EC Regulation 854/2004

CLASSIFICATION OF BIVALVE MOLLUSC PRODUCTION AREAS IN ENGLAND AND WALES

SANITARY SURVEY REPORT

Burry Inlet

2012

Cover photo: Burry Inlet from north shore.

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STATEMENT OF USE: This report provides information from a study of the information available relevant to perform a sanitary survey of bivalve mollusc classification zones in Burry Inlet. Its primary purpose is to demonstrate compliance with the requirements for classification of bivalve mollusc production areas, determined in EC Regulation 854/2004 laying down specific rules for the organisation of official controls on products of animal origin intended for human consumption. The Centre for Environment, Fisheries & Aquaculture Science (Cefas) undertook this work on behalf of the Food Standards Agency (FSA).

CONSULTATION:

Consultee	Date of consultation	Date of response
Environment Agency	20/07/2012	10/09/2012
Carmarthenshire Council	20/07/2012	14/09/2012
Swansea Council	20/07/2012	17/08/2012
Welsh Government Fisheries	20/07/2012	None received
Dwr Cymru - Welsh Water	20/07/2012	27/09/2012

DISSEMINATION: Food Standards Agency, Carmarthenshire Council, Swansea Council, Welsh Government Fisheries, Environment Agency.

RECOMMENDED BIBLIOGRAPHIC REFERENCE: Cefas, 2012. Sanitary survey of Burry Inlet. 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 of 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. Infectious disease outbreaks are more likely to occur in coastal areas, where bivalve mollusc production areas (BMPAs) are impacted by sources of microbiological contamination of human and/or animal origin.

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 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 the BMPA. 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 soft shell clams (*Mya arenaria*), cockles (*Cerastoderma edule*) and mussels (*Mytilus* spp.) within Burry Inlet.

1.2 AREA DESCRIPTION

THE ESTUARY

Burry Inlet is a large shallow estuary, which opens to Carmarthen Bay to the west and is located on the north side of the Gower Peninsula in south west Wales. It covers an area of about 45km^2, most of which is intertidal. The substrate is largely sand with mud in the more sheltered areas. The south shore is flanked by extensive areas of saltmarsh, whilst the north shore is more urbanised. Burry Inlet hosts the largest cockle fishery in Wales.

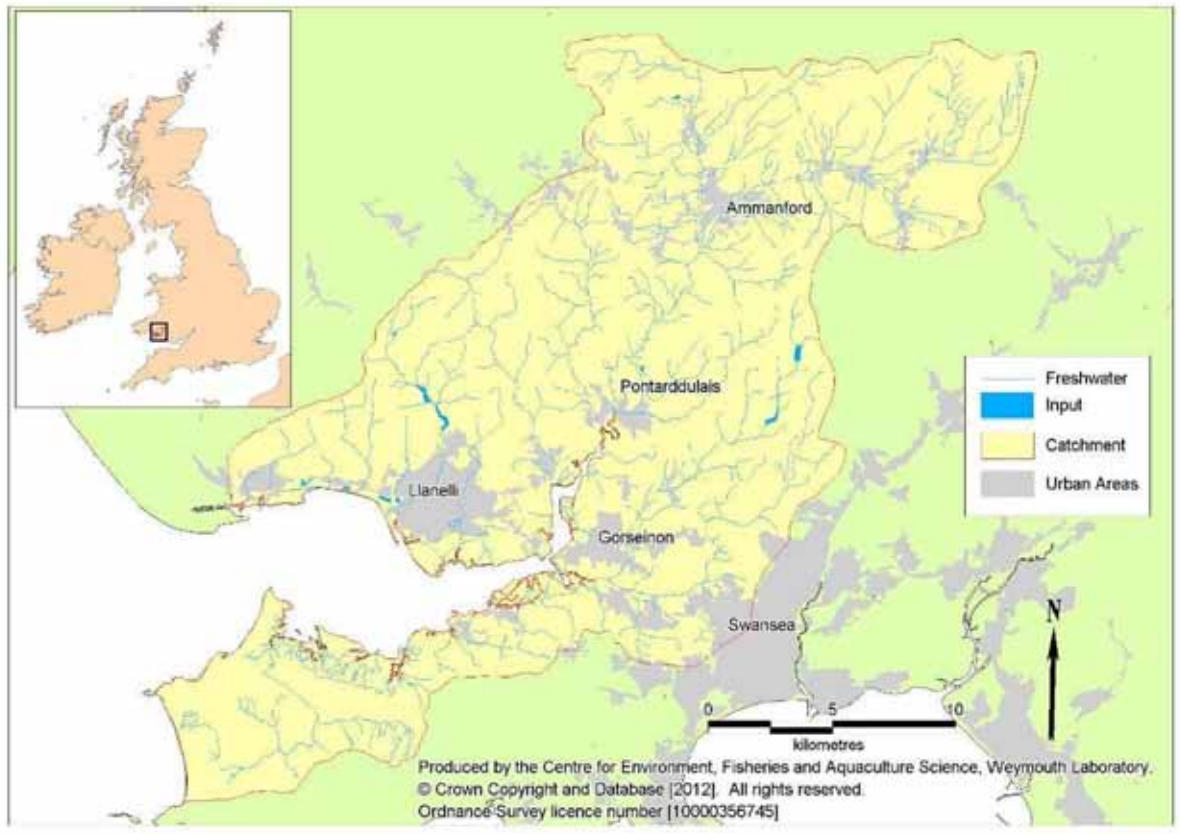


Figure 1.1 Location of Burry Inlet.

CATCHMENT

Burry Inlet has a catchment area of about 470km^2 in total. The largest individual freshwater input is the River Loughor, which discharges to the head of the estuary. There are numerous other rivers and streams discharging to various points within the estuary. The lower catchment is relatively low lying with some low hills. Within the upper catchment there are areas of higher relief either side of the Loughor Valley, up to a maximum elevation of 616m within the Black Mountains, in the extreme north east of the catchment. The watercourses draining to Burry Inlet are mainly surface water fed rather than groundwater fed so will tend to respond rapidly to rainfall (Environment Agency, 2007).

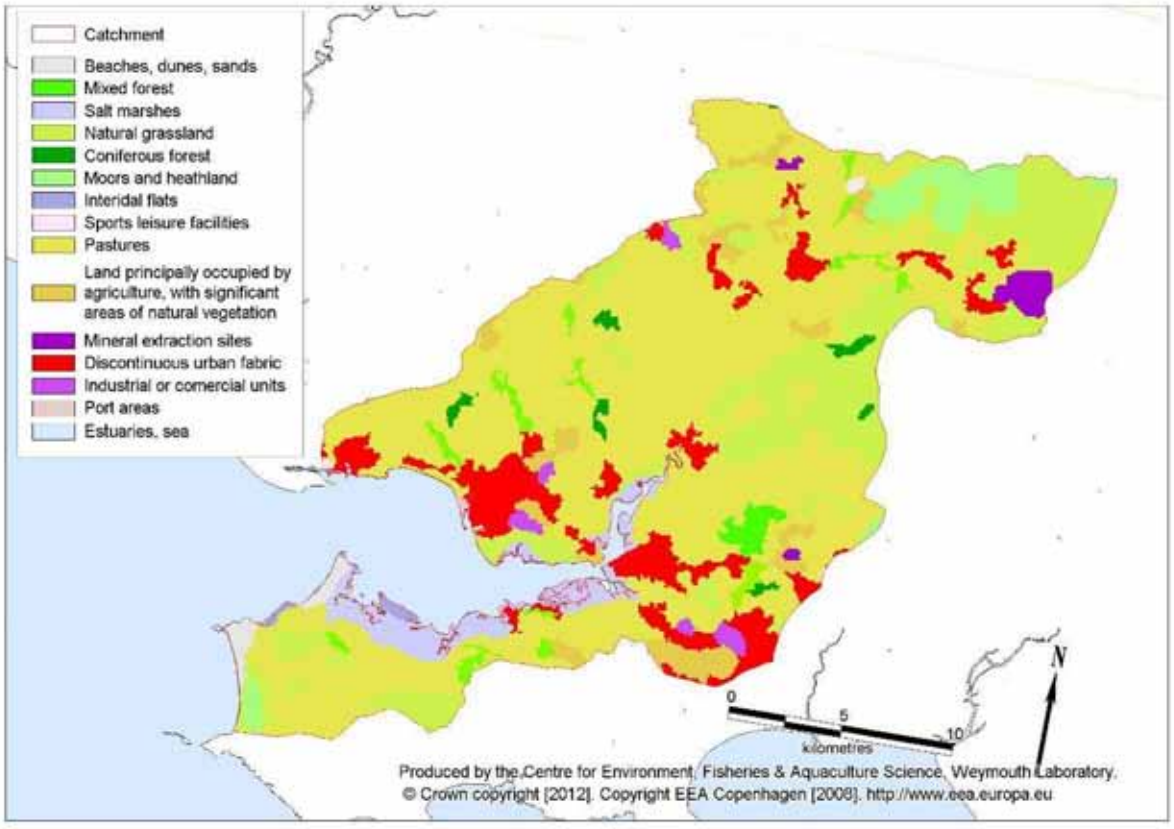


Figure 1.2 Land cover within the Burry Inlet catchment.

The majority of land within this area is pasture so agricultural runoff is likely to be of significance to Burry Inlet. There are also substantial urban areas which are mainly near the shores of the estuary. The upper catchment is largely rural in character. Different land cover types will generate differing levels of contamination in surface runoff. Highest faecal coliform contributions arise from developed areas, with intermediate contributions from the improved pastures and lower contributions from the other land cover 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 which may increase up to 100 fold.

2. SHELLFISHERIES

2.1 SPECIES, LOCATION AND EXTENT

This sanitary survey was prompted by an application for classification of an area off Pwll for the harvest of softshell clams. A further application was received whilst this sanitary survey was underway to classify a mussel farm at Burry Port. In addition to these new fisheries, there are existing classified fisheries for cockles and mussels within Burry Inlet.

COCKLES

Cockles within Burry Inlet have been the subject of an organised commercial fishery since Roman times (Woolmer, 2010). They have an almost continuous distribution throughout the estuary, but the main exploitable concentrations tend to fall within the beds shown in Figure 2.1, which was supplied with the application. Bed locations from CEFAS records, originally supplied in 2008 by the South Wales Sea Fisheries Committee (now Welsh Government Fisheries) are also shown. The precise distribution of stocks at commercial densities is likely to vary from year to year. A sampling plan will be needed for all of the estuary almost up to the Loughor Bridge, and some flexibility in RMP location is required to allow for the changing distribution of the stocks.

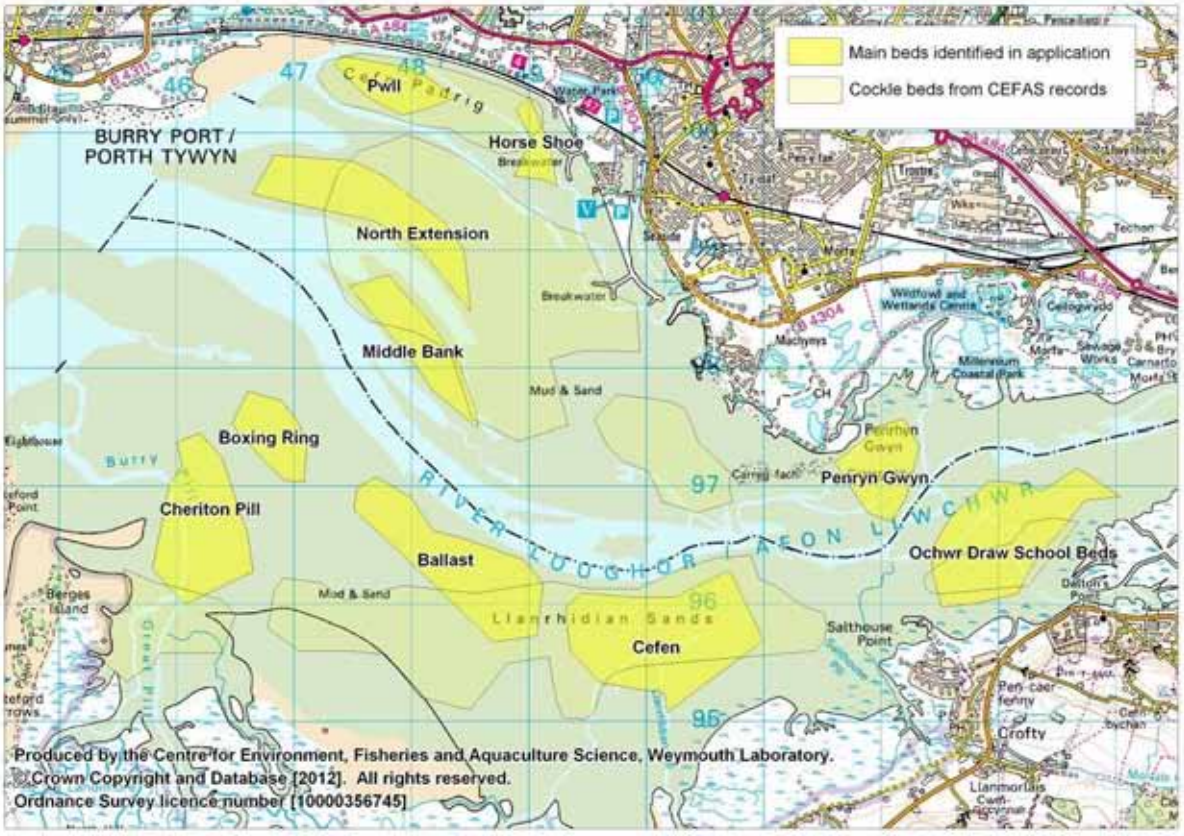


Figure 2.1. Locations of main cockle beds within Burry Inlet

Cockle stocks within Burry Inlet have suffered from unexplained mortalities since 2002. The fishery is now dominated by 1 year olds, which spawn then gradually die

off from late spring/summer through to autumn. The spawnings from these 1 year olds produce sufficient spatfall to maintain the population, but larger, older animals which were present historically are now scarce, and the majority (>90%) of one year olds die off by autumn. As a consequence gathering is only commercially viable from about April to October and landings are now dominated by smaller cockles. The lack of stock from winter through to spring may make sample collection problematic during these times.

MUSSELS

There are substantial stocks of mussels within Burry Inlet, but these have a more limited and patchy distribution than cockle stocks. The main area of commercial interest is around the lighthouse at Whiteford Point, but there are many further patches of this species at other locations such as Penrhyn Gwyn. Mussels are collected either as seed for relaying elsewhere or as market size stock. The feasibility of mussel culture is being investigated with Burry Dock, and an application to classify this site was received whilst this report was in preparation. Figure 2.2 shows a map of the mussel beds as supplied to CEFAS by the Countryside Council for Wales in 2005, as well as the location of the experimental mussel site in Burry Dock. Additionally, two mussel beds holding mature stock off Burry Port were identified in September 2012.

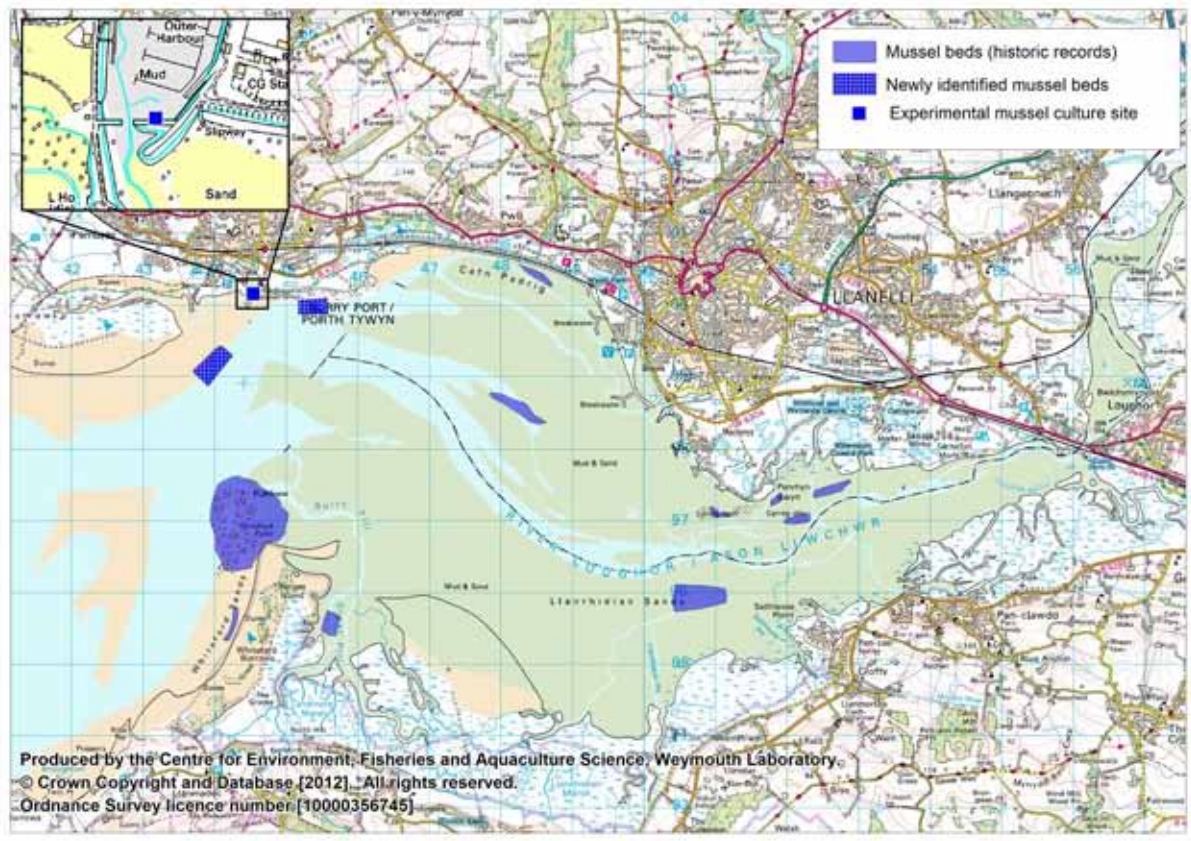


Figure 2.2. Mussel beds within Burry Inlet

It is likely that the exact distribution of wild mussels has changed slightly since the data presented above was collected as beds may be lost to erosion and new beds may form where there is a suitable substrate, such as areas of dead cockle shell.

Welsh Government Fisheries advise that the distribution in Figure 2.2 is reasonably accurate although detailed stock surveys are not undertaken regularly. A large proportion of stocks are 'seed' although in some areas significant amounts of market size mussels are present at times.

SOFT SHELL CLAMS

Classification of this species (*Mya arenaria*) has been requested within a relatively small area of about 0.5km^2 at Pwll. This species has not yet been subject to a commercial fishery, and current densities and spatial distribution of these stocks are uncertain. Investigations into the status of this species within Burry Inlet were carried out between 1979 and 1982 (Seafish, 1984). They were found to be distributed widely throughout the estuary, but confined to small patches, generally in muddier areas. Thirteen of these patches were found, the size of which was not generally recorded, but one was reported to be approximately 200m x 200m. The approximate location of these patches is reproduced in Figure 2.3, and although the exact distribution may be quite different now, this gives some insight into the possible extent within which there may be commercially viable stocks. No patches were found within the area for which classification was requested, but it is uncertain whether all parts of Burry Inlet were surveyed. Nevertheless Figure 2.3 suggests that if a successful fishery is established a much wider area may ultimately require classification.

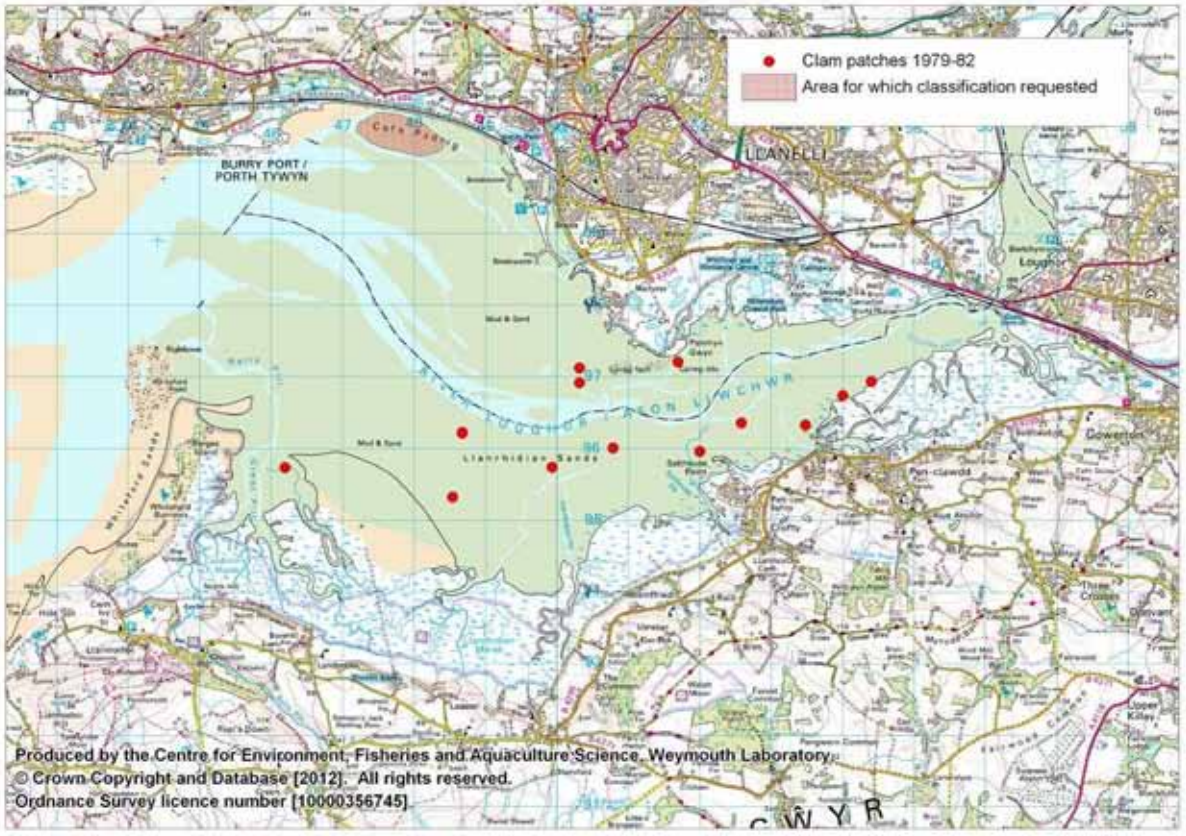


Figure 2.3. Area for which soft shell clam classification has been requested and approximate location of patches found between 1979 and 1982

Within these patches clams were recorded at some quite high densities, averaging 45.4 per m^2 with up to 112 per m^2 suggesting there may be large quantities present within Burry Inlet as a whole. The population was dominated by larger animals of 70-90mm in length and of 8-10 years in age, and recruitment was erratic, implying that fished stocks may take some years to recover. Established beds were susceptible to exposure or smothering induced by erosion or deposition of sediment as their burrowing ability is limited.

2.2 GROWING METHODS AND HARVESTING TECHNIQUES

All stocks considered in this report are wild, and are hand gathered when exposed by the tide. Cockles are raked from the sediment. Mussels are hand raked or hand picked, although grading machines may occasionally be used on the shore for the sorting of market size stocks. It is possible that dredges may be used to harvest the newly identified mussel beds off Burry Port. Softshell clams, which live up to 30cm under the surface of the substrate are to be gathered by hand digging.

2.3 SEASONALITY OF HARVEST, CONSERVATION CONTROLS AND DEVELOPMENT POTENTIAL

The Environment Agency, as grantee of the Burry Inlet Cockle Fishery Regulating Order is responsible for the management of the fishery. This role is under review but has been extended to March 2014. The fishery is only open to licence holders of which there are around 50. Historically, total allowable catches (TACs) have been determined annually on the basis of stock surveys, allowing 33% of the stock to be exploited via individual daily quotas for licence holders, and a minimum landing size of 19mm has applied.

Due to the recurring mortality events fishery managers have reduced the minimum landing size and increased daily quotas so licence holders could derive some income from the fishery before the stocks died off. The minimum size for cockles has now been reduced to 0mm (although in practice only animals over 10-12mm are marketable) with a maximum size of 19mm to protect older animals. There is no formal closed season. The current stock structure and mortality events effectively limit the fishery to the late spring through to autumn, the period when the one year old cockles are large enough to be marketed and still present in sufficient numbers for gathering to be viable. No Sunday or night gathering is permitted. Fishery managers may close the fishery or certain areas at any time for stock preservation reasons.

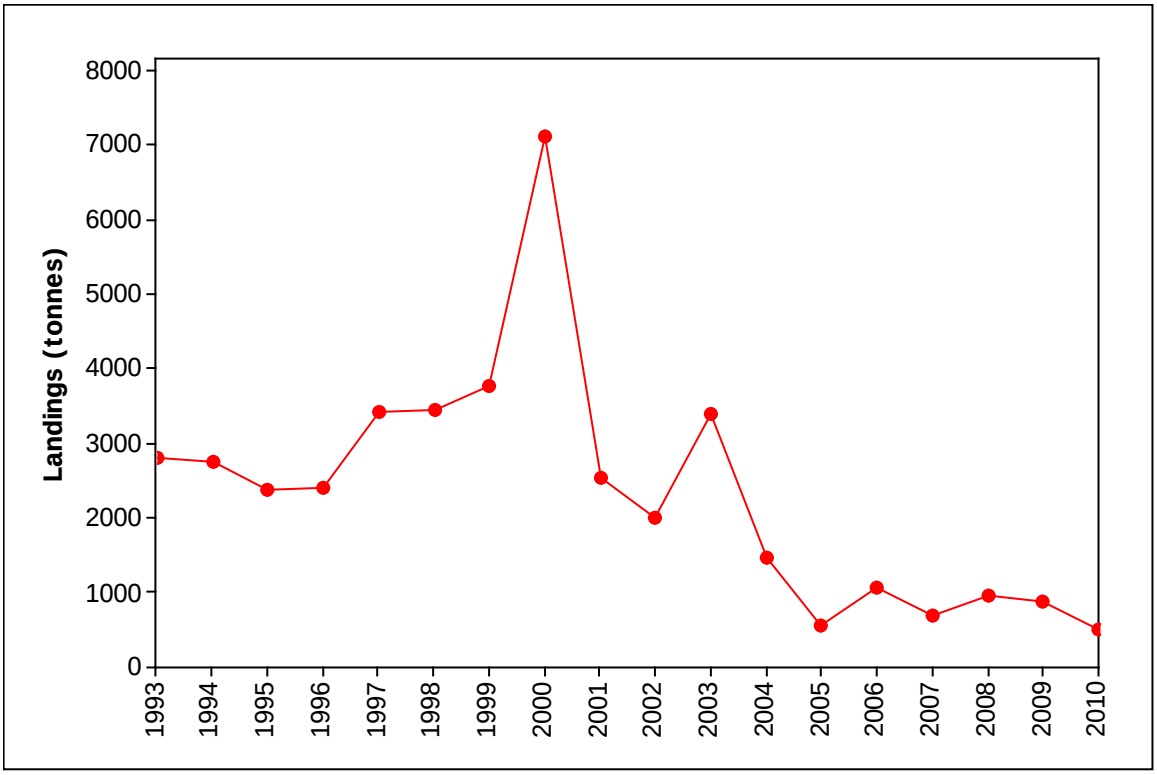


Figure 2.4 Cockle landings from Burry Inlet, 1993-2010.
Data from the South Wales Sea Fisheries Committee website (now WG Fisheries).

Cockle landings have fallen significantly since the onset of mortality events in 2002 and are now generally less than 1000 tonnes per annum, compared to about 3000 tonnes per annum previously (\Figure 2.4). A recent investigation into the cockle mortalities (Elliot *et al*, 2012) found no single obvious cause and concluded that '*either this new state stabilises and becomes typical for the area or the population gradually regains its former characteristics*'. The prospects for the fishery therefore remain uncertain but significant volumes will continue to be harvested.

The market mussel fishery has no closed season but is mainly exploited during the winter and spring. It is subject to a minimum landing size of 45mm. It is not subject to any quota restrictions and around 200 tonnes are taken annually, and current levels of exploitation are likely to continue (Welsh Government Fisheries, pers comm.). The taking of seed mussels requires authorisation from Welsh Government Fisheries. A hygiene classification is not required for this fishery as seed are transported to and relaid in classified areas, but separated from other shellfish, for growing periods exceeding 6 months prior to harvesting. The seed mussel fishery operates in late summer and early autumn, and is closed around the 30th of September for bird conservation reasons. Seed stocks are sent for relaying outside of Burry Inlet, typically to Ireland.

There is no minimum size or closed season for softshell clams. Viability of this fishery is dependent on receiving a B classification as the market is for live animals. The clams are likely to have a widespread (albeit patchy) distribution throughout the Inlet so if the fishery at Pwll meets with initial success there may be large potential for expansion. However, as the clams are long lived and recruitment is erratic, stocks may not hold up to sustained fishing pressure.

Gear limitations (hand gathering only) apply to all these fisheries, although it is possible that dredges may be authorised for use on the newly discovered mussel beds off Burry Port. Any shellfishery may be closed at any time by Welsh Government Fisheries for stock preservation reasons.

2.4 HYGIENE CLASSIFICATION

Table 2.1 Classification history for the Burry Inlet, 2001 onwards

Area	Species	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Northside	Cockles	B										
Northside (West)	Cockles								B	B	B-LT	B-LT
Northside-Penrhyn Gwyn	Cockles	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	
All other Northside Beds	Cockles		B	B								
Southside - all beds	Cockles	B			B							
Whiteford Point	Cockles					B	B		B	C	C	C
Machynys	Cockles	B		B	B	B-LT						
Daltons Point	Cockles	C	C	C								C(P)
Southside: South East 4	Cockles		C	C		B	C	C	C	C	C	C
Southside: All beds except South East 4 and Daltons Point	Cockles			B								
Southside (except South East 4)	Cockles		B									
Southside - Middle	Cockles											C(P)
Pwll	Mussels	C	C	C	C	C	C	C	C	B	B	B
Burry Port	Mussels	B	B	B	B	B	B-LT	B-LT	B-LT			
Whiteford Point	Mussels	B	B	B	B	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT	B-LT

P – preliminary classification

Current classification maps are shown for cockles in Figure 2.4 and mussels in Figure 2.5.

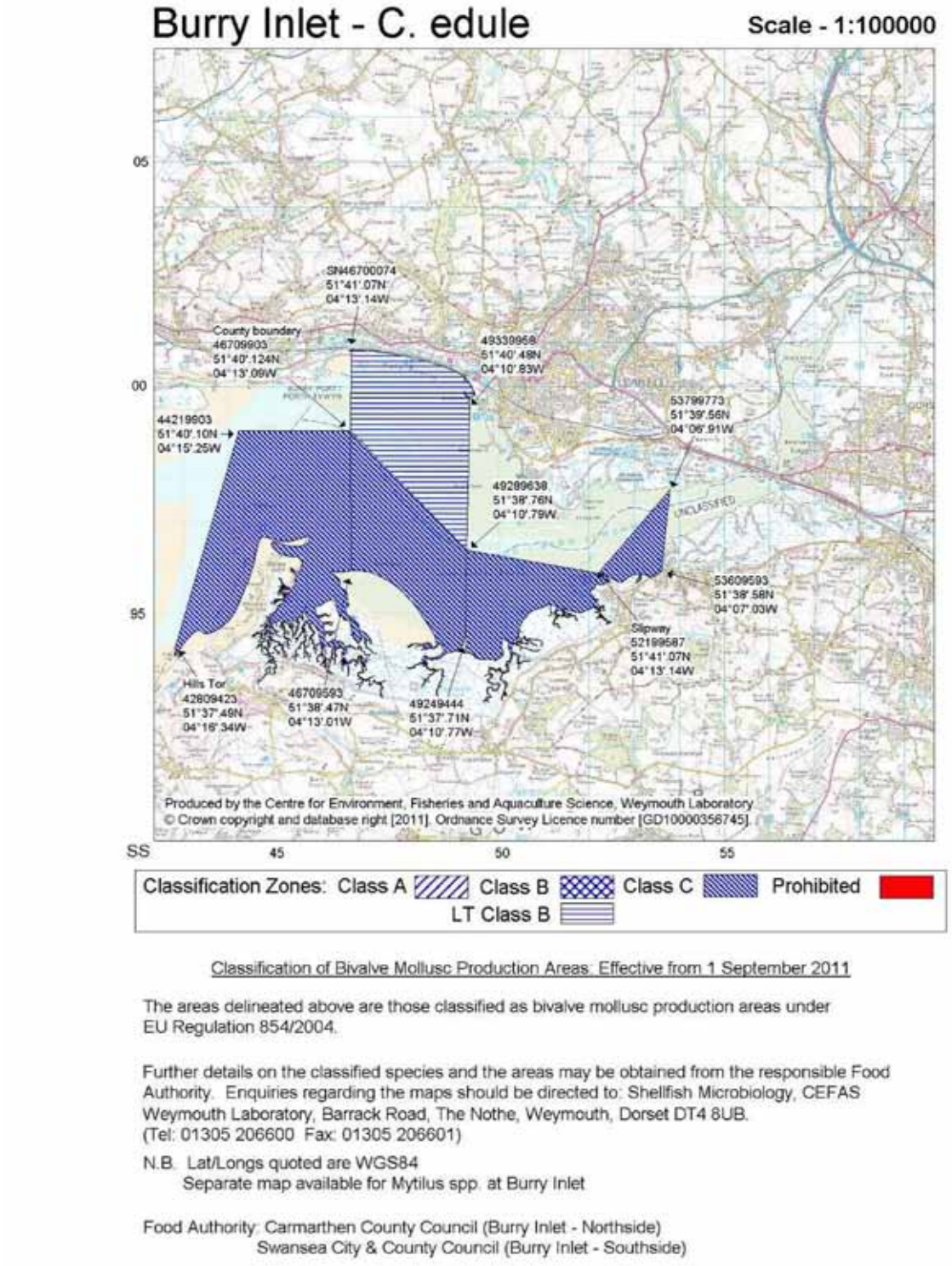
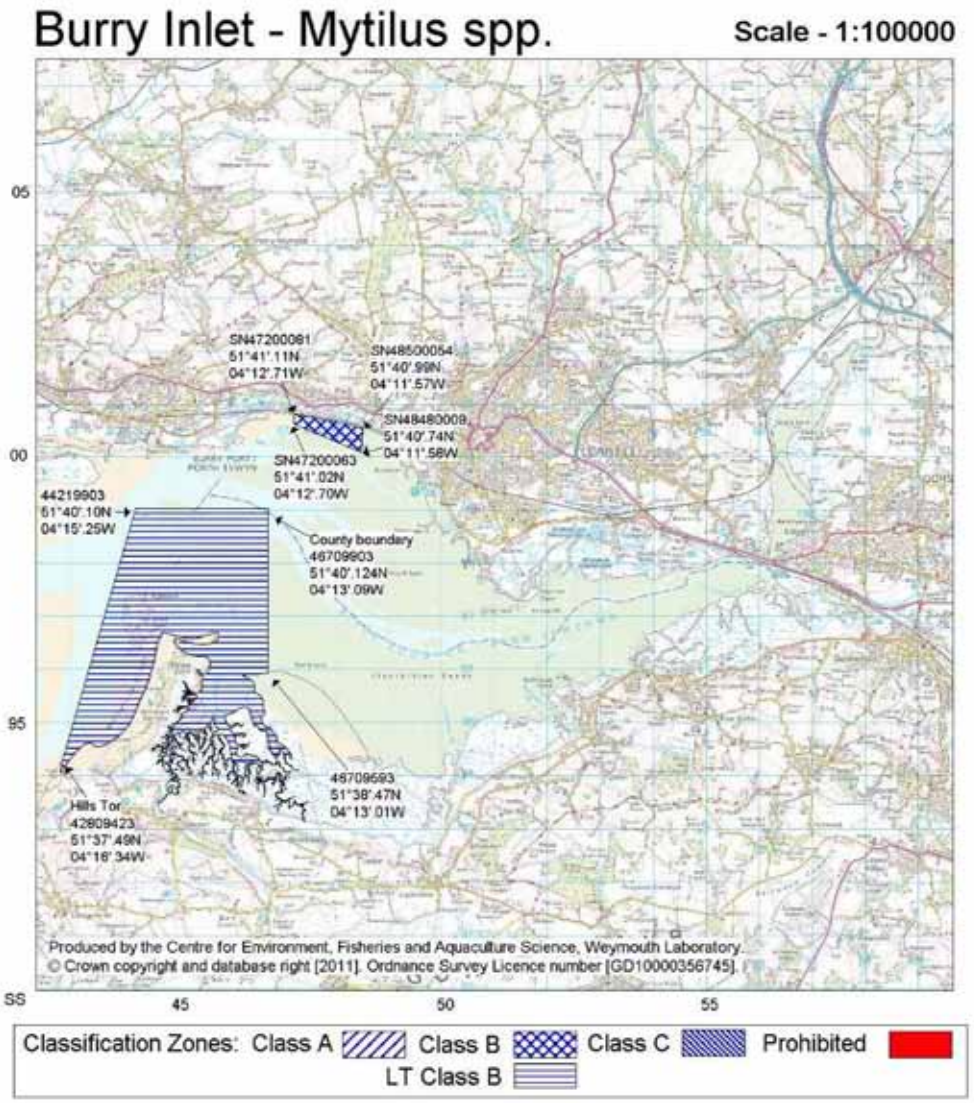


Figure 2.4 Current classifications cockles.



Classification of Bivalve Mollusc Production Areas: Effective from 1 September 2011

The areas delineated above are those classified as bivalve mollusc production areas under EU Regulation 854/2004.

Further details on the classified species and the areas may be obtained from the responsible Food Authority. Enquiries regarding the maps should be directed to: Shellfish Microbiology, CEFAS Weymouth Laboratory, Barrack Road, The Nothe, Weymouth, Dorset DT4 8UB.
(Tel: 01305 206600 Fax: 01305 206601)

N.B. Lat/Longs quoted are WGS84
Separate map available for C. edule at Burry Inlet

Food Authority: Carmarthen County Council (Burry Inlet - Northside)
Swansea City & County Council (Burry Inlet - Southside)

Figure 2.5 Current classifications for mussels

Neither the cockle or mussel classification currently covers all beds shown in Figures 2.1 and 2.2. Cockles beds on the south side hold a C classification whereas beds on the north side they hold B classifications. All mussels hold B classifications at present, although historically there have been C classifications at Pwll in recent years. The mussel classification does not cover all mussel beds shown in Figure 2.2. Table 2.2 summarises the post-harvest treatment required before bivalve molluscs can be sold for human consumption.

Table 2.2 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* $100g^{-1}$ 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* $100g^{-1}$ FIL in more than 10% of samples. No sample may exceed an upper limit of 46,000 *E. coli* $100g^{-1}$ 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* $100g^{-1}$ FIL	Relaying for, at least, two months in an approved relaying area or cooking by an approved method
Prohibited[6]	>46,000 *E. coli* $100g^{-1}$ 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*

3. OVERALL ASSESSMENT

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.

SHELLFISHERIES

For cockles, a sampling plan is required to cover the entire Burry Inlet up to about 2km downstream of the Loughor Bridge, and for the intertidal areas west of Whiteford Point. Cockles have an almost continuous distribution throughout the area although some areas support much higher (commercial) densities than others. The main exploitable beds will remain in roughly the same position from year to year but with some variations. Some flexibility around the exact location of RMPs will therefore be required. Samples should be taken at the point best representative of levels of contamination within each zone where sufficient stocks are present. Although this location may vary with stock availability such an approach should be suitably protective of the consumer without the need for continual revisions to the sampling plan. As there is no formal closed season, a year round (monthly) sampling plan is required. However, due to the current population structure there is little in the way of sizeable stock present through the winter and early spring. Although small numbers of cockles do survive through the mortality, sampling may be problematic during this time.

The same area will require classification for mussels, with an extra area to cover the newly discovered beds off Burry Port. As for cockles, some flexibility in RMP location will be required due to the patchy and changing distribution of sampleable stock. Due to the uncertainty surrounding the exact distribution the LEAs will need to establish the closest point to any recommended RMPs where samples can be reliably obtained. Classification has been requested for a small area within Burry Port docks, where mussel cultivation trials are being undertaken on the south east wall of the outer dock.

Classification has only been requested for a relatively small area of the inlet at Pwll for softshell clams. It is likely that if the clam fishery here is initially profitable, the local shellfish gathering community will direct more effort towards this species. Recruitment is thought to be sporadic, and animals are relatively long lived so stock may become locally depleted quite rapidly. Surveys of this species undertaken some years ago found them to be widely but very patchily distributed throughout Burry Inlet, from about 2km downstream of the Loughor Bridge through to Whiteford Point. Therefore a sampling plan should be provided for this species to cover both Pwll in the first instance, and for the wider estuary in case extension to the classification is required in the future. Again, some flexibility in RMP location will be required to ensure sufficient stocks are present.

SURROGATE SPECIES

The use of sample results from one species may potentially be used to classify other species if it is suitably representative, thereby reducing sampling effort and laboratory analysis costs. An investigation into the relative levels of *E. coli* accumulation in different bivalve species was recently carried out by Cefas on behalf of the FSA (Younger & Reese, 2011). Softshell clams were not considered in this investigation so no potential surrogates were identified. Cockles and mussels were found to be broadly equivalent, although a tendency for cockles to return more extreme high results than mussels was noted. It was therefore concluded that cockles and mussels may be used as surrogates for one another, but only after a period of parallel monitoring to confirm this on a site by site basis. Samples must be taken within 100m of each other (and preferably much closer) for valid comparisons to be made.

REDUCED SAMPLING FOR SEASONAL OR INACTIVE FISHERIES

All fisheries considered in this survey are potentially open on a year round basis so it is desirable for monthly monitoring to continue in order to maintain year round classifications.

POLLUTION SOURCES

FRESHWATER INPUTS

All rivers and streams carry some contamination from land runoff and so will require consideration in this assessment. Their impacts will be greatest where they enter the estuary, and within or immediately adjacent to any drainage channels they follow across the intertidal area.

Burry Inlet has a catchment area of about 470km^2 in total within which the dominant land use is pasture. About 75% of the catchment is drained by watercourses which meet the estuary upstream of the fisheries including the Loughor and the Lliw/Llan, the latter of which has significant urban areas within its catchment so may be expected to carry quite high levels of faecal indicator bacteria. There are numerous other smaller but nonetheless potentially significant watercourses draining to various points around the lower estuary. Therefore the influence of freshwater borne contamination is likely to be highest towards the up-estuary ends of the shellfish beds, so a general principle of locating RMPs at the eastern end of classification zones should be applied. Superimposed on this there may be more localised ‘hotspots’ associated with the freshwater inputs discharging in close proximity to the shellfish beds. These freshwater inputs tend to follow defined drainage channels across the intertidal area when the tide is out. Most of these watercourses have had spot flow measurements and/or bacteriological samples taken as part of Environment Agency investigations and/or during the shoreline survey of the area.

It is difficult to draw any conclusions about Pembrey Marsh River and Barnaby Pill as they were not measured and only sampled on one or two occasions, although Barnaby Pill was one of the larger watercourses seen on the north shore during the shoreline survey. Barnaby Pill is likely to be of some impact principally towards the

western end of shellfish beds at Pwll, but Pembrey Marsh River is not particularly close to any identified shellfisheries apart from the experimental mussel site within Burry Port Dock. The two streams entering Burry Port Dock (Kymer Canal and Nnant Dyfatty) generally carried moderate concentrations of faecal coliforms but will probably cause elevated levels of contamination within the enclosed dock area. The Dulais, Dafen and Lleidi appear broadly similar in terms of the bacterial loading they convey. These all appear to converge within the same drainage channel which runs along the north shore at Pwll so an RMP on the margins of this channel may capture their combined impacts, although perhaps not their individual peak influences. Streams draining from the Millennium Park marshes generally contained little in the way of contamination and so are not considered of particular importance.

On the south shore it is likely that the most significant 'hotspot' of runoff borne contamination within the areas requiring classification arises in the area where Burry Pill, Bennets Pill and Great Pill intertidal drainage channels appear to converge. An RMP set here should best capture contamination from these sources. Llanridian Pill and Salthouse Pill were also carrying significant bacterial loadings at the time of shoreline survey so RMPs within or adjacent to these channels will best capture contamination from these watercourses.

Volumes of runoff are generally higher in the late autumn and winter, although high flow events may occur at any time of the year. Increased levels of runoff are likely to result in an increased bacterial loading carried into coastal waters, particularly as river levels rise when heavy rain occurs following a dry period (the 'first flush').

HUMAN POPULATION

Total resident human population in census areas within or partially within the Burry Inlet catchment area was 196,724 at the last census in 2001. The largest town is Llanelli on the north shore of the estuary. The north west outskirts of Swansea also fall within the catchment. There are some villages on the south shore but this is more rural in character than the north shore. The upper catchment has some villages and the small town of Ammanford, but is much more rural in general character.

Carmarthenshire and the Gower Peninsula in particular are popular 'seaside' tourist destinations so a significant population increase may occur in some areas during the peak holiday months. As the attractions near Burry Inlet are largely outdoors, the peak season is likely to be summer. Increased population numbers will result in increased volumes of sewage treated by the sewage works so there may be some seasonality in the bacteriological loadings generated by these.

SEWAGE DISCHARGES

Most sewage effluent from continuous sources enters the estuary upstream of the shellfish beds via Llangennech, Llanelli, Llannant and Gowerton works direct to the estuary, as well as 11 further sewage works discharging to watercourses flowing into the estuary upstream of the Loughor Bridge. Llanelli, Llannant and Gowerton receive UV treatment so whilst the volumes of effluent they discharge are large, bacterial concentrations and hence loadings are very low, although they do have the

potential to generate very large bacterial loadings should problems arise with their disinfection systems. Llangennech only receives secondary treatment and so is likely to generate a higher bacterial loading than the other three main discharges combined. Therefore influence of continuous sewage discharges is likely to be highest towards the up-estuary ends of the shellfish beds, so a general principle of locating RMPs at the eastern end of classification zones should be applied.

Three small secondary sewage works discharge to two of the watercourses which drain to the estuary on the south shore (Burry Pill and Llanrhidian Pill), and one discharges to the Pembrey Marsh River on the north shore. These watercourses and their drainage channels across the intertidal shellfisheries will therefore carry elevated bacterial loadings.

The geographical distribution of intermittent discharges follows a similar pattern, with an additional series of outfalls along the north shore of the estuary from Burry Port through to the Llanelli STW. Available spill records indicate that spills occur regularly from those with monitoring equipment, and these spills occur largely as a result of surface water entering the sewers. This includes two outfalls which discharge via watercourse to the enclosed Burry Docks where the experimental mussel site is located as well as outfalls at Pwll and by Llanelli seafront and the Gowerton STW overflow. Recent improvements appear to have resulted in a reduction of spills from the Northumberland Road overflow at Llanelli seafront. The spill frequency from intermittent discharges associated with the smaller sewage catchments on the south shore and at Pembrey is uncertain.

Three cockle processing establishments discharge process effluent which contain very variable concentrations of indicator bacteria to Salthouse Pill, and there is also a potentially significant private sewage discharge from a caravan park to Llanrhidian Pill. Some small private domestic sewage discharges are present in the more rural areas of the catchment and any watercourses receiving such effluent will carry increased bacterial concentrations as a result, although private discharges are likely to be of minor impact in relation to other sources.

As the majority of sewage inputs are upstream of the shellfisheries a general presumption of higher impacts at the upstream end of the shellfish beds should be applied when determining the location of RMPs. On the south shore, contamination from small (secondary treated) sewage works discharging to Burry Pill and Llanrhidian Pill, and cockle processing effluent discharged to Salthouse Pill may cause elevated levels of contamination where these watercourses enter the estuary and adjacent to their drainage channels. Regular spills of storm sewage occur from intermittent discharges from Burry Port through to the Llanelli STW and from the Gowerton STW overflow, and these are will mainly occur during wet weather.

AGRICULTURE

The agricultural land within the catchment is almost all pasture and at the 2010 agricultural census this supported 71,540 sheep and 22,029 cattle, compared to a human population of just under 200,000. A large proportion of the pastures are within parts of the catchment drained by watercourses discharging to the estuary

upstream of the fishery so higher impacts towards the up-estuary ends of the shellfisheries are anticipated on this basis.

The primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush'). Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. There are also a few poultry and pig farms dotted throughout the area, mainly within the lower reaches the manure from which is likely to be applied periodically to agricultural land.

The large area of saltmarsh on the south shore is common land heavily used for the grazing of sheep and to a lesser extent horses. Numbers of sheep peak at around 4-6,000 from April to October, whereas only about 2-400 horses graze the marshes but on a year round basis. Much smaller numbers of cattle also graze on a small patch of saltmarsh at the Millennium Park during summer. Contamination deposited on the grazing marshes will be conveyed directly into the estuary via tidal inundation, which is a particularly direct and efficient pathway. Therefore significant livestock related inputs are anticipated to the southern half of the estuary particularly during spring tides, whereas the north shore will be largely unaffected by such occurrences.

In summary, the south shore and the upper reaches of the estuary will be most impacted by contamination of livestock origin. Therefore RMPs situated towards the up-estuary ends of the shellfish beds and by the drainage channels crossing southern intertidal areas are likely to capture peak levels of livestock related contamination. Livestock numbers are highest during summer and autumn so some seasonality in impacts may be anticipated. The flux of contamination from pastures will be highly rainfall dependent, whereas peak fluxes from grazing marsh may be anticipated on spring tides.

BOATS

Burry Inlet is shallow and largely intertidal making navigation difficult, so boat traffic is relatively light and limited to smaller craft. The vast majority of boat traffic is associated with Burry Port Marina on the north shore of the outer estuary where there are 450 berths for smaller vessels such as yachts, cabin cruisers and fishing boats. The marina and navigation routes to and from it are likely to receive overboard discharges from time to time. Given the large area of the estuary and relatively minor volumes of traffic impacts are unlikely to be significant in the main body of the estuary, and so boat traffic is of no material bearing on the sampling plan for the wild fisheries. In the confined docks there are many boats and much less dilution potential so discharges may cause a noticeable deterioration in water quality. This is of particular concern for the experimental mussel fishery within the docks, especially given that tidal exchange is limited by an automatic tidal flap gate at the dock entrance. The Good Practice Guide (EU Working Group on the Microbiological Monitoring of Bivalve Mollusc Harvesting Areas, 2010) states that 'areas within active harbours and marinas should not be used for the harvesting of bivalve

molluscs'. This clearly applies to the experimental mussel site, so it is recommended that this site should not be classified.

WILDLIFE

Burry Inlet attracts large numbers of overwintering waterbirds (wildfowl and waders), with peak counts averaging ~41,500 in recent years. Some species, such as oystercatchers (~14,000 overwintering individuals) are dependent on cockles and mussels and so will forage (and defecate) directly on the shellfish beds. However, 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 during the winter months. Other overwintering species such as grazing ducks and geese will mainly frequent the saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Therefore RMPs within or near to the drainage channels from saltmarsh areas will be best located to capture contamination from these species. There are much smaller numbers of waterbirds and seabirds in the area during the warmer months of the year so significant seasonal variation in impacts from birds may be anticipated. A few seals and otters are likely to be present but in small numbers and so impacts from these will be very minor as well as spatially unpredictable so will have no bearing on the sampling plan.

DOMESTIC ANIMALS

Dogs are exercised along the shores of Burry Inlet, and represent a potential source of diffuse contamination to the near shore zone. It is likely that the intensity of this is greatest on areas of foreshore adjacent to urban areas, so to RMPs set adjacent to urban areas would be best placed to capture contamination of canine origin. Dogs are likely to be of minor importance relative to some other sources.

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 3.1 and Figure 3.1.

Table 3.1 Qualitative assessment of seasonality of important sources of contamination.

Pollution source	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Land runoff												
Continuous sewage discharges												
Intermittent sewage discharges												
Grazing on the saltmarshes												
Waterbirds												
Boats (Burry Marina site only)												

Red - high risk; orange - moderate risk.

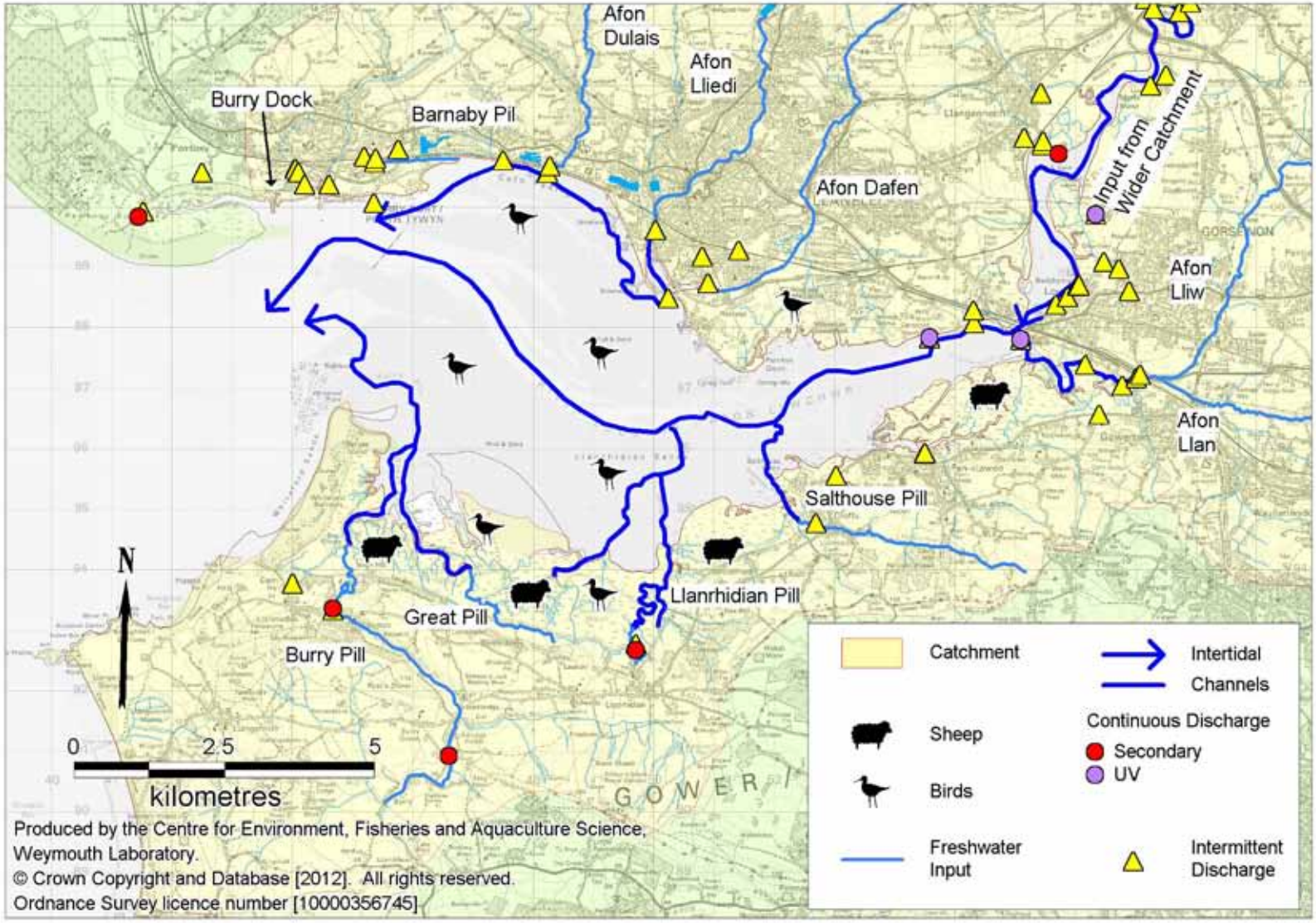


Figure 3.1 Significant sources of microbiological pollution to Burry Inlet.

HYDRODYNAMICS

Burry Inlet is a large estuary about 20km in length and covering an area of about 45km^2, most of which is intertidal and is bisected by a central river channel. Its shallow nature will reduce the potential for dilution, but will promote tidal exchange. The south shore is flanked by extensive saltmarshes, which are regularly inundated by tides, and the north shore is more engineered with flood defences extending along much of it. Upstream of the Loughor Bridge the estuary is relatively narrow. The estuary is constricted where it passes under the Loughor Bridge, so some mixing of the water column is likely to occur here. Downstream of the Loughor Bridge, where all shellfish stocks are located, it gradually widens to about 6km. Drainage channels cut through the intertidal areas here, most of which carry land runoff and associated contamination towards the central channel. Higher concentrations of faecal indicator organisms are therefore likely to arise in these drainage channels and the main river channel around low water when dilution potential is lowest. A barrier dune (Whiteford Point) protrudes from the south shore of the mouth of the estuary which provides some shelter from the prevailing south westerly wind for most of the estuary.

Tidal amplitude is large at about 7.5m on spring tides, and 3.6m on neap tides, and this drives extensive water movements within Burry Inlet. Tidal streams are bi-directional, with relatively clean water from the Atlantic Ocean entering and moving up the estuary on the flood tide, and with the ebb tide carrying contamination from shoreline sources out through the estuary. Modelling studies indicate that the main tidal streams align with the central channel, and approach 2m/s on spring tides in the main channel off Burry Port. Peak neap tide current velocities are just under half those on spring tides. Tidal excursion through the main channel is likely to be in the approximate order of up to 15km on spring tides and about 7km on neap tides.

Away from the main river channels tidal current velocities are much lower. In most places they run parallel to the shore so impacts from shoreline sources will arise to either side of them, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. This applies to the north shore between Burry Port and Pwll, and on both the north and south shore upstream of Penrhyn Gwyn and Salthouse Point. In some of the wider parts of the estuary tidal flows run perpendicular to the shore. This occurs along the south shore from Whiteford Point to Salthouse Point and is evidenced by the north-south orientation of the drainage channels here. Contamination from shoreline sources here will tend to be pushed back towards the shore during the flood and dissipate towards the central channel on the ebb, largely via any defined drainage channels. To the west of Llanelli, modelling suggests the ebb flows run parallel to the shore through a channel along the seafront then bend round and head towards the main channel at the north 'Y' shaped groyne at mid tide. However, the channel parallel to the seafront continues along the shore to Pwll so the last of the ebb tide is likely to follow this course instead. The combined impacts of shoreline sources at Llanelli seafront (Rivers Lleidi, Dafen and the Northumberland Pumping Station) are therefore likely to be most acute in the channel running along Llanelli seafront.

On this basis the highest concentrations of indicator bacteria are therefore anticipated within the drainage channels and the main channels around low water so

RMPs should be located to reflect this. Across the estuary as a whole, all sources discharging upstream of the Loughor Bridge may potentially impact anywhere within the fisheries, whereas impacts from shoreline sources on the north and south shores will be largely confined to north and south of the central channel respectively. Therefore, zoning arrangements based on a dividing line running down the central channel should be applied as the two sides of the estuary are subject to difference sources of contamination.

Volumes of freshwater entering Burry Inlet are very low in relation to volumes of water exchanged by tides. Significant turbulent mixing of the water column is likely to occur at the Loughor Bridge, where the estuary is constricted. Therefore the outer estuary can be considered well mixed and stratification and associated density driven circulation is unlikely to be of significance. Salinity was negatively correlated with levels of faecal coliforms in surface water samples throughout Burry Inlet, so the salinity profile of the estuary is likely to reflect the spatial profile of runoff related contamination. Salinity measurements taken by the Environment Agency indicate average salinity is similar from Pembrey through to Ochor Draw, and is slightly lower than that of full strength seawater (29-33ppt), although the average does decrease slightly through this stretch. As the estuary narrows upstream of Ochor Draw average salinities drop rapidly to 13ppt just upstream of the Loughor Bridge. On this basis a general principle of locating RMPs as far up-estuary as possible would best capture contamination associated with freshwater inputs. This recommendation will be of greatest relevance towards the up-estuary ends of the shellfish beds where the salinity gradient is steepest.

Strong winds may modify tidal circulation at times by driving surface currents. These in turn create return currents at depth or along sheltered margins. Burry Inlet is most exposed to the west, and the prevailing wind direction is from the south west. Winds from a westerly direction will tend to push surface water up-estuary. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. As well as driving surface currents, onshore winds will create wave action. There is a long fetch across the open Atlantic to the west, so energetic wave action will occur in the areas exposed to this direction during strong westerly winds. The seaward shoreline of Whiteford Point and the north shore of the outer estuary are likely to be most exposed to incoming swells although offshore sandbanks will attenuate this to some extent. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides. It is however concluded that wind related effects have little bearing on the sampling plans although they may be a consideration when investigating the causes of high results.

The experimental mussel farm is located within Burry Dock, which receives several potentially significant sources of contamination (Kymer Canal, Nnant Dyfatty, and several intermittent discharges). Water levels are maintained over the lower part of the tidal cycle by a flap gate which opens for about 2 hours either side of high water. Tidal exchange through its entrance only occurs when the gate is open so contamination is likely to build up here outside of this window, and tidal exchange is likely to be limited to a proportion of the water within the docks. As a consequence higher levels of indicator bacteria are anticipated here and these will tend to peak

about 2 hours before high water. As it receives freshwater inputs from two watercourses, and is impounded for over half the tidal cycle to maintain water levels whilst the tide is out, stratification of the water column may well occur here at times, so peak levels of freshwater associated contamination may tend to be entrained at the top of the water column.

SUMMARY OF EXISTING MICROBIOLOGICAL DATA

Burry Inlet has a wealth of microbiological testing results for both shellfish flesh and seawater, derived from the hygiene classification monitoring programme and various Environment Agency programmes and investigations. Figure 3.2 shows the locations sampled since the most recent major upgrade to local sewerage networks (2005). The Burry Port site does not lie at the experimental mussel site within Burry Port docks, which has never been sampled.

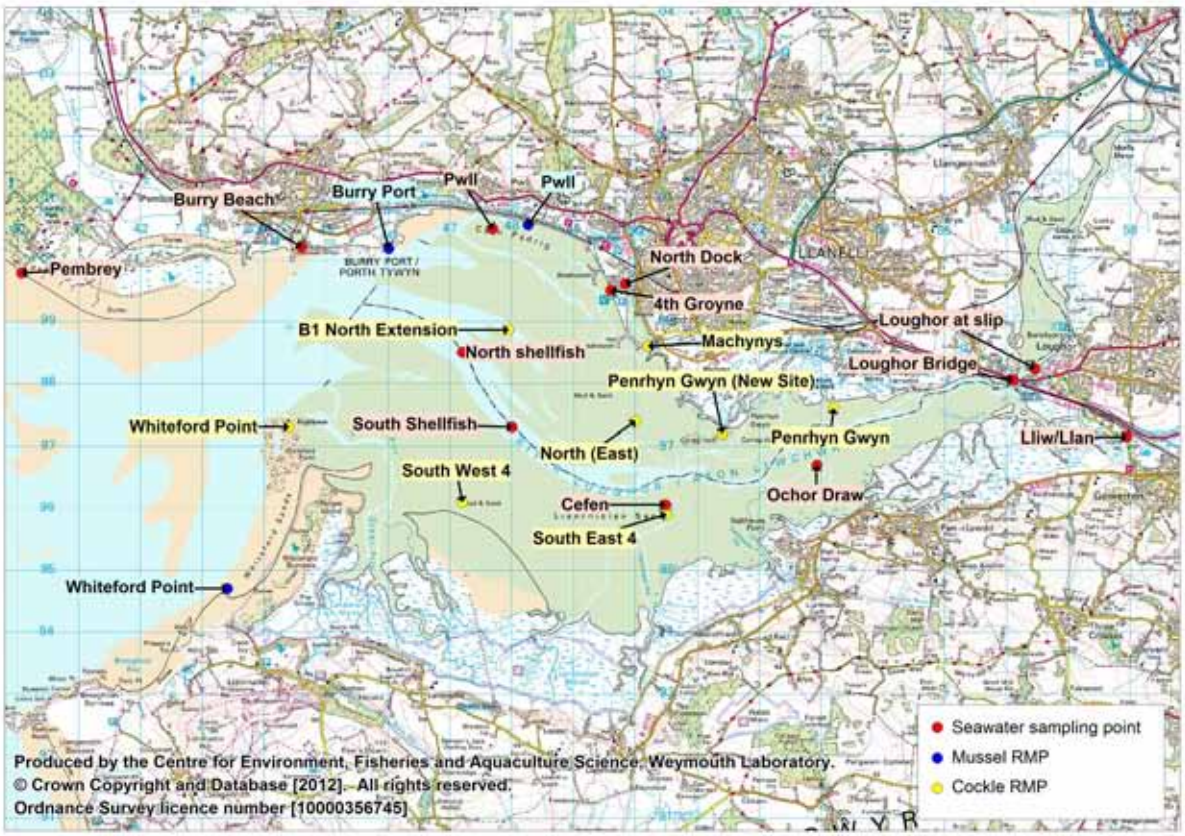


Figure 3.2. Location of shellfish and seawater sampling locations referred to in this assessment

Water sample results indicate that levels of faecal coliforms at most sites are broadly similar. The three uppermost sites (Loughor Bridge, Loughor at slip and Lliw/Llan) were only sampled on between 2 and 5 occasions but levels of faecal coliforms here were consistently two orders of magnitude higher than at most other sites in the outer estuary. All other sites were sampled on a minimum of 35 occasions, and so were subject to more detailed analyses. Paired (same day) samples taken from the four main channel sites (North Shellfish, South Shellfish, Cefen and Ochor Draw) showed a gradual increase in levels of faecal coliforms towards the upper estuary, and results for Ochor Draw and Cefen were significantly higher than for the other

two. This again reinforces the general principle of higher levels of contamination further up-estuary although it is possible that this effect may have been a consequence of the increased proximity to the south shore of the further up stream sites. A 'hotspot' of contamination was observed at 4th Groyne where average results were about an order of magnitude higher than all other sites in the outer estuary. This perhaps derives from a combination of the Rivers Lleidi and Dafen and intermittent discharges to Llanelli seafront (primarily Northumberland PS).

For the one water sampling site where seasonality could be effectively investigated (North Dock) levels of faecal coliforms were significantly higher on average in the autumn compared to the spring. It is uncertain whether this is representative of the estuary as a whole as it lies within an enclosed dock area in Llanelli. Correlations between faecal coliforms and tidal state on the spring/neap tidal cycle were found at the three outermost sites (Pembrey, Burry Beach and North Shellfish) with a tendency for fewer low results on spring tides at one and no clear overall pattern at the other two. This perhaps indicates that sources several km up the estuary are of some significance. Correlations were found between faecal coliforms and tidal state on the high/low tidal cycle at all sites apart from Pwll. At the nearshore sites slight tendencies for higher results on the ebb tide were seen suggesting that upstream sources were of some significance. At the mid estuary sites slight tendencies for higher results during the lower half of the tidal cycle could be seen, which is consistent with the lower dilution potential in the main channel at such times.

A fairly strong and consistent influence of rainfall on faecal coliform results was detected at some sites, namely the nearshore bathing waters sites sampled on more than 50 occasions (Pembrey, Burry Beach and North Groyne). The influence of rainfall was much weaker at the mid channel sites. All sites apart from Pwll showed very strong correlations between levels of faecal coliforms and salinity. This suggests that runoff borne contamination is of high significance to the estuary as a whole, but at Pwll there may be another (rainfall independent) source of greater local significance.

Four of the cockle RMPs and three mussel RMPs were sampled on more than 10 occasions since the start of 2006. Of the four cockle RMPs, two were on the northern side of the estuary (B1 North Extension and Penrhyn Gwyn) and two on the southern side (Whiteford Point and South East 4). Across all four RMPs, results were variable ranging from within the Class A range up to prohibited levels or >18,000 *E. coli* MPN/100g. On both the south and the north side, results were higher both on average and in terms of the proportions of results exceeding 4600 *E. coli* MPN/100g at the up-estuary site. A comparison of 32 paired (same day) samples from the two main cockle RMPs on the north side revealed a correlation between these samples but no significant difference in mean result. A comparison of paired (same day) sample results between the two cockle RMPs on the south side of the estuary revealed a significant correlation between them and also significantly higher results on average at South East 4 than at Whiteford Point. It was not possible to undertake meaningful paired comparisons between sites on the north and south side as only a few paired (same day) samples had been taken for the various north-south combinations.

Across the three mussel RMPs, results were again quite variable ranging from Class A to Class C equivalent. A comparison of all results from these RMPs showed they were significantly higher at Pwll compared to Burry Port. A comparison of 36 paired (same day) samples taken at Burry Port and Pwll again revealed a significant difference and also a correlation. Comparisons of the 21 paired samples from Pwll and Whiteford Point showed a correlation and no significant difference in average result.

Over a four day period in March 2012, a series of 39 shellfish flesh samples were collected by the Environment Agency from various locations within Burry Inlet and tested for *E. coli*. Cockles on the north side showed a slight tendency for higher results up-estuary. A similar effect over a smaller scale was also observed across the mussel beds at Whiteford Point. Cockle results on the south side also appear to show an underlying tendency for higher results up-estuary, but with some localised higher results mainly in the general vicinity of the Llanrhidian Pill drainage channel. All results were <1000 *E. coli* MPN/100g indicating that contamination levels at the time of survey were low relative to average and peak levels found during routine classification monitoring so the spatial pattern may differ at times of higher contamination fluxes.

Overall, these spatial analyses of levels of *E. coli* in shellfish flesh reinforce the conclusion that levels of contamination generally increase towards the head of the estuary, and suggests they are higher on the south side than the north side. They also suggest that there are some variable sources such as land runoff which affect the entire estuary at times.

There was no significant seasonal variation at the two cockle RMPs on the north side of the estuary. On the south side significant seasonal variation was found at the two main cockle RMPs where results were significantly higher in the summer and autumn compared to the spring at both. This suggests that the north and south sides of the estuary are subject to differing contaminating influences. Across the three mussel RMPs, significant seasonal variation was not found at Burry Port but was found at Pwll and Whiteford Point. At Pwll results were significantly higher in the winter compared to the spring, and at Whiteford Point results were significantly higher in the summer compared to the spring. Again, differing seasonality was observed on the south and north sides of the estuary, and the seasonal pattern at Whiteford Point was similar to that observed in cockles from both south side RMPs. This consistent pattern on the south side may reflect seasonal patterns of grazing on the adjacent marshes.

As all shellfish samples were collected when exposed by the tide, no analyses of results against the high/low tidal cycle were undertaken. Correlations were found between levels of *E. coli* in shellfish and the state of tide on the spring neap cycle at B1 North Extension, South East 4 and Whiteford Point (cockles) and for Burry Port and Whiteford Point (mussels). For the cockle RMPs a tendency for higher results during spring tides was seen at Whiteford Point and to a lesser extent at South East 4, whereas no pattern could be discerned when the data for B1 North Extension was plotted. For the mussel RMPs a similar tendency for higher results during spring tides was seen at Whiteford Point and less clearly at Burry Port. The consistent tendency for higher results on spring tides on the south side may indicate that tidal

inundation of the grazing marshes is associated with higher levels of contamination. Alternatively it could mean that sources several km away are of some significance.

Positive correlations between *E. coli* results and rainfall were detected at all the RMPs investigated. For cockles the correlations were generally strongest at Penrhyn Gwyn and weakest at Whiteford Point, perhaps reflecting their relative proximity to the head of the estuary. For mussels correlations were generally strongest at Pwll and weakest at Burry Port, again possibly reflecting their positions relative to the main freshwater inputs.

The main conclusions arising from analyses of bacteriological monitoring results which have a major influence on the sampling plan are:

- There is a general tendency for higher levels of contamination towards the head of the estuary, and this gradient becomes steeper up-estuary from Salthouse Point where the estuary narrows. This reflects the shape of the estuary and the location of the main sources of land runoff and treated sewage.
- Differing patterns of seasonality suggest the north and south sides of the estuary are subject to differing sources of contamination. The summer/autumn peak in results together with the tendency for higher results on spring tides suggests livestock are of significance on the south side.
- On the north side there appears to be an area where levels of contamination are elevated, within the channel running along the Llanelli seafront.
- On the south side there may be an area where levels of contamination are elevated in the vicinity of the Llanrhidian Pill channel.

4. RECOMMENDATIONS

4.1 Differing sources of contamination impact either side of the estuary channel, as evidenced by modelled tidal streams and microbiological monitoring results, so the wild cockle and mussel fisheries should be classified into separate zones lying either side of the mid estuary channel. This dividing line aligns with the administrative boundary between Carmarthen and Swansea Councils.

4.2 It is recommended that wild cockle and mussel fisheries on both the north side and the south side are divided into three zones (Figure 5.1). Within each zone the RMPs should be located as close as possible to the most significant identified source(s) of contamination to be best protective of public health.

4.3 The rationale for the recommended RMP locations (see Figure 5.1) for each of these six zones are described in Table 4.1 below.

Table 4.1. Recommended RMP locations for the wild cockle and mussel fisheries

Zone	RMP	NGR	Explanation
Burry North (East)	Penrhyn Gwyn (existing cockle RMP)	SS 5320 9760	To capture contamination from up-estuary sources.
Burry North (Central)	Llanelli Seafront	SS 4961 9847	To capture contamination from Lleidi, Dafen and intermittent discharges to Llanelli Seafront.
Burry North (West)	By Burry Dock	SS 4452 9991	To capture contamination from Burry Docks and Pembrey Marsh River. Will only require classification for mussels.
Burry South (East)	Ochor Draw	SS 5367 9715	To capture contamination from up-estuary sources
Burry South (Central)	South East 4 (existing cockle RMP)	SS 5050 9590	To capture contamination from the Llanridian Pill channel
Burry South (West)	Burry Pill Channel	SS 4601 9609	To capture contamination from the Burry and Great Pill channels

4.4 The species sampled should be mussels and cockles. Mussels should be of a marketable size (>45mm). Currently smaller cockles (<19mm) are acceptable as these are representative of the stocks being fished. This requirement should be reviewed annually in consultation with Welsh Government Fisheries. Parallel monitoring results where samples of both species are taken from within 100m of each other should be assessed by the competent authority (the FSA) after one years monitoring to determine whether one of the species may be used to classify both.

4.5 Samples should be taken on a monthly basis to maintain a full classification. Any areas which are currently unclassified can be awarded a provisional classification following 10 samples taken not less than 1 week apart, or a full classification following one year of monthly monitoring.

4.6 Should any of these zones be inactive the LEAs have two options to consider. If sampling frequency is reduced to quarterly, the zone may be maintained as 'temporarily declassified', and can be reclassified as soon as monthly sampling is

reinstated. If sampling within a zone is stopped completely then the zone will be fully declassified at the subsequent annual classification review.

4.7 Usually a tolerance of 100m is applied around RMPs for wild stocks. It is however recognised that there may not be sufficient stock even within this tolerance, particularly for mussels which have a more patchy distribution. Safe access to some points may be difficult under certain conditions. Should this be the case, samples should be taken as close as is possible to the recommended RMP location, and the location sampled should be recorded by GPS to an accuracy of 10m, and this location should be recorded on the sample submission form.

4.8 A single zone off Pwll should be established in the first instance for softshell clams (Figure 5.2). The RMP should be set at SN 4813 0049 to best capture contamination from the Dulais and from intermittent sewage outfalls here. A maximum tolerance of 100m should be applied. A provisional classification can be awarded following 10 samplings taken no less than 1 week apart. A full classification can be awarded after one year of monthly monitoring.

4.9 Should this fishery expand further zones may be opened up based on the sampling plans for wild cockles and mussels (Figure 5.1).

4.10 It is recommended that the experimental mussel farm should not be classified for reasons detailed in the assessment.

5. SAMPLING PLAN

GENERAL INFORMATION

Location Reference

Production Area	Burry Inlet
Cefas Main Site Reference	M038
Ordnance survey 1:25,000 map	Explorer 178 and 164
Admiralty Chart	1167

Shellfishery

Species/culture	Mussels (*Mytilus* spp.)	Wild
	Cockles (*Cerastoderma edule*)	Wild
	Softshell clams (*Mya arenaria*)	Wild
Seasonality of harvest	No formal closed season for any species	

Local Enforcement Authority

Name	Carmarthenshire County Council Ty Elwyn Town Hall Square Llanelli SA15 3AP
Environmental Health Officer	Mark Liley
Telephone number (	01554 742250
Fax number Ê	01554 742115
E-mail š	MLiley@carmarthenshire.gov.uk
Name	Environmental Health Department Swansea City & County Council The Guildhall Swansea SA1 4PE
Environmental Health Officer	Keith James
Telephone number (	01792 635640
Fax number Ê	01792 648079
E-mail š	keith.james@swansea.gov.uk

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, 2010) indicates that sanitary assessments should be fully reviewed every 6 years, so this assessment is due a formal review in 2018. 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. Species sampling requirements may also require interim review in the light of changes in landing size for a particular species.

Table 5.1 Number and location of representative monitoring points (RMPs) and frequency of sampling for classification zones within Burry Inlet

Classification zone	RMP	RMP name	NGR	Latitude & Longitude (WGS84)	Species	Growing method	Harvesting technique	Sampling method	Tolerance	Frequency	Comments
Burry North (East)	B038M /B038X	Penrhyn Gwyn	SS 5320 9760	51° 39.48' N 04° 07.42' W	Cockles/ mussels [a]	Wild	Hand	Hand	100m [b]	Monthly	Existing cockle RMP, mussels should be available nearby if a classification is needed.
Burry North (Central)	B038Y/ B038Z	Llanelli Seafront	SS 4958 9861	51° 39.96' N 04° 10.58' W	Cockles/ mussels [a]	Wild	Hand	Hand	100m [b]	Monthly	Mussels should be sampled from the rock groyne here if present.
Burry North (West)	B38AA	Off Burry Port	SS 4452 9991	51° 40.58' N 04° 15.01' W	Mussels [a]	Wild	Dredge	Hand	100m [b]	Monthly (or weekly for provisional)	New RMP. Sample from breakwater extending from Burry Port docks.
Burry South (East)	B38AB/ B38AC	Ochor Draw	SS 5367 9715	51° 39.24' N 04° 07.00' W	Cockles/ mussels [a]	Wild	Hand	Hand	100m [b]	Monthly	New RMP. Not thought to be significant stocks of mussels within this zone so mussel classification probably not required.
Burry South (Central)	B038I/ B38AD	South East 4	SS 5050 9590	51° 38.52' N 04° 09.72' W	Cockles/ mussels [a]	Wild	Hand	Hand	100m [b]	Monthly	Existing cockle RMP, mussels should be available nearby if a classification is needed.
Burry South (West)	B38AE/ B38AF	Burry Pill Channel	SS 4601 9609	51° 38.55' N 04° 13.61' W	Cockles/ mussels [a]	Wild	Hand	Hand	100m [b]	Monthly	New RMP. Stocks of both cockles and mussels should be present here
Pwll Softshells	B038V	Cefn Padrig East	SN 4813 0049	51° 40.95' N 04° 11.89' W	Softshell clams	Wild	Hand	Hand	100m	Monthly (or weekly for provisional)	New RMP.

[a] Should classification of this zone for softshell clams be required, the same monitoring and zoning arrangements should be used for this species.

[b] If stocks of this species are not present within this tolerance then samples should be taken from as near as possible to the recommended RMP and the location sampled should be recorded to 10m accuracy by GPS. There is considerable uncertainty regarding the distribution of softshell clams

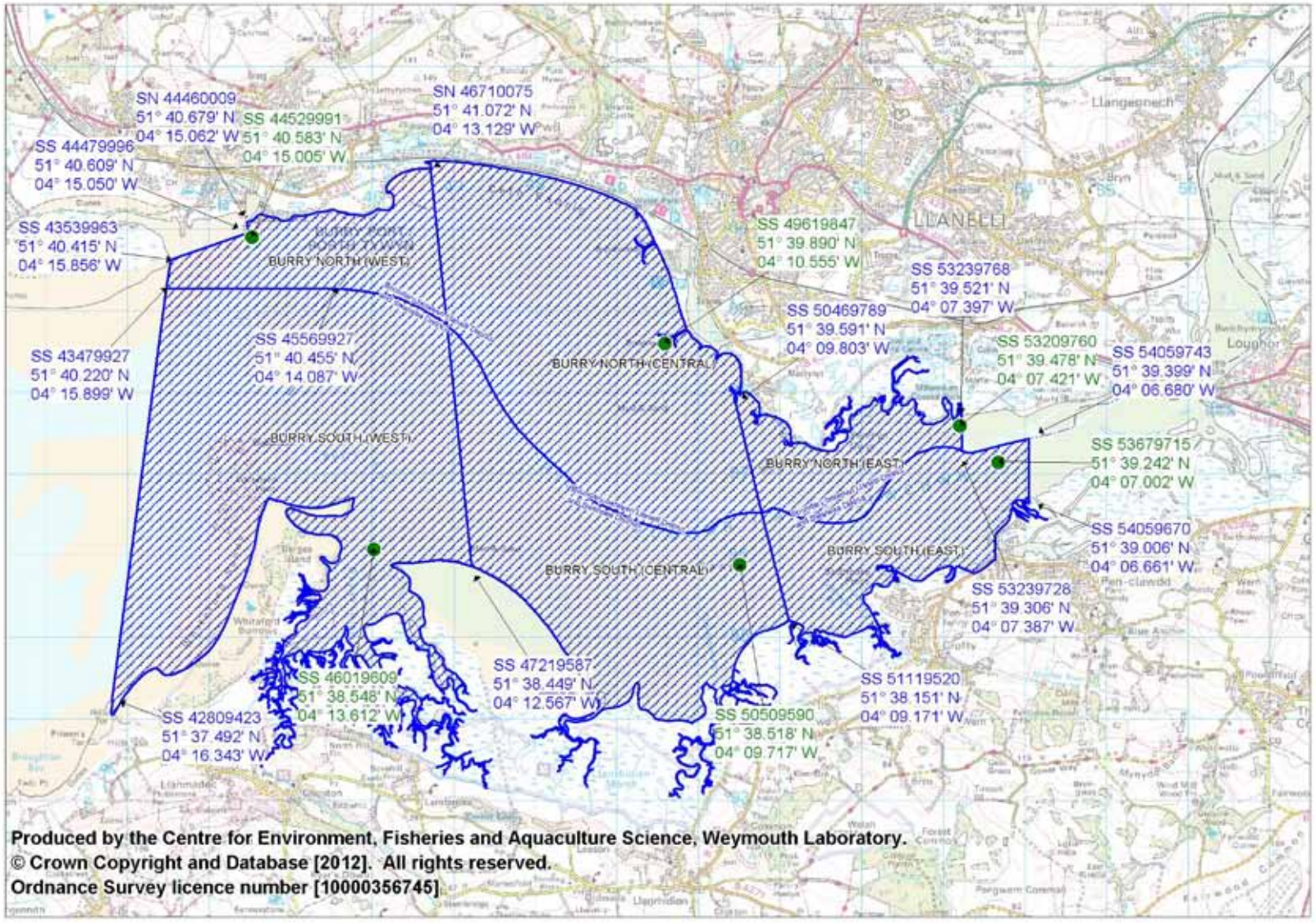


Figure 5.1 Recommended classification zone boundaries and RMP locations for mussels and cockles

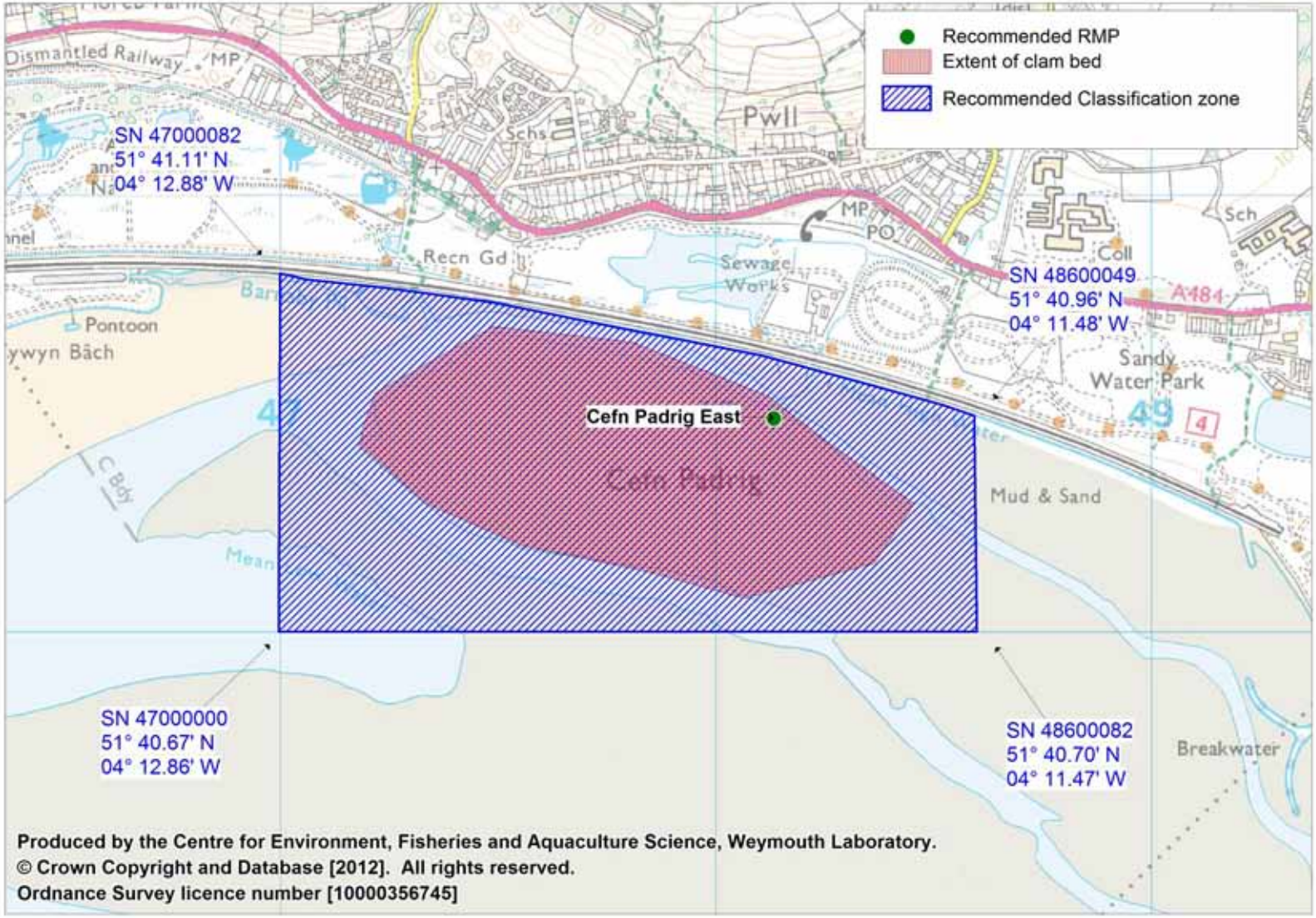


Figure 5.2 Recommended classification zone boundaries and RMP location for softshell clams at Pwll

APPENDICES

APPENDIX I
HUMAN POPULATION

The distribution of resident human population by Super Output Area Boundary totally or partially included within the Burry Inlet catchment area is shown in Figure I.1. Total resident human population in the census areas within or partially within the catchment area was 196,724 at the last census in 2001.

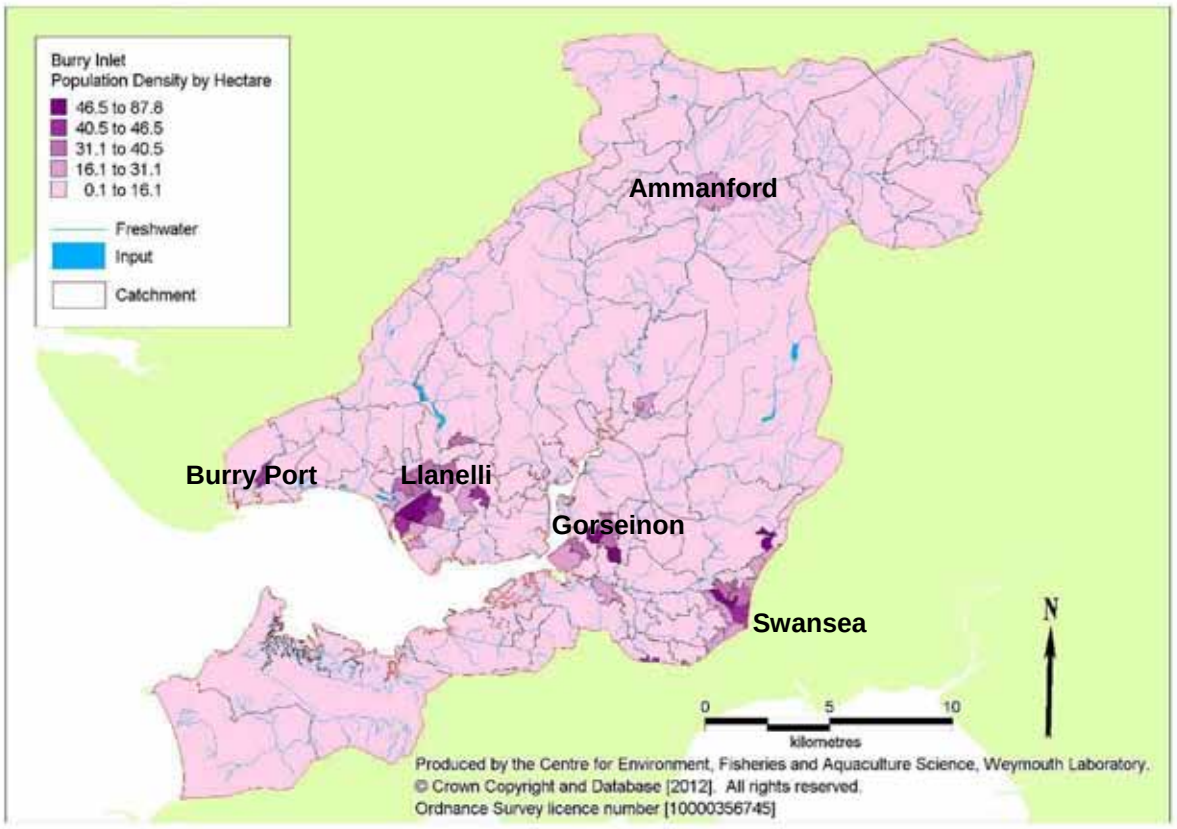


Figure I.1 Human population density in the Burry Inlet catchment area.
Source: ONS, Super Output Area Boundaries (Lower layer). Crown copyright 2004. Crown copyright material is reproduced with the permission of the Controller of HMSO.

The majority of the catchment area is rural in character and sparsely populated, particularly within the upper reaches. The largest town is Llanelli on the north shore of the estuary. The north west outskirts of Swansea also fall within the catchment. There are some villages on the south shore but this is more rural in character. The upper catchment has some villages and the small town of Ammanford. Watercourses draining populated areas are likely to carry contamination from urban runoff and sewage discharges, and tend to carry higher levels of faecal indicator bacteria (Kay *et al*. 2008a).

Carmarthenshire and the Gower Peninsula in particular are popular 'seaside' tourist destinations. South West Wales (Pembrokeshire, Carmarthenshire, Swansea and Port Talbot) has a population of 652,000 and approximately 150,000 bed spaces for visitors (SWWTP, 2011) so a significant population increase may occur in some areas during the peak holiday months. As the attractions near Burry Inlet are largely

outdoors, the peak season is likely to be summer. Increased population numbers will result in increased volumes of sewage treated by the sewage works.

APPENDIX II
HYDROMETRIC DATA: RAINFALL

Wales is one of the wetter regions of England and Wales, but rainfall varies considerably across the region. Areas with higher elevations tend to receive higher rainfalls, so rainfall will be higher in the upper Loughor catchment than in coastal areas. Figure II.1 presents a boxplot of daily rainfall totals by month for a rain gauge located at Penclacwydd, within the Millennium Coastal Park just south of Llanelli so should be representative of rainfall in the immediate vicinity of Burry Inlet.

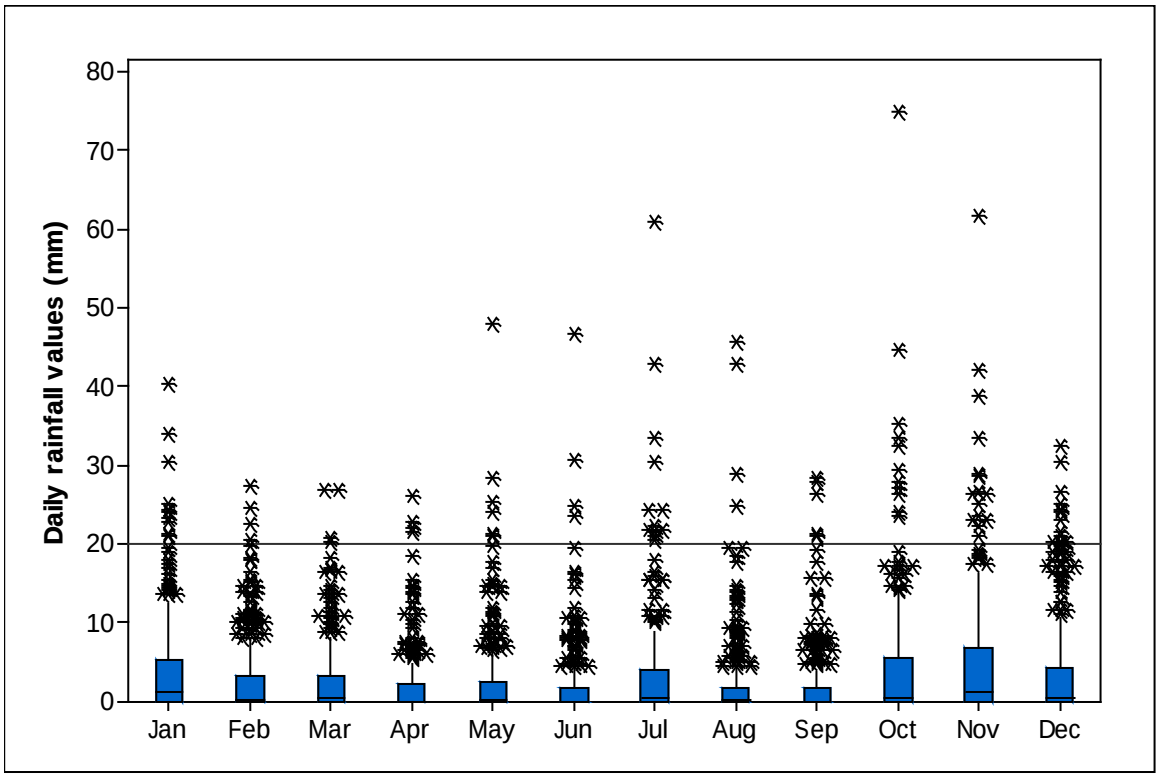


Figure II.1 Boxplot of daily rainfall totals at Penclacwydd, January 2002 to February 2011.
Data provided by the Environment Agency.

Rainfall is generally highest from October to January, and lower through the rest of the year. A secondary peak is apparent in July as a result of a series of wet Julys from 2007 to 2010, and this pattern is not apparent in long term averages for the region (Met Office 2012). There was no rainfall on 40.4% of days. Rainfall exceeding 20mm occurred on 2.8% of days, and occurred in every month of the year. High rainfall events were generally more frequent and of a higher intensity during the second half of the year.

Rainfall may lead to the discharge of raw or partially treated sewage from combined sewer overflows (CSO) and other intermittent discharges as well as runoff from faecally contaminated land (Younger *et al.*, 2003). RMPs located in parts of shellfish beds closest to rainfall dependent discharges and freshwater inputs will best capture contamination from such sources. Relationships between levels of *E. coli* and faecal coliforms in shellfish and water samples and recent rainfall are investigated in detail in Appendices XI and XII.

APPENDIX III
HYDROMETRIC DATA: FRESHWATER INPUTS

Burry Inlet has a catchment area of about 470km^2 in total. The largest individual freshwater input is the River Loughor, which discharges to the head of the estuary. There are numerous other rivers and streams discharging to various points within the estuary.

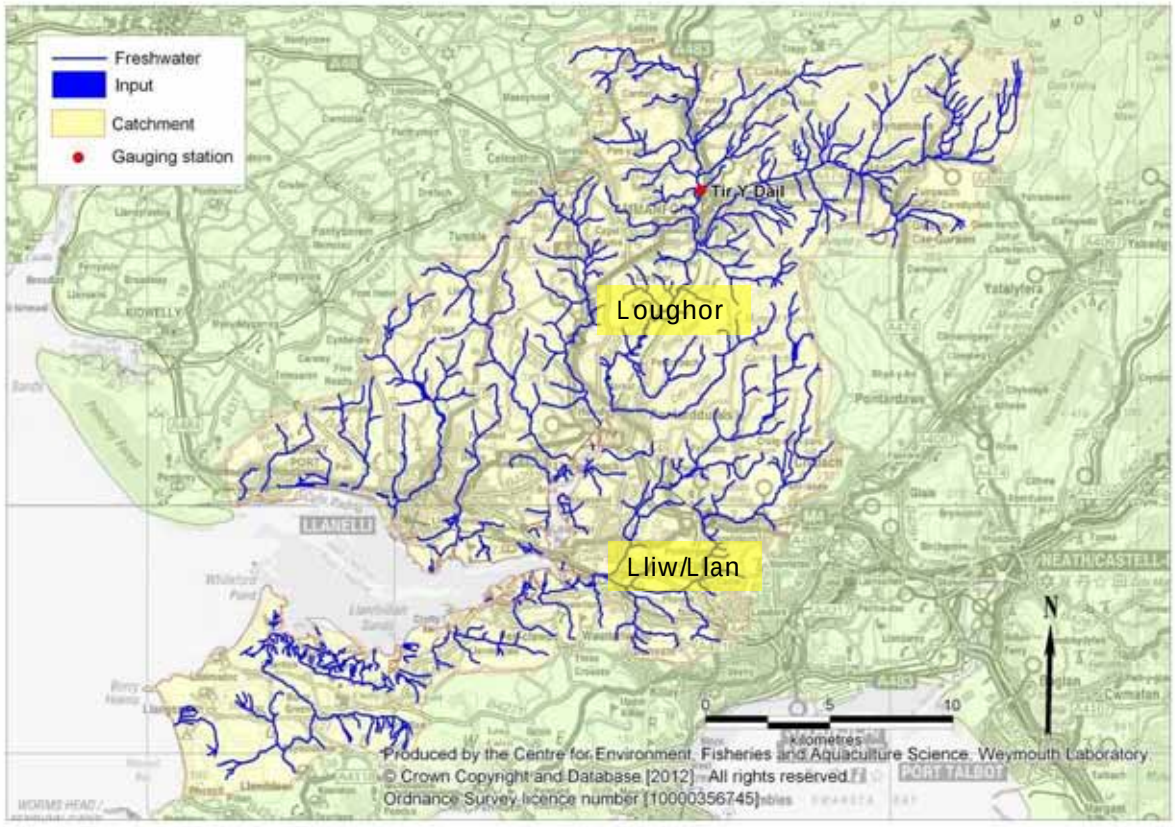


Figure III.1 Freshwater inputs to Burry Inlet.

The watercourses draining to Burry Inlet are mainly surface water fed rather than groundwater fed so will tend to rise rapidly in response to rainfall (Environment Agency, 2007) particularly in the upper catchment which is of higher elevation. About 75% of the catchment is drained by watercourses which meet the estuary upstream of the fisheries including the Loughor and the Lliw/Llan. There is only one river flow gauging station within the catchment (see Figure III.1) and this is located at Tir Y Dail, within the upper catchment of the Loughor. With a catchment area of 46.4km^2 it covers only about 10% of the Burry Inlet catchment. As it is in the upper catchment it is perhaps more representative of the upland areas where flows are likely to respond most rapidly to rainfall.

A boxplot of mean daily flow records by month are presented in Figure III.2. Mean daily flows averaged 2.2 m^3/s, with peaks of up to 25 m^3/s recorded. Given that this covers only 10% of the catchment, freshwater inputs of roughly 10 times these amounts are anticipated to Burry Inlet as a whole. Flows were highest on average from October to February, but high flow events (>10m^3/sec) occurred in most months of the year. A secondary peak in flows can be seen in July, although this is likely to be due to the unusual series of wet Julys during the period presented (Appendix II).

Therefore lowest flows are generally anticipated from April to August, but high flow events may occur at any time of the year. The seasonal pattern of flows is not entirely dependent on rainfall as during the colder months there is less evaporation, less transpiration, and soils are more likely to be waterlogged so higher proportion of rainfall will run off. Increased levels of runoff are likely to result in an increased bacterial loading carried into coastal waters. They will also decrease residence time in rivers so contamination from more distant sources may have an increased impact during high flow events.

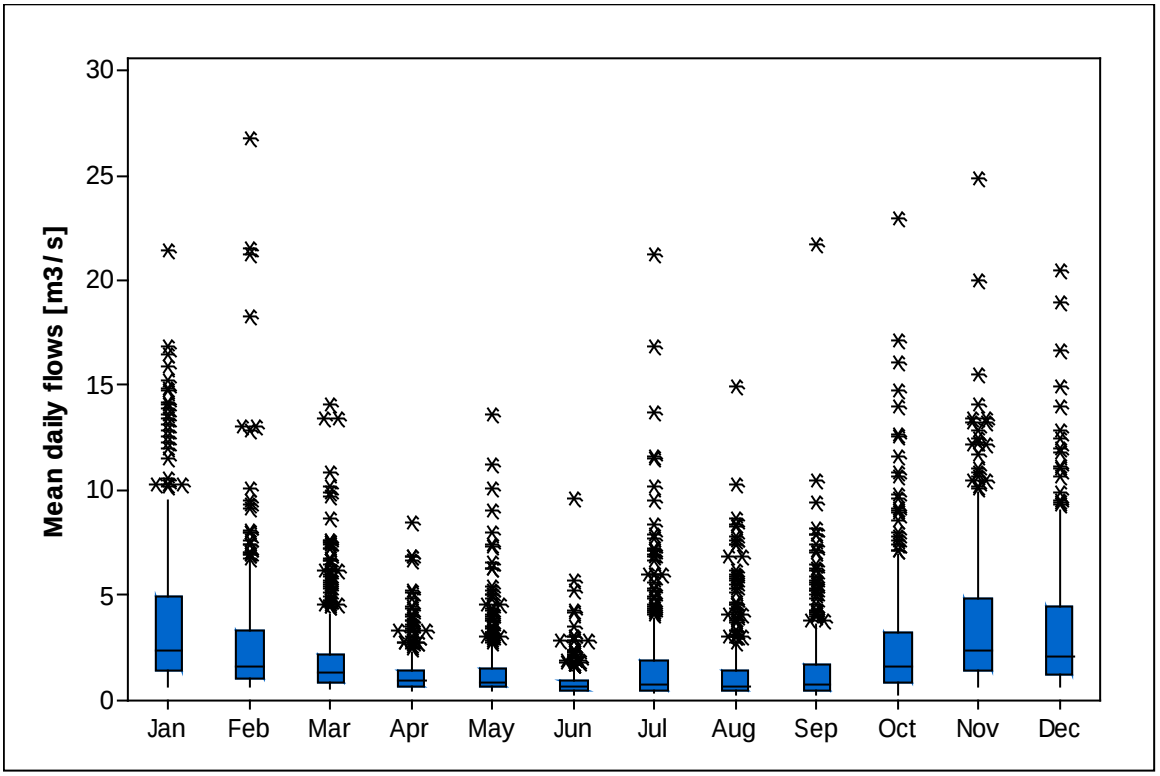


Figure III.2 Boxplot of mean daily flow records from Tir Y Dail, January 2002 to January 2012
Data from the Environment Agency

During the shoreline survey, which was conducted under dry conditions, watercourses which could be safely accessed were sampled for *E. coli* and spot flow measurements were made. The results are presented in Table III.1 and Figure III.3.

Table III.1. *E. coli* sample results, measured discharge and calculated E. coli loadings (clockwise from Burry Port)

Ref No.	Watercourse name	Date and time	NGR	*E. coli* (cfu/100ml)	Measured discharge (m^3/sec)	Loading *(E. coli/* day)
1	Kymer Canal	18/04/2011 09:05	SN 44370 00500	18	0.059	$9.2x10^8$
2	Afon Cwm Mawr Trib	18/04/2011 10:21	SN 47276 00867	45	0.021	$8.0x10^8$
3	Dulais Trib	18/04/2011 10:40	SN 48132 00689	15	0.080	$1.0x10^9$
4	Dulais (u/s conf with 3)	18/04/2011 10:47	SN 48257 00649	132	0.068	$7.7x10^9$
5	Unnamed stream	18/04/2011 12:26	SS 51821 97973	41	0.189	$6.7x10^9$
6	Bynea SPS Outfall	18/04/2011 14:00	SS 55312 98095	56	0.001	$5.8x10^7$
7	Morlais River	19/04/2011 11:00	SS 52674 94808	400	0.069	$2.4x10^{10}$
8	Llanrhidian Pill	19/04/2011 11:34	SS 50072 92965	700	0.036	$2.2x10^{10}$
9	Great Pill	19/04/2011 12:02	SS 47693 93085	1100	0.420	$4.0x10^{11}$
10	Bennetts Pill	19/04/2011 12:30	SS 46715 93380	680	0.232	$1.4x10^{11}$
11	Burry Pill	19/04/2011 12:59	SS 45101 93137	80	0.380	$2.6x10^{10}$

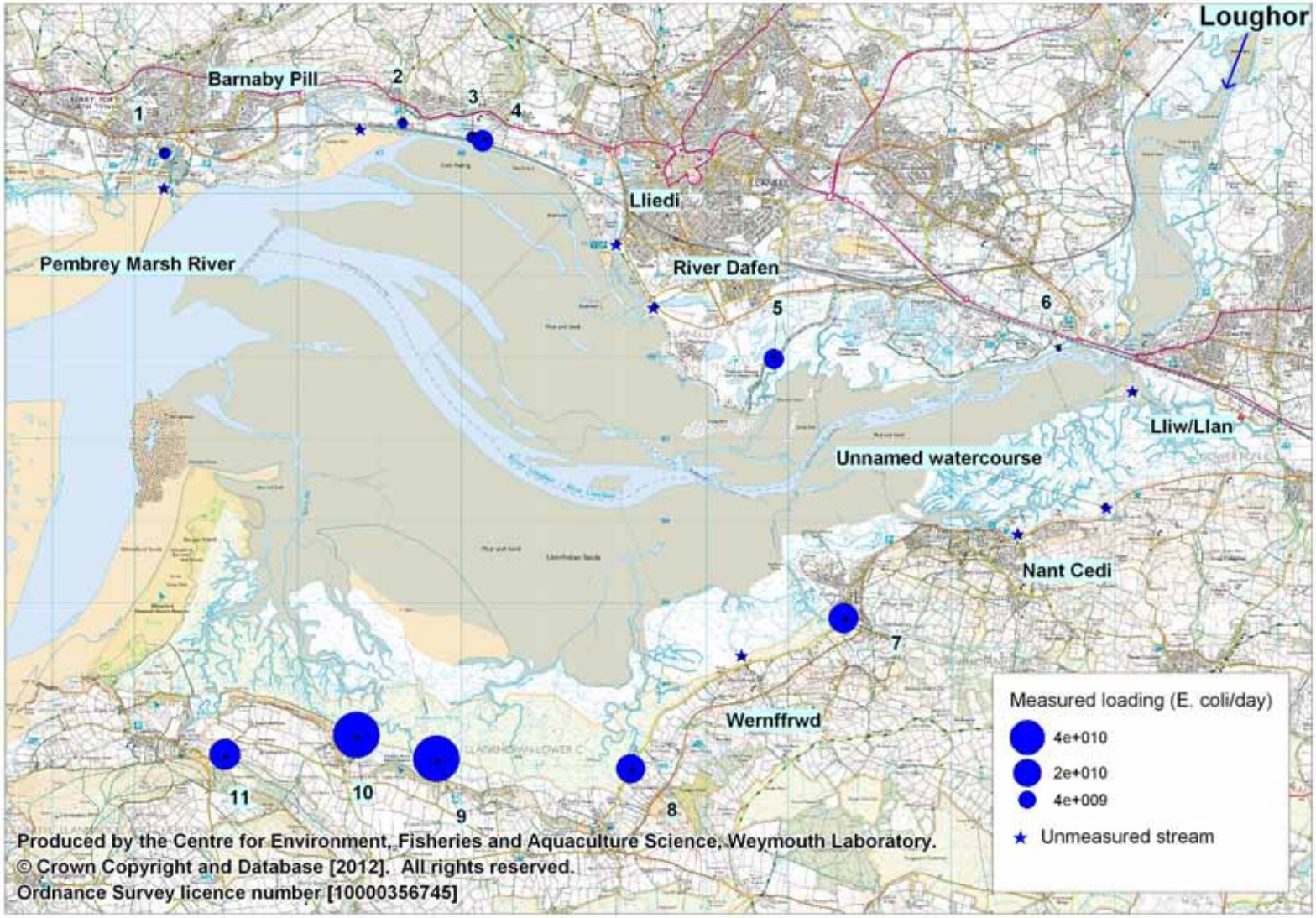


Figure III.3. Measured stream loadings from shoreline survey, and other potentially significant watercourses (unmeasured)

It is apparent that the sampled streams on the north shore were generally carrying much lower concentrations and loadings of *E. coli* compared to the streams on the south shore. Four significant streams on the north shore were not sampled and measured due to access difficulties (Pembrey Marsh River, Barnaby Pill, Lliedi and Dafen), and these were relatively large in terms of volumes discharged. The most significant watercourses on the south shore were all sampled and measured, with the exception of the Lliw/Llan, which discharges in close proximity to the Loughor Bridge. A few of the smaller watercourses on the south shore were not sampled or measured.

Selected watercourses draining to Burry Inlet have been sampled by the Environment Agency and tested for faecal coliforms. Summary statistics of these results are presented in Table III.2, and the locations sampled are shown in Figure III.4. Results were reported here as faecal coliforms (presumptive), and so are not directly comparable with the results presented in Table III.1.

Table III.2. Summary of bacteriological sampling results from the lowest downstream point on each watercourse sampled (clockwise from Burry Port).

Watercourse name	NGR	Year sampled	Faecal coliforms results cfu/100ml (presumptive)			
			No.	Geomean	Min.	Max.
Pembrey Marsh River	SN4364500014	2011	2	525	18	15000
Kymer Canal	SN4434000472	2009-2011	10	1374	380	20000
Nnant Dyfatty	SN4461600556	2011	3	1045	390	2480
Barnaby Pill	SN4668000820	2011	1	140	140	140
Afon Cwm Mawr Trib	SN4726800860	2009-2011	8	1239	92	11000
River Dulais	SN4825900673	2005-2011	33	706	91	30000
Lliedi	SS4992899423	2005-2011	34	2181	455	>10000
River Dafen	SS5030098600	2005-2006	22	2698	64	19800
Penclacwydd Point C	SS5336098040	2002-2012	111	73	4	>10000
Penclacwydd Point B	SS5384097840	2002-2012	114	87	<2	220000
Loughor Trib	SS5592796112	2010	1	340	340	340
Nnant Cedi	SS5482695857	2010	1	24000	24000	24000
Salthouse Pill	SS5244294767	2009	1	800	800	800
Wernffrwd	SS5131594693	2010	1	260	260	260
Llanrhidian Pill	SS5011093673	2011	5	1875	818	4200
Great Pill	SS4765193101	2011	5	728	520	2000
Bennetts Pill	SS4631793635	2009	2	826	462	1480
Burry Pill	SS4506593127	2003-2011	9	3936	520	24000

Original data from the Environment Agency.

Many of these watercourses were sampled on only one or two occasions, and on different days from each other, so caution is required when deriving conclusions about their relative impacts. Spot flow measurements were taken at four of these watercourses on multiple occasions (but not generally at the furthest downstream point), the results of which are summarised in Table III.3.

Table III.3 Spot flow measurements

Watercourse	NGR	Year	No.	Discharge (m^3/sec)		
				Mean	Min.	Max.
Dulas (Pwll Road Br.)	SN4856000848	2003-2005	20	0.103	0.016	0.233
Dafen (Below Halfway PS)	SN5248400346	2002-2009	110	0.230	0.003	7.69
Lliedi (below culvert)	SN5076800535	2003-2005	20	0.290	0.027	0.628
Burry Pill (Cheriton Road Br.)	SS4506593127	2003-2004	6	0.461	0.110	1.41

Original data from the Environment Agency

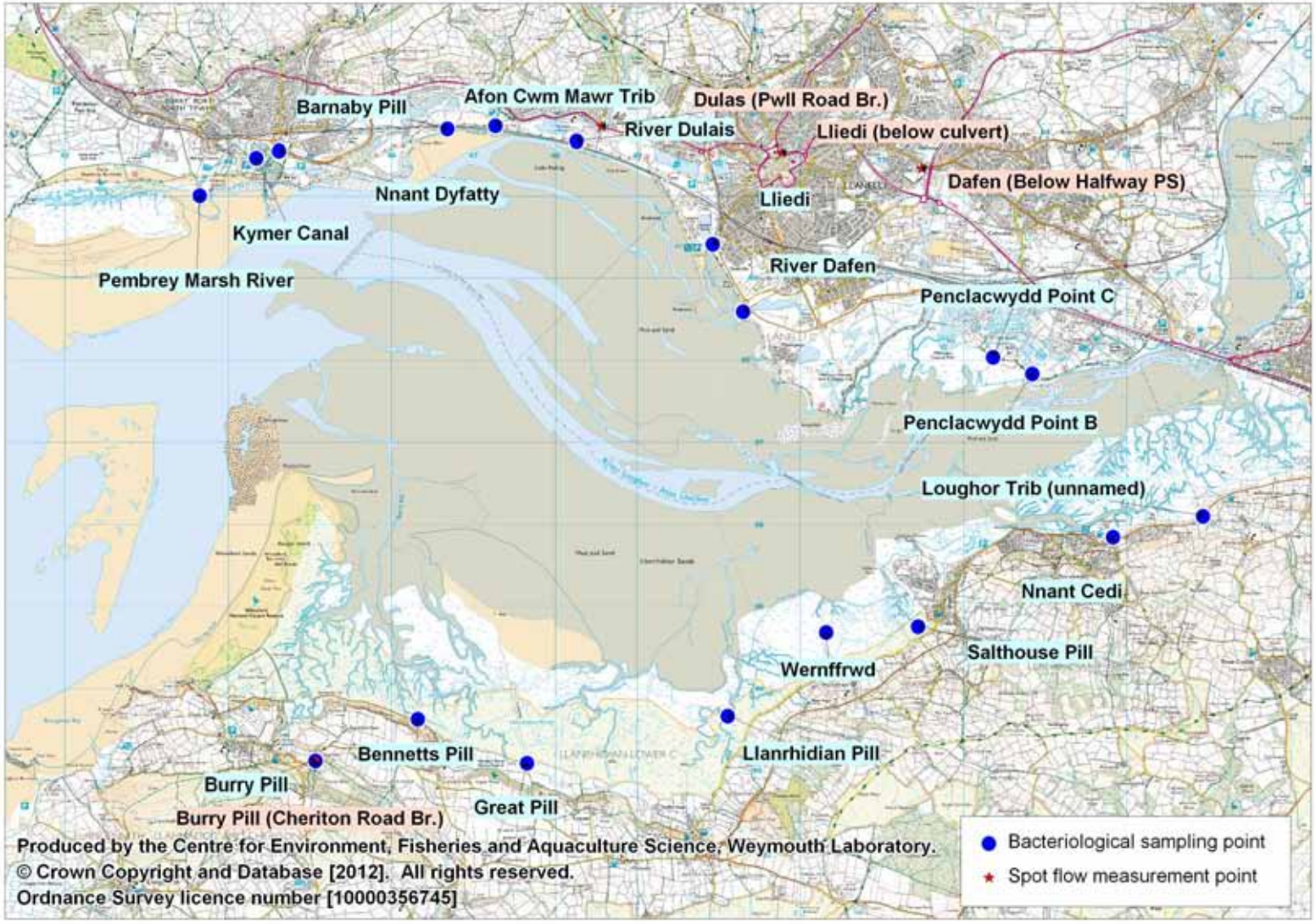


Figure III.4. Environment Agency stream survey sites

In conclusion, all rivers and streams carry some contamination from land runoff and so will require consideration in the assessment. Their impacts will be greatest at their confluence with the estuary, and in shellfish beds within or immediately adjacent to the drainage channels they follow across the intertidal area. Volumes of runoff are generally higher in the late autumn and winter, although high flow events may occur at any time of the year. The main freshwater input is the Loughor, which enters the estuary about 5km upstream of the Loughor Bridge and follows the central channel at low water. The second largest input is the Lliw/Llan which enters on the south shore by the Loughor Bridge where its channel joins the main central channel. These are likely to be of significance to water quality in the estuary as a whole, and their influence will generally be greatest towards the upstream end of the shellfisheries, and most acute within the central channel at low water.

There are many smaller watercourses which are likely to be of more localised impact. It is difficult to draw any conclusions about Pembrey Marsh River and Barnaby Pill as they were not measured and only sampled on one or two occasions on different days, although Barnaby Pill was one of the larger watercourses seen on the north shore during the shoreline survey. The two streams entering Burry Dock (Kymer Canal and Nnant Dyfatty) generally carried moderate concentrations of faecal coliforms but will probably cause elevated levels of contamination within the enclosed dock area. The Dulais, Dafen and Lleidi appear broadly similar to Burry Pill in terms of the bacterial loading they convey. These all appear to converge within the same drainage channel which runs along the north shore at Pwll. There is relatively little contamination flowing from the marshes at Millennium Park (Penclacwydd). Shoreline survey results suggest that the main watercourses draining to the south shore carry higher levels of contamination compared to those on the north shore but this does not appear to be the case in the more extensive set of results from Environment Agency surveys. On the south shore it is likely that the most significant ‘hotspot’ of runoff borne contamination within the areas requiring classification arises in the area where Burry Pill, Bennets Pill and Great Pill converge although Llanridian Pill and Salthouse Pill were also carrying significant bacterial loadings at the time of shoreline survey.

APPENDIX IV
HYDROGRAPHIC DATA: BATHYMETRY

Burry Inlet is a large, west facing coastal plain type estuary about 20km in length and covering an area of about 45km^2. It is characterised by a meandering central river channel flanked by large gently undulating intertidal areas. There are no fisheries above the Loughor Bridge, where the estuary is relatively narrow (<1km) and has a north south orientation. The bridge lies at a constriction in the estuary where tidal flows are likely to accelerate and mixing of the water column will occur. At the Loughor Bridge, the estuary beds round to assume an east west orientation and between here and Llanelli it estuary widens to about 6km. It then narrows to about 3.5km between Burry Port and Whiteford Point, a barrier dune which protrudes from the southern shore. The depth and width of the main channel increases here to a maximum of 9.3m below chart datum in Whiteford Pool, between Pembrey Burrows and Whiteford Point. Outside of Whiteford Point the main channel splits into three. There is a bar and extensive sandbanks across at the mouth of the estuary where the maximum depth at chart datum is 2.1m at the entrance to South Channel. The shallow nature of Burry Inlet will reduce the potential for dilution, but will promote tidal exchange.

Several drainage channels cut through the intertidal areas, most of which carry land runoff and associated contamination. A training wall was constructed south of Llanelli in an attempt to divert the main channel towards the north shore to aid shipping traffic to Llanelli and Burry Port, but this has since been breached and the channel cuts through it. There are significant areas of saltmarsh bordering the inlet, mainly on the south side, parts of which are inundated on the larger tides (Robins, 2009). The north side has a more engineered shore, with flood defences extending most of its length, although there is an area of saltmarsh at the Millennium Park.

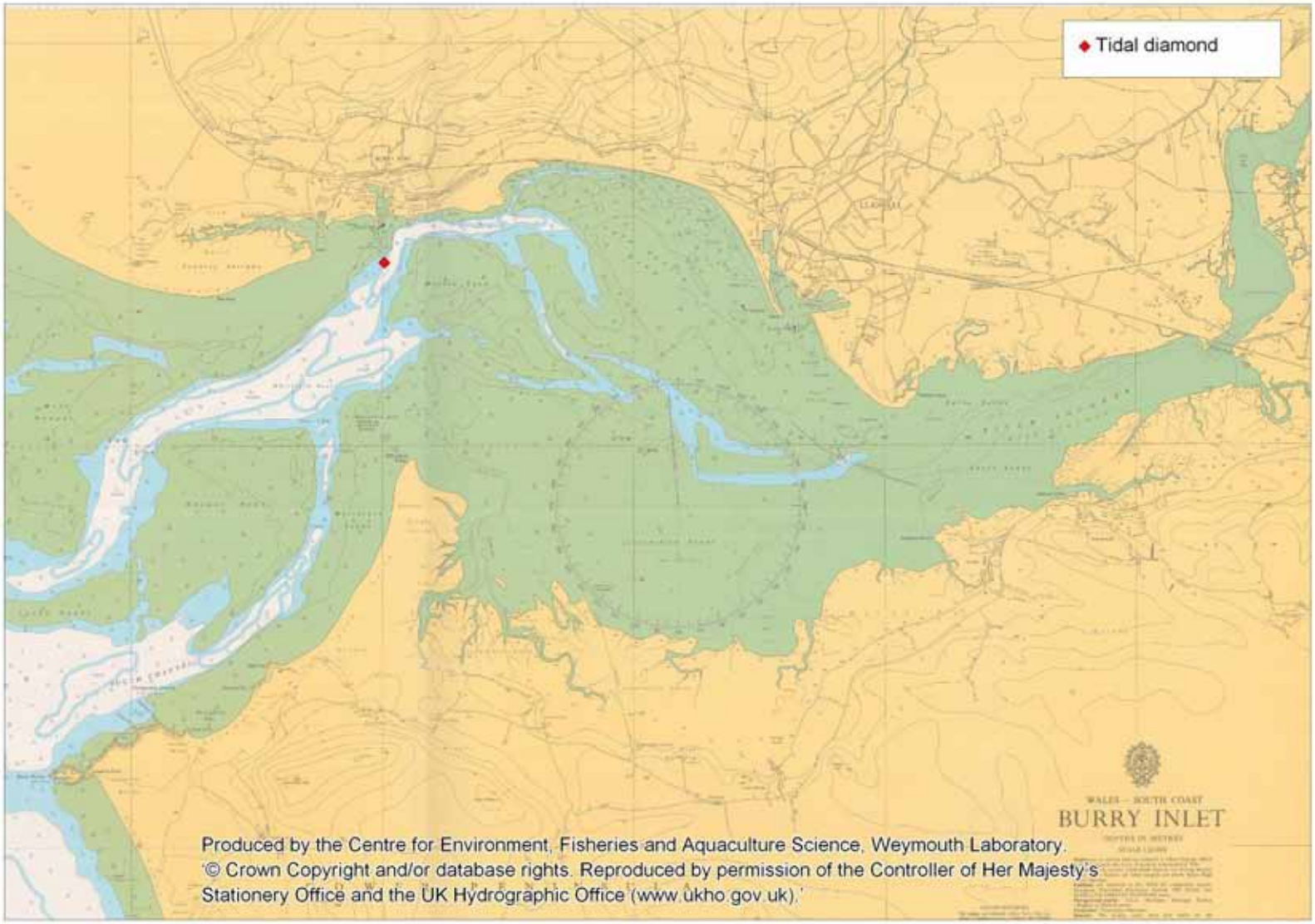


Figure IV.1 Bathymetry chart of Burry Inlet

APPENDIX V
HYDRODYNAMIC DATA: TIDES AND CURRENTS

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. Tidal amplitude is large (Table V.1) and this drives extensive water movements within Burry Inlet.

Table V.1 Tide levels and ranges at various tidal stations within Burry Inlet.

	Height (m) above Chart Datum				Range (m)	
Port	MHWS	MHWN	MLWN	MLWS	Springs	Neaps
Burry Port	8.60	6.60	3.00	1.10	7.50	3.60
Llanelli	7.80	5.80	-	-	-	-

Data from the Proudman Oceanographic Office

The flood tide will convey relatively clean water originating from the open Atlantic Ocean into the estuary, whereas the ebb tide will carry contamination from shoreline sources out through the estuary. Figure V.1 presents an overview of modelled tidal streams through the outer estuary, at peak flood and ebb during spring tides (Robins, 2009).

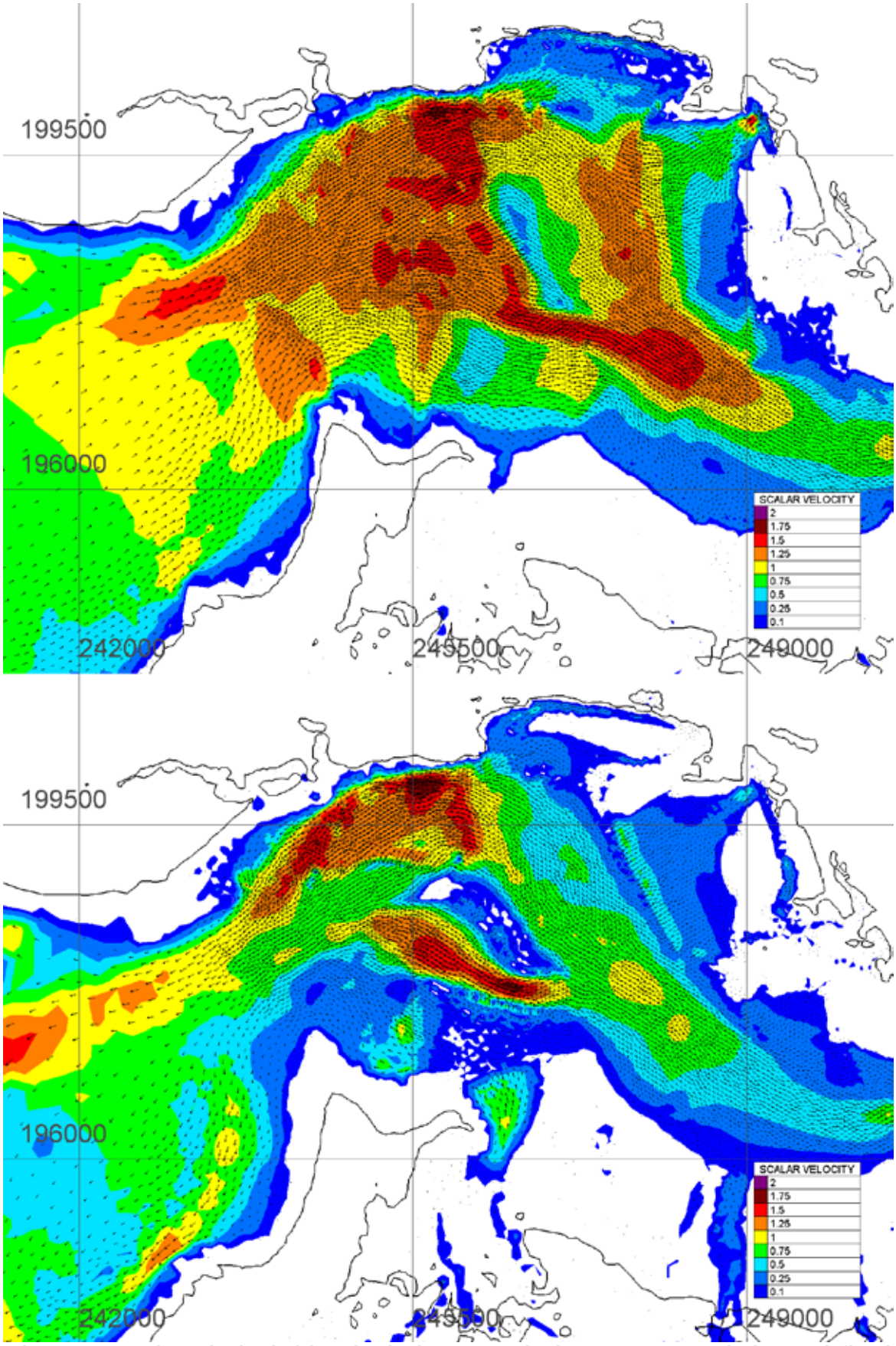


Figure V.1 Scalar velocity (m/s) and velocity vectors in the outer estuary during peak flood (top) and ebb (bottom) flow, from Robins (2009). *Reproduced with permission of the author.*

The general pattern of tidal circulation is bi-directional, with water moving up the estuary on the flood and back out on the ebb. The tidal regime is ebb dominant (Defra, 2002). The main flows align with the central channel, splitting around a slightly elevated bank in the middle of the estuary. The main channel runs closest to the shore off Burry Port which is where the strongest flows arise (1.6 m/s on the flood and 1.9 m/s on the ebb). On higher elevations towards the shore current velocities are much lower (generally less than 0.5m/s). On the north shore from Pembrey to Pwll tidal streams run parallel to the shore. Immediately west of Llanelli ebb flows run parallel to the shore in a northerly direction up to the north groyne where they bed round and flow towards the main channel. On the south side by the Llanrhidian/Llandiemore marshes, main flows across the areas closest to the shore run north south and follow the main drainage channels. Upstream of the area represented in Figure VI.1 to the Loughor Bridge flows are mainly parallel to the shore although in some places there are perpendicular flows associated with saltmarsh drainage channels (Robins, 2009). Taking an average peak flow rate through the central channel on spring tides of 1m/s (as estimated from Figure V.1) a very rough estimate of tidal excursion (the distance a particle would travel during the course of a single flood or ebb tide) on spring tides would be in the order of 12-15km. The tidal diamond at Burry Port (Figure IV.1) was not used to estimate tidal excursion as it is situated in the part of the estuary where tidal currents are fastest so would give a significant overestimate. Therefore sources a considerable distance away may impact on the shellfisheries, particularly those discharging to the main channel. The tidal diamond just off Burry Port shows peak neap tide velocities are just under half the velocities on spring tides.

Given these circulation patterns, contamination from shoreline sources such as small watercourses will be transported parallel to the shore between Burry Port and Pwll, and on both the north and south shore upstream of Penrhyn Gwyn and Salthouse Point. Impacts will arise to either side of them, and the magnitude of their impacts will decrease with distance as the plume spreads and becomes more diluted. Contamination from shoreline sources where tidal streams are more perpendicular to the shore will tend to remain near to its source during the flood and dissipate towards the central channel on the ebb, largely via any defined drainage channels. On this basis the highest concentrations of indicator bacteria are therefore anticipated within the drainage channels and the main channels around low water and RMPs should be located to reflect this.

Within Burry Dock classification has been requested for an experimental mussel farm. The docks are a small enclosed water body where water levels are maintained by an automatic tidal flap gate (Carmarthenshire Council, 2012). This limits any possible tidal exchange of water through its relatively small entrance to about 2 hours either side of high water. As a consequence contamination from any sources discharging direct to the docks has the potential to build up to much higher levels than would occur in the open waters of the main estuary.

Freshwater inputs may significantly modify the circulation of water around estuaries via density effects. Robins (2009) estimated the tidal prism on spring tides to be 7.228×10^{11} m^3 for Burry Inlet. The volumes of freshwater entering the estuary per day are several orders of magnitude lower than this, perhaps about $2x10^7$ m^3 per day during major flood events, extrapolating Loughor flow data to the entire catchment

area (Appendix III). Therefore the system will be well mixed so significant stratification is unlikely to occur and density effects will not modify tidal streams. Within the confined waters of Burry Port dock, which receives some freshwater inputs, stratification of the water column may well occur. Therefore mussel RMPs should be located at the surface where the water may be of a lower salinity and where freshwater borne contamination will tend to be entrained.

Tidally driven currents may also be modified by the effects of wind. Strong winds will 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^{-1}) would drive a surface water current of about 1 knot or 0.5 m s^{-1}. The area is most exposed to the west, and the prevailing wind direction is from the south west. Exact effects are dependent on the wind speed and direction as well as state of the tide and other environmental variables so a great range of scenarios may arise. Winds from a westerly direction will tend to push surface water up-estuary. As well as driving surface currents, onshore winds will create wave action. There is a long fetch across the open Atlantic to the west, so energetic wave action will occur in the areas exposed to this direction during strong westerly winds. The seaward shoreline of Whiteford Point and the north shore of the outer estuary are likely to be most exposed to incoming swells although offshore sandbanks will attenuate this to some extent. This may resuspend any contamination held within the sediments of the intertidal zone, temporarily increasing levels of contamination within the water column until it is carried away by the tides.

Higher levels of indicator bacteria in seawater have been correlated with lower salinities at sites throughout Burry Inlet (Appendix XI). The spatial profile of salinity across the estuary is therefore of relevance to the sampling plan as this will provide an approximate representation of the spatial profile of runoff borne contamination. Results of salinity measurements taken by the Environment Agency from 2002 onwards are presented in Figure V.3 and the locations sampled are shown in Figure V.2. The number of measurements taken at each location ranged from 29 to 206 so should give a good indication of the range of salinities likely to arise at each location under various tidal and river flow conditions, although there may be some bias towards different states of the tide at different sites for practical reasons.

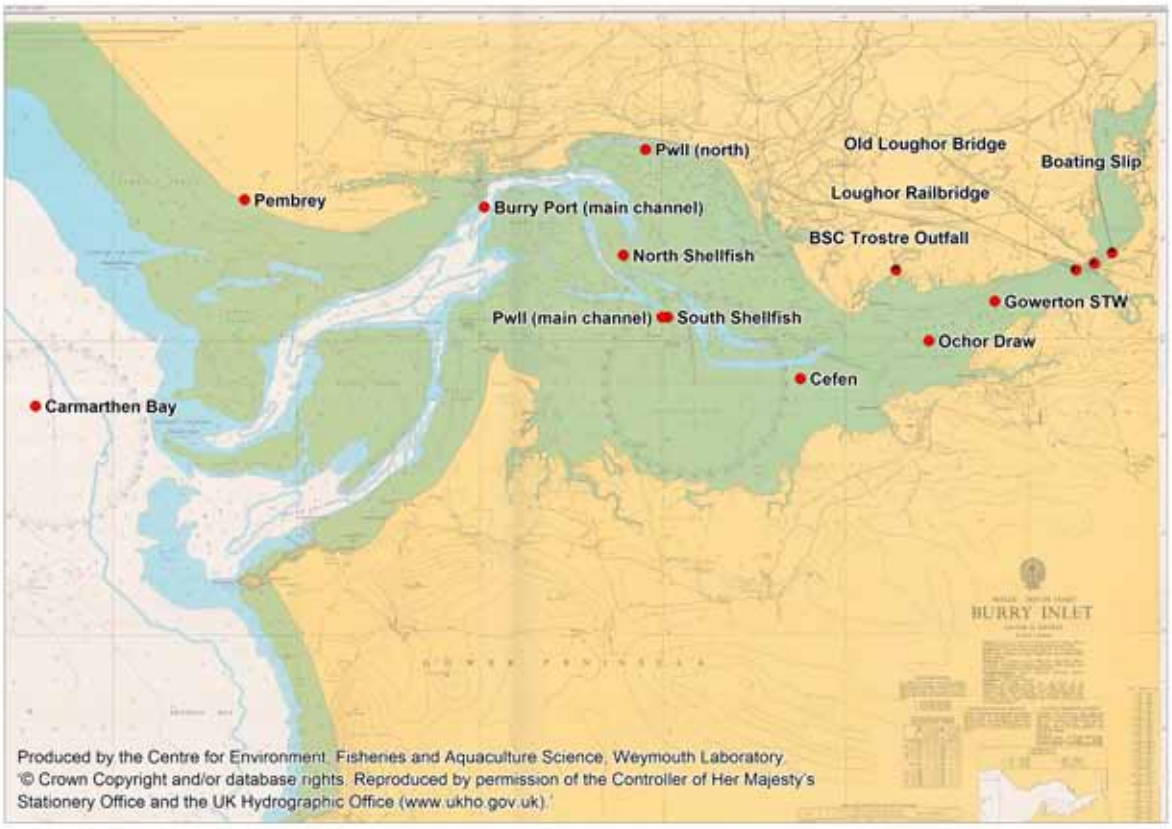


Figure V.2 Location of salinity measurements. *Data from the Environment Agency*

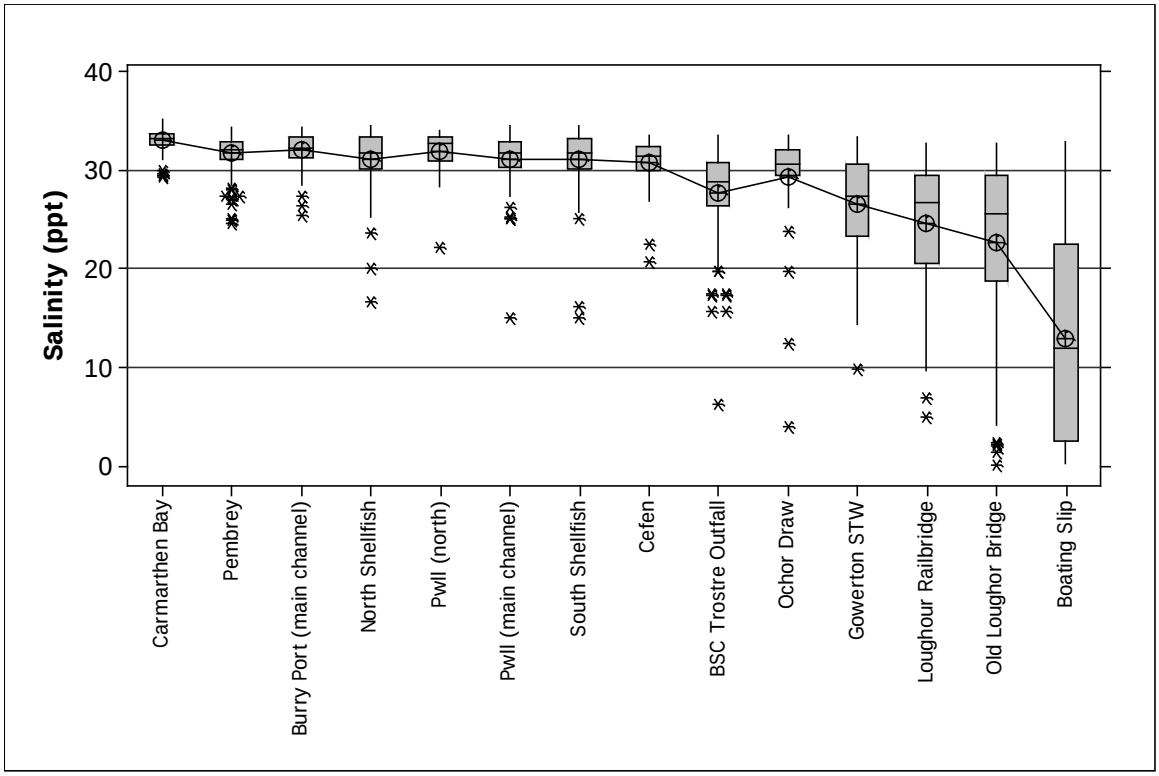


Figure V.3 Boxplot of salinity measurements by location, with added symbol for mean salinity and connect line between the mean symbols. *Data from the Environment Agency*

Salinity within the main body of the estuary in which the shellfish beds are situated (from Pembrey to Ochor Draw) is similar on average throughout, but slightly lower than that of full strength seawater, and decreases very slightly on average with distance upstream. The exception to this is BSC Trostre Outfall point which is within a creek that receives some freshwater so is not representative of the main body of the estuary. Some salinities of under 20ppt have been recorded throughout this area, but the average remains above 30ppt as far upstream as Cefen. As the estuary narrows upstream of Ochor Draw average salinities drop rapidly, and at the Old Loughor Bridge they ranged from 0.06 to 32.67ppt. On this basis a general principle of locating RMPs as far up-estuary as possible would best capture contamination associated with freshwater inputs.

APPENDIX VI
METEOROLOGICAL DATA: WIND

Wales is one of the windier parts of the UK, particularly its west facing coasts (Met Office, 2012). The strongest winds are associated with the passage of deep areas of low pressure close to or across the UK. The frequency and strength of these depressions is greatest in the winter half of the year, especially from November to February, and this is when mean speeds and gusts are strongest (Met Office, 2012).

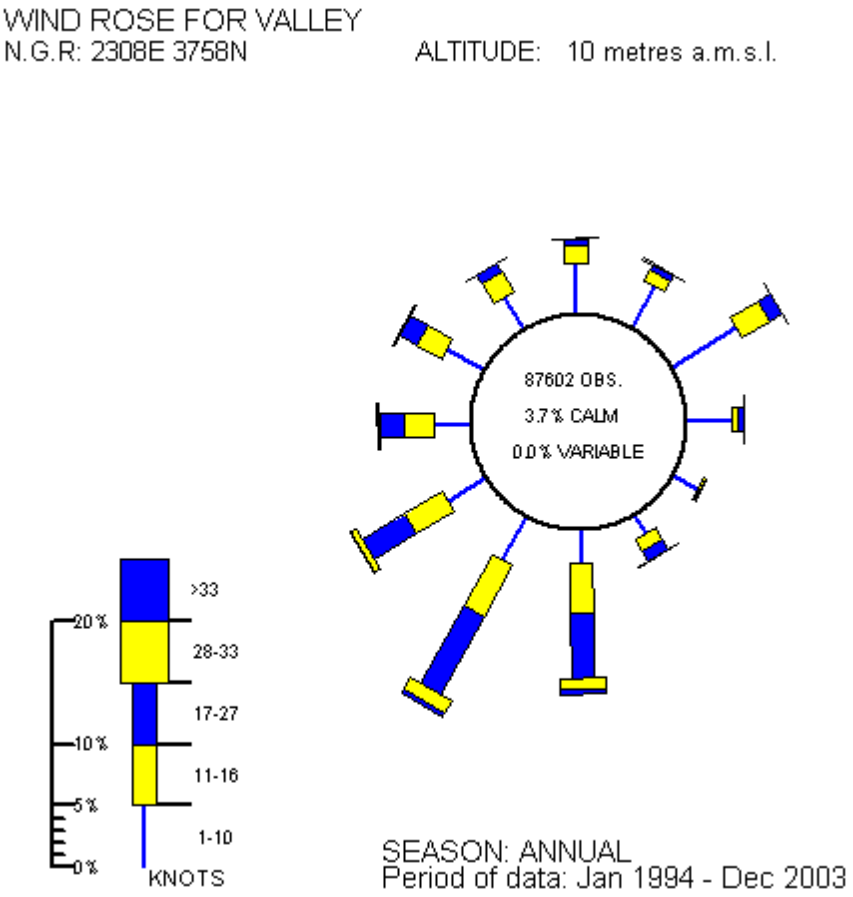


Figure VI.1 Wind rose for Valley.
Produced by the Meteorological Office. Contains public sector information licensed under the Open Government Licence v1.0

The wind rose for Valley (Anglesey) is typical of coastal locations in Wales. The prevailing wind direction is from the south west and the strongest winds usually blow from this direction. A higher frequency of north easterly winds occurs during spring. Given its wide mouth and west facing aspect the outer Burry Inlet will be quite exposed to westerly winds, although the southern half is afforded some shelter from Whiteford Point. The shellfish beds on the seaward side of Whiteford Point are even more exposed to the prevailing winds and incoming swells.

APPENDIX VII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: SEWAGE DISCHARGES

Details of all consented discharges were taken from the Environment Agency's national discharge database (January 2012). There are a total of 18 water company owned sewage treatment works within the Loughor catchment (Figure VII.1 and Table VII.1). Four major discharges are direct to Burry Inlet, namely Llangennech, Llannant, Gowerton and Llanelli. Three of these (Llanelli, Gowerton and Llannant) employ UV disinfection which provides an additional reduction in faecal coliforms of up to 3 logs (Table VII.2). Therefore the bacterial loading which they emit should be low, and any impacts on *E. coli* levels in shellfish will be largely confined to the vicinity of their outfalls. It must be noted that UV disinfection is less effective at removing viruses than bacteria, and the majority of reported bivalve related illness outbreaks in the UK are associated with norovirus (e.g. Lees, 2000). Should the UV plants fail, the *E. coli* loading discharged by these works may increase by about 3 orders of magnitude. The only bacteriological testing data of final effluents from these held by the Environment Agency were three samples from Llanelli STW prior to the improvement works. Llangennech STW also discharges direct to the estuary and is likely to generate a much larger bacterial loading than the other three combined as it only receives secondary treatment.

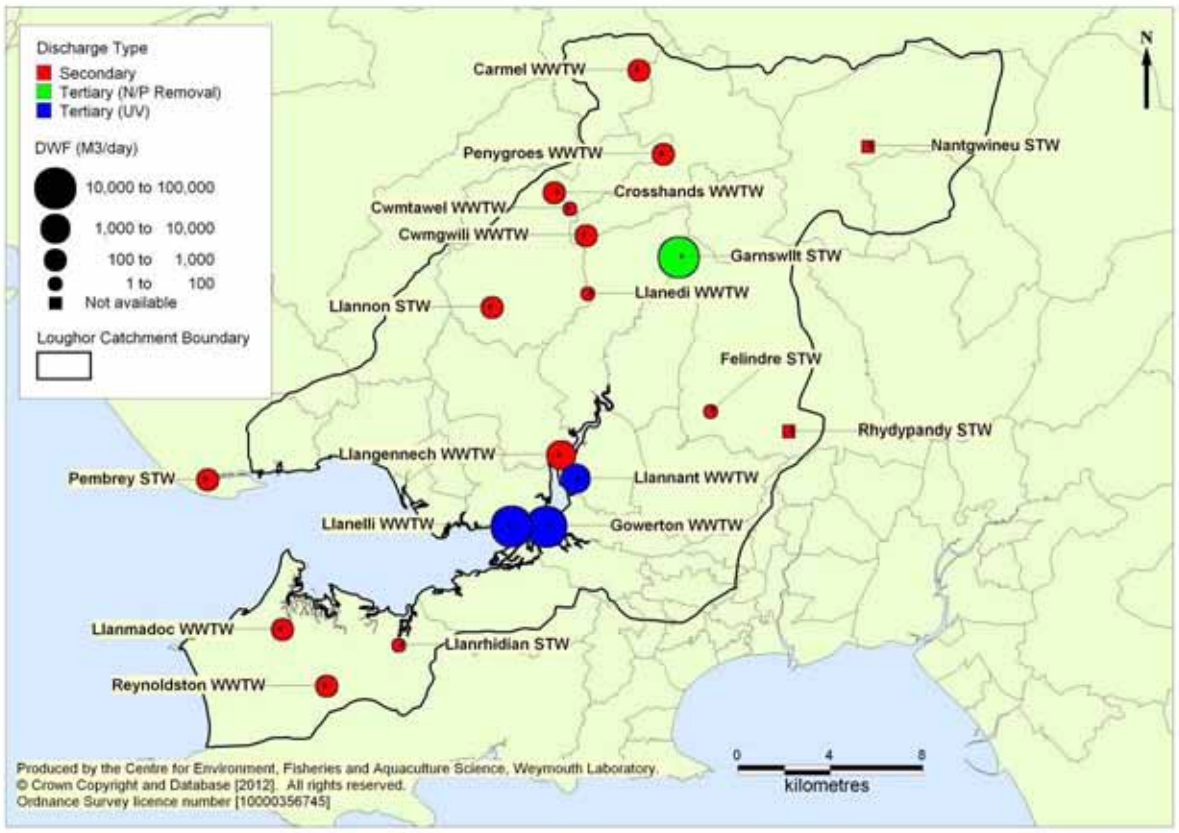


Figure VII.1 Locations and size of continuous discharges within the Loughor catchment.

Table VII.1 Details of major continuous water company sewage discharges to the area

Name	Location	DWF (m^3/day)	Treatment Level	Estimated bacterial loading (faecal coliforms/day)*	Receiving Water
Llanmadoc WWTW	SS4467493383	282	Secondary	$9.31x10^{11}$	Burry Pill
Reynoldston WWTW	SS4659690941	299	Secondary	$9.87x10^{11}$	Burry Pill
Llanrhidian STW	SS4970092700	61	Secondary	$2.01x10^{11}$	Llanrhidian Pill
Llannon STW	SN5374007250	460	Secondary	$1.52x10^{12}$	River Marlais
Llanelli WWTW	SS5457697854	25920	Tertiary (UV)	$7.26x10^{10}$	Loughor Estuary
Gowerton WWTW	SS5608797833	22978	Tertiary (UV)	$6.43x10^{10}$	Loughor Estuary
Crosshands WWTW	SN5642012208	882	Secondary	$2.91x10^{12}$	River Gwili
Llangennech WWTW	SN5672100904	1678	Secondary	$5.54x10^{12}$	Loughor Estuary
Cwmtawel WWTW	SN5710911509	23	Secondary	$7.59x10^{10}$	River Gwili
Llannant WWTW	SS5733699894	4314	Tertiary (UV)	$1.21x10^{10}$	Loughor Estuary
Cwmgwili WWTW	SN5780210355	378	Secondary	$1.25x10^{12}$	River Gwili
Llanedi WWTW	SN5787507839	72	Secondary	$2.38x10^{11}$	River Gwili
Carmel WWTW	SN6008517490	100	Secondary	$3.30x10^{11}$	River Marlais
Penygroes WWTW	SN6113913867	484	Secondary	$1.60x10^{12}$	River Lash
Garnswllt STW	SN6180509433	17385	Tertiary (P Removal)	$5.74x10^{13**}$	River Loughor
Felindre STW	SN6318002760	77	Secondary	$2.54x10^{11}$	River Lliw
Pembrey STW	SS4143899855	499.4	Secondary	$1.65x10^{12}$	Pembrey Marsh
Rhydypandy STW	SN6655001930	Not given	Secondary	-	River Llan
Nantgwineu STW	SN6997014200	Not given	Secondary	-	Nant Gwineu

*Based on geometric base flow averages from a range of UK STWs (Table VII.2). These estimates are intended for comparative purposes only, and bacterial loadings generated by each STW are likely to fluctuate significantly

**Estimated bacterial loading (FC/day) calculated using secondary treatment figure in Table VII.2 in the absence of a geometric mean equivalent for tertiary treatment employing phosphate removal. Therefore actual bacterial loading may be lower than the figure presented.

There are a series of 15 other STWs throughout the wider catchment, all of which discharge to watercourses. Of these 11 are received by watercourses that in turn flow into the estuary upstream of the Loughor Bridge. These 11 STWs are likely to add significantly to the bacterial loading received by the upper estuary. Garnswllt STW, the largest of these by far, discharges to the River Loughor and receives tertiary treatment to remove phosphate. Although this is not a disinfection process as such, the additional step may reduce the levels of faecal indicator bacteria in the final effluent so the estimated loading in Table VII.1 could be an overestimate.

Three small continuous water company discharges are received by watercourses which drain to the south shore. Llanmadoc and Reynoldston STW's discharge to the Burry Pill and Llanrhidian STW discharges to the Llanrhidian Pill so these two watercourses will carry contamination from human sewage to shellfish beds on the south shore. There is another small STW (Pembrey STW) on the north shore which discharges to the Pembrey Marsh River west of Burry Port. All receive secondary treatment.

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

Treatment Level	Flow			
	Base-flow		High-flow	
	n	Geometric mean	n	Geometric mean
Primary (12)	127	$1.0x10^7$	14	$4.6x10^6$
Secondary (67)	864	$3.3x10^5$	184	$5.0x10^5$
Tertiary (UV) (8)	108	$2.8x10^2$	6	$3.6x10^2$

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

In addition to the continuous sewage discharges, there are a large number of intermittent water company discharges within the area associated with the sewerage networks. Figure VII.2 shows the locations of these as well as private discharges directly to or within close proximity to the estuary. In addition to these there are many other intermittent outfalls and private discharges distributed around more inland areas of the Loughor catchment.

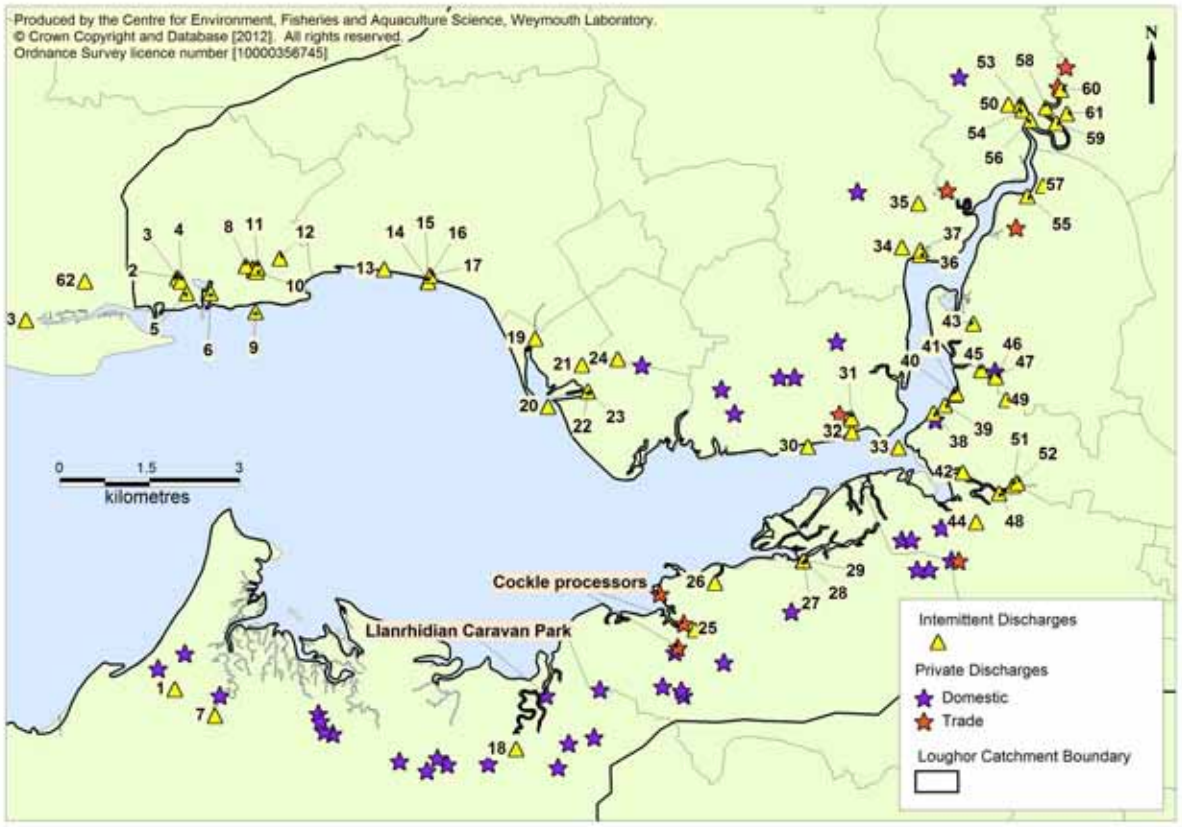


Figure VII.2 Intermittent and private discharges situated around the shore of the Loughor estuary.

Table VII.3 Details of intermittent discharges situated around the Loughor estuary.

ID	Name	Location	Type
1	Llanmadoc PS No.2	SS4400093800	Storm & Emergency
2	SPS Heol Vaughan	SN4403900656	Storm & Emergency
3	Heol Vaughan SPS	SN4404300650	Storm & Emergency
4	Ashburnham PS	SN4410000600	Storm & Emergency
5	Shoreline PS Burry Port	SN4420000400	Storm & Emergency

ID	Name	Location	Type
6	Burry Port SPS	SN4460000400	Storm & Emergency
7	Llanmadoc PS No. 1	SS4467093360	Storm & Emergency
8	Church Road CSO	SN4518800858	Storm & Emergency
9	Burry Port PS	SN4535000090	Storm & Emergency
10	CSO at Burry Port SPS	SN4536200761	Storm & Emergency
11	Bryn Avenue CSO	SN4538300826	Storm & Emergency
12	Dyfatty Park SPS	SN4575600984	Storm & Emergency
13	SWO behind Talbot Inn Pwll	SN4750000800	Storm & Emergency
14	Pwll SPS	SN4822700591	Storm & Emergency
15	Pwll PS	SN4823000590	Storm & Emergency
16	Yard Bridge CSO	SN4827000698	Storm & Emergency
17	Yard Bridge CSO	SN4827000698	Storm & Emergency
18	Llanrhidian PS	SS4970092800	Storm & Emergency
19	Cambrian PS	SS5002399642	Storm & Emergency
20	Northumberland Outfall	SS5023498505	Storm
21	Trinity Yard SWO Timber Merchant	SS5080099200	Storm
22	Northumberland PS	SS5081698835	Storm & Emergency
23	Northumberland PS	SS5090098760	Storm & Emergency
24	Penyfan Quarry SWO	SS5140099300	Storm
25	New Crofty SPS	SS5269094792	Storm & Emergency
26	Holythorne Crofty SPS	SS5301895578	Storm & Emergency
27	Benson Road CSO	SS5449195945	Storm & Emergency
28	New Penclawdd SPS	SS5449595950	Storm & Emergency
29	Penclawdd Sewerage Scheme SSO	SS5450095950	Storm
30	Llanelli STW	SS5457697854	Storm & Emergency
31	Bynea PS (Emergency)	SS5530098310	Storm & Emergency
32	Bynea SPS upstream	SS5531198093	Storm & Emergency
33	Gowerton WWTW	SS5608797833	Storm & Emergency
34	Rear of Trio Engineering	SN5614401168	Storm
35	250m d'stream of Glan-Yr-Afon	SN5641901902	Storm
36	Llangennech PS	SN5644301043	Storm & Emergency
37	SSO at Llangennech PS	SN5645601118	Storm
38	SWO at Gwydwr Place	SS5667098400	Storm
39	SWO near Broadoak Colliery	SS5686098530	Storm
40	Ben Hughes Foundry CSO	SS5702698708	Storm & Emergency
41	SWO 100yds u/s of Broadoak Colliery	SS5705098724	Storm
42	SSO at Rhosog PS	SS5716097420	Storm
43	Llannant WWTW	SS5733699894	Storm & Emergency
44	SSO at Cefn Stylle PS	SS5738596590	Storm
45	Brynafon Road CSO	SS5747099115	Storm & Emergency
46	Heol Pentre Bach CSO	SS5771099002	Storm & Emergency
47	Borough Road CSO	SS5771099001	Storm & Emergency
48	SWO 165 yds d/s of Island	SS5777097070	Storm
49	SWO near Loughor Crossroads	SS5789098620	Storm
50	Manholes 62 and 11 from SSO	SN5792003550	Storm
51	Copper Meadow PS	SS5800097200	Storm & Emergency
52	SWO approx 70yds u/s R'way Bridge	SS5807097250	Storm
53	SWO at Hendy on left bank	SN5813003550	Storm
54	270m d/s road	SN5815603462	Storm
55	SWO Waun Gron Castell	SN5824002021	Storm
56	Hendy SPS	SN5828803294	Storm & Emergency
57	Grovesend Gorseinon PS	SN5850002200	Storm & Emergency
58	Ynys Tomenlle CSO	SN5854703503	Storm & Emergency
59	SWO 400 yds d/s confluence Dulais	SN5872003240	Storm
60	SWO 60 yds u/s confluence Dulais	SN5880003800	Storm
61	Pontardulais PS	SN5890003400	Storm & Emergency
62	Links Pembrey PS	SN4250000600	Storm
63	Pembrey WWTW	SS4151599947	Storm

Discharges highlighted in yellow have spill information presented in Figure VII.3

The majority of intermittent outfalls are located on the north shore, and around the upper estuary upstream of Loughor Bridge. A few intermittent outfalls are associated with the less extensive sewerage networks located on the south shore adjacent to the shellfisheries. Spill data was available for several of these, one of which was the Gowerton STW overflow, and the rest of which were within the Llanelli STW catchment which runs from Burry Port through to Llanelli.

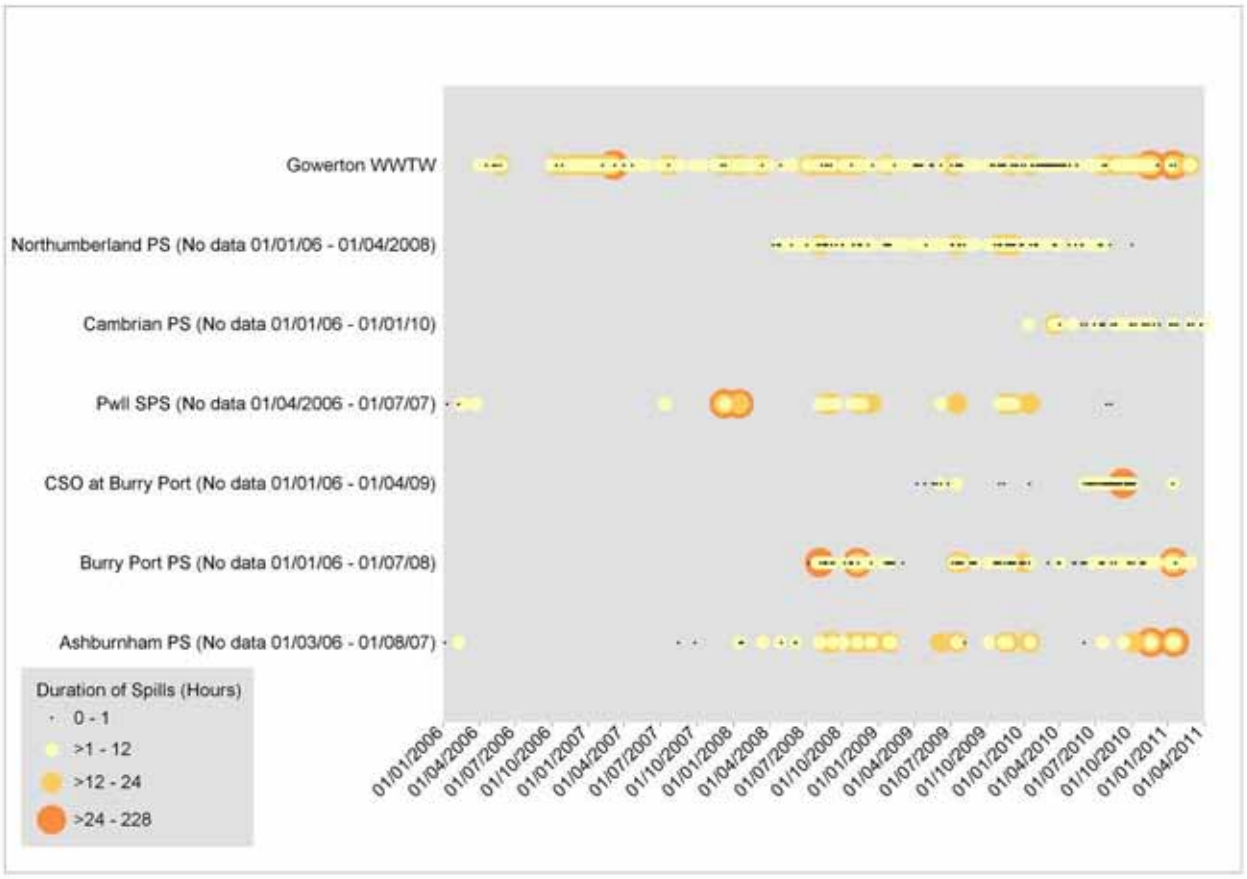


Figure VII.3 Bubbleplot showing number of spills and duration in hours from intermittent discharges within the Loughor catchment.

The majority of spills recorded were minor due to their short duration (0-12 hours) although some longer duration spills of up to almost 10 days were recorded. The associated spill volumes are uncertain and volumes discharged per unit time will vary from outfall to outfall. Gowerton WWTW spilled at a fairly consistent rate between 2006 and 2011 showing the highest number of spills (709) and greatest combined duration (3552 hours) across the time period compared with all the other discharges. This outfall discharges to the south shore just downstream from the Loughor Bridge.

There have been issues associated with the rising main pump away scheme from Pwll, Llanelli and Burry Port due to the large amount of surface water collected by the network. This has resulted in spills occurring at the Northumberland Outfall at Llanelli seafront and other outfalls along the north shore. These issues were due to have been addressed by March 2010 via enhanced storm sewage storage and UV

disinfection of storm flows from Northumberland outfall and Llanelli STW. Spill frequency appears to have reduced significantly at Northumberland as a consequence and the additional treatment should reduce the bacterial concentrations within any overflow discharges from here.

Cambrian PS represented the lowest number of spills (58) throughout the recorded time period with only one spill discharging over 12 hours. Pwll SPS had a relatively low number of spills over the time period (88 in total), but the average duration of spills were higher compared with other outfalls with 61% spilling 12 hours or more.

There are three overflows in the Burry Port area for which spill data was available. Burry Port PS discharges to the estuary off from Burry Port, and spills are regularly recorded here. The other two of these (CSO at Burry Port and Ashburnham) discharge to watercourses that drain into Burry Docks, and both of these spill on a fairly regular basis. Therefore the experimental mussel site within Burry Docks is likely to be subject to regular contamination by storm sewage.

No information is available on spill frequency for other intermittent discharges to the Loughor Estuary so it is difficult to assess their impact apart from noting their location and potential to discharge untreated sewage. In addition to water company sewerage networks, there are 210 private discharges within the Loughor catchment, 50 which are trade related and 160 are domestic in nature. Of these private discharges 121 discharge to soakaway, 38 to watercourses, and one direct to the Loughor Estuary. Of most significance are discharges from three cockle processing establishments to Salthouse Pill and one from a caravan park which discharges to Llanrhidian Pill. The cockle processing plants discharge processing water from cooking and depuration intermittently, with a combined consented maximum discharge volume of 55.7 m^3/day. The bacteriological content of the effluent from these plants is very variable, with limited bacteriological testing showing faecal coliform concentrations ranging <10 to >10^7 cfu/100ml. The caravan park at Llanrhidian is served by a batch reactor (equivalent to secondary treatment) discharging to Llanrhidian Pill with a consented maximum discharge volume of 100m^3/day. In practice this discharge, being a batch process, is intermittent, and the volumes discharged vary with site occupancy but are usually much lower than the consented figure (Environment Agency, pers comm.).

The other private sewage discharges are generally small, serving a single property or a small group of properties, typically using septic tanks or small package treatment plants. The domestic discharge direct to the estuary is from a residential property discharging up to 5 cubic metres per day of effluent (treatment unknown) on the south shore of the estuary just downstream of the Loughor Bridge. The small private discharges may they make a contribution to levels of *E. coli* in some watercourses, but overall impacts from these are anticipated to be minor. It is not anticipated that those draining to soakaway will have any contaminating effect on coastal waters.

In summary, the greatest volumes of effluent derived from continuous sources enter the estuary upstream of the shellfish beds via Llangennech, Llanelli, Llannant and Gowerton works direct to the estuary, as well as 11 further sewage works discharging to watercourses flowing into the estuary upstream of the Loughor Bridge.

Loadings generated by Llanelli, Llannant and Gowerton UV treated discharges are likely to be small, although they do have the potential to generate very large bacterial loadings should problems arise with their disinfection systems. As the majority of sewage inputs are upstream of the shellfisheries a general presumption of higher impacts at the upstream end of the shellfish beds should be applied when determining the location of RMPs. Three small sewage works discharge to watercourses which drain to the estuary on the south shore. These watercourses (Burry Pill and Llanrhidian Pill) and their drainage channels across the intertidal shellfisheries will therefore carry elevated bacterial loadings. The Pembrey STW will impact on the estuary via the Pembrey Marsh River, which discharges at Burry Port. The geographical distribution of intermittent discharges follow a similar pattern, with the notable addition of a series of outfalls along the north shore of the estuary from Burry Port through to the Llanelli STW. Available spill records indicate that spills occur regularly from those with monitoring equipment. This includes two outfalls which discharge via watercourse to the enclosed Burry Docks where the experimental mussel site is located as well as outfalls at Pwll and by Llanelli seafront. Three cockle processing plants may impact on Salthouse Pill from time to time, and a discharge from a caravan park to Llanrhidian Pill may also be of significance at times. Some small private domestic sewage discharges are present in the more rural areas of the catchment and any watercourses receiving such effluent will carry increased bacterial concentrations as a result, although private discharges are likely to be of very minor impact in relation to other sources.

APPENDIX VIII
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: AGRICULTURE

Table VIII.1 presents livestock numbers and densities for the entire catchment area draining to Burry Inlet. This data was provided by Welsh Government and is based on the 2010 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 VII.1 should give a reasonable indication of the numbers of livestock within the catchment.

Table VIII.1 Summary statistics from 2010 livestock census for entire Burry Inlet catchment

	Numbers				Density (animals/km^2)			
Catchment name	Cattle	Pigs	Sheep	Poultry	Cattle	Pigs	Sheep	Poultry
Loughor	22,029	549	71,540	35,459	47	1	152	75

The agricultural land within the catchment is almost all pasture and this supports large numbers of sheep and cattle. There are also relatively small numbers of pigs and poultry farmed in the area. Most, if not all watercourses draining to the estuary have considerable areas of pasture within their catchments (Figure 1.2). Significant diffuse inputs associated with grazing livestock are therefore anticipated. Manure from pig and poultry operations is typically spread on nearby farm land (Defra, 2009). Sewage sludge may also be spread on agricultural land, but the Environment Agency have only two records of such occurrences in the Loughor catchment from 2009-2012.

Of a more local significance, the large area of saltmarsh on the south shore is common land heavily used for the grazing of sheep and to a lesser extent horses. Sheep are more numerous on the saltmarsh from April to October, but may be present year round. Peak numbers are in the order of 4-6,000. The only time when they are likely to be largely absent from the marshes is during the lambing season (March). Smaller numbers of horses also use the saltmarsh here (2-400) and these are a year round presence (Welsh Government, pers. comm.). Some cattle are grazed on the relatively small area of saltmarsh at the Millennium Park on the north shore during the summer (Wildfowl and Wetlands Trust, 2012). It is likely that numbers are very low (perhaps up to 50 animals) relative to the numbers of sheep on the south side marshes as only 25 hectares are grazed. During the shoreline survey (April) 122 horses were recorded on the saltmarsh on the south shore and 405 sheep were seen in fenced fields behind these marshes but not on the marshes themselves. It is likely that further livestock was present along the south shore, but not seen. No livestock was recorded on the north shore.

The concentration of faecal coliforms excreted in the faeces of animal and human and corresponding loads per day are summarised in Table VIII.1.

Table VIII.1 Levels of faecal coliforms and corresponding loads excreted in the faeces of warm-blooded animals.

Farm Animal	Faecal coliforms (No. g^{-1} wet weight)	Excretion rate (g day^{-1} wet weight)	Faecal coliform load (No. day^{-1})
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).

The primary mechanism for mobilisation of faecal matter deposited on pastures into watercourses is via land runoff, so fluxes of livestock related contamination into the estuary will be highly rainfall dependent. Peak concentrations of faecal indicator bacteria in watercourses are likely to arise when heavy rain follows a significant dry period (the 'first flush'). Runoff from the majority of the Burry Inlet catchment area enters the estuary upstream of the fishery, so higher impacts may be anticipated towards the up-estuary ends of the shellfish beds on this basis. On the south shore however, large numbers of sheep use the saltmarsh for grazing, and contamination from these may be carried into the estuary via tidal inundation as well as runoff. The latter is a particularly direct and predictable mechanism which may result in large amounts of faecal matter being washed into the southern half of the estuary during spring tides. An Environment Agency study conducted in the Ribble estuary found a significant increase in levels of faecal coliforms within saltmarsh creeks in grazed areas as the tide started to ebb following tidal inundation (Dunhill, 2003) so this is a recognised phenomenon.

There is likely to be seasonality in levels of contamination originating from livestock. Numbers of sheep and cattle will increase significantly in the spring, with the birth of lambs and calves, and decrease in the autumn when animals are sent to market. Highest sheep counts on the grazing marshes on the south shore of the estuary are reported to occur from April to October. During winter cattle may be transferred from pastures to indoor sheds, and at these times slurry will be collected and stored for later application to fields. Timing of these applications is uncertain, although farms without large storage capacities are likely to spread during the winter and spring. Poultry/pig manure and sewage sludge may be spread at any time of the year. Therefore peak levels of contamination from sheep and cattle may arise 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 on a more localised basis if wet weather follows a slurry application which is more likely in winter or spring.

APPENDIX IX
SOURCES AND VARIATION AND MICROBIOLOGICAL POLLUTION: BOATS

Burry Inlet is shallow and largely intertidal making navigation difficult, so boat traffic is relatively light and limited to smaller craft. The vast majority of boat traffic is associated with Burry Port Marina. This Marina has 450 berths for vessels up to 11m in length and with a maximum draft of 1.5m. A range of services are available but there is no sewage pumpout facility (Reeds Nautical Almanac, 2012). Access to the dock is limited to a window of up to 2 hours either side of high water, and water levels within it are maintained by an automatic tidal flap gate (Carmarthenshire Council, 2012). Boats navigating to and from the marina are unlikely to deviate from the main outer channel or to venture further up-estuary than the marina. About 140 boats were recorded within the marina during the shoreline survey, but occupancy levels and associated traffic are likely to be higher during the summer months. The only other boats seen on the shoreline survey were an abandoned barge at Pwll and four covered dinghies in the creek at Pen-clawwd, none of which are likely to be of significance.

These smaller vessels, such as yachts, pleasure craft and fishing vessels are not covered by the specific sewage disposal regulations for commercial shipping, and so are likely to make overboard discharges, although this practice is discouraged. It is quite likely that boats may tend to discharge their tanks upon arriving within the relative calm of the estuary and shortly after leaving the marina so the navigation route may be receive such discharges. It is likely that the majority of boat movements occur around high water when navigation is easiest and the potential for dilution is greatest. The marina may also be subject to inputs from overboard discharges, particularly where boats are in overnight occupation, although these may be less likely within the marina setting as onshore facilities are easily accessible and overboard discharges are somewhat antisocial in a confined and crowded marina.

To conclude, overboard discharges from boats are likely to be mainly confined to the marina and associated navigation routes through the very outer reaches of the estuary. There is considerable uncertainty about the extent to which these discharges occur and whether they will impact significantly on shellfish hygiene. Given the large area of the estuary and relatively minor volumes of traffic impacts are unlikely to be significant in the main body of the estuary. In the confined docks there are many boats and much less dilution potential so impacts are potentially highest here. Volumes of small boat traffic will peak during the summer, as will levels of overnight occupancy, so any impacts would be greatest at these times.

APPENDIX X
SOURCES AND VARIATION OF MICROBIOLOGICAL POLLUTION: WILDLIFE

Studies in the UK have found significant concentrations of microbiological contaminants (thermophilic campylobacters, salmonellae, faecal coliforms and faecal streptococci) from intertidal sediment samples supporting large communities of birds (Obiri-Danso and Jones, 2000). Burry Inlet contains a diversity of habitats, notably the largest continuous area of saltmarsh in Wales as well as vast areas of intertidal mud/sandflats, both of which attract large numbers of overwintering waterbirds (wildfowl and waders). An average total count of 41,518 waterbirds was reported over the five winters up to 2009/10 for Burry Inlet (Holt *et al*, 2011).

Some species, such as oystercatchers (~14,000 overwintering individuals) are dependent on cockles and mussels and so will forage (and defecate) directly on the shellfish beds across a wide area. They may tend to aggregate in certain areas holding the highest densities of bivalves of their preferred size and species, but this will change from year to year. Contamination via direct deposition may be quite patchy, with some shellfish containing quite high levels of *E. coli* with others a short distance away unaffected. 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 during the winter months.

Other overwintering species such as grazing ducks and geese will mainly frequent the saltmarsh, where their faeces will be carried into coastal waters via runoff into tidal creeks or through tidal inundation. Therefore RMPs within or near to the drainage channels from saltmarsh areas will be best located to capture contamination from this source.

Some bird species such as eider ducks and relatively small numbers of waders remain in the area to breed in the summer, but the majority migrate elsewhere to breed. Bird numbers and potential impacts on the hygiene status of the fisheries are therefore much lower during the summer. No seabird breeding colonies (gulls, cormorants etc) were identified within Burry Inlet during the Seabird 2000 survey (Mitchell *et al*, 2004) although it is uncertain what level of coverage the area received. No large aggregations of birds were recorded during the shoreline survey which was undertaken in April.

There are about 5000 grey seals in west Wales and their main stronghold is the Pembrokeshire coast. The nearest colony to Burry Inlet is at Caldey Island (Kiely *et al*, 2000) about 30km to the west. No formal count data for this colony could be found, but anecdotal information from a tour boat operators website indicated a year round presence of around 80 pairs (http://saundersfootboattrips.co.uk/seal.htm). They are likely to forage widely so seals will enter Burry Inlet from time to time but only in small numbers and their presence will be unpredictable both spatially and temporally. One seal was seen on the north shore between Penrhyn Gwyn and the Loughor Bridge during the shoreline survey. Due to their low numbers and high mobility the presence of seals will not influence the sampling plan.

Otters are present within Burry Inlet (JNCC, 2008). No information on numbers was available but the population is likely to be small. Otters generally tend to favour the more secluded areas with access to watercourses. However, given their likely wide distribution and small numbers otters have no material bearing on the sampling plan.

No other wildlife species which have a potentially significant influence on levels of contamination within shellfish within the survey area have been identified. Dogs are exercised along the north shore primarily, and also represent a potential source of diffuse contamination to the near shore zone. It is likely that the intensity of this is greatest on areas of foreshore adjacent to urban areas.

APPENDIX XI
MICROBIOLOGICAL DATA: SEAWATER

The Environment Agency has undertaken bacteriological testing of seawater samples from a variety of locations around Burry Inlet to monitor for compliance against the Bathing Waters Directive (Council of the European Communities, 1975) and the Shellfish Waters Directive (European Communities, 2006). Some additional samples were taken for investigative purposes. Figure XI.1 shows the locations of the points sampled as well as the extent of the Shellfish Waters protected areas.

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

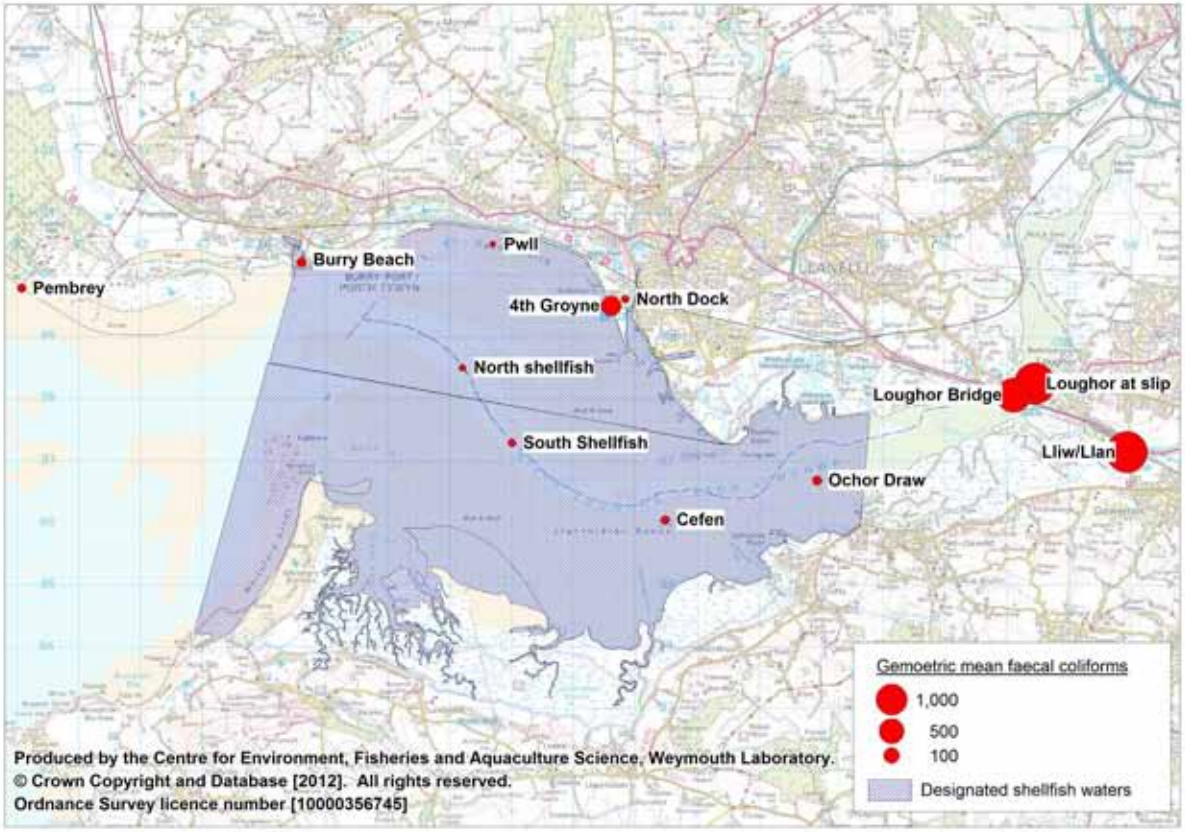


Figure XI.1 Environment Agency bacteriological sampling points graduated by geometric mean faecal coliform results (2006 onwards) and current shellfish water designation

As a result of the major upgrades to the Llanelli sewerage scheme in 2005, only results from 2006 onwards were considered in these analyses. Table XI.1 and Figure XI.2 summarise the results of samples tested for faecal coliform (presumptive). Bathing Waters sites are only usually sampled from May to September, whereas shellfish waters sites are sampled year round and investigative/other samples may be taken at any time as required. As a consequence direct comparisons of results from the different locations should be treated with some caution due to the differing temporal and seasonal profiles of sampling.

Table XI.1 Summary statistics for bacteriological samples taken by the Environment Agency 2006 onwards

			Faecal coliforms presumptive results (cfu/100ml)				
Site	1st sample	Last sample	No.	Geomean	Min.	Max.	Reason
Pembrey	05/05/2006	20/09/2011	125	13.1	<2	6000	Bathing water (designated)
Burry Beach	03/05/2006	13/09/2011	123	19.9	<2	8000	Bathing water (undesignated)
North shellfish	21/02/2006	15/09/2011	61	7.7	<2	1560	Shellfish water
Pwll	20/04/2009	15/09/2011	35	3.6	<2	269	Other/Investigative
South Shellfish	21/02/2006	15/09/2011	39	8.4	<2	1040	Shellfish water
4th Groyne	03/05/2006	22/09/2009	88	218.3	<2	>100000	Bathing water (undesignated)
North Dock	15/04/2008	10/01/2012	51	11.4	<2	2160	Bathing water (undesignated)
Cefen	02/04/2009	01/09/2011	38	13.7	<2	2440	Other/Investigative
Ochor Draw	02/04/2009	15/09/2011	39	18.9	<2	33000	Other/Investigative
Loughor Bridge	11/01/2010	19/05/2011	2	1412.5	132	15000	Other/Investigative
Loughor at slip	21/11/2011	19/12/2011	5	5296.6	2000	13000	Other/Investigative
Lliw/Llan	11/01/2010	19/12/2011	5	3784.4	1636	10000	Other/Investigative

Data from the Environment Agency

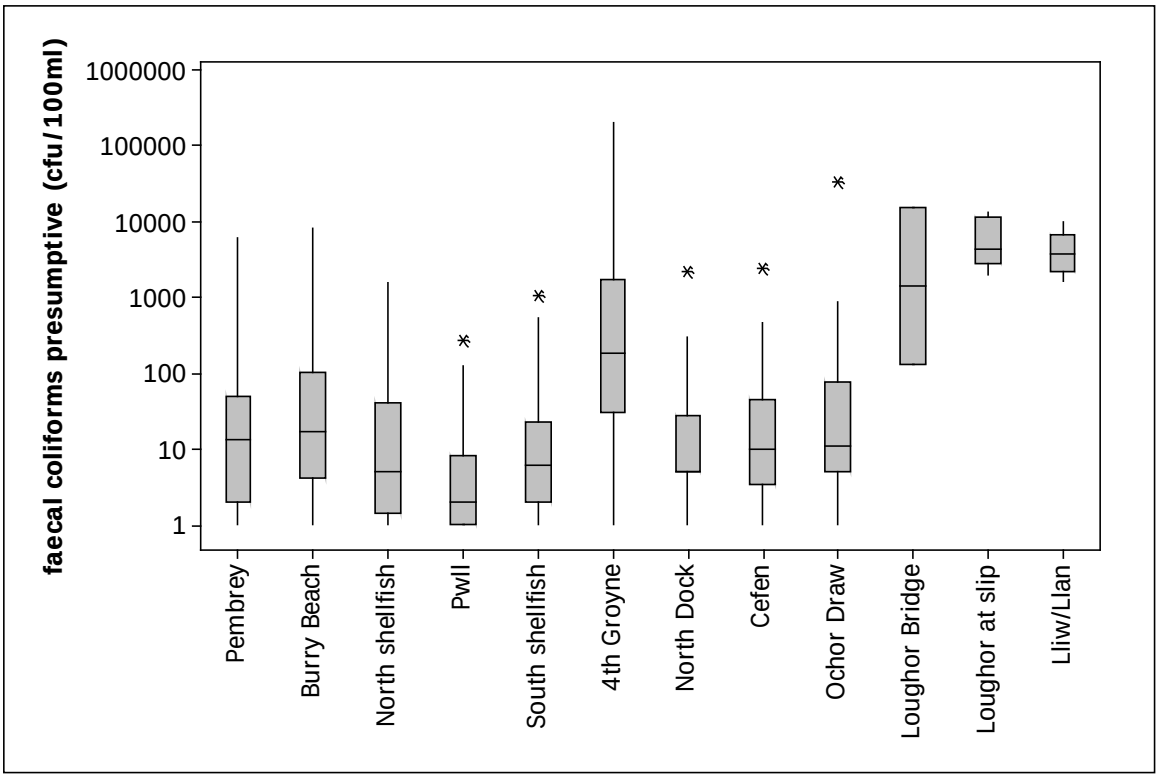


Figure XI.2 Boxplot of seawater bacteriological results from west to east, 2006 onwards
Data from the Environment Agency

Although few samples were taken from the three most easterly (upstream) points the results suggest a marked deterioration in water quality at the Loughor Bridge and up the creek into which the Lliw/Llan feeds. A hotspot of contamination is apparent at the 4th Groyne, which is located on the beach just off Llanelli. Samples taken within the nearby enclosed North Dock at Llanelli did not however show elevated concentrations of faecal coliforms relative to the rest of the estuary.

The four mid estuary sites (North Shellfish, South Shellfish, Cefen and Ochor Draw) were sampled on the same day on 16 occasions permitting a more robust assessment of the spatial variation in relation to distance from the estuary mouth.

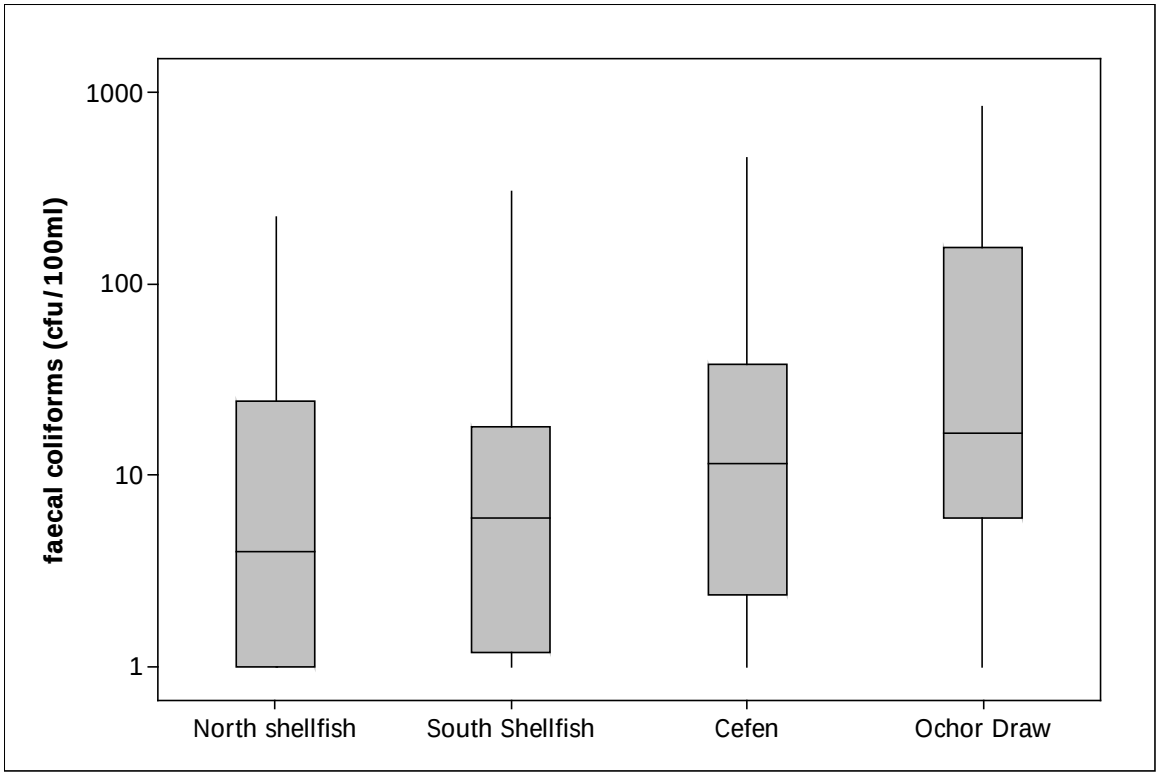


Figure XI.3 Boxplot of paired sample results from mid estuary sites
Data from the Environment Agency

Results steadily increased on average with distance from the mouth of the estuary, although this may have been due in part to site locations in relation to the main channel and the south shore. Significant differences in results between the four sites were found (2-way ANOVA, p=0.000). A post ANOVA test (Tukeys comparison) indicated that results at Cefen and Ochor Draw were significantly higher than at the other two sites. A significant effect of sample date was also found (2-way ANOVA, p=0.000) indicating that levels of contamination varied in a similar manner across the four sites with time.

SEASONAL VARIATION

The only site for which samples were taken in sufficient numbers in all four seasons to permit a seasonal analysis was North Dock.

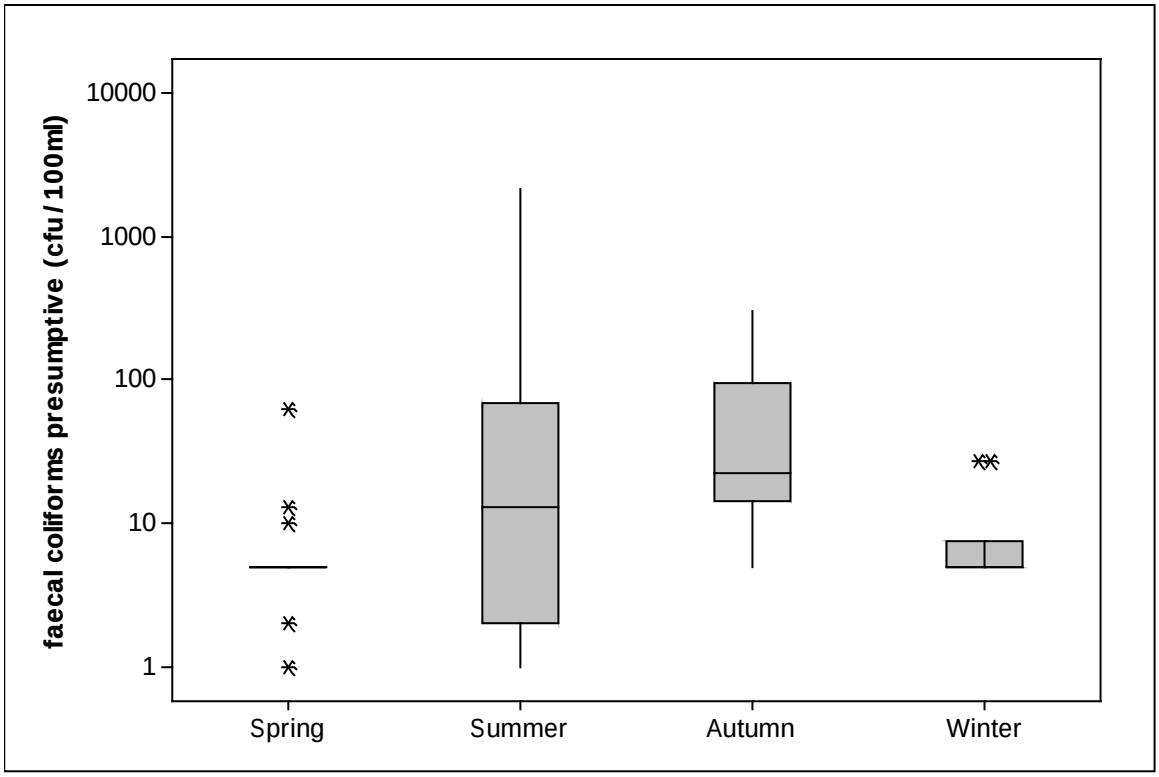


Figure XI.4 Boxplot of results at North Dock by season
Data from the Environment Agency

A significant seasonal effect was found (One way ANOVA, p=0.014) with results for the autumn significantly higher than for the spring (Tukeys comparison).

INFLUENCE OF TIDE

To investigate the effects of tidal state on faecal coliform results, circular-linear correlations were carried out against the spring/neap tidal cycle for each monitoring point where at least 30 samples had been taken since 2006 against both the spring/neap and high/low tidal cycle. Table XI.2 presents the results of these correlations, and statistically significant correlations are highlighted in yellow.

Table XI.2 Circular-linear correlation coefficients (r) and associated p values for faecal coliforms results against the spring/neap and high/low tidal cycles

		Spring/neap		High/low	
Site	**No.**	**r**	**p**	**r**	**p**
Pembrey	125	0.282	0.000	0.273	0.000
Burry Beach	123	0.302	0.000	0.218	0.003
North Shellfish	61	0.235	0.040	0.421	0.000
Pwll	36	0.214	0.219	0.177	0.357
South Shellfish	39	0.179	0.314	0.639	0.000
4th Groyne	88	0.145	0.166	0.254	0.004
North Dock	50	0.223	0.097	0.419	0.000
Cefen	38	0.124	0.586	0.415	0.002
Ochor Draw	39	0.217	0.183	0.431	0.001

Data from the Environment Agency

Figure XI.5 presents polar plots of $\log_{10}$ faecal coliform results against the spring neap tidal cycle for those sites where a significant correlation was found. Full/new

moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 100 faecal coliforms/100ml or less are plotted in green, those from 101 to 1000 are plotted in yellow, and those exceeding 1000 are plotted in red.

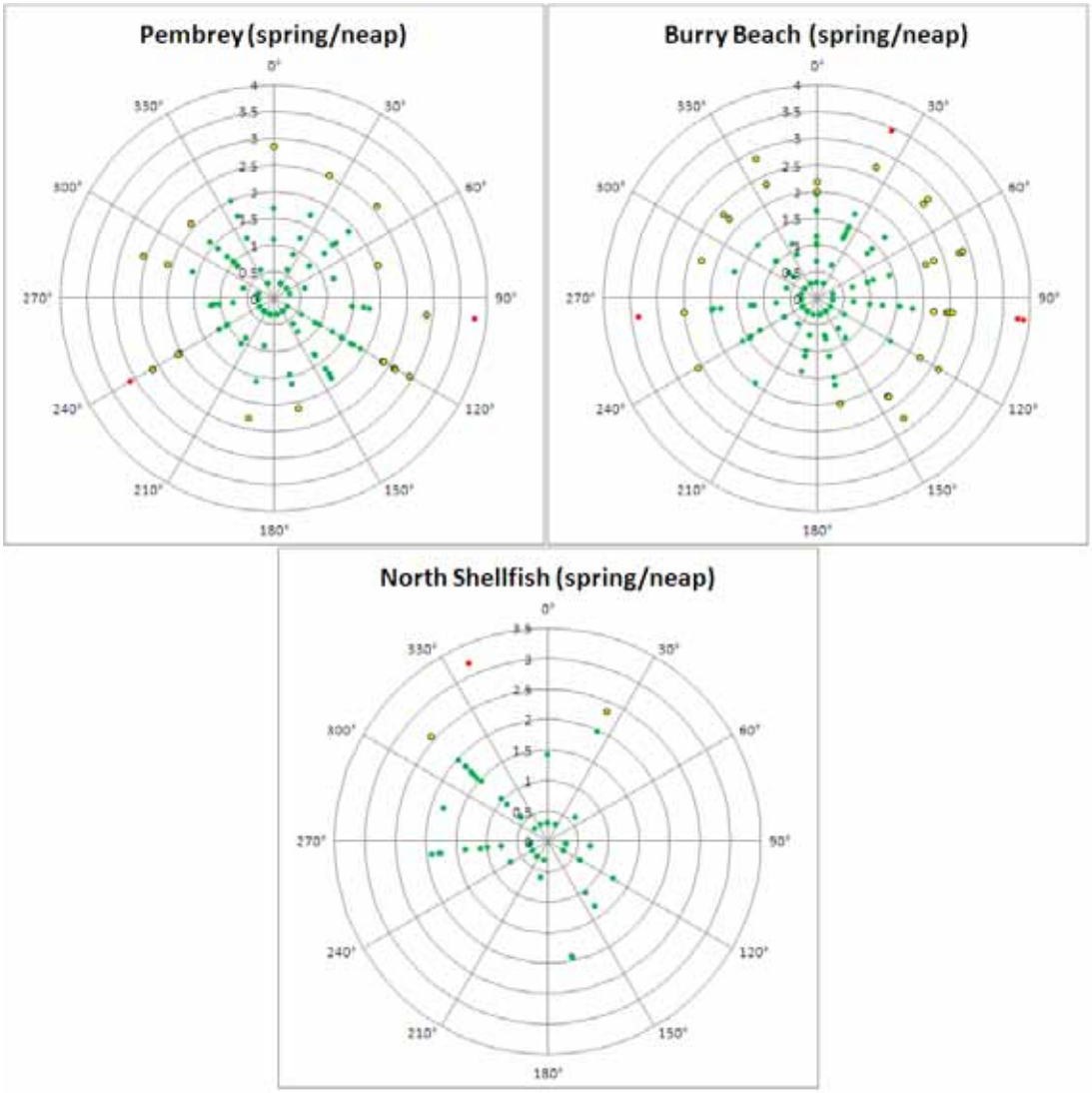


Figure XI.5 Polar plots of log_{10} faecal coliform results against the spring neap tidal cycle for sites where significant correlations were detected. *Data from the Environment Agency*

No strong patterns in relation to the spring/neap tidal cycle are apparent in Figure XI.5. A very slight tendency for fewer low results around spring tides can be seen at Burry Beach. The three sites where correlations were found were the three outermost sites. This may imply that sources a significant distance up-estuary are of some importance to these sites.

Figure XI.6 presents polar plots of log_{10} faecal coliform results against the high/low tidal cycle for those sites where a significant correlation was found. High water is at 0° and low water is at 180°.

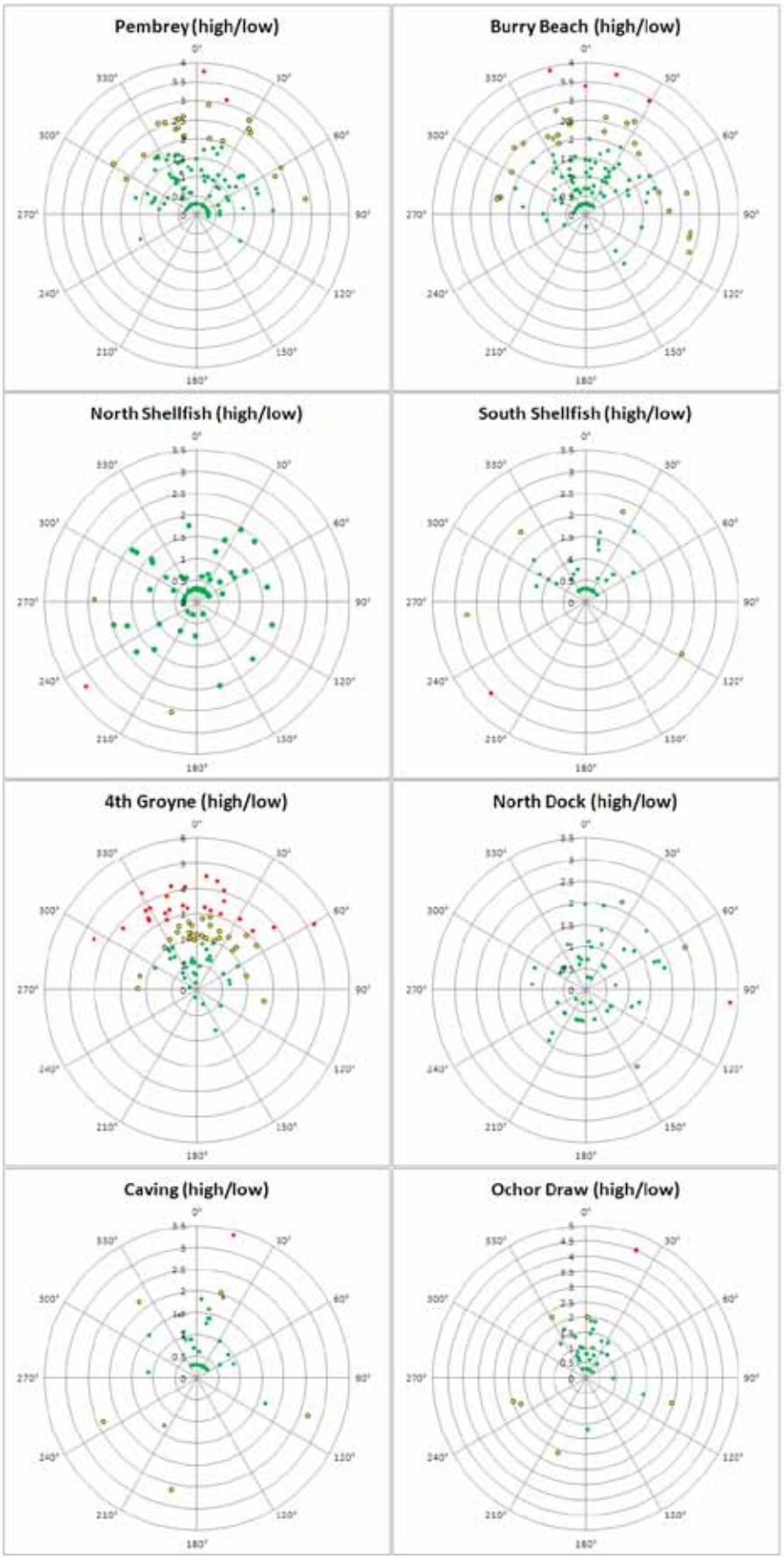


Figure XI.6 Polar plots of log_{10} faecal coliform results against the spring neap tidal cycle for sites where significant correlations were detected. *Data from the Environment Agency*

Correlations between levels of faecal coliforms and the high/low tidal cycle were observed at all sites apart from Pwll. For Burry Beach, 4th Groyne and North Dock Figure XI.6 suggests a tendency for fewer low results during the ebb tide. At the mid estuary sites, although sampling was generally undertaken in the upper half of the tidal cycle, results were lower on average during the lower half of the tidal cycle. No pattern is apparent for Pembrey.

RESULTS IN RELATION TO SALINITY

For six of the sites salinity measurements were taken at the time of sampling on most occasions. Figure XI.7 presents scatterplots of faecal coliforms against salinity for each of these sites, and also shows the results of Pearsons correlations between the two variables.

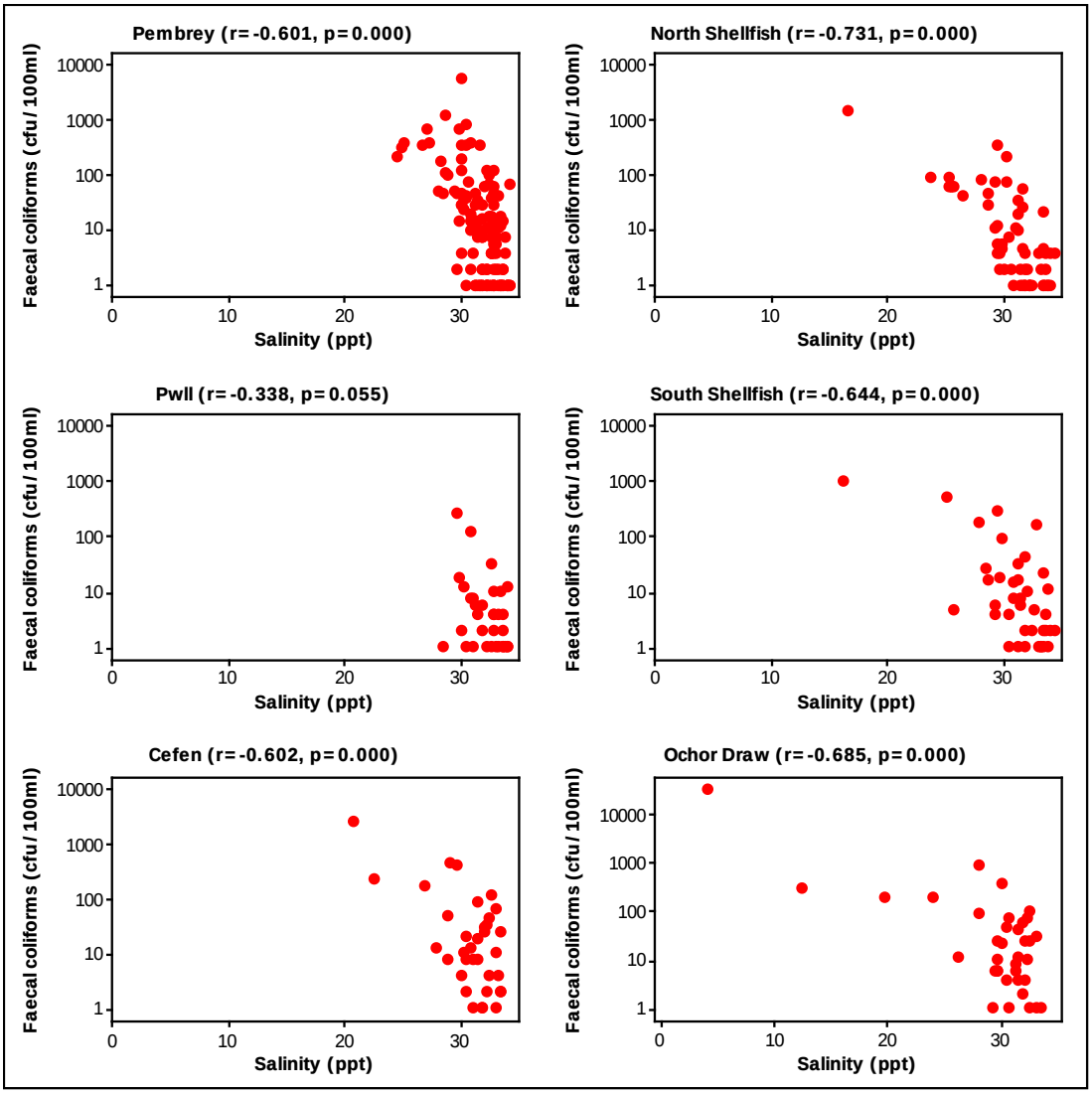


Figure XI.7 Scatterplots of faecal coliforms against salinity, with Pearson correlation coefficients (r) and associated p values. *Data from the Environment Agency*

At all sites apart from Pwll highly significant negative correlations were found between salinity and faecal coliforms. This suggests that land runoff is a significant

contaminating influence throughout most of the estuary, although it appears that there may be other sources of more importance at Pwll. As may be anticipated, the range of salinities encountered tended to increase with distance up-estuary.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination Spearman's rank correlations were carried out between faecal coliforms results and rainfall recorded at the Penclacwydd weather station (Appendix II for details) over various periods running up to sample collection. These are presented in Table XI.3, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XII.3 Spearman's Rank correlations between rainfall recorded at Penclacwydd and faecal coliforms results

	Site	Pembrey	Burry Beach	North Shellfish	Pwll	South Shellfish	4th Groyne	North Dock	Cefen	Ochor Draw
	No.	105	103	26	25	25	88	36	27	27
24 hour periods prior to sampling	1 day	0.426	0.316	0.188	0.318	0.15	0.391	0.39	0.135	0.124
	2 days	0.251	0.293	0.027	0.452	0.041	0.561	0.418	0.454	0.555
	3 days	0.355	0.299	0.238	0.217	0.287	0.361	0.537	-0.037	-0.032
	4 days	0.385	0.200	0.454	-0.169	0.536	0.414	0.224	0.196	0.138
	5 days	0.379	0.289	0.291	0.096	0.329	0.177	0.051	-0.163	-0.025
	6 days	0.309	0.265	0.224	-0.076	0.367	0.323	0.253	-0.091	-0.039
	7 days	0.309	0.129	0.341	0.382	0.545	0.225	0.275	0.337	0.443
Total prior to sampling over	2 days	0.425	0.321	-0.007	0.535	0.019	0.538	0.443	0.317	0.318
	3 days	0.456	0.361	0.094	0.526	0.114	0.579	0.565	0.335	0.309
	4 days	0.476	0.358	0.208	0.362	0.277	0.575	0.518	0.374	0.265
	5 days	0.471	0.407	0.25	0.263	0.308	0.528	0.515	0.209	0.135
	6 days	0.503	0.440	0.275	0.264	0.364	0.512	0.525	0.258	0.229
	7 days	0.512	0.410	0.341	0.259	0.428	0.525	0.545	0.301	0.250

Data from the Environment Agency

Correlations between faecal coliforms and recent rainfall were found at all sites. These were strongest and most consistent at the sites sampled for bathing waters monitoring (Pembrey, Burry Beach and 4th Groyne). Such sites were sampled most often and through the summer months only. A much weaker influence of rain was found at the other sites, which were sampled throughout most of the year and on much fewer occasions. The exception to these generalisations was North Dock, which although listed as an undesignated bathing water was sampled on a year round basis and was more strongly influenced by rainfall. This may be a consequence of its enclosed nature and urban surrounds.

APPENDIX XII
MICROBIOLOGICAL DATA: SHELLFISH FLESH

As a result of the major upgrades to the Llanelli sewerage scheme in 2005, only results from 2006 onwards were considered in these analyses.

SUMMARY STATISTICS AND GEOGRAPHICAL VARIATION

The geometric mean results of shellfish flesh monitoring from all RMPs sampled from 2006 onwards are presented in Figure XII.1. Summary statistics are presented in Table XII.1 and boxplots for sites sampled on 10 or more occasions Figure XII.2.

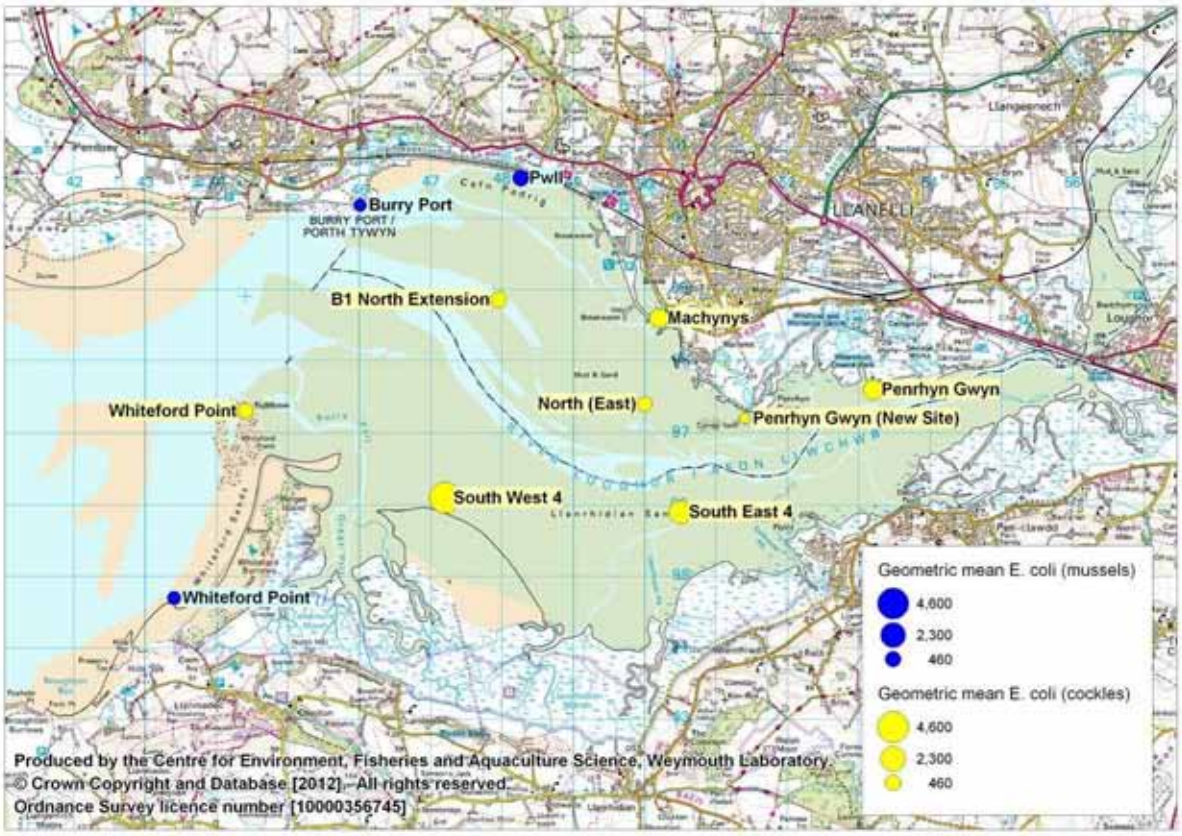


Figure XII.1 RMPs active since 2006

Table XII.1 Summary statistics of* E. coli *results (MPN/100g) from cockle and mussel RMPs sampled from 2006 onwards

RMP	Species	No.	Date of first sample	Date of last sample	Geometric mean	Min.	Max.	% over 230	% over 4600
Penrhyn Gwyn	Cockles	39	12/06/2006	18/07/2011	982	70	>18000	74%	26%
Penrhyn Gwyn (New)	Cockles	4	12/06/2006	07/11/2006	124	40	500	25%	0%
Machynys	Cockles	6	22/01/2007	16/07/2007	881	200	5400	67%	17%
North (East)	Cockles	6	17/07/2006	07/09/2009	369	40	790	83%	0%
B1 North Extension	Cockles	61	06/11/2006	09/01/2012	541	40	92000	69%	7%
South East 4	Cockles	60	15/05/2006	09/11/2011	1799	20	>180000	88%	32%
South West 4	Cockles	3	12/06/2006	23/10/2006	4564	1100	>18000	100%	33%
Whiteford Point	Cockles	56	25/04/2006	09/11/2011	478	<20	>18000	57%	18%
Burry Port	Mussels	38	16/01/2006	27/04/2009	246	<20	>18000	45%	8%
Pwll	Mussels	68	16/01/2006	09/01/2012	597	<20	9200	75%	10%
Whiteford Point	Mussels	64	25/04/2006	09/11/2011	341	<20	16000	56%	13%

Of these RMPs, four were sampled on less than 10 occasions so will not be considered in detail in the following analyses (Penrhyn Gwyn (New), Machynys, North (East) and South West 4).

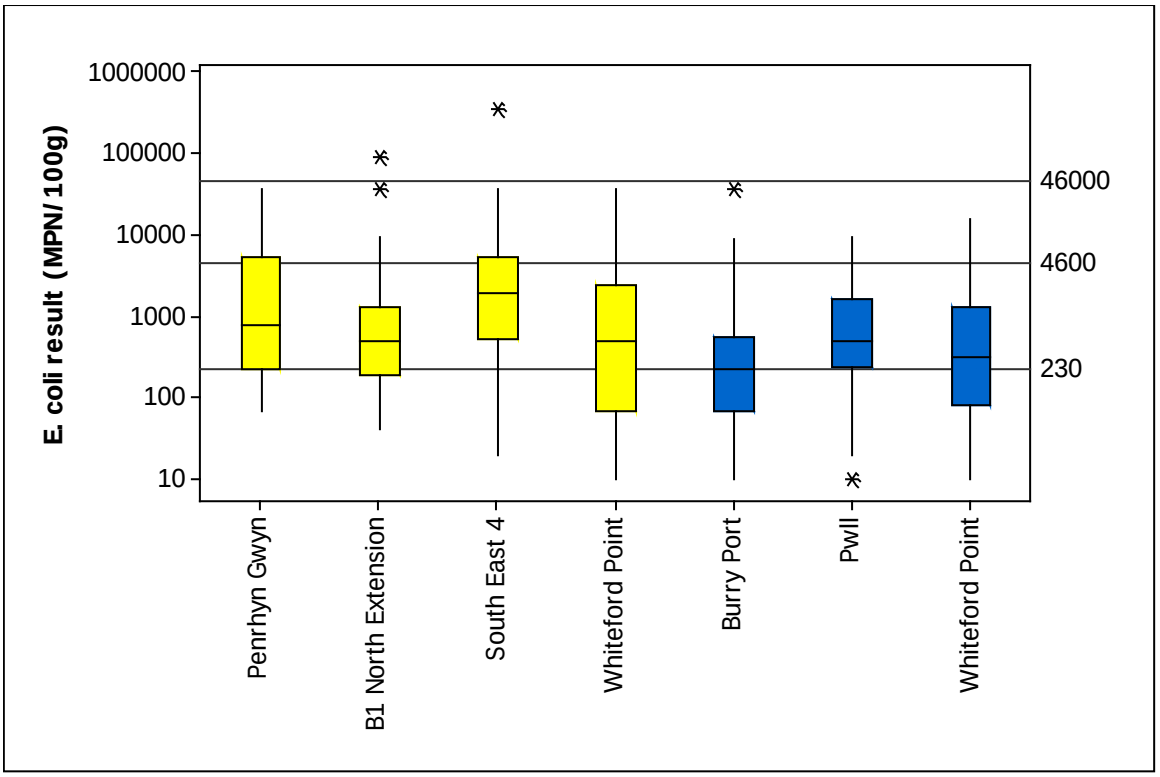


Figure XII.2 Boxplots of* E. coli *results from RMPs sampled on 10 or more occasions from 2006 onwards, cockles in yellow, mussels in blue

Across the four main cockle RMPs, results were variable ranging from within the Class A range up to prohibited levels or >18,000 *E. coli* MPN/100g. On both the south and the north side, results were generally higher at the innermost site with higher proportions of results exceeding 4600 *E. coli* MPN/100g. A comparison of all results from these four RMPs showed they were significantly higher at South East 4 compared to both B1 North Extension and Whiteford Point (One-way ANOVA, p=0.000, Tukeys comparison).

The two main RMPs on the north side (Penrhyn Gwyn and B1 North Extension) were sampled on the same day, and hence under the same environmental conditions on 32 occasions, permitting a more robust comparison of paired samples. This revealed a correlation between paired samples (Pearson's correlation, r=0.505, p=0.003) and no significant difference in mean result for these samples (paired T-test, p=0.325). The two main RMPs on the south side (South East 4 and Whiteford Point) were sampled on the same day on 46 occasions. A comparison of these paired samples revealed a significant correlation (Pearson's correlation, r=0.527, p=0.000) with significantly higher results on average at South East 4 (paired T-test, p=0.000). It was not possible to undertake meaningful paired comparisons between sites on the north and south side as fewer than 20 same day samples were taken for each of these pairings.

Across the three mussel RMPs, results were again variable ranging from Class A to Class C equivalent. A comparison of all results from these RMPs showed they were significantly higher at Pwll compared to Burry Port (One-way ANOVA, p=0.031, Tukeys comparison). A comparison of 36 paired (same day) samples taken at Burry Port and Pwll again revealed a significant difference (paired T-test, p=0.001) and also a correlation (Pearsons correlation, r=0.455, p=0.005). Comparisons of the 21 paired samples from Pwll and Whiteford Point showed no significant difference in average result (paired T-test, p=0.661) and a correlation (Pearsons correlation, r=0.549, p=0.010).

Overall, these analyses suggest that levels of contamination increase towards the head of the estuary, and are higher on the south side. They also suggest that there are some variable sources such as land runoff which affect the entire estuary in a similar way.

ENVIRONMENT AGENCY BACTERIOLOGICAL SURVEY

Between the 11th and 15th March 2012, a series of 39 shellfish samples were taken by the Environment Agency from various locations and tested for *E. coli* as part of investigations into bacteriological contamination within the Burry Inlet Shellfish Waters. Figure XII.3 presents a thematic map of these results.

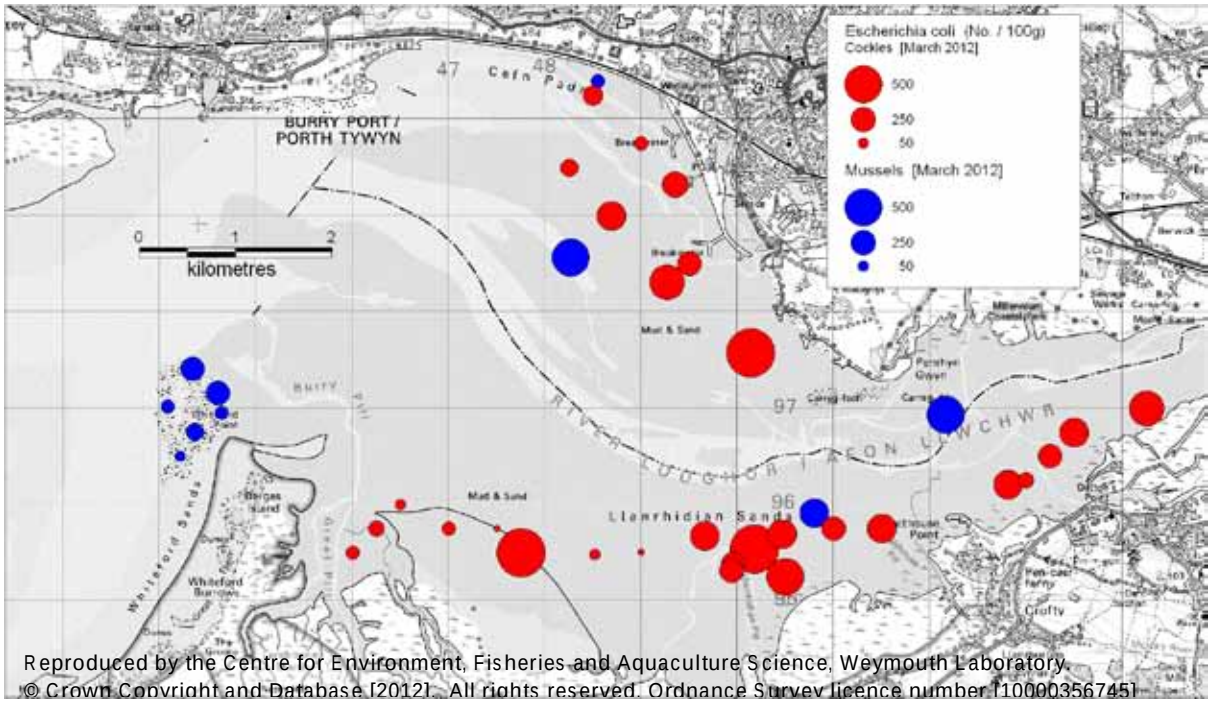


Figure XII.3. Thematic map of bacteriological survey results.
Data from the Environment Agency.

North side cockles appear to show a slight tendency for higher results up-estuary which would be consistent with large up-estuary sources being of most importance (e.g. rivers). A similar effect over a smaller scale can perhaps also be seen at Whiteford Point mussels. Cockle results on the south side also appear to show an underlying tendency for higher results up-estuary. Superimposed on this there appear to be some localised hotspots on the south side. All results were <1000 *E.*

coli MPN/100g indicating that contamination levels at the time of survey were low relative to average and peak levels found during routine classification monitoring.

OVERALL TEMPORAL PATTERN IN RESULTS

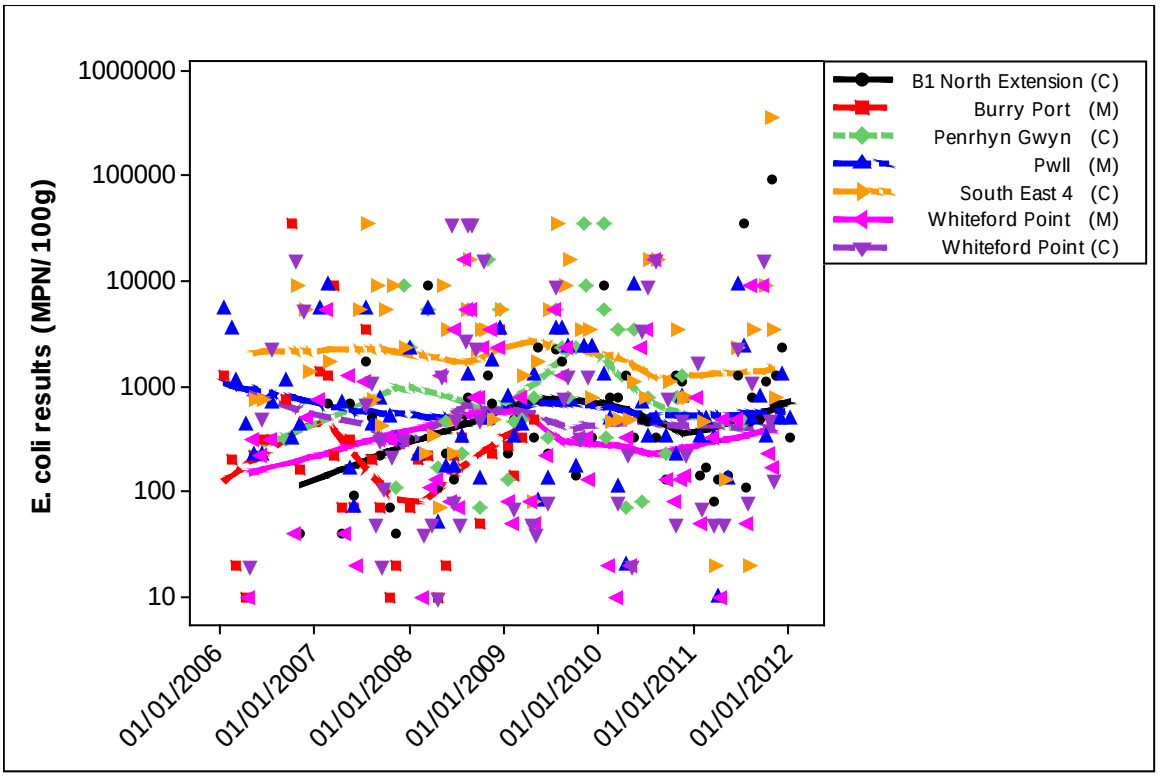


Figure XII.4
Scatterplot of* E. coli *results by RMP and date, overlaid with loess lines for each RMP

Figure XII.4 shows some fluctuations over the years, but there is no consistent pattern apparent across the estuary as a whole.

SEASONAL PATTERNS OF RESULTS

The seasonal patterns of results from 2006 onwards were investigated by RMP for all RMPs where at least 30 samples had been taken.

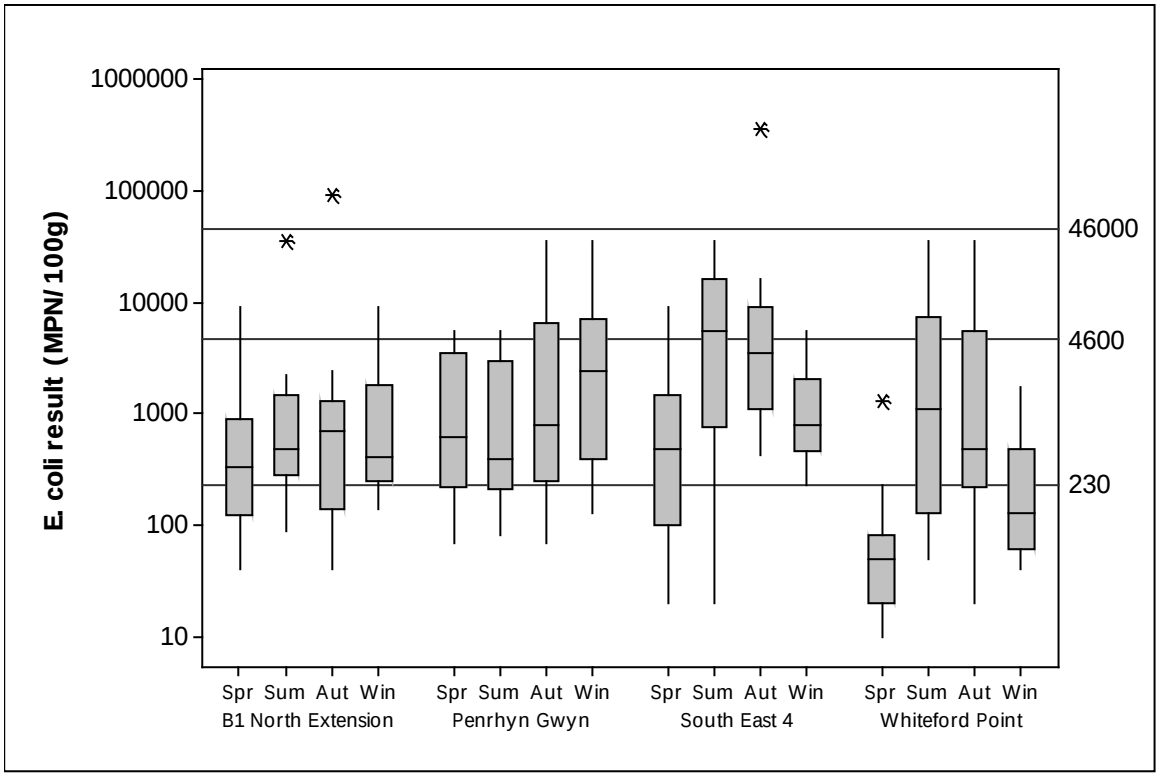


Figure XII.5 Boxplot of cockle* E. coli *results by RMP and season

There was no significant seasonal variation at the two sites on the north side of the estuary (One way ANOVA, p=0.553 for Penrhyn Gwyn and 0.781 for B1 North Extension). On the south side significant seasonal variation was found at both RMPs (One way ANOVA, p=0.004 for South East 4 and 0.000 for Whiteford Point). A post ANOVA test (Tukey comparison) indicated that results were significantly higher in the Summer and Autumn compared to the spring at both sites. This suggests that the north and south sides of the estuary are subject to differing contaminating influences.

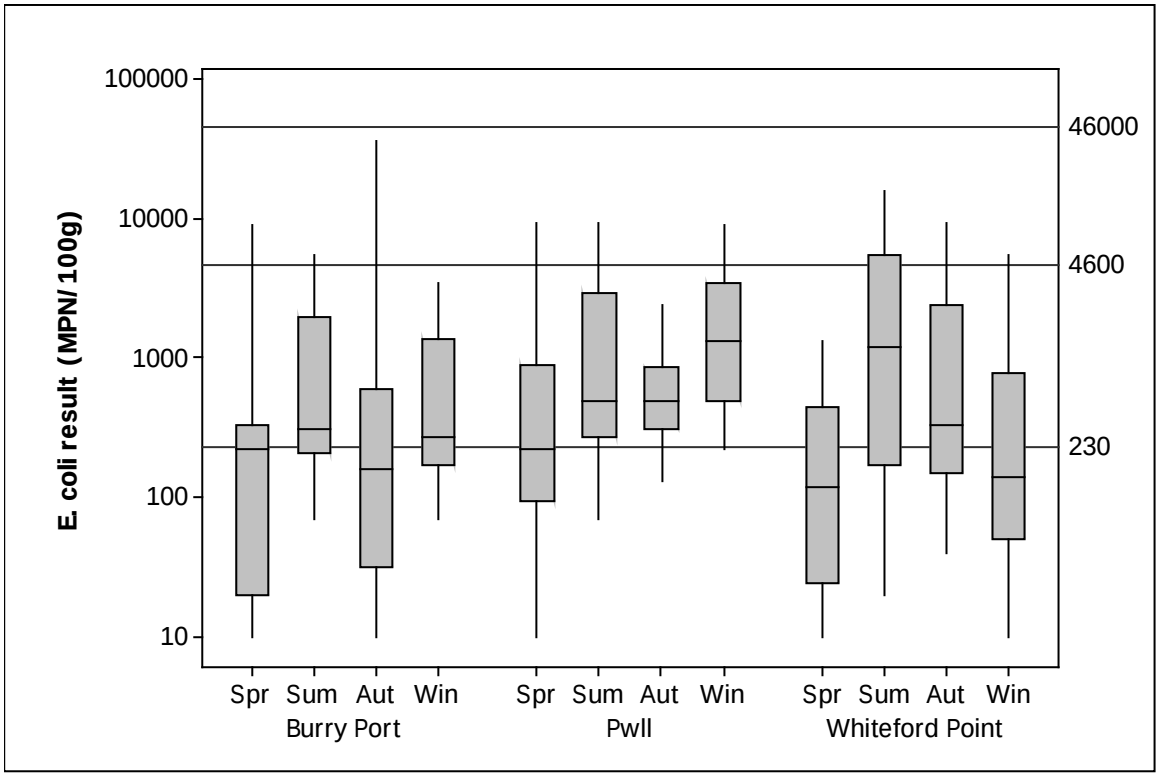


Figure XII.6 Boxplot of mussel* E. coli *results by RMP and season

Significant seasonal variation was not found at Burry Port (one way ANOVA, p=0.323), but was found at Pwll and Whiteford Point (one way ANOVA, p=0.012 and 0.009 respectively). Post ANOVA tests (Tukeys comparison) indicated that results at Pwll were significantly higher in the winter compared to the spring, and that results at Whiteford Point were significantly higher in the summer compared to the spring. Again, differing seasonal patterns were observed on the south and north sides of the estuary, and the seasonal pattern at Whiteford Point was similar to that observed in cockles from both south side RMPs which may reflect seasonal patterns of grazing on the adjacent marshes.

INFLUENCE OF TIDE

To investigate the effects of tidal state on *E. coli* results, circular-linear correlations were carried out against the spring/neap tidal cycle for each RMP where at least 30 samples had been taken since 2006. As all samples were collected when exposed by the tide, no analyses of results against the high/low tidal cycle were undertaken. No correlations between the spring/neap cycle and levels of *E. coli* for mussels at Pwll (circular-linear correlation, r=0.198, p=0.077) or for cockles at Penrhyn Gwyn (circular-linear correlation, r=0.210, p=0.205). Significant correlations at the 0.05 level were found at all other RMPs investigated. Figures XII.7 to XII.11 present polar plots of $\log_{10}$ *E. coli* results against the spring neap tidal cycle for each of these latter RMPs. Full/new moons occur at 0º, and half moons occur at 180º, and the largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results of 230 *E. coli* MPN/100g less are plotted in green, those from 231 to 4600 are plotted in yellow, and those exceeding 4600 are plotted in red.

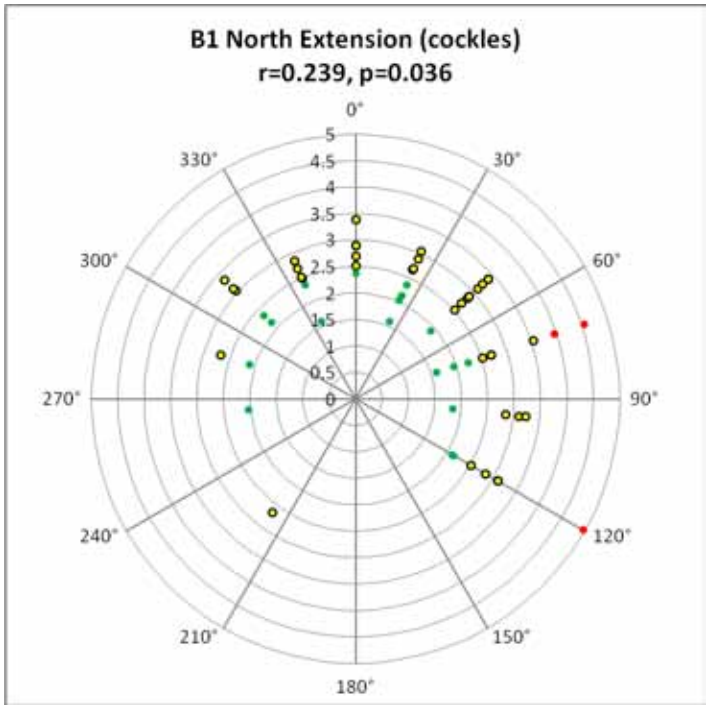


Figure XII.7 Polar plots of log_{10} E. coli results (MPN/100g) against tidal state for B1 North Extension cockles

At B1 north extension the correlation is weak and there are no strong patterns apparent in Figure X11.7.

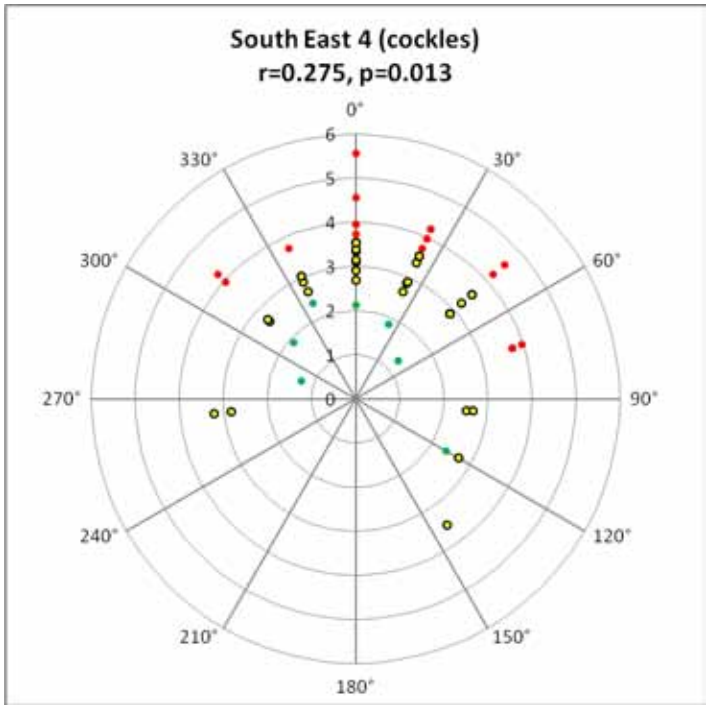


Figure XII.8 Polar plots of log_{10} E. coli results (MPN/100g) against tidal state for South East 4 cockles

Again, the correlation at South East 4 is relatively weak but results are generally higher from 0 to 90° (i.e. during spring tides) compared to the rest of the tidal cycle.

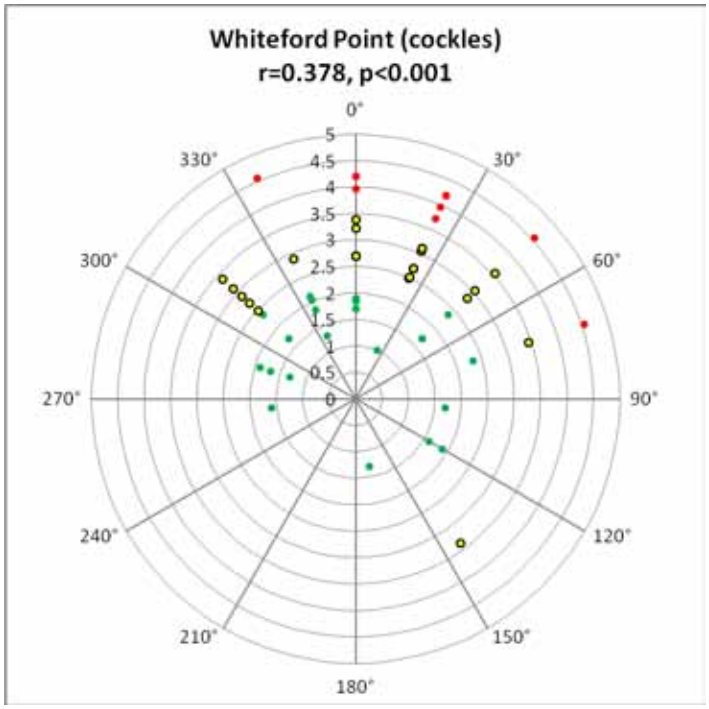


Figure XII.9 Polar plots of log_{10} E. coli results (MPN/100g) against tidal state for Whiteford Point cockles

At Whiteford point the correlation is stronger, and results tend to be higher during spring tides (0-90°).

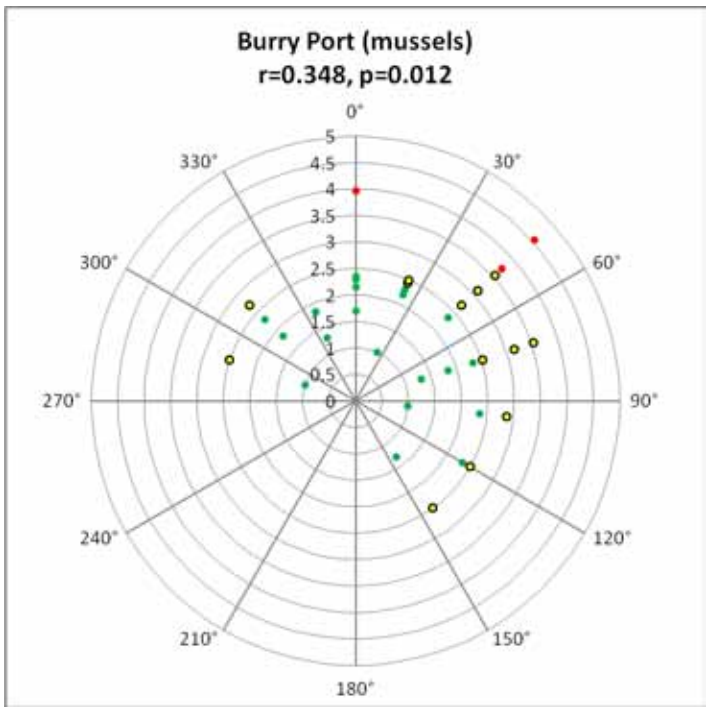


Figure XII.10 Polar plots of log_{10} E. coli results (MPN/100g) against tidal state for Burry Port mussels

A similar but weaker tendency for higher results on spring tides can also be seen at Burry Port.

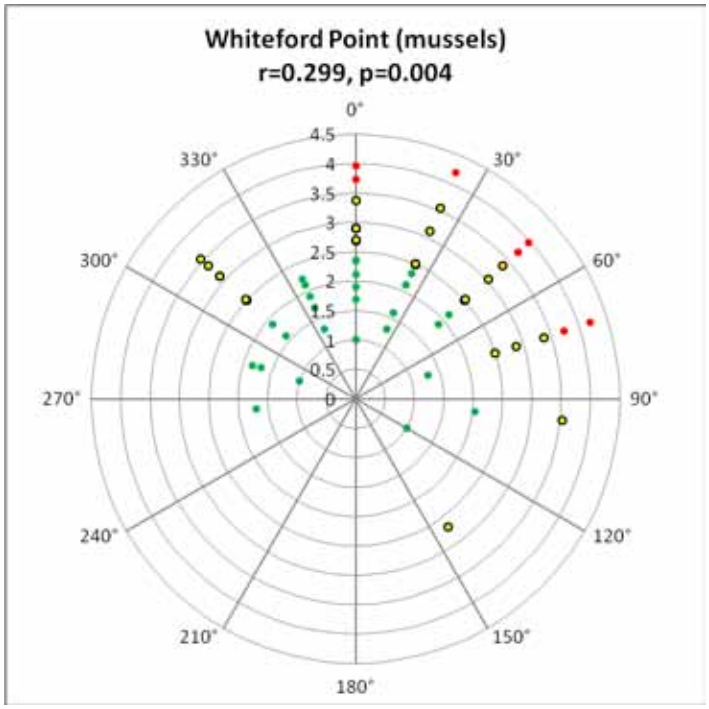


Figure XII.11 Polar plots of log_{10} E. coli results (MPN/100g) against tidal state for Whiteford Point mussels

As for cockles at Whiteford Point, there appears to be a tendency for higher results to arise during the larger spring tides.

INFLUENCE OF RAINFALL

To investigate the effects of rainfall on levels of contamination within shellfish samples Spearman's rank correlations were carried out between *E. coli* results and rainfall recorded at the Penclacwydd weather station (Appendix II for details) over various periods running up to sample collection. These are presented in Table XII.2, and statistically significant correlations ($p<0.05$) are highlighted in yellow.

Table XII.2 Spearman's Rank correlations between rainfall recorded at Penclacwydd and shellfish hygiene results

	Site	Penrhyn Gwyn	B1 North Extension	South East 4	Whiteford Point	Burry Port	Pwll	Whiteford Point
	Species	Cockles	Cockles	Cockles	Cockles	Mussels	Mussels	Mussels
	No.	38	45	51	48	36	56	55
24 hour periods prior to sampling	1 day	0.336	0.287	0.142	0.233	0.073	0.310	0.280
	2 days	0.263	0.099	0.202	0.357	0.318	0.343	0.115
	3 days	0.644	0.342	0.381	0.186	0.188	0.376	0.205
	4 days	0.455	0.146	0.258	0.189	0.272	0.360	0.319
	5 days	0.547	0.482	0.273	0.160	0.506	0.274	0.185
	6 days	0.141	0.096	0.290	0.097	0.263	0.024	0.128
	7 days	0.471	0.296	0.261	0.251	0.420	0.317	0.078
Total prior to sampling over	2 days	0.350	0.230	0.163	0.324	0.318	0.405	0.256
	3 days	0.488	0.290	0.314	0.406	0.284	0.416	0.314
	4 days	0.577	0.375	0.365	0.397	0.434	0.488	0.382
	5 days	0.700	0.480	0.369	0.369	0.467	0.519	0.367
	6 days	0.685	0.462	0.418	0.300	0.499	0.492	0.334
	7 days	0.675	0.445	0.415	0.290	0.530	0.485	0.290

Some influence of rainfall was detected at all the RMPs investigated. For cockles the correlations were generally strongest at Penrhyn Gwyn and weakest at Whiteford Point, perhaps reflecting their relative proximity to the head of the estuary. For mussels correlations were generally strongest at Pwll and weakest at Burry Port, again possibly reflecting their positions relative to the main freshwater inputs.

APPENDIX XIII
SHORELINE SURVEY

Date (time): 18th April 2011 (08:30-15:00 BST) and
19th April 2011 (09:00-14:00 BST)

Applicant: Mr D. Taylor

Cefas Officer: Alastair Cook

Local Enforcement Authority Officer: Mark Liley, Carmarthenshire Council

Area surveyed: North shore from Burry Port to Loughor Bridge.
Selected parts of the south shore from Loughor Bridge to Cheriton

Weather: 18th April – winds E force 2, 14°C, sunny
19th April – winds E force 3, 18°C, sunny

Tidal predictions (Milford Haven):
Admiralty TotalTide – Burry Port 51°41'N 4°15'W Wales. Times GMT+0100. Predictions are based on Milford Haven.

18/04/2011			19/04/2011		
Low	01:04	0.7m	Low	01:49	0.6m
High	07:02	9.1m	High	07:47	9.1m
Low	13:30	0.6m	Low	14:13	0.6m
High	19:25	9.1m	High	20:09	9.1m

Predicted heights are in metres above Chart Datum

Objectives: (a) confirm the location of sources of contamination to the shoreline; (b) identify any additional sources of contamination in the area and; (c) obtain further details of the extent and *modus operandi* of the shellfisheries. A full list of recorded observations is presented in Table XIII.1 and the locations of these observations are mapped in Figure XIII.1. Photographs referenced in the Table XIII.1 are presented in Figures XIII.3-18. The survey was undertaken by foot, covering the area from Burry Port to Loughor Bridge on the north shore, and selected sections of the south shore from Loughor Bridge to Cheriton.

Description of Fishery

The survey was prompted by an application to harvest soft shell clams (*Mya arenaria*) in an area off Pwll on the north side of the estuary. The area indicated in the application covers about 0.5km^2. It is believed this population has established fairly recently and is mainly confined to this relatively small area. Densities and exact distributions are unknown. The clams are to be harvested by digging by hand. The viability of this fishery is dependent on it receiving classification of B or better as the market is for live animals.

Also within Burry inlet are substantial stocks of cockles (*Cerastoderma edule*) and mussels (*Mytilus* spp.) both of which are currently classified and harvested commercially by a number of fishermen. Further details on these will be obtained and presented in the full sanitary survey report.

Sources of contamination

The north shore of the survey area from Burry Port to Loughor Bridge is served by Llanelli STW, which discharges about 1km to the west of Loughor Bridge (observation 21). Associated with the Llanelli sewerage network are a series of intermittent discharges along this shoreline (observations 6, 8, 10, 12, 22).

The Gowerton STW outfall, on south shore immediately adjacent to the Loughor Bridge was seen from the road but not visited or recorded as a waypoint. A sewage works was also seen at Cheriton (observation 52) but it was not possible to access the outfall. A disused sewage works was seen at Crofty (observation 38). Four pumping stations were also recorded on the south shore (observations 27, 31, 36 and 40). In addition, a further outfall was seen at Crofty (observation 35) which had recently discharged foul water, possibly from another pumping station which was not directly observed.

Livestock are likely to be a significant contaminating influence to Burry Inlet, and all of these were recorded on the south shore. Here there are extensive areas of saltmarsh grassland, large parts of which may be covered at high water, upon which 122 horses were noted. Deposition of faecal matter onto intertidal areas is a particularly direct pathway of contamination to coastal waters. Large numbers of sheep were recorded on fenced fields by the south shore (about 405 in total) but not on the marshes. A few horses and cattle were also noted in fields adjacent to the south shore (15 of each). It is likely that further livestock was present along this shore, but not seen. Although no livestock was recorded on the north shore some horse droppings were seen in the tideline in one isolated area (observation 17) which according to a notice on the gate appeared to have originated from one abandoned animal.

Burry Inlet is almost all intertidal, so boat traffic is generally fairly light and limited to smaller craft. A marina was seen at Burry Port where about 140 boats were recorded (observations 1 and 3), mainly small to medium sized yachts and cabin cruisers. Four small cabin cruisers were seen in a small tidal creek on the south shore (observation 32).

Waterbirds are present throughout the area, and there is a wetland bird reserve at the Millennium Coastal Park just south of Llanelli, but no major aggregations of birds were recorded. A seal was seen hauled out by the main channel just to the west of Loughor Bridge. Dog walkers were seen on the beach at Burry Port.

Sample results

Spot flow gauging and sampling was undertaken on watercourses draining to Burry Inlet where access was possible and the watercourses were not too large to safely wade across. These are presented in Table XIII.2. A seawater sample was also

taken from a tidal creek on the south shore. One of the streams which could not be sampled (Barnaby Pill) discharges immediately to the west of the clam bed at Pwll (observation 7), and was considerably larger than the other watercourses in the vicinity of this shellfish bed.

The results of these indicated that watercourses on the south shore generally carried much higher levels of contamination to those on the north shore. A seawater sample from the tidal creek at Pen-clawwd also contained relatively high levels of *E. coli*.

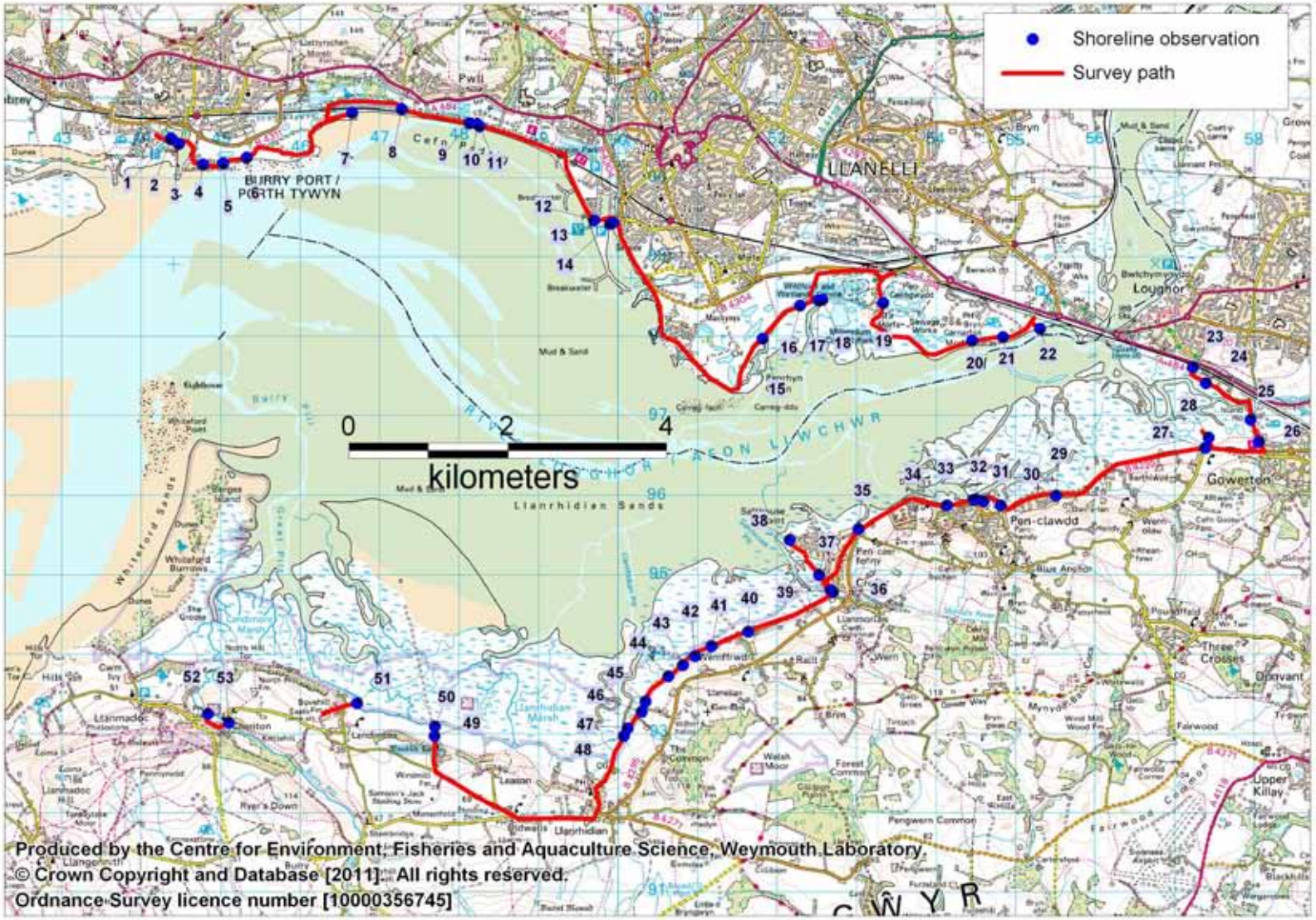


Figure XIII.1. Locations of shoreline observations

Table XIII.1. Details of shoreline observations

No.	Date and time	Position	Photograph	Observation
1	18-APR-11 09:03	SN 44374 00483		6 cabin cruisers and 15 dinghies in inner harbour
2	18-APR-11 09:05	SN 44370 00500		Surface water outfall 20cmx20cmx1.485m/s. Water sample 1
3	18-APR-11 09:13	SN 44469 00431	Figure XIII.3	Surface water outfall impossible to access. About 120 boats in Burry Harbour (yachts and cabin cruisers)
4	18-APR-11 09:23	SN 44772 00173		3 dogs on beach
5	18-APR-11 09:27	SN 45029 00184	Figure XIII.4	Possibly disused inspection cover on shore
6	18-APR-11 09:32	SN 45324 00256		Red buoy and marker post
7	18-APR-11 10:00	SN 46649 00817	Figure XIII.5	River, too large to measure, not possible to access to sample.
8	18-APR-11 10:21	SN 47276 00867	Figure XIII.6	Stream 40cmx12cmx0.430m/s. Water sample 2. Sewer outfall pipe alongside
9	18-APR-11 10:40	SN 48132 00689		Stream 200cmx10cmx0.400m/s.. Water sample 3.
10	18-APR-11 10:46	SN 48231 00673	Figure XIII.7	Old sewage works. Pipe on shore.
11	18-APR-11 10:47	SN 48257 00649		Stream 160cmx16cmx0.265m/s. Water sample 4
12	18-APR-11 11:23	SS 49697 99463	Figure XIII.8	Possible pumping station enclosure.
13	18-APR-11 11:28	SS 49897 99418		Culverted stream and another one on opposite bank
14	18-APR-11 11:31	SS 49935 99434	Figure XIII.9	Surface water outfall under bridge. Not possible to access watercourse below bridge to sample and measure.
15	18-APR-11 12:26	SS 51821 97973		Stream 120cmx20cmx0.789m/s. Water sample 5
16	18-APR-11 12:38	SS 52292 98387		8 geese on saltmarsh. No livestock visible.
17	18-APR-11 12:47	SS 52522 98454	Figure XIII.10	Horse droppings in tideline
18	18-APR-11 12:49	SS 52566 98460	Figure XIII.11	Creek, not flowing
19	18-APR-11 13:16	SS 53335 98421		2 horses
20	18-APR-11 13:43	SS 54454 97946		Gateway Caravan Park
21	18-APR-11 13:50	SS 54846 97989	Figure XIII.12	Llanelli STW outfall marker post about 1/2 way between here and previous waypoint
22	18-APR-11 14:00	SS 55312 98095	Figure XIII.13	1 seal. Outfall pipe, flowing, 45cmx1cmx0.267m/s. Water sample 6
23	19-APR-11 08:46	SS 57238 97612	Figure XIII.14	Cattle shed, 15 dairy cattle. Sewage pipeline heading out across flooded field.
24	19-APR-11 08:53	SS 57398 97409		3 horses. Sewage pipeline running alongside road
25	19-APR-11 08:57	SS 57960 96950		Gowerton Caravan Park. Pipeline still running alongside road
26	19-APR-11 09:00	SS 58070 96670		30 sheep in field. 50 sheep in next field
27	19-APR-11 09:05	SS 57390 96594		Sewage pumping station
28	19-APR-11 09:07	SS 57436 96724		Dung heap
29	19-APR-11 09:30	SS 55513 96000	Figure XIII.15	20 horses on saltmarsh

No.	Date and time	Position		Observation
30	19-APR-11 09:42	SS 54815 95878		15 horses on saltmarsh
31	19-APR-11 09:46	SS 54594 95928	Figure XIII.16	Sewage pumping station
32	19-APR-11 09:50	SS 54499 95953		End of outfall pipe, trickle coming out. 4 small cabin cruisers in creek
33	19-APR-11 09:52	SS 54475 95944		Seawater sample 7 from tidal creek
34	19-APR-11 10:06	SS 54141 95877		8 horses on saltmarsh
35	19-APR-11 10:16	SS 53025 95580	Figure XIII.17	Outfall pipe grey water present, Not flowing.
36	19-APR-11 10:26	SS 52703 94782		Pumping station overflow
37	19-APR-11 10:33	SS 52532 94996		4 horses in paddock. 10 horses out on saltmarsh
38	19-APR-11 10:44	SS 52161 95439		Disused and abandoned sewage works
39	19-APR-11 11:00	SS 52674 94808		Stream 255cmx11cmx0.247m/s. Water sample 8
40	19-APR-11 11:11	SS 51637 94281		Sewage pumping station. 22 horses out on marsh.
41	19-APR-11 11:15	SS 51177 94098		8 horses on saltmarsh
42	19-APR-11 11:16	SS 50969 93976		6 horses on saltmarsh
43	19-APR-11 11:18	SS 50813 93859		30 sheep in field
44	19-APR-11 11:25	SS 50635 93719		15 sheep and 5 horses in fields
45	19-APR-11 11:27	SS 50345 93405		6 horses in field
46	19-APR-11 11:27	SS 50295 93274		5 horses on saltmarsh
47	19-APR-11 11:29	SS 50118 93064		50 sheep/lambs in field. 8 horses on marsh
48	19-APR-11 11:34	SS 50072 92965		30 sheep in field. 5 horses on marsh. Stream 65cmx30cmx0.187m/s. Water sample 9.
49	19-APR-11 11:58	SS 47687 92965		About 200 sheep in 2 fields
50	19-APR-11 12:02	SS 47693 93085		Stream 300cmx70cmx0.200m/s. Water sample 10. 9 horses on marsh
51	19-APR-11 12:30	SS 46715 93380		Stream 180cmx20cmx0.645m/s. Water sample 11. 3 horses.
52	19-APR-11 12:51	SS 44837 93244	Figure XIII.18	Sewage works
53	19-APR-11 12:59	SS 45101 93137		Stream 680cmx15cmx0.373, Water sample 12.

Figure XIII.2. Locations of water samples annotated with* E. coli *result

Table XIII.2. Details of water samples taken

Sample no.	Date and time	Position	Type	Source	Width (m)	Depth (m)	Flow (m/s)	*E. coli* (cfu/100ml)	Discharge (m^3/day)	*E. coli* (cfu/day)
1	18-APR-11 09:05	SN 44370 00500	Freshwater	Unnamed culvert	0.20	0.20	1.485	18	5132	9.2×10^8
2	18-APR-11 10:21	SN 47276 00867	Freshwater	Unnamed stream	0.40	0.12	0.430	45	1783	8.0×10^8
3	18-APR-11 10:40	SN 48132 00689	Freshwater	Unnamed stream	2.00	0.10	0.400	15	6912	1.0×10^9
4	18-APR-11 10:47	SN 48257 00649	Freshwater	Afon Dulais	1.60	0.16	0.265	132	5861	7.7×10^9
5	18-APR-11 12:26	SS 51821 97973	Freshwater	Unnamed stream	1.20	0.20	0.789	41	16361	6.7×10^9
6	18-APR-11 14:00	SS 55312 98095	Freshwater	Bynea SPS outfall	0.45	0.01	0.267	56	104	5.8×10^7
7	19-APR-11 09:52	SS 54475 95944	Seawater	Unnamed creek				600		
8	19-APR-11 11:00	SS 52674 94808	Freshwater	Morlais River	2.55	0.11	0.247	400	5986	2.4×10^{10}
9	19-APR-11 11:34	SS 50072 92965	Freshwater	Unnamed stream	0.65	0.30	0.187	700	3151	2.2×10^{10}
10	19-APR-11 12:02	SS 47693 93085	Freshwater	Unnamed stream	3.00	0.70	0.200	1100	36288	4.0×10^{11}
11	19-APR-11 12:30	SS 46715 93380	Freshwater	Unnamed stream	1.80	0.20	0.645	680	20062	1.4×10^{11}
12	19-APR-11 12:59	SS 45101 93137	Freshwater	Burry Pill	6.80	0.15	0.373	80	32872	2.6×10^{10}

Conclusions

There are major sewage discharges near the Loughor Bridge, with one on either side of the estuary. A small sewage works was also seen at Cheriton. A number of intermittent discharges are present on either side of the Inlet. Significant impacts from livestock are expected on the south shore. This appears to be reflected in the much higher concentrations of *E. coli* in watercourses here. The presence of horses and their droppings on the intertidal salt grassland represents a particularly direct route of contamination. Diffuse inputs from waterbirds and perhaps dogs may be expected throughout the area.

At Pwll, there are several sources which might cause noticeable spatial variation across the clam beds. These include three small watercourses, one of which discharges towards the western end and two of which discharge through the same outlet at the eastern end. Neither of these were carrying a large bacterial loading at the time of survey. Also towards the eastern end is an intermittent sewer overflow. In addition to these sources, there is a larger watercourse (Barnaby Pill) approximately 500m to the west of the bed.

Photographs

Figure XIII.3

Figure XIII.4

Figure XIII.5

Figure XIII.6

Figure XIII.7

Figure XIII.8

Figure XIII.9

Figure XIII.10

Figure XIII.11

Figure XIII.12

Figure XIII.13

Figure XIII.14

Figure XIII.15

Figure XIII.16

Figure XIII.17

Figure XIII.18

References

ASHBOLT, J. N., GRABOW, O. K., SNOZZI, M., 2001. Indicators of microbial water quality. *In* Fewtrell, L. and Bartram, J. (Eds). Water quality: guidelines, standards and health. IWA Publishing, London. pp. 289−315.

BROWN J., 1991. The final voyage of the Rapaiti. A measure of surface drift velocity in relation to the surface wind. *Marine Pollution Bulletin* 22: 37-40.

CARMARTHENSHIRE COUNCIL, 2012. Website description of Burry Port Marina. http://www.carmarthenshire.gov.uk/English/leisure/countryside/BurryPortMarina/Pages/homepage.aspx. Accessed March 2012

COUNCIL OF THE EUROPEAN COMMUNITIES, 1975. Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water. *Official Journal* L031: 0001-0007.

DEFRA, 2009. Pigs and Poultry Farm Practices Survey 2009 – England. http://www.defra.gov.uk/evidence/statistics/foodfarm/enviro/farmpractice/documents/FPS2009-pigspoultry.pdf. Accessed 25 October 2010.

DUNHILL, I., 2003. A preliminary study into the change in faecal indicator concentration of estuarine water attributable to tidal inundation of saltmarsh. Bruen, M. (editor) (2003) In Diffuse Pollution and Basin Management. Proceedings of the 7th International Specialised IWA Conference, Dublin, Ireland.

ELLIOTT, M., BURDON, D., CALLAWAY, R., FRANCO, A., HUTCHINSON, T., LONGSHAW, M., MALHAM, S., MAZIK, K., OTTO, Z., PALMER, D., FIRMIN, C., SMITH, T., WITHER, A. (2012). Burry Inlet Cockle Mortalities Investigation 2009-2011. Technical Report to Environment Agency Wales. Institute of Estuarine and Coastal Studies, University of Hull. 17 January 2012.

ENVIRONMENT AGENCY, 2001. Water Quality Consenting Standard. Consenting Disinfection Systems – Minimum Pathogen Removal Requirements. Environment Agency Internal Document.

ENVIRONMENT AGENCY, 2007. The Tawe, Loughor and Gower Catchment Abstraction Management Strategy.

EUROPEAN COMMUNITIES, 2004. EC Regulation No 854/2004 of the European Parliment and of the Council of 29 April 2004 laying down specific hygiene rules on products of animal origin intended for human consumption. *Official Journal of the European Communities* L226: 83-127.

EUROPEAN COMMUNITIES, 2006. Directive 2006/113/EC of the European parliament and of the Council of 12 December 2006 on the quality required of shellfish waters (codified version). Official Journal of the European Communities L376: 14-20.

EU WORKING GROUP ON THE MICROBIOLOGICAL MONITORING OF BIVALVE HARVEST AREAS (2010). Microbiological Monitoring of Bivalve Harvest Areas. Guide to Good Practice: Technical Application. Issue 4, August 2010.

GELDREICH, E.E. 1978. Bacterial and indicator concepts in feces, sewage, stormwater and solid wastes. *In* Berg, G. (ed.). *Indicators of Viruses in Water and Food.* MI: Ann Arbor.

HOLT, C., AUSTIN, G., CALBRADE, N., MELLAN, H., MITCHELL, C., STROUD, D., WOTTON, S., MUSGROVE, A., 2011. Waterbirds in the UK 2009/10. The Wetland Bird Survey.

HUGHES, C., GILLESPIE, I.A., O'BRIEN, S.J., 2007. Foodborne transmission of infectious intestinal disease in England and Wales 1992-2003. *Food Control* 18: 766−772.

JNCC, 2008. Information sheet on the Burry Inlet RAMSAR wetland. http://jncc.defra.gov.uk/pdf/RIS/UK14001.pdf

KAY, D, CROWTHER, J., STAPLETON, C.M., WYLER, M.D., FEWTRELL, L., ANTHONY, S.G., BRADFORD, M., EDWARDS, A., FRANCIS, C.A., HOPKINS, M. KAY, C., MCDONALD, A.T., WATKINS, J., WILKINSON, J., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. Water Research 42, 442-454.

KAY, D., CROWTHER, J., STAPLETON, C.M., WYER, M.D., FEWTRELL, L., EDWARDS, A., FRANCIS, C.A., MCDONALD, A.T., WATKINS, J., WILKINSON, J., 2008b. Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42: 442-454.

KIELY, O., LIGARD, D., MCKIBBEN, M., CONNOLLY, N., BAINES, M. (2000). Grey Seals : Status and Monitoring in the Irish and Celtic Seas. Maritime Ireland / Wales INTERREG Report No. 3

LEE, R.J., YOUNGER, A.D., 2002. Developing microbiological risk assessment for shellfish purification. *International Biodeterioration and Biodegradation* 50: 177−183.

LEES, D.N., 2000. Viruses Viruses in bivalve shellfish. *Int. J. Food. Microbiol.* 59: 81-116.

MET OFFICE, 2012. Regional Climates. Available at: http://www.metoffice.gov.uk/climate/regional/ Accessed March 2012.

MITCHELL, P. IAN, S. F. NEWTON, N. RATCLIFFE & T. E. DUNN, 2004. Seabird Populations of Britain and Ireland, Results of the Seabird 2000 Census (1998-2002). T&AD Poyser, London.

OBIRI-DANSO, K., JONES, K., 2000. Intertidal sediments as reservoirs for hippurate negative campylobacters, salmonellae, and faecal indicators in three EU recognised bathing waters in North-West England. *Water Research* 34(2): 519−527.

REEDS, 2011. Reeds Nautical Almanac 2012.

ROBINS, P.E. (2009). Development of a morphodynamic model of the Burry Inlet to inform future management decisions. CCW Contract Science Report No 898b.

SEAFISH,1984. Burry Inlet/Three Rivers: A survey of shellfish stocks. Technical report No. 261.

SWWTP, 2011. South West Wales Tourist Partnership Annual Report 2010-2011 http://www.swwtp.co.uk/media/files/SWWTP_AR_11_ENG.pdf.

WILDFOWL AND WETLANDS TRUST, 2012. Web page at http://www.wwt.org.uk/what-we-do/saving-wetlands/wwt-reserves/our-nature-reserves/llanelli/ accessed May 2012.

WOOLMER, A. P., 2010. Provisional Review and Advice of Cockle Management in the Burry Inlet. Report to the Environment Agency from the Shellfish Association of Great Britain.

YOUNGER, A.D., LEE, R.J., LEES, D.N. 2003. Microbiological monitoring of bivalve mollusc harvesting areas in England and Wales: rationale and approach. In: Villalba, A., Reguera, B., Romalde, J. L., Beiras, R. (eds). Molluscan Shellfish Safety. Consellería de Pesca e Asuntos Marítimos de Xunta de Galicia and Intergovernmental Oceanographic Commission of UNESCO, Santiago de Compostela, Spain. pp. 265−277.

YOUNGER, A.D., REESE, R.A.R.,. 2011. *E. coli* accumulation compared between mollusc species across harvesting sites in England and Wales. Cefas/FSA internal report.

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
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
NWSFC	North Western Sea Fisheries Committee
OSGB36	Ordnance Survey Great Britain 1936
mtDNA	Mitochondrial DNA
PS	Pumping Station
RMP	Representative Monitoring Point
SAC	Special Area of Conservation
SSSI	Site of Special Scientific Interest
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. Ebb-dominant estuaries have asymmetric tidal currents with a shorter ebb phase with higher speeds and a longer flood phase with lower speeds. In general, ebb-dominant estuaries have an amplitude of tidal range to mean depth ratio of less than 0.2.
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 N^{th} 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 a skewed data such as one 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 data set, 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”.

Summary of consultations on draft report

Consultee	Comment	CEFAS response
Environment Agency	Cockle processing plant discharges and Llanrhidian Holiday Centre batch reactor potentially significant sources not fully explored in report.	Further details added and discussed.
	Garnswllt STW does not have N removal, only P removal.	Corrected
	One very low salinity recorded by the agency at Burry North though to be a data transfer error.	Outlying result removed from analyses.
DCWW (Welsh Water)	None	
Carmarthenshire Council	Please include extra zone to cover possible mussel dredge fishery identified in September 2012.	Added to sampling plan.
	Consider whether the EA (fisheries management) enforcement boundaries could be used as classification zone boundaries.	These do not really align with the reasoning behind the assessment and zoning plan. Some small adjustments made to zone boundaries so they align with visible landmarks to improve enforceability of zones.
Swansea Council	Access to Ochor Draw RMP is difficult during winter months.	As identified in the recommendations, please sample as close to the RMP as possible and record location sampled.
Welsh Government Fisheries		

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