Scottish Sanitary Survey Report

Sanitary Survey Report
Stevenston Sands
NA 207 and 647
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The hydrographic assessment and the shoreline survey and its associated report were undertaken by SRSL, Oban.

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Appendices

I. Executive Summary

Stevenston Sands is located within Irvine Bay on the Firth of Clyde. The sanitary survey for Stevenston Sands was undertaken in response to standard classification applications for banded wedge clams (*Donax vittatus*) and razor clams (*Ensis* sp.). These followed fast track applications for both species.

The available information indicates that both species occur across most of Irvine Bay. The wedge clams are harvested by dredging and the razor clams are harvested by diving. Both fisheries are presumed to potentially operate year-round.

The principal sources of faecal contamination in the area are:

- The Stevenston and Meadowhead secondary treated sewage works outfalls and associated CSOs, including the storm interceptor sewer.
- Point and diffuse sources of pollution entering the rivers Irvine and Garnock as far upstream as Kilmarnock
- CSOs in the Saltcoats and Stevenston area.

Additional contamination will arise from point and diffuse sources entering Stevenston Burn and potentially from yachts at moorings at each end of Irvine Bay and within the Irvine River.

Contamination from the continuous sources will occur under all weather conditions and will impact at the discharge locations and up to 4 km from this, with the direction of impact depending on the tidal state: to the northwest on a flood tide and to the southeast on an ebb tide, with the greatest transport distance occurring at spring tides. Further contamination will occur after significant rainfall events both from the CSOs and from diffuse pollution entering the watercourses.

It is recommended that the wedge clam production area comprise the extents covered by the previous fast track and standard applications and that sampling be continued in the zone previous recommended as the pRMZ. It is recommended that two razor clam production areas cover the expected extent of the bed, excluding that already covered by the North Bay production area, and that sampling is undertaken in an RMZ in each intended to reflect contamination arising from the Irvine/Garnock confluence and the Stevenston discharges for one and the Meadowhead discharges for the other. Sampling should be undertaken monthly in light of the limited monitoring data available for the area.

II. Sampling Plan

Production Area	Stevenston Sands - Wedge Clams	Stevenston Sands Razors North	Stevenston Sands Razors South
Site Name	Stevenston Sands	Stevenston Sands N	Stevenston Sands S
SIN	NA-627-1238-23	NA-647-1355-16	TBD
Species	Wedge Clams	Razor Clams	Razor Clams
Type of Fishery	Dredged	Dived	Dived
Boundaries of RMZ	The zone bounded by lines drawn from NS 2660 4025 to NS 2740 3980 to NS 2710 3940 to NS 2630 3983 and back to NS 2660 4025	The zone bounded by lines drawn from NS 2530 3970 to NS 2530 4030 to NS 2680 3950 to NS 2680 3890 and back to NS 2530 3970	The zone bounded by lines drawn from NS 2910 3690 to NS 3950 3730 to NS 3050 3590 to NS 3010 3560 and back to NS 2910 3690
Tolerance (m)	Not applicable	Not applicable	Not applicable
Depth (m)	Not applicable	Not applicable	Not applicable
Method of Sampling	Dredging	Diving	Diving
Frequency of Sampling	Monthly	Monthly	Monthly
Local Authority	North Ayrshire Council	North Ayrshire Council	North Ayrshire Council
Authorised Sampler(s)	David Wilson Martin Scott	David Wilson Martin Scott	David Wilson Martin Scott
Local Authority Liaison Officer	Frances Gemmell Catherine Riley	Frances Gemmell Catherine Riley	Frances Gemmell Catherine Riley
Production area boundaries	The area bounded by lines drawn from NS 2494 4102 to NS 2675 4042 to NS 2765 3990 to NS 2909 2877 to NS 2892 3843 to NS 2475 4065	The area bounded by lines drawn from NS 2195 4075 to NS 2306 4184 to NS 2390 4137 to NS 2371 4106 to NS 2447 4066 to NS 2494 4102 to NS 2698 4028 to NS 2827 3936 to NS 2691 3790 to NS 2600 3867 and to NS 2195 4075	The area bounded by lines drawn from NS 2827 3936 to NS 2909 2877 to NS 3172 3579 to NS 3200 2450 to NS 2800 3450 to NS 2800 3698 to NS 2691 3790

III. Report

1. General Description

Stevenston Sands is a production area in the Clyde Sea, off the Ayrshire coast. It lies in the local authority area of North Ayrshire. Located within Irvine Bay, the site is adjacent to Stevenston beach and faces south-west towards the Isle of Arran. Irvine Bay totals a distance of approximately 12 km (not allowing for the curve of the bay) between Saltcoats at the northern end and Troon at the southern end. Stevenston Sands is located towards the northern end of Irvine Bay. The general location of Stevenston Sands is shown in Figure 1.1.

The coast around Irvine Bay is densely populated, with the settlements of Stevenston, Saltcoats, Ardrossan, Irvine and Troon lying almost directly on the shoreline. Slightly further away lie the two largest towns in North Ayrshire; Ayr and Kilmarnock.

This sanitary survey is being undertaken due to the submission of a standard application for classification of the area for the harvest of banded wedge clams (*Donax vittatus*). A subsequent application was made for the harvest of razor clams (*Ensis* spp.) in the same area, and consideration of the razor clam fishery has been included in this report.

Figure 1.1 Location of Stevenston Sands

2. Fishery

There are two fisheries at Stevenston Sands, one for banded wedge clam (*Donax vittatus*) and one for razor clams (*Ensis* spp.). Both fisheries exploit wild beds.

The banded wedge clam area was previously the subject of a provisional Representative Monitoring Point (RMP) assessment. The area considered in that assessment is shown in Figure 2.1 and consisted of the combined extents of three fast track applications and one standard application for classification. A preliminary representative monitoring zone (pRMZ) was recommended, rather than an RMP, within the area bounded by lines drawn from NS 2660 4025 to NS 2740 3980 to NS 2710 3940 to NS 2630 3983 and back to NS 2660 4025. The standard production area has been named Stevenston Sands – Wedge Clams and has been assigned a SIN of NA-627-1238-23. The wedge clams are harvested by dredging.

The application for razor clams is comprised of three fast-track areas; Stevenston Sands Razors 1, 2 & 3 (SINS respectively given as: NA-648-1357-16; NA-649-1358-16; NA-650-1359-16). The extent of these is shown in Figure 2.1. A standard application will run alongside the three fast track areas and will encompass the area covered by the three fast tracks: the standard application area has been given a SIN of NA-647-1355-16. No RMP (or RMZ) has yet been assigned for the standard application. The razor clams will be harvested by diving. The fast track application for Stevenston Sands Razors 2 was rejected by FSAS in August 2013 due to an official control sample returning a class C result.

As the fisheries exploit wild populations the extent of the shellfish beds is uncertain. No comprehensive stock assessments have been conducted. The extent plotted in Figure 2.1 has been estimated is based on the known preferred substrate type and depth range for the species, species location information from the national biodiversity network (http://data.nbn.org.uk/) and seabed substrate information from the SSMEI Clyde Pilot document; The Process of Developing a Seabed Habitat Map for the Firth of Clyde (Tresadern, 2008). As both species are present at similar depths and substrate types, the same fishery extent has been shown for both species.

The North Bay classified razor clam production area also lies within the southern extent of the estimated shellfish bed. This area received a sanitary survey in 2011, which recommended the current production area boundary and a representative monitoring zone, shown in Figure 2.1. An RMP that does not lie within the RMZ is also currently identified for this production area.

Figure 2.1 Stevenston Sands fishery area

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Stevenston Sands. The last census was undertaken in 2011, however detailed 2011 census data was unavailable at the time of writing this report. Updated 2010 population totals for the localities of Ardrossan, Saltcoats, Stevenston, Kilwinning, Irvine and Troon were available from the National Records of Scotland (2012). The census area data shown in Figure 3.1 is from the 2001 census.

Localities are described by the General Register Office for Scotland as "more recognisable towns and cities … which can be found within settlements and have a minimum population of 500 people" (National Records of Scotland, 2012). The 2010 populations of the localities in the survey area are listed in Table 3.1.

Table 3.1 Total population for localities (2010)

Localities	2010 Total population
Ardrossan	10,610
Saltcoats	12,170
Stevenston	8,880
Kilwinning	16,140
Irvine	32,490
Troon	14,580
Total Population	94,870

Figure 3.1 and Table 3.1 show that both the total population and the population density are high for the towns of Ardrossan, Saltcoats, Stevenston, Kilwinning, Irvine and Troon. The population density for the census output areas surrounding these towns is low in comparison.

This stretch of coastline has good transport infrastructure, connecting it with Glasgow, Northern Ireland, the Isle of Arran and the Kintyre peninsula: this increases the transient population. Clyde Marina in Ardrossan has 250 fully serviced berths, a boatyard and facilities including car parking, toilets and showers (Clyde Marina, 2013). Caledonian MacBrayne runs two ferry services from Ardrossan, one to Brodick on the Isle of Arran with 6 sailings, 7 days a week during March to October and a new service runs to Campbeltown on the Kintyre peninsula, with 3 sailings a day, 4 days a week during May to September (Caledonian MacBrayne, 2013). A second marina is situated at Troon, with 400 berths and facilities including toilets and showers (Troon Yacht Haven, 2013). Troon also has a port with freight and ferry services. Between March and October, P&O operate a daily express service to Larne, Northern Ireland. There are pump-out facilities for onboard sewage wastes at both marinas (Sail the Net, 2013 a; Sail the Net, 2013 b). There is a slipway at Stevenston opposite the production area. Irvine Harbour, located on the River Irvine, is now closed to commercial boat traffic but has a slipway for dinghies and has 68 moorings for pleasure vessels (NPL Estates, 2013). Facilities (toilets and showers) for visiting vessels are provided by a nearby water sports club. There are no pump-

out facilities for onboard sewage facilities at Irvine. There is no additional anchorage available along the stretch of coastline between Troon and Ardrossan. Occupied boats or yachts may have heads that discharge directly overboard leading to faecal contamination of the surrounding water: detection of elevated faecal coliform levels has been reported up to 300 metres away from marinas (Sobsey *et. al*., 2003).There is one railway station in Troon and three railway stations in Ardrossan, all of which are linked to the Ayrshire Coast line. Prestwick airport is located 7km southeast of Troon.

The area between Ardrossan and Troon hosts 9 golf courses, 2 bathing beaches, and a large holiday park at Saltcoats with approximately 600 pitches, including caravan holiday homes, touring pitches, seasonal touring pitches and camping pitches (Park Resorts, 2013). Troon Harbour and Barassie Beach (north of Troon harbour) are popular with windsurfers and kite surfers, who may use the area outside the traditional bathing season.

Due to the large towns in the area and close proximity of Ardrossan, Saltcoats and Stevenston to the fishery, it is likely that sewage discharges from both settlements will contribute to the faecal contamination of the shellfish bed. Due to the large holiday park at Saltcoats and capacity for visiting pleasure vessels in the area, it is expected that the population of the area will increase significantly during the summer holiday months. Any overboard discharges from boats visiting the Irvine moorings could contribute to the *E. coli* loading at the Irvine/Garnock confluence. Impacts from human sources to the water quality of the shellfish bed are likely to be seasonal, peaking during the summer months when visitor numbers are higher.

Figure 3.1 Population map for the area in the vicinity of Stevenston Sands

4. Sewage Discharges

Information on sewage discharges to the area around Stevenston Sands was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Data requested included the name, location, type, size (in either flow or population equivalent), level of treatment, sanitary or bacteriological data, spill frequency, discharge destination (to land or to waterbody or to sea), any available dispersion or dilution modelling studies, and whether improvements were in work or planned.

Scottish Water and SEPA datasets were compared to ensure accuracy and were also compared to bathing water reports for Irvine and Saltcoats (SEPA, 2013a; SEPA, 2013b). Where differences were observed clarification was sought from the data providers. Data was also cross-checked with that included in the North Bay sanitary survey report, published in 2011, as that considered sewage discharges to the southern end of Irvine bay. As the area around Irvine Bay is densely populated, many households are on public sewage networks. There are two sewage treatment works (STW) which service the area; Stevenston Sewage Treatment Works (CAR/L/1003264) which has a design population equivalent (PE) of 90000 (consented dry weather flow (DWF) = 45961 m^3/day) and Meadowhead Sewage Treatment Works (CAR/L/1003265) which has a design PE of 313333 (consented DWF = 85782 m^3/day). The PE values given by SEPA and Scottish Water for the two STWs differed. The Scottish Water values were lower which suggest that they may represent connected PE.

Scottish Water provided effluent monitoring data including biological oxygen demand (BOD) for Stevenston STW for the period of 18/01/2012 – 16/01/2013 and Meadowhead STW between 18/01/2012 – 23/01/2013. For the limited periods reported, the geometric mean BOD was for Stevenston STW 4.5 mg/l and Medowhead STW 7.0 mg/l. These are within the range expected for secondary treated sewage. No microbiological data were provided for either of the discharges.

There are combined sewer overflows (CSO) and emergency overflows (EO) associated with these two STWs. Meadowhead STW has a CSOs and two EOs (one intake and one intermediate), which discharge through the same outfall (also known as the Gailes pumping station (PS) outfall) as the final effluent. Another EO associated with the Gailes pumping station discharges slightly closer to shore.

Scottish Water have recently installed storm interceptor sewers through Irvine and a part of Kilmarnock. These collect storm sewage flows greater than the capacity of the foul sewer, up to a 1 in 5 year storm flow. Interceptor flows are discharged via the Gailes PS outfall to Irvine Bay. Discharges through the Gailes PS outfall receive screening and then passed to diffuser sets on the seabed rather than to a single point outfall. The range of these sets was provided by SEPA as NS 3049 3549 to NS 3034 3545 and NS 2891 3530 to NS 2971 3528. In addition, trade effluent from a GlaxoSmithKline (GSK) factory bypasses the STW and discharges through the

Gailes PS outfall, while the sewage effluent from the factory passes through the STW. SEPA report that the bacteriological quality of the trade effluent portion is not known, but thought to be low. GSK retain a private outfall, though this is reported to be used only rarely.

Therefore, the main Meadowhead outfall pipes receive both treated sewage effluent from the STW, screened storm sewage from the interceptor sewer, and trade effluent from a GlaxoSmithKline factory.

Stevenston STW has one CSO and one EO which discharge through the same outfall as the final effluent and one EO which discharges onto the shore. This was observed in the shoreline survey and is listed as observation 8 in Table 4.3.

Any CSOs and EOs not directly associated with the treatment works are combined into two sewer network licences; Stevenston Sewage Network (CAR/L/1026164) and Meadowhead Sewage Network (CAR/L/1026135). These networks cover a large area from West Kilbride in the North, to Ayr in the South and out East past Kilmarnock along the River Irvine (Dempsey, et al., 2008): the two networks contain a total of 199 CSOs and EOs. However not all these discharge to the production area or water courses emptying into the production area.

The SEPA bathing water report for Irvine Beach identified that CSOs comprised the main risk of sewage contamination to bathing water at the beach, which lies north of the production area. An assessment of the impact of development on the sewerage network was undertaken by Atkins on behalf of Scottish Water and the Ayrshire Joint Structure Plan and Transportation Committee (Atkins, 2005). It identified 126 CSOs within the catchment for Meadowhead STW and a further 41 within the catchment for Stevenston STW.

For the purposes of this survey, only those discharging to sea or to within 3km of the production area have been considered. However it is important to recognise that a large part of the complex sewerage infrastructure in the area lies well upstream of the sea. Comment received from SEPA subsequent to release of the draft of this survey identified that studies carried out to inform the interceptor sewer project indicated that CSOs discharging from central Kilmarnock, over 20 km upstream, could have an impact at the bathing water and therefore presumably also at the shellfishery.

Annual spill frequencies reported by Atkins for the Meadowhead CSOs ranged from 0 to 193 per year. Scottish Water are currently undertaking extensive improvement works to the stormwater provision by upgrading the trunk sewerage line and increasing the flow capacity to Meadowhead STW (due to be completed in late 2013). These improvements are anticipated to improve water quality at the nearby bathing waters.

Table 4.1 lists the public sewer discharges which discharge in or close to the production area, or to watercourses within 3km of the production area. Where data files appeared to contain the same data on more than one row, the duplicate data was removed. Where data files contained entries that were nearly identical but differed only in name or NGR, and it was not possible to determine which was correct, both entries have been presented.

Table 4.1 Public Sewage Discharges

No.	Licence Number	NGR	Site Name	Dicharge Type	Treatment	Discharges To	PE
1	CAR/L/1003264	NS 2665 3924	Stevenston STW, FE/CSO/EO	FE CSO EO	Secondary 6mm screen	Firth Of Clyde	94885
2	CAR/L/1003264	NS 2738 4014	Stevenston STW, (FE) PS EO	EO		Firth Of Clyde	-
3	CAR/L/1003265	NS 3034 3546	Meadowhead STW, FE/CSO/EO (inlet & intermediate)	FE CSO EO	Secondary 6mm screen 15mm screen	Firth Of Clyde	401078
4	CAR/L/1003265	NS 3170 3480	Meadowhead STW, Gailes pumping station EO	EO	40mm screen	Firth Of Clyde	-
5	CAR/L/1026164	NS 2380 4260	South Parkhouse Bridge (No. 5) CSO, Ardrossan	CSO		Stanley Burn	-
6	CAR/L/1026164	NS 2386 4266	47 Parkhouse Road CSO, Ardrrossan	CSO		Stanley Burn	-
7	CAR/L/1026164	NS 2404 4205	Holm Plantation / Bute Terrace CSO, Saltcoats	CSO		Stanley Burn	-
8	CAR/L/1026164	NS 2660 4160	Hillside PS CSO EO Stevenston	CSO/EO		Stevenston Burn	-
9	CAR/L/1026164	NS 2670 4130	Canal Crescent SPS No. 1 CSO/EO Stevenston	CSO/EO		Stevenston Burn	-
10	CAR/L/1026164	NS 2256 4169	Harbour Road No. 2 SPS CSO/EO, Ardrossan	CSO/EO		Firth Of Clyde	-
11	CAR/L/1026164	NS 2280 4330	27 North Crescent Road CSO, Ardrossan	CSO		Firth Of Clyde	-
12	CAR/L/1026164	NS 2301 4300	11 North Crescent Road (No. 7) CSO, Ardrossan	CSO		Firth Of Clyde	-
13	CAR/L/1026164	NS 2310 4180	Bath Rocks No. 1 CSO, Ardrossan	CSO		Firth Of Clyde	-
14	CAR/L/1026164	NS 2321 4201	1 Arran Place (No. 8) CSO, Ardrossan	CSO		Firth Of Clyde	-
15	CAR/L/1026164	NS 2351 4284	1 McDowall Avenue (No. 6) CSO, Ardrossan	CSO		Firth Of Clyde	-
16	CAR/L/1026164	NS 2490 4100	Coalruffie / Seaview Road CSO, Saltcoats	CSO		Firth Of Clyde	-
17	CAR/L/1026164	NS 2523 4110	CANAL PLACE SPS CSO/EO	CSO/EO		Firth Of Clyde	-

No.	Licence Number	NGR	Site Name	Dicharge Type	Treatment	Discharges To	PE
18	CAR/L/1026164	NS 2522 4109	Sandylands Promenade CSO/EO, Saltcoats	CSO		Firth Of Clyde	-
19	CAR/L/1026164	NS 3032 3975	Almswall PS EO Kilwinning	EO		Land	-
20	CAR/L/1026164	NS 2422 4080	SALTCOATS CANAL PLACE WWPS	EO		Firth Of Clyde	-
21	CAR/L/1026164	NS 2525 4123	SALTCOATS CANAL PLACE WWPS	EO		Firth Of Clyde	-
22	CAR/L/1026164	NS 2666 4033	55 Shore Road CSO, Stevenston	CSO		Firth Of Clyde	-
23	CAR/L/1026164	NS 2683 4021	Moorpark Road East CSO, Stevenston	CSO		Firth Of Clyde	-
24	CAR/L/1026135	NS 3001 3764	Magnum Centre (NW Corner) CSO, CSO to Irvine Bay, Meadowhead	CSO		Firth Of Clyde	-
25	CAR/L/1026135	NS 3001 3764	Harbour SPS (Gottries Crescent)	CSO		Firth Of Clyde	-
26	CAR/L/1026135	NS 3065 3122	Harbour PS CSO/EO Troon	CSO/EO		Firth Of Clyde	-
27	CAR/L/1026135	NS 3081 3822	142 Harbour Street / Cross Keys CSO	CSO		River Irvine	-
28	CAR/L/1026135	NS 3083 3710	Beach Park SPS CSO/EO 2009	CSO/EO		Firth Of Clyde	-
29	CAR/L/1026135	NS 3111 3825	Harbour Road Sports Club	CSO		River Irvine	-
30	CAR/L/1026135	NS 3209 3363	Barassie PS, CSO to Firth of Clyde, Troon	CSO		Firth Of Clyde	-
31	CAR/L/1026135	NS 3213 3390	Barassie PS CSO Barassie	CSO		Firth Of Clyde	-
32	CAR/L/1026135	NS 3215 3138	Pan Rocks PS CSO Troon	CSO		Firth Of Clyde	-
33	CAR/L/1026135	NS 3268 3194	Troon Maple Grove PS CSO	CSO		Darley Burn	-
34	CAR/L/1026135	NS 3303 3184	Marr Screening Chamber CSO Troon (Troon, Marr College CSO)	CSO		Darley Burn	-
35	CAR/L/1026135	NS 3002 3761	Harbour SPS EO (Gottries Crescent), Irvine (Irvine Harbour WWPS)	EO		Firth Of Clyde	-
36	CAR/L/1026135	NS 3213 3390	Barassie PS EO Barassie	EO		Firth Of Clyde	-
37	CAR/L/1026135	NS 3254 3389	Barassie PS EO Barassie	EO		Firth Of Clyde	-
38	CAR/L/1026135	NS 3268 3194	Maple Grove PS Troon	EO		Darley Burn	-
39	CAR/L/1026135	NS 3152 3178	Pan Rocks PS EO Troon	EO		Firth Of Clyde	-
40	CAR/L/1026135	NS 3218 3142	Pan Rocks PS EO Troon	EO		Firth Of Clyde	-

Private sewage discharges

SEPA provided information on 69 private sewage discharges, mostly septic tanks with two small sewage treatment works. Of these 69 private sewage discharges, 24 discharge into watercourses which flow into the production area and 45 discharge to land. None discharge directly to the production area

Information was provided pertaining to a further 79 consented discharges, for which the type of discharge was not explicitly stated. Clarification was sought from SEPA, however no response had been received at the time of writing. Therefore, the 51 consents for which PE or other flow data was given are presumed to be septic tanks. Upon examination of the locations provided for these discharges, it is considered most likely that they discharge to land or soakaway.

As noted in the North Bay sanitary survey report (2011) a paper mill is situated south of Shewalton, east of the A78. According to the 2008 environmental statement for the mill, over the year it discharged 2,991,229 m^3 of effluent to water, which included sanitary waste (UPM-Kymmene, 2009). Although paper mill effluent normally contains non-pathogenic faecal indicator bacteria in the absence of a septic waste stream (Archibald, 2000), this mill does note the inclusion of sanitary waste in the effluent. Information subsequently provided by SEPA identified that the UPM waste discharges into the inlet to the Meadowhead STW.

Table 4.2 Consented Private Discharges to Watercourses

No.	Consent Ref.	NGR	Name	Discharge Type	PE	Discharge to
1	CAR/R/1073458	NS 35035 40528	Old Manse, 5 Kirkhill, Old Perceton, Irvine	STE	10	Annick Water
2	CAR/R/1074756	NS 35035 40550	1 and 3 Kirkhill Cottages, Irvine	STE	10	Annick Water
3	CAR/R/1075242	NS 31241 44404	1 Bannoch Cottage, Old Glasgow Rd, Kilwinning	STE	5	Annick Water
4	CAR/R/1075951	NS 35355 39170	14 TO 16, 21, 22,25 Perceton Row	STE	40	Annick Water
5	CAR/R/1012105	NS 34533 33319	Collennan Farm, Loans, Troon, Ayrshire	STE	5	Barassie Burn
6	CAR/R/1022135	NS 29484 45109	Cartleburn Farmhouse, Dalry Road, Kilwinning	STE	6	Cartle Burn
7	CAR/L/1003343	NS 34843 32097	Highgrove House Hotel,Old Loans Road,Troon	STW	60	Cross Burn
8	CAR/R/1077457	NS 33234 33923	Highfield Farm, Auchengate, Irvine	STE	5	Gailes Burn
9	CAR/R/1020912	NS 37137 35207	N0. 7 Smallholding, Harperland, Dundonald, KA	STE	5	Harperland Burn
10	CAR/R/1019262	NS 26573 44476	Diddup Farm,Saltcoats,Ayrshire	STE	6	Laught Burn
11	CAR/R/1063168	NS 27001 43527	6 HOLDING, GREENHEAD, STEVENSTON	STE	5	Loch Canal
12	CAR/R/1063393	NS 26513 42415	Kerelaw Mains, Stevenston, Ayrshire	STE	10	Quarerl Burn
13	CAR/R/1072651	NS 26520 42384	Breakplough Cottage, Stevenson, Ayrshire	STE	5	Quarerl Burn
14	CAR/R/1052656	NS 29647 45745	1 & 2 Dalgarven Mill Cottages, Kilwinning	STE	10	River Garnock

No.	Consent Ref.	NGR	Name	Discharge Type	PE	Discharge to
15	CAR/R/1032439	NS 30920 41850	Travelling Peoples Site,Kilwinning Rd,Irvine	STE	30	River Garnock
16	CAR/R/1050003	NS 31391 42991	Corsehillhead Farm, Kilwinning	STE	6	River Garnock
17	CAR/R/1063118	NS 30905 44360	Castleton Farm, Blair Rd, Kilwinning	STE	5	River Garnock
18	CAR/R/1097201	NS 35013 36948	Shewalton Lodge & Tanglewood, Irvine	STE	12	River Irvine
19	CAR/R/1033724	NS 28720 44136	New house at Whitehirst Park Farm, Kilwinning	STW	6	Smithston Burn
20	CAR/R/1051252	NS 32705 29492	Meadowland	STE	5	South Bay
21	CAR/R/1063128	NS 27061 43614	7 & 7A Greenhead Holding, Stevenston	STE	12	Stevenston Burn
22	CAR/R/1063140	NS 27023 43361	Glenburnie, 5 Greenhead Holding, Stevenston	STE	5	Stevenston Burn
23	CAR/R/1056671	NS 25646 47120	Little Ittington Farm, Ardrossan, Ayrshire	STE	5	Unnamed tributary
24	CAR/R/1008999	NS 26117 45031	Meikle Laught Farm, Saltcoats	STE	7	Gale Burn

In addition to the discharges listed above, SEPA subsequently identified a trade effluent and sewage discharge from Chemring Energetics having a PE of approximately 200 at NS 2816 3689, which lies over 1km offshore of the fast-track production areas. They also identified a surface water outfall serving the NPL industrial estate which discharges offshore to the north of the estate, as well as a small discharge from the former Big Idea site (now closed) into the mouth of the River Irvine.

When combined, the private discharges have a total PE of 1354. Discharges to watercourses, as listed in Table 4.2, have a combined PE of 275. No discharges to land were located near the shoreline and therefore they are not considered to pose a direct risk to contamination at the fishery.

Shoreline Survey Discharge Observations

Fifteen observations of sewage infrastructure were noted during the shoreline surveys. These are listed in Table 4.3 below.

Table 4.3 Discharge-associated observations made during the shoreline survey

No.	Date	Associated photograph	Description
1	15/05/2013	Appendix 5; Fig 11	Concrete covered pipe which looks like it is coming from John Robertson Ham Curers in Ardrossan
2	15/05/2013	-	Pipe covered in concrete
3	14/05/2013	-	Sewage treatment plant only just visible behind railway line. No visible pipes/discharge.*
4	15/05/2013		Sandylands Promenade PS discharge pipe.
5	15/05/2013	Appendix 5; Fig 13	Very large pipe encased in concrete. Could not see if flowing as sea is backed up.
6	14/05/2013	-	Location of Steventson ST.
7	14/05/2013	Appendix 5; Fig 10	Large concrete pipe running directly from factory/Stevenston No discharge. Green algae growing around it. Metal gate with chain across it.
8	14/05/2013	-	Smaller concrete pipe. No discharge. Green algae growing in pipe.
9	15/05/2013	Appendix 5; Fig 14	Sanitary debris on beach.
10	16/05/2013	Appendix 5; Fig 20	At least 4 sanitary towels floating in the sea, several more seen over approximately half an hour's walk along shore.
11	16/05/2013	Appendix 5; Fig 19	Metal pipe on concrete pillars, no flow, approx. 2 feet diameter.
12	16/05/2013	-	Concrete pipe part exposed by sand. End of pipe not visible, approx. 50 cm diameter, not flowing.
13	16/05/2013	Appendix 5;Fig 16 & 17	Public toilets
14	16/05/2013	Appendix 5; Fig 15	An abundance of litter and debris along shore including personal sanitary waste.

* Upon later assessment of the information, this was determined to most likely be Sandylands Promenade PS

Observation 1 was noted to appear to be coming from the ham processing plant. However, it also appears to be very near the reported location of Bath Rocks No. 1 CSO. A water sample taken of the outflow from this pipe returned a result of <1000 *E. coli*/100 ml, below the limit of detection of the dilution range used in the test for this sample. This suggests that the effluent was not likely to have contained sewage. However, it is possible that the CSO pipe may also carry surface water overflow and therefore it is not clear whether the pipe represents a separate outfall from the processing plant or the CSO pipe.

It should be noted that there is a reported potential for viral contamination from this area, over and above that which has usually been associated with sewage discharges in the UK. Hepatitis E virus was found in mussels collected at Ardrossan Beach, as reported in a letter to the online journal Emerging Infectious Diseases (Crossan *et al*., 2012). The Ardrossan Beach sample site was located around the outfall from an abattoir and meat processor (which may have been the pipe noted in Observation 1), and the study suggested that the virus detected in the mussels was most likely of human and/or porcine origin.

Observation 2 appears to relate to Saltcoats, Coalruffie//Seaview Rd CSO.

Observations 3 and 4 report Sandylands Promenade PS to the north and a discharge pipe, which is likely its CSO and EO outfall. While this was correctly identified as sewage infrastructure on the shoreline survey report, it is in fact a pumping station not a sewage treatment plant as stated in the observation.

Observation 5 was reported by SEPA to be the outfall from Moorpark South CSO Stevenston.

Observation 6 reports a large concrete encased pipe going out to sea. This most likely relates to Moorpark Road East CSO.

Observations 7 and 8 refer to two concrete pipes on the shore. Both pipes had green algae growing around their ends indicating possibly high nutrient effluent. At the time of the survey neither pipe was discharging. SEPA identified that observation 7 related to the EO from Stevenston STW.

Observation 10 and 11 are both observations of sanitary debris such as sanitary towels and cotton buds. Sanitary debris is indicative of release of untreated sewage either through CSOs or EOs.

Observation 12 reports a metal pipe supported on concrete pillars. No discharge was noted. This does not appear to correlate with any discharge locations provided by SEPA or Scottish Water.

Observation 13 reports a metal pipe partially buried under sand and seems to extend out into the river Irvine. No discharge was noted. This does not appear to correlate with any discharge locations provided by SEPA or Scottish Water.

Observation 14 notes public toilets. No discharges were noted so these are likely connected to the public network system and are unlikely to have a direct impact on the surrounding area.

Observation 15 again reports sanitary debris, indicating release of untreated sewage.

The relative locations of the reported and observed discharges and the fishery are shown in Figure 4.1.

Summary

Overall, the area has sewage discharges and associated overflows serving a large population and therefore the risk of contamination to waters of the production areas is significant. Highest risk is around the main outfalls (FE, CSO and EO) from Meadowhead STW, which discharges within 100m west of the southern extent of Stevenston Sands Razors 3, and Stevenston STW which discharges into the western side of Stevenston Sands Razors 2 and around the mouth of the River

Irvine/River Garnoch, which discharges near the boundary between Stevenston Sands Razors 2 and Stevenston Sands Razors 3.

The entire near-shore area of the bay is affected by intermittent discharges, and while these should improve with the system improvements currently being undertaken by Scottish Water, this remains a highly urbanised environment that will be affected by sewage contamination and is therefore of higher risk in terms of shellfish production.

List of Acronyms

CSO	Combined Sewage Overflow
DWF	Dry weather flow
EO	Emergency Overflow
FE	Final Effluent
PE	Population Equivalent
PS	Pumping Station
ST	Septic Tank
STW	Sewage Treatment Works
WWPS	Wastewater Pumping Station

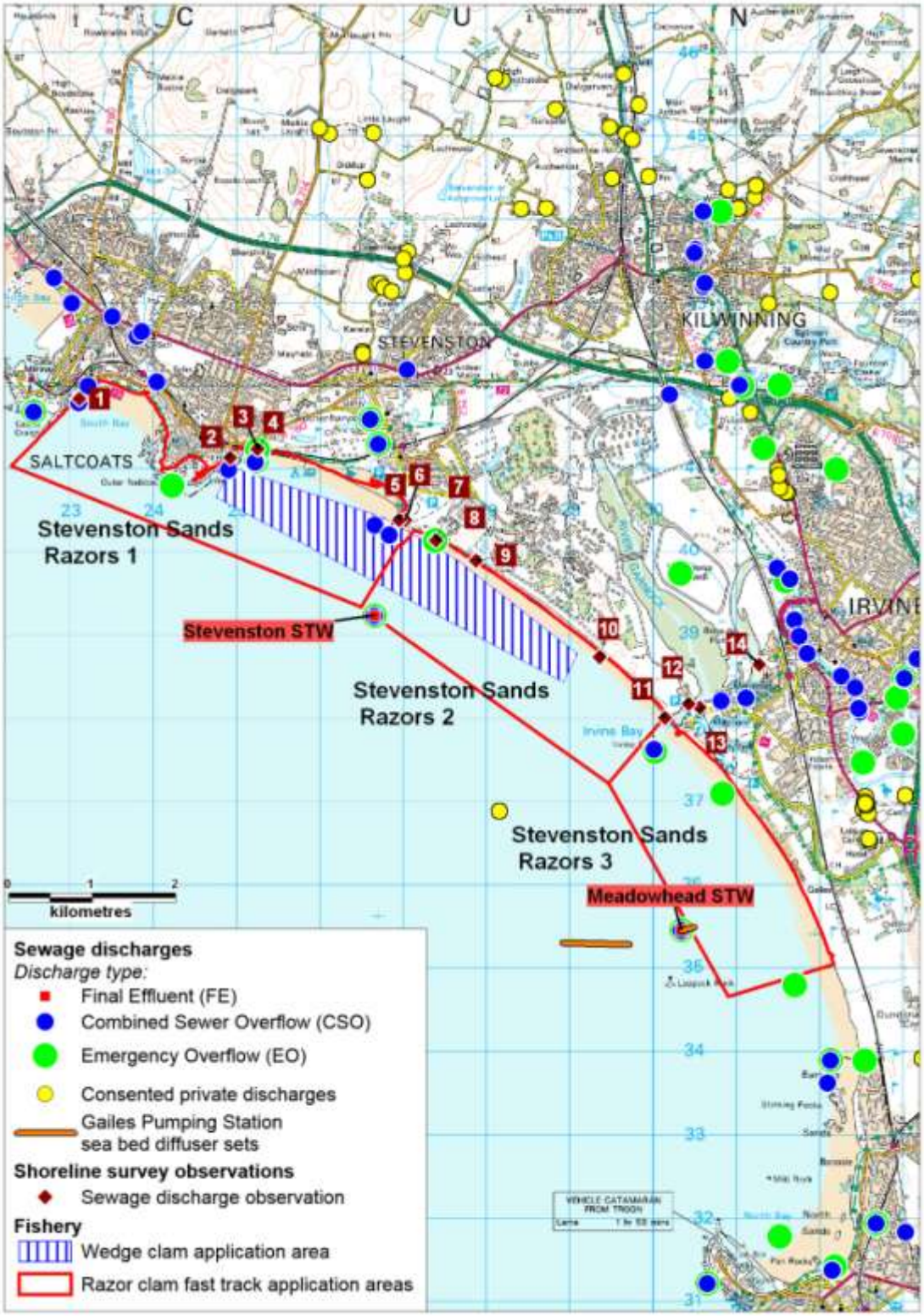


Figure 4.1 Map of discharges for Stevenston Sands

5. Agriculture

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Ardrossan, Stevenston, Kilwinning, Irvine, Dreghorn and Dundonald parishes. Reported livestock populations for the parish in 2012 are listed in Table 5.1. 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 5.1 Livestock numbers in agricultural parishes along the Stevenston Sands coastline 2012

	Ardrossan		**Stevenston**		**Kilwinning**		**Irvine**		**Dreghorn**		**Dundonald**	
	26 km^2		16 km^2		45 km^2		16 km^2		23 km^2		50 km^2	
	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	0	0	*	*	*	*	*	*	*	*
Poultry	*	*	*	*	11	15026	*	*	*	*	12	403
Cattle	16	4648	6	1064	22	4019	*	*	15	3779	20	3361
Sheep	*	*	*	*	*	*	*	*	*	*	19	1886
Other horses and ponies	*	*	8	43	19	110	5	74	5	26	17	90

The numbers of pigs, poultry and sheep were not reported for most parishes due to the small number of holdings. Cattle were present in moderate numbers (in relation to parish size) in all parishes except Irvine where numbers were not reported due to the small number of holdings.

There are two bathing waters with associated catchments in the fishery area. The Saltcoats/Ardrossan bathing water covers South Beach which is the small bay located between on the border of the Saltcoats and Ardrossan agricultural parish boundaries. The catchment draining into the bathing water extends to 9 km^2 and is predominantly rural (68%) with agriculture the main land use. The Saltcoats/Ardrossan bathing waters profile (2013) states that there are several dairy farms in the catchment with the surrounding fields used for grazing and growing grass for silage. The Irvine bathing water is located south of the River Irvine and extends approximately 2.3 km along the coastline. The associated catchment however covers 732 km^2 and is predominantly rural (88%) with agriculture the main land use. The SEPA Irvine bathing water profile (2013) identifies that the upland areas of the catchment support both beef and sheep farming whilst the middle and lower catchments support intensive dairy farming. The report identifies more than 400 farms within the catchment drain into the Irvine bathing water and pollution from

agricultural run-off is thought to occur in the River Irvine. The Irvine catchment is one of fourteen diffuse pollution priority catchments in Scotland, with protection work started in 2010 due to be completed in 2015. Both the Diffuse Pollution Management Advisory Group and Scotland's Environmental and Rural Services group aim to tackle diffuse pollution in the Irvine area by providing co-ordinated education and advice to rural land managers.

The average overall grazing intensities in the River Irvine catchment during May to September are 1.3 cattle, 0.9 beef cattle and 2 sheep per hectare (Aitken, et al., 2001). During the same time frame, approximately 437,000 tons of agricultural waste is produced with 36% of stored slurry and 21% of solid manure spread on the catchment. Dairy cattle enterprises were reported to be concentrated around the major centres of population, Irvine and Kilmarnock, with beef cattle intensity highest in the Kilwinning area. The majority of the catchment is reported as having a low intensity of sheep as is reflected by the 2012 livestock numbers listed for the neighbouring agricultural parishes in Table 5.1. The size of the cattle and dairy industry within the area is reflected by the production of wastes during animal storage, as listed in Table 5.2.

Table 5.2 Production of wastes during animal storage (6 months)[1]

Parish	Dairy Waste Storage (t)	Beef Waste Storage (t)	Total Storage (t)
Stevenston	2,080	643	2,722
Kilwinning	14,424	5,335	19,760
Irvine	916	275	1,191
Dundonald	10,589	2,776	13,365
Dreghorn	17,744	346	18,090
Ardrossan	12,765	2,673	15,438
Total	58,518	13,048	70,616

[1](Aitken, *et al*., 2001)

The locations and extents of the parish areas are shown in Figure 5.1. Overall, the River Irvine catchment has above national average stocking densities as although it only has 1.5% of the total agricultural land area of Scotland, it has 15% of the total number of dairy cows, highlighting the importance of the area to the Scotland's dairy industry.

An additional significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit on 15th January 2013. During the shoreline survey no livestock or farms were observed along the survey route. Cattle were heard at the abattoir in Saltcoats but were not seen. The sewage discharge from the abattoir is discussed in Section 4. It was observed that arable and cattle farming dominate the landscape inland from Saltcoats to Irvine.

Wyer *et al* (1999) looked at agricultural source pollution within the River Irvine catchment, and studies indicated that relatively little of the faecal indicator bacteria loadings found during base flow conditions were attributable to agricultural sources. This proportion increases, however, after heavy rainfall.

Overall, agricultural sources of faecal contamination to the fishery is likely to be moderate due to the large cattle and dairy industry present in the area. Agricultural waste and faecal matter is likely to run off into the River Irvine and depending on flow dynamics in the bay would affect the southern end of the fishery. The Saltcoats/Ardrossan catchment would also contribute to faecal contamination at the northeastern end of the shellfish beds. Contamination is expected to increase during May to September when stored slurry and solid manure is spread over both catchments.

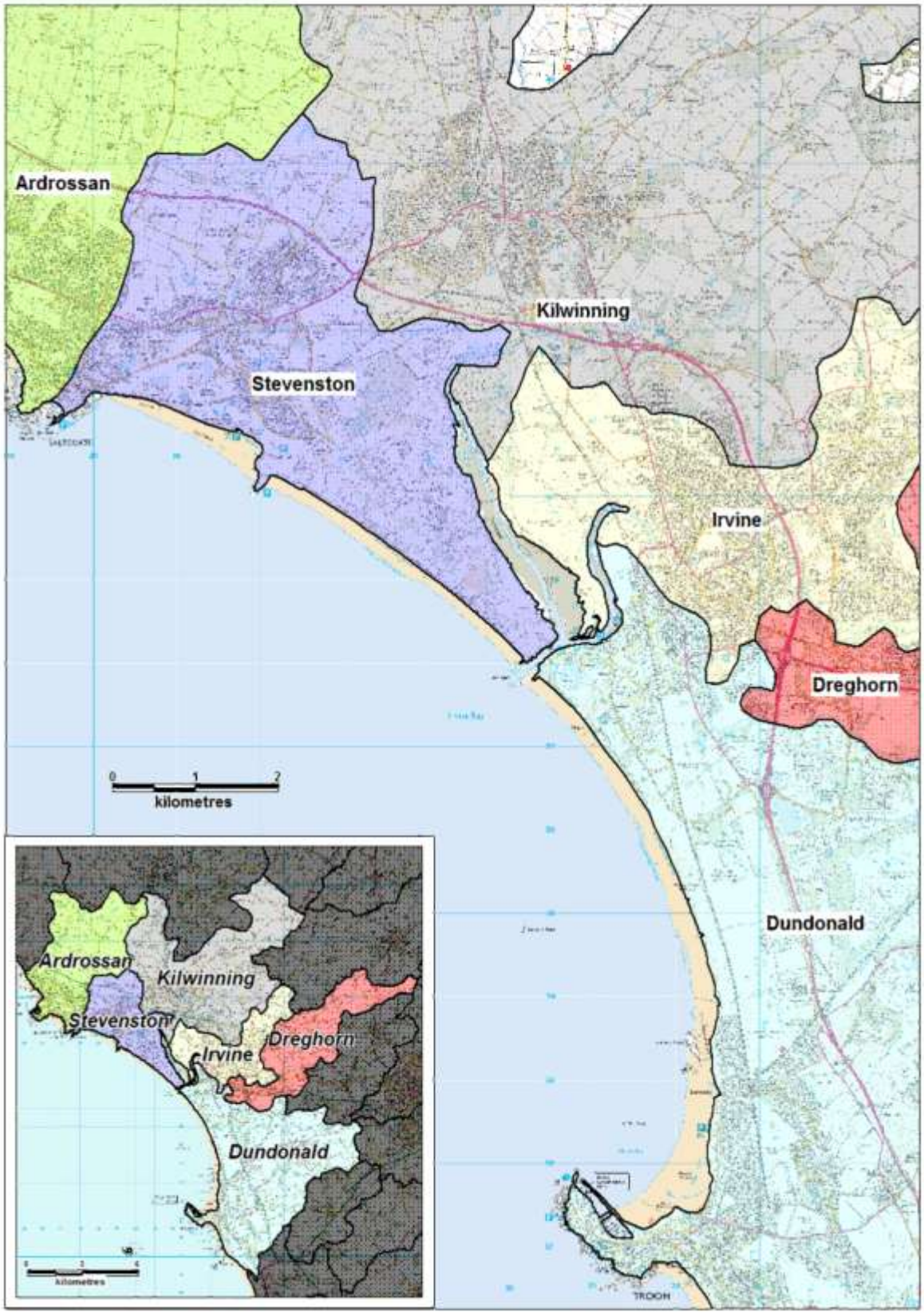


Figure 5.1 Agricultural parish boundaries

6. Wildlife

Seals

The common/harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*) are commonly found around the sandy beaches at Stevenston Sands.

In a study by the Special Committee on Seals (SCOS, 2011) the harbour seal population in the general area was noted to have varied over the last decade. Population counts from aerial surveys for years 2007 and 2009 were at 5914 for the area spanning Ardnamarchan Point to the Mull of Kintyre, whilst in 2000 and 2003 it was at 7003. No seals were observed along Stevenston beach, but were noted to the north and west of the Firth of Clyde on the Isle of Arran.

Aerial population counts of grey seals have also been conducted, with between 5-20 seals observed along Stevenston beach. A large group of approximately 100 individuals was also noted west on the Mull of Kintyre.

No seals were observed during the shoreline survey.

Cetaceans

Regular sightings of cetaceans have been recorded for the Firth of Clyde, the water body adjacent to Stevenston Sands. The most commonly spotted is the harbour porpoise (*Phocoena phocoena*), with Risso's dolphins (*Grampus griseus*), minke whales (*Balaenoptera acutorostrata*) also recorded (Hebridean Whale and Dolphin Trust, 2013). No cetaceans were observed during the survey.

Seabirds

Seabird 2000 census data (Mitchell, et al., 2004) for the area within a 5 km radius of Stevenston Sands was obtained and is summarised in Table 6.1. This census, undertaken between 1998 and 2002 covered twenty five species of seabird that breed regularly in Britain and Ireland.

There are two key colonies of birds to the north and south of Stevenston Sands that are comprised of *Larus* spp*.* and *Phalacrocorax* spp*.* These areas are comprised of nesting sites, and to the south territory for the *Phalacrocorax sp.* and *Larus marinus*. Individuals and smaller colonies of nesting species were also noted on land surrounding Stevenston Sands.

Table 6.1 Seabird species found at Stevenston Sands, from the Seabird Census 2000.

Common name	Species	Count*	Site
Lesser Black-backed Gull	*Larus fuscus*	7666	Occupied nests and Territory
European Herring Gull	*Larus argentatus*	3046	Occupied nests and Territory
Great Blacked-backed Gull	*Larus marinus*	400	Occupied territory
Great Cormorant	*Phalacrocorax carbo*	44	Occupied nests
European Shag	*Phalacrocorax aristotelis*	498	Occupied nests
Black Guillemot	*Cepphus grylle*	356	Individuals on sea

*Counts relating to occupied nests or territories multiplied by 2 to reflect the number of individuals present

Several key bird habitats lie close to Stevenston Sands. The Garnock estuary south of Stevenston hosts significant populations of wintering and migratory waders and wildfowl. Numbers of duck and other waterfowl can peak at >1000 in winter. (Ardeer Friends, 2103a). In autumn, waterflowl (particularly geese and swans) migrate through the area.

The golf courses surrounding Stevenston Sands also provide ponds that support a large breeding waterbird population. Greater scaup use the area around Auchenharvie Golf Course to roost: the site is now classified as a site of national importance for the species (Ardeer Friends, 2013b). Other birds that have been noted in the area include several species of Skua (Anon, 2011).

During the shoreline survey birds were the only wildlife observed. The most numerous were gulls with approximately 274 observed along the shoreline. The densest collection was observed on the roof of the abattoir noted at Saltcoats. Crows were the second most common species observed and nine swans were also observed.

Deer

There are anecdotal accounts of Roe deer around the local nature reserve at Ardeer (Irvine Bay Regeneration Company, 2011). Two Roe deer were observed grazing on fields at the Nobel Business Park, near the Irvine/Garnock confluence.

Otters

There is some evidence of the Eurasian otter (*Lutra lutra*) in the area around Stevenston Sands. At Kerelaw Glen, otters are reported to use Stevenston Burn to travel between Stevenston Beach and Ashgrove Loch, further inland. (Ardeer Friends, 2013c). No otters were seen during the shoreline survey.

Overview

A summary of seabird census data and shoreline survey wildlife observations is shown on the map in Figure 6.1. Species potentially impacting on Stevenston Sands include seals, cetaceans, seabirds and deer. The most significant source of faecal contamination associated with wildlife is likely to be that from seabirds. However, as the population data indicates significant sites at both ends of the area, and shoreline survey observations

noted the presence of numbers of birds in between those sites, the contamination from seabirds is likely to occur from time to time across the shellfish beds.

Figure 6.1 Map of wildlife around Stevenston Sands

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1 below:

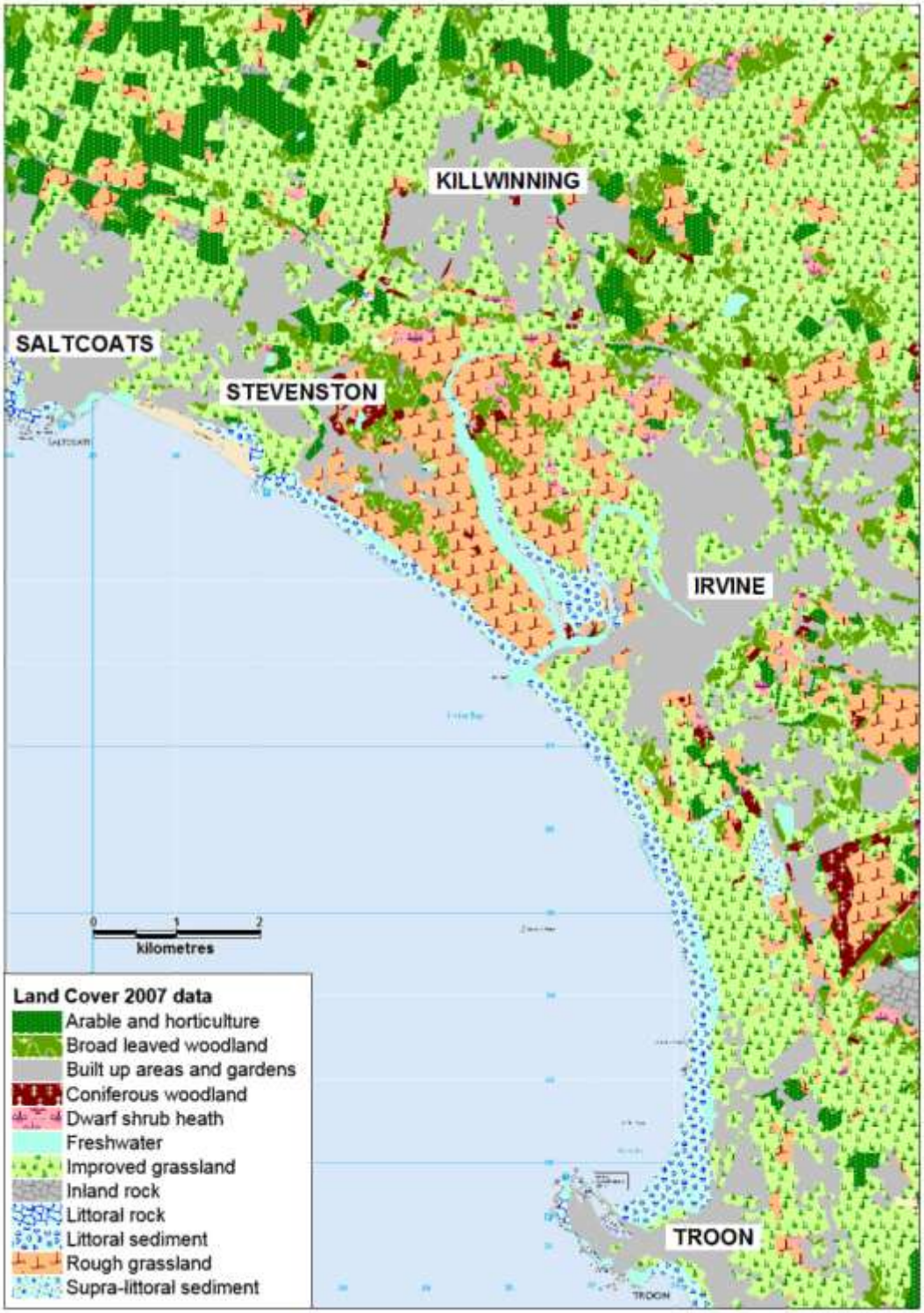


Figure 7.1 LCM2007 land cover data for Stevenston Sands

Built-up area, improved grassland, arable and rough grassland are the predominant land cover types on the low-lying shoreline adjacent to the Stevenston Sands shellfish bed. The towns of Saltcoats, Stevenston, Kilwinning, Irvine and Troon are shown as built up areas and gardens, surrounded by arable land, rough grassland and improved grassland. Some of the developed area of Stevenston and areas of improved and rough grassland border the shellfish bed.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 1.2 – 2.8x10^9 cfu/km^2/hr for urban catchment areas, approximately 8.3x10^8 cfu/km^2/hr for areas of improved grassland and approximately 2.5x10^8 cfu cfu/km^2/hr for rough grazing (Kay, *et al*., 2008). 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).

The highest potential contribution of contaminated run-off to the Stevenston Sands shellfish bed is from the urban/suburban areas of Saltcoats, Stevenston and Irvine, the areas of improved grassland located along the shoreline and the areas of agricultural land located inland. The potential contribution of contaminated run-off to the shellfish farm would be highest in these areas.

8. Watercourses

There are two large rivers and one smaller watercourse entering Irvine Bay in the vicinity of Stevenston Sands. The rivers are the Irvine and Garnock, which actually combine before reaching the sea: the combined flow is referred to as the Irvine/Garnock confluence in this report. The Irvine and Garnock also receive flow from a number of other watercourses, including Lugton Water, Dusk Water, Rye Water and Bombo Burn (River Garnock) and Annick Water and Carmel Water (River Irvine).

The shoreline survey was conducted between the 14th and 16th May 2013. No precipitation fell over the 48 hrs preceding the survey: during the survey rain fell on the morning of the 14th May and there was a shower early afternoon on the 16th May.

During the shoreline survey only one watercourse, Stevenston Burn was measured, whilst the two large rivers were deemed too unsafe to measure accurately. Samples were taken at all three watercourses observed during the survey and are listed in Table 8.1.

Table 8.1 Watercourse observations for Stevenston Sands

No.	Date	NGR	Description	Width (M)	Depth (m)	Flow (m^3/d)	*E. coli* (cfu/ 100 ml)	Loading (*E. coli* per day)
1	15/05/2013	NS 2660 4085	Stevenston Burn	6.93	0.25	27000	2600	$7.1x10^{11}$
2	16/05/2013	NS 3127 3865	River Irvine	Too wide to measure			600	-
3	16/05/2013	NS 3047 3808	Garnock and Irvine rivers	Too wide to measure			700	-

-No value calculated

For the North Bay Sanitary Survey Report (FSAS/Cefas, 2012), an average combined flow of the two rivers of 5.7 m^3/s was used to estimate loading. Using the *E. coli* result for the sample taken at the confluence of the rivers (Table 8.1, No.3; 700 *E. coli* cfu/100 ml) yields an estimated loading of 3.4×10^{12} *E. coli*/day. The loading estimated for Stevenston Burn from the recent shoreline survey measurements was $7.1x10^{11}$ *E. coli* per day. Overall freshwater-borne contamination is expected to have a significant impact on the fishery, predominantly from the mouth of the Irvine/Garnock but also in the vicinity of Stevenston Burn.

Subsequent information on the results of bacteriological monitoring undertaken by SEPA at the River Irvine/River Garnock confluence during the 2013 bathing season showed a range from <100 to 75000 *E. coli*/100 ml, while samples taken at Stanley Burn ranged from 300 to 39000 *E. coli*/100 ml. SEPA noted that the upper range values were associated with rainfall events. These values indicate that the sample results obtained during the shoreline survey were relatively low compared to contamination levels found during rainfall events.

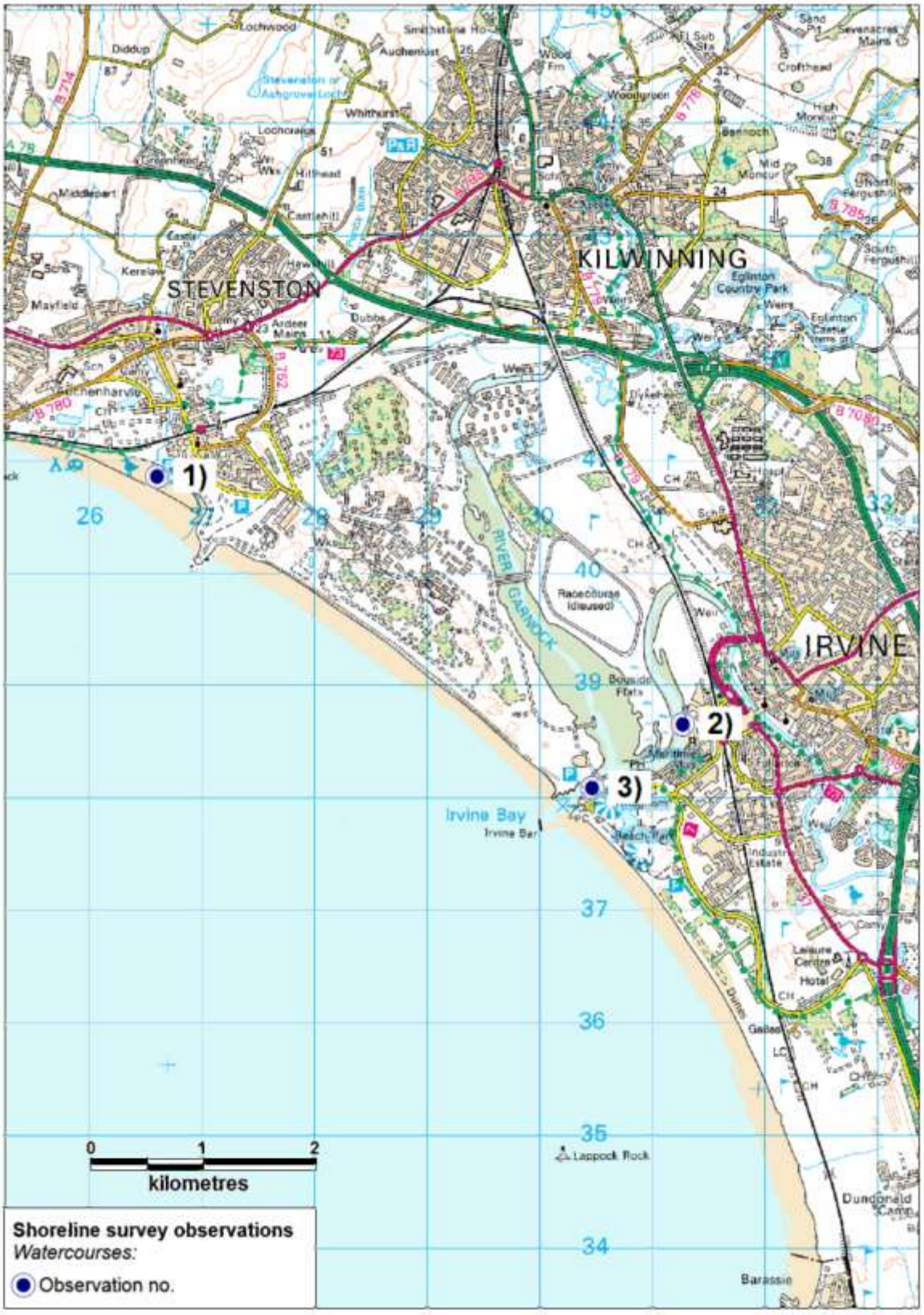


Figure 8.1 River/stream sampling locations at Stevenston Sands

9. Meteorological Data

The nearest weather station is located at Gailes, situated approximately 6 km south east of the fishery; however data for this station was unavailable at the time of writing this report. The second nearest weather station is located at Hunterston No 3, situated approximately 14 km north west of the fishery; however data was unavailable for 23 % of the days during January 2007 – August 2012. The third nearest weather station with a more complete rainfall data history is located at Prestwick Gannet, situated approximately 17 km south east of the fishery. Rainfall data was available for January 2007 – August 2012 at the time of writing this report. The nearest wind station is also situated at Prestwick Gannet. Conditions may differ between this station and the fishery due to the distances between them. Data for these stations was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Stevenston Sands.

9.1 Rainfall

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 box and whisker plots in Figures 9.1 and 9.2, present a summary of 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 at the midline. 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 *.

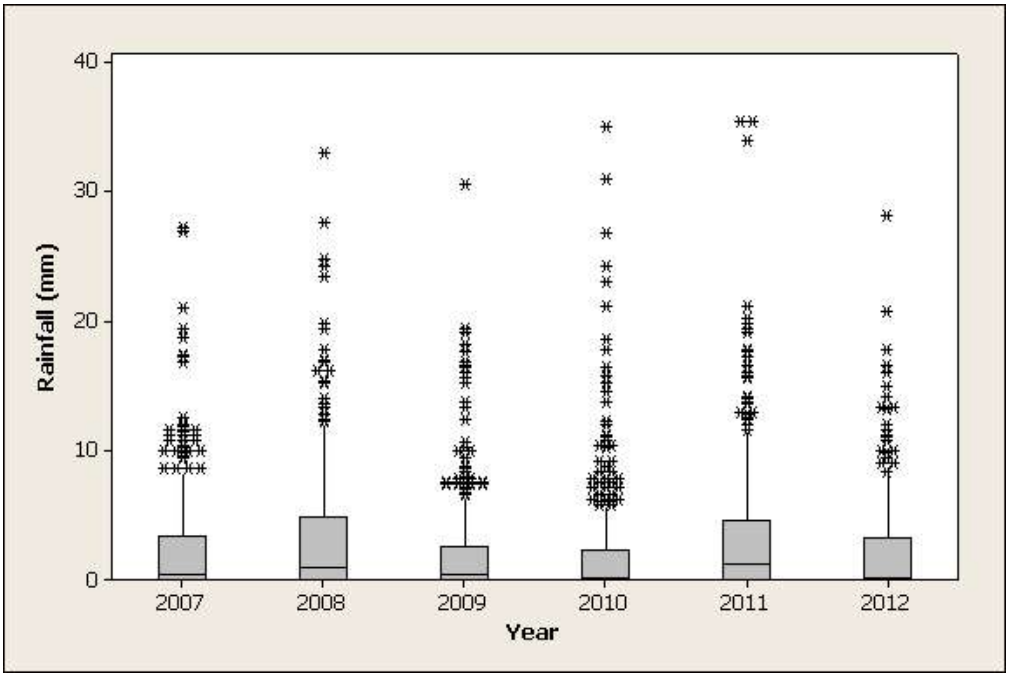


Figure 9.1 Box plot of daily rainfall values by year at Prestwick Gannet (2007 – 2012)

Daily rainfall values varied from year to year, with 2010 being the driest year. The wettest year was 2008. Extreme (for the area) rainfall values of more than 30 mm/d occurred in four out of the six years, although the number of more extreme rainfall events varied between those years.

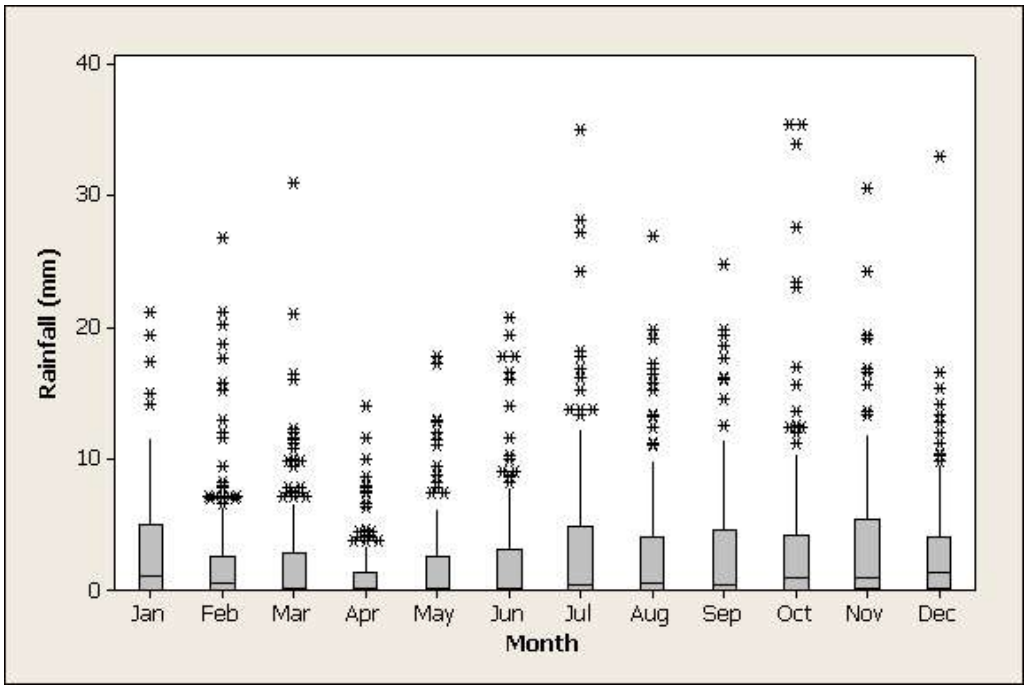


Figure 9.2 Box plot of daily rainfall values by month at Prestwick Gannet (2007 – 2012)

Daily rainfall values were higher during the summer, autumn and winter. Weather was drier from February to June. Rainfall values exceeding 30 mm/d were seen in March,

July, November and December. No rainfall values >200 mm/day were seen in April and May.

For the period considered here (2007 – 2012) 56 % of days received daily rainfall of less than 1 mm and 7 % of days received rainfall of over 10 mm.

It is therefore expected that run-off due to rainfall will be higher during the summer, autumn and winter months. However, extreme rainfall events leading to episodes of high run-off can occur in most months and when these occur during generally drier periods, they are likely to carry higher loadings of faecal material that has accumulated on pastures when greater numbers of livestock were present.

9.2 Wind

Wind data was collected from Prestwick Gannet and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

Overall the predominant annual wind direction is WSW. There was no marked change in wind direction throughout the months; however winds were stronger in the winter months than in the summer months.

Wind is an important factor in the spread of contamination as it has the ability to drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the production area.

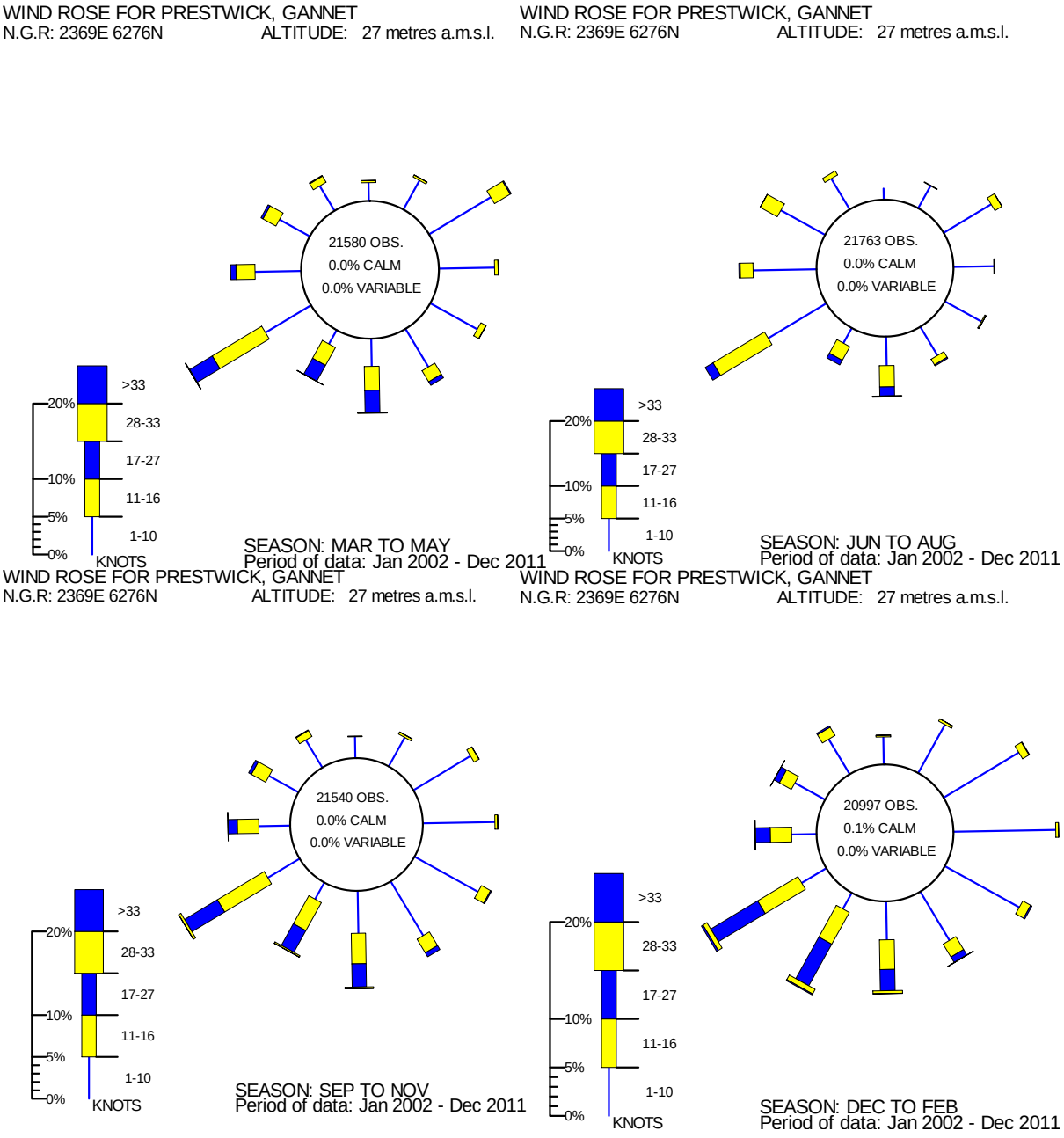


Figure 9.3 Seasonal wind roses for Prestwick Gannet

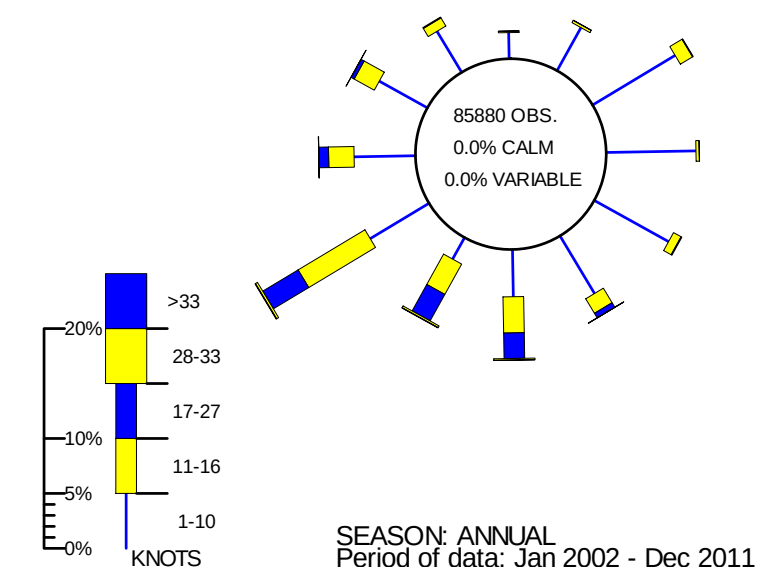


Figure 9.4 Annual wind rose for Prestwick Gannet

10. Classification Information

Stevenston Sands has been the subject of multiple fast track applications for both wedge clams and razor clams and also standard track applications for each species. There is no full classification applying for either species as at the time of drafting this report. Fuller information on the fast track applications is given in Section 2.

However there have been multiple fast track production areas on the site and some are currently effective. South of Stevenston Sands, there is an area at North Bay that is classified for razor clams. North Bay was first given a classification for razor clams (*Ensis* spp) in 2006. The historical and current classifications for the area are shown below.

Table 10.1 North Bay (Razor Clam) Classification history

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2006	B	B	B	B	A	A	A	A	A	A	A	A
2007	B	B	B	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	A	A	A	A	A	A	A
2009	A	A	A	A	A	A	A	A	A	A	A	A
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A	A	A	A	A	A	A	A	A	A
2012	A	A	A	A	A	A	A	A	A	A	A	A
2013	A	A	A									

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all wedge clam samples assigned against the fast track sites within the Stevenston Sands production area for the period between 01/01/2008 to the 11/07/2013 were extracted from the FSAS database in July 2013 and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. These results have been combined into a Stevenston Sands site for ease of analysis. All *E. coli* results were reported as most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid. Results for razor clam samples assigned to North Bay production area for the period between 01/01/2008 to the 11/07/2013 were also extracted and validated in July 2013. Three new fast track applications for razor clams have been submitted for Stevenston Sands, plus one standard application covering all three fast track areas. Razor clam results from North Bay are included as they will indicate the potential contamination levels and effect of environmental variables that will pertain at the southern end of the Stevenston Sand razor areas.

All sample results reported as <20 *E. coli MPN*/100 g were reassigned a value of 10 *E. coli MPN*/100 g for the purposes of statistical evaluation and graphical representation.

Stevenston Sands Fast Track – Wedge clams

All sixteen fast track wedge clam samples were recorded as validated. The first eight fast track samples had unverified NGRs, with a further two unverified taken in 2013. One sample taken in April 2013 plotted ashore and was omitted from analysis. All samples were received at the laboratory within 48 hr window of sample collection, with box temperatures of <8°C.

North Bay – Razor clams

Two North Bay razor clam samples were recorded in the database as rejected and were omitted from further analysis. All samples assigned to North Bay had verified NGRs. One sample plotted on the shoreline, outside of the estimated extent of the razor clam bed and was omitted. Two samples had incorrect NGR prefix grid letters and were assigned the correct prefix of ‘NS’. All samples were received at the laboratory within 48 hr window of sample collection, with box temperatures of <8°C. Twenty-four samples had *E. coli* results of <20 *E. coli* MPN/ 100 g.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary		
Production area	Stevenston Sands Wedge Clams	North Bay
Site	Stevenston Sands Fast Track	Barassie
Species	Wedge clams	Razor clams
SIN	NA-627-1239-23 and NA-638-1284-23	SA-337-719-16
Location	Various	Various
Total no of samples	16	51
No. 2008	-	7
No. 2009	-	8
No. 2010	-	11
No. 2011	-	10
No. 2012	6	11
No. 2013	10	4
Results Summary		
Minimum	20	<20
Maximum	3500	5400
Median	790	20
Geometric mean	588	32
90 percentile	2240	228
95 percentile	3500	1800
No. exceeding 230/100g	13 (81%)	3 (6%)
No. exceeding 1000/100g	6 (38%)	3 (6%)
No. exceeding 4600/100g	0	1 (2%)
No. exceeding 18000/100g	0	0

Fast track sampling for Stevenston Sands was started in 2012. Over 80% of the samples assessed here yielded results >230 *E. coli* MPN/ 100 g, with a median level of 790 *E. coli* MPN/ 100 g.

Sampling at North Bay has increased in frequency since 2009. The majority of sample results have been low, with only 6% exceeding 230 *E. coli* MPN/ 100 g, although those three results were all greater than 1000 *E. coli* MPN/ 100 g. The median was low at 20 *E. coli* MPN/ 100 g.

Too few samples have been taken at Stevenston Sands to undertake analyses with respect to environmental factors and so this is only shown for the razors at North Bay.

11.3 Overall geographical pattern of results

The locations for the samples with verified locations are shown in Figure 11.1 with the symbol size graduated by the magnitude of the *E. coli* result.

Figure 11.1 Stevenston Sands wedge clam and North Bay razor clam sampling locations

Fast track samples for Stevenston Sands have been taken at the headland just south of Stevenston Beach (East Shore). All seven samples were taken <500 m apart. North Bay razor clam samples have been taken 6 km southwards of the Stevenston Sands

samples, within North Bay. Samples have been taken within <1 km of one another. The majority of samples taken between years 2011 to 2013 were within <500 m of the RMP, with samples taken in years 2008-2010 mainly taken approximately 700 m southeast of the RMP. The highest result was taken in 2009, <700 m south of the RMP.

Samples of the two species have been taken at opposite ends of Irvine Bay and there is no information on spatial effects between the location of the two sampling clusters.

11.4 Overall temporal pattern of results

Scatterplots of individual species *E. coli* results against date are presented in Figures 11.2 and 11.3.

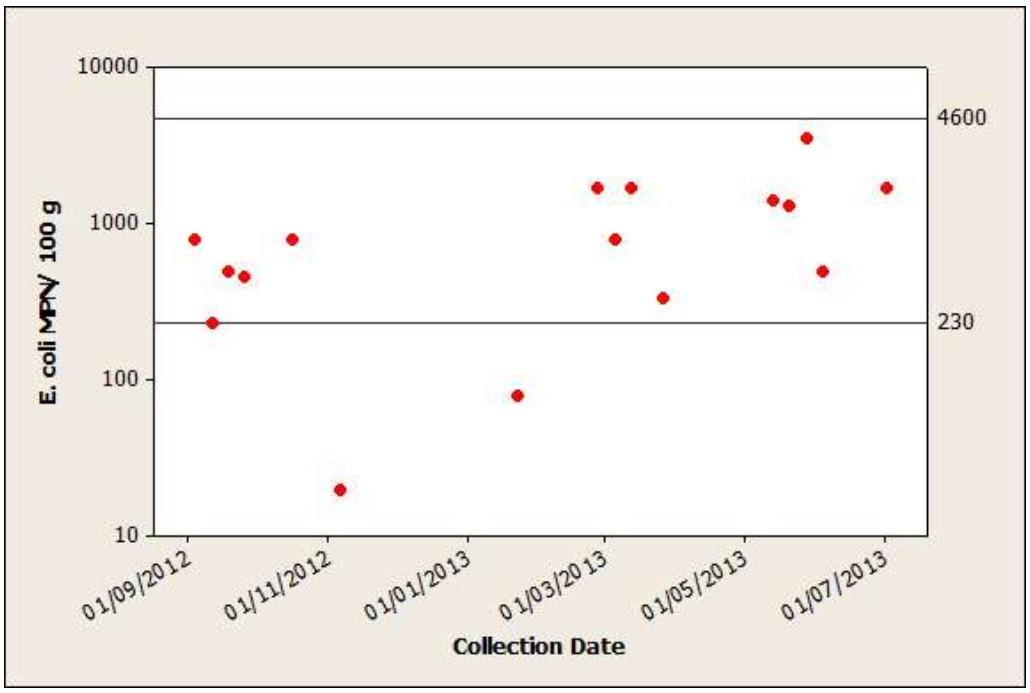


Figure 11.2 Scatterplot of Stevenston Sands wedge clam *E. coli* results by date

Too few results are available to determine whether there has been any trend in the level of contamination in the wedge clams. The majority of the results of samples taken in 2013 were between 1000 and 4600 *E. coli* MPN/ 100 g.

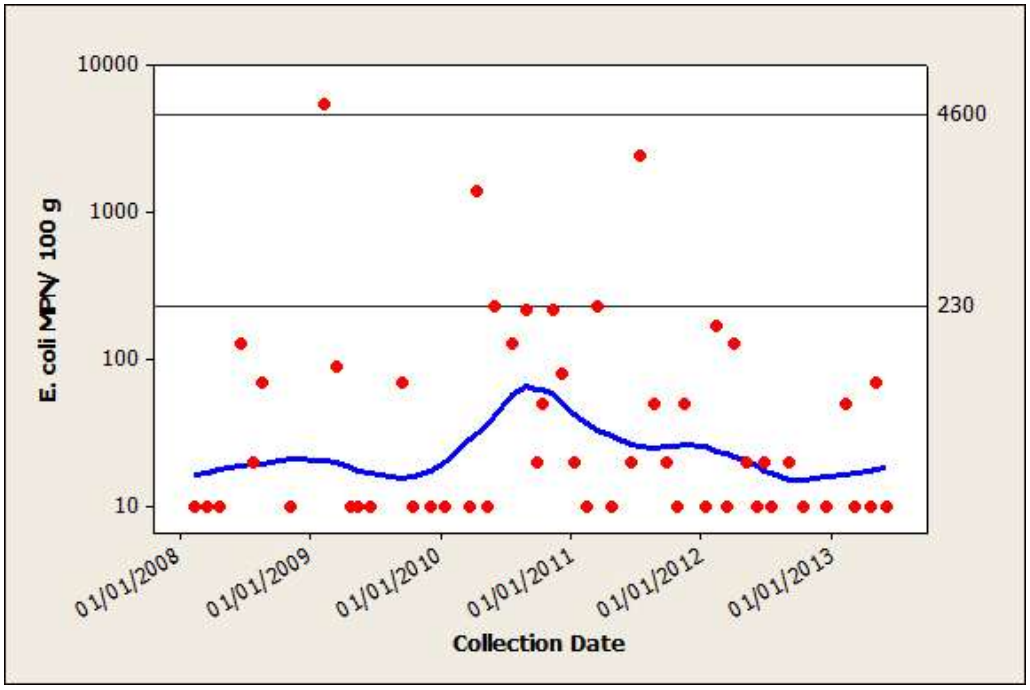


Figure 11.3 Scatterplot of North Bay razor clam *E. coli* results by date with a lowess line

The dataset in Figure 13.3 is fitted with a lowess trend line. Lowess trendlines allow for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the lowess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

Contamination levels in razor clam samples increased between years 2010 and 2011, with an increase in number of results >100 *E. coli* MPN/ 100 g. The highest results occurred in years 2009, 2010 and 2011.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns in human distribution. All of these can affect levels of microbial contamination, causing seasonal patterns in results. Scatterplots of individual species *E. coli* results by month, overlaid with a lowess line are presented for North Bay razors in Figure 11.4. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis).

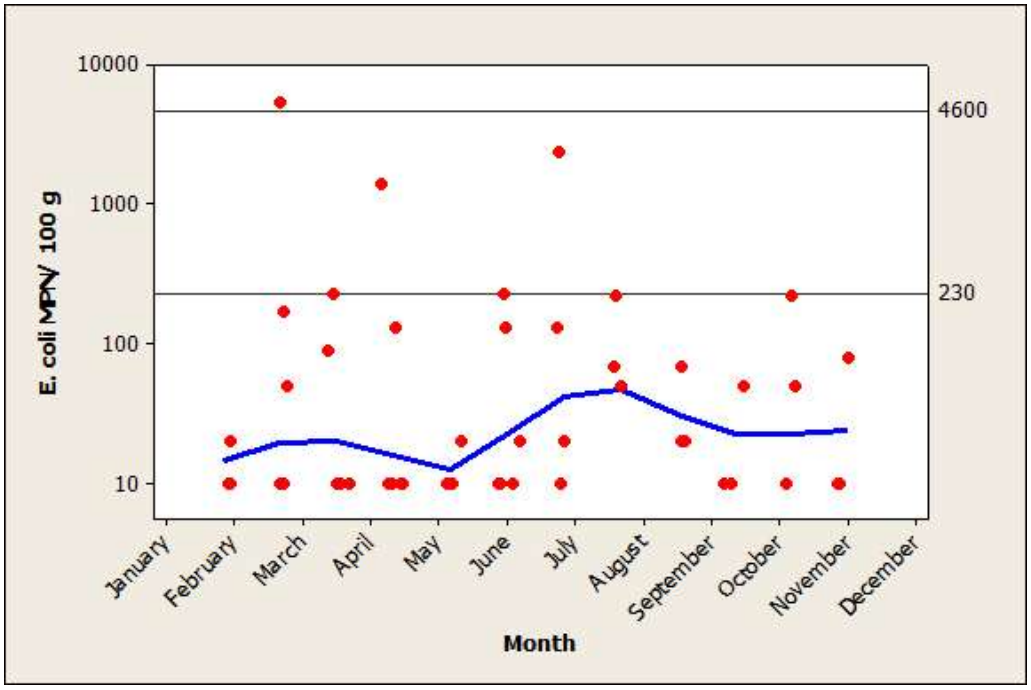


Figure 11.4 Scatterplot of North Bay razor clam *E. coli* results by month, fitted with a lowess line

Sampling varied across months with only two samples taken in November, compared to six taken in March, April and June. No samples were taken in December or January. The highest result was from a sample taken in February. All months except for August had contamination levels of <20 *E. coli* MPN/ 100 g.

For statistical evaluation, seasons were split into spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). Boxplots of individual *E. coli* results by season are presented in Figure 11.5. No statistically significant difference was found between razor clam results by season (one-way ANOVA, $F = 0.58$, $p = 0.629$, Appendix 4).

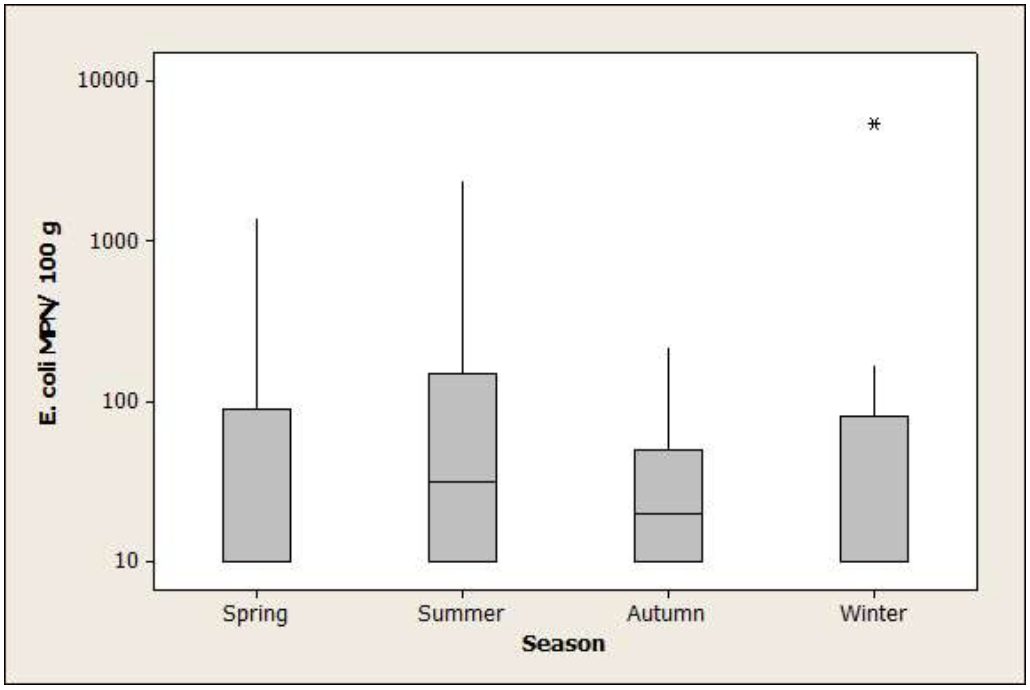


Figure 11.5 Boxplot of North Bay razor clam *E. coli* results by season

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, wind, sunshine and temperature can all influence the flux of faecal contamination into growing waters (Mallin et al, 2001; Lee and Morgan, 2003). The effects of these influences can be complex and difficult to interpret. This section aims to investigate and describe the influence of these factors individually (where appropriate environmental data is available) on the sample results using basic statistical techniques.

11.6.1 Analysis of results by recent rainfall

The nearest weather station with available rainfall data was at Prestwick, approximately 16.8 km SE of the production area. Rainfall data was purchased from the Meteorological Office for the period of 01/01/2008 to 31/12/2012 (total daily rainfall in mm). Data was extracted from this for North Bay razor clam sampling occasions between 01/01/2008 until 31/12/2012.

Two-day antecedent rainfall

A scatterplot of razor clam *E. coli* results against total rainfall recorded on the two days prior to sampling is presented in Figure 11.6. Rainfall was recorded 44 of 51 razor clam samples. Jittering was applied to individual results from razor clam and Pacific oyster samples at 0.01 (x-axis) and 0.001 (y-axis) respectively.

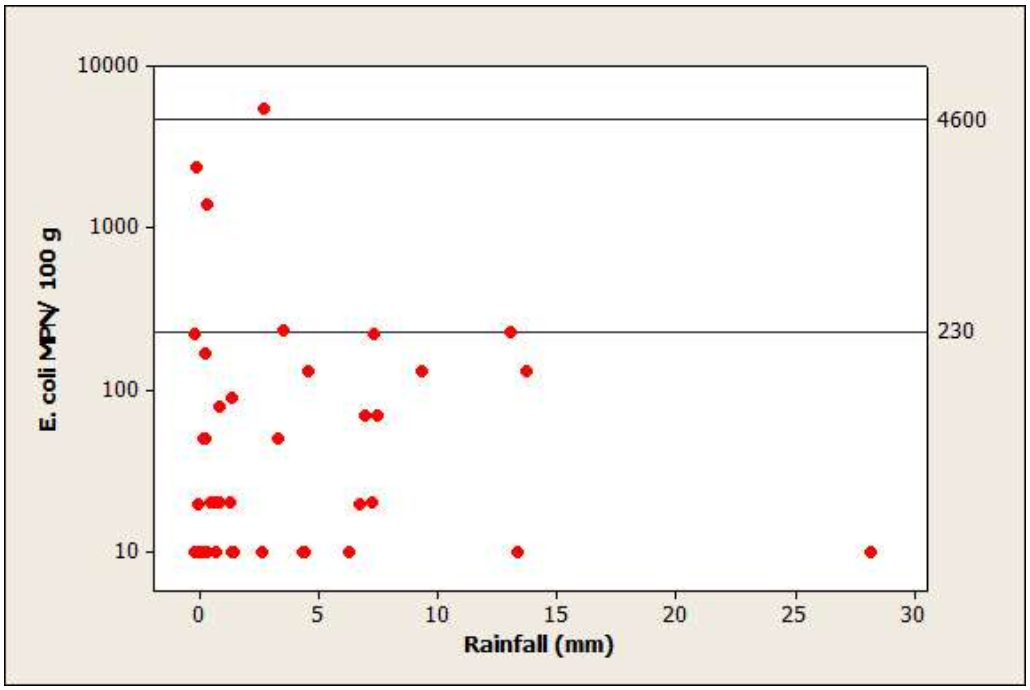


Figure 11.6 Scatterplot of North Bay razor clam *E. coli* results against rainfall in the previous two days

No significant correlation was found between razor clam results and 2-day rainfall (Spearman's rank correlation r = 0.150, p = 0.332). The highest *E. coli* results (>1000 *E. coli* MPN/ 100 g) were seen after low levels of rainfall (<5 mm) over the two days prior to sampling.

Seven-day antecedent rainfall

The effects of heavy rainfall may take differing amounts of time to be reflected in shellfish sample results in different system, the relationship between rainfall in the previous seven days and sample results was investigated in an identical manner to the above. A scatterplot of razor clam *E. coli* results against total rainfall recorded for the seven days prior to sampling is presented in Figure 11.7. Jittering was applied to results at 0.02 (x-axis) and 0.001 (y-axis) respectively.

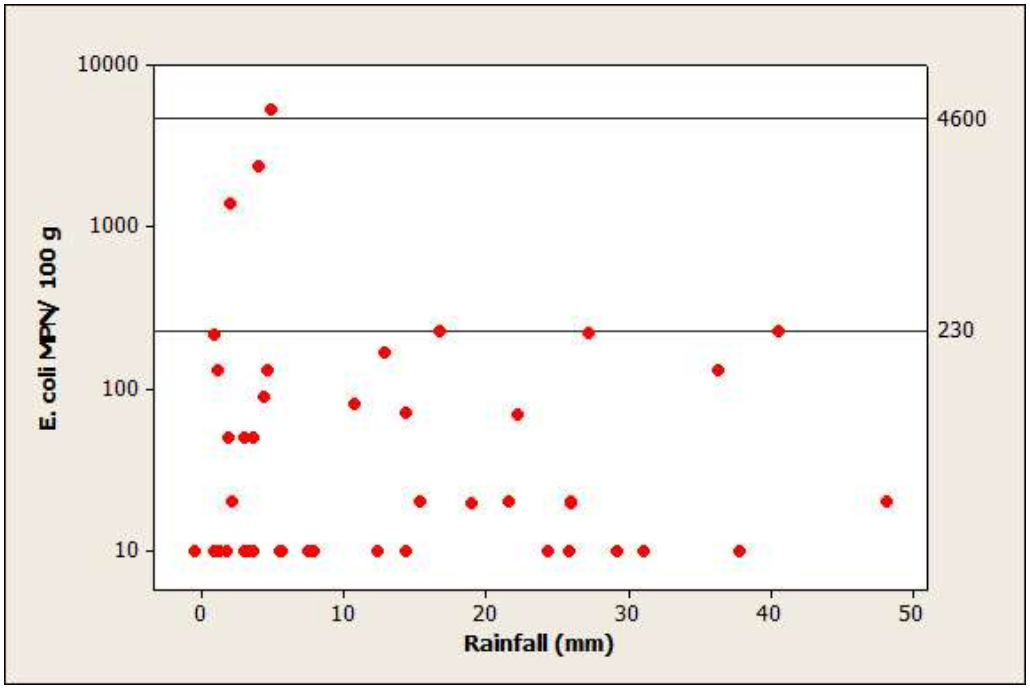


Figure 11.7 Scatterplot of North Bay razor clam *E. coli* results against rainfall in the previous seven days

No significant correlation was found between razor clam results and 7-day rainfall. (Spearman's rank correlation r = 0.061, p = 0.695). High *E. coli* results were seen after low levels of rainfall over the seven days prior to sampling.

11.6.2 Analysis of results by tidal height and state

Spring/Neap Tidal Cycle

Spring tides are large tides that occur fortnightly and are influenced by the state of the lunar cycle. They reach above the mean high water mark and therefore increase circulation and particle transport distances from potential contamination sources located on the shoreline. The largest (spring) tides occur approximately two days after the full/new moon, located at about 45^{o} on the polar plot. The tides then decrease to the smallest (neap) tides, at about 225^{o}, before increasing back to spring tides. Polar plots of individual species *E. coli* results against the lunar cycle are presented in Figures 11.8. It should be noted that local meteorological conditions such as wind strength and direction can influence height of tides and this is not taken into account.

Neap tides

Decreasing tides

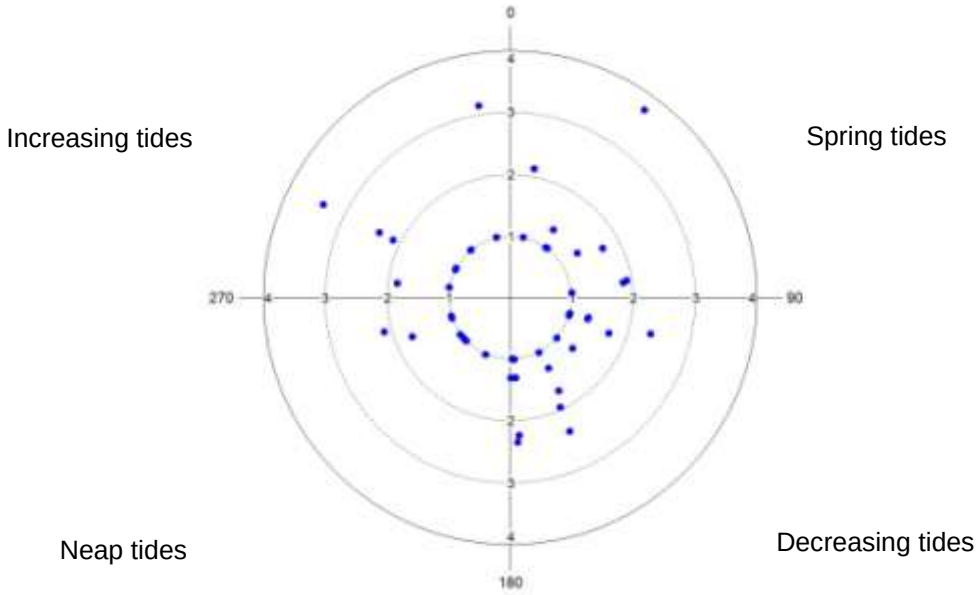


Figure 11.8 Polar plot of North Bay razor clam log_{10} *E. coli* results on the spring/neap tidal cycle

No statistically significant correlation was found between North Bay razor clam log_{10} *E. coli* results and the spring/neap tidal cycle (circular-linear correlation r = 0.168, p = 0.258).

High/Low Tidal Cycle

High and low water data from Troon were extracted from POLTIPS-3 in July 2013. This site was the closest to the production area and it is assumed that tidal flow will be very similar between sites. A polar plot of *E. coli* results against the high/low tidal cycle is shown in Figure 11.9. No statistically significant correlation was found between North Bay razor clam log_{10} *E. coli* results and the high/low tidal cycle (circular-linear correlation r = 0.096, p = 0.643).

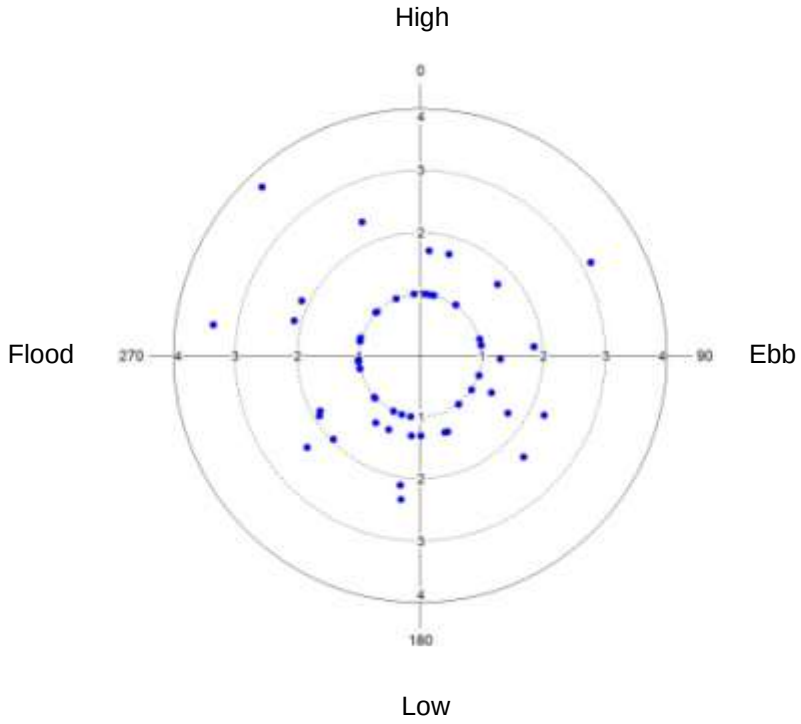


Figure 11.9 Polar plot of North Bay razor clam log_{10} *E. coli* results on the high/low tidal cycle

11.6.3 Analysis of results by water temperature

Water temperature can affect survival time of bacteria in seawater (Burkhardt, *et al*., 2000). It can also affect the feeding and elimination rates in shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. Water temperature is obviously closely related to season. Any correlation between temperatures and *E. coli* levels in shellfish flesh may therefore not be directly attributable to temperature, but to the other factors e.g. seasonal differences in livestock grazing patterns. Scatterplots of North Bay razor clam *E. coli* results against water temperature are presented in Figure 11.10. Water temperature was only recorded for 28 of 51 razor clam results. Jittering was applied at 0.02 (x-axis) and 0.001 (y-axis) respectively.

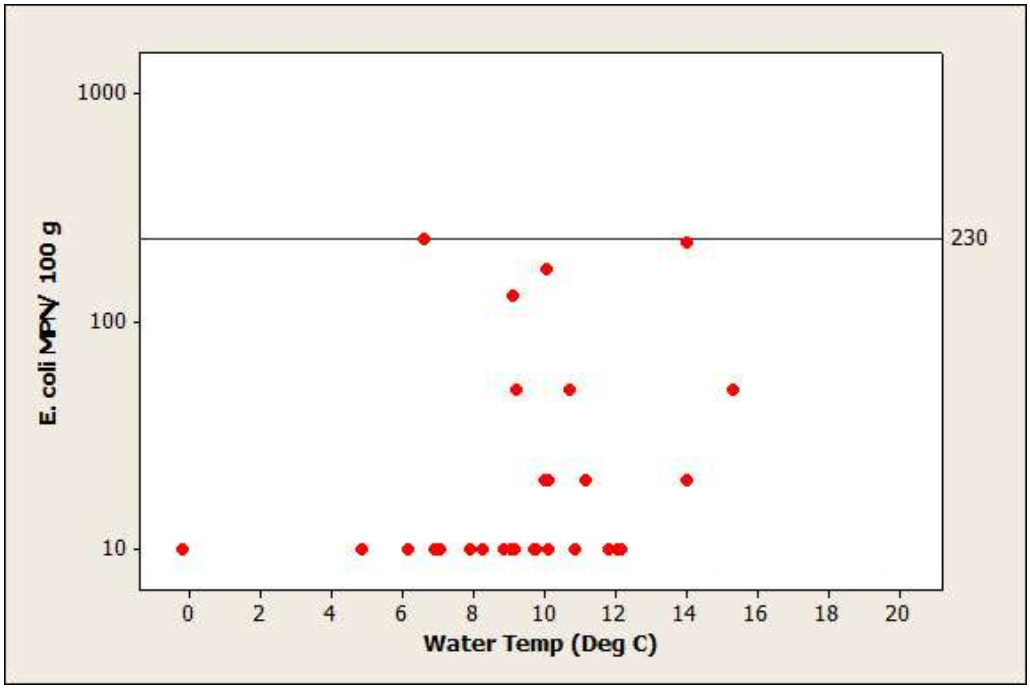


Figure 11.10 Scatterplot of North Bay razor clam *E. coli* results and water temperature

No statistically significant correlation was found between razor clam *E. coli* results and water temperature (Spearman's rank correlation r = 0.290, p = 0.134).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence and hence freshwater-borne contamination at a site. Salinity measurements were only reported for 9/51 North Bay razor clam samples and so analysis was not undertaken for this variable.

11.7 Evaluation of results over threshold values for each site

Wedge clam sampling results exceeding 1000 *E. coli* MPN/100 g for Stevenston Sands fast track site are listed in Table 11.2.

Table 11.2 Stevenston Sands wedge clam *E. coli* results >1000 *E. coli* MPN/100 g

Collection Date	*E. coli* (MPN/ 100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal state (high /low)	Tidal State (spring /neap)
26/02/2013	1700	Unverified	-	-	4	-	Low	Spring
12/03/2013	1700	Unverified	-	-	5	-	Flood	Spring
13/05/2013	1400	NS 2678 4024	-	-	5	-	Ebb	Spring
20/05/2013	1300	NS 2685 3991	-	-	7	-	Ebb	Neap
28/05/2013	3500	NS 2682 3990	-	-	11	-	Ebb	Spring

-No data available

Five of the 16 samples taken at Stevenston Sands fast track classification had results >1000 *E. coli* MPN/ 100 g. Contamination levels varied between 1300 and 3500 *E. coli* MPN/ 100 g. The highest result of 3500 was attributed to a sampling location off the promontory at Beach Park, near to the centre of the RMZ (see Figure 11.1). Samples were taken between February and May 2013, with three of the elevated samples taken in May. Sampling locations were similar, though unverified for two of the samples. Rainfall data was not available for these dates. Water temperature varied between 4-11^{o}C. Three of five samples were taken on an ebb tide and four of five samples on a spring tide.

Razor clam results exceeding 1000 *E. coli* MPN/100 g for North Bay are listed in Table 11.3.

Table 11.3 North Bay razor clam *E. coli* results >1000 *E. coli* MPN/100 g

Collection Date	E. coli (MPN/ 100g)	Location	Two day rainfall (mm)	Seven day rainfall (mm)	Salinity (ppt)	Tidal state (high/low)	Tidal State (spring/neap)
10/02/2009	5400	NS 3155 3357	2.8	4.8	-	Flood	Spring
13/04/2010	1400	NS 3155 3357	0.0	1.8	-	High	Increasing
13/07/2011	2400	NS 3173 3420	0.0	3.6	34	Flood	Increasing

-No data available

Only three samples had elevated results, which varied between 1400 and 5400 *E. coli* MPN/ 100 g. One result was taken in each year between 2009 and 2011, in the months February, April and July. The highest result was taken in February 2009. Two of the samples were attributed to the same location at NS 3155 3357, off Stinking Rocks. However, a large proportion of the sampling locations recorded for North Bay razors had the same NGR to 10 m accuracy.

Rainfall in the two and seven days prior to sampling was low. No water temperatures were recorded for these samples. One salinity measurement was recorded at 34 ppt for the sample taken in 2011. All three results were taken between a flood and a high tide, and on a spring/increasing tidal state.

11.8 Summary and conclusions

Stevenston Sands Fast Track – Wedge Clams

Sixteen samples have been taken for the Fast Track site at Stevenston Sands from September 2012 to July 2013. Sample results have varied between 20 and 3500 *E. coli* MPN/ 100 g, with 13 of16 results exceeding 230 *E. coli* MPN/ 100 g. There was an upward trend in results between February to May, with the highest result taken in May 2013. Ten of the samples had unverified NGRs, with the remaining six taken close to the headland to the south of Stevenston Beach. There were too few results available to analyse the effect of environmental factors.

North Bay - Razors

Razor clam sample have all been taken within North Bay, approximately 6 km south of where the fast track wedge clam samples have been taken. Most results have been <20 *E. coli* MPN/ 100 g although three results exceeded 1000 *E. coli* MPN/ 100 g.

No statistically significant correlation was found with any of the environmental variables investigated.

Overall

From the limited extent of data available for the wedge clams at Stevenston Sands, it appears that they are markedly more contaminated than the razor clams at North Bay. It is not possible from the present data to determine whether this is due to the respective geographical locations, species differences, or both. There is also no data from intermediate locations to determine spatial effects across the bay.

12. Designated Waters Data

Shellfish Water

Stevenston Sands does not lie within a designated shellfish growing water. The nearest designation is the North Ayrshire shellfish growing waters located 6 km north of the fishery and is therefore not considered to be representative of the area.

Bathing Waters

Irvine

The Irvine designated bathing water lies immediately southwest of the mouth of the Irvine/Garnock confluence and thus is immediately adjacent to the Stevenston Sands Razors 3 fast track area. A review of historical compliance of the site with the bathing water standard identified that since 2000, the site has met the mandatory standard (but not the guideline standard) in 8 years and failed the standard in 4 years (in 2004, 2009, 2010 and 2011; EEA, 2013). This indicates that the bathing water at that location is subject to significant contamination on at least a periodic basis.

The Irvine bathing water is part of the SEPA daily water quality prediction and signage network (SEPA, 2013A). Throughout the bathing season daily water quality predictions are displayed on an electronic message sign and are also available via the SEPA website and the Beachline phone number (08452 30 30 98).

Saltcoats/Ardrossan

The Saltcoats/Ardrossan (South Beach) designated bathing water lies to the northeast of Stevenston Sands. A review of historical compliance of the site with the bathing water standard identified that since 2000, the site has met the mandatory standard (but not the guideline standard) in 8 years and failed the standard in 4 years (in 2000, 2001, 2008 and 2009; EEA, 2013). This indicates that the bathing water at that location is subject to significant contamination on at least a periodic basis.

Saltcoats/Ardrossan designated bathing water is also part of the SEPA daily water quality prediction and signage network (SEPA, 2103B).

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

The region under assessment is within an area defined as the Clyde Sea. The Clyde Sea is defined as the marine tidal inlet which encompasses the Firth of Clyde and the Clyde Estuary and the sea lochs to the north of the Firth and Loch Ryan to the south (Scottish Government, 2012). The Firth of Clyde is the body of water in the southern part of the Clyde Sea that forms the seaward boundary with the North Channel which is the deep water passage between Scotland and Northern Ireland. The Clyde Estuary refers to the area of water of the Clyde River particularly where it exits into the northern part of the Firth of Clyde.

Stevenston Sands in North Ayrshire is situated on the eastern edge of the Firth of Clyde. Stevenston Sands is located within Irvine Bay, north of Irvine roughly 35 km southwest of Glasgow. Irvine Bay takes the form of a long scallop-shaped embayment between Ardrossan and Troon and is approximately 14 miles in length. The coastline around Stevenston Sands is heavily populated and contains four main settlements: Irvine to the southeast where most of the land is very flat, Stevenston to the north, Ardrossan/Saltcoats to the northwest and the town of Troon, a busy golfing area, to the south. Ardrossan is the main ferry terminal for sailings to the Isle of Arran and is an extremely popular tourist destination. The hydrographic study area also contains Ayr Bay situated south of Troon. The study area in its entirety is shown in Figure 13.1 and is contained within the red lines.

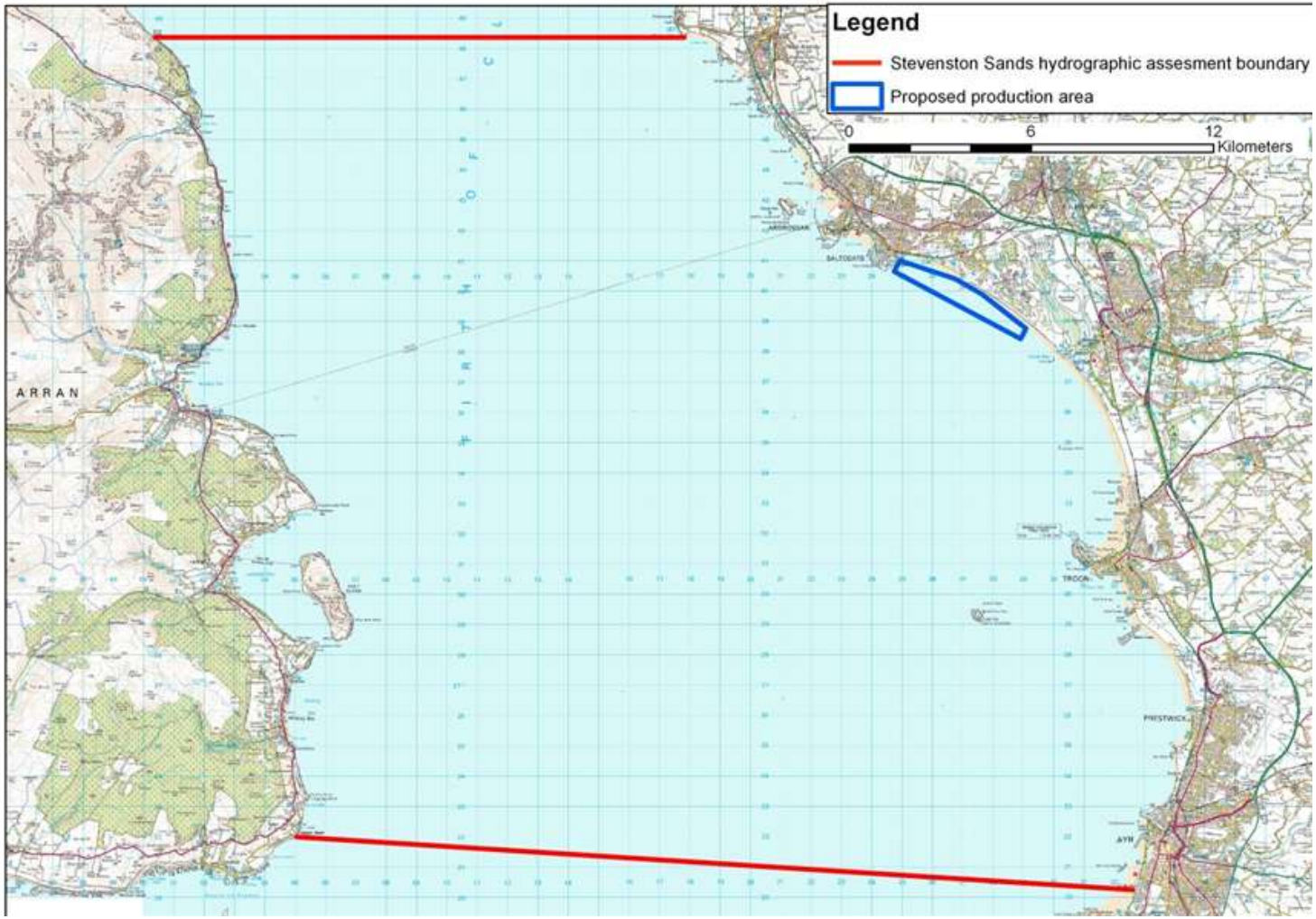


Figure 13.1 Extent of hydrographic study area

Coordinates for the middle of the Firth of Clyde:

55° 37.27’ N 004° 45.09’ W

NS 16995 33429

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

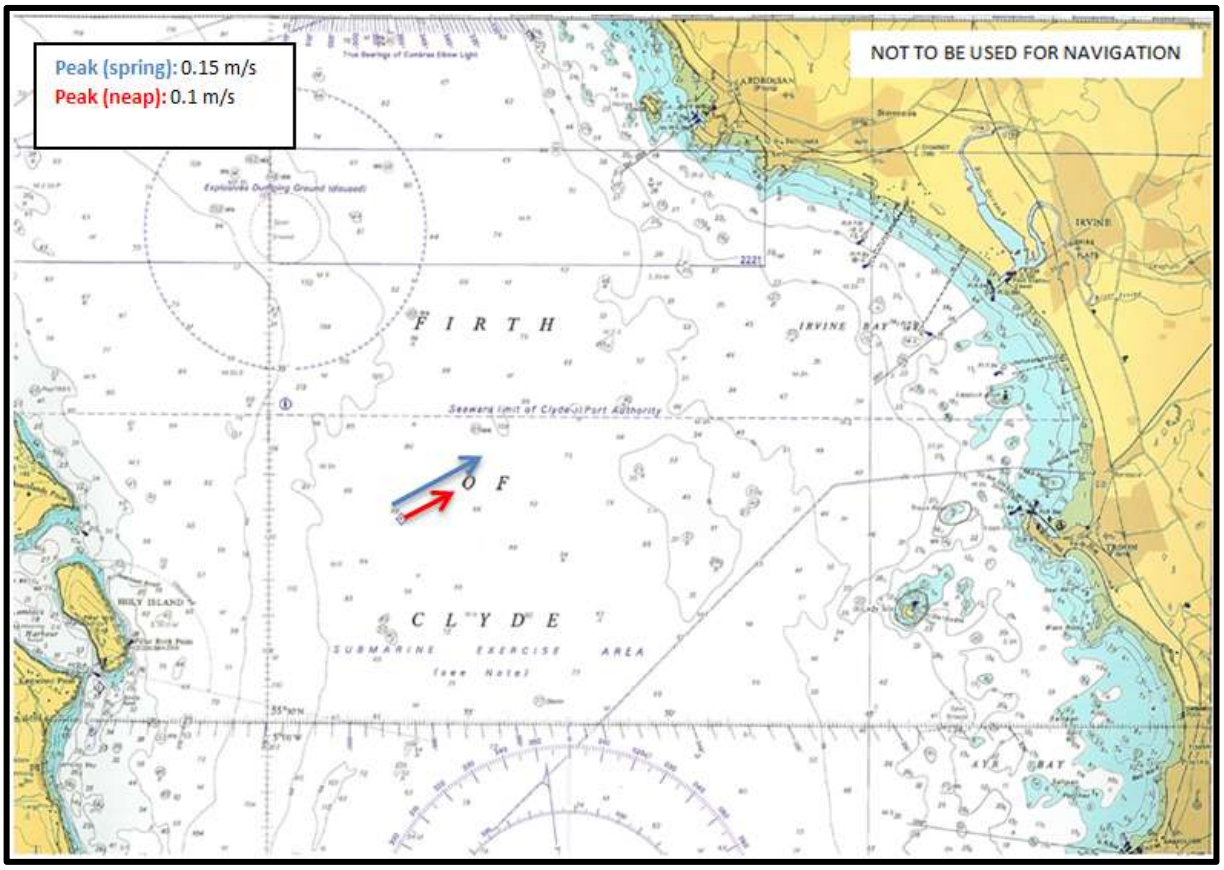


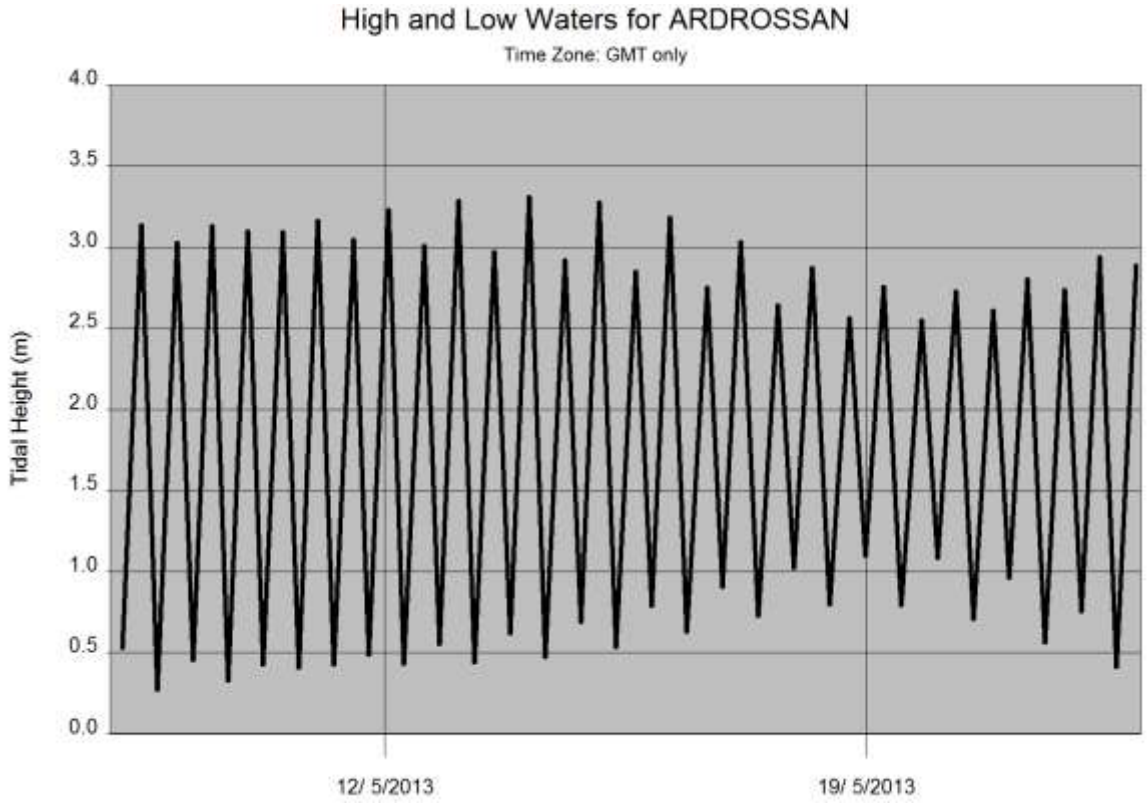
Figure 13.2 Admiralty chart (2126) extract for Stevenston Sands. Note that the length of the peak flow arrows approximately equate with the transport distance during the flood or ebb phases of the tide.

Figure 13.2 shows the relatively simple bathymetry of Stevenston Sands and the wider assessment area of the Firth of Clyde. The Firth of Clyde is a wide and deep coastal embayment. Between the Isle of Arran and the Ayrshire coast, the Firth contains a large basin called the Arran Basin. The Firth has an area of 3680 km^2 (Muller, et al., 1995b) and a volume of 1 x 10^{11} m^3 (Dooley, 1979). The maximum charted depth is 175 m in the Arran Deep opposite Ardrossan to the north of the study area. The Firth of Clyde is separated from the North Channel by a sill at a depth of 40-50 m (Dooley, 1979; Rippeth, et al., 1995) in the southwest. The particular bathymetry of the area is typical of a wide fjord system (Muller, et al., 1995) where the circulation is influenced by the pressure gradients created by wind, tide and freshwater input (Edwards, et al., 1986). Within Irvine Bay which faces SW, the gradient of the slope offshore increases gradually and uniformly to around 15 m within a distance of around 1 km from the shore. Irvine Bay has a maximum depth of 48 m where it then opens out to the Firth of Clyde.

13.2.2 Tides

The study area in the Firth has the typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information. The nearest location to Stevenston Sands for tidal predictions is Ardrossan.

Standard tidal data for Ardrossan are given below (from Admiralty Surveys) and the spring/neap cycle of tidal height around the time of the planned survey (15th May 2013) is shown in figure 13.3.



Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Figure 13.3 Two week tidal curve for Ardrossan.

Tidal Heights for Ardrossan (from Admiralty Chart 2126):
Mean High Water Springs = 3.2 m
Mean Low Water Springs = 0.5 m
Mean High Water Neaps = 2.7 m
Mean Low Water Neaps = 1.1 m

Tidal Ranges:
Mean Spring Range = 2.7 m
Mean Neap Range = 1.6 m

13.2.3 Tidal Streams/Currents

Tidal currents in the Firth of Clyde are typically weak in the deep water and are generally < 0.2 m/s in magnitude for most of the year (Edwards, et al., 1986; Lewis,

1986; Simpson & Rippeth, 1993). Tidal currents are weak due to the attenuation of the tide as it propagates from the North Channel and crosses the broad, shallow sill at the entrance to the Clyde Sea (Edwards, et al., 1986). Further, rotational effects due to Coriolis forces can be important in this relatively wide fjord.

There is a tidal diamond in the middle of the Firth of Clyde at the same latitude as Troon approximately 17 km offshore from which the following assessments on tidal flow are derived. However it should be remembered that data at tidal diamonds may only be relatively crude indications of flow characteristics derived from short current records (e.g. Bell and Carlin, 1998).

The flow is generally aligned in the directions of 050°/230°. The flood tide flows predominantly northeast (NE) and the ebb flows southwest (SW) but the flow is not strongly rectilinear along the axis of the Firth of Clyde. The maximum rates are 0.3 knots (0.15 m/s) at springs and 0.2 knots (0.10 m/s) at neaps. There will be variations to these values across the assessment area in the vicinity of bays and headlands but these values of peak flow are comparable with those reported in the scientific literature (Simpson & Rippeth, 1993).

In general, residual flows in the Firth of Clyde are related to distribution of freshwater over the area further enhanced by any large-scale wind forcing (Lewis, 1986). Due to the rather persistent stratification, there is typically a two layer flow with residuals in the upper layer being mainly southward with a magnitude of ~0.01 m/s (Midgley, et al., 2001).

Within Irvine Bay where the proposed production area is located, there are some direct measurements of residual flow and of dispersion (Lewis, 1986). Residual flow has been measured in two directions, alongshore and offshore. The mean residual current alongshore has been estimated as approximately 0.05 m/s in a northwest direction (Lewis, 1986) with greatest velocity in the surface waters of approximately 0.08 – 0.1 m/s. In the offshore direction, there is a bi-directional circulation with surface waters flowing offshore with a return flow of < 0.01 m/s. This circulation is greatest opposite the Irvine-Garnock Estuary.

The north-westerly residual flow in Irvine bay is also reproduced in a 3D model covering the North Channel and Clyde Sea giving a depth mean flow speed of around 0.02 m/s (Davies & Hall, 2000). This flow pattern and rate is enhanced during SW winds such that a cyclonic gyre (anti-clockwise) is set up within the assessment area.

Dispersion in the surface waters of Irvine Bay has been measured using dye release experiments (Lewis, 1986). The main conclusion of this work is that dispersion is enhanced by vertical mixing in the surface layer such that variation in surface flow with depth causes the dye patch to spread. The evolution of the dye patch showed elongation in the alongshore direction and advection to the northwest over the first

eight hours following release. Later the patch moved offshore and southwards, marking out a circular path consistent with the residual currents.

The average longitudinal dispersion (in the alongshore direction) was 2.17 m^2/s and the average transverse dispersion (in the offshore direction was 0.25 m^2/s (Lewis, 1986). Both of these values are greater than 0.1 m^2/s which is a typical default value for SEPA management purposes for particulate deposition modelling (SEPA, 2005).

13.2.4 River/Freshwater Inflow

The mean annual run off for the Clyde Sea is typically 300 m^3/s with a large seasonal variation of ± 200 m^3/s (Midgley, et al., 2001). Other estimates of annual run off for the region are 60 – 700 $m^3\ s^{-1}$ (Poodle, 1986).

The Clyde Estuary to the north is the source of two thirds of the freshwater input into the Firth (Edwards, et al., 1986). In the year August 1989 – July 1990 it provided 4390 x 10^6 m^3 of freshwater into the Firth and, combined with the freshwater input from the rivers Ayrshire, Arran and the sea loch system which amounted to 1880 x 10^6 m^3, this gives a total input of freshwater into the Firth of Clyde of 6270 x 10^6 m^3 (Muller, et al., 1995b). In the same period, the total rainfall over the Firth of Clyde was approximately 5190 x 10^6 m^3. This was calculated from the average daily rainfall measurements collected from three gauging stations at Rothesay, Carskiey and Doonholm.

The Firth of Clyde is described as a ROFI (Region of Freshwater Influence) and has a mean annual salinity of between 32.5 and 32.8 (Edwards, et al., 1986) with the fresher areas being within the Inner Firth and the salinity gradually increasing towards the North Channel (S = 34).

At Stevenston Sands there are three main rivers that flow into the area. The River Garnock, River Irvine and Lugton water combine into one large freshwater pathway through an estuary mouth around 100 m wide (Lewis, 1986)) which discharges into Irvine Bay. The combined long term average flow rate for River Garnock and River Irvine is 15 $m^3\ s^{-1}$ with a seasonal range of 0.2 – 570 $m^3\ s^{-1}$ (Poodle, 1986).

To the south of the study area the River Ayr has a long term average flow rate of 15.5 $m^3\ s^{-1}$ with a seasonal range of 0.6 – 400 $m^3\ s^{-1}$ (Poodle, 1986), therefore of comparable magnitude to the estuary in Irvine Bay.

The inshore waters of Irvine Bay are highly influenced by the input of brackish water from the Irvine-Garnock Estuary and are therefore stratified because of this input. Reported values in the surface are as low as s = 20 (Lewis, 1986).

In the surface layers of the Arran Basin, the water is of consistently low salinity with typical values at < 32.5. Higher salinity waters exist at depth near the Ayrshire coast (Dooley, 1979).

Overall, the Clyde Sea demonstrates fairly persistent stratification during the year by combination of thermal and freshwater inputs (Simpson & Rippeth, 1993). The strongest stratification occurs in the summer during periods of thermal warming and moderate freshwater discharge. The effect being to create a surface layer that can respond to wind forcing. During winter the stratification is dominated by the increase in freshwater discharge. However, there are periods where the water column can become fully mixed after periods of strong winds and intense surface cooling (Cottier, et al., 2004) leading to complete renewal of the deep waters in the Firth of Clyde (Rippeth & Simpson, 1996).

13.2.5 Meteorology

Irvine Bay is exposed predominantly to southwest winds. The rocky peninsula protruding from Troon lends itself to increasing shelter in the bay but only in the southern reaches. Previous studies have noted that persistent SW winds can set up a cyclonic (anti-clockwise) circulation in Irvine Bay and the adjacent Firth (Davies & Hall, 2000).

During the summer months, there can be wind from the ENE but in general, the wind direction in the area is WSW. In the winter months, winds were stronger than in summer months and there was no significant bias in wind direction throughout the seasons.

Water in Irvine Bay is strongly influenced by meteorological forcing (Lewis, 1986). Atmospheric pressure gradient on water surface elevation and the large scale wind field is the biggest influence on the alongshore residual flow. The residual movement was not influenced to a significant degree by local-scale winds although waters closest to Irvine Bay within 10 m of the shore displayed greater propensity to be affected by changes in the local wind than offshore waters (Lewis, 1986).

The input of freshwater flow is seasonally dependent. Within this area, in general the heaviest rainfall occurs in November, December and January and conversely the months with the least rainfall are generally May, June and July (Poodle, 1986).

The closest area with adequate rainfall data is at Prestwick Gannet which is situated roughly 17 km southeast of Stevenston Sands. Due to the distance between these two areas, environmental conditions may vary. However, the data may still be useful in identifying any trends in seasonal meteorological patterns. The data spanned from January 2007 – August 2012 and is distinct from the rain/river data reported in 2.4.2.

There were differing rainfall levels from year to year with the highest rainfall in 2008 and the least in 2010. Rainfall reached more than 30 mm/d throughout 2008 to 2011 but not in 2007 or 2012.

The highest rainfall was in November with the rain increasing from June to January. The least rainfall occurred from February to May. Over 30 mm/d of rain was recorded

in March, July, November and December. 56% of days from 2007 to 2012 had rainfall below 1 mm with over 10 mm of rainfall being recorded on 7% of the days. Consequently, it can be assumed that run-off because of rainfall will be high throughout both the summer and winter months. However, whilst a general seasonal pattern in rainfall can be deduced from the historic data, periods of high rainfall can be recorded in the majority of months.

13.2.6 Model Assessment

Whilst there is a considerable amount of in situ data for this location, it was not appropriate to set up a box model run for the Firth of Clyde due to the unconstrained nature of the study area.

Some 3D modelling work has been undertaken in the past (Davies & Hall, 2000) and the key results from this have been reported in 1.2.3 and 1.2.5. Although a tidal surge model does exist (developed by SEPA), we are not aware of any high resolution circulation models.

Simple box modelling work has been done previously (Rippeth, et al., 1995) but this was only able to reproduce the seasonal changes in stratification in Clyde Sea deep water locations and gave rather little impression of circulation and dispersion in Irvine Bay.

13.3 Hydrographic Assessment

13.3.1 Surface flow

Assessment of the literature for the Firth of Clyde and particularly the Stevenston Sands site indicate that freshwater inflow has an important bearing on the surface flow characteristics. This surface flow is further modified by large scale wind forcing with local winds influencing on waters very close to the coast, within water depths of < 10 m.

The water generally shows prolonged stratification which becomes weaker in the autumn/winter such that there is occasional full convective mixing. However, this is much less likely close to sources of freshwater, for example within Stevenston Sands, which will sustain the stratified nature of the water.

Tidal flow is generally weak and not aligned along the axis of the Firth of Clyde. There is rather little information for tidal flow at Stevenston Sands but we presume it will broadly follow the coast northwards on the flood and south on the ebb. The tidal excursion in the Firth of Clyde during a flood or ebb phase of the tide is typically 2.3 km and 1.5 km at mean springs and mean neaps respectively. This should be considered to be the best estimate of surface transport during each phase of the tidal cycle.

Residual flows in the Firth of Clyde are reported to be typically slow at 0.01 m/s to the south. Over 12 hours this would result in a net transport of around 0.5 km. Residual flow in Stevenston Sands is reported to be around 0.05 m/s, perhaps even reaching 0.1 m/s in the surface, generally in the northwest direction. Over 12 hours this would result in a net transport of between 2 - 4 km.

The dominance of the south westerly winds is likely to sustain the residual flow and may even enhance them.

Dispersion measurements in Irvine Bay have indicated that the dispersion rates are greater than those prescribed by SEPA management guidelines and will result in an alongshore and offshore transport. Again, dispersive behaviour will be enhanced with wind forcing.

13.3.2 Exchange Properties

Due to tidal currents being generally weak within the Firth of Clyde, the flushing of water is rather long compared to smaller, more tidally energetic sea lochs. Estimates of renewal time of water in the Clyde range from four weeks (Steele, et al., 1973) to two months (Edwards, et al., 1986) but exchange can be enhanced (i.e. reduced residence time) through wind forcing. However, in general we would expect the larger area of the Firth of Clyde to be weakly flushed.

In the area of Stevenston Sands, the measured and persistent alongshore residual current and the relatively high dispersion rates indicate that in the proposed fishery area the waters may be flushed more effectively than in the adjacent Firth of Clyde. However, it is likely that there is a through flow of water at Stevenston Sands with water being advected from further south, potentially carrying pollutants through the site.

Much of this assessment is based on a mature body of literature that is itself based on extensive measurement. The assessment site is relatively simple in terms of topography, however, no high resolution circulation or exchange model is available for the site. Therefore the confidence level of this assessment is MEDIUM/HIGH.

14. Shoreline Survey Overview

The shoreline survey was conducted between the 14th and 16th May 2013. No precipitation fell in the 48 hrs prior to the survey, with rain only recorded on the morning of the 14th and a light shower on the 16th May. The remaining weather was dry and warm, with temperatures between 3-14^{o}C. Wind speed prevented the survey taking place on the 13th May, and progressively decreased from the first day of surveying on the 14th.

The fishery at Stevenson Sands is a new banded wedge clam fishery that is anticipated to be dredged year round. The harvester Mr Jonathan Moore has expressed concerns about the exposed location of the fishery to extreme and unpredictable weather, which may prevent him from carrying out regular fishing. The harvester also mentioned future plans for razor clam harvesting, using divers.

Pipes presumed to relate to sewage discharges were noted at Sandylands Promenade and Stevenston Public toilets were observed on the shore at Irvine Bay, though no obvious pipes or discharges were observed from these.

Sandylands Holiday Park is situated in Saltcoats. It covers a substantial area of land along the coastline. No pipes/discharges were observed from the holiday park. The Island of Arran lies on the opposite side of the Firth of Clyde, and is a popular tourist destination with ferry links to Ardrossan and Troon (south of Stevenston Sands). No boats were seen in Saltcoats harbour during the survey. Two yachts were observed beyond the mouth of Irvine bay with 14 pleasure boats berthed further up river.

A large industrial plant sits approximately 500 m from the rocky shore of Ardeer Point where East Shore meets Irvine Bay. The previous ICI Nobel explosives complex is now a combination of the Stevenston Industrial Estate and the Nobel Business Park. These sites lie above Irvine Bay, retained by sea defences and fencing. This restricted area continues to Irvine Harbour from the Ardeer Point.

The shoreline between Saltcoats and Ardeer Point is rocky with little sand. Sand beaches backed by sand dune developments stretch from Saltcoats to Irvine Bay. Behind the shore at Ardeer Point stretching to Irvine Bay is the Beach Park; a grassland area. To the south of this area is the Nobel Business Park, which is not accessible to the public, with parts of it under re-development. No woodland/ plantation forest or farming areas and improved pasture were noted.

The land between Ardrossan and Saltcoats is comprised of housing, retail and industrial units, with Stevenston Industrial Estate and the Nobel Business Park situated close to the shoreline. Beach Park recreational area extends along the shoreline from Saltcoats to Outer Nebboc, with housing and a primary school lying just behind this area. The beach area by Saltcoats and Sandylands Holiday park is used extensively for leisure purposes including dog walking, sports and walking. To

the southwest lies Auchenharvie Golf Course. A ham curers and abattoir (John Robertson Ham Curers) was situated in Ardrossan next to the shore, with a pipe noted to shore. No farms or livestock were noted on the survey, and though cows were heard at the abattoir in Saltcoats they were not seen. Arable and cattle farming dominated the landscape inland from Saltcoats and Irvine.

Three watercourses were noted along the survey; the small Stevenston Burn, and the two very large rivers Garnock and Irvine. These two rivers merge a short distance before reaching the shore. Due to access issues, these rivers could not be measured.

Gulls were the most common wildlife observed during the survey, with a large number seen on top of the abattoir at Saltcoats. Smaller numbers of other birds such as swallows, blackbirds, eiders, crows, ducks and swans were also seen at various points during the survey. Crows were often seen pecking amongst brown foam washed up on the beach. Two roe deer were seen grazing land on the Nobel Business Park.

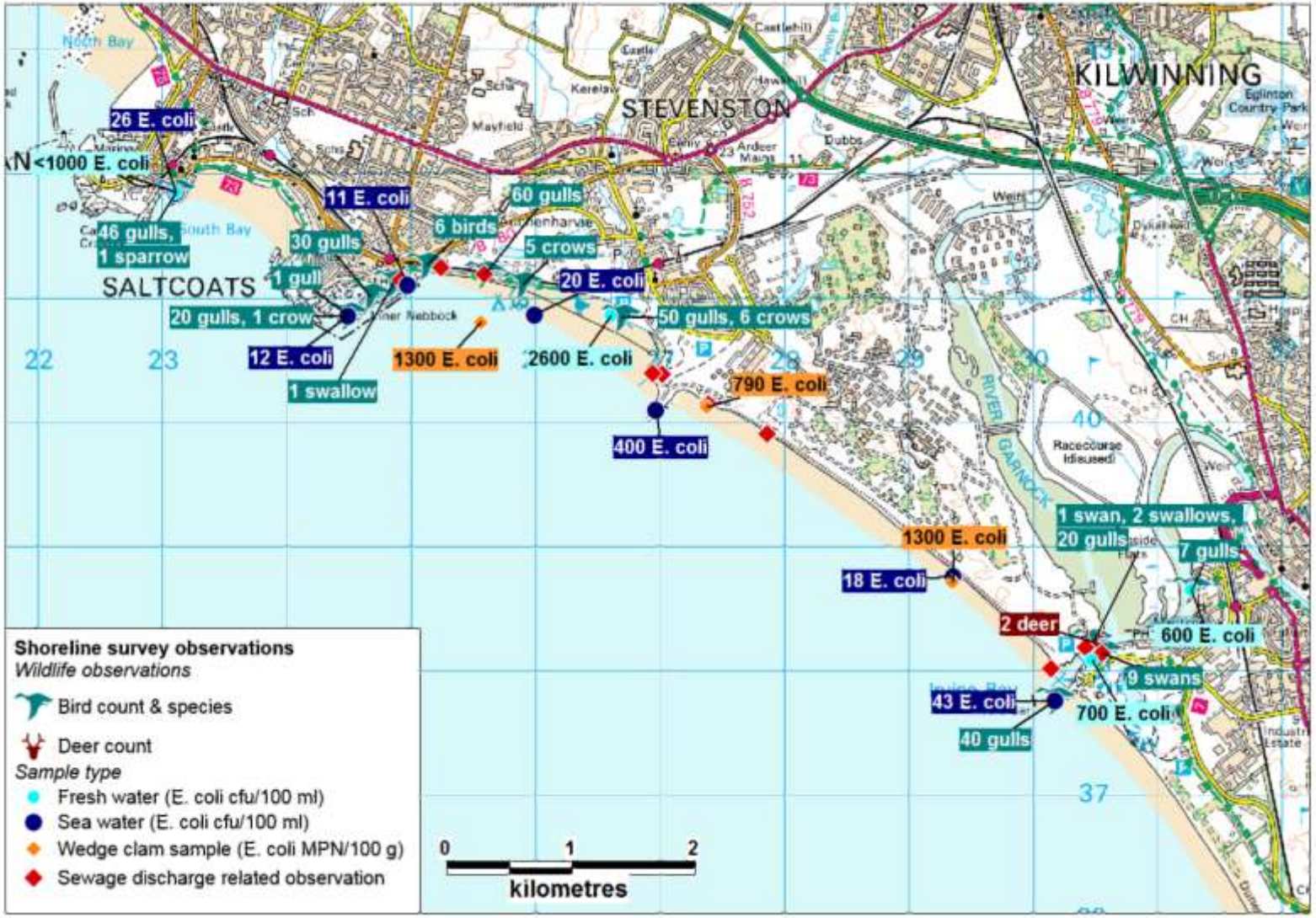


Figure 14.1 Principal shoreline survey observations at Stevenston Sands

15. Overall Assessment

Human sewage impacts

The principal continuous sewage discharges that will impact on the wedge clam and razor clam beds are those associated with the Stevenston and Meadowhead STWs, which both receive secondary treatment. The Stevenston Sands discharge will impact directly on the Stevenston Sands wedge clam production area and the Stevenston Sands 1 and 2 razor clam areas. Minor contamination in this area will originate from consented private discharges in the catchment of Stevenston Burn. The Meadowhead STW discharge will impact directly on the Stevenston Sands 3 razor clam area. In addition, contamination arising from public and private continuous discharges in the Irvine and Garnock catchments will impact on the southwestern end of the wedge clam bed and directly on the Stevenston Sands 2 and 3 razor clam areas. The along shore currents in the area will carry contamination from these sources across the adjacent shellfish areas, with the direction of impact depending on the whether the tide is rising or falling.

The three sources of contamination from continuous discharges will also be the focus of additional contamination by diluted but untreated (screened only) sewage during significant rainfall events due to the presence of combined sewer overflows and the new storm interceptor sewers from Irvine and Kilmarnock. Given that the continuous discharges are secondary treated, this is likely to result in increased *E. coli* loadings into the environment. The northwestern end of the wedge clam bed, the Stevenston Sands 1 razor clam area and the northwestern part of the Stevenston Sands 2 razor clam area will also be subject to additional rainfall-related contamination arising from CSOs in the Saltcoats and Stevenston areas. SEPA provided comment that CSOs from as far upstream as Kilmarnock have been found to potentially impact the Irvine bathing water and therefore these are also likely to affect water quality at the shellfishery.

There are also several consented emergency discharges located around Irvine Bay and in the Irvine/Garnock catchments. These are unlikely to operate but, if they do, will mean that the shellfish in the area of the discharge will be impacted by untreated sewage until the event causing the discharge is rectified.

Agricultural impacts

Irvine Bay will be significantly impacted by faecal contamination from farm animals, primarily from cattle but also from sheep. The contamination will primarily be associated with the Irvine/Garnock confluence but there will also be some associated with Stevenston Burn.

A research study reported the presence of hepatitis E in wild mussels gathered in the vicinity of a pig processing unit.

Wildlife impacts

Although there are identified concentrations of seabirds to the northwest and south of Irvine Bay, it is likely that contamination from that source will occur across the bed. Any impact is likely nto be small in comparison with the human sewage and farm animal sources.

Seasonal variation

Human sewage loading is likely to be greatest from May to September due to tourism in the area. Although there will be seasonal fluctuations in the amount of farm animals in the area, the effect will be reduced by the large proportion of animals being dairy cattle. Stored slurry and solid manure is expected to be spread over the catchments from May to September.

Rainfall is highest from July to January and so a greater tendency to CSO spills and run-off events would be expected during this period. There was insufficient histrocial E. coli data for Stevenston Sands wedge clams to investigate seasonal or rainfall effects but no significant association with either factor was seen with the historical razor clam E. coli data from North Bay. However, results >1000 *E. coli* MPN/100 g were seen between February and May at Stevenston Sands (albeit on a limited data set) and between February and July at North Bay.

Rivers and streams

The two identified watercourse sources of contamination are the Irvine/Garnock confluence and Stevenston Burn. Both are impacted by sewage and farm animal sources. Although at the time of the shoreline survey, the concentration of *E. coli* in Stevenston Burn was higher than at the Irvine/Garnock confluence, the much higher flow at the latter means that the estimated loading was correspondingly greater (3.4×10^{12} *E. coli*/day compared to 7.1×10^{11} *E. coli*/day.

Movement of contaminants

Both freshwater inflow and winds will modify currents close to shore. Tidal flow is generally weak and it is presumed that it will broadly follow the coast northwards on the flood tide and south on the ebb. The tidal excursion in the Firth of Clyde during a flood or ebb phase of the tide is typically 2.3 km and 1.5 km at mean springs and mean neaps respectively. Residual flows in the Firth of Clyde are reported to be typically slow at 0.01 m/s to the south. Over 12 hours this would result in a net transport of around 0.5 km. Residual flow in Stevenston Sands is reported to be around 0.05 m/s, perhaps even reaching 0.1 m/s in the surface, generally in the northwest direction. Over 12 hours this would result in a net transport of between 2 - 4 km. The prevalent southwesterly winds are likely to sustain or enhance the net movement. Dispersion in the area is expected to be significant and will be enhanced by wind forcing. While flushing is generally weak in

most of the Firth of Forth, it is expected that it will be greater within the Stevenston Sands area.

Temporal and geographical patterns of sampling results

The limited geographical areas that have been sampled for wedge clams (towards Saltcoats) and razor clams (at North Bay towards Troon) show markedly different levels of contamination, with a much greater proportion of wedge clam results exceeding 230 *E. coli* MPN/100g. There is no data from areas between these on which to base an estimation of variation across Irvine Bay. While the wedge clam samples have been taken in the vicinity of the pRMZ for Stevenston Sands, none of the more recent North Bay razor clam samples have been taken from within the recommended RMZ for that production area.

The numbers of Stevenston Sands wedge clam samples are too limited to undertake an assessment of temporal trend and, at the time of assessment of data for this report, no samples had been taken at Stevenston Sands razor clam areas 1, 2 and 3. A temporal assessment of trend in razor clam *E. coli* results at North Bay showed that the overall level of contamination has stayed the same since 2008, except for an increase during 2010 and early 2011.

Conclusions

Both the wedge clam and razor clam beds will be subject to significant sewage and diffuse pollution. This will occur on a continuing basis but will be elevated after significant rainfall events. Contamination will predominantly arise from the areas of the Stevenston and Meadowhead outfalls and the Irvine/Garnock confluence, with additional contamination after heavy rainfall from the CSOs in the Saltcoats/Stevenston area. Transport of contamination at mean tide will exceed 2 km over an ebb or flood tide and, on top of this, there will be a net movement of contamination to the north west due to the residual flow in the area.

16. Recommendations

Stevenston Sand Wedge Clams

Production area

It is recommended that the production area be described as the area bounded by lines drawn from NS 2494 4102 to NS 2675 4042 to NS 2765 3990 to NS 2909 2877 to NS 2892 3843 to NS 2475 4065. This corrects erroneous grid references given in the pRMP assessment, and covers the extent of the fast track and standard application areas.

RMZ

It is recommended that an RMZ be used, rather than an RMP, in order to better allow for variation in stock density. It is proposed that the RMZ previously recommended on a provision basis should be used. This is defined as follows: the zone bounded by lines drawn from NS 2660 4025 to NS 2740 3980 to NS 2710 3940 to NS 2630 3983 and back to NS 2660 4025.

Actual sampling locations should be recorded to at least 10 m accuracy.

Tolerance

It is not appropriate to define a tolerance as the use of an RMZ allows for latitude in sampling.

Depth of sampling

Not applicable as this is a dredged fishery.

Frequency

Monthly monitoring is recommended due to the sparsity of monitoring data for the area.

Stevenston Sand Razors North

Production area

It is recommended that the production area is defined as: the area bounded by lines drawn from NS 2195 4075 to NS 2306 4184 to NS 2390 4137 to NS 2371 4106 to NS 2447 4066 to NS 2494 4102 to NS 2698 4028 to NS 2827 3936 to NS 2691 3790 to NS 2600 3867 and to NS 2195 4075.

The production area has been defined to include the majority of the diveable area for razor clams (see Section 2) and abuts the North Bay razor production area. It should be noted that the production area includes the location of the Stevenston Sands and

Meadowhead outfalls and would need to be reviewed if the policy on exclusion (buffer) zones were to be changed.

RMZ

It is recommended that an RMZ also be used here, rather than an RMP, in order to better allow for variation in stock density. The proposed area for this is: The zone bounded by lines drawn from NS 2530 3970 to NS 2530 4030 to NS 2680 3950 to NS 2680 3890 and back to NS 2530 3970.

Actual sampling locations should be recorded to at least 10 m accuracy.

The location of this RMZ is intended to reflect contamination arising directly from the Irvine/Garnock confluence and that arising from the Stevenston and Meadowhead outfalls as transported over the ebb and flood tides respectively. It may not reflect the peak concentrations from either of the outfalls but this would only be possible with the use of multiple RMZs or RMPs. The RMZ does not cover the location where hepatitis E has previously been found in wild mussels. However, that location would not pose the most significant general risk from faecal contamination.

Tolerance

It is not appropriate to define a tolerance as the use of an RMZ allows for latitude in sampling.

Depth of sampling

Not applicable as this is a dived fishery.

Frequency

Monthly monitoring is recommended due to the sparsity of monitoring data for the area.

Stevenston Sand Razors South

Production area

It is recommended that the production area is defined as: the area bounded by lines drawn from NS 2827 3936 to NS 2909 2877 to NS 3172 3579 to NS 3200 2450 to NS 2800 3450 to NS 2800 3698 to NS 2691 3790.

The production area has been defined to include the majority of the diveable area for razor clams (see Section 2) and abuts the North Bay razor production area. It should be noted that the production area includes the location of the Stevenston Sands and Meadowhead outfalls and would need to be reviewed if the policy on exclusion (buffer) zones were to be changed.

RMZ

It is recommended that an RMZ also be used here, rather than an RMP, in order to better allow for variation in stock density. The proposed area for this is: the zone bounded by lines drawn from NS 2910 3690 to NS 3950 3730 to NS 3050 3590 to NS 3010 3560 and back to NS 2910 3690.

Actual sampling locations should be recorded to at least 10 m accuracy.

The location of this RMZ is intended to reflect contamination arising directly from the Irvine/Garnock confluence and that arising from the Stevenston and Meadowhead outfalls as transported over the ebb and flood tides respectively. It may not reflect the peak concentrations from either of the outfalls but this would only be possible with the use of multiple RMZs or RMPs. The RMZ does not cover the location where hepatitis E has previously been found in wild mussels. However, that location would not pose the most significant general risk from faecal contamination.

Tolerance

It is not appropriate to define a tolerance as the use of an RMZ allows for latitude in sampling.

Depth of sampling

Not applicable as this is a dived fishery.

Frequency

Monthly monitoring is recommended due to the sparsity of monitoring data for the area.

Figure 16.1 Map of recommendations at Stevenston sands

17. References

Aitken, M., Merrilees, D. W. & Duncan, A., 2001. *Impact of Agricultural Practices and Catchment Characteristics on Ayrshire Bathing Waters,* Edinburgh: Scottish Executive Central Research Unit.

Anon, 2011. *Bird Forum; Ayrshore Seabirds.* [Online] Available at: http://www.birdforum.net/showthread.php?t=201293 [Accessed 16 07 2013].

Ardeer Friends, 2013. *Garnock Estuary.* [Online] Available at: https://sites.google.com/site/stevenstonconservation/Home/garnock-estuary [Accessed 16 07 2013].

Ardeer Friends, n.d. *Kerelaw Glen.* [Online] Available at: https://sites.google.com/site/stevenstonconservation/Home/kerelaw-glen [Accessed 16 07 2013].

Atkins, 2005. *Ayrshire Joiint Structure Plan; Development Impact Assesment,* s.l.: Atkins.

Brown, J., 1991. The final Voyage of Rapaiti:A measure of surface drift velocity in relation to the surface wind. *Marine Pollution Bulletin,* 22(1), pp. 37-40.

Caledonian MacBrayne, 2013. *Summer timetables & fares.* [Online] Available at: http://www.calmac.co.uk/timetables/calmac-summer-timetables.htm [Accessed 16 07 2013].

CEFAS, 2011. *North Bay Sanitary Survey Report,* Weymouth: CEFAS.

Centre for Ecology and Hydrology, 2012. *83009 - Garnock at Kilwinning.* [Online] Available at: http://www.ceh.ac.uk/data/nrfa/data/station.html?83009 [Accessed 16 07 2013].

Clyde Marina, n.d. *Clyde Marina Facility.* [Online] Available at: http://www.clydemarina.com/facilities.shtml [Accessed 16 07 2013].

Cottier, F., Inall, M. & Griffiths, C., 2004. Seasonal variations in internal wave energy in a Scottish sea loch. *Ocean Dynamics,* 54(3-4), pp. 340-347.

Davies, A. M. & Hall, P., 2000. The response of the North Channel of the Irish Sea and Clyde Sea to wind forcing. *Continental Shelf Research,* 20(8), pp. 897-940.

Dempsey, P., Murrell, K. & Downy, K., 2008. *Intergrated Catchment Modelling of the Irvine Catchment, Scotland.* Edinburgh, 11th International Conference on Urban Drainage.

Dooley, H. D., 1979. Factors influencing water movements of the Firth of Clyde. *Estuarine and Coastal Marine Science,* 9(5), pp. 631-641.

Edwards, A. et al., 1986. *Clyde Sea hyrography.* Edinburgh, The Royal Society of Edinburgh, pp. 67-83.

Gauthier, G. & Bedard, J., 1986. Assessment of faecal output in geese. *Journal of Applied Ecology,* 23(1), pp. 77-90.

General Register Office for Scotland, 2012. *Mid-2010 Populations Estimates for Settlements and Localities in Scotland.* [Online] Available at: http://www.gro-scotland.gov.uk/statistics/theme/population/estimates/special-area/settlements-localities/mid-2010/tables.html [Accessed 16 07 2013].

Hebridean Whale and Dolphin Trust, 2013. *Recent Sightings.* [Online] Available at: http://www.whaledolphintrust.co.uk/sightings-recent-sightings.asp [Accessed 16 07 2013].

Irvine Bay Regeneration Company, 2011. *Coastal summer programme highlights park potential.* [Online] Available at: http://www.irvinebay.co.uk/news/586_coastal_summer_programme_highlights_park_potential [Accessed 16 07 2013].

Kay, D. et al., 2008a. Faecal indicator organism concentrations and catchment export coefficients in the UK. *Water Research,* 42(10/11), pp. 2649-2661.

Kay, D. et al., 2008. Faecal indicator organism in concentration sewage and treated effluents. *Water Research,* 42(1/2), pp. 442-454.

Lewis, R. E., 1986. *The Hydrography of Irvine Bay and its relation to the Clyde Sea Area.* Edinburgh, Royal Society of Edinburgh, pp. 117-126.

Midgley, R. P., Simpson, J. H., Hyder, P. & Rippeth, T. P., 2001. Seasonal cycle of vertical structure and deep water renewal in the Clyde Sea. *Estuarine, Coastal and Shelf Science,* 53(6), pp. 813-823.

Mitchell, I. P., Newton, S. F., Ratcliffe, N. & Dunn, T. E., 2004. *Seabird populations of Britain and Ireland: results of the Seabird 2000 census (1998-2002),* London: T & A D Poyser.

Muller, F. L. L., Balls, P. W. & Tranter, M., 1995b. Annual geochemical mass balances in waters of the Firth of Clyde. *Oceanologica Acta,* 5(18), pp. 511-521.

Muller, F. L. L., Balls, P. W. & Tranter, M., 1995. Process controlling chemical distributions in the Firth of Clyde (Scotland). *Oceanologica Acta,* 5(8), pp. 493-509.

National Records of Scotland, 2012. *Mid 2010 Population Estimates for Settlements and Localities in Scotland,* Newport: National Statistics.

NPL Estates, n.d. *Irvine Harbour Co. Layout of Moorings.* [Online] Available at: http://www.nplestates.com/newsletters/Irvine%20Harbour%20Moorings.jpg [Accessed 16 07 2013].

Park Resorts, n.d. *Sandylands Holiday Park in Ayrshire.* [Online] Available at: http://www.park-resorts.com/holiday-parks/scotland/sandylands/ [Accessed 16 07 2013].

Poodle, T., 1986. *Fresh water inflows to the Firth of Clyde.* Edinburgh, Royal Society of Edinburgh, pp. 55-66.

Rippeth, T. P., Midgley, R. P. & Simpson, J. H., 1995. The seasonal cycle of stratification in a Scottish Fjord. In: C. H. K. E. H. L. HR Skojldal, ed. *Ecology of Fjords and Coastal Waters.* Tromsø: Elsevier Science, pp. 85-92.

Rippeth, T. P. & Simpson, J. H., 1996. The frequency and duration of episodes of complete vertical mixing in the Clyde Sea. *Continental Shelf Research,* 7(16), pp. 933-947.

Sail the Net, n.d. a. *Clyde Marina, Ardrossan, Ayrshire, United Kingdom.* [Online] Available at: http://www.sail-the-net.com/marinas/europe/united-kingdom/ayrshire/Ardrossan/Clyde-Marina.html [Accessed 16 07 2013].

Sail the Net, n.d. b. *Troon Yacht Haven, Troon, Ayrshire, United Kingdom.* [Online] Available at: http://www.sail-the-net.com/marinas/europe/united-kingdom/ayrshire/troon/Troon-Yacht-Haven.html [Accessed 16 07 2013].

Scottish Government, 2012. *Clyde Ecosystem Review; Scottish Marine and Freshwater Science Voilume 3,* Edinburgh: Scottish Govenrment.

SEPA, 2013a. *Bathing Water Profile: Irvine,* Stirling: SEPA.

SEPA, 2013b. *Bathing Water Profile: Saltcoats/Androssan,* Sterling: SEPA.

Simpson, J. H. & Rippeth, T. P., 1993. The Clyde Sea: a model of the seasonal cycle of stratification and mixing. *Estuarine Coastal and Shelf Science,* 37(2), pp. 129-144.

Special Committee on Seals, 2011. *Scientific Advice on Matters Related to the Management of Seal Populations: 2011.* [Online] Available at: www.smru.st-andrews.ac.uk/documents/389.pdfShare [Accessed 12 02 2013].

Steele, J. H. et al., 1973. Pollution Studies in the Clyde Sea Area. *Marine Pollution Bulletin,* 4(10), pp. 153-157.

Tresadern, S., 2008. *The Process of Developing a Seabed Habitat Map for the Firth of Clyde,* Clydebank: Scottish Sustainable Marine Environment Initiative.

Troon Yacht Haven, 2013. *Facilities at Troon.* [Online] Available at: http://www.yachthavens.com/troon/our-haven/facilities-at-troon.aspx [Accessed 16 07 2013].

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1. 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 50-170 kg. 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 & 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 (Gauthier & Bedard, 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 National Heritage, n.d.). 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.

Alderisio, K. A. & DeLuca, N., 1999. Seasonal enumeration of fecal coliform bacretia from the feces of ring-billed gulls (Larus delawerensis) and Canada geese (Branta canadensis). *Applied and Environmental Microbiology,* 65(12), pp. 5628-5630.

Gauthier, G. & Bedard, J., 1986. Assessment of faecal output in geese. *Journal of Applied Ecology,* 23(1), pp. 77-90.

Poppe, C. et al., 1998. Salmonella typhimurium DT104: a virulent and drug-resistant pathogen. *The Canadian Veterinary Journal,* 39(9), pp. 559-565.

Scottish National Heritage, n.d. *Otters and Development.* [Online] Available at: http://www.snh.org.uk/publications/on-line/wildlife/otters/biology.asp [Accessed 10 10 2012].

Stoddard, R. A. et al., 2005. Salmonella and Campylobacter spp. in Northern Elephant Seals, California. *Emerging Infections Diseases,* 11(12), pp. 1967-1969.

2. 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	$1.7 \times 10^{7*}$ (+)	1.4×10^{7}	2.0×10^{7}	282	$2.8 \times 10^{6*}$ (-)	2.3×10^{6}	3.2×10^{6}
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^{7}	2.0×10^{7}	79	$3.5 \times 10^{6*}$ (-)	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	$1.0 \times 10^{7*}$ (+)	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	$3.3 \times 10^{5*}$ (-)	2.9×10^{5}	3.7×10^{5}	184	$5.0 \times 10^{5*}$ (+)	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	$2.8 \times 10^{5*}$ (-)	2.2×10^{5}	3.5×10^{5}	93	$5.1 \times 10^{5*}$ (+)	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}		
Reed bed/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, et al., 2008)

Table 3 – Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu $100ml^{-1}$) under base- and high-flow conditions at the 205 sampling points and for various subsets, and results of paired t-tests to establish whether there are significant elevations at high flow compared with base flow

FIO	*n*	Base Flow			High Flow		
Subcatchment land use		Geometric mean	Lower 95% CI	Upper 95% CI	Geometric mean[a]	Lower 95% CI	Upper 95% CI
Total coliforms							
All subcatchments	205	5.8×10^{3}	4.5×10^{3}	7.4×10^{3}	7.3×10^{4}**	5.9×10^{4}	9.1×10^{4}
Degree of urbanisation							
Urban	20	3.0×10^{4}	1.4×10^{4}	6.4×10^{4}	3.2×10^{5}**	1.7×10^{5}	5.9×10^{5}
Semi-urban	60	1.6×10^{4}	1.1×10^{4}	2.2×10^{4}	1.4×10^{5}**	1.0×10^{5}	2.0×10^{5}
Rural	125	2.8×10^{3}	2.1×10^{3}	3.7×10^{3}	4.2×10^{4}**	3.2×10^{4}	5.4×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	6.6×10^{3}	3.7×10^{3}	1.2×10^{4}	1.3×10^{5}**	1.0×10^{5}	1.7×10^{5}
≥75% Rough Grazing	13	1.0×10^{3}	4.8×10^{2}	2.1×10^{3}	1.8×10^{4}**	1.1×10^{4}	3.1×10^{4}
≥75% Woodland	6	5.8×10^{2}	2.2×10^{2}	1.5×10^{3}	6.3×10^{3}*	4.0×10^{3}	9.9×10^{3}
Faecal coliform							
All subcatchments	205	1.8×10^{3}	1.4×10^{3}	2.3×10^{3}	2.8×10^{4}**	2.2×10^{4}	3.4×10^{4}
Degree of urbanisation							
Urban	20	9.7×10^{3}	4.6×10^{3}	2.0×10^{4}	1.0×10^{5}**	5.3×10^{4}	2.0×10^{5}
Semi-urban	60	4.4×10^{3}	3.2×10^{3}	6.1×10^{3}	4.5×10^{4}**	3.2×10^{4}	6.3×10^{4}
Rural	125	8.7×10^{2}	6.3×10^{2}	1.2×10^{3}	1.8×10^{4}**	1.3×10^{4}	2.3×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	1.9×10^{3}	1.1×10^{3}	3.2×10^{3}	5.7×10^{4}**	4.1×10^{4}	7.9×10^{4}
≥75% Rough Grazing	13	3.6×10^{2}	1.6×10^{2}	7.8×10^{2}	8.6×10^{3}**	5.0×10^{3}	1.5×10^{4}
≥75% Woodland	6	3.7×10	1.2×10	1.2×10^{2}	1.5×10^{3}**	6.3×10^{2}	3.4×10^{3}
Enterococci							
All subcatchments	205	2.7×10^{2}	2.2×10^{2}	3.3×10^{2}	5.5×10^{3}**	4.4×10^{3}	6.8×10^{3}
Degree of urbanisation							
Urban	20	1.4×10^{3}	9.1×10^{2}	2.1×10^{3}	2.1×10^{4}**	1.3×10^{4}	3.3×10^{4}
Semi-urban	60	5.5×10^{2}	4.1×10^{2}	7.3×10^{2}	1.0×10^{4}**	7.6×10^{3}	1.4×10^{4}
Rural	125	1.5×10^{2}	1.1×10^{2}	1.9×10^{2}	3.3×10^{3}**	2.4×10^{3}	4.3×10^{3}
Rural subcatchments with different dominant land uses							
≥75% Imp. pasture	15	2.2×10^{2}	1.4×10^{2}	3.5×10^{2}	1.0×10^{4}**	7.9×10^{3}	1.4×10^{4}
≥75% Rough Grazing	13	4.7×10	1.7×10	1.3×10^{2}	1.2×10^{3}**	5.8×10^{2}	2.7×10^{3}
≥75% Woodland	6	1.6×10	7.4	3.5×10	1.7×10^{2}**	5.5×10	5.2×10^{2}
[a] Significant elevations in concentrations at high flow are indicated: **po0.001, *po0.05.							
[b] Degree of urbanisation categorised according to percentage built-up land: 'Urban' (X10.0%), 'Semi-urban' (2.5–9.9%) and 'Rural' (o2.5%).							

Source: (Kay, et al., 2008a)

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 x 108
Cow	230,000	23,600	5.4 x 109
Duck	33,000,000	336	1.1 x 1010
Horse	12,600	20,000	2.5 x 108
Pig	3,300,000	2,700	8.9 x 108
Sheep	16,000,000	1,130	1.8 x 1010
Turkey	290,000	448	1.3 x 108
Human	13,000,000	150	1.9 x 109

Source: (Gauthier & Bedard, 1986)

3. Statistical Data

One-way ANOVA: LogEC versus Season

```
Source DF SS MS F P
Season 3 0.738 0.246 0.53 0.664
Error 48 22.247 0.463
Total 51 22.985

S = 0.6808 R-Sq = 3.21% R-Sq(adj) = 0.00%


 Individual 95% CIs For Mean Based on
 Pooled StDev
Level N Mean StDev -------+---------+---------+---------+--
1 16 1.4201 0.6629 (----------*----------)
2 14 1.6971 0.7057 (-----------*----------)
3 11 1.4081 0.4397 (-------------*-------------)
4 11 1.5333 0.8513 (-------------*-------------)
 -------+---------+---------+---------+--
 1.20 1.50 1.80 2.10

Pooled StDev = 0.6808
Grouping Information Using Tukey Method

Season N Mean Grouping
2 14 1.6971 A
4 11 1.5333 A
1 16 1.4201 A
3 11 1.4081 A

Means that do not share a letter are significantly different.

Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of Season

Individual confidence level = 98.94%

Season = 1 subtracted from:

Season Lower Center Upper -------+---------+---------+---------+--
2 -0.3854 0.2770 0.9394 (----------*----------)
3 -0.7210 -0.0121 0.6969 (-----------*----------)
4 -0.5958 0.1131 0.8221 (-----------*----------)
  -------+---------+---------+---------+--
  -0.60 0.00 0.60 1.20


Season = 2 subtracted from:

Season Lower Center Upper -------+---------+---------+---------+--
3 -1.0183 -0.2891 0.4402 (-----------*----------)
4 -0.8931 -0.1638 0.5655 (-----------*----------)
  -------+---------+---------+---------+--
  -0.60 0.00 0.60 1.20


Season = 3 subtracted from:

Season Lower Center Upper -------+---------+---------+---------+--
4 -0.6466 0.1252 0.8970 (------------*------------)
  -------+---------+---------+---------+--
  -0.60 0.00 0.60 1.20
```

4. Hydrographic Assessment 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.

MHW. Mean High Water, The highest level that tides reach on average.

MHWN. Mean High Water neap, The highest level that tides reach on average during neap tides.

MHWS. Mean High Water spring, The highest level that tides reach on average during spring tides

MLW. Mean Low Water, The lowest level that tides reach on average.

MLWN. Mean Low Water neap, The lowest level that tides reach on average during neap tides.

MLWS. Mean Low Water spring, The lowest level that tides reach on average during spring tides.

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. spring tides occur during or just after new moon and full moon when the tide-generating force of the sun acts in the same direction as that of the moon, reinforcing it. The tidal range is greatest and tidal currents strongest during spring tides.

neap tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neap 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. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

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.

5. Shoreline Survey Report

Report Title	Stevenston Sands Shoreline Survey Report
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067

Document Number	B0067_Shoreline 0011
Revision	Issue 01
Date	19/06/2013

Revision History

Revision	Changes	Date
A	Issue for internal review	11/06/2013
01	First formal issue to CEFAS	19/06/2013
02	Revision following comments at issue 01	12/07/2013

	Name & Position	Date
Author	Alison Clarke, Eilidh Cole	11/06/2013
Checked	Andrea Veszelovszki	11/07/2013
Approved	Andrea Veszelovszki	12/07/2013

SRSL, Scottish Marine Institute, Oban, Argyll, PA37 1QA, tel 01631 559 470, www.samsrsl.co.uk

Shoreline Survey Report

Production area: Stevenston Sands

Site name: Stevenston Sands

SIN: NA-207-1238-23

Species: Banded wedge clam (*Donax vittatus*).

Harvester: Mr Jonathan Moore

Local Authority: North Ayrshire

Status: Requesting classification. New application.

Date Surveyed: 14th – 16th of May 2013

Surveyed by: Eilidh Cole, Alison Clarke

Existing RMP: N/A

Area Surveyed: The region from Inner Nebbock by Saltcoats Harbour to the estuary of River Garnoch/River Irvine in Irvine Bay with an additional sampling point on the north side of South Bay by Ardrossan.

Weather

No precipitation over the previous 48 hours period however the start of the survey was delayed a day due to severe gale force winds.

Tuesday 14th May 2013 - Rain in the morning with blustery winds. Dry and quite warm by the afternoon, temperatures ranged between 6-11degrees °C. Cloud cover – 40%. Wind speed - 25 knots. Wind direction – S/SW. Sea state 5, rough.

Wednesday 15 May 2013 - Sunny morning remaining dry and bright all day. Cloud cover – 50%. Wind speed - 4 km/h. Wind direction - SW. Sea state 2, calm (rippled). Temperatures ranged during the day between 3-12 degrees °C.

Thursday 16 May 2013 - No rain since Tuesday morning. Dry and warm with the exception of one very brief and light shower at approx. 2pm. Cloud cover –

60-70%. Sea state 4, moderate. Temperatures ranged between 4-14 degrees °C during the day.

Stakeholder engagement during the survey

Both the harvester and sampling officer were very helpful and cooperative during pre-survey arrangements. The sampling officer for the area Mr Martin Scott was offered to join boat sampling but due to his other commitments and the uncertain weather conditions, he could not attend.

Prior arrangements to board the harvester's vessel to collect shellfish samples were cancelled due to the weather conditions preceding the survey. Instead Mr Moore contacted the survey team and the survey co-ordinator and arranged for collection of a shellfish sample from his sorting station in West Kilbride on the 15th of May. With the shellfish sample he also provided coordinates from where it was collected and pinpointed the sample area on the shoreline survey plan. During collection the harvester's boat was visible to the survey team from the shore confirming the sample location.

Fishery

Stevenston Sands faces west on the Ayrshire coast. The fishery is located along the coast of the towns of Saltcoats and Stevenston and further south into the direction of Irvine. The shellfish bed and substrate beyond is sandy with rocks to the north at Inner Nebbock and Nebbock (by Saltcoats).

The fishery is new, with the harvester, Mr Jonathan Moore, still going through the initial classification process of sampling, with commercial fishing not yet started. The plan is to harvest Banded wedge clam, year round by dredger, however, the seasonality and frequency of harvesting are not yet known, with the harvester expressing concerns about the exposed location of the fishery to extreme and unpredictable weather, which might prevent him from carrying out regular fishing. The harvester also mentioned plans for razor clam harvesting, using divers, in the future.

Sewage Sources

Saltcoats, Ardrossan and Stevenston are all densely populated towns that lie just back from the shore. Pipes were visible for Sandylands Promenade PS (waypoint 25) and potentially Stevenston ST (waypoint 15, not confirmed) but neither were accessible for sampling. No pipes or discharges were observed during the survey in relation to the Magnum Centre.

Sandylands Holiday Park is a large caravan park that is situated in Saltcoats near to Ardeer. No pipes or discharges were observed coming directly from the holiday park during the survey.

The Nobel Business Park is situated just behind the shore of the Irvine Bay just north of where River Garnoch flows into the bay. Although much of this site is in use and being developed, no pipes or discharges were observed during the survey.

There is a ham curing company, John Robertson Ham Curers, situated in Ardrossan next to the shore. A pipe was observed running from the ham curers onto the shore, from which a fresh water and extra seawater sample were taken.

Public toilets were observed on the more southerly portion of the survey route on the shore at Irvine Bay. No obvious pipes or discharges were observed from these.

Seasonal Population

Sandylands Holiday Park covers a substantial area of land on the Saltcoats coastline. Campers from the park can access Stevenston Sands via a footpath through the sand dunes. In addition the Island of Arran, on the opposite side of the Firth of Clyde, is a popular tourist destination, with ferry links to Ardrossan and Troon.

Boats/Shipping

No boats were seen in Saltcoats harbour during the survey. Low tide revealed a very rocky seabed. To the south of Arran a large tanker was observed stationary throughout the survey and Mr Moore's dredger was working s/westerly from Inner Nebbock, approx. ½ mile from the shore on day two of the survey.

Two yachts were observed beyond the mouth of Irvine bay with 14 pleasure boats berthed further up river. The bridge over the River Garnock remains open, possibly to allow taller vessels to pass through but is inaccessible to pedestrians.

Farming and Livestock

Two roe deer were seen grazing on the private land of the former ICI Nobel explosives plant.

There were no farms or livestock on the survey route. Cows were heard at the abattoir in Saltcoats but nor seen.

Arable and cattle farming dominated the landscape inland from Saltcoats and Irvine.

Land Use

The land between Ardrossan and Saltcoats comprised housing, retail and industrial units (Stevenston Industrial Estate and Nobel Business Park) in close proximity to the shore.

The extensive Beach Park recreational areas, separated by the Stevenston Burn and sand dunes, are laid to grass. These green belts stretch to the rocky lookout point at Outer Nebbock. Housing and a primary school lie behind this area.

Where East Shore meets Irvine Bay, a large industrial plant sits approximately 500 meters from the rocky shore of Ardeer Point. The previous ICI Nobel explosives complex is now a combination of the Stevenston Industrial Estate and the Nobel Business Park. These sites sit above Irvine Bay, retained by sea defences and fencing. This restricted area continues to Irvine Harbour from the Ardeer Point.

Auchenharvie Golf Course is situated south west of Sandylands Holiday Park. Auchenharvie is a public 9-hole golf course and appeared well used on each of the 3 survey days.

The beach area particularly by Saltcoats and the Sandylands Holiday park is used extensively for leisure purposes including dog walkers, sports and walking.

Land Cover

Saltcoats is a heavily populated town and land cover around this area was predominantly housing and small businesses. The shore around this urban area was very rocky with little sand. This was also the case at Ardeer Point midway along the shoreline survey route. The majority of the remaining shoreline survey was on long stretches of sandy beach with sand dunes and housing further back from the shore. No woodland or plantation forest was observed along the survey route and neither was any type of farming or improved pasture.

The Beach Park is a large area of grassland for public use which is located behind the shore at Ardeer point, approximately midway along the shoreline survey route between East Shore and Irvine Bay. This area seems to be well used by dog walkers and members of the public.

The land south of the Beach Park along Irvine Bay is predominantly used by the Nobel Business Park and is not accessible by the public. Although parts of this Business Park are not in use, it is under development for future use. The land between the shore and the business park is rough grassland and sand dunes.

Watercourses

Few watercourses were observed along the shoreline survey route. A small watercourse Stevenston Burn was situated on East Shore just before Ardeer Point and was easily accessible via a small footbridge.

Two very large watercourses, the River Garnock and River Irvine, were situated further south towards in Irvine Bay. These two rivers merge a short distance before reaching the shore. Unfortunately these rivers were difficult to access due to their width and depth and no bridge was present to enable safe access for measurements.

No other watercourses were observed during the survey.

Wildlife/Birds

Many seagulls were observed during the course of the survey, a large number of which were seen on top of the abattoir at Saltcoats. Much smaller numbers of other birds such as swallows, blackbirds, eiders, crows, ducks and swans were also seen at various points during the survey. Crows were often seen pecking amongst brown foam washed up on the beach.

Other wildlife was scarce and only included two roe deer grazing on the land of the Nobel Business Park.

Shoreline Survey Map – Stevenston Sands

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Figure 1. Map of Stevenston Sands waypoints (Ardrossan and Saltcoats, north end of production area)

Figure 2. Map of Stevenston Sands waypoints (Stevenston, middle of production area)

Figure 3. Map of Stevenston Sands waypoints (Irvine region, south of production area)

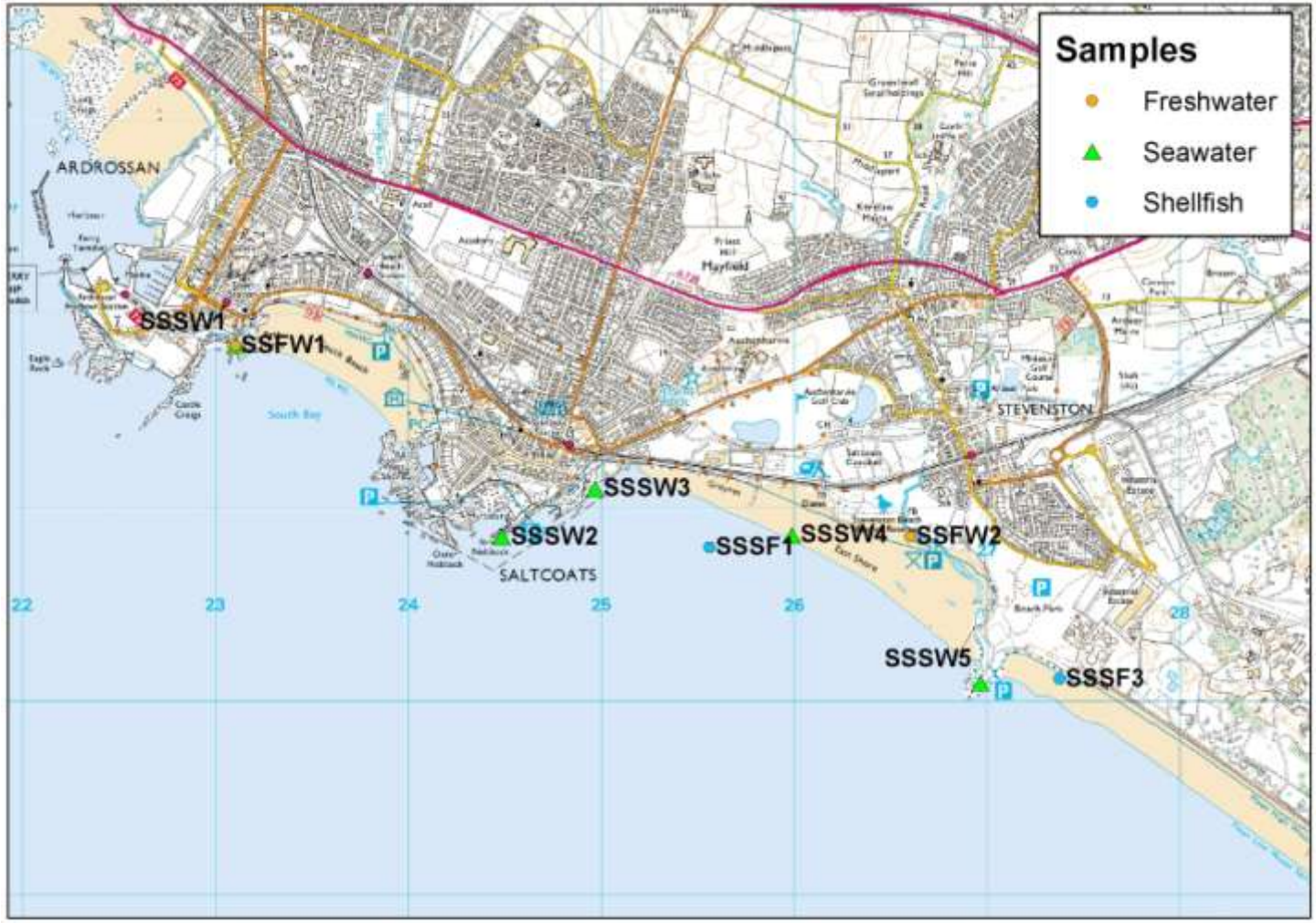

Figure 4. Map of Stevenston Sands samples

Figure 5. Map of Stevenston Sands samples

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	14/05/2013	13:46	NS 24484 40853	224485	640853			Start of survey day one. Seawater sample taken then discarded due to time constraint on the day as observations started in the afternoon. Sample was collected from this location the following day (Waypoint 21).
2	14/05/2013	13:55	NS 24480 40855	224481	640856			Harbour pier end at Inner Nebbock. No boats or vessels in the harbour itself and only one tanker out at sea. One seagull flying. Sea very choppy.
3	14/05/2013	14:09	NS 24673 41004	224673	641005	Fig 6		Approximately 30 seagulls flying and one blackbird. End of the harbour pier inland.
4	14/05/2013	14:13	NS 24858 41113	224858	641114			Brown froth all along rocky shore looking SE to Irvine Bay. One swallow. A lot of litter and debris on the beach such as plastic bottles and wrappings.
5	14/05/2013	14:24	NS 25122 41256	225122	641256			Six black and white birds in the water, possibly eiders. Railway line running next to shore line behind a wall.
6	14/05/2013	14:34	NS 25487 41206	225487	641207			Waypoint marked in error.
7	14/05/2013	14:36	NS 25382 41220	225383	641221			Waypoint taken in error.
8	14/05/2013	14:38	NS 25244 41239	225245	641240			Sewage treatment plant (Sandylands Promenade PS) only just visible behind railway line, this was identified by the fisherman from waypoint 7. No pipes are visible as tide was quite high (this was visited on next day – waypoint 25). No visible pipes/discharge coming from treatment plant. The abattoir possibly connects to this according to the fisherman.
9	14/05/2013	15:17	NS 25591 41181	225592	641182	Fig 7		Blue abattoir building with concrete outhouses. No visible pipes/discharges. Approximately 60 gulls on roof of building.
10	14/05/2013	15:23	NS 25892 41097	225893	641098	Fig 8		Brown foam all along beach. Five crows pecking in amongst it. A lot of general litter along shore.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
11	14/05/2013	15:29	NS 26101 41051	226102	641052			Waypoint taken approximately 100m from caravan park. No visible pipes or discharges.
12	14/05/2013	15:46	NS 26624 40866	226624	640866	Fig 9		Bridge over small river (Stevenston Burn). No sample taken on this day due to time constraints, sample was taken the following day (waypoint 28). Slow moving water. Looks brown and sandy.
13	14/05/2013	15:48	NS 26690 40832	226690	640833			Approximately 50 seagulls and 6 crows on beach next to river. Sea very choppy.
14	14/05/2013	16:04	NS 27025 40383	227026	640383			Large factory with outbuildings approximately 500 m from shore, also the location of Steventson ST.
15	14/05/2013	16:17	NS 27383 40147	227383	640148	Fig 10		Large concrete pipe running directly from factory/Stevenston ST noted in waypoint 14 into sea. No discharge. Green algae growing around it. 1.52 m diameter. Metal gate with chain across it. No sample taken.
16	14/05/2013	16:21	NS 27393 40143	227393	640143			Smaller concrete pipe. No discharge. No sample taken. Green algae growing in pipe. Metal gate over pipe bolted shut. Diameter approximately 2 feet.
17	15/05/2013	7:35	NS 23107 41840	223108	641841		SSSW1	Seawater sample taken. Extra sample not on survey plan, associated with waypoint 18.
18	15/05/2013	7:46	NS 23106 41838	223107	641838			Seawater sample taken from shore just beyond John Robertson Ham Curers in Ardrossan. Bad smell in the air.
19	15/05/2013	7:47	NS 23109 41841	223110	641841	Fig 11	SSFW1	Freshwater sample taken from pipe by John Robertson Ham Curers, query contamination. Extra sample not on survey plan, associated with waypoint 20.
20	15/05/2013	7:48	NS 23109 41844	223109	641844	Fig 11		Freshwater sample taken from concrete covered pipe which looks like it is coming from John Robertson Ham Curers in Ardrossan. Pipe is surrounded by clear rock pools due to low tide. There is an abundance of periwinkles and limpets. Pipe diameter - 46 cm; flow - 25ml/2secs. Depth - 2 cm. 46 seagulls

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								and 1 sparrow.
21	15/05/2013	8:22	NS 24489 40849	224490	640849		SSSW2	Seawater sample 2. Planned sample, revisited from 14/05/13, associated with Waypoint 22 (and waypoint 1 from 14/05/13).
22	15/05/2013	8:23	NS 24489 40849	224489	640849			Twenty seagulls and 1 crow. One photographer with a tripod on the rocks on shore. Tanker berthed out to sea in a SW direction as previous day (waypoint related to Waypoint 2 from previous day). Sea state is calm.
23	15/05/2013	8:55	NS 24919 41136	224919	641137			Pipe covered in concrete. No flow. Tide out. Dry and cloudy.
24	15/05/2013	8:59	NS 24970 41099	224970	641099		SSSW3	Planned seawater sample.
25	15/05/2013	9:16	NS 25246 41238	225246	641238			Sandylands Promenade PS discharge pipe. No access by foot at low tide. Too rocky for shellfish sample in this bay, no sand.
26	15/05/2013	9:59	NS 25990 40859	225990	640860		SSSW4	Planned seawater sample. Associated with waypoint 27.
27	15/05/2013	10:02	NS 25990 40858	225991	640859			Seawater sample taken at location opposite of caravan park. Harvester's dredger can be seen approximately half a mile out to sea.
28	15/05/2013	10:24	NS 26604 40852	226605	640852	Fig 12	SSFW2	Planned freshwater sample from Stevenston Burn (which was visited yesterday). Associated with waypoint 29.
29	15/05/2013	10:28	NS 26607 40856	226607	640857	Fig 12		River width - 6.93 m; depth 1 - 30 cm; Flow 1 - 0.192 m/s; SD 1 - 0.008. Depth 2 - 20 cm; Flow 2 - 0.171 m/s; SD 2 - 0.012. Met with Roger Griffiths, District Ranger from Eglinton Country Park Visitor Centre who was supervising some school children doing a beach clean-up.
30	15/05/2013	11:45	NS 26946 40385	226947	640386	Fig 13		Very large pipe encased in concrete. Could not see if flowing as sea is backed up. There was a fisherman with a hand line sitting at the end of the pipe.
31	15/05/2013	11:59	NS 26967 40096	226967	640097		SSSW5	Planned seawater sample. Associated with waypoint 32.
32	15/05/2013	12:00	NS 26965 40096	226965	640097			Seawater sample taken at the end of point. Rocky shore with no sand, unable to find any shellfish at this section. The point is a

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								car park area with a good look out point towards the sea. Well used by people arriving by car to walk their dogs along the beach and on the grass along the shore. Several dog walkers as well as photographers and rod fishermen.
33	15/05/2013	12:25	NS 27869 39901	227869	639901	Fig 14		Sanitary debris on beach.
34	15/05/2013	12:59	NS 29361 38753	229362	638754		SSSW6	Planned seawater sample. Associated with waypoint 35.
35	15/05/2013	12:59	NS 29360 38753	229361	638754			Sample taken from shoreline along long section of beach instead of from boat. Windy. Litter and debris along beach such as plastic bottles, wrappers, general waste.
36	16/05/2013	8:34	NS 31274 38649	231275	638650	Fig 15	SSFW3	Planned freshwater sample from River Irvine. Associated with waypoint 37.
37	16/05/2013	8:36	NS 31274 38649	231275	638650	Fig 15		Sample taken from River Irvine as planned. Sample taken across from the Maritime Museum at low tide. Seven seagulls and 14 boats docked. An abundance of litter and debris along shore including personal sanitary waste. Was unable to identify width, depth or flow of the river as it was too wide and deep and the wind at the water's edge was pushing the flow back. There was no access point/bridge to allow taking these measurements safely.
38	16/05/2013	8:52	NS 30556 38139	230557	638139	Fig 16 & 17		Bridge over where Rivers Garnock and Irvine join. No access due to incomplete bridge and locked gates. 9 swans swimming in water. Thirty seagulls flying and in water. One dead seagull on riverside. Eight ducks in water. Car park next to river providing access to beach and public toilets.
39	16/05/2013	9:00	NS 30470 38083	230471	638083		SSFW4	Planned freshwater sample from where rivers Garnock and Irvine join. Associated with waypoint 40.
40	16/05/2013	9:06	NS 30473 38082	230474	638083			Bad smell in the air. People arriving by car to access the beach. Dog walkers seen along the beach and on promenade. Appears

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								to be generally cleaner and with less litter than previous locations of this survey. River is too wide, and too deep to measure safely due to dysfunctional bridge.
41	16/05/2013	9:14	NS 30181 37754	230181	637754		SSSW7	Planned seawater sample taken from point where river opens into bay.
42	16/05/2013	9:15	NS 30181 37753	230182	637754			Irvine sands remarkably cleaner than Saltcoats. Less visible litter and debris on beach. Beyond point out to sea there were 7 yachts and 1 tanker. Twenty seagulls on shore and 20 flying. Dog walkers all along beach.
43	16/05/2013	11:27	NS 30478 38232	230479	638232	Fig 18		Other side of bridge at 'The Big Idea' business venture, now closed down. Sandy Shore access was permitted by Trevor Fotheringham, site manager and NPL harbour master. Security clearance and vehicle escort was provided by Trevor through the Chemring Energetics site and through the Nobel Business Park. No photographs or waypoints were taken as all electronic equipment was required to be turned off until safely through the site and onto the beach. Wildlife seen included 2 deer, one swan, 2 swallows and 20 seagulls. In contrast to the beach on the other side of the bridge, this side had much more litter and debris.
44	16/05/2013	11:29	NS 30425 38179	230426	638180			Concrete pipe part exposed by sand. End of pipe not visible, approx. 50 cm diameter, not flowing.
45	16/05/2013	11:35	NS 30146 38014	230146	638014	Fig 19		Metal pipe on concrete pillars, no flow, approx. 2 feet diameter.
46	16/05/2013	12:00	NS 29354 38711	229354	638711	Fig 20	SSSF2	Planned shellfish sample. Associated with waypoint 47.
47	16/05/2013	12:13	NS 29360 38736	229361	638737	Fig 20		Shellfish sample take from shore as boat access was not available. Wedge clams were fairly easy to spot in sediment as they had various species of seaweed attached to their shells. At least 4 sanitary towels floating in the sea, several more seen

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								over approximately half an hours walk along shore. Information was gathered from a local dog walker who said that a dolphin had recently been washed up on the beach approximately 3 months ago and was in the local press.
48	16/05/2013	13:39	NS 27376 40116	227377	640117		SSSF3	Start of shellfish collection. Associated with waypoint 49.
49	16/05/2013	13:45	NS 27060 40217	227060	640218			End of shellfish collection. This shellfish sample was collected back at the point midway along the shoreline route. As shellfish were scarce, the sample was taken over a short distance.
50	15/05/2013	12:15	NS 25564 40796	225565	640796		SSSF1	Planned shellfish sample kindly taken by Mr Jonathan Moore from his boat.

Photographs referenced in the table can be found attached as Figures 6 – 20.

Sampling

Water samples were collected at the sites marked on the Stevenston Sands samples map shown in Figures 4 and 5.

All the samples were transferred to a Biotherm 10 or Biotherm 25 box with ice packs and posted to the Glasgow Scientific Services (GSS) for *E.coli* analysis. All the samples were posted on the day of collection and all the samples were received the following day. The sample temperatures on arrival at the laboratory were recorded between 1.5 and 1.8 °C.

Seawater samples were tested for salinity by GSS and the results were reported in mg Chloride per litre. These results have been converted to parts per thousand (ppt) using the formula:

$$\text{Salinity (ppt)} = 0.0018066 \times Cl \ \text{(mg/L)}$$

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	15/03/2013	SSSW1	NS 23107 41840	Seawater	26	33.78
2	15/03/2013	SSFW1	NS 23109 41841	Freshwater	< 1000	
3	15/03/2013	SSSW2	NS 24489 40849	Seawater	12	33.78
4	15/03/2013	SSSW3	NS 24970 41099	Seawater	11	33.42
5	15/03/2013	SSSW4	NS 25990 40859	Seawater	20	33.24
6	15/03/2013	SSFW2	NS 26604 40852	Freshwater	2600	
7	15/03/2013	SSSW5	NS 26967 40096	Seawater	400	33.42
8	15/03/2013	SSSW6	NS 29361 38753	Seawater	18	33.42
9	16/03/2013	SSFW3	NS 31274 38649	Freshwater	600	
10	16/03/2013	SSFW4	NS 30470 38083	Freshwater	700	
11	16/03/2013	SSSW7	NS 30181 37754	Seawater	43	29.45

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100g)
1	15/05/2013	SSSF1	NS 25564 40796	Shellfish	1300
2	16/05/2013	SSSF2	NS 29354 38711	Shellfish	1300
3	16/05/2013	SSSF3	NS 27376 40116	Shellfish	790

Salinity Profiles

No salinity profiles were taken during this survey as it was not possible to sample from the harvester's boat. Therefore the shellfish samples collected by the shoreline survey team were taken from the shore.

Photographs

Figure 6. End of the harbour pier inland at Inner Nebbock. Associated with Waypoint 3.

Figure 7. Blue abattoir building with concrete outhouses. No visible pipes or discharges. Approximately 60 gulls on roof of building. Associated with Waypoint 9.

Figure 8. Brown foam all along beach. Five crows were also seen pecking in amongst it. Associated with Waypoint 9.

Figure 9. Bridge over Stevenston Burn. Slow moving water. Looks brown and sandy. Associated with Waypoint 12.

Figure 10. Large concrete pipe extending out to sea, no discharge. Green algae growing around it. Metal gate with chain across it. There is a factory inshore, directly opposite the pipe. No sample. Associated with Waypoint 15.

Figure 11. Freshwater sample (SSFW1) taken from concrete covered pipe which looks like it is coming from Ham Curers behind. Abundance of periwinkles and limpets observed. Associated with Waypoint 19 & 20.

Figure 12. Planned freshwater sample from river (SSFW2). Associated with Waypoint 28 & 29.

Figure 13. Very large pipe encased in concrete. Could not see if was flowing as tide was over the end of the pipe. Fisherman with a hand line sitting at the end of the pipe. Associated with Waypoint 30.

Figure 14. Debris on beach. Associated with Waypoint 33.

Figure 15. Sample taken from River Irvine as planned (SSFW3). Sample taken across from the Maritime Museum at low tide. Associated with waypoint 36 & 37.

Figure 16. Bridge over Rivers Garnock and Irvine. No access due to incomplete bridge and locked gates. Associated with waypoint 38.

Figure 17. Locked gates at bridge over Rivers Garnock and Irvine. Associated with waypoint 38.

Figure 18. Other side of bridge at 'The Big Idea'. Associated with Waypoint 43.

Figure 19. Metal pipe on concrete pillars, no flow. Associated with Waypoint 45.

Figure 20. Planned shellfish sample (SSSF2). Shellfish sample taken from shore as boat access was not available. Wedge clams were fairly easy to spot in sediment as they had various species of seaweed attached to their shells. Associated with waypoint 46 & 47.