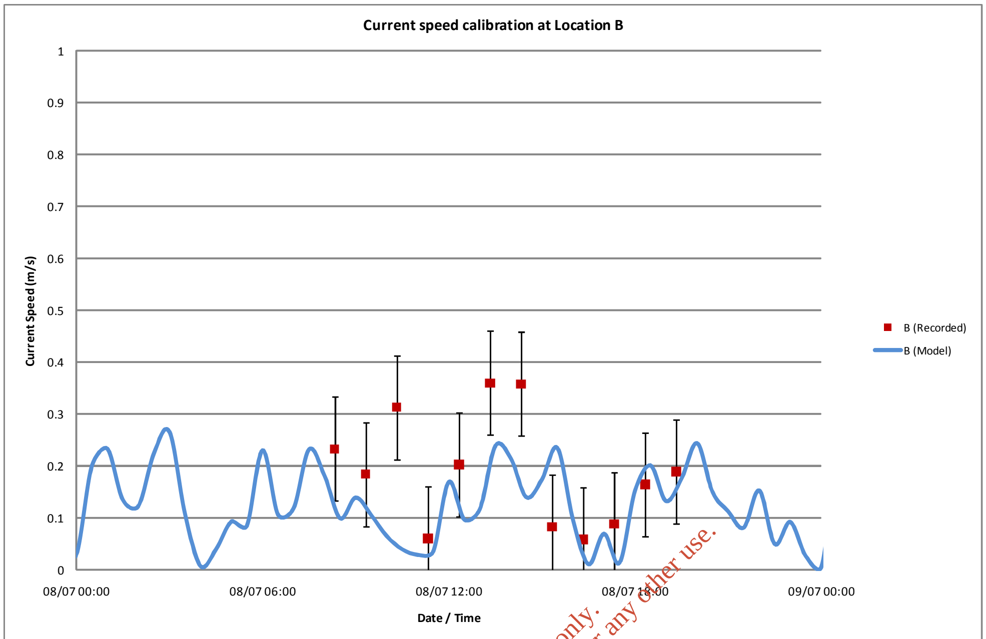

Figure 33: Current speed calibration at location B (08/07/09)

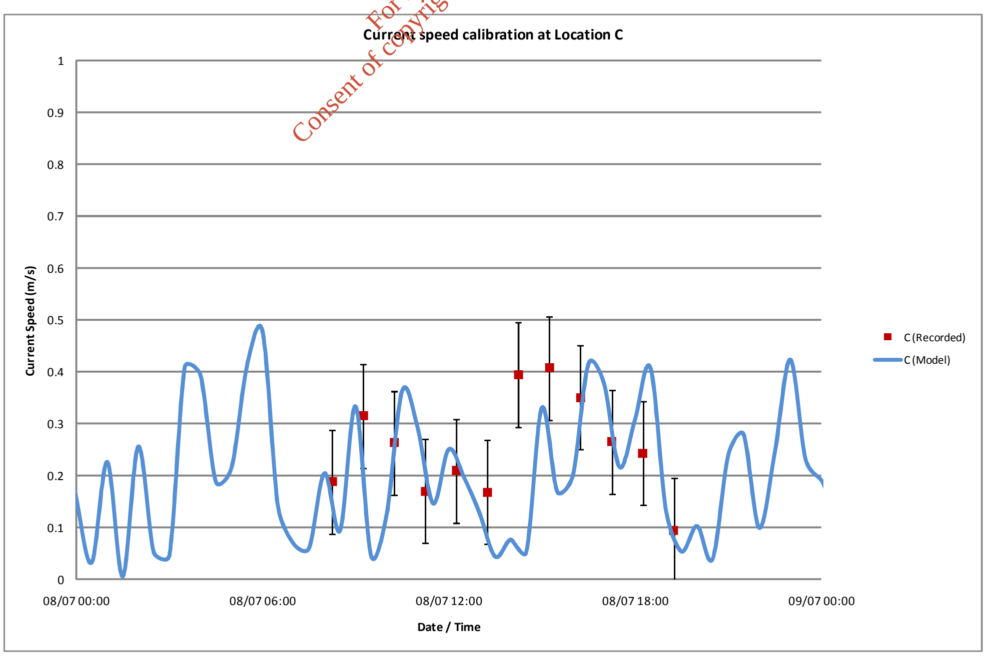

Figure 34: Current speed calibration at location C (08/07/09)

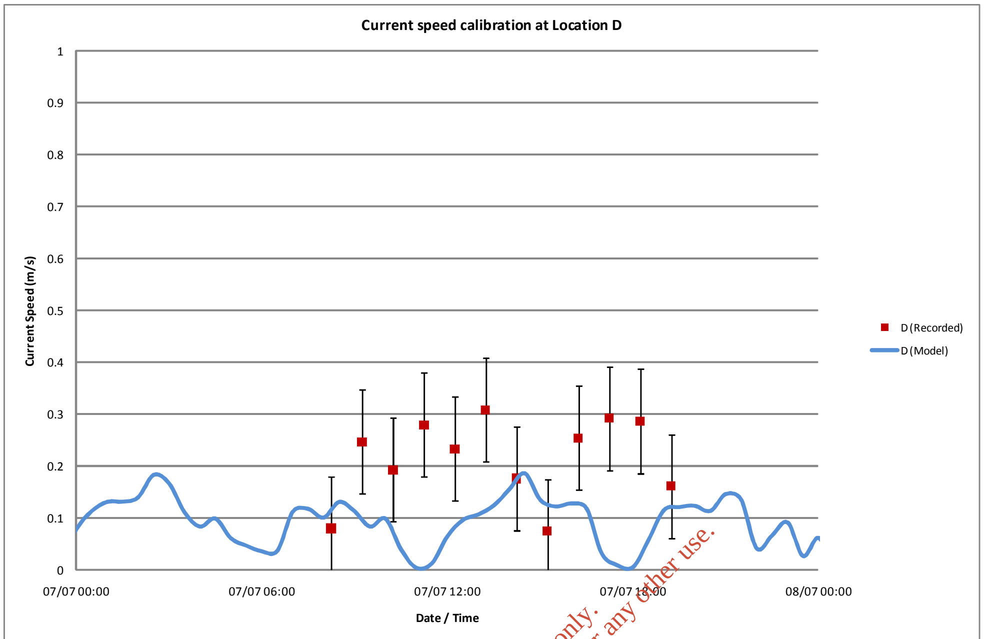

Figure 35: Current speed calibration at location D (07/07/09)

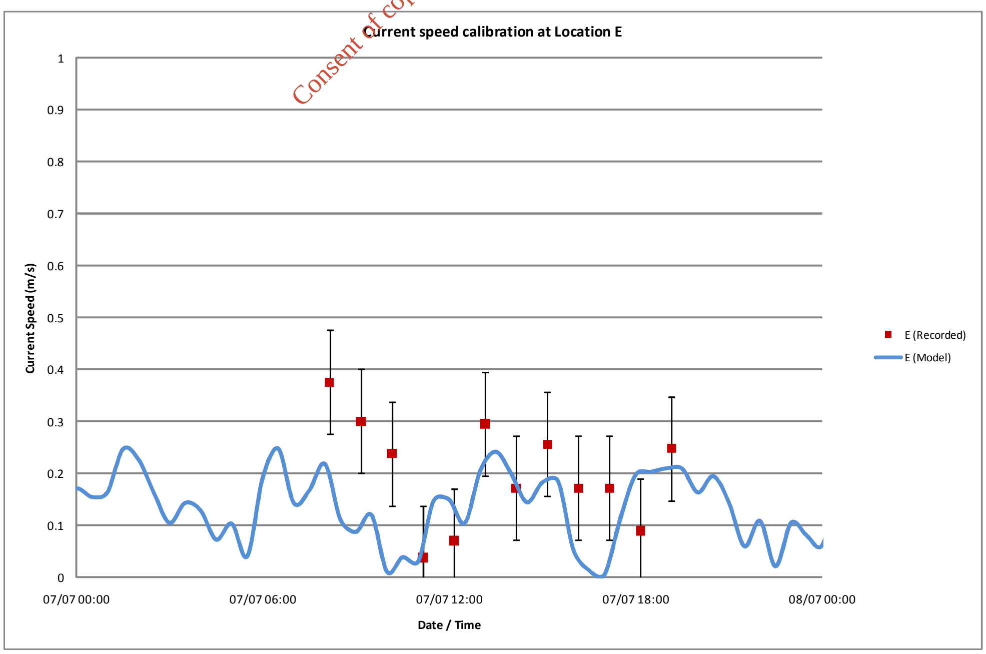

Figure 36: Current speed calibration at location E (07/07/09)

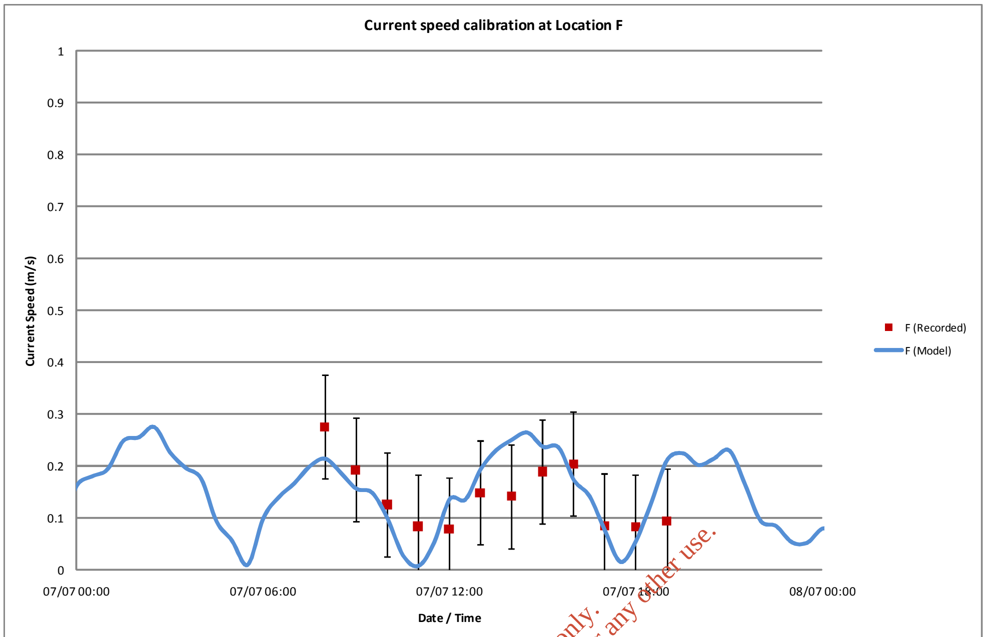

Figure 37: Current speed calibration at location F (07/07/09)

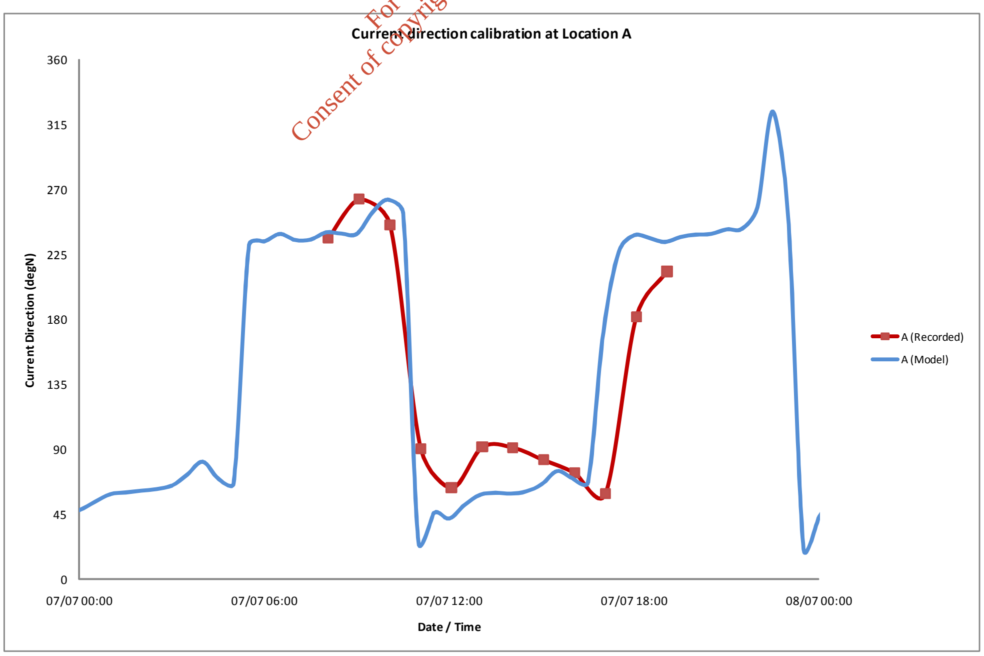

Figure 38: Current direction calibration at location A (07/07/09)

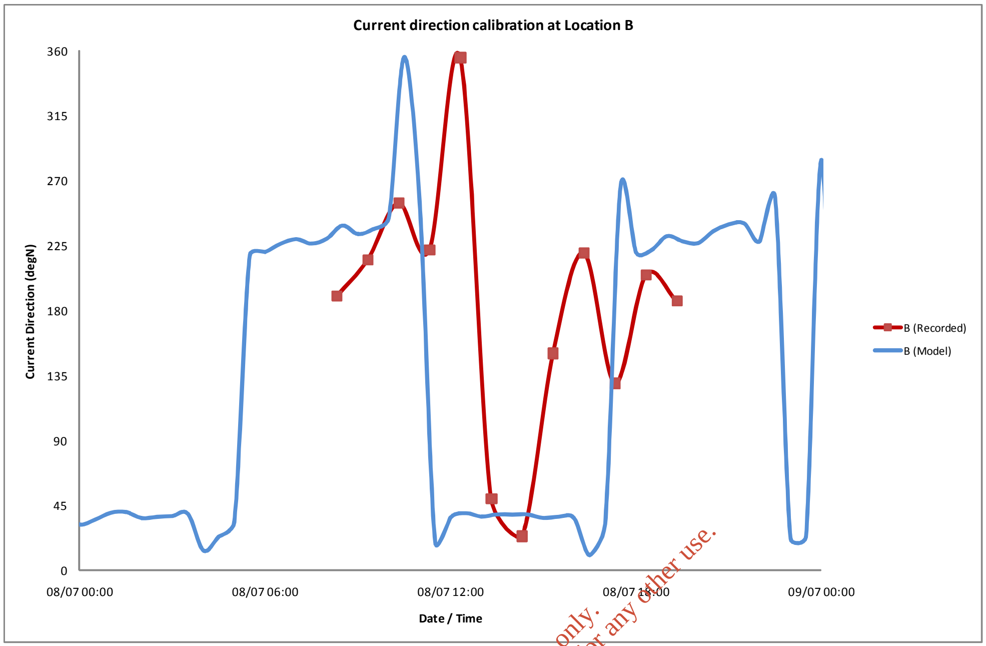

Figure 39: Current direction calibration at location B (08/07/09)

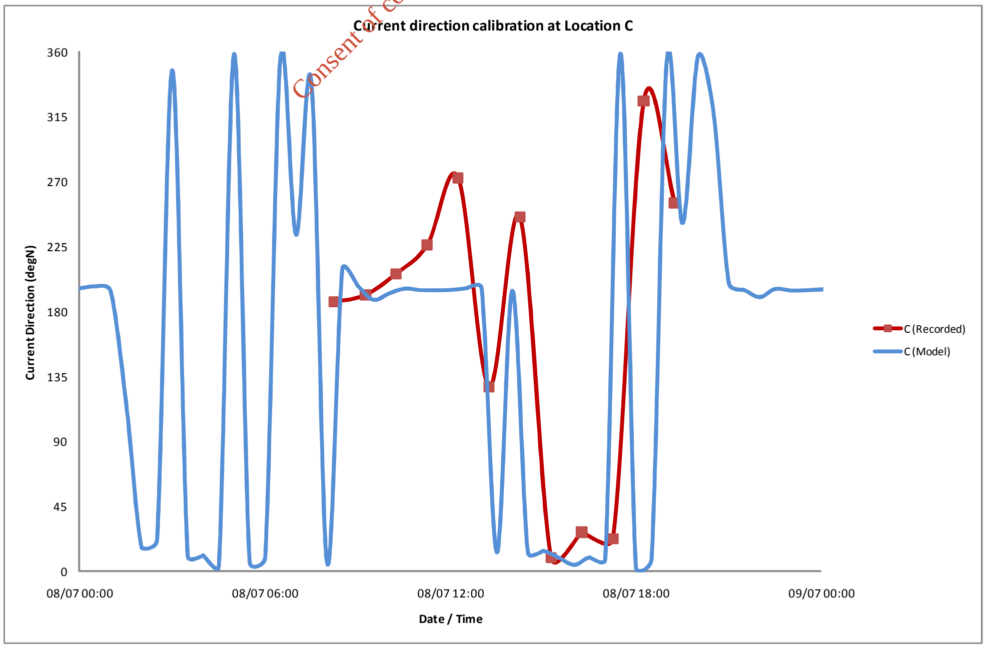

Figure 40: Current direction calibration at location C (08/07/09)

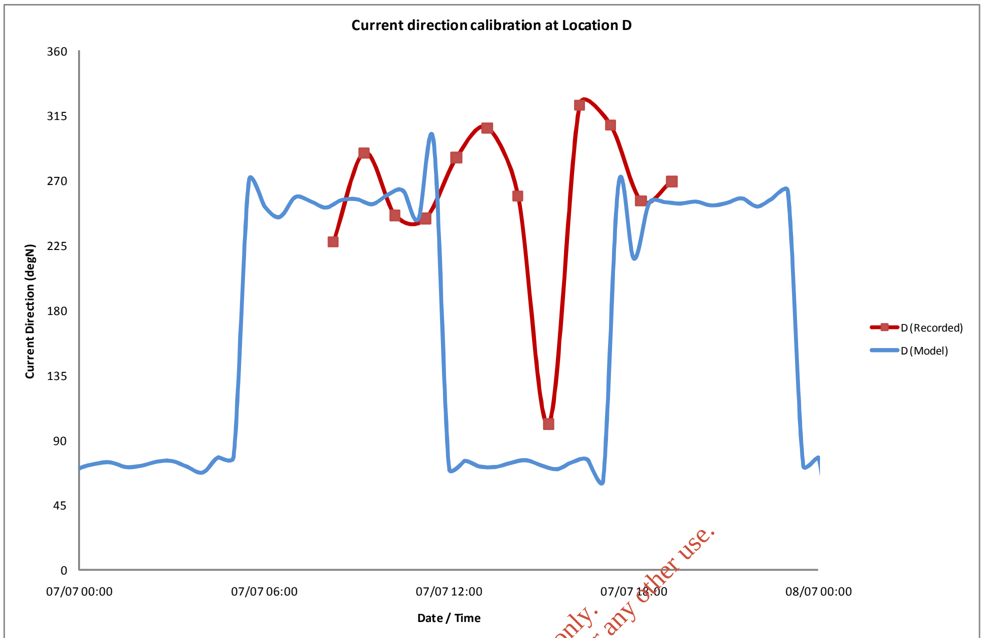

Figure 41: Current direction calibration at location D (07/07/09)

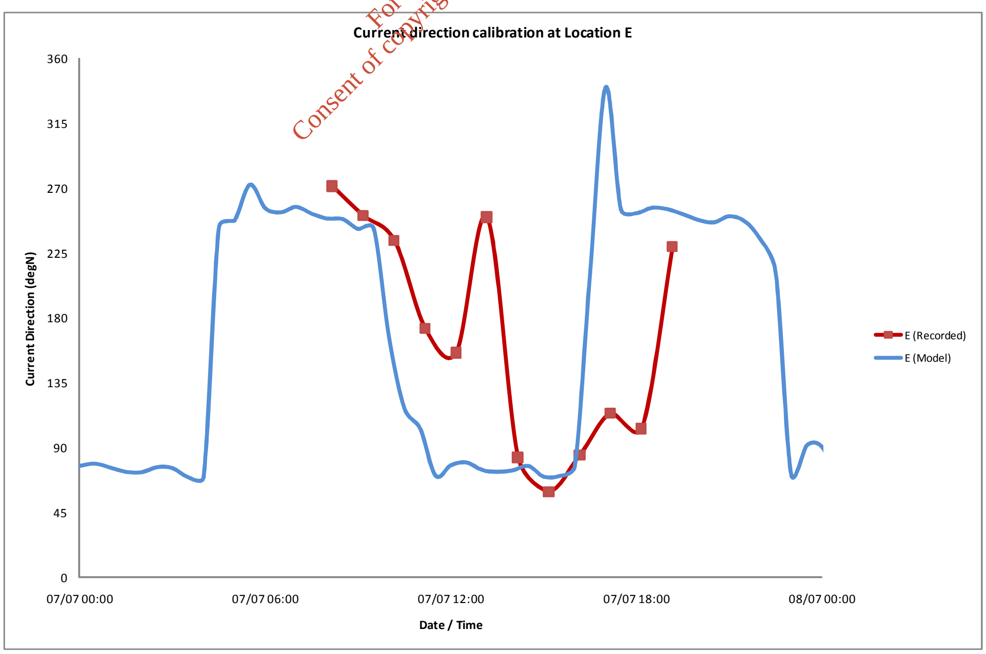

Figure 42: Current direction calibration at location E (07/07/09)

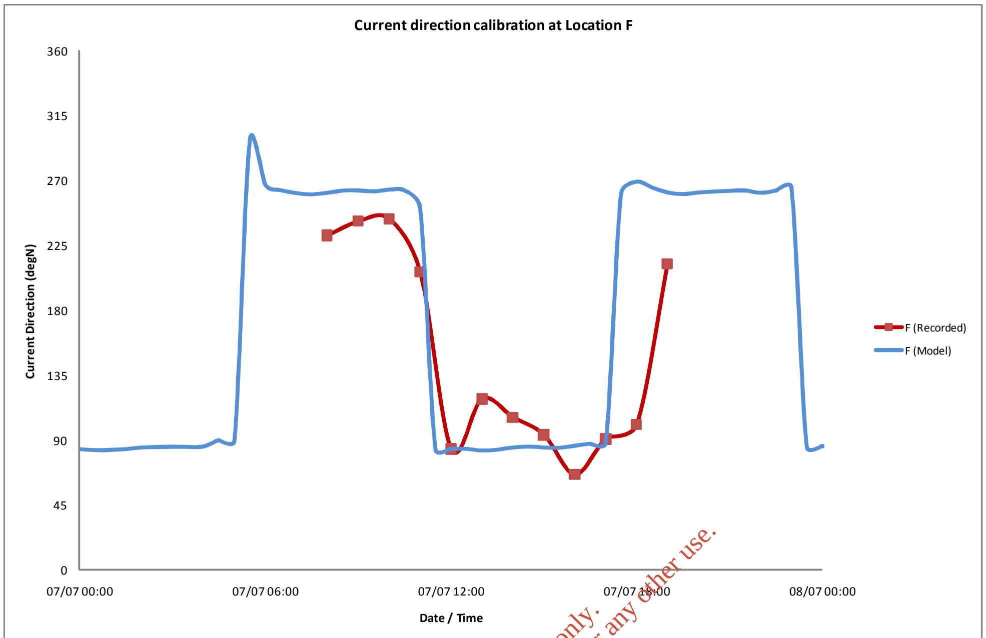

Figure 43: Current direction calibration at location F (07/07/09)

3.7 Hydrodynamic model calibration: Drogue Releases

3.7.1 10No. drogues were released from the DAFF outfall location on 29/06/09 at 08:45, one hour before high water, and continuously tracked until 21:28.

3.7.2 Simulated release of particles in the numerical model was undertaken at the same locations and times as the drogue survey on the date in question. Results from the particle tracking simulations were plotted at hourly intervals.

3.7.3 Figure 44 presents the predicted transport of a neutrally buoyant particle by the numerical model, superimposed on the recorded positions of the drogues released on 29/06/09.

3.7.4 Drogue locations, represented by flags in Figure 44, and particle results, represented by circles in Figure 44, are colour coded in hourly intervals after release.

3.7.5 The black line in Figure 44 represents the path of the drogues in the day of the field survey; the pink line represents the path of the simulated particle in the numerical model.

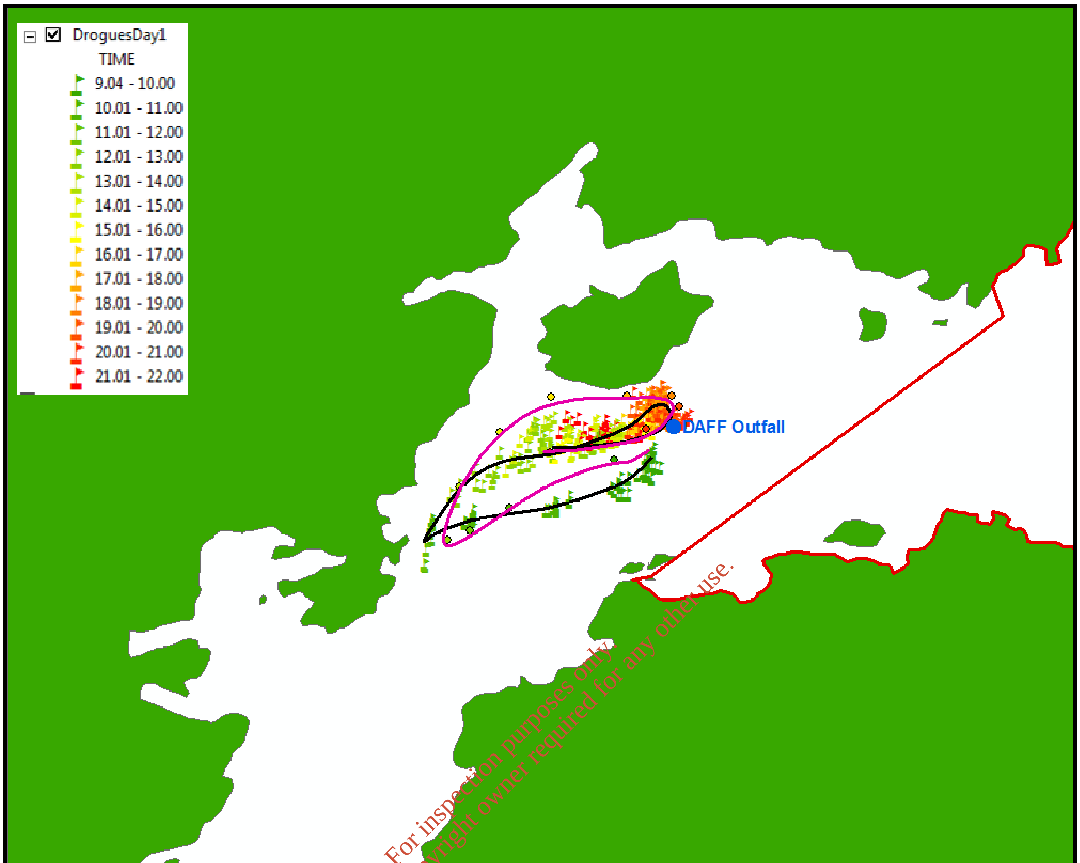

Figure 44: Drogue calibration 29/06/2009

3.7.6 The particle simulated in the numerical model shows good general agreement with the recorded transport of the drogues on 29/06/09.

3.7.7 10No. drogues were released from Point B on 30/06/09 at 08:35, two hours before high water, and continuously tracked until 21:03.

3.7.8 Simulated release of particles in the numerical model was undertaken at the same locations and times as the drogue survey on the date in question. Results from the particle tracking simulations were plotted at hourly intervals.

3.7.9 Figure 45 presents the predicted transport of a neutrally buoyant particle by the numerical model, superimposed on the recorded positions of the drogues released on 30/06/09.

3.7.10 Drogue locations, represented by flags in Figure 45, and particle results, represented by circles in Figure 45, are colour coded in hourly intervals after release.

3.7.11 The black line in Figure 45 represents the path of the drogues in the day of the field survey; the pink line represents the path of the simulated particle in the numerical model.

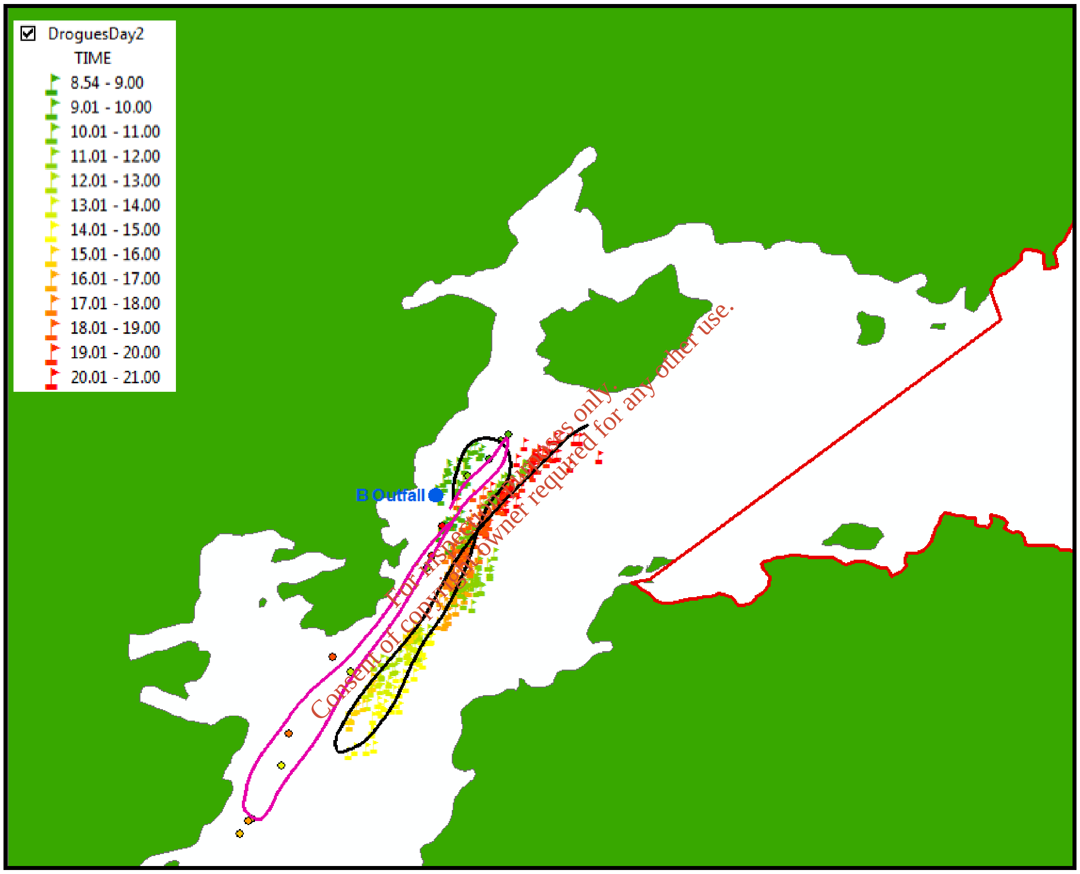

Figure 45: Drogue calibration 30/06/2009

3.7.12 The particle simulated in the numerical model shows good general agreement, though slightly greater transport on the ebb tide, when compared with the recorded transport of the drogues on 30/06/09.

3.7.13 10No. drogues were released from the DAFF outfall location on 07/07/09. They were first deployed at 08:45, two hours before low water, and thereafter were recovered and released on an hourly basis until 21:03.

3.7.14 Simulated release of particles in the numerical model was undertaken at the same locations and times as the drogue survey on the date in question. Results from the particle tracking simulations were plotted at hourly intervals.

3.7.15 Figure 46 presents the predicted transport of a neutrally buoyant particle by the numerical model, superimposed on the recorded positions of the drogues released on 07/07/09.

3.7.16 Drogue locations, represented by flags in Figure 46, and particle results, represented by circles in Figure 46, are colour coded according in hourly intervals after 08:45.

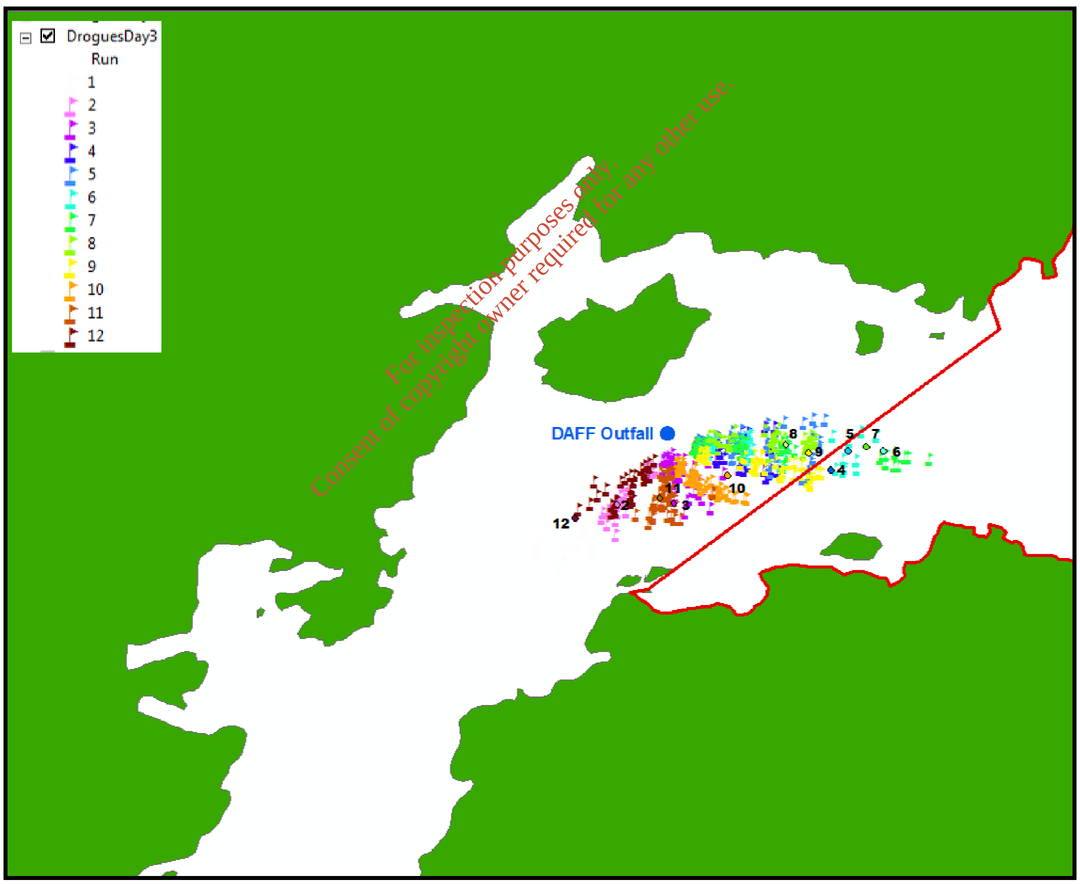

Figure 46: Drogue calibration 07/07/2009

3.7.17 Figure 47 presents the predicted transport of a neutrally buoyant particle by the numerical model, superimposed on the recorded positions of the drogue released during Day 4 of the drogue survey.

3.7.18 The particle simulated in the numerical model shows good general agreement with the recorded transport of the drogues on 07/07/09.

3.7.19 10No. drogues were released from the E outfall location on 08/07/09. They were first deployed at 08:45, 2.5 hours before low water, and thereafter were recovered and released on an hourly basis until 19:46.

3.7.20 Simulated release of particles in the numerical model was undertaken at the same locations and times as the drogue survey on the date in question. Results from the particle tracking simulations were plotted at hourly intervals.

3.7.21 Figure 47 presents the predicted transport of a neutrally buoyant particle by the numerical model, superimposed on the recorded positions of the drogues released on 08/07/09.

3.7.22 Drogue locations, represented by flags in Figure 47, and particle results, represented by circles in Figure 47, are colour coded according in hourly intervals after 08:45.

3.7.23 The particle simulated in the numerical model shows good general agreement with the recorded transport of the drogues on 08/07/09.

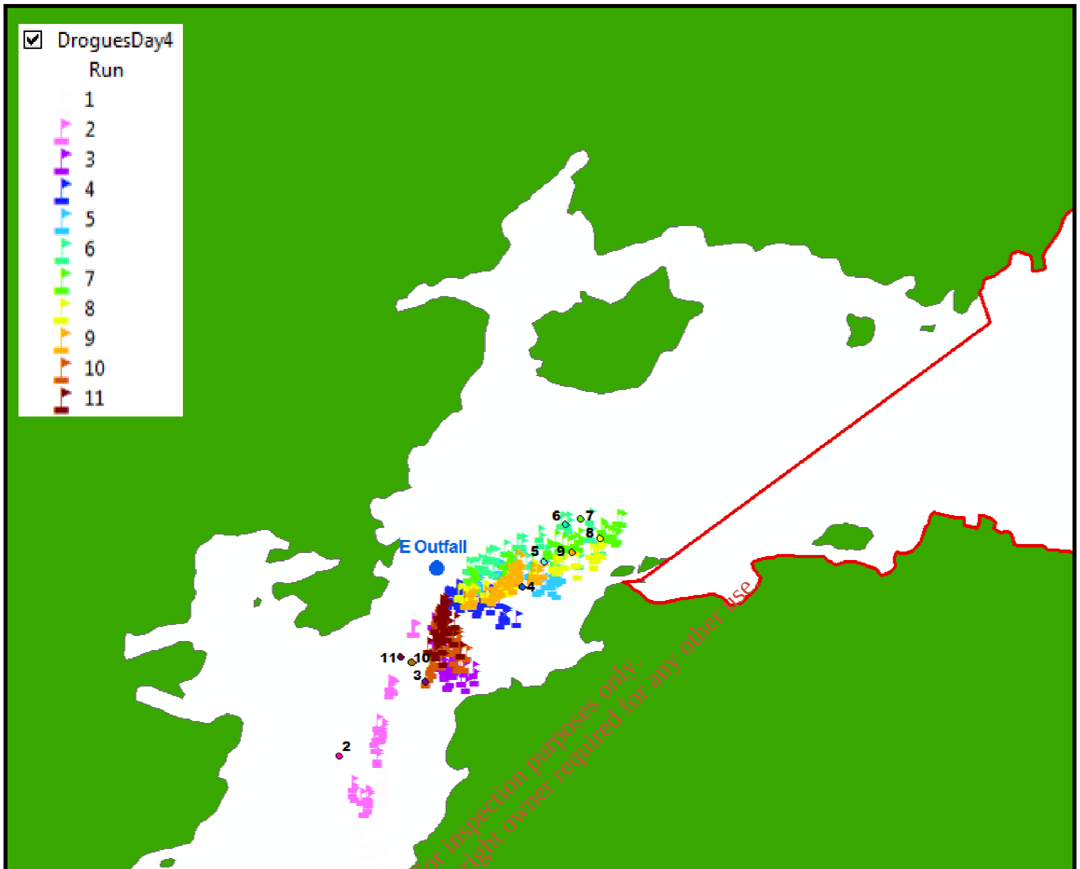

Figure 47: Drogue calibration 08/07/2009

3.8 Hydrodynamic model current vectors

3.8.1 Presented in Figure 48 through Figure 55 are the velocity vectors as predicted by the calibrated numerical model throughout the area of interest at four stages of the tide; namely mid ebb, low water, mid flood and high water for both a neap and spring tide respectively.

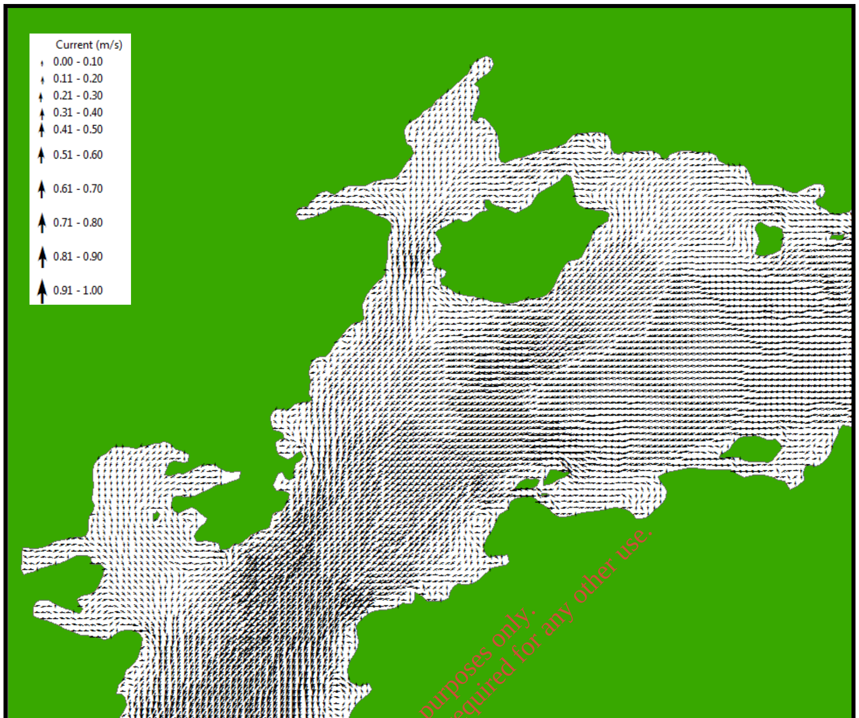

Figure 48: Current vectors mid ebb neap tide.

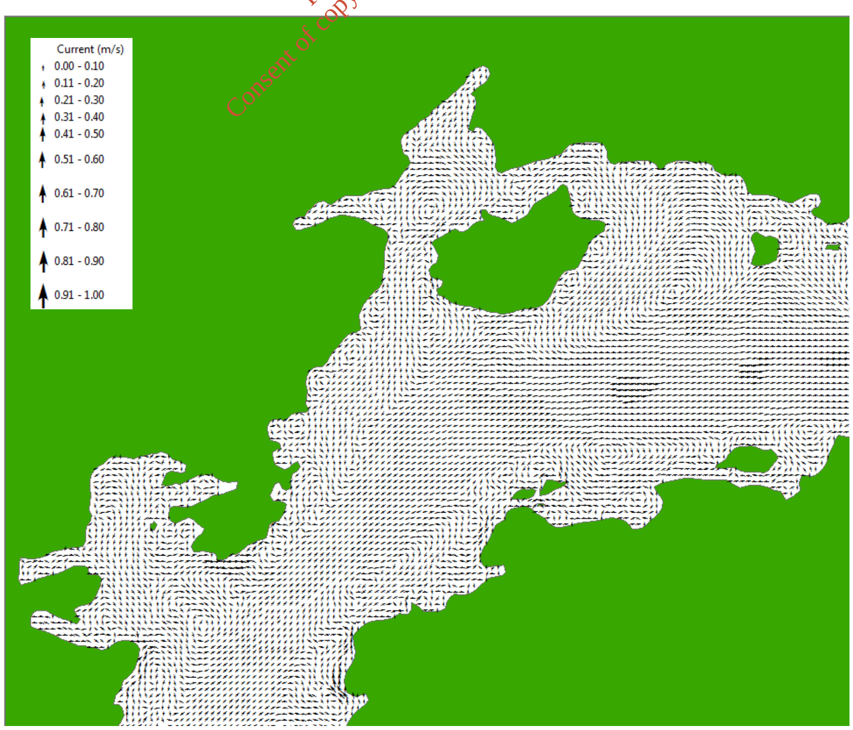

Figure 49: Current vectors low water neap tide.

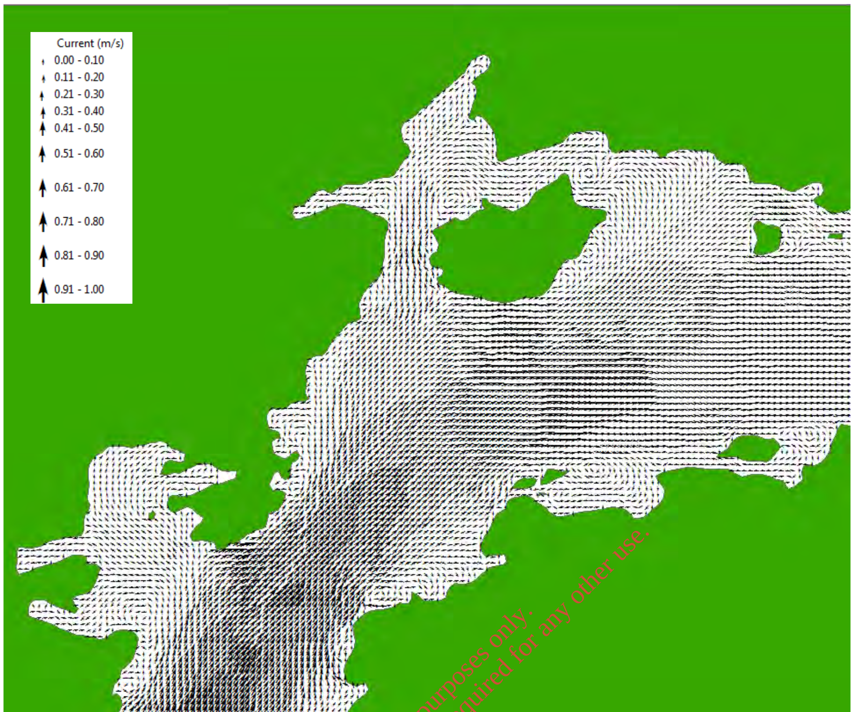

Figure 50: Current vectors mid flood neap tide.

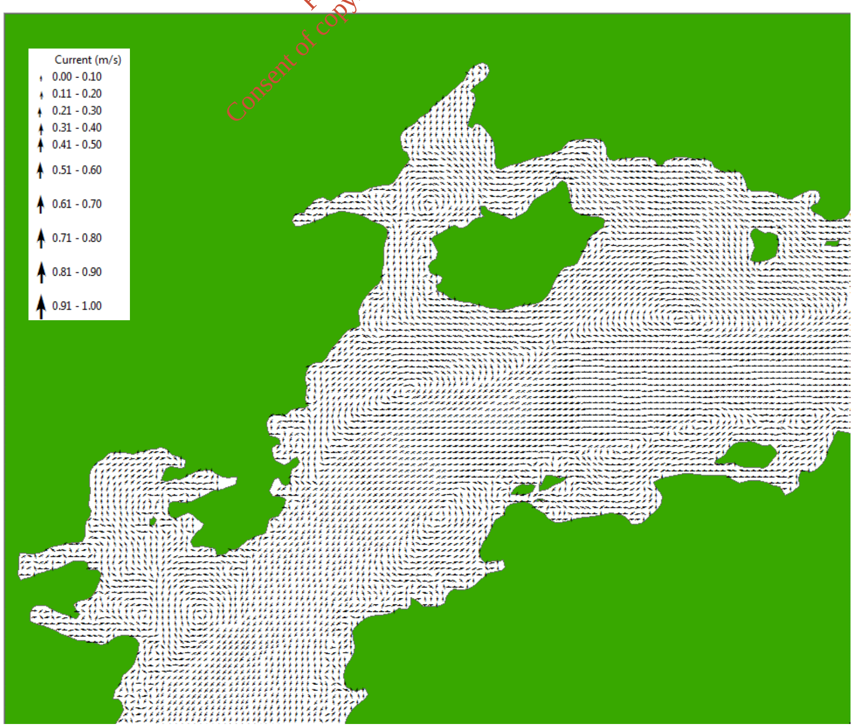

Figure 51: Current vectors high water neap tide.

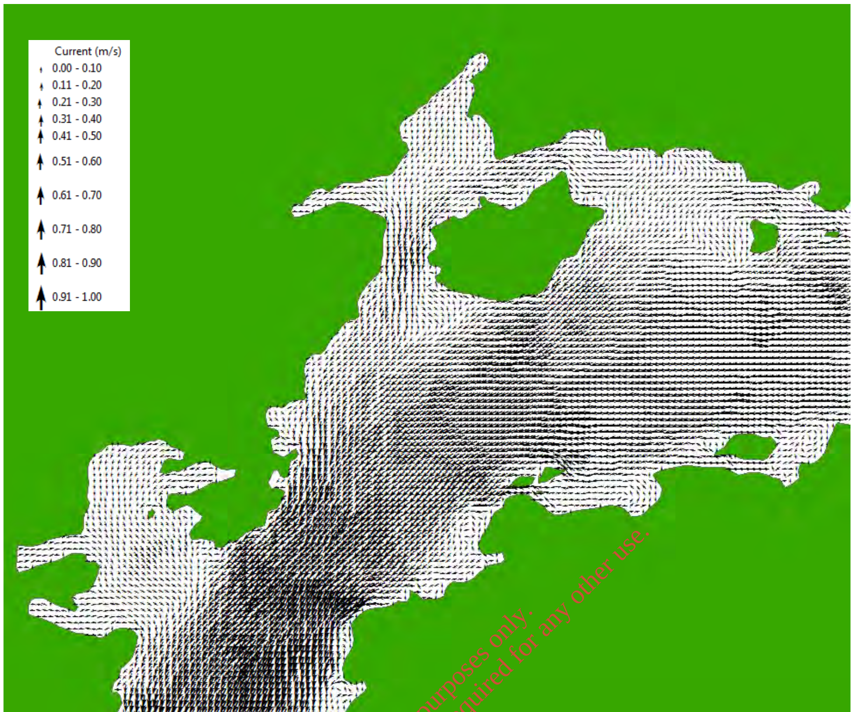

Figure 52: Current vectors mid ebb spring tide.

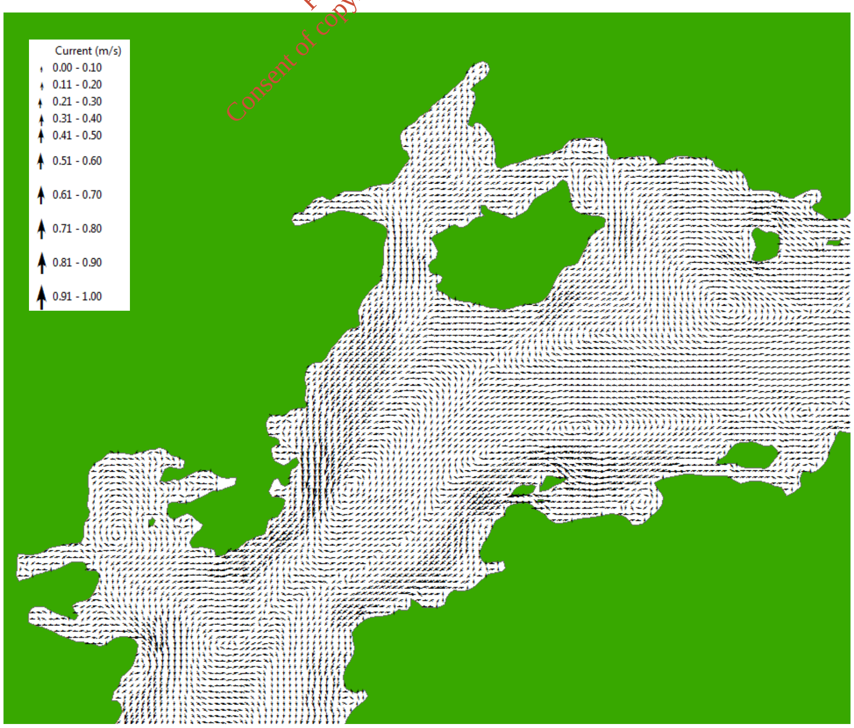

Figure 53: Current vectors low water spring tide.

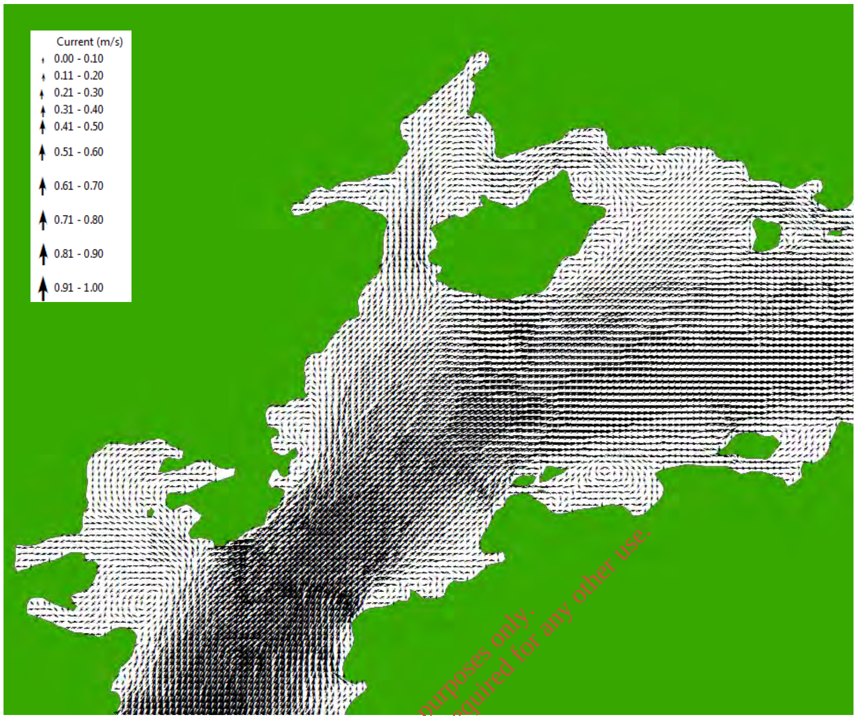

Figure 54: Current vectors mid flood spring tide.

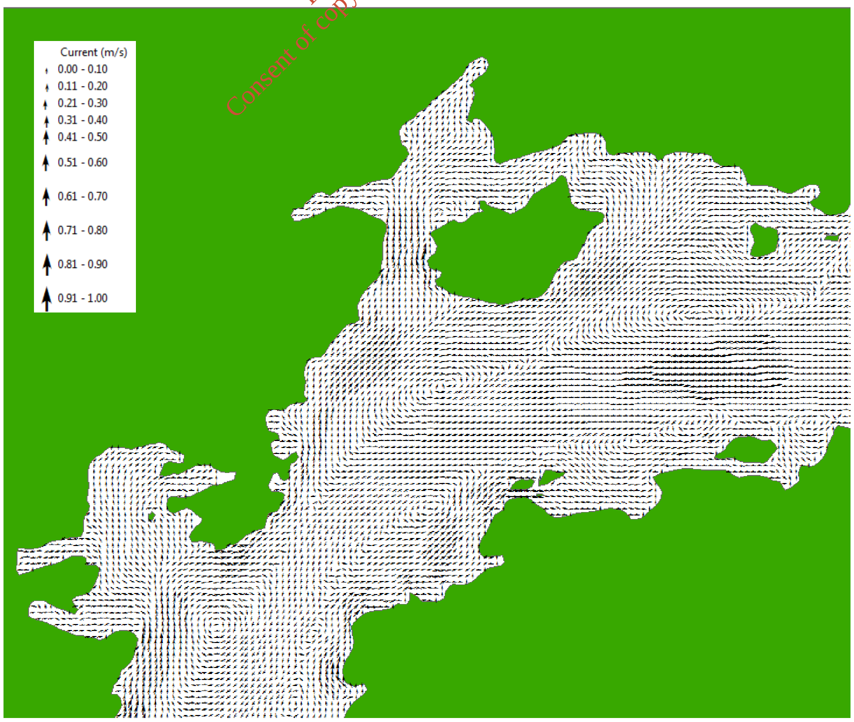

Figure 55: Current vectors high water spring tide.

3.9 Calibration Discussion.

3.9.1 The hydrodynamic model was calibrated by comparing model predictions against field measurements of water surface elevations, long term current speeds, short term current speeds, drogue releases and dye releases for given environmental conditions.

3.9.2 The hydrodynamic model accurately predicted the tidal range and phase at Castletownbere Harbour tide gauge station as presented in Figure 8 to Figure 10.

3.9.3 The hydrodynamic model accurately predicted the long term current speeds and directions recorded by the ADCP at Location B, including the change in current magnitude and direction on both flood and ebb tides and over a spring neap cycle, as presented in Figure 11 to Figure 18.

3.9.4 The hydrodynamic model predicted to a fair degree of accuracy the short term current speeds and directions at location A through F for the June recorded dataset as presented in Figure 20 to Figure 31.

3.9.5 The hydrodynamic model predicted to a fair degree of accuracy the short term current speeds and directions at locations A, C & F for the July recorded dataset as presented in Figure 32 to Figure 43.

3.9.6 The hydrodynamic model predicted with less accuracy the short term current speeds and directions at locations B,D & E for the July recorded dataset as presented in Figure 32 to Figure 43.

3.9.7 The hydrodynamic model accurately simulated the transport of the drogues released during all four surveys as presented in Figure 44 to Figure 47, showing only slightly greater transport on an ebbing tide and slightly less transport on a flooding tide.

4. Model Scenarios

4.1 Introduction

4.1.1 MarCon Computations International Ltd., were commissioned by Tobin Consulting Engineers to undertake a detailed mathematical modelling study of Castletownbere in order to determine the optimum location(s) and possible impacts on the receiving waters of discharging effluent from the proposed Castletownbere Sewage Scheme and Regional Water Supply Scheme outfalls.

4.1.2 The calibrated hydrodynamic and solute transport model of Castletownbere was used to undertake a range of modelling scenarios, in consultation with the client, pursuant to the above objectives.

4.1.3 The model scenarios are listed in Table 1, with specific details pertaining to each model scenario tabulated in the relevant model scenario sections below.

Scenario No.	Outfalls	Parameter	Condition	Purpose
1	B1 & E	FCL*	T90 = 24hr	Sensitivity
2	B1 & E	FCL*	T90 = 36hr	Sensitivity
3	B1 & E	FCL*	T90 = 48hr	Sensitivity
4	B1 & E	FCL**	Outfall location	Analysis
5	B1-70m & E-70m	FCL**	Outfall location	Analysis
6	B1+70m & E+70m	FCL**	Outfall location	Analysis
7	B1 & E	FCL**	Adverse wind	Analysis
8	B1-70m & DAFF	All	Proposed	Analysis
8b	B1-70m & DAFF	FCL***	Proposed	Analysis
9	Existing outfalls	All	3xDWF	Baseline
10	Existing outfalls	All	Storm flow	Analysis
11	Proposed overflows	All	Storm flow	Analysis
12	B1-70m	FCL*	1hr ebb tide discharge	Analysis

Table 1: Model Scenarios

*no disinfection (effluent concentration = 2,000,000 mpn/100ml)
**disinfection (effluent concentration = 150,000 mpn/100ml)
***minimal disinfection (effluent concentration = 1,000,000 mpn/100ml)

4.2 Water Quality Standards.

4.2.1 Shellfish area

4.2.1.1 The Shellfish Water Directive (79/923/EEC) states that a mandatory value of <300 faecal coliforms/100ml applies "in the shellfish flesh and intervalvular fluid", and as a footnote it also adds that – "however, pending the adoption of another Directive, on the protection of the consumers of shellfish products, it is essential that this value (i.e 300 faecal coliforms/100ml) be observed in the waters in which live shellfish directly edible by man.

4.2.1.2 A further EC Directive 'laying down the health conditions for the production and the placing on the market of live bivalve molluscs' (CEC,1991c) reiterated the water quality parameters of the earlier Directive as well as additional guidelines for harvesting, transportation, and purification centres.

4.2.1.3 International standards are even stricter however, with the World Health Organisation, WHO, and the United Nations Environmental Programme, UNEP, requiring that the faecal coliform median or geometric mean must not to exceed 14 MPN/100 ml, and that not more than 10 percent may exceed 43 MPN/100 ml (MPN = Most Probable Number). These standards have also been adopted by the National Shellfish Sanitation Program, NSSP, in the US.

4.2.1.4 For the purpose of this study, the more rigorous international standards defined by the WHO and UNEP, above, were chosen to report against.

4.2.2 Trophic Status

4.2.2.1 In 2001, the EPA completed the development of a set of Trophic Status Assessment criteria for Irish estuaries and bays, based on the definition of eutrophication employed in the Urban Waste Water Treatment Directive (Council of the European Communities (CEC), 1991a) and, in relation to nitrogen only, in the Nitrates Directive (CEC, 1991b).

4.2.2.2 The Trophic Status Assessment system comprises criteria for; the enrichment of water by nutrients (as indicated by measurement of dissolved inorganic nitrogen and phosphorus concentrations); the accelerated growth of algae (as indicated by measurement of chlorophyll concentrations) and undesirable disturbance (as indicated by measurement of oxygen status).

4.2.2.3 The threshold values in respect of each of the criteria were derived with reference to the normal values that would typically be observed in waters with low levels of pollution or nutrient enrichment and are tabulated below in Table 2.

4.2.2.4 This approach is broadly in line with that taken in the WFD, whereby the quality status of particular water bodies is assessed by comparison with those that exhibit the corresponding natural, un-impacted condition.

Category A: (Nutrient Enrichment)	**Numeric Criterion**	**Statistic**	**Applicable Period**
Dissolved Inorganic Nitrgoen (DIN)	> 0.25 mg/l N	Median	Winter or Summer
Orthophosphate	> 0.40 µg/l P	Median	Winter or Summer
Category B: (accelerated growth)	**Numeric Criterion**	**Statistic**	**Applicable Period**
Chlorophyll	>10 µg/l or >20 µg/l	Median and 90%ile	Summer
Category C: (Undesirable disturbance)	**Numeric Criterion**	**Statistic**	**Applicable Period**
Dissolved Oxygen	< 80% or >120%	5%ile and 90%ile	Summer

Table 2: EPA Eutrophic Assessment Criteria.

4.3 Scenario 1

4.3.1 The purpose of this scenario was to investigate the impact at the boundary of the designated shellfish area of discharging untreated faecal coliforms from the proposed outfall locations of B1 & E utilizing a T90 (time during which the original organism population would reduce by 90%) value of 24hours.

4.3.2 Details pertaining to Scenario 1 are tabulated below in Table 3.

Outfall	Flow (m^3/s)	FCL (MPN/100ml)	T90 (hrs)
B1	0.031	2×10^6	24
E	0.031	2×10^6	24

Table 3: Details for Scenario 1

4.3.3 Using the above discharges the numerical model was used to estimate the concentration of faecal coliforms throughout the study area during the course of a spring-neap tidal cycle.

4.3.4 The faecal coliform, loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.3.5 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.3.6 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of faecal coliforms be reached throughout the water body.

4.3.7 Figure 56 presents the predicted faecal colifom concentrations at the boundary of the designated shellfish area from both the B1 and E outfalls.

4.3.8 Results from the scenario are summarised in Table 4.

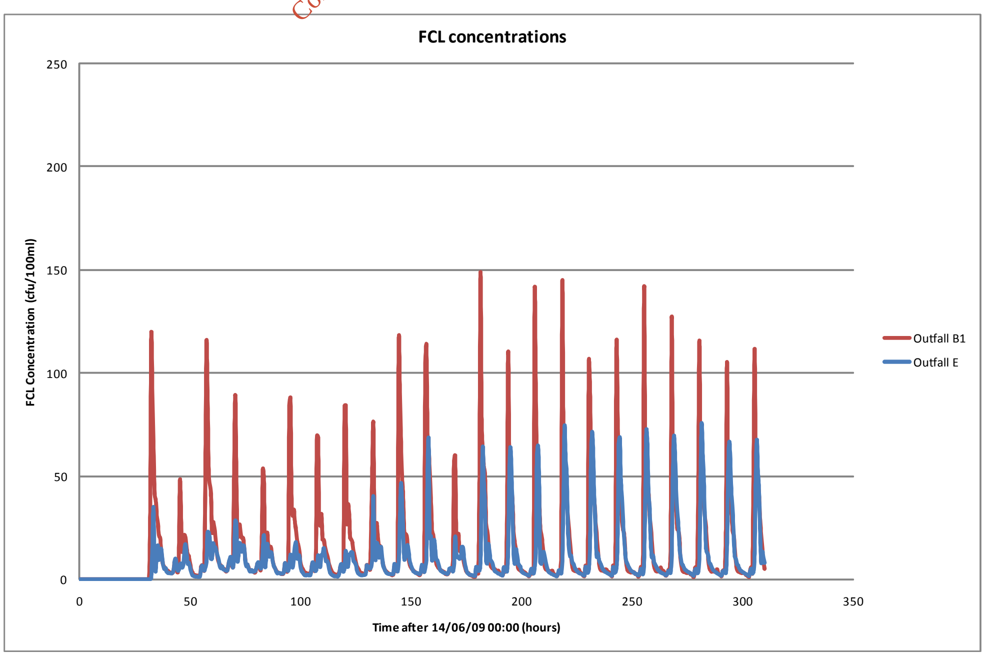

Figure 56: Scenario 1 predicted FCL concentrations

Outfall	Geometric Mean	Maximum	Median	%time >43
B1	9.0	148.5	6.1	13.2
E	6.5	75.3	6.0	6.0

Table 4: Summary of Scenario 1 predicted FCL concentrations

4.4 Scenario 2

4.4.1 The purpose of this scenario was to investigate the impact at the boundary of the designated shellfish area of discharging untreated faecal coliforms from the proposed outfall locations of B1 & E utilizing a T90 (time during which the original organism population would reduce by 90%) value of 36hours.

4.4.2 Details pertaining to Scenario 2 are tabulated below in Table 5.

Outfall	Flow (m^3/s)	FCL (MPN/100ml)	T90 (hrs)
B1	0.031	2×10^6	36
E	0.031	2×10^6	36

Table 5: Details for Scenario 2

4.4.3 Using the above discharges the numerical model was used to estimate the concentration of faecal coliforms throughout the study area during the course of a spring-neap tidal cycle.

4.4.4 The faecal coliform, loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.4.5 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.4.6 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of faecal coliforms be reached throughout the water body.

4.4.7 Figure 57 presents the predicted faecal colifom concentrations at the boundary of the designated shellfish area from both the B1 and E outfalls.

4.4.8 Figure 58 to Figure 65 present snapshots of the faecal coliform plume from outfall B1 at low water, mid flood, high water and mid ebb on both a neap and spring tide respectively.

4.4.9 Results from the scenario are summarised in Table 6.

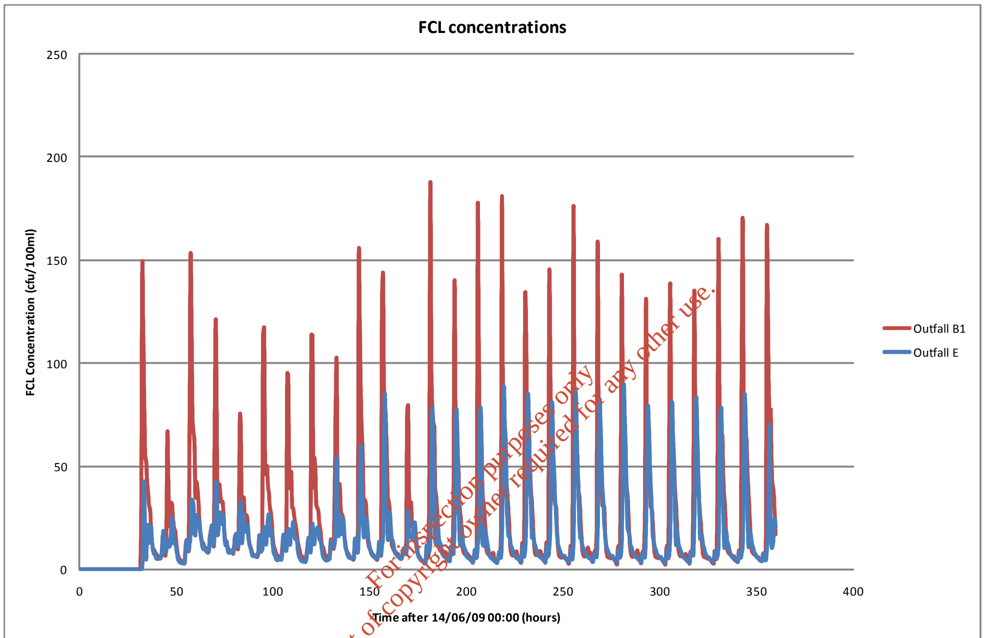

Figure 57: Scenario 2 predicted FCL concentrations

Outfall	Geometric Mean	Maximum	Median	%time >43
B1	15.2	187.6	11.0	19.0
E	11.0	89.5	10.5	9.1

Table 6: Summary of Scenario 2 predicted FCL concentrations

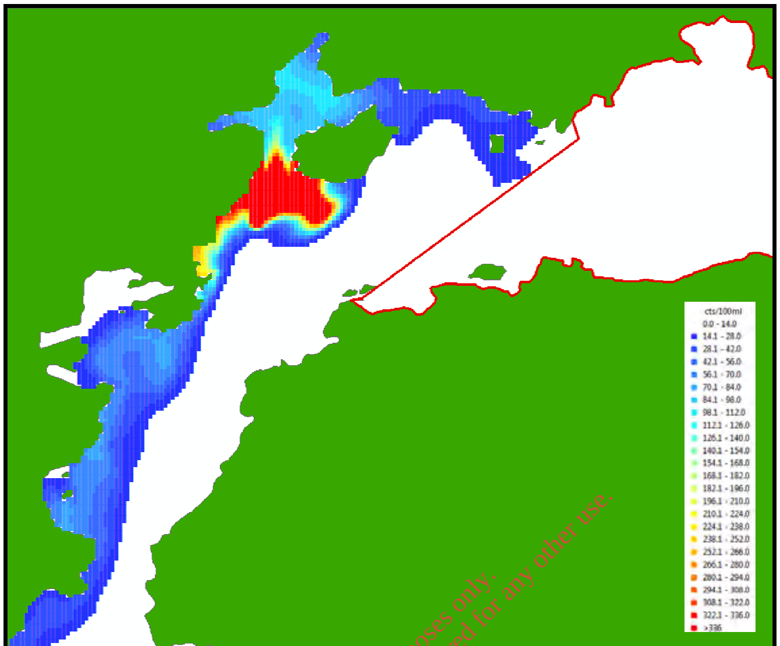

Figure 58: Scenario 2 faecal coliform concentrations neap tide low water

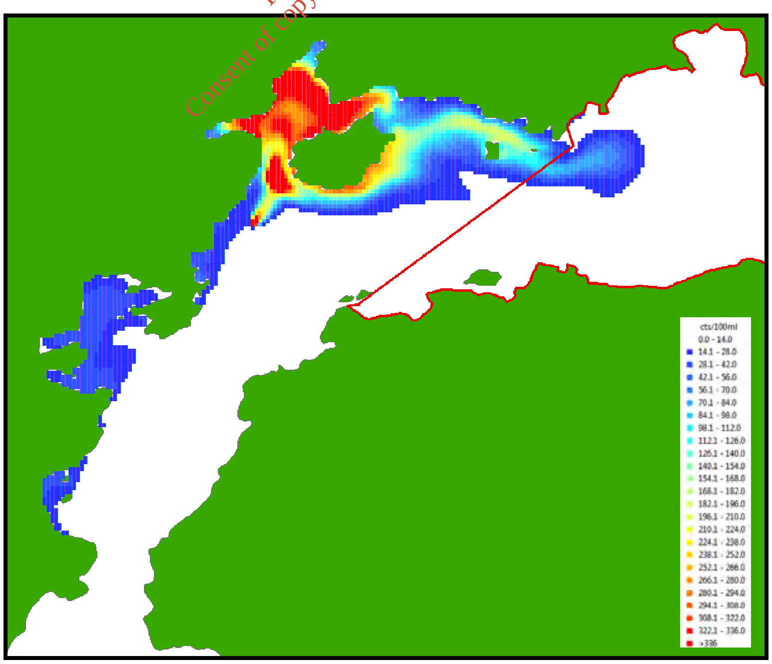

Figure 59: Scenario 2 faecal coliform concentrations neap tide mid flood

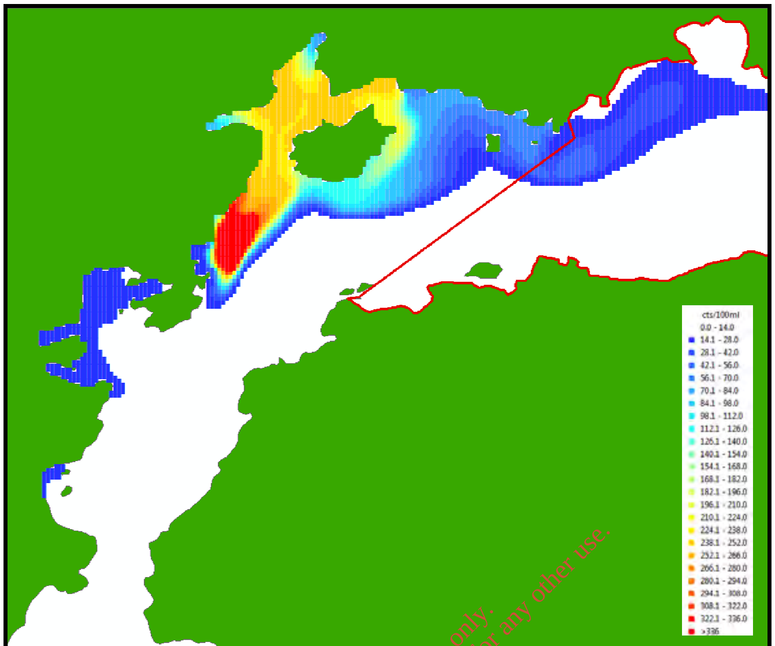

Figure 60: Scenario 2 faecal coliform concentrations neap tide high water

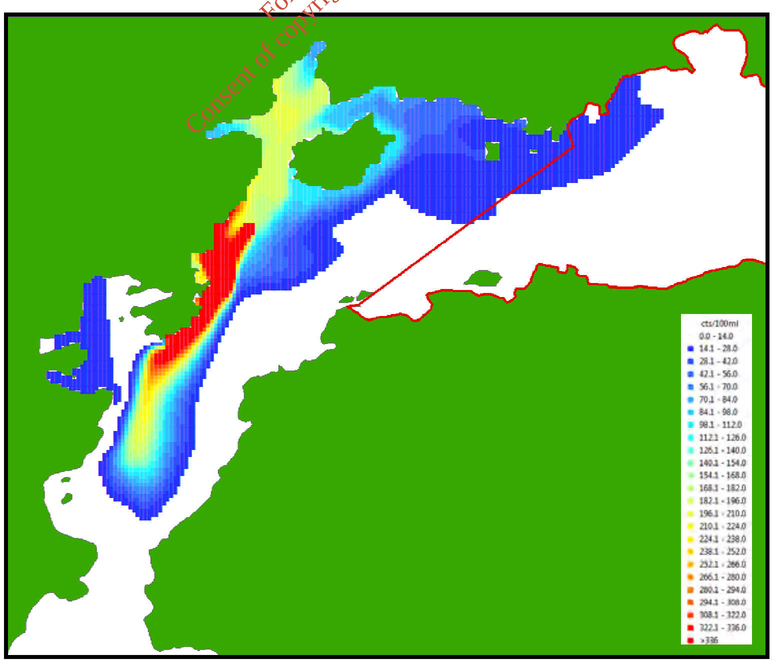

Figure 61: Scenario 2 faecal coliform concentrations neap tide mid ebb

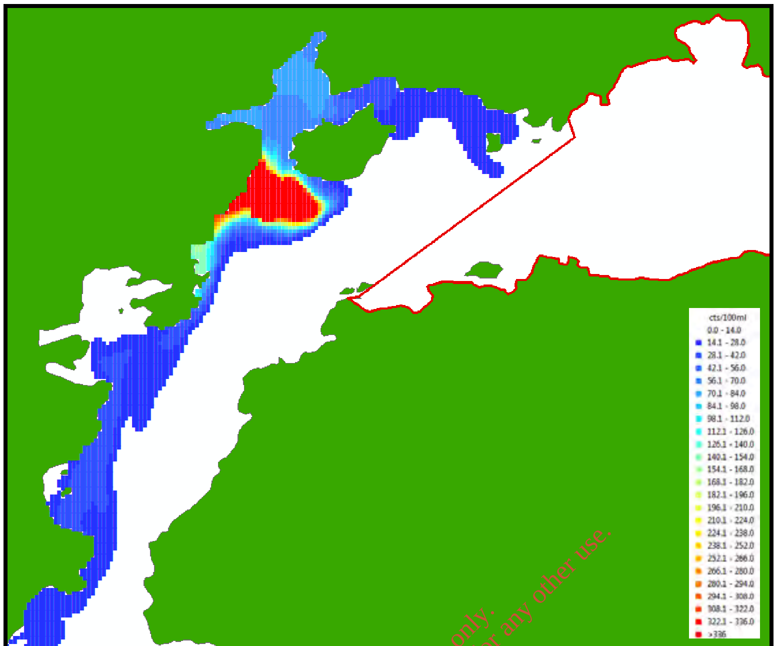

Figure 62: Scenario 2 faecal coliform concentrations spring tide low water

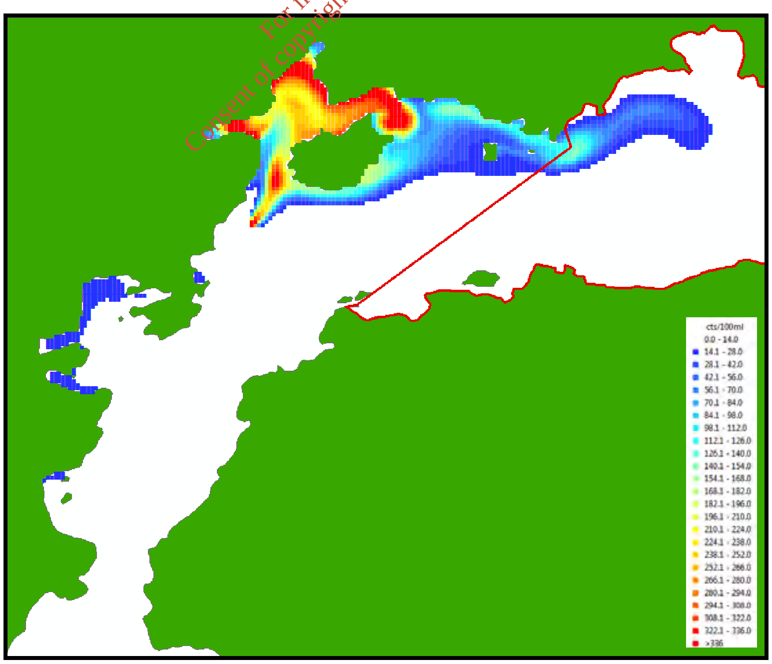

Figure 63: Scenario 2 faecal coliform concentrations spring tide mid flood

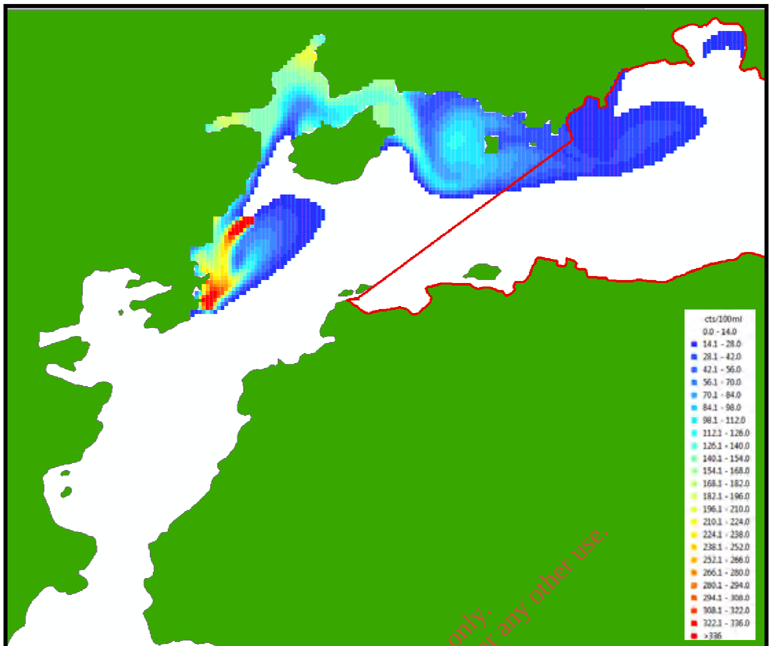

Figure 64: Scenario 2 faecal coliform concentrations spring tide high water

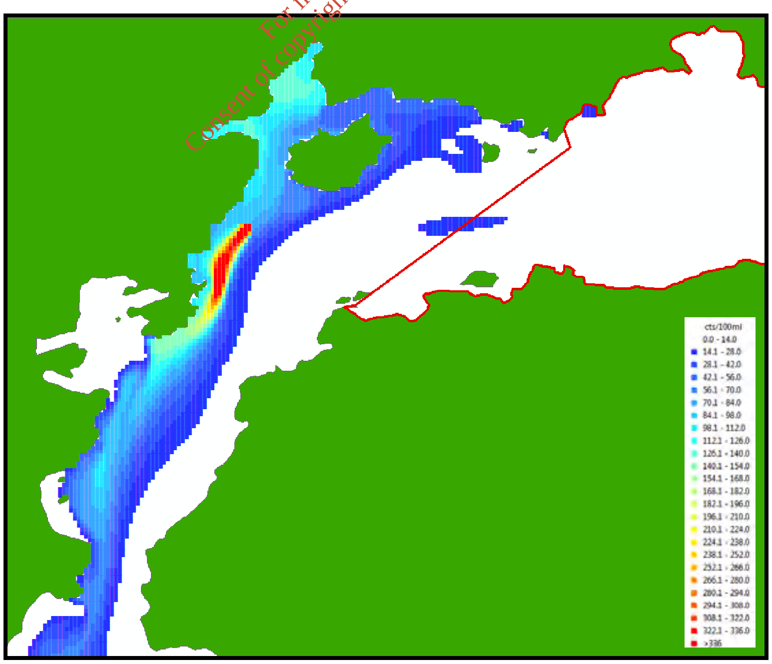

Figure 65: Scenario 2 faecal coliform concentrations spring tide mid ebb

4.5 Scenario 3

4.5.1 The purpose of this scenario was to investigate the impact at the boundary of the designated shellfish area of discharging untreated faecal coliforms from the proposed outfall locations of B1 & E utilizing a T90 (time during which the original organism population would reduce by 90%) value of 48hours.

4.5.2 Details pertaining to Scenario 3 are tabulated below in Table 7.

Outfall	Flow (m^3/s)	FCL (MPN/100ml)	T90 (hrs)
B1	0.031	2×10^6	48
E	0.031	2×10^6	48

Table 7: Details for Scenario 3

4.5.3 Using the above discharges the numerical model was used to estimate the concentration of faecal coliforms throughout the study area during the course of a spring-neap tidal cycle.

4.5.4 The faecal coliform, loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.5.5 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.5.6 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of faecal coliforms be reached throughout the water body.

4.5.7 Figure 66 presents the predicted faecal colifom concentrations at the boundary of the designated shellfish area from both the B1 and E outfalls.

4.5.8 Results from the scenario are summarised in Table 8.

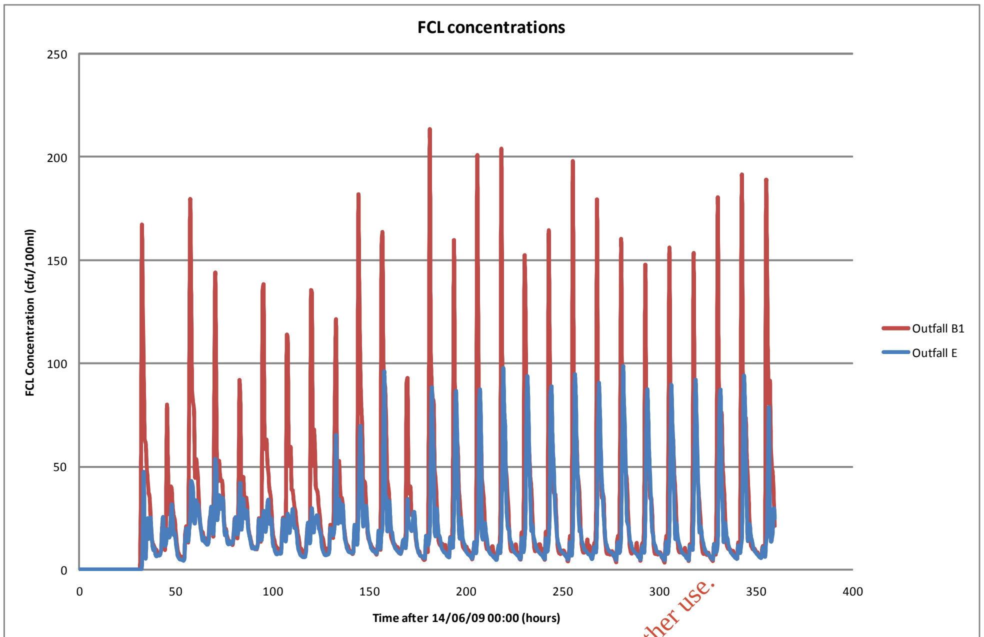

Figure 66: Scenario 3 predicted FCL concentrations

Outfall	Geometric Mean	Maximum	Median	%time >43
B1	20.3	213.1	15.7	24.7
E	14.7	98.1	14.0	10.3

Table 8: Summary of Scenario 3 predicted FCL concentrations

4.6 Scenario 4

4.6.1 Based on the predicted faecal coliform concentrations at the boundary of the designated shellfish area results from Scenario 1 through Scenario 3 as presented above, it was obvious that the proposed discharge of untreated faecal coliform material would not ensure compliance of the designated shellfish area with best practice international regulation faecal coliform median concentration values of 14 MPN/100ml.

4.6.2 The purpose of this scenario was to investigate the impact at the boundary of the designated shellfish area of discharging treated faecal coliforms from the proposed outfall locations of B1 & E utilizing a T90 (time during which the original organism population would reduce by 90%) value of 36 hours.

4.6.3 A T90 value of 36 hours was adopted for all subsequent scenarios as representing a conservative decay rate for faecal coliforms in the marine environment, after consultation with the consulting engineers.

4.6.4 The concentrations of faecal coliforms in the treated effluent discharge were defined as 150,000 counts/100ml following discussions with the consulting engineers.

4.6.5 Details pertaining to Scenario 4 are tabulated below in Table 9.

Outfall	Flow (m^3/s)	FCL (MPN/100ml)	T90 (hrs)
B1	0.031	1.5×10^5	36
E	0.031	1.5×10^5	36

Table 9: Details for Scenario 4

4.6.6 Using the above discharges the numerical model was used to estimate the concentration of faecal coliforms throughout the study area during the course of a spring-neap tidal cycle.

4.6.7 The faecal coliform, loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.6.8 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.6.9 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of faecal coliforms be reached throughout the water body.

4.6.10 Figure 67 presents the predicted faecal colifom concentrations at the boundary of the designated shellfish area from both the B1 and E outfalls.

4.6.11 Figure 68 to Figure 75 present snapshots of the faecal coliform plume from outfall B1 at low water, mid flood, high water and mid ebb on both a neap and spring tide respectively.

4.6.12 Results from the scenario are summarised in Table 10.

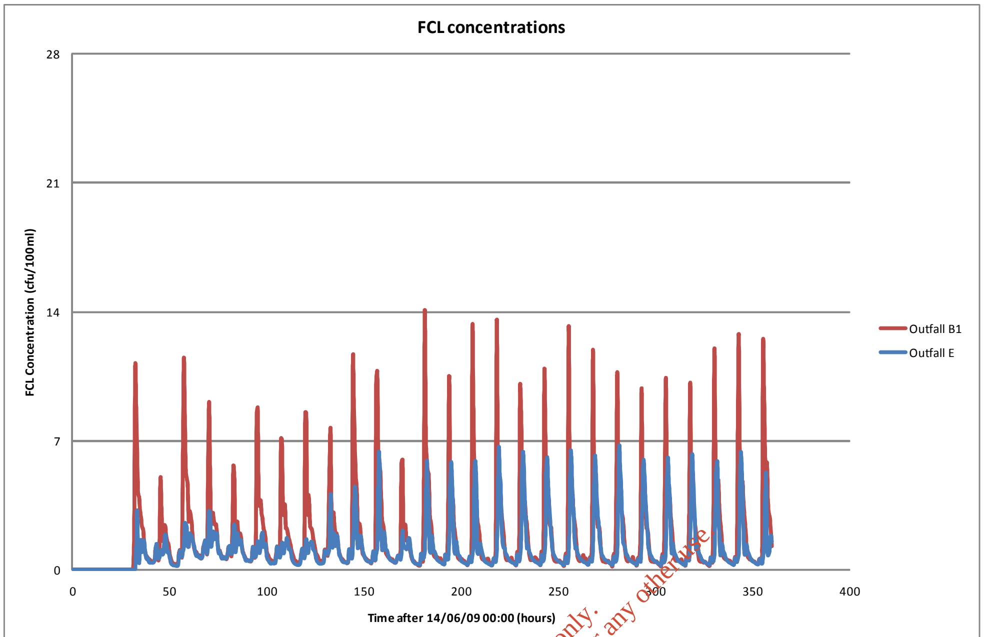

Figure 67: Scenario 4 predicted FCL concentrations

Outfall	Geometric Mean	Maximum	Median	%time > 43
B1	1.1	14.1	0.8	0.0
E	0.8	6.7	0.8	0.0

Table 10: Summary of Scenario 4 predicted FCL concentrations

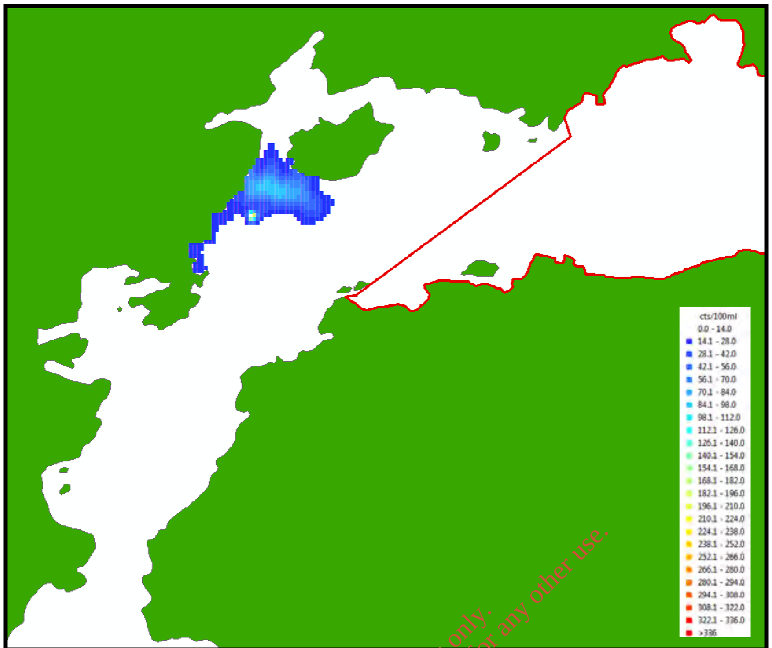

Figure 68: Scenario 4 faecal coliform concentrations neap tide low water

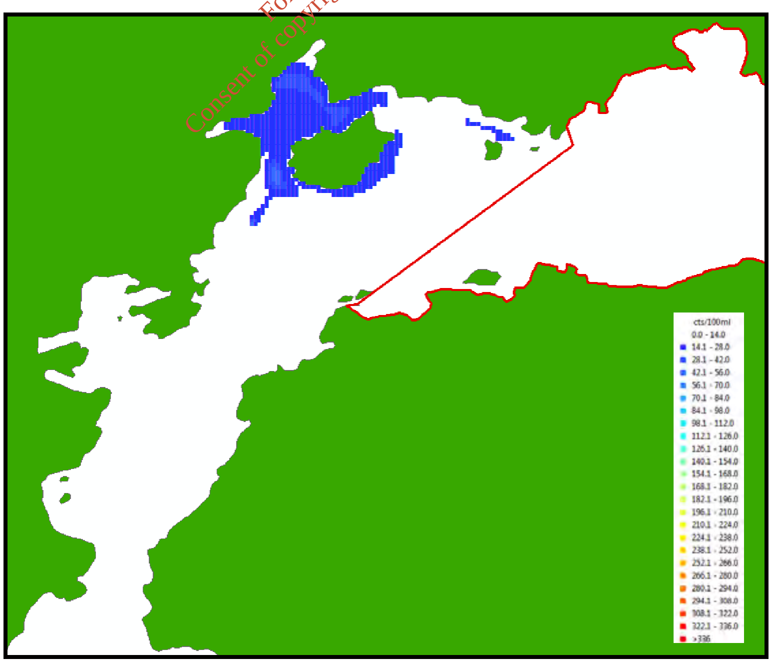

Figure 69: Scenario 4 faecal coliform concentrations neap tide mid flood

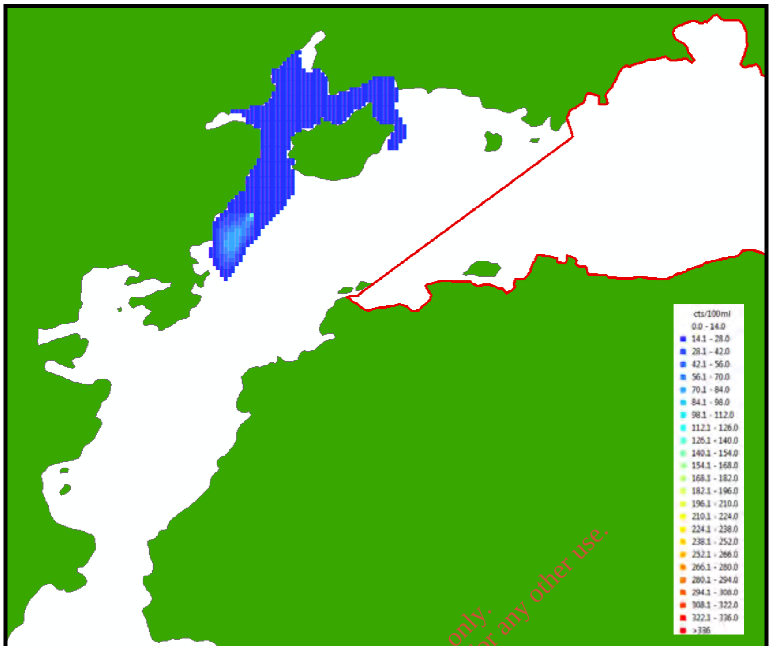

Figure 70: Scenario 4 faecal coliform concentrations neap tide high water

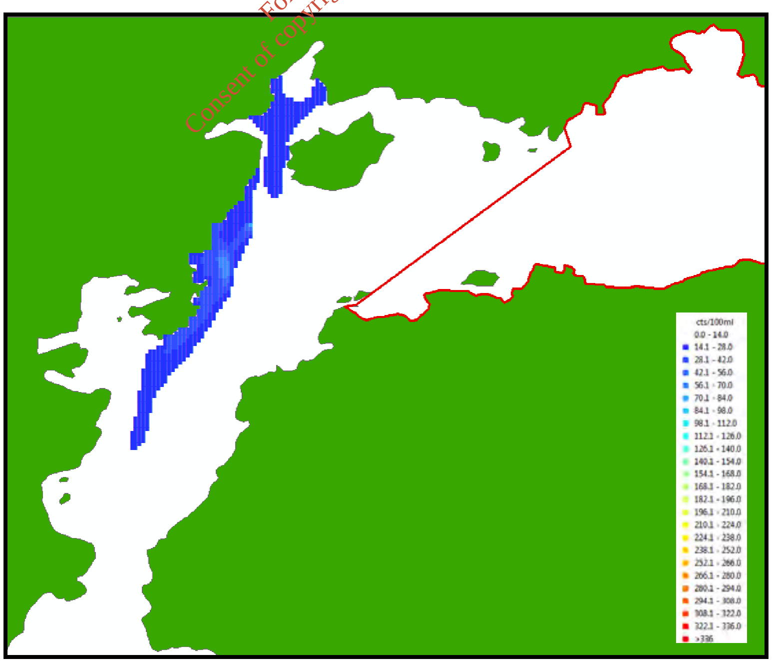

Figure 71: Scenario 4 faecal coliform concentrations neap tide mid ebb

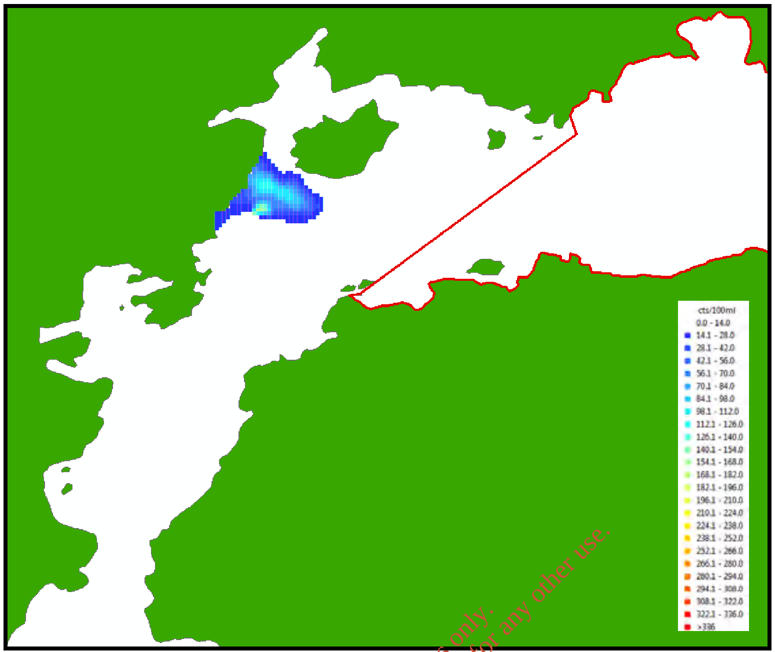

Figure 72: Scenario 4 faecal coliform concentrations spring tide low water

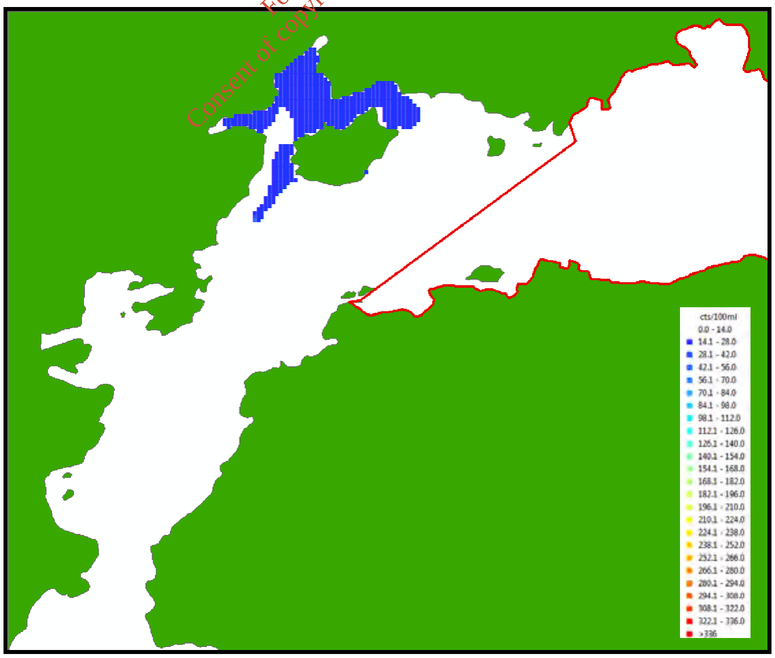

Figure 73: Scenario 4 faecal coliform concentrations spring tide mid flood

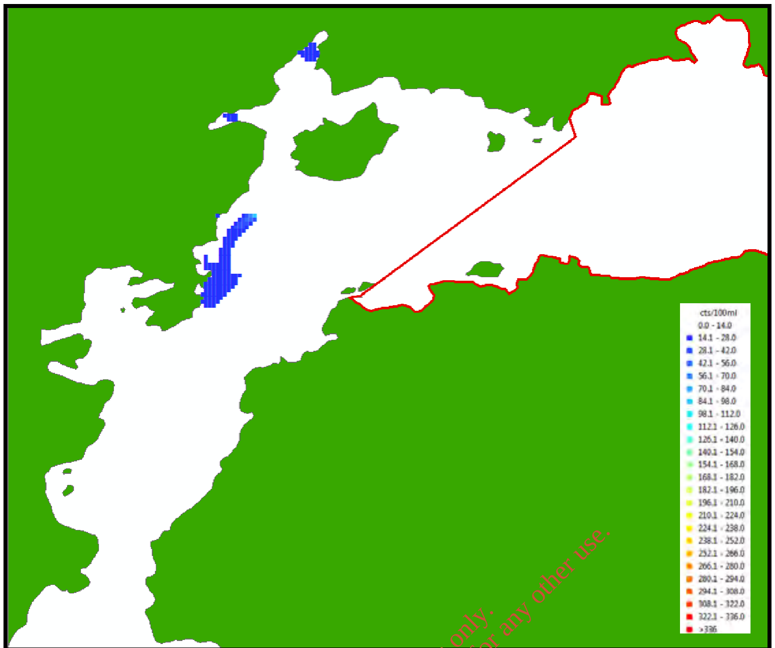

Figure 74: Scenario 4 faecal coliform concentrations spring tide high water

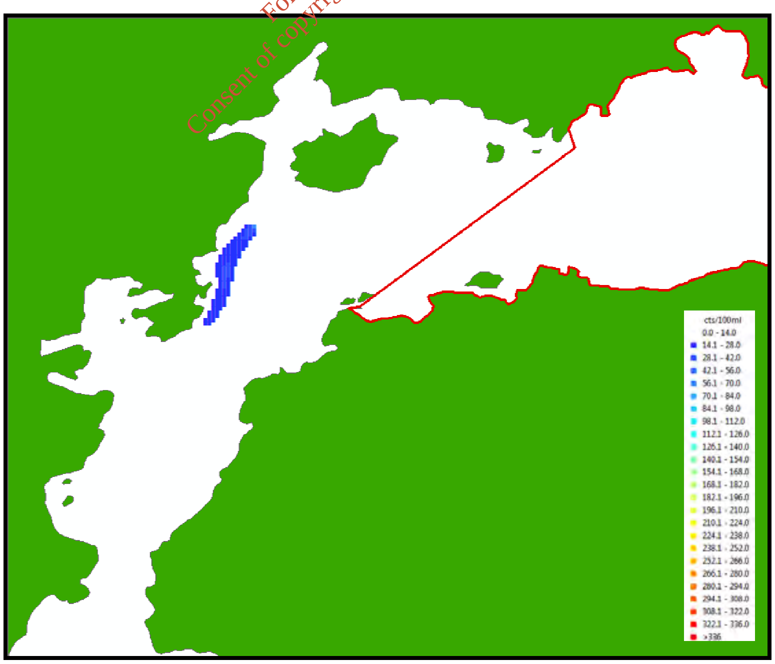

Figure 75: Scenario 4 faecal coliform concentrations spring tide mid ebb

4.7 Scenario 5

4.7.1 The purpose of this scenario was to investigate the impact at the boundary of the designated shellfish area of discharging treated faecal coliforms from the proposed outfall locations of B1-70m & E-70m.

4.7.2 Location B1-70m is sited 70m closer to the shore in shallower water than the original proposed B1 outfall and location E-70m is sited 70m closer to the shore in shallower water than the original proposed E outfall

4.7.3 Details pertaining to Scenario 5 are tabulated below in Table 11.

Outfall	Flow (m^3/s)	FCL (MPN/100ml)	T90 (hrs)
B1-70m	0.031	1.5×10^5	36
E-70m	0.031	1.5×10^5	36

Table 11: Details for Scenario 5

4.7.4 Using the above discharges the numerical model was used to estimate the concentration of faecal coliforms throughout the study area during the course of a spring-neap tidal cycle.

4.7.5 The faecal coliform, loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.7.6 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.7.7 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of faecal coliforms be reached throughout the water body.

4.7.8 Figure 76 presents the predicted faecal colifom concentrations at the boundary of the designated shellfish area from both the B1-70m and E-70m outfalls.

4.7.9 Figure 77 to Figure 84 present snapshots of the faecal coliform plume from outfall B1-70m at low water, mid flood, high water and mid ebb on both a neap and spring tide respectively.

4.7.10 Results from the scenario are summarised in Table 12.

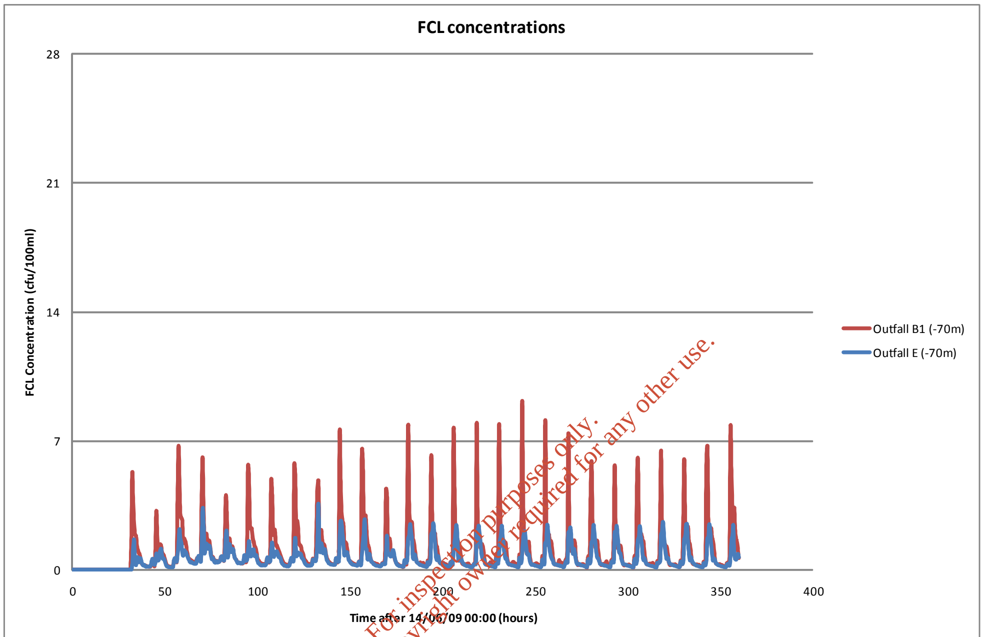

Figure 76: Scenario 5 predicted FCL concentrations

Outfall	Geometric Mean	Maximum	Median	%time > 43
B1-70m	0.6	9.1	0.5	0.0
E-70m	0.4	3.6	0.4	0.0

Table 12: Summary of Scenario 5 predicted FCL concentrations

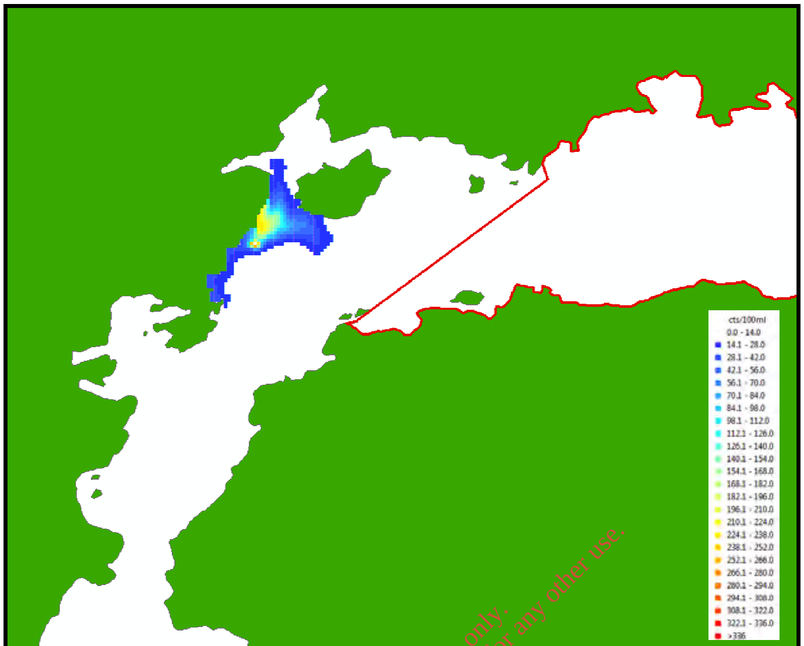

Figure 77: Scenario 5 faecal coliform concentrations neap tide low water

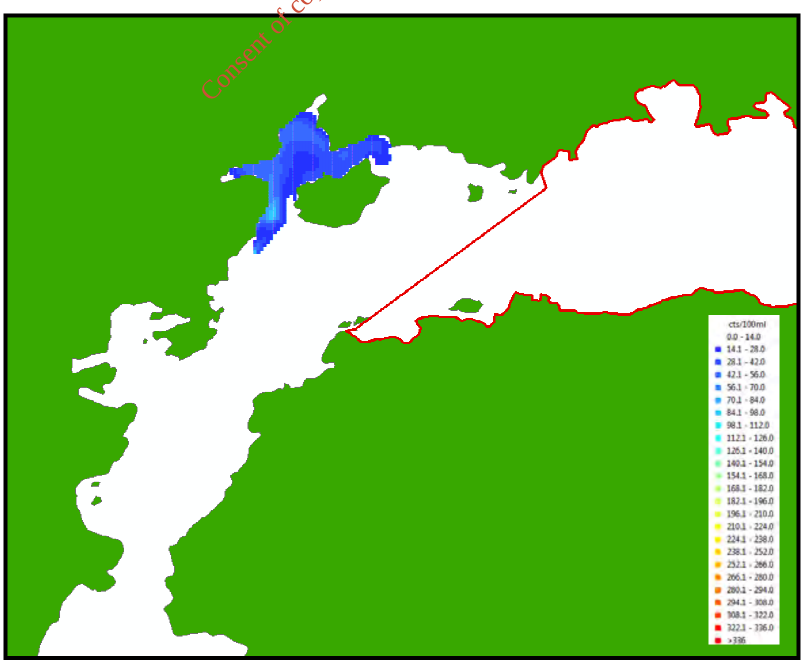

Figure 78: Scenario 5 faecal coliform concentrations neap tide mid flood

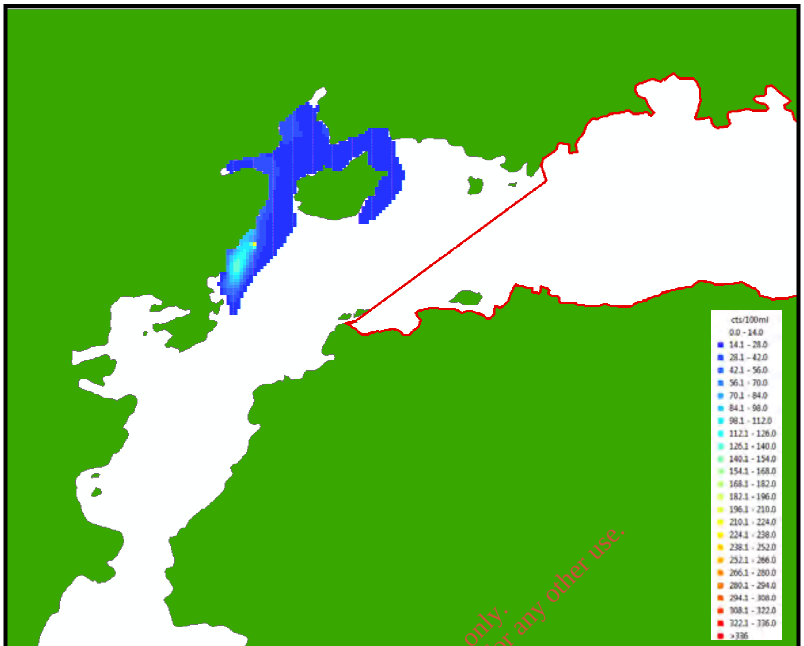

Figure 79: Scenario 5 faecal coliform concentrations neap tide high water

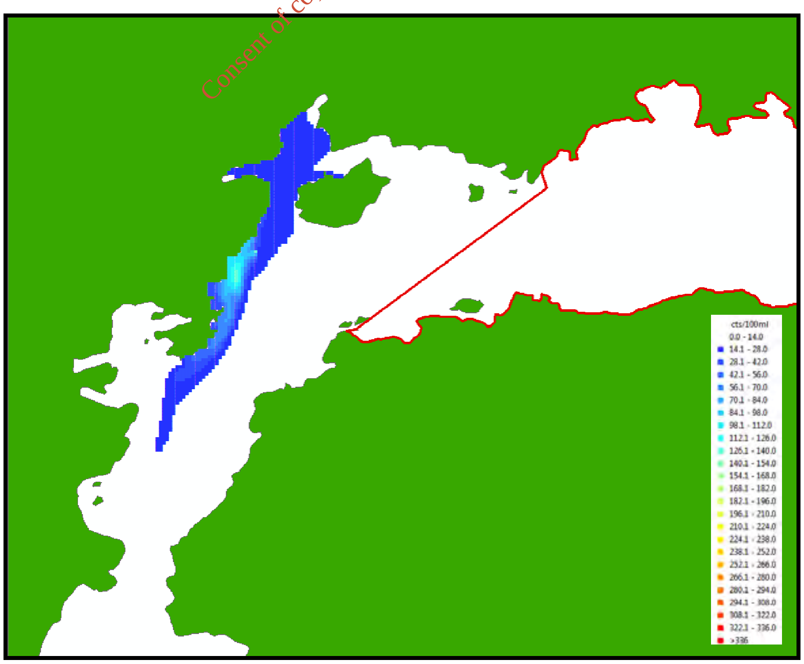

Figure 80: Scenario 5 faecal coliform concentrations neap tide mid ebb

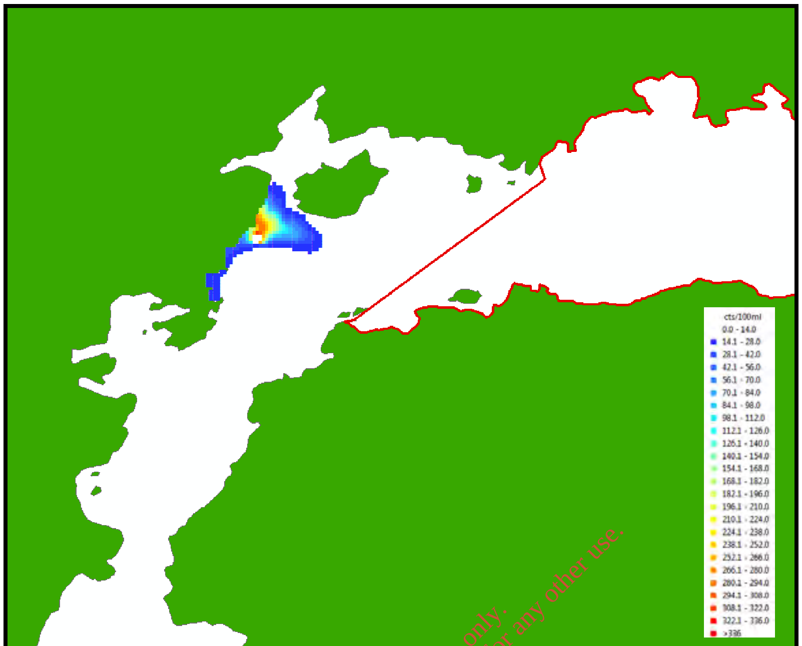

Figure 81: Scenario 5 faecal coliform concentrations spring tide low water

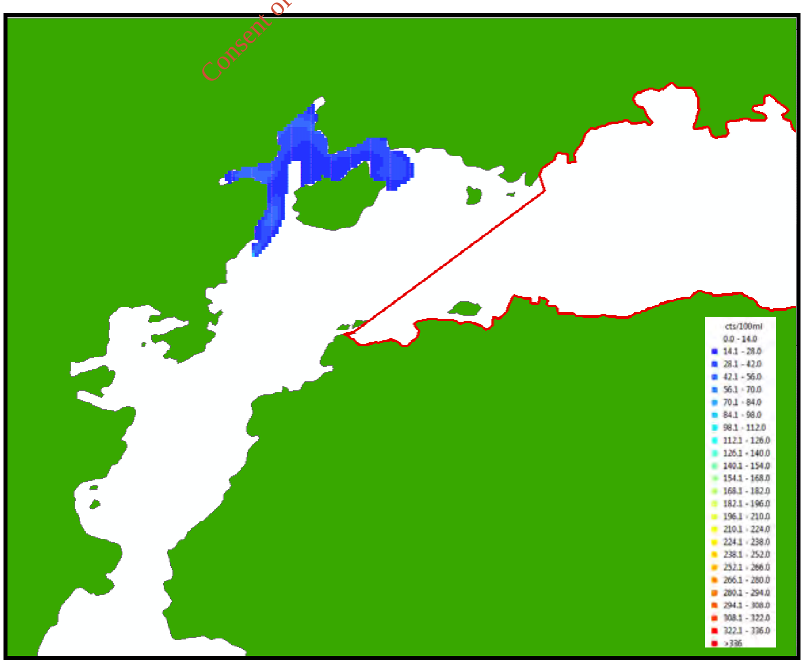

Figure 82: Scenario 5 faecal coliform concentrations spring tide mid flood

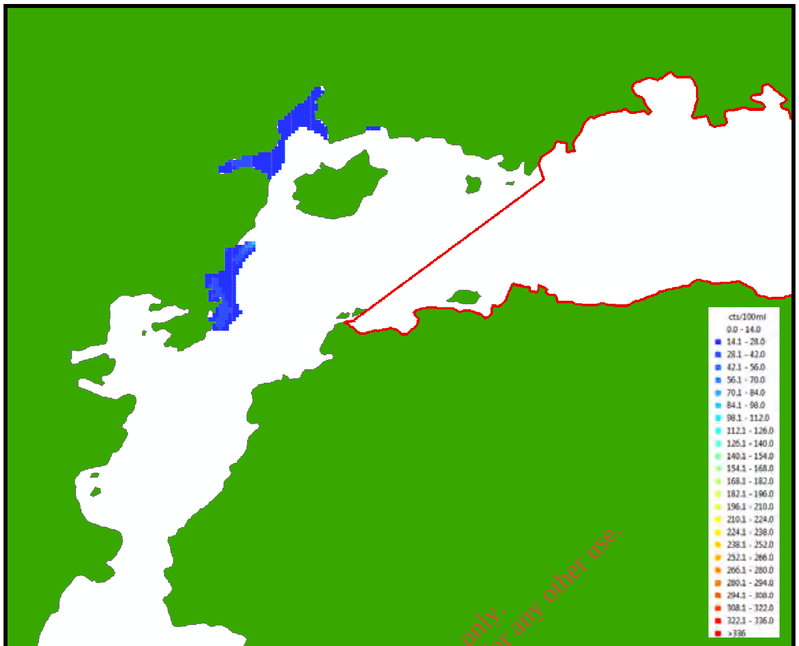

Figure 83: Scenario 5 faecal coliform concentrations spring tide high water

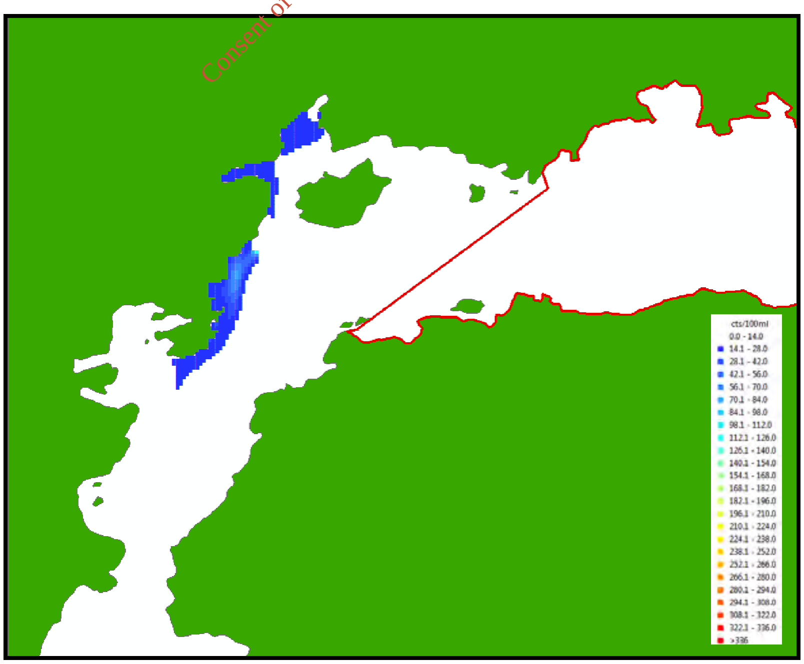

Figure 84: Scenario 5 faecal coliform concentrations spring tide mid ebb

4.8 Scenario 6

4.8.1 The purpose of this scenario was to investigate the impact at the boundary of the designated shellfish area of discharging treated faecal coliforms from the proposed outfall locations of B1+70m & E+70m.

4.8.2 Location B1+70m is sited 70m further from the shore in deeper water than the original proposed B1 outfall and location E+70m is sited 70m further from the shore in deeper water than the original proposed E outfall

4.8.3 Details pertaining to Scenario 6 are tabulated below in Table 13.

Outfall	Flow (m^3/s)	FCL (MPN/100ml)	T90 (hrs)
B1-70m	0.031	1.5×10^5	36
E-70m	0.031	1.5×10^5	36

Table 13: Details for Scenario 6

4.8.4 Using the above discharges the numerical model was used to estimate the concentration of faecal coliforms throughout the study area during the course of a spring-neap tidal cycle.

4.8.5 The faecal coliform, loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.8.6 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.8.7 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of faecal coliforms be reached throughout the water body.

4.8.8 Figure 85 presents the predicted faecal colifom concentrations at the boundary of the designated shellfish area from B1+70m and E+70m outfalls.

4.8.9 Figure 86 to Figure 93 present snapshots of the faecal coliform plume from outfall B1+70m at low water, mid flood, high water and mid ebb on both a neap and spring tide respectively.

4.8.10 Results from the scenario are summarised in Table 14.

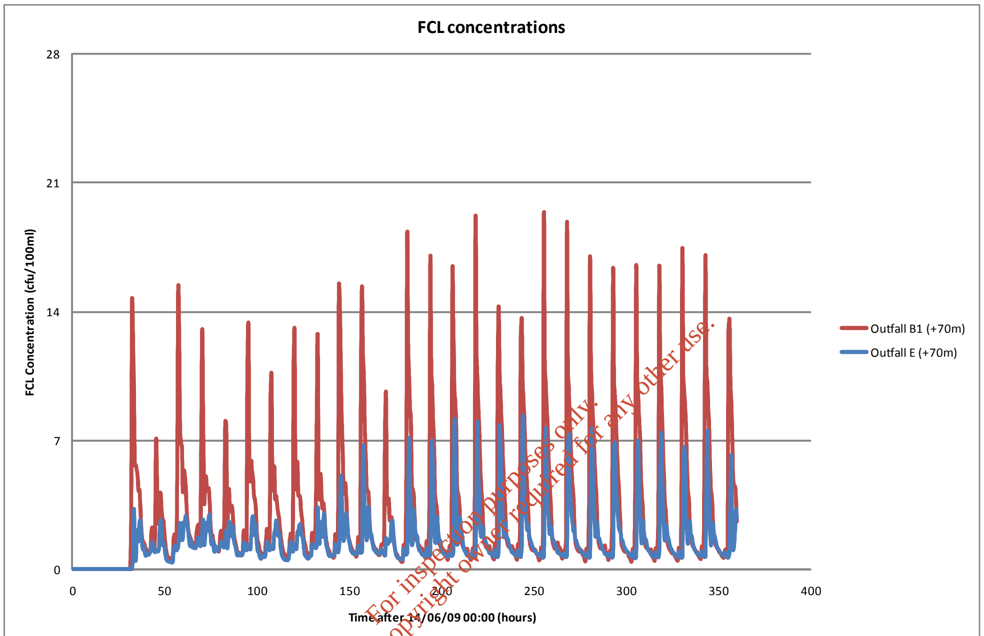

Figure 85: Scenario 6 predicted FCL concentrations

Outfall	Geometric Mean	Maximum	Median	%time > 43
B1+70m	2.1	19.2	1.5	0.0
E+70m	1.3	8.1	1.2	0.0

Table 14: Summary of Scenario 6 predicted FCL concentrations

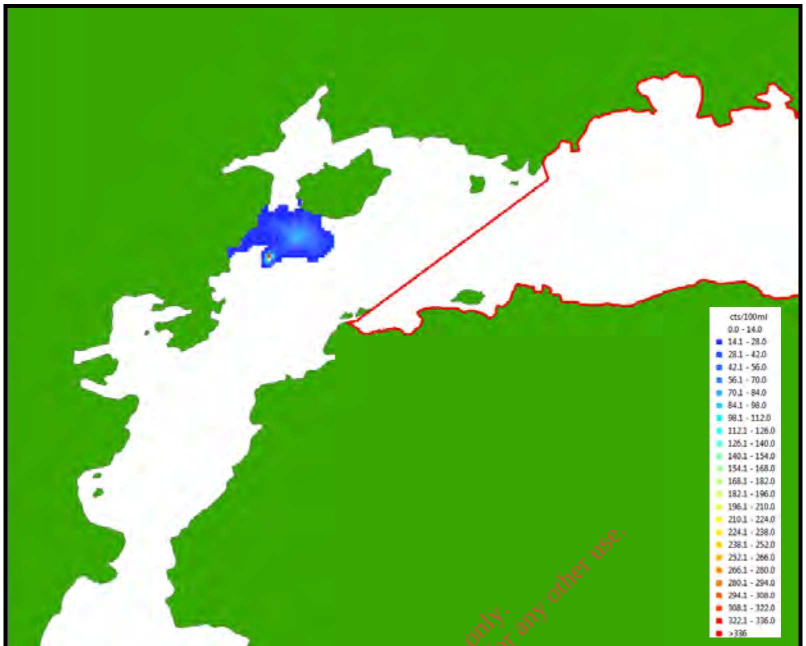

Figure 86: Scenario 6 faecal coliform concentrations neap tide low water

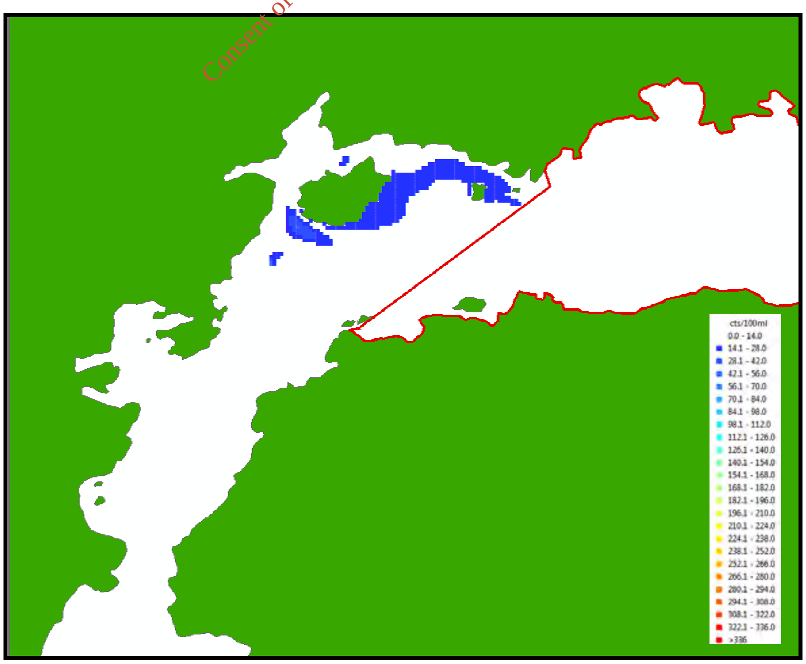

Figure 87: Scenario 6 faecal coliform concentrations neap tide mid flood

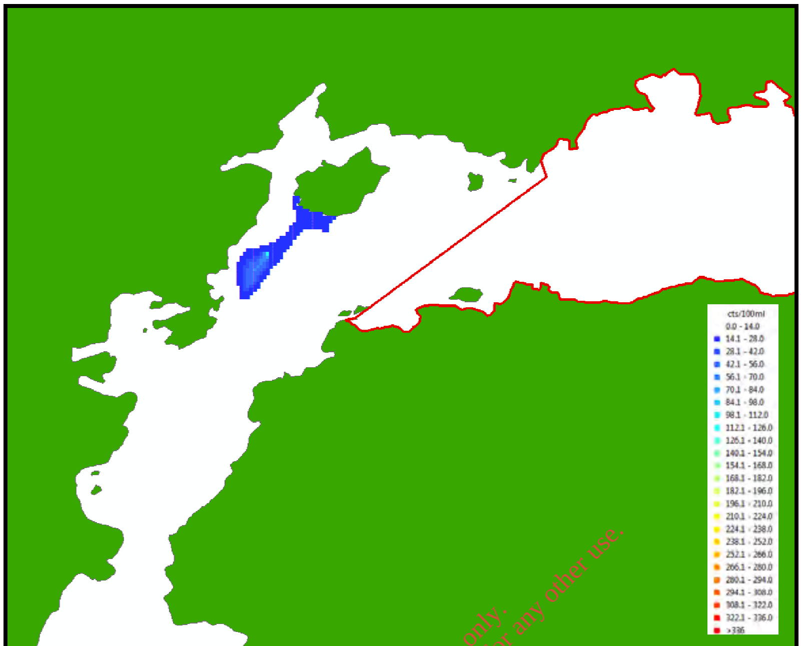

Figure 88: Scenario 6 faecal coliform concentrations neap tide high water

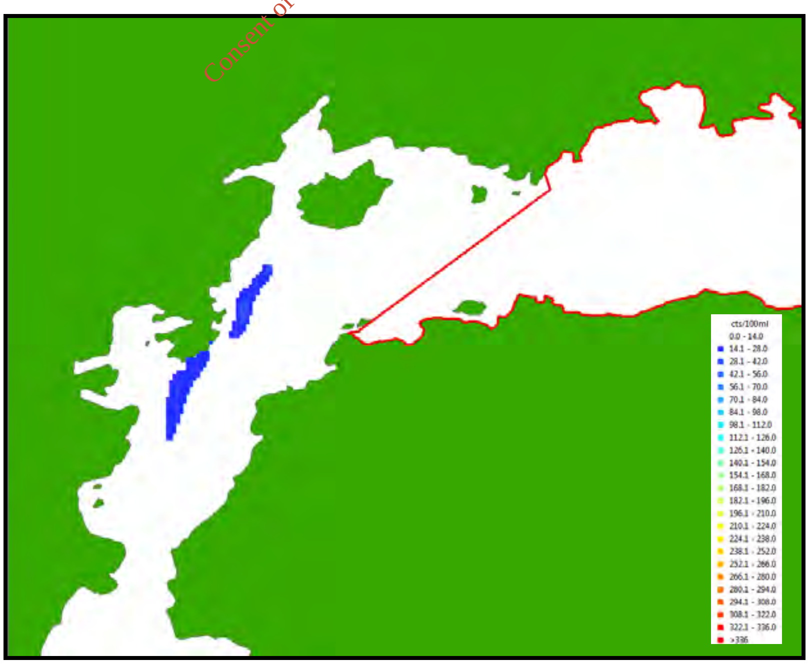

Figure 89: Scenario 6 faecal coliform concentrations neap tide mid ebb

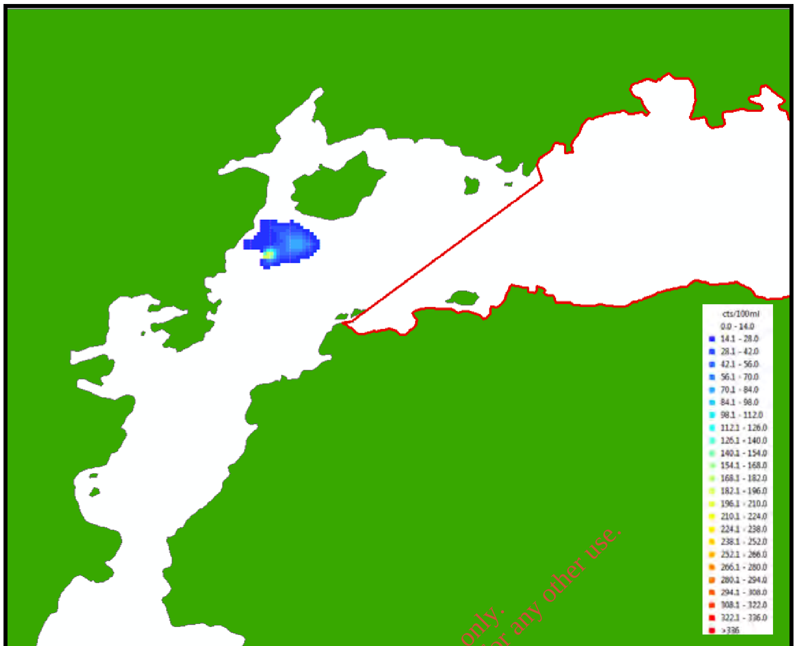

Figure 90: Scenario 6 faecal coliform concentrations spring tide low water

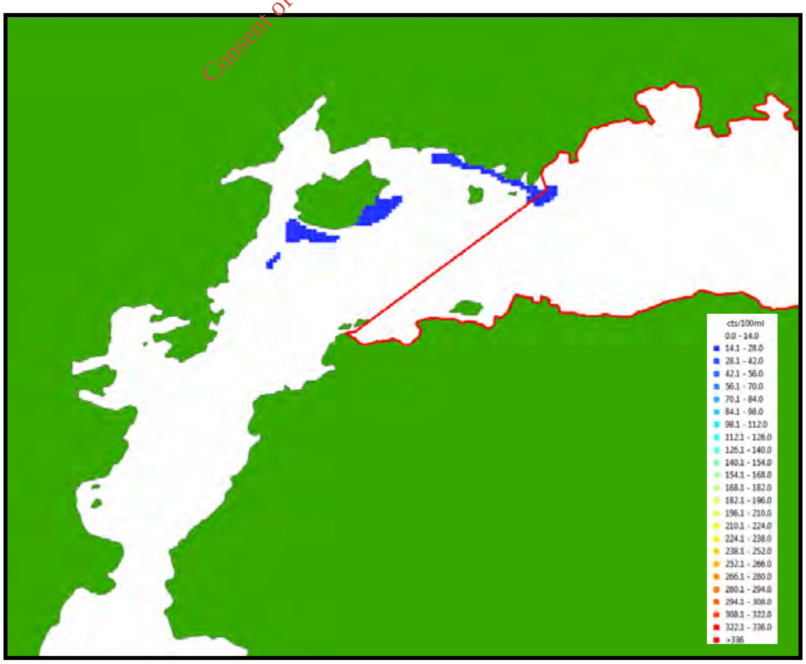

Figure 91: Scenario 6 faecal coliform concentrations spring tide mid flood

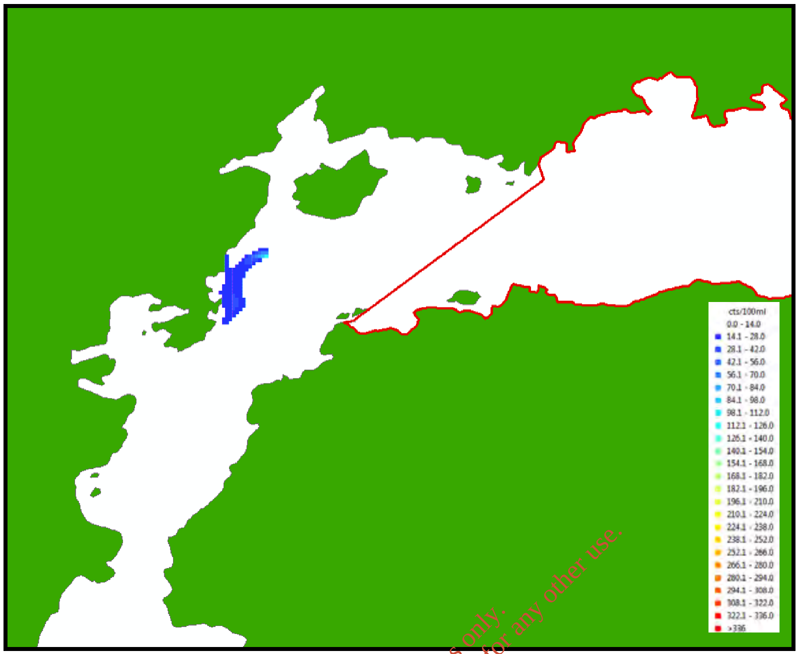

Figure 92: Scenario 6 faecal coliform concentrations spring tide high water

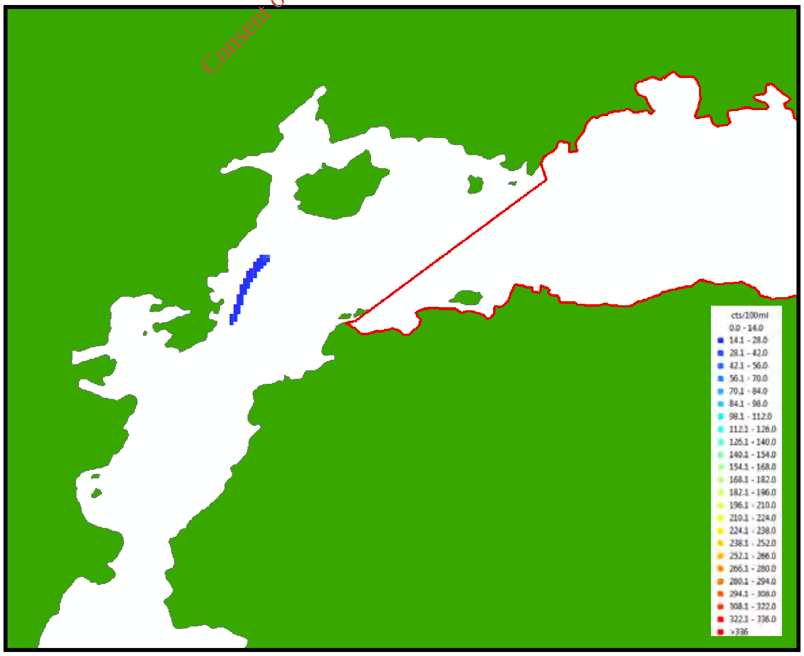

Figure 93: Scenario 6 faecal coliform concentrations spring tide mid ebb

4.9 Scenario 7

4.9.1 The purpose of this scenario was to investigate the impact at the boundary of the designated shellfish area of discharging treated faecal coliforms from the proposed outfall locations of B1 & E with potential adverse Force 6 wind blowing from a southwesterly direction (225°N).

4.9.2 Details pertaining to Scenario 7 are tabulated below in Table 15.

Outfall	Flow (m^3/s)	FCL (MPN/100ml)	T90 (hrs)
B1-70m	0.031	1.5×10^5	36
E-70m	0.031	1.5×10^5	36

Table 15: Details for Scenario 7

4.9.3 Using the above discharges the numerical model was used to estimate the concentration of faecal coliforms throughout the study area during the course of a spring-neap tidal cycle.

4.9.4 The faecal coliform, loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.9.5 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.9.6 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of faecal coliforms be reached throughout the water body.

4.9.7 Figure 94 presents the predicted faecal colifom concentrations at the boundary of the designated shellfish area from both the B1and E outfalls subject to a Force 6 wind from the southwest.

4.9.8 Results from the scenario are summarised in Table 16.

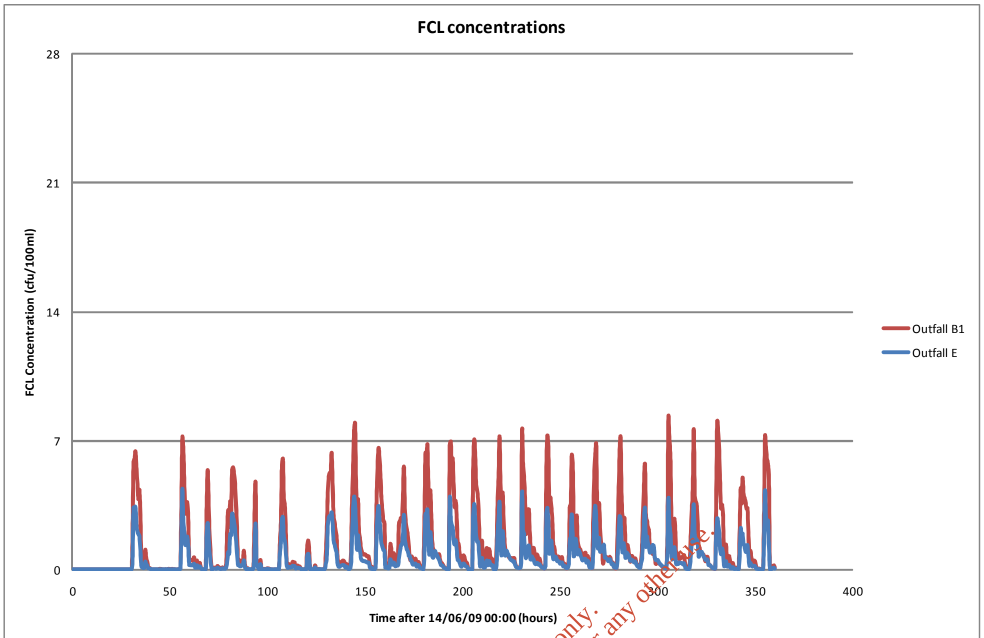

Figure 94: Scenario 7 predicted FCL concentrations

Outfall	Geometric Mean	Maximum	Median	%time > 43
B1	0.3	9.1	0.5	0.0
E	0.2	4.4	0.3	0.0

Table 16: Summary of Scenario 7 predicted FCL concentrations

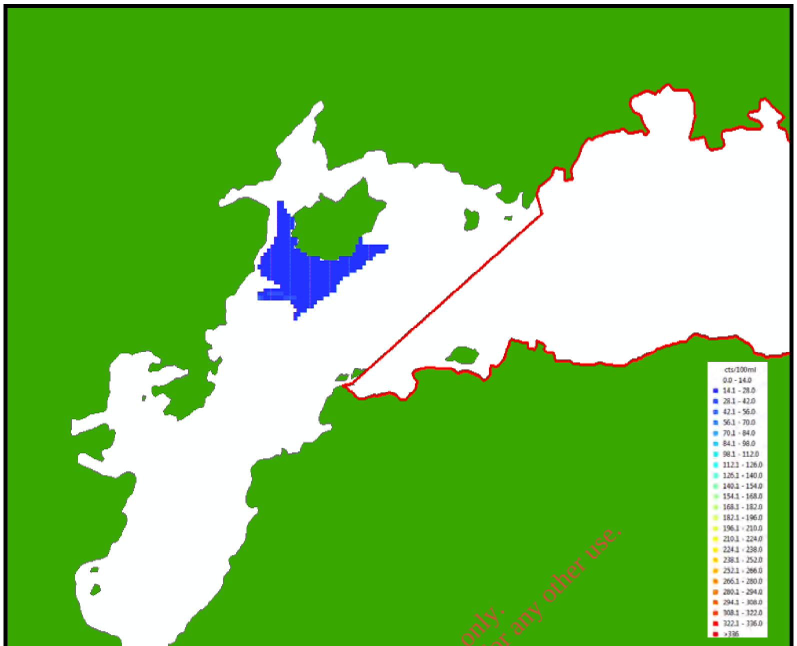

Figure 95: Scenario 7 faecal coliform concentrations neap tide low water

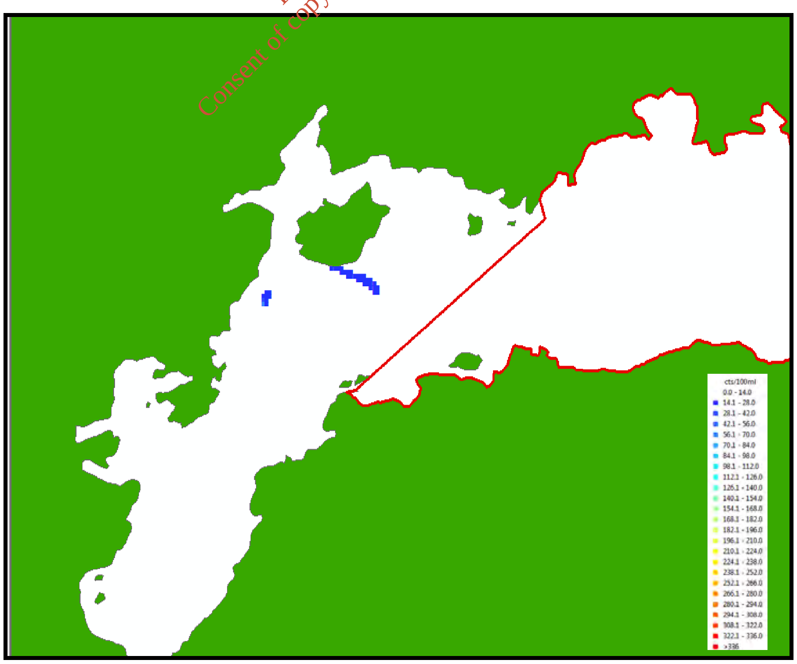

Figure 96: Scenario 7 faecal coliform concentrations neap tide mid flood

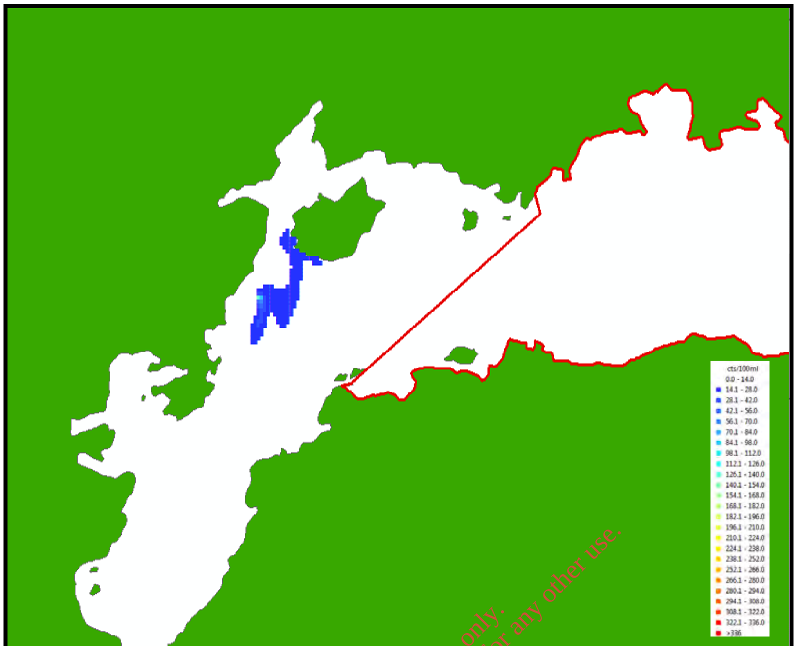

Figure 97: Scenario 7 faecal coliform concentrations neap tide high water

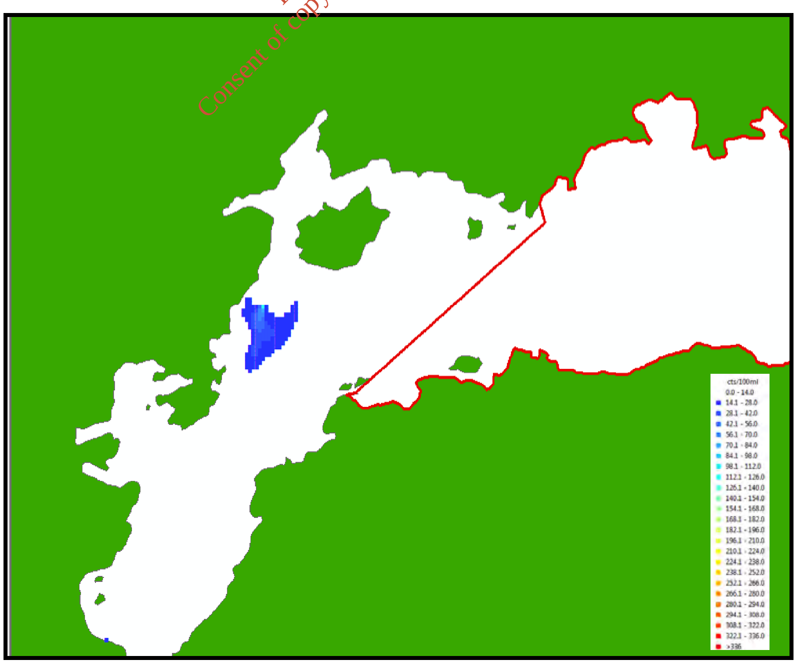

Figure 98: Scenario 7 faecal coliform concentrations neap tide mid ebb

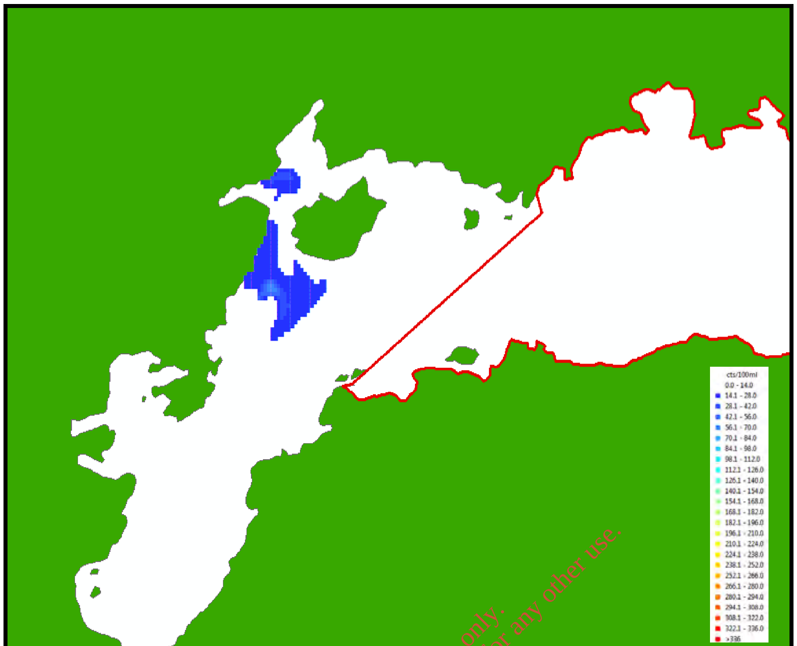

Figure 99: Scenario 7 faecal coliform concentrations spring tide low water

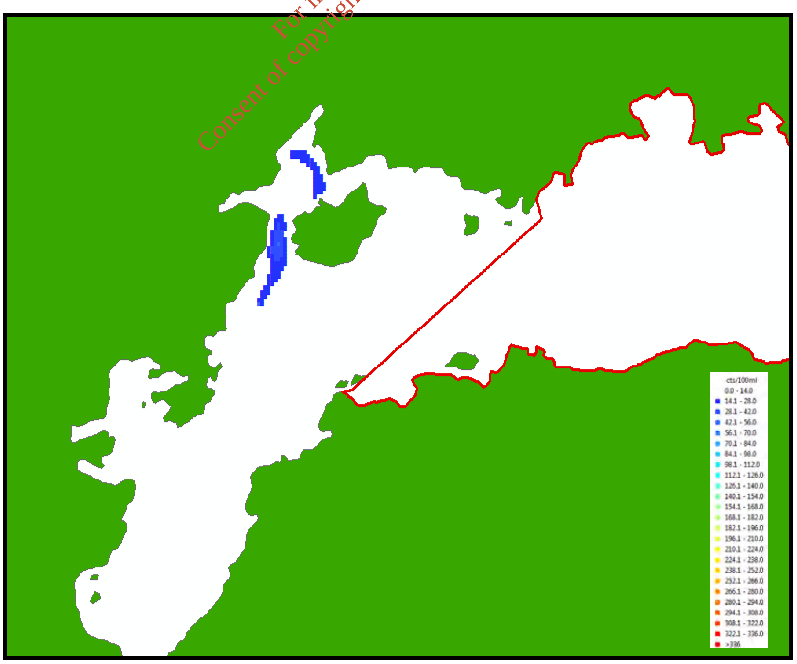

Figure 100: Scenario 7 faecal coliform concentrations spring tide mid flood

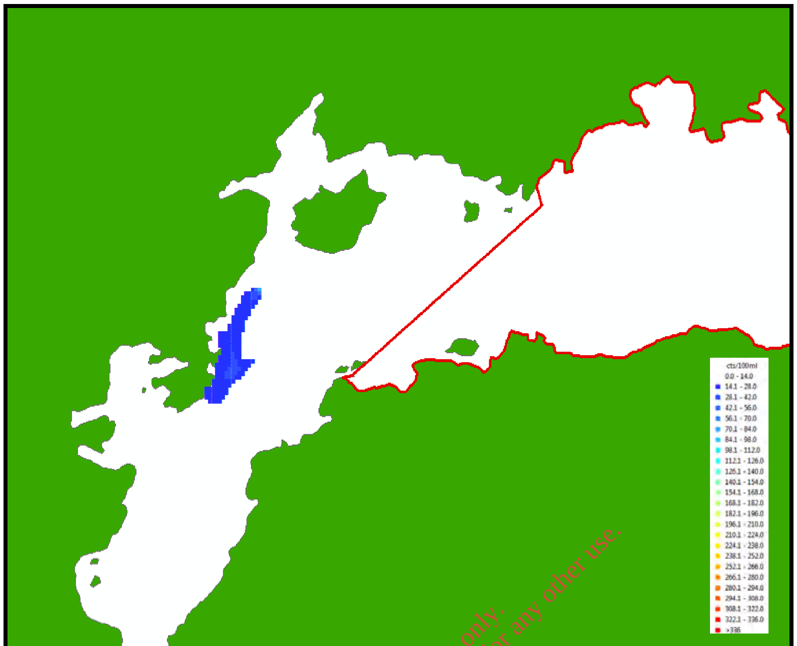

Figure 101: Scenario 7 faecal coliform concentrations spring tide high water

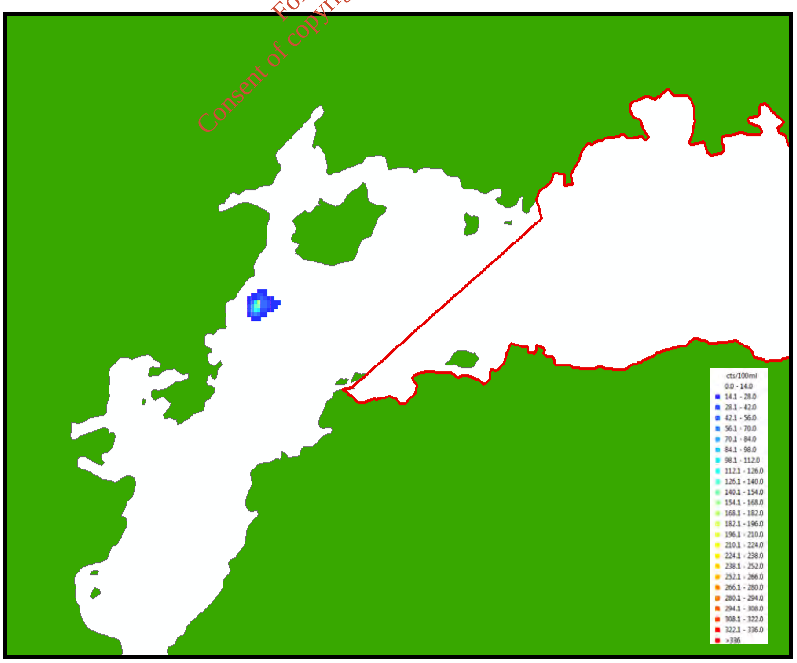

Figure 102: Scenario 7 faecal coliform concentrations spring tide mid ebb

4.10 Scenario 8

4.10.1 The purpose of this scenario was to investigate the impact on the water quality of the receiving waters of Castletownbere by discharging treated effluent from the proposed future configurations of outfalls in Castletownbere, namely outfall B1-70m and DAFF outfall.

4.10.2 Details pertaining to Scenario 8 are tabulated below in Table 17.

Outfall	Flow (m^3/s)	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
B1-70m	0.031	7.5×10^5	1.5×10^5	25	125	40	9	35
DAFF	0.009	1.1×10^3	3.0	808	5348	318	126	469

Table 17: Details for Scenario 8

4.10.3 Using the above discharges the model was used to estimate the concentrations of the various parameters throughout the study area over the course of a spring-neap tidal cycle.

4.10.4 All loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.10.5 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.10.6 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of each parameter be reached throughout the water body.

4.10.7 All model predictions were output at the boundary of the designated shellfish area as being representative of the water body as a whole.

4.10.8 Figure 103 presents the predicted faecal and total colifom concentrations, Figure 104 presents the predicted BOD and COD concentrations, Figure 105 presents the predicted DIN and P concentrations and Figure 106 presents the predicted suspended solids concentrations.

4.10.9 Results from the scenario are summarised in Table 18.

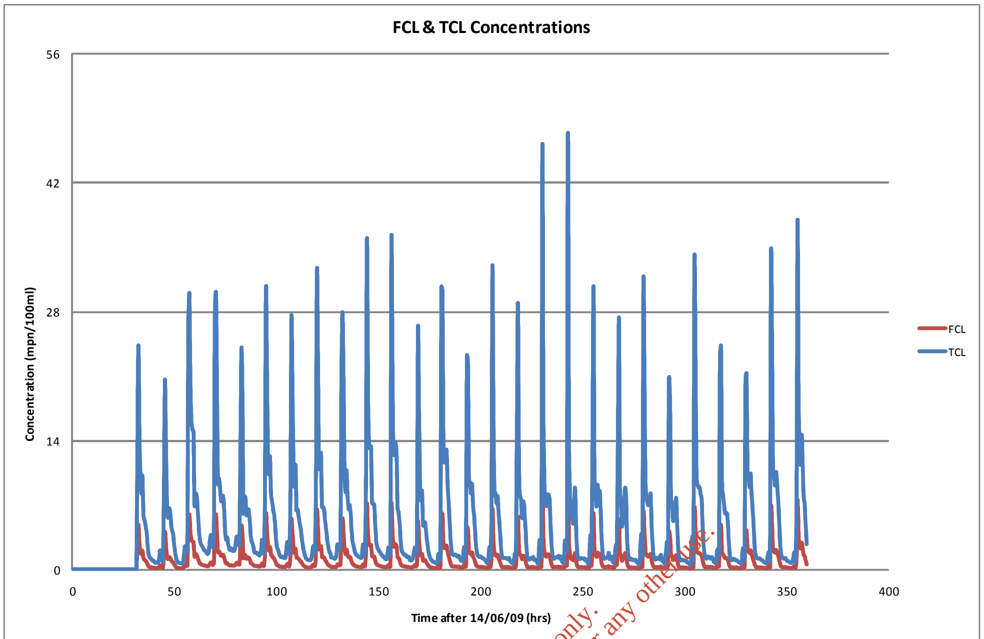

Figure 103: Scenario 8 predicted FCL & TCL concentrations

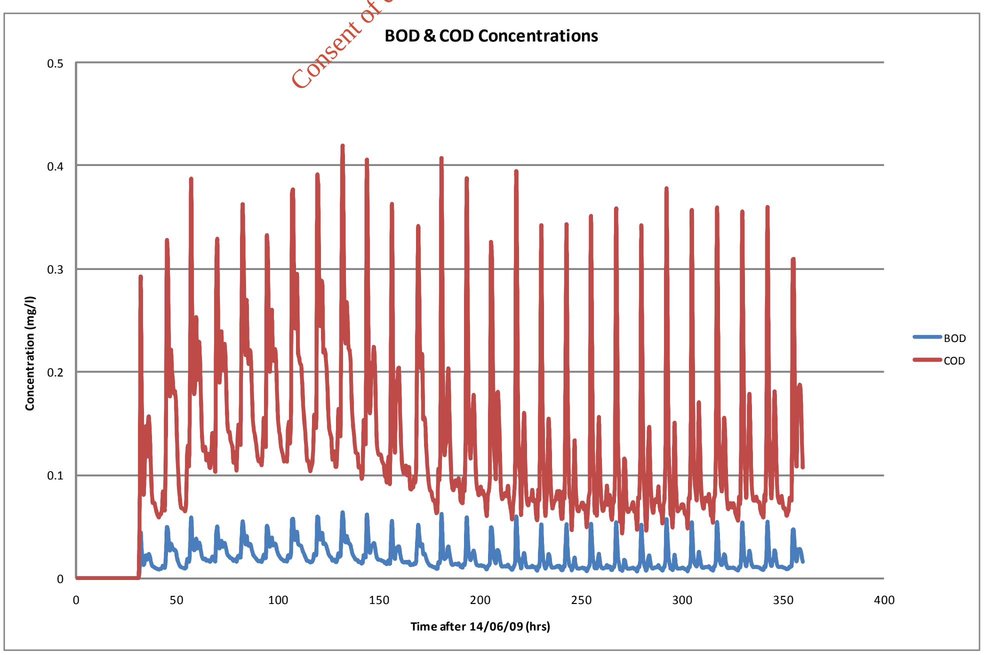

Figure 104: Scenario 8 predicted BOD & COD concentrations

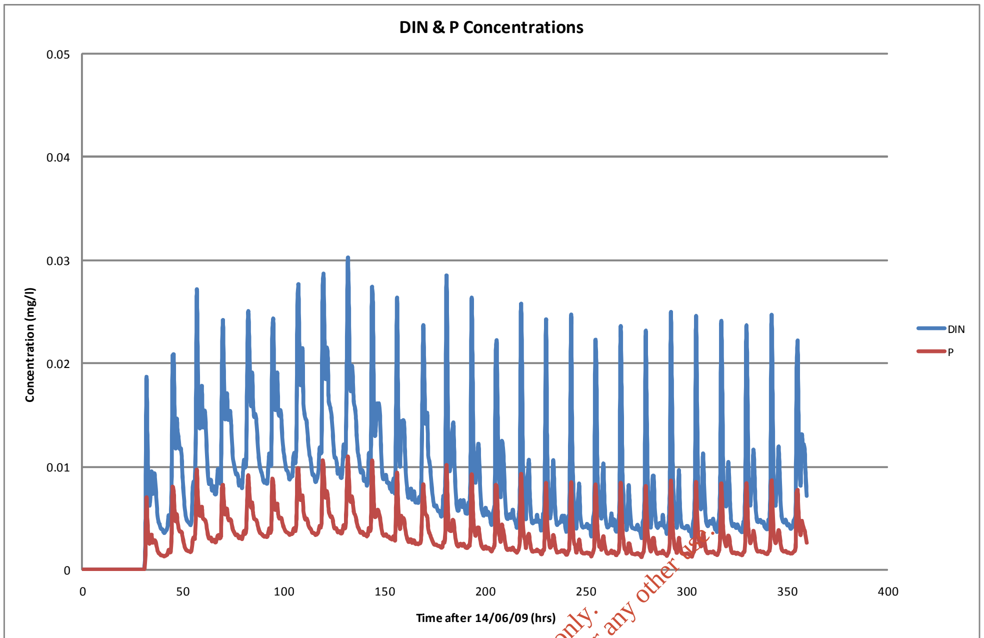

Figure 105: Scenario 8 predicted DIN & P concentrations

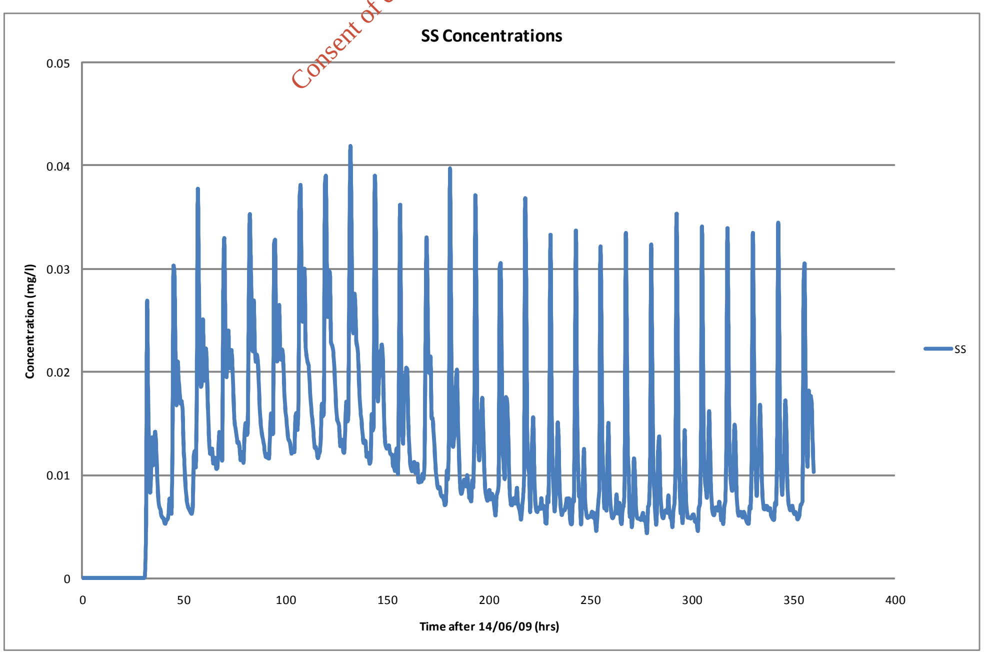

Figure 106: Scenario 8 predicted Suspended Solids concentration

Run No. 8 Proposed operating conditions.							
	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
Geometric Mean	3.089	0.615	0.017	0.117	0.008	0.003	0.011
Maximum	47.370	9.464	0.064	0.418	0.030	0.011	0.042
Median	2.424	0.484	0.016	0.111	0.008	0.003	0.011

Table 18: Summary of results for Scenario 8

4.11 Scenario 8b

4.11.1 The purpose of this scenario was to investigate the impact on the water quality of the receiving waters of Castletownbere by discharging only marginally disinfected faecal coliform effluent from the proposed future configurations of outfalls in Castletownbere, namely outfall B1-70m and DAFF outfall.

4.11.2 Details pertaining to Scenario 8b are tabulated below in Table 19.

Outfall	Flow (m^3/s)	FCL (MPN/100ml)
B1-70m	0.031	1.0×10^6
DAFF	0.009	3.0

Table 19: Details for Scenario 8b

4.11.3 Using the above discharges the model was used to estimate the faecal coliform concentrations throughout the study area over the course of a spring-neap tidal cycle.

4.11.4 The loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.11.5 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.11.6 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum concentrations be reached throughout the water body.

4.11.7 All model predictions were output at the boundary of the designated shellfish area as being representative of the water body as a whole.

4.11.8 Figure 107 presents the predicted faecal colifom concentrations, with results from the scenario summarised in Table 20.

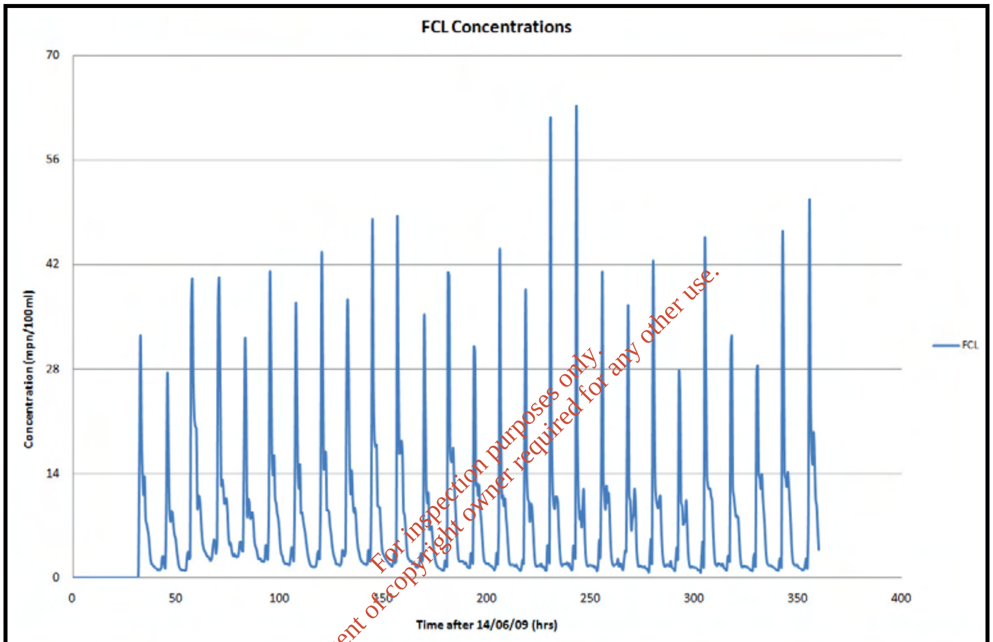

Figure 107: Scenario 8b predicted FCL concentration.

Run No. 8b Marginal FCL disinfection.	
	FCL (MPN/100ml)
Geometric Mean	4.023
Maximum	63.091
Median	2.272
% time > 43	1.360

Table 20: Summary of results for Scenario 8b

4.12 Scenario 9

4.12.1 The purpose of this scenario was to investigate the impact on the water quality of the receiving waters of Castletownbere by discharging effluent from the existing outfalls in Castletownbere for normal flow conditions, (3 x DWF).

4.12.2 Details pertaining to Scenario 9 are tabulated below in Table 21 and were taken from the flow and load survey undertaken in Castletownbere.

Outfall	Flow (litre/s)	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
DAFF	8.680	1.1×10^3	3	808	5348	318	126	469
Came Pt.	0.714	1.0×10^8	1.0×10^6	250	500	25	6	240
Came Woods	0.225	1.0×10^8	1.0×10^6	134	441	25	6	249
Main Outfall	9.000	1.0×10^8	1.0×10^6	250	500	25	6	240
BrandyHall Br.	0.390	1.0×10^8	1.0×10^6	13	34	25	6	28
Hospital	1.668	1.0×10^8	1.0×10^6	137	403	25	6	128

Table 21: Details for Scenario 9

4.12.3 Using the above discharges the model was used to estimate the concentrations of the various parameters throughout the study area during the course of a spring-neap tidal cycle.

4.12.4 All loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.12.5 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.12.6 The duration of the each simulation was sufficiently long enough to allow steady state conditions to be attained, thus ensuring the maximum levels of each parameter be reached throughout the water body.

4.12.7 Figure 108 presents the predicted faecal and total colifom concentrations, Figure 109 presents the predicted BOD and COD concentrations, Figure 110 presents the predicted DIN and P concentrations and Figure 111 presents the predicted suspended solids concentrations.

4.12.8 Figure 112 to Figure 119 present snapshots of the faecal coliforms within the area of interest at low water, mid ebb, high water and mid flood on both a neap and spring tide respectively.

4.12.9 All model predictions were output at the boundary of the designated shellfish area and are summarised in Table 22.

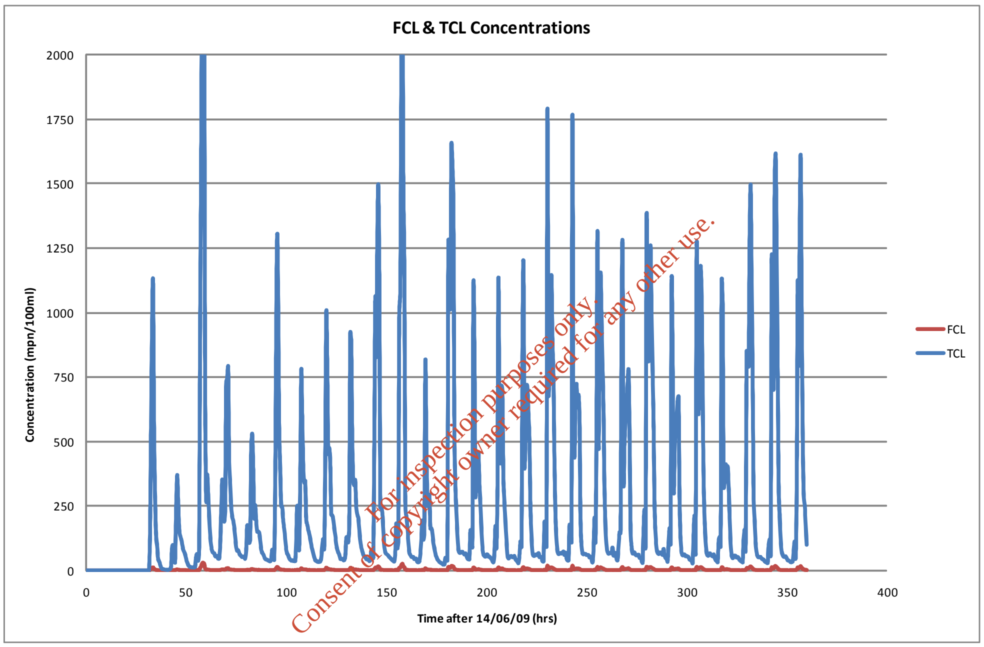

Figure 108: Scenario 9 predicted FCL & TCL concentration

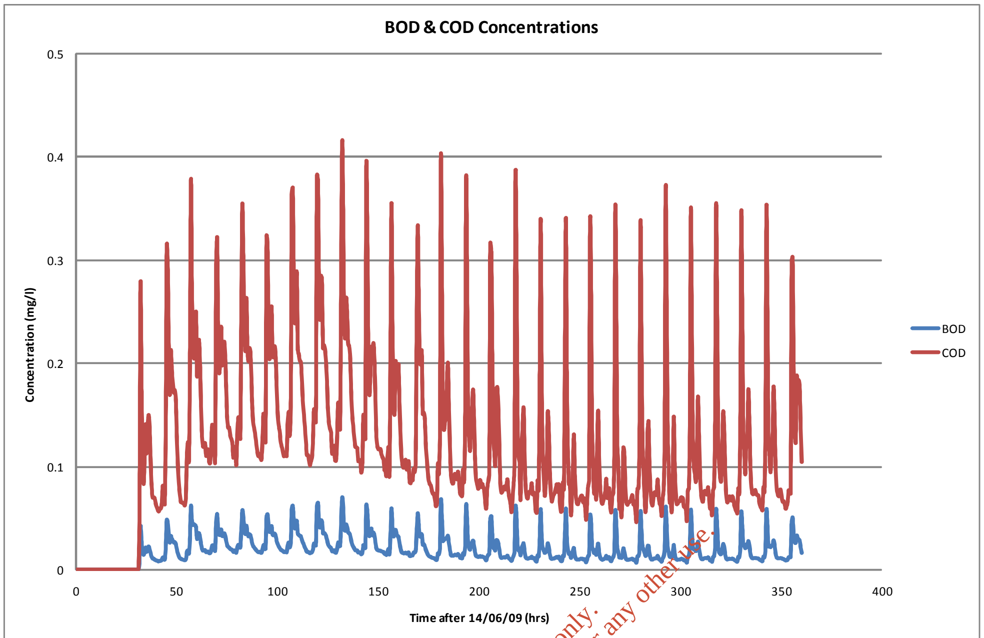

Figure 109: Scenario 9 predicted BOD & COD concentrations

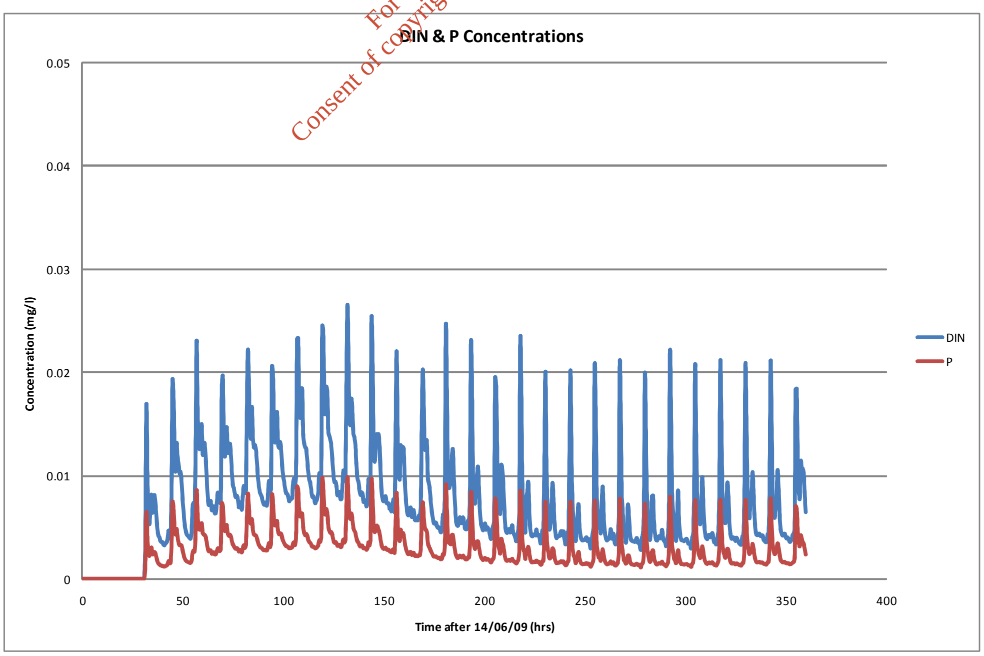

Figure 110: Scenario 9 predicted DIN & P concentrations

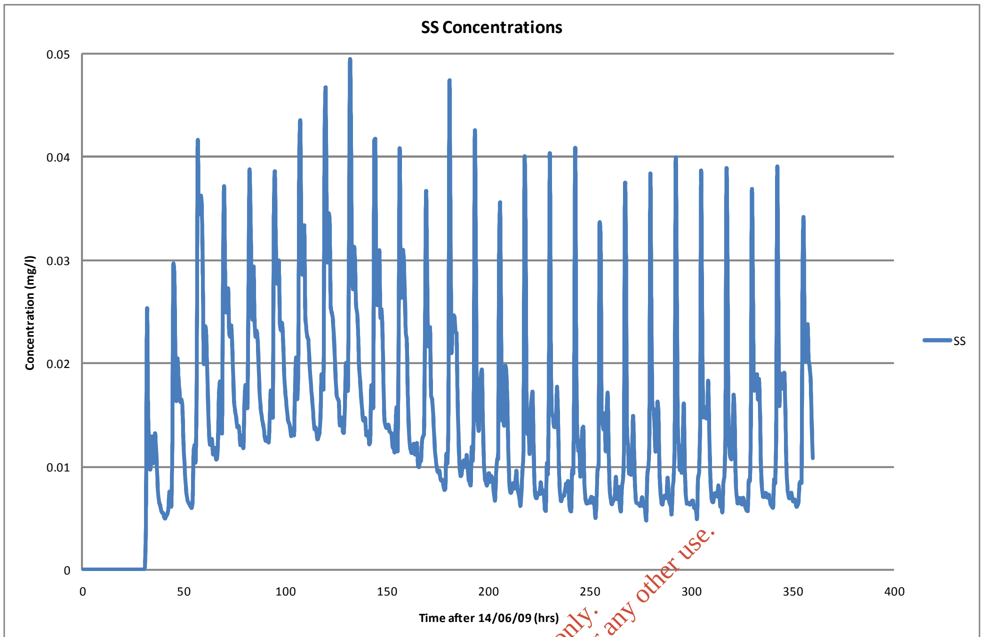

Figure 111: Scenario 9 predicted suspended solids concentration

Run No. 9 Existing conditions (3 x DWF).							
	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
Geometric Mean	130.400	1.303	0.018	0.115	0.007	0.003	0.013
Maximum	2883.525	28.835	0.070	0.415	0.026	0.010	0.049
Median	92.868	0.929	0.018	0.110	0.007	0.003	0.013

Table 22: Summary of results for Scenario 9

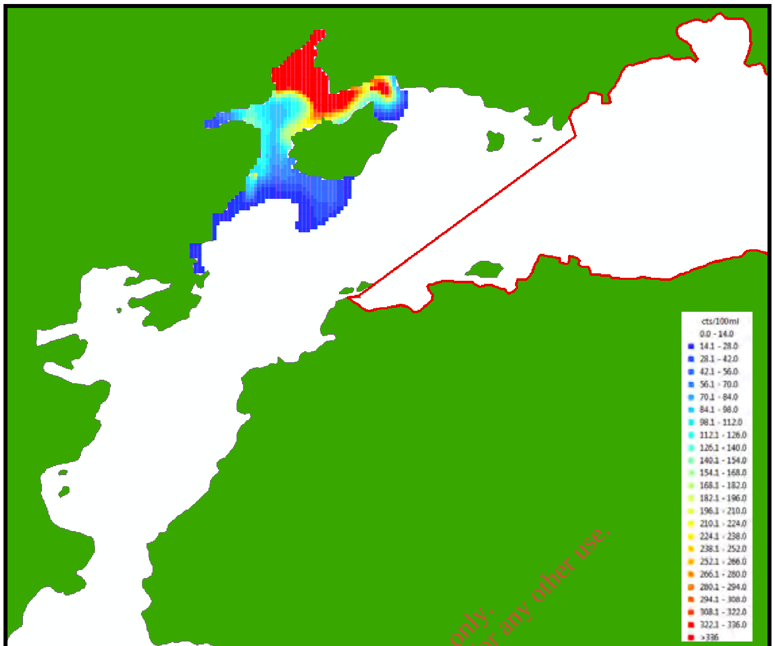

Figure 112: Scenario 9 faecal coliform concentrations neap tide low water

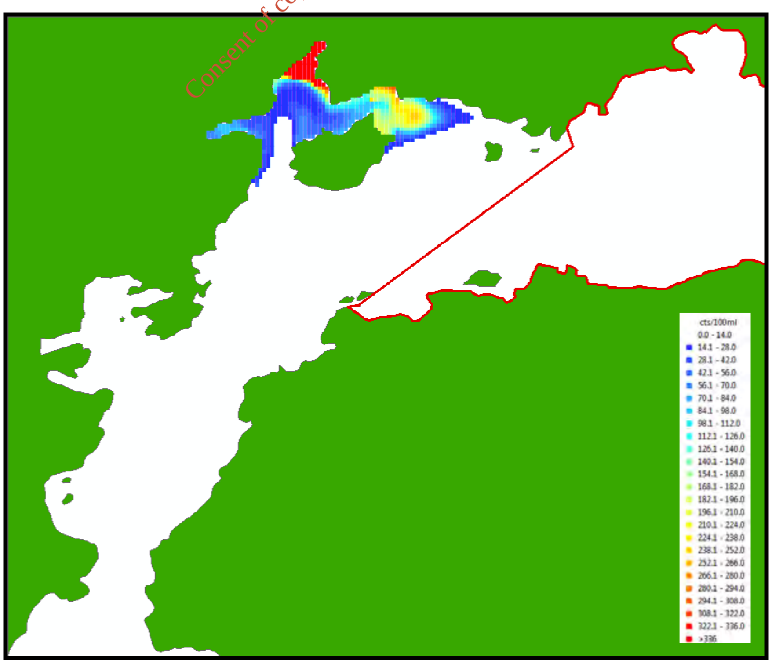

Figure 113: Scenario 9 faecal coliform concentrations neap tide mid flood

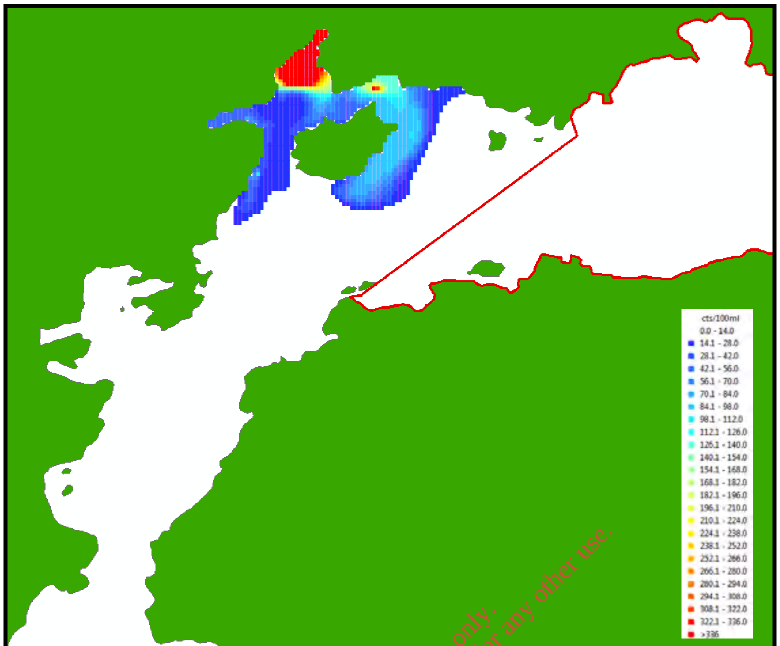

Figure 114: Scenario 9 faecal coliform concentrations neap tide high water

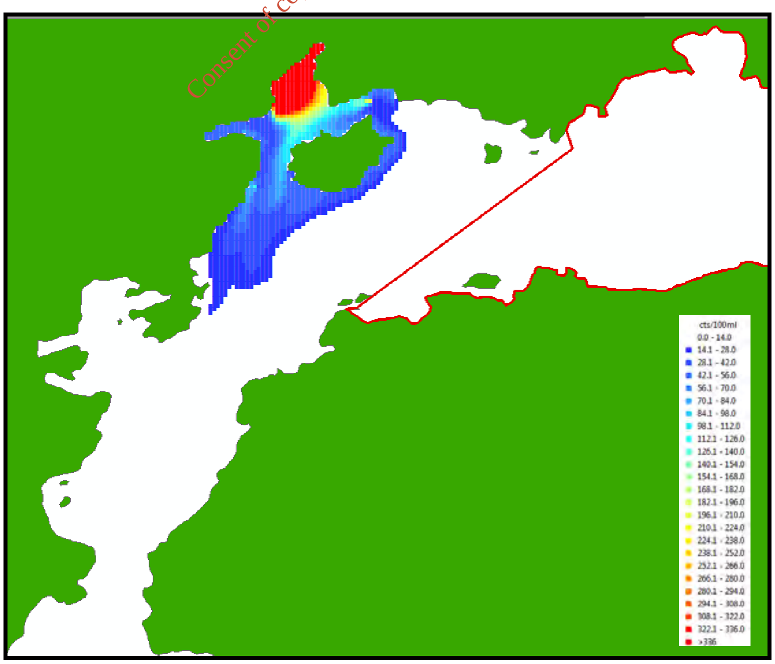

Figure 115: Scenario 9 faecal coliform concentrations neap tide mid ebb

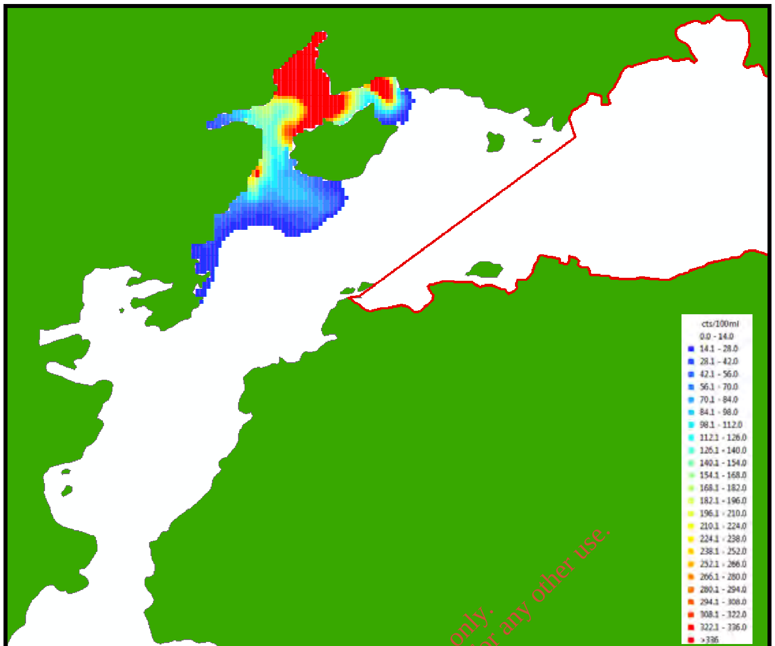

Figure 116: Scenario 9 faecal coliform concentrations spring tide low water

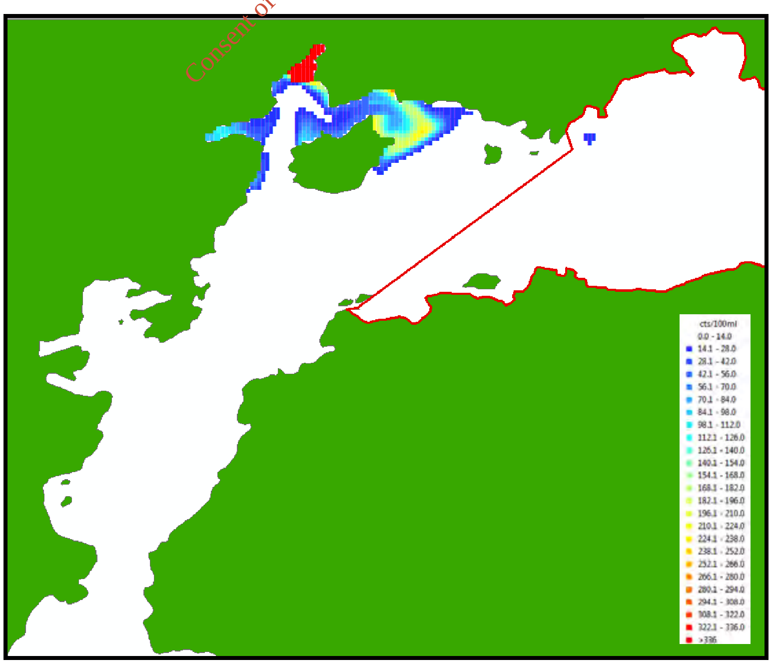

Figure 117: Scenario 9 faecal coliform concentrations spring tide mid flood

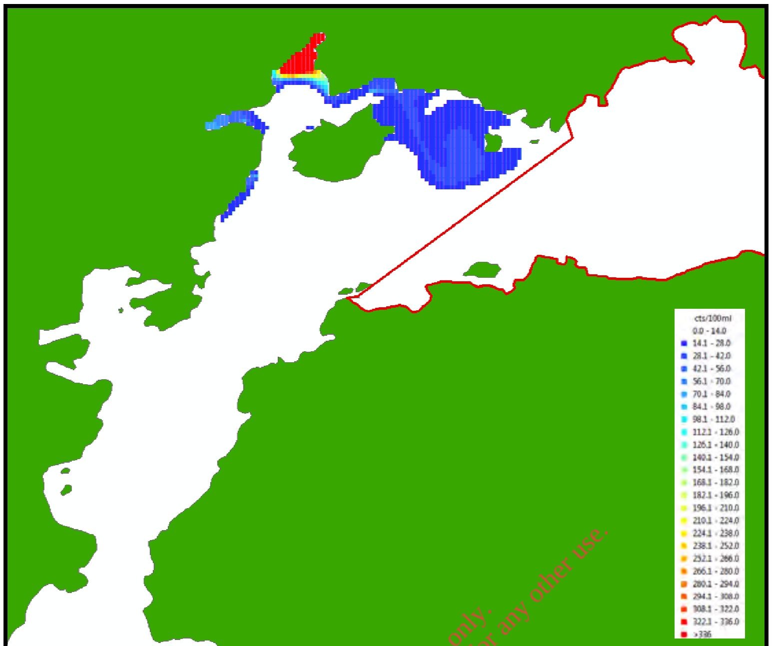

Figure 118: Scenario 9 faecal coliform concentrations spring tide high water

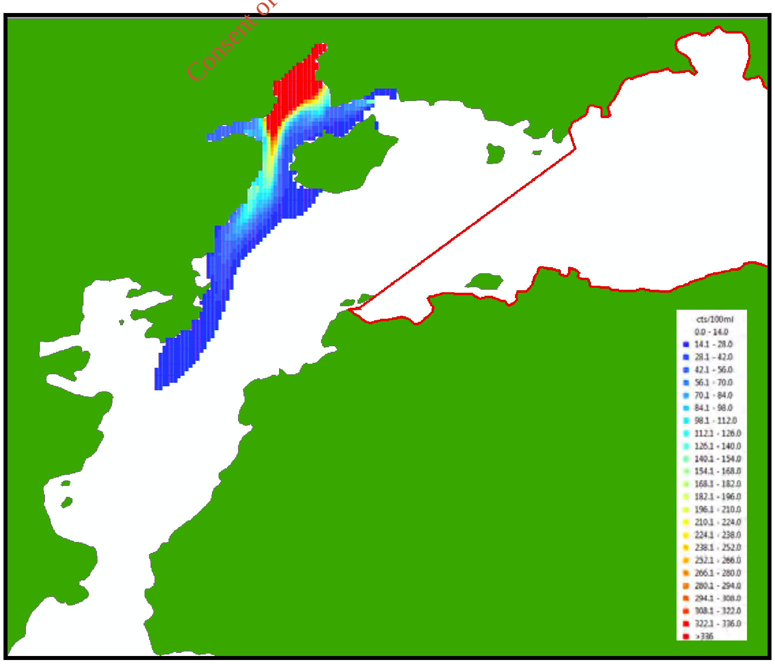

Figure 119: Scenario 9 faecal coliform concentrations spring tide mid ebb

4.13 Scenario 10

4.13.1 The purpose of this scenario was to investigate the impact on the water quality of the receiving waters of Castletownbere by discharging effluent from the existing outfalls in Castletownbere for maximum storm flow conditions.

4.13.2 Details pertaining to Scenario 10 are tabulated below in Table 23.

Outfall	Flow (litres/s)	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
DAFF	9.0	1.1×10^3	3	808	5348	318	126	469
Came Pt.	8.8	1.0×10^8	1.0×10^6	250	500	25	6	240
Came Woods	1.2	1.0×10^8	1.0×10^6	134	441	25	6	249
Main Outfall	111.0	1.0×10^8	1.0×10^6	250	500	25	6	240
BrandyHall Br.	14.1	1.0×10^8	1.0×10^6	13	34	25	6	28
Hospital	20.9	1.0×10^8	1.0×10^6	137	403	25	6	128

Table 23: Details for Scenario 10

4.13.3 Using the above discharges the model was used to estimate the concentrations of the various parameters throughout the study area during the course of a spring-neap tidal cycle.

4.13.4 All loadings were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.13.5 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.13.6 The duration of the simulation was sufficient to allow steady state conditions to be attained, thus ensuring the maximum levels of each parameter be reached throughout the water body.

4.13.7 Figure 120 presents the predicted faecal and total colifom concentrations, Figure 121 presents the predicted BOD and COD concentrations, Figure 122 presents the predicted DIN and P concentrations and Figure 123 presents the predicted suspended solids concentrations.

4.13.8 All model predictions were output at the boundary of the shellfish designated waters and are summarised in Table 24.

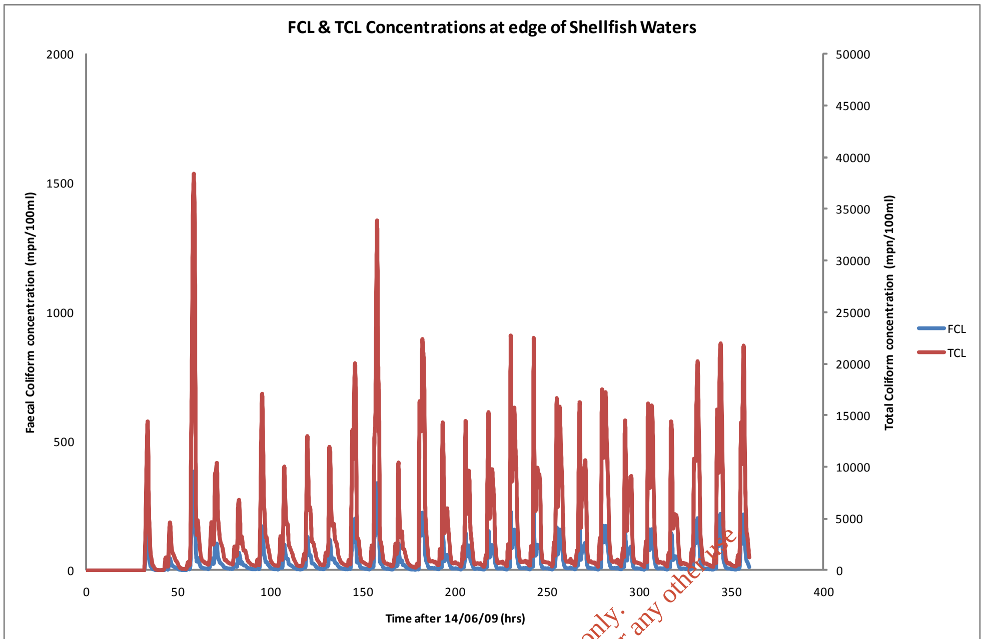

Figure 120: Scenario 10 predicted FCL concentrations

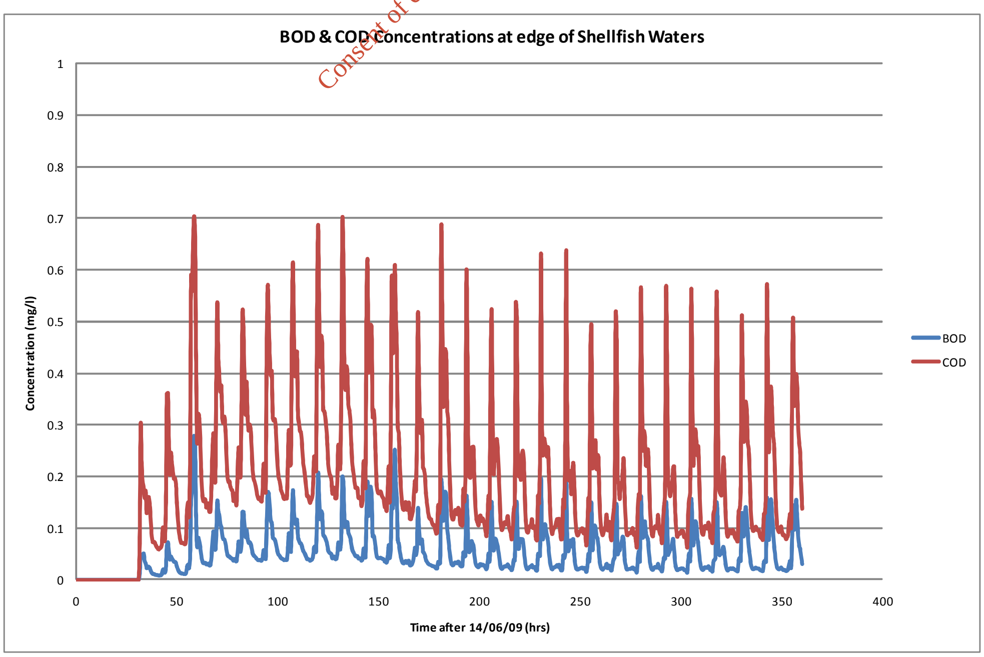

Figure 121: Scenario 10 predicted BOD & COD concentrations

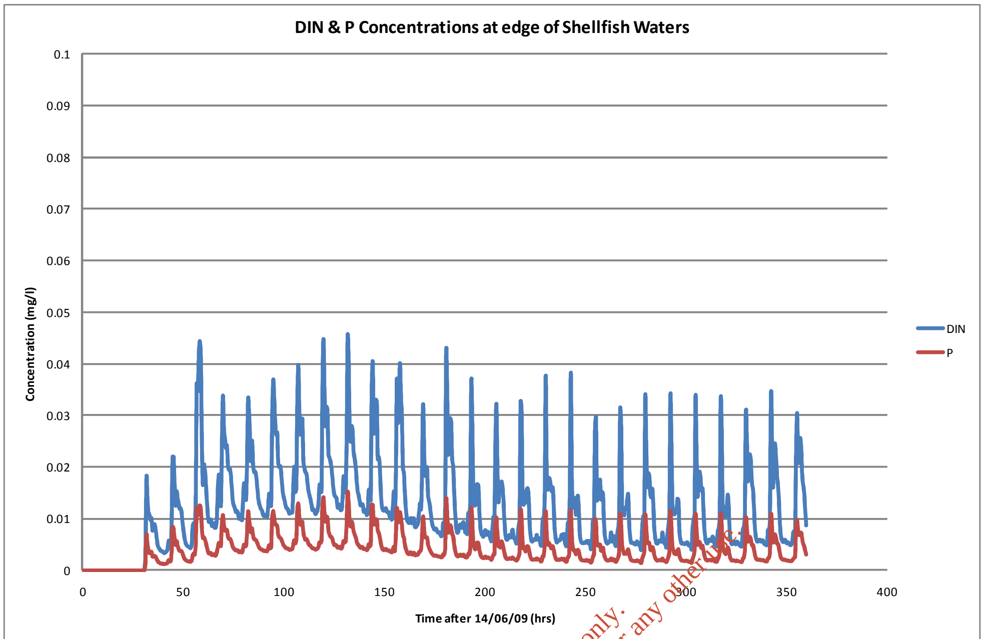

Figure 122: Scenario 10 predicted DIN & P concentrations

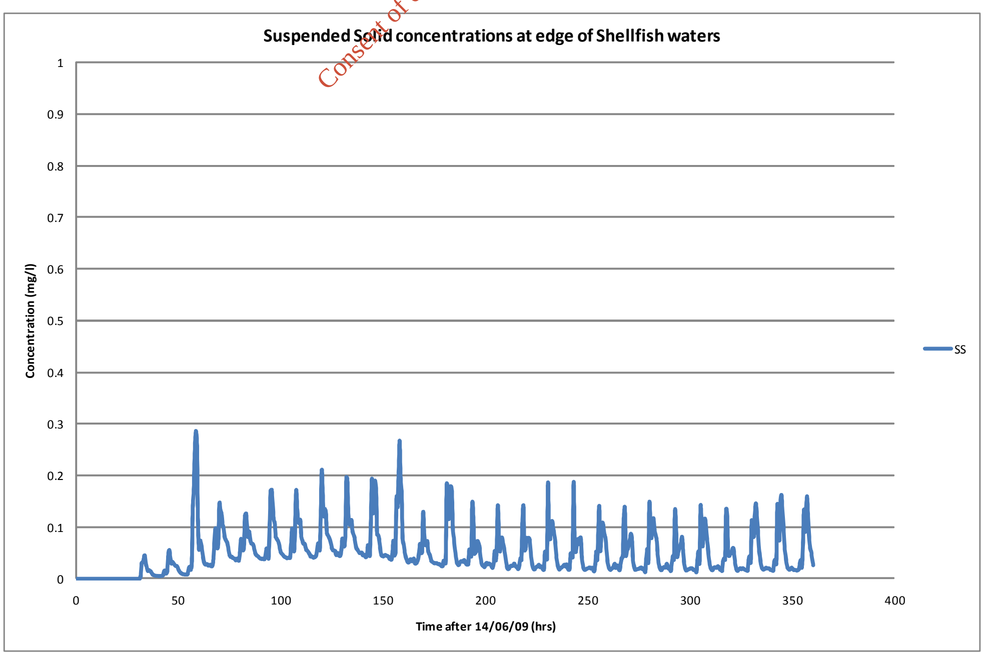

Figure 123: Scenario 10 predicted suspended solids concentration

Run No. 10 Existing conditions (storm flows).							
	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
Geometric Mean	$1.6x10^3$	16.20	0.044	0.173	0.011	0.003	0.042
Maximum	$3.8x10^4$	383.79	0.278	0.704	0.045	0.015	0.287
Median	$1.2x10^3$	12.14	0.042	0.169	0.011	0.004	0.043

Table 24: Summary of results for Scenario 10

4.14 Scenario 11

4.14.1 The purpose of this scenario was to investigate the impact on the water quality of the receiving waters of Castletownbere by discharging effluent from the proposed future configuration of outfalls in Castletownbere for maximum storm flow conditions.

4.14.2 Loadings associated with the main B1-70m and DAFF outfall were specified as continuous discharge after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.14.3 Loadings associated with the pumping station overflows were specified as discharging for 15 mins (PS4), 29 mins (PS2 & PS3), or 54 mins (PS6 & B1-70m overflow) at hour 231 of the simulation corresponding to a flooding spring tide.

4.14.4 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.14.5 The duration of the simulation was sufficient to allow steady state conditions to be attained, thus ensuring the maximum levels of each parameter be reached throughout the water body.

4.14.6 Details pertaining to Scenario 11 are tabulated below in Table 25.

Outfall	Flow (m3/s)	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
B1-70m	0.031	5.0×10^6	1.0×10^6	25	125	40	9	35
DAFF	0.009	1.1×10^3	3.0	250	5348	318	126	469
PS2	0.015	1.0×10^8	1.0×10^6	250	500	25	6	240
PS3	0.005	1.0×10^8	1.0×10^6	250	500	25	6	240
PS4	0.063	1.0×10^8	1.0×10^6	250	500	25	6	240
PS6	0.015	1.0×10^8	1.0×10^6	250	500	25	6	240
B1-70 overflow	0.142	1.0×10^8	1.0×10^6	250	500	25	6	240

Table 25: Details for Scenario 11

4.14.7 Using the above discharges the model was used to estimate the concentrations of the various parameters throughout the study area during the course of a spring-neap tidal cycle.

4.14.8 Figure 124 presents the predicted faecal and total coliform concentrations, Figure 125 presents the predicted BOD and COD concentrations, Figure 126 presents the predicted DIN and P concentrations and Figure 127 presents the predicted suspended solids concentrations.

4.14.9 All model predictions were output at the boundary of the shellfish designated waters and are summarised in Table 26.

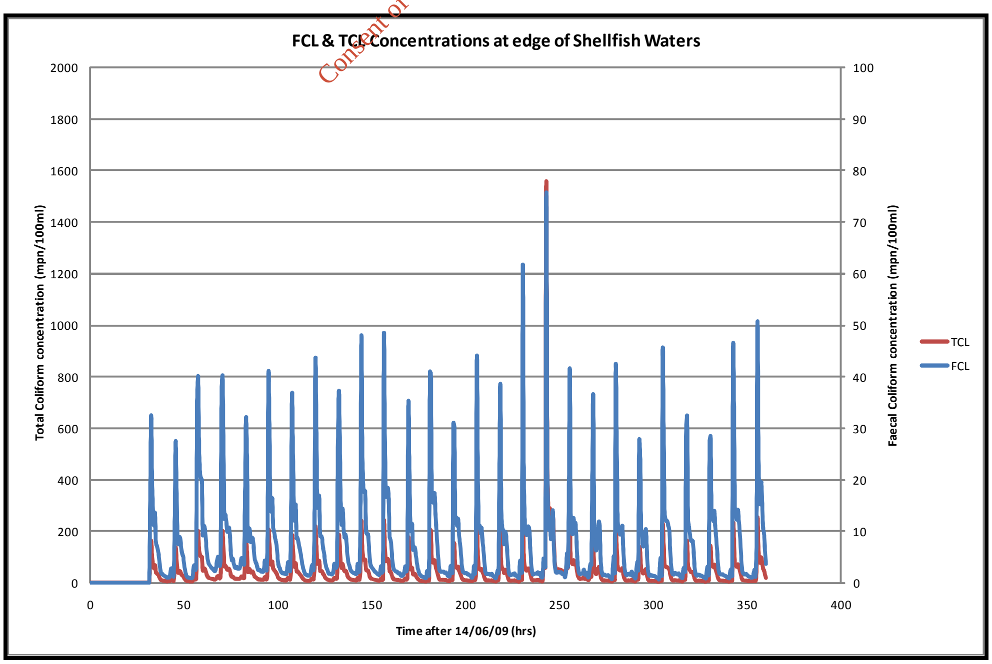

Figure 124: Scenario 11 predicted FCL & TCL concentrations

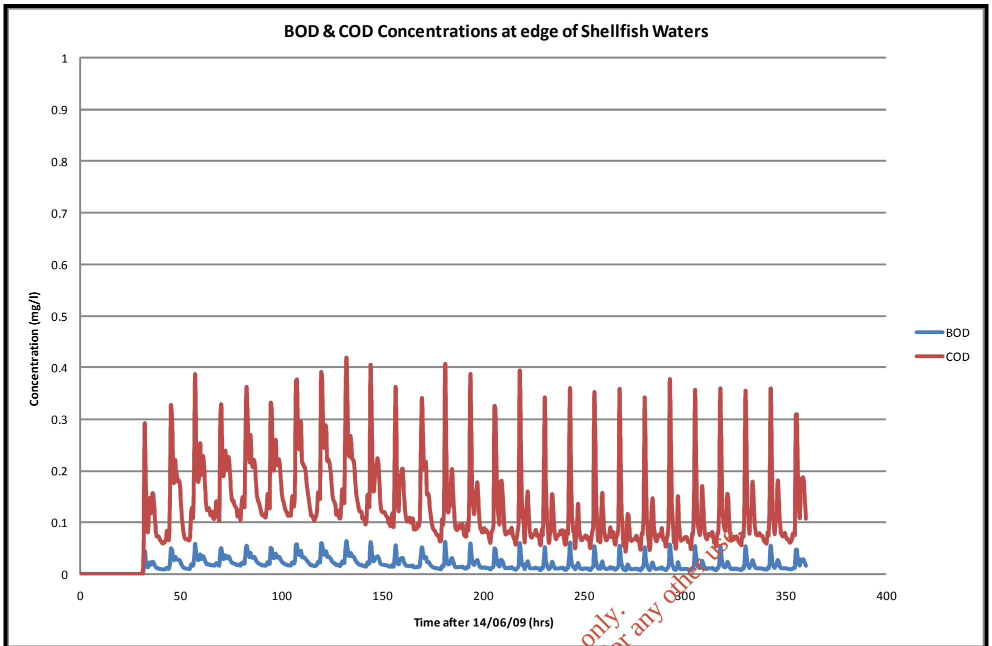

Figure 125: Scenario 11 predicted BOD & COD concentrations

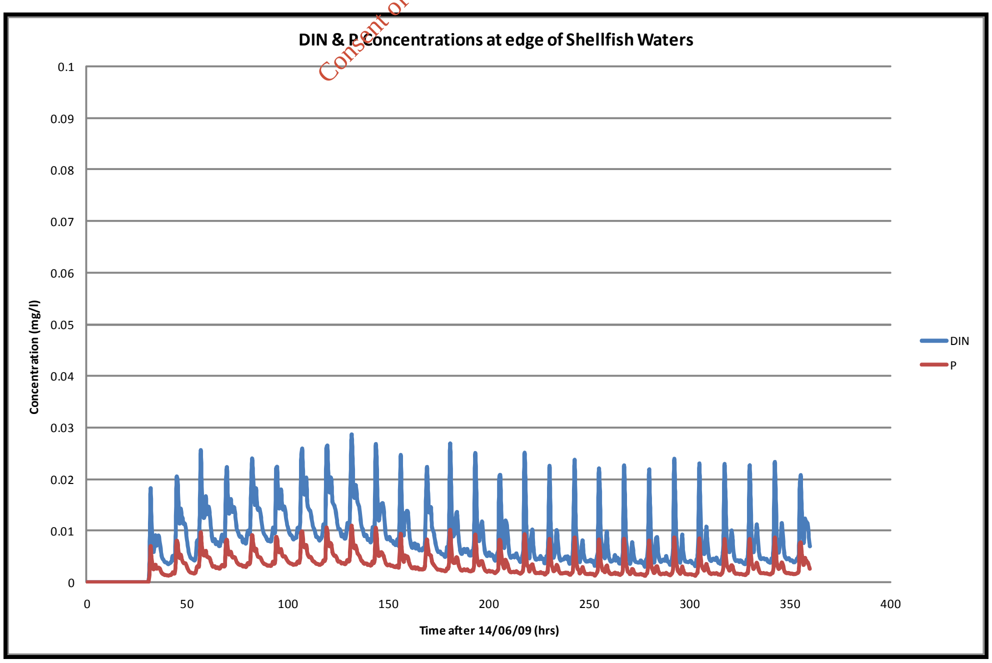

Figure 126: Scenario 11 predicted DIN & P concentrations

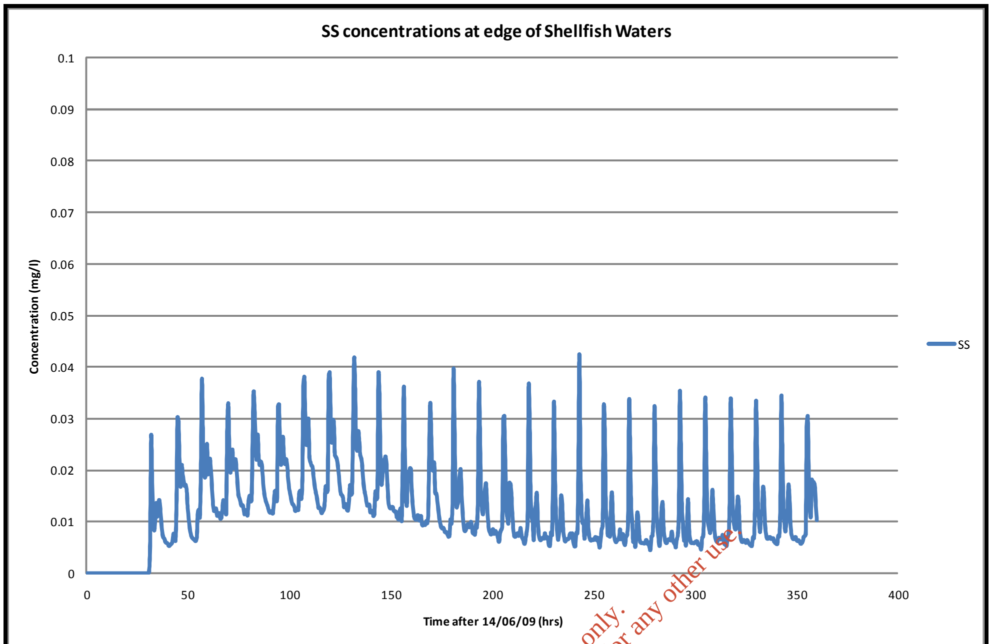

Figure 127: Scenario 11 predicted suspended solids concentration

Run No. 11 Proposed conditions (storm flows).							
	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
Geometric Mean	410.575	4.065	0.016	0.114	0.007	0.008	0.011
Maximum	7.5×10^3	75.618	0.064	0.418	0.029	0.031	0.042
Median	324.156	3.24	0.020	0.110	0.009	0.010	0.010

Table 26: Summary of results for Scenario 11

4.15 Scenario 12

4.15.1 The purpose of this scenario was to investigate the impact on the water quality of the receiving waters of Castletownbere by discharging faecal coliform effluent from the proposed B1-70m outfall location in Castletownbere during ebbing tides only.

4.15.2 The coliform loading associated with the B1-70m outfall were specified as intermittent discharges after two tidal cycles of the numerical model had executed, which ensured that hydrodynamic cold start effects had dissipated.

4.15.3 The discharge operated over a 1 hour period on each tide, from two hours after high water to three hours after high water.

4.15.4 The model simulations were performed a over a spring-neap tidal cycle (350 hours) using a time intervals of 15 seconds.

4.15.5 The duration of the simulation was sufficient to allow steady state conditions to be attained, thus ensuring the maximum levels of each parameter be reached throughout the water body.

4.15.6 Details pertaining to Scenario 12 are tabulated below in Table 25.

Outfall	Flow (m3/s)	FCL (MPN/100ml)
B1-70m	0.212	2.0 x 10^6

Table 27: Details for Scenario 12

4.15.7 Using the above discharges the model was used to estimate the concentrations of faecal coliforms throughout the study area during the course of a spring-neap tidal cycle.

4.15.8 Figure 128 presents the predicted faecal concentrations at the boundary of the designated shellfish waters over the course of the simulation and summarised in Table 28.

Run No. 12 No FCL disinfection.	
	FCL (MPN/100ml)
Geometric Mean	1.499
Maximum	41.755
Median	1.326
% time > 43	0.0

Table 28: Summary of results for Scenario 12

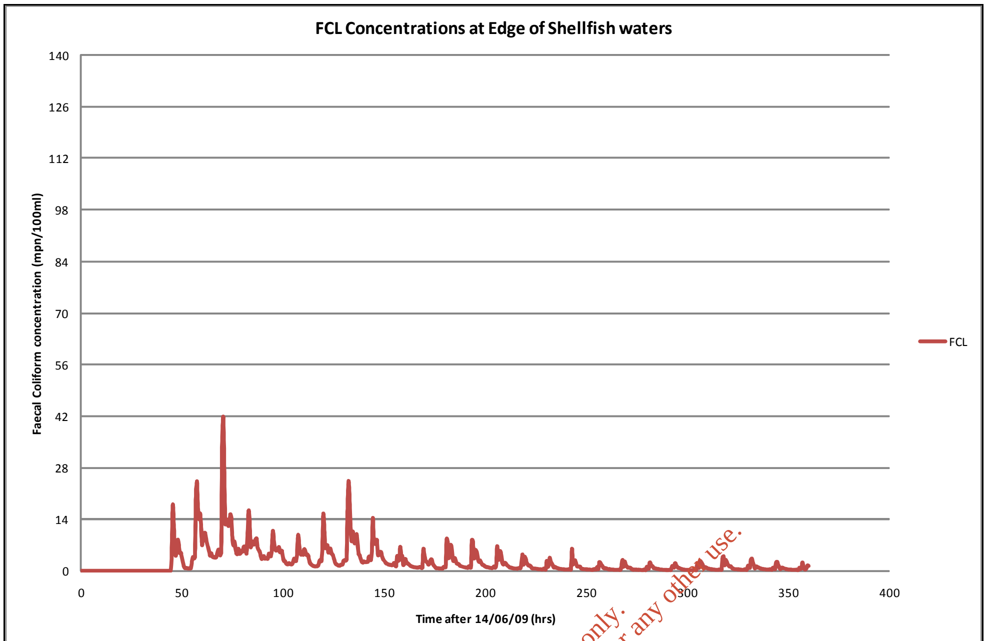

Figure 128: Scenario 12 predicted FCL concentrations

4.16 Summary of Results

4.16.1 Untreated effluent discharges

4.16.1.1 The sensitivity of model predictions to variation in T90 decay times was assessed for the T90 values of 24hrs, 36hrs, and 48hrs.

4.16.1.2 The maximum, geometric mean and median values for the predicted faecal coliform concentrations at the boundary of the designated shellfish area arising from the B1 outfall location for each of the three scenarios (1, 2 & 3) are tabulated in Table 29.

Scenario	Effluent	T90 (hrs)	Geometric Mean	Maximum	Median	%time >43
1	Raw	24	9.0	148.5	6.1	13.2
2	Raw	36	15.2	187.6	11.0	19.0
3	Raw	48	20.3	213.1	15.7	24.7

Table 29: Summary of results from Scenarios 1, 2 & 3 for outfall location B1

4.16.1.3 Except for Scenario 1, (T90 = 24 hrs), the geometric mean concentration of faecal coliforms at the boundary of the shellfish designated waters exceeded the international regulatory criterion of 14MPN/100ml when discharged from outfall location B1.

4.16.1.4 In all scenarios, the concentrations of faecal coliforms at the boundary of the shellfish designated waters exceeded the international regulatory criterion of not more than 10% of samples allowed to exceed 43MPN/100ml when discharged from outfall location B1.

4.16.1.5 The maximum, geometric mean and median values for the predicted faecal coliform concentrations at the boundary of the designated shellfish area arising from the E outfall location for each of the three scenarios (1, 2 & 3) are tabulated in Table 30.

Scenario	Effluent	T90 (hrs)	Geometric Mean	Maximum	Median	%time > 43
1	Raw	24	6.5	75.3	6.0	6.0
2	Raw	36	11.0	89.5	10.5	9.1
3	Raw	48	14.7	98.1	14.0	10.3

Table 30: Summary of results from Scenarios 1, 2 & 3 for outfall location E

4.16.1.6 Only for Scenario 3, (T90 = 48hrs), was the geometric mean concentration of faecal coliforms at the boundary of the shellfish designated waters exceeded the international regulatory criterion of 14MPN/100ml, when discharged from outfall location E.

4.16.1.7 Again, only for Scenario 3, the concentrations of faecal coliforms at the boundary of the shellfish designated waters exceeded the international regulatory criterion of not more than 10% of samples allowed to exceed 43MPN/100ml, when discharged from outfall location E.

4.16.1.8 Given the inherent uncertainty relating to the accurate quantification of T90 decay rates in the marine environment it is recommended than un-disinfected faecal coliform material not be discharged through either outfall B1 or E.

4.16.2 Optimum outfall location(s)

4.16.2.1 The model was used to predict the faecal coliform concentrations at the boundary of the designated shellfish area arising from discharging disinfected effluent through outfalls B1 & E1 (Scenario 4) and to determine the merit in moving either outfall closer onshore by 70m (Scenario 5: B1-70m, E-70m) or further offshore by 70m (Scenario 6: B1+70m, E+70m)

4.16.2.2 The maximum, geometric mean and median values for the predicted faecal coliform concentrations at the boundary of the designated shellfish area arising from discharging disinfected effluent through the B1, B1-70m and B1+70m outfall locations are tabulated in Table 31.

Scenario	Effluent	T90 (hrs)	Geometric Mean	Maximum	Median	%time > 43
4	Treated	36	1.1	14.1	0.8	0.0
5	Treated	36	0.6	9.1	0.5	0.0
6	Treated	36	2.1	19.2	1.5	0.0

Table 31: Summary of results from Scenarios 4, 5 & 6 for outfalls B1, B1-70, B1+70 respectively

4.16.2.3 In all cases, the geometric mean concentration of faecal coliforms at the boundary of the designated shellfish area are well below the international regulatory criterion of 14MPN/100ml when discharged from outfall location B1, B1-70 or B1+70.

4.16.2.4 In all cases, the international regulatory criterion of not more than 10% of samples allowed to exceed 43MPN/100ml is met when coliforms were discharged from outfall location B1, B1-70 or B1+70.

4.16.2.5 Based on the results from Scenarios 4, 5 & 6, the model predicts that outfall location B1-70 is the optimum outfall location when assessing the potential impacts on the designated shellfish area.

4.16.2.6 The maximum, geometric mean and median values for the predicted faecal coliform concentrations at the boundary of the designated shellfish area arising from discharging disinfected effluent through the E, E-70m and E+70m outfall locations are tabulated in Table 32.

Scenario	Effluent	T90 (hrs)	Geometric Mean	Maximum	Median	%time > 43
4	Treated	36	0.8	6.7	0.8	0.0
5	Treated	36	0.4	3.6	0.4	0.0
6	Treated	36	1.3	8.1	1.2	0.0

Table 32: Summary of results from Scenarios 4, 5 & 6 for outfalls E, E-70, E+70 respectively

4.16.2.7 In all cases, the geometric mean concentration of faecal coliforms at the boundary of the designated shellfish area were well below the international regulatory criterion of 14MPN/100ml when discharged from outfall location E, E-70 or E+70.

4.16.2.8 In all cases, the international regulatory criterion of not more than 10% of samples allowed to exceed 43MPN/100ml is met when coliforms were discharged from outfall location E, E-70 or E+70.

4.16.2.9 Based on the results from Scenarios 4, 5 & 6, the model predicts that outfall location E-70 is the optimum outfall location when assessing the potential impacts on the designated shellfish area.

4.16.3 Potential adverse wind conditions

4.16.3.1 The model was used to predict the faecal coliform concentrations at the boundary of the designated shellfish area arising from discharging disinfected effluent through outfalls B1 & E in calm conditions (Scenario 4) and to predict the faecal coliform concentrations at the boundary of the designated shellfish area arising from discharging disinfected effluent through outfalls B1 & E in potential adverse wind conditions of a Force 6 wind blowing from the southwest (Scenario 7)

4.16.3.2 The maximum, geometric mean and median values for the predicted faecal coliform concentrations at the boundary of the designated shellfish area arising from discharging disinfected effluent through the B1 outfall location for calm and force 6 southwesterly wind conditions are tabulated in Table 33.

Scenario	Wind	T90 (hrs)	Geometric Mean	Maximum	Median	%time > 43
4	Calm	36	1.1	14.1	0.8	0.0
7	F6 SW	36	0.3	4.4	0.3	0.0

Table 33: Summary of results from Scenarios 4 & 7 for outfall locations B1

4.16.3.3 In all cases, the geometric mean concentration of faecal coliforms at the boundary of the shellfish designated waters are well below the international regulatory criterion of 14MPN/100ml when discharged from outfall location B1 for both calm and southwesterly wind conditions.

4.16.3.4 In all cases, the international regulatory criterion of not more than 10% of samples allowed to exceed 43MPN/100ml is met when coliforms were discharged from outfall location B1 for both calm and southwesterly wind conditions.

4.16.3.5 Based on the results from Scenarios 4 & 7, the model predicts that southwesterly winds will have an advantageous effect in increasing the dilution of the faecal coliforms by moving the effluent plume into the deeper waters of the main channel.

4.16.4 Assessment of existing and proposed outfalls: Normal operations

4.16.4.1 The model was used to predict the concentrations of all parameters of interest at the boundary of the designated shellfish water arising from discharging treated and disinfected effluent through the proposed future outfalls in Castletownbere for design flow conditions (Scenario 8: B1-70 & DAFF) and to predict the concentrations of all parameters at the boundary of the designated shellfish water arising from discharging current effluent loads through the existing outfalls in Castletownbere (Scenario 9).

4.16.4.2 The model was also used to predict the concentrations of faecal coliforms at the boundary of the designated shellfish water arising from discharging marginally disinfected effluent through the proposed future outfalls in Castletownbere for design flow conditions (Scenario 8b: B1-70 & DAFF).

4.16.4.3 The maximum, geometric mean and median values for the predicted concentrations of the parameters of interest at the boundary of the designated shellfish area arising from discharging treated and disinfected effluent through the proposed outfall locations are tabulated in Table 34, (Scenario 8), the existing outfall locations are tabulated in Table 35, (Scenario 9) and the marginally disinfected faecal coliform discharges in Table 36, (Scenario 8b).

Run No. 8 Proposed operating conditions.							
	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
Geometric Mean	3.089	0.615	0.017	0.117	0.008	0.003	0.011
Maximum	47.370	9.464	0.064	0.418	0.030	0.011	0.042
Median	2.424	0.484	0.016	0.111	0.008	0.003	0.011

Table 34: Summary of results for Scenario 8

Run No. 9 Existing conditions (3 x DWF).							
	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
Geometric Mean	130.400	1.303	0.018	0.115	0.007	0.003	0.013
Maximum	2883.525	28.835	0.070	0.415	0.026	0.010	0.049
Median	92.868	0.929	0.018	0.110	0.007	0.003	0.013

Table 35: Summary of results for Scenario 9

Run No. 8b Marginal FCL disinfection.	
	FCL (MPN/100ml)
Geometric Mean	4.023
Maximum	63.091
Median	2.272
% time > 43	1.360

Table 36: Summary of results for Scenario 8b

4.16.4.4 For all parameters of concern, the normal operation of the proposed outfall at location B1-70m, results in either approximately the same, or lower concentration within the designated shellfish area, when compared with the existing 3xDWF operation of the current outfalls. Most notable is the reduction in both TCL and FCL concentrations.

4.16.4.5 With respect to discharging marginally treated faecal coliforms from the proposed outfalls, the model predicted that the impact on the designated shellfish waters would be greater than that predicted for current effluent loads, but would still meet the international criteria for shellfish waters classification

4.16.5 Assessment of existing and proposed outfalls: Storm flow operation

4.16.5.1 The model was used to predict the concentrations of all parameters of interest at the boundary of the designated shellfish water arising from discharging treated effluent through the proposed future outfalls in Castletownbere for storm flow conditions (Scenario 11: B1-70 & DAFF) and to predict the concentrations of all parameters at the boundary of the designated shellfish water arising from discharging current effluent loads through the existing outfalls in Castletownbere (Scenario 10) for recorded stormflow conditions.

4.16.5.2 The maximum, geometric mean and median values for the predicted concentrations of the parameters of interest at the boundary of the designated shellfish area arising from discharging treated effluent through the existing outfall locations are tabulated in Table 37 and the proposed outfall locations in Table 38.

4.16.5.3 The results show that under storm flow conditions, the proposed future configuration of outfalls and storm overflows results in an improved water quality situation within Castletownbere when compared to the existing situation with the shellfish standards continuing to be met during and after the storm event.

Run No. 10 Existing conditions (storm flows).							
	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
Geometric Mean	1.6×10^3	16.20	0.044	0.173	0.011	0.003	0.042
Maximum	3.8×10^4	383.79	0.278	0.704	0.045	0.015	0.287
Median	1.2×10^3	12.14	0.042	0.169	0.011	0.004	0.043

Table 37: Summary of results for Scenario 10

Run No. 11 Proposed conditions (storm flows).							
	TCL (MPN/100ml)	FCL (MPN/100ml)	BOD (mg/l)	COD (mg/l)	DIN (mg/l)	P (mg/l)	SS (mg/l)
Geometric Mean	410.575	4.065	0.016	0.114	0.007	0.008	0.011
Maximum	7.5×10^3	75.618	0.064	0.418	0.029	0.031	0.042
Median	324.156	3.24	0.020	0.110	0.009	0.010	0.010

Table 38: Summary of results for Scenario 11

4.16.6 Assessment of tidal discharge for proposed outfall

4.16.6.1 The model was used to predict the concentrations of faecal coliforms at the boundary of the designated shellfish water arising from discharging un-disinfected faecal coliform effluent from the proposed B1-70m outfall location in Castletownbere for a one hour period during ebbing tides only.

4.16.6.2 The maximum, geometric mean and median values for the predicted concentrations of faecal coliforms at the boundary of the designated shellfish area arising from discharging un-disinfected faecal coliform effluent from the proposed B1-70m outfall location in Castletownbere is tabulated in Table 39.

Run No. 12 No FCL disinfection.	
	FCL (MPN/100ml)
Geometric Mean	1.499
Maximum	41.755
Median	1.326
% time > 43	0.0

Table 39: Summary of results for Scenario 12

4.16.6.3 The results show that discharging untreated faecal coliform effluent through the proposed B1-70m outfall for one hour on ebbing tides results in improved water quality conditions at the boundary of the designated shellfish area when compared with a continuous discharge of marginally disinfected coliform effluent from the same location, (Scenario 8b).

4.16.6.4

5. Discussion

5.1 Decay rates

5.1.1 Assigning accurate T90 decay rates to coliforms is very difficult without accurate scientific analysis of the actual microbes and the ambient water.

5.1.2 T90 decay rates vary widely depending on, inter alia, sunlight intensity, turbidity, day/night, salinity, temperature, etc.

5.1.3 Previous studies by MarCon in the United Kingdom have used T90 values as high as 120 hours based on laboratory analysis. Studies by other consultants in Ireland have adopted T90 values as low as 12 hours. Internationally, it has been shown that the T90 value can range from as little as 4 hours to in excess of 200 hours, depending on the parameters mentioned previously.

5.1.4 The T90 value of 36 hours adopted in this current study can be considered to be a representative average value.

5.1.5 Decay rates of BOD and COD are well understood and are not as widely influenced by ambient environmental conditions as the coliform T90 decay rates. The decay rate used in the current study for BOD & COD was the deoxygenation rate coefficient K_1 and assumed a value of 0.23 day^{-1}.

5.1.6 No decay rate was applied to Dissolved Inorganic Nitrogen, DIN, and Inorganic Phosphorus, P, as nutrient modeling is a complex subject and requires a considerable amount of temporal and spatial data for organic and inorganic compounds and chlorophyll-a, for all point and diffuse sources to ensure accurate calibration of nutrient cycling modules within numerical models.

5.1.7 Modeling DIN and P as conservative substances had the effect of predicting the worst case scenarios for effluent discharges as the nutrients are not taken up by phytoplankton and removed from the dissolved inorganic pool but instead transported throughout the model domain in a conservative manner.

5.1.8 Suspended solids were modeled as cohesive suspended sediment with a median particle size of 60µm. Only settlement of the suspended solids was allowed. No re-suspension was allowed.

5.2 Water quality predictions

5.2.1 The predicted concentrations of the various parameters of interest in the current study, as presented above, did not account for the ambient concentrations of the various parameters as no sampling was commissioned to determine the these concentrations.

5.2.2 Predictions from the numerical model for all scenarios should be considered in addition to background concentrations.

5.2.3 Faecal coliforms

5.2.3.1 With no disinfection of the faecal coliform effluent prior to discharge, there is a possibility that the designated shellfish areas may not meet the required classification criteria.

5.2.3.2 For marginally disinfected coliform effluent, the median concentrations of faecal coliforms, FCL, at the boundary of the shellfish designated waters arising from the normal operation of the proposed discharge was predicted to be only 2.272MPN/100ml above long term normal background levels.

5.2.3.3 For marginally disinfected coliform effluent, the maximum concentrations of faecal coliforms, FCL, at the boundary of the shellfish designated waters arising from the normal operation of the proposed discharge was predicted to be only 63.091 MPN/100ml above long term normal background levels.

5.2.3.4 For marginally disinfected coliform effluent, the predicted geometric mean concentrations at the boundary of the designated shellfish area arising from the normal operation of the proposed discharge , (4.023 MPN/100ml), are well below international limits of 14 MPN/100ml and no more than 10% > 43MPN / 100ml.

5.2.3.5 For disinfected coliform effluent, the median concentrations of faecal coliforms, FCL, at the boundary of the shellfish designated waters arising from the normal operation of the proposed discharge was predicted to be only 0.5 MPN/100ml above long term normal background levels.

5.2.3.6 For disinfected coliform effluent, the maximum concentrations of faecal coliforms, FCL, at the boundary of the shellfish designated waters arising from the normal operation of the proposed discharge was predicted to be only 9.1 MPN/100ml above long term normal background levels.

5.2.3.7 For disinfected coliform effluent, the predicted geometric mean concentrations at the boundary of the designated shellfish area arising from the normal operation of the proposed discharge , (0.6 MPN/100ml), are well below international limits of 14 MPN/100ml and no more than 10% > 43MPN / 100ml.

5.2.3.8 Based on the results of the modeling study the proposed outfall location at B1-70m will not have any adverse impact on the designated shellfish area with respect to faecal coliform concentrations should marginally disinfection of the faecal coliform effluent be undertaken.

5.2.3.9 It would be possible to discharge untreated faecal coliform effluent from the proposed B1-70m discharge without adverse impact on the designated shellfish area by discharging for a period of 1 hour during the mid ebb phase of the tidal cycle. This would necessitate the construction of holding tanks at the treatment works.

5.2.4 Dissolved Inorganic Nitrogen

5.2.4.1 The median concentration of Dissolved Inorganic Nitrogen, DIN, predicted within the water body arising from the proposed discharge, when modeled conservatively, was predicted to be only 0.008 mg/l above long term normal background levels.

5.2.4.2 The median concentration of DIN predicted at the proposed B1-70m outfall location, when modeled conservatively, was predicted to be 0.065 mg/l above long term normal background levels.

5.2.4.3 The EPA eutrophic assessement threshold for DIN > 0.25 mg/l cannot be accurately reported against without information pertaining to background water sampling analysis.

5.2.4.4 However, as the B1-70m outfall location will be the principle source of DIN discharging to the water body in the future, (excluding any agricultural diffuse sources), it is likely that the EPA eutrophic assessement criterion will be met.

5.2.5 Orthophosphate

5.2.5.1 The median concentration of Orthophosphate, P, predicted within the water body arising from the proposed discharge, when modeled conservatively, was predicted to be only 0.003 mg/l, (3 µg/l), above long term normal background levels.

5.2.5.2 The median concentration of P predicted at the proposed B1-70m outfall location, when modeled conservatively, was predicted to be 0.014 mg/l, (14 µg/l), above long term normal background levels.

5.2.5.3 The EPA eutrophic assessement threshold for P > 40 µg/l cannot be accurately reported against without information pertaining to background water sampling analysis.

5.2.5.4 However, as the B1-70m outfall location will be the principle source of P discharging to the water body in the future, (excluding any agricultural diffuse sources), it is likely that the EPA eutrophic assessement criterion will be met.

5.2.6 Dissolved Oxygen and Chlorophyll-a

5.2.6.1 Dissolved Oxygen and Chlorophyll-a were not included in the scope of work for the current study.

5.2.7 The above findings are based on the results of the numerical model predictions and do not take into account existing background concentrations of nutrients within the water body, nor any source of diffuse pollution emanating from the surrounding countryside given the lack of available data.

5.3 Storm overflows

5.3.1 A storm overflow event was simulated assuming normal discharge from the proposed outfall location combined with overflows through the proposed pumping stations resulting in predicted median and geometric mean FCL concentrations at the boundary of the designated shellfish area of approximately 3.24 MPN/100ml and 4.06 MPN/100ml respectively

5.3.2 The storm overflow simulation as executed was representative of a 1:20 year design event provided by the client.

5.3.3 Both the predicted median concentration, (approx. 3.24 MPN/100ml) and the predicted geometric mean concentration (approx. 4.06 MPN/100ml), meet the international limit of 14 MPN/100ml for the classification of approved shellfish area, for adverse pollution conditions.

5.3.4 The median concentration of Dissolved Inorganic Nitrogen, DIN, predicted within the water body arising from the proposed storm overflows, when modeled conservatively, was predicted to be only 0.009 mg/l above long term normal background levels, thus meeting the EPA eutrophic assessement criterion.

5.3.5 The median concentration of Orthophosphate, P, predicted within the water body arising from the proposed discharge, when modeled conservatively, was predicted to be only 0.010 mg/l, (9 µg/l), above long term normal background levels.

5.4 Outfall location

5.4.1 The results of the modeling study predict that discharges from outfall location E result in marginally lower median FCL concentrations at the boundary of the designated shellfish area than discharges from outfall location B1, B1-70 or B1+70m.

5.4.2 The maximum difference between predicted geometric mean concentrations at the boundary of the designated shellfish area arising from discharges from any of the E or B locations under normal operating conditions was less than 1.7 MPN/100ml. (Outfall B1+70 versus Outfall E1-70m)

5.4.3 Although discharges from any of the E locations resulted in marginally lower FCL concentrations at the boundary of the designated shellfish area the cost of pipeline construction to location E would not warrant the marginal improvement in water quality at the designated shellfish area.

5.4.4 The option of siting the discharge closer to shore at location B1-70m results in lower mena FCL concentrations at the boundary of the designated shellfish area when compared with Locations B1 or B1+70m.

5.4.5 The siting of the outfall at B1-70m will also reduce the costs associated with the construction of the pipeline out to location B1.

5.4.6 It is not recommended that outfall B1 be moved any closer to shore than the proposed B1-70m locations as water depths become very shallow, resulting in less initial dilution, the possibility of the outfall becoming exposed on extreme low water spring tides, or the possibility of effluent plumes becoming 'bank attached' and impacting on the shoreline.

5.4.7 Results presented in this report have shown the effluent plume interacting with the shoreline.

5.4.8 For an accurate assessment of the near field effects (<250m) arising from siting the outfall at location B1-70m it is recommended that an near field initial mixing model such as CORMIX or PLUMES be applied.

5.5 Other

5.5.1 It is not expected that the proposed maintenance dredging of the navigation channel to Castletownbere Harbour will have an impact on the water quality predictions resulting from discharges arising from the proposed outfall location(s).

5.5.2 It is not expected that any infrastructure development to the harbour (pier, quay, extensions, etc) will have an impact on the water quality predictions resulting from discharges arising from the proposed outfall location(s).

6. Conclusion

6.1 MarCon Computations International Ltd., MarCon, were commissioned by Tobin Consulting Engineers to undertake a detailed mathematical modelling study of Castletownbere in order to determine the optimum location(s), discharge standards and possible impacts on the receiving waters of discharging effluent from the proposed Castletownbere Sewage Scheme and Regional Water Supply Scheme outfalls.

6.2 MarCon developed a two dimensional computational model of Castletownbere and calibrated the model predictions against available field data.

6.3 In consultation with the consulting engineers, MarCon executed a range of scenarios to determine the optimum outfall location, discharge standard and determine the impacts on the receiving waters of Casteltownbere arising from discharges from the proposed outfall and to determine the relative improvements in the water quality compared to the existing arrangement of outfalls.

6.4 Based on the 6No. preferred outfall locations and the results of the model scenarios executed for this study the proposed outfall location of B1-70m was determined to represent the optimum outfall location in terms of impact on water quality in the designated shellfish area and in terms of relative construction costs.

6.5 It was predicted that the continuous discharge of untreated effluent to the receiving water body would result in the designated shellfish waters failing to meet international standards for approved shellfish cultivation, therefore a discharge standard for faecal coliforms of 1,000,000 MPN/100ml has been proposed.

6.6 It was predicted that the tidally controlled discharge of untreated effluent to the receiving water body for a one hour period on an ebbing tide would result in the designated shellfish waters meeting international standards for approved shellfish cultivation.

6.7 Based on the results of the model scenarios executed for this study it was determined that the normal operation of the outfall at the proposed outfall location of B1-70m will not result in adverse impacts on the water quality of the designated shellfish area; none of the criteria in the more rigorous international classification of shellfish water for approved growing areas would be breached.

6.8 Based on the results of the model scenarios executed for this study it was determined that the operation of the outfall at the proposed outfall location of B1-70m under 1:20 year storm flow conditions will not result in adverse impacts on the water quality of the designated shellfish area; the criteria in rigorous international classification of shellfish water for approved growing areas would be met.

6.9 Based on the results of the model scenarios executed for this study it was determined that the operation of the outfall at the proposed outfall location of B1-70m will not result in adverse impacts on the water quality of the harbour when compared against the EPA eutrophic assessment criteria.

6.10 A number of recommendations have been made in order to improve the current state of understanding in relation to the water quality in Castletownbere and the high resolution, near-field impacts of the proposed outfall at location B1-70m.

7. Recommendations

7.1 It is recommended that water quality sampling be undertaken within Castletownbere to determine the background concentrations of the various parameters of concern to the current study; this would facilitate more accurate interpretation of the model predictions.

7.2 It is recommended that laboratory analysis of the decay of faecal coliforms in the ambient water from Castletownbere be undertaken to accurately determine the T90 decay rates for the organisms to facilitate more accurate interpretation of the model results.

7.3 It is recommended that a near-field assessment be undertaken for outfall location B1-70m to determine accurately the initial dilution capacity of the immediate vicinity and the potential for the development of shore line attached plumes.