Scottish Sanitary Survey Project

Report - Restricted Sanitary Survey

Kirkcaldy Bay Razors

FF 580

August 2011

Cefas

Food Standards Agency
food.gov.uk
Buidheann Inbhe-Bìdhe

Report Distribution – Kirkcaldy Bay

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* Distribution of both draft and final reports to relevant agency personnel and harvesters is undertaken by FSAS.

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I. Executive Summary

A restricted-scope sanitary survey was undertaken at Kirkcaldy Bay, Fife in response to submission of a standard application for classification of the area for the harvest of razor clams (*Ensis* spp.). Kirkcaldy Bay lies on the north shore of the outer Firth of Forth, adjacent to the town of Kirkcaldy and north of Edinburgh. The area has been the subject of a number of fast track classifications, a proportion of which overlap the area identified in the standard application. The spread of the applications indicates a wider potential fishery area than that specified within the standard application.

The survey recorded significant sources of faecal contamination to the fishery from human sewage. The largest of these sources is the Kirkcaldy WWTW outfall, which discharges within the area identified in the application. A smaller discharge, with lower treatment level, is located north of the identified area.

Diffuse pollution is carried to the bay via Tiel Burn and East Burn, both of which flow through both arable farmland and urban areas before reaching the sea and therefore would be potential pathways for contamination from animal faeces to reach the beach. Both of these burns provide significant loadings of faecal contaminants to the bay, particularly during wet weather.

Although the area had not been monitored historically, samples had been submitted in 2010 in support of a fast track classification for Krikaldy Linktown, which was located approximately 1km south of the current proposed northern fishery boundary. These showed significant contamination in the shellfish, with 50% of samples identified in the production area exceeding 230 *E. coli* MPN/100 g. This is indicative of significant faecal contamination to the area.

Analysis of information available on water currents suggests that contaminants are likely to be carried parallel to shore and up to 6 km away from the source over the course of a flood or ebb tide.

It was recommended that the production area boundaries exclude the northernmost section of the area identified by the harvester, as this Kirkcaldy WWTW outfall lies within it. A representative monitoring zone is recommended to allow sufficient scope for regular collection of samples, and this spans an area along the northern production area boundary. Sampling should continue on a monthly basis.

II. Sampling Plan

PRODUCTION AREA	Kirkcaldy Bay Razors
SITE NAME	Site 1
SIN	FF 580 105 316
SPECIES	Razor clam
TYPE OF FISHERY	Wild
NGRS OF RMZ BOUNDARY	Area bounded by lines drawn from NT 2850 9100 to NT 2967 9100, NT 2967 9100 to NT 2967 9053, NT 2967 9053 to NT 2850 9053, and NT 2850 9053 to NT 2850 9100
TOLERANCE (M)	N/A
DEPTH (M)	N/A
METHOD OF SAMPLING	Hand dived
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Fife Council
AUTHORISED SAMPLER	John Lecyn
LOCAL AUTHORITY LIAISON OFFICER	John Lecyn

III. Report

1. Area Overview

The Kirkcaldy Bay fishery lies on the outer part of the Firth of Forth, north of Edinburgh. The bay is approximately 3 km from the northern to southern end. The Fife Coastal Path passes along the shore of Kirkcaldy Bay. The shoreline is heavily populated with the town of Kirkcaldy extending along the entire western shoreline of the fishery.

A restricted sanitary survey at Kirkcaldy Bay was conducted in response to receipt of an application to classify the bay for commercial harvest of razor clams (*Ensis* spp.).

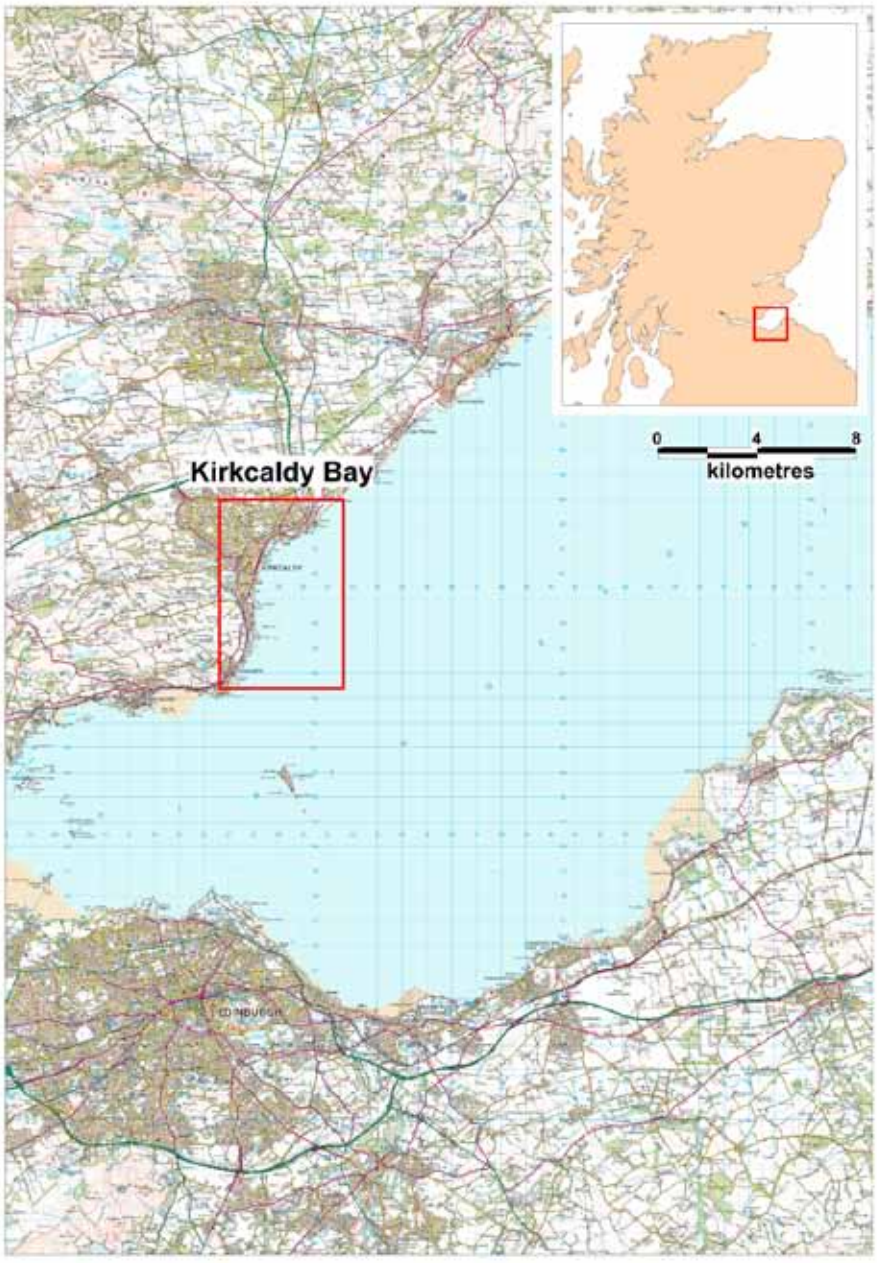

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Figure 1.1 Location of Kirkcaldy Bay

1.1 Land Use

The Land Cover Map 2000 data for the area is shown in Figure 6.1 below:

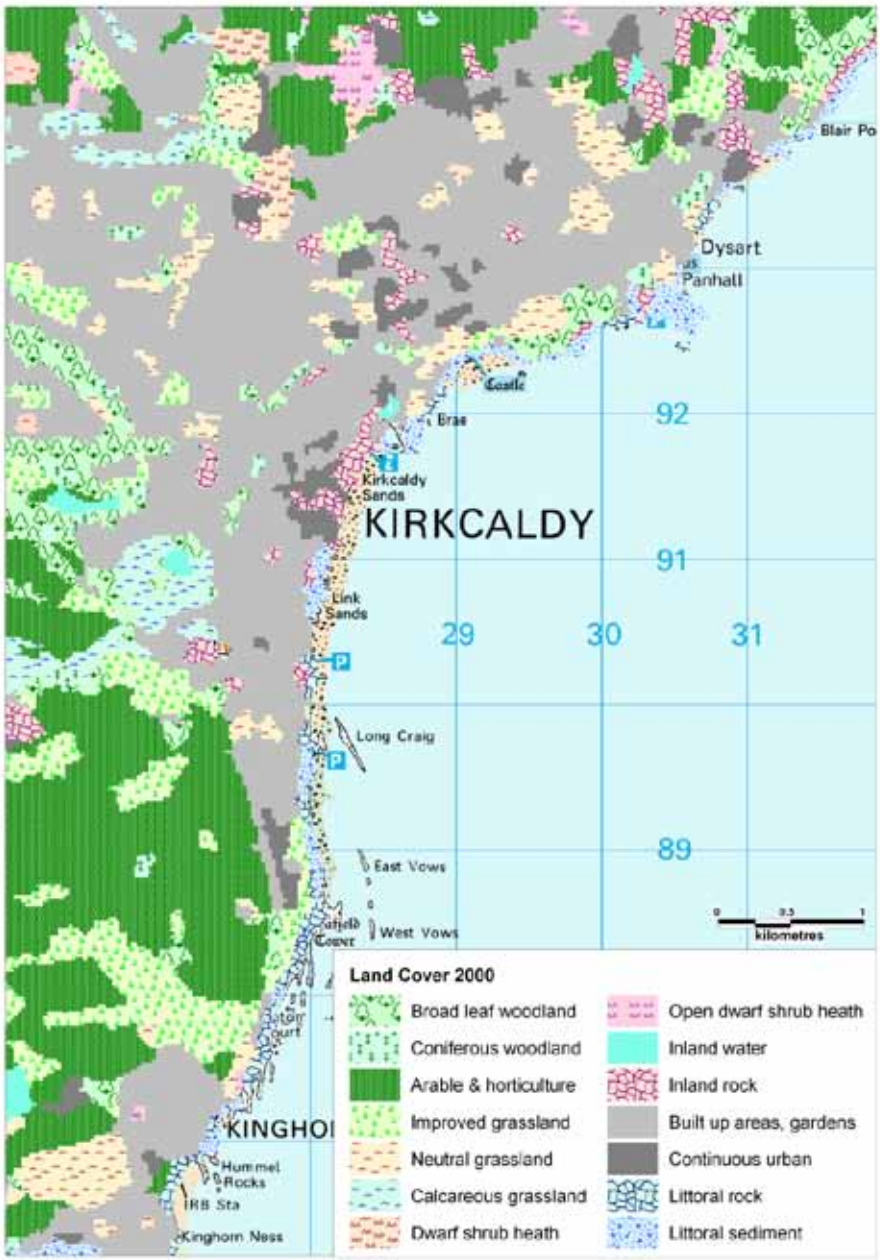

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Figure 1.2 LCM2000 class land cover data for Kirkcaldy Bay

There are urban and built up areas with a substantial area of arable land and improved grassland south of Kirkcaldy. To the north are mixed patches of arable and mixed grassland. Small patches of calcareous grassland, open dwarf shrub heath, broad leaf woodland and neutral grassland are found interspersed throughout the area. Developed areas correspond with the major settlements in the area.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be highest for urban catchment areas (1.2 – 2.8x10^9 cfu km^{-2} hr^{-1}) and lower for areas of improved grassland (approximately 8.3x10^8 cfu km^{-2} hr^{-1}) and rough grazing (approximately 2.5x10^8 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). Lowest contributions would be expected from areas of woodland (approximately 2.0x10^7 cfu km^{-2} hr^{-1}). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay *et al*. 2008).

Therefore, the expected contribution of faecal indicator bacteria attributable to land cover type would be highest along the section of coastline immediately adjacent to Kirkcaldy and Dysart where there is the largest area of urban catchment. There would also be a potential contamination in this respect from Kinghorn to the South.

Risk of faecal contamination attributable to land cover type is high along the entire coastline adjacent to the fishery. Although there are some small areas of natural grassland and woodland alongside the shoreline, land cover around these small patches is of a higher risk category.

1.2 Human Population

Human population figures were obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Kirkcaldy Bay. Figure 1.3 shows the population density of the census output areas that are adjacent to Kirkcaldy Bay.

The shoreline adjacent to Kirkcaldy Bay is heavily populated. The Kirkcaldy locality, which includes Dysart has a population of 46912 (2001). South of Kirkcaldy is the settlement of Kinghorn with a population of 2835 (2001). Figure 1.3, shows the population density of the census output areas adjacent to Kirkcaldy Bay. Population density for the census output areas is represented by area colour with darker areas containing a greater number of people per hectare.

The area is popular with tourists and day visitors due to its proximity to Edinburgh to the south and St Andrews to the north. The Fife Coast Path runs adjacent to Kirkcaldy Bay. There are two caravan/ campsites in the wider area, indicating a seasonal influx in people. There are two harbours in the vicinity of the fishery, the main one at Kirkcaldy and a smaller one at Dysart. There is a small vessel anchorage area in the centre of the bay.

The Kirkcaldy Bay coastline is densely populated, especially towards the northern end. It is therefore likely that associated faecal pollution from human sources to the shellfish bed will be high. A seasonal increase in pollution from human-related sources is expected during the summer months, as campgrounds and caravan parks reach full capacity and boating activity increases.

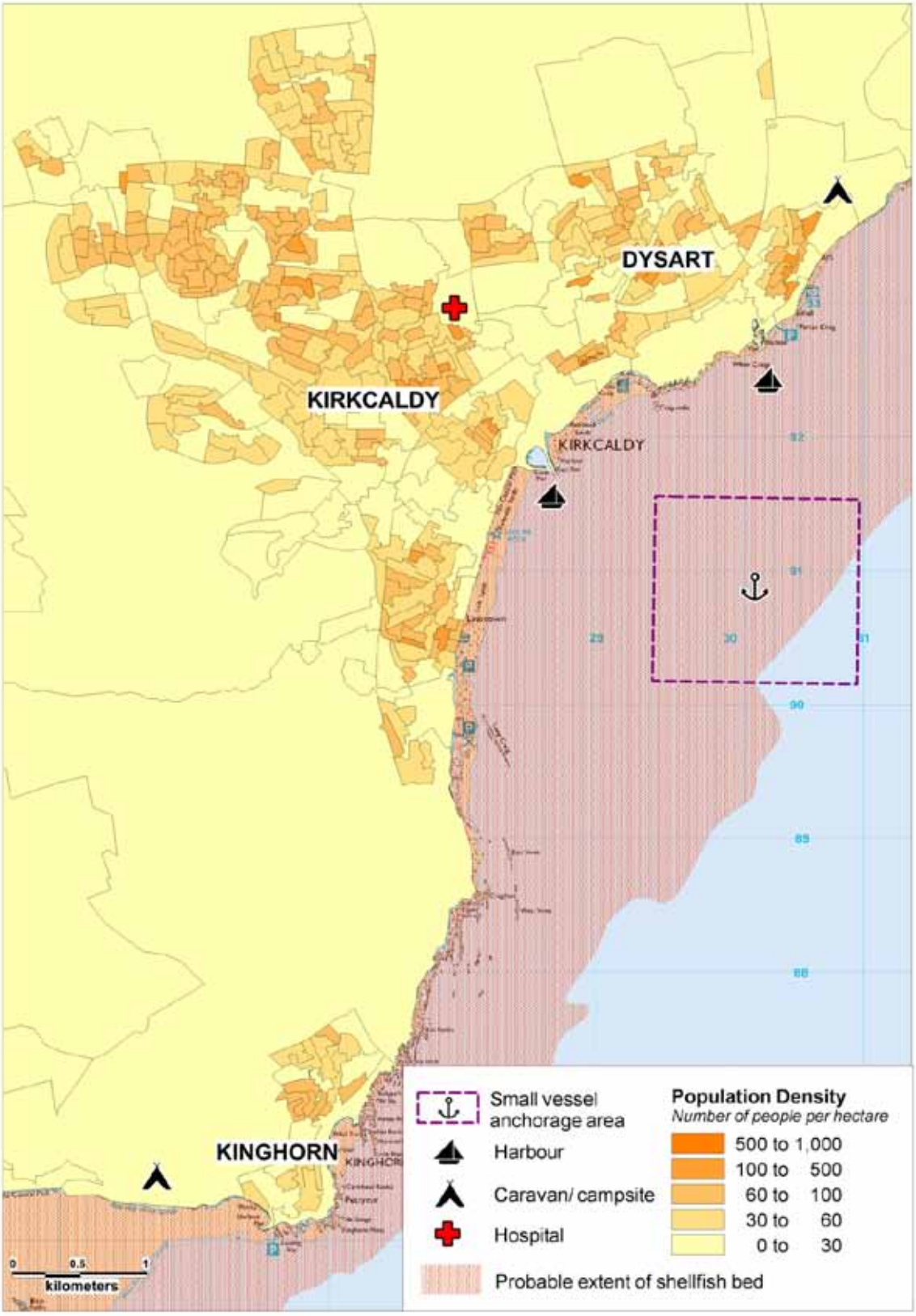

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Figure 1.3 Population density of census output areas surrounding Kirkcaldy Bay

2. Fishery

The fishery at Kirkcaldy Bay Razors (FF 580 105 316) is comprised of a wild razor clam (*Ensis* spp.) bed.

The harvester indicated that the razor clam bed occupies most of the bay, stretching down to Burntisland and beyond to the west, with patches between the reefs all the way north to West Wemyss. The razor clams are gathered by divers and the area is fished by a number of different harvesters all year round, depending on weather conditions. Although razor clams are found within and beyond Kirkcaldy Bay, the harvesters indicated they only dive up to depths of 12 m and there are not likely to be razor clams present past depths of 15 m.

On the application form the harvester identified the intended harvest area as the area bounded by lines drawn between NT 2850 9200 to NT 3000 9200, NT 3000 9200 to NT 3000 8800, NT 3000 8800 to NT 2850 8800 and NT 2850 8800 to NT 2850 9200. This area is shown in Figure 2.1. It should be noted that this area overlaps land at the north-western corner. The razor bed at Kirkcaldy Bay does not lie within designated shellfish growing waters.

There have been numerous fast track applications for sites within close vicinity to Kirkcaldy Bay including:

Wemyss Bay Razors – 11th March 2011
Link Sands Fast Track – 24th February 2011
Kirkcaldy Linktown – 18th August 2010
Forth Estuary: Kinghorn – 30th September 2009
Forth Estuary: Kirkcaldy Sands – 20th September 2009
Forth Estuary: Dysart – 8th July 2009
Forth Estuary: Kirkcaldy Sands – 17th October 2008
Forth Estuary: Dysart – 8th July 2008
Wemyss Razors - 20th December 2007

The previous fast track production areas suggest that the razor bed stretches north of Wemyss and beyond the 15 m depth contour. Figure 2.1 shows the relative positions of the razor clam fishery, the intended harvest area of Kirkcaldy Bay and previous fast track application production areas.

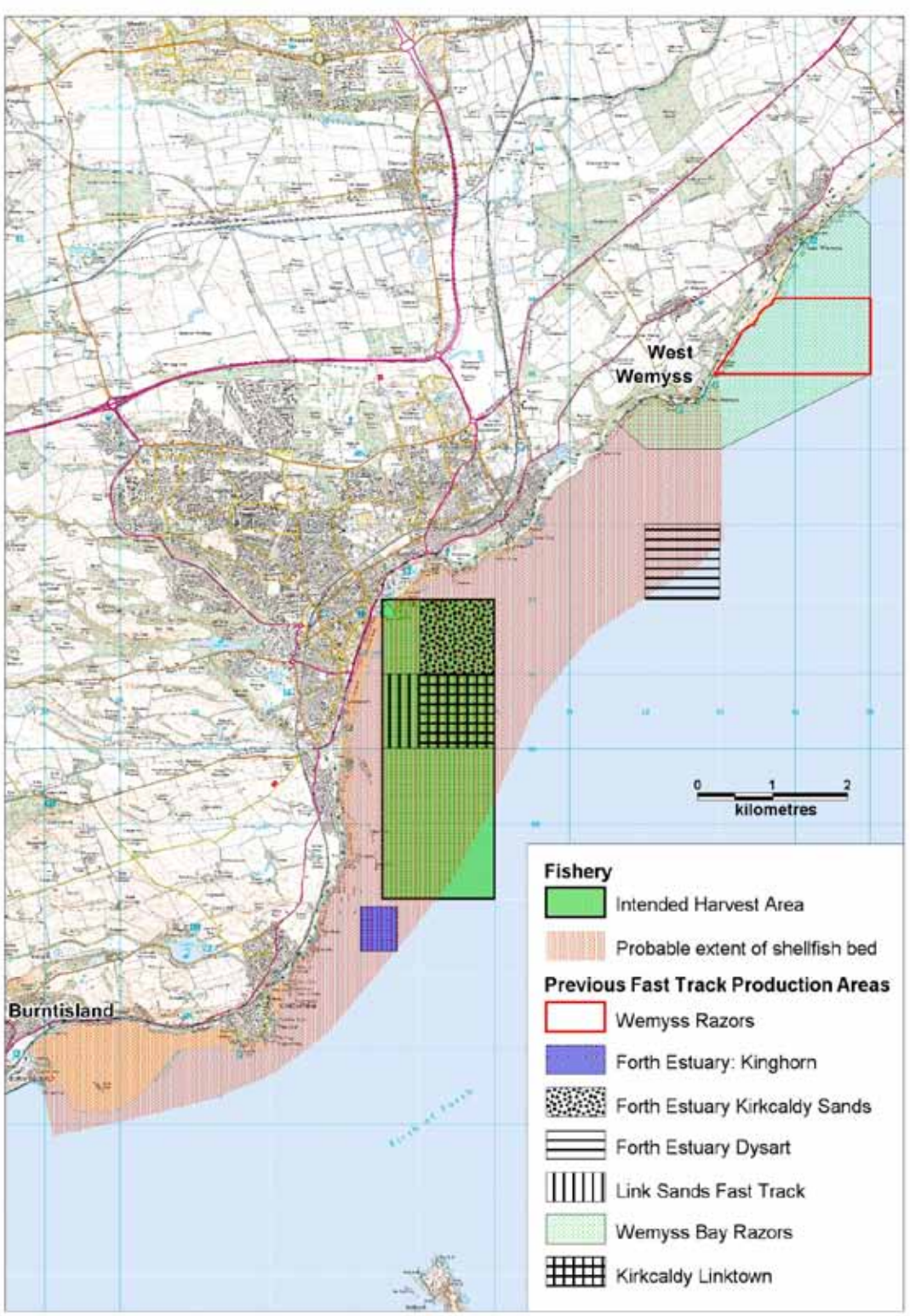

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Figure 2.1 Kirkcaldy Bay fishery and previous fast track areas

3. Sewage Discharges

Information on active sewage discharges to the area within 9 km of Kirkcaldy Bay was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified community sewage discharges as detailed in Table 3.1 and shown mapped in Figure 3.1. A short list of acronyms used in the tables is given at the end of this section.

Table 3.1 Sewage discharges identified by Scottish Water

SEPA Discharge Consent No.	Discharge Name	NGR of Discharge	Type	Level of Treatment	Design PE	Consented Flow DWF m^3 day	Consented Flow Other m^3 day
CAR/L/1001244	Buchanan Court Outfall Kirkcaldy	NT 2815 9065	Intermittent			912	Overflow operates at 63.3 l/s
CAR/L/1003808	Charlotte St Outfall Kirkcaldy	NT 2830 9115	Intermittent			3917	Overflow operates at 272 l/s
	Port Brae CSO	NT 2842 9178	Intermittent			770	Overflow operates at 187 l/s
	Kirkcaldy WWTW EO/CSO*	NT 2873 9177	Intermittent	EO - 20 mm screening CSO – 6mm screening & storm storage			Overflow operates at 1600 l/s
	Kirkcaldy WWTW	NT 2935 9163	Continuous	Secondary	73000	19000	Overflow operates at 450 l/s
	Kirkcaldy WWTW EO*	NT 2865 9221	Intermittent	20 mm screening			
	Boreland and Partanhall Outfall Kirkcaldy	NT 3040 9280	Intermittent			95	Overflow operates at 6.6 l/s
	Fishermens Hut CSO	NT 3061 9298	Intermittent	6 mm screening		1720	
CAR/L/1079398	Dysart Outfall Kirkcaldy	NT 3060 9315	Intermittent			1140	Overflow operates at 79.21 l/s
CAR/L/1001463	West Wemyss CSO/EO/ WWPS	NT 3290 9482	Intermittent	6 mm screening	200	52	CSO Overflow operates at 10 l/s
	West Wemyss ST	NT 3310 9486	Continuous	Septic tank	470	110	

*No information on consented flow volume or PE was provided

No sanitary or microbiological data were provided for these discharges. The total loading from the Kirkcaldy continuous discharge is estimated to be $6.3x10^{13}$ faecal coliforms per day, based on base flow values reported in the literature (Kay et al 2008). Loading contributed by CSO discharges is likely to be significantly higher when they operate as they will not be treated. Similarly, the estimated loading from the West Wemyss septic tank would be

$4.8x10^{12}$, which although smaller in volume receives a lower level of treatment than the Kirkcaldy discharge.

Table 3.2 below lists Information provided by SEPA on consented discharges within the request area. The data has also been mapped in Figure 3.1.

Table 3.2 SEPA discharge consents

No.	Ref No.	NGR of Discharge	Design PE	Consented flow m^3/ day
1	CAR/L/1001244	NT 2813 9060	-	912
2	CAR/L/1003808	NT 2829 9111	-	3917
3	CAR/L/1079398	NT 3062 9309	-	1140
4	CAR/L/1001573	NT 3148 9398	-	-
5	CAR/R/1079398	NT 3133 9419	-	-
6	CAR/R/1067269	NT 3058 9464	-	-
7	CAR/R/1067419	NT 3147 9507	-	-
8	CAR/L/1001463	NT 3290 9480	-	-
9	CAR/R/1067296	NT 3295 9519	-	-
10	CAR/R/1067149	NT 3300 9523	-	-
11	CAR/R/1067509	NT 3293 9527	-	-
12	CAR/R/1067324	NT 3271 9547	-	-

Information concerning the discharge location, design PE and/or consented flow m^3/day was not provided by SEPA for the majority of the consents.

Sewage infrastructure recorded during the shoreline survey is listed in Table 3.3 and mapped in Figure 3.1.

Although Figure 3.1 shows that much of the coast adjacent to the intended harvest area may be subject to some form of septic discharge, assuming that the observed pipes do flow under some conditions, the main community discharges are located within and adjacent to the northern end of the area and also a short way further north. There are no main community discharges south of Buchanan Court Outfall. The main Kirkcaldy treatment works discharges within the intended harvest area. A number of intermittent discharges are also located at and to the north of the harvest area. Therefore, in addition to exposure to the continuous treated discharges, the shellfish will be exposed to untreated sewage following rainfall causing flows to exceed the trigger levels and in the case of any equipment malfunction causing EO operation. The former will occur more frequently but the latter may cause a greater degree of contamination.

Table 3.3 Sewage related observations recorded during the shoreline survey

No.	Date	NGR	Description
1	17/05/2011	NT 2789 8859	Sanitary debris - cotton buds
2	17/05/2011	NT 2796 8899	Outfall pipe, no flow
3	17/05/2011	NT 2794 8910	Brick outfall pipe, with water flow, flow rate 0.279 m/s, depth 5cm
4	17/05/2011	NT 2797 8923	Cast iron pipe cover
5	17/05/2011	NT 2809 8944	Outfall pipe with mussels, minimal flow
6	17/05/2011	NT 2792 8968	Plastic pipes leading on to the shore. No flow
7	17/05/2011	NT 2790 8986	Concrete outfall pipe. Sanitary waste evident
8	17/05/2011	NT 2800 9057	Unknown pipe
9	17/05/2011	NT 2801 9061	Outfall pipe, not flowing. Evidence of previous flow
10	17/05/2011	NT 2803 9068	Outfall pipe, with seabirds at end of the pipe
11	17/05/2011	NT 2821 9133	Outfall pipe, no flow
12	17/05/2011	NT2823 9138	Outfall pipe, no flow
13	17/05/2011	NT 2823 9140	Outfall pipe, no flow
14	17/05/2011	NT 2824 9142	Outfall pipe, no flow
15	17/05/2011	NT 2825 9145	Small outfall pipe, with flow small mussel shells
16	17/05/2011	NT 2827 9150	Small outfall pipe, no flow
17	17/05/2011	NT 2829 9156	Small outfall pipe, no flow
18	17/05/2011	NT 2832 9161	Small outfall pipe, no flow
19	18/05/2011	NT 2840 9178	Outfall pipe with evidence of faecal contamination at upper outfall
20	18/05/2011	NT 2843 9178	Outfall pipes with slight flow
21	18/05/2011	NT 2841 9178	Outfall pipe with slight flow
22	18/05/2011	NT 2849 9182	Four outfalls inside Kirkcaldy Harbour. Strong smell of sewage and evidence of sanitary debris
23	18/05/2011	NT 2874 9181	Presumed Scottish Water outfall and possible line of long sea outfall
24	18/05/2011	NT 3030 9288	Dysart car park Scottish Water pumping station
25	18/05/2011	NT 3050 9306	Scottish Water pumping Station at Eastern end of survey area. (Called Fishermens Hut)
26	18/05/2011	NT 3023 9284	Sewage overflow in Dysart village which drains into Dysart harbour. Scottish Water informed of the leak by Fife Council

List of acronyms

CSO	Combined Sewer Overflow
DWF	Dry Weather Flow
EO	Emergency Overflow
PE	Population Equivalent
ST	Septic Tank
STE	Sewage Treated Effluent
WWPS	Wastewater Pumping Station
WWTW	Wastewater Treatment Works

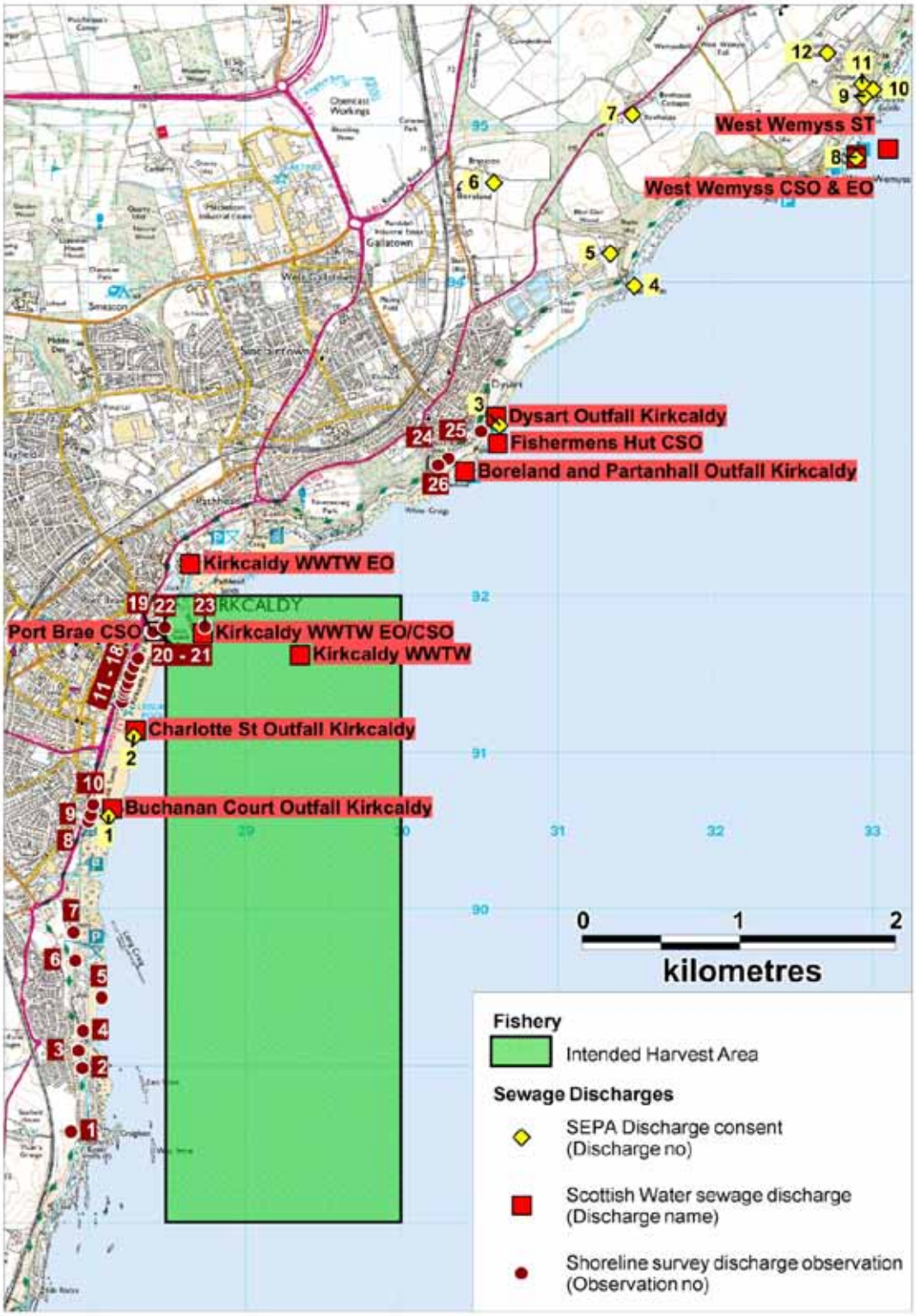

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Figure 3.1 Kirkcaldy Bay sewage discharges

4. Animals

4.1 Livestock

Agricultural census data to parish level was requested from the Rural Environment, Research and Analysis Directorate (RERAD) for the parishes of Kirkcaldy & Dysart and Kinghorn (see Figure 4.1). Reported livestock populations for the parishes for 2009 - 2010 are listed in Table 4.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 4.1 Livestock numbers in Kirkcaldy & Dysart and Kinghorn: 2009 - 2010

Parish:	Kirkcaldy & Dysart		Kinghorn	
Total area (km^2):	38.92		21.15	
Year:	2009 - 2010		2009 - 2010	
	Holdings	*Numbers*	*Holdings*	*Numbers*
Cattle	5	678	5	415
Sheep	*	*	*	*
Horses and ponies	6	18	7	27
Other	0	0	0	0

* Data withheld for reasons of confidentiality

Both agricultural parishes extend 7 km inland at the greatest extent. Very little data on livestock numbers were available, as information was withheld due to the small number of farms reporting data in each parish. From the data provided, cattle appeared to be the predominant animals in terms of total number. However, no information on sheep was provided and each holding is likely to have larger numbers of sheep than cattle. Horses and ponies are also present in small numbers in each parish. The numbers above are likely to be an understatement of livestock populations as a whole, as these figures do not account for animals that may be kept on small holdings or crofts which do not report farm census data.

Livestock numbers on the surrounding land as a whole are likely to be at their highest during the summer months when young animals are present. Although it was not investigated for this specific area, it is common during the winter months for livestock to be kept in barns causing a likely increase in slurry production and higher runoff from hard standing areas. Slurry is often applied to fields in the spring and summer months. Seasonal variation in the presence of livestock is therefore expected to lead to higher rates of deposition on the land at these times.

No livestock was observed in the area surveyed during the 17th – 18th May or on the 27th June 2011. Figure 4.1 shows the agricultural parishes surrounding Kirkcaldy Bay.

As the area adjacent to the shore is predominantly urban and suburban, farms are more likely to be located inland. Therefore, any faecal contamination from farm animal sources entering the bay is likely to be transported from inland via the burns covered in Section 6.

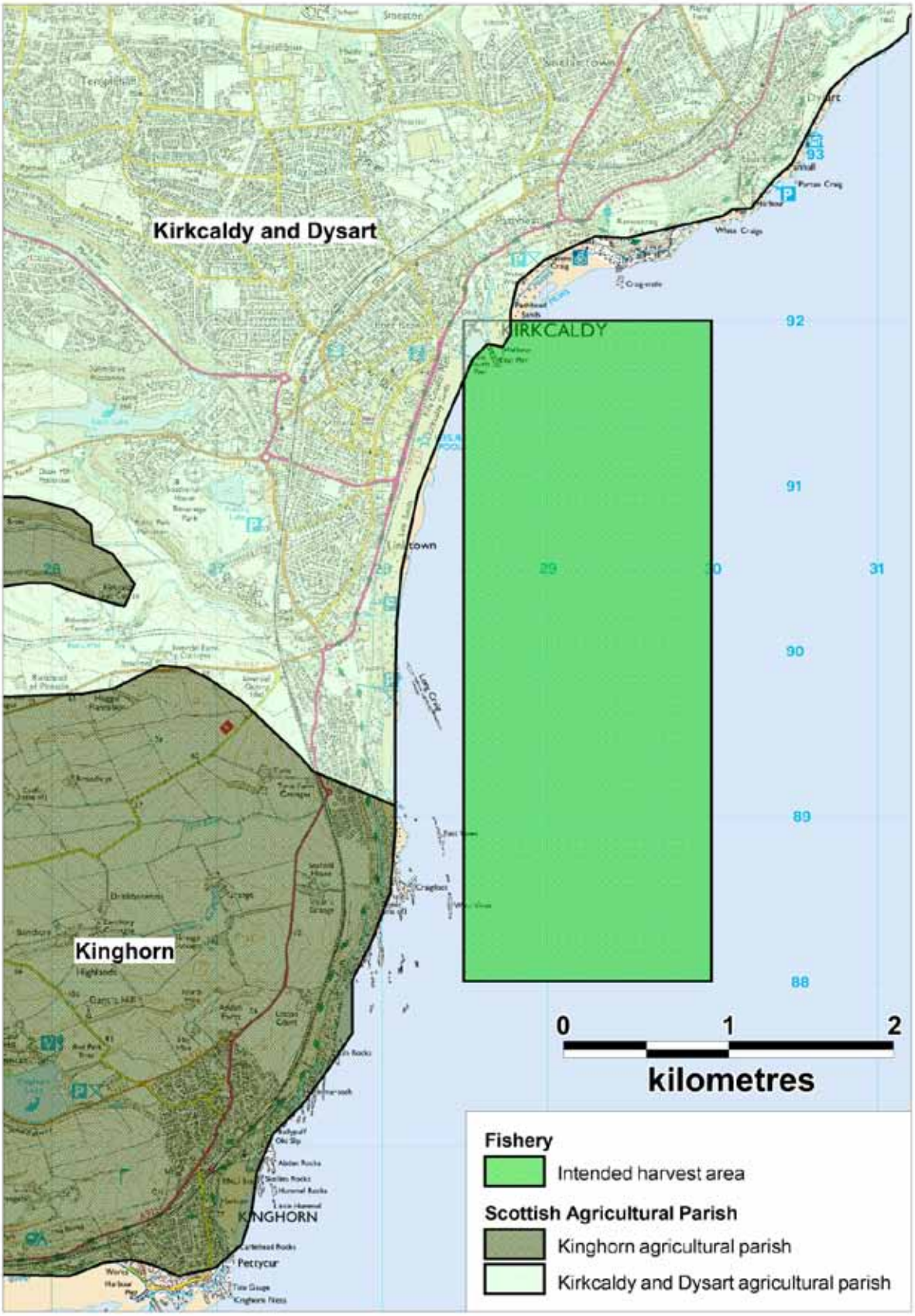

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Figure 4.1 Kirkcaldy & Dysart and Kinghorn agricultural parishes

4.2 Wildlife

During the shoreline survey walk on the 17th and 18th May, an unspecified number of sea birds were observed at the end of an outfall pipe on the beach and approximately 75 sea birds were observed on the rocks towards the southern end of Kirkcaldy Bay.

Seabird 2000 data provided for Kirkcaldy Bay, based on observations taken in 1999 and 2002, indicated populations of breeding sea birds on the island of Inchkeith, 4 km south off the fishery, where there are substantial numbers of gulls (approx. 7,000) and smaller populations of guillemots (approx. 48), kittiwakes (approx. 349), cormorants (approx. 85), shags (approx. 21), northern fulmars (approx. 381), puffins (approx. 1,641) and razorbills (approx. 57). The Forth Seabird Group also undertakes an annual seabird count at Inchkeith. A recent survey conducted in 2009 indicated that fulmar population has decreased to approx. 247, the shags have increased to approx. 162 and the puffins have decreased to approx. 1157. The remaining populations are similar to the Seabird 2000 data. The actual total counts and distribution of the Seabird 2000 data in the close vicinity of the bay has been mapped in Figure 4.2.

Inchkeith and the surrounding area has established Atlantic Grey Seal colonies. A seal pup survey was conducted by The Forth Seabird Group in 2008 and recorded a total of 54 seals (cows, bulls and pups) at Kinghorn Harbour and 43 seals (cows, bulls and pups in Kirkcaldy Harbour. The common porpoise is reported to be widespread in the Firth of Forth (Fife Coast and Countryside Trust, 2006). Bottlenose dolphins are also common and seen all year round, especially between June to October. Approximately 40-60 bottlenose dolphins have summered off the coast of Fife every year since 1992.

Faecal contamination from sea birds may therefore be significant and are likely to be greatest in the period from Spring to Autumn. Seals are likely to contribute to background levels of contamination in the area, though their numbers are relative to the volume of water in the bay and therefore their impact is expected to be limited. In both cases, there is no evidence that the effects will differ spatially across the fishery.

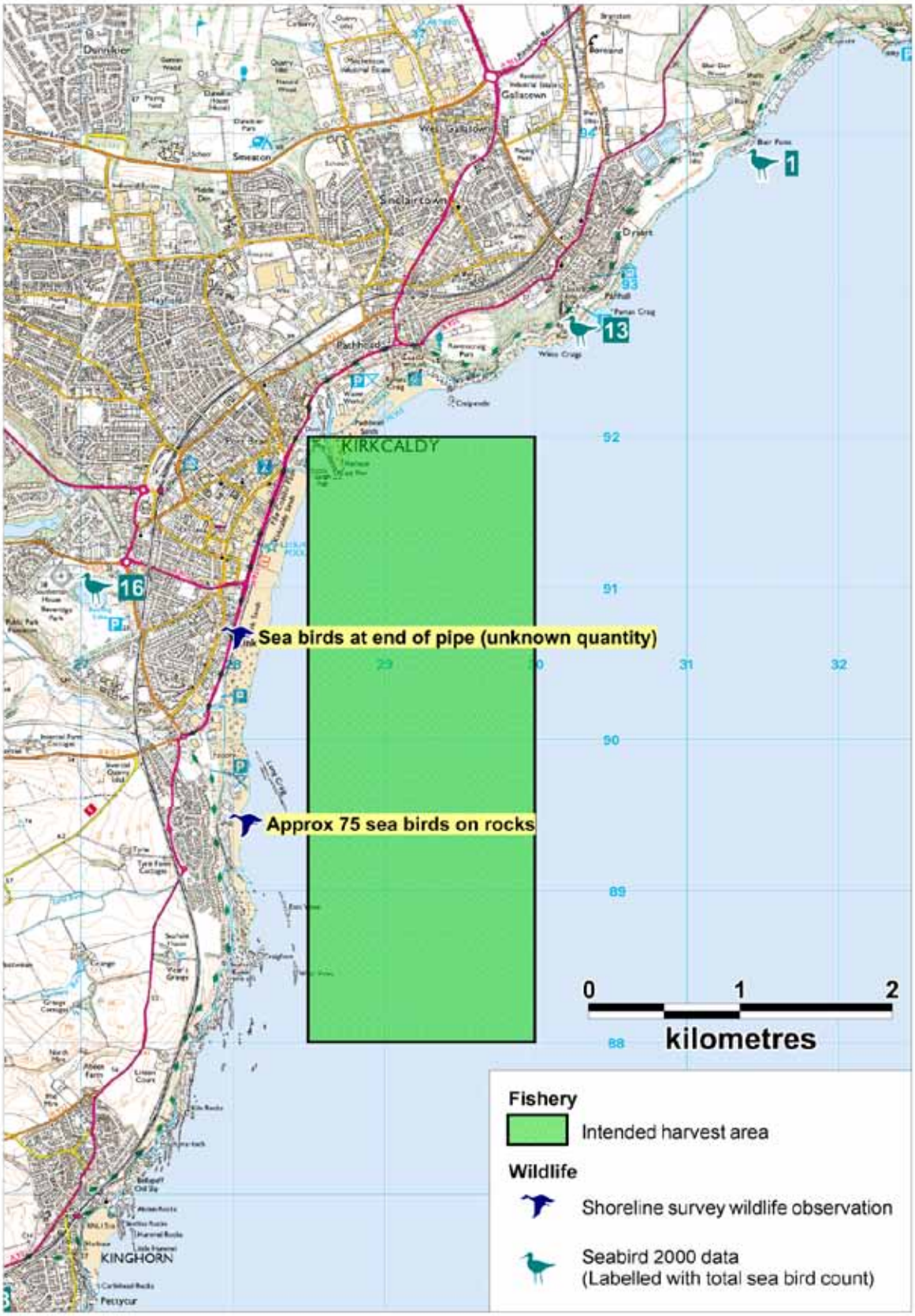

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Figure 4.2 Wildlife observations at Kirkcaldy Bay and Seabird2000 data

5. Rainfall

Rainfall data for Leven Silverburn, located 13 km northeast of Kirkcaldy Bay was available for 2004-2010 inclusive apart from the months of December 2005, April 2006 and August 2009. Daily rainfall values for this station were purchased from the UK Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. Rainfall data for a closer station, Kirkcaldy: Carberry was incomplete and not suitable for the present analyses.

5.1 Rainfall at Leven Silverburn

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The influence of rainfall on microbiological quality will depend on factors such as local geology, topography, land use and sewerage infrastructure. Figures 5.1 and 5.2 present box and whisker plots summarising the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median marked as a line within the box. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol '*'.

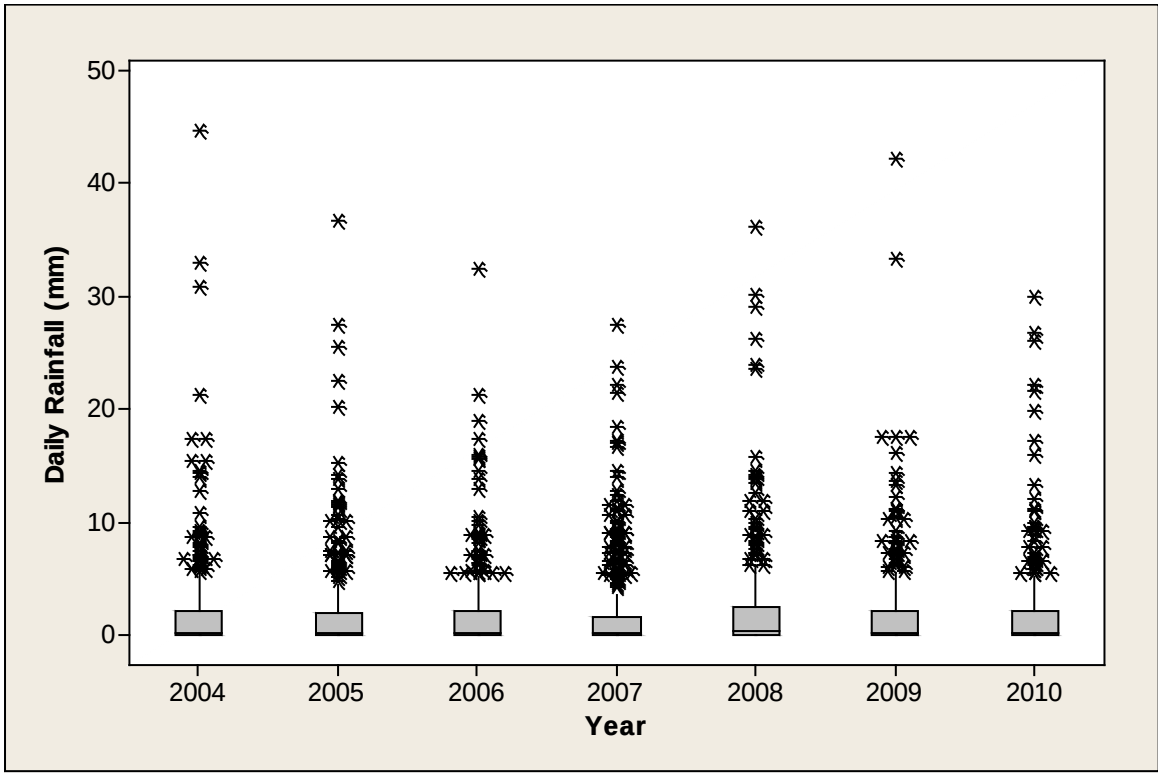

Figure 5.1 Box plot of daily rainfall values by year at Leven Silverburn, 2004-2010

Figure 5.1 shows that rainfall patterns were similar between the years presented here, with 2007 the driest and 2008 the wettest. Daily rainfall was generally very low over the period.

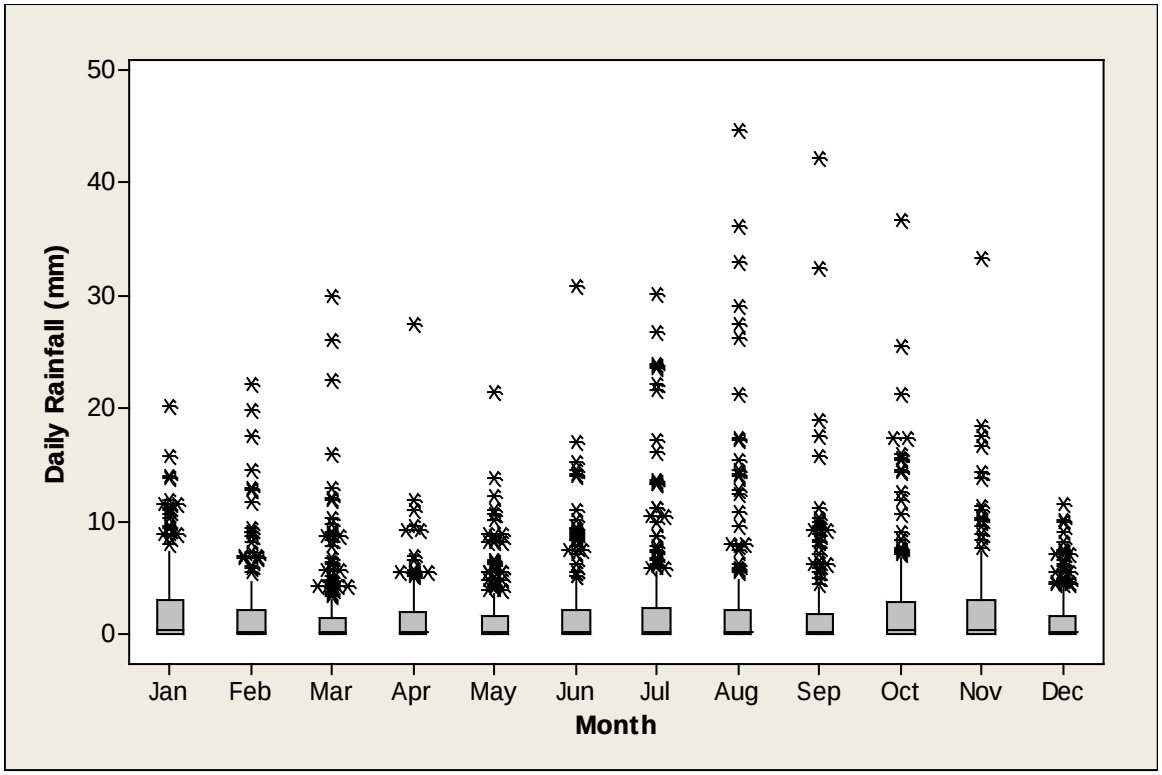

Figure 5.2 Box plot of daily rainfall values by month at Leven Silverburn, 2004-2010

Weather was generally wetter in October, November and January. The more extreme events (>30 mm in a day) tended to occur from June to November (one occurred in March). For the period considered here (2003-2010), 65% of days experienced rainfall less than 1 mm, and 4% of days experienced rainfall of 10 mm or more.

In general, it is expected that levels of runoff associated with rainfall will be higher during the late autumn/early winter when daily rainfall levels are at their peak. However, increases in contamination carried into the bay via rainfall runoff may be higher after extreme rainfall events during the summer months when there is likely to be a greater 'first-flush' effect after periods of dry weather.

6. River Flow

There are no gauging stations on burns or streams along the Kirkcaldy Bay coastline. Kirkcaldy Bay is adjacent to a large urban area to the north and far south with moderate to steep terrain in between.

Freshwater inputs to the bay are limited to a small number of burns which drain developed urban areas. There are no major rivers in the area. Due to the size of Kirkcaldy there may be sources of industrial pollution. The watercourses listed in Table 6.1 were recorded, and sampled and measured where possible, during the shoreline survey. The locations are shown on the map presented in Figure 6.1. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

The shoreline walk was undertaken in windy and wet weather conditions.

Table 6.1 Watercourse loadings and *E. coli* results for Kirkcaldy Bay

No	Sample number	Grid Ref	Description	Width (m)*	Depth (m)	Flow (m/s)	Flow in m^3/day	*E. coli* (cfu/ 100ml)	Loading (*E. coli* per day)
1	Water 4	NT 27869 90198	Tiel Burn	4.2	0.22	0.506	40396	2000	8.1×10^{11}
2	Water 13	NT 28644 91887	East Burn	4.4	0.15	0.048	2737	3000	8.2×10^{10}

* The width of both burns was not recorded during the shoreline survey, so width were determined from satellite images.

During the shoreline survey, two fresh water inputs were recorded discharging into Kirkcaldy Bay (see Figure 6.1). Fresh water samples were collected at both streams. Both burns discharge directly into the bay and East Burn discharges into the north west corner of the intended harvest area. Tiel Burn had an *E. coli* loading per day of 8.1×10^{11} and East Burn had an *E. coli* loading per day of 8.2×10^{10}.

The loadings were derived from measurements made during wet weather and loadings during dry weather would be expected to be significantly less. Given the large urban areas and moderately steep sided nature of the land surrounding the bay, there is also the potential for direct run-off after rainfall.

Although both burns run through urban areas at their seaward ends, their catchments extend inland for several kilometres through a mixture of arable and wooded areas. The watercourses would therefore be potential pathways for contamination from animal faeces to enter the beach. Tiel Burn would be expected to have the greatest potential effect on the microbiological quality of the razors.

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Figure 6.1 Stream loadings and *E. coli* results at Kirkcaldy Bay

7. Historical *E. coli* Monitoring Data

Monitoring results were available from fast track classification sampling undertaken between March 2009 and May 2011 for three different production areas within Kirkcaldy Bay. All data extracted from the database were validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

One sample had no valid result and was excluded from analysis. One sample had the result reported as <20, and was assigned a nominal value of 10 for statistical assessment and graphical presentation. Two samples had a reported sampling location that fell 43 km north of the production area and were excluded from analysis. Seven samples were erroneously reported with NGRs beginning in NO, which placed them 100 km north of the fishery. These were corrected to NT. Of the corrected samples, two were reported has having come from a location west of the fishery and approximately 150 m above MLWS. These have been included in the table and map following, however their location should be regarded with caution.

All *E. coli* results are reported in most probable number per 100g of shellfish flesh and intravalvular fluid.

As there were relatively few samples from each fast track area, and samples from all three areas were reported from within or near the proposed fishery area, they have been considered together and a summary of sampling and results for all areas is presented in Table 7.1.

Table 7.1 Shellfish sample *E. coli* results for Kirkcaldy

Sampling Summary	
Production area	Forth Estuary: Kirkcaldy, Kirkcaldy Linktown, and Link Sands
Site	Various
Species	Razor clams
SIN	FF 450, FF 509, FF 556
Location	Various
Total no of samples	14
No. 2009	5
No. 2010	5
No. 2011	4
Results Summary	
Minimum	<20
Maximum	9200
Median	30
Geometric mean	353.5
90 percentile	7100
95 percentile	9200
No. exceeding 230/100g	7 (50%)
No. exceeding 1000/100g	3 (21%)
No. exceeding 4600/100g	2 (14%)
No. exceeding 18000/100g	0 (0%)

The results indicate that the razor clams are relatively highly contaminated on occasions. In many areas razor clams tend to yield low *E. coli* results and the data for Kirkcaldy implies significant sources of contamination in the locality. Sample results are shown mapped in Figure 7.1 below. Although high results are often expected nearer shore, at Kirkcaldy the highest results were recorded toward the middle part of the proposed area, in both presumed nearshore and in off shore samples.

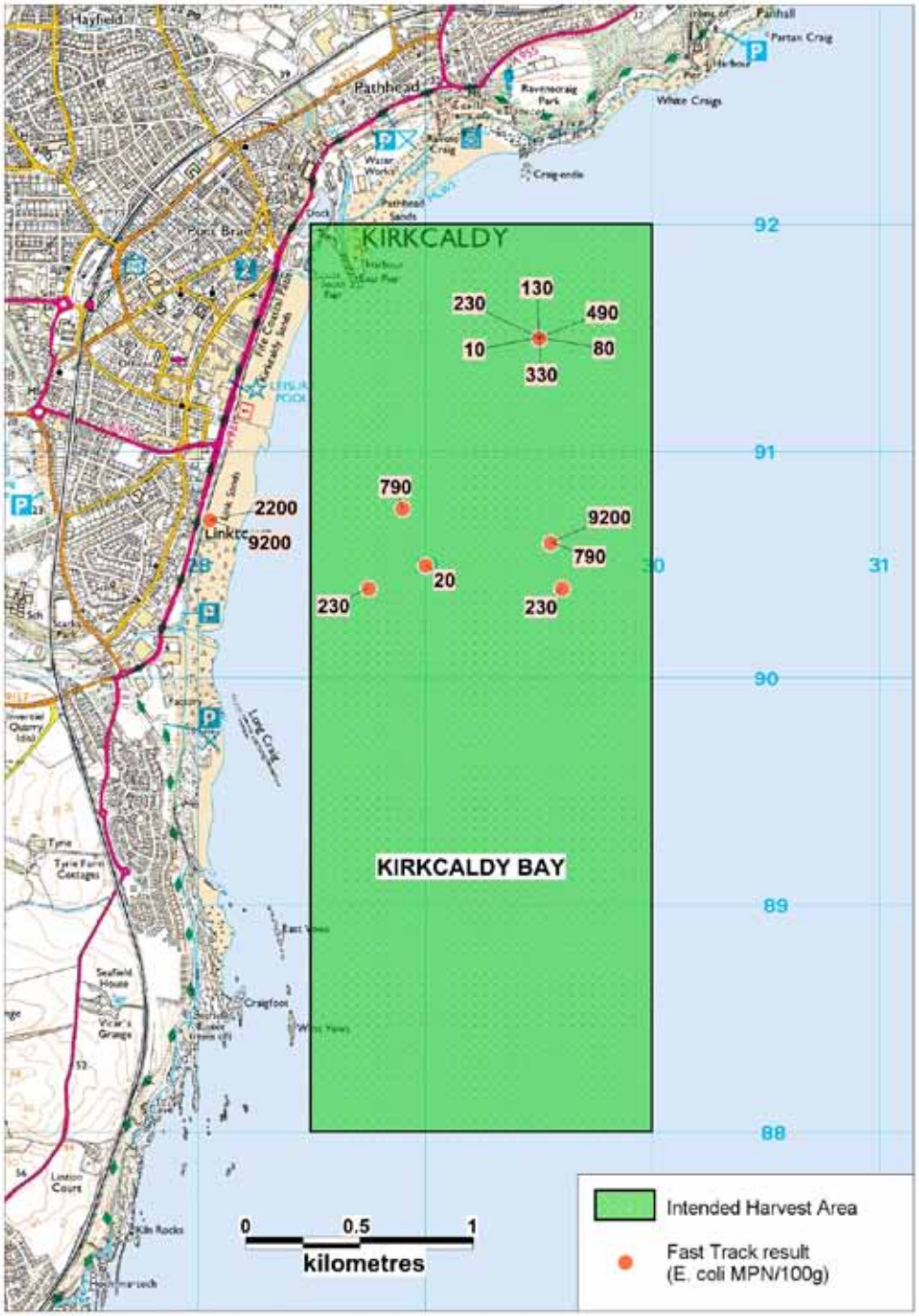

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Figure 7.1 Fast track *E. coli* results at Kirkcaldy

Table 7.2 Monitoring data for Kirkcaldy Bay, by year

	2009	2010	2011
Jan	-	-	-
Feb	-	**490**	**230**
Mar	**80**	**20**	**790**
Apr	-	-	**2200**
May	-	**9200**	**9200**
Jun	-	**790, 230**	-
Jul	**330**	-	-
Aug	**230, 130**	-	-
Sep	**10**	-	-
Oct	-	-	-
Nov	-	-	-
Dec	-	-	-
SIN:	**FF 450**	**FF 509**	**FF 556**

No results were obtained during October to January. Peak results occurred during April and May; however there are insufficient data on which to draw any conclusions regarding seasonality. As there is little continuity in sampling over the year, it is not possible to draw any conclusions regarding changes in contamination levels over time in this area.

Monitoring results from sampling undertaken under the fast track classifications indicates significant levels of contamination at the fishery and that highest contamination levels were found well inside the area boundaries identified.

8. Bathymetry and Hydrodynamics

The Hydrographic Chart for the area is shown in Figure 8.1.

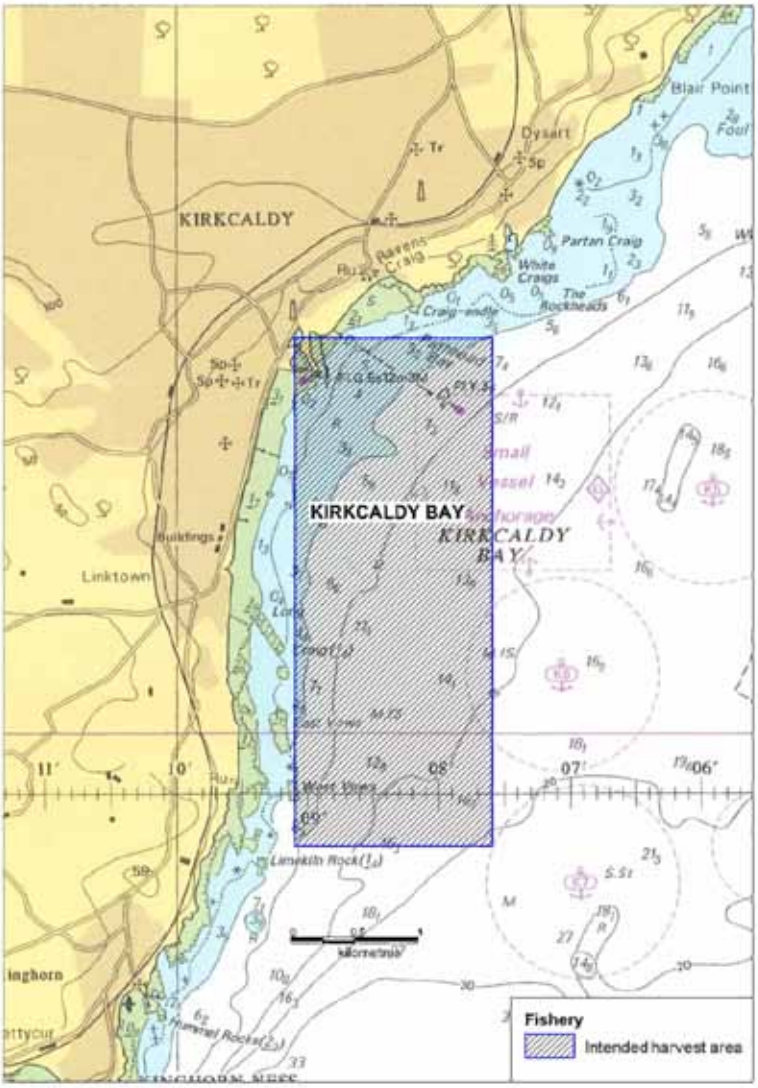

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Figure 8.1 Bathymetry at Kirkcaldy Bay

Kirkcaldy Bay is located on the north side of the Firth of Forth. It lies in approximately a north to south direction and the distance from one end to the other is approximately 8 km. It is open to the Firth of Forth in the east. A drying area 100 to 200 m wide extends along most of the bay with rocky outcrops at points. Below MLWS, the bay shelves relatively gently to the 10 m mark approximately one km from shore (the actual distance varies along the bay). The area covered by the fast track production area (shown in Figure 8.1) extends out to depths approaching 20 m. The chart identifies a small vessel anchorage that occupies part of the outer bay towards its northern end.

8.1 Tidal Curve and Description

The two tidal curves below are for Kirkcaldy, located on the western side of Kirkcaldy Bay. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 17/05/11 and the second is for seven days beginning 00.00 BST on 24/05/11. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle, including the dates of the shoreline survey.

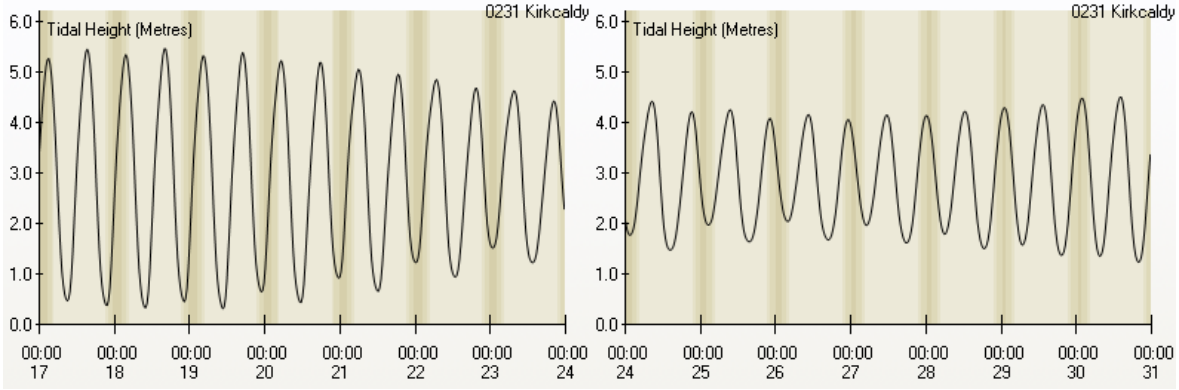

Figure 8.2 Tidal curves for Kirkcaldy

The following is the summary description for Kirkcaldy from TotalTide:

0231 Kirkcaldy is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal.

HAT	5.9 m
MHWS	5.3 m
MHWN	4.1 m
MSL	2.88 m
MLWN	1.8 m
MLWS	0.6 m
LAT	-0.3 m

Predicted heights are in metres above Chart Datum. The tidal range at spring tide is 4.7 m, and at neap tide 2.3 m, and so the area is macrotidal (mean spring range greater than 4 m).

8.2 Currents

Tidal stream information was available for several stations in the Firth of Forth. The location of the stations in the part containing Kirkcaldy Bay, together with the tidal streams for peak flood and ebb tide, are presented in Figures 8.3 and 8.4. One of the stations, SN023H, is located on the outer edge of Kirkcaldy Bay, and is depicted in figure 8.1 by the diamond labelled G situated on the eastern side of the small vessel anchorage.

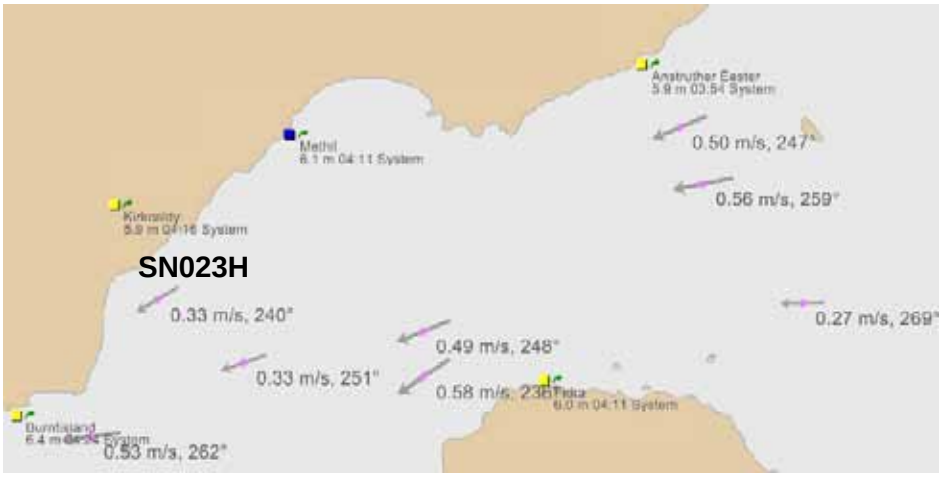

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Figure 8.3 Spring flood tide in the Firth of Forth

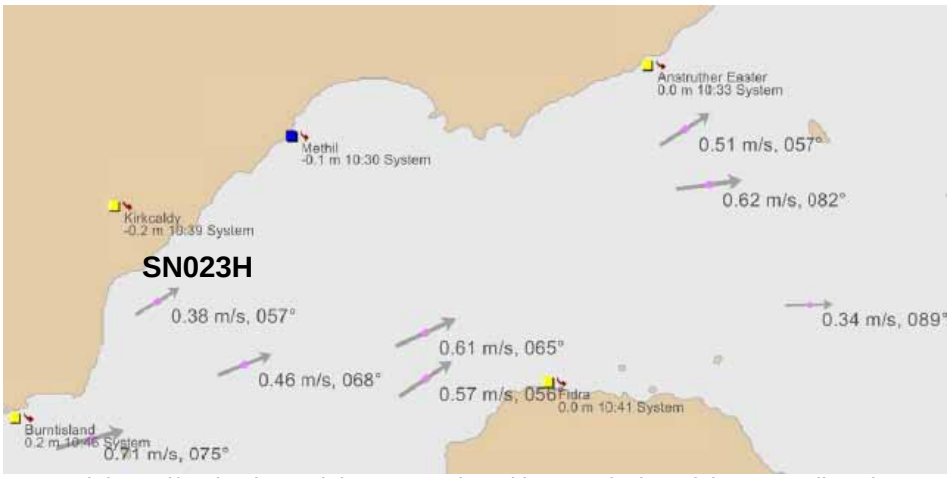

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Figure 8.4 Spring ebb tide in the Firth of Forth

Table 8.1 Tidal streams for station SN023H (56°06.30'N 3°06.79'W) (taken from TotalTide)

Time	Direction	Spring rate (m/s)	Neap rate (m/s)
-06h		0.00	0.00
-05h	237°	0.15	0.05
-04h	236°	0.31	0.15
-03h	236°	0.36	0.21
-02h	241°	0.26	0.15
-01h	243°	0.21	0.10
HW	250°	0.10	0.05
+01h	055°	0.15	0.10
+02h	061°	0.26	0.15
+03h	061°	0.31	0.15
+04h	056°	0.31	0.15
+05h	057°	0.26	0.10
+06h	080°	0.05	0.05

It should be noted that the maximum current speeds shown in Figures 8.3 and 8.4 are slightly higher than those given in Table 8.1, although all of the data were derived from TotalTide.

The general tendency is therefore for the currents to travel directly up the firth during flood tide and directly down the firth during ebb tide. This situation will relate to the outer part of the razor fishery. However, nearer to shore the currents will tend to follow the sweep of the bay. The current patterns will be more complex around the headlands and associated rocky outcrops at each end of the bay. At a maximum current speed of approximately 0.4 m/s, contaminants would be expected to travel a maximum of nearly 6 km over a flood or ebb tide, ignoring any effects of dilution or dispersion.

Dyke (1987) reviewed available information on currents in the Firth of Forth. He identified a number of key points:

- The lack of freshwater input means that the firth acts more like an inlet or embayment than an estuary
- Currents are small and difficult to measure; measured tidal velocities are in the order of 0.5 m/s
- The prevailing wind direction is along the axis of the firth and, due to the weak currents, wind-driven flows may be significant
- The occurrence of a halocline, and thus potentially density driven flows, occurs intermittently, usually in February or March, and the location varies.
- Residual current speeds range from 0.016 to 0.089 m/s, due largely to wind effects, but also influenced by density effects.
- There may be a residual flow along the northern coast near Pittenweem that is of the order of 0.02 m/s to seaward and may operate when the water is stratified.
- In general, the circulation in the firth is for the flooding tide to travel mainly up the northern side of the main channel and for the ebbing tide to travel along the southern coast of the firth.
- Further extensive surveys were needed to confirm the available data.

The conclusion with regard to circulation within the firth would imply that sources of pollution north of the fishery are likely to have a greater impact along the length of the bay than sources south of the fishery. However, the information from TotalTide, and that from other sources quoted below, does not support a significant differential effect in the vicinity of Kirkcaldy Bay.

SEPA and Scottish Water were approached for information on any modelling that might have been undertaken in support of sewage improvement schemes but none was available. Hydrodynamic modelling had been undertaken to support the Environmental Statement for the Forth Replacement Crossing (Jacobs ARUP, 2009). Much of the data used in the model came from UKHO TotalTide. The eastern boundary of the modelled area lay immediately to the east of Largo Bay (running south from Elie and thus a significant distance east of Kirkcaldy Bay) while the western boundary lay near the Kincardine Bridge. However, the main outputs naturally concentrated on the proposed area of the crossing in the vicinity of Queensferry and no detailed information was provided in the Environmental

Statement regarding predicted current speeds in the vicinity of Largo Bay. Predicted current speeds at several tidal diamond locations were similar to the TotalTide predictions. Modelled spring tide flows to the east of the crossing ranged from less than 0.25 m/s near the shores to 1 m/s at the centre of the channel with the peak neap speeds being significantly less than these. The current direction was essentially bidirectional, with the flows following the shoreline within bays. Salinity monitoring undertaken in support of the modelling showed values of 34.4 to 34.8 practical salinity units (PSU) to the south-west of Kirkcaldy Bay and 34.9 to 35.0 psu to the north-east.

8.3 Conclusions

Depths within Kirkcaldy Bay are restricted (principally <10 m) compared to the adjacent firth although they reach approximately 17 m at the outer edges of the bay, including parts of the identified intended harvesting area. Dilution of contaminants arising within the bay or from the adjacent coastline will be limited on the western side of the harvesting area but more significant on the eastern side. Current speeds are relatively low with a maximum less than 0.4 m/s (<1 knot) at springs. However, at this speed, contaminants could be taken a distance of approximately 6 km over the course of a flood or ebb tide, ignoring any dilution or dispersion. Current direction will tend to follow the shoreline, including around the bay. There may be eddies on the flood tide in the vicinity of the northern and southern limits of the bay that will complicate the general current flow but, in general, it is expected that contamination will be taken parallel to the shore. Strong winds along the axis of the firth may increase the ebb currents and the resulting residual current will tend to carry contaminants seawards over the course of consecutive tides. The effect of south-westerly winds will be to increase the transport of contaminants on the ebb tide, and reduce it on the flood tide. Salinity in the area will be largely that of full-strength seawater and density driven flows will not be expected as far down the firth as Kirkcaldy Bay.

9. Shoreline Survey Overview

A restricted shoreline survey of the Kirkcaldy Bay shoreline was undertaken by staff from Fife Council on the 17th and 18th May 28th 2011 under windy and wet weather conditions. The boat work was undertaken by the harvester and staff from Fife Council on the 27th June 2011 under calm conditions with persistent showers. Detailed observations can be found in Appendix 4. A summary of the most significant findings can be found below.

The razor clam bed occupies the majority of Kirkcaldy Bay.

There are two large settlements; Kirkcaldy and Dysart in the vicinity of the fishery. The town of Kirkcaldy is heavily populated and urbanised. There is a sewage works and associated outfall at eastern side of the Kirkcaldy harbour. There is a sewage pumping station(s) at the eastern end of Dysart. A large number of outfall pipes were observed along the seafront of Kirkcaldy, approximately half of which were not flowing at the time of survey.

There are a harbour and small boat marina at Kirkcaldy. The harbour entrance was being dredged at the time of the survey. There is an anchorage for cargo vessels approximately one kilometre offshore. The anchorage regularly holds approximately 6 sea going cargo vessels at any one time. There is a small harbour at Dysart which has between 20 and 40 small leisure yachts. There are also several creel boats in the area.

There was no livestock or evidence of livestock observed in the area surrounding Kirkcaldy Bay at the time of the shoreline survey.

Seabirds were seen in groups at 2 locations

Water samples were taken from significant and accessible watercourses, flowing outfall pipes and of sea water around the area. The fresh water samples taken from the burns contained 2000 and 3000 *E. coli* cfu/100 ml. Water samples taken from outfall pipes contained either <1000 or 1000 *E. coli* cfu/100 ml in all cases. Sea water samples contained varying levels of *E. coli*. Sea water samples taken offshore at the location of the razor samples contained 0 *E. coli* cfu/100 ml in all cases. A total of four sea water samples were collected. Four sea water samples taken at various locations along the bay contained between 21 – 38 *E. coli* (cfu/100 ml). A sea water sample taken north of Kirkcaldy harbour had a higher result and contained 300 *E. coli* cfu/100 ml and a sea water sample taken south of Kirkcaldy harbour contained the highest result of 3600 *E. coli* cfu/100 ml.

Three razor samples were collected from the bay. The sample from the northern end of the bay contained <20 *E. coli* MPN/100 g, the sample from the middle of the bay contained 170 *E. coli* MPN/100 g and the sample from the southern end of the bay contained 330 *E. coli* MPN/100 g.

A map is provided in Figure 9.1 that shows the relative locations of the most significant findings of the shoreline survey.

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Figure 9.1 Summary of shoreline observations

10. Overall Assessment

Fishery

Although an intended harvest area has been identified within Kirkcaldy Bay, it has been identified that the razor bed stretches between West Wemyss in the north to Burntisland in the south (and beyond), and will occupy the area from mean low water springs to approximately 15 m depth. Density of razors will vary across this area.

Human sewage inputs

Human sewage inputs represent the main source of faecal contamination of the razor bed and the northern end of the intended harvest area is potentially exposed to the highest concentration of discharges. The Kirkcaldy continuous and intermittent discharges are actually located within the intended harvest area. More extreme rainfall events have previously occurred from June to November and therefore this period may be subject to a greater number of CSO spill events. Discharges in the vicinity of Burntisland, not considered specifically in this report, will impact on the microbiological quality of the razor bed to the south of the intended harvest area.

Agricultural inputs

Faecal contamination from farm animals is likely to be minor in comparison to that from human sources and with respect to the identified harvest area is likely to enter the sea via the two measured watercourses. Other farm animal inputs from nearer the coast may occur outside the larger Kirkcaldy conurbation, and thus may affect other parts of the razor bed.

Wildlife inputs

The two measured watercourses may also carry faecal contamination from wildlife sources inland of Kirkcaldy. Direct deposition of faecal matter by sea birds will contribute to faecal contamination of the seawater in the intended harvest area but is likely to be relatively minor in comparison to the human faecal inputs. Despite the two concentrations of sea birds seen during the shoreline survey, there is no evidence to suggest that the inputs from this source will have a consistent spatial effect over time. Contamination is likely to be higher during the spring to autumn period when bird numbers will be greatest. Some contributions may occur from sea mammals but this is likely to be sporadic and could affect most parts of the outer fishery.

Rivers and streams

Calculated *E. coli* loadings from the two burns measured during the shoreline survey were moderate to high. The measurements and sampling were undertaken during wet weather and loadings may be significantly lower during dry weather. The burn with the highest calculated loading would impact on the water quality on the western side of the middle of the intended harvest area. Contamination from

the other stream would contribute to the contamination of the northern end of the area.

Analysis of results

The results of the limited number of razor samples previously taken in the area show that the shellfish bed is intermittently contaminated to relatively high levels, with a maximum result of 9,200 *E. coli* MPN/100 g. Problems with the recording of the location of sampling meant that the results could not be considered spatially.

Movement of contaminants

Currents will tend to follow the shore within the bay although there may be more complicated currents at the headlands and rocky outcrops. Contamination may be carried a significant distance (approximately 4 km) at spring tides. Dilution of contaminants will be greater towards the eastern side of the fishery and will be greatest at high spring tide. Conversely, dilution will be least towards the western side of the fishery at low spring tides.

Overall conclusions

The most significant sources of faecal contamination are the sewage discharges that are located towards, and beyond, the northern end of the intended harvest area. Contamination from these is likely to be greatest in the north-western part of the intended harvest area, with least dilution occurring at low tide springs. Much of this contamination will be taken away from most of the harvest area during the ebb tide but will then impact on other parts of the razor bed to the north-east. The middle and southerly parts of the harvest area will be impacted by contamination from the sewage discharges during the flood tide although dilution will be greater. In general, contamination from the sewerage systems will be greater following heavy rainfall. Contamination from the two burns will add to that from the sewage discharges.

Discharges to the north-east of the identified harvest area will impact on the north-east side of that area during the flood tide.

11. Recommendations

Production area

The recommended production area is the area bounded by lines drawn from NT 2850 9100 to NT 3000 9100, NT 3000 9100 to NT 3000 8800, NT 3000 8800 to NT 2850 8800 and NT 2850 8800 to NT 2850 9100.

This excludes the part of the intended harvest area that overlaps the land and also the part that is in the immediate vicinity of the main continuous and intermittent Kirkcaldy sewage discharges. Given the likely effects of both current, tide and rainfall, it is unlikely that a sampling programme will adequately reflect the microbiological risk in the close vicinity of those discharges.

Representative Monitoring Zone (RMZ)

The recommended RMZ is an area bounded by lines drawn from NT 2850 9100 to NT 2967 9100, NT 2967 9100 to NT 2967 9053, NT 2967 9053 to NT 2850 9053, and NT 2850 9053 to NT 2850 9100. Samples should be taken from within this zone.

The use of the RMZ will allow for sampling over a significant area and for variations in density of stock, while targeting the part of the production area likely to be most impacted by the identified sources of contamination.

Tolerance

Given that an RMZ is recommended, a tolerance is not applicable.

Depth

Not applicable.

Frequency

Given the limited monitoring history for this area, monthly sampling frequency is recommended. If seasonal harvesting is subsequently identified, sampling could be restricted to the season and the period immediately preceding it.

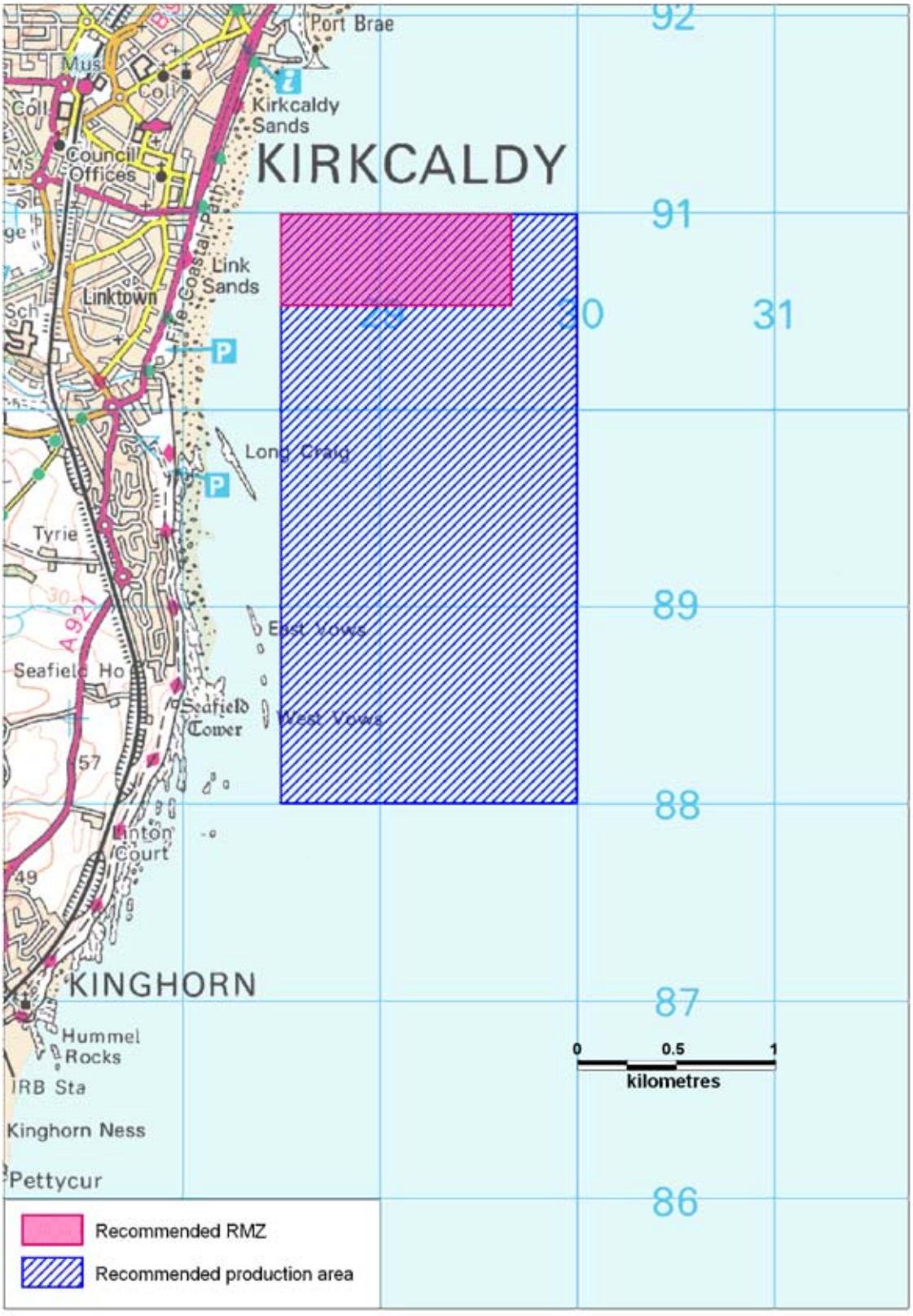

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Figure 11.1 Recommendations for Kirkcaldy Bay

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13. List of Figures and Tables

Appendices

1. **General Information on Wildlife Impacts**
2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Hydrographic Methods**
4. **Shoreline Survey Report**

General Information on Wildlife Impacts

Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Both species can be found along the west coast of Scotland.

Common seal surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage.

According to the Scottish Executive, in 2001 there were approximately 119,000 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides.

Adult Grey seals weigh 150-220 kg and adult common seals 50-170kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

The concentration of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21×10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

Both bacterial and viral pathogens affecting humans and livestock have been found in wild and captive seals. *Salmonella* and *Campylobacter* spp., some of which were antibiotic-resistant, were isolated from juvenile Northern elephant seals (*Mirounga angustirostris*) with *Salmonella* found in 36.9% of animals stranded on the California coast (Stoddard et al 2005). *Salmonella* and *Campylobacter* are both enteric pathogens that can cause acute illness in humans and it is postulated that the elephant seals were picking up resistant bacteria from exposure to human sewage waste.

One of the *Salmonella* species isolated from the elephant seals, *Salmonella typhimurium*, is carried by a number of animal species and has been isolated from cattle, pigs, sheep, poultry, ducks, geese and game birds in England and Wales. Serovar DT104, also associated with a wide variety of animal species, can cause severe disease in humans and is multi-drug resistant (Poppe et al 1998).

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin

faeces, in large part because the animals are widely dispersed and sample collection difficult.

A variety of cetacean species are routinely observed around the west coast of Scotland. Where possible, information regarding recent sightings or surveys is gathered for the production area. As whales and dolphins are broadly free ranging, this is not usually possible to such fine detail. Most survey data is supplied by the Hebridean Whale and Dolphin Trust or the Shetland Sea Mammal Group and applies to very broad areas of the coastal seas.

It is reasonable to expect that whales would not routinely affect shellfisheries located in shallow coastal areas. It is more likely that dolphins and harbour porpoises would be found in or near fisheries due to their smaller physical size and the larger numbers of sightings near the coast.

Birds

Seabird populations were surveyed all over Britain as part of the SeaBird 2000 census. These counts are investigated using GIS to give the numbers observed within a 5 km radius of the production area. This gives a rough idea of how many birds may be present either on nests or feeding near the shellfish farm or bed.

Further information is gathered where available related to shorebird surveys at local bird reserves when present. Surveys of overwintering geese are queried to see whether significant populations may be resident in the area for part of the year. In many areas, at least some geese may be present year round. The most common species of goose observed during shoreline surveys has been the Greylag goose. Geese can be found grazing on grassy areas adjacent to the shoreline during the day and leave substantial faecal deposits. Geese and ducks can deposit large amounts of faeces in the water, on docks and on the shoreline.

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). An earlier study found that geese averaged from 5.23 to 18.79 defecations per hour while feeding, though it did not specify how many hours per day they typically feed (Bedard and Gauthier, 1986).

Waterfowl can be a significant source of pathogens as well as indicator organisms. Gulls frequently feed in human waste bins and it is likely that they carry some human pathogens.

Deer

Deer are present throughout much of Scotland in significant numbers. The Deer Commission of Scotland (DCS) conducts counts and undertakes culls of deer in areas that have large deer populations.

Four species of deer are routinely recorded in Scotland, with Red deer (*Cervus elaphus*) being the most numerous, followed by Roe deer (*Capreolus capreolus*), Sika deer (*Cervus nippon*) and Fallow deer (*Dama dama*).

Accurate counts of populations are not available, though estimates of the total populations are >200,000 Roe deer, >350,000 Red deer, < 8,000 Fallow deer and an unknown number of Sika deer. Where Sika deer and Red deer populations overlap, the two species interbreed further complicating counts.

Deer will be present particularly in wooded areas where the habitat is best suited for them. Deer, like cattle and other ruminants, shed *E. coli*, *Salmonella* and other potentially pathogenic bacteria via their faeces.

Other

The European Otter (*Lutra lutra*) is present around Scotland with some areas hosting populations of international significance. Coastal otters tend to be more active during the day, feeding on bottom-dwelling fish and crustaceans among the seaweed found on rocky inshore areas. An otter will occupy a home range extending along 4-5km of coastline, though these ranges may sometimes overlap (Scottish Natural Heritage website). Otters primarily forage within the 10 m depth contour and feed on a variety of fish, crustaceans and shellfish (Paul Harvey, Shetland Sea Mammal Group, personal communication).

Otters leave faeces (also known as spraint) along the shoreline or along streams, which may be washed into the water during periods of rain.

References:

Alderisio, K.A. and N. DeLuca (1999). Seasonal enumeration of fecal coliform bacteria from the feces of Ring-billed gulls (*Larus delawarensis*) and Canada geese (*Branta canadensis*). *Applied and Environmental Microbiology*, 65:5628-5630.

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Lisle, J.T., Smith, J.J., Edwards, D.D., andd McFeters, G.A. (2004). Occurrence of microbial indicators and *Clostridium perfringens* in wastewater, water column samples, sediments, drinking water and Weddell Seal feces collected at McMurdo Station, Antarctica. *Applied and Environmental Microbiology*, 70:7269-7276.

Scottish Natural Heritage. http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp. Accessed October 2007.

Tables of Typical Faecal Bacteria Concentrations

Summary of faecal coliform concentrations (cfu 100ml-1) for different treatment levels and individual types of sewage-related effluents under different flow conditions: geometric means (GMs), 95% confidence intervals (Cis), and results of t-tests comparing base- and high-flow GMs for each group and type.

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	282	2.8×10^{6} * (-)	2.3×10^{6}	3.2×10^{6}
Crude sewage discharges	252	1.7×10^{7} * (+)	1.4×10^{7}	2.0×10^{7}	79	3.5×10^{6} * (-)	2.6×10^{6}	4.7×10^{6}
Storm sewage overflows					203	2.5×10^{6}	2.0×10^{6}	2.9×10^{6}
Primary	127	1.0×10^{7} * (+)	8.4×10^{6}	1.3×10^{7}	14	4.6×10^{6} (-)	2.1×10^{6}	1.0×10^{7}
Primary settled sewage	60	1.8×10^{7}	1.4×10^{7}	2.1×10^{7}	8	5.7×10^{6}		
Stored settled sewage	25	5.6×10^{6}	3.2×10^{6}	9.7×10^{6}	1	8.0×10^{5}		
Settled septic tank	42	7.2×10^{6}	4.4×10^{6}	1.1×10^{7}	5	4.8×10^{6}		
Secondary	864	3.3×10^{5} * (-)	2.9×10^{5}	3.7×10^{5}	184	5.0×10^{5} * (+)	3.7×10^{5}	6.8×10^{5}
Trickling filter	477	4.3×10^{5}	3.6×10^{5}	5.0×10^{5}	76	5.5×10^{5}	3.8×10^{5}	8.0×10^{5}
Activated sludge	261	2.8×10^{5} * (-)	2.2×10^{5}	3.5×10^{5}	93	5.1×10^{5} * (+)	3.1×10^{5}	8.5×10^{5}
Oxidation ditch	35	2.0×10^{5}	1.1×10^{5}	3.7×10^{5}	5	5.6×10^{5}		
Trickling/sand filter	11	2.1×10^{5}	9.0×10^{4}	6.0×10^{5}	8	1.3×10^{5}		
Rotating biological contactor	80	1.6×10^{5}	1.1×10^{5}	2.3×10^{5}	2	6.7×10^{5}		
Tertiary	179	1.3×10^{3}	7.5×10^{2}	2.2×10^{3}	8	9.1×10^{2}		
Reedbed/grass plot	71	1.3×10^{4}	5.4×10^{3}	3.4×10^{4}	2	1.5×10^{4}		
Ultraviolet disinfection	108	2.8×10^{2}	1.7×10^{2}	4.4×10^{2}	6	3.6×10^{2}		

Source: Kay, D. et al (2008) Faecal indicator organism concentrations in sewage and treated effluents. *Water Research* 42, 442-454.

Comparison of faecal indicator concentrations (average numbers/g wet weight) excreted in the faeces of warm-blooded animals

Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^{8}
Cow	230,000	23,600	5.4×10^{9}
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^{8}
Pig	3,300,000	2,700	8.9×10^{8}
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^{8}
Human	13,000,000	150	1.9×10^{9}

Source: Adapted from Geldreich 1978 by Ashbolt et al in World Health Organisation (WHO) Guidelines, Standards and Health. 2001. Ed. by Fewtrell and Bartram. IWA Publishing, London.

Hydrographic Methods

The new EU regulations require an appreciation of the hydrography and currents within a region classified for shellfish production with the aim to "determine the characteristics of the circulation of pollution, appreciating current patterns, bathymetry and the tidal cycle." This document outlines the methodology used by Cefas to fulfil the requirements of the sanitary survey procedure with regard to hydrographic evaluation of shellfish production areas. It is written as far as possible to be understandable by someone who is not an expert in oceanography or computer modelling. A glossary at the end of the document defines commonly used hydrographic terms e.g. tidal excursion, residual flow, spring-neap cycle etc.

The hydrography at most sites will be assessed on the basis of bathymetry and tidal flow software only. Selected sites will be assessed in more detail using either: 1) a hydrodynamic model, or 2) an extended consideration of sources, available field studies and expert assessment. This document will consider the more basic hydrographic processes and describes the common methodology applied to all sites.

Background processes

Currents in estuarine and coastal waters are generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences.

Tidal flows often dominate water movement over the short term (approximately 12 hours) and move material over the length of the *tidal excursion*. Tides move water back and forth over the tidal period often leading to only a small net movement over the 12 hours tidal cycle. This small net movement is partly associated with the *tidal residual* flow and over a period of days gives rise to persistent movement in a preferred direction. The direction will depend on a number of factors including the bathymetry and direction of propagation of the main tidal wave.

Wind and density driven current also lead to persistent movement of water and are particular important in regions of relatively low tidal velocities characteristic of many of the water bodies in Scottish waters. Whilst tidal flows generally move material in more or less the same direction at all depths, wind and density driven flows often move material in different directions at the surface and at the bed. Typical vertical profiles are depicted in Figure 1. However, it should be understood that in a given water body, movement will often be the sum of all three processes.

In sea lochs, mechanisms such as "wind rows" can transport sources of contamination at the edge of the loch to production areas further offshore. Wind rows are generated by winds directed along the main length of the loch. An illustration of the waters movements generated in this way is given in Figure 2. As can be seen the water circulates in a series of cell that draw material across the loch at right angles to the wind direction. This is a particularly common situation for lochs with high land on either side as these tend to act as a steering mechanism to align winds along the water body.

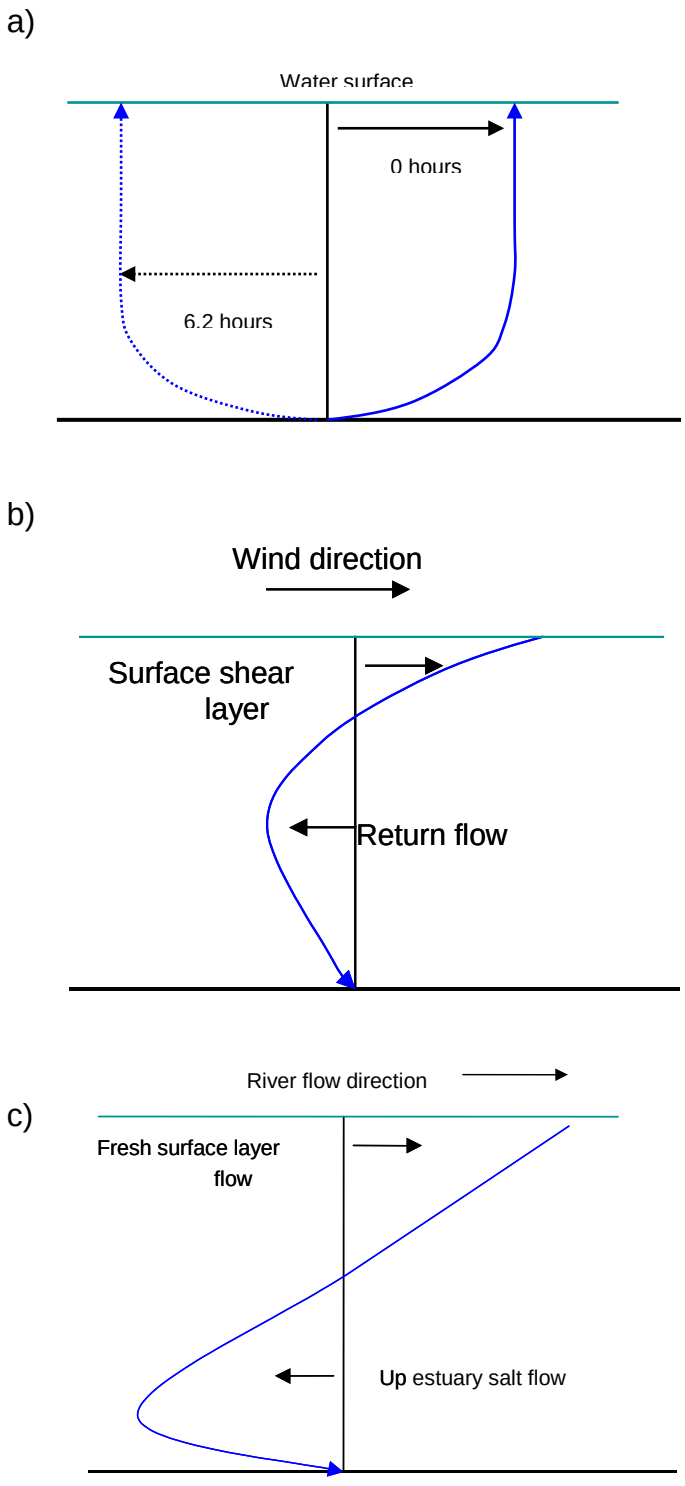

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction over a period of 6.2 hours. b) wind driven current profile, c) density driven current profile.

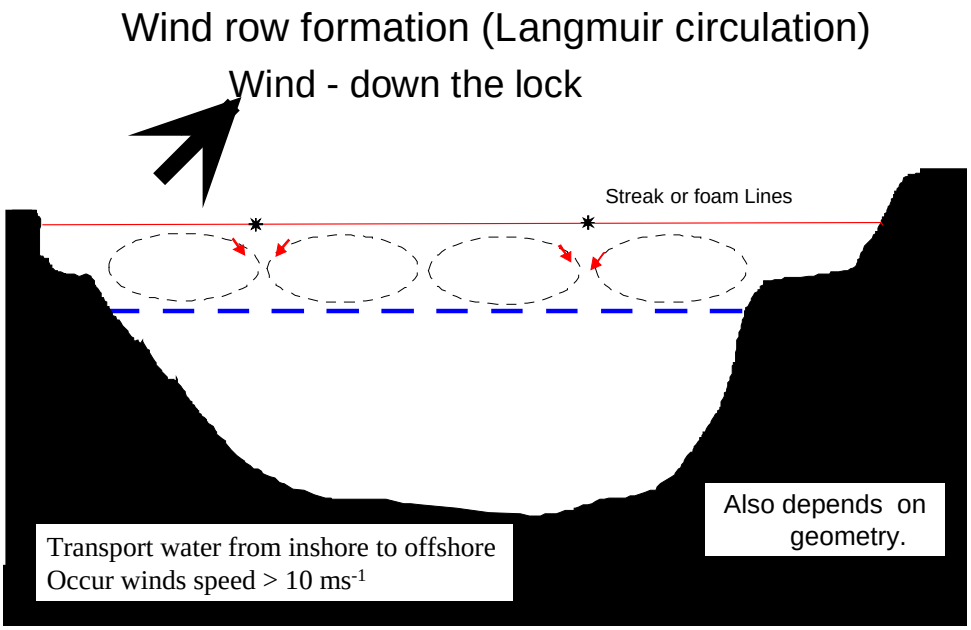

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

In this approach the assessment requires a certain amount of expert judgment and subjectivity enters in. For all production areas, the following general guidelines are used:

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main 'region of influence' around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin 'plumes'.

Many Scottish shellfish production areas occur within sea lochs. These are fjord-like water bodies consisting of one or more basins, deepened by glacial activity and having relatively shallow sills that control the mixing and flushing processes. The sills are often regions of relatively high currents, while the basins are much more tranquil often containing higher density water trapped below a fresh lower density surface layer. Tidal mixing primarily occurs at the sills.

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can

be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

In addition to movement of particles by currents, dilution is also an important consideration. Dilution reduces the effect of an individual point source although at the expense of potentially contaminating a larger area. Thus class A production areas can be achieved in water bodies with significant faecal coliform inputs if no transport pathway exists and little mixing can occur. Conversely a poor classification might occur where high mixing causes high and permanent background concentrations arising from many weak diffuse sources.

References

European Commission 1996. Report on the equivalence of EU and US legislation for the Sanitary Production of Live Bivalve Molluscs for Human Consumption. EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish, August 1996.

Glossary

The following technical terms may appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.

Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.

Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For near shore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.

Tidal range. The difference in height between low and high water. Will change over a month.

Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.

Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.

Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.

Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.

Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.

Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%)of the wind speed.

Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).

Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.

Shoreline Survey Report

Production area:	Firth of Forth	
Site name:	Kirkcaldy	
SIN:	FF 580 1053 16	
Species:	*Ensis spp*	
Harvester:	Various harvesters	
Local Authority:	Fife Council	
Status:	New application	
Date Surveyed:	Shoreline walk - 17th and 18th May 2011	
	Offshore boat work – 27th June 2011	
Surveyed by:	John Lecyn	Fife Council
	Nan Knight	Fife Council
	Alistair Little	Fife Council
	Laura Gray	Fife Council
Existing RMP:	Not yet assigned	
Area Surveyed:	Seafield Tower to Dysart (see Figure 1)	

Weather observations
17th May - Mainly dry with light showers and moderate winds
18th May - Moderate to strong winds with heavier showers
27th June - For survey boat work was calm with persistent showers

General Description
The area surveyed runs roughly west to east on the north side of the Firth of Forth at Kirkcaldy, Fife. There is a rocky shore at the extreme western end, a seawall with a sand/shingle beach and harbour in the mid part ending with a small rocky shore with a sand/shingle beach at the eastern edge of the survey area. The majority of the survey area is heavily urbanised and roads separate the shoreline from commercial developments and domestic housing.

At the western end of the survey area are new housing developments with more housing developments planned for the future. At the eastern end of the survey area lays the village of Dysart.

Fishery
Natural razor clam beds (*Ensis* sp.) are found within Kirkcaldy Bay.

Human Sewage Sources
There are two large settlements; Kirkcaldy and Dysart in the vicinity of the fishery. There is a sewage works and associated outfall at eastern side of the Kirkcaldy harbour. There is a sewage pumping station at the eastern end of Dysart.

There was limited evidence on the shoreline of plastics etc. normally associated with incomplete screening at the sewage works. At a housing development on the western side of Kirkcaldy harbour there was evidence of

direct discharge of sewage. On the seawall at Kirkcaldy there were a substantial amount of surface water drainage pipes that discharge surface water and associated debris directly into the sea/beach. There is a sewage works and discharge outlet at the Eastern end of Kirkcaldy harbour.

Livestock
No livestock were observed in the survey area at the time of the shoreline survey. The immediate area on the periphery of the urban zone is primarily arable with some dairy cattle and sheep.

Seasonal Population
The village of Dysart has a picturesque harbour area and does attract some tourists. Some of the homes may be second or holiday homes.

Boats/Shipping
There is a harbour and small boat marina at Kirkcaldy. The harbour entrance is currently being dredged and is expected to re-open after a twenty year gap for small cargo ships carrying grain for the flourmill at the harbour. There is an anchorage for cargo vessels approximately one kilometre offshore. The anchorage regularly holds approximately 6 sea going cargo vessels at any one time. There is a small harbour at Dysart which has between 20 and 40 small leisure yachts. There are also several creel boats in the area.

Land Use
The Kirkcaldy area is heavily urbanised with commercial and domestic housing land use prevalent. Ravenscraig Park separates Kirkcaldy from Dysart and is popular with recreational walkers.

Wildlife/Birds
The Firth of Forth is a significant area for migratory birds. Many species of migratory and resident seabirds can be observed on the shore at low water. There are colonies of seals near the survey area and dolphins are periodically observed. The rocks at the western edge of the survey area near Seafield Tower may become a designated “haul out” site for seals under the Marine (Scotland) Act 2010.

Rivers/Streams
The main freshwater inputs were the Tiel Burn at the western end of the survey area and East Burn at the eastern edge of Kirkcaldy harbour. There were numerous potential freshwater inputs but few showed evidence of flow during the survey.

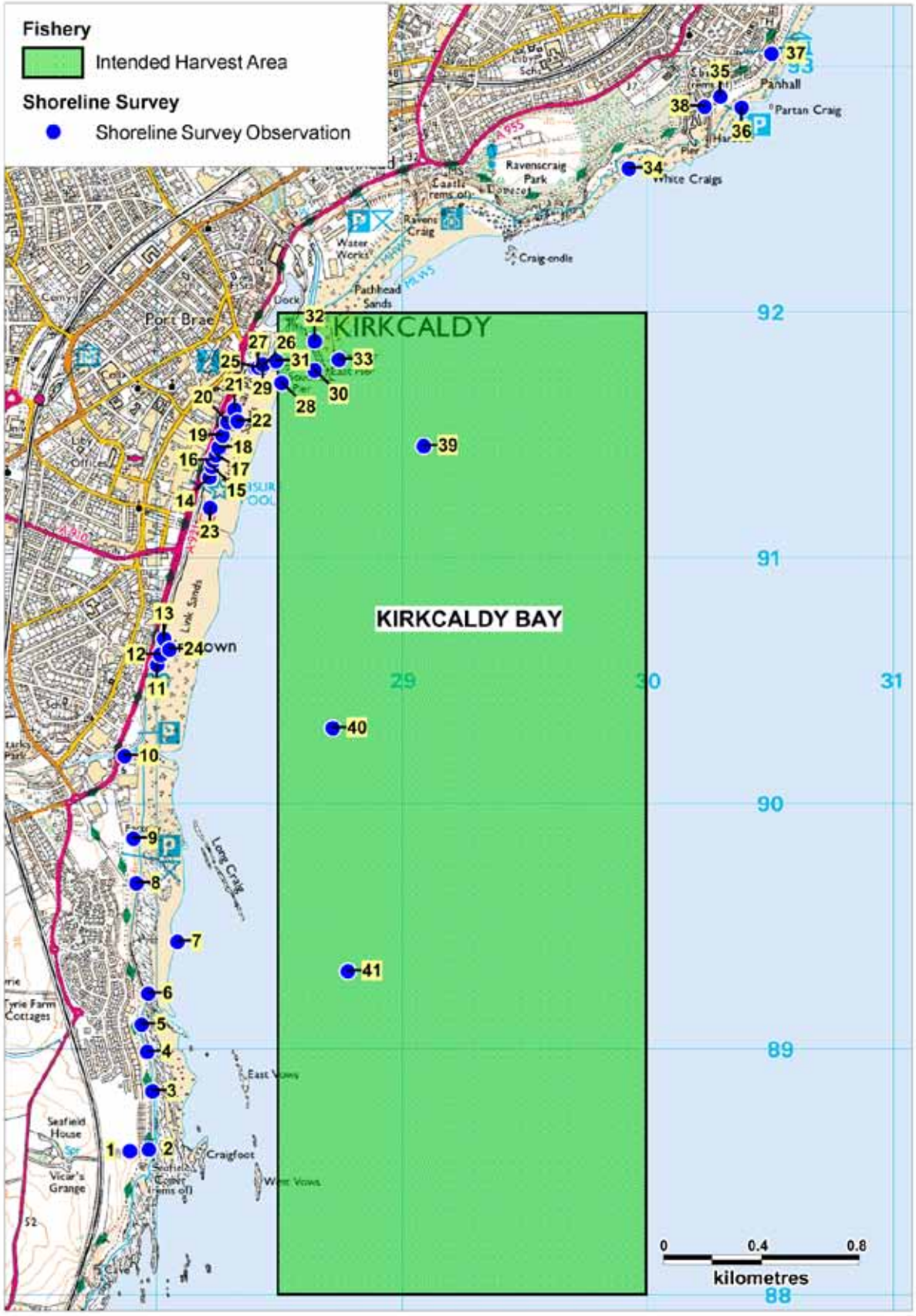

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Figure 1. Shoreline Observations

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	17/05/2011	08:45	NT 27890 88590	327890	688590	Figure 4		Sanitary debris - cotton buds
2	17/05/2011	08:50	NT 27968 88597	327968	688597			Seafield Tower
3	17/05/2011	08:50	NT 27983 88833	327983	688833			Land drain, no flow
4	17/05/2011	09:00	NT 27961 88994	327961	688994			Outfall pipe, no flow
5	17/05/2011	09:10	NT 27939 89105	327939	689105	Figure 5	SAMPLE1	Brick outfall pipe, with water flow, flow 0.279 m/s, depth 0.05 m. Location of water sample no.1 (SAMPLE 1 - fresh water)
6	17/05/2011	09:30	NT 27966 89231	327966	689231			Cast iron pipe cover
7	17/05/2011	09:40	NT 28085 89443	328085	689443	Figure 6	SAMPLE2	Outfall pipe with mussels, minimal flow, location of water sample no.2 (SAMPLE 2 - fresh water). Approximately 75 sea birds on rocks
8	17/05/2011	09:55	NT 27917 89680	327917	689680			Plastic pipes leading on to the shore. No flow
9	17/05/2011	10:00	NT 27905 89862	327905	689862	Figure 7	SAMPLE3	Concrete outfall pipe, location of fresh water sample no.3 (SAMPLE3 - fresh water). Sanitary waste evident
10	17/05/2011	10:10	NT 27869 90198	327869	690198	Figure 8	SAMPLE4	Tiel Burn Flow 1 - 0.623 m/s, Depth 0.20 m Flow 2 - 0.443 m/s, Depth 0.32 m Flow 3 - 0.453 m/s, Depth 0.15 m Location of water sample no.4 (SAMPLE4 - fresh water)
11	17/05/2011	10:15	NT 28001 90569	328001	690569	Figures 9 & 10	SAMPLE5	Unknown pipe. Possibly seawater rather than freshwater pool, Location of water sample no.5 (SAMPLE5 - fresh water). Dog walking area
12	17/05/2011	11:25	NT 28015 90610	328015	690610			Outfall pipe, no flow. Evidence of previous flow
13	17/05/2011	10:40	NT 28030 90676	328030	690676	Figure 11		Outfall pipe, with seabirds at end of the pipe. No access for sample.
14	17/05/2011	10:50	NT 28215 91333	328215	691333	Figure 12		Outfall pipe, no flow
15	17/05/2011	11:06	NT 28225 91378	328225	691378			Outfall pipe, no flow
16	17/05/2011	11:09	NT 28229 91402	328229	691402	Figure13		Outfall pipe, no flow
17	17/05/2011	11:12	NT 28241 91423	328241	691423			Outfall pipe, no flow
18	17/05/2011	11:15	NT 28252 91453	328252	691453	Figure 14	SAMPLE6	Small outfall pipe, with flow small mussel shells. Location of

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								water sample no. 6 (SAMPLE6 - fresh water)
19	17/05/2011	11:18	NT 28268 91503	328268	691503			Small outfall pipe, no flow
20	17/05/2011		NT 28289 91558	328289	691558			Small outfall pipe, no flow
21	17/05/2011		NT 28317 91609	328317	691609			Small outfall pipe, no flow
22	17/05/2011		NT 28329 91562	328329	691562			Seawater with scum on incoming tide
23	17/05/2011		NT 28217 91209	328217	691209		SAMPLE7	Location of water sample no.7 (SAMPLE7 - sea water)
24	17/05/2011		NT 28052 90632	328052	690632		SAMPLE8	Location of water sample no. 8 (SAMPLE8 - sea water)
25	18/05/2011		NT 28401 91780	328401	691780	Figures 15 & 16	SAMPLE9	Outfall pipe with evidence of faecal contamination at upper outfall, location of water sample no.9 (SAMPLE9 - fresh water)
26	18/05/2011		NT 28428 91779	328428	691779	Figure 17	SAMPLE10	Outfall pipes with slight flow, location of water sample no.10 (SAMPLE10 - fresh water)
27	18/05/2011		NT 28414 91781	328414	691781	Figure 18		Outfall pipe with slight flow
28	18/05/2011		NT 28509 91719	328509	691719		SAMPLE11	Location of water sample no.11 (SAMPLE11 - sea water)
29	18/05/2011		NT 28432 91792	328432	691792	Figure 19		Scottish Water pump at Kirkcaldy Harbour
30	18/05/2011		NT 28643 91769	328643	691769	Figure 20		Dredging operations at Kirkcaldy Harbour at high tide
31	18/05/2011		NT 28488 91807	328488	691807	Figure 21	SAMPLE12	Four outfalls inside Kirkcaldy Harbour. Unable to measure flow due to fast flow and soft mud. Strong smell of sewage and evidence of sanitary debris. Location of water sample no.12 (SAMPLE 12 - fresh water)
32	18/05/2011		NT 28644 91887	328644	691887		SAMPLE13	East Burn running on the Eastern arm of Kirkcaldy harbour wall and waste water from sewage treatment works Flow 1 - 0.031 m/s, depth 0.10 m Flow 2 - 0.043 m/s, depth 0.15 m Flow 3 - 0.069 m/s, depth 0.20 m Smell of sewage and opaque colour to water Location of water sample no.13 (SAMPLE 13 - fresh water)
33	18/05/2011		NT 28743 91812	328743	691812	Figure 22	SAMPLE14	Presumed Scottish Water outfall and possible line of long sea outfall. Location of water sample no.14 (SAMPLE 14 - sea water)
34	18/05/2011		NT 29925 92591	329925	692591		SAMPLE15	Location of foreshore water sample no.15 (SAMPLE15 - sea water) taken in front of Ravenscraig Park salinity 37 ppt

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
35	18/05/2011		NT 30296 92884	330296	692884	Figures 23 & 24		Dysart car park and Scottish Water pumping station
36	18/05/2011		NT 30384 92839	330384	692839		SAMPLE16	Seal observed offshore. Location of water sample no.16 (SAMPLE 16 – sea water)
37	18/05/2011		NT 30505 93058	330505	693058	Figure 25		Scottish Water pumping Station at Eastern end of survey area. (Called Fishermens Hut)
38	18/05/2011		NT 30233 92843	330233	692843	Figure 26		Sewage overflow spillage in Dysart village which drains into Dysart harbour. Scottish Water informed of the leak by Fife Council.
39	27/06/2011		NT 29088 91461	329088	691461		SW1, R1	Location of water sample no. SW1 (sea water) and razor clam sample no.1 (Harbour) Taken by boat. Salinity 0.35 ppt
40	27/06/2011		NT 28717 90312	328717	690312		SW2, R2	Location of water sample no. SW2 (sea water) and razor clam sample no.2 (Linktown) Taken by boat. Salinity 0.38 ppt
41	27/06/2011		NT 28779 89322	328779	689322		SW3, R3	Location of water sample no. SW3 (sea water) and razor clam sample no.3 (Seafield) Taken by boat. Salinity 0.30 ppt
42	18/05/2011		Unknown			Figure 27		Photograph of Kirkcaldy Harbour showing approximately 17 inaccessible outfalls (no grid reference)

*Times were not recorded for observations 20 – 35.
Photographs referenced in the table can be found attached as Figures 4 – 27.

Sampling

Water and shellfish samples were collected at sites marked on the maps in Figures 2 and 3 respectively. Bacteriology results follow in Tables 2 and 3. Samples were shipped on the day of sampling via Royal Mail 24 hr special delivery to Glasgow Scientific Services for *E. coli* analysis. Water samples numbered 1 – 16 arrived at the laboratory within 24 hours and razor samples numbered 1 – 3 and sea water samples SW1 – SW3 arrived at the laboratory within 48 hours. The box temperatures on arrival varied from 2.9 – 6.3˚C, which was within the recommended temperature range of 2-8˚C.

Samples of seawater were tested for salinity by the laboratory using a salinity meter under controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. Note that this is equivalent to ppt.

Table 2. Water sample *E. coli* results

No.	Sample Ref.	Date	Position	Type	*E. coli* (cfu/100 ml)	Salinity (g/L)
1	SAMPLE1	17/05/2011	NT 27939 89105	Fresh water	<1000	
2	SAMPLE2	17/05/2011	NT 28085 89443	Fresh water	<1000	
3	SAMPLE3	17/05/2011	NT 27905 89862	Fresh water	<1000	
4	SAMPLE4	17/05/2011	NT 27869 90198	Fresh water	2000	
5	SAMPLE5	17/05/2011	NT 28001 90569	Fresh water	1000	
6	SAMPLE6	17/05/2011	NT 28252 91453	Fresh water	<1000	
7	SAMPLE7	17/05/2011	NT 28217 91209	Sea water	21	36.9
8	SAMPLE8	17/05/2011	NT 28052 90632	Sea water	31	
9	SAMPLE9	18/05/2011	NT 28401 91780	Fresh water	1000	
10	SAMPLE10	18/05/2011	NT 28428 91779	Fresh water	<1000	
11	SAMPLE11	18/05/2011	NT 28509 91719	Sea water	3600	34.9
12	SAMPLE12	18/05/2011	NT 28488 91807	Fresh water	<1000	
13	SAMPLE13	18/05/2011	NT 28664 91887	Fresh water	3000	
14	SAMPLE14	18/05/2011	NT 28743 91812	Sea water	300	33.4
15	SAMPLE15	18/05/2011	NT 29925 92591	Sea water	23	34.7
16	SAMPLE16	18/05/2011	NT 30384 92839	Sea water	38	36.5
17	SW1	27/06/2011	NT 29088 91461	Sea water	0	36
18	SW2	27/06/2011	NT 28717 90312	Sea water	0	36.2
19	SW3	27/06/2011	NT 28779 89322	Sea water	0	36

Table 3. Shellfish sample *E. coli* results

No.	Sample Ref.	Date	Position	Site	Species	Depth (m)	*E. coli* MPN/100 g
1	R1	29/06/2011	NT 29088 91461	Site 1	Razor clam	NA	<20
2	R2	29/06/2011	NT 28717 90312	Site 1	Razor clam	NA	170
3	R3	29/06/2011	NT 28779 89322	Site 1	Razor clam	NA	330

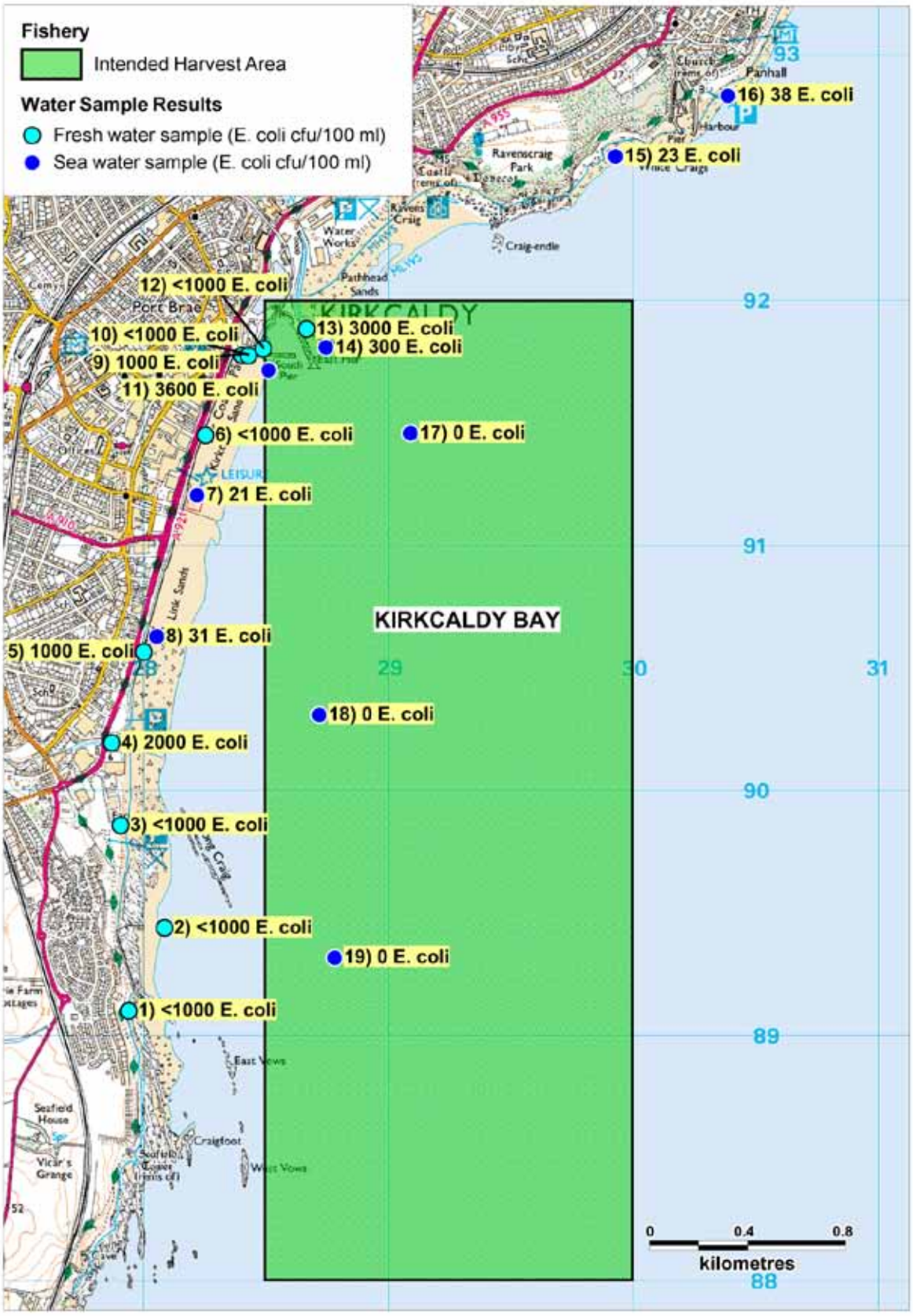

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Figure 2. Water sample results

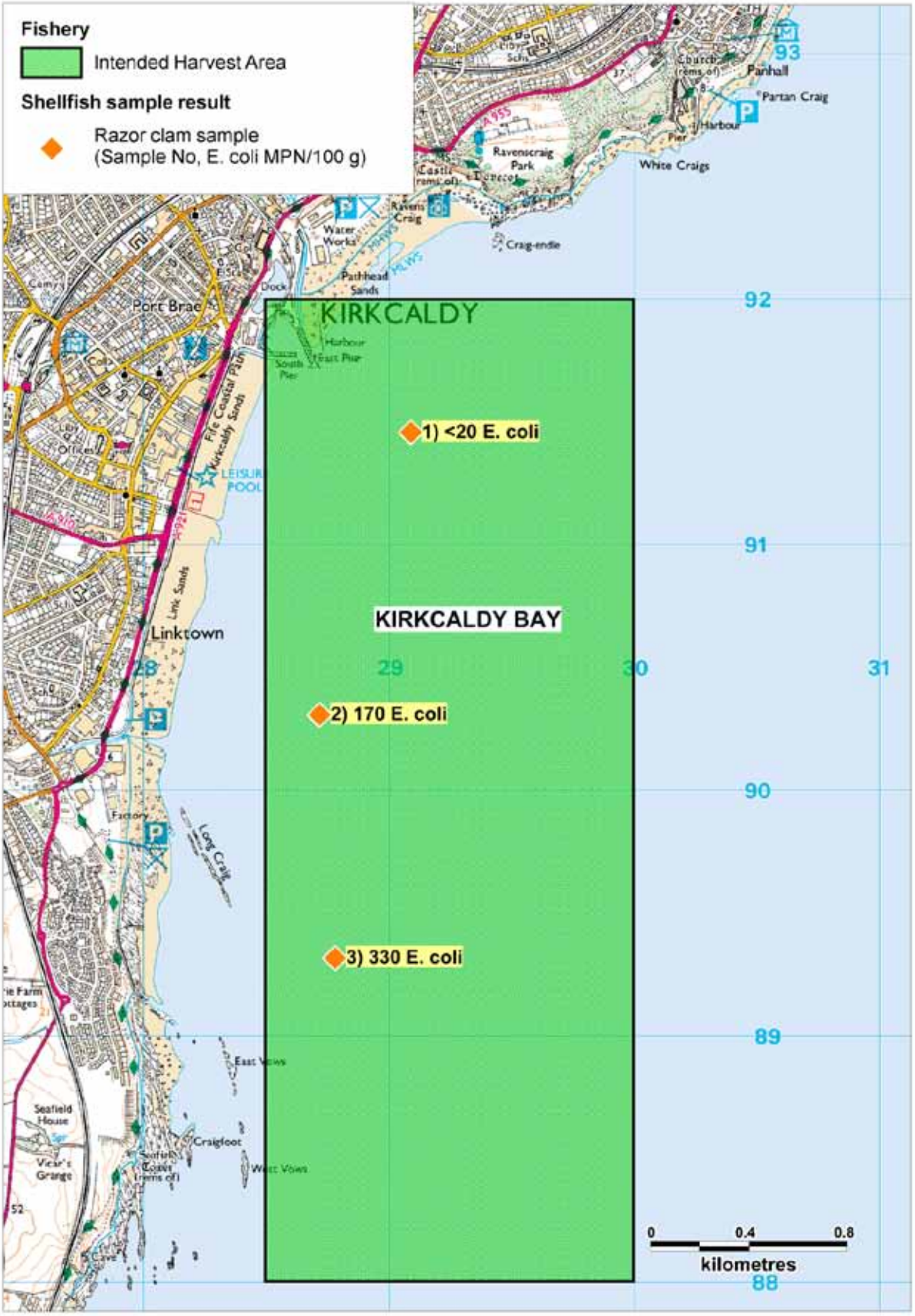

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Figure 3. Shellfish sample result

Photographs

Figure 4 – Sanitary debris (cotton buds) on shoreline

Figure 5 – Outfall pipe, location of fresh water SAMPLE1

Figure 6. Outfall pipe with mussels growing around the edge

Figure 7. Concrete outfall, location of fresh water SAMPLE3

Figure 8. Tiel Burn, location of fresh water SAMPLE4

Figure 9. Unknown pipe leading from wall

Figure 10. Unknown pipe (also shown in Figure 9)

Figure 11. Outfall pipe, with sea birds at the end

Figure 12. Outfall pipe, no flow

Figure 13. Outfall pipe, no flow

Figure 14. Outfall pipe, with mussel growing around it. Location of fresh water SAMPLE6

Figure 15. Outfall pipe with evidence of faecal contamination

Figure 16. Evidence of faecal contamination in top outfall shown in Figure 15

Figure 17. Outfall pipe, location of fresh water SAMPLE10

Figure 18. Outfall pipe with slight flow

Figure 19. Scottish Water pump, Kirkcaldy Harbour

Figure 20. Dredging operations in Kirkcaldy Harbour

Figure 21. Four outfalls inside Kirkcaldy Harbour, location of fresh water SAMPLE12

Figure 22. Presumed Scottish Water outfall, location of sea water SAMPLE14

Figure 23. Dysart carpark and Scottish Water pumping station

Figure 24. Scottish Water pumping station - Dysart

Figure 25. Scottish Water pumping station – Fishermans Hut

Figure 26. Sewage overflow spillage in Dysart Village

Figure 27. Seventeen inaccessible outfalls leading into Kirkcaldy Harbour