MWH

STATES OF GUERNSEY - BELLE GREVE OUTFALL

DISCHARGE OF PRELIMINARY TREATED WASTEWATER TO THE LITTLE RUSSEL

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SUMMARY

Historically, wastewater has been discharged to the Little Russel through the Belle Greve long sea outfall (LSO), after receiving preliminary treatment. Environmental monitoring over a number of years has not appeared to identify any significant impacts of this approach (for example bathing waters quality sampling, shellfish flesh sampling).

The States of Guernsey are keen to understand the potential implications the current discharge regime might have with regard to the impact on the environment, the impact on bathing waters and shellfish harvesting areas. As the States of Guernsey are not members of the Union, the Union Directives concerned with the above issues are not legally binding. They are, however, recognised as providing a good benchmark for the assessment of environmental impact, and it is the aim of the States to be broadly compliant with the aims of these Directives as part of their management strategy for wastewater treatment and disposal.

This report describes the method for the assessment of the current wastewater disposal strategy against key Directive standards. It uses a combination of predictive modelling approaches and field data collection to establish the likely impacts of the Belle Greve discharge, in the context of these Directives.

The assessment is being undertaken to determine the environmental impact of discharges from the Belle Greve outfall:

To quantify impacts over a wide range of conditions, for a number of receivers, and several different standards

Set the Belle Greve discharge in the context of European environmental legislation, and UK policy and standards

Determine what, if any, impacts there are, and to identify any necessary remediation, including enhanced treatment

The study is divided into four categories:

- Initial Dilution standards, and the predicted concentrations of standard determinands arising from initial dilution
- Standards for nutrients (phosphate and nitrate) that were used for Urban Waste Water Treatment Directive (UWWTD) studies to identify potential eutrophication
- Standards for ecological change used for UWWTD studies to identify impacts to benthic communities arising from deposition of suspended solids
- Bathing Waters water quality standards and Shellfish Waters quality standards

The study considers the various legislative and policy standards used in the UK, and identifies the standards that are to be used for the assessment of the Belle Greve discharge. These standards include:

- AMP2 Guidelines policy standards (initial dilution)
- UWWTD standards in the UK (nutrient impacts, suspended solids)
- Bathing Waters Directive (bathing waters quality)
- Shellfish waters Directive and the Food Hygiene Directive (shellfish quality)

A field data collection programme was undertaken, to collect hydrodynamic and water quality data. The report describes the field studies undertaken to support the modelling study, and how the data has been used to calibrate and validate the coastal model.

The report describes the models and approaches used for the assessment of the potential impacts of the Belle Greve discharge. This includes the development of the Guernsey Coastal Modelling System (GCMS), a dynamic 2D model of the coast of Guernsey and surrounding seas. The model was built using well known and globally accepted software, and built to the standards set out by the environmental regulators in the UK.

The GCMS provides a tool for the assessment of impacts from the Belle Greve discharge, and in the longer term for many potential purposes, including:

- Future water quality studies
- Coastal processes
- Tidal renewable power
- Coastal engineering
- Wave modelling

Almost all of the UWWTD studies, bathing waters and shellfish waters assessments in the UK have been carried out using similar models and similar approaches and standards.

The report describes the results of the study. The report provides a very detailed consideration of the approaches and study methods, as well as detailed reporting concerning the results.

In summary, the results and conclusions are as below:

Initial Dilution

The existing outfall does not meet UK minimum requirements for initial dilution. This is primarily due to the lack of a sufficient diffuser section.

The implementation of the environmental design for a diffuser will deliver compliance with the initial dilution standard.

Near Field modelling

Near field (‘Zone A’) modelling suggests that almost all requirements are met by the existing outfall. The provision of a sufficient diffuser section to meet initial dilution requirements would allow all conditions to be met.

Nutrients

There is no indication that the discharge presents any adverse impacts with regard to nutrients. Nutrient levels arising from the Belle Greve discharge represent a small fraction of the concentrations considered acceptable under the standards used in previous studies in the UK.

Suspended Solids

There is no indication that the deposition of suspended solids has any adverse impact on the benthic habitat. Deposition is very slight, primarily due to the strong current regime entraining suspended solids, leading to effective transport and dispersion.

Bacterial modelling

The results of the bacterial modelling indicated that for:

Belle Greve long sea outfall

- *E. coli* concentrations at all of the designated bathing waters are predicted to be less than 100 ec/100ml.
- Intestinal enterococci concentrations at all of the designated bathing waters are predicted to be less than 25 ie/100ml.

Red Lion short sea outfall

- *E. coli* concentrations at all of the designated bathing waters are predicted to be less than 15 ec/100ml.
- Intestinal enterococci concentrations at all of the designated bathing waters are predicted to be less than 2 ie/100ml.

The Red Lion discharge does not discharge regularly, and its impacts are therefore considered negligible. Current improvements to the sewerage network and the handling of wet weather flows will decrease the operation of the Red Lion outfall still further.

The Belle Greve discharge does not impact significantly on any of the identified bathing waters. Consideration of the highest quality threshold concentration shows that it is never exceeded at any bathing water.

The two shellfish harvesting areas in the vicinity of the discharge are not significantly impacted. The Herm harvesting area is not affected by the discharge plume at all, and the Houmet Paradis harvesting area is predicted to meet the local standard, and also the standard currently required in England & Wales. These predictions are supported by the monitoring data available for both harvesting areas.

It is therefore considered that the Belle Greve discharge does not significantly impact the designated sensitive receivers (Bathing Waters and Shellfish Waters)

Conclusions

In conclusion, the study has demonstrated:

- The initial dilution of the discharge is insufficient to satisfy UK standards. This can be resolved by installing a diffuser section for the outfall.

- The environmental design for the diffuser section would suggest a requirement for seven ports (diameter 0.2m) with a minimum spacing of 11m. The hydraulic design of the diffuser and outfall would need to be confirmed by design engineers.
- The concentration of solids, BOD, ammonia and COD after initial dilution fall within UK standards (some after the imposition of a new diffuser section).
- The nitrogen and phosphorus concentrations predicted by the simulation are below the limits which would indicate (or increase the risk of) the potential for eutrophication (e.g. Algal blooms)
- The Benthic assessment has indicated a very small deposition around the outfall and therefore the present discharge has no significant impact on the benthos.
- Bathing Waters and Shellfish Harvesting Areas are not predicted to be significantly impacted by the Belle Greve outfall – i.e. compliance is maintained

Whereas the UWWTD suggests a minimum of primary treatment for wastewater discharges for a population the size of Guernsey, all of the studies conducted would suggest that there is no adverse affect from the Belle Greve discharge.

The results of the study would therefore suggest that the current level of treatment, whilst not strictly conforming with the UWWTD:

- Protects the surrounding waters from the risks of eutrophication
- Protects the surrounding waters from deleterious local impacts of waste water discharges
- Protects Bathing and Shellfish Waters
- Does not pose a risk to the local benthic community due to deposition of suspended solids

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GLOSSARY

ADCP – Acoustic Doppler Current Profiler*. A type of current meter used for collecting field data*

AMP – Asset Management Plan*. The five year investment cycle controlling investment in the water industry in England and Wales*

Bathing Water *– a beach designated under the Bathing Waters Directive as an area where significant recreational contact with the water takes place, and as such certain standards are required in order to mange risks to human health. Regular sampling takes place in order for standard to be assessed and reported.*

Biological Oxygen Demand (BOD) *– The organic material within wastewater uses up oxygen as it decomposes or reacts with material in the environment. This can be formally analysed and quantified to identify the BOD – expressed as mg/l. Controlling the BOD of wastewater is a fundamental element of wastewater treatment (along with the control of suspended solids) as it has the capacity to de-oxygenate the local environment, with significant impact to the local ecology.*

CEFAS *– Centre for Environment, Fisheries and Aquaculture Science. An Agency of DEFRA, concerned with a number of marine scientific issues including shellfish quality in England and Wales*

CSTT Report *– The Comprehensive Studies Task Team Report was the UK report which set out the standards to be met to determine a body of water as Less Sensitive under the UWWTD.*

DAIN – Dissolved Available Inorganic Nitrogen*. A measure of available nitrogen, an excessive concentration of which may lead to eutrophication*

DAIP – Dissolved Available Inorganic Phosphate*. A measure of available phosphate, an excessive concentration of which may lead to eutrophication*

DEFRA *– Department for Agriculture, Food and Rural Affairs. The Government Department responsible for environmental issues and environmental legislation. The Environment Agency and CEFAS are agents of DEFRA.*

Dynamic 2D model *– a mathematical model which actively represents tides, currents and changing water depths. 2D indicates that both horizontal axes of movement are* *represented, but the vertical axis (depth) is assumed to be perfectly mixed. A model suitable for well mixed waters not subject to issues such as stratification by temperature or salinity.*

Environment Agency *– Government Agency responsible for environmental and flooding protection in England & Wales. This includes the setting of discharge consents, abstraction consents, and the setting of policies designed to meet legislative targets.*

Escherichia coli (E. coli) *– one of the faecal indicator organisms used as a standard in the rBWD. It is considered equivalent with the term faecal coliform*

Eutrophication *– the mechanism of nutrient enrichment which leads to significant change to the ecological status of a water body. The term now indicates anthropogenic influence, and is typically characterised by unexpected or increased algal blooms in coastal waters*

Faecal coliform *- the faecal indicator organisms used as a standard in the Shellfish Waters and harvesting areas standards. It is considered equivalent with E. coli.*

Faecal Indicator Organism (FIO) *– these are organisms that are regarded as indicators of the presence of wastewater in a sample, and therefore as indicators of the potential presence of pathogenic organisms. These FIOs are used instead of testing for pathogens, as FIOs are consistently present in wastewater, whereas pathogenic organisms may or may not be present in a particular sample. FIOs also do not replicate in the environment, a feature essential for any indicator species. H* ***Food Hygiene Directive*** *– European legislation controlling the member state legislation for the protection of all manner of food related issues, including hygiene standards for harvested shellfish. Replace the Shellfish Hygiene Directive.*

Guernsey Coastal Modelling System (GCMS) *– a dynamic 2D model of the coastline of Guernsey and the surrounding area, sufficiently resolved to undertake water quality and hydrodynamic modelling assessments*

Initial Dilution *– the dilution (dispersion) of a discharge immediately after leaving the discharge pipe. In a marine environment, it describes the dilution achieved as the buoyant plume rises from the discharge point to the surface. Initial dilution minimum standards are often set in order to stop the formation of unsightly surface slicks.*

Intestinal enterococci - one of the faecal indicator organisms used as a standard in the rBWD

Preliminary Treatment *– process in a WwTW, usually involving screening of solids, and grit removal.*

***Primary Treatment** – process in a WwTW, occurring after preliminary treatment, usually involving the settlement of solids which are retained, with the liquid waste moving on to secondary treatment, or discharge.*

***Revised Bathing Waters Directive (rBWD)** – the 2006 revision of the original 1976 Directive. The Directive sets out thresholds of bacterial concentration which are required in order to effectively manage the risk of exposure to potentially harmful organisms arising from waste water discharges at designated Bathing Waters.*

***Scottish Environment Protection Agency** - Government Agency responsible for environmental and flooding protection in Scotland. This includes the setting of discharge consents, abstraction consents, and the setting of policies designed to meet legislative targets.*

***Secondary Treatment** – a process in a WwTW, occurring after primary treatment, which provides biological treatment to improve the quality of the wastewater. This will then be discharged, or passed for further treatment*

***Shellfish Hygiene Directive** – Directive for the protection of human health regarding the consumption of shellfish flesh. Sets bacterial standards to be met to meet compliance standards allowing shellfish to be harvested for consumption, and also sets certain pre-consumption treatments that may be required.*

***Shellfish Waters Directive** – European Union legislation which sets water quality standards for the protection of designated Shellfish Waters, within which harvesting areas will be identified, where shellfish are collected for human consumption.*

***Tertiary treatment** - a process in a WwTW, occurring after secondary treatment, to provide additional treatment to deliver effluent of a very high quality. Examples include ultra-violet disinfection or membrane filtration treatment. This effluent will then be discharged back to the environment.*

***UWWTD – Urban Waste Water Treatment Directive**. The European Union Directive which set out standards for sewerage systems and wastewater treatment in the Union.*

***Waste Water Treatment Works (WwTW)** – facility for the treatment of wastewater (sewage) prior to discharge back to the environment, usually by a process which might include screening of solids, settlement of solids, biological treatment and ultra-violet disinfection. The particular processes involved will depend on individual works, but each will be designed to meet the consent standards set by the environmental regulator*

1 INTRODUCTION

1.1 Overview

Historically, wastewater has been discharged to the Little Russel through the Belle Greve long sea outfall (LSO), after receiving preliminary treatment. Environmental monitoring over a number of years has not appeared to identify any significant impacts of this approach (for example bathing waters quality sampling, shellfish flesh sampling).

In additional, storm water discharges are made intermittently from the Red Lion short sea outfall.

The States of Guernsey are keen to understand the potential implications the current discharge regime might have with regard to the impact on the environment, the impact on bathing waters and shellfish harvesting areas. As the States of Guernsey are not members of the Union, the Union Directives concerned with the above issues are not legally binding. They are, however, recognised as providing a good benchmark for the assessment of environmental impact, and it is the aim of the States to be broadly compliant with the aims of these Directives as part of their management strategy for wastewater treatment and disposal.

This study provides a method for the assessment of the current wastewater disposal strategy against key Directive standards. It uses a combination of predictive modelling approaches and field data collection to establish the likely impacts of the Belle Greve discharge, in the context of these Directives.

The assessment is being undertaken to determine the environmental impact of discharges from the Belle Greve outfall:

To quantify impacts over a wide range of conditions, for a number of receivers, and several different standards

Set the Belle Greve discharge in the context of European environmental legislation, and UK policy and standards

Determine what, if any, impacts there are, and to identify any necessary remediation, including enhanced treatment

1.2 Geographical Overview

The position of the Belle Greve LSO is shown in Figure 1.1. The LSO catchment comprises the catchments of St Peter Port and surrounding areas. The location of the only intermittent discharge in the area is also shown together with the approximate locations of the bathing waters and shellfish harvesting areas designated by the States of Guernsey.

1.3 Oceanographic Overview

The tidal streams in the area of the Channel Islands[i] rotate in an anticlockwise direction. Residual current can be considerable and around the time of spring tides anticlockwise residual currents can reach 0.6 m/s around Guernsey. There is a well known front between Guernsey and Jersey.

The area around Guernsey is known to be very high energy in nature, which would indicate that it can be expected to disperse wastewater very quickly. Researchers from the Peninsula School of Marine Renewable Energy and from the School of Environment and Australian Rivers found that there was an extreme tidal stream area around Guernsey[ii].

1.4 Belle Greve Wastewater Treatment

The Belle Greve facility treats 99% of the island's wastewater, around 16,000 tonnes per day. The treatment works provides preliminary treatment to the islands wastewater. This level of treatment provides a significant improvement on the aesthetic quality of the discharge, but does not significantly alter the concentrations of the major pollutants.

1.5 The Studies

The study is divided into four categories:

- Initial Dilution standards, and the predicted concentrations of standard determinands arising from initial dilution
- Standards for nutrients (phosphate and nitrate) that were used for Urban Waste Water Treatment Directive (UWWTD) studies to identify potential eutrophication
- Standards for ecological change used for UWWTD studies to identify impacts to benthic communities arising from deposition of suspended solids
- Bathing Waters water quality standards and Shellfish Waters quality standards

1.6 Overview of the Report

The report is divided into a number of sections which are briefly described below:

Chapter 1 **Introduction**, this chapter.

Chapter 2 **Water Quality Standards and Parameters**, which describes the legislative background and the water parameters considered.

Chapter 3 **Field Surveys**, which describes the field surveys which were specificall3 carried out for this study.

Chapter 4 **Initial Dilution Modelling**, which describes the modelling which was carried out in order to ensure that initial dilution criteria have been met.

Chapter 5 **Zone A Modelling**, which described the modelling which has been carried out in the very near field (i.e. Zone A), close to the outfall position.

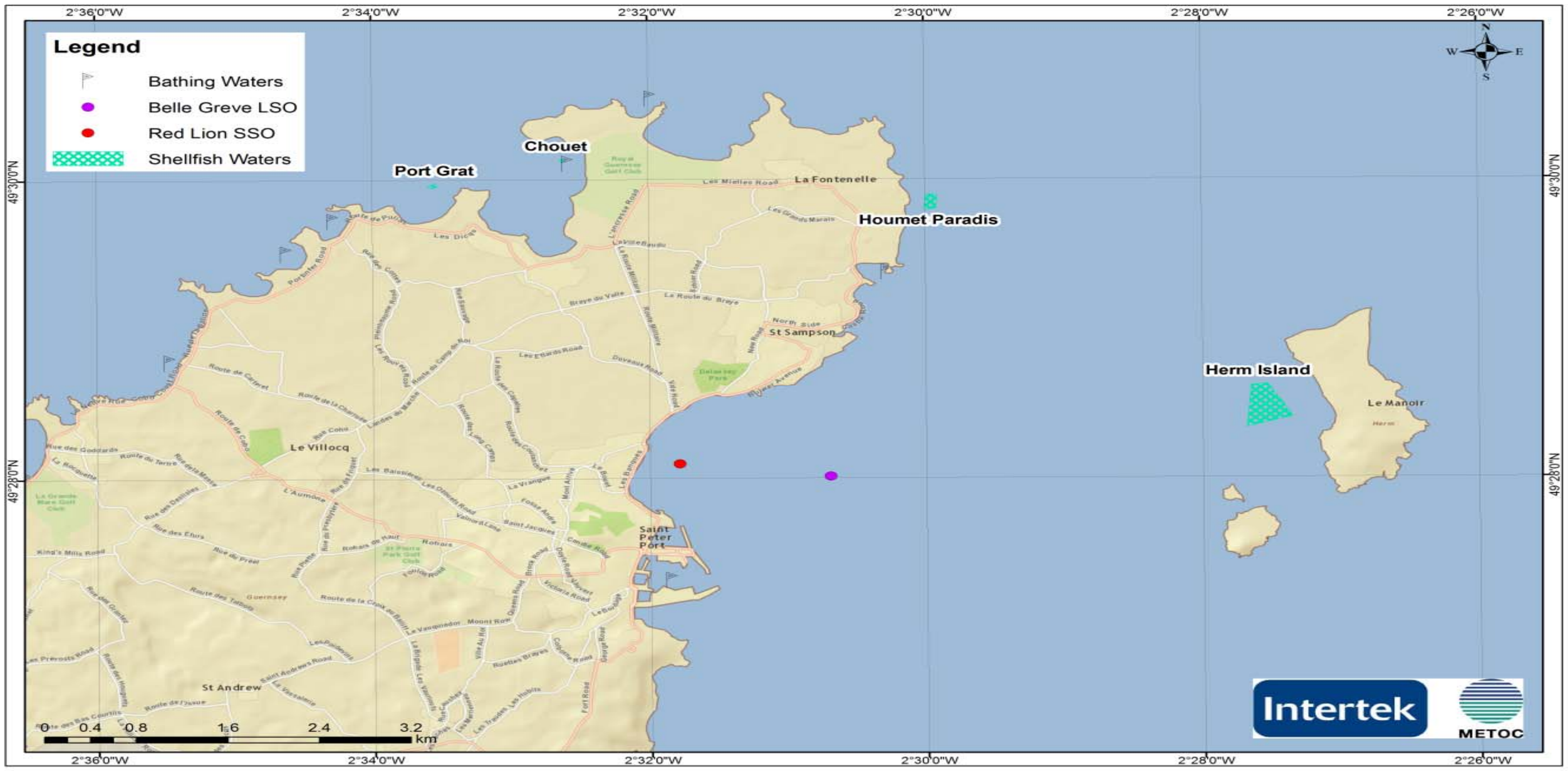
Chapter 6 **Coastal Modelling Methodology**, which gives a brief overview of the calibration and validation and a more complete description of the model set ups for the model simulations used in this study.

Chapter 7 **Nutrient Modelling**, which describes the nutrient modelling and its results, taking into account concentrations measured during the field survey.

Chapter 8 **Bacterial Modelling**, which describes the bacterial modelling and its results for discharges from both the Belle Greve outfall and the intermittent discharges from the Red Lion Combined Sewer Overflow.

Chapter 9 **Conclusions and Recommendations**

Figure 1-1: Geographical Overview of the Area around Guernsey



2 WATER QUALITY STANDARDS AND PARAMETERS

2.1 ASSET MANAGEMENT PLAN 2 (AMP2) GUIDELINES FOR INITIAL DILUTION

The AMP2 guidelines arose from the investment cycle which operates in England and Wales post 1989 privatisation. The water industry works on a five year investment cycle, with each cycle having an Asset Management Plan (AMP) which identifies the investment objectives and costs for that period. We are currently in AMP5 (i.e. the 5th investment period since privatisation). The 'AMP2 Guidelines' were, therefore, a set of guidelines identified for the purposes of the AMP2 investment period. They represent a number of policies and standards which helped in the early stages of wastewater improvements, and indeed a number of them are still relevant for design proposes today.

The purpose of the guidance is to describe general standards for continuous discharges of wastewater effluent to tidal waters, including initial dilution standards for use in circumstances where there is a high degree of public water use for recreational or amenity purposes. The purpose of the guidance is to prevent any more than occasional offence arising from visual evidence of discharge. The standards set in the guidance note relate to the location of wastewater ports and the initial dilution necessary to ensure aesthetic acceptability.

Effluent discharged to tidal waters is typically buoyant; that is, a surface layer of effluent may form in the absence of adequate initial dilution. This may result in discolouration at the sea surface, possibly giving rise to a slick due to the presence of fats, oils and greases (FOGs) in the effluent.

The guidance note sets standards for initial dilution within, or in close proximity to, those waters which are regularly used by the public for recreational activities.

The basic need to eliminate density differences between effluent and receiving water to allow uniform dispersion requires:

- 50 dilutions, to be achieved on a 95 %ile basis for secondary effluents.
- 100 dilutions, to be achieved on a 95 %ile basis for primary effluents.

Initial dilution can also help to dilute levels of contaminants such as heavy metals to compliant concentrations. In the absence of any industrial discharges from the Belle Greve outfall, or any evidence that these type of contaminants are significantly present in the discharge, the consideration of these types of contaminants is not taken any further in this study.

2.2 URBAN WASTEWATER TREATMENT DIRECTIVE

The Urban Waste Water Treatment Directive[iii] concerns the collection, treatment and discharge of urban waste water and the treatment of waste water from certain industrial sectors. Article 4 states that urban waste water discharges into coastal waters from agglomerations of more than 10,000 population equivalent (p.e.) must be subject to secondary treatment or an equivalent treatment. However, under Article 6, the UWWTD provides scope for 'Less Sensitive Areas', termed High Natural Dispersion Areas (HNDAs) in the UK, to be identified. Within these areas, urban waste water discharges from agglomerations of between 10,000 and 150,000 p.e. may be subjected to treatment less stringent than secondary or equivalent treatment if they receive at least primary treatment and if comprehensive studies carried out indicate that such discharges would not adversely affect the environment.

The UWWTD[iii] does not detail the content of a comprehensive study. The Comprehensive Studies Task Team (CSTT), established by the Marine Pollution Monitoring Management Group, was commissioned by the UK Department of the Environment to develop guidelines for carrying out comprehensive studies. The CSTT Report produced in 1994[iv] (revised 1997[v]) offers guidance to dischargers and regulators on the objectives, standards and methodology to be applied in undertaking comprehensive studies for the purposes of Article 6 of the UWWTD.

The UWWTD is concerned with the provision of 'adequate' sewerage. Under the terms of the Directive, which defines the purpose of the sewerage system to 'prevent pollution', we have considered for the purposes of this study that the sewerage system should be defined as adequate if it prevents pollution.

2.2.1 Nutrients

In accordance with the CSTT guidelines[iv,v], studies of the waste water effluent released into the marine environment around the Belle Greve LSO were carried out within nested zones of potential effect. The two areas focused on within this study are the receiving waters known as Zone B, also termed the nutrient box and the surrounding waters known as Zone C. These waters have been described in the guidelines as follows:-

2.2.1.1 Zone B

2.2.1.1.1 Zone Designation

Zone B is designated as

> **'a zone in which discharged dissolved nutrients have residence times of 1 x 10^5s or a few days, the timescale of phytoplankton growth in favourable circumstances. Nutrients are dispersed through this zone mainly (in Channel Island waters) by tidal movements.'**

2.2.1.1.2 Impact Assessment

The potential for eutrophication arising from a waste water discharge has been highlighted as an area of study by the CSTT Report[iv,v]. The Report identifies phosphorus and nitrogen as the nutrient parameters which should be examined to determine the potential for eutrophication in receiving waters. Threshold limits, which describe 'adverse effects' in relation to the nutrient parameters within Zone B, are defined in the guidelines[iv,v] in the following manner:

An adverse effect is considered to occur within Zone B if it is hypernutrified and there is evidence of the likelihood of eutrophication3. Where the contribution to the eutrophic state by the discharge in question is insignificant, then the discharge is considered to cause no adverse effects to the area. There is considered to be no adverse effect if:

a) Outwith any area of local effect, there are no observations showing winter DAIN > 12 mmol m-3 (in the presence of 0.2 mmol-DAIP m^{-3}), and that predictions for the steady state nutrient concentrations show no evidence or likelihood of hypernutrification.

b) Where hypernutrification has been demonstrated or predicted: there are no summer observations showing chlorophyll > 10 mg m^{-3} and that predictions illustrate that conditions would not allow phytoplankton growth to exceed losses: that is, there is no evidence, or likelihood of eutrophication.

c) Where eutrophication has been demonstrated or predicted which can be termed anthropogenic3,4: the application of secondary treatment will reduce the predicted maximum chlorophyll concentration by less than 1 mg chl m^{-3}.

2.2.1.2 Zone C

2.2.1.2.1 Zone Designation

Zone C is designated as

'a larger region in which the residence time of water is 10^6 to 10^7s (10 to 100 days), sufficiently long for its dissolved nutrient concentration to be increased by mineralisation of particulates. Dispersion on this larger scale results from residual circulation as well as tidal movements'

2.2.1.2.2 Impact Assessment

The CSTT Reportiv,v states that

The contribution of nutrients from waste water discharges into Zone C must be considered in relation to eutrophication. The Zone is defined in terms of hydrographically realistic management units. Within these units, all discharged waste waters are ranked according to their nitrogen and phosphorus contribution. If the discharge under consideration, contributes more than 5% of the total anthropogenic nutrient input, detailed hydrodynamic models should be used to predict the potential for eutrophication if the discharge were secondary rather than primary treated.

2.2.2 Dissolved Oxygen and Biochemical Oxygen Demand

2.2.2.1 Zone Designation

Zone A is defined as:

> **Zone A is the local scale, within which sinking particles mostly reach the seabed and in which the residence time of discharged water (or neutrally buoyant tracer) is a few hours, too short for nutrients to be converted into phytoplankton**

The average current speed under neap tidal conditions has been found to be approximately 0.27 m/s. If a residence time of 3 hours is assumed then it can be assumed that Zone A will cover an area with a radius of approximately 1500 metres.

2.2.2.2 Impact Assessment

Both particulate and dissolved BOD contribute to an oxygen demand within the water column. Particulate organic matter settling to the bottom will also contribute to sediment oxygen demand.

> **It has been estimated that where BOD levels deviate by less than 1.5 mg/l, the resulting impact on DO levels will be less than 0.5 mg/l. Where the median DO level is maintained above 7 mg/l, a change of 0.5 mg/l in concentrations can be assumed to cause no adverse affect**

2.2.3 Suspended Solids and Organic Carbon

The principal effect of suspended solids and organic carbon is on the benthos.

The guidelines[iv,v] specify that:

> **It is proposed that an adverse effect exists when primary treatment induces a significant change in community structure at a distance greater than 100 metres from the outlet which would not have occurred had secondary treatment been installed. Having regard for the inherent variability of marine communities, a number of variables should be examined. Levels of acceptable change within the sphere of waste influence compared to a reference site are as follows:**

Total abundance	**+200% of reference station value**
Total taxa	**+50% of reference station value**
Total biomass	**+50% of reference station value**

2.3 THE BATHING WATER DIRECTIVE

The efforts of the European Union[vi] (EU) to ensure clean and healthy bathing waters commenced in the 1970s. The 2006 Bathing water Directive[vii] (the "new" Directive, repealing by 2014 the "old" 1976 Bathing Water Directive[viii]) has the purpose to preserve, protect and improve the quality of the environment and to protect human health. The provisions of the Directive include a number of obligations for Member States, as well as rules generally applicable all across the EU.

The new Directive is often referred to as the revised Bathing Waters Directive (rBWD) in the UK.

The rBWD has four levels of compliance: Excellent; Good; Sufficient; and Poor. The standards are assessed statistically using data collected during the current bathing season and the three preceding bathing seasons, making a four-year rolling assessment period providing approximately 80 samples (4 x 20 samples per year).

It is assumed that the BW concentrations fit a log-normal distribution and percentiles are calculated on that basis. These derived percentiles are then compared to the standards set out in Table 1 3 to establish the compliance of the Bathing Water.

Table 2-1: Compliance standards for the rBWD

For coastal waters and transitional waters					
	Parameter	Excellent quality	Good quality	Sufficient quality	Reference methods of analysis
1	Intestinal enterococci (ie/dl)	100 (*)	200 (*)	185 (**)	ISO 7899-1 or ISO 7899-2
2	*Escherichia coli* (ec/dl)	250 (*)	500 (*)	500 (**)	ISO 9308-3 or ISO 9308-1
(*) Based upon a 95-percentile evaluation. (**) Based upon a 90-percentile evaluation.					

The key aspect of these standards is that they are assessed statistically over a four-season period, and the magnitude of failure is an important component of compliance or failure (unlike the standards for the 1976 Directive).

The calculations for rBWD standards have been carried out under the following assumptions:

- Faecal coliforms (used in the 1976 Directive and current sampling regimes) are equivalent to *E. coli* (ec - used in the rBWD)
- Faecal streptococci (used in the 1976 Directive and current sampling regimes) are equivalent to intestinal enterococci (ie - used in the rBWD)

This assumption, instigated by the environmental regulators in the UK, is important, as it means that existing sampling data can be used to analyse performance under the rBWD.

Three Bathing Waters are considered likely to perhaps fall under the influence of Belle Greve (all others are considered sufficiently distant that impacts are unlikely):

- Pembroke
- Bordeaux
- Havelet

All three are shown in Figure 1.1.

The nature of the modelling study means that if any others are impacted, then these will be shown on the output (i.e. no bathing waters are assumed to be not affected and discounted; all are present in the model domain).

2.4 SHELLFISH WATERS STANDARDS

Shellfish legislation is again health legislation (like the Bathing Waters Directive). Its role is to protect human health, and is not an environmental protection measure *per se*.

Principally, legislation is designed to ensure that the quality of shellfish flesh to be consumed does not present an unacceptable risk to human health.

Principal legislation is the Food Hygiene Directive (replacing the Shellfish Hygiene Directive) and the Shellfish Waters Directive.

The Shellfish Waters Directive provides standards for a wide ranging set of parameters, and is based on water quality. There is no statutory standard for faecal indicator organisms, but there is a Guideline standard of 300 faecal coliforms/100mg flesh.

The Food Hygiene Directive sets out classes of quality, based again on levels of bacteria/100g of flesh.

In the UK, the Food Standards Agency manages and reports on shellfish flesh quality. It is aided in this by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) which manages designation, sampling and analysis of shellfish quality. It designates Harvesting Areas, and these are subjected to regular sampling, on the basis of which they are provisioned into the following classes:

Table 2-2: Shellfish flesh quality standards

Category	Criteria	Treatment
Class A	Molluscs must contain less than 230 *E. coli* per 100 grams of flesh	Can be harvested for direct human consumption
Class B	90% of sampled molluscs must contain less than 4,600 E. coli per 100 grams of flesh; 10% of samples must not exceed 46,000 E. coli per 100 grams of flesh	Can go for human consumption after purification in an approved plant or after relaying in an approved Class A relaying area or after an EC approved heat treatment process
Class C	Molluscs must contain less than 46,000 E. coli per 100 grams of flesh	Can go for human consumption only after relaying for at least two months in an approved relaying area followed, where necessary, by treatment in a purification centre, or after an EC approved heat treatment process
Class D	Above 46,000 *E. coli* per 100 grams of flesh	Must not be harvested or offered for human consumption

The current aim in England and Wales is the achievement of Class B shellfish Waters as a minimum. The Environment Agency has set out a policy which links water quality to the shellfish flesh class that can be achieved.

Under the terms of this policy, demonstrating that a Harvesting Area has less than 1500 faecal coliforms/100ml water for 97% of the time, will deliver Class B flesh quality (i.e. the standard being aimed for in England and Wales).

Using the 1500 fc/100ml as an absolute threshold (i.e. assuming compliance 100% of the time), it can be seen that the lower concentration thresholds of the rBWD serve as a proxy for the shellfish standards – that is, compliance with bathing waters standards (as absolute thresholds for 100% compliance) automatically provides compliance with this Shellfish Waters standard.

There are two Harvesting Areas in the locality:

Herm (sampling data show Class A performance presently)

Houmet Paradis (sampling data show Class B performance presently).

Both are shown on Figure 1.1.

The nature of the modelling study means that if any others are impacted, then these will be shown on the output (i.e. no harvesting areas are assumed to be not affected and discounted; all are present in the model domain).

3 FIELD SURVEYS

The scope of work for the field survey was designed to serve two purposes:

- Hydrographic and oceanographic data for the calibration and validation of the hydrodynamic and water quality model.
- Water column and benthic sampling to fulfil the requirements of the methodology set out in CSTT guidelines[iv,v].

The scope of work to which the field survey programme was designed, is set out in Appendix A.

The results of the field survey are discussed below.

3.1 Hydrographic and Oceanographic Survey

The results of the hydrographic and oceanographic survey are reported in detail in the sub-contractors report.

3.2 Water Quality

3.2.1 Results

The results of the water quality sampling are presented in Appendix B. Full details are included in the sub-contractor's report, but the key elements of the water quality data are discussed below.

3.2.2 Analysis

The sampling results have been compared to the standards set out in the CSTT document[iv,v].

Dissolved Oxygen

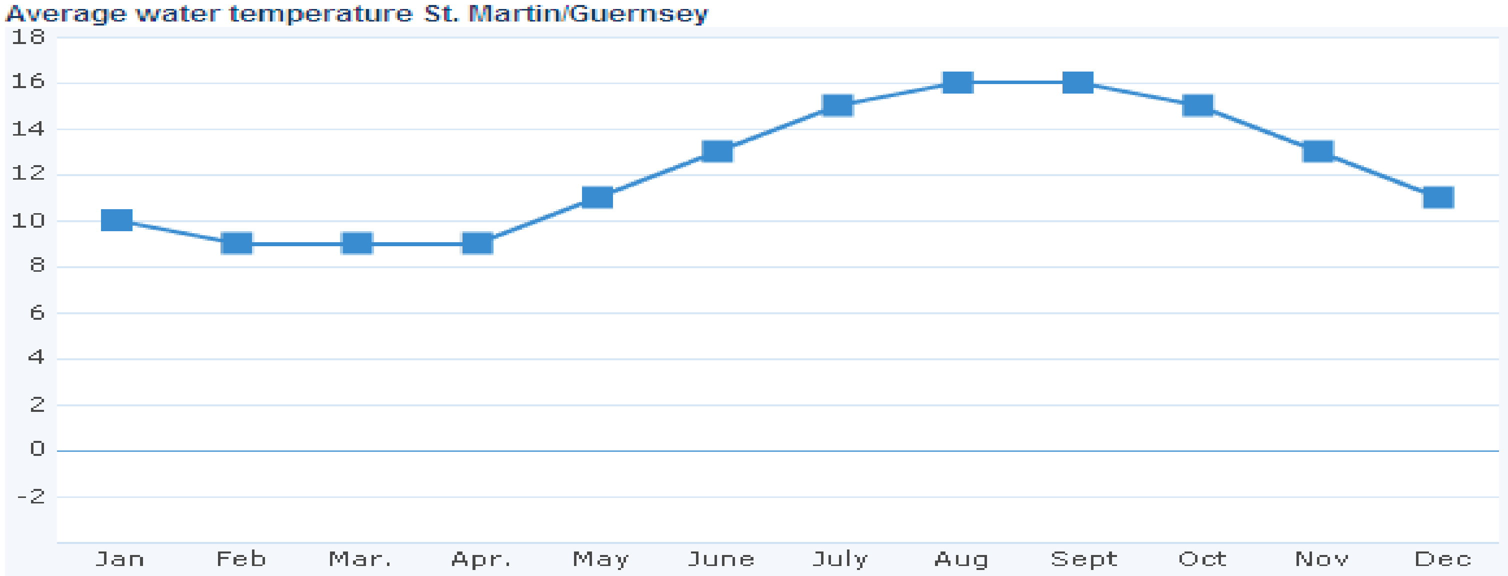
Back ground dissolved oxygen concentrations were measured at Site H2 over a neap tidal cycle on 23rd August 2011. A statistical analysis of these data is provided in Table 3-1.

Table 3-1: Statistical Analysis of Dissolved Oxygen Concentrations

Statistic	Temperature (oC)	DO (% sat)	DO (mg/l)
Maximum	18.35	106.01	8.23
Mean	17.18	95.89	7.46
Median	16.85	95.56	7.49
Minimum	16.74	93.90	7.14
Standard Deviation	0.60	1.97	0.20
Count	48	48	48

These results show that dissolved oxygen concentrations were found to be above 7 mg/l in all cases. Sea temperatures in late August are likely to represent close to maximum sea temperature in the area. The measurements on this day represent worse case conditions. Indeed a plot of sea temperatures at St Martin's Bay (Figure 3-1) shows that these recorded sea temperature are likely to be from the upper range of sea temperatures which might be experienced in the area.

Figure 3-1: Monthly Average Sea Temperatures at St Martin's Bay



The solubility of oxygen in water is inversely proportional to temperature. Therefore at lower temperatures than those recorded on this day, even higher dissolved concentrations are likely to be found.

Nutrients and Chlorophyll-a

The results of the nutrient sampling is provided in Table 3-1, expressed as DAIN, DAIP and Chlorophyll-a. The results show that concentrations in excess of the CSTT limit of 12 mmol/m^3 of DAIN was only measured once at Site 6 during a mid ebb tide. This is somewhat surprising in that Site 6 is some 1km from the outfall discharge point. The results show that concentrations in excess of the CSTT limit of 0.2 mmol/m^3 of DAIP was only measured once at Site 6 during the same mid ebb tide. High nutrient concentrations were not observed at this or any other site under other tidal conditions. No samples analysed for chlorophyll showed concentrations in excess of 10 mg Chla/m^3, demonstrate that eutrophication was not evident during the field survey.

Table 3-2: Nutrient and Chlorophyll-a Concentrations

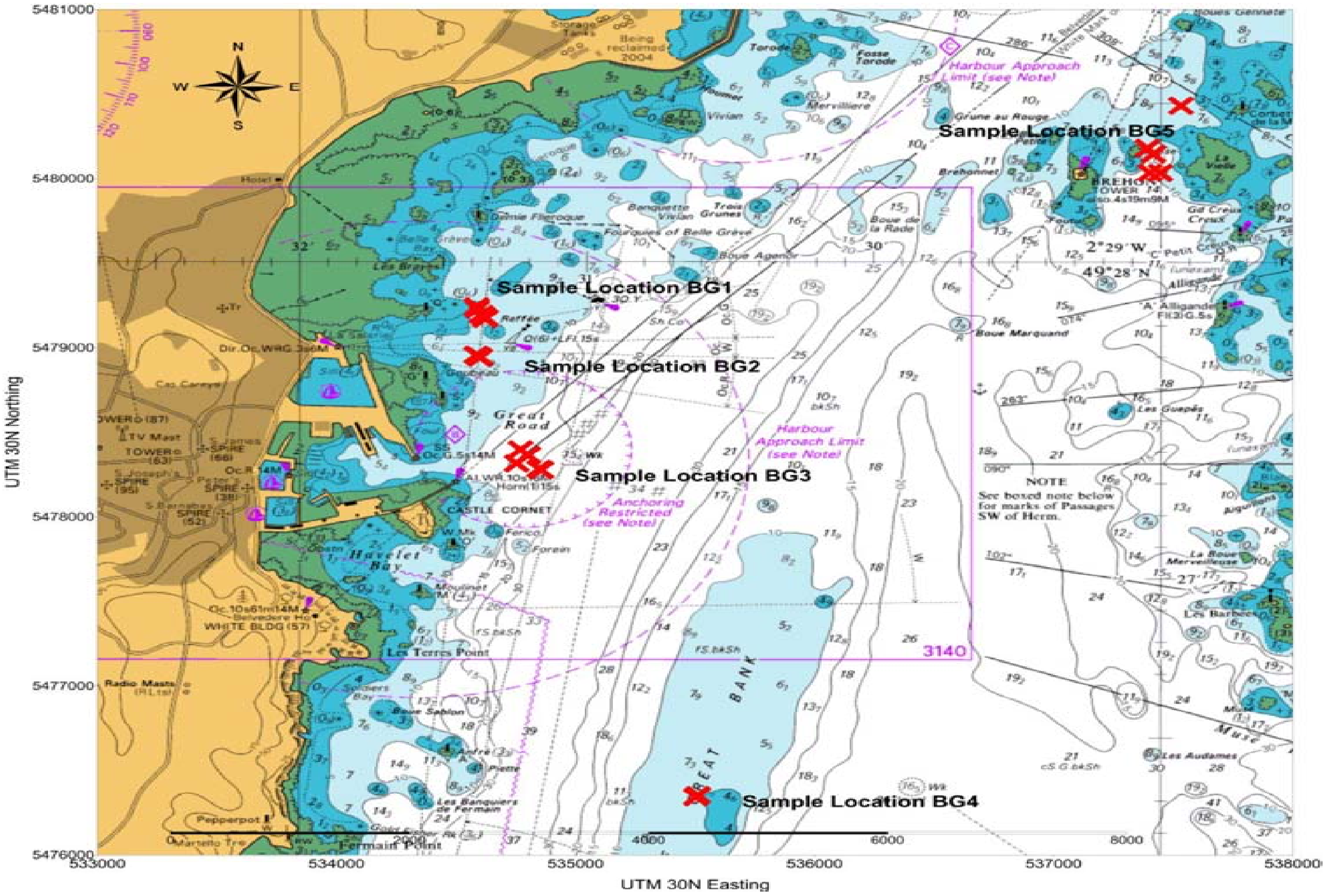
Site and Tidal State	DAIN (mmol/m3)	DAIP (mmol/m3)	Chlorophyll-a (ug/l)
Site 1 Surface ME	1.00	0.07	1.07
Site 1 Surface LW	1.03	0.07	0.90
Site 1 Surface MF	1.10	0.09	0.97
Site 1 Surface HW	1.05	0.08	1.13
Site 1 Mid depth ME	1.13	0.07	
Site 1 Mid depth LW	1.11	0.06	
Site 1 Mid depth MF	1.01	0.07	
Site 1 Mid depth HW	1.06	0.07	
Site 2 Surface ME	9.83	0.07	0.89
Site 2 Surface LW	1.01	0.07	1.18
SIte 2 Surface MF	1.00	0.07	0.90
Site 2 Surface HW	1.00	0.07	1.71
Site 2 Mid depth ME	1.01	0.07	
Site 2 Mid depth LW	1.01	0.08	
Site 2 Mid depth MF	2.25	0.11	
Site 2 Mid depth HW	1.00	0.07	
Site 3 Surface ME	1.00	0.06	1.06
Site 3 Surface LW	2.85	0.15	1.15
Site 3 Surface MF	1.00	0.08	0.90
Site 3 Surface HW	1.04	0.07	1.04
Site 3 Mid depth ME	1.01	0.07	
Site 3 Mid depth LW	1.99	0.11	
Site 3 Mid depth MF	1.02	0.08	
Site 3 Mid depth HW	1.05	0.08	
Site 4 Surface ME	1.49	0.10	0.75
Site 4 Surface LW	1.07	0.07	0.90
Site 4 Surface MF	1.00	0.09	0.89
Site 4 Surface HW	1.00	0.08	1.04
Site 4 Mid depth ME	1.37	0.08	
Site 4 Mid depth LW	1.45	0.10	
Site 4 Mid depth MF	1.19	0.08	
Site 4 Mid depth HW	1.67	0.06	
Site 5 Surface ME	1.15	0.07	0.80
Site 5 Surface LW	1.14	0.08	0.66
Site 5 Surface MF	1.00	0.07	0.79
Site 5 Surface HW	1.53	0.09	0.66
Site 5 Mid depth ME	1.27	0.10	
Site 5 Mid depth LW	1.35	0.08	
Site 5 Mid depth MF	1.00	0.07	
Site 5 Mid depth HW	1.31	0.10	
Site 6 Surface ME	13.24	0.64	0.97

Site 6 Surface LW	1.01	0.08	0.77
Site 6 Surface MF	1.00	0.07	0.92
Site 6 Surface HW	1.00	0.08	0.89
Site 6 Mid depth ME	1.45	0.11	
Site 6 Mid depth LW	1.04	0.07	
Site 6 Mid depth MF	1.09	0.11	
Site 6 Mid depth HW	1.04	0.08	
Site 7 Surface ME	1.44	0.07	0.88
Site 7 Surface LW	1.34	0.08	0.77
Site 7 Surface MF	1.02	0.09	0.95
Site 7 Surface HW	1.01	0.09	0.87
Site 7 Mid depth ME	1.31	0.06	
Site 7 Mid depth LW	1.05	0.07	
Site 7 Mid depth MF	1.00	0.07	
Site 7 Mid depth HW	1.01	0.08	
Site 8 Surface ME	2.32	0.06	0.85
Site 8 Surface LW	1.00	0.07	0.83
Site 8 Surface MF	1.00	0.08	1.03
Site 8 Surface HW	1.20	0.09	0.66
Site 8 Mid depth ME	1.70	0.08	
Site 8 Mid depth LW	1.08	0.08	
Site 8 Mid depth MF	1.00	0.09	
Site 8 Mid depth HW	1.05	0.07	

3.3 BENTHIC SAMPLING

Benthic sampling was undertaken at five sites, which are shown in Figure 3.2 below.

Figure 3-2: Benthic Sampling Sites



The reference site was Site 5, as initial analysis demonstrated that the discharge from Belle Greve was unlikely to interfere with this site.

However, it was impossible to collect data from the reference site as the substrate (rock) prevented collection.

The data for sites 1-4 is presented below

A summary of the benthic data is shown below:

Table 3-3: Benthic Survey Results

Taxon	Abundance (N)	Diversity (S)	Biomass (B)
1A	293	37	0.1278
1B	625	63	0.1922
2A	285	51	0.1598
2B	355	47	0.3398
3A	347	48	0.4952
3B	336	42	0.2323
4A	265	53	0.3345
4B	560	78	2.6486

Each site had two sample stations (1A & 1B, 2A & 2B, etc). Each site is broadly comparable in terms of abundance, diversity and biomass, with site 4B skewing the data somewhat in terms of biomass.

Without a functioning reference site, comparison with CSTT standards is difficult. However, a consideration of the data in context with data regarding sediment deposition allows us to draw some conclusions from the data. We have no evidence to suggest that there is any significant deposition of suspended solids from the outfall and no evidence that nutrient levels are significantly elevated. Both of these issues may cause impacts to the benthic community, either by changing substrate/habitat conditions (settling of solids) or changing community structure (nutrient changes affecting algal populations for example).

The data for the sample sites, which range from close to the outfall site to a site some distance away, show comparability. This would indicate that there are no local effects (i.e. at the outfall discharge point), which might be an issue considering that there is not an effective diffuser operating at this moment in time. A lack of local impact would support the conclusion that there is no impact to the benthic community in general. In association with the data regarding solids deposition and nutrient levels, the data would therefore indicate that there is no significant impact on the benthos due to the discharge.

4 INITIAL DILUTION MODELLING

The WRc equations were applied to the results of the hydrodynamic modelling extracted at the location of the current discharge point over the period 27/12/2009 to 06/01/2010. The following parameters relating to the discharge were applied.

Table 4-1: Parameters used in the Initial Dilution Calculations

Parameter	Value	Unit
Average Daily Flow (ADF)	0.23	m3/s
No of Ports	1	
Port diameter	0.5	m
Soffit depth	0.5	m
Depth to Mean Sea Level	12.82	m
Distance between ports	1	m
Flow per port	0.23	m3/s
Jet velocity	1.18	m/s
Froude number	3.30	
Buoyant flux	0.06	(m4/s3)

The average daily flow was calculated based on a population of 75,000, an assumed infiltration rate of 40% and the assumption that ADF = 1.25 . DWF.

The results of the initial dilution calculations are presented in Table 4.2.

Table 4-2: Initial dilution Preliminary Results

Percentile	Initial Dilution
5%	175
10%	157
15%	138
20%	119
25%	103
30%	89
35%	71
40%	48
45%	46
50%	44
55%	43
60%	40
65%	37
70%	33
75%	31
80%	30
85%	28
90%	26
95%	25

The results of the initial dilution calculations indicate that the existing outfall, which is without a diffuser section, is failing to meet the standards set out in the AMP2 Guidelines for primary treated discharges. These results indicate that a diffuser section would be required to meet the standard.

Initial analysis indicates that a 7 port diffuser section, each with a diameter of 0.2m, would be required to meet the initial dilution requirement. Each port should have a minimum spacing of 11m. A full engineering appraisal of the installation of the diffuser, including consideration of the hydraulic implications of the environmental solution identified in this report, should be undertaken. The parameters used in this analysis are provided in Table 4.3 and the results of the initial dilution calculations are provided in Table 4.4.

Table 4-3: Parameters used in the Diffuser Initial Dilution Calculations

Parameter	Value	Unit
Average Daily Flow (ADF)	0.23	m3/s
No of Ports	7	
Port diameter	0.2	M
soffit depth	0.5	M
Depth to Mean Sea Level	12.82	M
Distance between ports	5 to 10	M
Flow per port	0.03	m3/s
Jet velocity	1.05	m/s
Froude number	4.7	

Parameter	Value	Unit
Buoyant flux	0.009	(m4/s3)

Table 4-4: Diffuser Initial Dilution Results

Percentile	Initial Dilution
5%	1228
10%	1098
15%	964
20%	832
25%	724
30%	622
35%	498
40%	372
45%	329
50%	317
55%	308
60%	296
65%	282
70%	270
75%	253
80%	217
85%	123
90%	110
95%	103

The proposed environmental design for a diffuser section is confirmed as providing the necessary dilutions.

5 ZONE A MODELLING

The initial dilution calculations have been used in order to calculate the concentration of a number of parameters directly after their release into the environment. This is a very conservative approach as this provides for mixing in the immediate wastewater plume not necessarily across the whole of Zone A. Zone A has been estimated to have a radius of 1.5 kilometres while the radius of the initial dilution zone varies from 3 to 9 metres This approach, therefore, provides much additional scope for further dilution to reach the standards set in the guidelines.

Typical and well established values for the per capita production of Suspended Solids, BOD and ammonia were applied to the flow established for a population of 75,000 and the resulting concentrations were used in subsequent calculations. The per capita load and the calculated concentrations are provided in Table 5.1.

Table 5-1: Per Capita Loads and Derived Concentrations

Parameter	Per Capita Load	Unit	Concentration	Unit
Solids	80	g/h/d	300	mg/l
BOD	60	g/h/d	225	mg/l
Ammonia	7	g/h/d	26	mg/l

Time series plots of concentration for each of the parameters are provided in Appendix C (Figure C-1 Suspended solids, Figure C-2 BOD, Figure C-3 ammonia)

In addition, the dilution calculations were carried out for the proposed new diffuser arrangement. Similarly, time series plots of concentration for each of the parameters are provided in Appendix C (Figure C-4 Suspended solids, Figure C-5 BOD, Figure C-6 ammonia).

Statistics relating to the water quality concentrations are presented in Table 5-1.

The results show that currently, the additional BOD concentration around the outfall resulting from wastewater discharges, is predicted to exceed 10 mg/l for less than 5% of the time. If the outfall is improved to provide 100 dilutions at the 95 %'ile then, then the additional BOD concentration in the receiving waters is predicted to be less than 2.2 mg/l for more than 95 percent of the time and less than 1.5 mg/l for more than 84% of the time.

Further analysis of the model results show that in the period when additional concentrations are predicted to exceed 1.5 mg/l, the average plume width is predicted to be less than 7 metres. In order for the predicted concentration of BOD in the wastewater plume to be reduced to 1.5 mg/l, the average plume width in these cases would need to be increased to around 11 metres. This plume width is a factor of 30 smaller than the predicted width of Zone A.

Table 5-2: Modelled Concentrations in the Near Field Receiving Waters

Percentile	Suspended Solids (mg/l)		BOD (mg/l)		Ammonia (mg/l)	
	Current	Future	Current	Future	Current	Future
95%	12.18	2.92	9.13	2.19	1.07	0.26
90%	11.42	2.74	8.56	2.05	1.00	0.24
85%	10.75	2.45	8.06	1.83	0.94	0.21
80%	10.13	1.38	7.60	1.04	0.89	0.12
75%	9.56	1.18	7.17	0.89	0.84	0.10
70%	9.05	1.11	6.79	0.83	0.79	0.10
65%	8.02	1.06	6.02	0.80	0.70	0.09
60%	7.46	1.01	5.60	0.76	0.65	0.09
55%	7.05	0.97	5.29	0.73	0.62	0.09
50%	6.76	0.94	5.07	0.71	0.59	0.08
45%	6.54	0.91	4.90	0.68	0.57	0.08
40%	6.22	0.81	4.66	0.61	0.54	0.07
35%	4.21	0.60	3.16	0.45	0.37	0.05
30%	3.37	0.48	2.53	0.36	0.30	0.04
25%	2.90	0.41	2.17	0.31	0.25	0.04
20%	2.52	0.36	1.89	0.27	0.22	0.03
15%	2.18	0.31	1.63	0.23	0.19	0.03
10%	1.91	0.27	1.43	0.20	0.17	0.02
5%	1.71	0.24	1.28	0.18	0.15	0.02

This Zone A modelling (which can effectively be considered to be the consideration of the dilution of these determinands due to initial dilution), demonstrates that with the proposed diffuser in place, then all of the determinands meet required standards very close to the outfall. There are no predicted significant impacts to the surrounding environment.

6 COASTAL MODELLING METHODOLOGY

Intertek METOC's existing calibrated and verified 1350 metre model of the English Channel and the North Sea was used as the basis of the nutrient modelling approach and the newly constructed Guernsey Coastal Modelling System (GCMS) was used for the bacterial modelling.

Both of these models were constructed using the MIKE21 software platform, a proven modelling system that is deployed worldwide for all manner of coastal assessment, including water quality, bacterial modelling, coastal process modelling, wave modelling. Tidal renewable energy modelling and flood modelling. It is the most common modelling system used in the UK for these types of water quality studies.

Water quality parameter can be modelled using two basic approaches within MIKE series of models and most other complex modelling systems:

- Particle tracking;
- Advection and dispersion.

The water quality module of MIKE series of models which employs the advection and dispersion technique has been applied in this instance. The intrinsic advantages in the advection and dispersion approach make it the most appropriate model to apply in this case.

The advection and dispersion modelling technique simulates the movement and dispersion of water quality parameters dissolved or suspended in the body of water. This means that the movement of water quality parameters is always correctly represented. In the past, the high computing overhead inherent in applying this technique meant that it could only be used with models of relatively coarse resolution. However, as a result of the increase in computer speed and power, it has been possible to apply the advection and dispersion model to detailed studies such as this one for Guernsey.

6.1 Model Calibration and Validation

A summary of the results of the calibration and validation of the GCMS is provided in Appendix D.

6.2 MODEL ASSESSMENT

6.2.1 Time Period

The model assessment will be carried out for both spring and neap conditions and over a time frame appropriate to the type of assessment.

- Nutrients - a period of a number of months in order to give the non-decaying nutrients time to build up in the water column, which is sometimes referred to as reaching dynamic equilibrium..
- Bacteria - a period of some days as bacteria decay relatively quickly and so will reach dynamic equilibrium relatively quickly.

6.2.2 Water Quality Parameters

The parameters which have been considered are:

- Nitrogen Cycle (DAIN, ammonia, nitrite, nitrate, organic nitrogen)
- Phosphates (inorganic and organic)
- Chlorophyll
- Faecal Coliforms
- Faecal Streptococci
- Suspended solids

6.2.3 Model Output

Contour plots will be provided of the predicted concentrations of:

- DAIN
- DAIP
- Potential for the growth of Chlorophyll
- Faecal Coliforms
- Faecal Streptococci

Results were obtained for a range of spring and neap tidal conditions. In addition, time series plots of the predicted concentrations at locations agreed with the regulator have been provided.

In addition, a plot of the modelled depth of deposited suspended solids has been provided.

7 NUTRIENT MODELLING

7.1 ZONE B MODELLING

7.1.1 Background and Assumptions

The modelling method and assumptions are, in all cases, conservative.

- The calibrated and validated 1350 metre model of the English Channel and North Sea was used for the model assessment..
- Nutrient components. DAIN and DAIP have both been modelled. It has been assumed that the whole of the organic components of DAIN and DAIP have been mineralised to the available chemical species. This is a conservative assumption.
- Model period in excess of 7 months. This very long simulation period allows the concentration of nutrients in the water column to reach a dynamic equilibrium at a considerable distance from the Channel Islands. This is a relatively long time period when compared to the time period over which DAIN and DAIP are likely to build up in the coastal environment. Typically, nutrients build up in the autumn and winter months until a point in the spring when, if nutrient concentrations are sufficient, algal populations increase and nutrient levels decrease dramatically.
- Background concentrations have been assumed to be zero in the modelling. In effect, the excess nutrients resulting from the discharge have been modelled.
- Decay rate. No decay of or other changes to nutrients has been assumed.
    - Denitrification. Nitrates are reduced to atmospheric nitrogen (a process known as denitrification) and so the overall amount of DAIN in the water column is reduced. This process has not been included. This is a conservative assumption.
    - Atmospheric nitrogen fixation. Lightning causes atmospheric nitrogen to react with oxygen to form nitrates. This process has not been included in the assessment as this component forms part of the background concentration.
    - Biological nitrogen fixation. Blue green algae reduce atmospheric nitrogen to ammoniated compounds. This process has not been included in the assessment as this component forms part of the background concentration.
    - There is a dynamic equilibrium between the components of DAIN (ammonia, nitrite and nitrate)

$$NH_3 \leftrightarrow NO_2 \leftrightarrow NO_3$$

However, the overall amount of the nutrient in the system does not change.

- Organic phosphorus is mineralised to form ortho-phosphate. Ortho-phosphate is buffered in the marine environment. This means that as more phosphate is added to the water column then more phosphate is precipitated to the seabed. Similarly, as phosphate in the water column is consumed by algal then phosphate stored in the seabed comes back into solution. This process means that phosphate is relatively constant in the sea (in contrast to the situation found in rivers). Phosphate for this reason is not normally the critical parameter in seawater.

7.1.2 Model Results

The model results are presented in Appendix E. The results are presented in two formats:

- Contour plots of the maximum concentration of DAIN and DAIP
- Time series plots of the concentration of DAIN and DAIP at a number of locations around the Channel Islands.
- The maximum nitrogen and phosphorus concentrations predicted during the course of the modelling are presented in the Table 7-1 below together with the limits which would allow algal growth and a comparison between the maxima and those limits.

Table 7-1: Modelled Maximum Concentrations in the Water Column

	DAIN (mmol/m3)	DAIP (mmol/m3)
Max Modelled Conc	0.202	0.014
Allowable Limits	12.000	0.200
% of allowable limit	2	7

7.1.3 Analysis of Model and Survey Results

The model results show that in Zone B and beyond, the maximum modelled excess DAIN and DAIP concentrations are a very small percentage of the allowable limit.

Analysis of the survey results show that

- 63 of the 64 averaged measured DAIN concentrations are below the CSTT limit
- 45 of the 64 averaged measured DAIP concentrations are below the CSTT limit. The average DAIP concentration is 0.196 mmol/m3, which is very close to the guideline value. DAIP is, in general, not a critical parameter for algal growth in coastal waters. In normal circumstances, there will be just about enough DAIP in the water column to promote algal growth, which is reflected in these results.
- Three (3) sub-samples (3 sub samples make up one averaged sample) from Site 6 on the mid-ebb tide were found to have concentrations above or just below 12 mmol/m3. However, this site is some 1 km from the outfall and so is unlikely to be grossly affected by nutrients from the discharge point when sites much closer to the outfall are not affected in the same way. The DAIP concentration at this site and for this tidal state was found to be 0.16 mmol/m3, which indicates that there is no substantial human derived nutrient load at this point. The mid-depth sub-samples at this location at the same tidal state did not show elevated

concentrations. These results have been discounted from further analyses.

- One sub-sample from Site 2 on the mid-ebb tide was found to have a concentration of 27.4 mmol/m3, substantially above the 12 mmol/m3 limit. The accompanying DAIP concentration (0.8 mmol/m3) for this sub-sample was also in excess of the guideline value indicating that there is a potential that the sample may have been contaminated by nutrient derived from a human origin. However, the other two sub-samples show very low values from both DAIN and DAIP, indicating that it likely that this sub-sample is spurious.

7.2 Zone C Assessment

Zone C is designated as an area in which the residence time of water is 10 to 100 days, sufficiently long for its dissolved nutrient concentration to be increased by mineralisation of particulates. Dispersion on this larger scale results from residual circulation as well as tidal movements. The Zone C assessment has been carried out by considering the large bay in which stretches from the headland at Auderville to the headland at Roscoff.

Nutrient discharges to this zone can be from both human sources and from agricultural sources. Agricultural source, in general, discharge to rivers and subsequently to the sea. The major water course discharging to this area is La Rance. However, it has proved very difficult to obtain water quality information relating to rivers in France.

The initial analysis has focussed on a comparison of the human populations contributing to the zone. The estimated populations of the French Departments and the Channel Islands are provided in Table 7-2 below. Secondary treatment is estimated to remove 20% of the nutrient load. It has been assumed that all discharges from the French Departments are treated to secondary standard, although it is by no means certain that all rural discharges are treated to such a high standard. This is a conservative assumption.

Table 7-2: populations of Communities Discharging to Zone C

Name	Population	Estimated Population Discharging to Zone C	Notional Population assuming secondary treatment	Percentage of Overall population (%)	Comment
Manche	492,563	350,000	280,000	18.2	Assumed 70% effluent discharges to this Zone
Ile et Vilaine	954,851	954,851	764,000	49.8	Assumed 100% effluent discharges to this Zone
Cote d'Armor	570,861	400,000	320.000	20.9	Assumed 70% effluent discharges to this Zone
Jersey	92,500	92,500	92,500	6.0	Assumed 100% effluent discharges to this Zone
Guernsey*	75,000	75,0000	75,0000	4.9	Assumed 100% effluent discharges to this Zone
Alderney	2,400	2,400	2,400	0.2	Assumed 100% effluent discharges to this Zone
Sark	600	600	600	0.0	Assumed 100% effluent discharges to this Zone
Herm	60	60	60	0.0	Assumed 100% effluent discharges to this Zone

* Design population for modelling purposes

Based on this analysis, discharges from Belle Greve would represent just below 5% of the human nutrient budge in this area. However, rivers are known to be major contributors to coastal nutrient loads and so the nutrient load from Guernsey is likely to represent a much smaller percentage contribution to the overall nutrient load to this zone.

Therefore, there is no need to carry out further detailed analysis to predict the potential for eutrophication if the discharge were secondary treated.

8 BACTERIAL MODELLING (BATHING WATERS AND SHELLFISH WATERS)

Bacterial discharges from Belle Greve outfall and the Red Lion CSO have been modelled using the GCMS. In each case, the results have been presented as contour plots and as time series plots at the designated bathing waters.

8.1 Impact of Belle Greve Outfall

The model parameters are outlined below.

- Decay rate Faecal coliforms 15 hours and faecal streptococci 30 hours
- Flow 0.23 m3/s (equivalent to a population of 75,000)
- Wind conditions
    - Calm
    - Speed 5 m/s Direction 0°N.
    - Speed 5 m/s Direction 60°N.
    - Speed 5 m/s Direction 120°N.
    - Speed 5 m/s Direction 180°N
    - Speed 5 m/s Direction 240°N.
    - Speed 5 m/s Direction 300°N.

These wind conditions were applied across the whole simulation in each case.

Standards were assumed to be thresholds, and the percentile compliance levels were ignored. That is, it was assumed that the standard had to be met 100% of the time, and therefore any breach of the threshold would indicate the potential for Belle Greve to impact the Bathing Water. This is a conservative assumption.

The highest threshold (100 bacteria/100ml water) was the basis for the initial assessment.

If this was met, then all other standards (including the Shellfish standard) would be met.

This study did not consider the potential for other sources to impact on the receivers.

8.1.1 Faecal Coliforms

The results of the model assessment for discharges of faecal coliforms from Belle Greve outfall are presented in Appendix F. The results are presented as maximum concentration plots and time series plots.

8.1.2 Faecal Streptococci

The results of the model assessment for discharges of faecal streptococci from Belle Greve outfall are presented in Appendix F. The results are presented as maximum concentration plots and time series plots.

8.2 Impact of Discharges from the Red Lion CSO

The model parameters are outlined below.

Decay rate	Faecal coliforms 15 hours and faecal streptococci 30 hours
Flow	2,000 m3 discharged across a 3 hour period
Wind conditions	Calm
Tides	Spring and neap
Tidal phase	High water, mid ebb, low water and mid flood

8.2.1 Faecal Coliforms

A selection of time series results for discharges from the Red Lion CSO have been supplied in Appendix G. Many of the plots show little or no impact, so only those plots which show impacts higher than 10 ec/100ml have been included.

8.2.2 Faecal Streptococci

A selection of time series results for discharges from the Red Lion CSO have been supplied in Appendix G. Many of the plots show little or no impact, so only those plots which show impacts higher than 1 ie/100ml have been included.

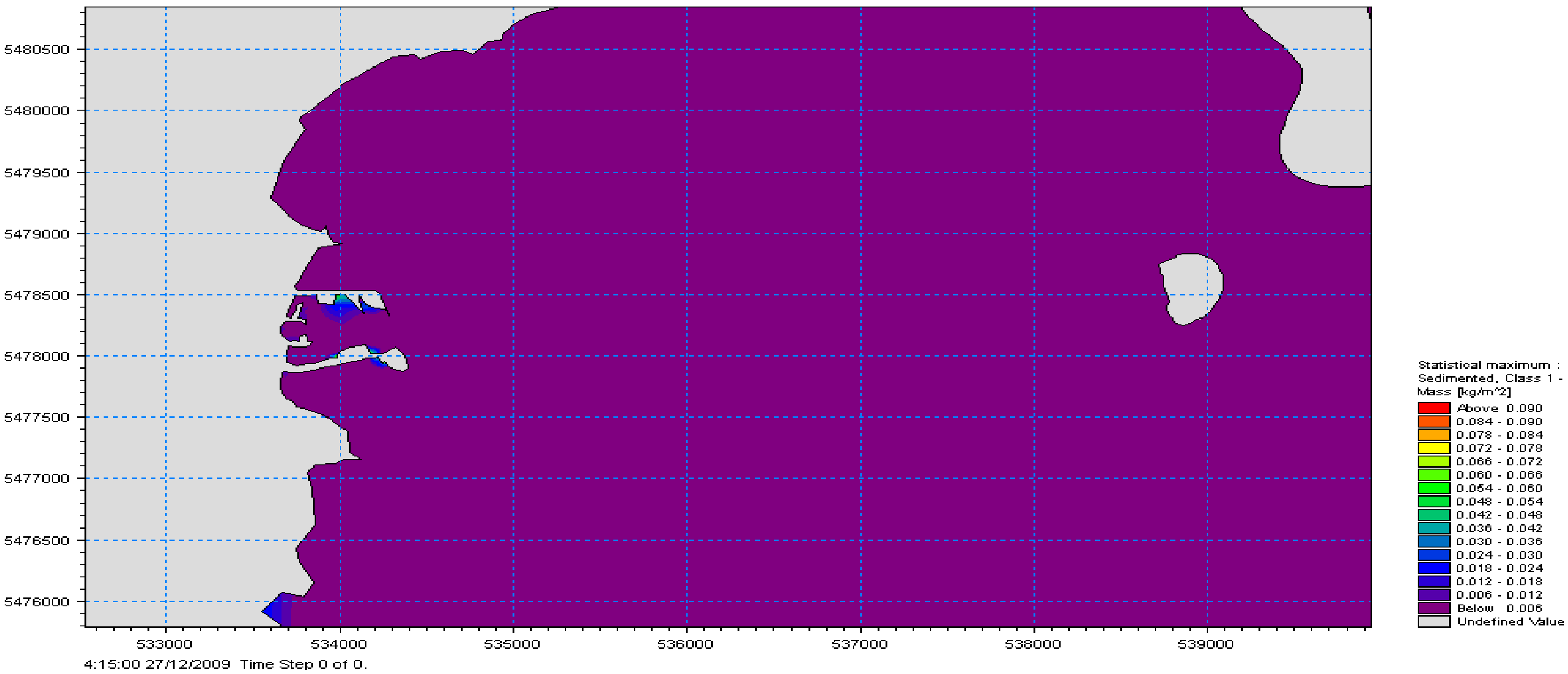
9 BENTHIC AND SEDIMENT MODELLING

Sediment discharges from Belle Greve outfall have been modelled using the GCMS.

The model parameters are outlined below.

- Flow — 0.23 m3/s (equivalent to a population of 75,000)
- Wind conditions — Calm
- Particle size distribution — The particle size distribution for a typical preliminary discharge was applied.
- Sediment concentration — The concentration was based on that calculated during the Zone A assessment.
- The maximum depth distribution in millimetres has been presented in Figure 9-1.

Figure 9-1: Maximum Modelled Depth of Sediment



The results show that there is little or no deposition close to the outfall, while a very small amount of deposition is shown to occur around the harbour.

On this basis it was considered that there was no case for further benthic modelling, as the low levels of deposition would not result in any significant impacts being reported.

10 CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

10.1.1 Initial Dilution

The initial dilution requirements set out in the AMP2 guidelines are not currently met.

The implementation of the environmental design for a diffuser will deliver compliance with the initial dilution standard.

10.1.2 Zone A

The concentration of BOD in the Zone A is predicted to be met in the initial surface boil for the majority of tidal conditions. Improvements to the outfall would ensure that the condition would be met under even more tidal conditions. A very few additional dilutions would be required to meet the standard, which would easily be met within Zone A.

The provision of the recommended diffuser would deliver the necessary improvements.

10.1.3 Nutrient Assessment

The nutrient assessment took into account both the nutrient modelling and the results of the nutrient field survey. The assessment show that discharges from Belle Greve outfall are predicted to provide additional nutrient loads which are only a small percentage of the guideline standard. The data indicates that nutrient from the Belle Greve outfall will not lead to nutrient in excess of the standard within Zone B.

The assessment of discharges to Zone C indicated that discharges from Belle Greve outfall represent less than 5% of the total nutrient discharges to the zone. Therefore, these discharges need not be considered further.

10.1.4 Bacterial Assessment

The results of the bacterial modelling indicated that for:

Belle Greve long sea outfall

- Faecal coliform concentrations at all of the designated bathing waters are predicted to be less than 100 ec/100ml.
- Faecal streptococci concentrations at all of the designated bathing waters are predicted to be less than 25 ie/100ml.

Red Lion short sea outfall

- Faecal coliform concentrations at all of the designated bathing waters are predicted to be less than 15 ec/100ml.
- Faecal streptococci concentrations at all of the designated bathing waters are predicted to be less than 2 ie/100ml.

The Red Lion discharge does not discharge regularly, and its impacts are therefore considered negligible. Current improvements to the sewerage network and the handling of wet weather flows will decrease the operation of the Red Lion outfall still further.

It is therefore considered that the Belle Greve discharge does not significantly impact the designated sensitive receivers (Bathing Waters and Shellfish Waters)

10.1.5 Sediment Assessment

The sediment assessment showed that suspended solids are not predicted to settle close to the Belle Greve outfall. There is no indication that any significant deposition occurs. The highly dynamic and energetic nature of the site would mean that deposition of solids to any meaningful level is highly unlikely.

The data from the benthic survey would support the conclusion that the discharge is not adversely affecting the benthic community.

10.2 RECOMMENDATIONS

The study has demonstrated:

- The initial dilution of the discharge is insufficient to satisfy UK standards. This can be resolved by installing a diffuser section for the outfall.
- The environmental design for the diffuser section would suggest a requirement for seven ports (diameter 0.2m) with a minimum spacing of 11m. The hydraulic design of the diffuser and outfall would need to be confirmed by design engineers.
- The concentrations of solids, BOD, ammonia and COD after initial dilution fall within UK standards (some after the imposition of a diffuser section).
- The nitrogen and phosphorus concentrations predicted by the simulation are below the limits which would indicate (or increase the risk of) the potential for eutrophication (e.g. Algal blooms)
- The Benthic assessment has indicated a very small deposition around the outfall and therefore the present discharge has no significant impact on the benthos.
- Bathing waters and Shellfish Harvesting Areas are not predicted to be significantly impacted by the Belle Greve outfall – i.e. compliance is maintained

Whereas the UWWTD suggests a minimum of primary treatment for wastewater discharges for a population the size of Guernsey, all of the studies conducted would suggest that there is no adverse affect from the Belle Greve discharge.

The results of the study would therefore suggest that the current level of treatment, whilst not strictly conforming with the UWWTD:

- Protects the surrounding waters from the risks of eutrophication
- Protects the surrounding waters from deleterious local impacts of waste water discharges
- Protects Bathing and Shellfish Waters

- Does not pose a risk to the local benthic community due to deposition of suspended solids

11 REFERENCES

[1] R. D. Pingree and G. T. Mardella. Tidal flows around the Channel Islands. Journal of the Marine Biological Association of the United Kingdom (1987), 67 : pp 691-707

[1] Emma V. Sheehan, Timothy F. Stevens, Martin J. Attrill. A Quantitative, Non-Destructive Methodology for Habitat Characterisation and Benthic Monitoring at Offshore Renewable Energy Developments.

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[1] CSTT. Comprehensive Studies for the Purposes of Articles 6 and 8.5 of DIR91/271 EEC. The Urban Waste Water Treatment Directive. 1994

[1] CSTT. Comprehensive Studies for the Purposes of Articles 6 and 8.5 of DIR91/271 EEC. The Urban Waste Water Treatment Directive. 1997

[1] http://ec.europa.eu/environment/water/water-bathing/index_en.html

[1] EU. DIRECTIVE 2006/7/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. OJL.64/37/2006

[1] EEC. Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water. OJ L 31, 5.2.1976, p. 1–7

Appendix A Scope of Survey Work

FIGURES

TABLES

A.1 INTRODUCTION

It is required that hydrographic and benthic survey be carried out around the location of the Belle Greve outfall close to St Peter Port Guernsey.

The survey area will require a suite of survey work to be completed comprising:

- Hydrographic and oceanographic survey
  - Current meters
  - Depth profiles
  - Dye release with accompanying drogue release.
- Benthic survey
- Samples at impacted and reference sites
- Water quality survey

Samples at impacted and reference sites

- Bathymetry survey
  - survey local to discharge point, suitable for engineering assessment, and
  - a more general topographical survey of St Peter Port bay

A.1.1 PROJECT OVERVIEW

The survey will comprise of four components.

- Currents and levels monitoring - At sites specified in Section A.2, current speeds and directions through the water column should be measured over at least a 31-day period. In addition, water levels (elevations relative to a vertical datum) should also be measured, over the same 31-day period,
- Depth profiles - At each current monitoring site, independent measurements of current speed and direction, temperature and salinity are to be taken hourly through the water column over a 13-hour tidal cycle on both a spring and neap tide.
- Dye tracing – At sites specified in Section A.2, dye patch tracing undertaken for high and low water releases under both a spring and neap tide.
- Benthic sampling at sites specified in Section A.3.
- Water quality sampling at sites specified in Section A.3.
- Bathymetry survey in the area specified in Section A.4.

Depth Profiles, and Dye Tracing, must be collected during the same period as Currents and Levels Monitoring.

The most appropriate equipment must be selected for each component and location. It is anticipated that bottom-mounted Acoustic Doppler Current

Profilers (ADCP) with a pressure sensor will be used for component Currents and Levels Monitoring, but the surveyor should ensure that this is the most suitable instrument for each location. An alternative option may be to use an array of Direct Reading Current Meters (DRCM) through the water column and a tide gauge, which would also be acceptable, and possibly even preferable to an ADCP at some sites, depending on the water depth and prevailing conditions. The equipment and methodology to be used for these surveys should be stated.

A.1.2 DEFINITION OF SPRING AND NEAP TIDE

Spring conditions are defined as pertaining during the period when the tidal range exceeds MSTR-0.25(MSTR-MNTR), and neaps as the period during which the tidal range is lower than MNTR+0.25(MSTR-MNTR).

Where:

- MSTR: Mean Spring Tidal Range
- MNTR: Mean Neap Tidal Range

A.1.3 NOTE ON TECHNICAL SPECIFICATIONS

Technical Specifications drafted by Metoc describe acceptable equipment and methodologies by which the work is undertaken; these are presented in the sections below.

In addition to this document, the SEPA Site and Hydrographic Survey Requirements (for Applications for Consent to Discharge from Marine Cage Salmon Farms), hereafter referred as 'SEPA guidelines', provides a guide to technical requirements for equipment and survey techniques which have been used for a variety of similar studies, and these are deemed suitable as the reference for this survey.

A.1.4 HORIZONTAL AND VERTICAL REFERENCE

The coordinate system to be used during all reporting and charting shall be the Guernsey Grid. The vertical datum along all route components shall be Ordnance Datum Guernsey, OD(G).

Positional accuracy should be ±3m.

A.1.5 SURVEY LOCATIONS

Figure A.1 gives an overview of the survey area.

The locations of sites provided in this document are indicative, and may well be slightly amended. Final positions will be confirmed following award of contract and appointment of the client representative.

Details of proposed locations are provided in the relevant sub-sections below.

A.1.6 SURVEY PERSONNEL

For each survey vessel undertaking the data acquisition the survey team shall be sufficient to operate on a 16-hour/day basis.

All survey personnel shall be trained in the use of the equipment utilised during the study and where appropriate hold appropriate certificates for working onboard survey vessels. Training records for all personnel shall be provided for inspection.

The data shall be monitored and interpreted on board the survey vessel and at the site office by a qualified surveyor with at least five (5) years experience.

A.1.7 CALIBRATION OF INSTRUMENTS

Pre-deployment Checks

Checks shall be performed on each instrument before mobilisation/deployment to ensure that all the sensors and processing equipment specified in the Scope of Work are functioning correctly and that they are performing within the manufacturer's specifications.

If the performance of any sensor is found to be unsatisfactory, and outside the manufacturer's specification, then the Tenderer shall either discount it entirely or shall undertake a full re-calibration of the sensor, or instrument, in order to obtain calibration curves and/or equations which shall be applied to the gathered data.

Instrument calibration checks shall be undertaken in the presence of the client representative.

Post-deployment Checks

Calibration checks shall also be performed, where practicable, on each instrument on deployment.

Documentation on the final checks shall be provided to the client representative for approval prior to the final processing of the data.

If significant differences are evident between pre and post calibration checks, or if the instrument malfunctions during the measurement period, discussions shall be held with the client representative, in order to establish any requirements for additional calibrations and any corrections which shall be applied to the gathered data. The Client Representative may require re-calibration of an instrument at any time.

A.2 HEALTH AND SAFETY

Health and Safety considerations are of paramount importance. It is vital that the contractor undertakes the works in a safe and responsible manner and can demonstrate that acceptable health and safety procedures, risk assessments and method statements are complied with at all times.

The contractor shall provide all method statements, risk assessments and certifications (for instance, to demonstrate vessel suitability) prior to any works being undertaken.

- The contractor shall ensure that the personnel take all reasonable safety measures in relation to the work undertaken under the Contract, and conducts itself and themselves in a safe and proper manner carrying out all applicable obligations and duties under all relevant legislation.

- The contractor shall in addition observe and follow all guides, codes and recommendations issued or made relating to health and safety at work.
- The contractor shall supply, prior to commencement of the contract, a copy of its Health and Safety policy and procedures and safety record for all aspects of the contractor's services, which are necessary to complete the work. This inspection will not imply any seal of approval.

A.3 HYDROGRAPHIC SURVEY

A.3.1 SCOPE OF WORK

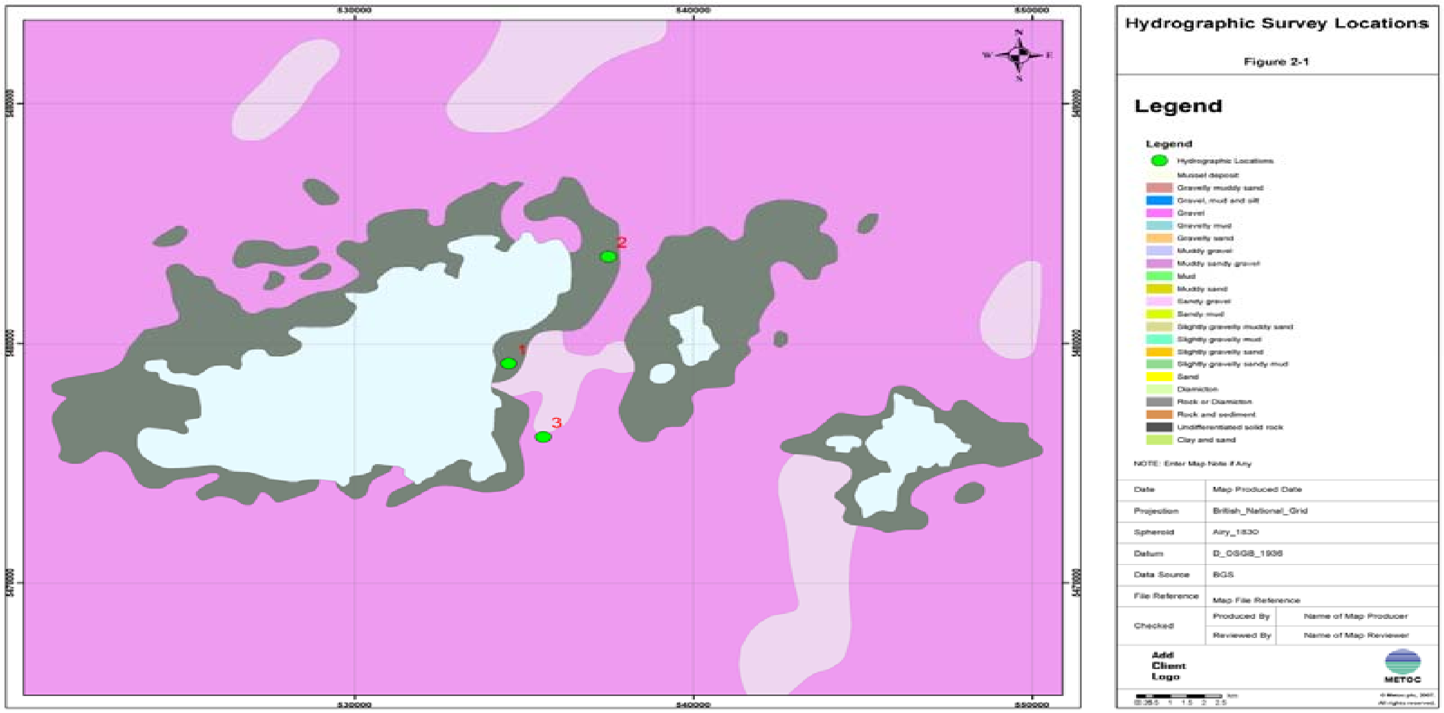
All permissions, notifications such as Notices to Mariners, and licences required to undertake the survey works shall be the responsibility of the Surveyor.

Each phase of marine work shall require vessel positioning by differential Global Positioning System. Heading determination will be provided by a gyro/survey compass. This navigation spread deemed to be part of the essential equipment of the survey vessel used under the contract.

A.3.2 SURVEY LOCATIONS

The hydrographic survey locations are shown in Figure A.1 and tabulated in Table A.1.

Figure A- 1: Hydrographic Survey Locations



Based upon BGS, with the permission of the British Geological Survey 2003/143

Table A- 1: Hydrographic Approximate Survey Locations

Location	Easting (UTM 30N m)	Northing (UTM 30N m)
H1	534540	5479150
H2	537480	5483625
H3	535560	5476090

A.3.3 INSTRUMENTATION

Prior to the survey, all instrumentation and equipment shall be checked and calibrated. Calibration results and certificates issued by the manufacturer shall be available for inspection and approved by Intertek-METOC.

A.3.4 METEOROLOGICAL CONDITIONS

Records of meteorological conditions will be made from the vessel at approximately hourly intervals during the 13-hour surveys of depth profiling, and dye tracing work. These will include:

- Time
- Position
- Wind Speed
- Wind direction
- Wave height
- Wave direction
- Sea state
- Visibility
- Cloud Cover
- Rainfall Observations

Measurements of wind speed and direction using a handheld anemometer shall be made at half-hourly intervals throughout survey operations (excluding the 30-day deployment of current meters). Notes on sea state and weather conditions shall also be made. Measurements should be averaged to hourly intervals for both speed and direction and reported as such.

A.3.5 CURRENT MONITORING

<u>Current Speed and Direction</u>

A long term (at least a 31-day period) deployment of current meters, capable of measuring currents through the water column, is required for all survey locations. This device will measure current speed and current direction in accordance with the requirements given in Section 1.

<u>Surface Elevations</u>

Surface elevations relative to a vertical datum, or total water depth should also be recorded over the 30-day period. Water depth measurements shall be acquired with an overall error budget that is compliant with IHO Standard S-44 Order 1 Surveys with regard to error budgets.

The Surveyor shall specify the method by which vertical control shall be undertaken to ensure error limits fall within those set out in S-44 Order 1 surveys.

Timing of Operations

The fixed measurements should be taken over at least a 31-day period starting either on a neap tide or a spring tide.

A.3.6 DEPTH PROFILES

Depth profiles of temperature, salinity, and current speeds and directions are required. These must be collected at Locations H1 to H3 during the 31-day current meter deployment. They will help determine the three-dimensional (3D) structure of the water column, and will also provide an independent check of the current meter data collected.

The depth profiles are required over two 13-hour periods, incorporating high and low water over both a neap and spring tide. However, it is acknowledged that this may not be possible, given the hours of daylight available during the survey. The minimum duration required is likely to be at least 8 hours.

Current Speed and Direction

At each current meter location, independent measurements of current speed and direction are required. Measurements are to be collected over two 13-hour periods (to be agreed – see note above) to incorporate high and low water during both a neap and a spring tide. The current profiles must be collected independently of the current monitoring data collected (component (a)).

Temperature and Salinity

At each current meter location, independent measurements of temperature and salinity are required. Measurements are to be collected through the water column over two 13-hour periods (to be agreed – see note above) to incorporate high and low water during both a neap and a spring tide, simultaneously with the current speed and direction profiles. An appropriate multi-parameter Conductivity, Temperature, Depth (CTD) probe will be used.

A.3.7 DISPERSION DATA

Rhodamine WT dye releases shall be made from Location H1, given in Table 2.1, at high and low water on both a spring and neap tides.

NB. It is possible that the client representative may suggest amending the release location at the time of the survey based on the prevailing conditions.

The dye patches shall be tracked and quantitative measurements shall be made at half hourly intervals at a depth within the range of 0.25-1.5m (actual depth to be decided on site). The dye patch shall be monitored using a fluorimeter taking data from an agreed depth. Sufficient dye will be released to enable the dye patch to be tracked for one tidal excursion (at least 6 hours – or until significant dilution to immeasurable concentrations has occurred).

Transects shall be taken through each dye patch to assess the position of maximum concentration and spread of dye.

Speeds and directions of winds will be measured during the dye tracing.

A.4 BENTHIC AND NUTRIENT SURVEYS

The client wishes to undertake a benthic survey to determine community structure at the discharge point.

The contractor should determine the appropriate method of sampling, accounting for local conditions.

One site at the discharge point should be surveyed, and also a suitable reference site should be identified and sampled. Costs for these two sites should be submitted, although there is the possibility that existing data the client holds may prove suitable for the reference site.

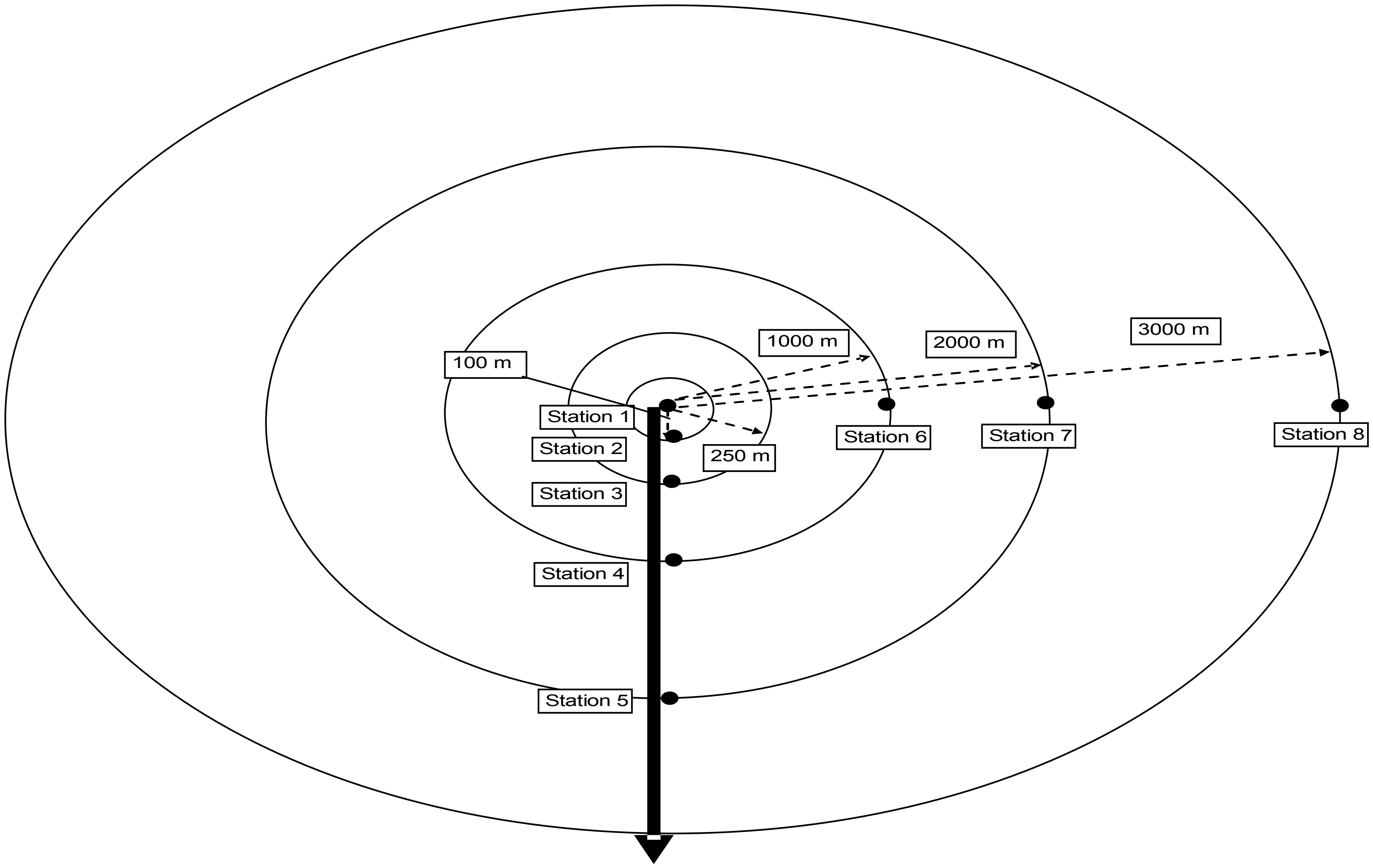
A.4.1 SAMPLE LOCATIONS

A sparse water quality grid consisting of 8 stations has been designed to maximize the spatial extent of the survey while allowing the samples to be collected at several different tidal states. The grid consists of eight stations, 5 lying in the principal direction of current flow and 3 lying perpendicular to the direction of current flow.

- Station W1/B1 above the diffuser
- Station W2/B2 100m from Station 1 in the direction of the flood tide axis;
- Station W3/B3 250m from Station 1 in the direction of the flood tide axis;
- Station W4 1000m from Station 1 in the direction of the flood tide axis;
- Station W5/B4 2000m from Station 1 in the direction of the flood tide axis;
- Station W6 1000m from Station 1 perpendicular to the direction of the flood tide axis;
- Station W7 2000m from Station 1 perpendicular to the direction of the flood tide axis;
- Station W8/B5 3000m from Station 1 perpendicular to the direction of the flood tide axis.

A diagram showing the location of sampling points in relation to the outfall and the direction of the flood tide is supplied in Figure A-2.

Figure A- 2: Nutrient Survey – Sampling Locations Diagram



The samples should be analysed for particle size as well as the identification of organisms to species level. A sieve size of 0.5mm should be used as standard, although a 1mm mesh would acceptable where the substrate is gravelly.

A.4.2 WATER QUALITY SURVEYS

The water quality survey should be carried out for neap tidal conditions, as far possible alongside the profiling survey (Section 2.6). The schedule of sampling is provided in Table A.2.

Table A- 2: Water quality sampling

Determinand	LW Slack	Mid Flood	HW Slack	Mid Ebb
DO Surface	✓	✓	✓	✓
DO Mid-depth		✓		✓
Temperature Surface	✓	✓	✓	✓
Temperature Mid-depth		✓		✓
Salinity Surface	✓	✓	✓	✓
Salinity Mid-depth		✓		✓
BOD_5 Surface	✓	✓	✓	✓
BOD_5 Mid-depth		✓		✓

Determinand	LW Slack	Mid Flood	HW Slack	Mid Ebb
Nutrients Surface	✓	✓	✓	✓
Nutrients Mid-depth	✓	✓	✓	✓
Chlorophyll-A Surface	✓	✓	✓	✓
PAR/Secchi Depth		✓		✓

In addition, 3 'nutrient blanks' should be analysed for the first and last run using low nutrient seawater: Totalling 6 nutrient blanks for QC purposes.

Samples should be submitted in triplicate for QC purposes.

All water quality samples should labelled and be kept at an appropriate temperature (between 2 and 4oC) and should be transferred to a designated laboratory as quickly as possible.

Water samples should be collected in containers which have previously been rinsed in distilled water.

The replicate samples should be filled by sub-sampling from the same bulk sample.

Samples for nutrient analysis should be filtered through in-line filter units directly into the bottles. Freezing of the samples should be considered if analysis cannot be carried out rapidly.

Chlorophyll samples should be filtered on site and filter papers submitted for analysis. Freezing of the samples should be considered if analysis cannot be carried out rapidly.

Although the client has lab facilities, allowance should be made for analysis at another location. We understand that transit to the Environment Agency's Lab at Starcross, Exeter, has been used by the client in the past.

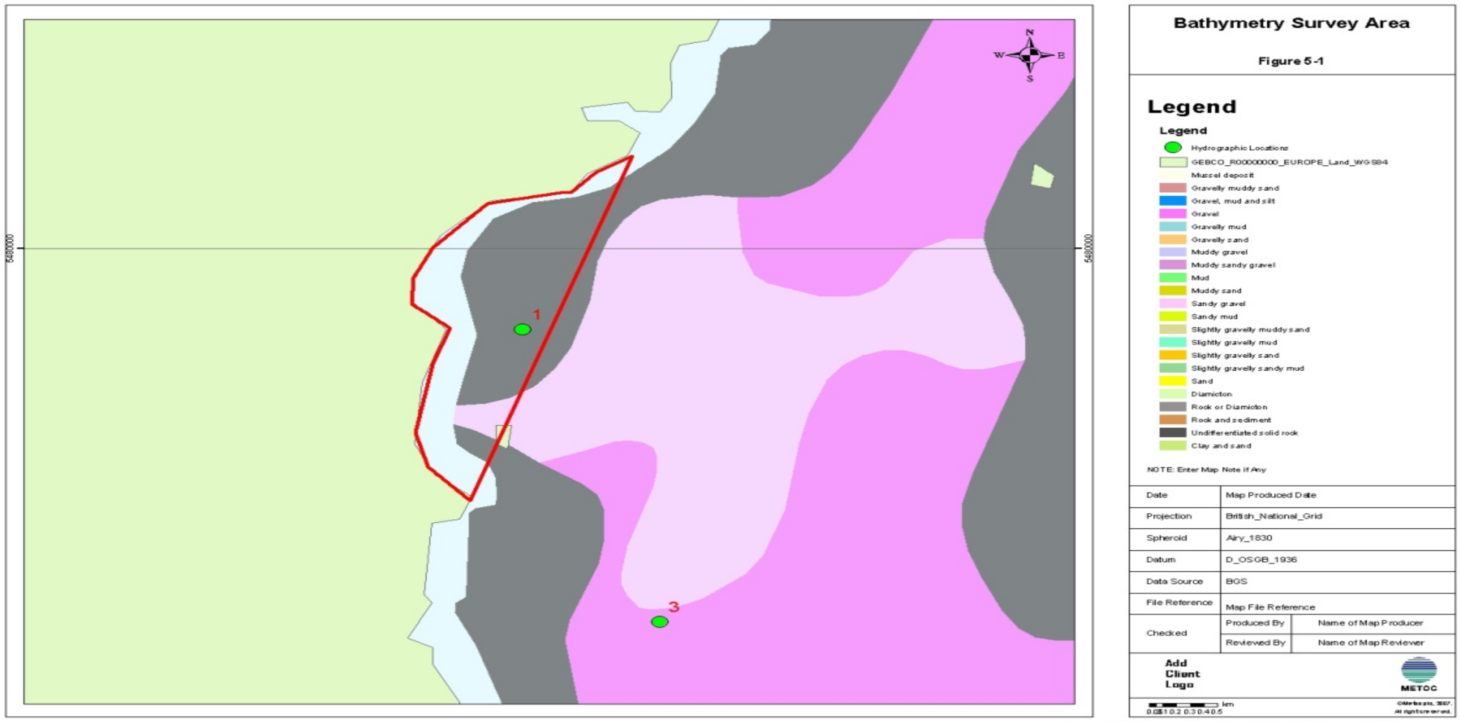
A.5 BATHYMETRY SURVEY

It is proposed that a bathymetry survey suitable for engineering assessment be carried out for the area from the headworks of the outfall to a point 500 metres beyond the outfall endpoint with a width of some 200m (i.e. 100m either side of the existing outfall). The bathymetric survey shall be performed along the outfall centre with crosslines, at regular intervals for the full length.

In addition, a topographical survey for the purposes of model bathymetry data shall be undertaken for the area of St Peter's Port bay. This is shown in the figure below.

Data acquisition shall be compliant with IHO Standard S-44 (Special Order) Surveys with regard to error budgets.

Figure A- 3: Bathymetry Survey Area



Based upon BGS, with the permission of the British Geological Survey 2003/143

Appendix B Water Quality Survey Results

TABLES

Table B- 1: Water Quality Field Survey Results – Low Water

Sample Description	Date/Time (GMT)	Temperature	Salinity	Ammoniacal Nitrogen Filtered as N	Nitrite Filtered as N	Total Oxidised Nitrogen Filtered as N	Nitrate (Calculated) as N	Ortho phosphate Filtered as P	Silicate Filtered as SiO2	Chlorophyll a
		°C	psu	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
Site 1 A Surface LW	27-JUL-11 08:35			7.30	1.30	< 7.00	< 5.70	< 2.00	111.0	0.99
Site 1 B Surface LW	27-JUL-11 08:35			7.20	1.60	< 7.00	< 5.40	< 2.00	122.0	0.83
Site 1 C Surface LW	27-JUL-11 08:35			7.70	1.70	< 7.00	< 5.30	2.80	134.0	0.89
Averages		15.18	35.17	7.40	1.53	7.00	5.47	2.27	122.3	0.90
Site 1 A Mid depth LW	27-JUL-11 08:35			8.20	1.09	< 7.00	< 5.91	< 2.00	106.0	
Site 1 B Mid depth LW	27-JUL-11 08:35			9.40	0.95	< 7.00	< 6.05	< 2.00	93.2	
Site 1 C Mid depth LW	27-JUL-11 08:35			8.10	1.80	< 7.00	< 5.20	< 2.00	139.0	
Averages		15.77	35.18	8.57	1.28	7.00	5.72	2.00	112.7	
Site 2 A Surface LW	27-JUL-11 08:45			< 7.00	0.99	< 7.00	< 6.01	< 2.00	104.0	1.41
Site 2 B Surface LW	27-JUL-11 08:45			< 7.00	0.98	< 7.00	< 6.02	< 2.00	107.0	1.15
Site 2 C Surface LW	27-JUL-11 08:45			7.40	1.60	< 7.00	< 5.40	2.40	137.0	0.99
Averages		15.76	35.18	7.13	1.19	7.00	5.81	2.13	116.0	1.18
Site 2 A Mid depth LW	27-JUL-11 08:45			< 7.00	0.83	< 7.00	< 6.17	< 2.00	90.3	
Site 2 B Mid depth LW	27-JUL-11 08:45			7.20	1.50	< 7.00	< 5.50	2.40	135.0	
Site 2 C Mid depth LW	27-JUL-11 08:45			7.01	1.50	< 7.00	< 5.50	2.90	139.0	
Averages		15.75	35.18	7.07	1.28	7.00	5.72	2.43	121.4	

Site 3 A Surface LW	27-JUL-11 08:55				29.40		1.40	<	7.00	<	5.60		4.00		125.0		1.36
Site 3 B Surface LW	27-JUL-11 08:55				34.60		1.80	<	7.00	<	5.20		5.40		138.0		1.04
Site 3 C Surface LW	27-JUL-11 08:55				34.80		1.90	<	7.00	<	5.10		4.70		145.0		1.04
Averages		15.72	35.16		32.93		1.70		7.00		5.30		4.70		136.0		1.15
Site 3 A Mid depth LW	27-JUL-11 08:55				20.20		1.96		9.10		7.14		3.70		144.0		
Site 3 B Mid depth LW	27-JUL-11 08:55				21.50		1.60		8.00		6.40		2.80		122.0		
Site 3 C Mid depth LW	27-JUL-11 08:55				17.00		1.70		7.70		6.00		3.40		124.0		
Averages		15.60	35.17		19.57		1.75		8.27		6.51		3.30		130.0		
Site 4 A Surface LW	27-JUL-11 09:06			<	7.00		1.30	<	7.00	<	5.70	<	2.00		101.0		0.99
Site 4 B Surface LW	27-JUL-11 09:06			<	7.00		1.01	<	7.00	<	5.99	<	2.00		93.2		0.83
Site 4 C Surface LW	27-JUL-11 09:06				8.20		1.90		8.90		7.00		2.70		131.0		0.89
Averages		15.57	35.18		7.40		1.40		7.63		6.23		2.23		108.4		0.90
Site 4 A Mid depth LW	27-JUL-11 09:06				10.30		2.07		9.60		7.53		2.80		131.0		
Site 4 B Mid depth LW	27-JUL-11 09:06				10.50		1.80		9.20		7.40		3.50		125.0		
Site 4 C Mid depth LW	27-JUL-11 09:06				11.50		2.08		10.00		7.92		3.06		135.0		
Averages		15.51	35.18		10.77		1.98		9.60		7.62		3.12		130.3		
Site 5 A Surface LW	27-JUL-11 09:20				7.50		1.20	<	7.00	<	5.80		2.20		91.1		0.73
Site 5 B Surface LW	27-JUL-11 09:20				9.70		2.10		9.70		7.60		2.90		131.0		0.57
Site 5 C Surface LW	27-JUL-11 09:20			<	7.00		0.92	<	7.00	<	6.08	<	2.00		76.3		0.68
Averages		15.47	35.18		8.07		1.41		7.90		6.49		2.37		99.5		0.66
Site 5 A Mid depth LW	27-JUL-11 09:20				10.10		1.70		8.90		7.20		3.00		117.0		

Site 5 B Mid depth LW	27-JUL-11 09:20				7.80		1.20	<	7.00	<	5.80		2.30		97.2		
Site 5 C Mid depth LW	27-JUL-11 09:20				14.60		1.50		8.50		7.00		2.20		103.0		
Averages		15.46	35.18		10.83		1.47		8.13		6.67		2.50		105.7		
Site 6 A Surface LW	27-JUL-11 10:10				7.50		1.70	<	7.00	<	5.30		2.80		137.0		0.68
Site 6 B Surface LW	27-JUL-11 10:00			<	7.00		1.20	<	7.00	<	5.80		2.06		111.0		0.73
Site 6 C Surface LW	27-JUL-11 10:10			<	7.00		1.50	<	7.00	<	5.50		2.90		126.0		0.89
Averages		15.78	35.12		7.17		1.47		7.00		5.53		2.59		124.7		0.77
Site 6 A Mid depth LW	27-JUL-11 10:10				7.30		1.70	<	7.00	<	5.30		2.50		141.0		
Site 6 B Mid depth LW	27-JUL-11 10:10				7.20		0.96	<	7.00	<	6.04		2.10		104.0		
Site 6 C Mid depth LW	27-JUL-11 10:10				8.30		1.40	<	7.00	<	5.60		2.20		125.0		
Averages		15.76	35.18		7.60		1.35		7.00		5.65		2.27		123.3		
Site 7 A Surface LW	27-JUL-11 09:57				10.10		1.70	<	7.00	<	5.30		3.20		134.0		0.83
Site 7 B Surface LW	27-JUL-11 09:57				15.00		1.10	<	7.00	<	5.90	<	2.00		102.0		0.66
Site 7 C Surface LW	27-JUL-11 09:57				10.00		1.40	<	7.00	<	5.60		2.60		123.0		0.83
Averages		15.69	35.18		11.70		1.40		7.00		5.60		2.60		119.7		0.77
Site 7 A Mid depth LW	27-JUL-11 09:57				7.90		0.85	<	7.00	<	6.15	<	2.00		89.9		
Site 7 B Mid depth LW	27-JUL-11 09:57			<	7.00		1.08	<	7.00	<	5.92		2.07		101.0		
Site 7 C Mid depth LW	27-JUL-11 09:57				8.20		1.20	<	7.00	<	5.80		2.20		109.0		
Averages		15.68	35.18		7.70		1.04		7.00		5.96		2.09		100.0		
Site 8 A Surface LW	27-JUL-11 09:43			<	7.00		1.70	<	7.00	<	5.30		2.10		135.0		0.78
Site 8 B Surface LW	27-JUL-11 09:43			<	7.00		1.40		7.10		5.70	<	2.00		119.0		0.73

Site 8 C Surface LW	27-JUL-11 09:43			<	7.00		1.77	<	7.00	<	5.23		2.50		140.0		0.99
Averages		15.72	35.18		7.00		1.62		7.03		5.41		2.20		131.3		0.83
Site 8 A Mid depth LW	27-JUL-11 09:43				8.70		1.60	<	7.00	<	5.40		2.80		130.0		
Site 8 B Mid depth LW	27-JUL-11 09:43			<	7.00		1.50	<	7.00	<	5.50		2.40		124.0		
Site 8 C Mid depth LW	27-JUL-11 09:43				8.70		1.20	<	7.00	<	5.80		2.40		115.0		
Averages		15.71	35.18		8.13		1.43		7.00		5.57		2.53		123.0		

Table B- 2: Water Quality Field Survey Results – Mid Flood

Eastings	Northings	Sample_Description	Date_Time_(GMT)	Temperature	Salinity	Ammon	Nitrite	TON	Nitrate	Orthophos	Silicate	Chlor
534539.9	5479150	Site_1_Av_Surface_MF	27-JUL-11__11:40	15.968	35.181	8.343333	1.456667	7	5.543333	2.933333	137	0.973333
534539.9	5479150	Site_1_Av_Mid_depth_MF	27-JUL-11__11:40	15.83	35.18	7.17	1.19	7.00	5.81	2.10	118.7	
534607.5	5478955	Site_2_Av_Surface_MF	27-JUL-11__11:50	16.01	35.18	7.00	1.18	7.00	5.82	2.20	118.3	0.90
534607.5	5478955	Site_2_Av_Mid_depth_MF	27-JUL-11__11:50	15.85	35.17	20.70	1.46	10.87	9.41	3.27	117.9	
534839.3	5478285	Site_3_Av_Surface_MF	27-JUL-11__12:00	15.95	35.20	7.00	1.53	7.00	5.47	2.63	136.0	0.90
534839.3	5478285	Site_3_Av_Mid_depth_MF	27-JUL-11__12:00	15.83	35.18	7.29	1.37	7.00	5.63	2.63	131.0	
535179.2	5477302	Site_4_Av_Surface_MF	27-JUL-11__12:21	15.87	35.18	7.00	1.80	7.00	5.20	2.73	144.3	0.89
535179.2	5477302	Site_4_Av_Mid_depth_MF	27-JUL-11__12:21	15.78	35.17	9.60	1.25	7.00	5.75	2.55	118.0	
535510.5	5476345	Site__5_Av_Surface_MF	27-JUL-11__12:30	15.81	35.19	7.00	1.34	7.00	5.66	2.16	117.0	0.79
535510.5	5476345	Site_5_Av_Mid_depth_MF	27-JUL-11__12:30	15.75	35.18	7.00	3.17	7.00	3.83	2.09	101.5	
535405.3	5479449	Site_6_Av_Surface_MF	27-JUL-11__13:18	15.93	35.18	7.00	1.03	7.00	5.97	2.17	111.7	0.92
535405.3	5479449	Site_6_Av_Mid_Depth_MF	27-JUL-11__13:18	15.89	35.18	8.20	1.39	7.00	5.61	3.30	122.4	
536385.2	5479788	Site_7_Av_Surface_MF	27-JUL-11__13:07	15.82	35.18	7.34	1.27	7.00	5.73	2.67	105.5	0.95
536385.2	5479788	Site_7_Av_Mid_Depth_MF	27-JUL-11__13:07	15.80	35.18	7.00	1.15	7.00	5.85	2.07	97.3	
537343.1	5480120	Site_8_Av_Surface_MF	27-JUL-11__12:52	15.86	35.18	7.00	1.14	7.00	5.86	2.43	104.3	1.03
537343.1	5480120	Site_8_Av_Mid_Depth_MF	27-JUL-11__12:52	15.82	35.18	7.03	1.67	7.00	5.33	2.93	135.3	

Table B- 3: Water Quality Field Survey Results – High Water

Eastings	Northings	Sample_Description	Date_Time_(GMT)	Temperature	Salinity	Ammon	Nitrite	TON	Nitrate	Orthophos	Silicate	Chlor
534539.9	5479150	Site_1_Av_Surface_HW	27-JUL-11__14:45	15.994	35.19332	7.633333	1.3	7	5.7	2.4	115.9333	1.13
534539.9	5479150	Site_1_Av_Mid_depth_HW	27-JUL-11__14:45	15.866	35.17267	7.833333	1.226667	7	5.773333	2.233333	109.3333	
534607.5	5478955	Site_2_Av_Surface_HW	27-JUL-11__14:55	16.02	35.17146	7.733333	1.263333	7	5.736667	2.316667	112.6333	1.13
534607.5	5478955	Site_2_Av_Mid_depth_HW	27-JUL-11__14:55	15.851	35.17345	20.7	1.456667	10.86667	9.41	3.266667	117.9333	
534839.3	5478285	Site_3_Av_Surface_HW	27-JUL-11__15:07	15.9463133	35.17836	14.21667	1.36	8.933333	7.573333	2.791667	115.2833	1.13
534839.3	5478285	Site_3_Av_Mid_depth_HW	27-JUL-11__15:07	15.8425743	35.17476	7.666667	1.416667	7	5.583333	2.4	114.5	
535179.2	5477302	Site_4_Av_Surface_HW	27-JUL-11__15:20	16.0373486	35.18012	10.94167	1.388333	7.966667	6.578333	2.595833	114.8917	1.13
535179.2	5477302	Site_4_Av_Mid_depth_HW	27-JUL-11__15:20	15.7701737	35.17702	9.304167	1.4025	7.483333	6.080833	2.497917	114.6958	
535510.5	5476345	Site_5_Av_Surface_HW	27-JUL-11__15:33	15.5231985	35.18519	11.83333	1.766667	9.566667	7.8	2.733333	122.6667	0.66
535510.5	5476345	Site_5_Av_Mid_depth_HW	27-JUL-11__15:33	15.5129276	35.17958	10.56875	1.584583	8.525	6.940417	2.615625	118.6813	
535405.3	5479449	Site_6_Av_Surface_HW	27-JUL-11__16:18	15.8115507	35.1783	11.20104	1.675625	9.045833	7.370208	2.674479	120.674	0.66
535405.3	5479449	Site_6_Av_Mid_Depth_HW	27-JUL-11__16:18	15.7827413	35.17798	10.8849	1.630104	8.785417	7.155313	2.645052	119.6776	
536385.2	5479788	Site_7_Av_Surface_HW	27-JUL-11__16:03	16.0641561	35.1784	11.04297	1.652865	8.915625	7.26276	2.659766	120.1758	0.66
536385.2	5479788	Site_7_Av_Mid_Depth_HW	27-JUL-11__16:03	15.7505367	35.179	10.96393	1.641484	8.850521	7.209036	2.652409	119.9267	
537343.1	5480120	Site_8_Av_Surface_HW	27-JUL-11__12:52	15.5062315	35.18784	11.00345	1.647174	8.883073	7.235898	2.656087	120.0512	0.66
537343.1	5480120	Site_8_Av_Mid_Depth_HW	27-JUL-11__12:52	15.5007507	35.1806	10.98369	1.644329	8.866797	7.222467	2.654248	119.989	

Table B- 4: Water Quality Field Survey Results – Mid Ebb

Eastings	Northings	Sample_Description	Date_Time_(GMT)	Temperature	Salinity	Ammon	Nitrite	TON	Nitrate	Orthophos	Silicate	Chlor
534539.9	5479150	Site_1_Av_Surface_ME	27-JUL-11__05:23	15.07	35.17	7.00	1.43	7.00	5.57	2.27	132.33	1.07
534539.9	5479150	Site_1__Av_Mid_depth_ME	27-JUL-11__05:23	15.77	35.17	8.67	1.41	7.20	5.79	2.03	132.00	
534607.5	5478955	Site_2_Av_Surface_ME	27-JUL-11__05:45	15.81	35.18	123.57	2.13	14.03	11.90	2.10	142.33	0.89
534607.5	5478955	Site_2_Av_Mid_depth_ME	27-JUL-11__05:45	15.78	35.18	7.20	1.43	7.00	5.57	2.10	131.67	
534839.3	5478285	Site_3_Av_Surface_ME	27-JUL-11__05:57	15.78	35.17	7.00	1.40	7.00	5.60	2.00	130.3	1.06
534839.3	5478285	Site_3_Av_Mid_depth_ME	27-JUL-11__05:57	15.50	35.18	7.10	1.45	7.00	5.55	2.23	121.2	
535179.2	5477302	Site_4_Av_Surface_ME	27-JUL-11__06:12	15.48	35.18	10.13	2.09	10.73	8.64	3.03	132.00	0.75
535179.2	5477302	Site_4_Av_Mid_depth_ME	27-JUL-11__06:12	15.48	35.18	9.43	1.67	9.73	8.07	2.37	113.00	
535510.5	5476345	Site_5_Av_Surface_ME	27-JUL-11__06:24	15.45	35.18	8.03	1.53	8.00	6.47	2.20	100.93	0.80
535510.5	5476345	Site_5_Av_Mid_depth_ME	27-JUL-11__06:24	15.45	35.18	9.20	1.72	8.64	6.92	3.04	111.70	
535405.3	5479449	Site_6_Av_Surface_ME	27-JUL-11__07:06	15.68	35.01	177.33	3.10	7.97	4.87	19.83	187.7	0.97
535405.3	5479449	Site_6_Av_Mid_depth_ME	27-JUL-11__07:06	15.57	35.17	12.20	1.84	8.17	6.32	3.30	125.7	
536385.2	5479788	Site_7_Av_Surface_ME	27-JUL-11__06:54	15.52	35.18	11.23	1.79	8.97	7.18	2.25	113.00	0.88
536385.2	5479788	Site_7_Av_Mid_depth_ME	27-JUL-11__06:54	15.46	35.18	10.60	1.27	7.73	6.47	2.01	90.40	
537343.1	5480120	Site_8_Av_Surface_ME	27-JUL-11__06:42	15.46	35.18	22.97	1.63	9.50	7.87	2.00	109.07	0.85
537343.1	5480120	Site_8_Av_Mid_depth_ME	27-JUL-11__06:42	15.46	35.18	14.13	1.83	9.60	7.77	2.43	116.53	

Appendix C Zone A Model Results

FIGURES

Figure C- 1: Time series plot of calculated Suspended Solids concentrations close to Belle Greve outfall

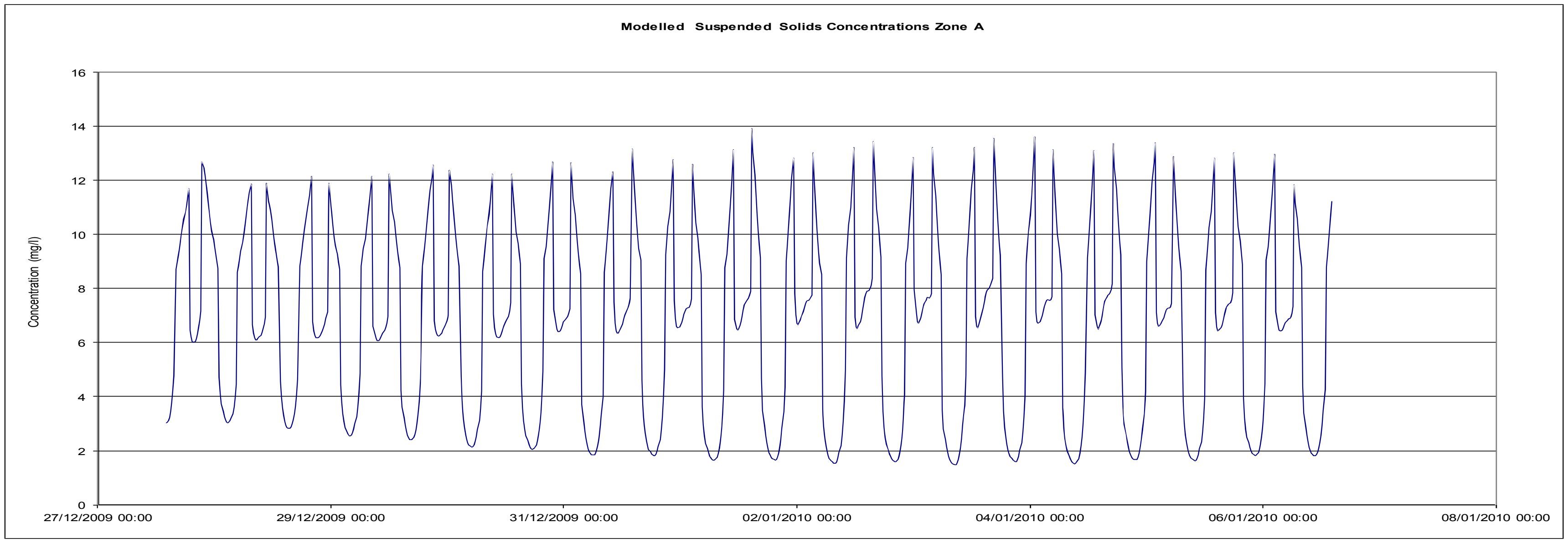


Figure C- 2: Time series plot of calculated BOD concentrations close to Belle Greve outfall

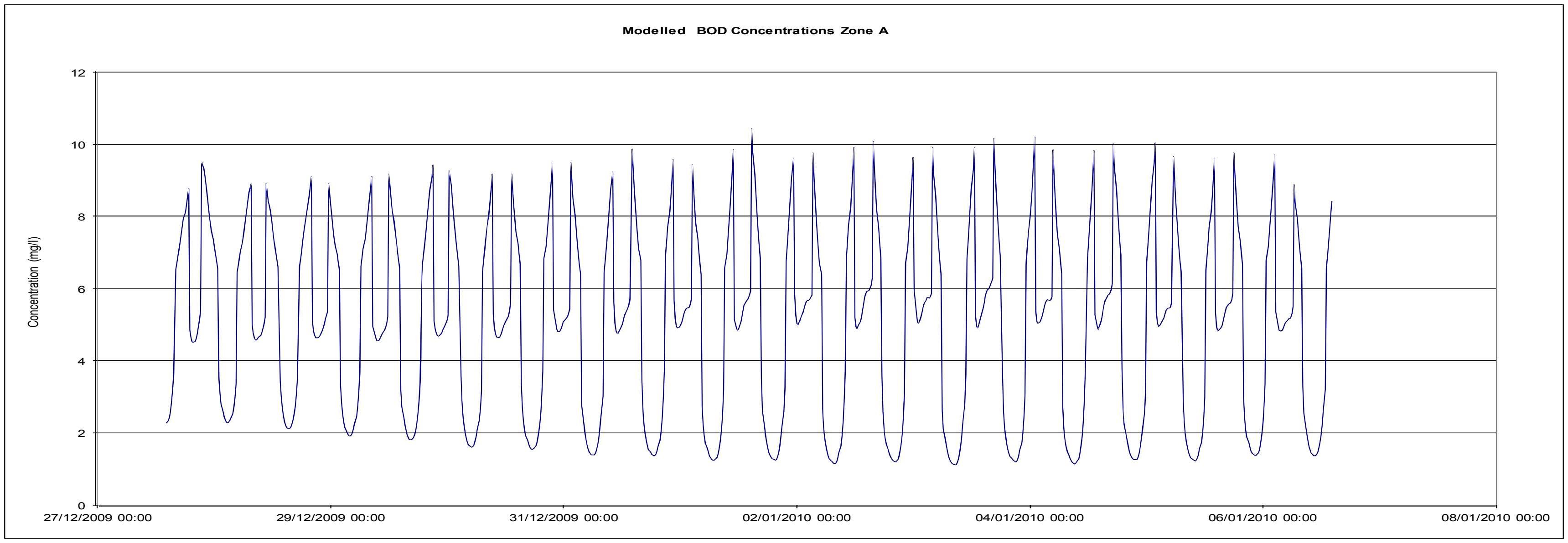


Figure C- 3: Time series plot of calculated Ammonia concentrations close to Belle Greve outfall

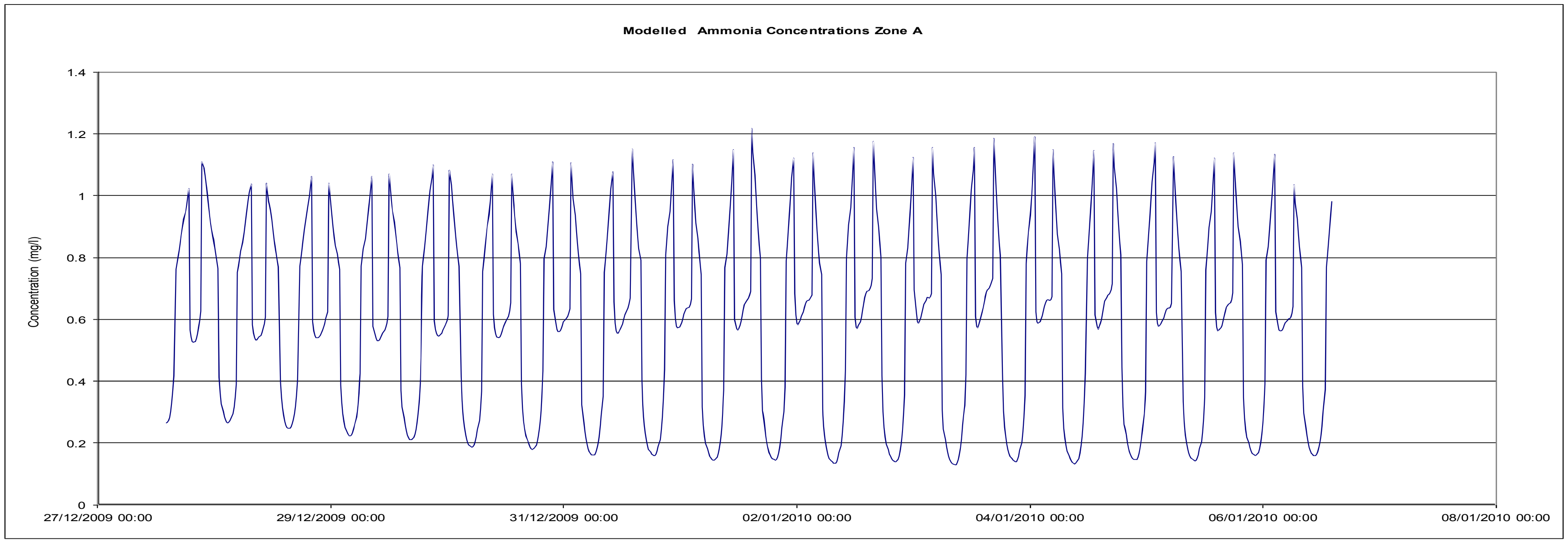


Figure C- 4: Time series plot of calculated Suspended Solids concentrations close to Belle Greve outfall

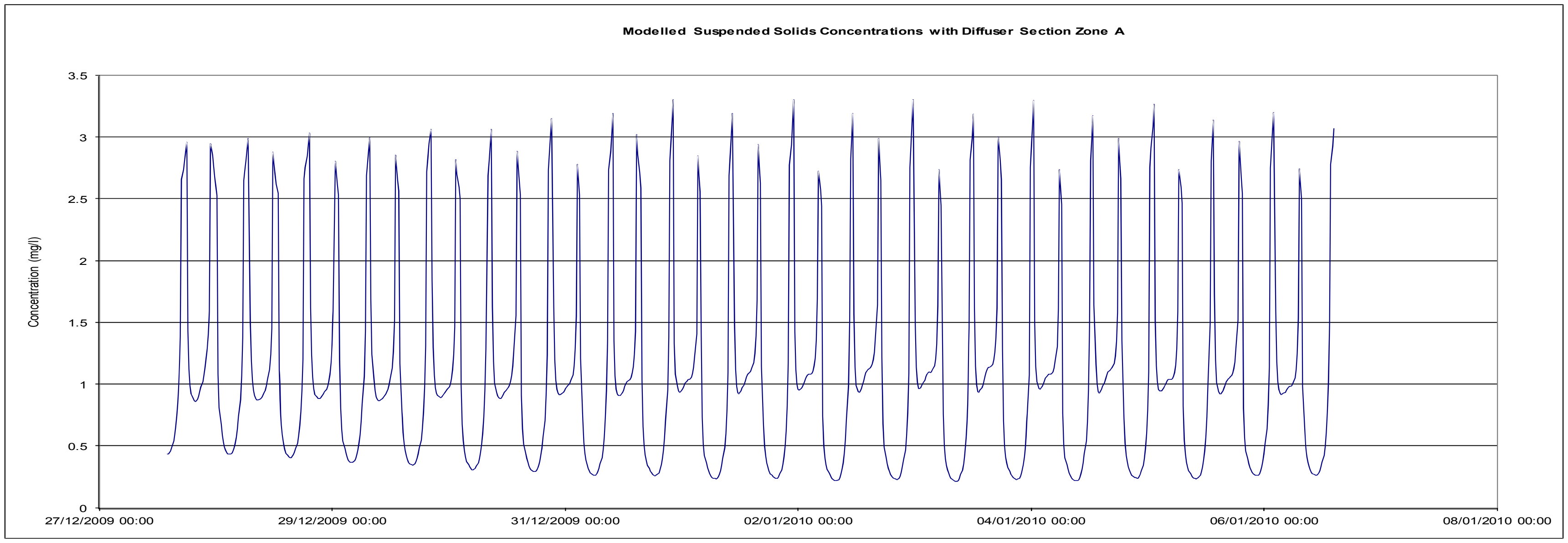


Figure C- 5: Time series plot of calculated BOD concentrations close to Belle Greve outfall

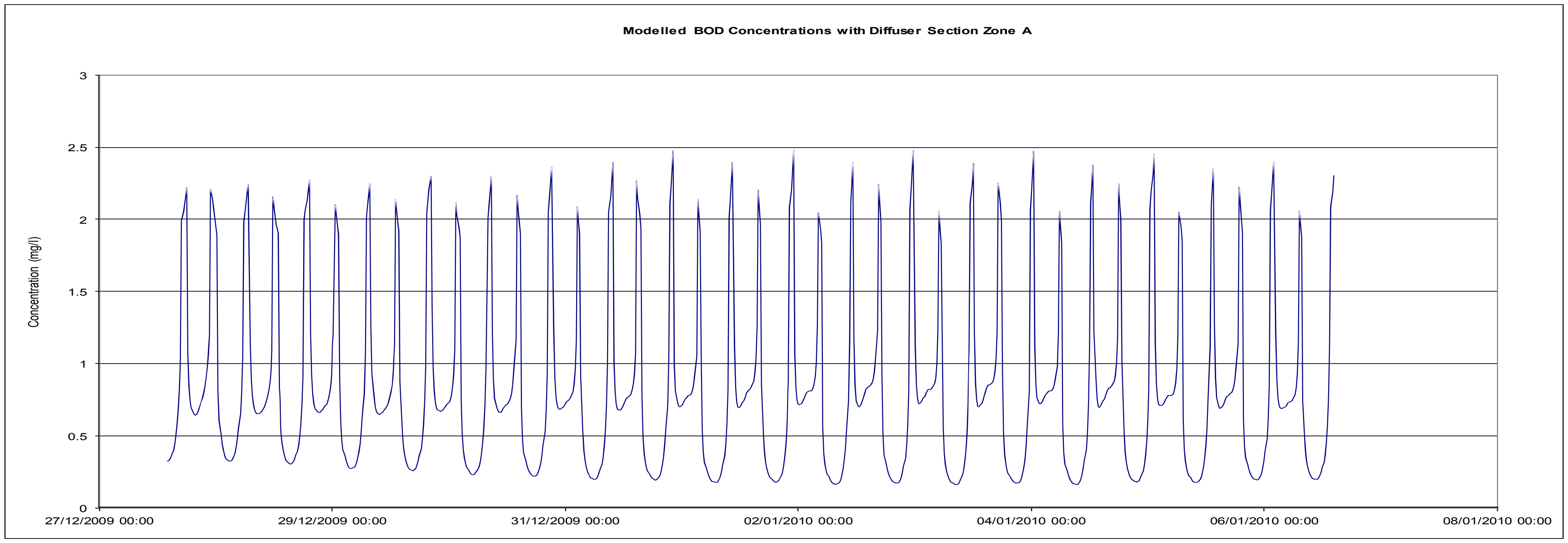
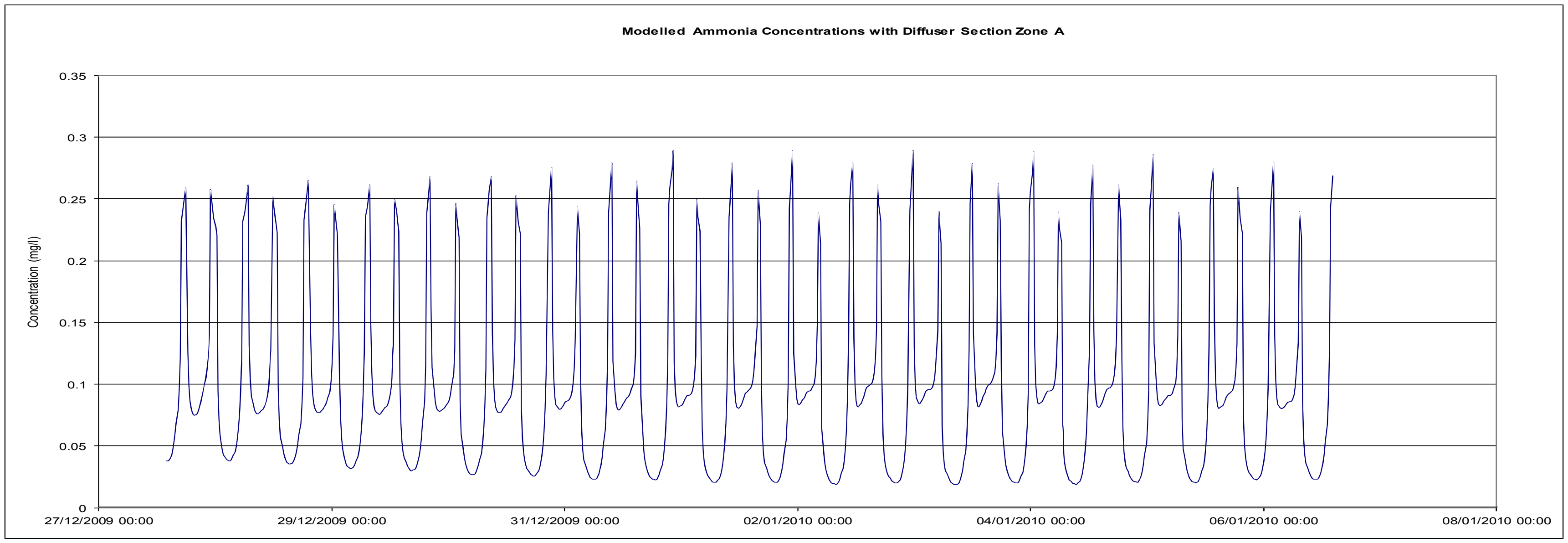


Figure C- 6: Time series plot of calculated ammonia concentrations close to Belle Greve outfall



Appendix D Brief Overview of the Model Calibration and Validation

FIGURES

Figure D- 1: Measured and Modelled Tidal Elevations Site H1.

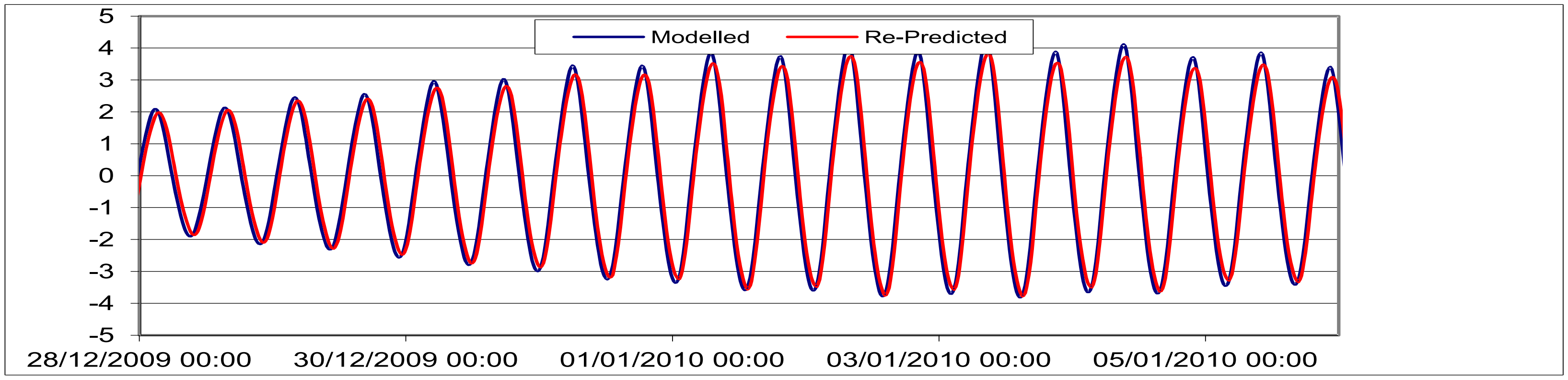


Figure D- 2: Measured and Modelled Tidal Elevations Site H2.

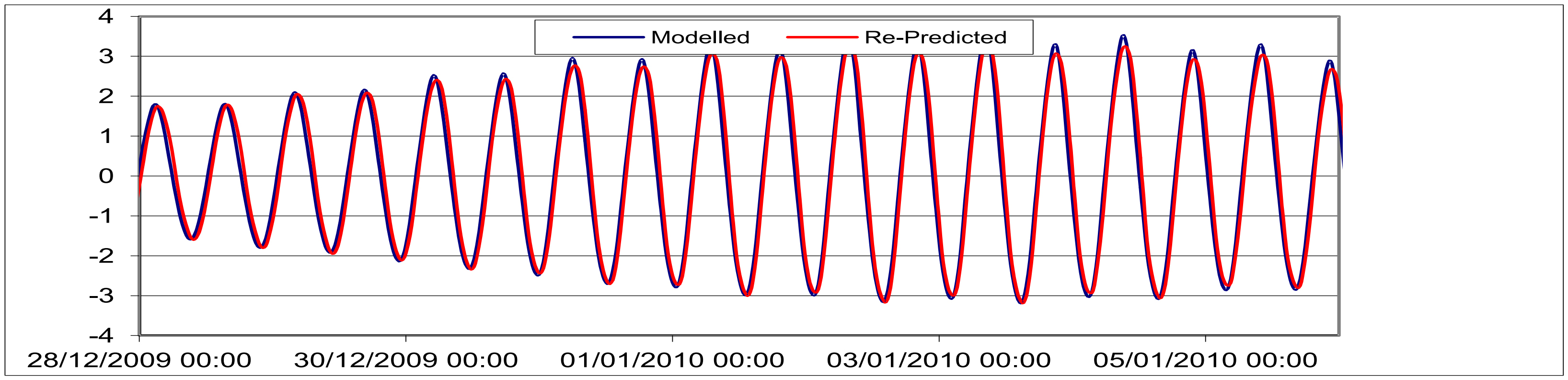


Figure D- 3: Measured and Modelled Tidal Elevations Site H3.

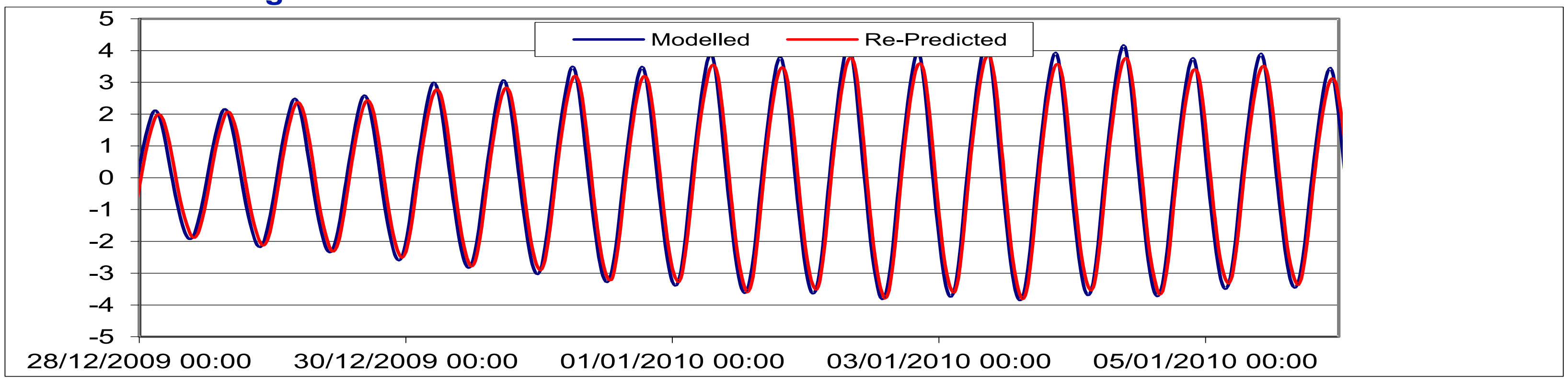


Figure D- 4: Measured and Modelled Current Speeds Site H1

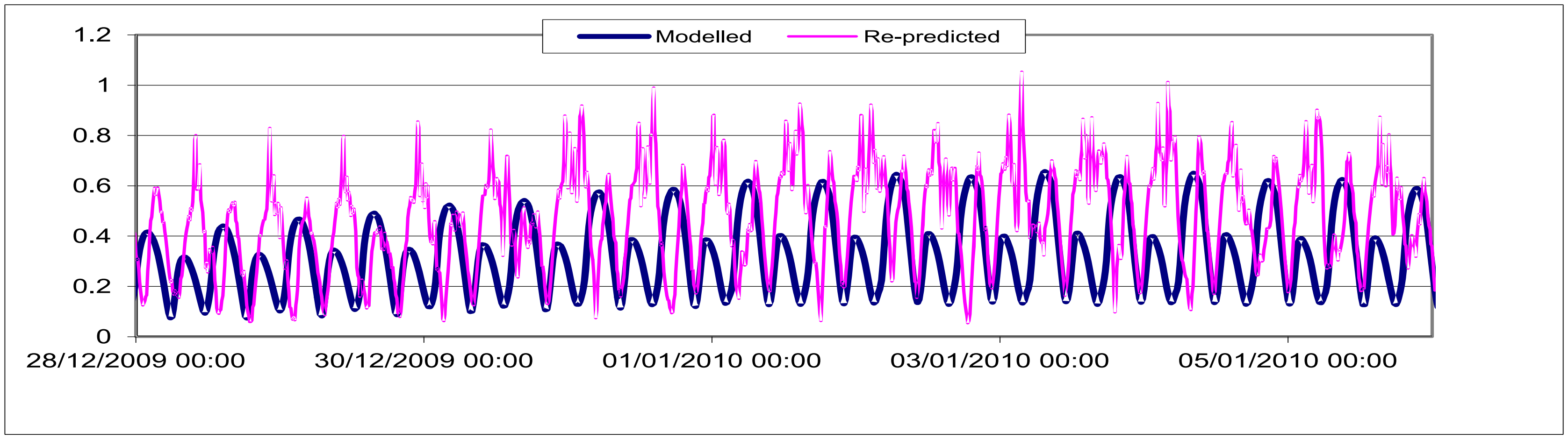


Figure D- 5: Measured and Modelled Current Speeds Site H2.

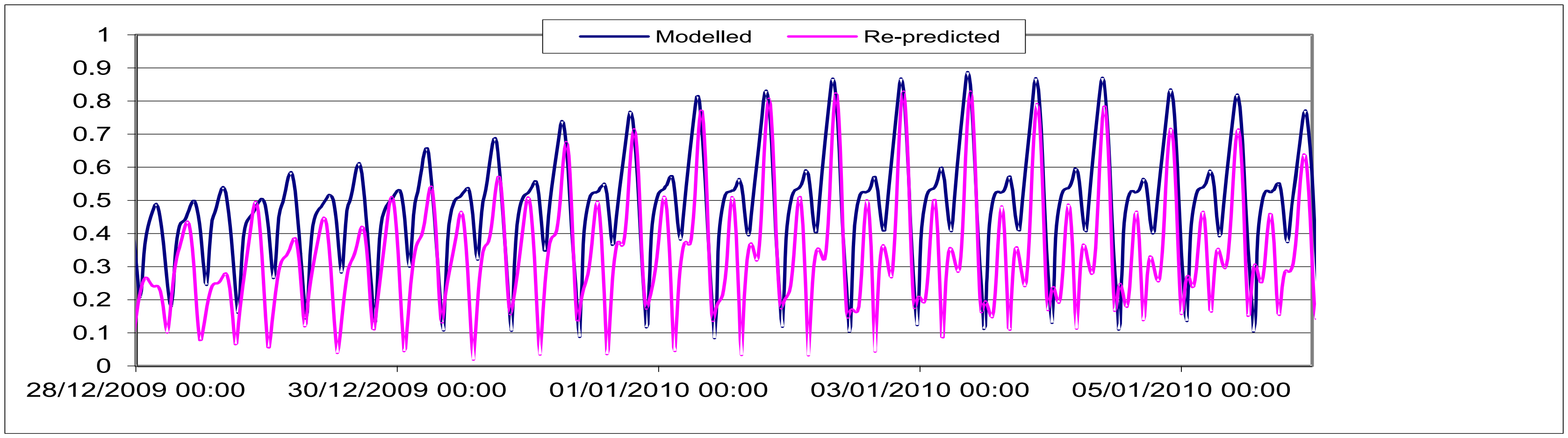


Figure D- 6: Measured and Modelled Current Speeds Site H3.

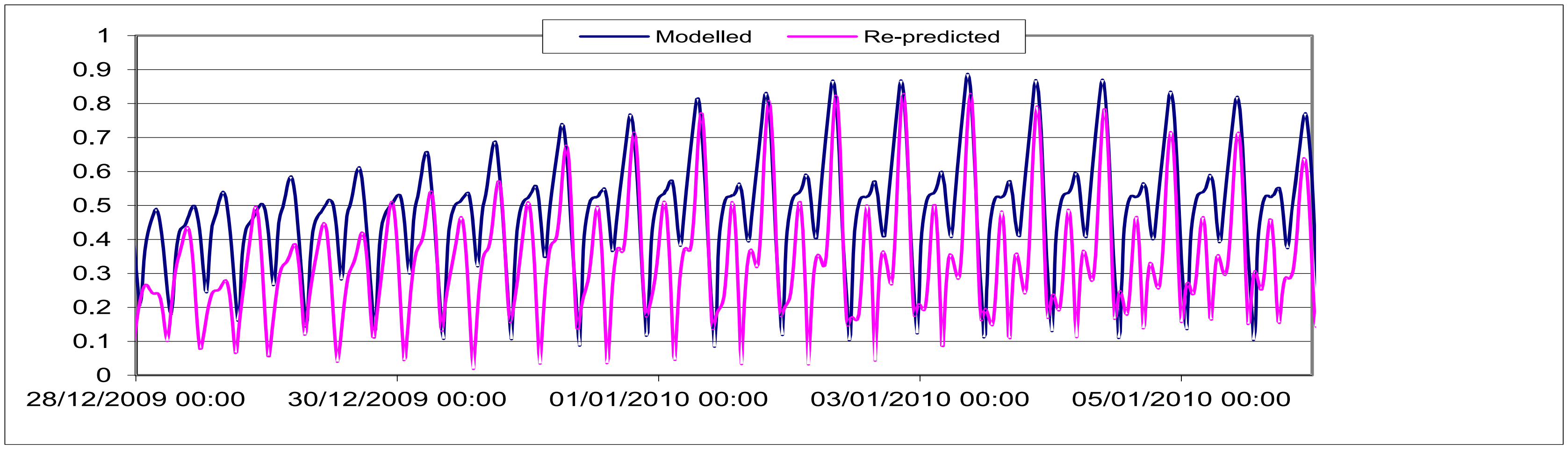


Figure D- 7: Measured and Modelled Current Directions Site H1.

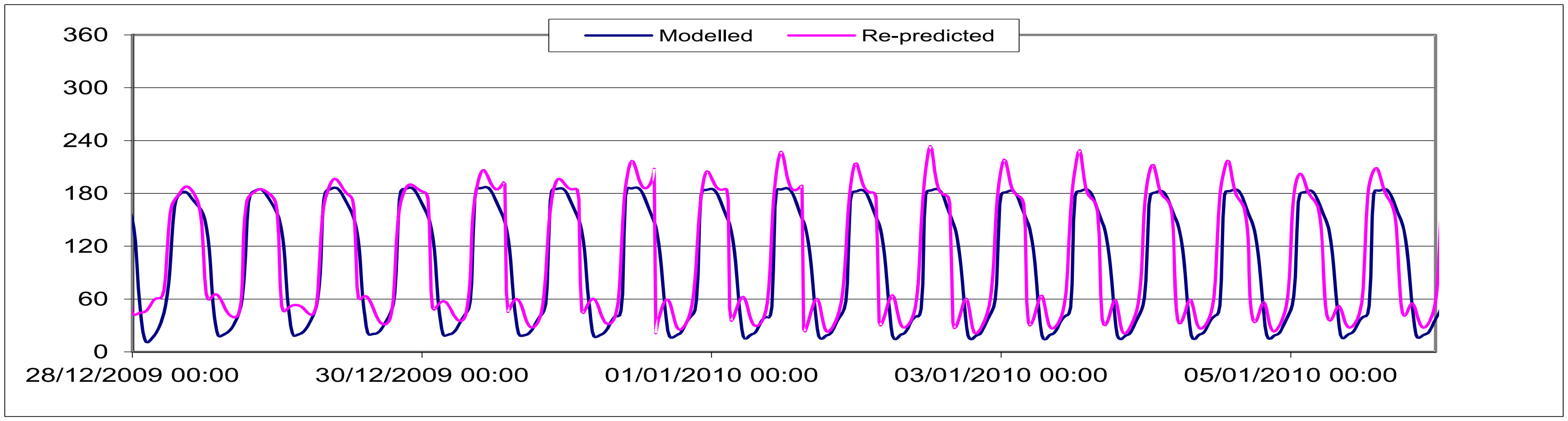


Figure D- 8: Measured and Modelled Current Directions Site H2

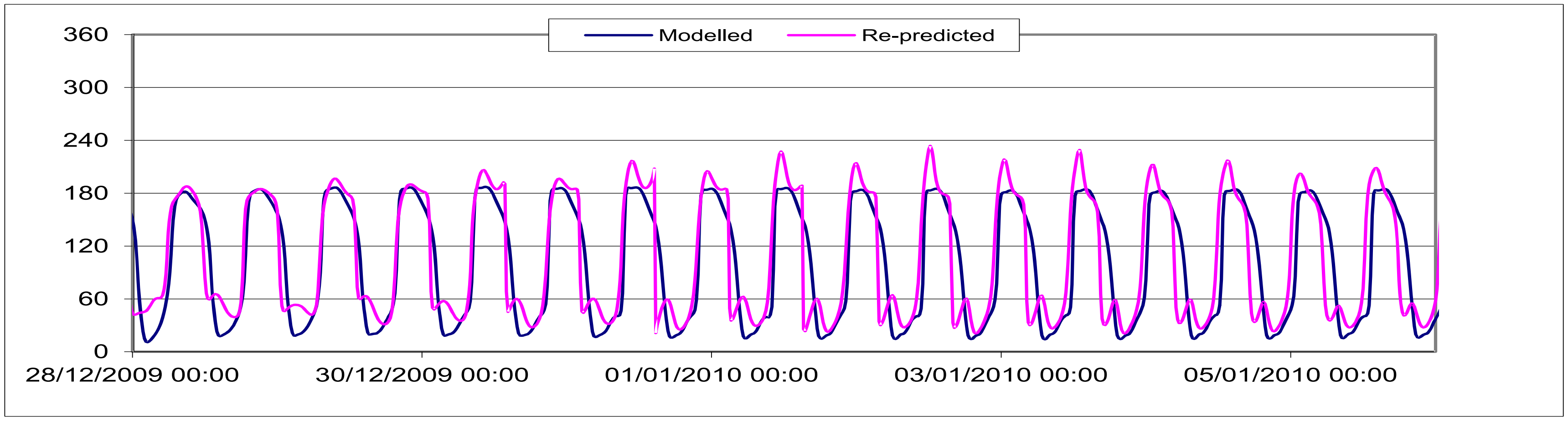
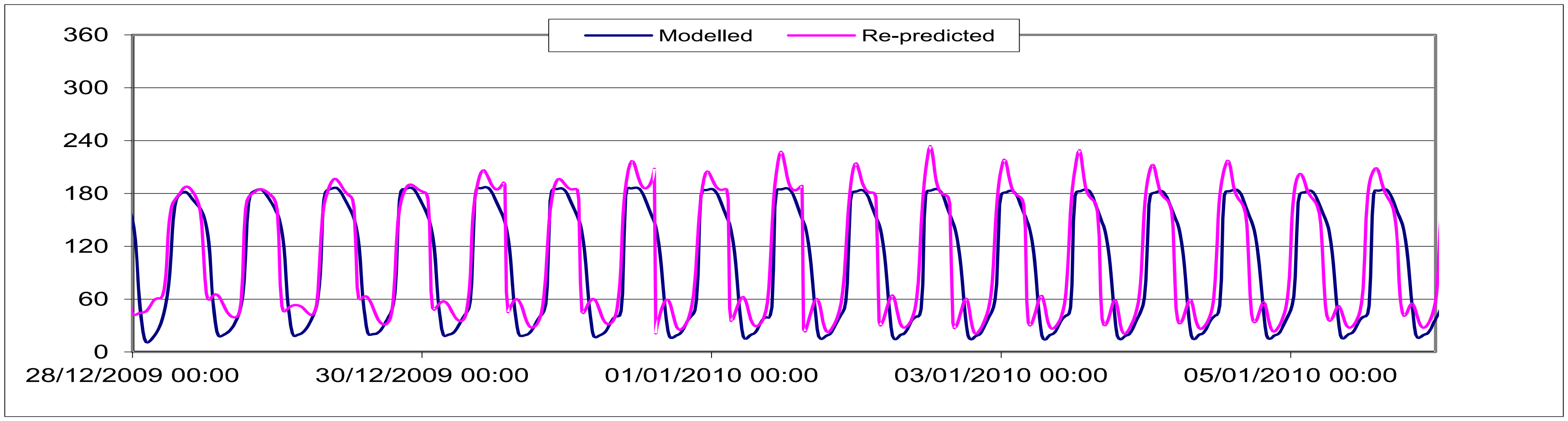


Figure D- 9: Measured and Modelled Current Directions Site H3



Appendix E Nutrient Modelling Results

FIGURES

Figure E- 1: Maximum Modelled DAIN Concentrations

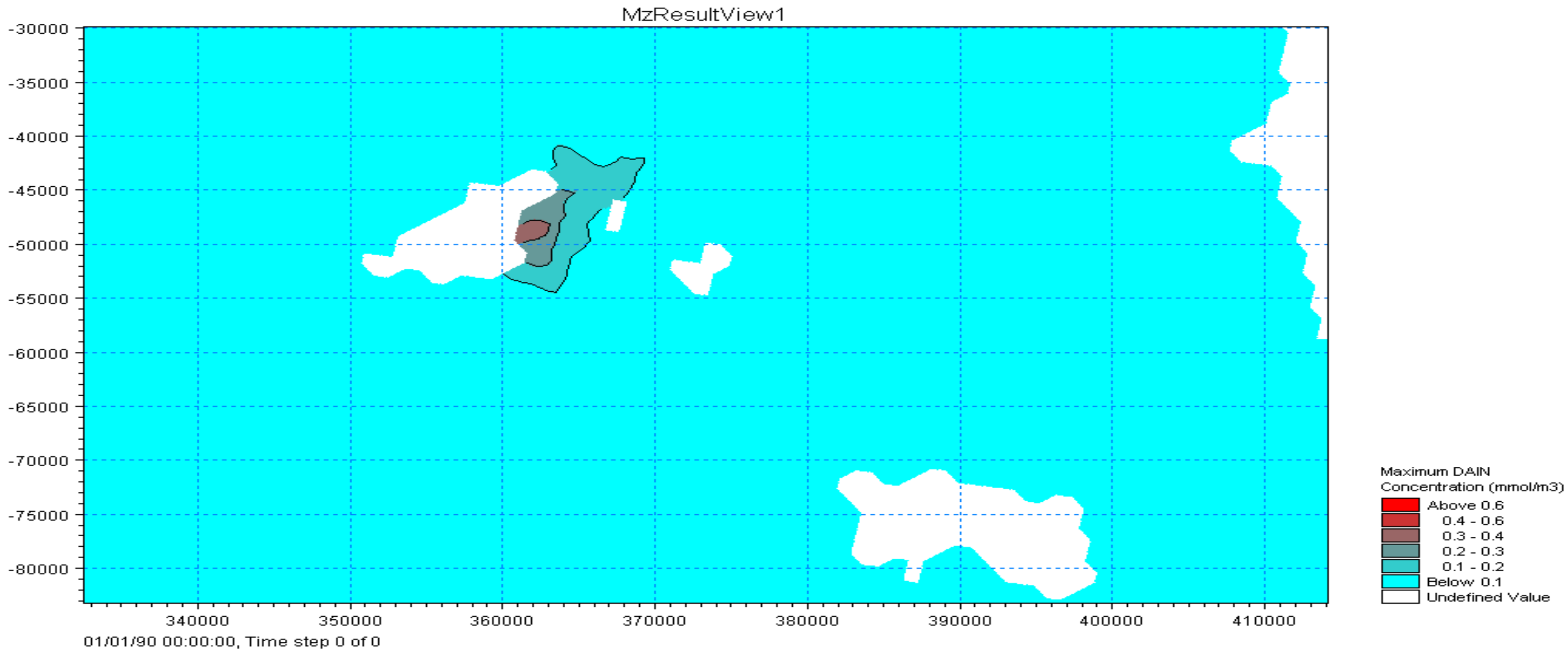
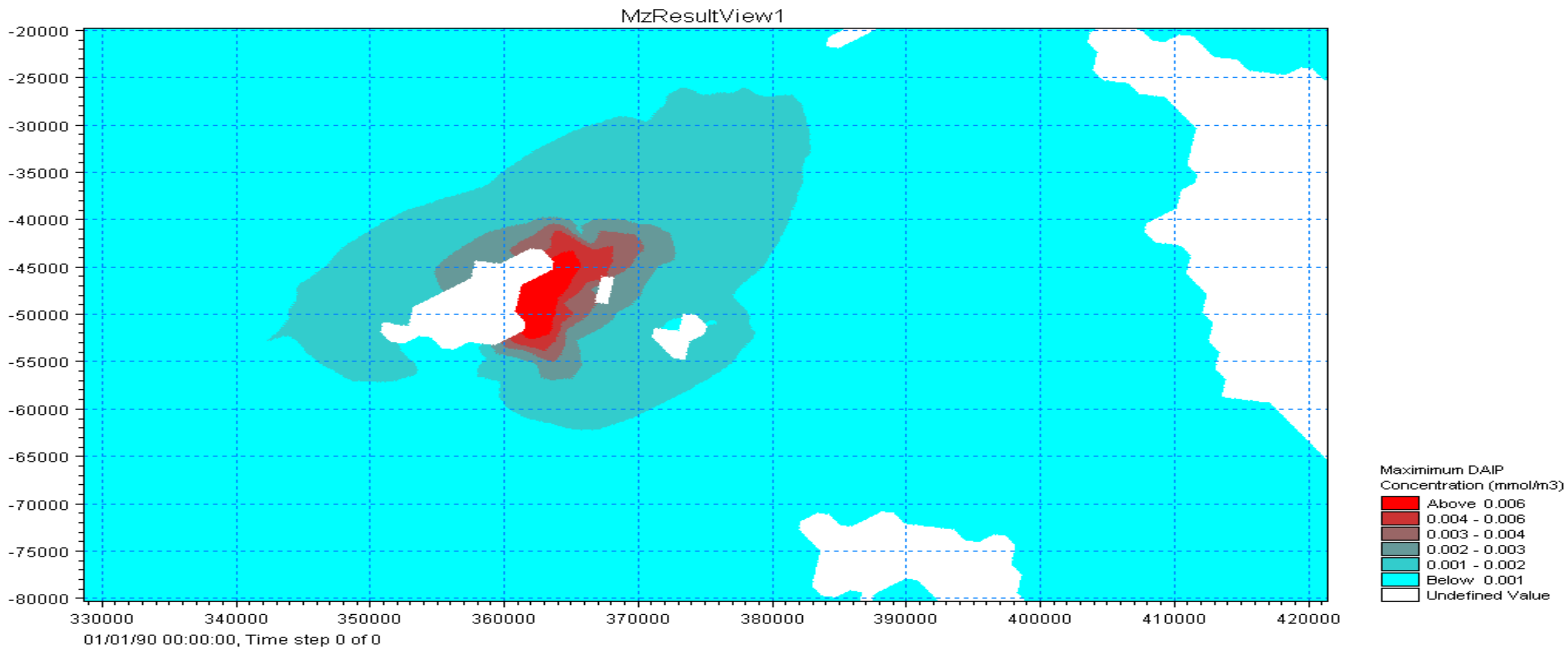


Figure E- 2: Maximum Modelled DAIP Concentrations



Appendix F Modelled Bacterial Concentrations Resulting from Belle Greve Outfall

FIGURES

Figure F- 1: Time Series Plot Faecal Coliforms Resulting from Belle Greve Outfall – Calm Conditions

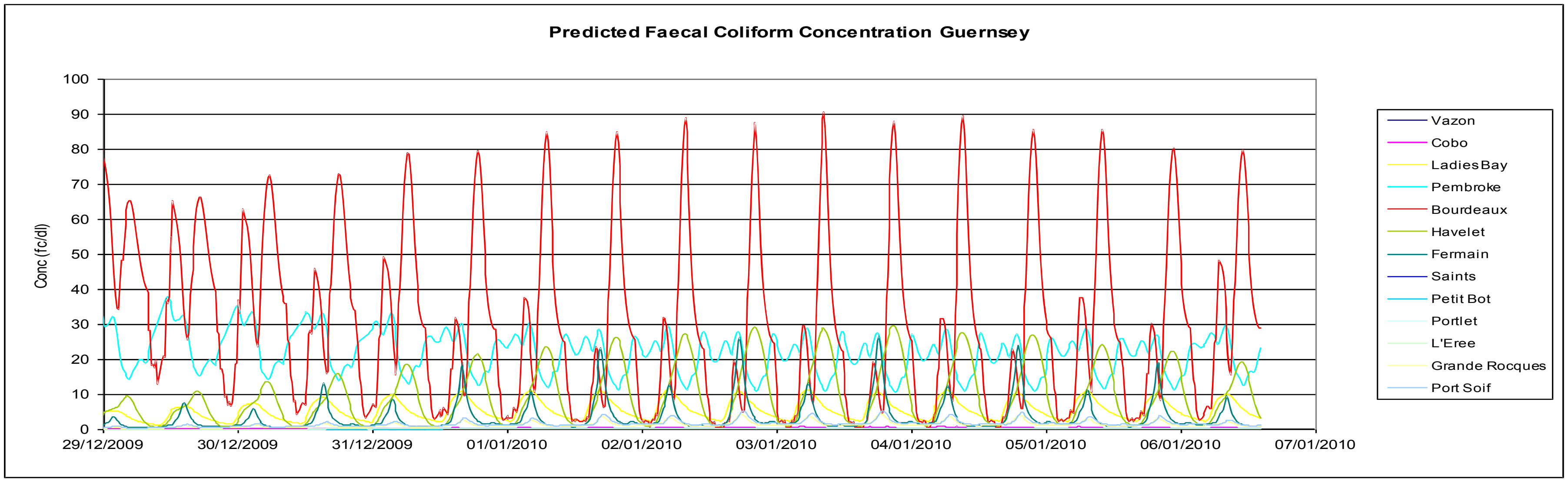


Figure F- 2: Time Series Plot Faecal Coliforms Resulting from Belle Greve Outfall – Wind Conditions 5m/s from North

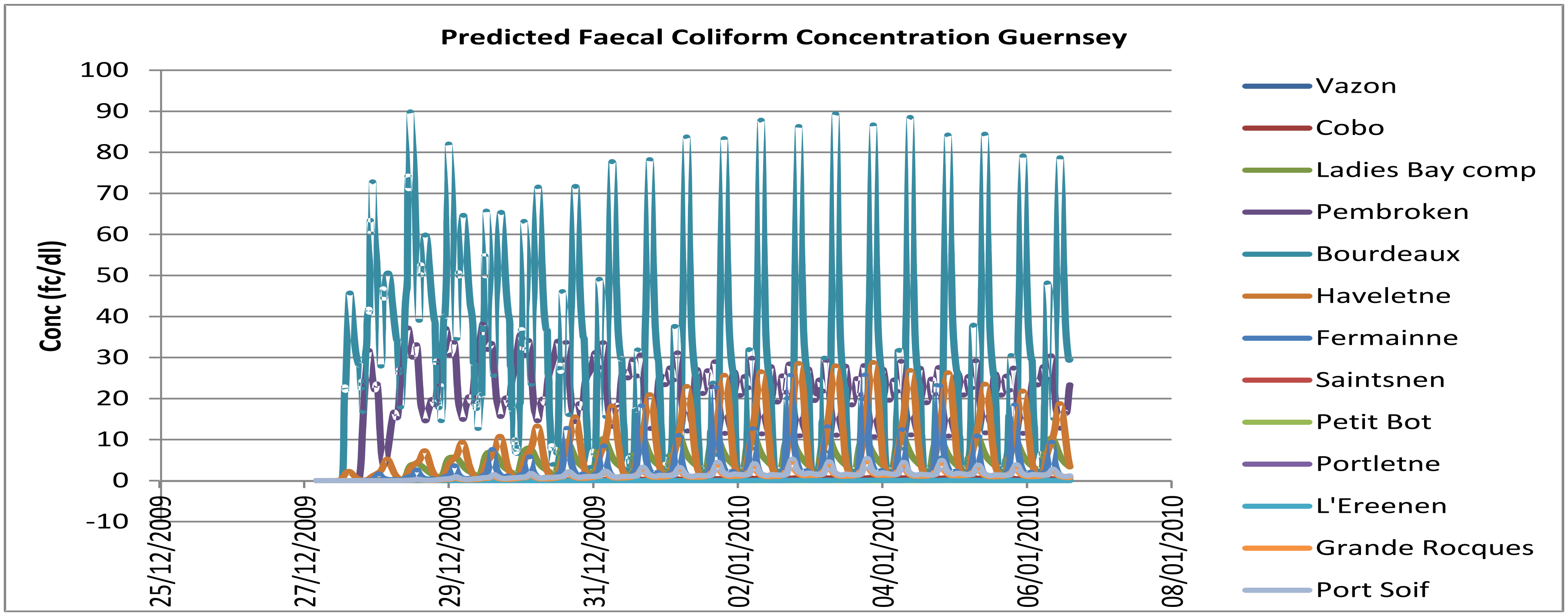


Figure F- 3: Time Series Plot Faecal Coliforms Resulting from Belle Greve Outfall – Wind Conditions 5m/s from North East

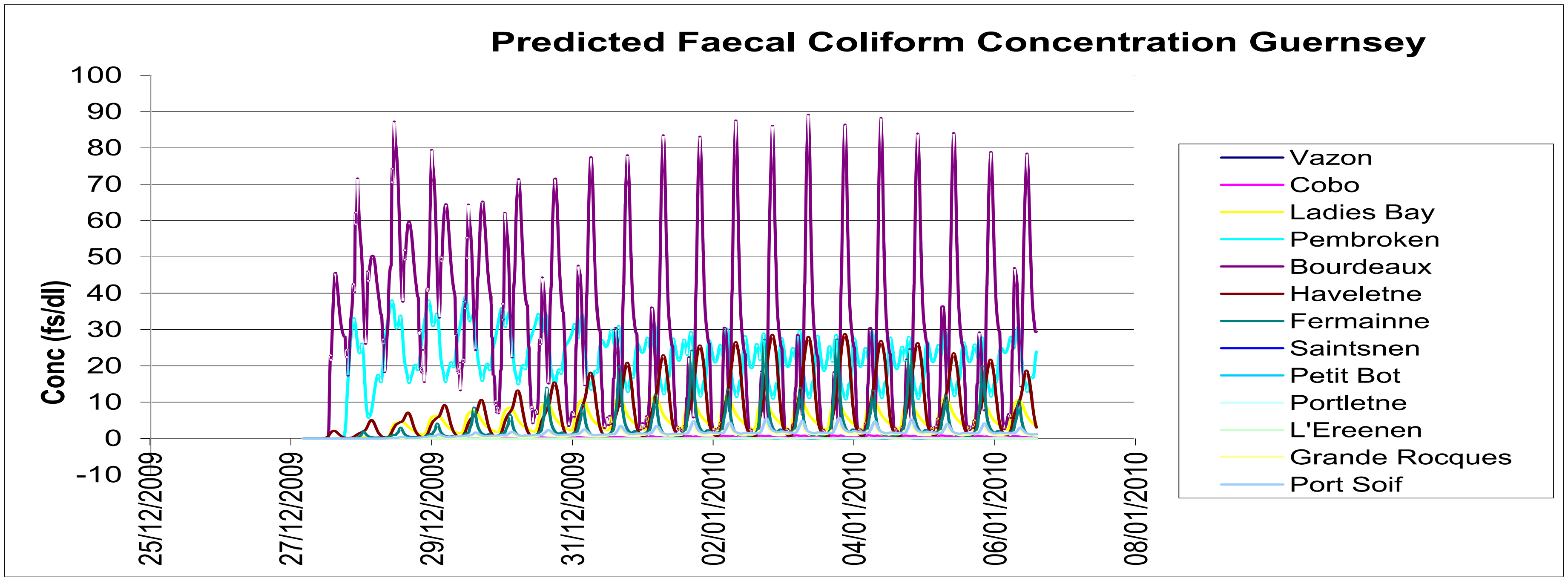


Figure F- 4: Time Series Plot Faecal Coliforms Resulting from Belle Greve Outfall – Wind Conditions 5m/s from South East

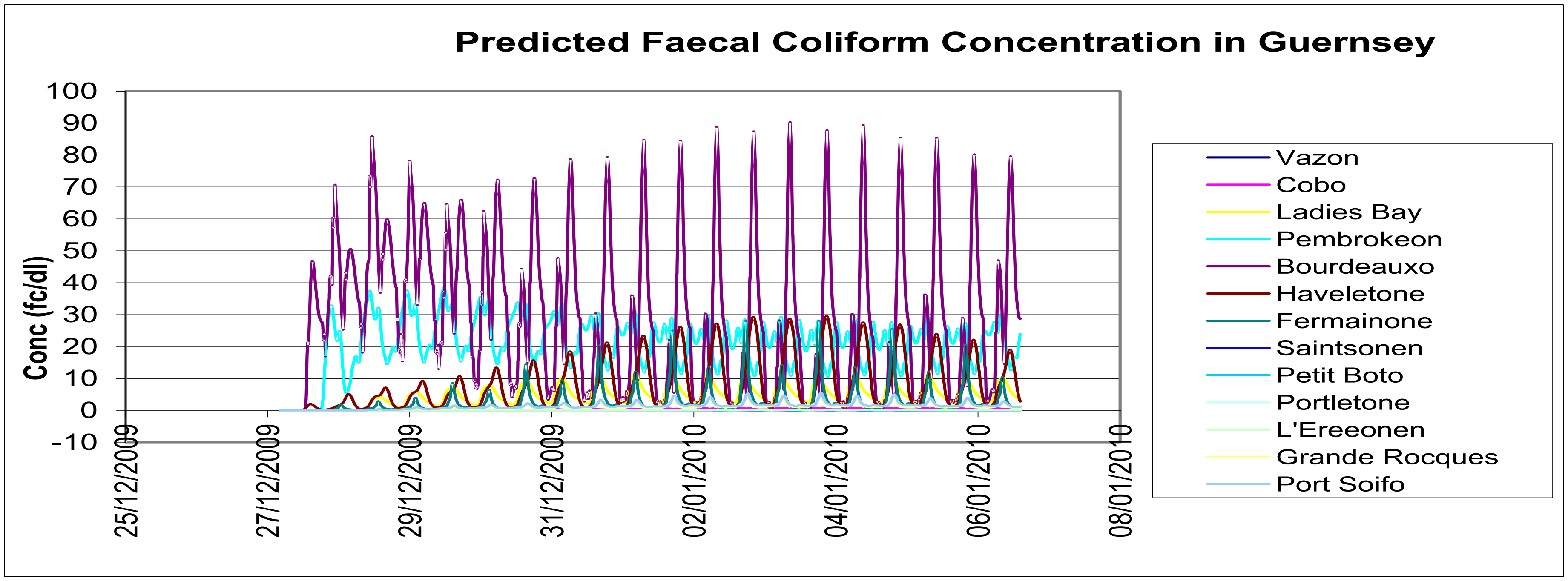


Figure F- 5: Time Series Plot Faecal Coliforms Resulting from Belle Greve Outfall – Wind Conditions 5m/s from South

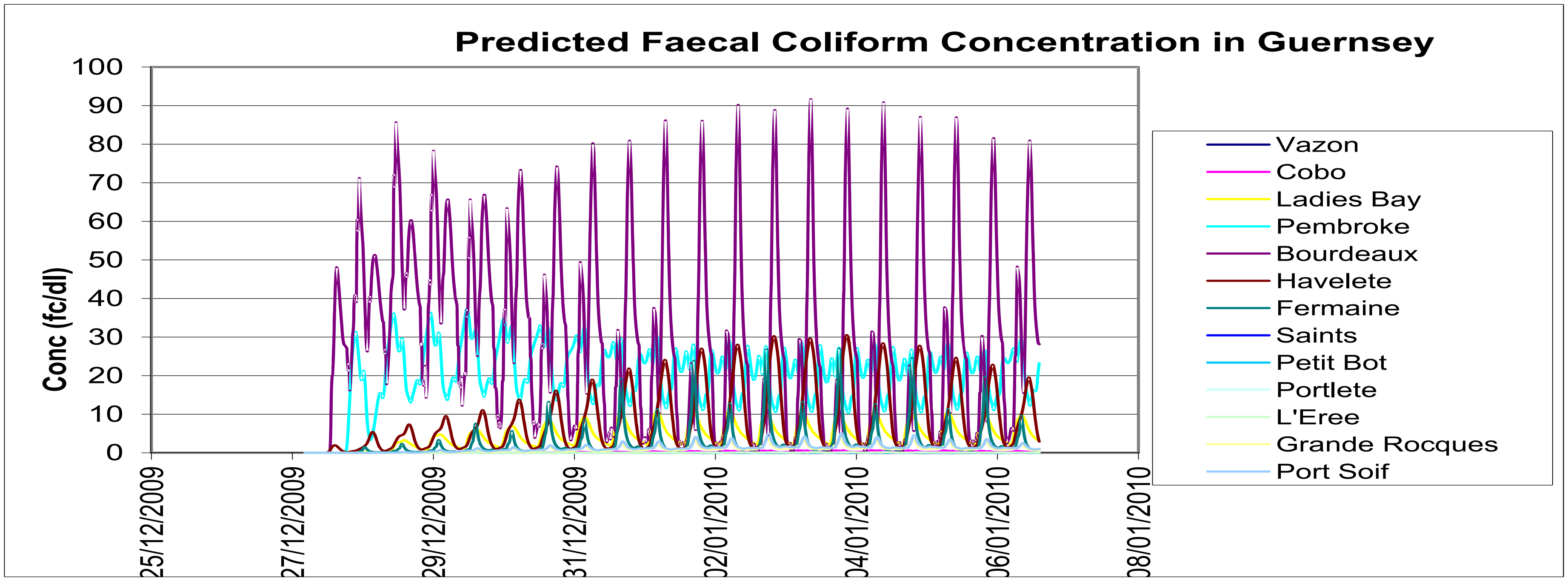


Figure F- 6: Time Series Plot Faecal Coliforms Resulting from Belle Greve Outfall – Wind Conditions 5m/s from South West

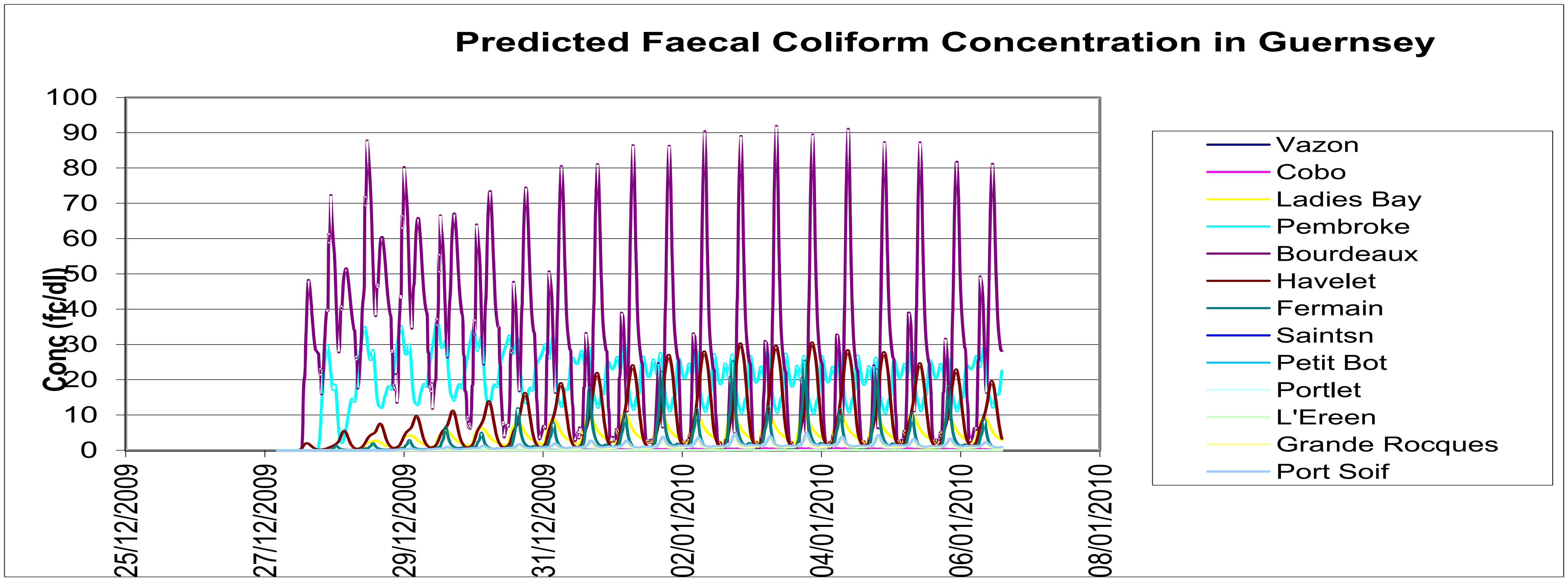


Figure F- 7: Time Series Plot Faecal Coliforms Resulting from Belle Greve Outfall – Wind Conditions 5m/s from North West

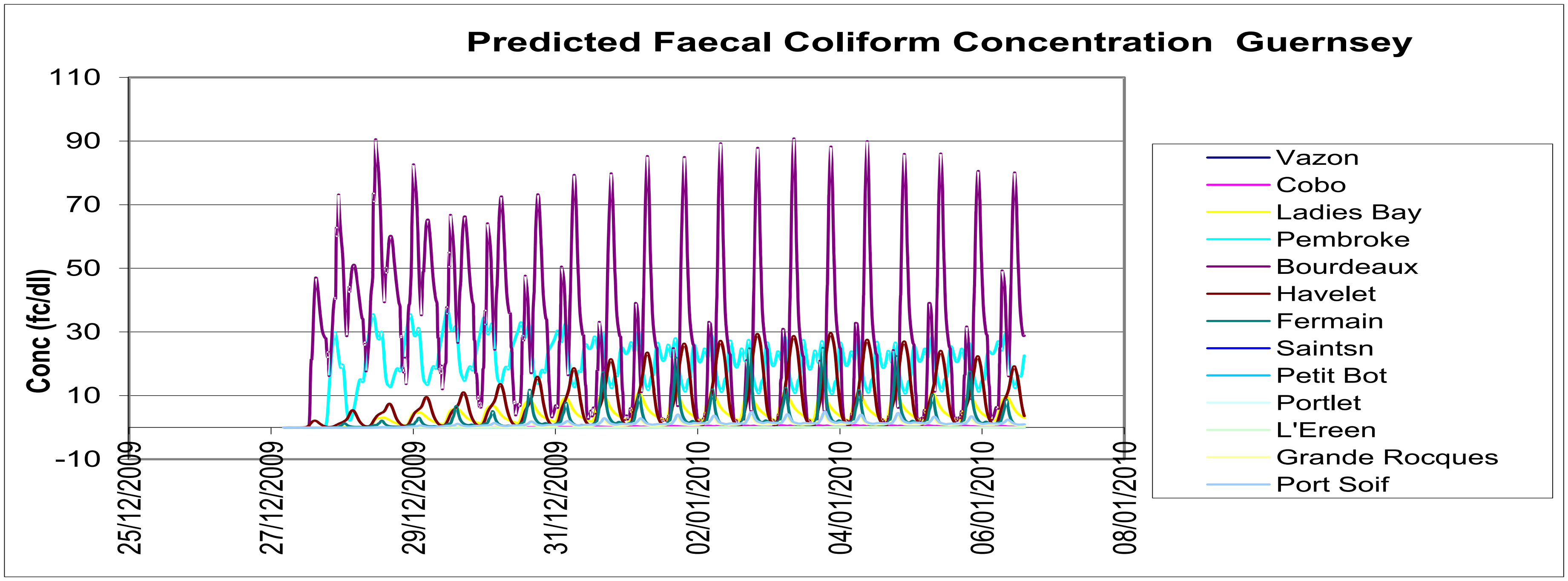


Figure F- 8: Maximum Concentration Plot Faecal Coliforms Resulting from Belle Greve Outfall – Calm Conditions

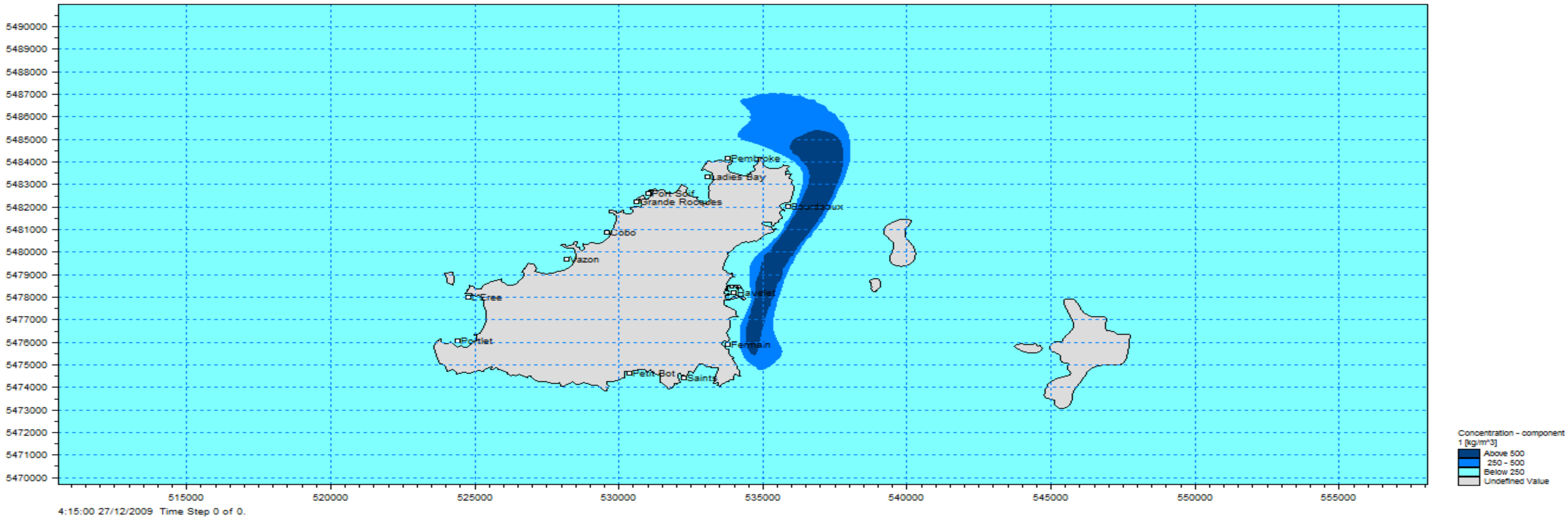


Figure F- 9: Time Series Plot Faecal Streptococci Resulting from Belle Greve Outfall – Calm Conditions

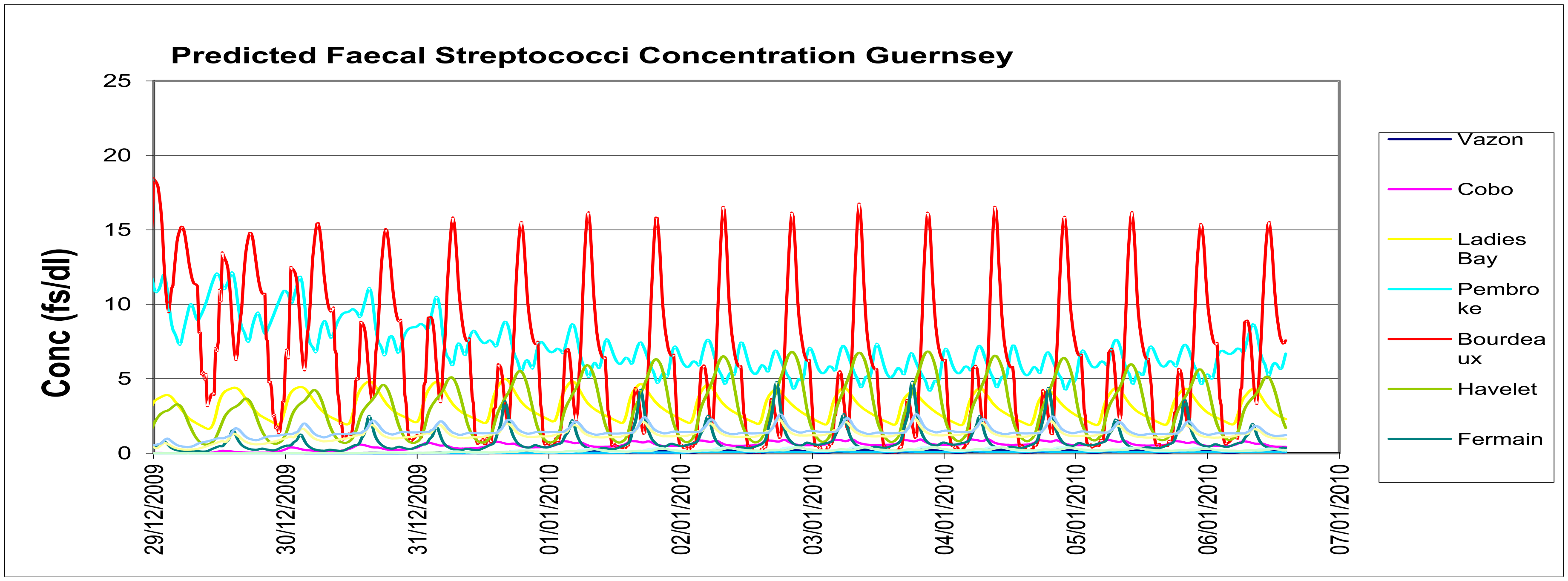


Figure F- 10: Time Series Plot Faecal Streptococci Resulting from Belle Greve Outfall – Wind Conditions 5m/s from North

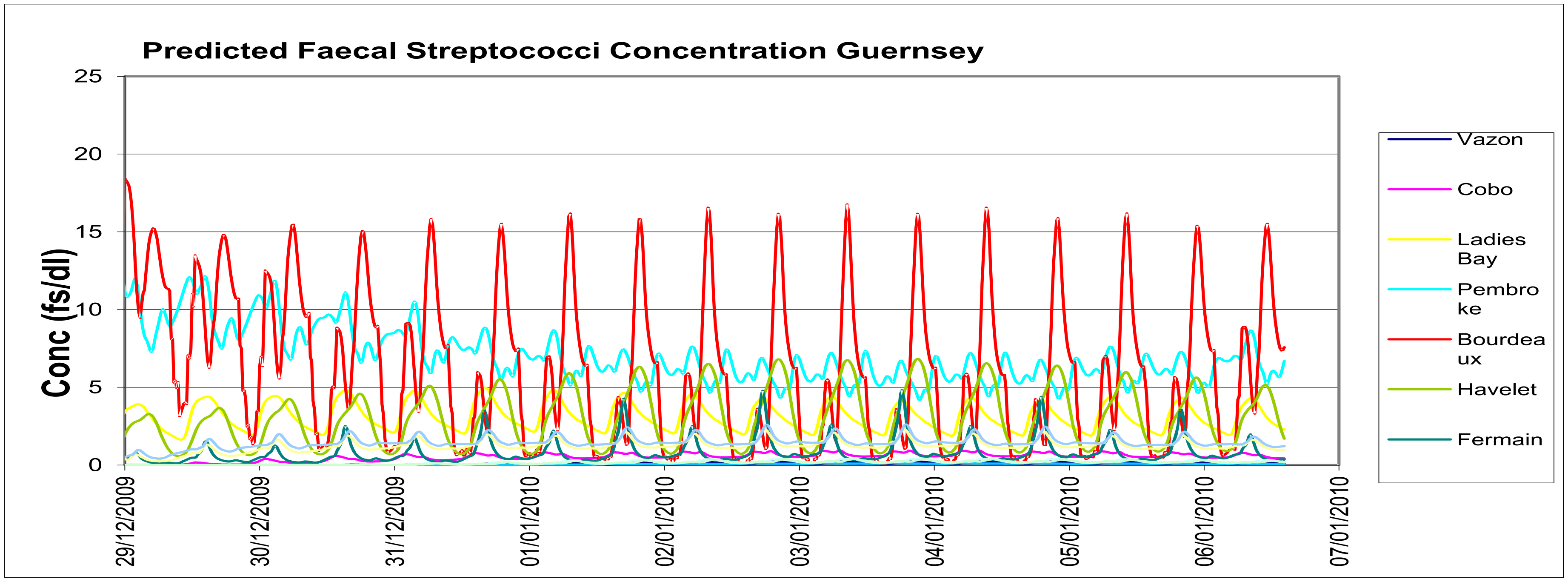


Figure F- 11: Time Series Plot Faecal Streptococci Resulting from Belle Greve Outfall – Wind Conditions 5m/s from North East

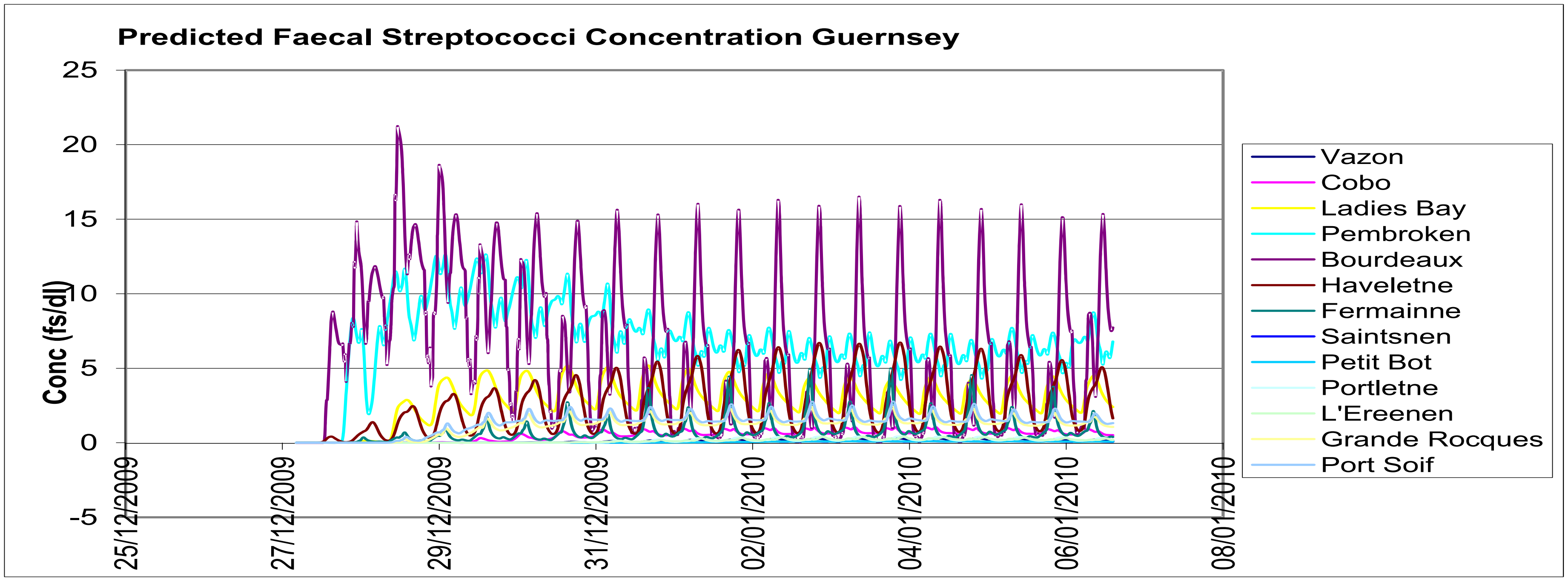


Figure F- 12: Time Series Plot Faecal Streptococci Resulting from Belle Greve Outfall – Wind Conditions 5m/s from South East

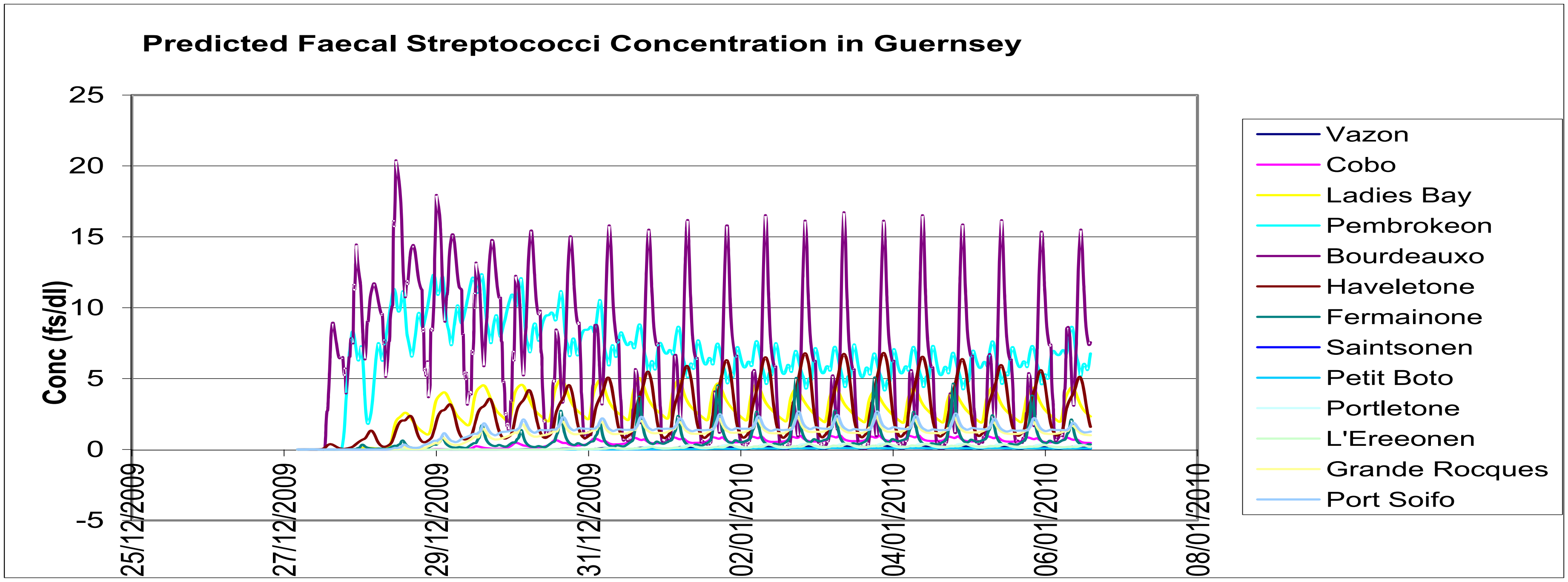


Figure F- 13: Time Series Plot Faecal Streptococci Resulting from Belle Greve Outfall – Wind Conditions 5m/s from South

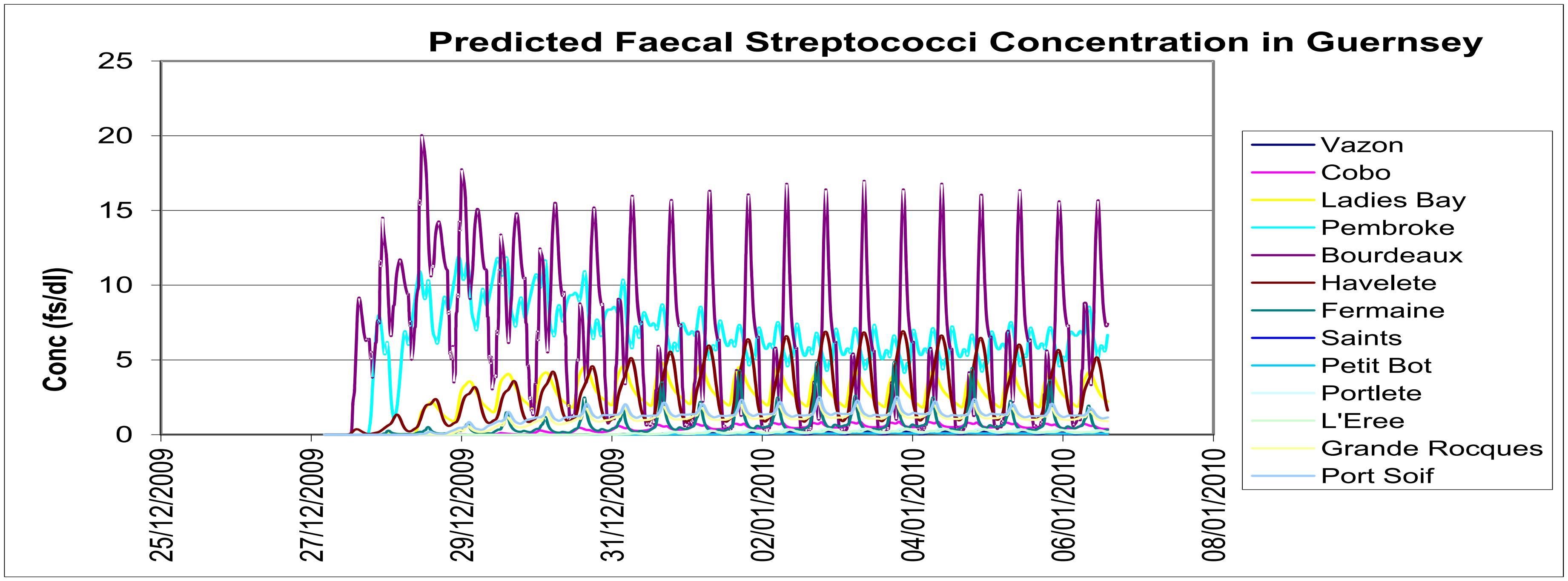


Figure F- 14: Time Series Plot Faecal Streptococci Resulting from Belle Greve Outfall – Wind Conditions 5m/s from South West

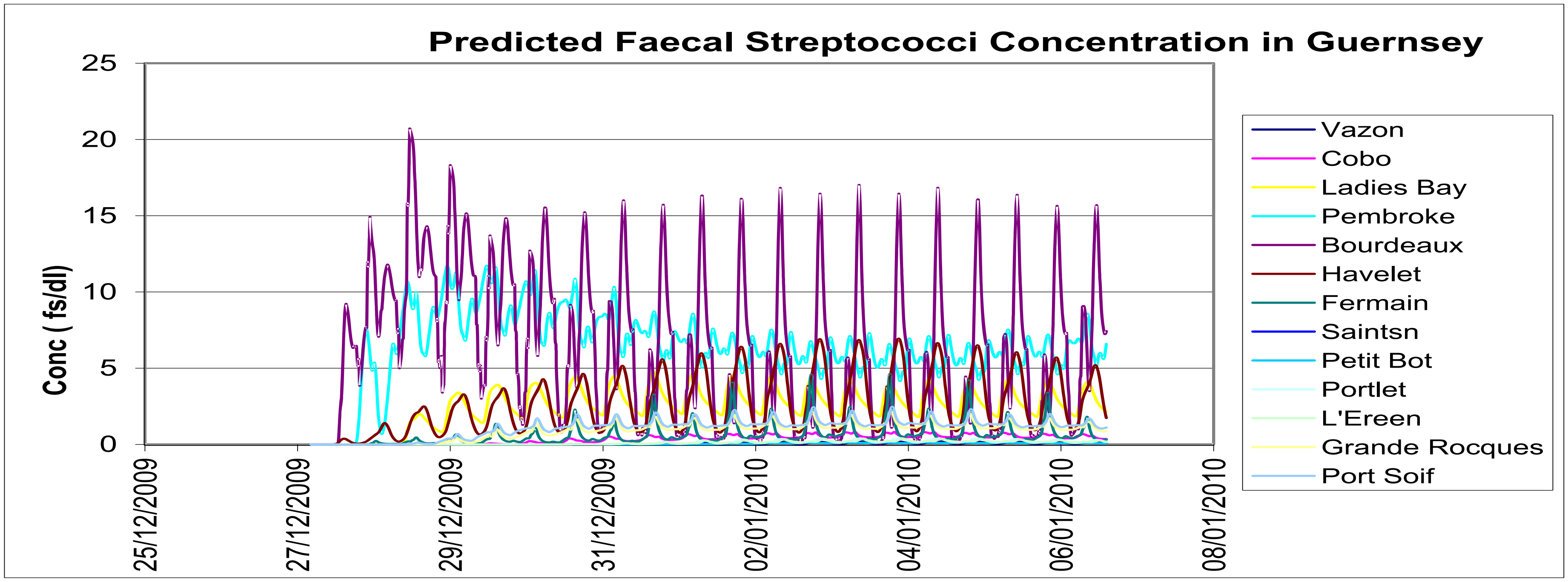


Figure F- 15: Time Series Plot Faecal Streptococci Resulting from Belle Greve Outfall – Wind Conditions 5m/s from North West

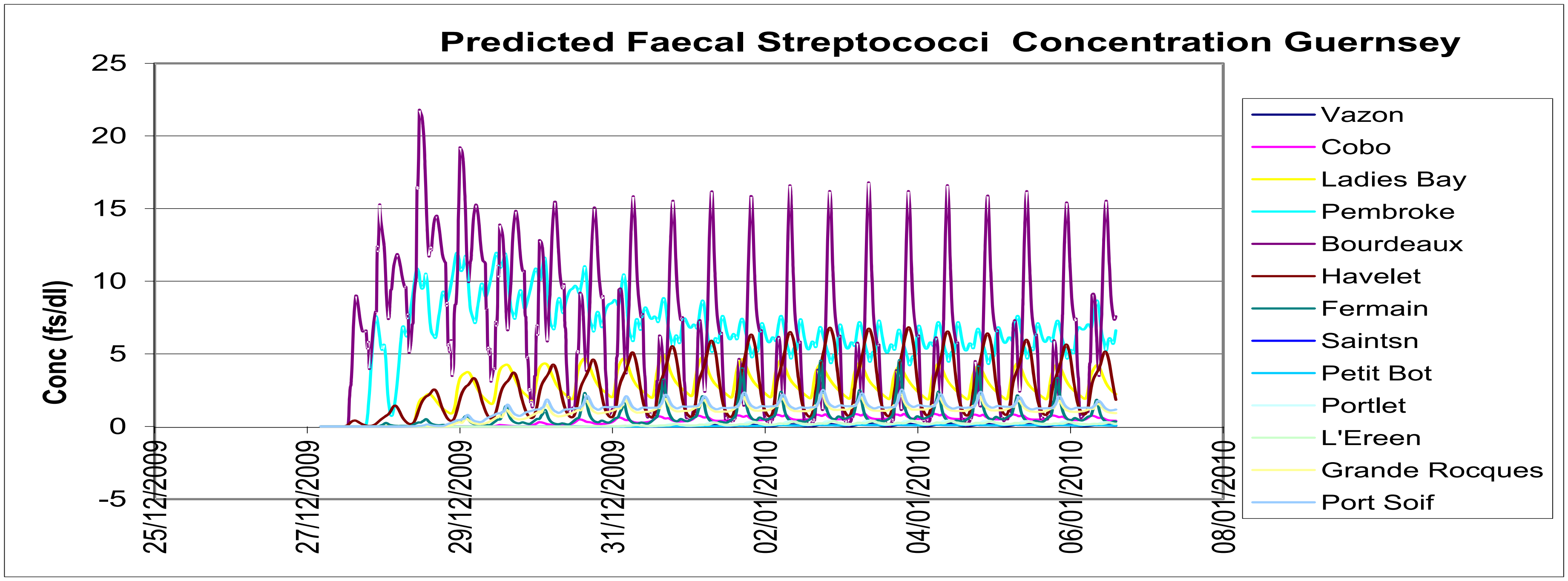
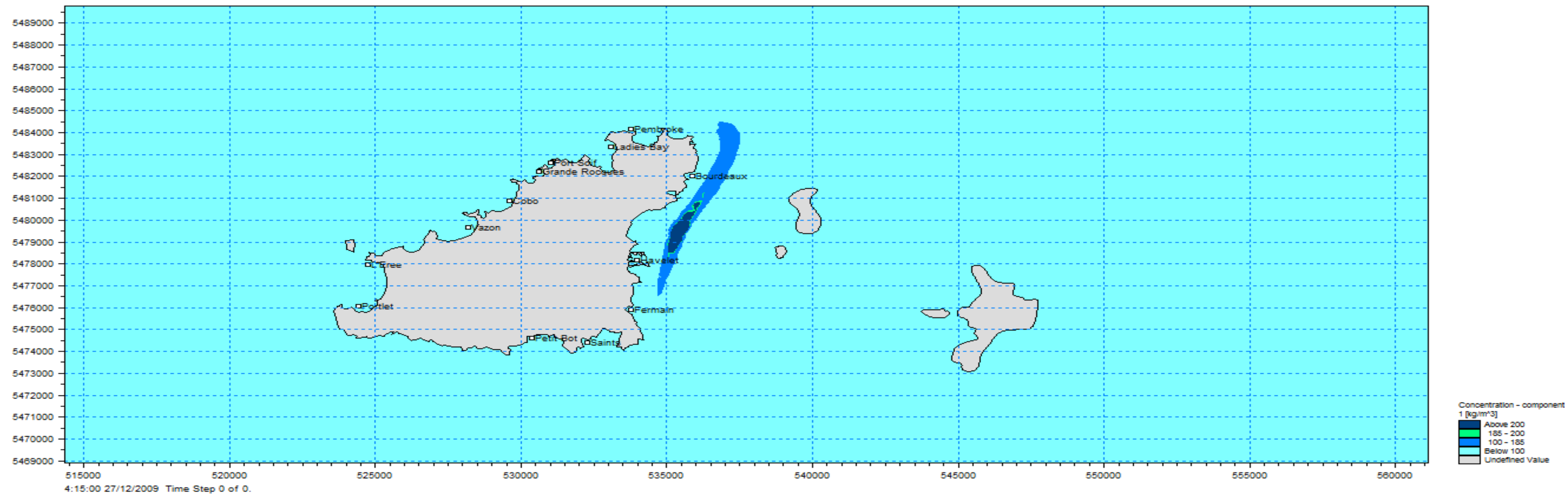


Figure F- 16: Maximum Concentration Plot Faecal Streptococci Resulting from Belle Greve Outfall – Calm Conditions



Appendix G Modelled Bacterial Concentrations Resulting from Red Lion CSO

Figure G- 1: Predicted Faecal Coliform Concentration Spring Mid Flood Red Lion

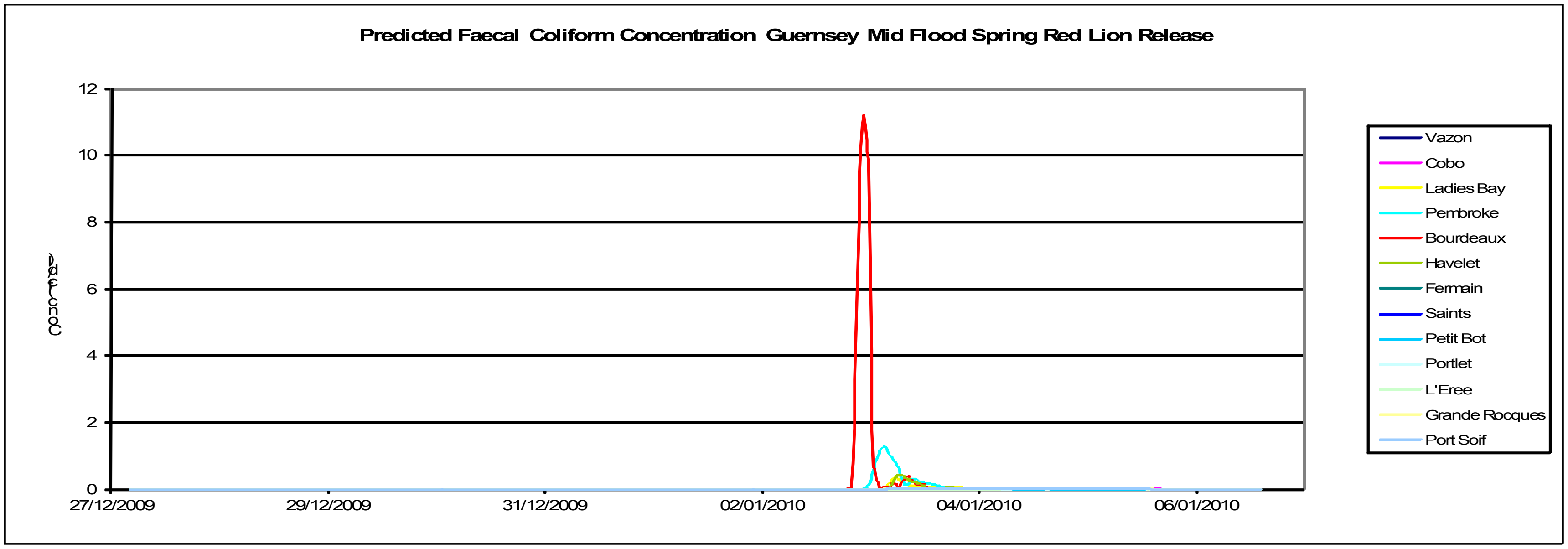


Figure G- 2: Predicted Faecal Coliform Concentration Spring Mid Ebb Red Lion

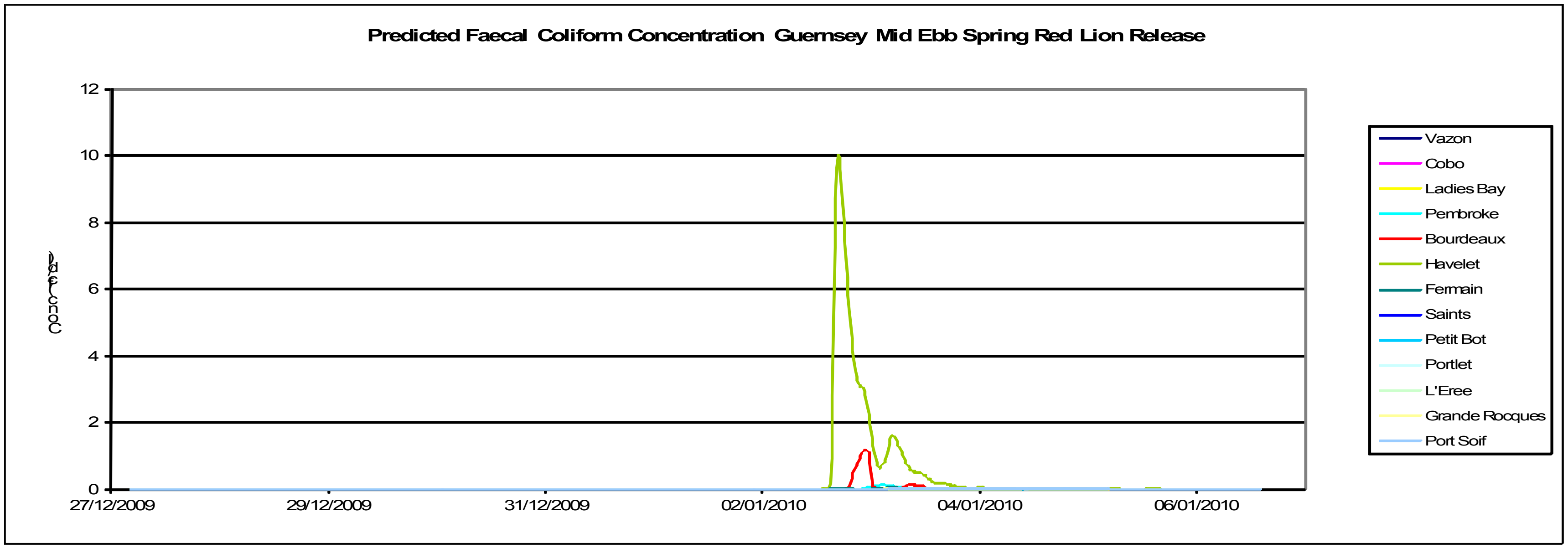


Figure G- 3: Predicted Faecal Coliform Concentration Spring High Water Red Lion

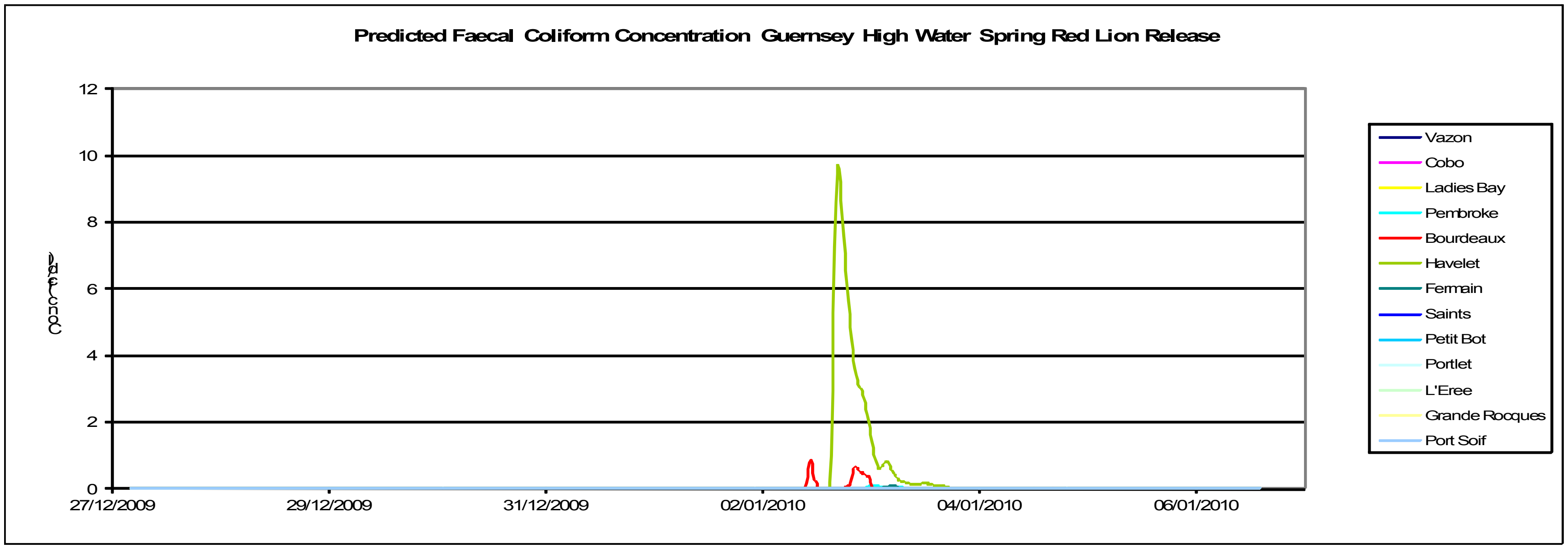


Figure G- 4: Predicted Faecal Streptococci Concentration Spring Mid Flood Red Lion

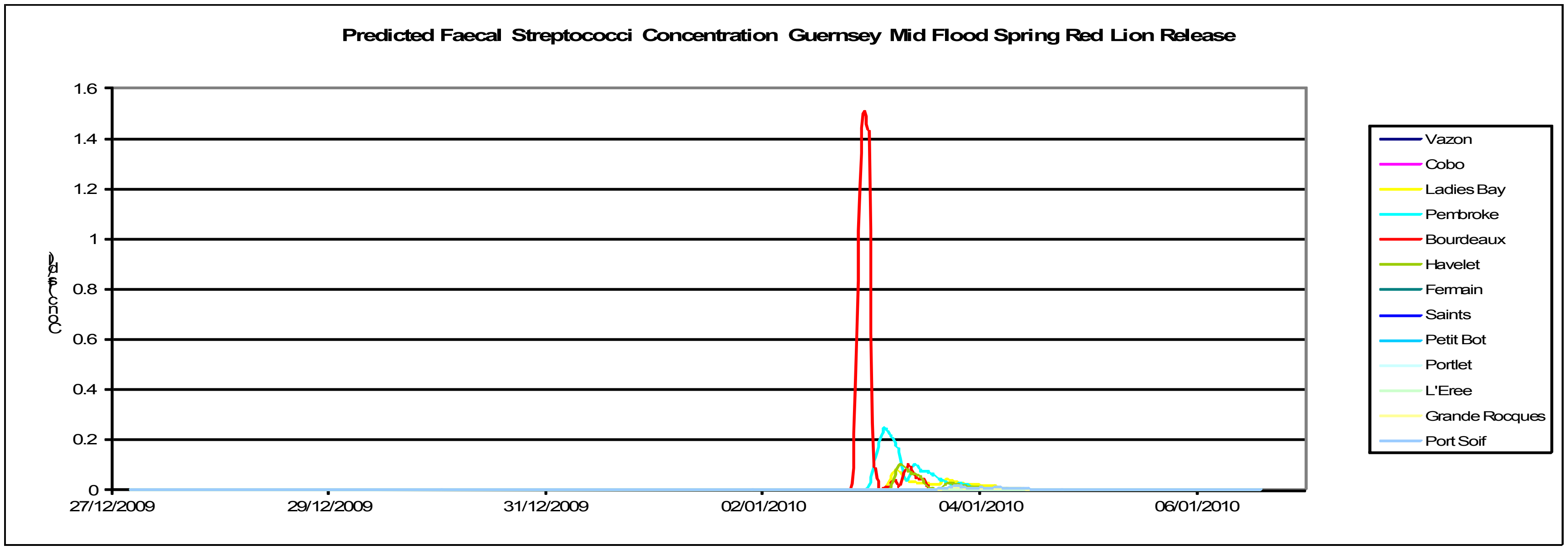


Figure G- 5: Predicted Faecal Streptococci Concentration Spring Mid Ebb Red Lion

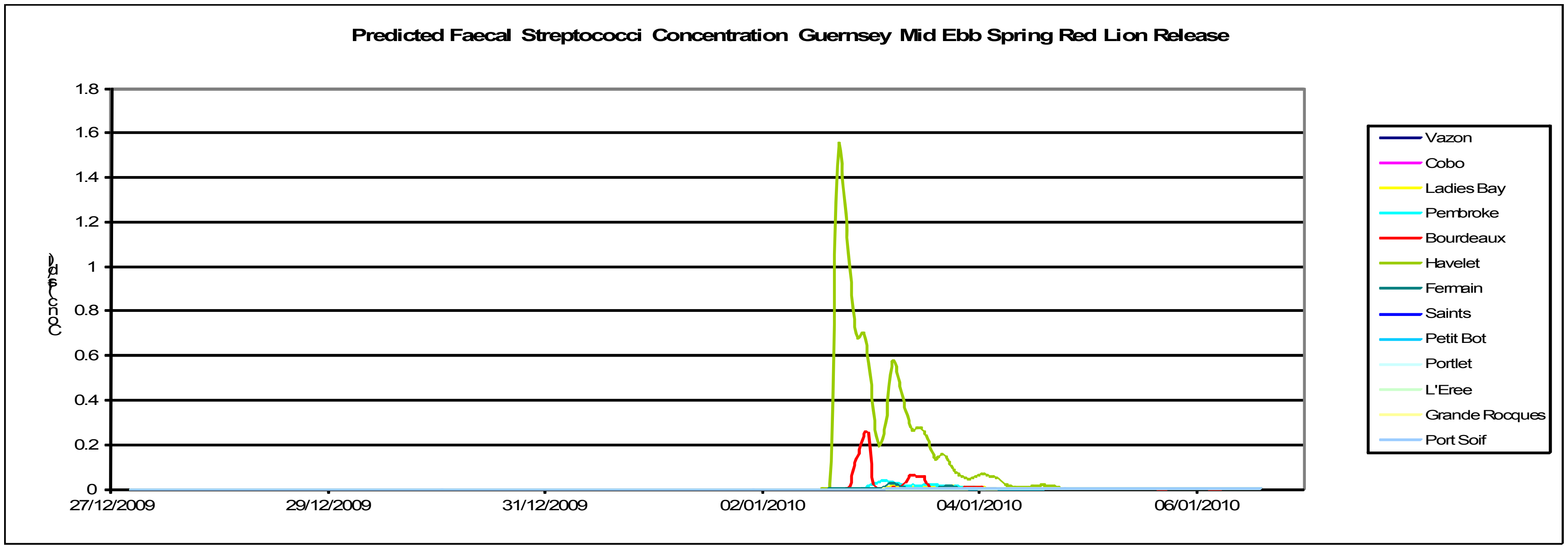


Figure G- 6: Predicted Faecal Streptococci Concentration Spring High Water Red Lion