Scottish Sanitary Survey Project

Sanitary Survey Report

Clift Sound and Stream Sound

SI 035, SI 036, SI 037, SI 038 and SI 373

December 2007

Cefas

FOOD STANDARDS AGENCY SCOTLAND
Buidheann Inbhe-Bìdhe an Alba

Report Distribution – Clift Sound

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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 in undertaken by the relevant local authority.

Table of Contents

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1. General description

Clift Sound lies between mainland Shetland and the islands of Trondra and West Burra. It is a steep-sided sound over 10km in length and less than 1km in width along much of its length that runs roughly North and South (Figure 1.1). Stream Sound separates Trondra from West Burra and connects Clift Sound to Lang Sound and the Atlantic. At its northern end lies the East Voe of Scalloway and the port of Scalloway. Clift Sound is exposed to winds from the South and Southwest.

Scalloway, the second largest settlement in Shetland with a population of approximately 1000, is located at the top of the sound. The land to either side of the remainder of the sound is sparsely populated.

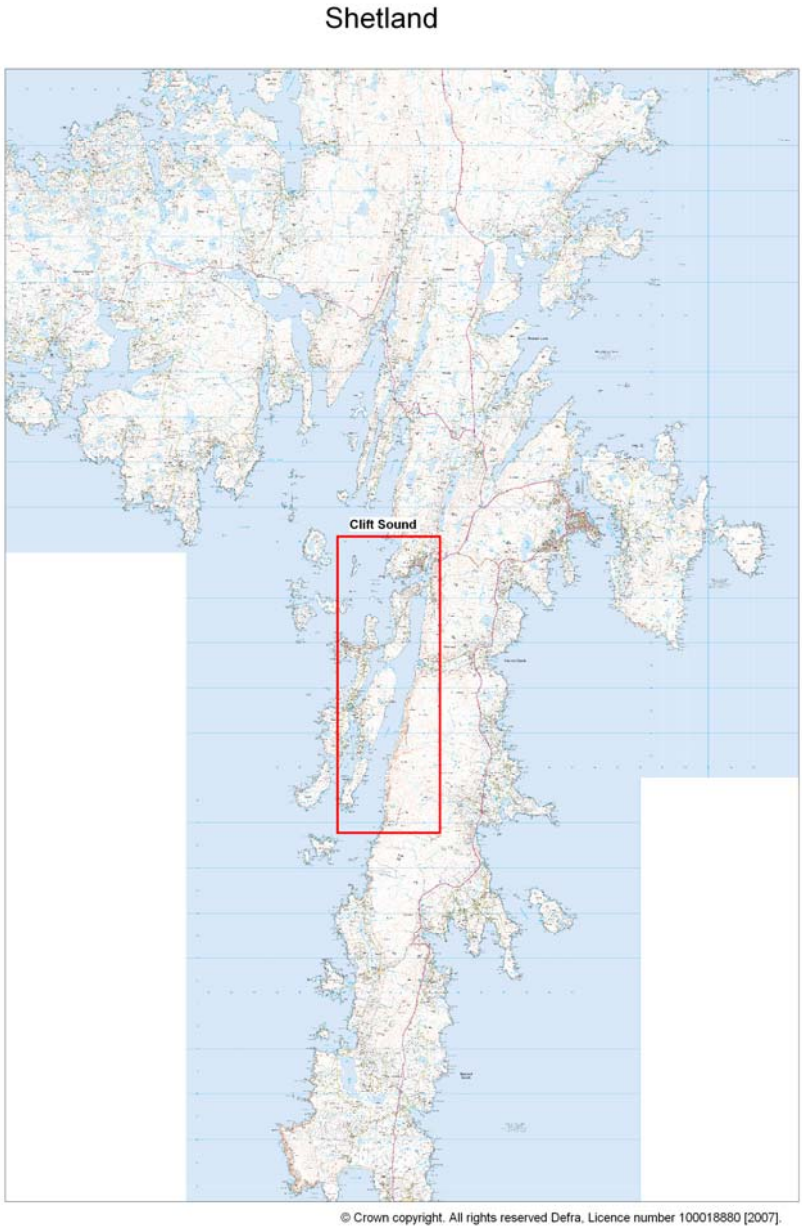

Figure 1.1. Location of Clift Sound

This survey covers the following production areas and sites listed in Table 1.1.

Table 1.1

Production Area	Site	SIN	Species
Clift Sound: Stream Sound	Stream Sound	SI 037 415 08	Common mussels
Clift Sound: Whal Wick	Whal Wick	SI 038 416 08	Common mussels
Clift Sound: E. Hogaland	East Hogaland	SI 035 414 08	Common mussels
Clift Sound: Booth	Booth	SI 036 413 08	Common mussels
Stream Sound: Uxness	Uxness	SI 373 762 08	Common mussels

Harvesters:
Booth, Whal Wick, and Uxness. Mr. Kenny Pottinger
E. Hogaland. Mr. Alan Manzie
Stream Sound. Demlane-Isle of Shuna Plc

This sanitary survey was triggered by the receipt of a new application for harvesting at East Hogaland. The other production areas were included in the survey due to their proximity to the East Hogaland site.

2. Fishery

All the shellfisheries in Cliftsound are rope grown mussels, using double headed long lines with droppers of up to 8 metres length.

Long lines attached to floats are laid out in parallel lines anchored at either end within the approved lease area. Vertical lines containing plastic pegs (droppers) are attached to the long lines. New lines are placed before or during spawning between May and early June and spat settle onto the droppers from the surrounding water. The spat are then left to grow for up to three years before reaching marketable size.

At the time of the shoreline survey, the East Hogaland site had four long lines, three of which had been recently placed and one of which had been recently extended. There was little harvestable stock with only one section of line containing sufficient mussels to collect a sample, most of which were of marginal size.

The Stream Sound site also had few mussels on. Two new lines had been recently added to the 4 lines already on the site. There was a dedicated sampling line at the representative monitoring point (RMP).

Booth was recently harvested and so there were no mussels on other than the dedicated sampling line on the RMP.

The site at Stream Sound: Uxness had 4 lines and all stock was of harvestable size. The harvester anticipated harvesting as soon as biotoxins closures were lifted some time in Sept/Oct.

Mature mussels are harvested by stripping the attached mussels from the droppers either by hand or by using a system of brushes mounted to a funnel. In some cases, harvested mussels are cleaned and sorted on the barge and in others they are taken back to a central facility for scrubbing and sorting.

As pressure from supermarkets to supply mussel year-round increases, some of the larger Shetland producers are harvesting during the May to August time frame when possible.

Figure 2.1 shows the relative locations of the mussel farms, Food Standard Agency Scotland designated Production Areas, seabed lease areas provided by the Crown Estate and Scottish Environmental Protection Agency (SEPA) designated shellfish growing waters (SGW).

The SEPA designated SGW boundary overlaps the bulk of the Stream Sound production area but does not encompass the entire production area. Any new production area at East Hogaland will lie completely within the SGW, however the majority of production within Clift Sound lies outwith it.

The representative monitoring point for the SGW is located at the far south western shore of the sound and as such lies a considerable distance from the shellfish farms currently located within the sound.

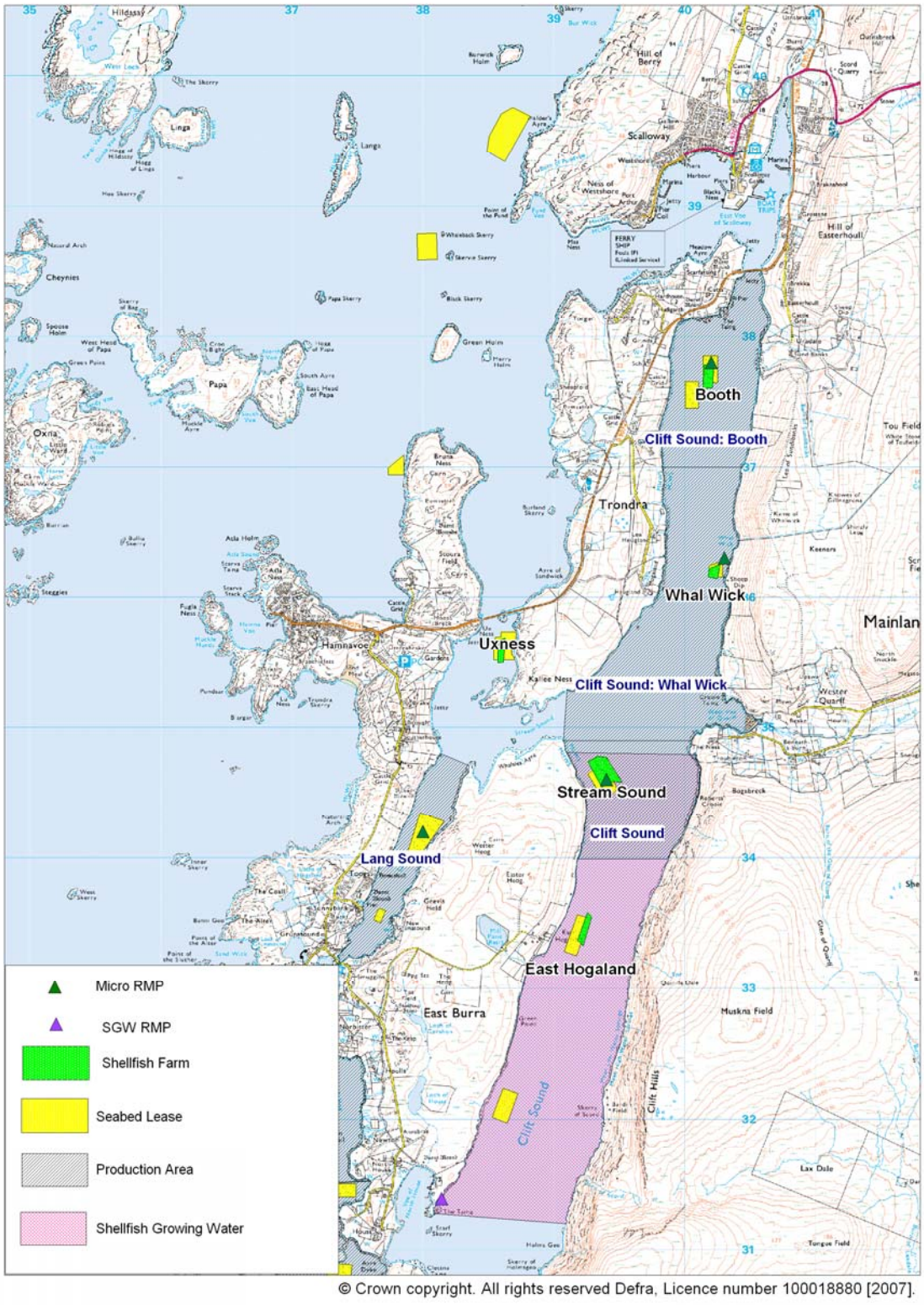

Figure 2.1 Map of Clift Sound fishery

3. Human population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output in the vicinity of Clift Sound.

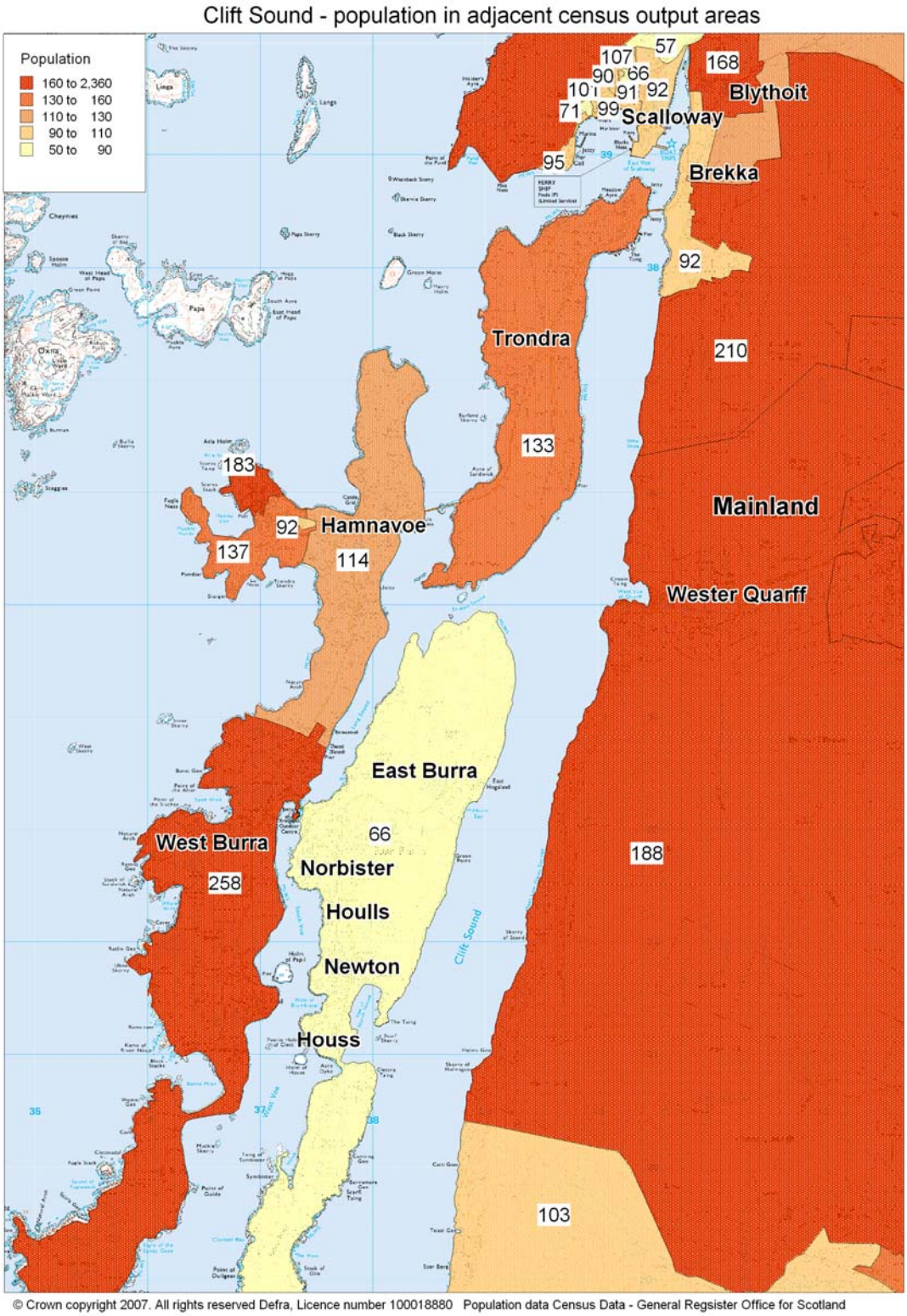

Figure 3.1 Population map for Clift Sound

The population for the six census output areas bordering immediately on central Clift Sound are:

60RD000018	66
60RD000147	92
60RD000015	103
60RD000133	133
60RD000149	188
60RD000142	210

There are also a further ten census output areas bordering the very northern end of Clift Sound:

60RD000002	57
60RD000075	92
60RD000126	66
60RD000071	99
60RD000073	107
60RD000124	71
60RD000125	95
60RD000072	101
60RD000074	90
60RD000146	168

At the northern tip of Clift Sound is the large town of Scalloway (population 812 at 2001 census) and on the northeastern side are the smaller settlements of Blythoit and Brekka. In the three other census output areas on the eastern side of the sound, the settlements and population are generally concentrated on the opposite side of the mainland, apart from one small coastal settlement, Wester Quarff, which is in the 60RD000149 census output area. On the western side of the sound is the settlement of Trondra on the northern island and East Burra, Norbister, Newton, Houlls and Houss on the southern island. Most of the population is concentrated in Scalloway towards the upper northern shore of the sound and any associated faecal pollution from human sources will be concentrated in this area.

For Shetland as a whole, the total number of holiday travellers in 2006 was estimated as 24,744 (compared to the 2001 census population of 21, 988) with the majority of tourists (66%) visiting during the peak summer season of June to September (Shetland Enterprise, Shetland Visitor Survey 2005/2006). There were 1740 bed spaces available according to 2005 VisitShetland records, 730 of which were in Lerwick with the remainder scattered around the islands. There is no explicit information on the number of visitors to this specific area. There are no known holiday parks or caravan sites in the immediate area of the voe, however wild camping is not discouraged and campers are advised to ask for landowner permission to set up camp and to dispose of toilet waste in a ‘discreet and responsible manner’. (Source: VisitShetland website). There could therefore be an increase in faecal contamination from human sources during the summer months but there is not sufficient information on which to base an estimate for this area.

4. Sewage Discharges

Community septic tanks and sewage discharges were identified by Scottish Water for the area around Clift Sound. They follow in Table 4.1. Plans are underway to improve works at Scalloway.

Table 4.1 Discharges identified by Scottish Water

Production Area	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m3/d	Consented flow (other) m3/d	Consented/ design PE	Q&S III Planned improvement?
Clift Sound	HU 371362	Hamnavoe, Burra	Continuous	Septic Tank	80		500	N
Clift Sound	HU38703930	Maa Ness	Continuous	Raw Outfall		75 l/s max	2850	Y
Clift Sound	HU 375336	North Toogs ST, Burra	Continuous	Septic Tank			250	N
Clift Sound	HU387111	Hulsidale, Hamnavoe	Continuous	Septic Tank		17 m3/d max	83	N

No sanitary or microbiological data were available for these discharges.

Scottish Water are currently installing four 200 m^3 capacity septic tanks at Maa Ness and replacing existing sewers from Port Arthur to Maa Ness. This will replace the screened raw outfall with septic tank treated effluent. The existing screening building and pumping station are to be removed. The consented discharge flow for Maa Ness as recorded in the table above included trade effluent from a fish processing facility that is no longer in operation (Scottish Water, personal communication) so the actual flow from the outfall would be considerably less than 75 l/s. It is anticipated that any effect of this work on the fishery in Clift Sound might be minimal as the outfall at Maa Ness is very distant. Improvements at Maa Ness may have a positive impact at the Stream Sound: Uxness fishery as it lies approximately 3 km due south of the Maa Ness outfall.

Sewers at Blacksness Pier will also be replaced due to seawater intrusion into the pipes. All of the work at Scalloway is due to complete by end of February 2008. If the sewers at Blacksness pier had been leaking into the harbour, their repair would remove a potential source of contamination to Scallaway harbour and the East Voe of Scalloway. Any effect would most likely be felt at the Booth site in the far north of the sound, which could have received contaminated water from the area of the East Voe of Scalloway.

Discharge consents held by SEPA and not already included in the Scottish Water table above are listed in Table 4.2 and both known and observed discharges are mapped in Figure 4.1 overleaf.

Discharges most likely to impact the fisheries at Clift Sound are emergency overflows at the pumping stations along the East Voe of Scalloway, and any private septic tank discharges to the sound at points near the fisheries, as well as septic tank effluent to the Burn of Quarff. A number of small private discharges were observed and it is anticipated that only those very near the fishery would have a significant impact. Due to the terrain and difficulties accessing the shoreline, it is anticipated that there are further septic tank discharges that were not either registered with SEPA or observed during the shoreline survey. The

Scottish Water septic tank at North Toogs would be most likely to affect the Uxness and Stream Sound sites.

Table 4.2 SEPA discharge consents for Clift Sound (excluding SW assets listed previously).

Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m3/d	Consented/ design PE	Notes
S10A	HU 407388	East Voe	Intermittent				Pumping station
S10B	HU 408396	East Voe	Intermittent	Sstorm sewage			Pumping station
S10D	HU 408393	Scalloway Harbour	Intermittent	Storm sewage			Pumping station
CAR/R/1009165	HU 39703776	The Old Schoolhouse	Continuous	Septic Tank		5	Domestic
CAR/R/1016138	HU 39943837		Continuous	Septic Tank		5	Domestic
CAR/R/1017815	HU 42683515		Continuous	Septic Tank		11	Domestic
CAR/R/1020324	HU 37843580		Continuous	Septic Tank		20	Domestic
CAR/R/1015982	HU 3692 3128	West Voe	Continuous	Septic Tank		13	Domestic

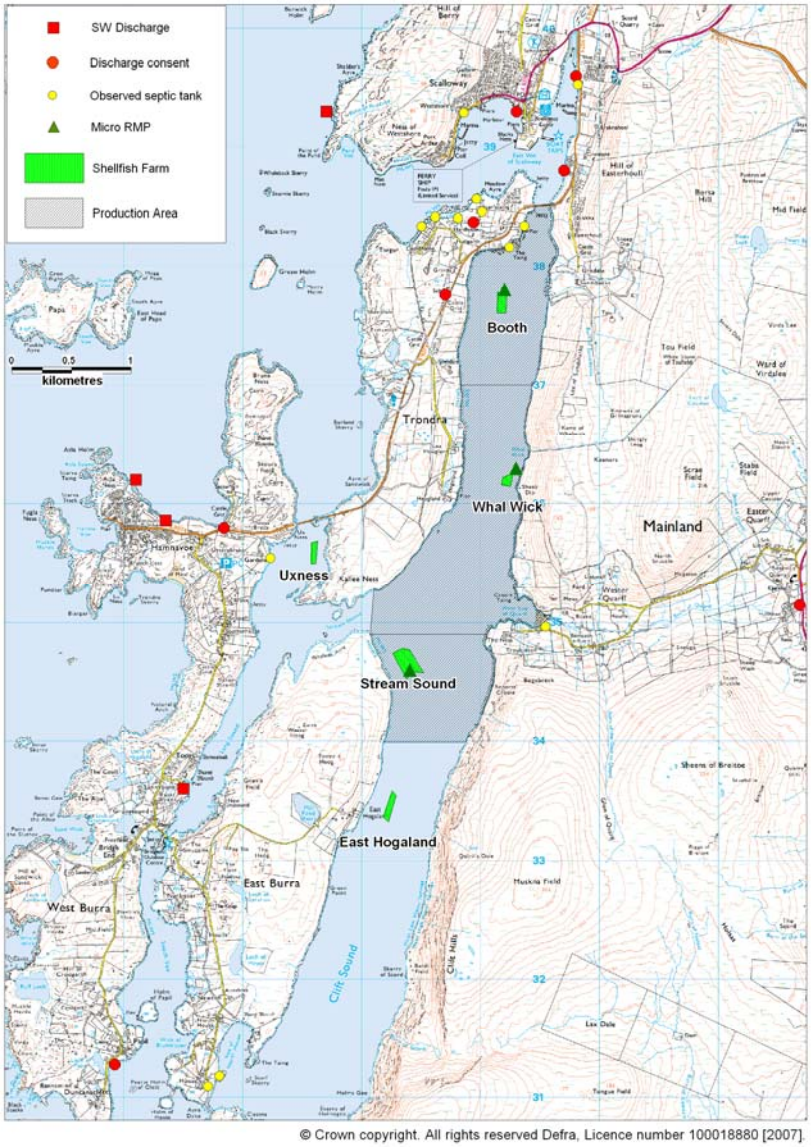

Figure 4.1 Map of discharges to Clift Sound

5. Geology and soils

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 researched 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 Shetland. 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 Shetland, 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 the Shetland regions mapped have an average surface % runoff of 44.3%, so it is likely that in this case they would be poorly draining.

Maps were produced using these seven soil type groups and whether they area characteristically freely or poorly draining. The map of component soils and their associated drainage classes for the area around Clift Sound can be found in Figures 5.1 and 5.2.

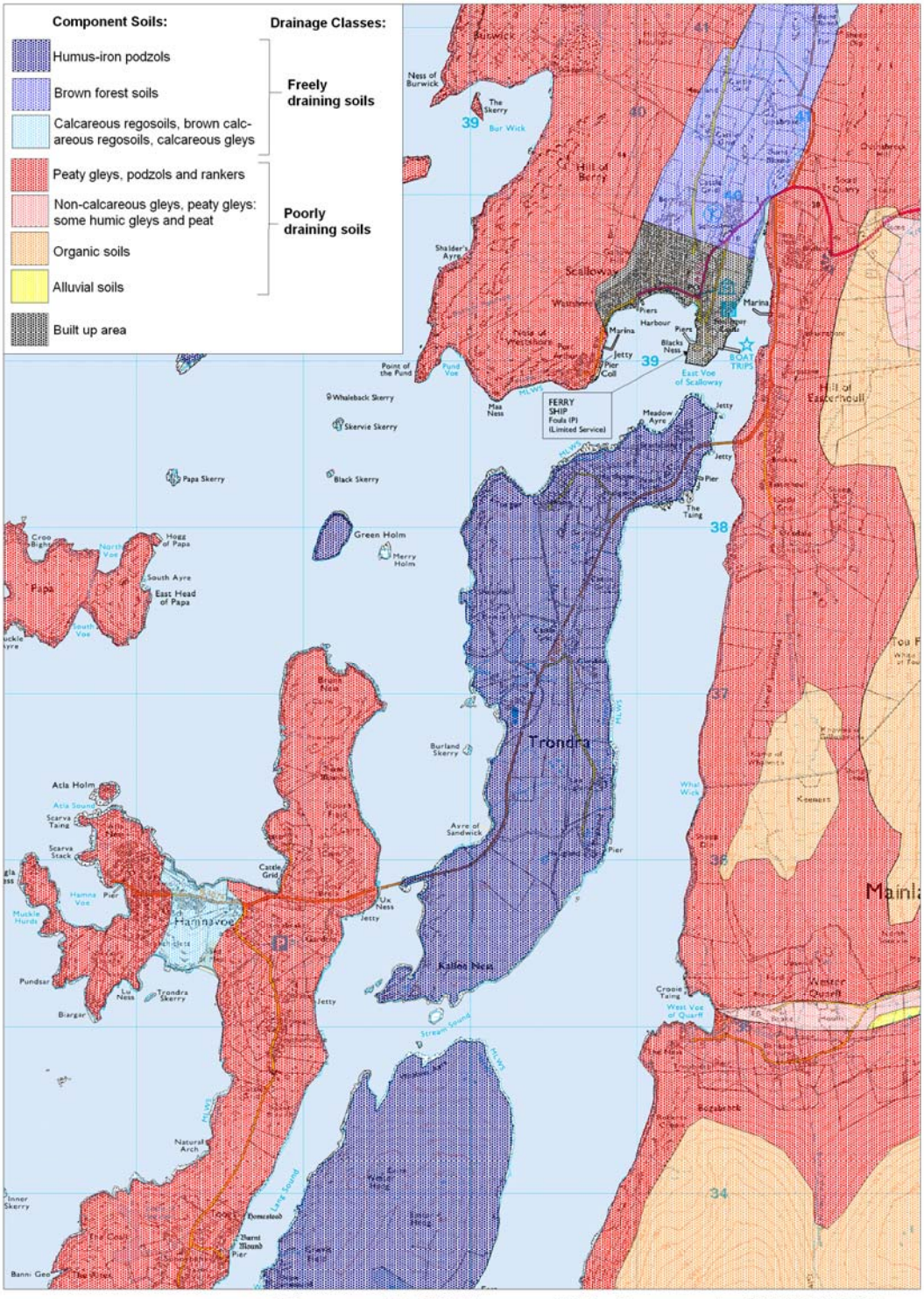

Figure 5.1 Component soils and drainage classes for Clift Sound North

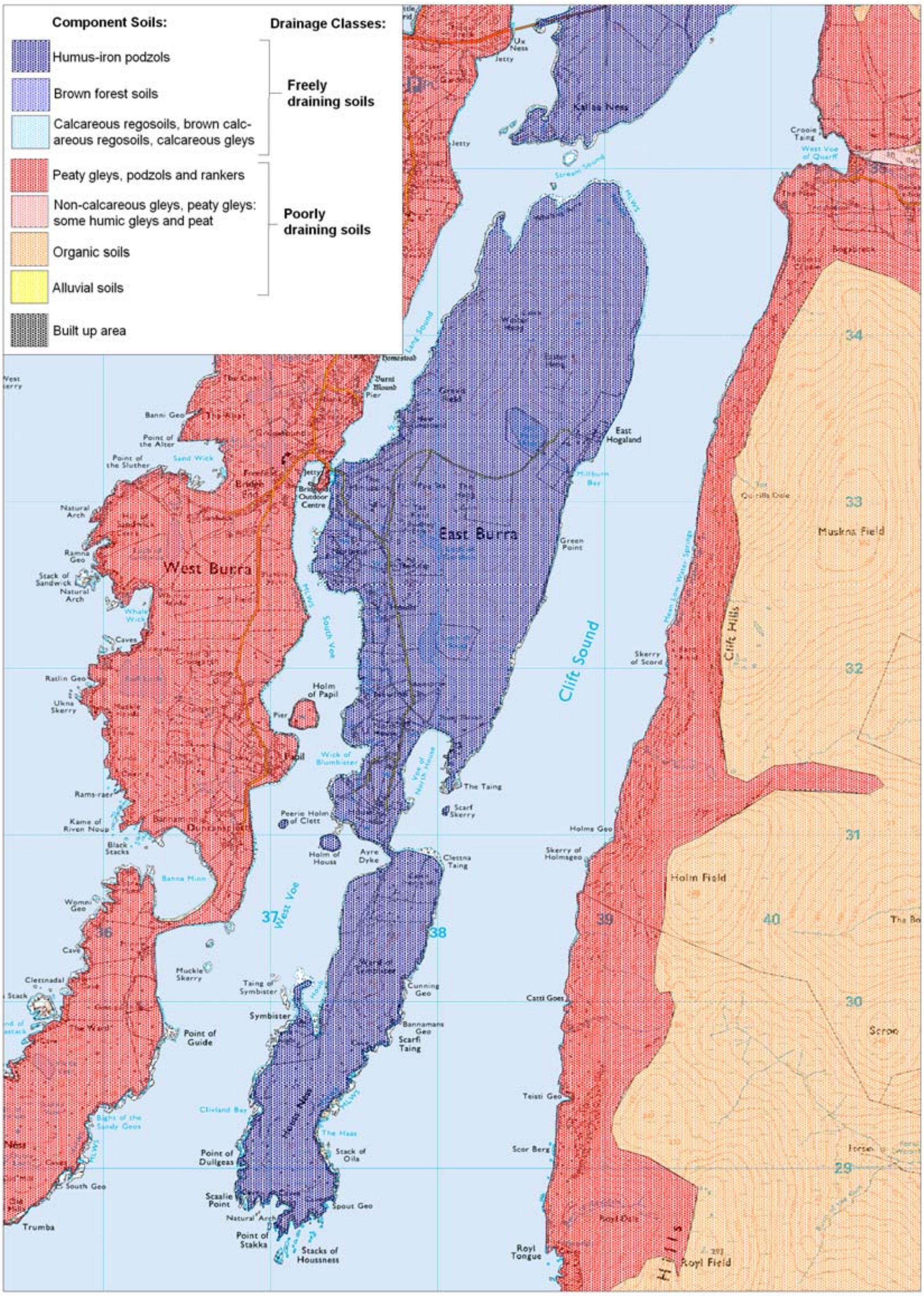

Figure 5.2 Component soils and drainage classes for Clift Sound South.

There are three main types of component soils visible in this area. The most dominant is composed primarily of humus-iron podzols. This soil type covers the islands East Burra and Trondra on the western coast of Clift Sound.

The second dominant soil type is composed of peaty gleys, podzols and rankers and stretches the whole eastern coast of the mainland to the east of Clift Sound.

The humus-iron podzols and peaty gleys, podzols and rankers, are the main soil types directly covering the Clift Sound coastline, however there are two additional soil groups worth mentioning. The first is the band of organic soils on the eastern coast of Clift Sound just behind the dominant peaty, gleys, podzols and rankers. The second is the small section of non-calcareous gleys, peaty gleys: some humic gleys and peat, half way up Clift Sound on the eastern coast, covering a small section of land leading to the West Voe of Quarff.

Poorly draining soils found along the eastern coast of Clift Sound are likely to contribute to higher levels of surface runoff. Along the western coast of Clift Sound, where the permeability of the soil is higher, runoff is likely to be reduced.

The potential for runoff contaminated with *E. coli* from human and/or animal waste is considerably higher along the eastern side of Clift Sound than along the western side.

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.

6. Land cover

The Land Cover Map 2000 data for the area is shown in Figures 6.1 and 6.2 below:

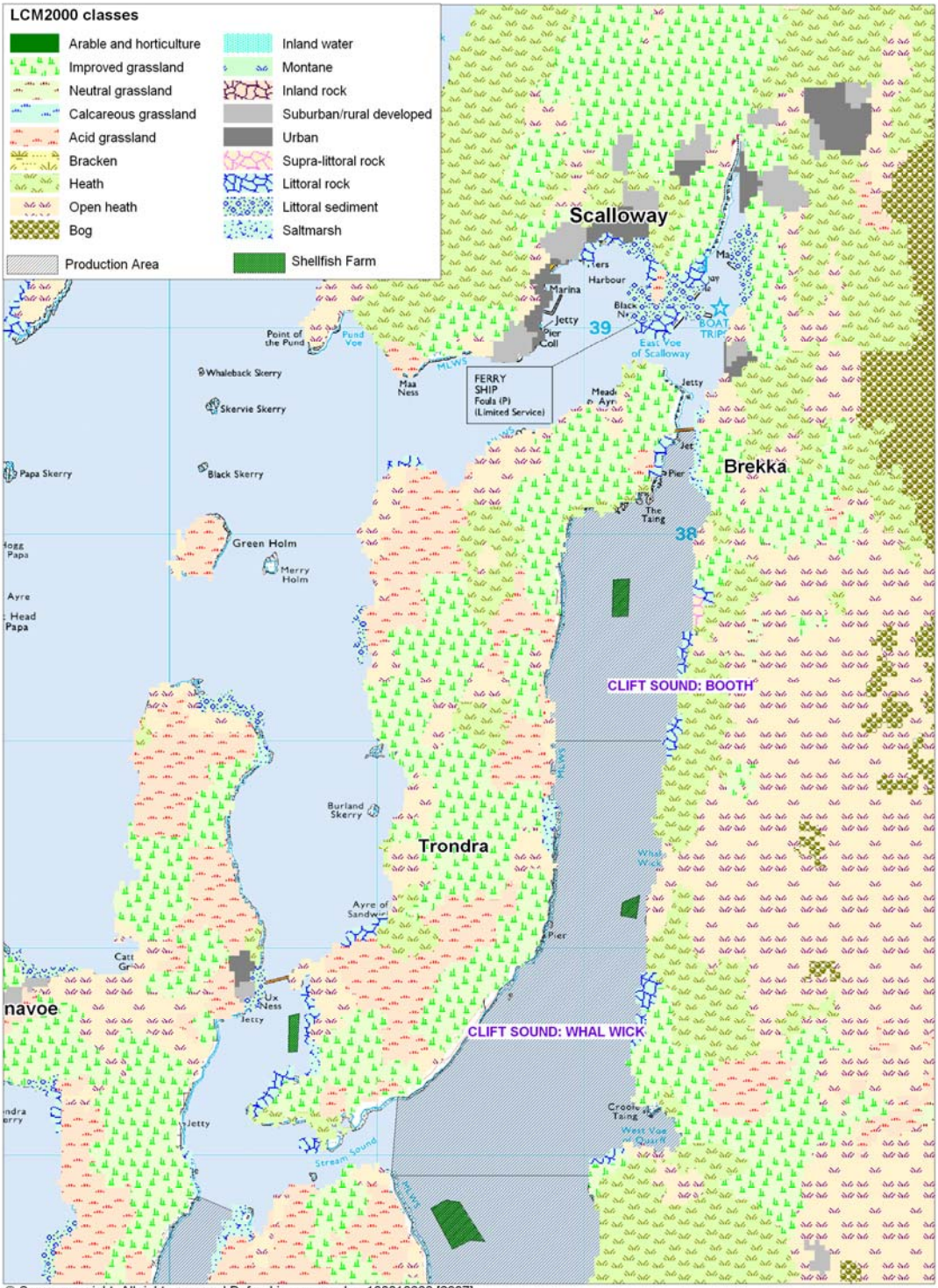

Figure 6.1 LCM2000 class data map for Clift Sound - north

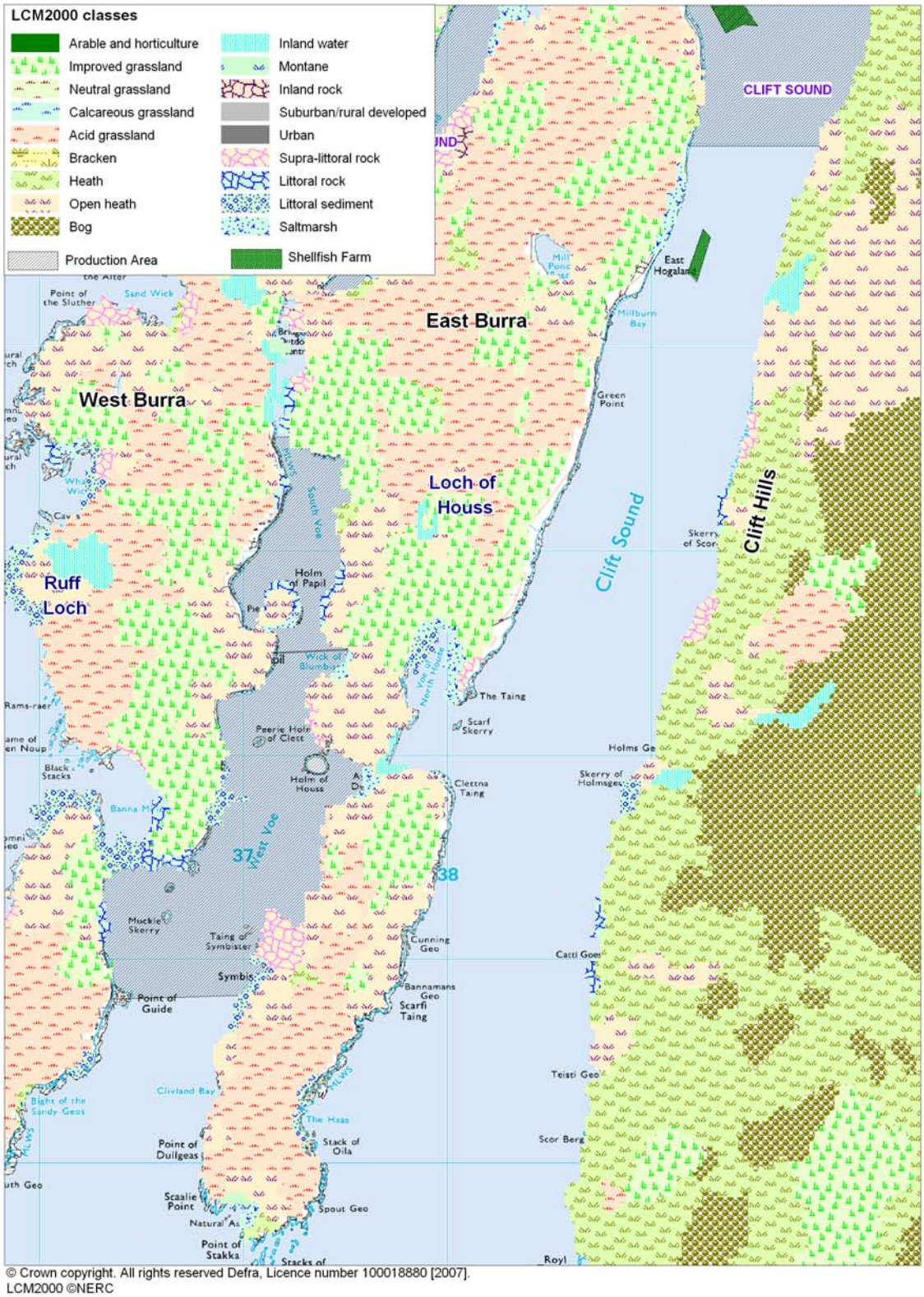

Figure 6.2 LCM2000 class data map for Clift Sound - south

Most of the land on the east side of Clift Sound is shown as heath and improved grassland along the coastline and open heath further inland. There are some areas of littoral rock running along this eastern coastline. The land cover on the west side of Clift Sound is more mixed with patches of improved grassland, acid grassland, heath and open heath. On the western coastline there are several areas of salt marsh and some littoral rock.

The faecal coliform contribution would be expected to be highest from developed areas (approx 1.2 – 2.8x10^{9} cfu km^{-2} hr^{-1}), with intermediate contributions from the improved grassland (approximately 8.3x10^{8} cfu km^{-2} hr^{-1}) and lowest from the other land cover types (approximately 2.5x10^{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 being expected to be highest, at more than 100-fold, for the improved grassland.

Within Clift Sound, higher contributions of faecal coliforms would be expected from areas of improved grassland at the head of the sound near the Booth production area, around the West Voe of Quarff adjacent to the Whal Wick production area,and along the eastern shore of the island of East Burra, nearest the East Hogaland site.

7. Farm Animals

Regulation (EC) No. 854/2004 requires the competent authority to

(a) make an inventory of the sources of pollution of human or animal origin likely to be a source of contamination for the production area;
(b) examine the quantities of organic pollutants which are released during the different periods of the year, according to the seasonal variations of both human and animal populations in the catchment area, rainfall readings, waste-water treatment, etc.

With regard to potential sources of pollution of animal origin, agricultural census data to parish level was requested from the Scottish Government. The request was declined on the grounds of confidentiality because the parishes in most cases contained only a small number of farms making it possible to determine specific data for individual farms. The only significant source of information was therefore the shoreline survey (see Appendix 17.1), which only relates to the time of the site visit between 11 and 16 May 2007 and again on 6 September.

The shoreline survey identified that sheep were grazed widely around the voe and that there were no significant concentrations in one or more areas over others. The geographical spread of contamination at the shores of the voe is therefore considered to be even (although random with regard to specific time and place) and therefore needs to be assumed that this factor does not have to be taken into account when identifying the location of a routine monitoring point (RMP).

A number of cattle were identified around the Wester Quarff area, potentially leading to slightly higher levels of contamination seen in the Burn of Quarff. This could potentially affect the Stream Sound and Whal Wick sites and so should be taken into account when establishing RMPs.

Local information (Shetland Agricultural Centre, personal communication) indicated that numbers of sheep in the period May to September was approximately double that in other periods. Any contamination due to this source is therefore likely to be increased during this period.

The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

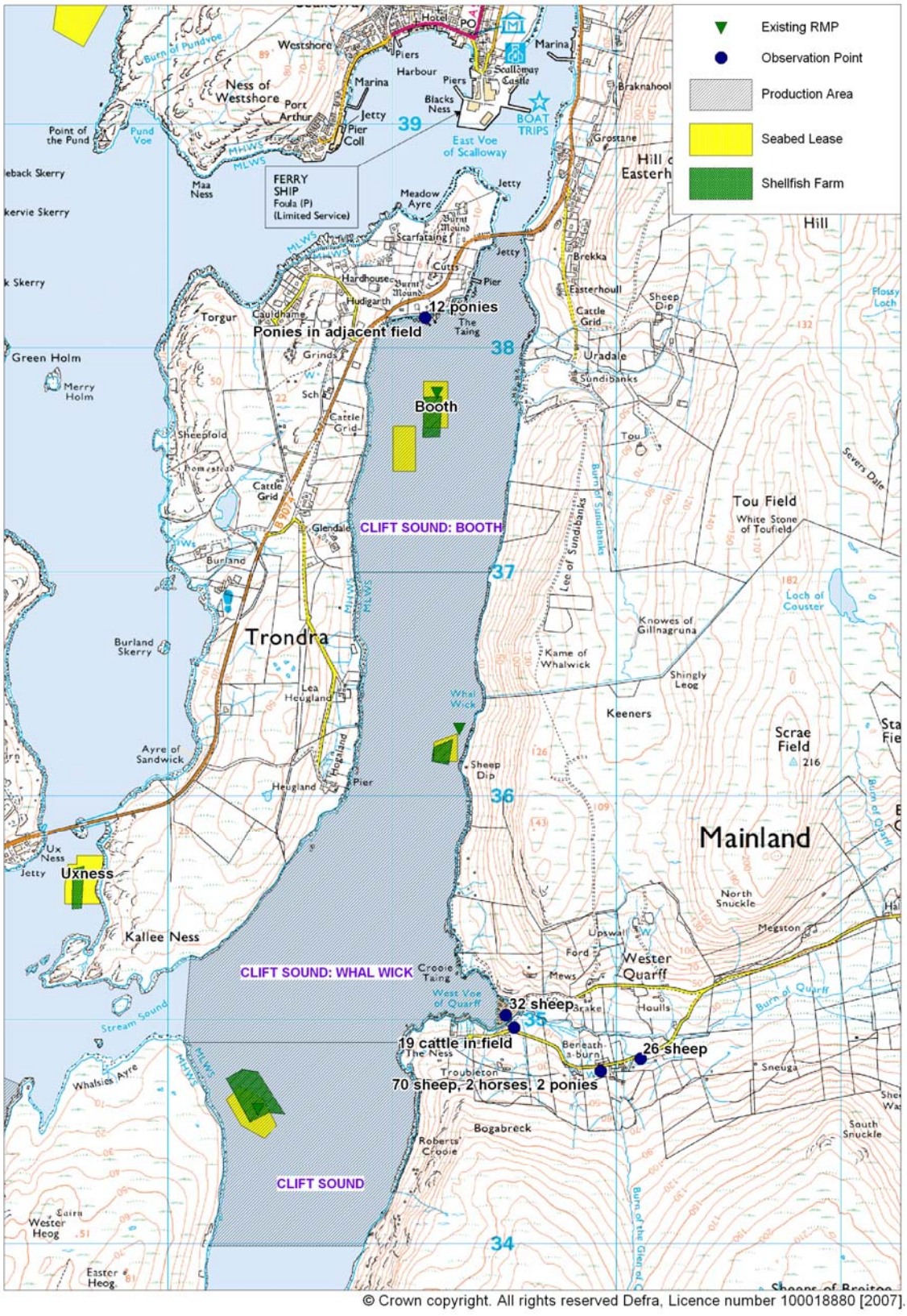

Figure 7.1. Map of livestock observations at Clift Sound

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 amount of *Escherichia 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 x 104 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle et al 2004).

Common seals surveys are conducted every 5 years and an estimate of minimum numbers is available through Scottish Natural Heritage. The Shetland-wide count in 2001 was 4883 harbour seals, though this was anticipated to be an underestimation of the total population (Sea Mammal Research Unit 2002). A further survey was to have been conducted in 2006, however the populations observed in Shetland had declined by approximately 40% on the 2001 survey and so detailed figures have been withheld pending further survey. A final report is expected in late 2007.

While there are no haulout sites recorded within Clift Sound itself, there are three small sites with a total of less than 15 individuals further south along the mainland as well as two larger sites outside the entrance to the sound.

According to the Scottish Executive, in 2001 there were approximately 119,00 grey seals in Scottish waters, the majority of which were found in breeding colonies in Orkney and the Outer Hebrides. While no mention was made of populations in Shetland in 2001, in 1996, the Shetland grey seal population was estimated to be around 3,500 (Brown & Duck 1996). Up to 70 grey seals reportedly feed at the Shetland Catch factory in Lerwick (Harrop 2003).

Seals have been observed lying between mussel floats in Shetland (R. Anderson, personal communication) so it is anticipated that there could be some impact to the fisheries though this may be spatially and temporally limited.

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.

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).

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 near Shetland by species.

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.

Little is known about the volume or bacterial composition of cetacean faeces. As mammals, it can be safely assumed that their guts will contain an unknown concentration of normal commensal bacteria, including *Escherichia coli*. There have been some sightings in and around Weisdale Voe, however these accounts are sparse. It is highly likely that cetaceans will be found from time to time in the sound and the impact of their presence is, as with pinnipeds, likely to be fleeting and unpredictable.

8.3 Seabirds

A number of seabird species breed in Shetland. These were the subject of a detailed census in 2000. Of the 25 seabird species identified as regularly breeding in Britain, 19 have substantial presence in Shetland (Mitchell et al 2004).

Table 8.2 Breeding seabirds of Shetland

Common name	Species	Population	Common name	Species	Population
Northern Fulmar	*Fulmarus glacialis*	188,544*	Northern Gannet	*Morus bassanus*	26,249
European Storm Petrel	*Hydrobates pelagicus*	7,503*	Great Cormorant	*Phalacrocorax carbo*	192*
European Shag	*Phalacrocorax aristotelis*	6,147	Arctic skua	*Stercorarius parasiticus*	1,120
Great Skua	*Stercorarius skua*	6,846*	Black-headed Gull	*Larus ridibundus*	586
Common Gull	*Larus canus*	2,424	Lesser Black-backed Gull	*Larus fuscus*	341
Herring Gull	*Larus argentatus*	4,027	Great Black-backed Gull	*Larus marinus*	2,875
Black-legged Kittiwake	*Rissa tridactyla*	16,732	Common Tern	*Sterna hirundo*	104
Arctic Tern	*Sterna paradisaea*	24,716	Common Guillemot	*Uria aalge*	172,681
Razorbill	*Alca torda*	9,492	Black Guillemot	*Cepphus grille*	15,739
Atlantic Puffin	*Fratercula arctica*	107,676*			

*Population number based on Apparently Occupied Sites, Territories, Nests or Burrows. These may equate to more than one adult.

Of these, some are pelagic except during the breeding season and so would not impact the fisheries except during the summer months.

The steep cliffs at Clift Sound provide favourable breeding sites for a number of seabird species. Northern fulmars, herring gulls and common gulls are all reported to breed in large numbers along Clift Sound (Mitchell et al,Seabird Census 2000). Arctic skuas, black-headed gulls and great skuas also breed there, though in lower numbers. It was not possible to tease out exact locations from the data available and so impact to specific fisheries is indeterminate.

It is not known what the *E. coli* content of their droppings is, however it is likely that rainfall runoff from around their colonies during the breeding season could impact shellfish areas located near the runoff.

8.4 Other

There is a significant population of European Otters (Lutra lutra) present in Shetland. Within Yell Sound, to the north of the main island, an otter survey was conducted in 2002 and an estimated 277 otters were recorded (Shetland Sea Mammal Group 2003). While otters may occur around the Clift Sound area, it is not considered to be home to a substantial population.

Coastal otters, such as those found in Shetland, 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 10m 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. While otters may occur around the Clift Sound area, it is not considered to be home to a substantial population.

Waterfowl (ducks and geese) are present in Shetland at various times of the year. Eider ducks feed on the mussel lines and are present, sometimes groups of 100 or more, throughout the year. Geese tend to pass through during migrations but do not linger in very large numbers as they do further south. Waterfowl impact on the fisheries in Clift Sound is likely to be mostly that of Eider ducks feeding on the mussel lines.

At Clift Sound, whilst large cetaceans and other marine mammals have been observed in the sound, their impact is not likely to be either spatially or temporally predictable.

Wildlife impact generally to the fisheries is likely to be minimal compared to the impact of diffuse pollution due to livestock. While some species can harbour bacteria and viruses that can cause illness in humans, their faeces are considered to pose a lower risk to human health than either human or livestock faecal contamination.

9. Meteorological data

The nearest weather station is located at Lerwick, approximately 5 km to the north east of the production area for which uninterrupted rainfall data is available for 2003-2006 inclusive. It is likely that the rainfall patterns at Lerwick are similar but not identical to those on Clift Sound and surrounding land due to their proximity, but it is not certain whether the local topography may result in differing wind patterns (Lerwick is on the east coast, Clift Sound is on the west coast). This section aims to describe the local rain and wind patterns and how they may affect the bacterial quality of shellfish within Clift Sound.

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 to 9.4 and Table 9.1 summarise the pattern of rainfall recorded at Lerwick. The box and whisker plots summarize the distribution of individual daily rainfall values (observations) by year (Figure 9.2) or by month (Figure 9.4). 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 *.

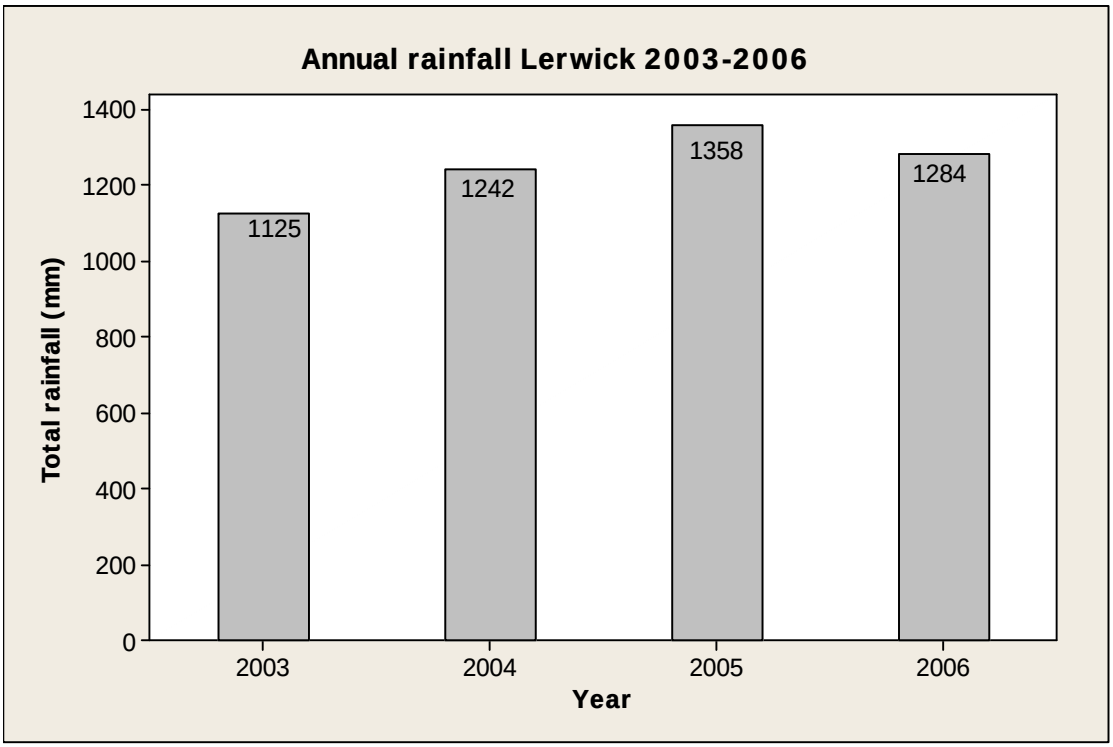

Figure 9.1 Lerwick total annual rainfall 2003-2006

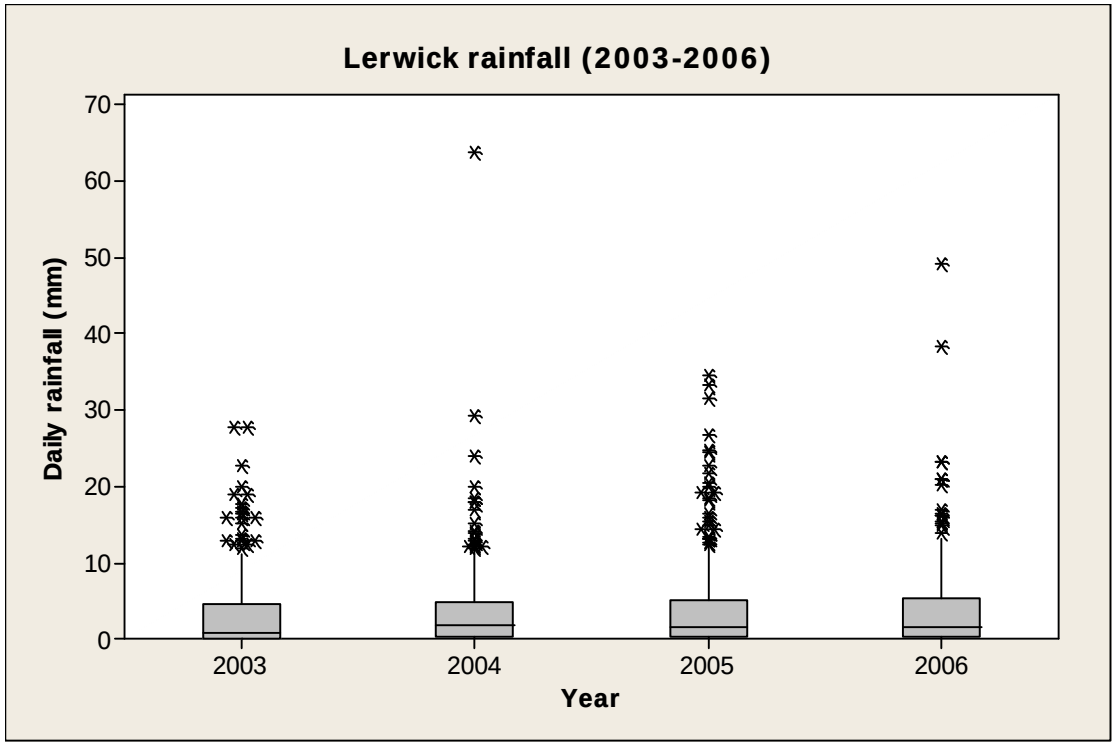

Figure 9.2 Box plot of mean daily rainfall by year

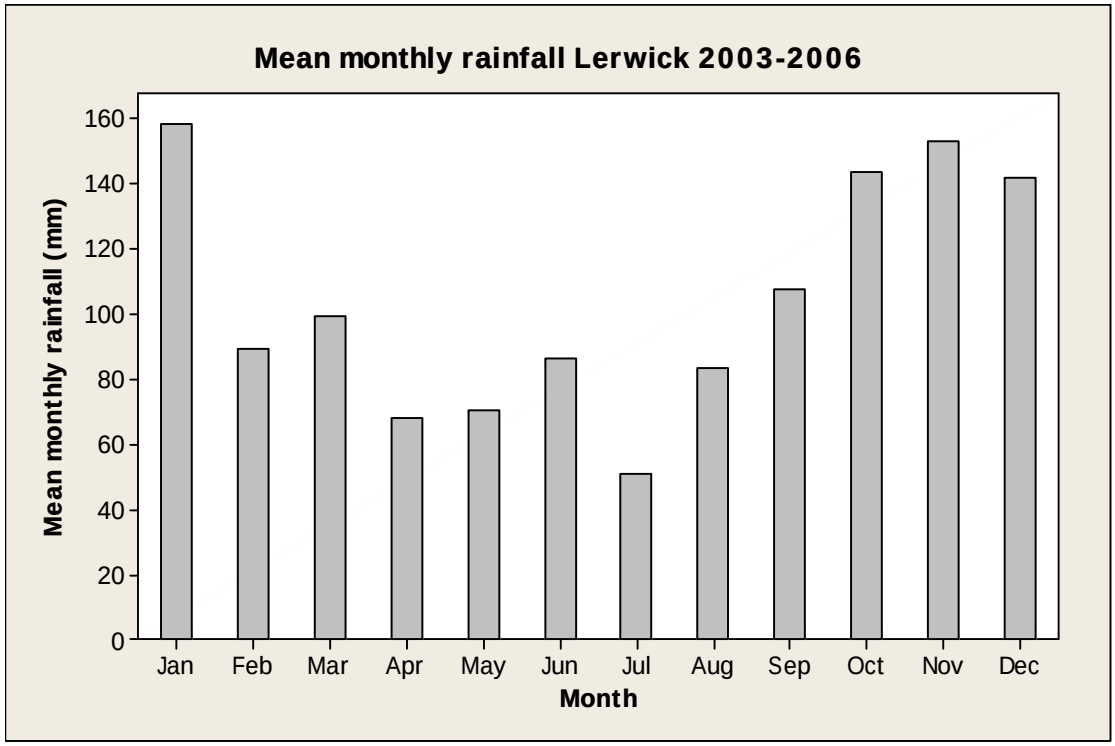

Figure 9.3 Mean monthly rainfall for Lerwick 2003-2006

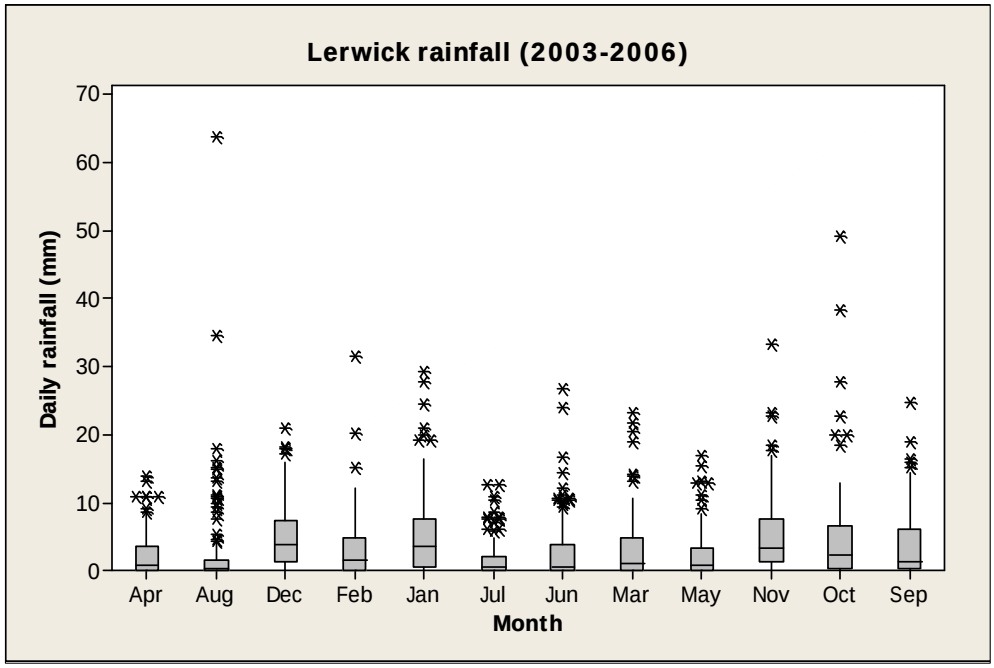

Figure 9.4 Box plot of mean daily rainfall by month

The wettest months were October, November, December and January. For the period considered here (2003-2006), only 19.9% of days experienced no rainfall. 44.6% of days experienced rainfall of 1mm or less.

A comparison of Lerwick rainfall data with Scotland average rainfall data for the period of 1970-2000 is presented in Table 9.3 (Data from Met office website © Crown copyright). This indicates that rainfall in Lerwick was lower than the average for the whole of Scotland for every month of the year, but there were fewer dry days in Lerwick during the autumn, winter and spring.

Table 9.1 Lerwick mean monthly rainfall vs Scottish average 1970-2000

Month	Scotland rainfall (mm)	Lerwick rainfall (mm)	Scotland - days of rainfall >= 1mm	Lerwick - days of rainfall >= 1mm
Jan	170.5	135.4	18.6	21.3
Feb	123.4	107.8	14.8	17.8
Mar	138.5	122.3	17.3	19
Apr	86.2	74.2	13	14.4
May	79	53.6	12.2	10.1
Jun	85.1	58.6	12.7	11.3
Jul	92.1	58.5	13.3	11
Aug	107.4	78.3	14.1	12.5
Sep	139.7	115.3	15.9	17.4
Oct	162.6	131.9	17.7	19.4
Nov	165.9	152.4	17.9	21.5
Dec	169.6	150	18.2	22.2
Whole year	1520.1	1238.1	185.8	197.9

It can therefore be expected that levels of rainfall dependant faecal contamination entering the production area from these sources will be higher during the autumn and winter months. As there are few dry days, it is likely that some contaminated runoff from pastures is to be expected throughout the wetter months. It is possible that faecal matter can build up on pastures during the drier summer months when stock levels are at their highest, leading to more significant faecal contamination of runoff at the onset of the wetter in the autumn.

9.2 Wind

Wind data collected at the Lerwick weather station is summarised by season and presented in figures 9.5 to 9.8.

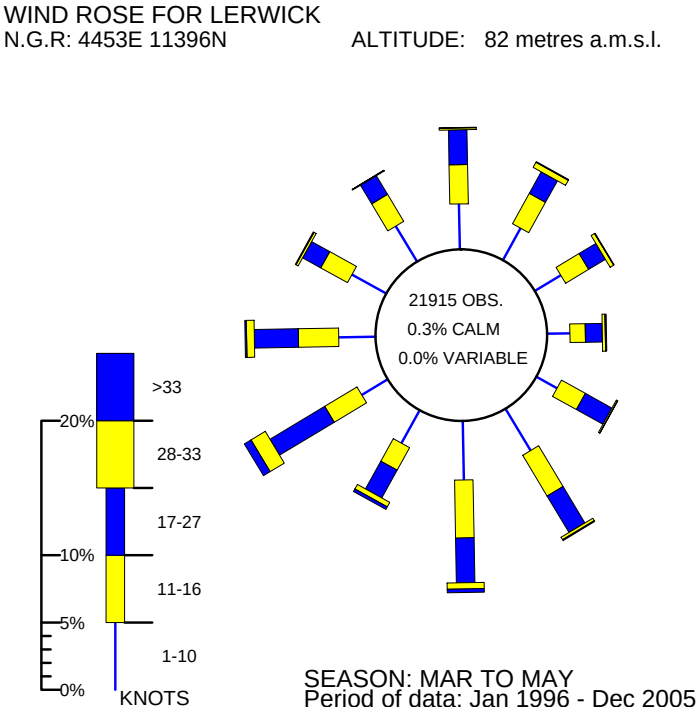

Figure 9.5 Wind rose for Lerwick March to May

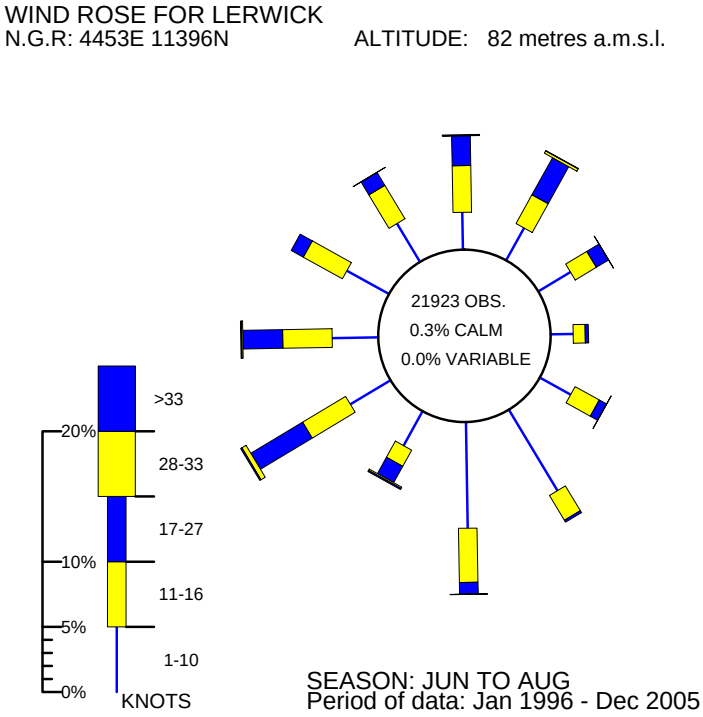

Figure 9.6 Wind rose for Lerwick June to August

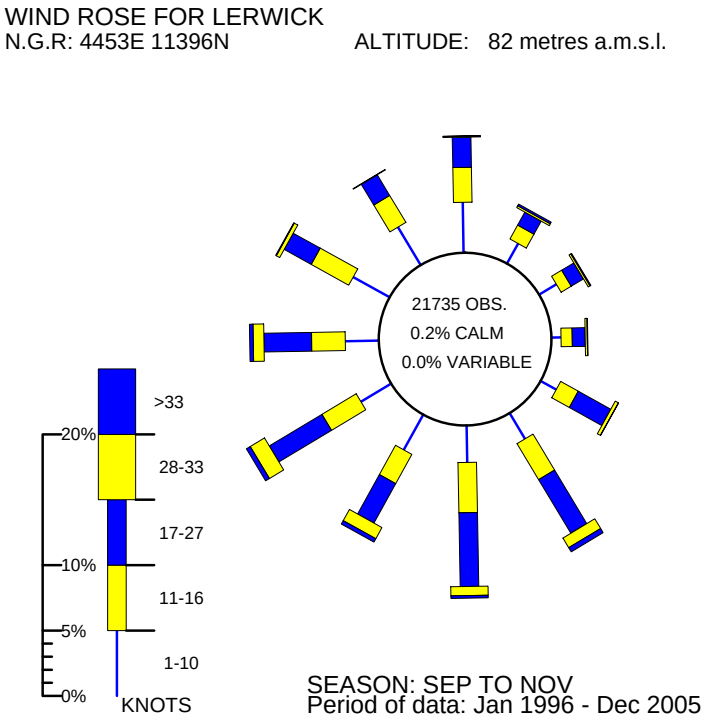

Figure 9.7 Wind rose for Lerwick September to November

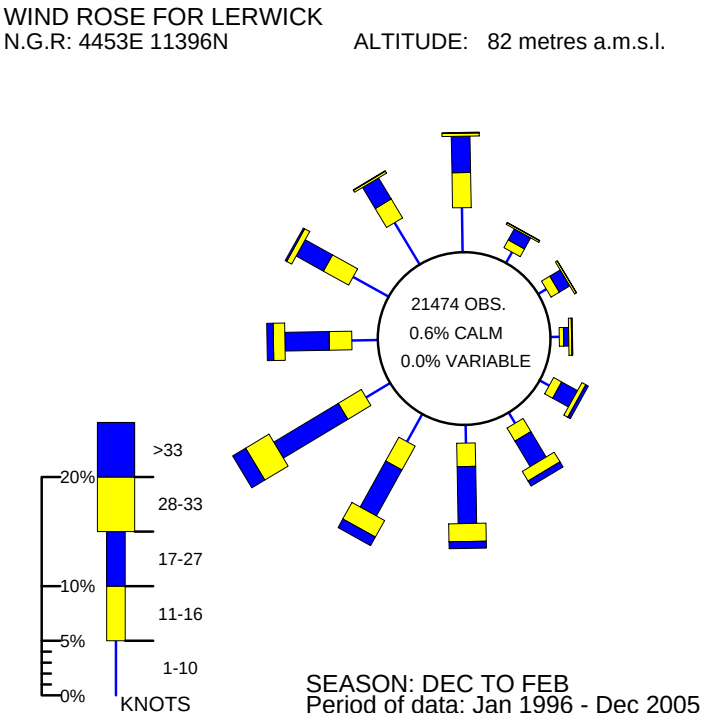

Figure 9.8 Wind rose for Lerwick December to February

Shetland is one of the more windy areas of Scotland with a much higher frequency of gales than the country as a whole. The wind roses show that the overall prevailing direction of the wind is from the south and west, and when it is blowing from this direction it is likely to be stronger than when blowing from other directions. Winds are generally lighter during the summer months and strongest in the winter. Clift Sound is narrow and faces SSW. The surrounding high ground will have the effect of channelling the wind up or down the Sound. The Ux Ness site is sheltered from wind from all directions by the surrounding land.

A strong SW wind combined with a spring tide may result in higher than usual tides, which will carry, accumulated faecal matter from livestock, above the normal high water mark, into the Sound.

Wind effects are likely to cause significant changes in water circulation within the voe as tidally influenced movements of water are relatively weak (see section 12). Winds typically drive surface water at about 3% of the wind speed (Brown, J., 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. These surface water currents create return currents, which may travel along the bottom or sides of the voe depending on bathymetry. Either way, strong winter winds will increase the circulation of water and hence dilution of contamination from point sources within the voe.

10. Current and historical classification status

Five separate production areas are considered in this report, of which two are new sites and are yet to be classified (Stream Sound, Ux Ness (SI 373 762 08) and Clift Sound, East Hogaland (SI 035 414 08). For the three established sites, classification history is presented in Tables 10.1 to 10.3. The location of the sites is presented in Figure 10.1

Table 10.1 - Classification history Clift Sound: Booth (SI 036 413 08).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	B	B	B	B	B	B	A	A	A	A	A	B
2006	B	B	A	A	A	A	A	A	A	A	A	A
2007	B	B	A	A	A	A	A	A	A	A	A	A

Table 10.2 - Classification history Clift Sound: Stream Sound (SI 037 415 08).

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

Table 10.3 - Classification history Clift Sound: Whal Wick (SI 038 416 08).

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

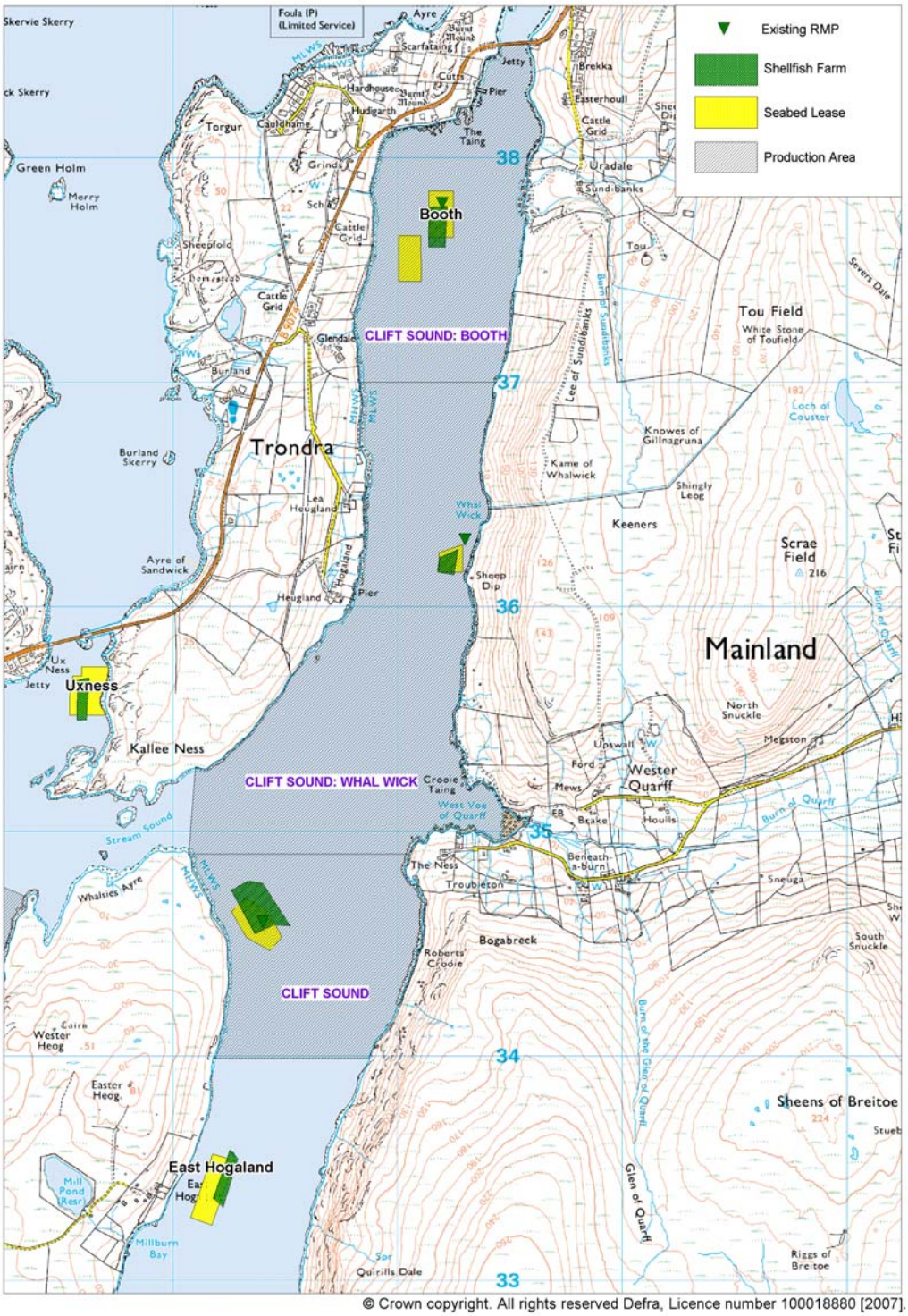

Figure 10.1 Map of production areas and sites within the Clift Sound and Stream Sound area

11. Historical *E. coli* data

11.1 Validation of historical data

All samples taken from production areas within Clift Sound and Stream Sound up to the end of 2006 were extracted from the database and validated according to the criteria described in the standard operating procedure for validation of historical *E. coli* data. The following adjustments were made to the results:

For Clift Sound: Booth (SI 036 413 08), in the 12 instances where a result of <20 was reported, it was given a nominal value of 10.

For Clift Sound: Stream Sound (SI 037 415 08), in the 12 instances where a result of <20 was reported, it was given a nominal value of 10. One sample reported as originating from a different production area (Clift Sound: East Hogaland) plotted within the Stream Sound production area, but was not used in the analysis.

For Clift Sound: Whal Wick (SI 038 416 08) in the 14 instances where a result of <20 was reported, it was given a nominal value of 10.

For Clift Sound East Hogaland (SI 035 414 08) one sample reported as originating from East Hogaland plotted in a different production area and was removed from the analysis (see above).

For Stream Sound: Ux Ness (SI373 762 08) no changes were made to the data.

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

11.2 Summary of microbiological results by sites

Common mussels were sampled from all 5 production areas covered by this report. For all sites/areas, the samples were taken from within or very close to (<30m) the boundaries of the Crown Estates leases. RMPs are listed for 3 of the 5 sites. All but one sample taken from these sites were taken from the RMP. This one sample taken from Clift Sound: Stream Sound was taken from within 130m of the RMP and in further analyses this will be treated as if it came from the same location as all the other samples from this production site. A summary of the sampling undertaken and the results obtained is presented in Table 11.1.

Table 11.1 - Summary of results from all sites within Clift Sound and Stream Sound

Sampling summary						
Production area	Clift Sound: Booth	Clift Sound: Stream Sound	Clift Sound: Whal Wick	Clift Sound	Stream Sound	Clift Sound & Stream Sound (5)
Site(s)	Booth	Stream Sound	Whal Wick	East Hogaland	Ux Ness	All (5)
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels
SIN	SI 036 413 08	SI 037 415 08	SI 038 416 08	SI 035 414 08	SI 373 762 08	All (5)
Location of RMP	HU402378	HU394346	HU403363	None listed	None listed	All (3)
Location sampled	HU402378	HU393347 and HU394346	HU403363	HU392335	HU386356	All (6)
Total no. of samples	27	44	41	1	5	118
Number in 2001	0	4	0	1	0	5
Number in 2002	0	8	0	0	0	8
Number in 2003	0	8	7	0	0	15
Number in 2004	7	6	11	0	0	24
Number in 2005	11	7	11	0	0	29
Number in 2006	9	11	12	0	5	37
Results summary (*E. coli* mpn/100g)						
Minimum	<20	<20	<20	40	20	<20
Maximum	750	9100	220	40	90	9100
Median	20	40	20	40	50	40
Geometric mean	27.2	45.2	28.8	40	47.9	34.5
90 percentile	110	202	110	40	82	110
95 percentile	250	286.5	110	40	86	233.5
No. exceeding 230/100g	2 (7%)	4 (9%)	0 (0%)	0 (0%)	0 (0%)	6 (5%)
No. exceeding 1000/100g	0 (0%)	3 (7%)	0 (0%)	0 (0%)	0 (0%)	3 (3%)
No. exceeding 4600/100g	0 (0%)	1 (2%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
No. exceeding 18000/100g	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Figure 11.1 presents a boxplot comparing the results by site, and Figure 11.2 presents a map showing the geometric mean result by year for each site (where sampled). Although the geometric mean results and the temporal distribution of sampling effort differs between sites, no statistically significant difference in results between sites was detected (one-way ANOVA, p=0.407).

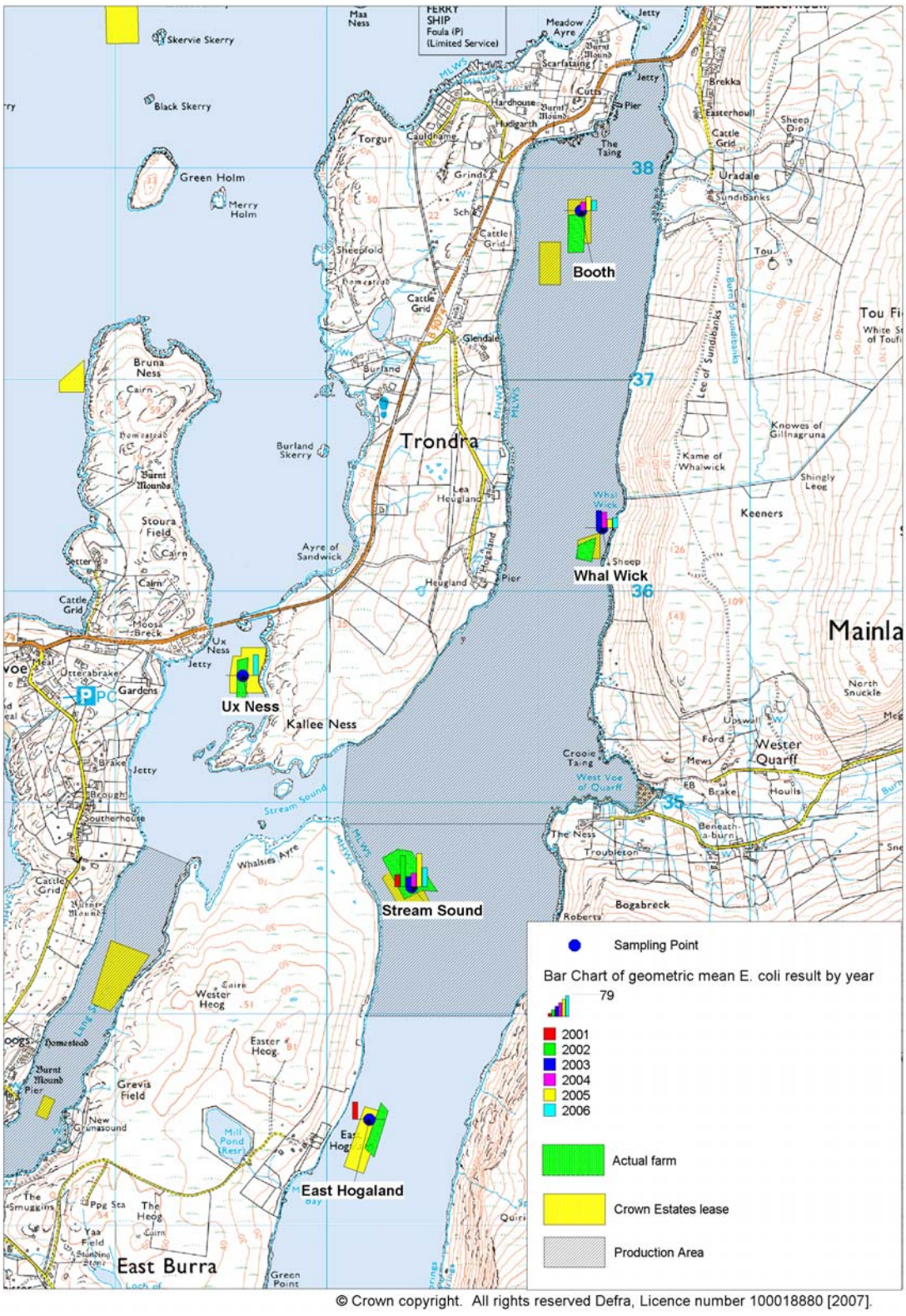

Figure 11.1 Map showing geometric mean result by year

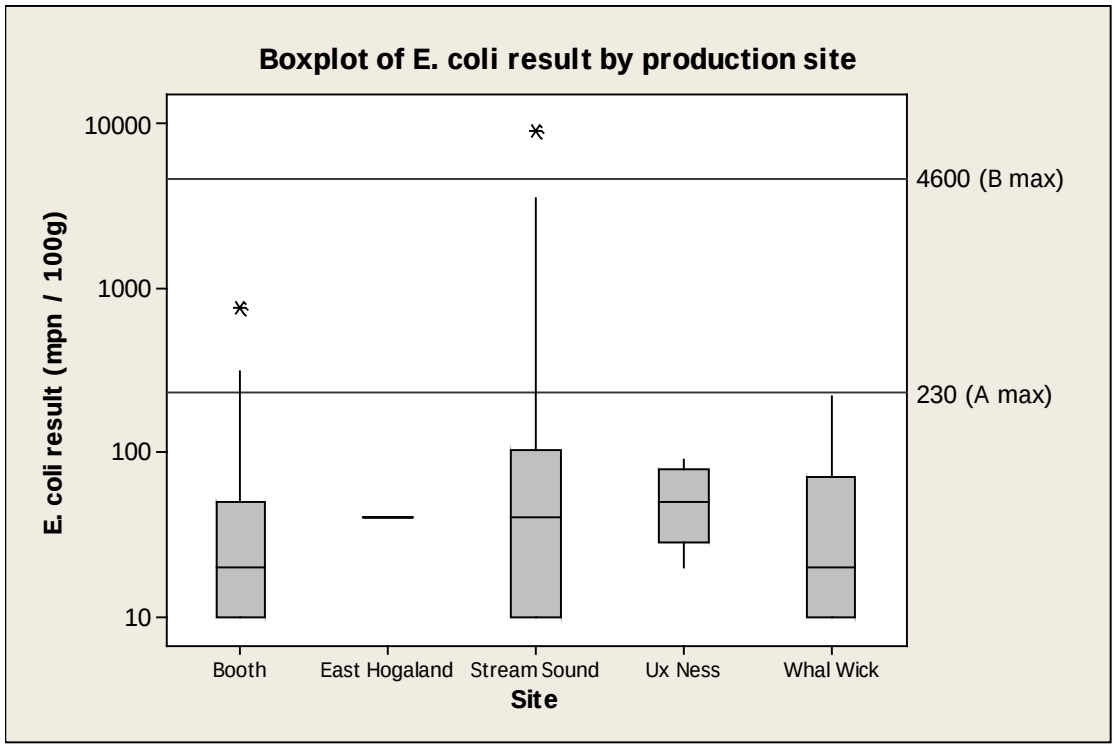

Figure 11.2 Box plot of *E. coli* result by site

11.3 Temporal pattern of results

Figures 11.3 and 11.4 present scatter plots of individual results against date for all samples taken from all 5 production areas. Both are fitted with trend lines to help highlight any apparent underlying trends or cycles. Figure 11.3 is fitted with a line indicating the geometric mean of the previous 5 samples, the current sample and the following 6 samples. Figure 11.4 is fitted with a loess smoother, a regression based smoother line calculated by the Minitab statistical software. Figure 11.5 presents the geometric mean of results by month (+ 2 times the standard error).

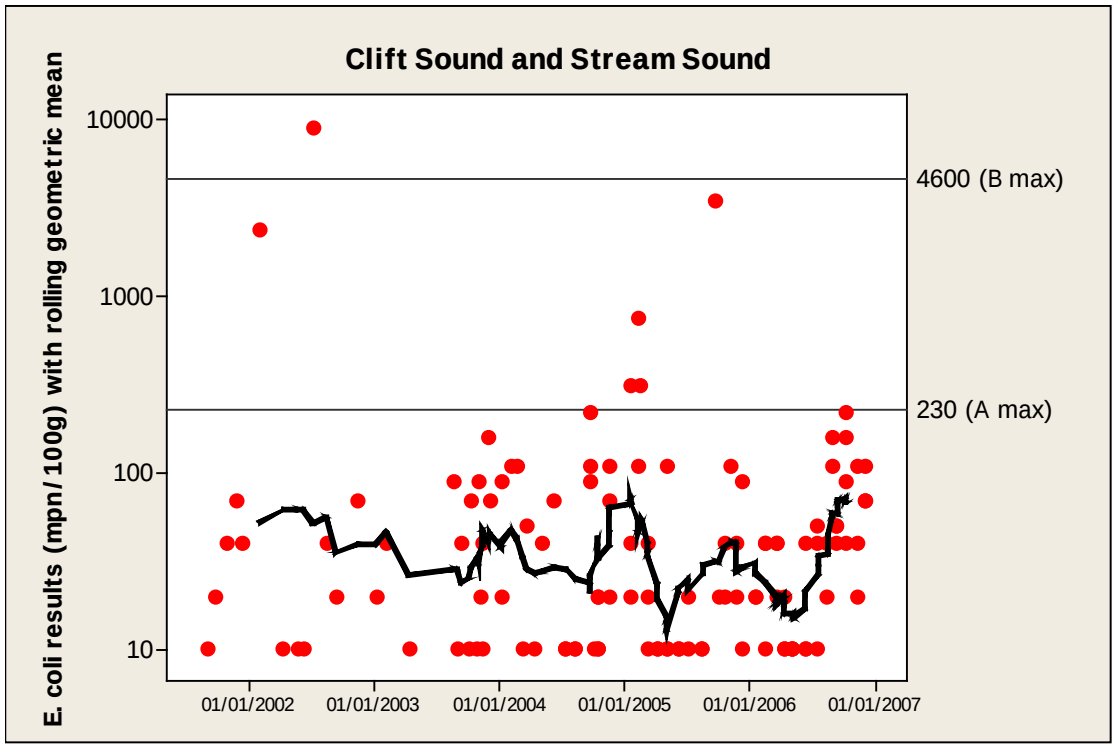

Figure 11.3 Scatter Plot of results by date with rolling geometric mean

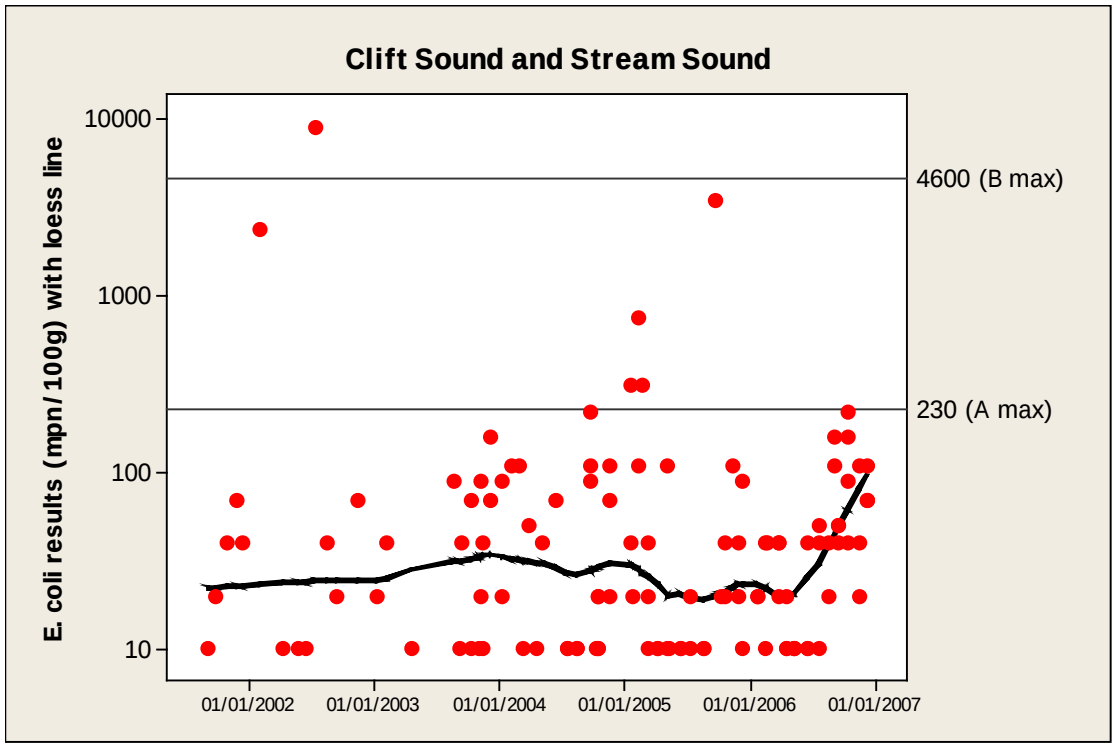

Figure 11.4 Scatter plot of results by date with loess smoother

No obvious underlying trends or cycles can be inferred from Figures 11.1, 11.3 and 11.4 aside from a slight deterioration in microbial quality in 2006.

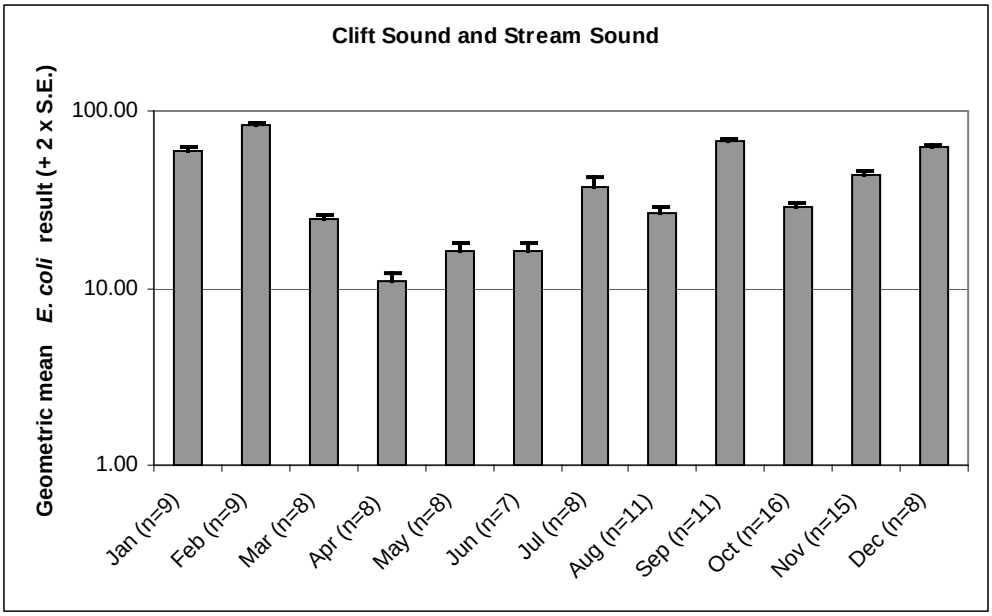

Figure 11.5 Geometric mean result by month

Lowest mean results were in April to June, with higher results in the autumn and winter months.

11.4 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. This analysis considers the 118 samples taken from all sites in Clift Sound and Stream Sound together from the start of sampling in 2001 to the end of 2006.

11.4.1 Analysis of results by season

Although not strictly an environmental variable in the same way as rainfall for example, season dictates not only weather patterns, but livestock numbers and movements, presence of wild animals and patterns of human occupation. Seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February).

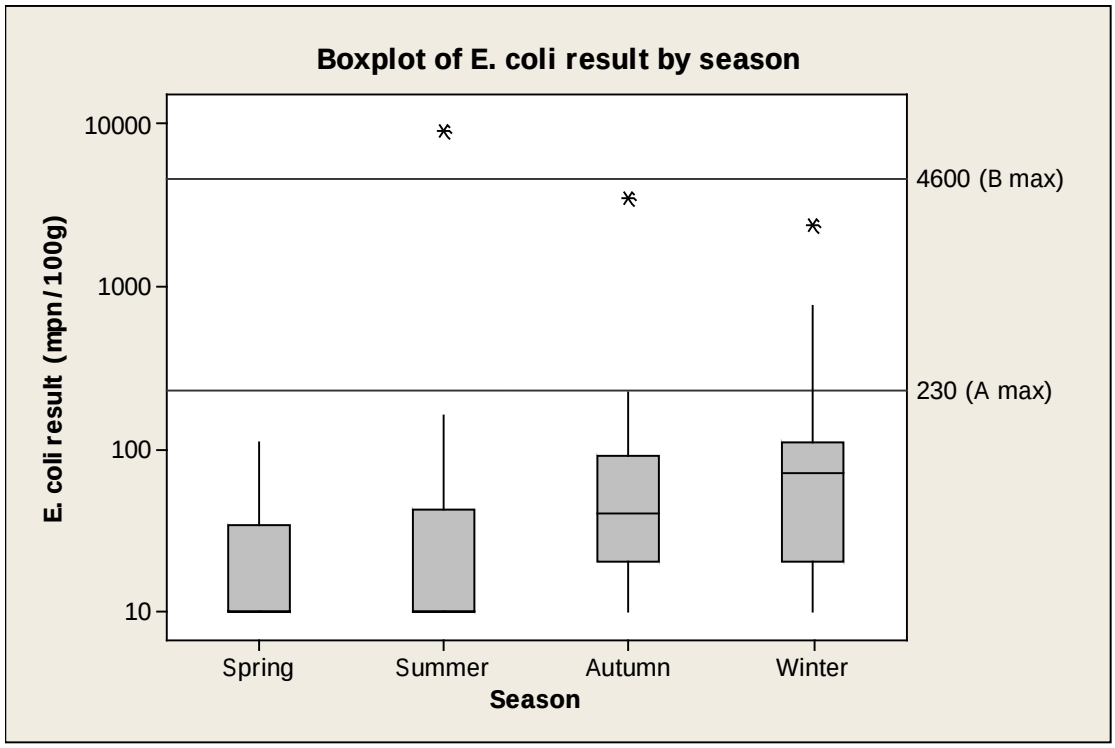

Figure 11.6 Box plot of *E. coli* result by season

A seasonal effect was observed, with higher results in the autumn and winter compared to spring. Results were also higher in the winter than the summer. The seasonal effects described above are statistically significant (One-way ANOVA, p=0.000; Appendix 18.5). Autumn is the period when livestock numbers peak before lambs are sent to market. Autumn also marks the start of the wetter period of the year, so at this time faecal contamination from agricultural runoff (probably the most important source of contamination in the area) will be at its highest level.

11.4.2 Analysis of results by recent rainfall

The nearest weather station is located at Lerwick, approximately 5 km to the north east of the production areas for which uninterrupted rainfall data is available for 2003-2006 inclusive.

The coefficient of determination was calculated for the *E. coli* results and rainfall in the previous 2 days at Lerwick. Figure 11.7 presents a scatterplot of *E. coli* result and rainfall, with a best fit line derived by regression. Figure 11.8 presents a boxplot of results by rainfall quartile ((quartile 1 = 0 to 0.85 mm, quartile 2 = 0.85 to 4.25 mm, quartile 3 = 4.25 to 10.3 mm, quartile 4 = more than 10.3 mm).

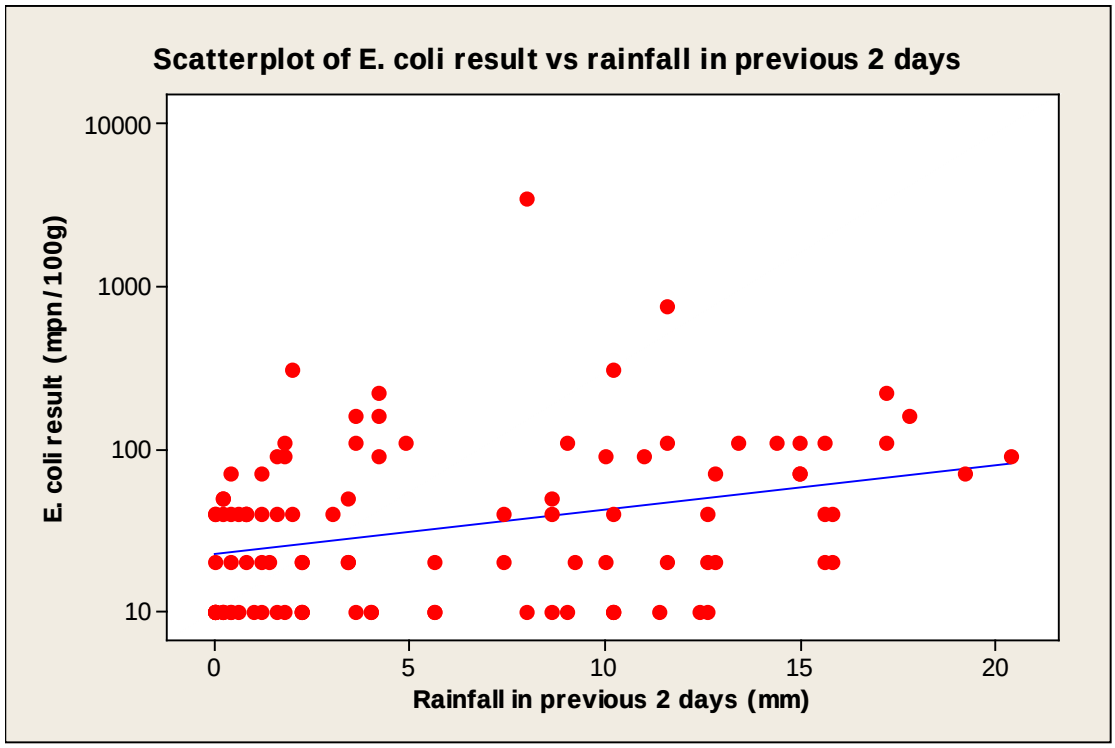

Figure 11.7 *E. coli* result v Lerwick rain in previous 2 days

The coefficient of determination indicates that there is a relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=9.6%, p=0.001; Appendix 18.5).

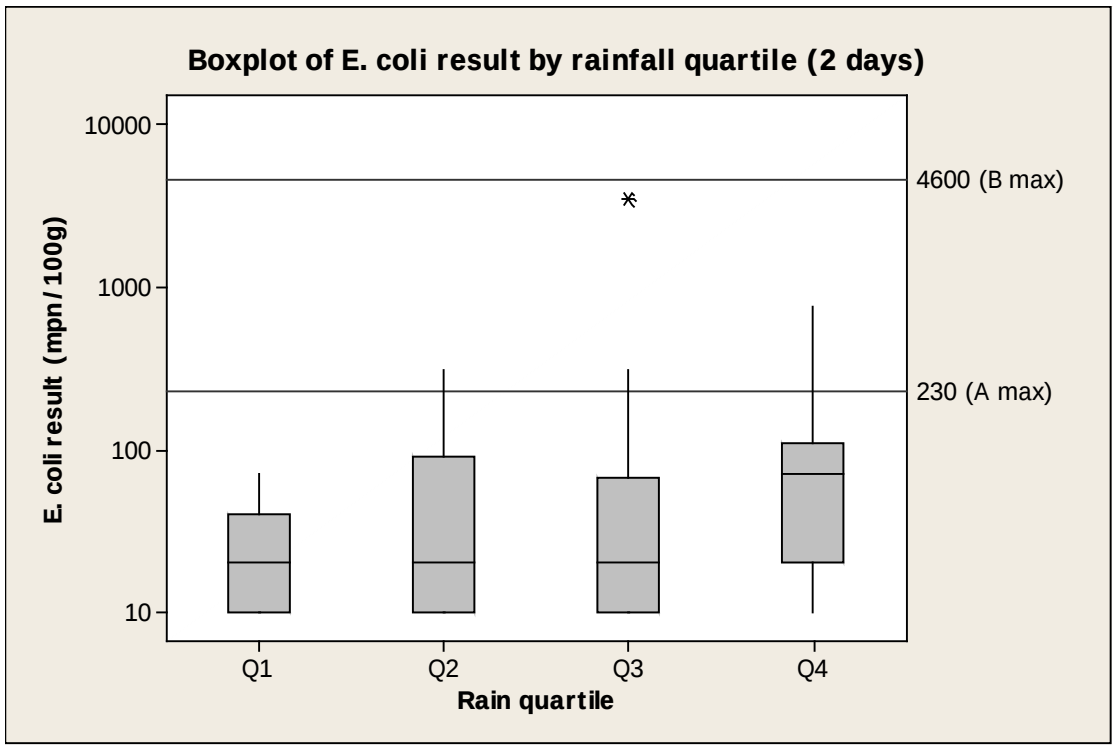

Figure 11.8 Box plot of *E. coli* result vs Lerwick rain in previous 2 days quartile

The relationship between rainfall quartile and result is statistically significant (One way ANOVA, p=0.011; Appendix 18.5).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results for Clift Sound and Stream Sound was investigated in an identical manner to the above. Interquartile ranges for 7 days rainfall were as follows; quartile 1 = 0 to 10.7 mm; quartile 2 = 10.7 to 20.1 mm; quartile 3 = 20.1 to 34.0 mm; quartile 4 = more than 34.0 mm.

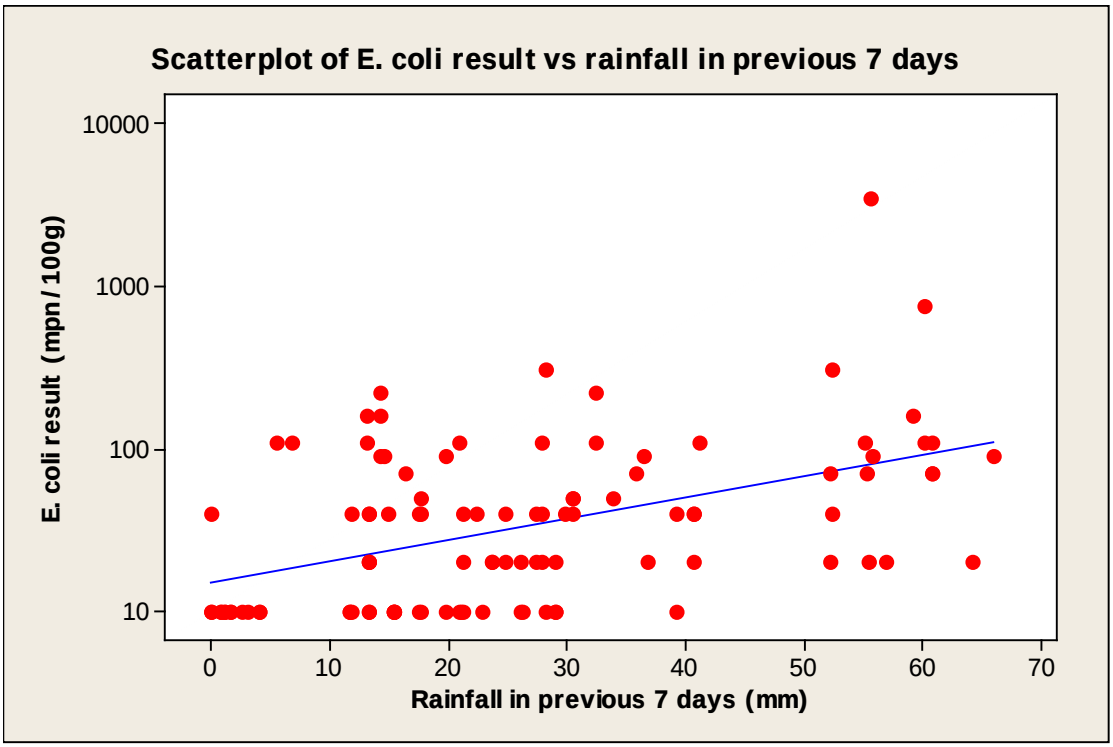

Figure 11.9 *E. coli* result vs Lerwick rain in previous 7 days

The ccoefficient of determination indicates that there is a statistically significant relationship between the *E. coli* result and the rainfall in the previous 7 days (Adjusted R-sq=21.2%, p=0.000; Appendix 18.5).

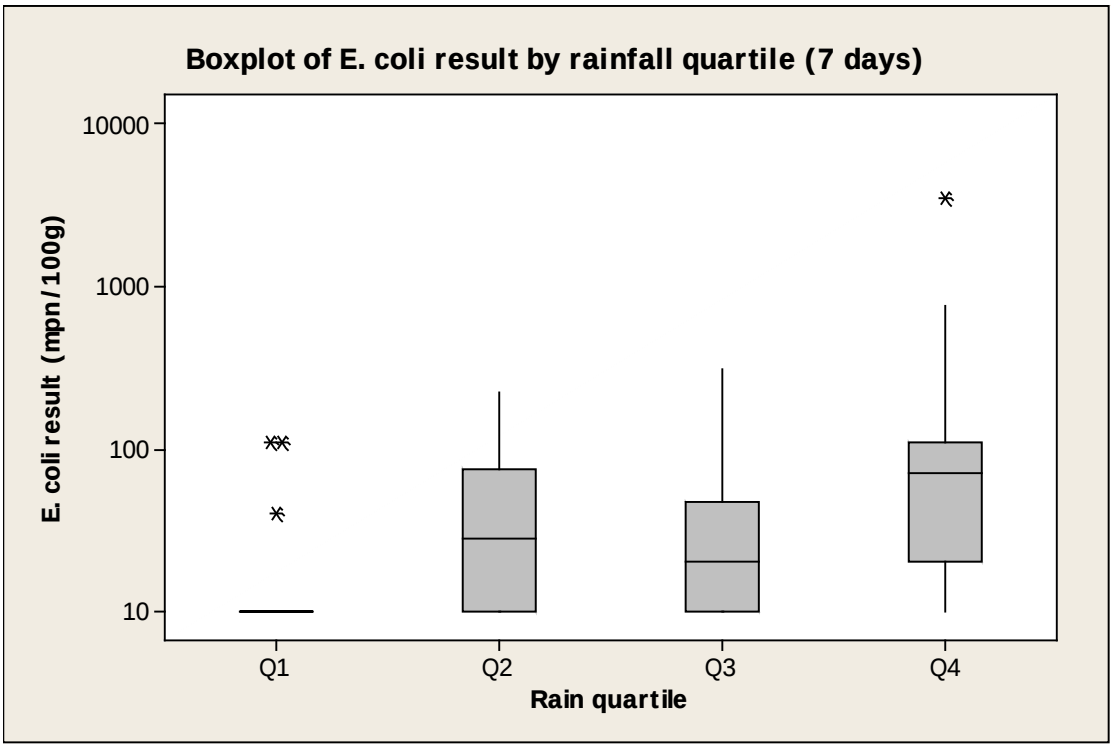

Figure 11.10 Box plot of *E. coli* result vs rainfall in previous 7 days quartile

The relationship between rainfall quartile and result is statistically significant (One way ANOVA, p=0.000; Appendix 18.5).

Overall, recent rainfall is associated with higher *E. coli* results whether rain in the previous 2 or 7 days is considered.

11.4.3 Analysis of results against lunar state

Lunar state dictates tide size, with the largest tides occurring 2 days after either a full or new moon. With the larger tides, circulation of water in the voe will increase, and more of the shoreline will be covered, potentially washing more faecal contamination from livestock into the voe. Tidal ranges in the area (as described in section 13) are small, ranging from 0.7 to 1.1m. Figure 11.11 presents a boxplot of *E. coli* results by size of tide categorised by lunar state at the time of sampling. It should be noted however that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account in Figure 11.11.

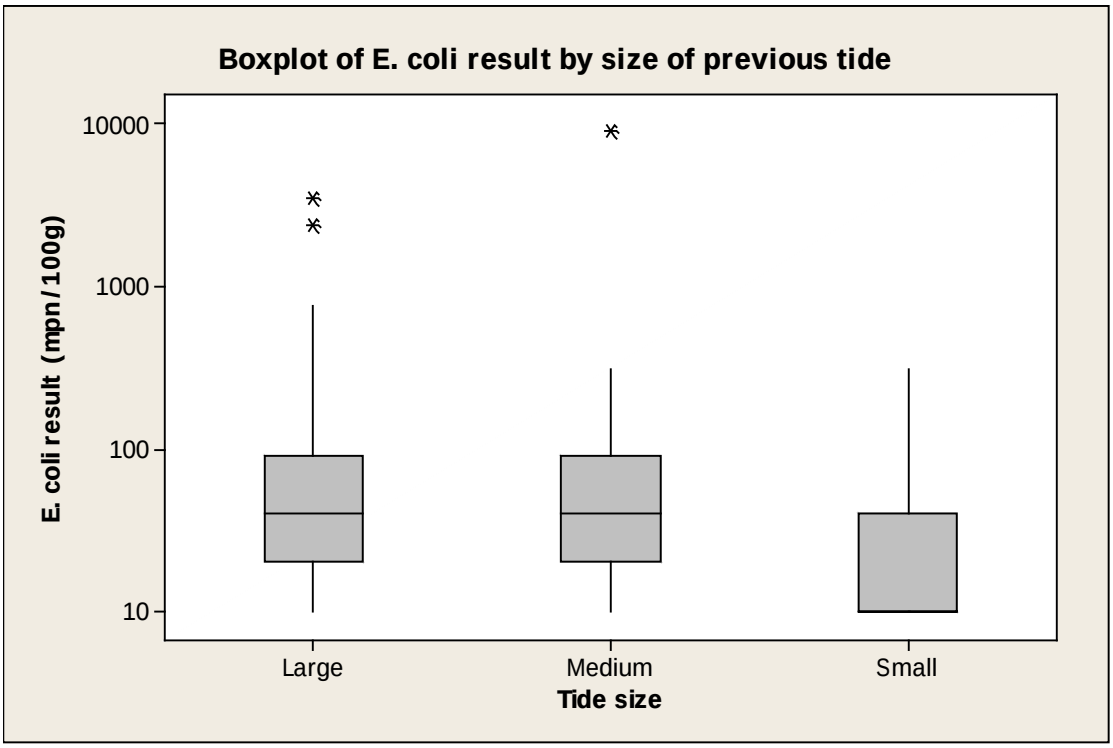

Figure 11.11 Box plot of E. coli result by size of tide

A statistically significant relationship between size of previous tide and *E. coli* result was found (One way ANOVA, p=0.017; Appendix 18.5) with higher results occurring on large tides compared to small tides.

When the effects of tide size were investigated for individual sites, although the trend for higher results on larger tides was visible, the differences in results between the tide sizes were not significant (Appendix 18.5).

11.4.4 Water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) as well as 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.

No data on water temperature either at the time of collection or from automatic data loggers deployed in the voe so no analysis was possible.

11.4.5 Wind direction

As discussed in section 9, wind speed and direction is likely to significantly change water circulation patterns in Clift Sound and Stream Sound. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Lerwick weather station, and mean result by mean wind direction in the previous 7 days is plotted in Figure 11.12. Wind direction data was available for 87 of the 118 samples.

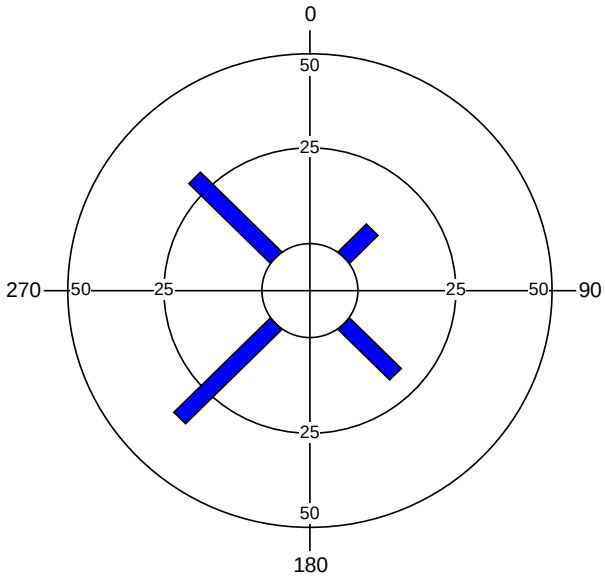

Figure 11.12 Circular histogram of mean *E. coli* result by wind direction

A significant correlation between wind direction and *E. coli* result was found (circular-linear correlation, r=0.341, p<0.001; Appendix 18.5). Results were higher when the wind was blowing from the south and west, suggesting that these winds may result in increased transport of faecal contamination into the production sites. However, as shown in section 9.2 winds blow predominantly from the south and west in this area, and thus the results may be skewed as most samples were taken under these wind conditions.

11.4.6 Discussion of environmental effects

A seasonal effect was found, with results in the autumn and winter being significantly higher than in other seasons. Significant rainfall effects were also observed with higher recent rainfall associated with higher levels of contamination. Contamination also tended to be higher on larger tides. Southerly and westerly winds were associated with increased contamination, but this should be interpreted with caution as few samples were taken during periods of easterly winds.

11.5 Sampling frequency

When a production area has had 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 may be decreased from monthly to bimonthly. This is not appropriate in the cases of Booth and Stream Sound, and Whal Wick as they have had seasonal classifications in the period 2004-2006. Whal Wick will require this assessment at the end of 2007, when it will have held a year round A classification for 3 years. Uxness and East Hogaland are yet to be classified.

12. Designated Shellfish Growing Waters Data

Part of the area considered in this report is a SEPA shellfish growing water which was designated in 2005. The extent of this and the SEPA designated monitoring point is shown on figure 12.1

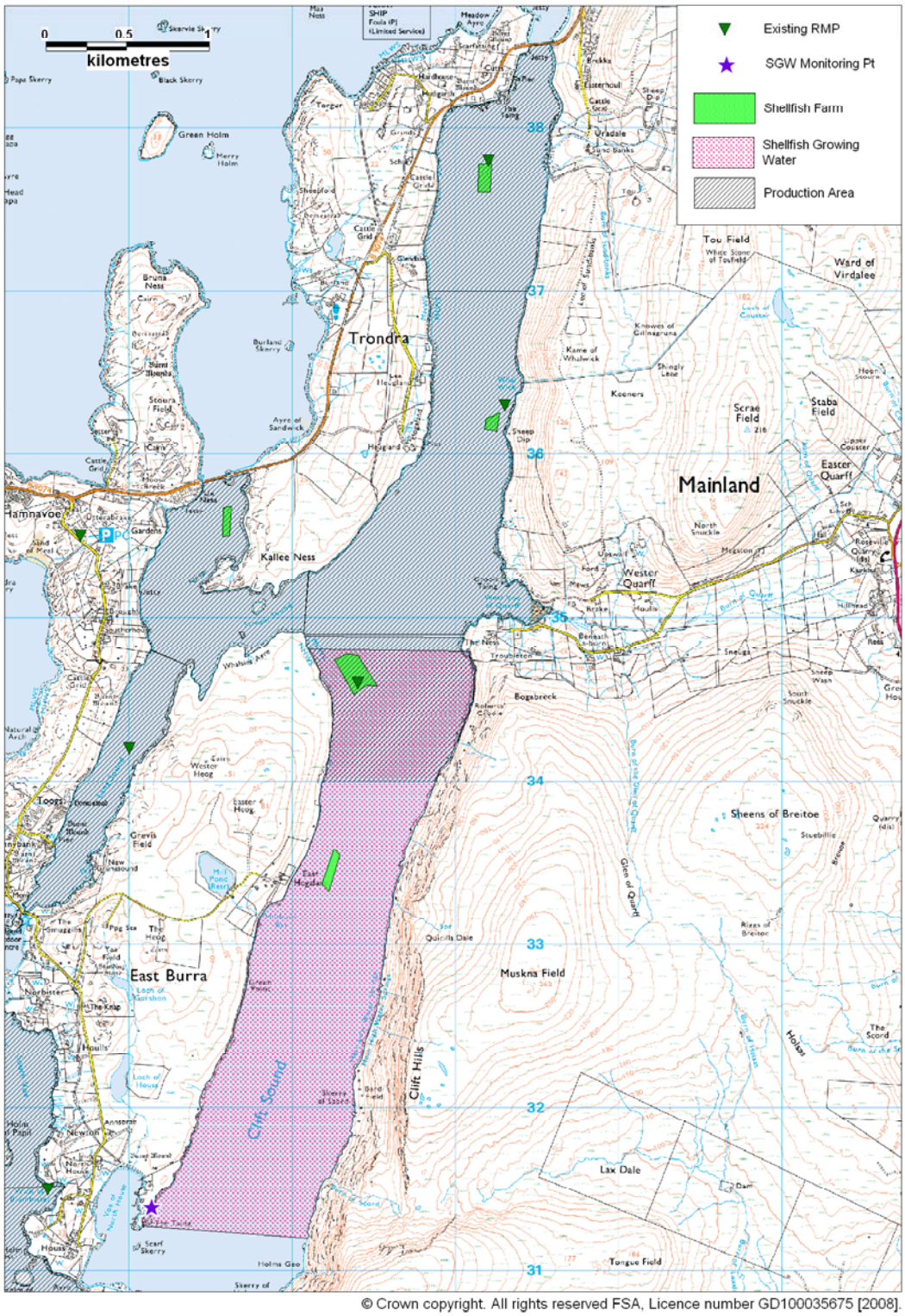

Figure 12.1 Map showing SEPA designated growing water and monitoring point.

The monitoring regime requires monthly testing for DO, salinity, pH and temperature, and biannual sampling for metals, Mercury, Arsenic, suspended solids and organohalogens in water. Monitoring started in July 2005, and results to the end of 2005 have been provided by SEPA. Monitoring results are presented in Table 12.1.

Table 12.1. Basic water quality parameters found at the monitoring point in 2005.

Date	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
pH	8.27	8.55	8.07	7.98	7.74	7.61
Temp (ºC)	12.19	14.15	12.18	11.77	9.95	8.23
Salinity (ppt)	35.47	35.39	35.21	35.16	33.69	35.21
DO (%)	140.20	215.20	128.60	129.70	110.90	107.80
DO (mg/L)	12.04	17.76	11.07	11.26	10.10	10.10
Colour (mg Pt/l - Hazen)	2.5					
Total suspended solids (mg/L)	22.2					

No monitoring of faecal coliforms in either water or shellfish had been carried out by SEPA.

13. Bathymetry and Hydrodynamics

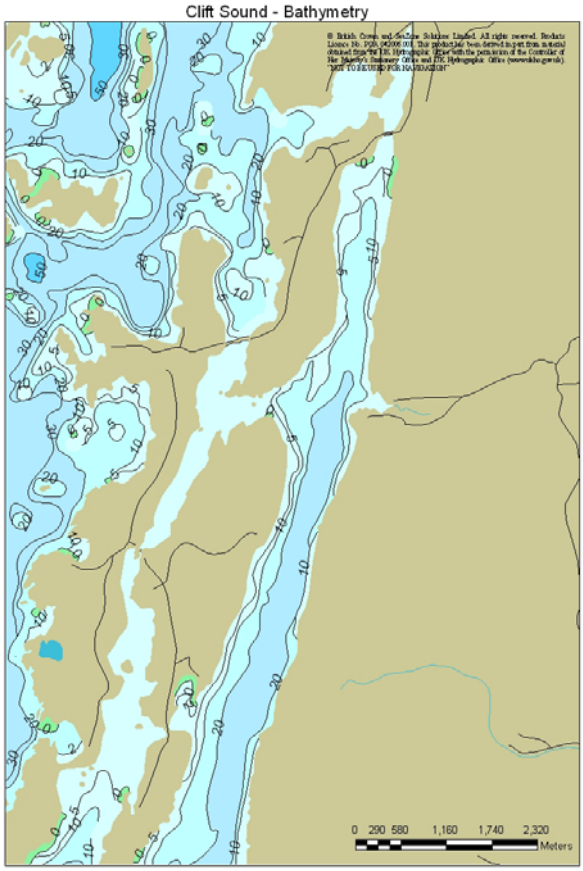

Figure 13.1 Clift Sound Bathymetry

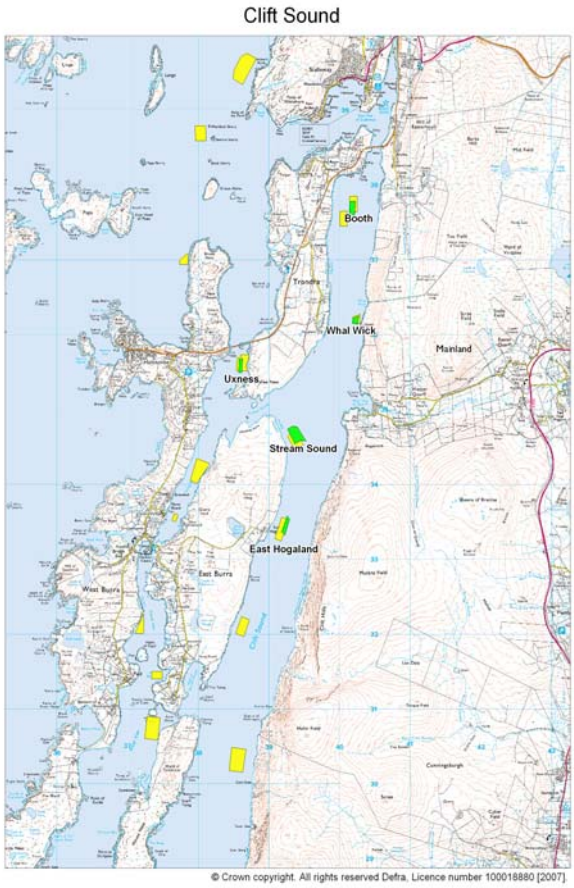

Figure 13.2 Clift Sound

The chart above shows that the depth ranges from less than 5 metres at the head of the Sound, with the presence of two drying areas, to more than 20 metres in the vicinity of the most southerly extent of the three production areas.

13.1 Tidal Curve and Description

The two tidal curves below are for the port of Scalloway at the north end of Clift Sound – they have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 10/05/07, the date of the shoreline survey. The second is for seven days beginning 00.00 GMT on 17/05/07. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

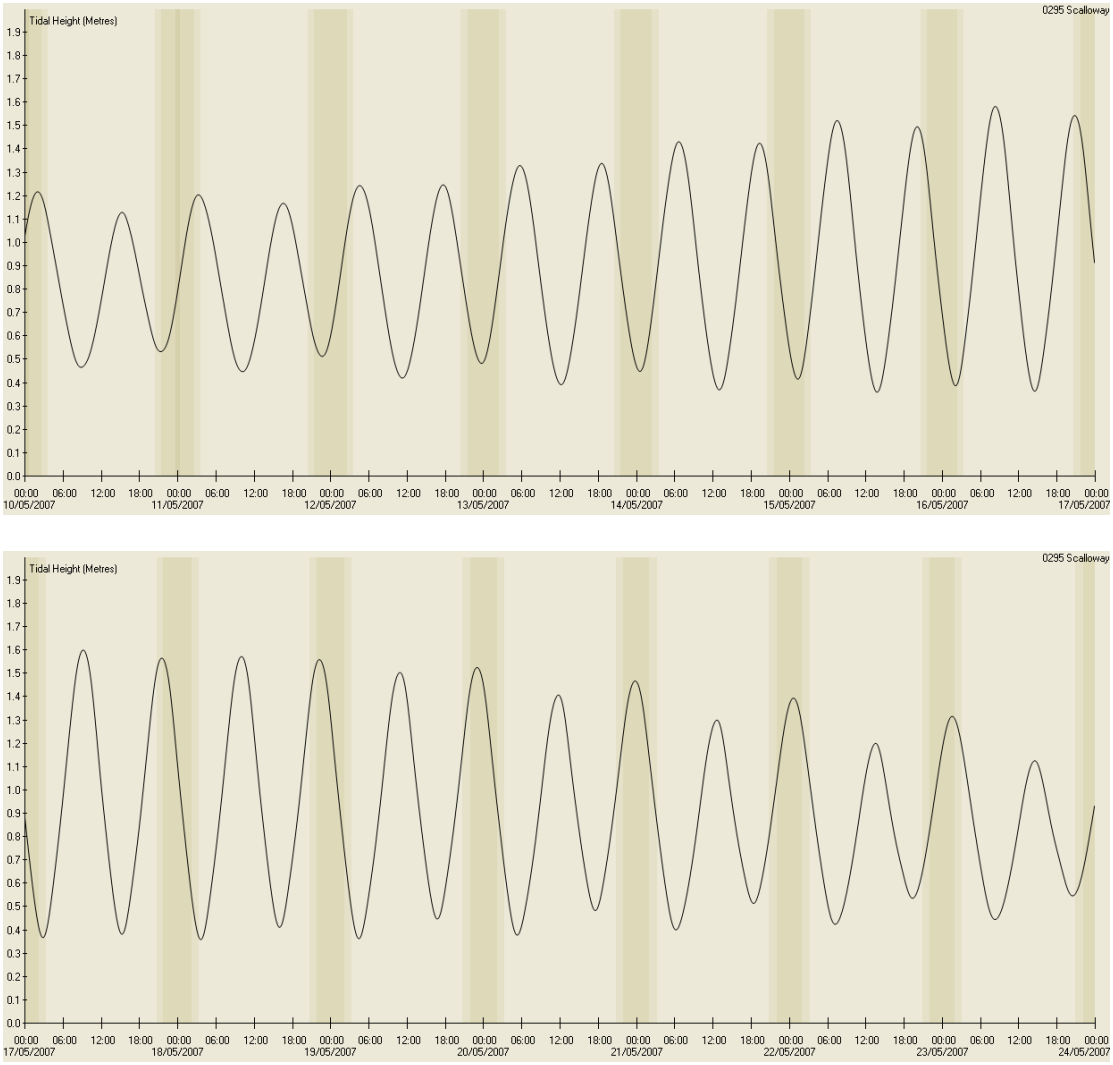

Figure 13.3 Scalloway tidal curves

The following is the summary description for Scalloway from TotalTide:

The tide type is Semi-Diurnal.

HAT	1.9 m
MHWS	1.6 m
MHWN	1.3 m
MLWN	0.6 m
MLWS	0.5 m

Predicted heights are in metres above chart datum. The tidal range at spring tide is therefore approximately 1.1 m and at neap tide 0.7 m.

13.2 Currents – Tidal Stream Software Output and Description

No tidal stream information is available for Clift Sound.

Conclusions

The Sound is deep and shelves steeply away from the edges and head - a large dilution will occur of any pollutants away from these areas although the extent will depend on the degree of stratification of the water in the vicinity of the source and the depth at which the pollution is introduced.

Tidal effects are likely to be most significant where restrictions in the width of the sound lead to increased currents during flood and ebb tides. These occur near the head of the sound just below the East Voe of Scalloway, and at Stream sound just north of the Uxness site and between the islands of Trondra and East Burra. Contaminants may be drawn through the constrictions depending upon tidal state and source location. While depths in the area between the islands are reported to be less than 5 meters, the mussel farm there has longlines down in excess of that depth, indicating that the charted depths may not be accurate in all areas.

Outside of these areas, tidal effects are expected to be limited with respect to the dispersion of pollutants and dispersion will therefore be wind and density dependent.

14. River Flow

There are no river gauging stations on rivers or burns feeding into Clift Sound.

Two significant streams were observed during the shoreline survey. Recorded dimensions and sample results can be found in Table 14.1. These represented the two largest freshwater inputs to Clift Sound.

Table 14.1 River flows and loadings – Clift Sound

Grid Ref	Description	Width	Depth	Meas. Flow	Flow in m3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli* per day)
HU 40801 39946	Stream - East Voe of Scalloway	3m	12cm	0.4 m/s	12442	120	1.5×10^{10}
HU 40543 34965	Burn of Quarff	11m	4.5cm	0.6 m/s	25661	200	3.8×10^{9}

Both watercourses constitute significant sources of faecal contaminants to their respective receiving waters. The locations of these relative to the production areas can be found in Figure 14.1.

The stream at the East Voe of Scalloway lies north of the site at Booth and contamination from the burn could flow south into Clift Sound and impact the mussel farm.

The Burn of Quarff feeds into the West Voe of Quarff, located along the eastern shore of Clift Sound approximately level with Stream Sound. Contamination carried into the sound from this burn could potentially impact the Stream Sound and Whal Wick sites.

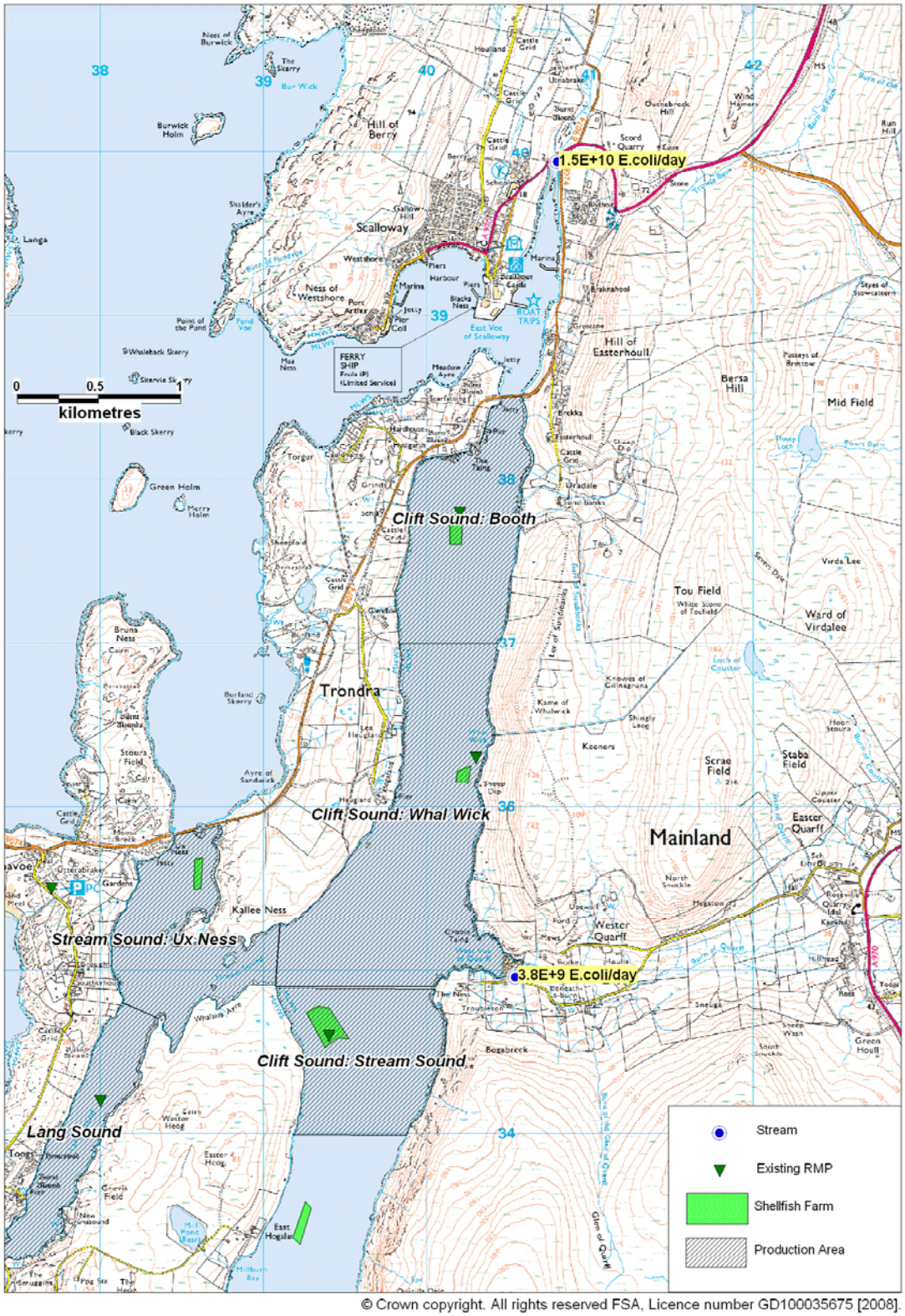

Figure 14.1 Location of major freshwater inputs to Clift Sound

15. Shoreline Survey Overview

The survey was initially triggered by the application for a new site at East Hogaland, south of the existing production areas. The most significant findings from the shoreline survey are mapped in Figure 15.1.

There were a number of homes on septic tanks along either side of the sound, though the overall area is thinly populated. No caravan sites or campgrounds were observed in the vicinity of the fisheries. The highest levels of *E. coli* were found in the northern end of the sound. Discharge leaking from a septic tank and a sample taken from a small stream on the northern end of Trondra both had counts of >3500 colony forming units (cfu) *E. coli* per 100 ml. A sample taken from a drainage pipe on Trondra also yielded 3,500 cfu *E. coli* per 100 ml. The nearest shellfish site to all three is Booth.

There were a number of salmon farms, as well as a halibut farm located in Clift Sound and storage barges (non-residential) intended to service the farms. While the fish farms themselves are not presumed to contribute to *E. coli* levels, the boats and any residential barges used to service them could be a source of faecal contamination to the sound.

The harbour at Scalloway contains a large number of boats that could be a further source of pollution if they discharge toilet waste directly overboard or have leaking waste systems.

Results of water and shellfish samples taken from the Uxness area indicated that higher levels of contamination than in some of the other areas tested. In particular, discharge from a private septic tank on the western shore opposite the shellfish farm had a count of 1600 cfu *E. coli* per 100 ml and a seawater sample taken from nearby had a count of 240 cfu *E. coli* per 100 ml. Two shellfish results of 90 and 100 mpn *E.coli* per 100 g of shellfish flesh were recorded from the site. As most of the shellfish results obtained during the survey yielded <20 *E. coli* per 100g, this was an indication that levels of faecal contamination may be generally higher in the area around Uxness.

During a second visit to Shetland, samples were taken from the Burn of Quarff where it empties into the West Voe of Quarff on the eastern shore of Clift Sound. Both water and shore mussels were collected, with the mussels containing a high level of contamination at 2400 mpn *E.coli* per 100g flesh. The water sample contained 200 cfu *E. coli*. This was probably due to the concentration of farms grazing cattle in the area of the burn as well as potential contamination from septic tank soakaways.

The entire area is used extensively for sheep grazing and sheep were observed along both sides of the sound and have access to the shoreline.

More detailed survey results can be found in the Shoreline Survey Report in the appendix.

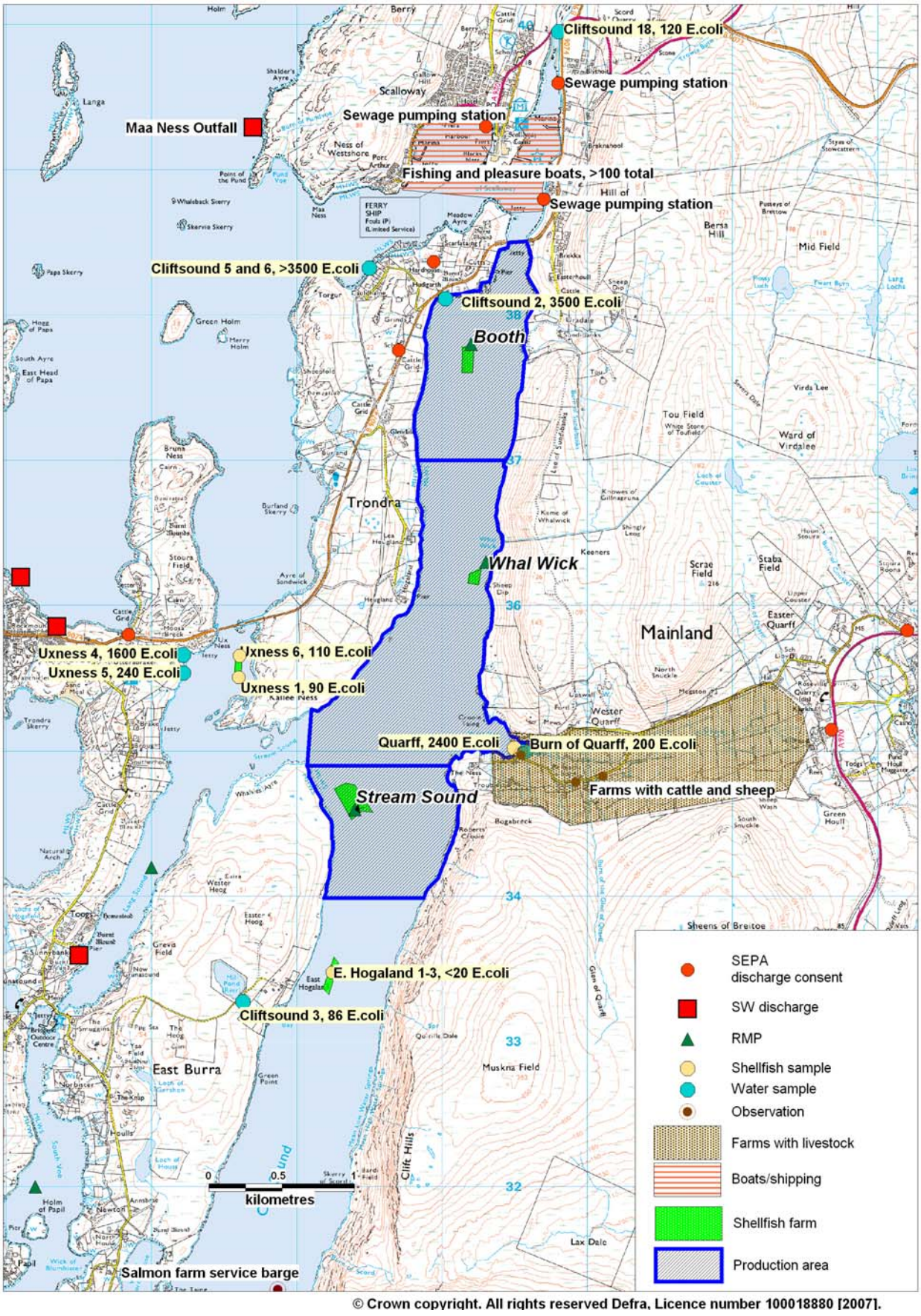

Figure 15.1 Map of significant findings from shoreline survey

16. Overall Assessment

Clift Sound receives relatively low impact from human sources of faecal contamination. Analysis of historical *E. coli* results and rainfall data would seem to indicate that the highest risk of faecal contamination occurs in the winter months.

The reason for this is not clear, but it can be hypothesised that this may be due to the increase in rain observed during late autumn and winter. Sheep excrement accumulating in fields during the summer months would then be washed in a flush into the voe when the rainfall increases in the early autumn. A statistically significant correlation was found between *E. coli* concentrations in mussels at Clift Sound mussel farms and rainfall as recorded at Lerwick.

Human Sewage Impacts

At Scalloway, sewage has been historically dumped via a raw sea outfall just north of the harbour. This is currently being upgraded to a system of large septic tanks that will serve Scalloway and the surrounding communities. There are additionally permitted overflows at the pumping stations around the harbour and East Voe of Scalloway. These would only overflow during periods of heavy rainfall, such as during the winter, potentially impacting most directly the mussel farm at Booth, which is the most northerly of the shellfish farms within Clift Sound. Based on data available at the time of this report, however, it was not possible to evaluate whether *E. coli* results coincided with sewage spills recorded in the East Voe of Scalloway.

Outside of Scalloway, the population around the sound is scattered and while there are some community septic systems it appears that many homes are on private septic tanks which are in an unknown state of repair or function.

During the shoreline survey conducted at Clift Sound, one private septic tank was observed to have overflown with solid waste in evidence on the ground around the tank though this was located along the north western shore of Trondra, well away from the shellfish farms. The Shetland population has remained steady over time and construction observed about the island is generally replacement for older housing. This should lead to an increasing number of households using modern, and presumably properly functioning, septic systems and so lessen the impact of poor treatment of septic waste on the fisheries in the sound. The effectiveness of soakaway systems in Shetland is adversely impacted by the geology, which tends to be poorly drained soils over bedrock thereby limiting the depth to which waste can soak before reaching rock and joining runoff into streams and burns.

At Wester Quarff, the Burn of Quarff drains an area of improved pastureland and settlements. Septic tanks were observed in the area and SEPA have recorded a permit to discharge septic tank effluent to land within the catchment are of this burn. The A970, which is the main route between Lerwick and Sumburgh Airport, passes along the eastern edge of the catchment and may contribute runoff into the burn. This burn flows into the sound to the east of the Stream Sound mussel farm and could also impact the Whal Wick farm to the north.

There is no accurate record of the number of private septic tanks in Shetland generally and in Clift Sound specifically because there has historically been no requirement to register them with SEPA or the local council. Current regulations, however, require registration for new construction or upon sale of an existing property so over time this information will eventually be captured.

An analysis of the human population distribution in Section 3 shows a higher concentration of people along the northern end of the sound, particularly around Scalloway. This coincides with the known and observed septic tank discharges in the area as can be seen in Figure 4.1. The area around Scalloway has a higher concentration of developed land and hardstanding that would contribute higher loadings of faecal bacteria in rain runoff thereby affecting farms in the northern reaches of the sound.

The geology on the East side of the sound is poorly draining and composed of mainly peaty gleys (Figure 5.1). This type of geology is associated with higher levels of runoff and decreased effectiveness of septic tank soakaways which would in turn lead to higher concentrations of faecal bacteria in burns and streams. The high concentrations of *E. coli* found in shore mussels collected from the mouth of the Burn of Quarff may be a result of contaminated runoff from grazed land and septic tank systems located along the burn.

The soils on the islands of Trondra and East Burra are classed as freely draining and effluent from properly functioning septic tanks in this area would be less likely to wash into the sound with surface runoff. The sites at Stream Sound, Uxness and East Hogaland are all located close to the shores of these islands.

Agricultural Impacts

Livestock and farming activities are an important factor in the use of land around Clift Sound. Much of the area is used for grazing with crofts or small farms along the eastern side of Trondra and Burra, as well as along the Burn of Quarff on the main island side of the sound. There is a concentration of cattle and sheep pasture along the Burn of Quarff. Rough grazing predominates the remainder of the area, with the steep hillsides being unsuitable for improvement.

Land cover here (Figure 6.1) is predominantly heathland with some improved grassland and peat bog. As mentioned previously, the soils along the eastern side of the sound are poorly draining indicating a greater likelihood of surface runoff carrying faecal bacteria from livestock droppings.

Agricultural practices can have a dramatic impact locally on water quality. Sheep are grazed throughout the area and can be observed accessing the shoreline. The Scottish Government has published a set of guidelines for management of farm waste and are working with farmers and crofters to encourage implementation of these guidelines. Further changes in the way agricultural subsidies are applied and paid are anticipated to lead to a decline in sheep population and hence the amount of sheep droppings in the area.

Agricultural waste runoff is more likely to impact on the fisheries located closer to the eastern edge of the sound and those nearest the Burn of Quarff [Booth, Whal

Wick and Stream Sound]. Farms on the western side of the sound [Uxness and East Hogaland] are likely to see lower impact from to agricultural runoff.

Wildlife Impacts

Wildlife impact, as discussed in section 8, is unpredictable. While large wild mammals such as whales, dolphins and seals do enter and use the sound, their presence is of limited duration and not temporally predictable. As there are no known seal haulout sites within or near the production areas, these are not considered to be a significant contributor to contamination levels. Seabirds may be contributors, with a number of seabirds breeding along the sides of the sound. All sites are likely to receive faecal inputs from birds such as cormorants, gulls, and arctic terns that roost on the floats and lines. While these impacts may be significant very locally (directly under the birds) the impact to the wider fishery is unpredictable.

Seasonal Variation

There is a strong seasonal component to the monitoring results, with higher levels of contamination apparent winter and to a lesser extent in autumn. This tends to coincide with higher historical average rainfall during those months.

The three existing production areas in Clift Sound have held seasonal classifications during the past five years, indicating observed seasonality in monitoring results. Booth has historically been classified B during January and February and higher *E. coli* concentrations observed at this time of year may be related to higher seasonal rainfall.

While in other areas of Shetland monitoring results correlated with the onset of heavier rainfall in the autumn, this trend was not as significant among the Clift Sound sites.

Seasonal changes in population due to an influx of tourists does not appear to affect the sites as monitoring results have not been high during the peak tourist months of July and August. Likewise, seasonal peaks in seabird populations along the cliffs of the sound do not appear to correspond with higher monitoring results as these populations peak in June and July.

Seasonal variation in livestock population may coincide with higher results observed in autumn as sheep have lambs in May and June that are then sent off to the mainland in October. During the period of May to October, the total population of sheep on grazing land around the island is roughly double what it is during the remainder of the year.

Meteorology and Movement of Contaminants

Analysis of wind and rainfall indicated a positive correlation between wind direction and *E. coli* results and correlation between rainfall for the previous 48 hours and 7 days and *E. coli* results (see section 9). Winds recorded from the west and southwest at Lerwick were correlated with higher results. However, most results were recorded on days when the winds were from these directions and therefore the data may be skewed. Local wind effects may differ somewhat as wind funnels through the sound and around headlands.

The bathymetric and hydrodynamic analysis provided in section 12 indicates that wind driven water movement would have a more significant effect than tides on the movement of contaminants. The sound is very open and mixing is likely to be tide driven at areas identified previously where the width of the sound is significantly constricted. This would affect the Stream Sound, Uxness and Booth fisheries primarily.

Wind driven mixing is likely to be more significant elsewhere in the sound. Freshwater input from the Burn of Quarff near the middle of the sound may ride over the denser salt layer in certain conditions. As bacterial contamination is likely to occur with fresh water runoff, it is expected that higher contamination levels may be seen in shallower water near sources of freshwater.

No significant difference was seen in historical *E. coli* results between samples taken from the different sites. However, the range of results from the Booth and Stream Sound sites include a number of results in the Class B range and some at Stream Sound beyond that indicating that there may be factors influencing the amount of contamination found at these two sites. One of these may be the likelihood of both sites being affected by higher currents passing from areas with contaminating sources on the ebb and flood tides.

Booth is located just to the south of the natural constriction formed at the head of the sound. To the north of this is the East Voe of Scalloway and a number of sewage pumping stations, marinas, fishing boats and other potential sources of contamination which would tend to pass through the fishery on an ebbing tide before dispersing more widely in the sound.

Stream Sound is located to the west of the Burn of Quarff and also to the northeast of the septic tank at North Toogs. These or other diffuse sources of pollution may impact on the levels of contamination seen at Stream Sound.

17. Recommendations

Based on analysis of historical monitoring data and the location of contaminating sources, the following recommendations are made with regard to the specific production areas located within Clift Sound. The relative positions of the recommended boundaries and RMPs are mapped in Figure 16.1.

As harvesting is generally rotational and there are mussels of differing maturity on different lines within a farm, it is recommended that either a dedicated sampling rope or bag of shellfish be placed on the RMP if mature stock is not guaranteed to be available for sampling within 20m of the RMP coordinates on a monthly basis. If bagged shellfish are to be used, they must be in place on the RMP for at least 2 weeks before being sampled.

Clift Sound: Booth (SI 036)

It is recommended that this be maintained as a separate production area. A minor adjustment to its boundary has been suggested in order to remove the part of the area closest to sources of contamination from the north. As there are no other available seabed leases in the area, the southern boundary has been moved to provide separation between the SI 036 and SI 038 immediately to the south.

Boundaries are recommended to include the area bounded by HU 3991 3800 to HU 4059 3800 and HU 4044 3700 to HU 3983 3700 extending to MHWS.

The RMP lies at the northern extremity of the farm and due to the likely impact from pollution sources to the north of the farm, this location should be retained. A slight adjustment to the coordinates is suggested that brings the monitoring point within 10m of the end of the lines. It is further recommended that samples be taken from a depth of 1-3m as contamination levels are expected to be fairly uniform across the depth of the lines and a deeper sampling depth is not indicated.

The recommended RMP is at HU 4020 3777 at a depth of 1-3m.

Sampling frequency is currently monthly and due to the existing seasonal classification it is recommended that this be retained.

Clift Sound: Whal Wick (SI 038)

The suggested boundary for the Whal Wick production area has been amended to bracket more closely the existing mussel farm. Pollution sources from the Burn of Quarff would be likely to have a more significant impact in the southern half of the existing production area and monitoring results from the current Whal Wick site would not be representative of contamination levels closer to the burn.

Boundaries are recommended to include the area bounded by HU 3979 3600 to HU 4035 3600 and HU 4038 3670 to HU 3983 3670 extending to MHWS.

As the site lies about 1km to the north of the West Voe of Quarff, but over 2km south of the northern entrance to the sound, the closest significant source of faecal contamination is likely to be the shoreline nearest the farm, followed by the burn of Quarff. There are likely to be septic tanks at Huegaland on the western shore of the sound opposite the mussel farm. However, due to drainage characteristics of the soil there is unlikely to be significantly contaminated runoff. It is recommended that the monitoring point be shifted to the southeastern section of the farm.

The recommended RMP is proposed at HU 4023 3616 at a depth of 1-3m.

While little difference was seen in *E. coli* results for samples taken at different depths during the shoreline survey, it is anticipated that mixing may be less of a factor at the location of this farm and that contaminants may be concentrated in a surface layer of fresher water from the burn and other shore runoff. A sampling depth of 1-3 metres is recommended as this will capture surface layer contamination if present.

This production area was considered for combination with the Booth production area to the north as their results are not statistically significantly different. However, the Booth site has had two B class results and as such carries a B classification for part of the year whereas the Whal Wick site has had an A classification for three years. Were these production areas to be combined, the Whal wick site would no longer be eligible for assessment for reduced sampling.

Monthly sampling is proposed until stability can be assessed early in 2008.

Clift Sound: Stream Sound (SI 037)

The Stream Sound production area would also be influenced by contaminants from the Burn of Quarff as well as any funnelled through Stream Sound from the north and west. As the Burn of Quarff is the nearest polluting source, the production area boundary has been recommended to exclude the east side of the sound nearest the Voe of Quarff. The southern boundary has been brought closer to the existing seabed lease as there are no other available leases in the area.

Contaminants in the vicinity of the mussel farm are likely to be well mixed due to the effect of water moving through the natural constriction at Stream Sound. However, as movement of contaminants on the eastern side of the voe is likely to differ it is recommended that the production area be further restricted to the western half of the sound.

Boundaries are recommended to include the area bounded by HU 3907 3490 to HU 3960 3490 to HU 3960 3423 to HU 3923 3423 extending to MWHS.

As 18% of the monitoring results obtained since 1991 exceeded permitted levels for Class A areas, this production area was not considered suitable for combination with adjacent production areas at either Uxness or East Hogaland. As there is no monitoring history as yet at the East Hogaland site, possible combination of these production areas will be reevaluated after sufficient history has been obtained. This

site is cannot be considered for reduced sampling based on long term stability of classification, so sampling frequency is recommended to remain monthly.

The recommended RMP is at HU 3933 3475 at a depth of 1-3m.

Clift Sound: East Hogaland (SI 035)

As the southernmost of the production areas, it is anticipated that East Hogaland will be most influenced by sources of contamination from farms and dwellings located along the western shore of the sound and less so from runoff carried from grazing above the cliffs opposite. The production area boundaries were recommended to exclude the areas closest to the habitations on the eastern side of the sound and to extend to the nearest grid lines.

Boundaries are recommended to include the area bounded by HU 3917 3386 to HU 3983 3386 and HU 3958 3300 to HU 3900 3300 to HU 3900 3341 extending to MHWS.

As it was not possible to sample multiple areas within the mussel farm on the day of shoreline survey, two monitoring points are recommended in the interim. These have been chosen to determine whether the site is more influenced by contaminants moving down the sound from the north or those from the shore nearest to the farm. It is likely that any faecal contamination in this area will be concentrated nearer the surface and so a sampling depth of 1-3m is recommended. As there will not be sufficient stock on site to harvest in 2008, it is expected that bagged shellfish will need to be placed at the recommended RMPs until sufficient monitoring history allows for exclusion of one of the interim points. These should be put in place at least 2 weeks prior to sampling.

The recommended RMPs are at HU 3927 3354 and HU 3920 3337 at a depth of 1-3m.

Sampling frequency is recommended to be monthly as no factors indicate that a more frequent sampling regime is necessary at this time.

This production area could be assessed for possible combination with the Clift Sound: Stream Sound production area after sufficient monitoring history has been compiled.

Stream Sound: Uxness (SI 373)

The Uxness mussel farm is located in a shallow area where restrictions of land would tend to create greater currents moving through the site. Pollutants would be more likely to be mixed and sediments may be resuspended due to the shallow depth and tidal range. The production area boundaries were chosen to extend across the narrowest part of the water body just south of the bridge to avoid confused eddies and currents around spit of land under the bridge and as it was a convenient point of reference. The southern boundary was similarly chosen for convenience of reference and lies to the north of two small islands to the west of Kallee Ness.

Boundaries are recommended to include the area bounded by HU 3845 3579 to HU 3868 3579 and HU 3811 3532 to HU 3854 3532 extending to MHWS.

The sampling depth is recommended to be 1-3m. As contaminants coming from the north are likely to be mixed and those from directly west of the farm are may be mixed or near the surface, samples taken from this depth will be likely to capture either occurrence.

The recommended RMP is at HU 3859 3567 at a depth of 1-3m.

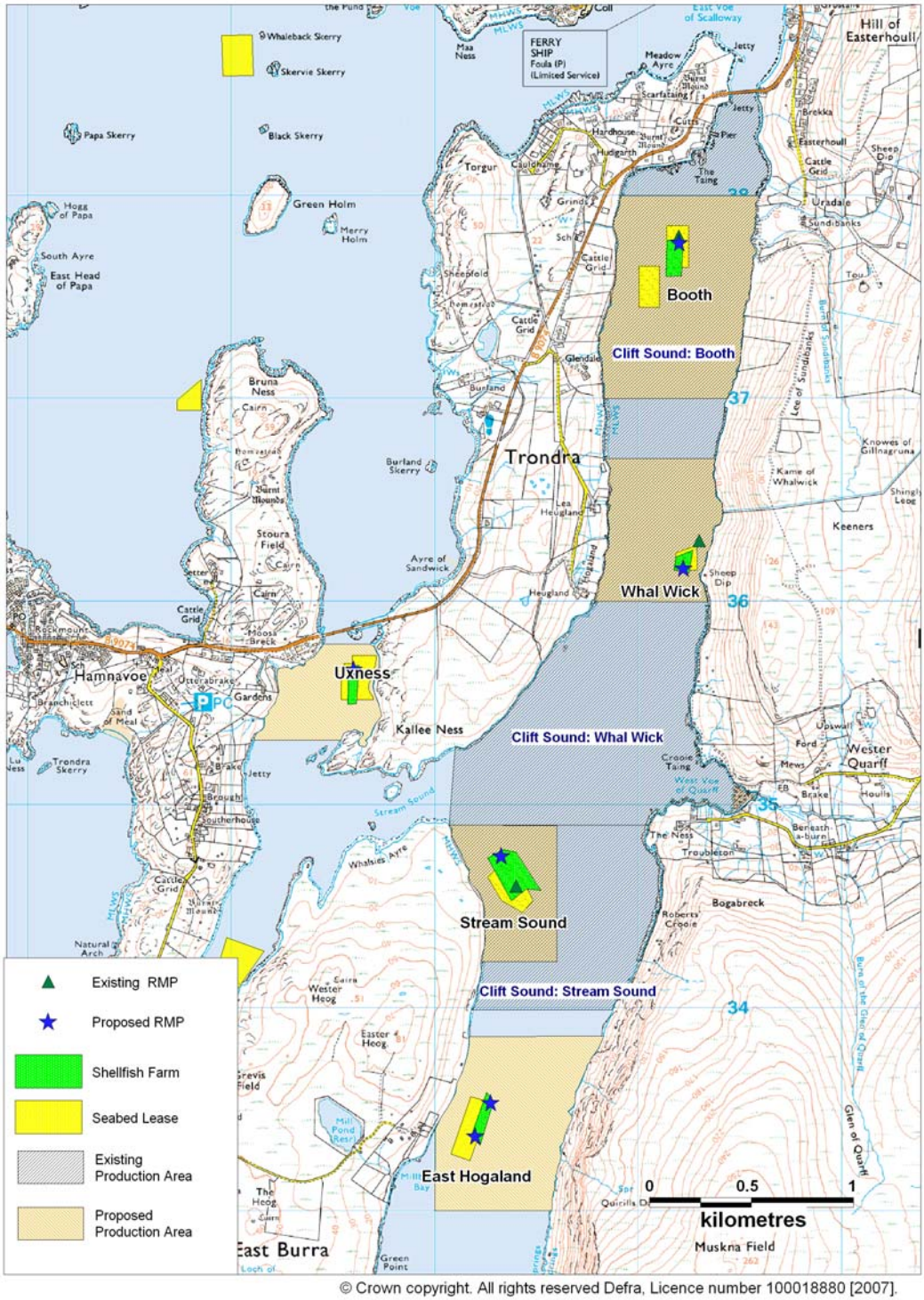

Figure 17.1. Map of recommendations for Clift Sound production areas

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19. List of Tables and Figures

Appendices

1. Shoreline Survey Report
2. Sampling Plan
3. Tables of Typical Faecal Bacteria Concentrations
4. Statistical Data
5. Hydrographic Methods

Shoreline Survey Report

Clift Sound
SI 035, SI 036, SI 037, SI 038
Stream Sound
SI 373

Scottish Sanitary Survey Project

Cefas

Shoreline Survey Report

Prod. areas:	Clift Sound and Stream Sound
Site names:	East Hogaland (SI 035), Stream Sound (SI 037), Whal Wick (SI 038), Booth (SI 036) and Stream Sound: Uxness (SI 373)
Species:	Common mussels
Harvester:	K. Pottinger, East Voe Shellfish; Demlane-Isle of Shuna plc.
Local Authority:	Shetland Islands Council
Status:	SI 035 is a new area. SI 373 was added in 2006. The remainder are existing areas.
Date Surveyed:	10, 16-17 May
Surveyed by:	Michelle Price-Hayward and Alastair Cook
Existing RMPs:	Booth HU402378, Stream Sound HU394346 Whal Wick HU403363
Area Surveyed:	See map in Figure 1

Weather observations

10 May. Dry, partly cloudy. Wind NNW force 3.
16 May. Dry, sunny. Wind variable, force 1.
17 May. Dry, sunny. Wind

Site Observations

Clift Sound was viewed from the shore to the greatest extent possible and from boat for those areas too steep to access on foot. The shoreline along the islands of Burra and Trondra were surveyed, as well as the mainland side of the sound and Scalloway Harbour.

Fishery

All the shellfisheries in Cliftsound are rope grown mussels, using double headed long lines with droppers of up to 8 metres length.

The East Hogaland site had 4 long lines, 3.5 of which were new. There was little harvestable stock with only one line containing sufficient mussels to collect a sample, most of which were of marginal size. Samples were taken from subsurface, mid line and bottom of that line.

The Stream Sound site also had few mussels on. Two new lines had been recently added to the 4 lines already on the site. There was a dedicated sampling line at the RMP. Two samples were taken from this, at 4m and 8m depths. There were insufficient mussels for sampling at the top of the line.

At the Whal Wick site, one set of samples was taken from just below the surface, the middle and the bottom of the line.

Booth was recently harvested and so there were no mussels on other than the dedicated sampling line. Samples were taken from 4m and 8m only as there were insufficient mussels at the top of the line.

Uxness had 4 lines on site and all stock was of harvestable size. The harvester anticipates harvesting Sept/Oct. Samples were taken from two lines at subsurface, midline and bottom of the lines.

Sewage/Faecal Sources

There were a number of homes on septic tanks along either side of the sound, though the overall area is thinly populated. The town of Scalloway sits at the northern end of Clift Sound and could be a source of contamination further down the sound. There was a sewage pumping station at Maa Ness that pumps to an outfall offshore outside Scalloway harbour. It was not possible to confirm the flow rate or exact location of the outfall. There was also a pumping station to a septic tank serving the community of Blydoit near the head of the East Voe of Scalloway as well as a pumping station at West Shore.

Some septic debris was observed, as well as malfunctioning private septic systems. These were associated with individual homes and did not discharge directly into any of the harvesting areas.

Seasonal Population

No caravan sites or campgrounds were observed in the vicinity of the fisheries. There may be some seasonality to occupation of some of the homes along the sound though this was not confirmed.

Boats/Shipping

There were a number of salmon farms, as well as a halibut farm located in Clift Sound and barges intended to service the farms. The harvester indicated that the barges were used for storage of feed and equipment and to the best of his knowledge was not provide accommodation for people working on the farms.

There were a 17 large fishing boats (Table 1, 53-4) and smaller work and pleasure boats moored in Scalloway harbour. There is an additional small boat marina located in the East Voe of Scalloway with space for 102 day boats with about 50% occupied at the time of survey (Table 1, 57).

Land Use

The area is used extensively for sheep grazing and sheep were observed along both sides of the sound. There was no arable agriculture in the vicinity, nor any intensive livestock rearing operations.

Wildlife/Birds

Small congregations of Eider ducks seen (Table 1, No.35) in Scalloway harbour. There were small numbers of terns and gulls seen flying around but not settled or accumulated in appreciable numbers. No cetaceans or other marine mammals were observed during the survey.

Specific observations taken on site are mapped in Figures 1 and 2 and listed in Table 1.

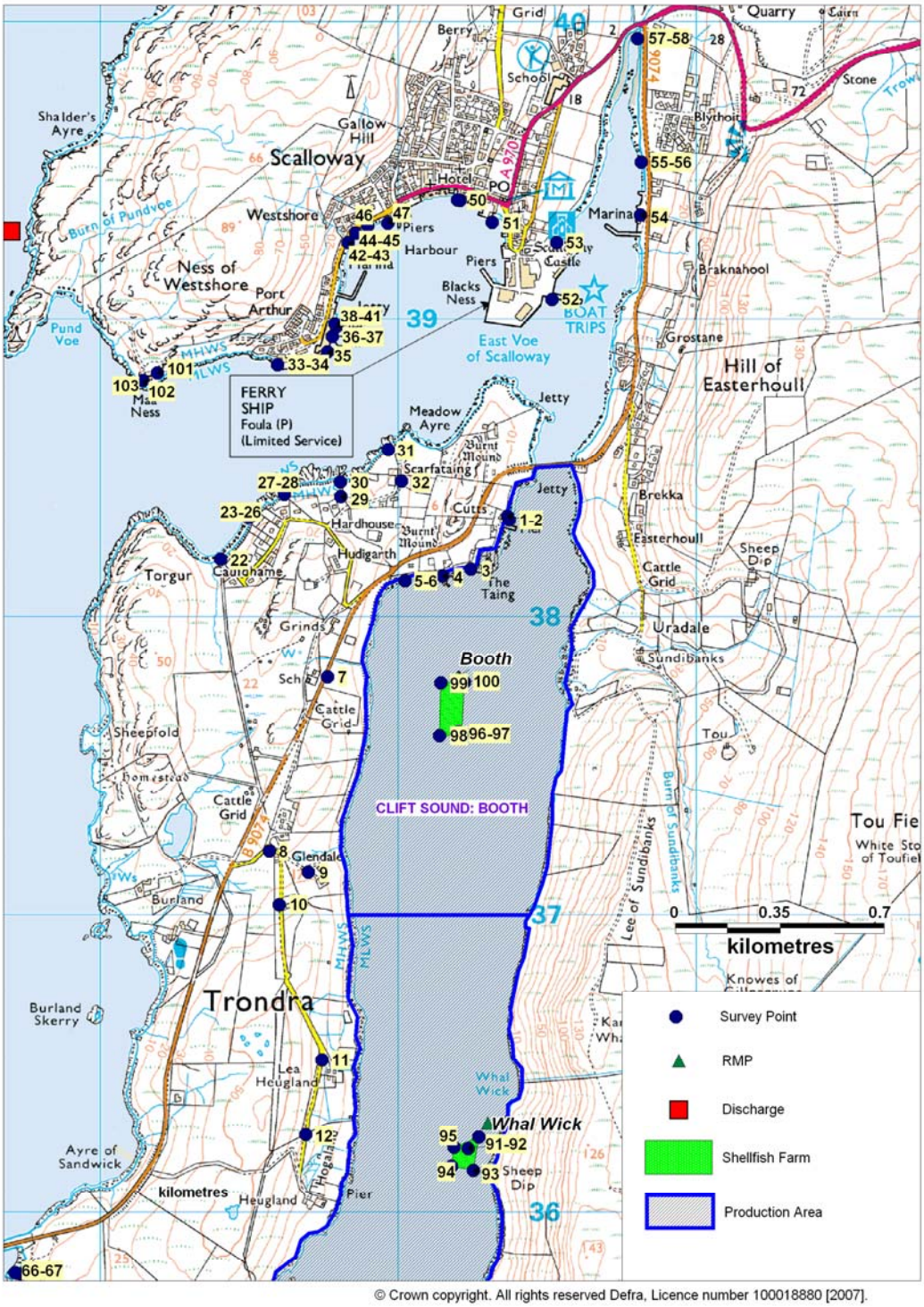

Figure 1. Clift Sound North survey points

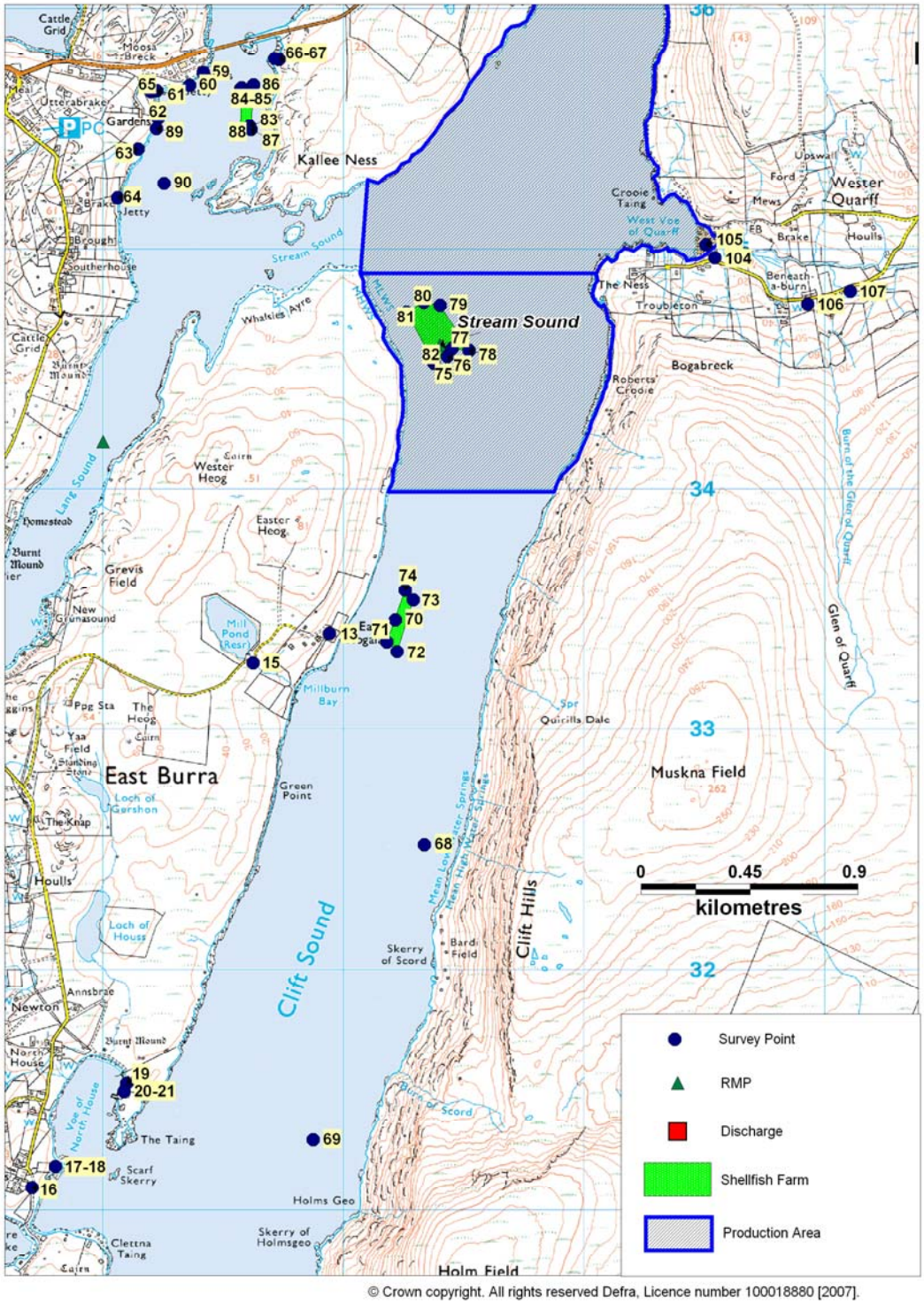

Figure 2. Clift Sound South survey points

Table 1. Shoreline Observations

No.	Date	NGR	Description	Photograph of Area
1	10/05/2007	HU 40365 38338	Septic tank on shoreline (water seepage observed) also jetty with boat moored up. 4 houses in area behind shoreline. Trondra, N end of sound.	Figure 6, 7
2	10/05/2007	HU 40371 38326	Water sample Clift Sound no. 1 (salt) taken 1010 where water seepage enters sea	
3	10/05/2007	HU 40242 38160	Probable septic tank soakaway into shoreline at The Taing, 1 house	Figure 8
4	10/05/2007	HU 40147 38138	House backing onto beach. Ponies in adjacent field	Figure 9
5	10/05/2007	HU 40021 38122	Possible cotton bud. Drainage from field through pipe, then percolating onto beach.	Figure 10
6	10/05/2007	HU 40021 38122	Water sample Clift Sound no. 2 (fresh) 1040 taken from drainage above.	
7	10/05/2007	HU 39761 37800	2 houses	
8	10/05/2007	HU 39567 37215	2 houses and 3 chalet noted on roadside away from shoreline. Glendale	
9	10/05/2007	HU 39697 37144	2 houses	
10	10/05/2007	HU 39600 37035	1 house	
11	10/05/2007	HU 39743 36513	2 barns 1 house 100m back from cliff edge. Lea Heugland	
12	10/05/2007	HU 39689 36261	3 houses 100m back from cliff edge. Across from Whal Wick.	
13	10/05/2007	HU 38941 33400	3 houses 50m back from cliff edge. East Hogaland.	Figure 11-13
14	10/05/2007	HU 38624 33277	Freshwater stream-sample see no. 15, drains mill pond reservoir.	Figure 14,15
15	10/05/2007	HU 38624 33277	Water sample Clift Sound no. 3 (fresh) 1155	
16	10/05/2007	HU 37705 31093	Septic tank, 4 or 5 houses behind some including ruins in process of renovation. new tank about to be installed. Houss.	Figure 16
17	10/05/2007	HU 37802 31181	Underground pipe leading from houses to soakaway on beach here. line of pipe just visible as broken ground. Voe of N House.	Figure 17
18	10/05/2007	HU 37802 31181	Water sample Clift Sound no, 4 (salt) 1215.	
19	10/05/2007	HU 38098 31527	Old broken pipe leading out into bay from old house on shoreline. Voe of N House.	
20	10/05/2007	HU 38088 31492	Scottish Seafarms building, jetty, 3 boats, workers on site. Voe of N House.	Figure18
21	10/05/2007	HU 38088 31492	Another 5 houses noted on surrounding hillside. Voe of N House.	
22	10/05/2007	HU 39403 38194	Jetty at Cauldhame.	
23	10/05/2007	HU 39500 38334	Septic overflow, pipe broken and leaking down shore as well as small trickle discharging direct to sea. flow < 1L per minute.	Figure 19, 20
24	10/05/2007	HU 39500 38334	Water sample Clift Sound no. 5 (fresh/foul) 1330.	
25	10/05/2007	HU 39507 38339	Freshwater stream (small).	Figure 21
26	10/05/2007	HU 39507 38339	Water sample Clift Sound no. 6 (fresh) 1335 taken from stream.	
27	10/05/2007	HU 39617 38412	4” pipe from house running out underwater.	
28	10/05/2007	HU 39617 38412	Water sample Clift 8 (salt) taken next to pipe 1345.	
29	10/05/2007	HU 39806 38404	Septic tank - overflow runs down to shoreline at HU 39804 38453 where seepage observed.	

No.	Date	NGR	Description	Photograph of Area
			Hardhouse.	
30	10/05/2007	HU 39804 38453	Water sample Clift Sound no. 7 (salt) taken where seepage enters water 1353.	
31	10/05/2007	HU 39965 38563	Septic tank overflow pipe running out under water . water sample Clift Sound no. 9.	
32	10/05/2007	HU 40010 38456	Concrete septic tank cover observed, no associated overflow running to the shoreline could be found.	Figure 22
33	10/05/2007	HU 39594 38848	Assorted hatchery intakes and outflows, one outflow running. Also 3 probable surface drain (4" plastic pipes) from next door houses running down to shore. NAFC Marince Centre - Scallaway.	Figure 23
34	10/05/2007	HU 39594 38848	Water sample Clift Sound no. 10 (salt) 1500 taken next to hatchery pipes.	
	10/05/2007	Scalloway harbour	8 eider ducks on harbour.	
35	10/05/2007	HU 39761 38891	Many inspection covers on shoreline.	Figure 24
36	10/05/2007	HU 39777 38943	6" plastic pipe running out underwater.	
37	10/05/2007	HU 39777 38943	Water sample Clift Sound no. 11 (salt) taken next to pipe 1505.	
38	10/05/2007	HU 39791 38975	6" plastic pipe and 2x2" flexible pipes running underwater.	
39	10/05/2007	HU 39791 38975	Water sample Clift Sound no. 12 (salt) taken next to pipe 1510.	
40	10/05/2007	HU 39786 38985	6" plastic pipe dripping onto shore.	
41	10/05/2007	HU 39786 38985	Water sample Clift Sound no. 13 (salt) taken from where dribble enters sea.	
42	10/05/2007	HU 39830 39260	4" surface water pipe onto shore, not running.	
43	10/05/2007	HU 39830 39260	12" surface water drain. water sample Clift Sound no. 14.	Figure 25
44	10/05/2007	HU 39856 39291	West Shore sewage pumping station (Scottish Water). 18" concrete pipe running to marker pole about 20m out from shore. Not sure if it was flowing or not.	Figure 26
45	10/05/2007	HU 39856 39291	Water sample Clift Sound no.15 (salt) taken from next to pumping station pipe 1530.	
46	10/05/2007	HU 39896 39315	2 surface water (storm) drains. 1 running but not enough to sample the freshwater.	
47	10/05/2007	HU 39964 39324	5 plastic pipes to beach, none flowing at time, probably for surface water.	
48	10/05/2007	HU 40197 39402	2 ft concrete pipe running underwater about 1m out, appeared to be flowing fairly strongly.	
49	10/05/2007	HU 40197 39402	Water sample Clift Sound no.16 (salt) taken next to large flowing concrete pipe.	
50	10/05/2007	HU 40206 39400	4" pipe running out underwater from underneath café.	
51	10/05/2007	HU 40314 39327	6" plastic pipe running out underwater.	
52	10/05/2007	HU 40514 39067	6 large fishing vessels in port.	
53	10/05/2007	HU 40531 39260	11 fishing vessels moored up,	
54	11/05/2007	HU 40811 39351	Marina with space for 102 boats (day boats) about 50% occupied,	Figure 27
55	11/05/2007	HU 40815 39529	Scottish Water Blydoit pumping station outfall pipe (6" pipe discharging 20m out underwater) impossible to say if its flowing.	Figure 28, 29
56	11/05/2007	HU 40815 39529	Water sample Clift Sound no. 17 (salt) taken alongside shoreward end of Blydoit outfall pipe	

No.	Date	NGR	Description	Photograph of Area
			1615.	
57	11/05/2007	HU 40801 39946	Freshwater burn 3m x 12cm x 0.4 m/s	Figure 30
58	11/05/2007	HU 40801 39946	Water sample Clift Sound no. 18 (fresh) 1622 from burn.	
59	17/05/2007	HU 38416 35737	Scottish Seafarms building on shoreline.	Figure 32
60	17/05/2007	HU 38360 35684	6" steel pipe probably from one of the sheds to sea not flowing.	
61	17/05/2007	HU 38223 35661	Very small natural stream. water sample Uxness no. 4 (fresh). salinity 35ppt where stream meets sea.	
62	17/05/2007	HU 38229 35545	6" ceramic septic outflow direct to sea. looked broken further up. water sample Uxness no. 5 38ppt salinity sea next to pipe.	
63	17/05/2007	HU 38146 35417	Small natural stream.	Figure 33
64	17/05/2007	HU 38060 35213	White pipe from top of cliff. probably septic overflow.	Figure 34, 35
65	17/05/2007	HU 38198 35657	1/8 acre cabbage patch.	
66	17/05/2007	HU 38731 35792	Fish shed, 3 small jettys, 3 boats.	
67	17/05/2007	HU 38713 35796	Water sample Uxness no. 6 salinity 36.5 ppt.	
68	16/05/2007	HU 39336 32521	Abandoned salmon cages.	
69	16/05/2007	HU 38873 31293	5 cages and barge someone at home.	
70	16/05/2007	HU 39214 33457	East Hogaland mussel samples no.1 (top) no. 2 (middle) no.3 (bottom). water sample East Hogaland no. 1, 35ppt salinity, temp 9.3C.	
71	16/05/2007	HU 39180 33366	Corner of East Hogaland mussel lines (4 lines of which 3.5 are new).	Figure 36
72	16/05/2007	HU 39222 33324	Corner of East Hogaland mussel lines.	
73	16/05/2007	HU 39289 33541	Corner of East Hogaland mussel lines.	
74	16/05/2007	HU 39255 33581	Corner of East Hogaland mussel lines.	
75	16/05/2007	HU 39376 34527	Stream Sound site has 6 lines.	Figure 37
76	16/05/2007	HU 39430 34555	Stream Sound mussel sample no. 1 (4m) and no. 2 (8m) none at top of line which is routine monitoring sample rope. water sample Stream Sound no.1, salinity 34.9ppt, temp. 9.2C.	
77	16/05/2007	HU 39450 34586	True corner of Stream Sound mussel lines – 2 lines currently set too far out, harvester to move.	
78	16/05/2007	HU 39521 34580	Corner of Stream Sound mussel lines (will be moved into point 10).	
79	16/05/2007	HU 39400 34768	Corner of Stream Sound mussel lines (will be moved into point 13).	
80	16/05/2007	HU 39334 34779	Corner of Stream Sound mussel lines.	
81	16/05/2007	HU 39260 34738	Corner of Stream Sound mussel lines.	
82	16/05/2007	HU 39365 34544	Corner of Stream Sound mussel lines.	
83	16/05/2007	HU 38610 35512	Uxness mussel samples no. 1 (top), no. 2 (middle), no. 3 (bottom). this dropper is 6m only. water sample Uxness no.1, salinity 35ppt, temp 9.4C.	Figure 38
84	16/05/2007	HU 38572 35670	Uxness mussel samples no. 4 (top), no. 5 (middle) , no.6 (bottom) this dropper is 8m. water sample Uxness no. 2, salinity 35ppt , temp 9.5C.	

No.	Date	NGR	Description	Photograph of Area
85	16/05/2007	HU 38576 35673	Corner of Uxness mussel lines.	
86	16/05/2007	HU 38626 35685	Corner of Uxness mussel lines.	
87	16/05/2007	HU 38615 35498	Corner of Uxness mussel lines.	
88	16/05/2007	HU 38573 35496	Corner of Uxness mussel lines.	
89	16/05/2007	HU 38222 35501	Water sample Uxness no. 3, salinity 35ppt, temp 9.7C.	
90	16/05/2007	HU 38254 35274	Halibut cages.	
91	16/05/2007	HU 40233 36214	Whal Wick mussel sample no.1 (top), no. 2 (middle) , no.3 (bottom). water sample Whal Wick no. 1, salinity 35ppt, temp 9.3C.	
92	16/05/2007	HU 40269 36253	Corner of Whal Wick mussel lines (8 short lines only 1 of which has mussels).	
93	16/05/2007	HU 40251 36141	Corner of Whal Wick mussel lines.	
94	16/05/2007	HU 40177 36155	Corner of Whal Wick mussel lines.	
95	16/05/2007	HU 40186 36218	Corner of Whal Wick mussel lines.	
96	16/05/2007	HU 40200 37615	Booth mussel sample no. 1 (4m) and no. 3 (8m) taken from routine monitoring rope which is the only rope with mussels on. Water sample Booth no. 1, salinity 35ppt , temp 9.3C.	
97	16/05/2007	HU 40212 37604	Corner of Booth mussel lines.	
98	16/05/2007	HU 40138 37603	Corner of Booth mussel lines.	
99	16/05/2007	HU 40141 37780	Corner of Booth mussel lines.	
100	16/05/2007	HU 40220 37784	Corner of Booth mussel lines.	
101	16/05/2007	HU 39191 38821	Maa Ness sewage pumping station.	
102	16/05/2007	HU 39142 38795	Maa Ness sewage pumping station.	
103	16/05/2007	HU 39104 38781	Maa Ness outfall pipe enters sea here.	
	10/05/2007	Scalloway harbour	Fish processors/wholesalers, port buildings & goods terminals, no obvious discharges but may be some under pilings.	
	10/05/2007	Scalloway harbour	No further sanitary debris seen on shoreline but lots of other rubbish washed up.	
104	06/09/2007 09:44	HU 40543 34965	New septic tank, for houses above road, 5 houses, 19 cattle and cattle droppings found on shoreline. Burn 11m x 4.5cm deep. Flow, 0.6 m/s. Water sample Quarf 1.	
105	06/09/2007 09:53	HU 40505 35020	Mussel sample Quarf 1. 32 sheep, 4 houses to the left up the hill. Burn steep sided with livestock, farms both sides, improved pasture.	
106	06/09/2007 10:08	HU 40928 34772	4 houses, 70 sheep, 2 horses and 2 ponies.	
107	06/09/2007 10:10	HU 41106 34826	3 houses, 26 sheep.	

Photos referenced in the table can be found attached as Figures 6-43.

General Observations

Discussion with the local agricultural office indicated that sheep populations had declined over the past decade with continued decline expected due to changes to agricultural subsidies being implemented this year.

The sheep population on Shetland roughly doubles during May-June as lambs are born. Ewes are kept in close to habitations for lambing, possibly increasing impact to coastal areas as many homes are located along the edges of the voes. The vast majority of lambs born in spring are then shipped to the mainland in September-October for finishing.

During winter when grazing is scarce, sheep will feed on seaweed at the shoreline. Sheep fed preferentially on seaweed produce a distinctly flavoured meat that is sold as a specialty product. Sheep can access the shoreline at all times of the year.

Agriculture is practiced within the crofting system on Shetland and many of the fenced areas observed along the voes represent individual crofts. Little in the way of arable agriculture is possible in due to soil infertility and climate so most of the crofts graze sheep or, more rarely, cattle.

Discussion with the local agricultural office indicated that sheep populations had declined over the past decade with continued decline expected due to changes to agricultural subsidies being implemented this year.

Homes in the area are widely distributed and do not appear to be on any sort of mains septic system but rather have individual septic tanks. There has historically been no requirement in Scotland to register these individual systems and so little record is available regarding their age, type, size or location. The Shetland Island Council currently provides a septic tank clean out service, for which it has recently begun to charge a fee.

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.

Sampling

Water and shellfish samples were collected at sites marked on the map. Samples were transferred to cool boxes after collection and transported to the laboratory where they were analysed for *E. coli* content. Samples were also tested for salinity by the laboratory using a salinity meter under more controlled conditions. These

results are more precise than the field measurements and are shown in Table 2, given in units of grams salt per litre of water. This is the same as ppt.

Water samples collected on 16 May were not processed due to the samples being misplaced at the laboratory. These included Uxness sample numbers 1-3, Whal Wick sample number 1, Booth sample number 1 and a sample collected off the outfall at Maa Ness sewage pumping station.
Bacteriology results follow in Tables 2 and 3.

Table 2. Water Sample Results

No.	Site	NGR	Type	*E. coli* (cfu/100ml)	Salinity (g/L)
1	Uxness 4	HU 38223 35661	Water	1600	0.2
2	Uxness 5	HU 38229 35545	Water	240	29.7
3	Uxness 6	HU 38713 35796	Water	<1	27.8
4	Cliftsound 1	HU 40371 38326	Water	4	28.4
5	Cliftsound 2	HU 40021 38122	Water	3500	0.1
6	Cliftsound 3	HU 38624 33277	Water	86	0.2
7	Cliftsound 4	HU 37802 31181	Water	10	29.3
8	Cliftsound 5	HU 39500 38334	Water	>30000	0.6
9	Cliftsound 6	HU 39507 38339	Water	>30000	0.2
10	Cliftsound 7	HU 39804 38453	Water	70	33.2
11	Cliftsound 8	HU 39617 38412	Water	8	26.3
12	Cliftsound 9	HU 39965 38563	Water	<1	28.1
13	Clift 10 Scal	HU 39594 38848	Water	<1	29.2
14	Clift 11 Scal	HU 39777 38943	Water	<1	28.6
15	Clift 12 Scal	HU 39791 38975	Water	<1	29.6
16	Clift 13 Scal	HU 39786 38985	Water	9	27.8
17	Clift 14 Scal	HU 39830 39260	Water	6	29.7
18	Clift 15 Scal	HU 39856 39291	Water	<1	28.6
19	Clift 16 Scal	HU 40197 39402	Water	4	29.4
20	Clift 17	HU 40815 39529	Water	<1	26.1
21	Clift 18	HU 40801 39946	Water	120	0.7
22	Wester Quarff	HU 40505 35020	Water	200	na

Table 3. Shellfish Sample Results

No.	Site	Type	*E. coli* (mpn/100g)	Depth (m)
1	Uxness 1	Mussel	90	0.5
2	Uxness 2	Mussel	<20	3
3	Uxness 3	Mussel	<20	6
4	Uxness 4	Mussel	20	0.5
5	Uxness 5	Mussel	20	4
6	Uxness 6	Mussel	110	8
7	Streamsound1	Mussel	<20	4
8	Streamsound2	Mussel	20	8
9	Booth	Mussel	20	4
10	Booth	Mussel	<20	8
11	E Hogaland 1	Mussel	<20	0.5

12	E Hogaland 2	Mussel	<20	4
13	E Hogaland 3	Mussel	<20	8
14	Whal Wick 1	Mussel	<20	0.5
15	Whal Wick 2	Mussel	<20	4
16	Whal Wick 3	Mussel	20	8
17	Wester Quarff	Mussel	2400	Shore

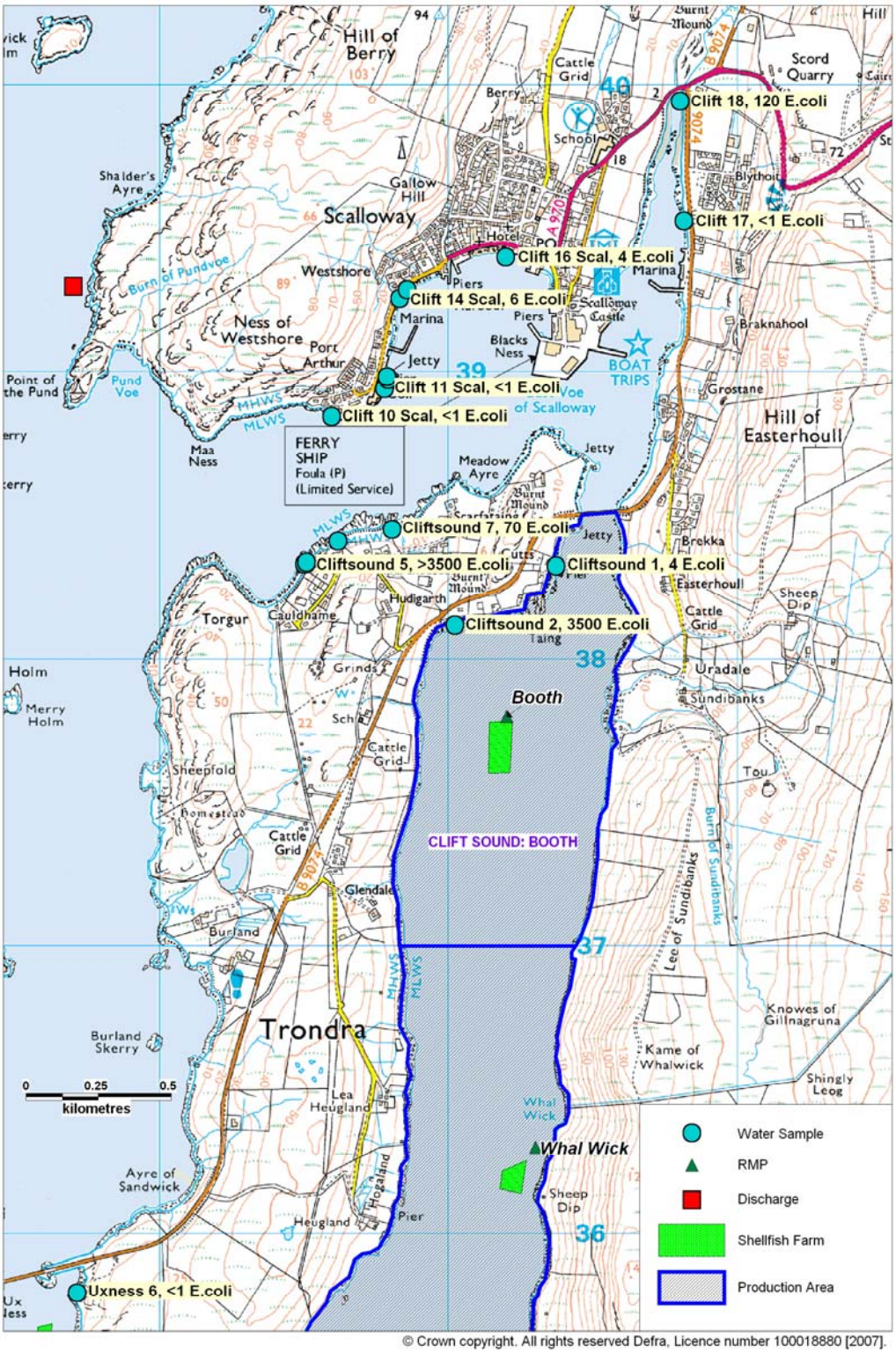

Figure 3. Clift Sound North water sample results

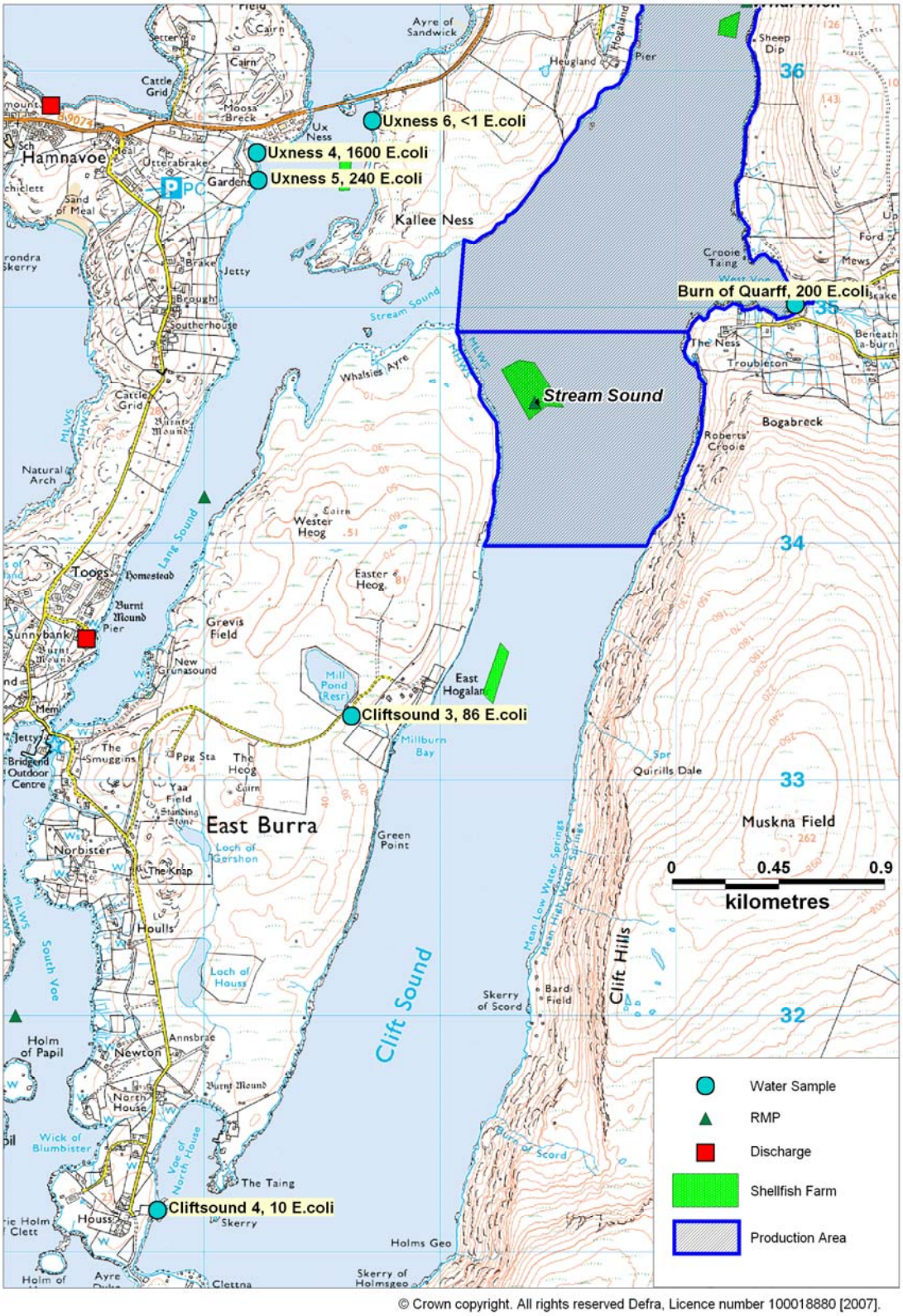

Figure 4. Clift Sound South water sample results

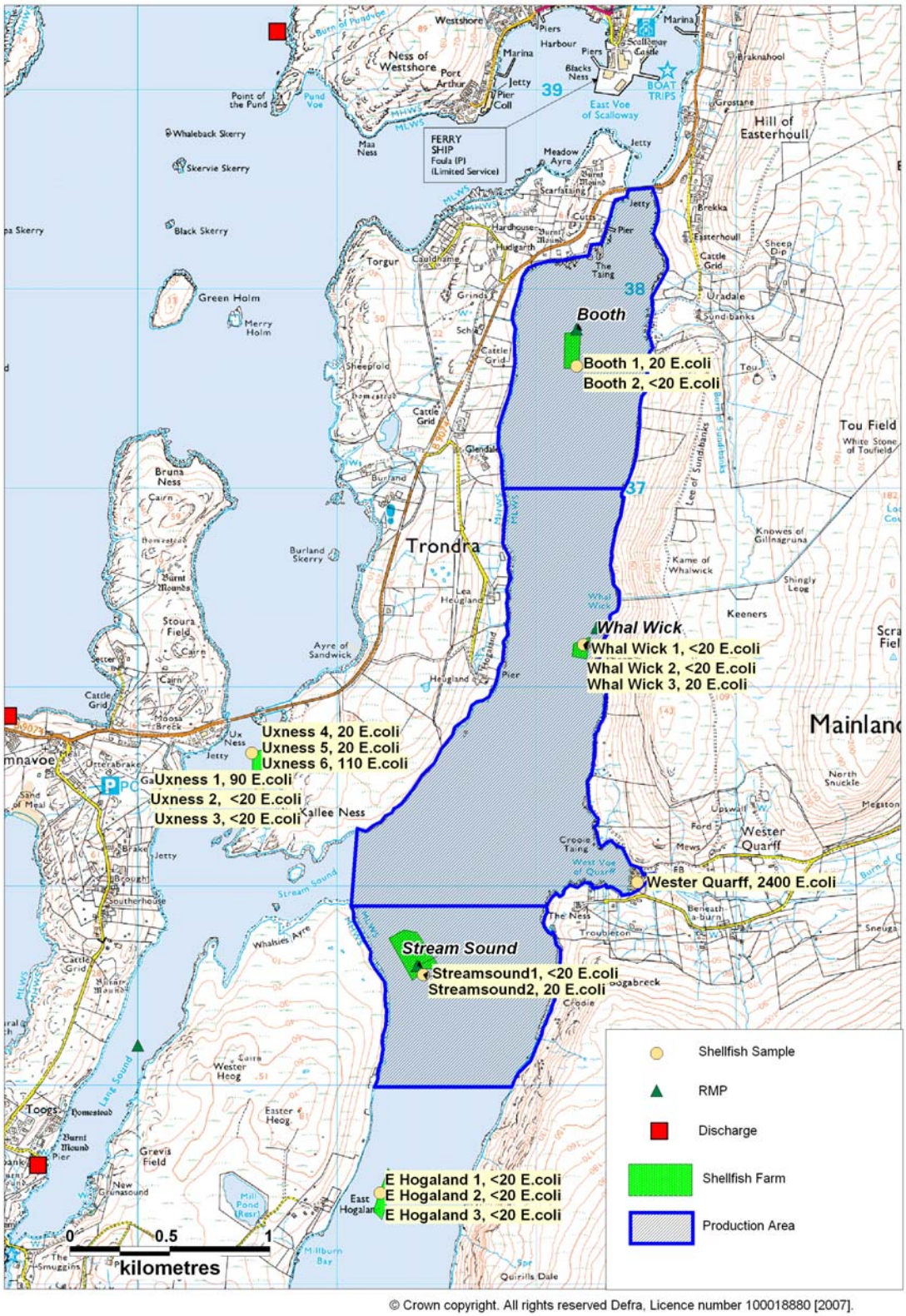

Figure 5. Clift Sound shellfish sample results

Photographs

Figure 6

Figure 7

Figure 8.

Figure 9.

Figure 10.

Figure 11.

Figure 12.

Figure 13.

Figure 14.

Figure 15.

Figure 16.

Figure 17

Figure 18.

Figure 19.

Figure 20.

Figure 21.

Figure 22.

Figure 23.

Figure 24.

Figure 25.

Figure 26.

Figure 27.

Figure 28.

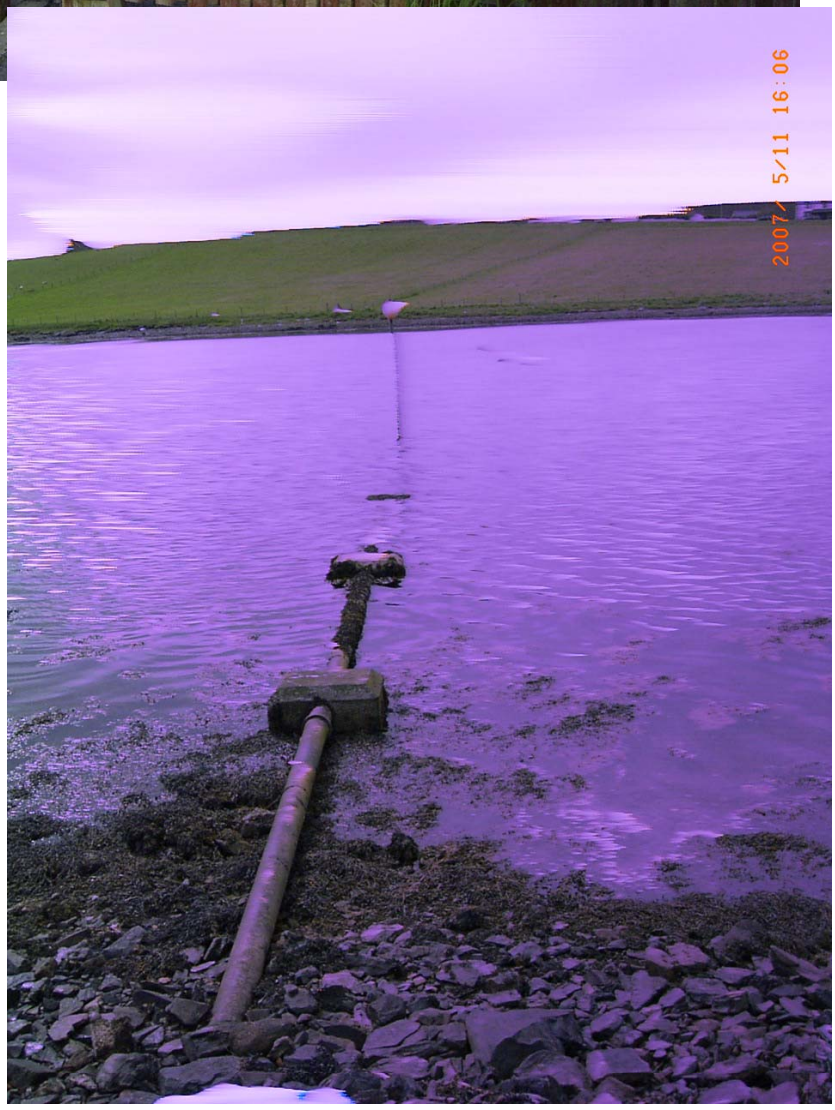

Figure 29.

Figure 30.

Figure 31.

Figure 32.

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Figure 33.

Figure 34.

Figure 35.

Figure 36.

Figure 37.

Figure 38.

Figure 39.

Figure 40.

Figure 41.

Figure 42.

Figure 43.

Sampling Plan for Clift Sound

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Clift Sound: Booth	Booth	SI 036 413 08	Common mussels	Long line	HU 4020 3777	44020	113777	20	1-3	Hand	Monthly	Shetland Islands Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
Clift Sound: Stream Sound	Stream Sound	SI 037 415 08	Common mussels	Long line	HU 3933 3475	43933	113475	20	1-3	Hand	Monthly	Shetland Islands Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
Clift Sound: Whal Wick	Whal Wick	SI 038 416 08	Common mussels	Long line	HU 4023 3616	44023	113616	20	1-3	Hand	Monthly	Shetland Islands Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
Clift Sound: East Hogaland	East Hoga-land	SI 035 414 08	Common mussels	Long line	HU 3927 3354	43927	113354	20	1-3	Hand	Monthly	Shetland Islands Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson
					HU 3920 3337	43920	113337							
Stream Sound: Uxness	Uxness	SI 373 762 08	Common mussels	Long line	HU 3859 3567	43859	113567	20	1-3	Hand	Monthly	Shetland Islands Council	Sean Williamson George Williamson Kathryn Winter Marion Slater	Dawn Manson

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

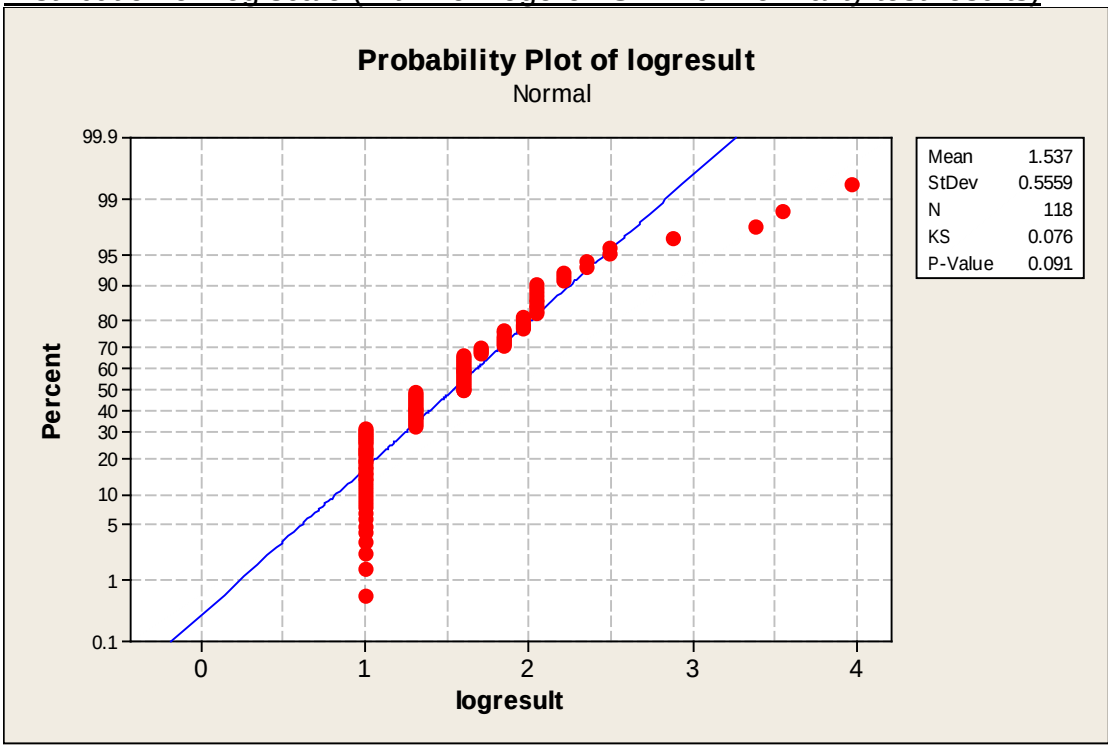
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000	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 analyses were undertaken using log transformed results (aside from the circular linear correlation) as this gives an approximately normal distribution.

Distribution on log scale (with Kolmogorov-Smirnov normality test results)



Section 11.2 ANOVA comparison of results by site

```
Source   DF      SS     MS     F      P
Site      4   1.245  0.311  1.01  0.407
Error   113  34.905  0.309
Total   117  36.150

S = 0.5558   R-Sq = 3.44%   R-Sq(adj) = 0.03%
```

```
                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N    Mean   StDev  --+---------+---------+---------+-------
Booth          27  1.4353  0.5112             (---*--)
East Hogaland   1  1.6021       *  (------------------*-----------------)
Stream Sound   44  1.6548  0.6930                  (--*-)
Ux Ness         5  1.6803  0.2513            (-------*-------)
Whal Wick      41  1.4593  0.4244             (--*--)
                                  --+---------+---------+---------+-------
                                  0.60      1.20      1.80      2.40

Pooled StDev = 0.5558
```

Section 11.4.1 ANOVA comparison of results by season

```
Source   DF      SS     MS     F      P
season    3   5.483  1.828  6.79  0.000
Error   114  30.667  0.269
```

```
Total   117  36.150

S = 0.5187   R-Sq = 15.17%   R-Sq(adj) = 12.93%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  -------+---------+---------+---------+--
1      24  1.2105  0.3115  (------*------)
2      26  1.4120  0.6518         (------*------)
3      42  1.6206  0.4953                  (----*----)
4      26  1.8295  0.5570                       (------*------)
                          -------+---------+---------+---------+--
                               1.20      1.50      1.80      2.10

Pooled StDev = 0.5187
```

Section 11.4.2 Regression analysis (log Result versus rain in previous 2 days).

```
The regression equation is
log result 2 day rain = 1.35 + 0.0275 rain 2 days


Predictor        Coef   SE Coef      T      P
Constant      1.34698   0.06645  20.27  0.000
rain 2 days  0.027512  0.007930   3.47  0.001


S = 0.469555   R-Sq = 10.5%   R-Sq(adj) = 9.6%


Analysis of Variance

Source           DF       SS      MS      F      P
Regression        1   2.6534  2.6534  12.03  0.001
Residual Error  103  22.7096  0.2205
Total           104  25.3631


Unusual Observations

     rain 2  log result
Obs    days  2 day rain     Fit  SE Fit  Residual  St Resid
  8    19.2      1.8451  1.8752  0.1138   -0.0301     -0.07 X
 31    20.4      1.9542  1.9082  0.1226    0.0460      0.10 X
 43    11.6      2.8751  1.6661  0.0634    1.2089      2.60R
 45     2.0      2.4914  1.4020  0.0560    1.0894      2.34R
 60     8.0      3.5441  1.5671  0.0483    1.9770      4.23R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.4.2 ANOVA comparison of log Result versus rainfall quartile (previous 2 days).

```
Source          DF      SS     MS     F      P
rain q 2 days    3   2.638  0.879  3.91  0.011
Error          101  22.725  0.225
Total          104  25.363

S = 0.4743   R-Sq = 10.40%   R-Sq(adj) = 7.74%


                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
```

```
Q1     27  1.2949  0.3110  (------*------)
Q2     31  1.5144  0.4768          (------*-----)
Q3     21  1.5134  0.6395        (--------*-------)
Q4     26  1.7412  0.4566                  (-------*------)
                           -----+---------+---------+---------+----
                              1.25      1.50      1.75      2.00

Pooled StDev = 0.4743
```

Section 11.4.2 Regression analysis (log Result versus rain in previous 7 days).

```
The regression equation is
log result 7 days rain = 1.18 + 0.0131 rain 7 days


Predictor        Coef   SE Coef      T      P
Constant      1.17603   0.07665  15.34  0.000
rain 7 days  0.013056  0.002434   5.37  0.000


S = 0.439979   R-Sq = 22.0%   R-Sq(adj) = 21.2%


Analysis of Variance

Source           DF       SS      MS      F      P
Regression        1   5.5720  5.5720  28.78  0.000
Residual Error  102  19.7453  0.1936
Total           103  25.3173


Unusual Observations

     rain 7   log result
Obs    days  7 days rain     Fit  SE Fit  Residual  St Resid
 16    66.0       1.9542  2.0377  0.1064   -0.0835     -0.20 X
 42    60.2       2.8751  1.9620  0.0937    0.9131      2.12R
 44    28.1       2.4914  1.5429  0.0434    0.9485      2.17R
 59    55.6       3.5441  1.9019  0.0839    1.6421      3.80R
 95    14.2       2.3424  1.3614  0.0519    0.9810      2.25R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large leverage.
```

Section 11.4.2 ANOVA comparison of log Result versus rainfall quartile (previous 7 days).

```
Source          DF      SS     MS     F      P
rain q 7 days    3   4.684  1.561  7.57  0.000
Error          100  20.633  0.206
Total          103  25.317

S = 0.4542   R-Sq = 18.50%   R-Sq(adj) = 16.06%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
Q1     15  1.1790  0.3827  (------*-------)
Q2     30  1.4571  0.4510            (-----*----)
Q3     32  1.4587  0.4125            (-----*----)
Q4     27  1.8364  0.5338                       (-----*-----)
                           --------+---------+---------+---------+-
                                 1.20      1.50      1.80      2.10
```

```
Pooled StDev = 0.4542
```

Section 11.4.3 ANOVA comparison of results by tide size

```
Source      DF      SS     MS     F      P
tide size    2   2.459  1.230  4.20  0.017
Error      115  33.691  0.293
Total      117  36.150

S = 0.5413   R-Sq = 6.80%   R-Sq(adj) = 5.18%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level    N    Mean   StDev  ----+---------+---------+---------+-----
Large   40  1.6819  0.5965                     (-------*--------)
Medium  47  1.5635  0.5463               (-------*-------)
Small   31  1.3108  0.4504  (---------*--------)
                           ----+---------+---------+---------+-----
                             1.20      1.40      1.60      1.80

Pooled StDev = 0.5413
```

Section 11.4.5 Circular linear correlation of results vs wind direction

CIRCULAR-LINEAR CORRELATION
clift circular linear correlation
Analysis begun: 11 December 2007 16:43:00

Variables (& observations)	r	p
Angles & Linear (87)	0.341	5.58E-5

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 and is not discussed in any detail in this document. 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 focus on this more detailed hydrographic assessment and describes the common methodology applied to all sites.

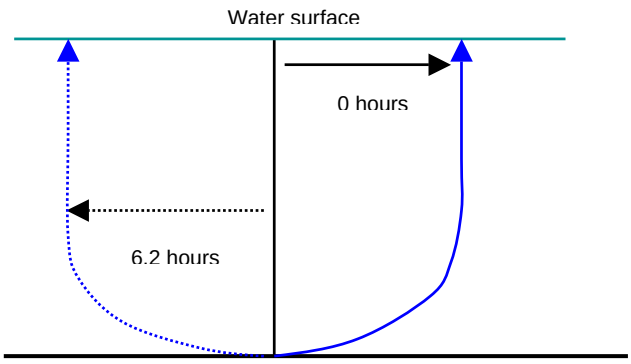
<u>Background processes</u>

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.

a)



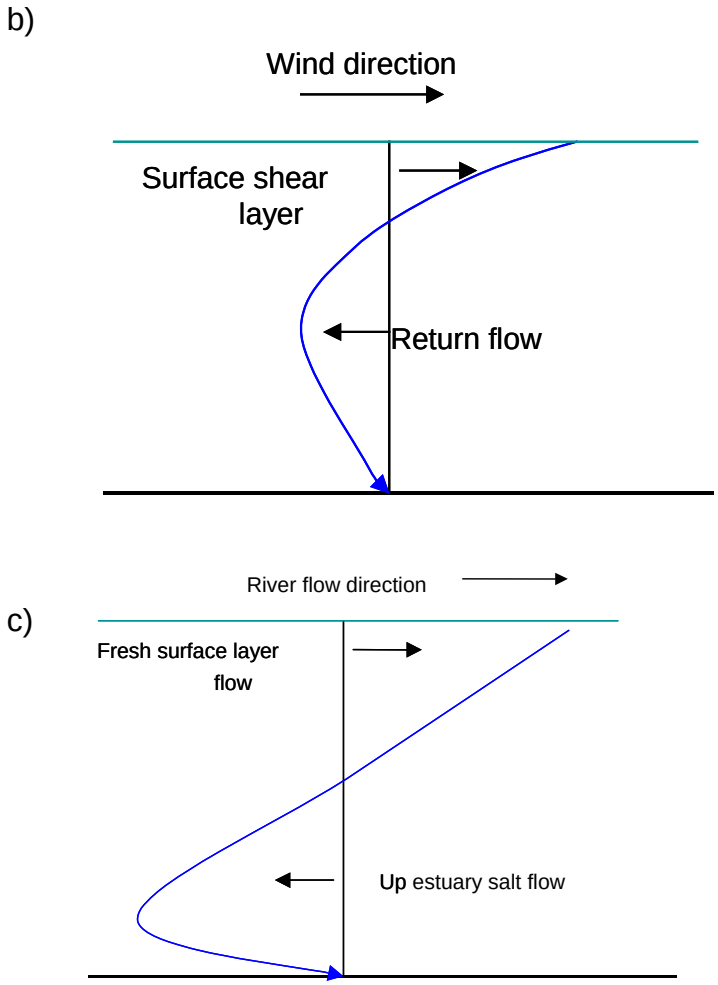


Figure 1. Typical vertical profiles for currents generated by different mechanisms. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main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

In sea lochs, currents associated with *windrows* can transport contaminated water near the shore to production areas further offshore. Windrows are often generated by winds directed along the main length of the loch. Figure 2 illustrates the water movements associated with this. As can be seen the water circulates in a series of cells 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.

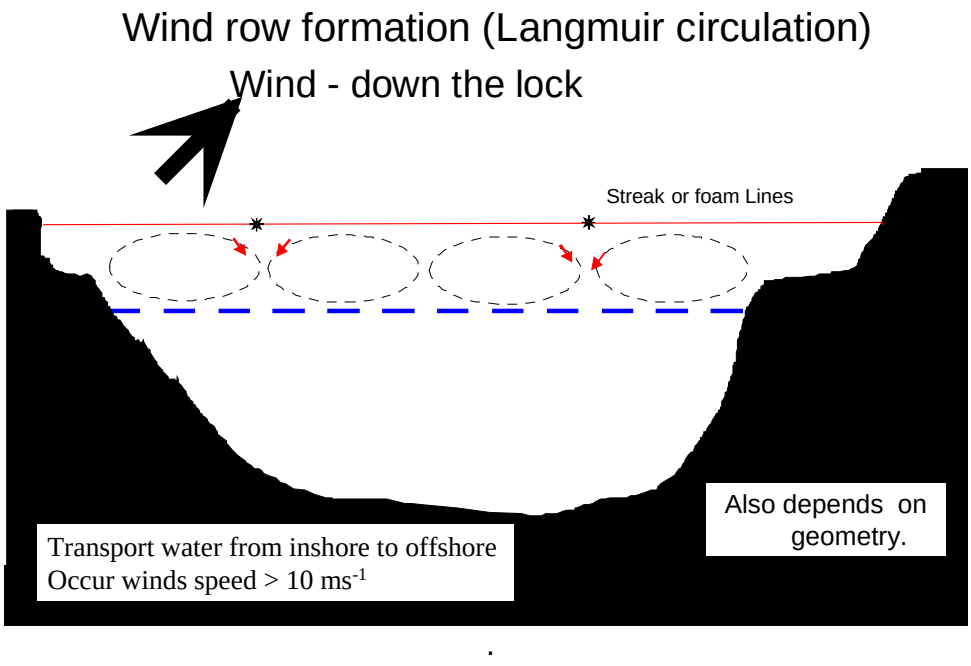


Figure 2: Schematic of wind driven 'wind row' currents. View is down the loch.The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.