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EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Hayle Harbour

November 2014

Food Standards Agency

Cover photo: Carnsew Pool weir

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Statement of use

This report provides a sanitary survey relevant to bivalve mollusc beds within Hayle Harbour, as required under EC Regulation 854/2004 which lays down specific rules for official controls on products of animal origin intended for human consumption. It provides an appropriate hygiene classification zoning and monitoring plan based on the best available information with detailed supporting evidence. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

Report prepared by

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3	Final	Andrew Younger	30/01/2015

Consultation

Consultee	Date of consultation	Date of response
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Cefas, 2014. Sanitary survey of Hayle Harbour. Cefas report on behalf of the Food Standards Agency, to demonstrate compliance with the requirements for classification of bivalve mollusc production areas in England and Wales under EC regulation No. 854/2004.

Contents

1. Introduction

1.1. Legislative Requirement

Filter feeding, bivalve molluscan shellfish (e.g. mussels, clams, oysters) retain and accumulate a variety of microorganisms from their natural environments. Since filter feeding promotes retention and accumulation of these microorganisms, the microbiological safety of bivalves for human consumption depends heavily on the quality of the waters from which they are taken.

When consumed raw or lightly cooked, bivalves contaminated with pathogenic microorganisms may cause infectious diseases (e.g. Norovirus-associated gastroenteritis, Hepatitis A and Salmonellosis) in humans. In England and Wales, fish and shellfish constitute the fourth most reported food item causing infectious disease outbreaks in humans after poultry, red meat and desserts (Hughes *et al.*, 2007).

The risk of contamination of bivalve molluscs with pathogens is assessed through the microbiological monitoring of bivalves. This assessment results in the classification of Bivalve Mollusc Production Areas (BMPAs), which determines the level of treatment (e.g. purification, relaying, cooking) required before human consumption of bivalves (Lee and Younger, 2002).

Under EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption, sanitary surveys of BMPAs and their associated hydrological catchments and coastal waters are required in order to establish the appropriate Representative Monitoring Points (RMPs) for the monitoring programme.

The Centre for Environment, Fisheries & Aquaculture Science (Cefas) is performing sanitary surveys for new BMPAs in England and Wales, on behalf of the Food Standards Agency (FSA). The purposes of the sanitary surveys are to demonstrate compliance with the requirements stated in Annex II (Chapter II paragraph 6) of EC Regulation 854/2004, whereby ‘if the competent authority decides in principle to classify a production or relay area it must:

a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;

b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.;

c) determine the characteristics of the circulation of pollutants by virtue of current patterns, bathymetry and the tidal cycle in the production area; and

d) establish a sampling programme of bivalve molluscs in the production area which is based on the examination of established data, and with a number of samples, a geographical distribution of the sampling points and a sampling frequency which must ensure that the results of the analysis are as representative as possible for the area considered.'

EC Regulation 854/2004 also specifies the use of *Escherichia coli* as an indicator of microbiological contamination in bivalves. This bacterium is present in animal and human faeces in large numbers and is therefore indicative of contamination of faecal origin.

In addition to better targeting the location of RMPs and frequency of sampling for microbiological monitoring, it is believed that the sanitary survey may serve to help to target future water quality improvements and improve analysis of their effects on shellfish hygiene. Improved monitoring should lead to improved detection of pollution events and identification of the likely sources of pollution. Remedial action may then be possible either through funding of improvements in point sources of contamination or as a result of changes in land management practices.

This report documents the information relevant to undertake a sanitary survey for mussels (*Mytilus* spp.) within Hayle Harbour. The area was prioritised for survey in 2014-15 as it is a new harvesting area. The razor (*Ensis* spp.) fishery in the adjacent St Ives Bay was subject to a sanitary survey in 2011, and has since ceased operations, so is not considered in this survey.

1.2. Area Description

The Hayle estuary is located on the north coast of West Cornwall, and drains to St. Ives Bay.

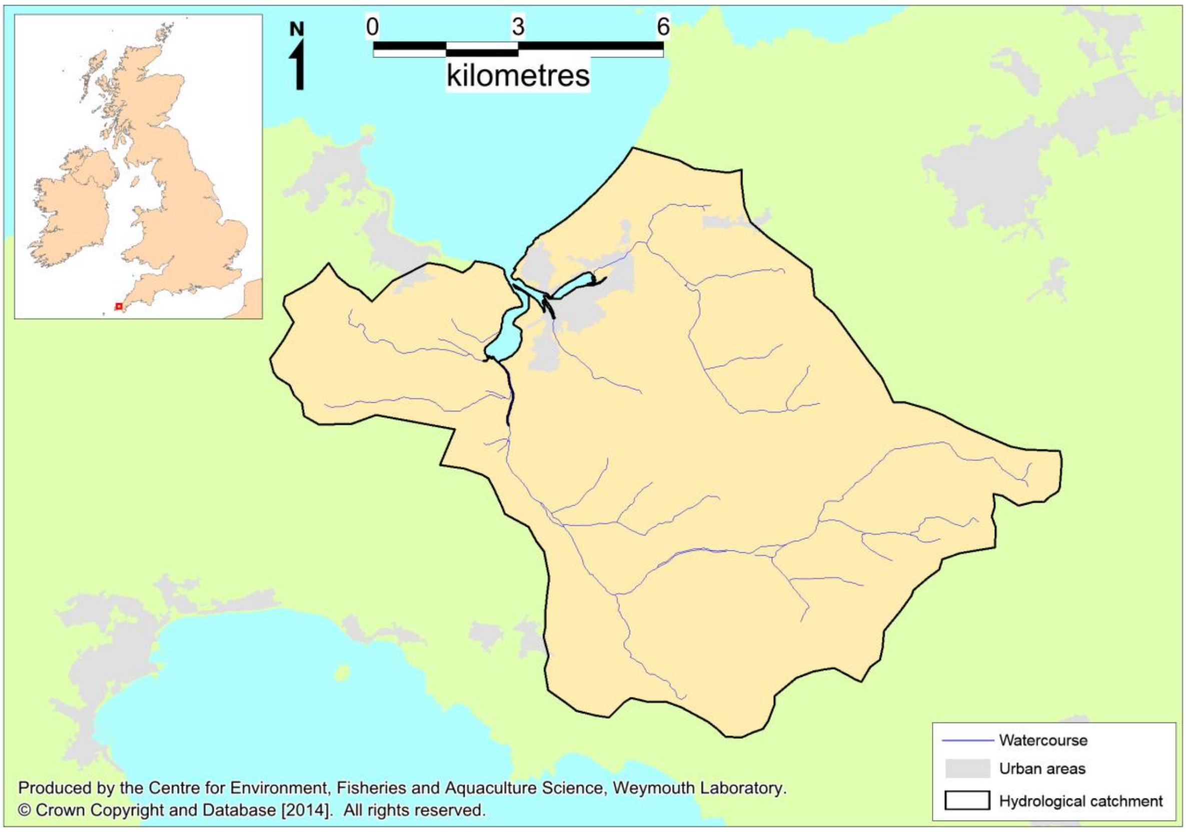

Figure 1.1: Location of the Hayle estuary

The town of Hayle lies on the banks of the estuary, and was formerly an industrial hub and a major port in the 18th and 19th centuries. Industry has since declined, the port is no longer in operation, and now the estuary supports only a fishing fleet. There are plans to undertake a series of major redevelopments in the harbour area, and the first work towards this have now started. The St Ives Bay area has a significant tourist industry, although Hayle itself is not a particular hotspot for tourism at present, and most of the catchment is devoted to agriculture. Two areas within the estuary support significant stocks of naturally occurring mussels, which are the subject of this report.

1.3. Catchment

The hydrological catchment, as estimated from topographical maps, covers an area of 96 km^2.

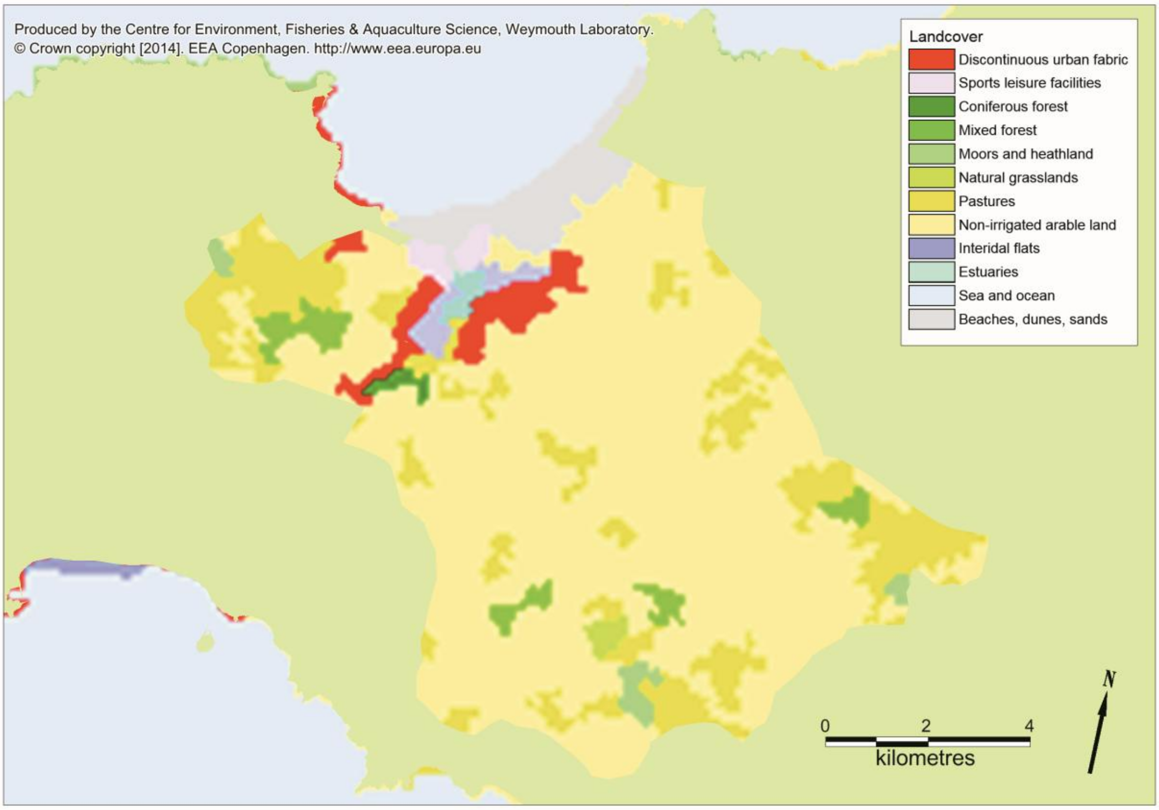

Figure 1.2: Land cover in the Hayle estuary catchment

Land cover in the catchment is mainly arable farmland, with some pockets of pasture and natural areas. The land immediately adjacent to the estuary is largely urbanised, whereas inland areas are sparsely populated. The catchment is drained by two principal watercourses (River Hayle and Angarrack Stream).

Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contribution arises from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land types (Kay *et al*. 2008a). The contributions from all land cover types would be expected to increase significantly after marked rainfall events, particularly for improved grassland, the contribution from which increases up to 100 fold.

Elevations rise to around 200 m in the southern part of the catchment. Although the underlying hydrogeology is reported to be impermeable throughout (NERC, 2012), there is significant groundwater storage so watercourses draining it do not respond particularly rapidly to rainfall.

2. Recommendations

The following two zones are proposed for mussels:

Copperhouse outlet

Sources of contamination to Copperhouse Pool are likely to be an influence on this mussel bed. These include the Angarrack Stream, Loggans Mill Leat, Phillack combined sewer overflow (CSO) and overwintering waterbirds. Contamination from Copperhouse Pool will be delivered to the mussel bed during the ebb tide. In the immediate vicinity of the mussel bed there are two point sources, the East Quay pumping station emergency overflow (PSEO) and a contaminated surface water pipe identified during the shoreline survey. These will impact most acutely on the up-stream end of the mussel bed on the western side of the channel. There may be some influence from sources to the outer estuary, as well as those to other parts of the inner estuary such as Lelant Water. Contamination from these would be delivered during the flood tide, although it is anticipated that it would be in a more dilute form than contamination from the local sources and from Copperhouse Pool. It is therefore recommended that the RMP is located at the upstream western end of the mussel bed.

A prohibited level result was obtained from the approximate location of the recommended RMP during the shoreline survey, and there is no reason why this sample should not be considered for classification purposes. If the competent authority decides that harvesting should be prohibited, then this zone cannot be upgraded until 2 years of improved monthly monitoring results are accrued, or if there is a significant change to the sources of contamination impacting upon it. The Environment Agency have been informed of the contaminated surface water pipe, and will investigate in the near future, but had not reported back at the time of writing.

Carnsew pool and outlet

There are no confirmed point sources of contamination in the immediate vicinity of the mussel bed in Carnsew Pool and its outlet channel. There may be some influence from sources to the outer estuary, as well as those to other parts of the inner estuary such as Lelant Water and Copperhouse Pool. Contamination from these would be delivered during the flood tide, albeit in a dilute form. Sources of contamination to Carnsew Pool are limited to minor diffuse inputs from birds and possibly dogs. Very limited microbiological monitoring suggested slightly higher levels of contamination in the outlet channel than in the pool. It is therefore recommended that the existing RMP named ‘Carnsen Creek’ is used to classify the whole of this zone.

Sampling requirements

Samples should be of mussels of a harvestable size. The sampling method should be hand collection. A tolerance of 10 m applies. The sampling frequency should be monthly throughout the year. Should a more rapid classification be required, then a provisional classification may be awarded once ten samples taken not less than a week apart have been submitted. Samples taken during 2012 should not be counted towards classification as they were taken over two years ago.

3. Sampling Plan

3.1. General Information

Location Reference

Production Area	St Ives Bay (Hayle Harbour)
Cefas Main Site Reference	M070
Ordnance survey 1:25,000 map	OS Explorer 105
Admiralty Chart Nos.	-

Shellfishery

Species/culture	Mussels	Wild
Seasonality of harvest	Year round	

Local Enforcement Authorities

Name	Cornwall Port Health Authority The Docks Falmouth TR11 4NR
Environmental Health Officer	Terry Stanley
Telephone number ☎	01326 211581
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3.2. Requirement for Review

The Guide to Good Practice for the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2014) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2020. The assessment may require review in the interim should any significant changes in sources of contamination come to light, such as the upgrading or relocation of any major discharges.

Table 3.1: Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within Hayle Harbour

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Copperhouse outlet	B088K	East Quay	SW 5573 3768	50° 11.314' N 05° 25.405' W	Mussels	Wild	Hand	Hand	10 m	Monthly for full classification, or 10 samples not less than 1 week apart for provisional classification	Prohibited level result recorded here during the shoreline survey. Will likely require investigation and remediation of a contaminated surface water pipe before sampling towards classification is a realistic proposition.
Carnsew Pool and outlet	B088J	Carnsen Creek	SW 5564 3743	50° 11.182' N 05° 25.471' W	Mussels	Wild	Hand	Hand	10 m	Monthly for full classification, or 10 samples not less than 1 week apart for provisional classification	

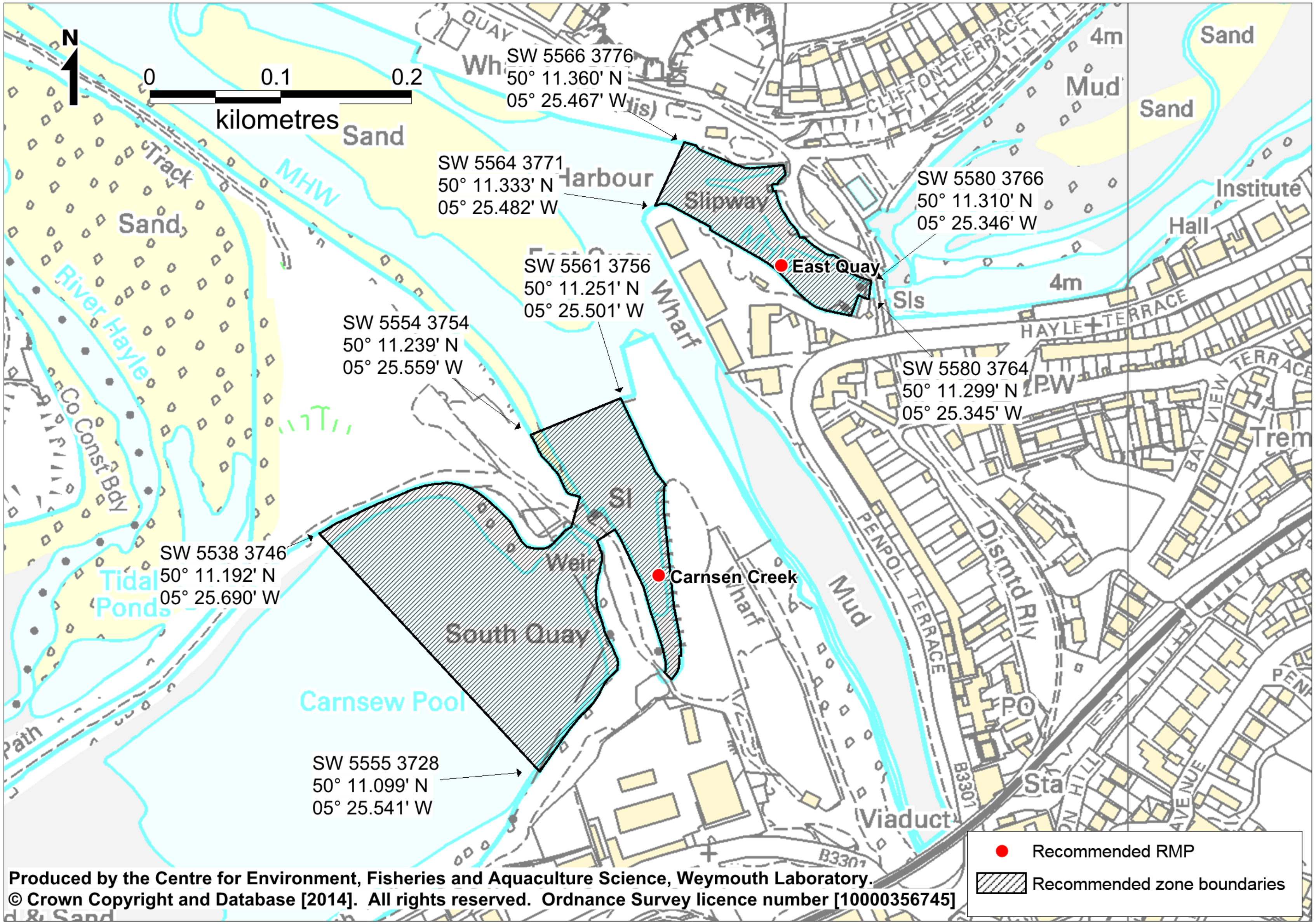

Figure 3.1: Recommended zoning and monitoring arrangements (mussels)

4. Shellfisheries

4.1. Description of fisheries

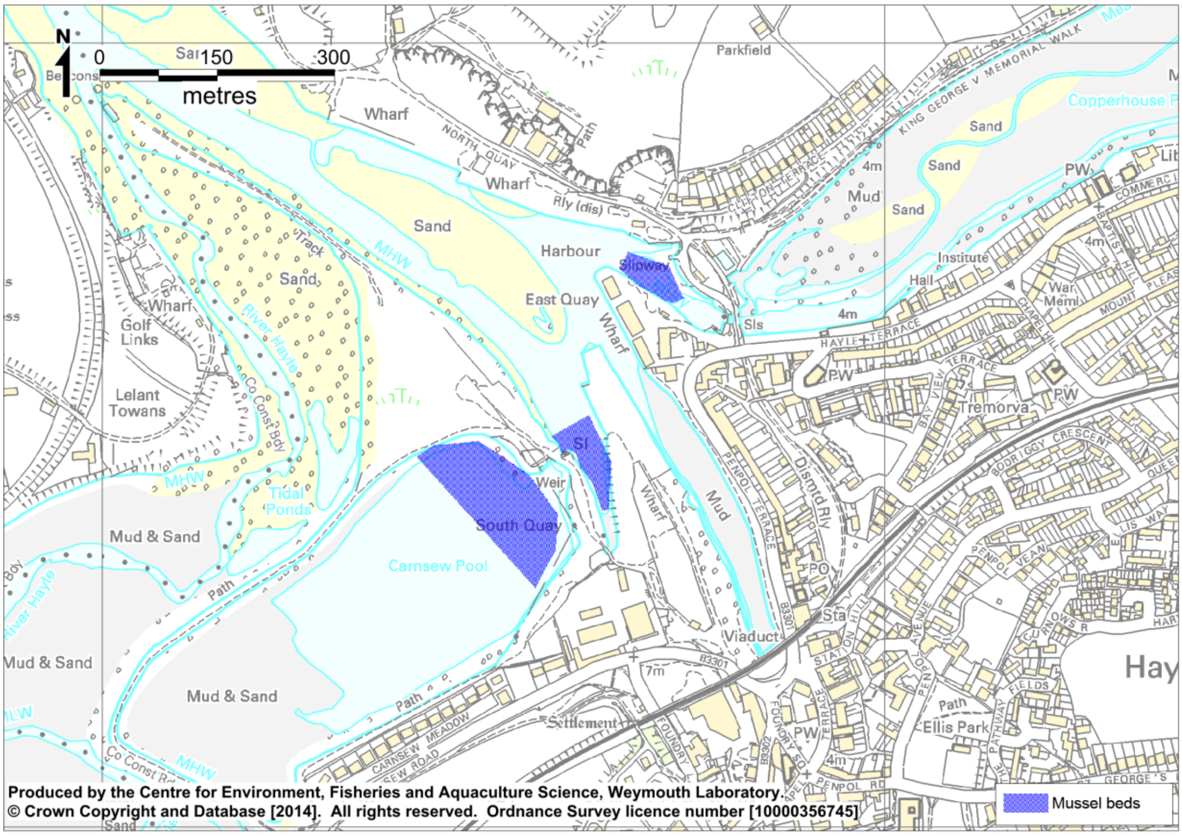

Figure 4.1: Location of mussel beds within Hayle Harbour

An application to harvest naturally occurring stocks of mussels from Hayle Harbour was received in August 2013. They occur in two relatively small areas around the outlets of Carnsew and Copperhouse Pools. These areas provide favourable growing conditions as they are well flushed and oxygenated due to tidal accelerations through the two pool outlets. Much of the stock is of a marketable size, including some very large individuals. Harvest will be via hand, although some stocks are not accessible via this method as they remain submerged at low tide. It is planned that a small number of local fishermen will operate the fishery in a sustainable manner, with input from the IFCA. Local depuration facilities and markets have been identified. In the future, it is possible that mussel culture on suspended ropes may be attempted here. A bulk clearance from the Carnsew outlet tunnels may be required in the near future to facilitate the installation of sluice gates here. This will be undertaken before the end of 2014, and the mussels will be re-deposited in Carnsew Pool.

Harvest may occur at any time of the year, although it is likely that the mussels will be in better condition during the autumn and winter once they have recovered from the spring/summer spawning. An annual production of around 20 tonnes is anticipated. No minimum size is specified for mussels within the district. The rights to the fishery are held privately by Hayle Harbour Authority.

4.2. Hygiene Classification

Although the adjacent St Ives Bay has historically been classified for both mussels and razors, nowhere within the Hayle estuary has ever been classified for the harvest of bivalve molluscs.

Table 4.1: Criteria for classification of bivalve mollusc production areas.

Class	Microbiological standard[1]	Post-harvest treatment required
A[2]	Live bivalve molluscs from these areas must not exceed 230 Most Probable Number (MPN) of *E. coli* 100 g^{-1} Fluid and Intravalvular Liquid (FIL)	None
B[3]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution MPN test of 4,600 *E. coli* 100 g^{-1} FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* 100 g^{-1} FIL	Purification, relaying or cooking by an approved method
C[4]	Live bivalve molluscs from these areas must not exceed the limits of a five-tube, three dilution Most Probable Number (MPN) test of 46,000 *E. coli* 100 g^{-1} FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli* 100 g^{-1} FIL[5]	Harvesting not permitted

[1] The reference method is given as ISO 16649-3.
[2] By cross-reference from EC Regulation 854/2004, via EC Regulation 853/2004, to EC Regulation 2073/2005.
[3] From EC Regulation 1021/2008.
[4] From EC Regulation 854/2004.
[5] This level is not specifically given in the Regulation but does not comply with classes A, B or C. The competent authority has the power to prohibit any production and harvesting of bivalve molluscs in areas considered unsuitable for health reasons.
[6] Areas which are not classified and therefore commercial harvesting of LBMs cannot take place. This also includes areas which are unfit for commercial harvesting for health reasons e.g. areas consistently returning prohibited level results in routine monitoring and these are included in the FSA list of designated prohibited beds

5. Overall Assessment

5.1. Aim

This section presents an overall assessment of sources of contamination, their likely impacts, and patterns in levels of contamination observed in water and shellfish samples taken in the area under various programmes, summarised from supporting information in the previous sections and the Appendices. Its main purpose is to inform the sampling plan for the microbiological monitoring and classification of the bivalve mollusc beds in this geographical area.

5.2. Shellfisheries

Two discrete areas require classification for the harvest of naturally occurring mussel stocks. The larger area is in the northern end of Carnsew Pool, and extends through the tunnels and out to the area adjacent to South Quay. The second is located between the East and North Quays, just downstream from the Copperhouse Pool sluice. Both hold stocks of a harvestable size. It is planned that the mussels will be harvested by hand, on a sustainable basis, by a few local fishermen. An annual production of around 20 tonnes is anticipated. In the future, it is possible that mussel culture on suspended ropes may be attempted here but there are no firm plans at this stage. A bulk clearance from the tunnels may be required in the near future to facilitate the installation of sluice gates here, and the mussels will be transferred to Carnsew Pool. It is a privately owned fishery, and although there is no formal minimum landing size, in practice only market sized mussels will be taken.

5.3. Pollution Sources

Freshwater Inputs

The hydrological catchment draining to the Hayle estuary covers an area of 96 km^2. Land within the catchment is mainly used as pasture or arable land, although the area immediately surrounding the estuary is largely urbanised. The two main freshwater inputs are the River Hayle and the Angarrack Stream, which drain to the head of Lelant Water and Copperhouse Pool respectively. There are also a number of smaller watercourses draining to various parts of the estuary, including several to Lelant Water, the Penpol River to the head of Penpol Creek, and the Loggans Mill Leat to the head of Copperhouse Pool. As such, the upper reaches of Lelant Water, Copperhouse Pool, and possibly Penpol Creek are likely to be most acutely impacted by land runoff.

Flow gauging records were available for two sites within the catchment, one on the lower reaches of the Hayle, and the other on the lower reaches of the Angarrack. Estimates of mean daily flow over the last decade were available for the former, whereas at the latter flow estimates made at 15 minute intervals were available for March to July of 2008. The average flow recorded on the Angarrack Stream during this period was 0.3 m^3/s, whereas it was roughly double this (0.58 m^3/s) at the gauging station on the Hayle throughout the same period. The average flow recorded at the gauging station on the Hayle (2005-2014) was 0.95 m^3/sec. Day to day variation in flows was relatively small, indicating that there is significant damping of the response to rainfall by the discharge and recharge of groundwater. Discharge here was lowest on average from May to September and highest on average during December and January, and elevated flow events are rare from April to October.

During the shoreline survey, samples were taken from most watercourses and enumerated for *E. coli*. The results show moderate concentrations of faecal coliforms in most freshwater inputs, including the Hayle (3,500 cfu/100 ml) and the Penpol River (4,500 cfu/100 ml). The Angarrack Stream was not sampled, but it is likely to be of a similar microbial composition to Loggans Mill Leat (840 cfu/100 ml) which draws water from it. Of particular relevance to the sampling plan was a surface drainage pipe from the East Quay, opposite the Copperhouse Pool sluice. The harbourmaster reports that this pipe flows continuously. A sample from this taken during the shoreline survey contained 290,000 faecal coliforms/100 ml. The result suggests that this pipe was receiving some foul water input at the time, and if this occurs on a continuous basis it is likely to be a major contaminating influence on the mussel bed at Copperhouse outlet. The Environment Agency have been informed about this outfall and intend to investigate in the near future, but had not yet reported any findings at the time of writing. The mussel bed in the Copperhouse outlet channel is also likely to be influenced by runoff draining to Copperhouse Pool, although the contaminated drainage pipe is likely to be a much more acute influence, and cause significant spatial variation across the mussel bed. There are no freshwater inputs to Carnsew Pool, or to the channel downstream of its outlet, so land runoff will not be such a direct influence here and will not be a major consideration in terms of RMP location.

Human Population

Total resident population within census areas contained within or partially within the Hayle Harbour catchment was approximately 28,000 at the time of the last census in 2011. Most of the population is concentrated around the harbour, and the largest settlement in the area is Hayle, which had a population of about 9,400. The St Ives Bay area is a very popular tourist destination, so the population in the catchment will increase significantly during holiday periods.

Sewage Discharges

Hayle and St Ives are served by Hayle STW, which discharges secondary treated effluent via a long sea outfall offshore from St Ives Bay. This will be of no impact within Hayle Harbour. There are two small continuous water company sewage works located inland, within the River Hayle catchment. The Nancegollan STW is the larger of the two, and discharges to a tributary of the River Hayle. It is consented to discharge a dry weather flow of 60 m^3/day of secondary treated effluent, and generates an estimated bacterial loading of $2x10^{11}$ faecal coliforms/day. It will therefore make a contribution to the bacterial loading delivered by the River Hayle, although some bacterial die-off during passage to the estuary is anticipated. The second sewage works (Trewithen Terrace) is consented to discharge a dry weather flow of 7.4 m^3/day. The receiving environment is unspecified in the database, but as it is located more than 1 km from the nearest surface watercourse it is assumed it discharges to soakaway. Whether it discharges to soakaway or to a tributary of the River Hayle, its influence on shellfish hygiene will be negligible.

In addition to the continuous sewage discharges, there are 8 intermittent water company discharges associated with the sewerage networks. Most are in the vicinity of the estuary, with two located further inland, one of which discharges to the Angarrack and the other to the Hayle. No spill records were available for any of these discharges, so it is difficult to assess their significance, aside from noting their locations, and their potential to spill untreated sewage. The East Quay PSEO is of most potential significance as it discharges directly onto the mussel bed in the Copperhouse Pool outlet channel. It is possible that the contaminated surface water pipe observed during the shoreline survey was actually this outfall, although it is believed that the discharge is made through another nearby larger pipe that was not flowing at the time. The Phillack CSO, which discharges to the upper reaches of Copperhouse Pool may also be an influence on this mussel bed. There are no intermittent discharges in Carnsew Pool or its outlet channel which could impact directly on the Carnsew Pool mussel bed.

Although the majority of properties within the catchment are served by water company sewerage infrastructure, there are also 169 permitted private discharges. Most of these are small, serving one or a small number of properties, and providing treatment via septic tank or package plant. The majority (134) discharge to soakaway so should be of no impact on the estuary, assuming they are functioning correctly. Of the 35 discharging to water, 27 discharge to the River Hayle and tributaries with a total consented volume of 53 m^3/day, and 7 discharge to the Angarrack Stream with a total consented volume of 21 m^3/day. These will make some contribution to the bacterial loadings delivered by these watercourses. There is one private discharge direct to the estuary at Lelant, which is consented to discharge up to 1 m^3/day of effluent which will be of negligible impact on the fishery.

Agriculture

Land use in the catchment is principally arable farming. There are also some pastures, mainly in the upper reaches of the catchment, and areas immediately adjacent to the estuary are largely urbanised. Agricultural census data indicates that there are potentially significant numbers of cattle, low numbers of sheep, a few pigs, and several poultry units.

Grazing animals (sheep and cattle) will directly deposit faeces on pastures, although during the winter cattle may be housed indoors and at these times slurry/manure is collected and stored for later application to fields. Manures from pig and poultry operations are generally collected, stored and applied to farmland as required. Sewage sludge may be applied to arable fields, although the extent to which this occurs within the catchment is uncertain.

Contamination from livestock will be carried into the estuary via watercourses draining areas of pasture or agricultural land onto which manures have been deposited or spread. The extent of this will depend not only on the numbers and distribution of livestock, or volumes and type of organic fertilizer applied, but also rainfall patterns, soil permeability, slope, and the degree of separation between fields and watercourses. To capture contamination of agricultural origin RMPs should generally be set in a position which most exposes them to land runoff from the larger watercourses.

The magnitude of flux of contamination from livestock sources to coastal waters will be highly dependent on rainfall. As well as significant day to day variations in response to rainfall, there are likely to be seasonal fluctuations in the amount of faecal indicator organisms of agricultural origin which are delivered to the estuary. Numbers of grazing animals are expected to peak following the birth of lambs and calves in the spring, then decline in the autumn as these animals are sent to market. Peak fluxes of contamination from cattle and sheep may therefore arise catchment-wide following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build-up of faecal material on pastures. Manure/slurry is typically applied in the winter, spring and autumn, and sewage sludge is usually applied to land in the region in February, March and September. Wet weather following a spreading may result in significant but more localised impacts.

Boats

The harbour accommodates 27 small fishing boats, 2 commercial boats and 107 small leisure boats. There are also a number of water-sports clubs which use the harbour for activities such as canoeing, rowing and jet-skiing. The fishing boats are generally small, and most are unlikely to have on board toilets. They moor at the North, East and South Quays. Penpol Creek is used for the mooring of small dinghy type pleasure craft, and again most if not all of these are too small to have on board toilets. Craft used for watersports will not make overboard discharges either. The harbour is not routinely used by larger vessels which will have on board toilets such as visiting yachts, as it is shallow and difficult to navigate. It is therefore concluded that there is likely to be little in the way of overboard discharges within the estuary as the vessels using it are generally too small. It is possible that the occasional larger vessel may visit and potentially make overboard discharges, either whilst tied up at one of the quays or on passage in and out of the area. Whilst leisure boat activity is likely to peak during the summer, significant increases in the number of overboard discharges is not anticipated because of their small size.

Wildlife

The Hayle estuary comprises a range of habitats including saltmarsh and intertidal mud and sand flats. These features support significant wildlife populations, some of which may be an influence on shellfish hygiene. The most significant of these is likely to be overwintering waterbirds (waders, wildfowl etc). The estuary is reported to support up to 18,000 of these, although the average peak count over the five winters up to 2012/13 was 6,127. Highest concentrations occur in Lelant Water and Copperhouse Pool. These birds may either deposit faeces directly on the intertidal, or on saltmarsh or coastal grasslands. As such their impacts may be considered as diffuse throughout intertidal areas, but may be concentrated in watercourses and any saltmarsh drainage channels. As the shellfish beds are not in close proximity to any such drainage channels, overwintering waterbirds will not influence the positioning of monitoring points even though they may at times make a significant contribution to counts of faecal indicator bacteria within shellfish.

In addition to overwintering waterbirds, seabirds such as gulls and terns are also present in the area. During a survey in 1999, 137 pairs of gulls were recorded nesting around the estuary, mainly within the town of Hayle. Their exact nest sites were not specified. These seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Most seabird species are likely to be present in the area all year round.

There is a grey seal colony at St Ives Bay, which uses haul out sites on Godrevy Island and at Mutton Cove. Average numbers are about 31 animals, although more than twice this amount was observed on occasions. They are present all year round, but numbers tend to peak in March. Whilst it is likely they enter the estuary on occasion, their presence will be spatially and temporally unpredictable, and their impacts can be considered as diffuse and minor at most. No other wildlife populations which may have a potentially significant influence on levels of contamination within shellfish in the Hayle estuary have been identified.

Domestic animals

Dog walking takes place on paths adjacent to the shoreline of the survey area, such as the path around Carnsew Pool. Dogs therefore represent a potential source of contamination to the near shore zone. As a diffuse source, this will have little influence on the location of RMPs.

Summary of Pollution Sources

An overview of sources of pollution likely to affect the levels of microbiological contamination to the shellfish beds is shown in Table 5.1 and Figure 5.1.

Table 5.1: Qualitative assessment of seasonality of important sources of contamination.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Agricultural runoff												
Urban runoff												
Continuous sewage discharges												
Intermittent sewage discharges	?	?	?	?	?	?	?	?	?	?	?	?
Birds												
Boats												

Red - high risk; orange - moderate risk; yellow - lower risk; white – little or no risk.

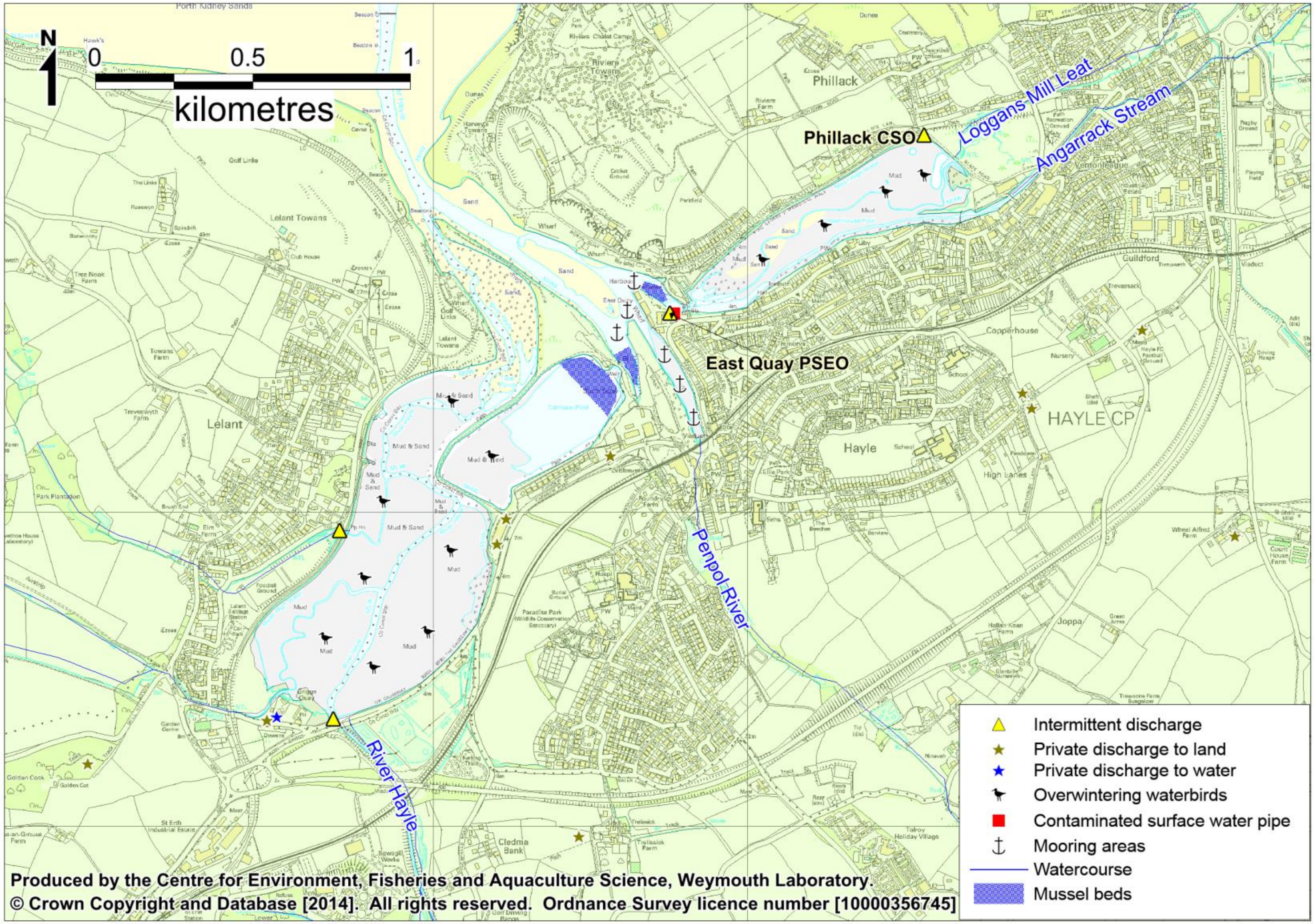

Figure 5.1: Summary of main contaminating influences

5.4. Hydrography

The Hayle estuary covers an area of 149 Ha, of which 91% is intertidal. Its shallow nature will mean that a large proportion of water is exchanged each tide, but will limit dilution potential. It consists of four hydrographically distinct water bodies (Lelant Water, Carnsew Pool, Penpol Creek and Copperhouse Pool) which converge in the harbour area to form a single channel which then connects to the open waters of St Ives Bay.

Lelant Water comprises intertidal mudflats, and receives freshwater input from the River Hayle and several smaller watercourses. It converges with the outer estuary channel a significant distance further down estuary (>500 m) than the other three. Carnsew Pool is a manmade enclosed pool, which connects to the harbour area to the west of South Quay over a weir and through two tunnels. The cill of the weir is at a level of about 3.9 m above chart datum so water is retained at low tide. A race forms over the weir as the pool drains. A second connection with sluice gates has recently been reinstated, about 100 m to the south of the tunnels. There are no freshwater inputs to Carnsew Pool. There is now a second connection via a recently reinstated sluice channel. Penpol Creek is a narrow intertidal creek which receives a small freshwater input at its head, and connects to the harbour area between East Quay and South Quay. Copperhouse Pool is largely made up of intertidal mudflats and drains to the harbour area through a sluice gate between the East Quay and North Quay. The tidal stream accelerates when it passes through the sluice. The sluice is usually left open, but may be closed around high water on larger tides for flood defence purposes, and is occasionally closed for a few tides to impound the pool for local events such as boat races. Copperhouse Pool receives freshwater inputs from the Angarrack Stream and Loggans Mill Leat. The Harbour area and outer estuary channel are both shallow, and whilst they do not dry out fully, bed elevations are higher than chart datum throughout. Regular dredging is required to maintain navigability.

Historically, sluice gates at Carnsew and Copperhouse Pool were used to retain water which was then released in the latter part of the ebb tide to flush sediment from the harbour area to maintain navigability. This practice will be reinstated at Carnsew Pool in 2015 to reduce reliance on dredging. It will be restricted to spring tides from April to August. This will result in significant increase in peak water flows across the mussel bed, which may scour them from some areas and result in a change in their spatial distribution.

The tidal amplitude at St. Ives is 5.8 m on spring tides, and 2.5 m on neap tides. This drives extensive water movements through the estuary across the twice daily high/low cycle. Tides flooding up the estuary and its various arms, then drain back out. The mussels in the Copperhouse outlet channel will be mainly influenced by sources to Copperhouse Pool on the ebb tide, and by sources to the North and East Quays and outer Harbour on the flood tide. The mussels at Carnsew Pool will be mainly influenced by sources to Carnsew Pool on the ebb tide, and sources to the East and South Quays, and outer Harbour on the flood. Contamination from sources discharging to Penpol Creek and Lelant Water will not be a direct influence on either mussel areas, although it may be carried back towards them in a more dilute form on flood tides. Peak tidal current velocities are reported to reach 2 m/s within a constriction in the outer estuary but are generally much slower in other areas. Exceptions to this are the Carnsew and Copperhouse outlets, where current velocities are greatly accelerated and turbulent mixing of the water column will occur. Due to the spatial variability in current speeds, it is not possible to make meaningful estimates of the distances over which contamination will be carried during the course of a tide.

Water circulation in estuaries may be significantly modified by the more dynamic effects of freshwater inputs and wind. Freshwater inputs are low in relation to the volumes of water exchanged tidally, so the estuary as a whole is considered well mixed and density driven circulation is unlikely to be of much significance. During periods of high runoff, salinity in the upper reaches of Lelant Water may drop as low as 29 ppt on springs and 15 ppt on neap tides. Salinity stratification may therefore develop in the upper areas of both Lelant Water and also probably Copperhouse Pool at times of high river flows. Density effects will drive a net seaward flow of less saline water at the surface, with a corresponding return of more saline water at depth. However, this is unlikely to occur in the vicinity of the mussels beds. There are no freshwater inputs to Carnsew Pool, and water draining from both pools will be subject to turbulent mixing as it passes through their respective outlets.

Strong winds will drive surface currents, and in turn these create return currents which may travel lower in the water column or along sheltered margins. Although the estuary is afforded some shelter from winds from all directions by the surrounding land, strong winds are likely to have some effect in the larger water bodies such as Lelant Water. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. Where strong winds blow across a sufficient distance of water they may create wave action, which may mobilise contamination entrained in intertidal sediments. Waves from St Ives Bay will not penetrate into the estuary, so any waves here will be generated locally. As the fetches are small, particularly in the vicinity of the mussel beds, it is anticipated that this effect is of relatively low significance here.

5.5. Summary of Existing Microbiological Data

The only bacteriological testing results available in the estuary derive from some very limited *E. coli* testing of mussel flesh in July 2012, and from mussel samples taken during the shoreline survey.

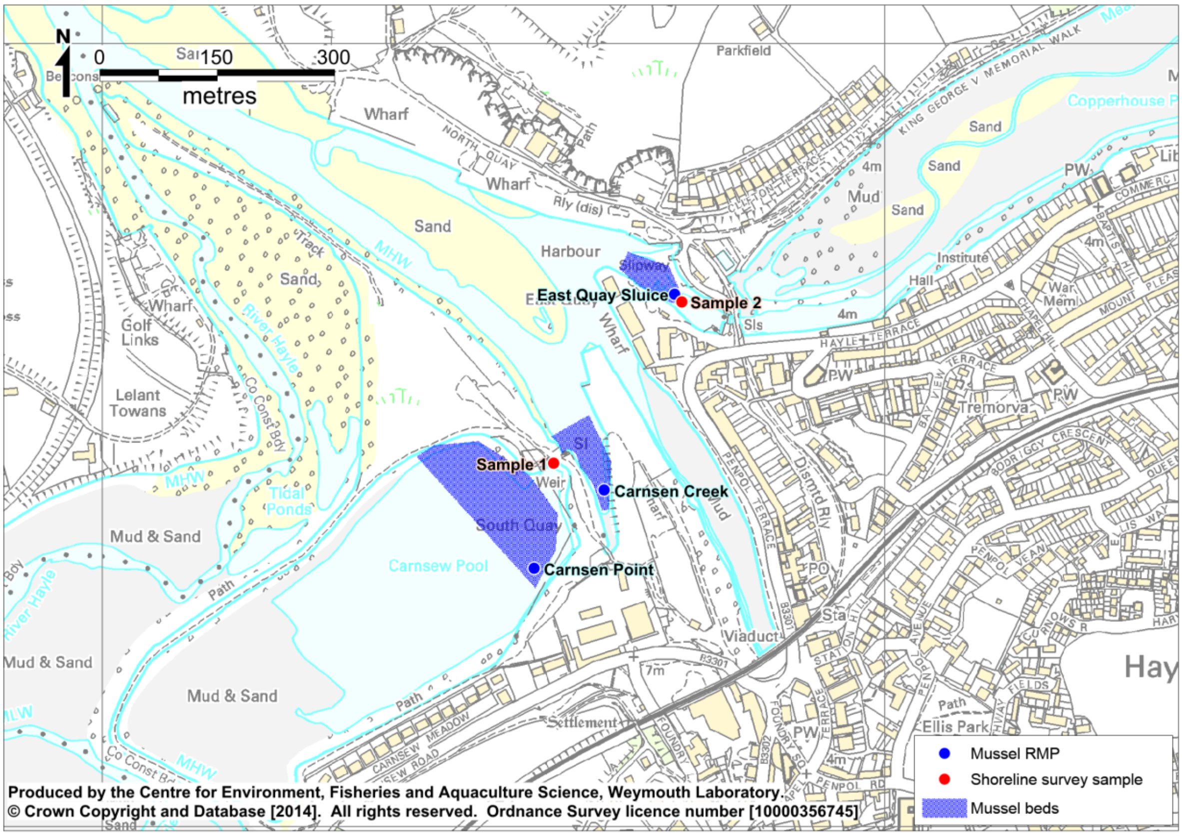

Figure 5.2: Microbiological sampling sites

In 2012, two samples were taken from each of three locations. The geometric mean result was highest at East Quay Sluice (1,455 *E. coli* MPN/100 g), and the highest individual result (9,200 *E. coli* MPN/100 g) was recorded here. Across the other two points the average result was higher at Carnsen Creek (426 *E. coli* MPN/100 g) than at Carnsen Point (185 *E. coli* MPN/100 g). Neither result exceeded 4,600 *E. coli* MPN/100 g at the latter two monitoring points.

Two samples were taken during the shoreline survey. Sample 1, from the Carnsew outlet tunnel, contained 4,600 *E. coli* MPN/100 g, but was not tested until 26 hours and 22 minutes after collection, so cannot currently be used for classification purposes[1]. Sample 2,from the Copperhouse outlet channel, was examined within the required timeframe, and contained 160,000 *E. coli* MPN/100 g. There is no

[1] This was extended to 48 hours in November 2014, after these samples were taken.

reason why this latter sample should not be used for classification purposes, in which case current protocols suggest that harvesting should be prohibited from this mussel bed. This may be upgraded following 2 years of improved monthly monitoring results, or if a significant change to sources of contamination occurs. There may be some scope for the latter, as the main source of contamination at the time the sample was collected is thought to be a surface water pipe that is suspected of receiving sewage from a non-permitted source.

Bacteriological survey

At the request of the FSA, bacteriological survey resource was used to acquire some additional mussel and water samples for bacteriological testing (see above) and some additional mussel samples for chemical (metals and PAHs) testing. Detailed consideration of the chemical testing falls outside the scope of this report, but the results were satisfactory.

Appendices

Appendix I. Human Population

Figure I.1 shows population densities in census output areas within or partially within the Hayle Harbour catchment area, derived from data collected from the 2011 census.

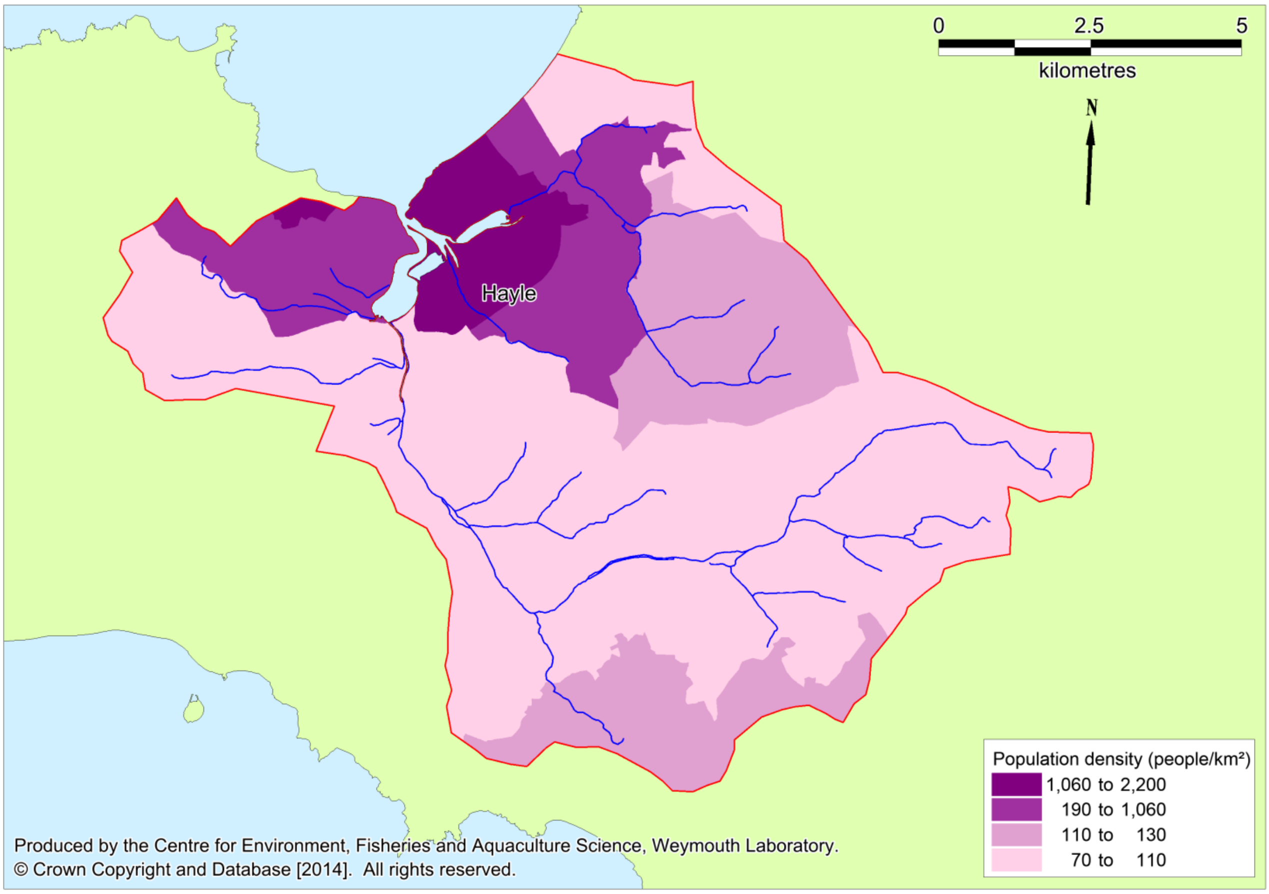

Figure I.1: Human population density in census areas in the Hayle Harbour catchment.

Total resident population within census areas contained within or partially within the catchment area was approximately 28,000 at the time of the last census. The largest settlement in the area is Hayle, which had a population of about 9,400 in the 2011 census. Most of the population is concentrated around the Harbour.

St Ives Bay is one of Cornwall's most popular tourist destinations with 37% of tourists in Cornwall either visiting or planning to visit in 2012 (Beaufort Research , 2013). In 2012, tourists stayed 954,600 nights in St Ives (The South West Research Company, 2013). The majority of visitors to Cornwall visit fishing villages and harbours, seaside resorts and remote sandy beaches (Beaufort Research , 2013). All of these destinations rely on good weather and so tourist numbers are likely to be highest during the spring and summer.

Appendix II. Sources and Variation of Microbiological Pollution: Sewage Discharges

Details of all consented sewage discharges within the Hayle Harbour hydrological catchment were taken from the most recent update of the Environment Agency national permit database (March 2014). These are mapped in Figure II.1.

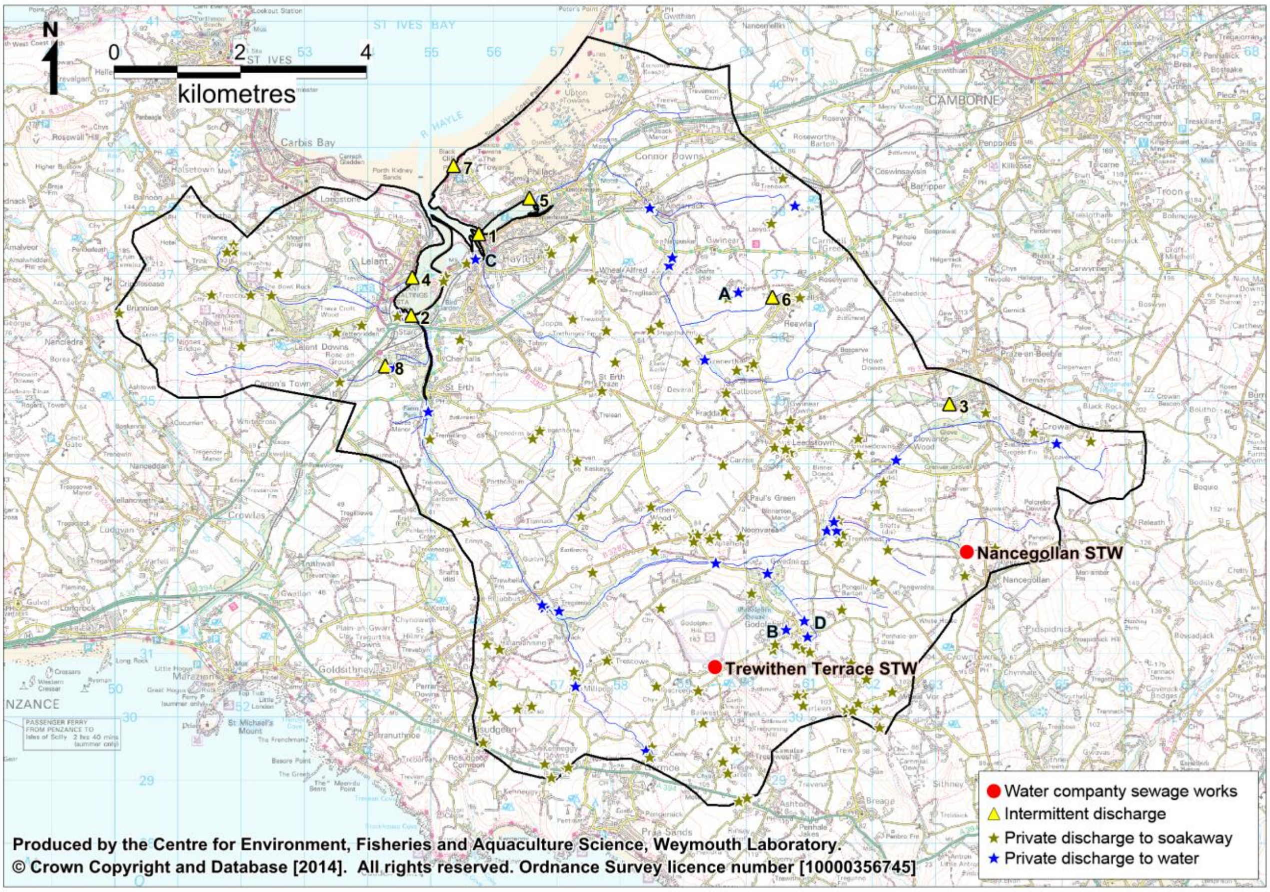

Figure II.1: All permitted sewage discharges to the Hayle Harbour catchment
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The towns of St Ives and Hayle are served by Hayle STW, which discharges secondary treated effluent via a long sea outfall offshore from St Ives Bay. This will be of no impact within Hayle Harbour. There are two small continuous water company sewage works discharging within the catchment, details of which are presented in Table II.1.

Table II.1: Details of continuous water company sewage works to the St Ives (Hayle Harbour) catchment

Name	NGR	Treatment	DWF (m^3/day)	Estimated bacterial loading (cfu/day)*	Receiving environment
Nancegollan STW	SW6349032620	Biological filtration	60	2.0×10^{11}	Nancegollan Stream
Trewithen Terrace STW	SW5950030800	Biological filtration	7.4	2.4×10^{10}	Unspecified

Data from the Environment Agency

*Faecal coliforms (cfu/day) based on geometric base flow averages from a range of UK STWs providing secondary treatment (Table II.2)

Table II.2: Summary of reference faecal coliform levels (cfu/100 ml) for different sewage treatment levels under different flow conditions.

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Storm overflow (53)	-	-	200	7.2×10^6
Primary (12)	127	1.0×10^7	14	4.6×10^6
Secondary (67)	864	3.3×10^5	184	5.0×10^5
Tertiary (UV) (8)	108	2.8×10^2	6	3.6×10^2

Data from Kay et al. (2008b).
n - number of samples.
Figures in brackets indicate the number of STWs sampled.

Both of these discharges are relatively small, undergo biological filtration, and are located inland. The Nancegollan STW is the larger of the two, and discharges to the upper reaches of the River Hayle catchment. It will therefore add to bacterial concentrations within this watercourse, although some bacterial die-off is anticipated in transit to the estuary. The Trewithen Terrace STW is located over 1 km from the nearest surface watercourse so it is assumed that it discharges to soakaway, and so should be of no impact on coastal waters.

In addition to the continuous sewage discharges, there are 8 intermittent water company discharges associated with the sewerage networks, details of which are shown in Table II.3. No spill records were available for any of these discharges.

Table II.3: Intermittent discharges to the St Ives (Hayle Harbour) catchment

No.	Name	Grid reference	Receiving water
1	East Quay PSEO	SW5575037630	Hayle estuary
2	Hayle STW	SW5468036340	Hayle estuary
3	Holiday Village PSEO	SW6321034940	River Hayle
4	Lelant PSEO	SW5470036940	Hayle estuary
5	Phillack CSO	SW5655738196	Hayle estuary
6	Relistian PSCSO/EO	SW6040036626	Angarrack Stream
7	Towans PSEO	SW5535638713	St Ives Bay
8	Treloweth PSEO	SW5427035540	River Hayle trib.

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The intermittent discharges are mostly in the vicinity of the estuary, with two located further inland. Without any information on spill frequencies it is difficult to assess their significance, aside from noting their locations, and their potential to spill untreated sewage. The East Quay PSEO and the Phillack CSO are of greatest potential impact on the mussel beds by virtue of their locations.

Although the majority of properties within the survey area are served by water company sewerage infrastructure, there are also 170 permitted private discharges. Table II.6 presents details of those consented to discharge of 4 m^3/day or more to water.

Table II.4: Details of private sewage discharges >4 m^3/day to the Hayle Harbour catchment

Ref.	Property served	Location	Treatment type	Max. daily flow (m^3/day)	Receiving environment
A	Bezurrel Farm Barns	SW5986036720	Package plant	9.6	Angarrack Stream trib.
B	Godolphin Cross STW	SW6062031380	Unspecified	17	Hayle trib.
C	The Old Godolphin Stores	SW6091031520	Package plant	4	Hayle trib.

The majority of private discharges are small, serving one or two properties. Where specified, these are generally treated by small septic tanks or package plants. Of the 169 private discharges, 134 discharge to soakaway so should be of no impact on the estuary, assuming they are functioning correctly. Of the 36 discharging to water, 27 discharge to the River Hayle and tributaries with a total consented volume of 53 m^3/day, and 7 discharge to the Angarrack Stream (total consented volume of 21 m3/day). One discharges directly to the estuary at Lelant, and is consented to discharge up to 1 m^3/day of effluent.

Appendix III. Sources and Variation of Microbiological Pollution: Agriculture

Land use in the catchment is principally arable farming. There are also some pastures, mainly in the upper reaches of the catchment, and areas immediately adjacent to the estuary are largely urbanised. Table III.1 presents livestock numbers and densities for the catchment, from the June 2013 census. Geographic assignment of animal counts in this dataset is based on the allocation of a single point to each farm, whereas in reality an individual farm may span the catchment boundary. Nevertheless, Table III.1 should give a reasonable indication of the numbers and types of livestock within the catchment.

Table III.1: Summary statistics from 2013 livestock census for the Hayle catchment

Cattle		Sheep		Pigs		Poultry	
No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)	No.	Density (no/km^2)
5,890	61.4	545	5.7	191	2.0	35,993	375.2

Data from Defra

The concentration of faecal coliforms excreted in the faeces of animals and humans and corresponding loads per day are summarised in Table III.2.

Table III.2: Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

Animal	Faecal coliforms (No./g wet weight)	Excretion rate (g/day wet weight)	Faecal coliform load (No./day)
Chicken	1,300,000	182	2.3×10^8
Pig	3,300,000	2,700	8.9×10^8
Human	13,000,000	150	1.9×10^9
Cow	230,000	23,600	5.4×10^9
Sheep	16,000,000	1,130	1.8×10^{10}

Data from Geldreich (1978) and Ashbolt et al. (2001).

Table III.1 indicates that there are potentially significant numbers of cattle, small numbers of sheep, a few pigs, and several poultry units. No livestock were recorded during the shoreline survey of the perimeter of the estuary.

Grazing animals (sheep and cattle) will directly deposit faeces on pastures, although during the winter cattle may be housed indoors and at these times slurry is collected and stored for later application to fields. Timing of slurry applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Many farms in Cornwall do not have long-term storage capacity for slurries and manure and, therefore, maintain these as a pile in fields (Roderick and Burke, 2004). For this reason, most farmers frequently apply manure and slurries during the winter, throughout the spring (February–March) for spring growth and some are applied in the autumn for winter cereals. Winter spreading is usually more frequent as farmers try to avoid over-topping their slurry stores. Lesser quantities are retained for the late spring and summer for second and third cut silage applications. Numbers of grazing animals are expected to peak following the birth of lambs and calves in the spring, then decline in the autumn as these animals are sent to market. Therefore it is likely that peak levels of contamination from cattle and sheep may arise in the harbour following high rainfall events in the summer, particularly if these have been preceded by a dry period which would allow a build-up of faecal material on pastures, or at a more localised level if wet weather occurs following a slurry application, and this is most likely in the winter or spring.

Manure/slurry from pig and poultry operations is typically collected and subsequently spread on nearby farmland (Defra, 2009) and this may occur at any time of the year. Sewage sludge is usually applied to land in February–March and in September (Lizbe Pilbeam, Natural England, pers. comm.), although it is not known whether this practice occurs within the St. Ives Bay catchment area.

Diffuse contamination from livestock will be carried into the bay via watercourses draining areas of pasture or agricultural land onto which manures have been spread. The extent of this will depend not only on the numbers and distribution of livestock, but also rainfall patterns, soil permeability, slope, and the degree of separation between fields and watercourses. To capture contamination of agricultural origin RMPs should be set in a position which most exposes them to plumes originating from these watercourses.

In conclusion, all significant watercourses draining to the estuary are likely to be impacted by contamination from agricultural sources at times. Contamination from agricultural sources will be carried into coastal waters via rivers and streams and the magnitude of this flux is likely to be highly dependent on rainfall. Some seasonality is expected, possibly with greatest overall inputs to the estuary following summer storms when numbers of animals on pastures are the highest, or on a more localised level in wet weather in the winter and spring from fields where slurry or manure has been recently applied.

Appendix IV. Sources and variation of microbiological pollution: Boats

The harbour at Hayle is mainly used by small fishing boats, as well as a number of small dinghy type pleasure boats. The area is also used for watersports such as kayaking and jetskiing. It is not generally used by visiting yachts as it can be difficult to navigate and access is restricted to higher states of the tide, although they do occasionally use the harbour.

Figure IV.1: Boating activity in Hayle Harbour

The harbour accommodates 27 fishing boats, 2 commercial boats and 107 leisure boats. There are also a number of sports clubs which are licensed to use the harbour, including a jet-ski club, canoe club and the local gig club (ING Real Estate, 2011). The fishing boats are generally small, and most are unlikely to have on board toilets. They moor at the North, East and South Quays. Penpol Creek is used for the mooring of small dinghy type pleasure craft, and again most if not all of these are too small to have on board toilets. Vessels used for watersports (kayaks etc) are also too small to make overboard discharges.

It is therefore concluded that there is likely to be little in the way of overboard discharges within the estuary as the vessels using it are generally too small. It is possible that the occasional larger vessel may visit and potentially make overboard discharges, either whilst tied up at one of the quays or on passage in and out of the area.

Appendix V. Sources and Variation of Microbiological Pollution: Wildlife

The Hayle estuary comprises of a range of habitats including saltmarsh and intertidal mud and sand flats. These features support significant wildlife populations. The area has been designated as a SSSI and most of the estuary is managed as a nature reserve by the RSPB.

The main wildlife population of relevance to shellfish hygiene is overwintering waterbirds (waders and wildfowl). Studies in the UK have found significant concentrations of microbiological contaminants (e.g. faecal coliforms) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). The estuary supports up to 18,000 of these according to its SSSI citation (Natural England, 2011). Over the five winters up to 2012/13 the average peak count was considerably lower, at 6,127 (Austin *et al*, 2014). The largest concentrations occur in Lelant Water and Copperhouse Pool. Numbers are likely to be higher in colder winters as the climate is mild here relative to the rest of the UK. Grazers, such as geese and ducks will forage on grasslands, saltmarsh, and intertidal vegetation. Their faeces will be carried into coastal waters via runoff into tidal creeks, tidal inundation of saltmarsh on larger tides, or may be deposited directly on intertidal flats. Drainage channels from saltmarsh areas or watercourses draining coastal grasslands may carry elevated levels of contamination during the winter. Waders, such as dunlin and oystercatchers feed on invertebrates and so will forage (and defecate) directly on intertidal flats. They may tend to aggregate in certain areas holding the highest densities of bivalves of their preferred size and species, but the various species are likely to have different preferences. Due to the diffuse and spatially unpredictable nature of contamination from wading birds it is difficult to select specific RMP locations to best capture this, although they may well be a significant influence particularly during the winter months.

In addition to overwintering waterbirds, seabirds such as gulls and terns are also present in the area. The Seabird 2000 survey carried out counts of breeding seabirds in the area during the early summer of 1999 (Mitchell *et al*, 2004). During this survey 137 pairs of gulls were recorded nesting around the estuary, mainly within the town of Hayle, but their exact nest sites were not specified. These seabirds are likely to forage widely throughout the area so inputs could be considered as diffuse, but are likely to be most concentrated in the immediate vicinity of the nest sites. Gulls are likely to be present in the area all year round.

There is a grey seal colony at St Ives Bay, which uses haul out sites on Godrevy Island and at Mutton Cove, which is the cove immediately to the east of Godrevy Point. Average numbers are about 31 animals, although more than twice this amount was observed on occasions. They are present all year round, but numbers tend to peak in March (Godrevy

Seal Group, 2005). Greatest and most consistent impacts will be in the immediate vicinity of their haul out sites. Whilst it is likely they enter the estuary on occasion, their presence will be spatially and temporally unpredictable, and their impacts can be considered as diffuse and minor at most. No other wildlife populations which may have a potentially significant influence on levels of contamination within shellfish in the Hayle estuary have been identified.

Appendix VI. Meteorological Data: Rainfall

The monthly rainfall data for the St Erth weather station are shown in Figure VI.1.

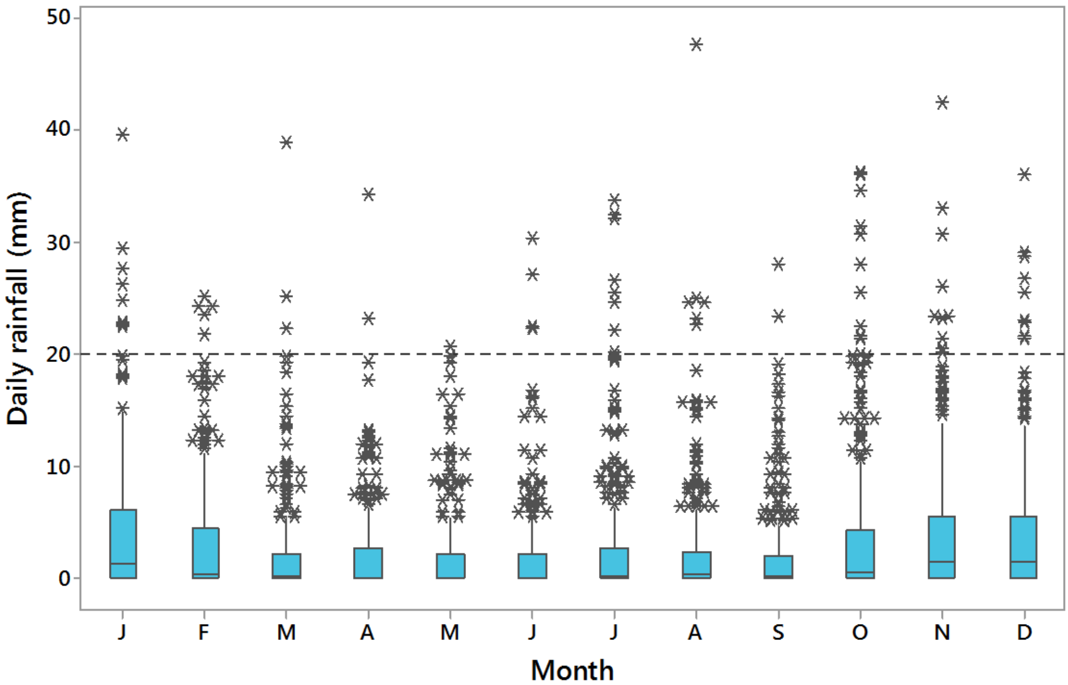

Figure VI.1: Boxplot of daily rainfall totals at St Erth, July 2005 to July 2014.
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The St Erth weather station received an average of 1065 mm per year between 2005 and 2014. The autumn and winter months (October to February inclusive) had the highest average rainfall, while May had the lowest average rainfall. Daily totals of over 20 mm were recorded on 2% of days, and in every month of the year. No rainfall was recorded on 41% of days.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSOs) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al*., 2003). Representative monitoring points located in parts of shellfish beds closest to rainfall dependent discharges and freshwater inputs will reflect the combined effect of rainfall on the contribution of individual pollution sources.

Appendix VII. Meteorological Data: Wind

The southwest is one of the more exposed areas of the UK. The strongest winds are associated with the passage of deep depressions and the frequency and strength of depressions is greatest in the winter so mean wind and maximum gust speeds are strongest at this time of year. As Atlantic depressions pass the UK, the wind typically starts to blow from the south or southwest, but later comes from the west or northwest as the depression moves away. The frequency and strength of depressions is greatest in the winter half of the year and this is when mean speeds and gusts are strongest (Met Office, 2012). Another seasonal pattern noted was the increased prevalence of winds from the north east during spring. Wind data for the period January 1992–December 1998 from Culdrose meteorological station, about 20 km to the south east of Hayle is presented in Figure VII.1.

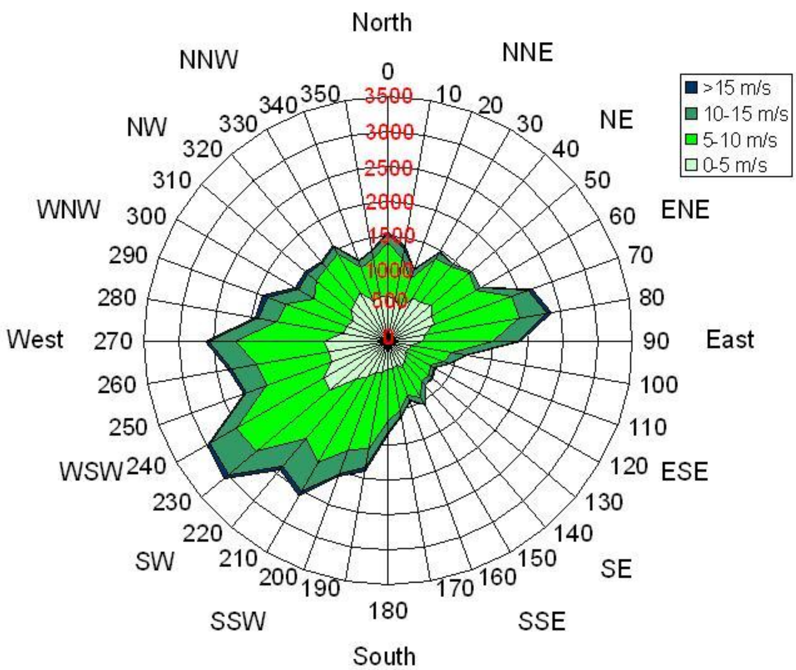

Figure VII.1: Wind rose showing mean wind speed direction by hourly count over the period January 1992–December 1998.

Derived from Culdrose meteorological station.

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Figure VII.1 indicates that the prevailing wind direction at Culdrose is from the south west. The Hayle estuary is enclosed and so is afforded shelter from winds from all directions, although winds from the north will blow up it. Strong winds may modify water circulation and generate some limited wave action in the larger water bodies within the estuary, such as Lelant Water and Copperhouse Pool.

Appendix VIII. Hydrometric Data: Freshwater Inputs

The hydrological catchment draining to the Hayle estuary, as estimated from topography, covers an area of 96 km^2. The two main freshwater inputs are the River Hayle and the Angarrack Stream.

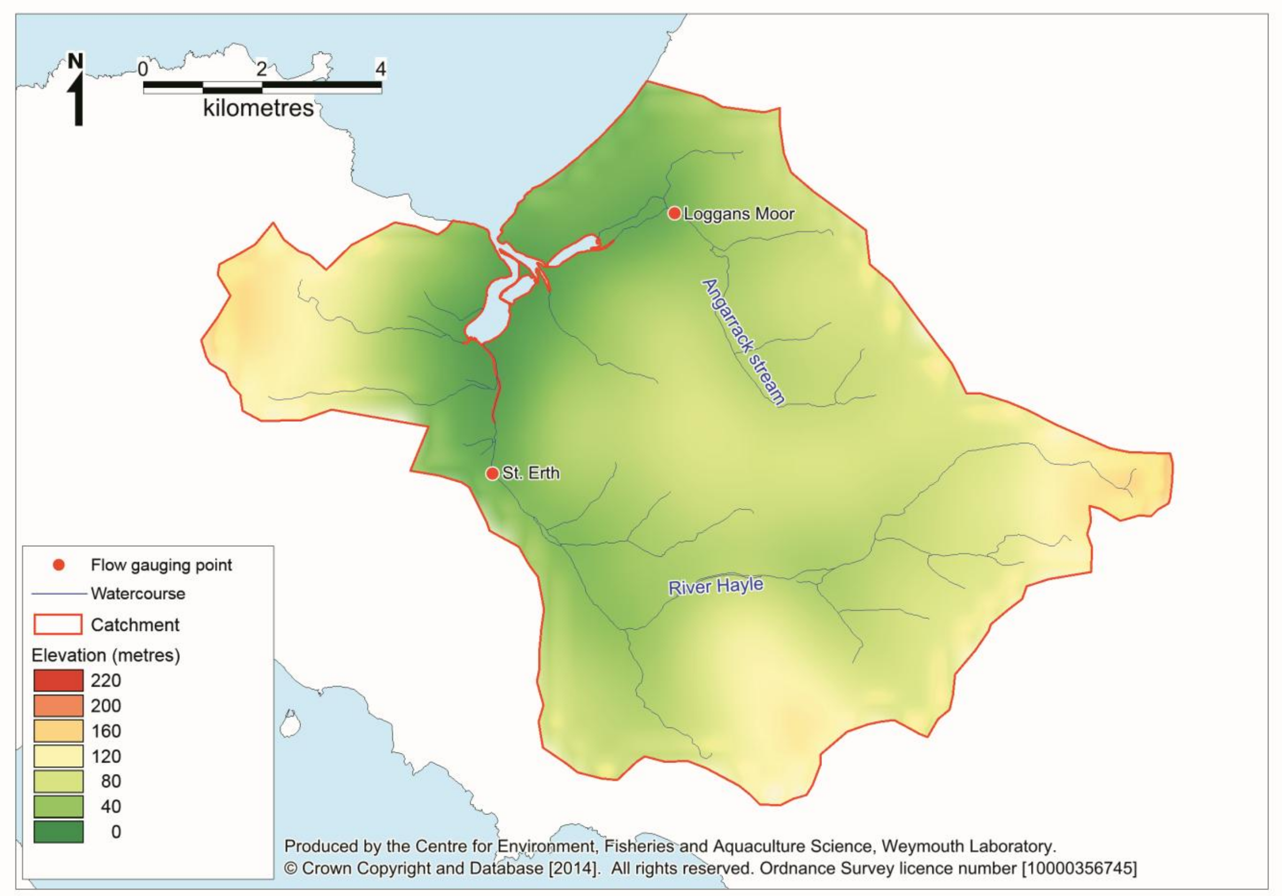

Figure VIII.1: Freshwater inputs to the Hayle estuary

Land within the catchment is mainly used as pasture or for arable crops. There are also some urban areas which are mainly located around the estuary. The maximum elevation is just over 200 m, and the hydrogeology is described as impermeable throughout. However, the St Erth catchment is described as slow responding due to significant groundwater storage, as is consistent with its base flow index[2] of 0.83 (NERC, 2012).

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[2] The base flow index may be considered as a measure of the proportion of the river runoff that derives from stored sources (groundwaters and lakes/reservoirs).

Flow gauging records were available for two sites within the catchment. At St. Erth on the River Hayle, records of mean daily flow from January 2005 to July 2014 were available. At Loggans Moor on the Angarrack Stream flow estimates made at 15 minute intervals were available for March to July of 2008. These are not presented in Table VIII.1 or Figure VIII.2, but for comparison, the average flow recorded here during this period was 0.3 m^3/s, whereas it was roughly double this (0.58 m^3/s) at St. Erth through the same period.

Table VIII.1: Summary flow statistics for the St Erth gauging station (2005-2014)

Watercourse	Station Name	Catchment Area (Km^2)	Mean annual rainfall (mm)	Mean Flow (m^3s^{-1})	Q95[1] (m^3s^{-1})	Q10[2] (m^3s^{-1})
Hayle	St Erth	47.6	1,077	0.95	0.25	1.94

[1]Q95 is the flow that is exceeded 95% of the time (i.e. low flow). [2]Q10 is the flow that is exceeded 10% of the time (i.e. high flow).

Data from NERC, 2012 and contains Environment Agency information © Environment Agency and database right

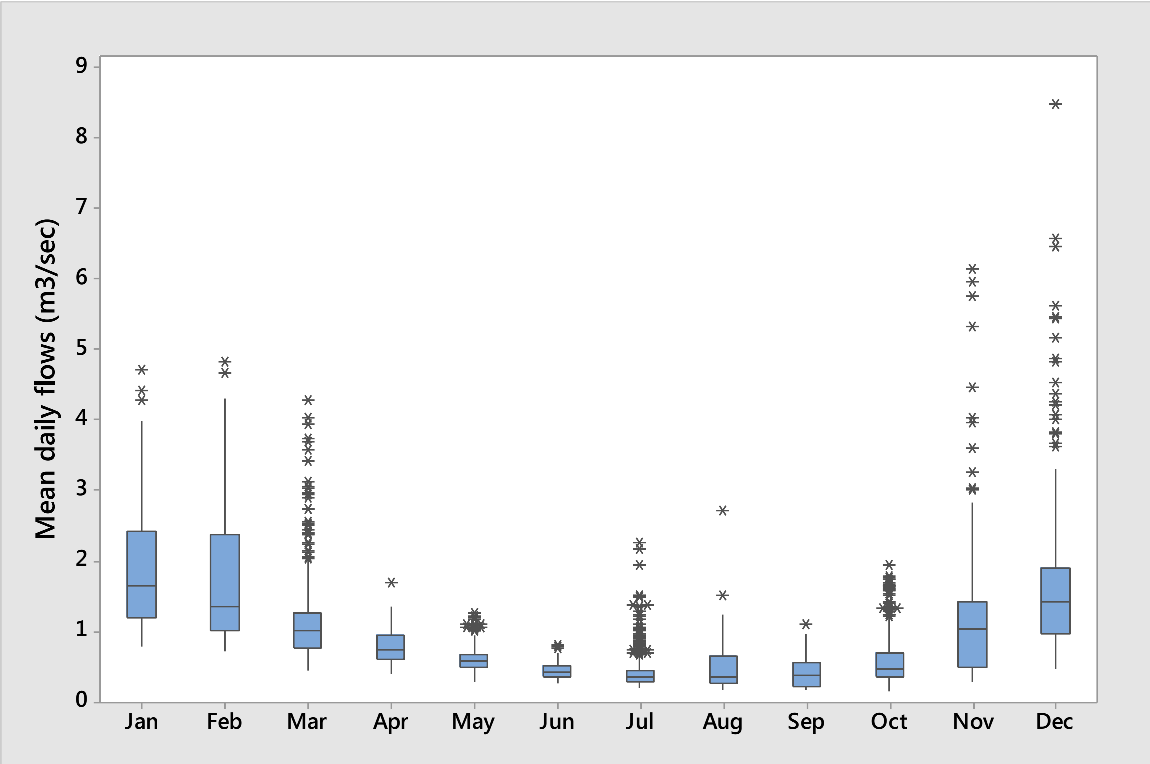

Figure VIII.2: Boxplots of mean daily flows by month for the St Erth gauging station
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Discharge at St. Erth was lowest on average from May to September and highest on average during December and January, and elevated flow events were rare from April to October. The seasonal pattern and the relatively low range of flows each month is consistent with a significant groundwater component to discharge.

During the shoreline survey of the perimeter of the estuary, samples and spot flow measurements were made where possible from all flowing freshwater inputs.

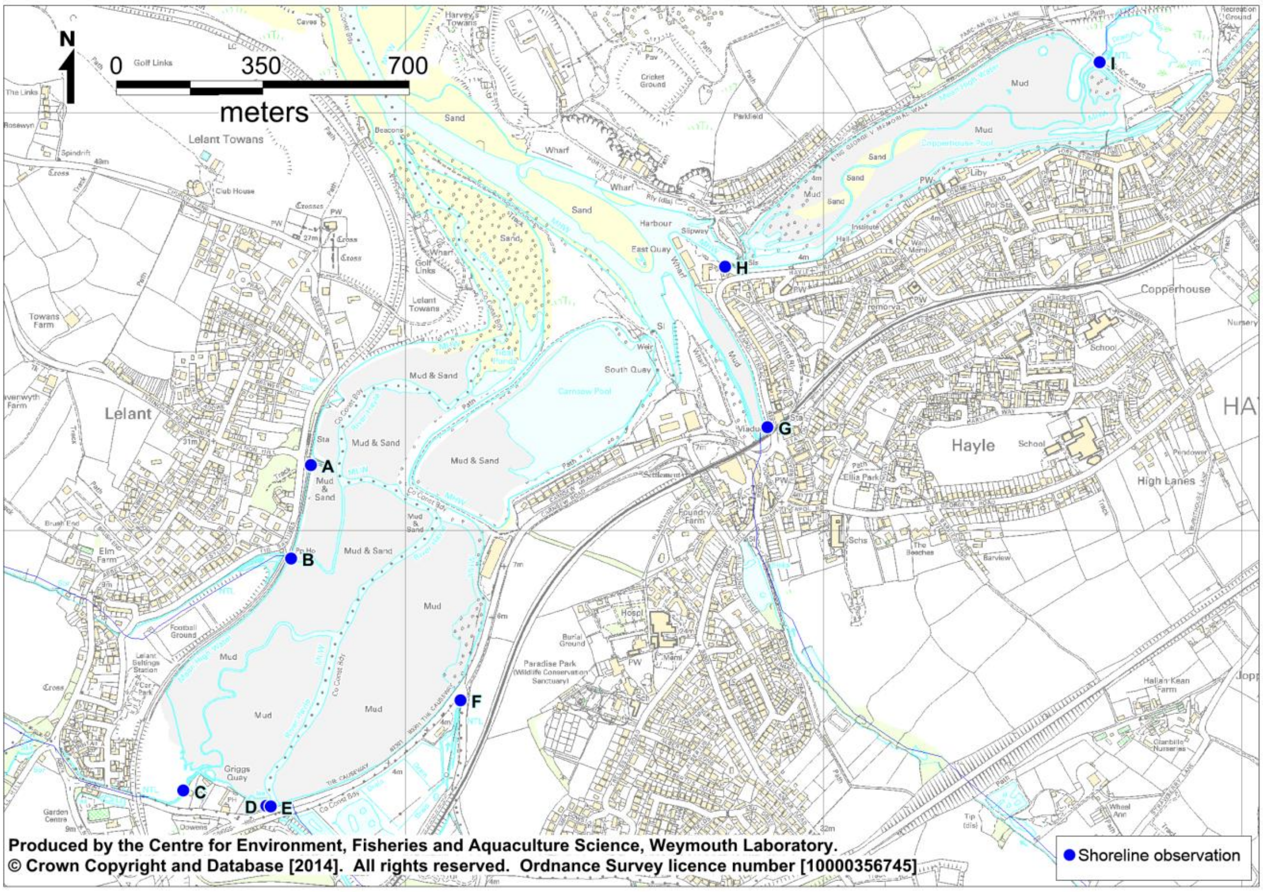

Figure VIII.3: Locations of shoreline stream samples

Table VIII.2: Shoreline survey stream sample results

Ref	Description	Flow (m^3/s)	*E. coli* concentration (cfu/100 ml)
A	Drainage pipe (flowing)	0.001	19,000
B	Stream (discharging via pipe with flap)	Not measured	2,100
C	Stream (flowing)	Not measured	3,300
D	Drainage pipe (flowing)	Not measured	8,500
E	River Hayle (flowing)	Not measured	3,100
F	Stream (flowing)	Not measured	5,100
G	Penpol River (flowing)	Not measured	4,500
H	Drainage pipe (flowing)	Not measured	290,000
I	Loggans Mill Leat (flowing)	Not measured	840

Although all flowing surface water inputs with the exception of the Angarrack Stream were successfully sampled, the surveyor was only able to access one of these to undertake a spot flow measurement. Without information on discharge rates it is not possible to assess the relative importance of these watercourses by calculating the bacterial loadings they were delivering at the time. The results show moderate concentrations of faecal coliforms in most freshwater inputs, including the River Hayle. The Angarrack Stream was not sampled, but it is likely to be of a similar microbial composition to Loggans Mill Leat, which draws water from it. Of particular relevance to the hygiene assessment was a surface drainage pipe from the East Quay, just downstream of the Copperhouse Pool sluice (H). A sample from this contained 290,000 faecal coliforms/100 ml, and it was described by the surveyor as flowing rapidly. The result suggests that this pipe was receiving some foul water input at the time, and if this occurs on a continuous basis it is likely to be a significant contaminating influence on the mussel bed here. The Harbourmaster reports that there is a constant discharge from this pipe.

Appendix IX. Hydrography

IX.1. Bathymetry

The Hayle estuary covers an area of 149 Ha, of which 91% is intertidal (Futurecoast, 2002). It has been significantly modified over the centuries with water-retaining bunds, storage reservoirs, and extensive sea defences. There are no detailed bathymetric charts of the Hayle estuary, so an aerial photograph is presented in Figure IX.1 instead.

The estuary essentially consists of four hydrographically distinct water bodies (Lelant Water, Carnsew Pool, Penpol Creek and Copperhouse Pool) which converge in the harbour area to form a single channel which connects to the open waters of St Ives Bay. The largest of these is Lelant Water, which is comprised of intertidal mudflats, and receives freshwater input from the River Hayle and several smaller watercourses. It converges with the outer estuary channel a significant distance further down estuary (>500 m) than the other three due to the presence of a man made wall (the Middle Weir). Carnsew Pool is a manmade enclosed pool, which connects to the harbour area to the west of South Quay over a weir and through two tunnels (cover photograph). The entrance to the pool is a significant constriction that causes a delay in tide and an acceleration in tidal streams. The cill of the weir is at a level of about 3.9 m above chart datum (Sea Sediments, 1983) so water is retained in the northern half of the pool at low tide. A second connection with sluice gates has recently been reinstated, about 100 m to the south of the tunnels. There are no freshwater inputs to Carnsew Pool. Penpol Creek is a narrow intertidal creek which receives a small freshwater input at its head, and connects to the harbour area between East Quay and South Quay.

Copperhouse Pool is largely composed of intertidal mudflats and drains to the harbour area through a sluice gate between the East Quay and North Quay. The sluice is operated by the Environment Agency for flood defence purposes, and is generally left open but may be closed during the flood tide on spring tides. It is also used to impound water within the pool several times of year for various events such as boat races. There will be an acceleration of flows through the sluice as it is a constriction. Copperhouse Pool receives two freshwater inputs, the Loggans Mill Leat and the Angarrack Stream, both of which drain to the upper reaches of the pool. The latter has been canalised in its lower reaches and follows a dredged channel which runs the length of the south shore of the pool. The Harbour area and outer estuary channel are both shallow, and whilst the area does not dry out fully, bed elevations are higher than chart datum throughout (Hayle Harbour Authority, 2011). Regular dredging is required to maintain navigability.

Historically, sluice gates at Carnsew and Copperhouse Pools were closed at high tide to hold back water in the two pools, which was subsequently released later during the ebb tide. The effect of this was to flush sediment from the harbour area out into the bay. It is planned that sluicing will be reinstated following the recent reinstallation of a sluice at Carnsew Pool, to reduce reliance on dredging. Further gates will have to be installed on the Carnsew tunnels. This will result in a significant increase in water flows across the mussel beds, which may scour them from some areas and result in a change in their spatial distribution. Sluicing will be restricted to spring tides from April to August for conservation reasons (Buro Hapold, 2011).

Figure IX.1: Aerial photograph of the Hayle Estuary
Bing Maps

IX.2. Tides and Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The tidal amplitude in the area is large, and this drives extensive water movements within the estuary.

Table IX.1: Tidal levels and ranges at St Ives

Port	Height above chart datum (m)				Range (m)	
	MHWS	MHWN	MLWN	MLWS	Spring	Neap
St Ives	6.6	4.9	2.4	0.8	5.8	2.5

Data from Admiralty TotalTide©

Tides in the estuary are bidirectional, flooding up the estuary and its various arms, then draining back out in the opposite direction on the ebb. Therefore, the mussel beds will be mainly subject to contamination from sources draining to their respective arms, and those discharging to the main channel down-estuary. The mussels down from the Copperhouse Sluice will be mainly influenced by sources to Copperhouse Pool on the ebb tide, and sources to the North and East Quays and outer Harbour on the flood tide. The mussels at Carnsew Pool will be mainly influenced by sources to Carnsew Pool on the ebb tide, and sources to the East and South Quays, and outer Harbour on the flood. Contamination from sources discharging to Penpol Creek and Lelant Water, will be of little influence on either, although it may be carried back towards them in a much more dilute form when the tide turns after low water. Peak tidal current velocities reach 2 m/s within a constriction in the outer estuary (adjacent to the northern end of the Middle Weir) but are generally much slacker in other areas. Current velocities are 2-3 times greater on spring tides compared to neap tides (Sea Sediments, 1983).

Circulation patterns in estuaries may be modified by density effects arising from inputs of freshwater. Freshwater inputs are low in relation to the volumes of water exchanged tidally, so the estuary as a whole is considered well mixed (Futurecoast, 2002). The main freshwater inputs are to the head of Lelant Water and the head of Copperhouse Pool. During periods of high runoff salinity in the upper reaches of Lelant Water may drop as low as 29 ppt on springs and 15 ppt on neap tides. Salinity stratification structures may therefore develop in the upper areas of both Lelant Water and also probably Copperhouse Pool at such times (Sea Sediments, 1983). Density effects will drive a net seaward flow of less saline water at the surface, with a corresponding return of more saline water at depth. Higher levels of runoff borne contamination will be entrained towards the surface. However, this is unlikely to occur to any degree in the vicinity of the mussels beds. There are no freshwater inputs to Carnsew Pool, and water draining from both Carnsew and Copperhouse Pool will be subject to turbulent mixing as it passes through their respective outlets.

Strong winds will modify surface currents. Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive surface water currents of about 0.5 m/s. These create return currents which may travel lower in the water column or along sheltered margins. The estuary is afforded some shelter from winds from all directions by the surrounding land. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great number of scenarios may arise. The prevailing south westerly winds for example will tend to push surface water down Carnsew Pool, but up Copperhouse Pool. Where strong winds blow across a sufficient distance of water they may create wave action. Where these waves break contamination held in intertidal sediments may be re-suspended. Waves from St Ives Bay will not penetrate into the estuary, so any waves here will be generated locally. As the fetches are small, particularly in the vicinity of the mussel beds, it is anticipated that this effect is of relatively low significance here.

Appendix X. Microbiological Data: Seawater

While there are several bathing water monitoring points in St Ives Bay, none of these are of direct relevance to the Hayle estuary. There are no shellfish waters in the area, and no other sources of microbiological testing results within the estuary have been identified.

Appendix XI. Microbiological Data: Shellfish Flesh

There are three RMPs in Hayle Harbour, all of which are for mussels. Their locations are shown in Figure XI.1, and summary statistics for sampling results are presented in Table XI.1.

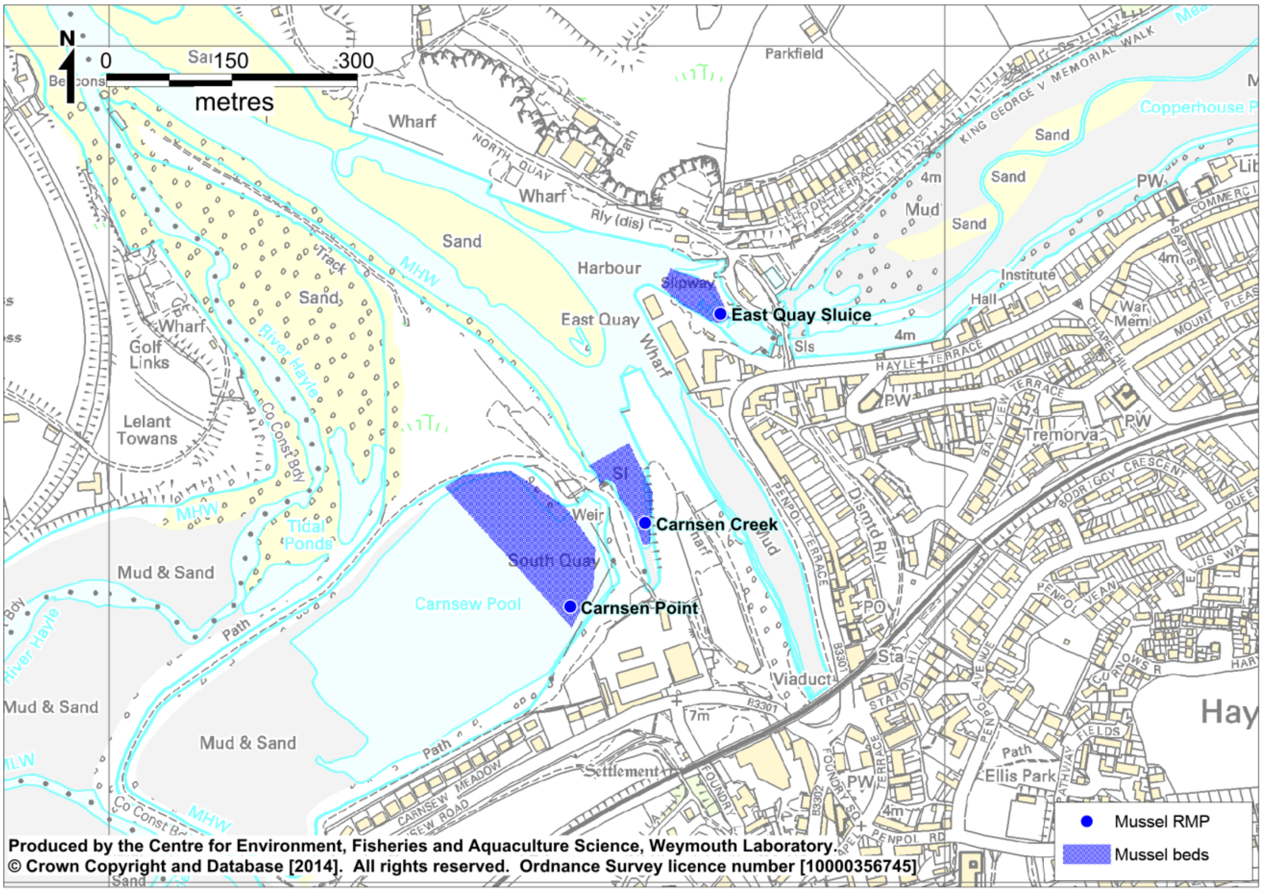

Figure XI.1: Mussel RMPs.

Table XI.1: Summary statistics of *E. coli* results (MPN/100 g) from Hayle Harbour

Site	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4,600	% over 46,000
Carnsen Point	Mussel	2	16/07/2012	30/07/2012	185.2	70	490	50.0	0.0	0.0
Carnsen Creek	Mussel	2	16/07/2012	30/07/2012	426.3	230	790	100.0	0.0	0.0
East Quay Sluice	Mussel	2	16/07/2012	30/07/2012	1,454.6	230	9,200	100.0	50.0	0.0

Only two samples were taken from each monitoring point, all of which were taken in July 2012. Sampling was then suspended pending a decision from the competent authority (the FSA) concerning the status of metal contamination in the area. The highest individual result, which was the only result exceeding 4,600 *E. coli* MPN/100 g, was taken from East Quay Sluice.

Appendix XII. Shoreline Survey Report

Date (time):
07/10/2014 (08:00 – 15:00)

Cefas Officers:
Rachel Parks

Local Enforcement Authority Officers:
Terry Stanley (Cornwall Port Health Authority)
Emma Walker (Cornwall Port Health Authority)

Area surveyed:

Hayle Harbour, Dynamite Quay to Black Cliff Beach, including Copperhouse Pool and Carnsew Pool

Weather:
7th October – Sunny spells 12.2 °C, wind bearing 0° at 24 km/h

Tides:
Admiralty TotalTide© predictions for St. Ives. All times are BST.

07/10/2014 (BST)	
High 04:45	6.6 m
High 17:07	7.0 m
Low 11:15	0.9 m
Low 23:38	0.6 m

XII.1. Objectives:

The shoreline survey aims to obtain samples of freshwater inputs to the area for bacteriological testing; confirm the location of previously identified sources of potential contamination; locate other potential sources of contamination that were previously unknown and find out more information about the fishery. A full list of recorded observations is presented in

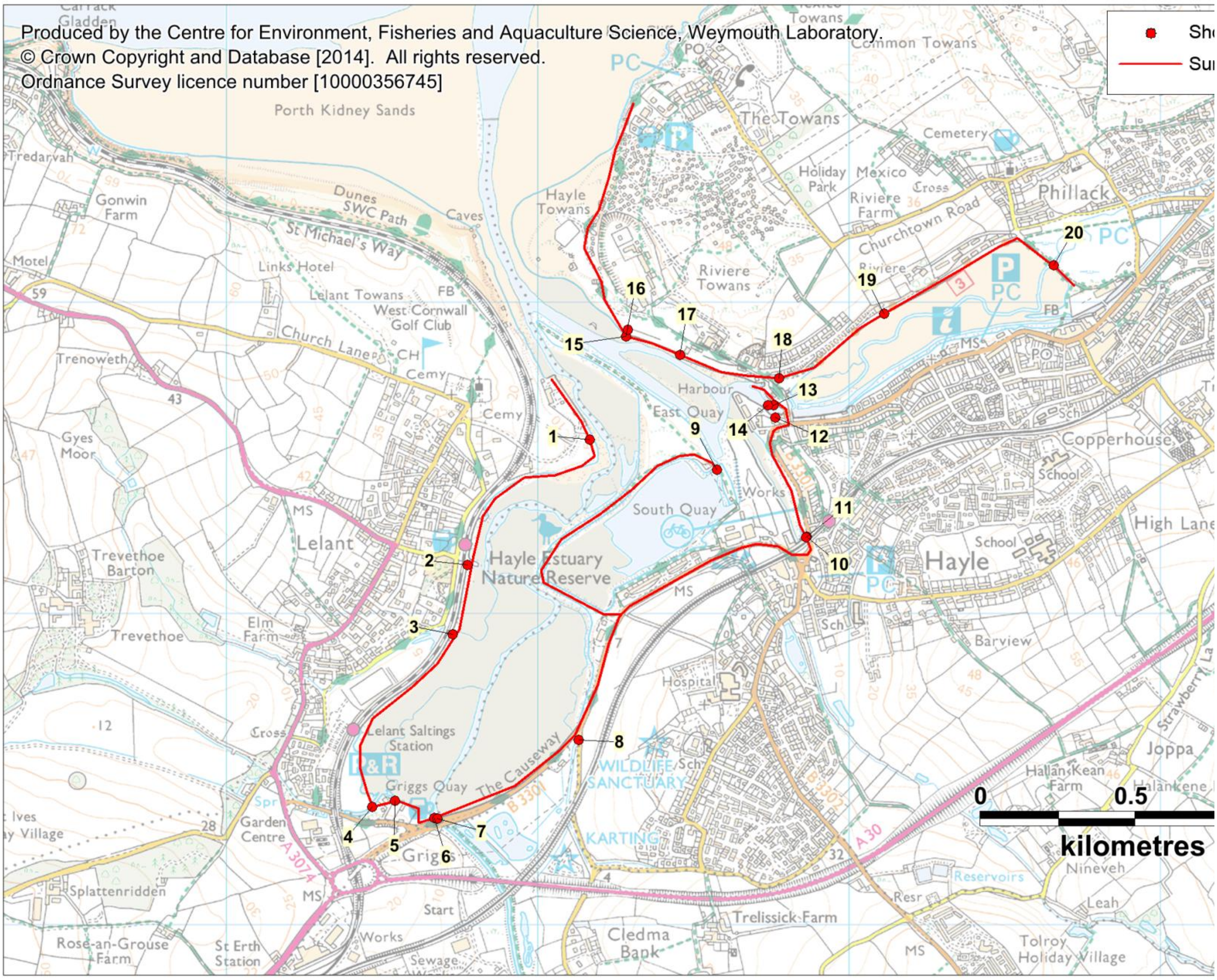

Figure XII.1: Locations of Shoreline Observations (Table XII.3 for details)

Table XII.1 and the locations of these observations are shown in Figure XII.1. The shoreline survey was undertaken over one day by foot.

XII.2. Description of Fishery

During the visit it was possible to meet with the applicant (Hayle Harbourmaster). The mussels are to be harvested by hand downstream of Copper House outlet channel, and in Carnsew Pool and outlet channel, although a high proportion of stocks are located subtidally. It is envisaged that a small number of local fishermen will operate the fishery in a sustainable manner, with input from the IFCA. In the future, it is possible that mussel culture on suspended ropes may be attempted here. At the time of survey, there were large quantities of mussels in the two tunnels which connect Carnsew Pool to Hayle Harbour. Approximately 20 tonnes were cleared from these tunnels a few years ago, and these tunnels will require clearing again before new sluice gates can be installed. Once a classification is received for mussels in Hayle Harbour they will be sent for depuration at a local depuration facility before being sold on the market to local restaurants and businesses.

XII.3. Sources of contamination

Sewage discharges

The outlet of East Quay PSEO was observed (observations 6). At this location there were two pipes. The larger of the two was believed to be the pumping station outfall, and was not flowing at the time. A smaller pipe about 10 m to the east was flowing and gave off a strong sewage smell. A sample taken from this pipe revealed an elevated *E. coli* result of 290,000 cfu/100 ml. A flow reading was not possible as the discharge was too large.

No other discharges were identified. Cotton buds were seen at observation 16 which indicates that there may have been some sewage contamination that had washed on to the beach in the past.

Freshwater inputs

The River Hayle was sampled (observation 7, sample ID H05) on the survey and had an *E. coli* concentration of 3,300 cfu/100 ml. Five smaller streams were also observed (Observation 3, 4, 8, 10 and 20). The streams had *E. coli* concentrations ranging between 840 and 5,100 cfu/100 ml. It was not possible to undertake spot flow gauging on most freshwater inputs for access reasons.

Livestock

No livestock were observed on the shoreline survey.

Wildlife

Aggregations of birds (between 30 and 400 individuals) were observed at three locations within the estuary (observations 1, 7 and 19).

Dog walking was evident along the footpath surrounding Carnsew Pool and between Black Cliff beach and along the footpath which runs alongside Copperhouse Pool.

XII.4. Shellfish Samples

Two mussel samples were collected as part of a bacteriological survey, and a water sample was also collected in the immediate vicinity of each mussel sample location. Samples were collected from Carnsew Pool and the mussel bed just downstream from the

Copperhouse Sluice (Table XII.3 for details). The samples from Carnsew Pool contained 4,600 *E. coli* MPN/100 g in the shellfish flesh and 70 cfu/100 ml in the water sample. Downstream of the Copperhouse Sluice the mussel sample contained 160,000 *E. coli* MPN/100 g and the water sample 3,900 cfu/100 ml. Water samples from the Copperhouse Sluice channel were taken just after low water and downstream from the surface water pipe and had an elevated *E. coli* concentration of 290,000 cfu/100 ml. An additional water sample was taken from the opposite side of the channel downstream of the Copperhouse Sluice and gave an *E. coli* concentration of 780 cfu/100 ml suggesting the impacts from the pipe here were mainly localised to the east side of the channel.

A shellfish sample could not be taken from the mussel bed just downstream from the Carnsew Sluice, as the area was covered by deep water at low tide and therefore inaccessible by foot.

The results for metals and PAHs analyses of shellfish samples collected as part of the bacteriological survey have been reported separately to FSA as their consideration in detail is outside the remit of this report. The results were satisfactory.

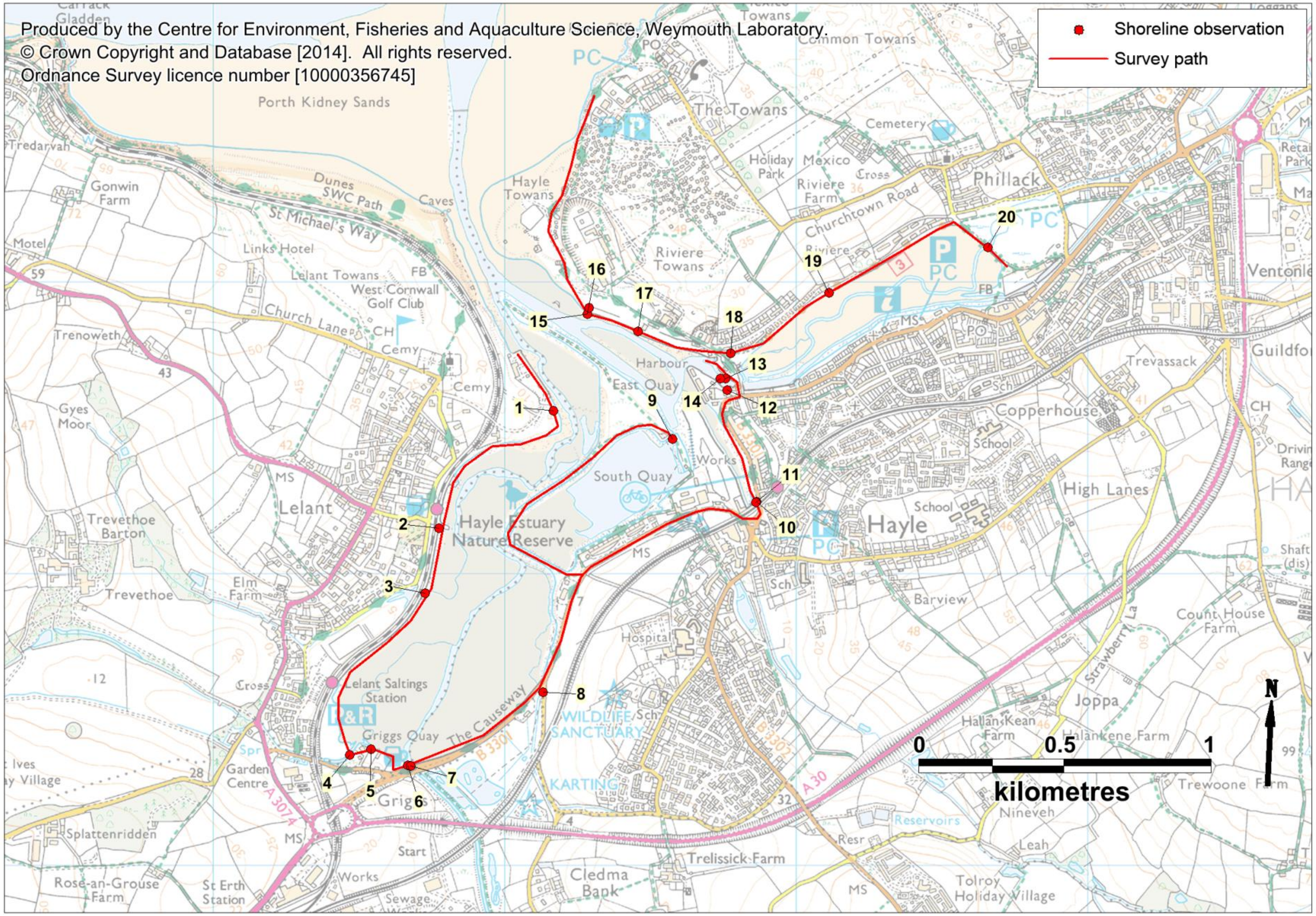

Figure XII.1: Locations of Shoreline Observations (Table XII.3 for details)

Table XII.1: Details of Shoreline Observations

Observation no	NGR	Date	Time	Description	Photo
1	SW5516737560	07/10/2014	08:46	~ 30 gulls	
2	SW5477337158	07/10/2014	08:59	Drainage pipe under railway line, flowing H01 (0.01m x 0.11m x 0.62m)	Figure XII.3
3	SW5472536934	07/10/2014	09:08	Stream discharging via large pipe with flap, flowing H02	Figure XII.4
4	SW5446836379	07/10/2014	09:27	Stream flowing H03	
5	SW5454136398	07/10/2014	09:40	Old pipe trickling (disused?)	Figure XII.5
6	SW5466636343	07/10/2014	09:45	Large pipe with grid, possible intermittent, flowing H04	Figure XII.6
7	SW5467636341	07/10/2014	09:49	River Hayle, flowing - H05. ~400 birds on the flats	Figure XII.7
8	SW5513036595	07/10/2014	10:05	Stream, flowing H06	Figure XII.8
9	SW5557537464	07/10/2014	10:49	Mussel sample and water sample H07 from Carsen Pool	Figure XII.9
10	SW5586337248	07/10/2014	11:23	2 x pipes. 1 with flap not flowing & 1 with sluice gate flowing H08	Figure XII.10
11	SW5586237246	07/10/2014	11:28	Drainage pipe, not flowing	
12	SW5577137680	07/10/2014	12:10	2 x large pipes (East Quay Emergency Overflow pipe and surface water pipe). Surface water pipe flowing H08B (sewage smell present)	Figure XII.11
13	SW5575637671	07/10/2014	12:27	Water sample from H09 from Copperhouse Pool	
14	SW5573937670	07/10/2014	12:31	Mussel sample and water sample H10 from Copperhouse Pool	
15	SW5528337892	07/10/2014	14:27	Pipe with flap dripping	Figure XII.12
16	SW5528837913	07/10/2014	14:29	Cotton wool buds along high water mark	
17	SW5545737833	07/10/2014	14:33	Large pipe with flap, not flowing	Figure XII.13
18	SW5577537757	07/10/2014	14:42	South West Water Pumping Station	Figure XII.14
19	SW5611337966	07/10/2014	14:52	~ 50 gulls	
20	SW5665738121	07/10/2014	15:02	Unnamed stream flowing H11	Figure XII.15

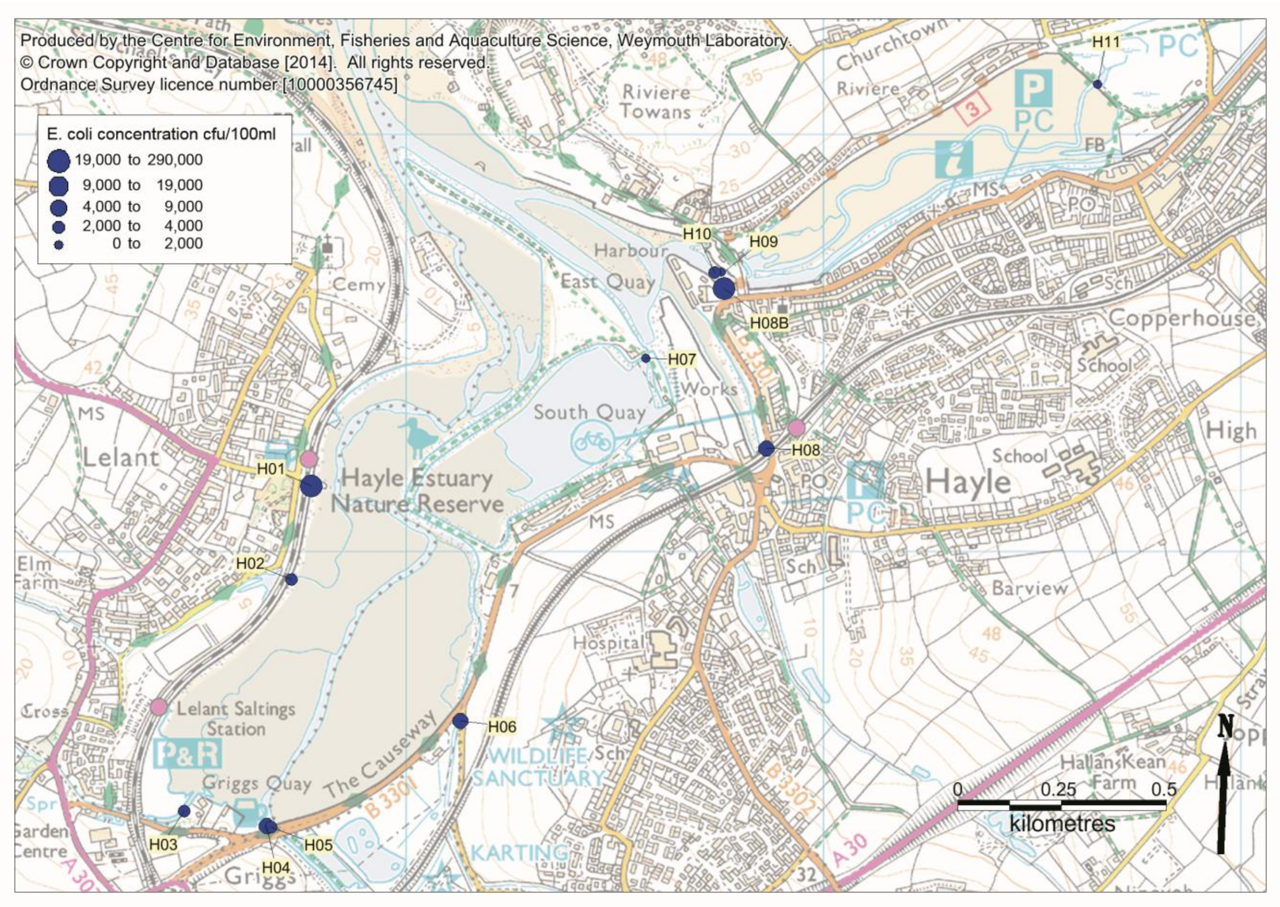

Figure XII.2: Water sample results (Table XII.2 and Table XII.2 for details)

Table XII.2: Water sample *E. coli* results, spot flow gauging results and estimated loadings.

Sample ID	Observation number	Description	Type	Flow (m^3/s)	*E. coli* conc. (cfu/100 ml)	*E. coli* loading (cfu/day)
H01	2	Drainage pipe	Freshwater	0.001	19,000	$1.2x10^{10}$
H02	3	Stream discharging via pipe with flap	Freshwater	-	2,100	-
H03	4	Stream flowing	Freshwater	-	3,300	-
H04	6	Large pipe with grid, flowing	Freshwater	-	8,500	-
H05	7	River Hayle	Freshwater	-	3,100	-
H06	8	Stream, flowing	Freshwater	-	5,100	-
H07	9	Carnsew Pool	Seawater	-	70	-
H08	10	Stream flowing through pipe/sluice	Freshwater	-	4,500	-
H08B	12	Surface water pipe flowing rapidly	Freshwater	-	290,000	-
H09	13	Downstream Copperhouse sluice	Seawater	-	780	-
H10	14	Downstream Copperhouse sluice	Seawater	-	3,900	-
H11	20	Stream flowing	Freshwater	-	840	-

Table XII.3 Shellfish sample *E.coli* results

Sample ID	Observation number	Date and Time	*E. coli* concentration (MPN/100 g)	NGR
H07	9	07/10/14 10:49	4,600	SW5557537464
H10	14	07/10/14 12:31	160,000	SW5573937670


Figure XII.3


Figure XII.4

Figure XII.5

Figure XII.6

Figure XII.7

Figure XII.8


Figure XII.9


Figure XII.10

Figure XII.11

Figure XII.12

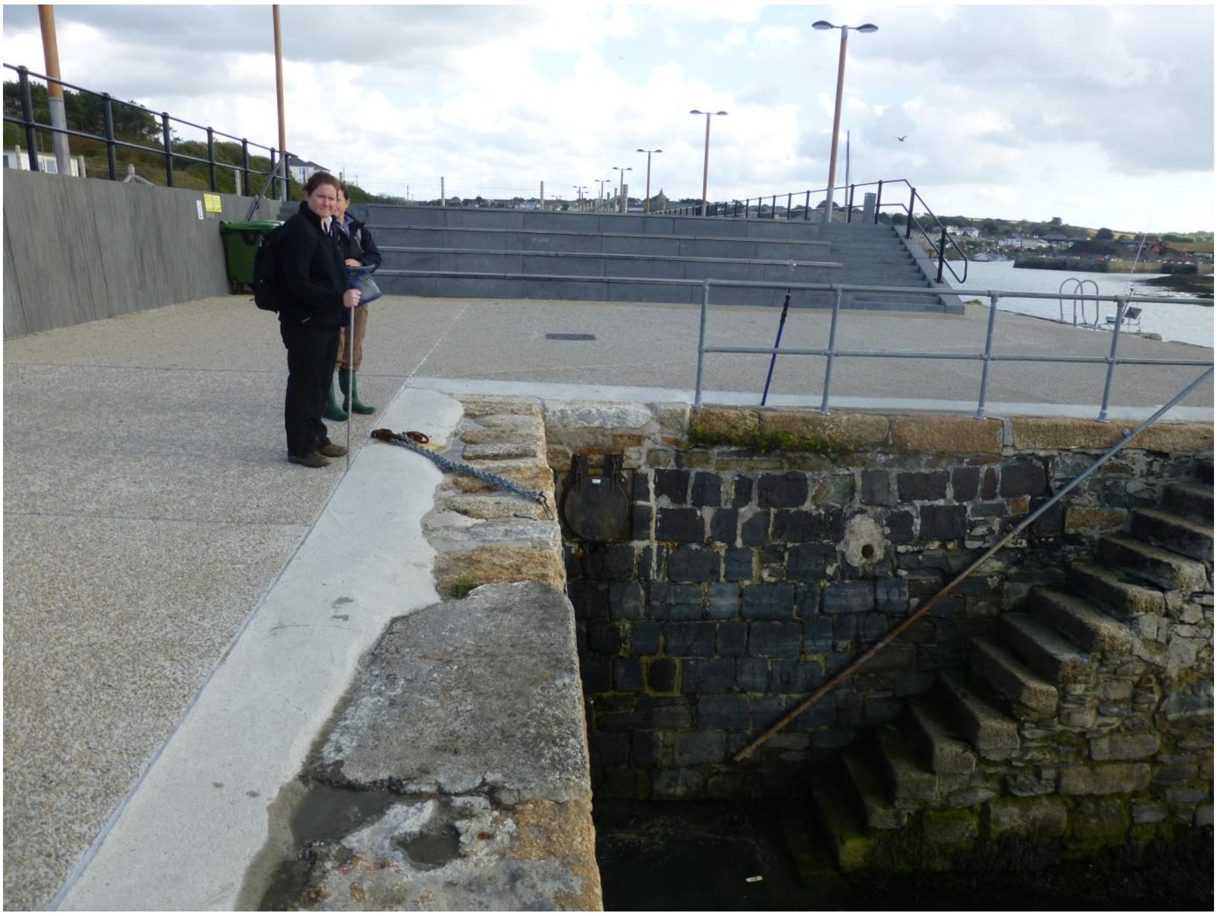

Figure XII.13

Figure XII.14

Figure XII.15

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List of Abbreviations

AONB	Area of Outstanding Natural Beauty
BMPA	Bivalve Mollusc Production Area
CD	Chart Datum
Cefas	Centre for Environment Fisheries & Aquaculture Science
CFU	Colony Forming Units
CSO	Combined Sewer Overflow
CZ	Classification Zone
Defra	Department for Environment, Food and Rural Affairs
DWF	Dry Weather Flow
EA	Environment Agency
E. coli	Escherichia coli
EC	European Community
EEC	European Economic Community
EO	Emergency Overflow
FIL	Fluid and Intravalvular Liquid
FSA	Food Standards Agency
GM	Geometric Mean
IFCA	Inshore Fisheries and Conservation Authority
ISO	International Organization for Standardization
Km	Kilometre
LEA (LFA)	Local Enforcement Authority formerly Local Food Authority
M	Million
M	Metres
Ml	Millilitres
Mm	Millimetres
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MPN	Most Probable Number
NM	Nautical Miles
NRA	National Rivers Authority
NW IFCA	North Western Inshore Fisheries and Conservation Authority
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
ppt	parts per thousand
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SHS	Cefas Shellfish Hygiene System, integrated database and mapping application
SSSI	Site of Special Scientific Interest
STW	Sewage Treatment Works
TACs	Total Allowable Catches
UV	Ultraviolet
WGS84	World Geodetic System 1984

Glossary

Bathing Water	Element of surface water used for bathing by a large number of people. Bathing waters may be classed as either EC designated or non-designated OR those waters specified in section 104 of the Water Resources Act, 1991.
Bivalve mollusc	Any marine or freshwater mollusc of the class Pelecypoda (formerly Bivalvia or Lamellibranchia), having a laterally compressed body, a shell consisting of two hinged valves, and gills for respiration. The group includes clams, cockles, oysters and mussels.
Classification of bivalve mollusc production or relaying areas	Official monitoring programme to determine the microbiological contamination in classified production and relaying areas according to the requirements of Annex II, Chapter II of EC Regulation 854/2004.
Coliform	Gram negative, facultatively anaerobic rod-shaped bacteria which ferment lactose to produce acid and gas at 37°C. Members of this group normally inhabit the intestine of warm-blooded animals but may also be found in the environment (e.g. on plant material and soil).
Combined Sewer Overflow	A system for allowing the discharge of sewage (usually dilute crude) from a sewer system following heavy rainfall. This diverts high flows away from the sewers or treatment works further down the sewerage system.
Discharge	Flow of effluent into the environment.
Dry Weather Flow (DWF)	The average daily flow to the treatment works during seven consecutive days without rain following seven days during which rainfall did not exceed 0.25 mm on any one day (excludes public or local holidays). With a significant industrial input the dry weather flow is based on the flows during five working days if production is limited to that period.
Ebb tide	The falling tide, immediately following the period of high water and preceding the flood tide.
EC Directive	Community legislation as set out in Article 189 of the Treaty of Rome. Directives are binding but set out only the results to be achieved leaving the methods of implementation to Member States, although a Directive will specify a date by which formal implementation is required.
EC Regulation	Body of European Union law involved in the regulation of state support to commercial industries, and of certain industry sectors and public services.
Emergency Overflow	A system for allowing the discharge of sewage (usually crude) from a sewer system or sewage treatment works in the case of equipment failure.
Escherichia coli (*E. coli*)	A species of bacterium that is a member of the faecal coliform group (see below). It is more specifically associated with the intestines of warm-blooded animals and birds than other members of the faecal coliform group.
E. coli O157	E. coli O157 is one of hundreds of strains of the bacterium Escherichia coli. Although most strains are harmless, this strain produces a powerful toxin that can cause severe illness. The strain O157:H7 has been found in the intestines of healthy cattle, deer, goats and sheep.
Faecal coliforms	A group of bacteria found in faeces and used as a parameter in the Hygiene Regulations, Shellfish and Bathing Water Directives, E. coli is the most common example of faecal coliform. Coliforms (see above) which can produce their characteristic reactions (e.g. production of acid from lactose) at 44°C as well as 37°C. Usually, but not exclusively, associated with the intestines of warm-blooded animals and birds.
Flood tide	The rising tide, immediately following the period of low water and preceding the ebb tide.
Flow ratio	Ratio of the volume of freshwater entering into an estuary during the tidal cycle to the volume of water flowing up the estuary through a given cross section during the flood tide.

Geometric mean	The geometric mean of a series of N numbers is the Nth root of the product of those numbers. It is more usually calculated by obtaining the mean of the logarithms of the numbers and then taking the anti-log of that mean. It is often used to describe the typical values of skewed data such as those following a log-normal distribution.
Hydrodynamics	Scientific discipline concerned with the mechanical properties of liquids.
Hydrography	The study, surveying, and mapping of the oceans, seas, and rivers.
Lowess	Locally Weighted Scatterplot Smoothing, more descriptively known as locally weighted polynomial regression. At each point of a given dataset, a low-degree polynomial is fitted to a subset of the data, with explanatory variable values near the point whose response is being estimated. The polynomial is fitted using weighted least squares, giving more weight to points near the point whose response is being estimated and less weight to points further away. The value of the regression function for the point is then obtained by evaluating the local polynomial using the explanatory variable values for that data point. The LOWESS fit is complete after regression function values have been computed for each of the n data points. LOWESS fit enhances the visual information on a scatterplot.
Telemetry	A means of collecting information by unmanned monitoring stations (often rainfall or river flows) using a computer that is connected to the public telephone system.
Secondary Treatment	Treatment to applied to breakdown and reduce the amount of solids by helping bacteria and other microorganisms consume the organic material in the sewage or further treatment of settled sewage, generally by biological oxidation.
Sewage	Sewage can be defined as liquid, of whatever quality that is or has been in a sewer. It consists of waterborne waste from domestic, trade and industrial sources together with rainfall from subsoil and surface water.
Sewage Treatment Works (STW)	Facility for treating the waste water from predominantly domestic and trade premises.
Sewer	A pipe for the transport of sewage.
Sewerage	A system of connected sewers, often incorporating inter-stage pumping stations and overflows.
Storm Water	Rainfall which runs off roofs, roads, gulleys, etc. In some areas, storm water is collected and discharged to separate sewers, whilst in combined sewers it forms a diluted sewage.
Waste water	Any waste water but see also “sewage”.

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