Scottish Sanitary Survey Project

Sanitary Survey Report
Ronas Voe
SI 522 and SI 523
October 2010

Cefas SSS F1006 V1.1 2012/11/01

Report Distribution – Ronas Voe

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

** Distribution of draft and final reports to harvesters is undertaken by the relevant local authority.

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1. General Description

Ronas Voe is Shetland's longest sea loch at approximately 9 km. The voe is located on the north-west mainland in Northmavine, and is dominated by Ronas Hill to the north. Ronas Hill is Shetland's highest hill at 450 m (1486 ft), and derives its name from its red granite rock. To the south of the voe is a small settlement called Heylor, and at the head of the voe is Swinster. Ronas Voe is relatively narrow, being only 200m at its most narrow point, and 1.5km wide at its mouth.

The outer half of the voe is more exposed to wave and tide action from the sea, with the shoreline much more rugged and eroded. The inner part of the voe is more protected from the sea and has a steep sided shoreline.

Figure 1.1 Location of Ronas Voe

2. Fishery

The sanitary survey was prompted by an application for classification of two new sites within and near to the existing Ronas Voe production areas. Both sites are operated by Blueshell Mussels Ltd, who also harvest mussels from two established sites South of Ayre of Teogs and Ronas Voe. These sites were the subject of a sanitary survey in September 2007.

Table 2.1 Shellfish aquaculture sites in Ronas Voe

Production Area	Site	SIN	Species
Ronas Voe	Ronas Voe	SI 239 441 08	Common mussel
Ronas Voe	South of Ayre of Teogs	SI 239 442 08	Common mussel
Ronas Voe 2	Clifts	SI 523 919 08	Common mussel
Not yet specified	West of Black Well	SI 522 918 08	Common mussel

The Ronas Voe and Ronas Voe 2 production areas are both defined as the area bounded by lines drawn between HU 2916 8113 and HU 2940 8157 extending to MHWS. The representative monitoring point (RMP), as given in the FSAS listing, is set at HU 310 806, however this does not lie on the existing mussel lines. Therefore, the actual sampling location in use according the North Atlantic Fisheries College sampling coordinator is HU 3273 8090, on western end of the southern set of long lines at the Ronas Voe site. In addition, the following points have been monitored on the other sites: HU 298 811 (South of Ayre of Teogs), HU 318 809 (Clifts), and HU 290 820 (West of Black Well).

The following recommendations were included in the June 2008 sanitary survey report for Ronas Voe, covering the Ronas Voe and South of Ayre of Teogs sites: "Given the clear difference in levels of contamination between the sites, it is recommended that the production area is split to allow them to be classified separately. Recommended boundaries for the Ronas Voe: South of Ayre of Teogs production area are 'the area bounded by lines drawn between HU 2916 8113 to HU 2940 8157 and HU 3046 8028 to HU 3046 8079 and extending to MLWS'. Recommended boundaries for the Ronas Voe: East production area are 'the area to the east of a line drawn between HU 3233 8108 and HU 3233 8065 and extending to MLWS.'. For the Ronas Voe: East production area, it is recommended that the RMP be set at HU 3292 8103. For the Ronas Voe: South of Ayre of Teogs production area, it is recommended that the RMP be set at HU 2967 8118.". The actual sampling location that has been used at the Ronas Voe site has differed from that recommended and routine monitoring has not been undertaken at South of Ayre of Teogs since prior to the 2008 report.

The fishery at the West of Black Well site coincides with Crown Estate lease area SH-29-2, however the site falls outside of the current production area. At the time of shoreline survey, it consisted of three double-headed long lines with 10m droppers. The two lines towards the middle of the voe have recently been laid. The near-shore line was one year old at the time of survey and the harvester planned to harvest the stock in July 2011 when it is mature.

The fishery at Clifts falls within the Crown Estate lease area with reference number SH-32-5. The site consists of six double-headed long lines with 10m droppers. Three of the lines had recently been laid and plans were to harvest these lines in 2.5 years time. The other three lines were 3 years old, and the stock was being harvested at the time of survey.

The locations of the fisheries at Ronas Voe and South of Ayre of Teogs were not specifically resurveyed at this time, though it was noted during the shoreline survey that the South of Ayre of Teogs site is now much larger than observed in 2007, consisting of two sets of 3 double-headed long lines. Figure 2.1 shows the position of the mussel lines, production area, seabed lease area, and monitoring points in Ronas Voe. For the purposes of illustration, the GIS file provided by Shetland Islands Council is used to represent the area approved for installation of the aquaculture sites as it coincides with the Crown Estate lease areas.

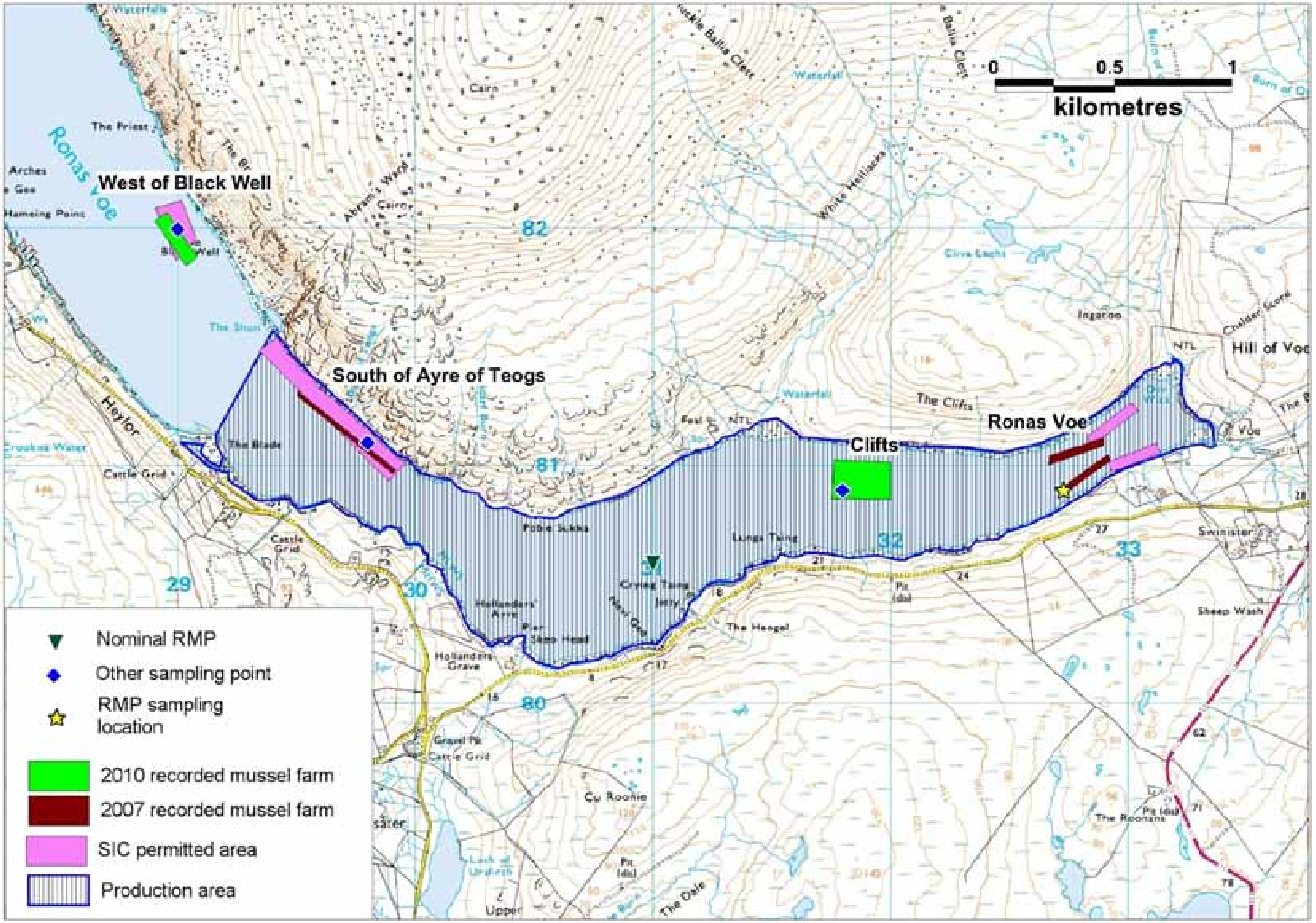

Figure 2.1 Map of Ronas Voe fishery

3. Human Population

Figure 3.1 shows information obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Ronas Voe. The last census was undertaken in 2001.

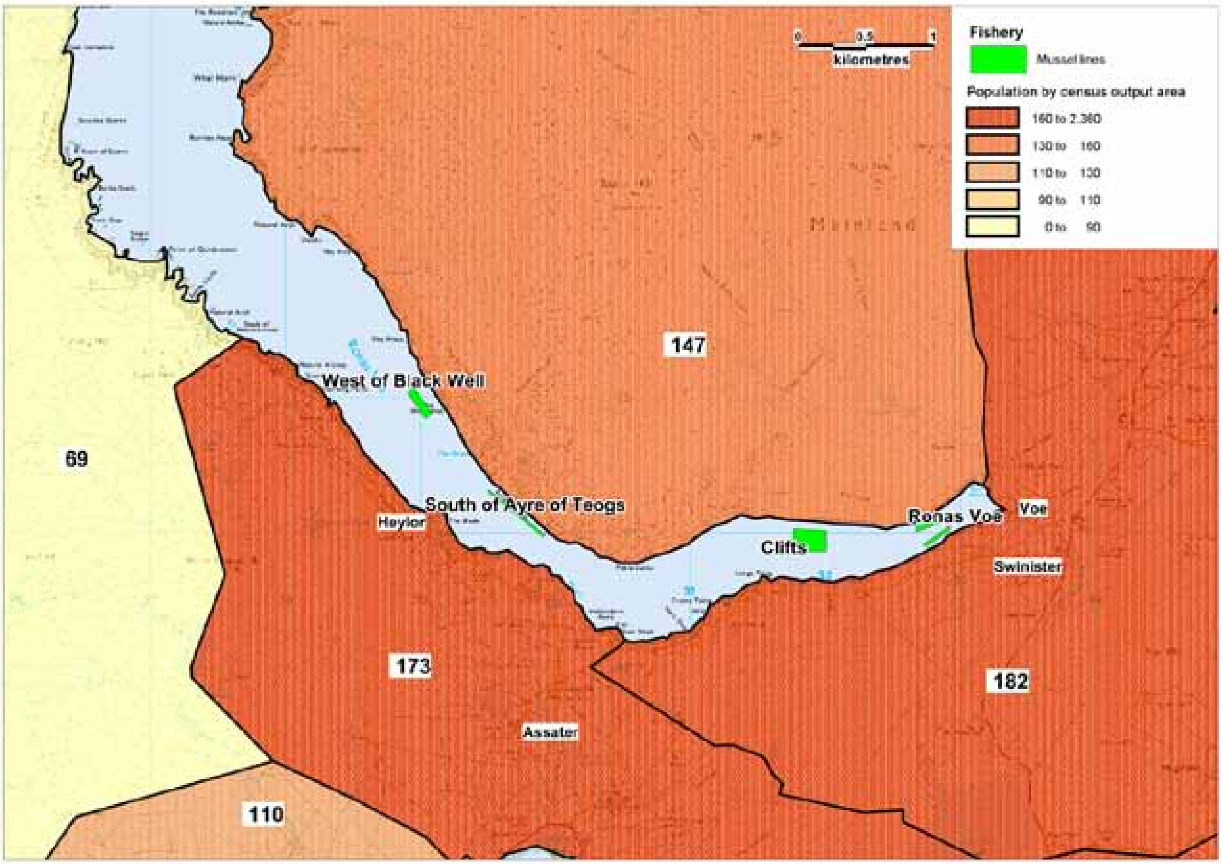

Figure 3.1 Human population surrounding Ronas Voe

There are four population census areas adjacent to Ronas Voe, with populations of 147, 182, 173 and 69. However, the geographic areas covered by each is very large and only a small fraction of the population live immediately adjacent to the coast. Another census area, with a population of 110, is located some distance from the southern shore.

There are no settlements on the northern shore of Ronas Voe. On the southern side of the voe are the small settlements of Heylor, Swinister, Assater and Voe. Most of the population is concentrated towards the eastern end of the shore and any associated faecal pollution from human sources will be likewise concentrated within this area.

Tourism in the area is not significant; there is one known holiday home in the area which is otherwise visited by small numbers of walkers and sea kayakers.

4. Sewage Discharges

Scottish Water identified no community septic tanks or sewage discharges for the area surrounding Ronas Voe. The Scottish Environment Protection Agency recorded a small number of discharge consents for the area. These are listed in Table 4.1. Details were provided on consents for other discharges that were located outside the extent of the area shown in Figure 4.1. These are not included in the list below.

Table 4.1 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented/ design PE	Discharges to
1	CAR/R/1039083	HU 28240 81770	Domestic sewage	not stated	-	5	land
2	CAR/R/1038154	HU 29860 79792	Domestic sewage	not stated	-	5	soakaway
3	CAR/R/1038171	HU 29664 79608	Domestic sewage	not stated	-	5	soakaway
4	CAR/R/1038155	HU 29760 79540	Domestic sewage	not stated	-	9	soakaway
5	CAR/R/1036608	HU 29643 79501	Domestic sewage	not stated	-	5	Mill Burn

Of the discharges listed above, all but one are to land or soakaway. Mill Burn discharges to Loch of Urafirth, which then flows into Urafirth which lies to the south. The three discharges to soakaway are likewise located in the catchment for Urafirth and so should not affect water quality at Ronas Voe even if they were to malfunction.

Septic tanks and/or pipes recorded during the shoreline survey in 2010, or the previous shoreline survey in 2007, are listed in Table 4.2. As there is no public sewerage provision in the area, all homes in the area are presumed to be on individual septic tanks, however only those tanks that were directly observed are included in the list below.

Table 4.2 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	22/06/2010	HU 2915 8094	Pipe running from house onto land. Septic tank near house across road (2007).
2	22/06/2010	HU 2936 8079	2 houses, no sign of outfall pipe, possible septic tank in garden
3	22/09/2007	HU 2923 8096	30cm ID pipe discharging to stream
4	22/09/2007	HU 2919 8095	Pipe below house with 2nd small pipe to stream
5	05/12/2007	HU 2901 8103	Septic tank, no outlet observed
6	05/12/2007	HU 2973 8056	Septic tank, no outlet observed
7	05/12/2007	HU 3337 8114	Septic tank, no outlet observed

Few potential discharges were identified in the vicinity, with no clear outfalls directly to the voe. The majority of the properties that have registered septic tanks with SEPA have systems that discharge to land or to soakaway. The majority of observed septic tanks were located on the south shore, opposite the South of Ayre of Teogs site, though one was also seen at the head of the voe. There were no homes on the north shore, so any impacts from human sewage will be from septic systems on the south shore.

It is not known whether there is a septic discharge associated with the Aqua Farm Ltd facility at Crying Taing.

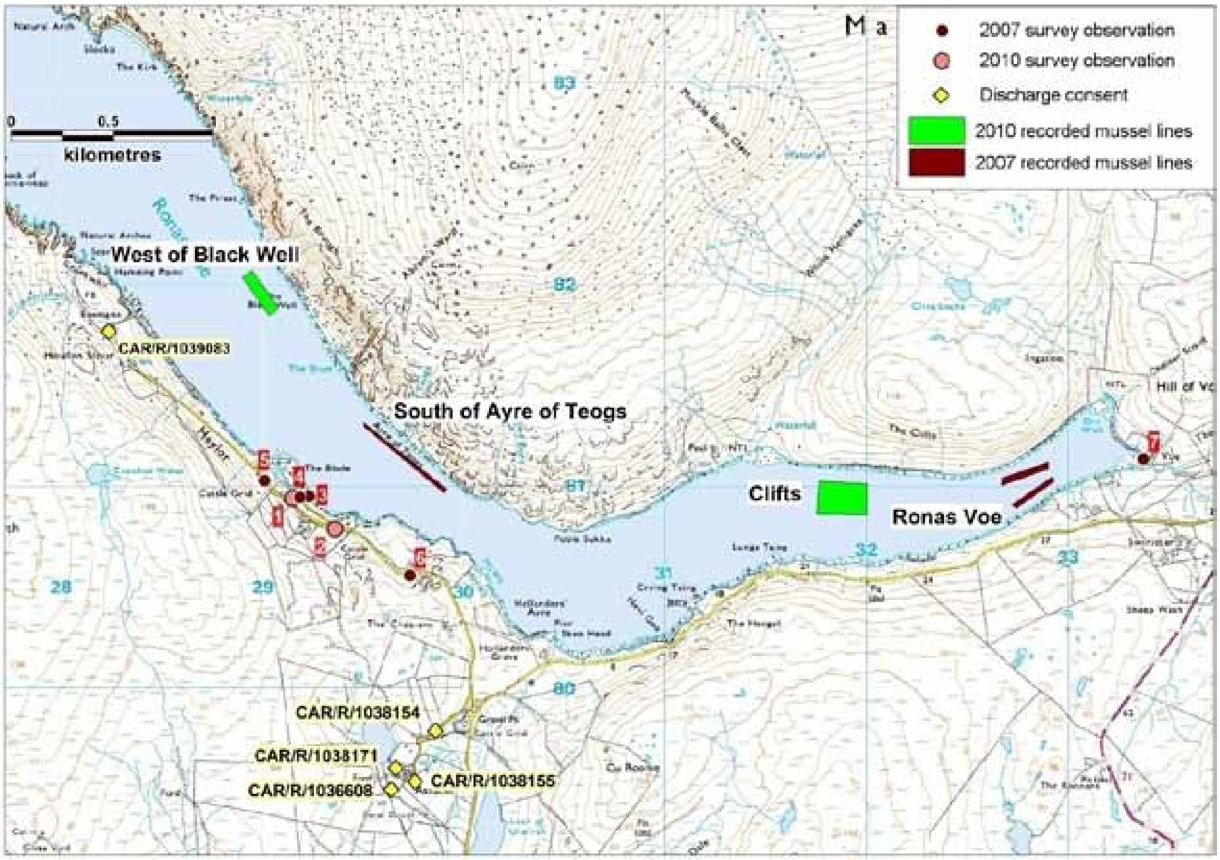

Figure 4.1 Map of discharges for Ronas Voe

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 3. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red, orange and pink indicate poorly draining soils.

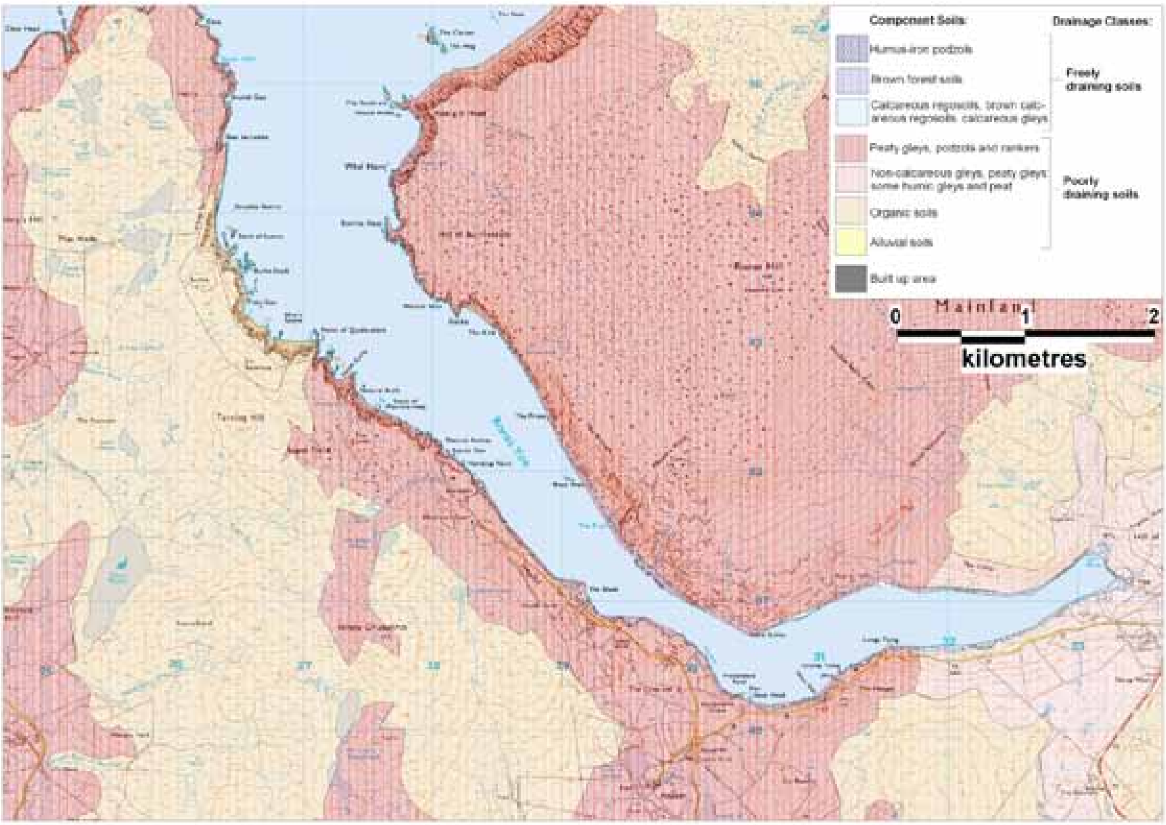

Figure 5.1 Component soils and drainage classes for Ronas Voe

Three types of component soils are present in the area: peaty gleys, podzols and rankers, organic soils, and non-calcareous gleys. All of these soils are poorly draining. Therefore, the potential for runoff contaminated with *E. coli* from human and/or animal waste is high for all the land surrounding the Ronas Voe fishery.

6. Land Cover

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

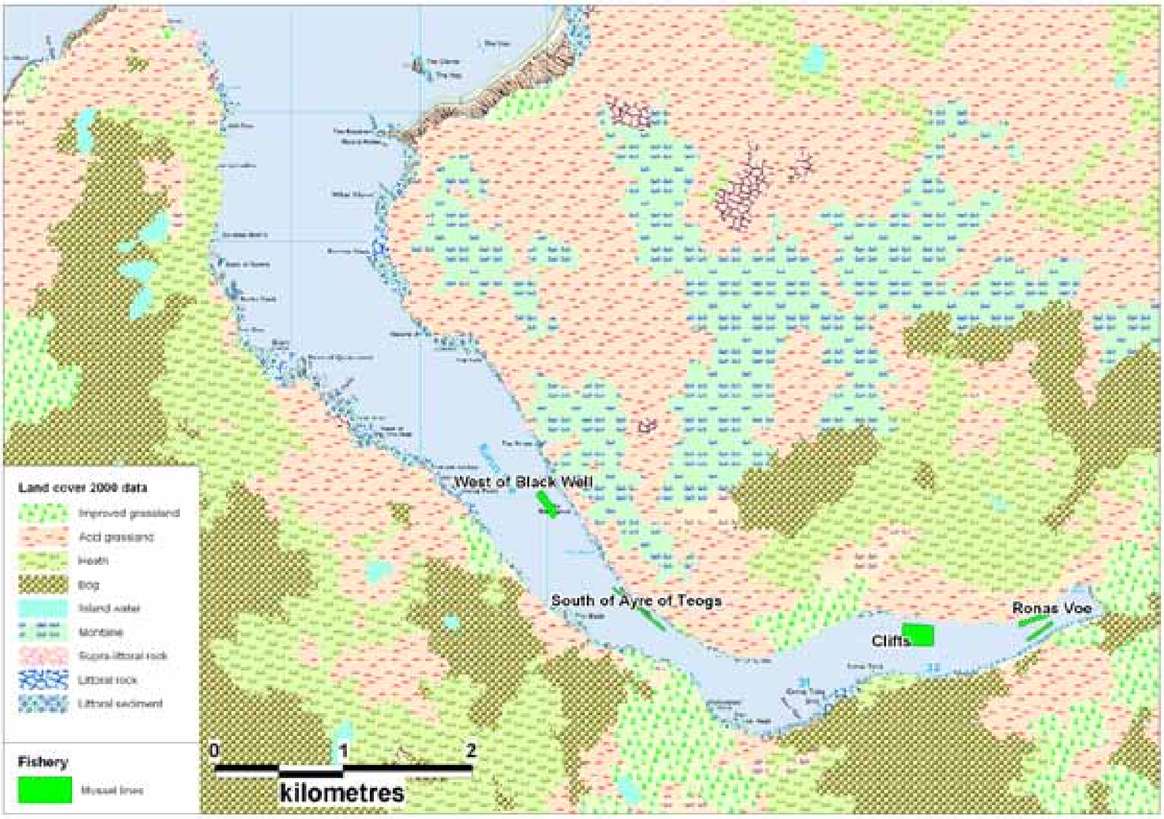

Figure 6.1 LCM2000 class land cover data for Ronas Voe

Five main types of land cover surround Ronas Voe, including improved grassland, acid grassland, bog, heath and open heath. On the southern coastline of the voe improved grassland, bog and acid grassland dominate the coastline. On the northern coastline of the voe, acid grassland and improved grassland cover much of the coast, with heath, bog and montane found further inland. There are areas of littoral sediment and littoral rock along much of the coastline of Ronas Voe.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8×10^9 cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3×10^8 cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5×10^8 cfu km^{-2} hr^{-1}) (Kay *et al*. 2008). The contributions from all land cover types would be expected to increase significantly after marked rainfall events. This would be expected to be highest, at more than 100-fold, for the improved grassland.

Therefore, the overall predicted contribution of contaminated runoff from these land cover types would be low to intermediate, and would be expected to increase significantly following rainfall events. It is likely that the areas of shoreline with improved grassland will be subject to higher levels of contamination.

7. Farm Animals

Agricultural census data to parish level was requested from the Scottish Government and this was provided by the Rural Environment, Research and Analysis Directorate (RERAD) for the parish Northmavine, encompassing a land area of 203.7 km^2. Reported livestock populations for the parishes in 2008 and 2009 are listed in Table 7.1. 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 7.1Livestock numbers in Northmavine parish 2008 - 2009

	Northmavine			
	2008		2009	
	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	*	*
Poultry	22	387	25	437
Cattle	24	571	23	566
Sheep	114	35817	114	35467
Horses and ponies	8	26	9	39

* Data withheld for reasons of confidentiality

Due to the large area of the Northmavine parish and missing data, an accurate representation for the number of livestock on the shore surrounding Ronas Voe is only available from the shoreline survey (see section 15 and Appendix 7). This only relates to the time of the site visit on 22nd to 23rd June 2010. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

Approximately 200 sheep were observed in total around the shoreline of Ronas Voe during the shoreline survey. However there was a relatively low amount of sheep droppings along the southern shore of the voe. There were also three cattle near the houses at the head of the voe, which had access directly on to the beach. Cow pats were observed on this beach. The number of cattle at the head of the voe was noted to have significantly declined since the 2007 sanitary survey, when 58 cattle were observed.

It is likely that the number of farm animals will be at a maximum in spring and summer and will then reduce following autumn livestock auctions.

Farm animals, principally sheep, will therefore be a significant source of faecal contamination within the voe. The contamination will reach the voe by three routes: via streams, by direct deposition in seawater, and by direct run-off following rainfall. The sheep can range relatively freely and so the distribution is likely to differ with time from that observed during the shoreline survey.

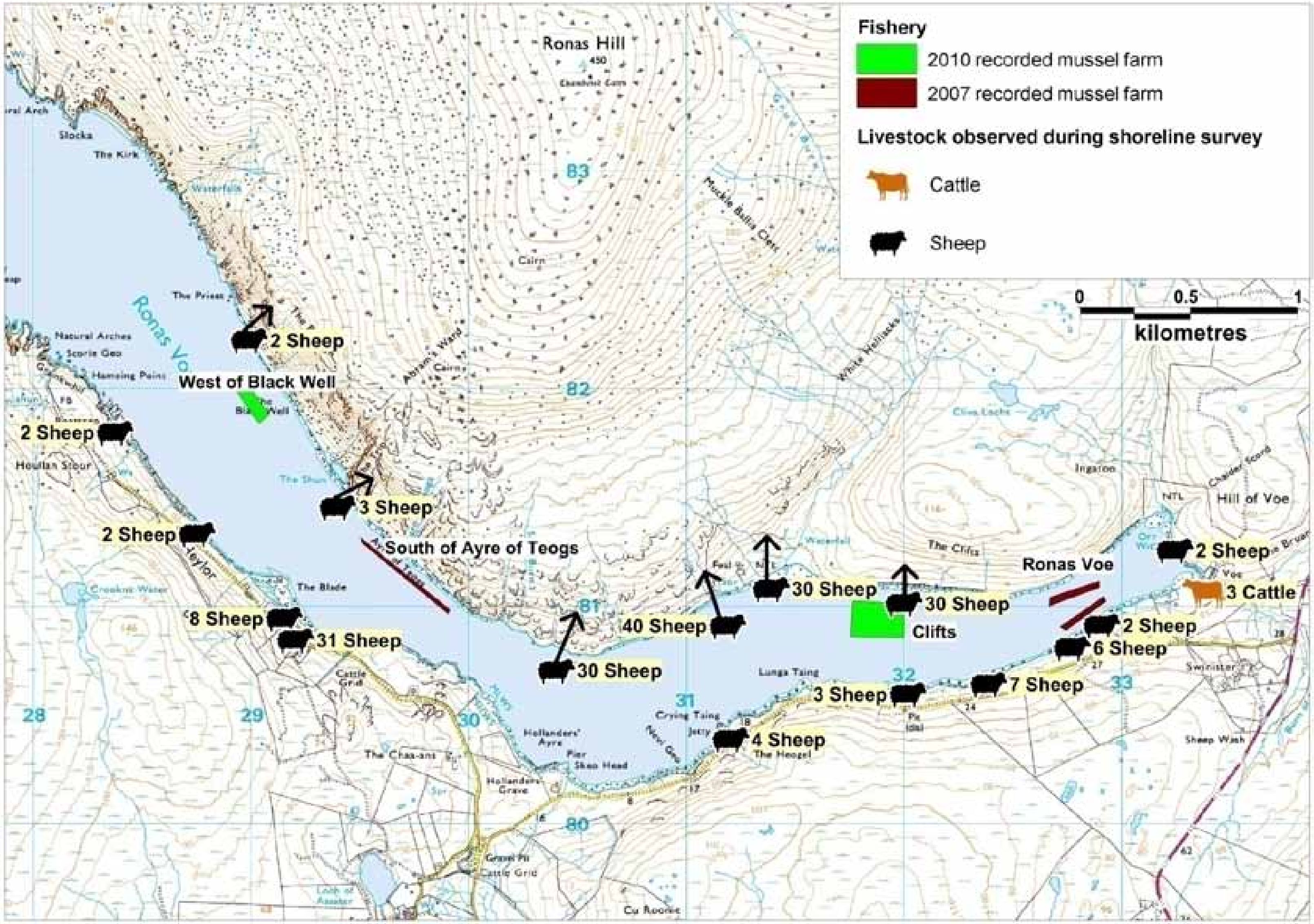

Figure 7.1 Livestock observations at Ronas Voe

8. Wildlife

8.1 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*). Shetland hosts significant populations of both species.

The Sea Mammal Research Unit (SMRU) has given 2006/8 counts of 3057 harbour seals: no separate figure was given for Ronas Voe (SMRU 2009). The grey seal pup production estimate for Shetland in 2008 was given as 819, with that in Rona's Voe (*sic*) given as 45.

The Ramsar listing for Ronas Hill-North Roe & Tingon identifies that the area provides a habitat for the common seal (*Phoca vitulina*) (http://www.ramsar.org/cda/en/ramsar-documents-list-annotated-ramsar-15868/main/ramsar/1-31-218%5E15868_4000_0__).

Seals will forage widely for food and it is likely that seals will feed near the mussel farms at some point in time. The population is relatively small in relation to the size of the area concerned and is highly mobile therefore it is likely that any impact will be limited in time and area and unpredictable.

8.2 Cetaceans

A variety of cetacean species are routinely observed near Shetland. During 2001-2002, there were confirmed sightings of the following species (Shetland Sea Mammal Group 2003):

Table 8.1 Cetacean sightings, Shetland 2001-2002

Common name	Scientific name	No. sighted*
Minke whale	*Balaenoptera acutorostrata*	28
Humpback whale	*Megaptera novaeangliae*	1
Sperm whale	*Physeter macrocephalus*	3
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
White-beaked dolphin	*Lagenorhynchus albirostris*	399
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	136
Striped dolphin	*Stenella coeruleoalba*	1
Risso's dolphin	*Grampus griseus*	145
Common dolphin	*Delphinus delphis*	6
Harbour porpoise	*Phocoena phocoena*	>500

*Numbers sighted are based on rough estimates based on reports received from various observers and whale watch groups.

Due to the relatively shallow sills, and distance from open sea, Ronas Voe is unlikely to host whales or larger cetacean species. It is likely that dolphins may be found from time to time in outer reaches of the voe and the impact of their presence is, as with pinnipeds, likely to be fleeting and unpredictable.

8.3 Other mammals

The Ramsar listing for Ronas Hill-North Roe & Tingon also identifies that the area provides habitat for the otter (*Lutra lutra*). No information was found regarding the number of otters in the area.

8.4 Seabirds

A number of seabird species breed in Shetland. These were the subject of a detailed census carried out between 1998 and 2002. Total counts of all species recorded in Ronas Voe are presented in Table 8.1. Where counts are of pairs of birds, the actual number of breeding adults will be double. This data is thematically mapped in Figure 8.1.

Table 8.1 Seabird counts in Ronas Voe

Common name	Species	Total Count	Method
Black guillemot	*Cepphus grylle*	188	Individuals on land
Atlantic puffin	*Fratercula arctica*	56	Occupied burrows
Northern fulmar	*Fulmarus glacialis*	2208	Occupied sites
Herring gull	*Larus argentatus*	5	Occupied territory
Great black-backed gull	*Larus marinus*	2	Occupied territory
European shag	*Phalacrocorax aristotelis*	27	Occupied nests

8.5 Summary

Faecal contamination arising from wild mammal sources is likely to be of a relatively low level and sporadic with respect to time and location. Seabirds are likely to be a more important source of contamination. Although some were seen towards the head of the voe during the shoreline survey, information from the Seabird 2000 survey indicates that they will predominate towards the outer end of the voe and thus will potentially have a greater impact on the West of Black Well and South of Ayre of Teogs sites.

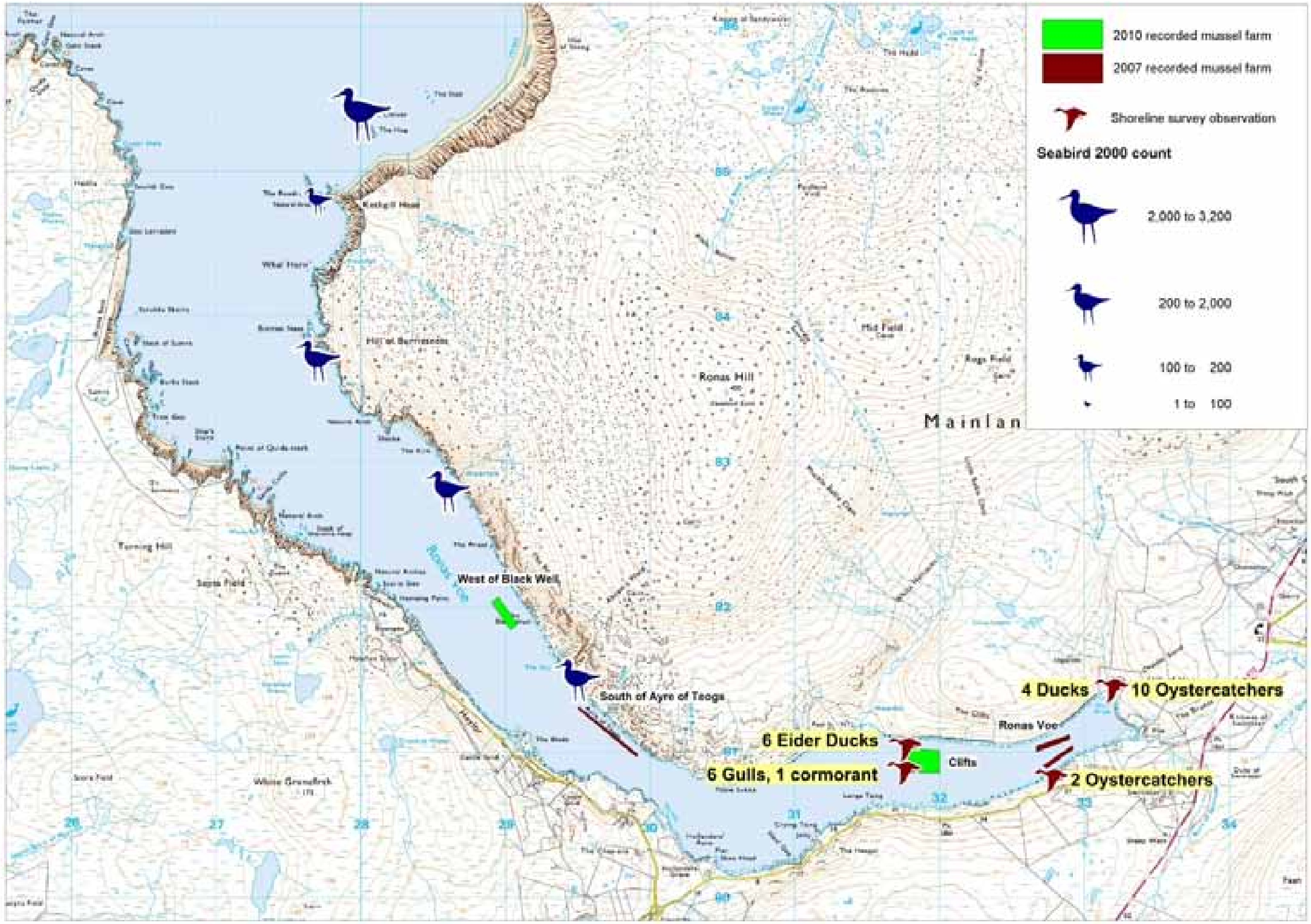

Figure 8.1 Seabird distributions and wildlife observations in Ronas Voe

9. Meteorological data

The nearest weather station is located at Uyeasound, approximately 33 km to the north east of the production area. Rainfall data was available for this station from 2003 to 2009 aside from 6 days in October 2006 and 2 days in October 2008. The nearest station for which wind data was also available was Lerwick, approximately 41 km to the south east. The two locations are therefore quite far apart and also differences in local topography may skew wind patterns differently. This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish at Ronas Voe.

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). Figures 9.1 and 9.2 present box and whisker plots summarising the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median 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 *.

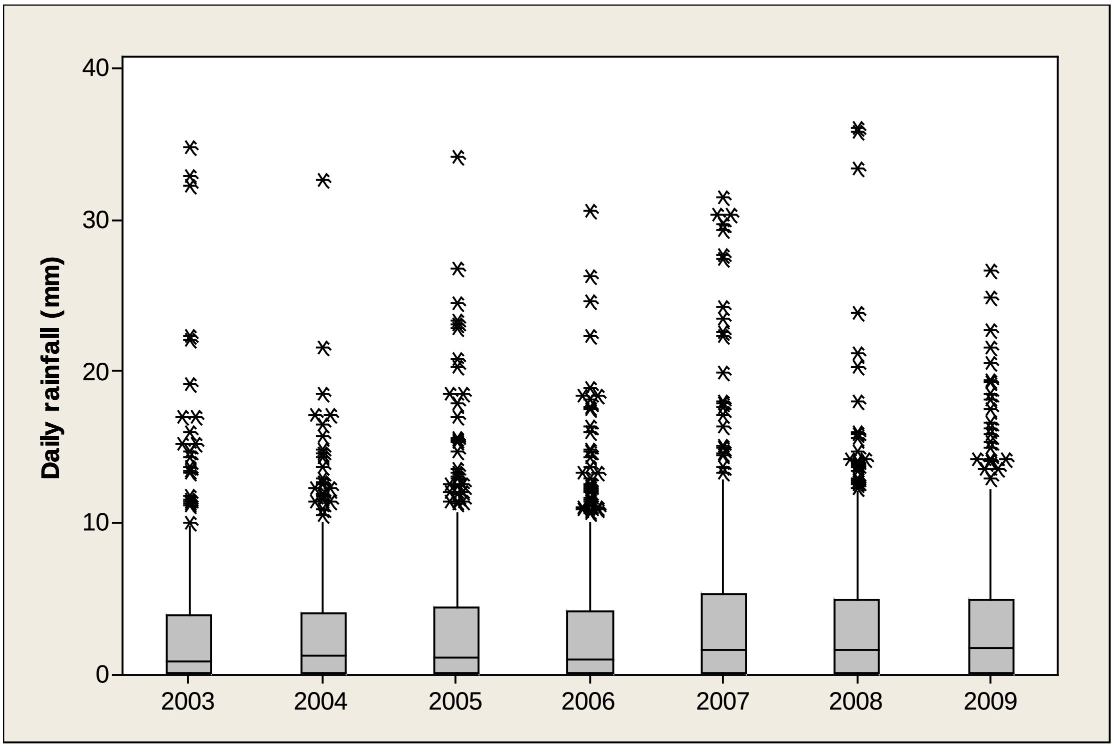

Figure 9.1 Box plot of daily rainfall values by year at Uyeasound, 2003-2009

Figure 9.1 shows that rainfall patterns were consistent between years at this station, with the most rain falling in 2007 and the least in 2003.

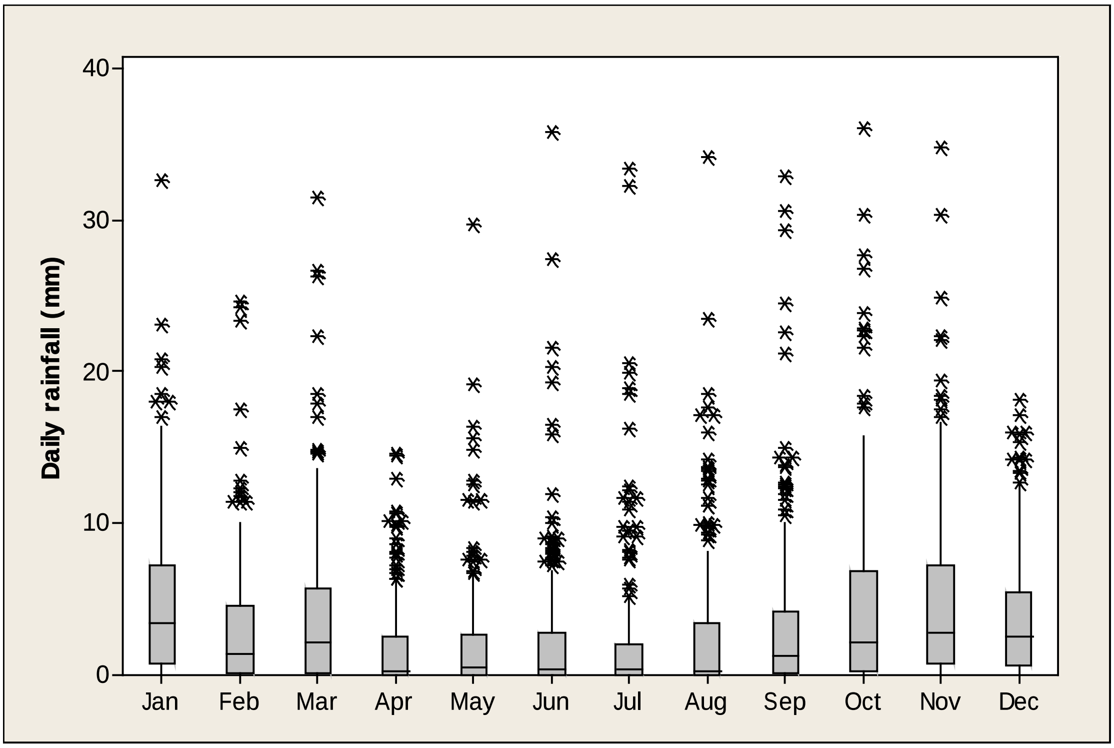

Figure 9.2 Box plot of daily rainfall values by month at Uyeasound, 2003-2009

Weather was generally wetter from October through to March. Days with very high rainfall (over 20 mm) occurred in all months aside from April and, unusually, December. For the period considered here, 46% of days experienced rainfall less than 1 mm, and 10% of days experienced rainfall of 10 mm or more.

It can therefore generally be expected that levels of run-off will be higher during the autumn and winter months. However, it is likely that associated faecal contamination entering the production area will be greatest when extreme rainfall events occur during summer or early autumn after a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest.

9.2 Wind

Wind data collected at the Lerwick weather station is summarised by season and presented in Figures 9.3 to 9.7.

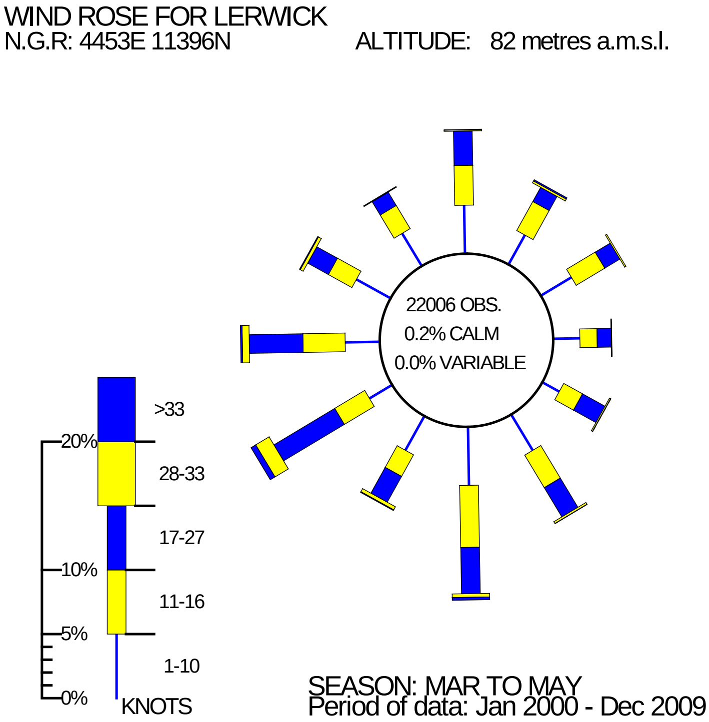

Figure 9.3 Wind rose for Lerwick (March to May)

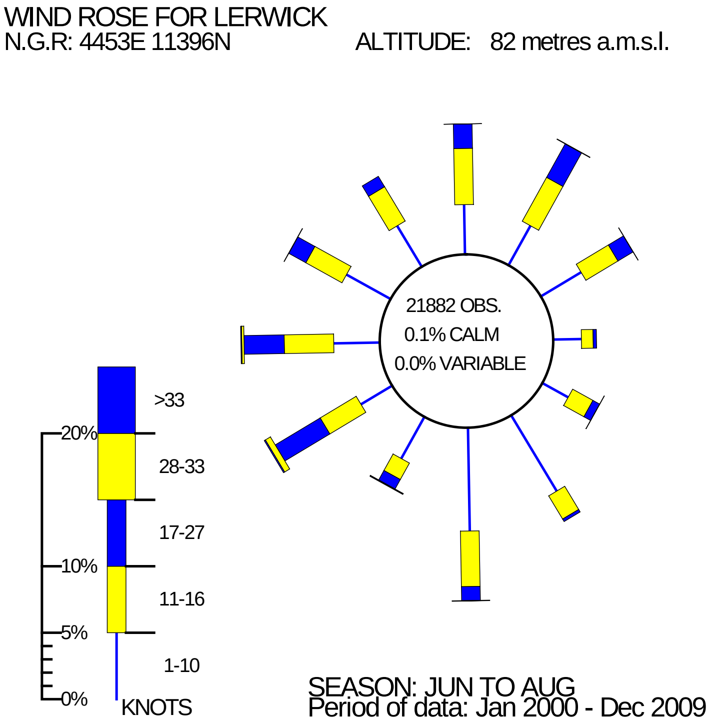

Figure 9.4 Wind rose for Lerwick (June to August)

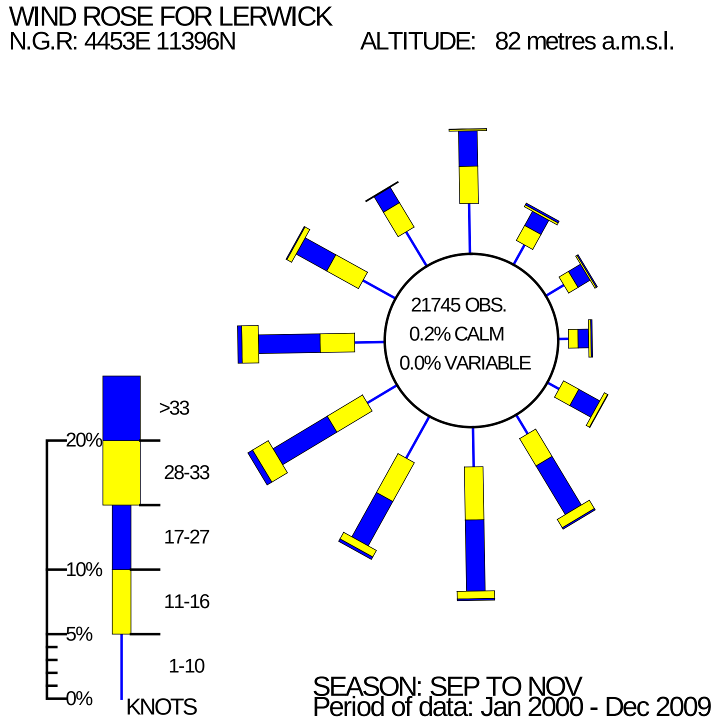

Figure 9.5 Wind rose for Lerwick (September to November)

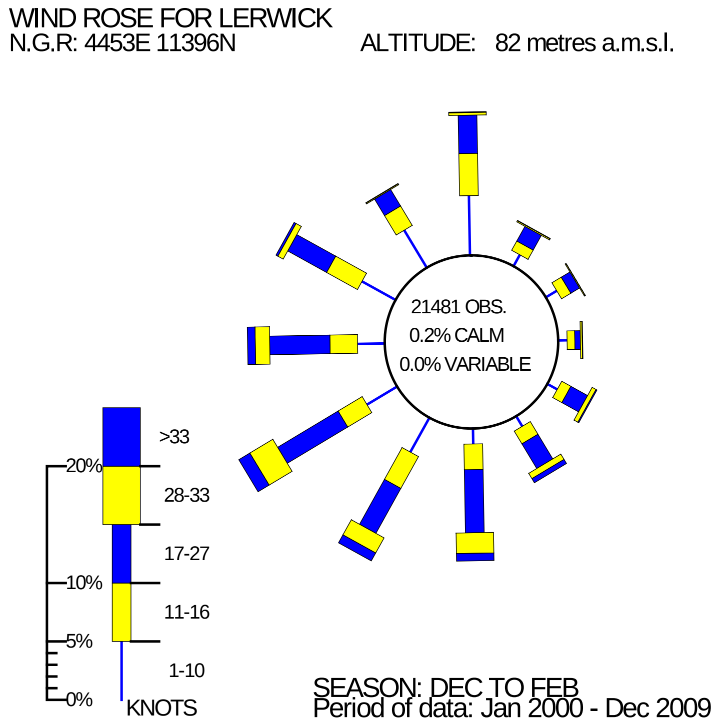

Figure 9.6 Wind rose for Lerwick (December to February)

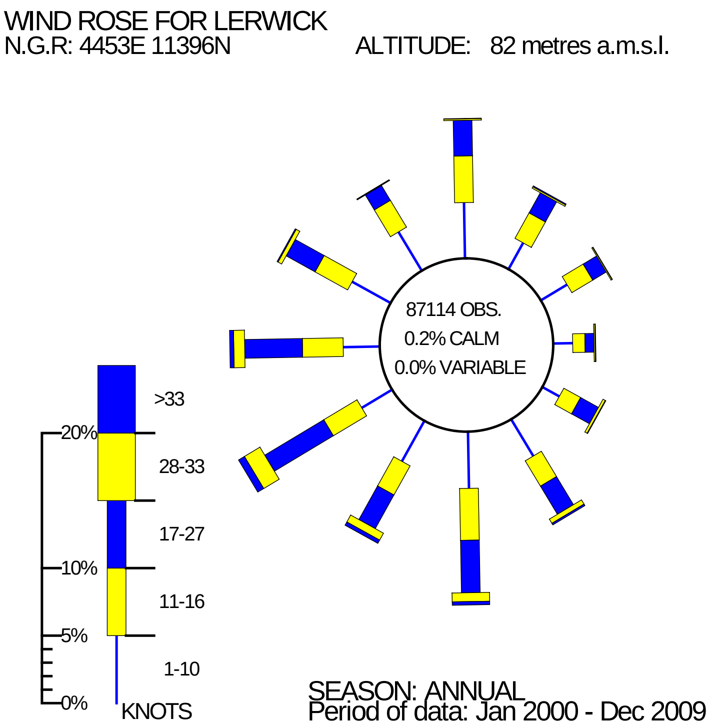

Figure 9.7 Wind rose for Lerwick (All year)

The prevailing wind direction at Lerwick is from the south and west, but wind direction often changes markedly from day to day with the passage of weather systems. There is a higher occurence of north easterly winds during the summer. Winds are generally lightest in the summer and strongest in the winter. Ronas Voe has a south-east to north-west orientation in its outer reaches, and an east west orientation in its inner reaches. It is surrounded by steep hills rising to 450 m in places, so winds will be funnelled up and down the voe, and this effect is likely to significantly skew wind patterns along the aspect of the loch.

Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. Therefore strong winds, particularly those from the directions to which it is most exposed will significantly alter the pattern of surface currents at within Ronas Voe. Strong winds may affect tide height depending on wind direction and local hydrodynamics. A strong wind combined with a spring tide may result in higher than usual tides, which will carry accumulated faecal matter from livestock, at and above the normal high water mark, into the production area.

10. Current and historical classification status

Classification records for Ronas Voe: Ronas Voe were available back to 2001.

Table 10.1 Classification history, Ronas Voe

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	A	A	A	A	A	A	B	B	B	B	B	B
2002	A	A	A	A	A	A	A	A	A	A	A	A
2003	A	A	A	A	A	A	B	B	B	B	A	A
2004	A	A	A	A	A	B	B	B	B	A	A	A
2005	A	A	A	A	A	A	B	B	A	A	A	A
2006	A	A	A	A	A	A	A	A	A	A	A	A
2007	A	A	A	A	A	B	B	B	B	B	B	B
2008	B	B	A	A	A	A	A	A	B	B	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									

Ronas Voe has held a year-round class A in four years – 2002, 2006, 2009 and 2010. In the other years, it has mainly tended to be class B during the latter half of the year, with the notable exception of 2008, when it was class B in January and February.

The production area Ronas Voe 2 was first given separate classification in 2010/11. This area includes the site South of Ayre of Teogs, which was included within the classification for Ronas Voe until this year.

Table 10.2 Classification history, Ronas Voe 2

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	A	A	A	A	A	A	A	A	A	A	A	A
2011	A	A	A									

11. Historical *E. coli* data

11.1 Validation of historical data

All classification *E. coli* results for mussel samples taken at Ronas Voe from the beginning of 2002 to the 10th May 2010 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

All reported sampling locations fell within Ronas Voe. One sample was recorded on the database twice at two different locations. The paper records were consulted and the incorrectly entered sample was excluded from this analysis.

All samples were received by the testing laboratory within two days of collection. Two samples had invalid results and so could not be used. One sample had a reported result of >18000, and this was assigned a nominal value of 36000 for statistical assessment and graphical presentation, and 43 samples had results reported as <20, and were assigned a nominal value of 10. All *E. coli* results are reported in most probable number (MPN) per 100 g of shellfish flesh and intravalvular fluid.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling History				
Production area	Ronas Voe	Ronas Voe	Ronas Voe 2	New area
Site	Ronas Voe	South of Ayre of Teogs	Clifts	West of Black Well
Species	Common mussels	Common mussels	Common mussels	Common mussels
SIN	SI-239-441-08	SI-239-442-08	SI-523-919-08	SI-522-918-08
Location	2 locations	HU 298 811	HU 318 809	HU 290 820
Total no of samples	83	46	6	6
No. 2002	9	0	0	0
No. 2003	10	7	0	0
No. 2004	10	12	0	0
No. 2005	12	12	0	0
No. 2006	12	12	0	0
No. 2007	10	3	0	0
No. 2008	9	0	0	0
No. 2009	9	0	0	0
No. 2010	2	0	6	6
Results Summary				
Minimum	<20	<20	<20	<20
Maximum	>18000	1300	2400	230
Median	40	20	45	20
Geometric mean	64	36	40	95
90 percentile	310	180	2300	225
95 percentile	750	430	2350	228
No. exceeding 230/100g	14 (17%)	3 (7%)	2 (33%)	0
No. exceeding 1000/100g	4 (5%)	1 (2%)	2 (33%)	0
No. exceeding 4600/100g	1 (1%)	0	0	0
No. exceeding 18000/100g	1 (1%)	0	0	0

11.3 Geographical pattern of results

Figure 11.1 presents the geometric mean result at each of the five reported sampling locations.

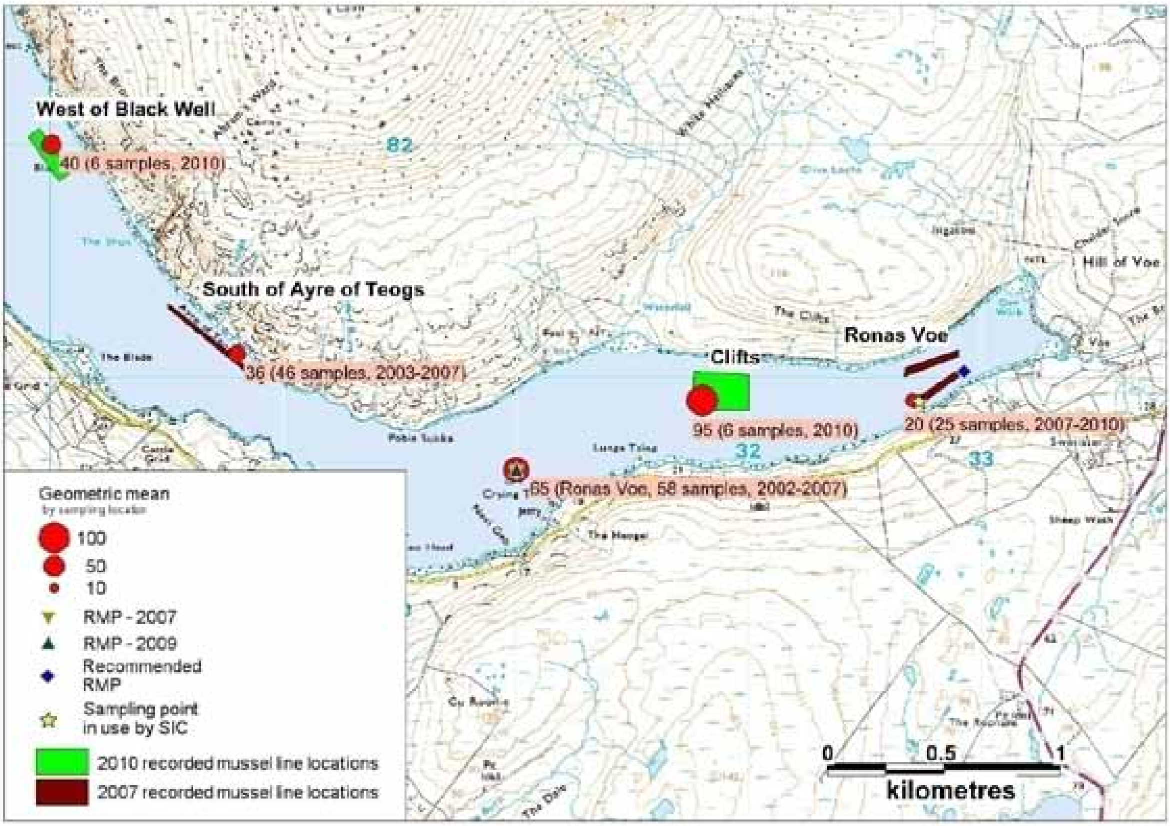

Figure 11.1 Map of geometric mean monitoring results

A total of 58 samples were reported from the nominal RMP from 2002-2007. These were recorded as originating from the Ronas Voe site, at the head of the voe, so the reported sampling location is inaccurate. The other four reported sampling locations appear to align with the locations of the sites from which they were reported but were only recorded to 100 m accuracy. In some cases, multiple sites were sampled on the same day, allowing for direct comparison of contamination levels at the different locations.

South of Ayre of Teogs and Ronas Voe were sampled on the same day and hence under the same environmental conditions on a total of 20 occasions between 2003 and 2007 inclusive. No samples were taken from South of Ayre of Teogs after 2007. Figure 11.2 presents a boxplot of these results.

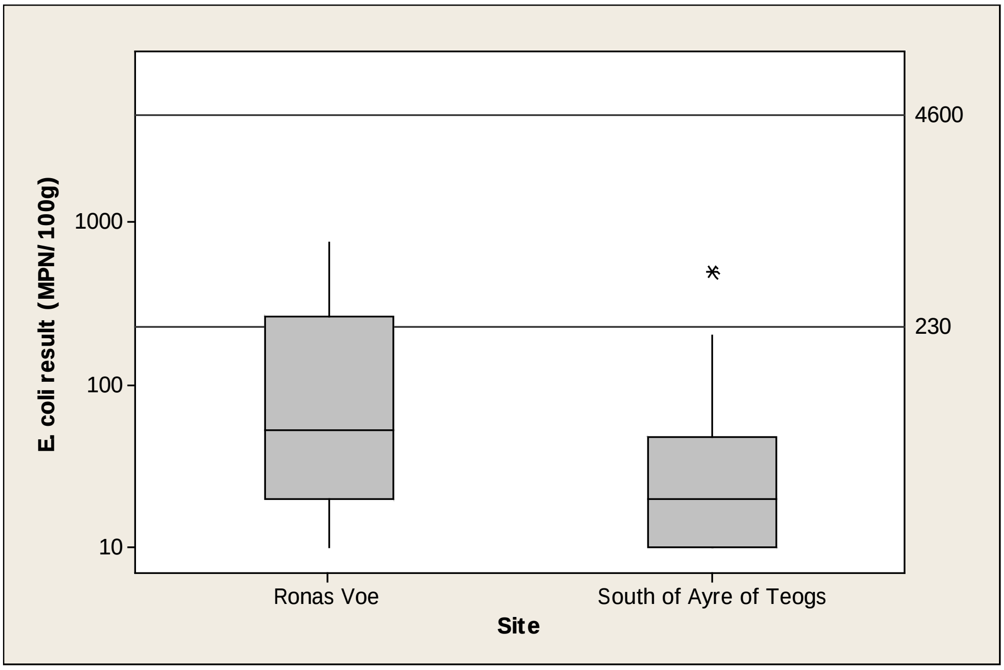

Figure 11.2 Boxplot of *E. coli* results from paired samples at Ronas Voe and South of Ayre of Teogs sites, 2003-2007

A significant difference in mean result was found between the two sites when the paired data presented in 11.2 was considered (paired T-test, T=2.44, p=0.025). Further, there was a greater proportion of results over 230 MPN/100 g at the Ronas Voe site (4/20 compared to 1/20), although this difference was not found to be significant (Fisher's exact test; p=0.182). As the sites are about 3 km apart, and a significant difference in mean result was found between them, results from these two sites are presented and analysed separately through the rest of this section.

Ronas Voe, Clifts and West of Black Well were all sampled on the same day on 5 occasions in 2010. As there were so few occasions, these results are shown in Table 11.2.

Table 11.2 Same-day sampling results from three sites, 2010.

Date	Ronas Voe	Clifts	West of Black Well
10/05/2010	50	<20	220
14/06/2010	<20	<20	20
12/07/2010	460	2200	20
09/08/2010	460	2400	230
13/09/2010	50	70	<20
11/10/2010	<20	<20	<20
Geometric mean	61	85	36

The pattern of results at Ronas Voe and Clifts are similar, indicating that these two sites may be subject to the same source of contamination and/or environmental variables affecting the extent of contamination. In the limited data set presented here, the pattern of contamination at West of Black Well does not show the same pattern as the other two which may indicate it is subject to a different contaminating source, or the effect of one or more different environmental variables. The geometric mean for this set of samples was much lower at West of Black Well than at the other two sites. However, a nested ANOVA performed on the data did not show any significant difference in levels of contamination between the three sites (p=0.188).

11.4 Overall temporal pattern of results

Variation in monitoring results over time was investigated for both the Ronas Voe and South of Ayre of Teogs sites using scatter plots against date fitted with trend lines calculated using two different techniques. These trend lines help to highlight any apparent underlying trends or cycles.

One of the trend lines joins the values representing the geometric mean of the previous 5 samples, the current sample and the following 6 samples and is referred to as a rolling geometric mean (black line). The other is a loess line (blue line), which stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The loess line 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 loess line will be influenced more by the data close to it (in time) and less by the data further away.

Ronas Voe

Figure 11.3 suggests an improvement in monitoring results from 2006 to 2008, with very low levels of contamination (<20 *E. coli* MPN/100g) in the majority of samples from 2008 onwards. A comparison of mean results for samples taken from 2002-2007 and those taken from 2008 onwards shows a highly significant difference (T-test, T=-3.86, p=0.000, Appendix 6).

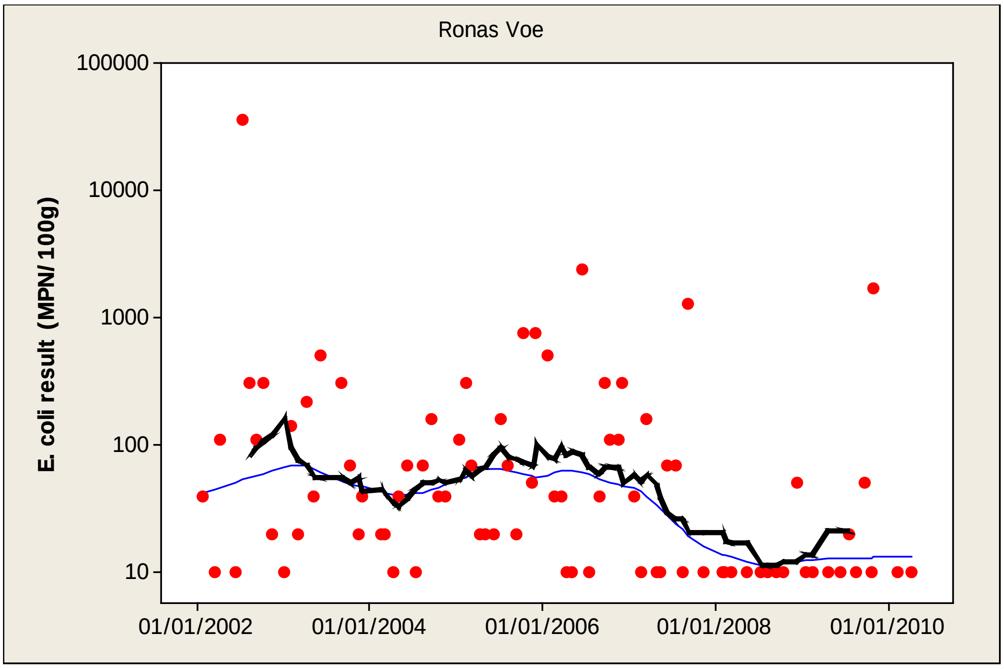

Figure 11.3 Scatterplot of *E. coli* results for Ronas Voe with rolling geometric mean line (black) and Loess line (blue)

The proportion of results of <20 *E. coli* MPN/100g changed from 22% to 79% when these two periods were compared, and this difference was also highly significant (Chi-Sq=20.993, p=0.000, Appendix 6). This suggests that either a major improvement in water quality occurred within Ronas Voe during 2007, or that this effect may be related to the change in reported sampling location that occurred in 2007, although it is unlikely that such strong and consistent within-site spatial variations exist given the generally diffuse nature of the contaminating sources.

South of Ayre of Teogs

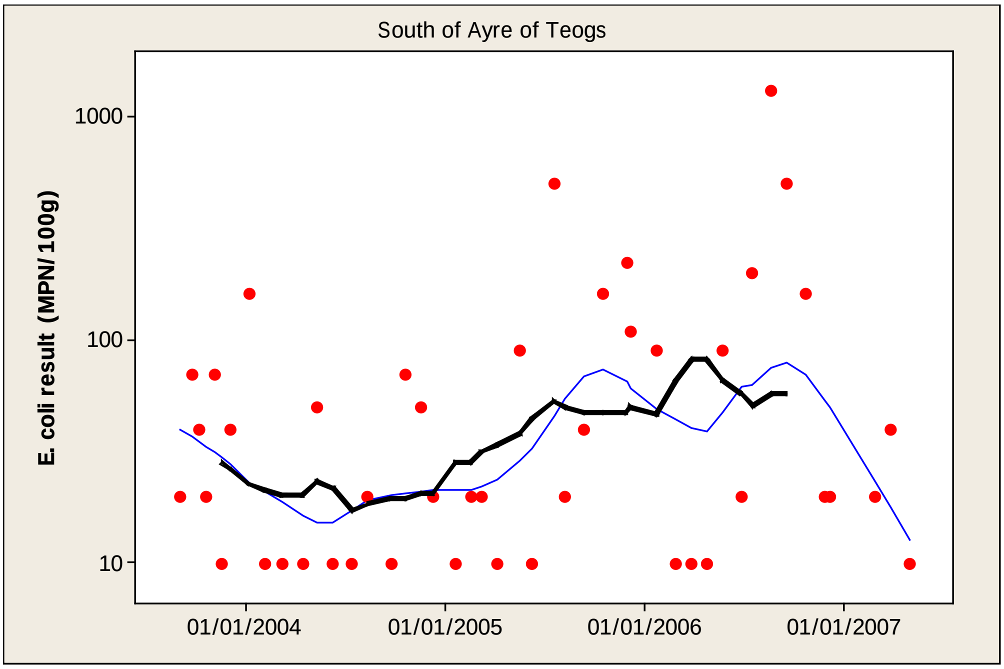

Figure 11.4 Scatterplot of *E. coli* results for South of Ayre of Teogs with rolling geometric mean line (black) and Loess line (line)

Figure 11.4 shows that higher results occurred in mid- to late-2005 and mid- to late-2006 than had been the norm prior to mid-2005. This was due to occasional higher peak results (including the only results over 220 *E. coli* MPN/100 g) and no results of <20 *E. coli* MPN/100g. No samples were taken after mid-2007 so it is not possible to confirm whether a similar improvement to that observed at the Ronas Voe site also happened at this site.

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 of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Figures 11.5 and 11.7 present scatterplots of *E. coli* result by month for the two sites, overlaid with Loess lines to help highlight any trends. For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February) and results by season presented as boxplots in Figures 11.6 and 11.8.

Ronas Voe

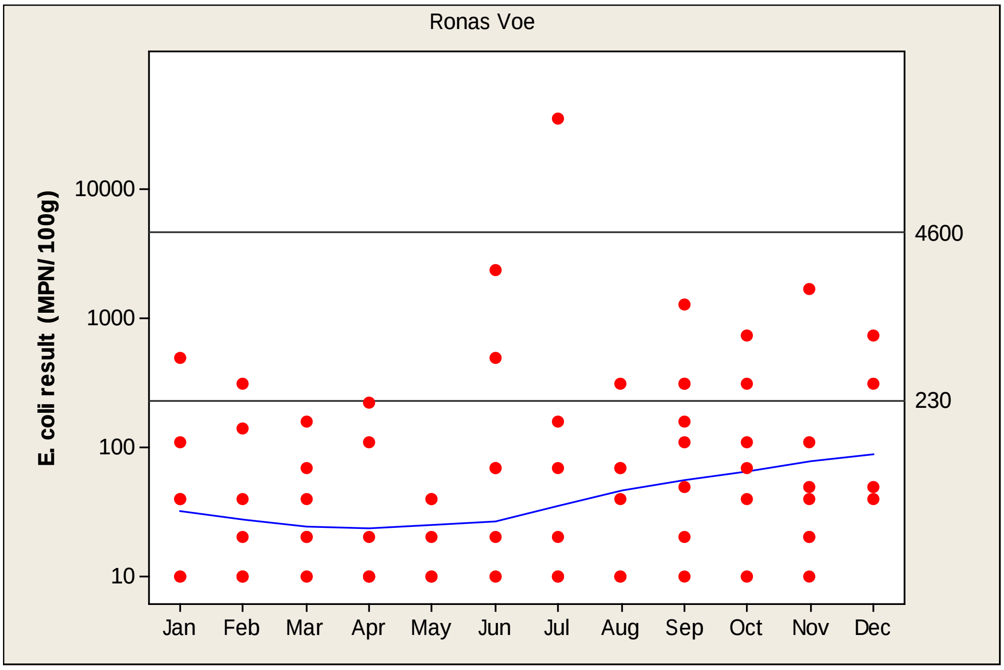

Figure 11.5 Scatterplot of *E. coli* results for Ronas Voe by month

No strong seasonal pattern is apparent in Figure 11.5, but there does appear to be an overall tendency for higher results in the second half of the year. Results greater than 230 *E. coli* MPN/100 g occurred during all months except March and May and the only result greater than 4600 *E. coli* MPN/100 g occurred in July.

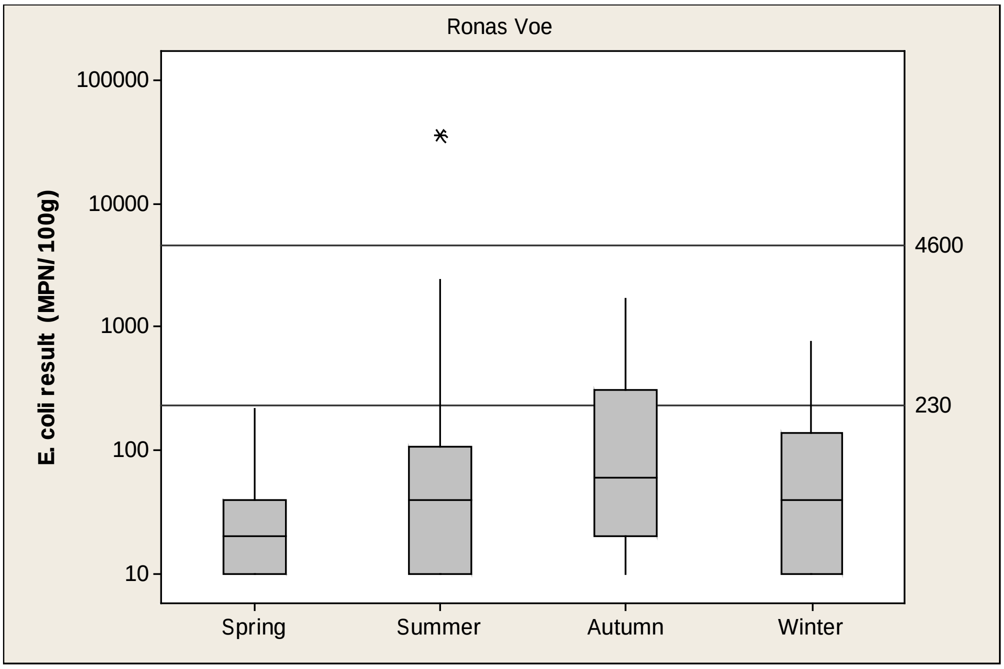

Figure 11.6 Boxplot of result by season for Ronas Voe

Figure 11.6 shows increasing mean results from spring to autumn, decreasing between autumn and winter. The only season in which no results greater than 230 *E. coli* MPN/100 g were recorded was Spring. No significant difference was found between results by season (One-way ANOVA, p=0.095, Appendix 6).

South of Ayre of Teogs

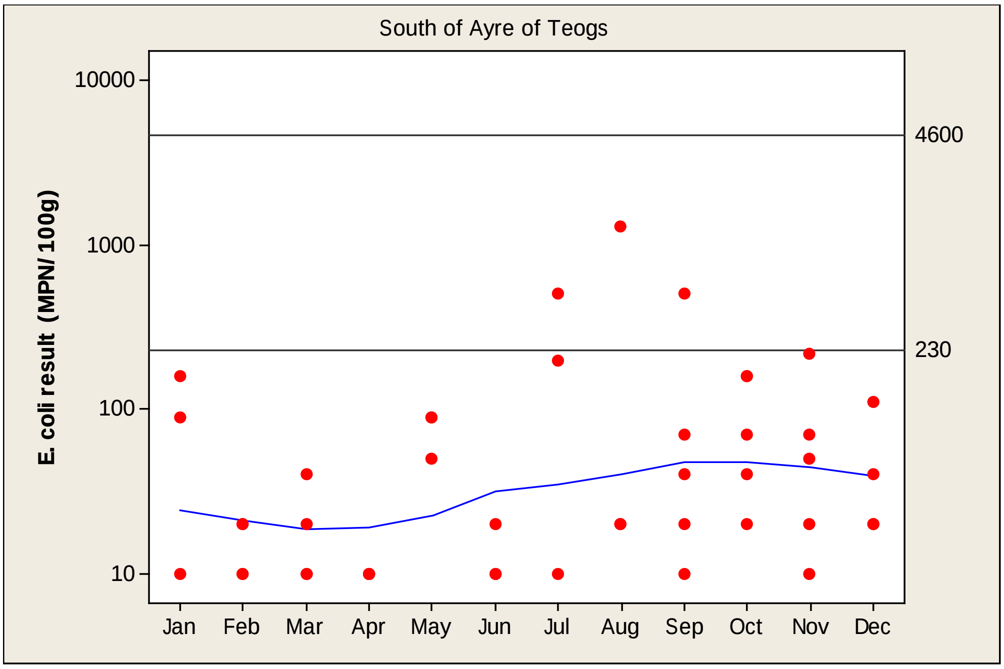

Figure 11.7 Scatterplot of *E. coli* results for South of Ayre of Teogs by month

Figure 11.7 suggests that results were higher overall in the autumn and lower in the spring, though the results over 230 *E. coli* MPN/100g occurred from July to September.

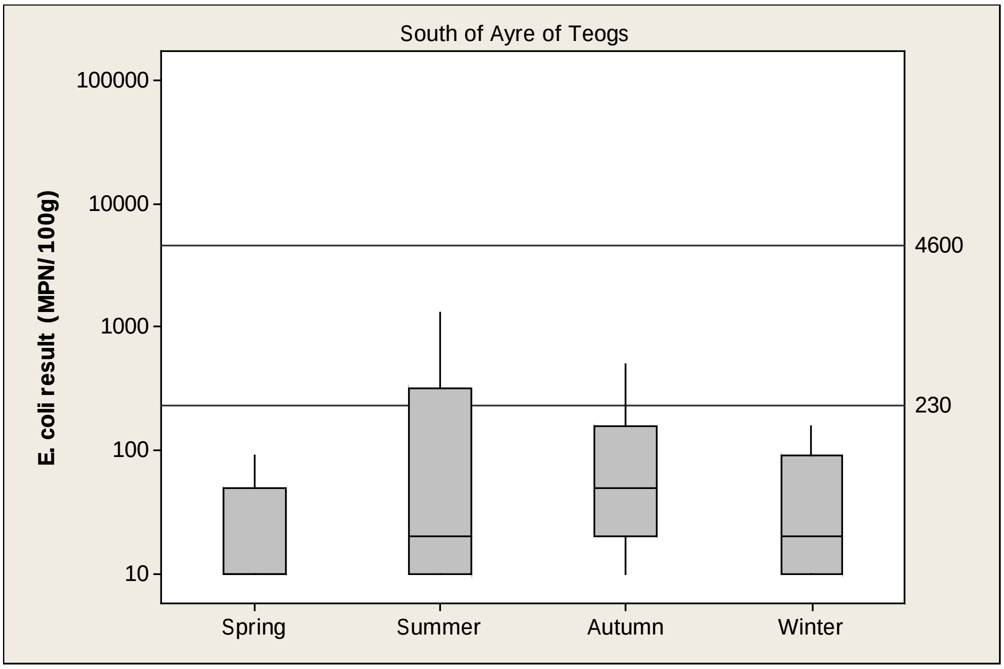

Figure 11.8 Boxplot of result by season for South of Ayre of Teogs

No results over over 230 *E. coli* MPN/100g occurred during either spring or winter. The median result was lowest in spring (when over half the results were <20 *E. coli* MPN/100 g). Highest results appeared to occur during summer and autumn, however no significant difference was found between results by season (One-way ANOVA, p=0.252, Appendix 6).

11.6 Analysis of results against environmental factors

Environmental factors such as rainfall, tides, winds, sunshine and temperatures can all influence the flux of faecal contamination into growing waters (e.g. Mallin et al, 2001; Lee & 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 is at Uyeasound, 33 km to the north east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2009 (total daily rainfall in mm). As the distance between the weather station and the site is so great, there is a strong possibility that rainfall experienced at Ronas Voe differed to that recorded at Uyeasound. Nevertheless, monitoring results were analysed against recorded rainfall. As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationships between rainfall in the previous 2 and 7 days and sample results was investigated and are presented below.

Two-day antecedent rainfall

Figures 11.9 and 11.10 present scatterplots of *E. coli* results against recorded rainfall for the two days previous to sampling.

Ronas Voe

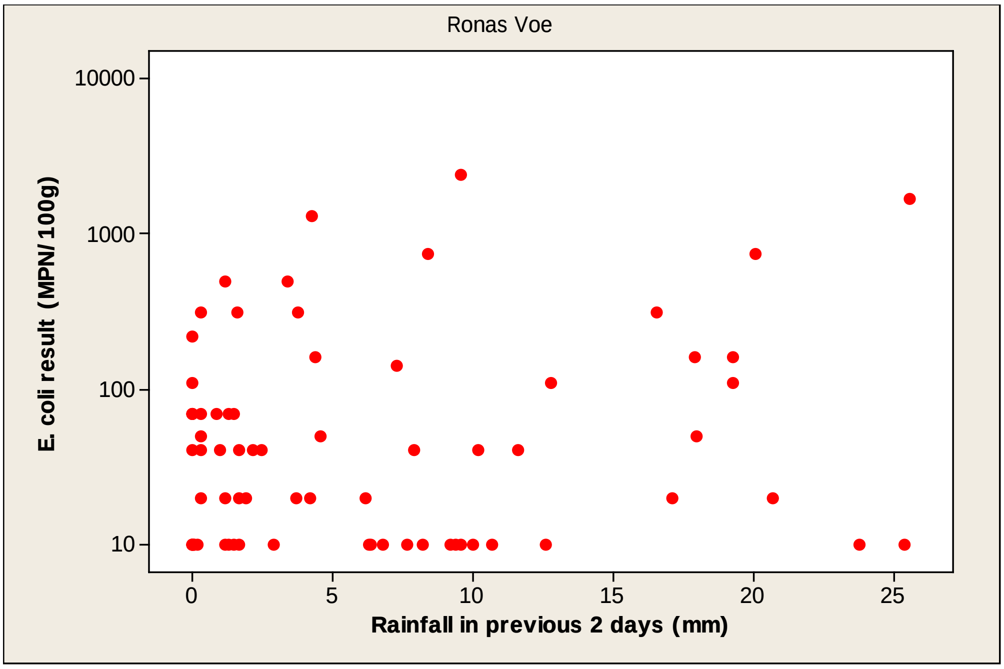

Figure 11.9 Scatterplot of result against rainfall in previous 2 days for Ronas Voe

A Spearman's Rank correlation was carried out between results and rainfall. No significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.079, p>0.10, Appendix 6).

<u>South of Ayre of Teogs</u>

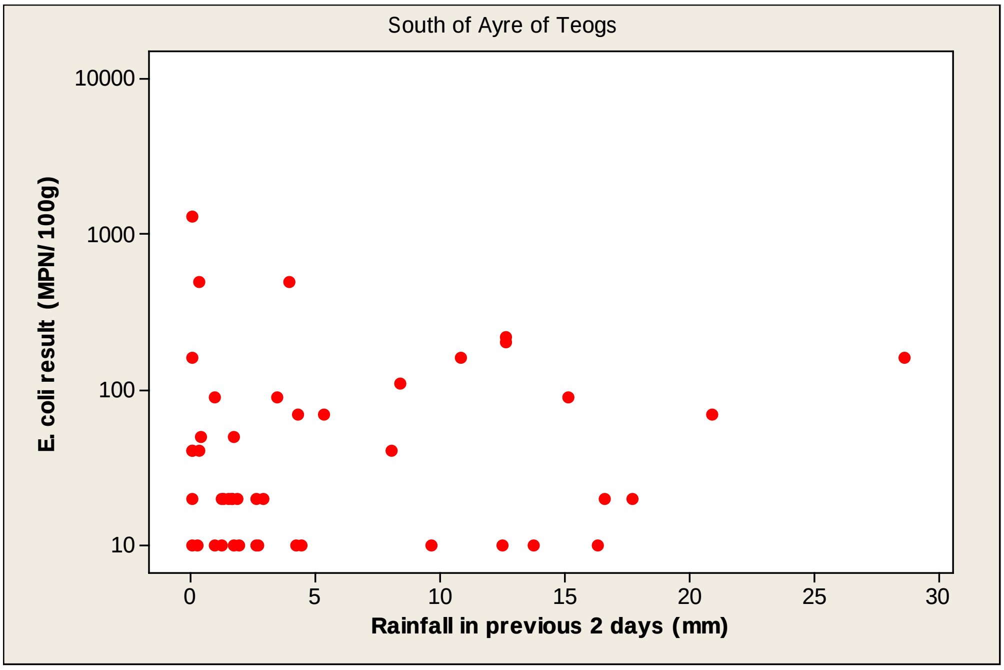

Figure 11.10 Scatterplot of result against rainfall in previous 2 days for South of Ayre of Teogs

No significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.043, p>0.25, Appendix 6) at the South of Ayre of Teogs site. Highest results were obtained after low recorded rainfall.

Seven-day antecedent rainfall

Figures 11.11 and 11.12 present scatterplots of *E. coli* results against rainfall recorded in the 7 days prior to the sampling date.

Ronas Voe

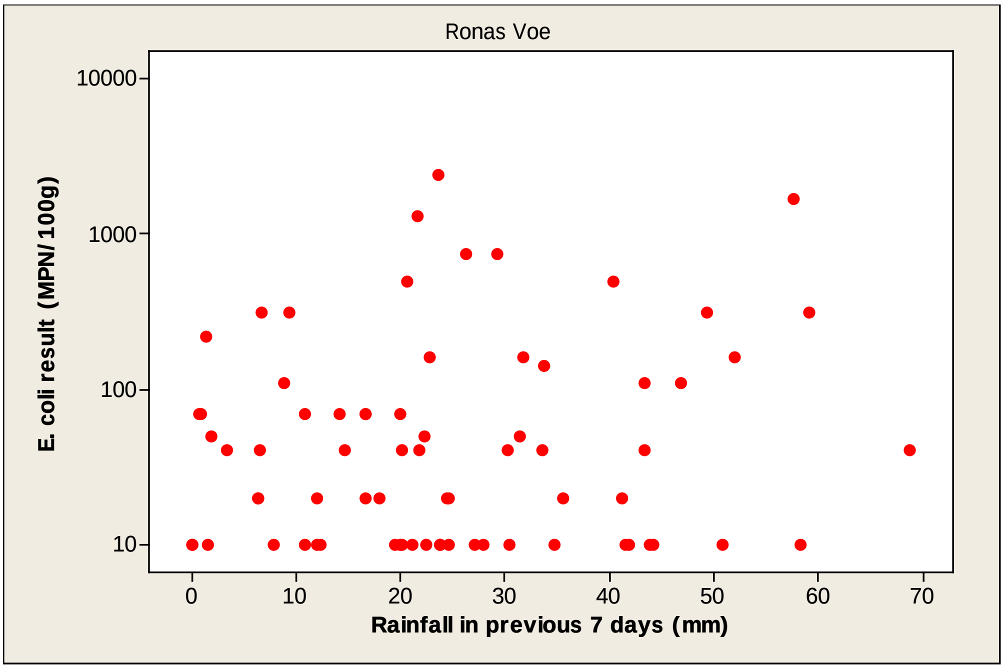

Figure 11.11 Scatterplot of result against rainfall in previous 7 days for Ronas Voe

No significant correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation=0.057, p>0.25, Appendix 6) at the Ronas Voe site.

South of Ayre of Teogs

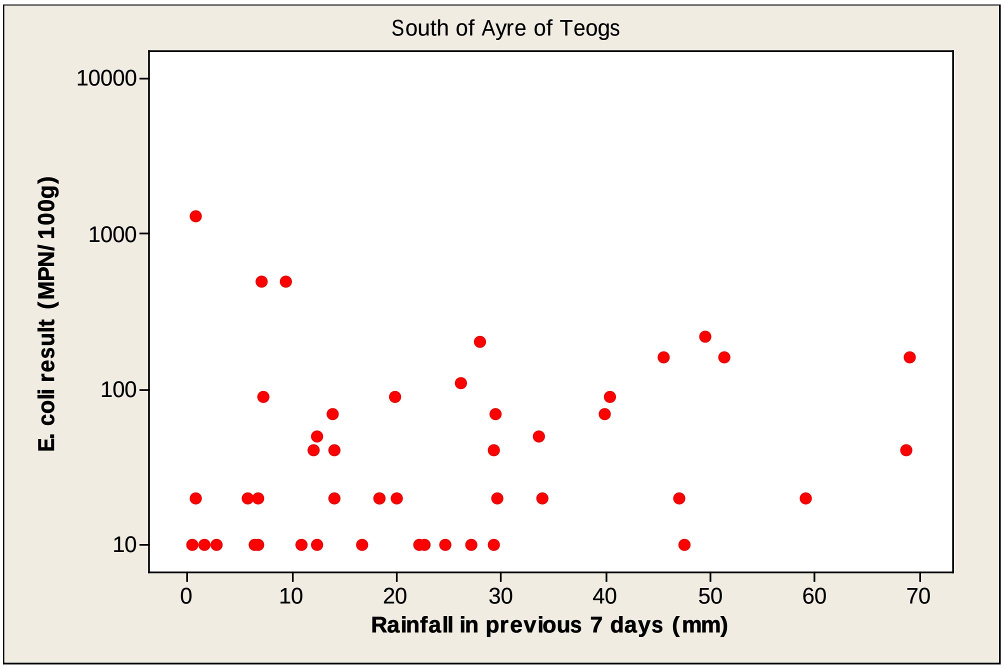

Figure 11.12 Scatterplot of result against rainfall in previous 7 days for South of Ayre of Teogs

A significant weak positive correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation=0.248, p<0.05, Appendix 6). However, the highest *E. coli* result occurred after very low rainfall and results greater than 230 *E.coli* MPN/100g also occurred at lower rainfall levels.

11.6.2 Analysis of results by tidal height and state

Spring/Neap Cycles

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the area. Figures 11.13 and 11.14 present polar plots of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle for Ronas Voe and South of Ayre of Teogs respectively. Full/new moons occur at 0º, and half moons occur at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. Results less than 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g are plotted in red. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

<u>Ronas Voe</u>

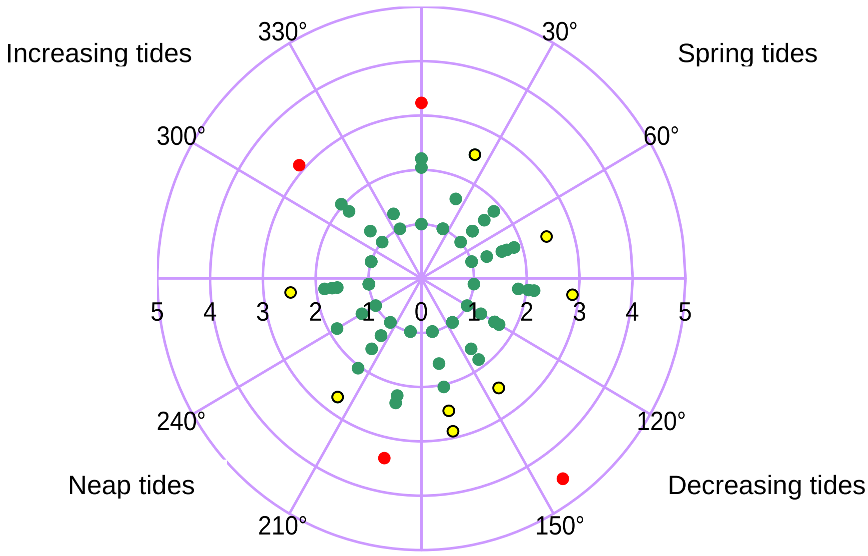

Figure 11.13 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle (Ronas Voe)

No significant correlation was found between *E. coli* results and the spring/neap cycle for Ronas Voe (circular-linear correlation, r=0.107, p=0.398, Appendix 6).

South of Ayre of Teogs

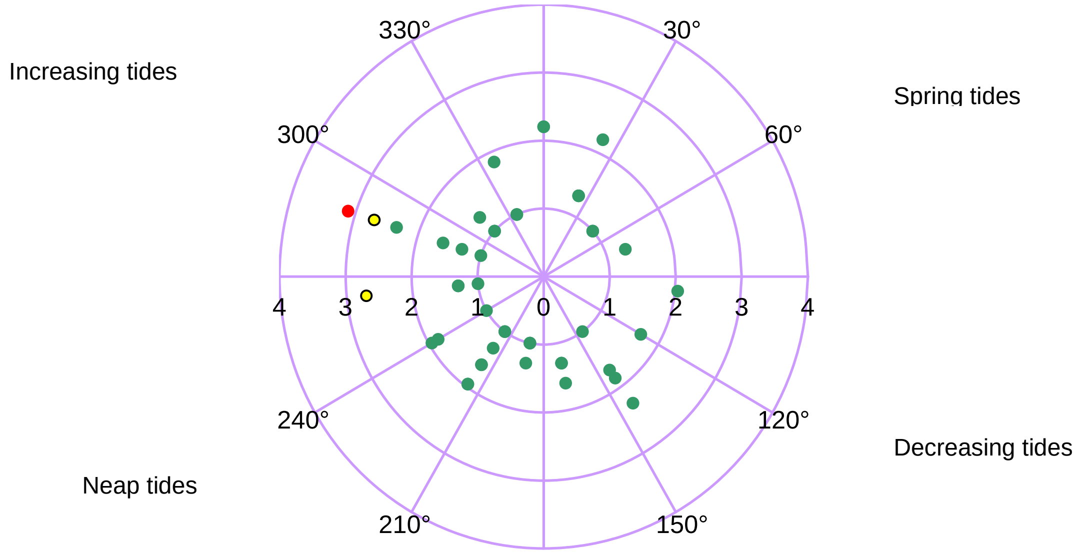

Figure 11.14 Polar plot of log10 *E. coli* results on the spring/neap tidal cycle for South of Ayre of Teogs

No significant correlation was found between *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.172, p=0.129, Appendix 6). Sampling was targeted towards spring tides.

High/Low Cycles

Direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the shellfisheries during this cycle. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figures 11.15 and 11.16 present a polar plots of log10 *E. coli* results on the lunar high/low tidal cycle for Ronas Voe and South of Ayre of Teogs respectively, for samples for which the time of collection was recorded. High water is located at 0º, and low water is located at 180º. Results less than 230 *E. coli* MPN/100 g are plotted in green, those between 230 and 1000 *E. coli* MPN/100 g are plotted in yellow, and those over 1000 *E. coli* MPN/100 g are plotted in red.

Ronas Voe

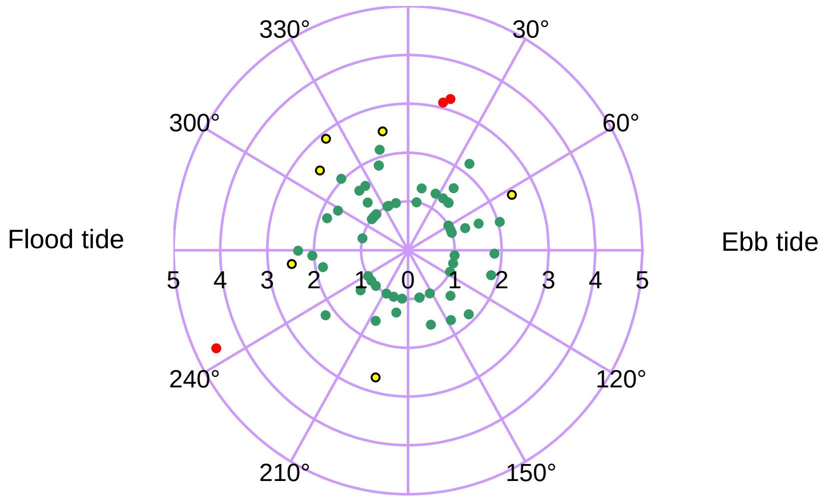

Figure 11.15 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle for Ronas Voe

No significant correlation was found between *E. coli* results and the high/low tidal cycle for Ronas Voe (circular-linear correlation, r=0.211, p=0.061, Appendix 6).

South of Ayre of Teogs

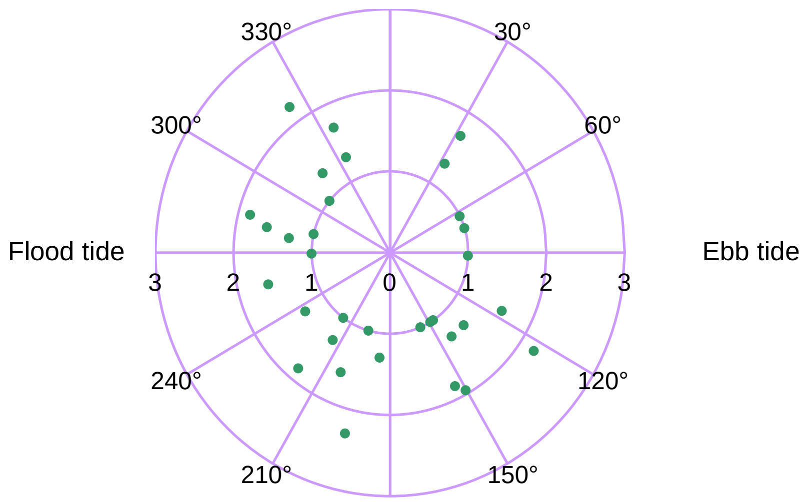

Figure 11.16 Polar plot of log_{10} *E. coli* results on the high/low tidal cycle for South of Ayre of Teogs

No significant correlation was found between *E. coli* results and the high/low tidal cycle for South of Ayre of Teogs (circular-linear correlation, r=0.071, p=0.858, Appendix 6).

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns. Figure 11.17 presents a scatterplot of *E. coli* results against water temperature for Ronas Voe. Water temperature was only recorded on 5 sampling occasions at South of Ayre of Teogs, so it was not possible to investigate the relationship between water temperature and *E. coli* results at that site.

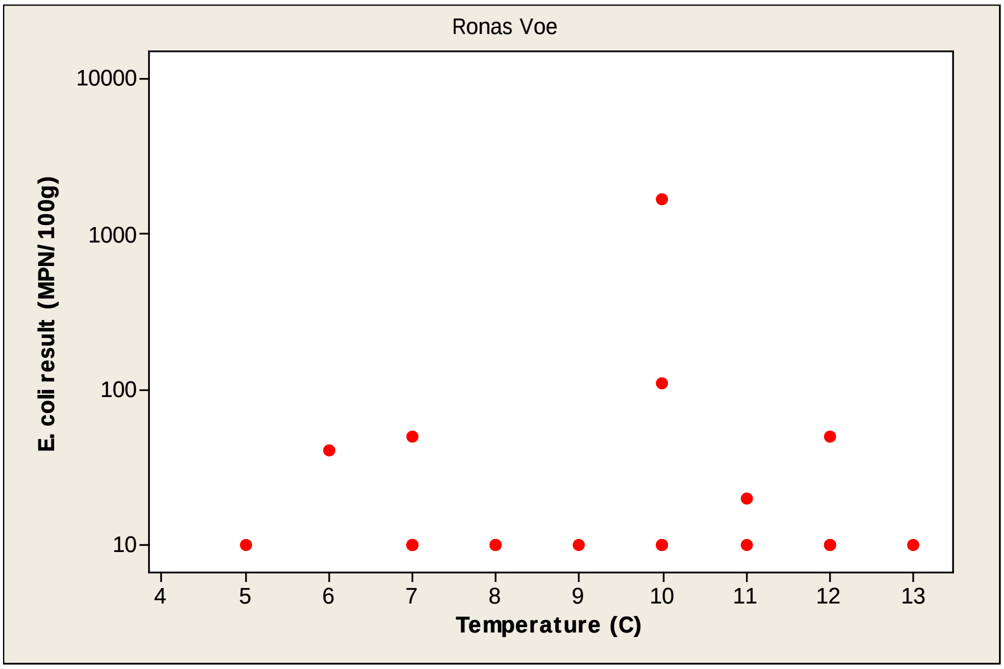

Figure 11.17 Scatterplot of result by water temperature for Ronas Voe

No significant correlation was found between *E. coli* result and water temperature at Ronas Voe (Spearman's rank correlation= -0.027, p>0.25, Appendix 6).

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns within the production area. However, the nearest wind station for which records were available was Lerwick, approximately 41 km to the south east. Given the differences in local topography and distance between the two it is likely that the overall patterns of wind direction would differ, and that the wind strength and direction may differ significantly at any given time. Therefore, it was not considered appropriate to compare *E. coli* results at Ronas Voe with wind readings taken at Lerwick.

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater-borne contamination at the site. Figures 11.18 and 11.19 present scatter plots of *E. coli* result against salinity for Ronas Voe and South of Ayre of Teogs respectively.

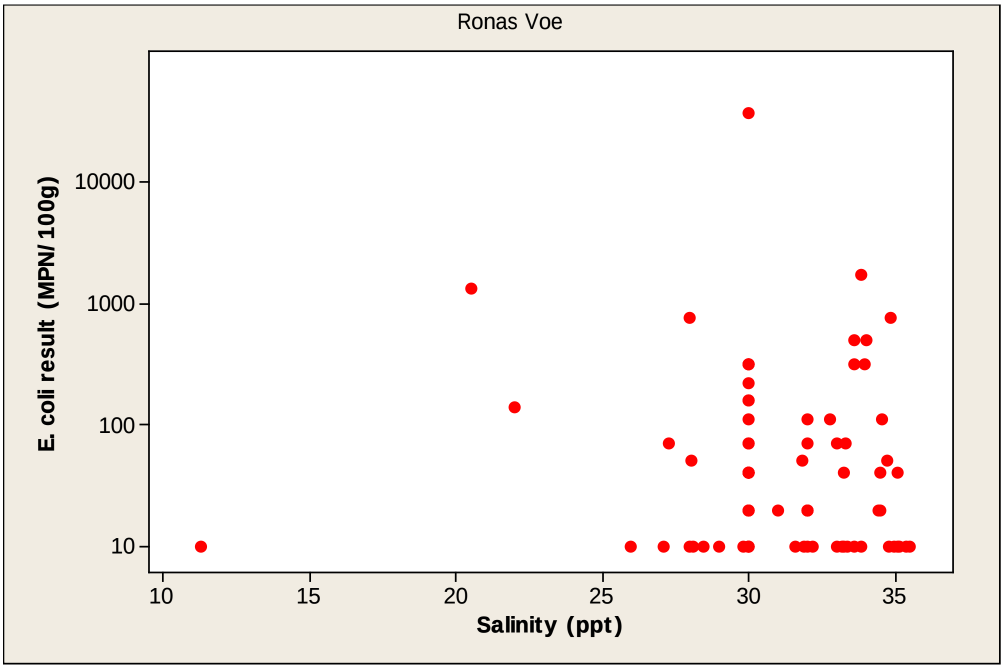

Figure 11.18 Scatterplot of result by salinity for Ronas Voe

No significant correlation was found between the *E. coli* result and salinity for Ronas Voe (Spearman's rank correlation= -0.061, p>0.25, Appendix 6).

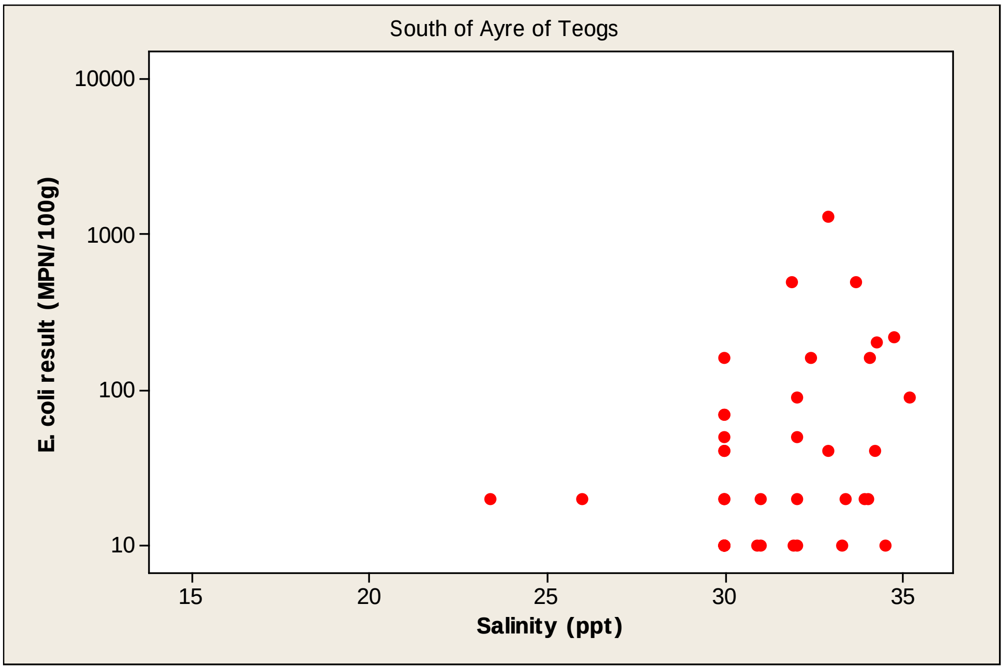

Figure 11.19 Scatterplot of result by salinity for South of Ayre of Teogs

A significant positive correlation was found between the *E. coli* result and salinity for South of Ayre of Teogs (Spearman's rank correlation= 0.360, p<0.025, Appendix 6). This correlation appears to be influenced by two results recorded at salinities below 30 ppt, both of which had low *E. coli* levels. Usually, the inflow of freshwater associated with lower salinities will result in higher *E. coli* in the water and potentially the shellfish. However, in this case there are few sources of freshwater near to the site and so the cause of this correlation is unclear.

11.7 Evaluation of results over 230 *E. coli* MPN/100g

A total of 7 samples gave a result of over 1000 *E. coli* MPN/100 g, details of which are presented in Table 11.3.

Table 11.3 Historic *E. coli* sampling results over 1000 *E. coli* MPN/100g

Collection date	Site	*E. coli* (MPN/100g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/ low)	Tidal state (spring/ neap)
16/07/2002	Ronas Voe	>18000	HU 310806	*	*	*	30	Flood	Decreasing
19/06/2006	Ronas Voe	2400	HU 310806	9.6	23.6	*	*	*	Neap
21/08/2006	South of Ayre of Teogs	1300	HU 298811	0	0.7	13	33	*	Increasing
10/09/2007	Ronas Voe	1300	HU 327809	4.3	21.6	*	21	High	Increasing
02/11/2009	Ronas Voe	1700	HU 327809	25.6	57.6	10	34	High	Spring
12/07/2010	Clifts	2200	HU 318809	*	*	12	34	Flood	Spring
09/08/2010	Clifts	2400	HU 318809	*	*	13	34	Ebb	Spring

* Data unavailable

Four of the seven samples were taken from the Ronas Voe site, including the only result greater than 18000 *E. coli* MPN/100 g, suggesting a potential for higher peak results at this site. High results tended to occur during the warmer months of the year, with only one outside the months of June-September. Three of the four samples for which rainfall records were available were taken following moderate to heavy rainfall. They were taken under a variety of tidal states.

11.8 Summary and conclusions

A comparison of results from samples taken on the same date from more than one site revealed that mean levels of contamination were significantly higher at the Ronas Voe site than at South of Ayre of Teogs. A higher proportion of the results greater than 230 MPN/100 g occurred at the Ronas Voe site than at the South of Ayre of Teogs site, although this difference was not statistically significant. For samples taken at more than one location on the same dates in 2010, the geometric mean was highest at Clifts and lowest at West of Black Well, with peaks in results at Clifts and Ronas Voe occurring at the same time. The highest results during this parallel sampling occurred at Clifts.

In terms of overall temporal patterns, levels of contamination decreased rapidly and significantly during 2007 at the Ronas Voe site. The reasons for this marked improvement are unclear. At South of Ayre of Teogs, a slight deterioration in results was seen from 2004 to 2007. As no samples were taken from this site after mid 2007, it was not possible to confirm whether a similar improvement to that observed at the Ronas Voe site occurred at this site.

Although no significant seasonal effect was found at either site, they showed similar general patterns of higher results in the summer and autumn. No correlation was found between *E. coli* results and water temperature at the Ronas Voe site: this relationship could not be investigated at the South of Ayre of Teogs site as water temperature was only recorded at that location on 5 occasions.

No correlation was between recent rainfall and *E. coli* results at the Ronas Voe site. No correlation between results and salinity were found at this site either. A weak positive correlation was found between *E. coli* in mussels and rainfall in the previous 7 days at the South of Ayre of Teogs site, but not with rainfall in the previous 2 days. In contradiction to this, a weak positive correlation was found between *E. coli* results and salinity. The association (albeit weak) of higher *E. coli* results with 7 day rainfall at the Ronas Voe site is surprising given the small size of the watershed.

No correlation between levels of *E. coli* in shellfish and tidal state on either the spring/neap or high/low tidal cycles was found at either site.

It should be noted that the relatively small amount of data precluded the assessment of the effect of interactions between environmental factors on the *E. coli* concentrations in shellfish.

11.9 Sampling frequency

When a production area has held the same (non-seasonal) classification for 3 years, and the geometric mean of the results falls within a certain range it is recommended that the sampling frequency be decreased from monthly to bimonthly. This is not appropriate for Ronas Voe as it held a seasonal classification in 2008.

12. Designated Shellfish Growing Waters Data

The Clifts site falls within the Ronas Voe designated Shellfish Growing Water. Monitoring began in 2003, and results to the end of 2006 were provided by SEPA. Monitoring results for faecal coliforms in mussels are presented in Table 12.1. Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. These results have been used in the analysis in Section 11 of this report and so are not repeated here.

The extent of the area and the location of the relevant monitoring points are shown on Figure 12.1.

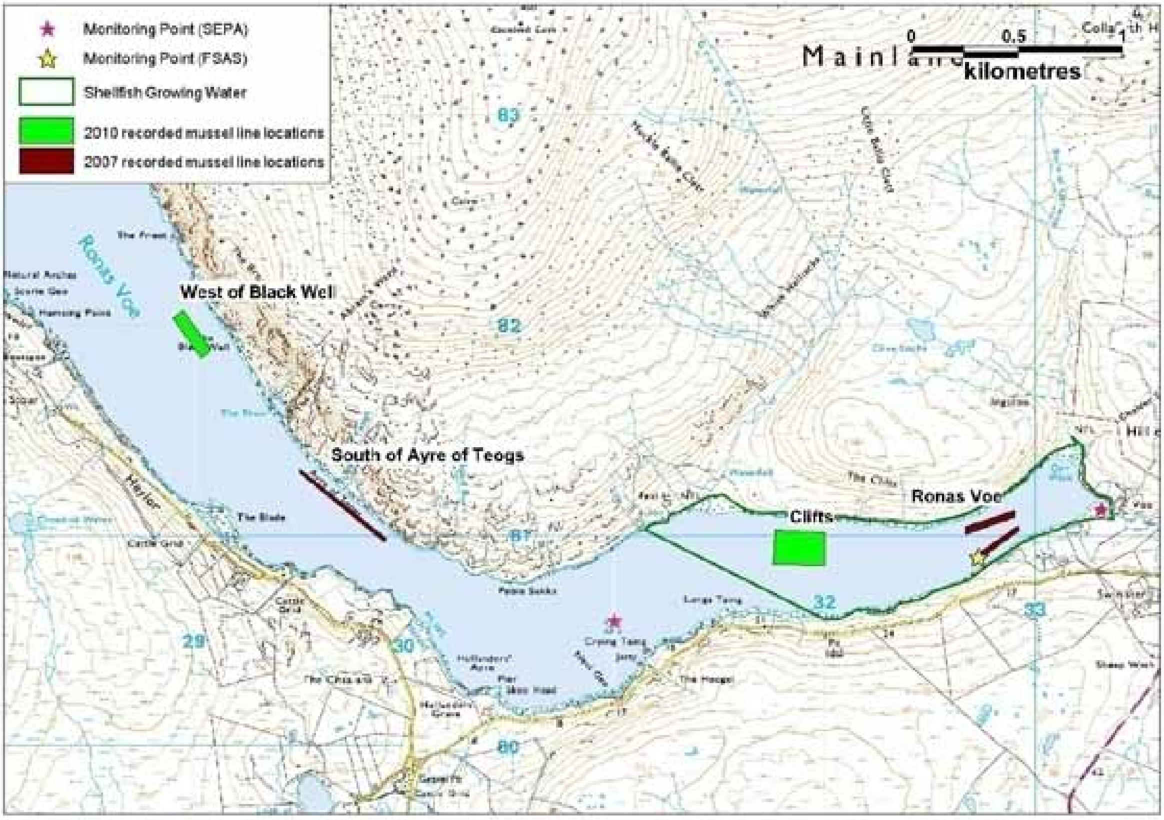

Figure 12.1 Map of Ronas Voe Shellfish Growing Water

Table 12.1. SEPA monitoring for shore mussels gathered from Ronas Voe

Year	Quarter	Faecal coliform results (FC/100g)	
		HU 310 806	HU 3331 8113
2003	Q1	140	-
	Q2	-	-
	Q3	-	2400
	Q4	-	310
2004	Q1	-	70
	Q2	-	90
	Q3	-	>18000*
	Q4	-	200
2005	Q1	-	90
	Q2	-	70
	Q3	-	16000
	Q4	-	9100
2006	Q1	-	500
	Q2	-	500
	Q3	-	310
	Q4	-	40
2007	Q1	-	20

* Assigned a nominal value of 36000 for the calculation of the geometric mean.

All samples except the first one were gathered from the shore at the head of the voe. The geometric mean result for all samples is 420 FC/100 g. Results ranged from 20 to >18000 faecal coliforms/100 g indicating large fluctuations in microbial contamination at this monitoring point, with highest results usually occurring in Quarter 3.

Although levels of faecal coliforms are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination. Consequentially, the results presented in Table 12.1 are not directly comparable with the other shellfish testing results presented in this report.

The overall level of contamination observed in shore mussels taken from the SEPA monitoring point at the head of the voe is higher than that seen in the rope grown mussels within the production area. This is not unexpected as the SEPA sampling site was located on the intertidal zone at the head of the voe, and hence nearer to sources of contamination, whereas the rope-grown mussels were located in deeper water which are further from the most probable sources of contamination and where this would have been subject to greater dilution.

13. River Flow

The Scottish Sea Lochs Catalogue gives the watershed for Ronas Voe as 30 km^2 (Edwards & Sharples, 1991). Given that the length of the voe is approximately 9 km, this means that the watercourses entering the voe only drain the land immediately surrounding it.

There are no gauging stations on burns or streams along the Ronas Voe coastline. The streams listed in Table 13.1 were measured and sampled during the shoreline survey. The weather was dry at the time the shoreline survey was undertaken. The locations are shown on the map presented in Figure 13.1. Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So, where normal scientific notation for 1000 is 1×10^3, in digital format it is written as 1E+3.

A number of dry streams and land drains were also observed during the shoreline survey. The weather was dry during the survey period.

Table 13.1 Stream loadings for Ronas Voe

No.	Sample number	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
1	RVFW1	HU 2845 8169	Outlet of stream	0.60	0.03	0.123	191	<10	$<1.9\times10^7$
2	RVFW3	HU 2863 8145	Stream running under road	0.30	0.07	0.072	47	50	2.4×10^7
3	RVFW4	HU 2890 8117	Stream in pipe running under road	0.25	0.02	1000ml in 25 secs[1]	5.8	<10	$<5.8\times10^5$
4	RVFW5	HU 2906 8102	Stream	0.20	0.07	0.034	41.1	<10	$<4.1\times10^6$
5	RVFW6	HU 2915 8094	Pipe running onto land - ?stream	-	-	30ml in 2 secs[1]	1.3	10	1.3×10^5
6	RVFW7	HU 3319 8143	Stream	4.0	0.05	0.031	535	10	5.4×10^7
7	RVFW8	HU 3338 8107	Stream	2.8	0.05	0.142	1720	20	3.4×10^8
8	RVFW10	HU 3189 8059	Stream	0.70	0.10	0.020	121	70	8.5×10^7
9	RVFW11	HU 3146 8116	Grud Burn	1.70	0.15	0.094	2070	20	4.1×10^8

[1]Too small to measure with a flow meter. Approximate time taken to fill a measured volume.

In general, the loadings calculated for the streams from the 2010 shoreline survey measurements and results were relatively low. The four watercourses with the highest loadings were numbers 6, 7, 8 and 9. Two of these were at the head of the voe and would potentially have most effect on water quality in the vicinity of the Ronas Voe site. The other two were on either shore in the vicinity of the Clifts site and would potentially have most impact there, with the burn on the northern shore being the close of the two to the lines. Some of the other streams on the southern shore opposite the West of Black well and South of Ayre of Teogs sites would cause localised deterioration of water quality and contribute to the background levels of *E. coli* in the vicinity, but would be unlikely to directly impact on the quality of the mussels at those sites. Streams on the north shore in the vicinity of those sites could not be measured and sampled. A seawater sample taken off the mouth of one of the streams yielded the highest result of all the seawater samples taken during the survey (8 *E. coli* cfu/100 ml), although this was still relatively low.

The loadings of all of the streams would be expected to increase significantly following moderate to heavy rainfall and thus their potential effects on the microbiological quality of the mussels would also increase. The dry streams and land drains would be expected to flow under such conditions. Some of the streams measured and sampled for the 2010 shoreline survey had also been measured and sampled in 2007. The surveys at that time were undertaken after and during rain and, in general, calculated loadings for those streams sampled in July 2007 were at least ten-fold higher than during the 2010 survey. Those streams sampled and measured in December 2007 yielded calculated loadings that were only slightly higher than those in 2010. This indicates that the faecal inputs to the voe from freshwater sources vary greatly with time and this may well be due to rainfall effects. Two streams that had been measured and sampled in the 2007 survey were in the vicinity of the West of Black Well and South of Ayre of Teogs sites and yielded calculated loadings at that time of 1.5×10^9 and 1.1×10^9 *E. coli*/day: these would be likely to impact on the quality of the mussels at those sites.

Given the steep sided nature of the land around the voe, there is also the potential for direct run-off after rainfall. All of these would be potential pathways for contamination from animal faeces to enter the voe.

The watercourses around the voe will be a significant route for faecal contamination of animal origin to enter the voe. Due to the relatively low loadings of those sampled during the shoreline surveys, any impact on the fisheries will be from nearby watercourses.

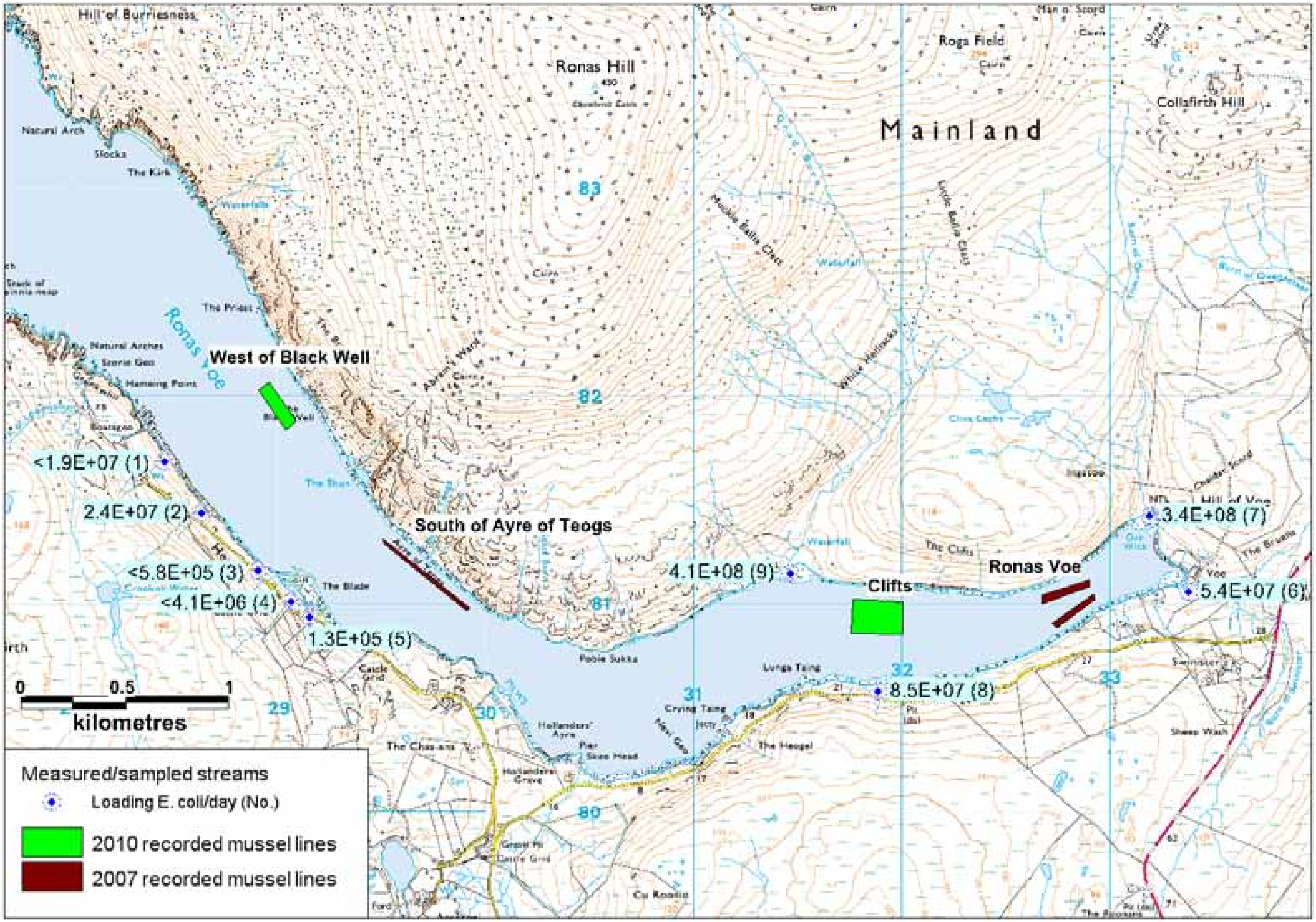

Figure 13.1 Map of stream loadings at Ronas Voe

14. Bathymetry and Hydrodynamics

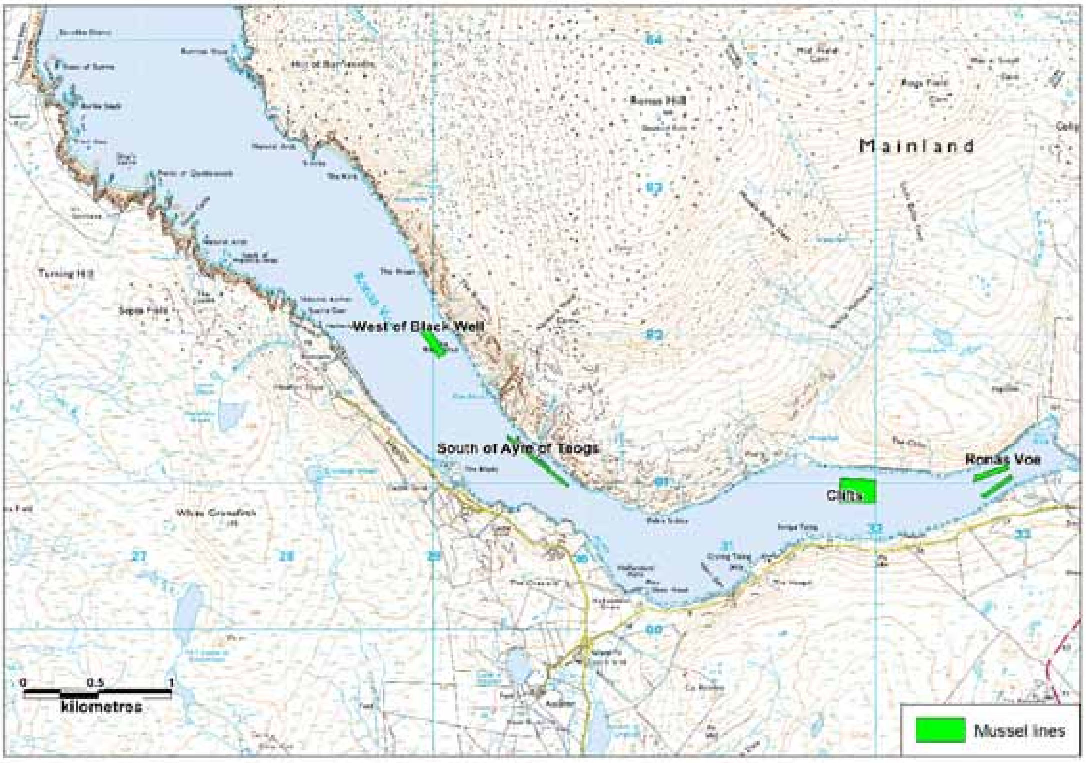

Figure 14.1 OS map of Ronas Voe

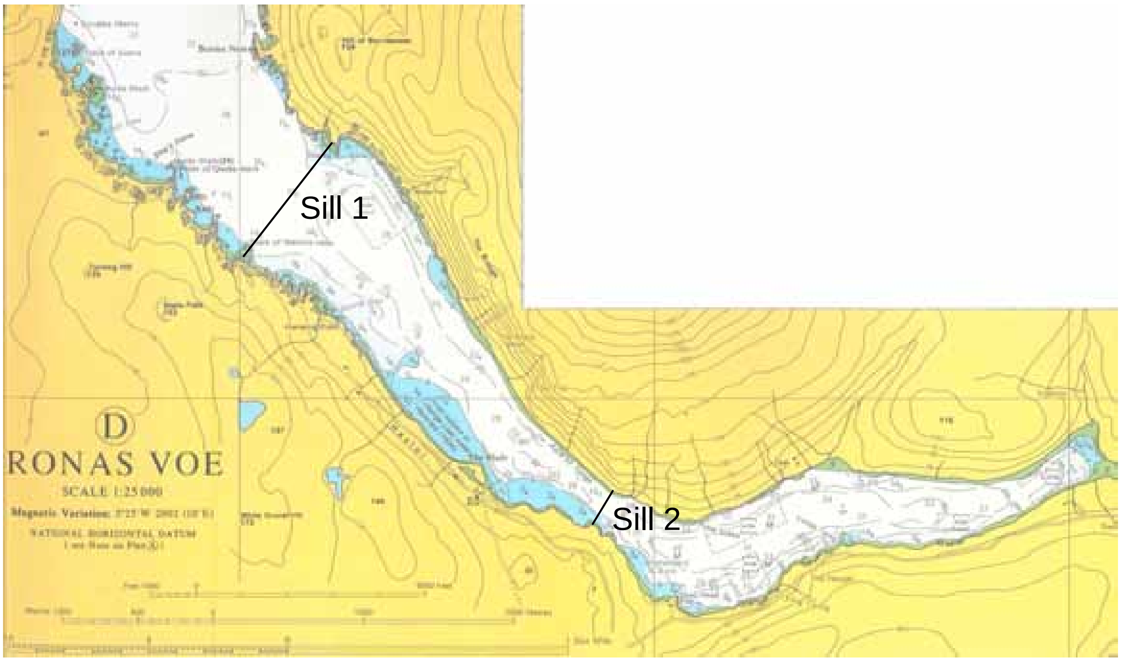

Figure 14.2 Bathymetry at Ronas Voe

Ronas Voe is a fjordic loch with two sills that split the loch into two main basins (see Figure 14.2) and an outer area. The Ronas Voe and Clifts mussel sites are located in the inner basin and the South of Ayre of Teogs and West of Black Well are located in the central basin. The overall length of the loch is 8.8 km and the maximum depth of the loch is 42 m (Edwards & Sharples, 1991). The bathymetry map above shows depths ranging from <5 metres to >30 metres with drying areas located at the head of the voe as well as along some stretches of both shores. The innermost basin is oriented generally east to west and is shallow at the head of the loch. In its main body, it is deeper than the central basin and shelves more steeply away from the sides of the voe. The calculated flushing time for the voe is given as 8 days which is long for the size of the voe (Edwards and Sharples,1991). Water flow to and from the inner basin will be constricted not only by the relatively shallow sill but also by the physical geography of the land as the loch is very narrow at the sill.

The calculated salinity reduction given by the Scottish Sea Loch Catalogue for the voe as a whole is 0.2 ppt. It is likely that any fresh water influence will be greatest at the head of the voe, given the shallow depth and that this is where the two main water courses enter.

14.1 Tidal Curve and Description

The two tidal curves below are for Esha Ness (Hamna Voe), a straight line distance of approximately 4.5 km from Ronas Voe, but approximately 10 km by sea. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 22/06/10 and the second is for seven days beginning 00.00 BST on 29/06/10. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle, including the dates of the shoreline survey.

The following is the summary description for Esha Ness from TotalTide:

0293A Esha Ness (Hamna Voe) is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	2.7 m
MHWS	2.3 m
MHWN	1.9 m
MSL	1.46 m
MLWN	1.1 m
MLWS	0.6 m
LAT	0.0 m

Predicted heights are in metres above Chart Datum. The average tidal range at spring tide is 1.7 m, and at neap tide 0.8 m, and so tidal ranges in the area are relatively small.

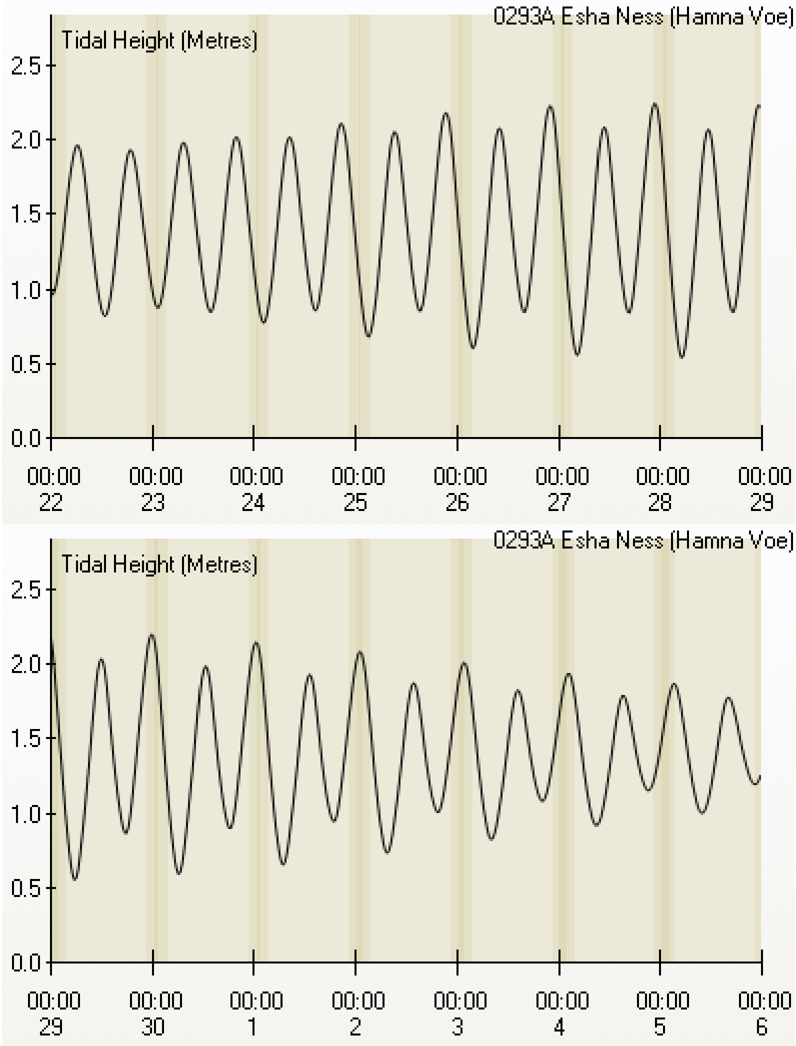

Figure 14.3 Tidal curves for Esha Ness

14.2 Currents

There is no tidal stream information for the vicinity of Ronas Voe.

Shetland Seafood Quality Control had undertaken a number of current meter studies in the nearby sounds to provide information in support of applications to SEPA to discharge from marine cage fish farms. Four were undertaken within Ronas Voe. Three of these had been undertaken on behalf of Scottish Sea Farms Ltd and one on behalf of Aqua Farm Ltd. Permission was granted for release of data from two of these studies, which were provided to Cefas with the agreement of the companies.

The locations at which the current meters were deployed are shown in Figure 14.4. The survey periods were as given in Table 14.1.

Three of the meter locations (Crying Taing, Ronas Voe South, Pobbie Sukka) were in the inner basin and one (Slocka) was in the central basin.

Table 14.1 Survey periods for the fish farm current meter studies

Location	NGR	Survey period
Crying Taing	HU 3085 8042	23/10/2006 – 8/11/2006
Ronas Voe, South Site	HU 3215 8075	8/11/2006 – 1/12/2006

Polar plots of the current directions and speeds at two of the four locations, together with the wind direction and speeds over the relevant periods, are shown in Figure 14.5.

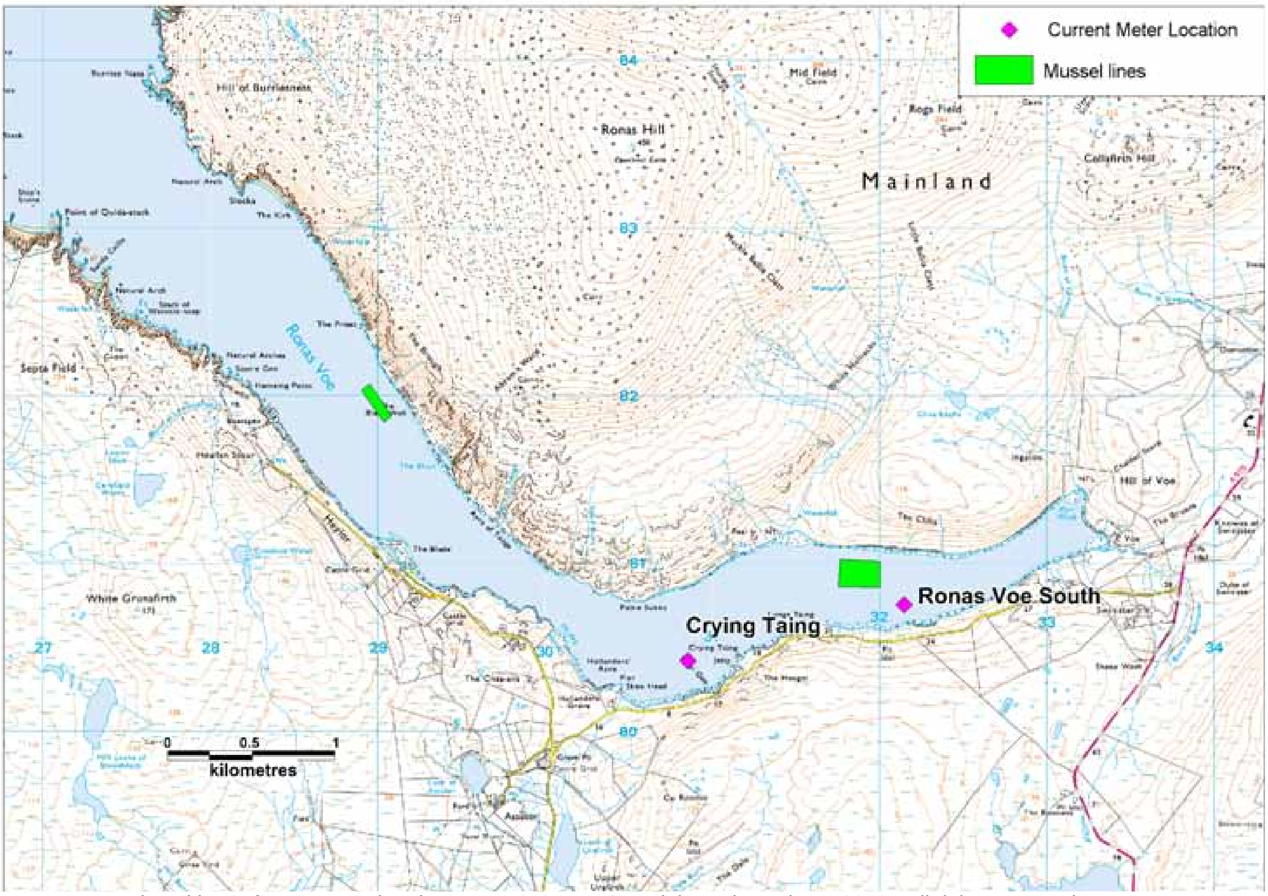

Figure 14.4 Locations of current meters

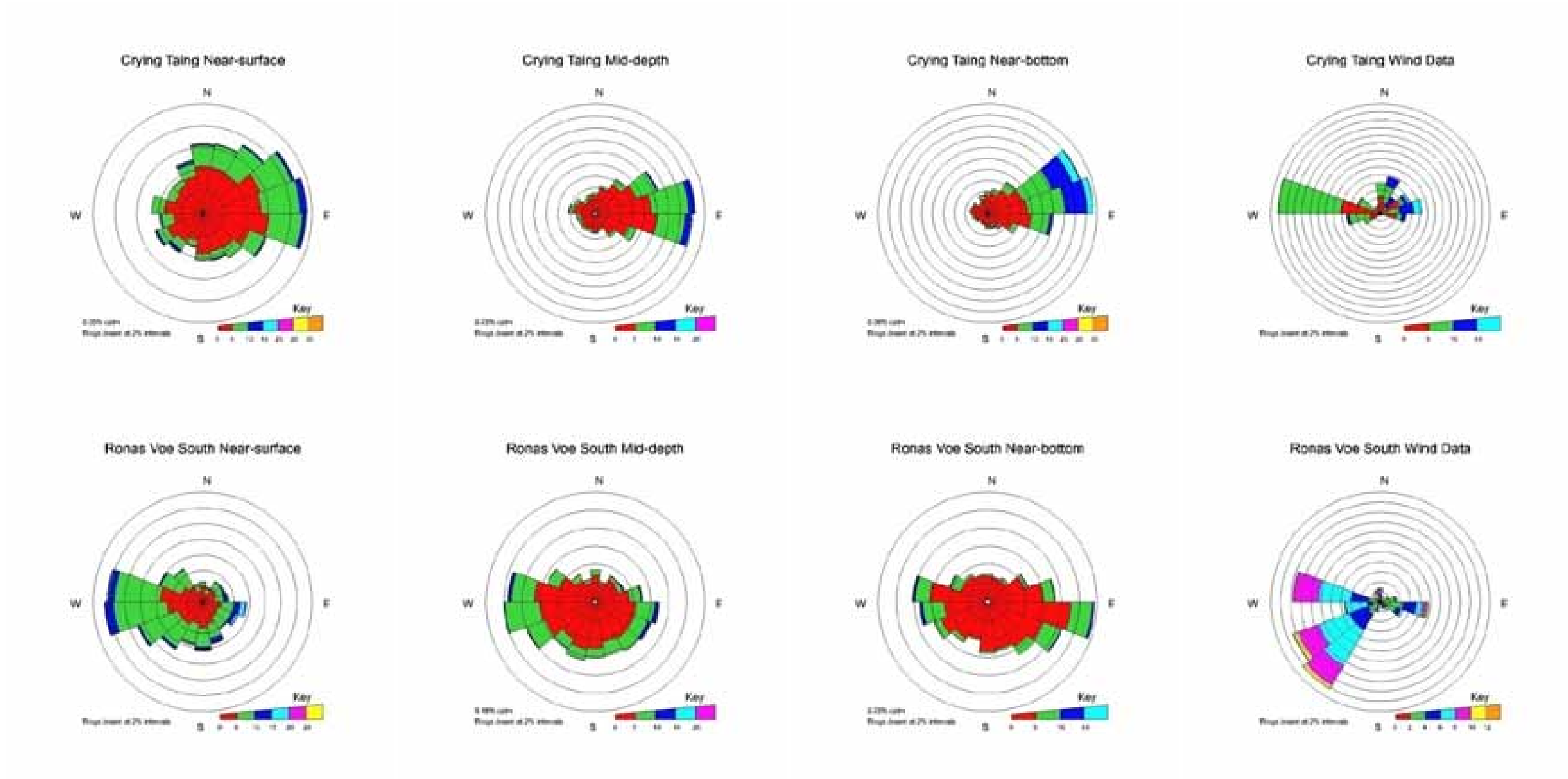

Figure 14.5 Current and wind plots for the Ronas Voe fish farm surveys

Currents measured in m/s. Wind measured in m/s. As per convention, currents are plotted against the direction towards which they are travelling while winds are plotted against the direction from which they are travelling. The length of each segment in a plot relates to the proportion of observations lying in that direction. The speed relates to the colour key beneath each plot. The proportion that each colour takes up in an individual segment relates to the proportion of observations in that direction having speed in that range.

In general, the recorded currents at the two locations in the upper voe ran parallel to the direction of that part of the voe. The current flows at both locations were weak: maximum values were approximately 0.3 m/s (0.6 knots) and mean values ranged from 0.03 to 0.06 m/s. The highest speeds were seen near the bottom at Crying Taing and near the surface at Ronas Voe South. The different current patterns seen at the two locations are likely to reflect the slightly different adjacent topography and the different wind direction during the recording periods.

The maximum transport distance of contaminants at 0.3 m/s, assuming no dispersion or dilution, would be a little over 4 km. At 0.06 m/s, the maximum transport distance would be less than 1 km.

14.3 Salinity profiles

The salinities shown in Table 14.2 were recorded during the 2010 shoreline survey.

Table 14.2 Salinity profiles recorded during the 2010 shoreline survey

Profile	**Site**	**Depth (m)**	**Salinity (ppt)**	**Temperature (°C)**
1	West of Black Well	Surface	26.98*	10.8
		3	37.15	10.6
		5	37.16	10.3
		10	37.22	9.8
2	West of Black Well	Surface	37.04	10.8
		3	37.17	10.5
		5	37.20	10.4
		10	37.24	9.7
3	Clifts	Surface	36.86	12.7
		3	37.13	12.4
		5	37.18	10.0
4	Clifts	Surface	36.84	12.7
		3	37.23	10.2
		5	37.24	10.0
		10	37.26	9.8
5	Clifts	Surface	36.88	12.7
		3	37.25	10.4
		5	37.18	10.2
		10	37.25	9.8

*Possible error in recording of surface salinity. Result may also be due to the fluctuating readings of the salinity metre during the first use in the survey.

In general the salinities at the two sites were similar. Apart from profile 1, where the accuracy of the surface salinity value was in doubt, there was only a slight increase in salinity with depth, with the difference between surface and depth measurements all being <0.5 ppt. This indicates that there was not a significant layering of fresh water at the surface. The temperature profiles differed between the two sites measured on this occasion, with the difference between surface and depth being greater at Clifts than at West of Black Well.

In the 2007 shoreline survey, little difference was seen between salinities at different depths at the South of Ayre of Teogs site and the values were all >34 ppt. Lower salinities were seen at the Ronas Voe site and, in three of the four profiles taken at that site, the surface values were lower than the depth values by more than 1 ppt.

14.4 Conclusions

Currents are weak with the general direction being parallel to the sides of the voe. Although the theoretical maximum transport distance is over 4 km, the voe is steeply shelving and deep in the vicinity of the mussel lines. Contamination from sources at the head of the loch will be taken over the mussel lines at the Ronas Voe site, with most contamination occurring at the eastern end of the lines. Contamination at the other sites is likely to impact greatest from sources adjacent to, and immediately either side of the sites and impact mostly on the lines nearest the shore.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 22nd and 23rd June 2010 under dry and calm weather conditions.

The fishery at the West of Black Well site consisted of three double mussel lines with 10m droppers. The two lines towards the middle of the voe have recently been laid. The near-shore line is a year old, and the harvester plans to harvest the stock in 1 to 1.5 years when the stock is mature.

The fishery at Clifts consisted of six double mussel lines with 10m droppers. Three of the lines had recently been laid, and it was planned are to harvest these lines in 2.5 years time. The other three lines were 3 years old and were being harvested.

It was noted during the shoreline survey that the South of Ayre of Teogs site is now much larger than previously observed in the 2007 shoreline survey, and now consists of two sets of 3 double lines.

No septic tanks, outfall pipes or sewage debris was observed during the shoreline survey. There were no large settlements in the area directly surrounding Ronas Voe. The area of highest human population was at Heylor, which consisted of approximately six houses. There were also three houses with an outbuilding at the head of the voe, and four other individual houses along the shoreline. There were no pipes observed entering the voe from these buildings, so it is assumed they had private septic tanks which discharge via soakaway to land.

During the shoreline survey, approximately 200 sheep were observed in total around the shoreline of Ronas Voe, and sheep droppings were observed in relatively low amounts all along the southern shore of the voe. There were also three cattle near the houses at the head of the voe, which is noted to be much less compared to the number observed during the 2007 survey, when 58 cattle were noted. The three cattle had access directly on to the beach, and cow pats were observed on the shore.

There were no flocks of birds observed in Ronas Voe, however small numbers of oystercatchers, gulls, terns, eider ducks and gulls were observed, some of which were directly on the mussel buoys.

Seawater samples taken during the shoreline survey contained low levels of *E. coli*. The sea water samples taken offshore in the vicinity of the mussel lines yielded results between <1 and 8 *E. coli* cfu/100ml. Salinity profiles taken at the mussel sites all indicated that there was little freshwater influence or stratification at the time, with all but one measurement indicative of full strength seawater.

Freshwater samples and discharge measurements were taken at most streams draining into the survey area. These streams contained low levels of contamination (<10 – 70 *E. coli* cfu/100ml). Most were small and drained areas of rough grassland, grazing fields and/or improved grassland.

At the West of Black Well site, mussel samples were taken from the east end of the mussel line at two different depths. The sample taken from the surface has a lower result of 50 *E. coli* MPN/100 g compared to the sample taken at a depth of 4 m, which had a result of 80 *E. coli* MPN/100 g.

At the Clifts site, mussel samples were taken from both ends of the mussel lines at three different depths. At the east end of the long line, samples were taken at depths of <1 m, 3 m and 8 m and all returned low results of <20 *E. coli* MPN/100 g. At the western end of the long line the results were higher and more varied. The highest result of 170 *E. coli* MPN/100 g was sampled at <1 m, a second sample of 80 *E. coli* MPN/100 g was sampled at 3 m and a third sample of 50 *E. coli* MPN/100 g was sampled at 8 m.

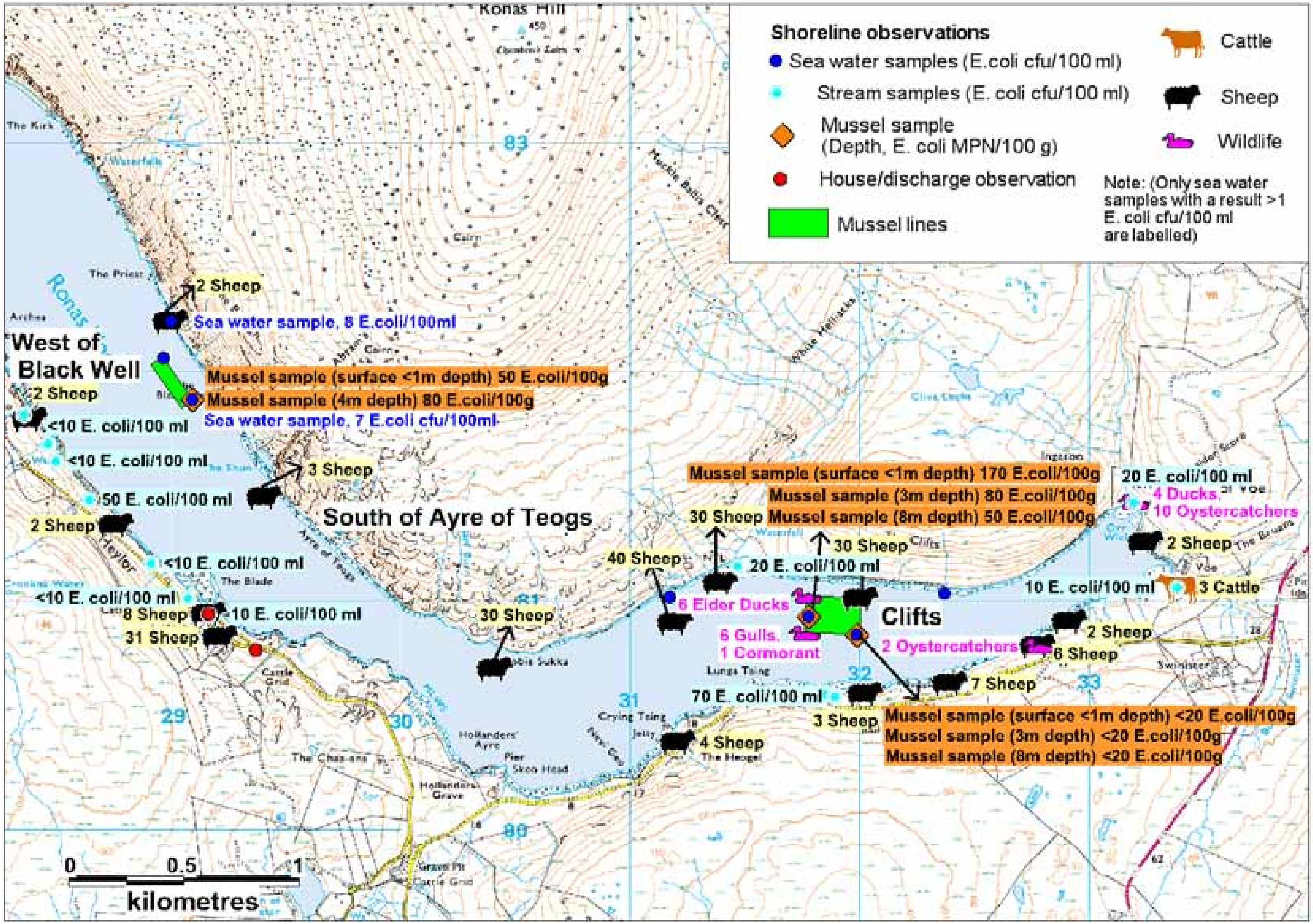

Figure 15.1 Summary of shoreline observations

16. Overall Assessment

16.1 Human sewage impacts

There are no Scottish Water discharges in the area and all the consented discharges identified by SEPA discharged to land or soakaway, or to a watercourse that did not enter the voe. Potential septic tank discharges observed during the shoreline surveys in 2007 and 2010 were located either at the head of the voe or on the southern shore of the voe opposite the South of Ayre of Teogs site. As the discharges will be from single dwellings, they are likely to have a localised impact on water quality in the voe.

Agricultural impacts

The largest potential source of faecal contamination from the perspective of farm animals is sheep. These are located all around the voe although, at the time of the 2010 shoreline survey, most were located on the northern shore. Faecal material from this source may impact via streams or, in times of heavy rain, through direct land run-off. During the shoreline survey this year, only 3 cattle were observed near the head of the voe. This is a far lower number than in 2007. If this low number is now the norm, the potential for contamination from this source would be low with any impact being more likely to occur at the southern lines on the Ronas Voe site.

Wildlife impacts

Seabirds are the principal identified source of possible faecal contamination within the voe from wildlife sources. Low numbers were observed at a number of locations during the shoreline survey. The Seabird 2000 survey indicates that larger numbers occur, at least part of the year, in the outer part of the voe. These would be likely to have the greatest impact at West of Black Well and, to some extent, at South of Ayre of Teogs.

Seasonal variation

There is no significant tourism in the area and there will be no consequent seasonal variation in contamination arising from the human population. The populations of farm animals are likely to be higher in spring and summer due to the presence of lambs and calves. Impacts from seabirds are likely to be higher during the summer nesting period. Rainfall tends to be higher from October to March. However, high rainfall events tend to occur through most of the year and the highest *E. coli* loadings to the voe may result from high rainfall events following dry periods during the time of highest farm animal occurrence: i.e. from May to September. There was no significant difference in shellfish *E. coli* results with season at either the Ronas Voe or South of Ayre of Teogs sites but all but one of the seven samples greater than 1000 *E. coli* MPN/100 g seen across three sites occurred during the period June to September. In general, in those years when B classification have applied for part of the year, this has been for periods in the second half of the year. In general, therefore, *E. coli* contamination in the voe tends to be higher in the summer/autumn period.

Rivers and streams

Calculated loadings for streams measured and sampled during the 2010 shoreline survey were generally low. Higher loadings were seen during the 2007 shoreline surveys and this emphasizes that the potential impact from these sources will vary markedly. The principal effect is likely to be on the eastern end of the lines at the Ronas Voe, resulting from the two large streams located at the head of the voe. A number of small streams located on the northern shore could not be accessed during the shoreline survey and these may cause localised impact on the mussels at West of Black Well and South of Ayre of Teogs. A seawater sample taken off the streams in the vicinity of the former site yielded a result of 8 *E. coli* cfu/100 ml. Although relatively low, this was the highest seawater result obtained during the survey and supports the possibility of contamination from such sources.

Hydrography and movement of contaminants

Ronas Voe is divided into three parts by the presence of two sills. The inner basin is the deepest and contains the Ronas Voe and Clifts mussel sites. The central basin is relatively deep and contains the West of Black Well and South of Ayre of Teogs sites. The depth means that faecal contamination will tend to be subject to significant dilution. The presence of the sills will tend to reduce movement of water between the parts of the voe. Tidal range is limited (average of 1.7 m at spring tide) and currents are weak (<0.3 m/s in the inner basin). The currents tend to follow the orientation of the voe. Available data on salinity indicates that slightly lower values (but still >34 ppt) are seen towards the head of the voe, presumably due to the influence of the two large streams at that location. However, there is not any evidence to support significant stratification within the voe. Sources of contamination close to the fisheries are therefore likely to be the most important.

Temporal and geographical patterns of sampling results

Most monitoring data applies to the Ronas Voe and South of Ayre of Teogs sites as the other two sites have only been stocked relatively recently. In general, levels of *E. coli* in mussels at the Ronas Voe site have been significantly higher than at the South of Ayre of Teogs site. Since 2006 there has been an apparent improvement in *E. coli* results at the former site: it is not possible to say whether this also occurred at the latter site as sampling there stopped in mid-2007. Comparison of a small number of parallel samples taken at Ronas Voe, Clifts and West of Black Well during 2010 showed that the pattern of occurrence higher and lower results at Ronas Voe and Clifts were similar to each other and slightly different to those at West of Black Well. This may reflect the fact that the former two sites are both located in the inner basin while the latter site is located in the central basin. In that limited data set, the peak results at Clifts were much higher than those at Ronas Voe.

Conclusions

Little human sewage enters the voe and contamination from farm animals, with potentially significant contributions from seabirds in the outer voe, will predominate. The depth of the basins, together with the weak currents, will mean that the mussels will only be impacted by sources local to the lines. The presence of a sill between the two basins, separating the four mussel farm sites naturally into two groups, will further limit transport of any contamination between the two groups. The available data indicates that contamination at Clifts is higher than at the Ronas Voe site. There is no indication that the contamination will differ significantly between the West of Black well and South of Ayre of Teogs sites.

17. Recommendations

It is recommended that the voe be split into two production areas, each containing two sites and located within the separate basins divided by a sill. Each production area will be subject to similar sources of contamination and influenced by the same environmental factors.

Ronas Voe East

Production area
It is recommended that the Ronas Voe East production area be defined as the area bounded by lines drawn between HU 3165 8112 and HU 3165 8063 and between HU 3300 8132 and HU 3300 8099 and extending to MHWS. This encompasses the Clifts and Ronas Voe sites. The western end is defined to exclude Grud Burn on the northern shore that could introduce diffuse pollution and the Aqua Farm Ltd site on the southern shore. The eastern end is excluded due to the potential for contamination from the rivers and farmland at the head of the voe.

RMP
It is recommended that the RMP be located on the Clifts site at HU 3177 8093. Although the large streams at the head of the voe will potentially contribute faecal contamination to the Inner production area, the results of parallel monitoring during 2010, together with the bacteriological results from the shoreline survey, indicate that the highest levels of contamination occur to the eastern end of the area.

Tolerance
The recommended sampling tolerance is 20 m to allow for movement of the lines.

Depth of sampling
Given the small amount of information from shoreline survey samples showing some general tendency within the voe towards higher results at the surface, it is recommended that samples from both RMPs are taken from 1 m depth.

Frequency
Due to the seasonal variation in results it is recommended that sampling be undertaken monthly.

Ronas Voe Mussels 2

Production area
It is recommended that the Ronas Voe Mussels 2 production area be defined as the area bounded by lines drawn between HU 2888 8249 and HU 2850 8217 and HU 2993 8073 and HU 3006 8096 and extending to MHWS. This encompasses the West of Black Well and South of Ayre of Teogs sites but excludes the southern shore of the voe in the area as this includes as number of presumed septic tank outlets as well as several watercourses that could cause introduce diffuse pollution.

RMP

It is recommended that the RMP be located on the West of Black Well site at HU 2908 8188. This location will reflect the sources of contamination that are likely to influence both sites in the recommended production area.

Tolerance

The recommended tolerance on sampling location is for both RMPs is recommended to be 20 m to allow for movement of the lines.

Depth of sampling

Given the small amount of information from shoreline survey samples showing some general tendency within the voe towards higher results at the surface, it is recommended that samples from both RMPs are taken from 1 m depth.

Frequency

Due to the short sampling history at West of Black well, and that South of Ayre of Teogs has not been monitored since 2007, it is recommended that monthly sampling be undertaken until sufficient data (e.g. 24 samples) is available to review for stability.

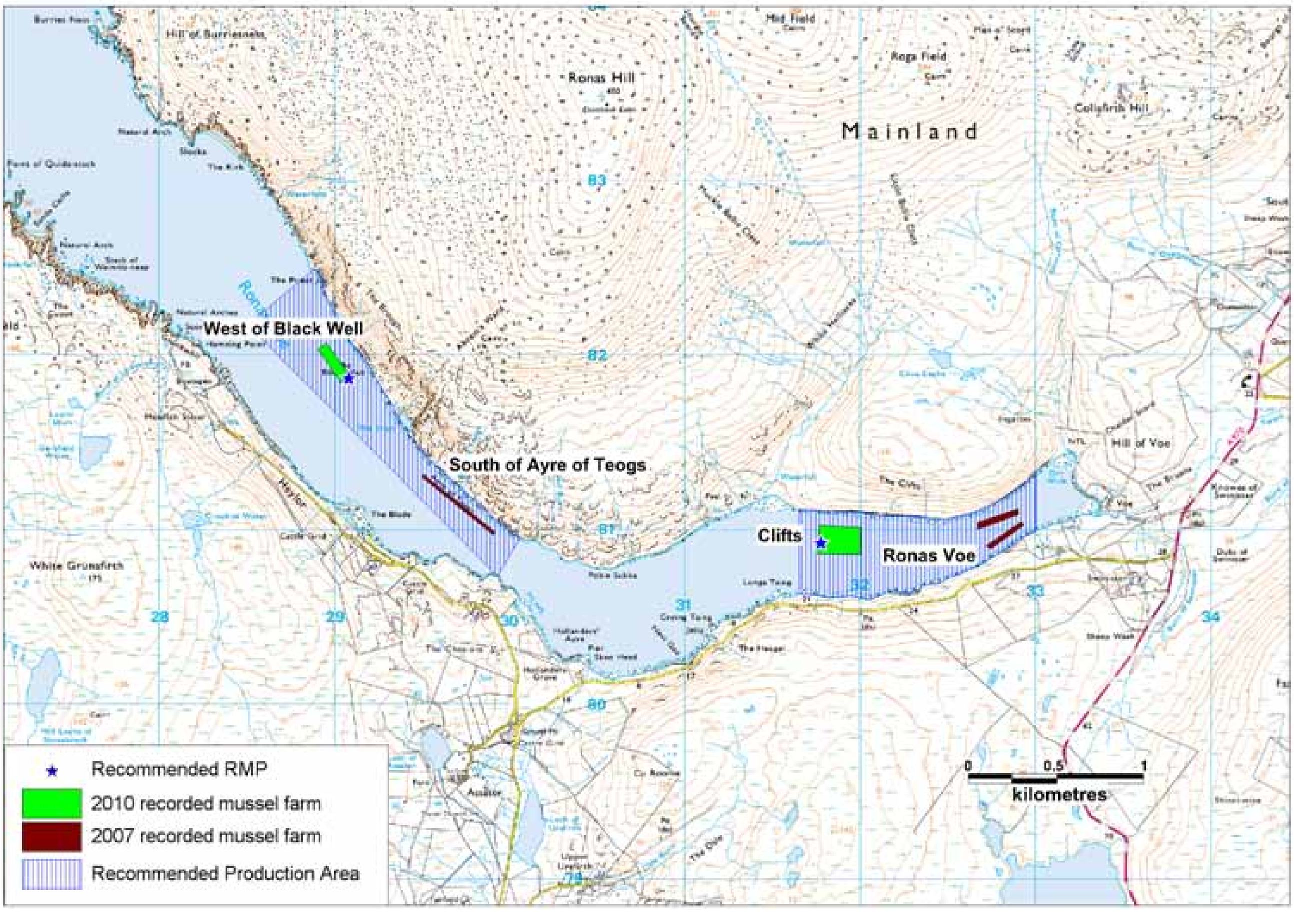

Figure 17.1 Map of recommendations at Ronas Voe

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6. **Statistical Data**
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Sampling Plan for Ronas Voe

PRODUCTION AREA	Ronas Voe East	Ronas Voe Mussels 2
SITE NAME	Clifts	West of Black Well
SIN	SI 523 919 08	SI 522 918 08
SPECIES	Common mussel	Common mussel
TYPE OF FISHERY	Mussel lines	Mussel lines
NGR OF RMP	HU 3177 8093	HU 2908 8188
EAST	431770	429080
NORTH	1180930	1181880
TOLERANCE (M)	20	20
DEPTH (M)	1	1
METHOD OF SAMPLING	Hand	Hand
FREQUENCY OF SAMPLING	Monthly	Monthly
LOCAL AUTHORITY	Shetlands Island Council	Shetlands Island Council
AUTHORISED SAMPLER(S)	Sean Williamson George Williamson Kathryn Winter Marion Slater	Sean Williamson George Williamson Kathryn Winter Marion Slater
LOCAL AUTHORITY LIAISON OFFICER	Dawn Manson	Dawn Manson

Table of Proposed Boundaries and RMPs

PRODUCTION AREA	Ronas Voe East	Ronas Voe Mussels 2
SPECIES	Common mussel	Common mussel
SIN	SI 523 919 08	SI 522 918 08
EXISTING BOUNDARY	Area bounded by lines drawn between HU 2916 8113 and HU 2940 8157 extending to MHWS	Area bounded by lines drawn between HU 2916 8113 and HU 2940 8157 extending to MHWS
EXISTING RMP	HU 310 806	HU 310 806
RECOMMENDED BOUNDARY	Area bounded by a line drawn between HU 3165 8112 and HU 3165 8063and between HU 3300 8132 and HU 3300 8099 and extending to MHWS	Area bounded by lines drawn between HU 2888 8249 and HU 2850 8217 and HU 2993 8073 and HU 3006 8096 and extending to MHWS
RECOMMENDED RMP	HU 3177 8093	HU 2908 8188
COMMENTS	Comprises part of the existing Ronas Voe/Ronas Voe 2 production areas (the definitions of the two existing areas are identical)	Comprises part of the existing Ronas Voe/Ronas Voe 2 production areas plus an extension to cover West of Black Well (the definitions of the two existing areas are identical)

Geology and Soils Assessment

Component soils and their associations were identified using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute. The relevant soils associations and component soils were then investigated to establish basic characteristics. From the maps seven main soil types were identified: 1) humus-iron podzols, 2) brown forest soils, 3) calcareous regosols, brown calcareous regosols, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils.

Humus-iron podzols are generally infertile and physically limiting soils for productive use. In terms of drainage, depending on the related soil association they generally have a low surface % runoff, of between 14.5 – 48.4%, indicating that they are generally freely draining.

Brown forest soils are characteristically well drained with their occurrence being restricted to warmer drier climates, and under natural conditions they often form beneath broadleaf woodland. With a very low surface % runoff of between 2 – 29.2%, brown forest soils can be categorised as freely draining (Macaulay Institute, 2007).

Calcareous regosols, brown regosols and calcareous gleys are all characteristically freely draining soils containing free calcium carbonate within their profiles. These soil types have a very low surface % runoff at 14.5%.

Peaty gleys, peaty podzols and peaty rankers contribute to a large percentage of the soil composition of Scotland. They are all characteristically acidic, nutrient deficient and poorly draining. They have a very high surface % runoff of between 48.4 – 60%.

Non-calcareous gleys, peaty gleys and humic gleys are generally developed under conditions of intermittent or permanent water logging. In Scotland, non-calcareous gleys within the Arkaig association are most common and have an average surface % runoff of 48.4%, indicating that they are generally poorly draining.

Organic soils often referred to as peat deposits and are composed of greater than 60% organic matter. Organic soils have a surface % runoff of 25.3% and although low, due to their water logged nature, results in them being poorly draining.

Alluvial soils are confined to principal river valleys and stream channels, with a wide soil textural range and variable drainage. However, the alluvial soils encountered within this region have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

These component soils were classed broadly into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the both the Macaulay Institute website and personal communication with Dr. Alan Lilly. GIS map layers were created for each class with poorly draining classes shaded red, pink or orange and freely draining classes coloured blue or grey. These maps were then used to assess the spatial variation in soil permeability across a survey area and it's potential impact on runoff.

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

Gley: A sticky, bluish-grey subsurface layer of clay developed under intermittent or permanent water logging.

Podzol: Infertile, non-productive soils. Formed in cool, humid climates, generally freely draining.

Rankers: Soils developed over noncalcareous material, usually rock, also called 'topsoil'.

Regosol: coarse-textured, unconsolidated soil lacking distinct horizons. In Scotland, it is formed from either quartzose or shelly sands.

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

As mammals, whales and dolphins would be expected to have resident populations of *E. coli* and other faecal indicator bacteria in the gut. Little is known about the concentration of indicator bacteria in whale or dolphin faeces, in large part because the animals are widely dispersed and sample collection difficult.

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

References:

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

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

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

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

Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	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		
Reedbed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

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

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

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

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

Statistical Data

All *E. coli* data was log transformed prior to statistical tests.

Section 11.3 Paired T-test comparison of results by site

```
Paired T for Ronas Voe - South of Ayre of Teogs

                         N   Mean  StDev  SE Mean
Ronas Voe               20  1.752  0.614    0.137
South of Ayre of Teogs  20  1.420  0.498    0.111
Difference              20  0.332  0.609    0.136


95% CI for mean difference: (0.047, 0.617)
T-Test of mean difference = 0 (vs not = 0): T-Value = 2.44  P-Value = 0.025
```

Section 11.3 Fisher's exact comparison of proportion of results over 230 *E. coli* MPN/100g by site

```
Using frequencies in number2


Rows: result2   Columns: site2

                South of
         Ronas   Ayre of
           Voe     Teogs  All

<=230       15        19   34
>230         5         1    6
All         20        20   40

Cell Contents:      Count


Fisher's exact test: P-Value =  0.181764
```

Section 11.4 T-test comparison of results up to 2007 and from 2008 onwards (Ronas Voe)

```
Two-sample T for log e coli result

C8          N   Mean  StDev  SE Mean
2008 on    19  1.207  0.539     0.12
pre 2008   64  1.794  0.706    0.088


Difference = mu (2008 on) - mu (pre 2008)
Estimate for difference:  -0.587
95% CI for difference:  (-0.895, -0.279)
T-Test of difference = 0 (vs not =): T-Value = -3.86  P-Value = 0.000  DF =
38
```

Section 11.4 Chi-square comparison of the proportion of results of <20 MPN/100g up to 2007 and from 2008 onwards (Ronas Voe)

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       pre 2008  2008 on  Total
    1        14       15     29
          22.36     6.64
          3.127   10.531
```

```
    2         50         4      54
           41.64     12.36
           1.679     5.656

Total         64        19      83

Chi-Sq = 20.993, DF = 1, P-Value = 0.000
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (Ronas Voe)

```
Source   DF      SS     MS     F      P
Season    3   3.211  1.070  2.20  0.095
Error    79  38.492  0.487
Total    82  41.703

S = 0.6980   R-Sq = 7.70%   R-Sq(adj) = 4.19%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
1      21  1.3544  0.4395  (---------*---------)
2      21  1.7505  0.9263               (---------*---------)
3      22  1.8805  0.6889                    (---------*---------)
4      19  1.6396  0.6457           (----------*---------)
                           -----+---------+---------+---------+----
                              1.20      1.50      1.80      2.10

Pooled StDev = 0.6980
```

Section 11.5 One way ANOVA comparison of *E. coli* results by season (South of Ayre of Teogs)

```
Source   DF      SS     MS     F      P
Season    3   1.242  0.414  1.42  0.252
Error    42  12.284  0.292
Total    45  13.527

S = 0.5408   R-Sq = 9.18%   R-Sq(adj) = 2.70%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      11  1.3191  0.4053  (----------*----------)
2       9  1.6686  0.8137            (------------*-----------)
3      15  1.7194  0.4966                 (--------*---------)
4      11  1.4551  0.4349       (----------*---------)
                           -------+---------+---------+---------+--
                                1.20      1.50      1.80      2.10

Pooled StDev = 0.5408
```

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall (Ronas Voe)

```
Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.079
```
n=72, p>0.10

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 2 day rainfall (South of Ayre of Teogs)

`Pearson correlation of ranked 2 day rain and ranked e coli for rain = 0.043`
n=46, p>0.25

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall (Ronas Voe)

`Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.057`
n=72, p>0.25

Section 11.6.1 Spearman's rank correlation for *E. coli* result and 7 day rainfall (South of Ayre of Teogs)

`Pearson correlation of ranked 7 day rain and ranked e coli for rain = 0.248`
n=46, p<0.05

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (Ronas Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 21 May 2010 14:44:21

Variables (& observations)	r	p
Angles & Linear (83)	0.107	0.398

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the spring/neap cycle (South of Ayre of Teogs)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 21 May 2010 14:49:38

Variables (& observations)	r	p
Angles & Linear (46)	0.095	0.679

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (Ronas Voe)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 15 June 2010 10:58:28

Variables (& observations)	r	p
Angles & Linear (66)	0.211	0.061

Section 11.6.2 Circular linear correlation for *E. coli* result and tidal state on the high/low cycle (South of Ayre of Teogs)

CIRCULAR-LINEAR CORRELATION
Analysis begun: 15 June 2010 10:59:04

Variables (& observations)	r	p
Angles & Linear (33)	0.071	0.858

Section 11.6.3 Spearman's rank correlation for *E. coli* result and water temperature (Ronas Voe)

```
Pearson correlation of ranked temperature and ranked E coli for temperature
=0.027
n=23, p>0.25
```

Section 11.6.5 Spearman's rank correlation for *E. coli* result and salinity (Ronas Voe)

```
Pearson correlation of ranked salinity and ranked e coli for salinity = -
0.061
```
n=73, p>0.25

Section 11.6.5 Spearman's rank correlation for *E. coli* result and salinity (South of Ayre of Teogs)

```
Pearson correlation of ranked salinity and ranked e coli for salinity =
0.360
n=41, p<0.025
```

Hydrographic Methods

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

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

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

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

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

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

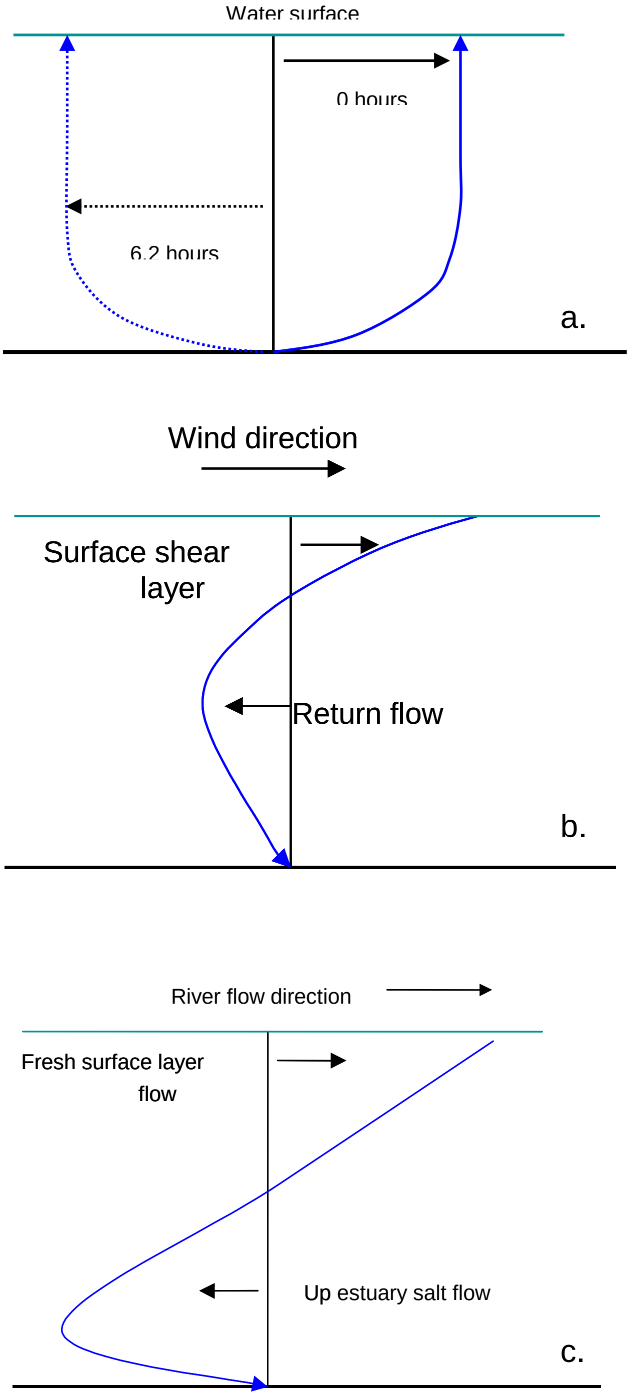

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

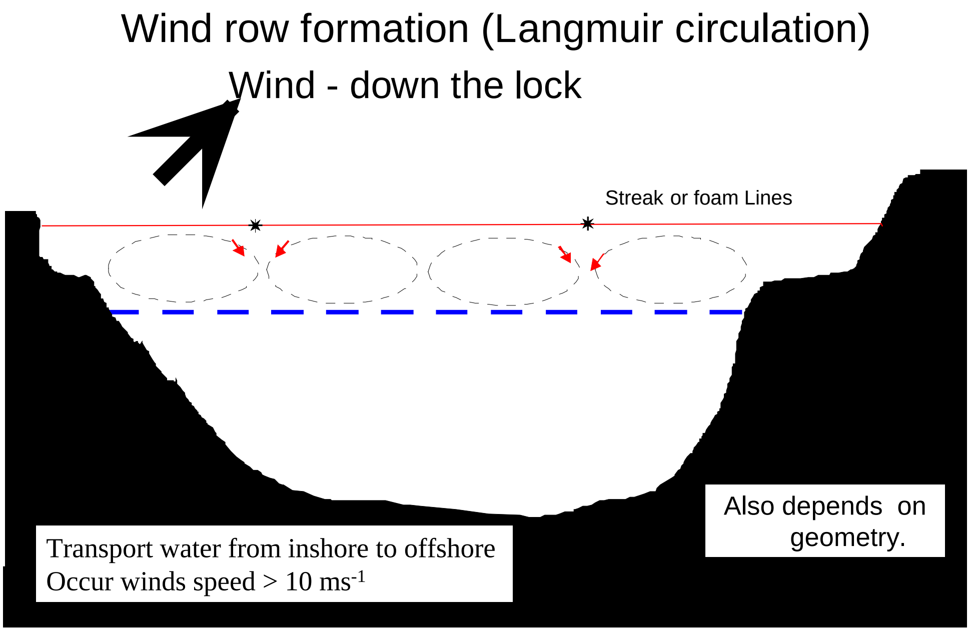

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Non-modelling Assessment

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

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

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

The catalogue of Scottish Sea Loch produced by the SMBA is used to quantify sills, volume fluxes and likely flow velocities. Because the flow is so constrained by the rapidly varying bathymetry, care has to be used in the extrapolation of direct measurements of current flow. Mean flow velocities can be estimated at the sills by using estimates of the sill area and the volume change through a tidal cycle. This in turn can be used to estimate the maximum distance travelled in a tidal cycle in the sill area. Away from the sill area, tidal velocities are general low and transport events are dominated by wind or density effects. Sea Lochs generally have a surface layer of fresher water; the extent of this depends on freshwater input, sill depth and quantity of mixing.

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Ronas Voe

SIN 523, 522

Scottish Sanitary Survey Project Cefas

Shoreline Survey Report

Production area:	Ronas Voe
Site name:	Clifts (SI 523 919 08), West of Black Well (SI 522 918 08)
Species:	Common Mussels
Harvester:	Michael Laurenson
Local Authority:	Shetland Islands Council
Status:	New
Date Surveyed:	22nd – 23rd June 2010
Surveyed by:	22nd June: Fran Hockley (Cefas), Nadia Nicolson (SIC), and Jessica Larkham (Cefas) 23rd June: Fran Hockley (Cefas), Jessica Larkham (Cefas), and Sean Williamson (NAFC)
Existing RMP:	HU 3273 8090
Area Surveyed:	See Figure 1.

Weather observations

Tuesday 22nd June: Overcast in the morning, turning to sunny spells in the afternoon. Light breeze.
Wednesday 23rd June: Overcast, light breeze

Site Observations

Fishery

West of Black Well:
The fishery at the West of Black Well (Figure 9) site consists of three double mussel lines with 10m droppers made in New Zealand manufactured 50mm Power Loop. The two lines towards the middle of the voe have recently been laid. The near-shore line is a year old, and the harvester plans to harvest the stock in 1 to 1.5 years when the stock is mature.

Clifts:
The fishery at Clifts (Figure 8) consists of six double mussel lines with 10m droppers made in New Zealand manufactured 50mm Power Loop. Three of the lines have recently been laid, and plans are to harvest these lines in 2.5 years time. The other three lines are 3 years old and are currently being harvested.

It was noted during the shoreline survey that the South of Ayre of Teogs site is now much larger than previously observed in the 2007 shoreline survey, and now consists of two sets of 3 double lines.

Sewage/Faecal Sources

Human:

The area of highest human population in the vicinity of Ronas Voe is at Heylor, which consists of approximately six houses. There are also three houses with an outbuilding at the head of the voe, and four other individual houses along the southern shore. There were no pipes observed entering the voe from these buildings, so it is assumed they contain private septic tanks which discharge via soakaway to land.

Livestock:
Approximately 200 sheep were observed in total around the shoreline of Ronas Voe (Figure 7A), and sheep droppings were observed in relatively low amounts all along the southern shore of the voe. There were also three cattle near the houses at the head of the voe (Figure 7B), which is noted to be much less compared to the number observed during the 2007 survey, when 58 cattle were noted. The three cattle had access directly on to the beach, and cow pats were observed on it.

Seasonal Population

The houses surrounding Ronas Voe appeared to be permanently occupied, and so there is unlikely to be a change in population throughout the year.

Boats/Shipping

A large boat was observed working on the fish farm in Ronas Voe (Figure 10), and a boat belonging to Blueshell mussels was observed working on the Clifts (Figure 8) and Ronas Voe mussel lines.

Land Use

Land cover surrounding Ronas Voe was grazed rough grassland, some improved grassland and enclosed improved grazing fields. The northern side of the voe was very steep sided, and led to Ronas Hill, which is Shetland's highest hill at 450m.

Wildlife/Birds

There were no flocks of birds observed in Ronas Voe, however small numbers of oystercatchers, gulls, terns, eider ducks and gulls were observed, some of which were directly on the mussel buoys (Cover photo).

General observations

Recorded observations apply to the date of survey only. Animal numbers were recorded on the day from the observer's point of view. This does not necessarily equate to total numbers present as natural features may obscure individuals and small groups of animals from view.

Dimensions and flows of watercourses are estimated at the most convenient point of access and not necessarily at the point at which the watercourses enter the voe or loch.

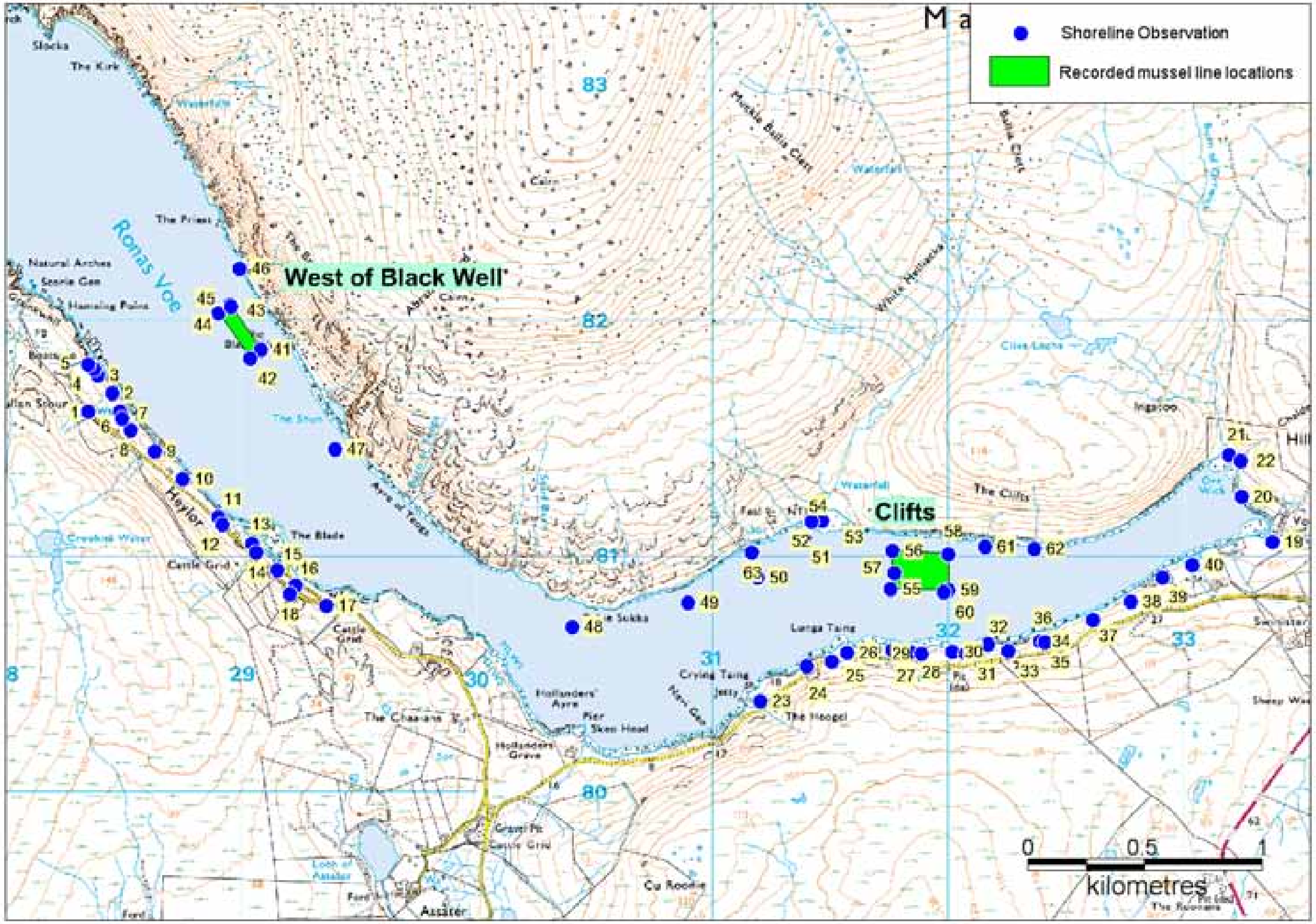

Figure 1 Map of Shoreline Observations

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	22/06/2010	09:12	HU 28350 81617	428350	1181617			Stream/Land drain
2	22/06/2010	09:17	HU 28452 81692	428452	1181692		RVFW1	Stream, flow 0.123 m/sec, depth 3cm, width 60cm
3	22/06/2010	09:24	HU 28389 81771	428389	1181771			Small stream. House 100m inland from point
4	22/06/2010	09:27	HU 28374 81798	428374	1181798			2 Sheep
5	22/06/2010	09:29	HU 28347 81818	428347	1181818			Stream , flow 0.209 m/sec, depth 2.5-8cm, width 20cm
6	22/06/2010	09:42	HU 28484 81617	428484	1181617	Figure 5A	RVFW2	Stream, hardly any flow, depth 8cm, width 40 cm
7	22/06/2010	09:52	HU 28494 81588	428494	1181588			Land drain with pipe running under road, trickle flow. Forming stream towards the voe
8	22/06/2010	09:56	HU 28531 81539	428531	1181539			Sheep field - see No. 18
9	22/06/2010	10:01	HU 28630 81447	428630	1181447	Figure 5B	RVFW3	Stream flowing under road, flow 0.072m/sec, depth 7cm, width 30cm
10	22/06/2010	10:16	HU 28751 81331	428751	1181331			Land drain with pipe running under road, dry. 2 sheep
11	22/06/2010	10:20	HU 28901 81169	428901	1181169	Figure 5C	RVFW4	Stream, pipe running under road. Flow 25secs to fill 1000ml, depth 2cm, width 25cm
12	22/06/2010	10:32	HU 28917 81136	428917	1181136			Land drain, slight trickle
13	22/06/2010	10:38	HU 29046 81054	429046	1181054			Two land drains through pipes close to house
14	22/06/2010	10:40	HU 29062 81018	429062	1181018	Figure 5D	RVFW5	Stream, flow 0.034 m/sec, depth 7cm, width 20cm
15	22/06/2010	10:46	HU 29152 80944	429152	1180944	Figure 5E	RVFW6	Pipe running from house onto land. Likely to be stream rather than sewage discharge as water was clean and not smelly. Fills up 30ml sample pot in 2secs. 8 sheep
16	22/06/2010	10:53	HU 29229 80881	429229	1180881			Land drain
17	22/06/2010	10:55	HU 29361 80792	429361	1180792			2 houses, no sign of outfall pipe, possible septic tank in garden
18	22/06/2010	10:59	HU 29204 80844	429204	1180844			Approximately 31 sheep in enclosed field. Stream running through western edge of field (currently

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								dry)
19	22/06/2010	11:36	HU 33377 81065	433377	1181065	Figure 7B	RVFW8	Stream, flow 0.143m/sec, depth 5 cm, width 280cm. 3 houses + 1 outbuilding, 3 cows
20	22/06/2010	11:47	HU 33245 81257	433245	1181257			Land runoff, smell of cow manure. 2 sheep
21	22/06/2010	11:53	HU 33190 81432	433190	1181432	Figure 6A	RVFW7	Stream, flow 0.031, depth 5cm, width 400cm. Fence preventing cows access to beach and stream. 10 oyster catchers, 2 ducks, 2 ducklings
22	22/06/2010	12:02	HU 33239 81406	433239	1181406	Figure 6B		Stream running onto beach
23	22/06/2010	12:37	HU 31204 80388	431204	1180388	Figure 10		Start of walk, fish farm HQ, 6 cages on opposite bank, 2 near side. 4 sheep. Mussel shells on beach
24	22/06/2010	12:44	HU 31400 80537	431400	1180537			Land drain
25	22/06/2010	12:47	HU 31505 80554	431505	1180554			Stream, pipe running under road.
26	22/06/2010	12:50	HU 31571 80594	431571	1180594			Stream/land drain. Stagnant
27	22/06/2010	12:55	HU 31763 80603	431763	1180603			Stream, not flowing.
28	22/06/2010	12:57	HU 31838 80598	431838	1180598		RVFW9	Stream, slight trickle
29	22/06/2010	13:04	HU 31885 80587	431885	1180587	Figure 5F	RVFW10	Stream, flow 0.020m/sec, depth 10cm, width 70cm
30	22/06/2010	13:13	HU 32018 80596	432018	1180596			3 sheep
31	22/06/2010	13:14	HU 32073 80588	432073	1180588			Stream, low flow
32	22/06/2010	13:17	HU 32169 80630	432169	1180630			Stream
33	22/06/2010	13:21	HU 32254 80600	432254	1180600			Stream/land drain
34	22/06/2010	13:24	HU 32388 80642	432388	1180642			7 sheep
35	22/06/2010	13:25	HU 32411 80639	432411	1180639			Dry stream, pipe under road
36	22/06/2010	13:27	HU 32489 80655	432489	1180655			Land drain/stream
37	22/06/2010	13:31	HU 32615 80732	432615	1180732			Stream
38	22/06/2010	13:35	HU 32773 80809	432773	1180809			6 sheep, 2 oyster catchers
39	22/06/2010	13:39	HU 32910 80912	432910	1180912			Stream through field. 2 sheep near stream
40	22/06/2010	13:43	HU 33036 80967	433036	1180967			House
41	23/06/2010	08:45	HU 29082 81880	429082	1181880	Figure 9	RV MUSSEL 1 (4m sample basket), RV MUSSEL 2 (surface) RVSW1	Corner of lines, salinity profile 1

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
42	23/06/2010	08:57	HU 29035 81841	429035	1181841			Corner of lines
43	23/06/2010	09:00	HU 28902 82032	428902	1182032			Corner of lines
44	23/06/2010	09:00	HU 28951 82069	428951	1182069			Corner of lines
45	23/06/2010	09:04	HU 28955 82062	428955	1182062		RVSW2	Salinity profile 2
46	23/06/2010	09:19	HU 28991 82221	428991	1182221	Figure 5G	RVSW3	Seawater sample taken where burn meets voe. 2 Sheep on shore
47	23/06/2010	09:22	HU 29398 81455	429398	1181455			3 Sheep on shore
48	23/06/2010	09:26	HU 30402 80705	430402	1180705			30 sheep on shore
49	23/06/2010	09:27	HU 30896 80805	430896	1180805	Figure 10		4 fish cages. 2 more on opposite side of voe
50	23/06/2010	09:28	HU 31190 80910	431190	1180910			40 sheep on shore
51	23/06/2010	09:35	HU 31389 81080	431389	1181080	Figure 7A		30 sheep on shore
52	23/06/2010	09:41	HU 31461 81155	431461	1181155	Figure 6C	RVFW11	Stream, flow 0.094 m/sec, depth 15cm, width 170cm
53	23/06/2010	09:47	HU 31464 81153	431464	1181153			Blank
54	23/06/2010	09:49	HU 31419 81149	431419	1181149			Mussel and clam shells on shore
55	23/06/2010	09:57	HU 31753 80861	431753	1180861	Figure 8		Corner of lines. 1 cormorant + 6 gulls on mussel buoys
56	23/06/2010	09:58	HU 31763 81025	431763	1181025			Corner of lines. 6 eider ducks
57	23/06/2010	10:00	HU 31771 80932	431771	1180932		RV MUSSEL 3 (surface) RV MUSSEL 4 (3m) RV MUSSEL 5 (8m) RVSW5	Mussel samples. Salinity profile 4
58	23/06/2010	10:12	HU 32000 81012	432000	1181012			Corner of lines. 30 sheep on shore
59	23/06/2010	10:13	HU 32000 80858	432000	1180858			Corner of lines
60	23/06/2010	10:13	HU 31980 80852	431980	1180852		RV MUSSEL 6 (Surface), RV MUSSEL 7 (Middle), RV MUSSEL 8 (bottom), RVSW6	Salinity profile 5
61	23/06/2010	10:29	HU 32156 81045	432156	1181045			Dry stream
62	23/06/2010	10:32	HU 32364 81033	432364	1181033		RVSW7	Dry stream. Seawater sample taken between two dry streams

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
63	23/06/2010	09:45	HU 31166 81016	431166	1181016		RVSW4	Seawater sample taken between two streams. Salinity profile 3

Photos referenced in the table can be found attached as Figures 5-10.

Sampling

Water and shellfish samples were collected at sites marked in the maps in figures 3 and 4.

The outer two lines in the West of Black Well site were only recently laid, therefore did not have any stock available for sampling. A sample was taken from a sampling basket at 4m depth at the southern end of the inner line, and also from the droppers near to the surface. There was not enough stock available for sampling at the northern end of this line.

Mussel samples collected from the Clifts mussel lines were taken from the north-west and south-east corners at three depths. The samples were noted to have a distinct smell to them during collection.

Bacteriology results follow in Tables 2 and 3.

Samples of seawater were tested for salinity by the laboratory using a salinity meter under controlled conditions. These results are shown in Table 2, given in units of grams salt per litre of water. This is the same as parts per thousand (ppt).

Salinity profiles were also taken at the points of five of the sea water samples to evaluate the effects of freshwater inputs onto the site.

Table 2 Water Sample Results

No.	Date	Sample	Grid Ref	Type	*E. coli* (cfu/100ml)	Salinity (g/L)
1	22/06/2010	Ronas Voe FW1	HU 28452 81692	Fresh water	<10	n/a
2	22/06/2010	Ronas Voe FW2	HU 28484 81617	Fresh water	<10	n/a
3	22/06/2010	Ronas Voe FW3	HU 28630 81447	Fresh water	50	n/a
4	22/06/2010	Ronas Voe FW4	HU 28901 81169	Fresh water	<10	n/a
5	22/06/2010	Ronas Voe FW5	HU 29062 81018	Fresh water	<10	n/a
6	22/06/2010	Ronas Voe FW6	HU 29152 80944	Fresh water	10	n/a
7	22/06/2010	Ronas Voe FW7	HU 33190 81432	Fresh water	10	n/a
8	22/06/2010	Ronas Voe FW8	HU 33377 81065	Fresh water	20	n/a
9	22/06/2010	Ronas Voe FW9	HU 31838 80598	Fresh water	<10	n/a
10	22/06/2010	Ronas Voe FW10	HU 31885 80587	Fresh water	70	n/a
11	23/06/2010	Ronas Voe FW11	HU 31461 81155	Fresh water	20	n/a
12	23/06/2010	Ronas Voe SW1	HU 29082 81880	Sea water	7	35.35
13	23/06/2010	Ronas Voe SW2	HU 28955 82062	Sea water	<1	35.35
14	23/06/2010	Ronas Voe SW3	HU 28991 82221	Sea water	8	35.15
15	23/06/2010	Ronas Voe SW4	HU 31166 81016	Sea water	<1	35.00
16	23/06/2010	Ronas Voe SW5	HU 31771 80932	Sea water	<1	34.89
17	23/06/2010	Ronas Voe SW6	HU 31980 80852	Sea water	<1	34.96
18	23/06/2010	Ronas Voe SW7	HU 32364 81033	Sea water	1	34.68

Table 3 Mussel Sample Results

No.	Date	Sample	Depth	Grid Ref	*E. coli* (MPN/100g)
1	23/06/2010	Ronas Voe MUSSEL 1	4m sample basket	HU 29082 81880	80
2	23/06/2010	Ronas Voe MUSSEL 2	Surface (<1m)	HU 29082 81880	50
3	23/06/2010	Ronas Voe MUSSEL 3	Surface (<1m)	HU 31771 80932	170
4	23/06/2010	Ronas Voe MUSSEL 4	3m	HU 31771 80932	80
5	23/06/2010	Ronas Voe MUSSEL 5	8m	HU 31771 80932	50
6	23/06/2010	Ronas Voe MUSSEL 6	Surface (<1m)	HU 31980 80852	<20
7	23/06/2010	Ronas Voe MUSSEL 7	3m	HU 31980 80852	<20
8	23/06/2010	Ronas Voe MUSSEL 8	8m	HU 31980 80852	<20

Table 4 Salinity profiles

Profile	**Date**	**Time**	**Position**	**Associated sample**	**Depth (m)**	**Salinity (ppt)**	**Temperature (°C)**
1	23/06/2010	8:45	HU 29082 81880	RVSW1	Surface	26.98*	10.8
					3	37.15	10.6
					5	37.16	10.3
					10	37.22	9.8
2	23/06/2010	09:04	HU 28955 82062	RVSW2	Surface	37.04	10.8
					3	37.17	10.5
					5	37.20	10.4
					10	37.24	9.7
3	23/06/2010	9:45	HU 31166 81016	RVSW4	Surface	36.86	12.7
					3	37.13	12.4
					5	37.18	10.0
4	23/06/2010	10:00	HU 31771 80932	RVSW5	Surface	36.84	12.7
					3	37.23	10.2
					5	37.24	10.0
					10	37.26	9.8
5	23/06/2010	10:13	HU 31980 80852	RVSW6	Surface	36.88	12.7
					3	37.25	10.4
					5	37.18	10.2
					10	37.25	9.8

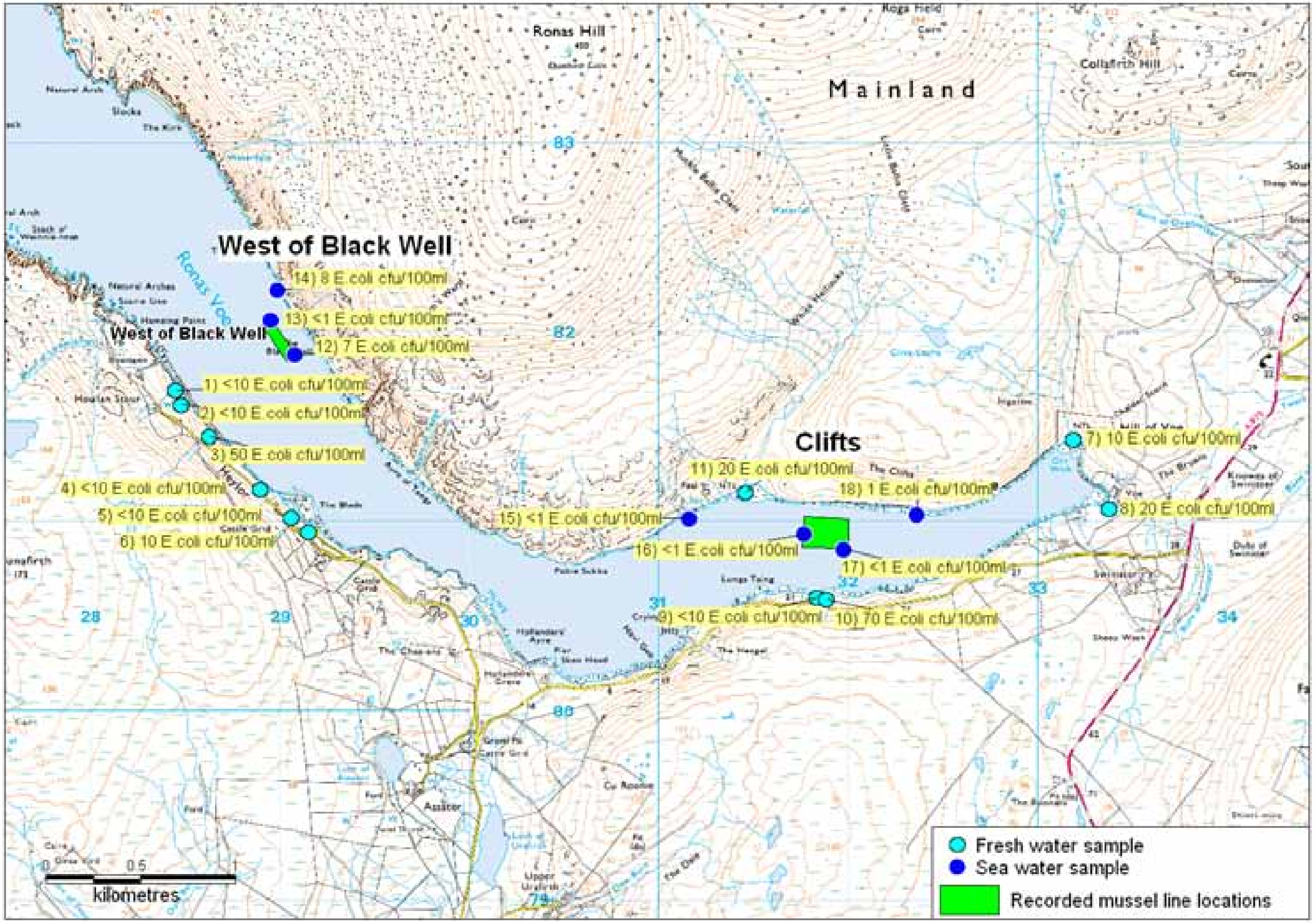

Figure 3 Water sample results map

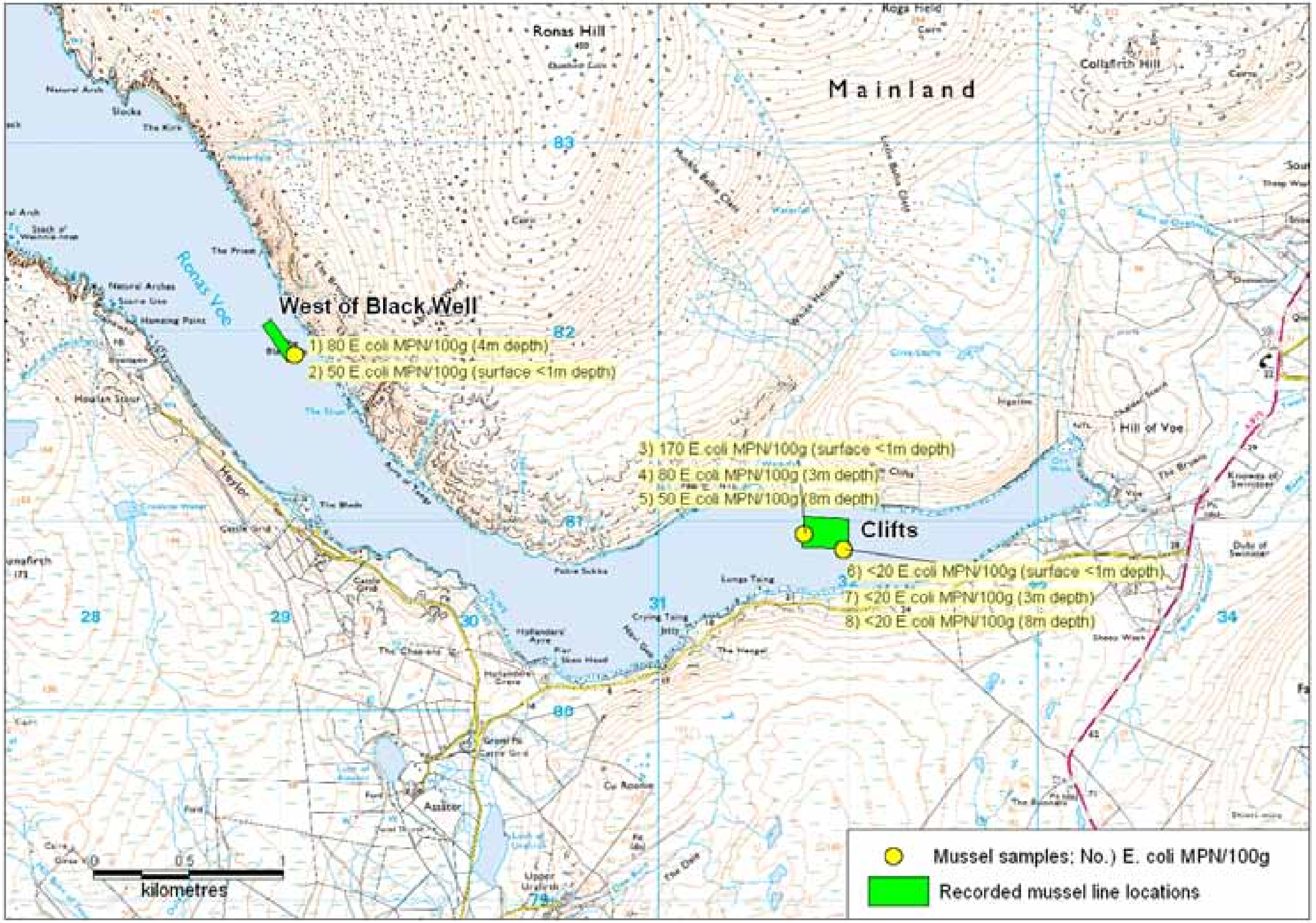

Figure 4 Shellfish sample results map

Photographs

Figure 5 Location of freshwater samples

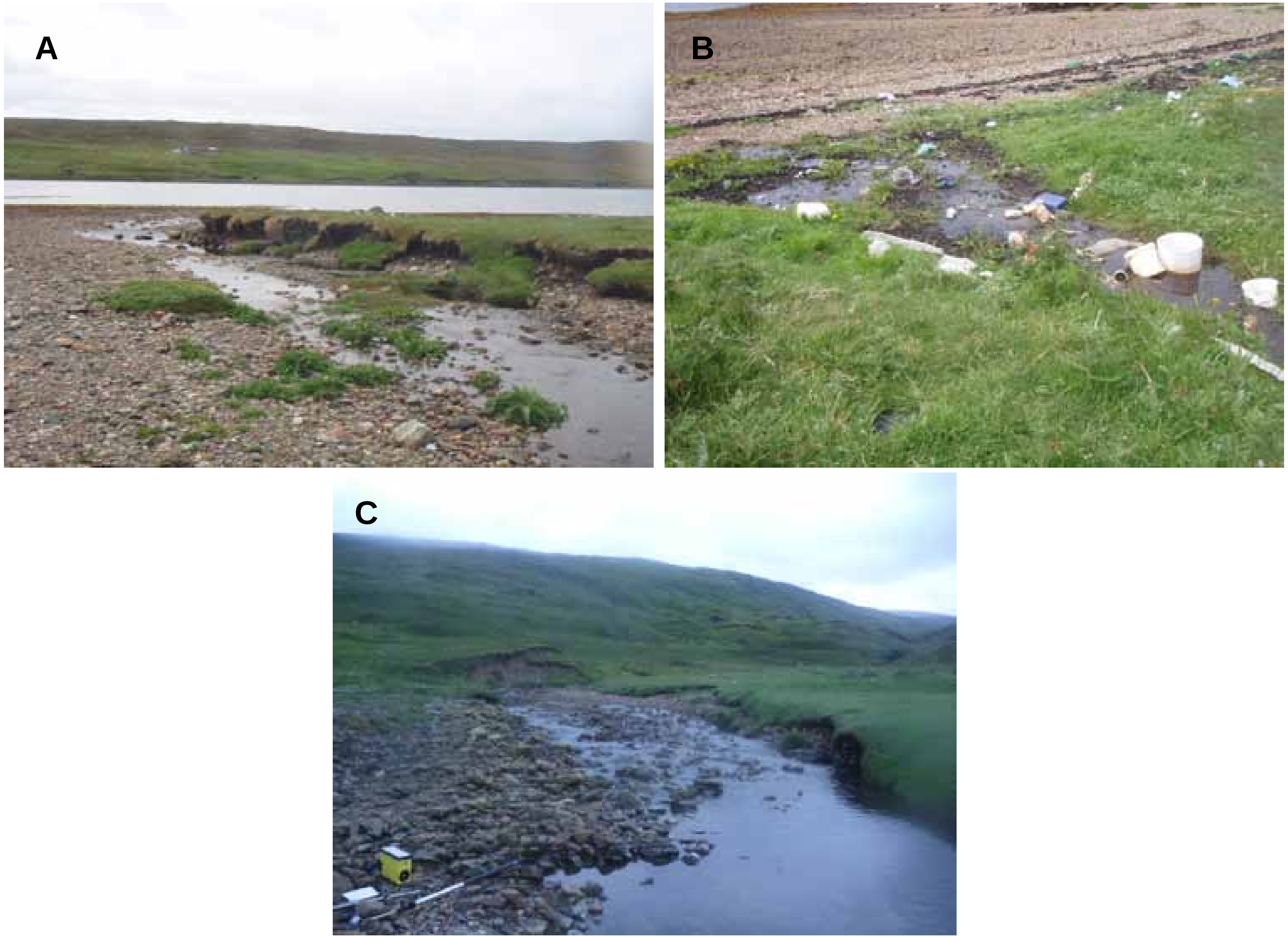

Figure 6 Location of freshwater samples

Figure 7 Livestock on shoreline of Ronas Voe

Figure 8 Clifts mussel lines

Figure 9 West of Black Well mussel lines

Figure 10 Ronas Voe salmon fishery, consisting of six salmon cages