Scottish Sanitary Survey Project

Sanitary Survey Report
Busta Voe Lee North
SI 327
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Report Distribution – Busta Voe Lee North

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1. General description

Busta Voe is the western arm of a larger water body divided into three parts: Busta Voe, Olna Firth, and Cole Deep. These are located on mainland Shetland (Figure 1.1). Busta Voe itself runs a length of 3km and Olna Firth approximately 5.5km. It is moderately sheltered and has a maximum depth of 39m in Busta Voe and 66m in Cole Deep.

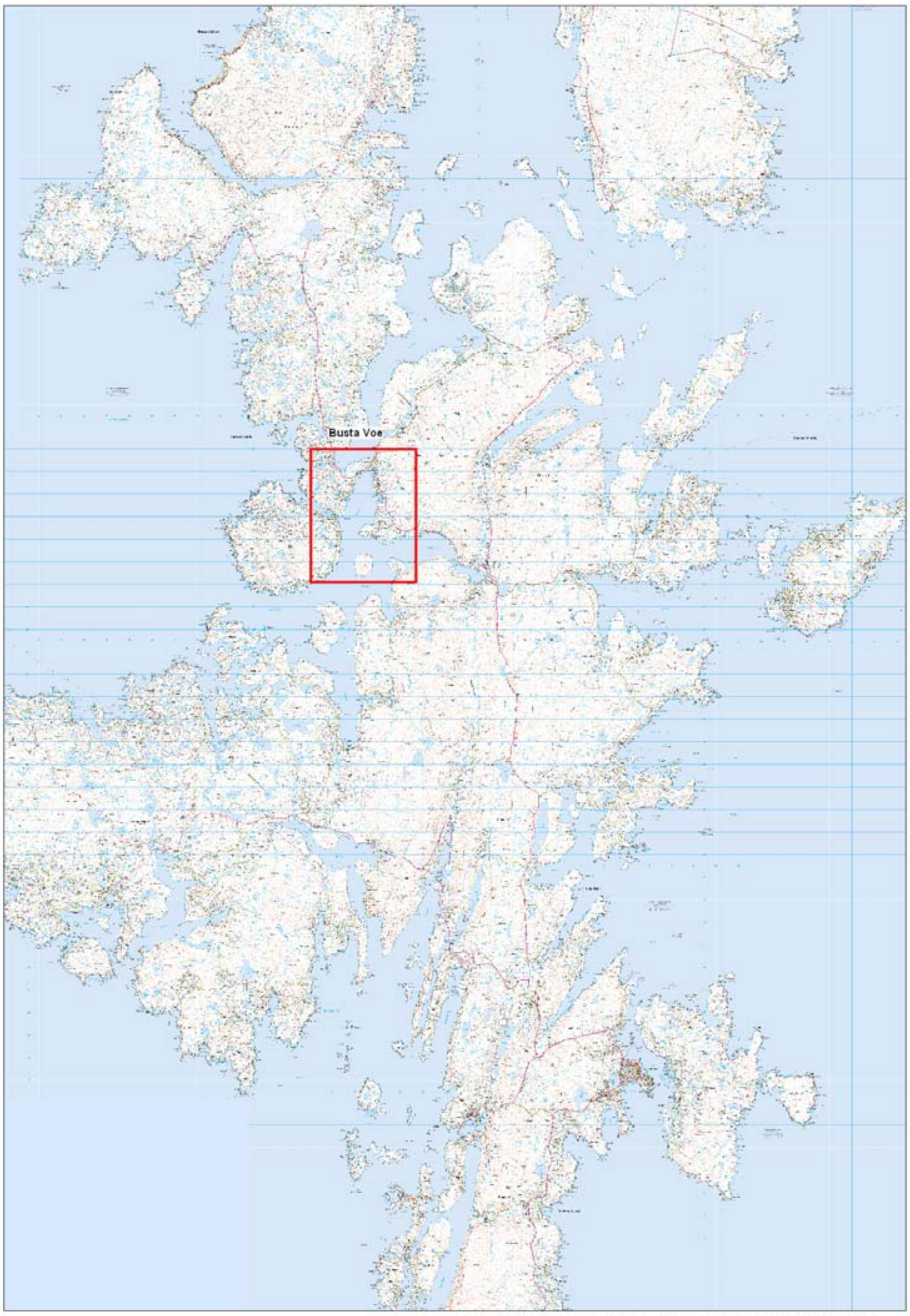


Figure 1.1 Location of Busta Voe

2. Fishery

The fishery at Busta Voe Lee North is comprised of five long line mussel (*Mytilus* sp.) farms as listed below:

Table 2.1 Mussel lines at Busta Voe

Site	SIN	Species
Hevden Ness	SI 327 755 08	Common mussels
Wetherstaness	SI 327 754 08	Common mussels
North of Linga	SI 327 753 08	Common mussels
Busta Voe	SI 327 409 08	Common mussels
Busta Voe Lee	SI 327 410 08	Common mussels

Current production area boundaries are given as the area bounded by lines drawn between HU 3614 6483 to HU 3657 6419 and from HU 3657 6419 to HU 3433 6460 and from HU 3420 6590 to HU 3420 6605 extending to MHWS. The entire production area lies within a designated Shellfish Growing Water.

Two RMPs are specified for microbiological monitoring within the production area. The nominal RMP grid references for this production area are HU 354 645 (North of Linga) and HU 257 662 (Hevden Ness). On the day of shoreline survey, it was found that a sampling bag used for *E. coli* monitoring samples was hung at grid reference HU 34845 66272 to a depth of 5 metres. Sampling bags are also in place on other sites within the production area for biotoxin monitoring.

At all 5 sites, mussels are grown on double-headed longlines to a depth of 10 metres. 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 on to the droppers from the surrounding water. The spat are then left to grow for up to three years before reaching marketable size.

At the Hevden Ness site, the harvester found the settlement rate on site had been greater on the top half of the lines last year so new lines on the site were tied up to keep the full length within the top 5 metres of water. It was thought this would allow better settlement along the full line. The lines were then fully extended in September to allow for the growth of the settled spat.

Mature mussels are harvested by stripping the attached mussels from the droppers 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.

Harvesting is done in rotation with different lines set out in different years to allow harvesting of some stock every year. The harvester at Busta Voe will harvest year round when possible in order to satisfy customer demand.

Spawning occurs in May, during which the meat yield declines substantially. Blooms of toxic algae typically occur during the summer, resulting in fishery closures during the remaining summer months. These usually clear up by September or October.

Figure 2.1 shows the relative positions of the mussel farms, Food Standard Agency Scotland designated Production Area and the Crown Estate lease areas.

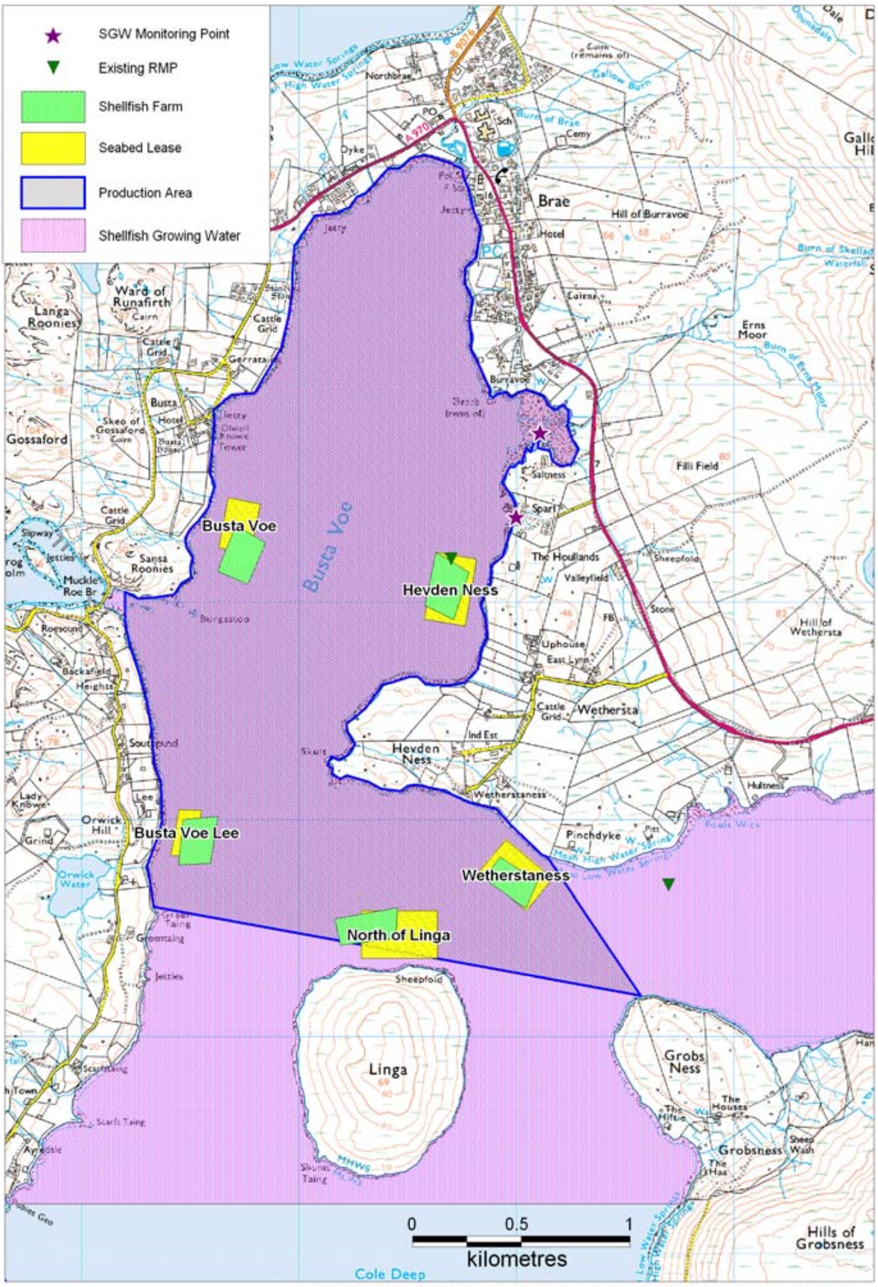
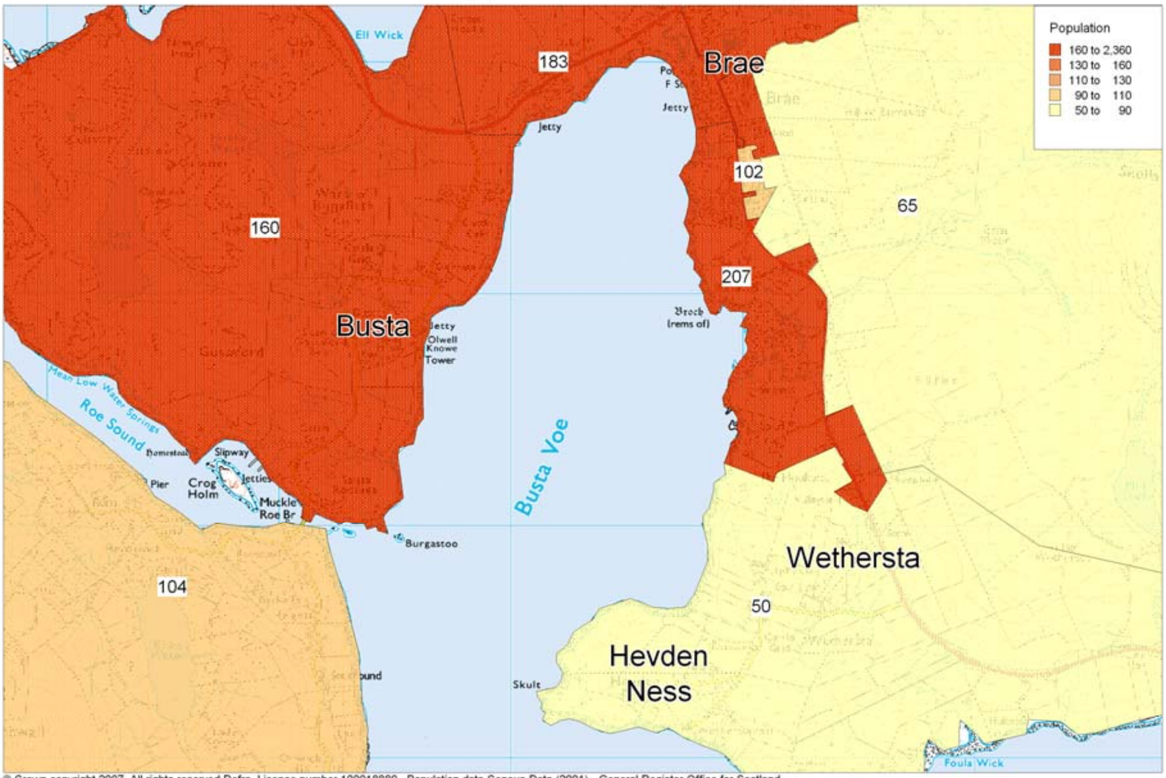


Figure 2.1 Map of the Busta Voe Lee North fishery

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 Busta Voe Lee.

Busta Voe - population in adjacent census output areas



 Population data Census Data (2001) - General Register Office for Scotland

Figure 3.1 Population map for Busta Voe Lee

The population for the seven census output areas bordering immediately on Busta Voe are:

60RD000137	50
60RD000066	65
60RD000123	102
60RD000037	104
60RD000038	160
60RD000120	183
60RD000122	207
Total	871

On the eastern side of the voe are the small settlements of Hevden Ness and Wethersa to the south and a large settlement, Brae to the north. On the western side of the voe is the settlement of Busta. Most of the population is concentrated towards the northern shore of the voe 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 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. 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 Busta Voe. They are detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

NGR	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m3/d	Consented Design PE	Q&S III Planned improvement?
HU 35706750	Sunnyside, Brae	Continuous	Septic Tank	242	1000	Y
HU 35706864	North Brae WWPS	Intermittent	Screened overflow	127	530	N
HU 403636	Voe	Continuous	Septic Tank	80		Y

No sanitary or microbiological data were available for these discharges.

A number of discharge consents were held by SEPA and are listed in Table 4.2. Two of these were for the community septic tanks at Brae and Voe while the remainder were for private tanks.

Table 4.2 Discharge consents held by SEPA

Ref No.	**NGR of discharge**	**Discharge Name**	**Discharge Type**	**Level of Treatment**	**Consented flow (DWF) m3/d**	**Consented/ design PE**	**Notes**
SD2	HU 403636	Voe	Continuous	Septic Tank	80	400	
SPC/N/60950(01)	HU 3570 6750	Sunnyside	Continuous	Septic Tank	242	1000	
CAR/R/1018415	HU 3435 6512	The Lea		Secondary?		5	Domestic
CAR/R/1018655	HU 4091 6463	Fograbrek		Septic Tank		6	Domestic

In addition, a number of septic tanks and outfall pipes were observed during the shoreline survey. These were not confirmed as active or discharging during the survey, however their locations have been included in the mapped discharges in Figure 4.1. In some cases, septic debris was noted on the shoreline which provided some evidence of a discharge. Further details can be found in the shoreline survey report in the appendix.

The discharge nearest a shellfish farm is a consented, treated discharge called The Lea (CAR/R/1018415). This discharge lies 0.17km northwest of the Busta Voe Lee mussel lines. According to the conditions of the discharge permit, effluent is treated by a package sewage treatment plant to specified levels of biochemical oxygen demand (BOD), ammoniacal nitrogen, and suspended solids (SS). No limit is specified on faecal coliforms or other indicator bacteria. The population equivalent (PE) specified is 5, indicating it is a very small discharge. If operating properly, its impact on the farm at Busta Voe Lee will be minimal.

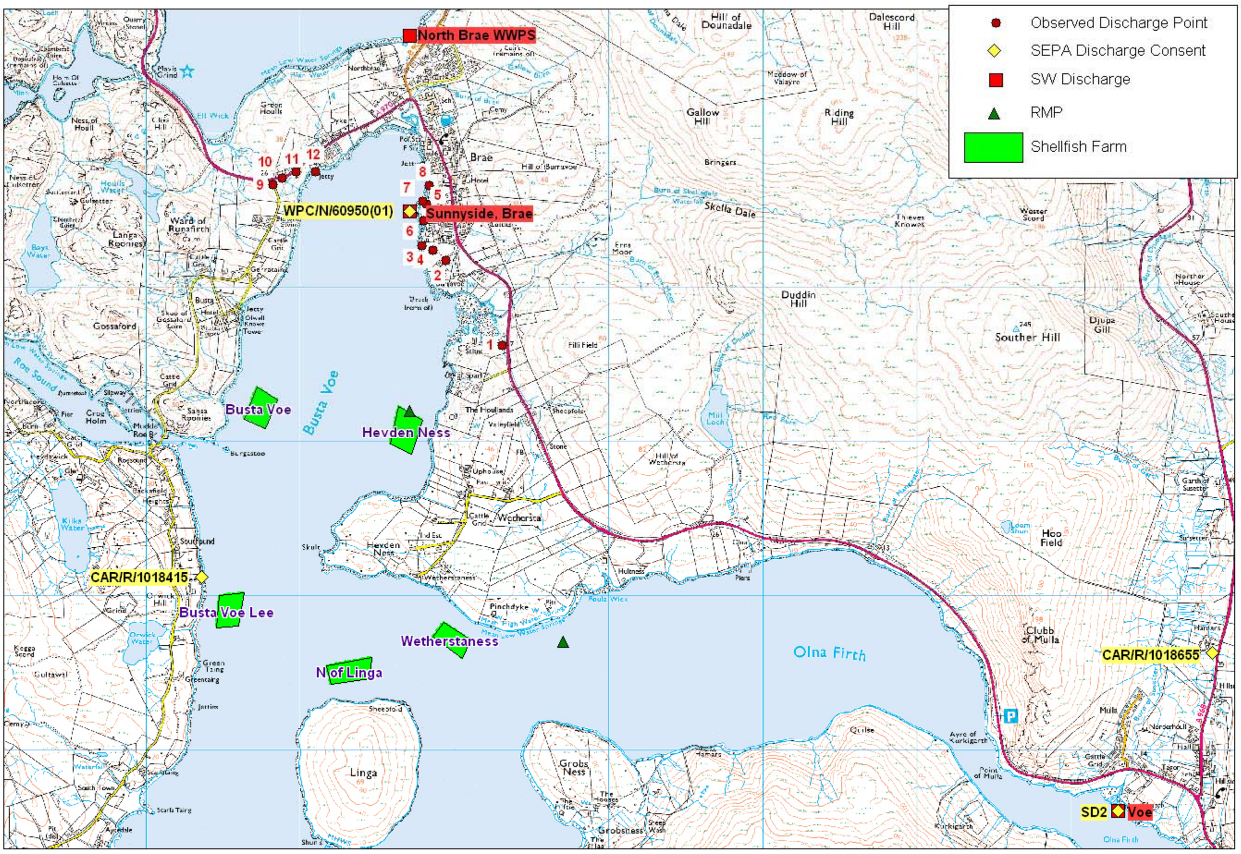


Figure 4.1 Map of discharges at Busta Voe

The majority of sewage input to the fishery is in the northern end of the Voe where there is both a large community septic tank at Brae as well as a number of smaller private tanks. These would be expected to have the greatest impact on the Busta Voe and Hevden Ness sites but could potentially impact all the sites in the production area.

An additional septic tank discharge into Olna Firth may impact the sites in the southern end of the production area, but as this discharge is both smaller and more distant than those around Brea it is likely to be a less significant source of contamination of the fisheries in Busta Voe.

Subsequent to the initial survey, in 2008 an upgrade to the existing Brae septic tank system was proposed including new tanks and a new outfall located approximately 40 metres southwest along the shoreline and 120 metres offshore. This would extend the outfall approximately 70 metres further offshore compared to the existing outfall.

5. Geology and soils

Using uncoloured soil maps (scale 1:50,000) obtained from the Macaulay Institute, component soils and their associations were investigated. 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 regosoils, calcareous gleys, 4) peaty gleys, podzols, rankers, 5) non-calcareous gleys, peaty gleys: some humic gleys, peat, 6) organic soils and 7) alluvial soils (see the glossary at the end of this section).

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% and can be classified as freely draining soils.

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. In addition, they also have a very high surface % runoff of between 48.4 – 60%, confirming that they are poorly draining.

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.

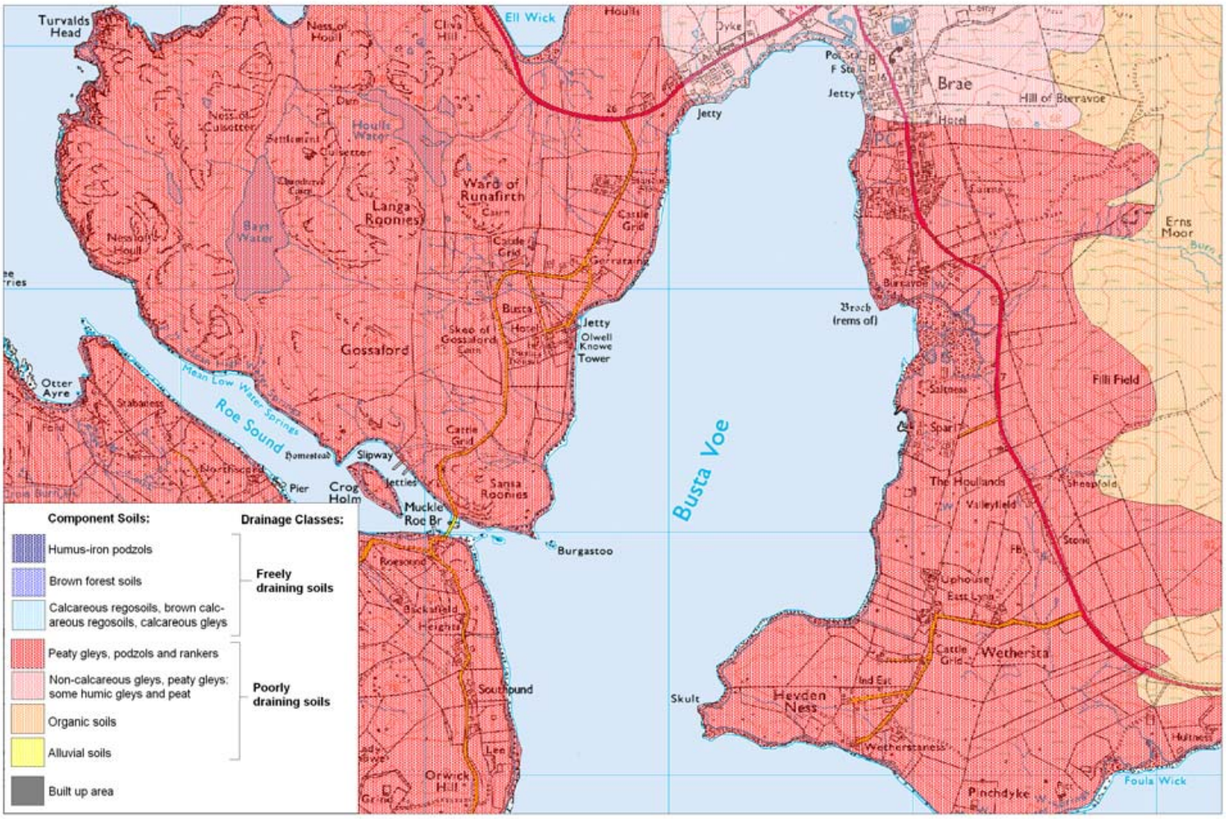


Figure 5.1 Map of component soils and drainage classes

Figure 5.1 shows a map of component soils and their associated drainage classes for the area of Busta Voe.

These component soils were broadly classed into two groups based on whether they are freely or poorly draining. Drainage classes were created based on information obtained from the Macaulay Institute website and personal communication with Dr. Alan Lilly. The humus-iron podzols are classed as freely draining soils and the remaining soil types are all classed as poorly draining soils.

There are three main types of component soils visible in this area. The most dominant is composed primarily of peaty gleys, (peaty) podzols and (peaty) rankers. This soil type dominates much of the eastern and western coast of Busta Voe.

The second important component soil types in this area, includes non-calcareous gleys, peaty gleys: some humic gleys and peat. This covers the very northern tip of Busta Voe. On the eastern coast behind the first two component soil types there is a third type: organic soils.

Understanding whether the land surrounding Busta Voe is either freely or poorly draining helps to indicate how much surface runoff and soil leaching could occur. In the peaty gleys, podzols and rankers that surround Busta Voe, surface run off is likely to be high, as they are often waterlogged and characteristically poorly draining. This provides an indication as to the potential for contamination due to diffuse pollution from livestock and whether it would be higher in certain areas.

In the case of Busta Voe, the potential for runoff contaminated with *E.coli* from animal waste is potentially very high, especially on the eastern and western coastline.

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 2000 data for the area is shown in Figure 6.1 below:

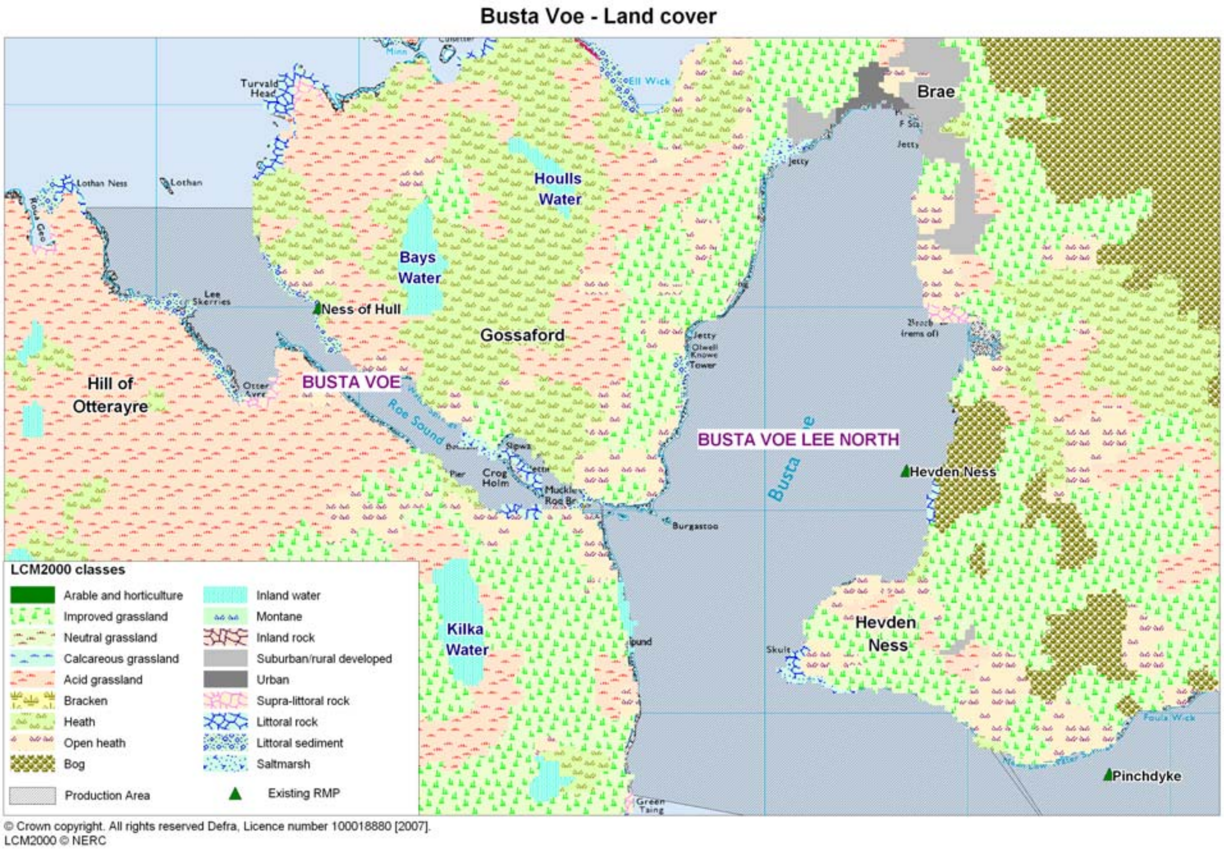


Figure 6.1 LCM2000 class data map for Busta Voe

Most of the land cover on the western side of Busta Voe Lee North is improved grassland and open heath. On the eastern side of Busta Voe Lee North it is more varied with patches of bog, acid grassland and heath amongst the improved grassland and acid grassland. On the eastern side of Busta Voe the land cover is predominantly acid grassland. On the western side of Busta Voe, it is a mix of acid grassland and heath. The are small areas of littoral rock and salt marsh at the area connecting Busta Voe to Busta Voe Lee North.

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

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), which only relates to the time of the site visit on 5-6 September 2007.

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).

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.

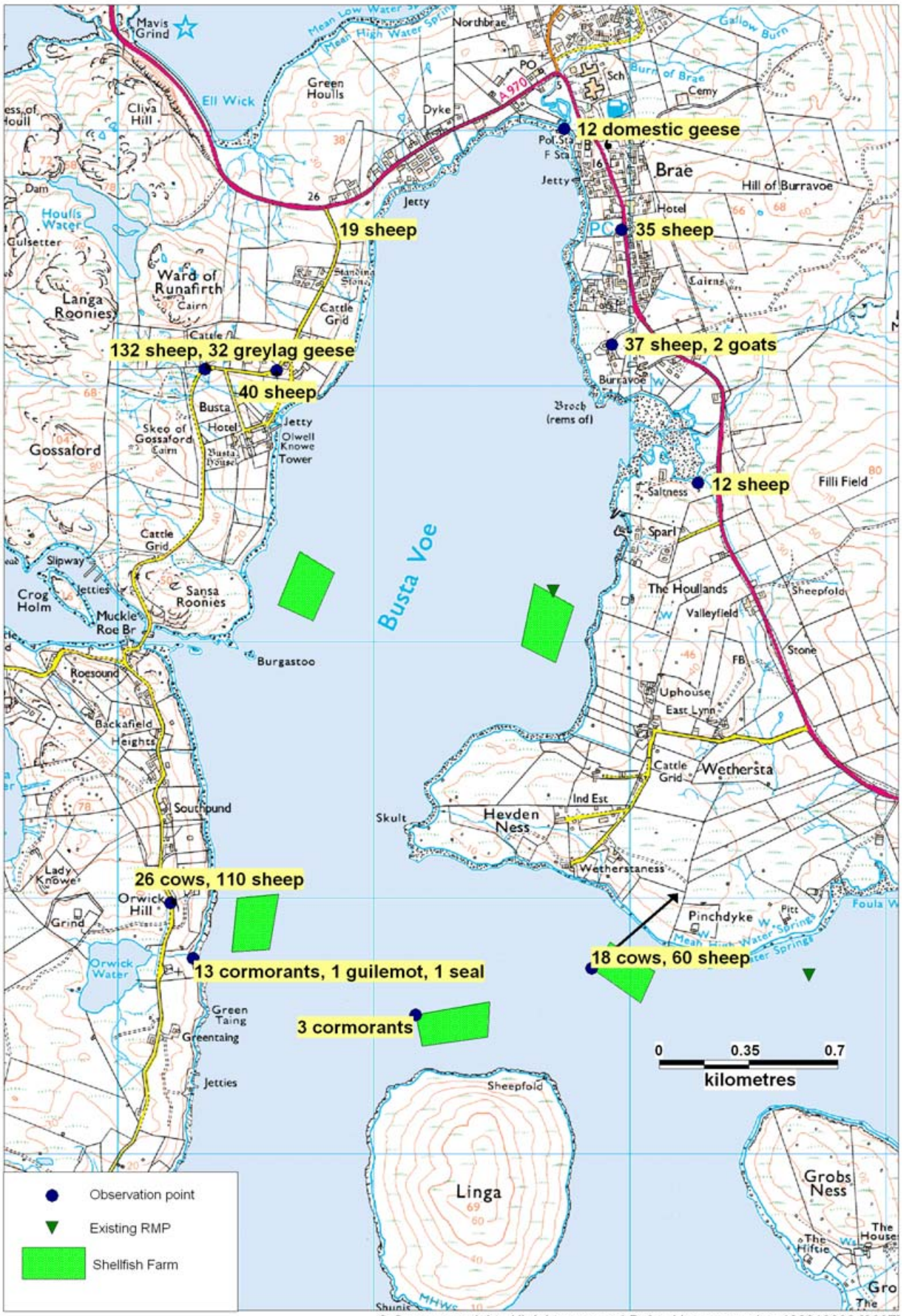


Figure 7.1 Map of animal observations at Busta Voe

8. Wildlife

8.1 Pinnipeds

Two species of pinniped (seals, sea lions, walruses) are commonly found around the coasts of Scotland: These are the European harbour, or common, seal (*Phoca vitulina vitulina*) and the grey seal (*Halichoerus grypus*). Shetland hosts significant populations of both species.

The amount of *E. coli* and other faecal indicator bacteria contained in seal faeces has been reported as being similar to that found in raw sewage, with counts showing up to 1.21 x 10^4 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 Busta Voe or the adjacent Olna Firth, one seal was recorded during the shoreline survey.

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 *E. coli*. 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 area around Busta Voe is not particularly well suited to the cliff nesting bird species. Nothern Fulmars, Great Skuas and various gulls have all been recorded as breeding in the area. The population of Skuas breeding at Olna Firth is small (<10 pairs) and reported to be declining. Northern Fullmars, and the common gull species breed ubiquitously around the island. Their specific distribution around Busta Voe was not available. It is therefore assumed that their distribution will be roughly even and not relevant to assessing the location of a representative monitoring point (RMP) for the Busta Voe Lee North production area.

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 nearest the runoff.

8.4 Other

There is a significant population of European Otters (*Lutra lutra*) present in Shetland.

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 Busta Voe 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. Greylag geese (32) were observed in a field during the shoreline survey. Geese tend to pass through during migrations but do not linger in very large numbers as they do further south. Eider ducks feed on the mussel lines and are present, sometimes groups of 100 or more, throughout the year. Waterfowl impact on the fisheries in Busta Voe is likely to be mostly that of Eider ducks feeding on the mussel lines.

Wildlife impact generally to the fisheries is likely to be minimal compared to the impact of diffuse pollution due to livestock. Wildlife impacts are further likely to be very localised and unpredictable. While some wildlife 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 Lerwick, approximately 26 km to the south 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 broadly similar but not identical to those on Busta Voe Lee North and surrounding land due to their proximity, but may differ on any given day. It is possible the local topography may result in differing wind patterns (Lerwick is on the east coast, Busta Voe Lee North 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 Busta Voe Lee North.

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 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 *.

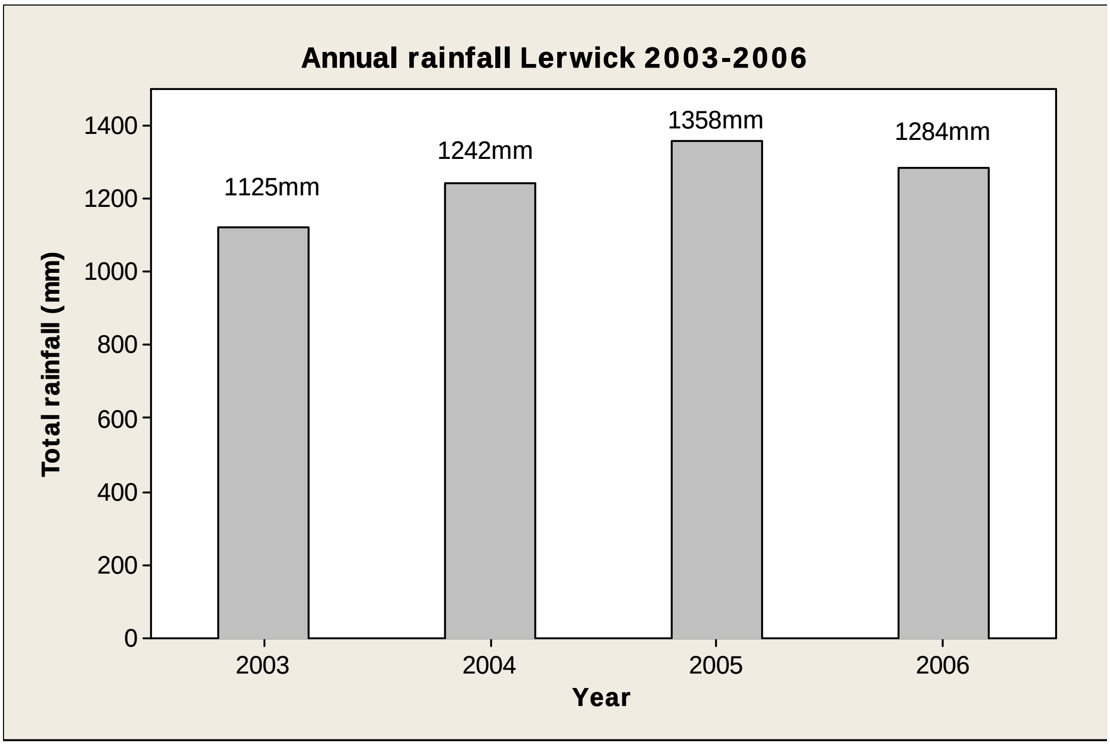


Figure 9.1 Bar chart of annual rainfall at Lerwick 2003-2006

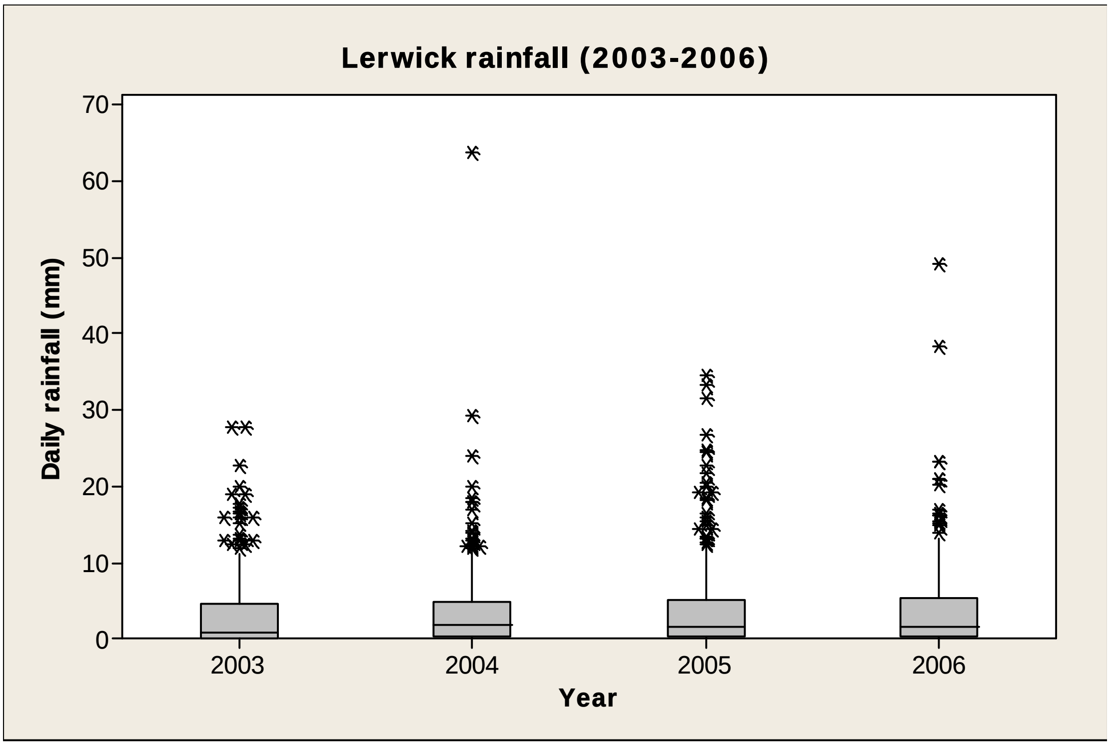


Figure 9.2 Boxplot of Lerwick rainfall 2003-2006

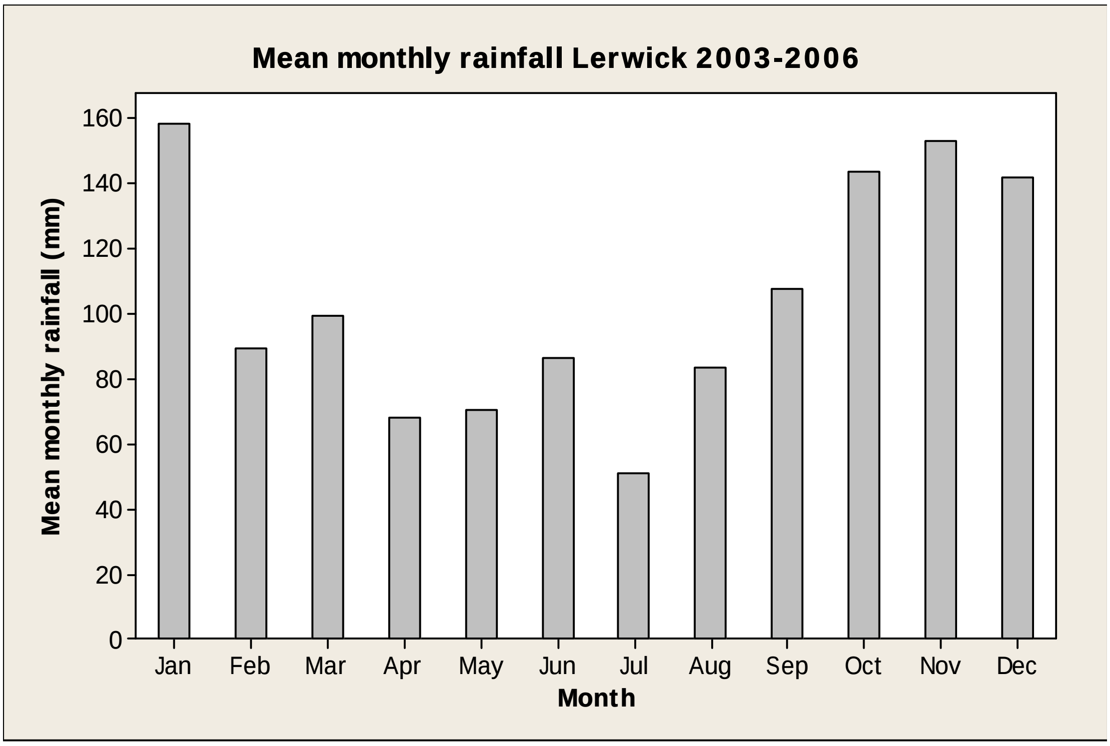


Figure 9.3 Mean monthly rainfall at Lerwick 2003-2006

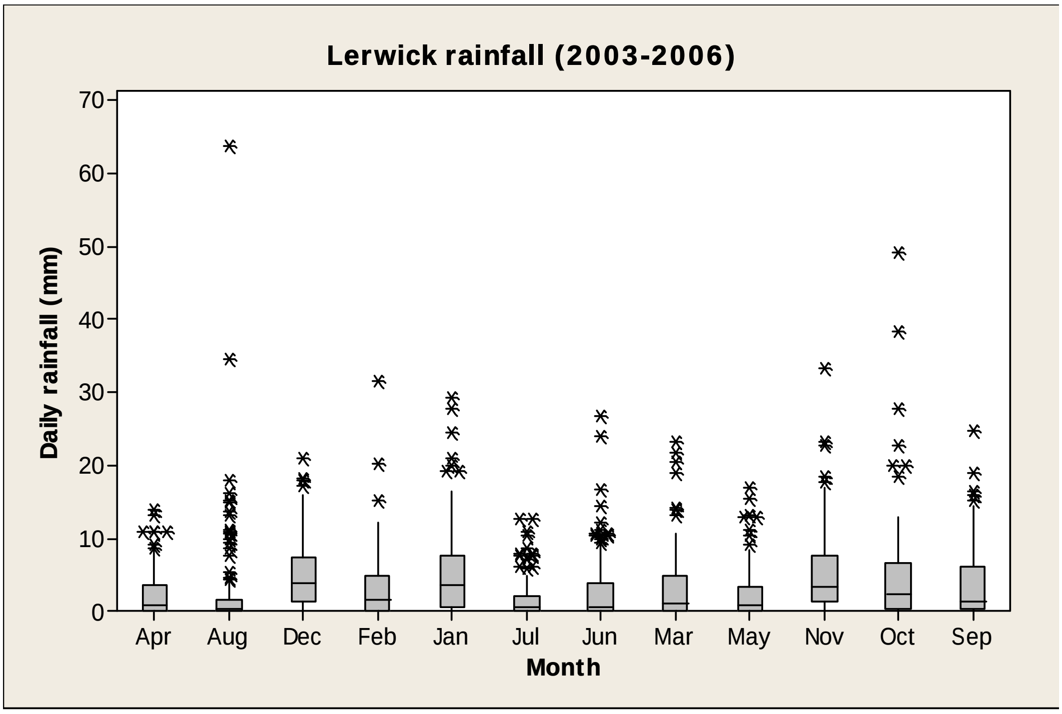


Figure 9.4 Boxplot of rainfall at Lerwick by month 2003-2006

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 9.1 (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 Comparison of Lerwick mean monthly rainfall with 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.

WIND ROSE FOR LERWICK
N.G.R: 4453E 11396N ALTITUDE: 82 metres a.m.s.l.

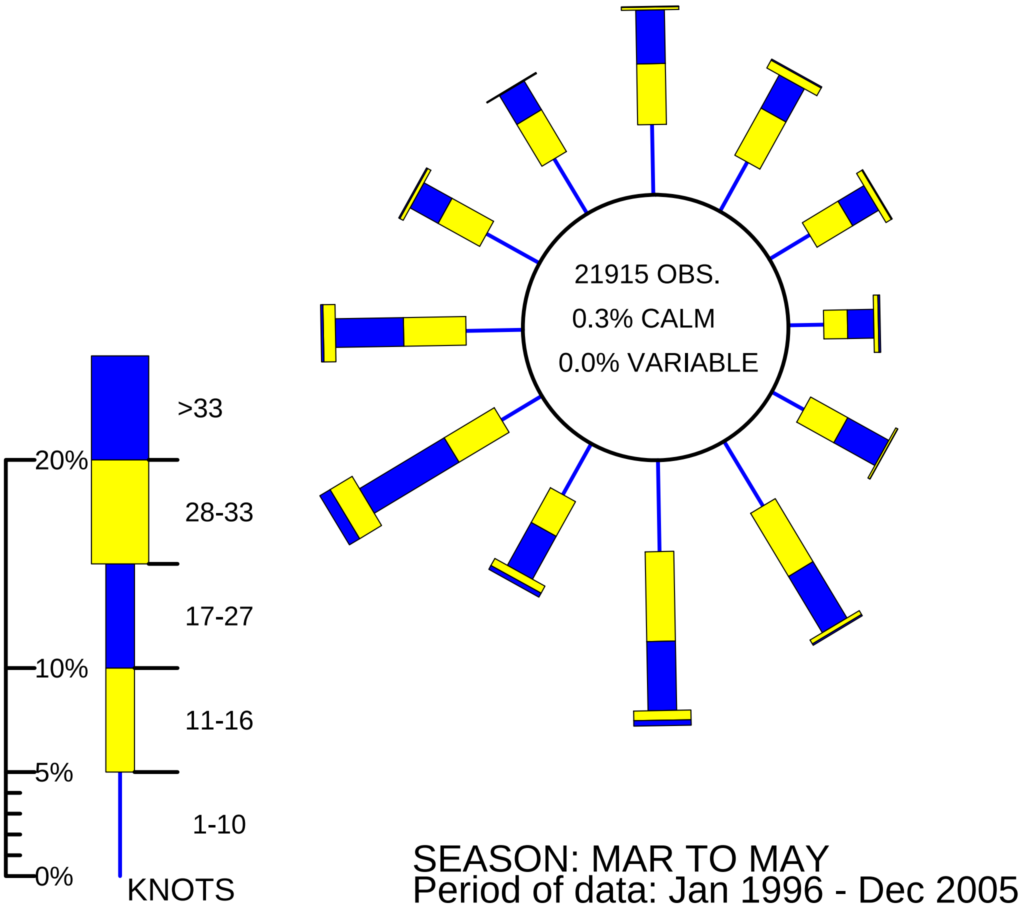


Figure 9.5 Wind rose for Lerwick (March to May)

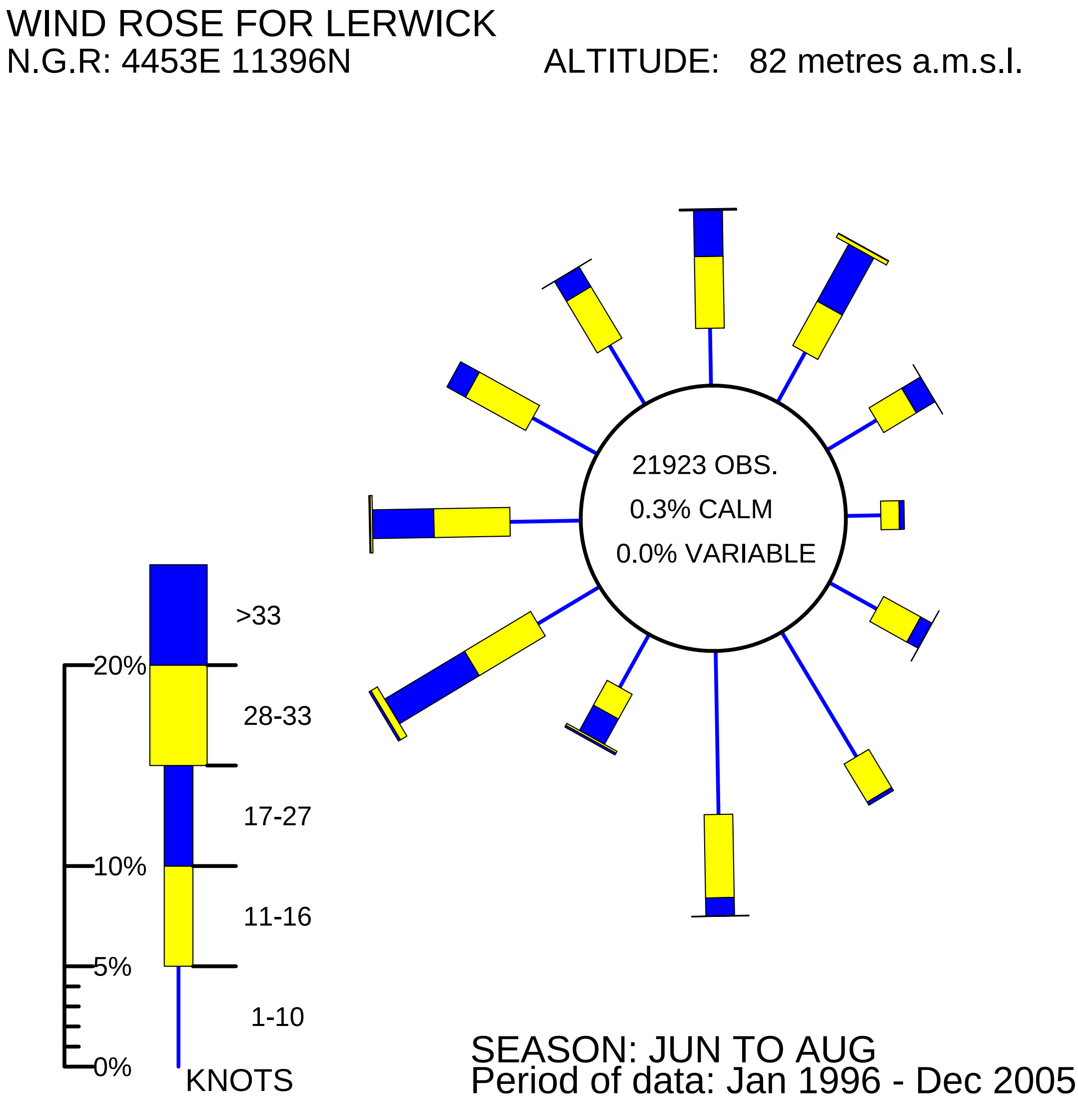


Figure 9.6 Wind rose for Lerwick (June to August)

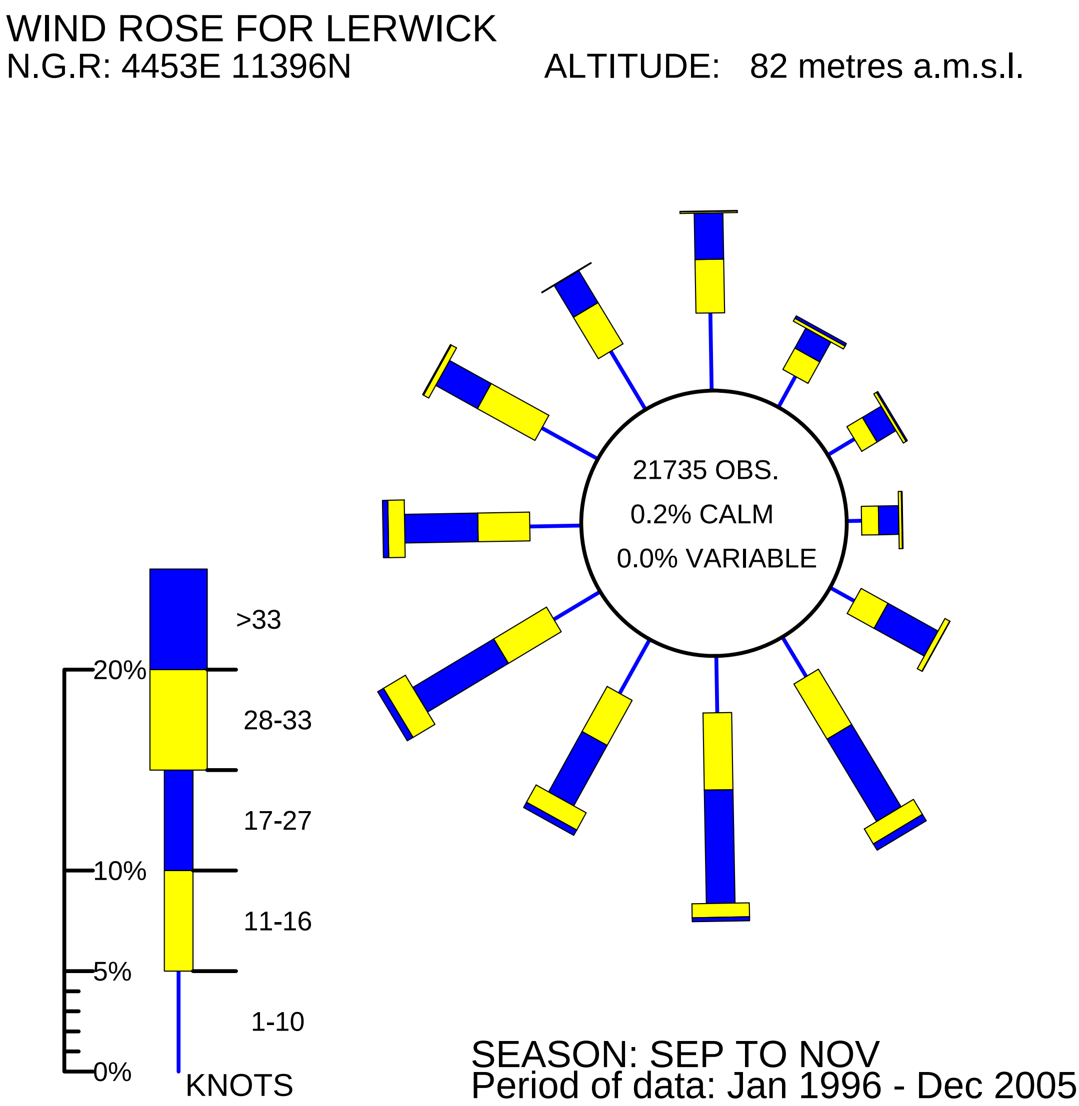


Figure 9.7 Wind rose for Lerwick (September to November)

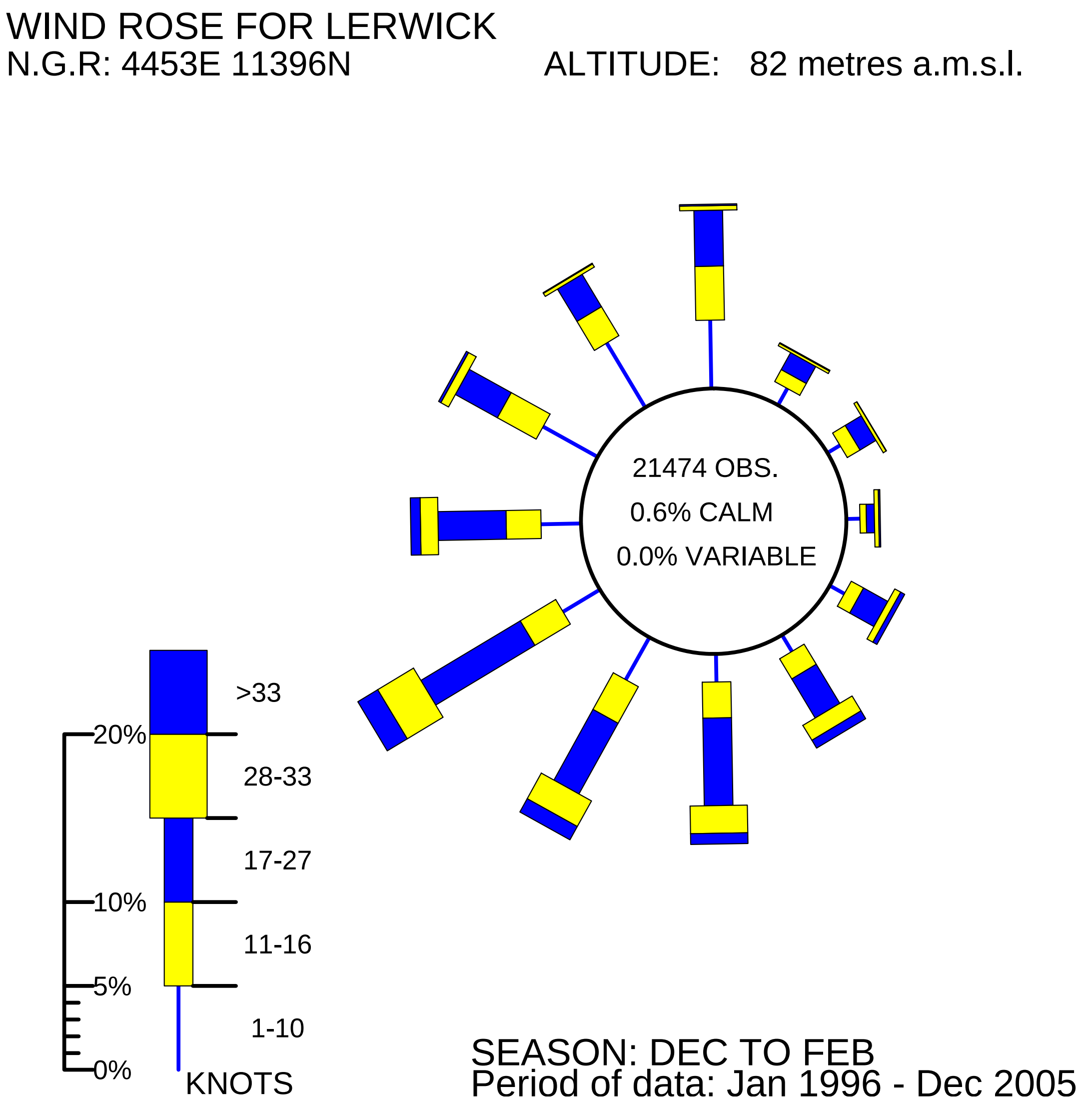


Figure 9.8 Wind rose for Lerwick (December to February)

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. Busta Voe Lee North faces south but is protected from Atlantic swells by islands and the mainland further south. These, and the surrounding low hills will also offer some protection from winds.

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

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 13). Winds typically drive surface water at about 3% of the wind speed (Brown, 1991) so a gale force wind (34 knots or 17.2 m/s) would drive a surface water current of about 1 knot or 0.5 m/s. These surface water currents create return currents, the path of which will depend on wind direction and local bathymetry. Strong winter winds will increase the circulation of water and hence dilution of contamination from point sources within the voe. A northerly wind will carry any contamination originating from the settlement of Brae towards the production sites.

10. Current and Historical Classification Status

The area has been classified for production since before 2001. The name of the production area, and its boundaries were changed to its' present form in 2005. Prior to 2005, the production area was called Busta Voe and Linga Voe (SI0301). The classification history is presented in Table 10.1. Currently, the area is classified as a year round A. The area contains 5 active farms all growing rope mussels. A map of the current production area is presented in Figure 10.1.

Table 10.1 - Classification history

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2001	A	A	A	A	A	A	A	A	B	B	A	A
2002	A	A	A	A	A	A	A	A	A	A	A	A
2003	A	A	A	A	A	A	A	A	A	A	A	A
2004	A	A	A	A	A	B	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	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 current Busta Voe Lee North production area

11. Historical *E. coli* Data

11.1 Validation of historical data

The results for all mussel samples taken from Busta Voe Lee North 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. No samples were rejected on the basis of geographical discrepancies. In the 44 instances where the result was reported as <20, it was assigned a nominal value of 10, and in the 2 instances the result was reported as >18000, it was assigned a nominal value of 36000 for the determination of the geometric mean and graphical presentation. One sample with an analysis date of 3 days post collection was rejected. 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 five sites within the production area as shown on Figure 11.1 and in Table 11.1. Where more than one location has been sampled for a particular site, the locations have been within a few hundred meters of each other, and have all been within or close to the appropriate Crown Estates lease boundaries. The charts summarising historical results presented on Figure 11.1 have combined all results from different locations for each site.

Table 11.1 - Summary of results from Busta Voe Lee North

Sampling summary						
Production area	Busta Voe Lee North	Busta Voe Lee North	Busta Voe Lee North	Busta Voe Lee North	Busta Voe Lee North	Busta Voe Lee North
Site	All sites combined	Busta Voe	Busta Voe Lee	Hevden Ness	North of Linga	Wetherstaness
Species	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels	Common mussels
SIN	SI327	SI32740908	SI32741008	SI32775508	SI32775308	SI32775408
Location	All sites (5) and locations (9)	HU347663, HU347667, HU347665, HU347662	HU344649, HU346649	HU357662	HU354645	HU359648
Total no of samples	202	90	90	8	7	7
No. 1999	16	8	8	0	0	0
No. 2000	19	9	10	0	0	0
No. 2001	24	12	12	0	0	0
No. 2002	24	12	12	0	0	0
No. 2003	26	13	13	0	0	0
No. 2004	23	12	11	0	0	0
No. 2005	24	12	12	0	0	0
No. 2006	46	12	12	8	7	7
Results Summary						
Minimum	<20	<20	<20	<20	<20	<20
Maximum	>18000	5400	>18000	>18000	1100	1100
Median	40	40	40	330	160	220
Geometric mean	55.3	50.6	46.2	260	157	106
90 percentile	500	310	419	11300	1010	740
95 percentile	748	415	610	23700	1060	920
No. exceeding 230/100g	34 (17%)	11(12%)	13 (14%)	4 (50%)	3 (43%)	3 (43%)
No. exceeding 1000/100g	8 (4%)	2 (2%)	3 (3%)	1 (13%)	1 (14%)	1 (14%)
No. exceeding 4600/100g	3 (1%)	1 (1%)	1 (1%)	1 (13%)	0 (0%)	0 (0%)
No. exceeding 18000/100g	2 (1%)	0 (0%)	1 (1%)	1 (13%)	0 (0%)	0 (0%)

A comparison of results reveals a significant difference between the sites (one way ANOVA, p=0.006, Appendix), with Hevden Ness yielding higher results than Busta Voe and Busta Voe Lee (Table 11.2, Figure 11.2). On 6 occasions in 2006 all 5 sites were sampled on the same day. No significant difference between results obtained for the different sites was found when they were compared (2-way ANOVA, p=0.242, Appendix). Post ANOVA tests can be found in the Appendix.

Table 11.2 - Comparison of results (*E. coli* mpn/100g) obtained from the 5 sites

	Busta Voe		Busta Voe Lee		Hevden Ness		North of Linga		Wetherstaness	
	Geometric mean	No.	Geometric mean	No.	Geometric mean	No.	Geometric mean	No.	Geometric mean	No.
1999	60.8	8	69.5	8	-	0	-	0	-	0
2000	34.1	9	103	10	-	0	-	0	-	0
2001	48.7	12	30.7	12	-	0	-	0	-	0
2002	35.2	12	21.9	12	-	0	-	0	-	0
2003	112	13	49.2	13	-	0	-	0	-	0
2004	47.7	12	24.4	11	-	0	-	0	-	0
2005	57.1	12	53.5	12	-	0	-	0	-	0
2006	35.7	12	83.3	12	260	8	157	7	106	7

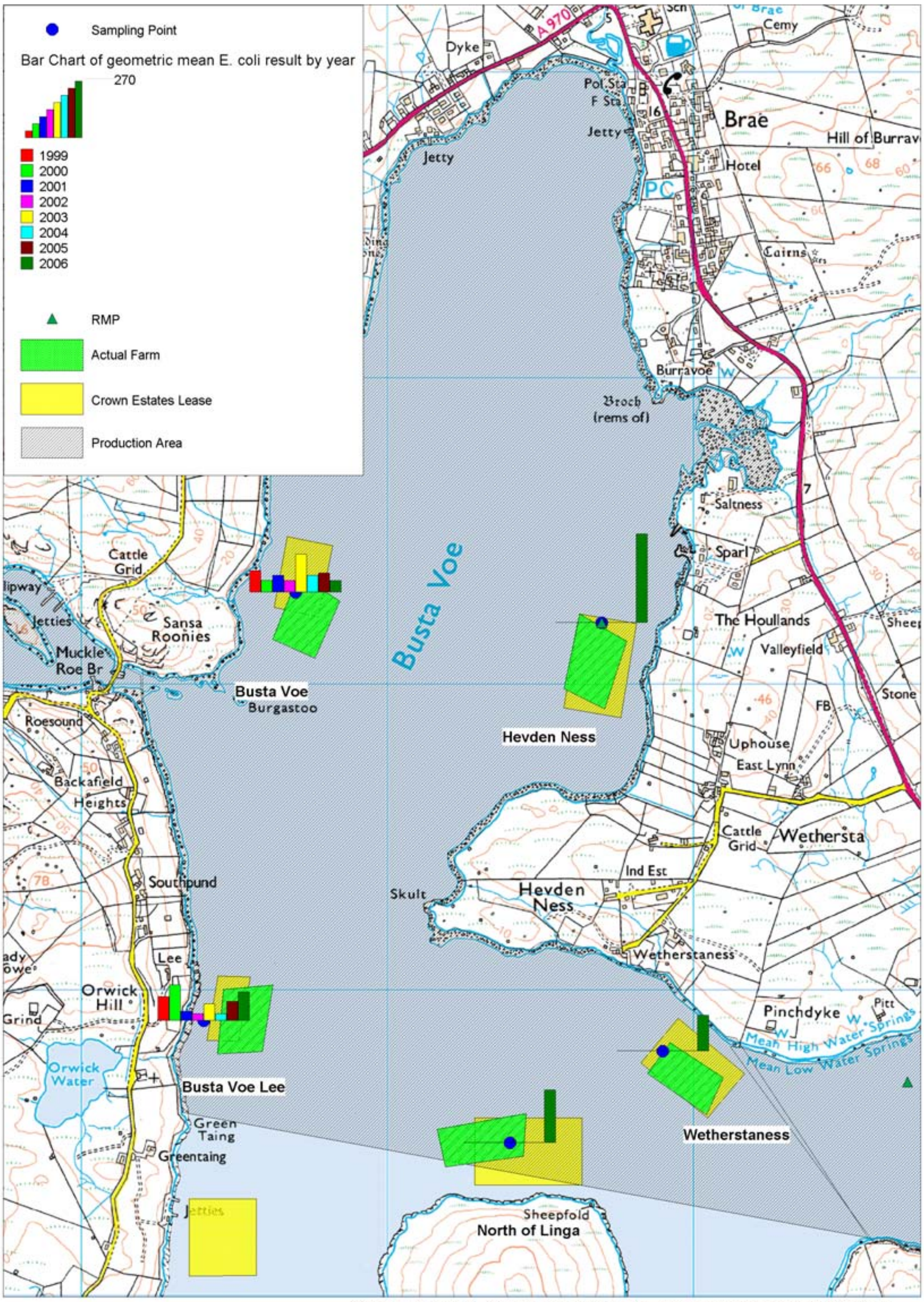


Figure 11.1 - Geometric mean result by year and site

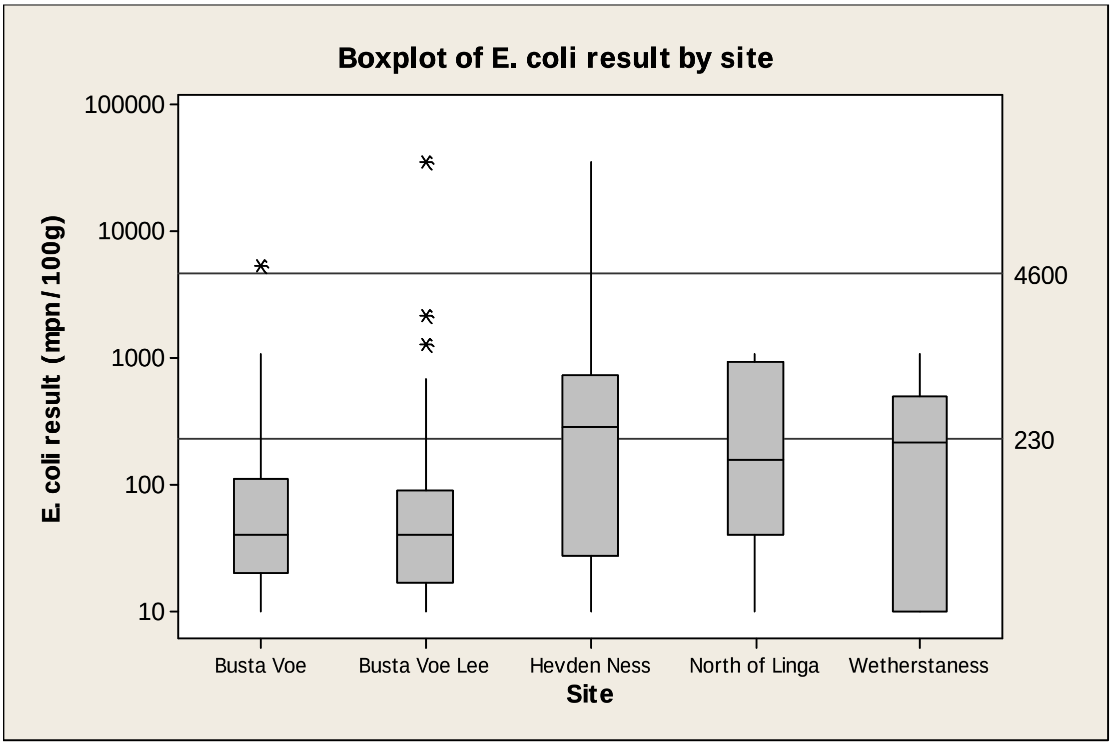


Figure 11.2 Boxplot of shellfish *E. coli* result by site

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 Busta Voe Lee North. 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 lowess 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).

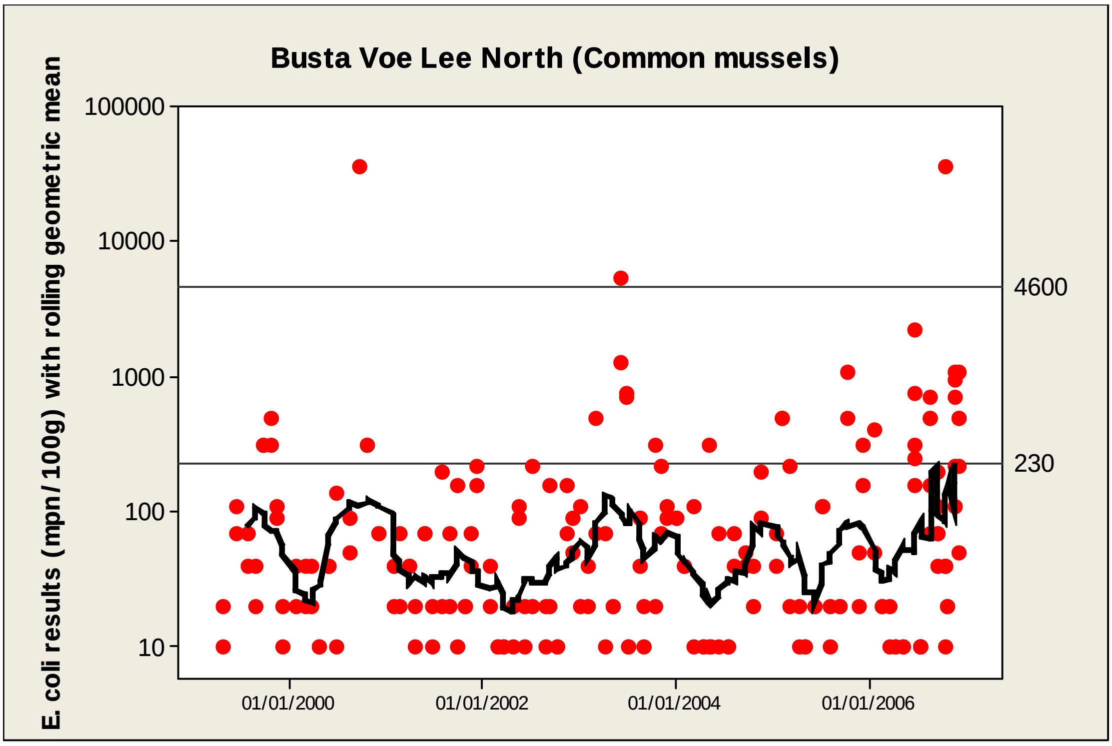


Figure 11.3 - Scatterplot of shellfish *E. coli* result by date with rolling geometric mean

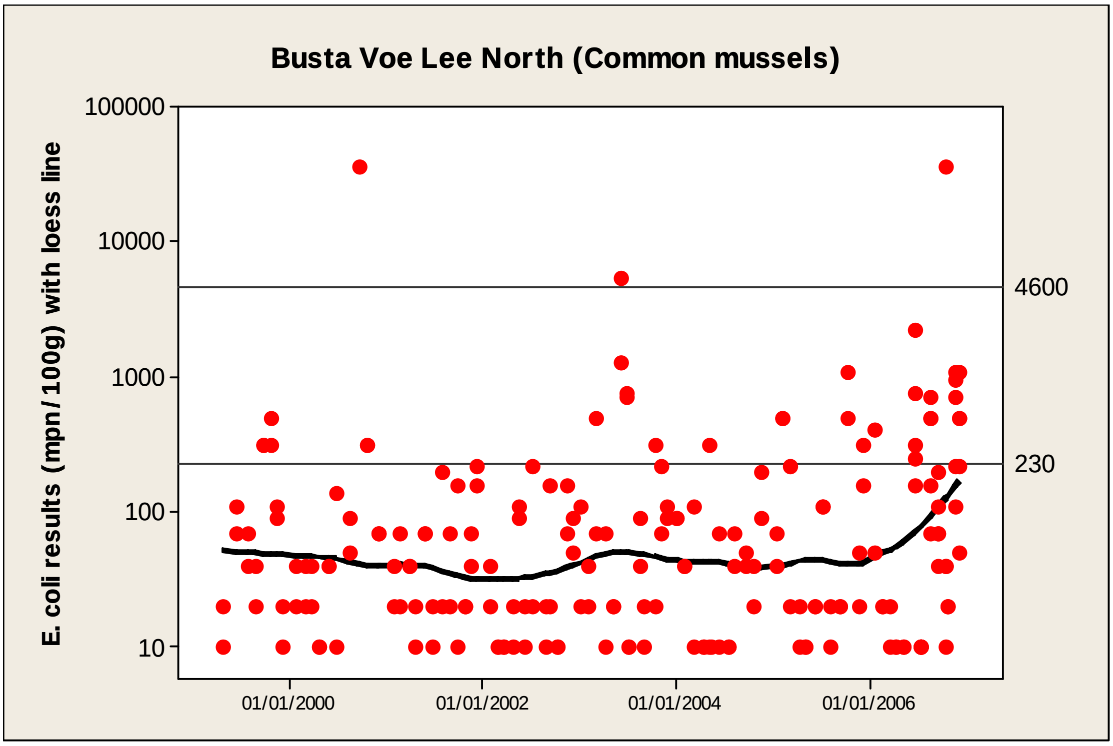


Figure 11.4 - Scatterplot of shellfish *E. coli* result by date with loess smoother

A slight increase in contamination in 2006 can be visualised in Figures 11.3 and 11.4 although this may be attributable to the higher results obtained for the new sites for which monitoring started in 2006.

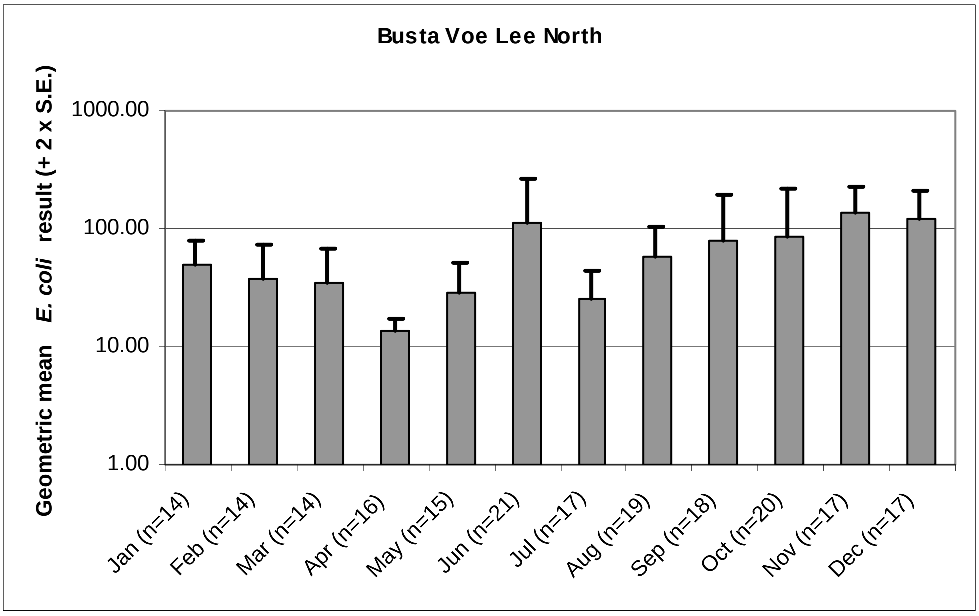


Figure 11.5 - Geometric mean shellfish *E.coli* result by month

Highest mean results were seen in June, November and December.

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 202 samples taken from Busta Voe Lee North from the start of sampling in 1999 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).

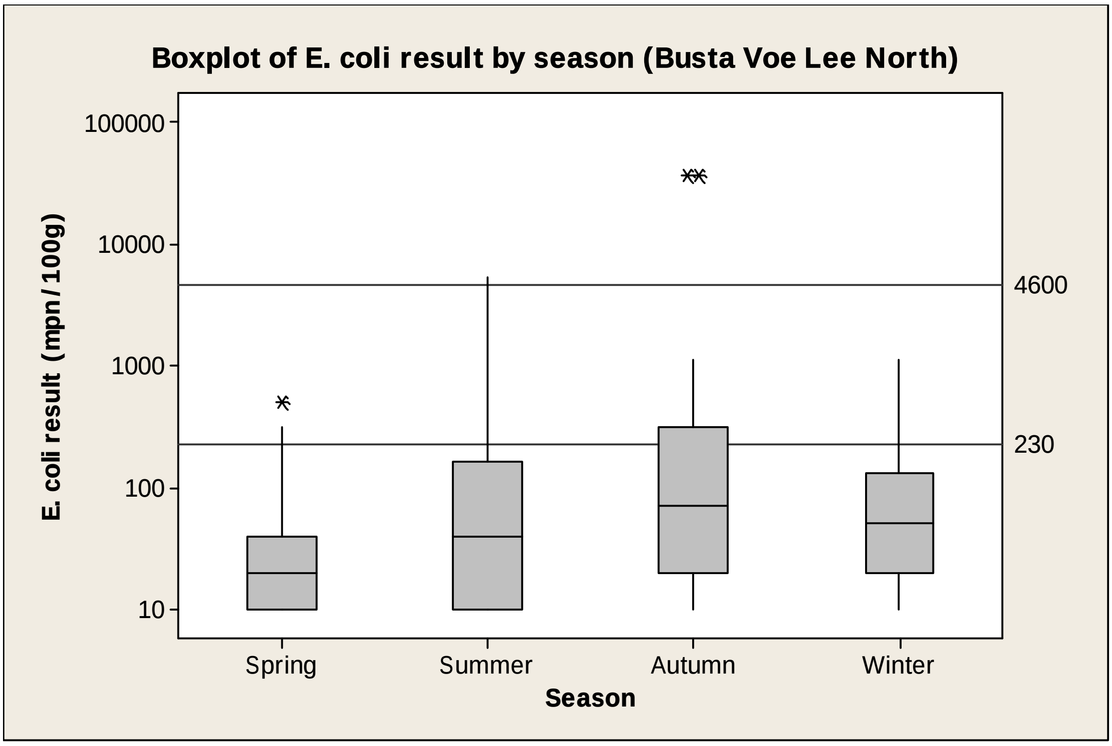


Figure 11.6 Boxplot of shellfish *E.coli* result by season

A seasonal effect was observed, with lowest results in the spring compared to all other seasons. The seasonal effect is statistically significant (One-way ANOVA, p=0.000, Appendix). This was confirmed using post ANOVA tests as found in the Appendix.

11.4.2 Analysis of results by recent rainfall

The nearest weather station is Lerwick, approximately 9.5 km to the south east of the production area for which uninterrupted rainfall data is available for 2003-2006 inclusive.

The coefficient of determination was calculated for *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).

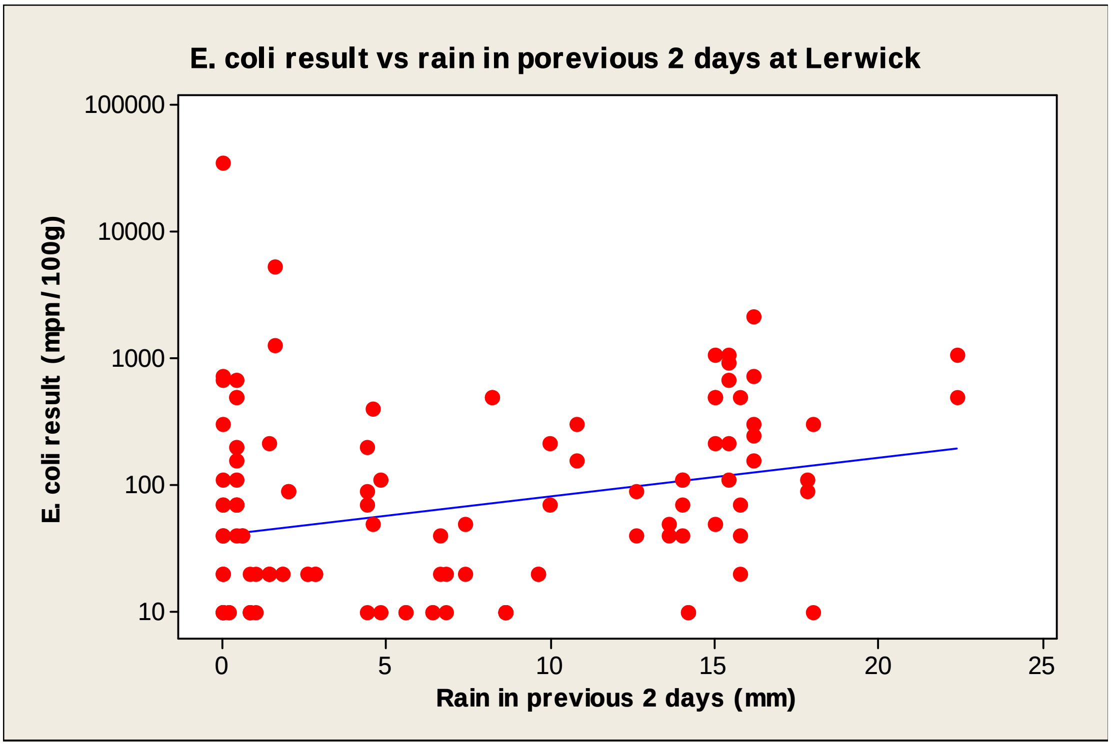


Figure 11.7 Scatterplot of shellfish *E.coli* result against rainfall in previous 2 days

The coefficient of determination indicates that there is a very weak positive relationship between the *E. coli* result and the rainfall in the previous two days (Adjusted R-sq=6.7%, p=0.003, Appendix).

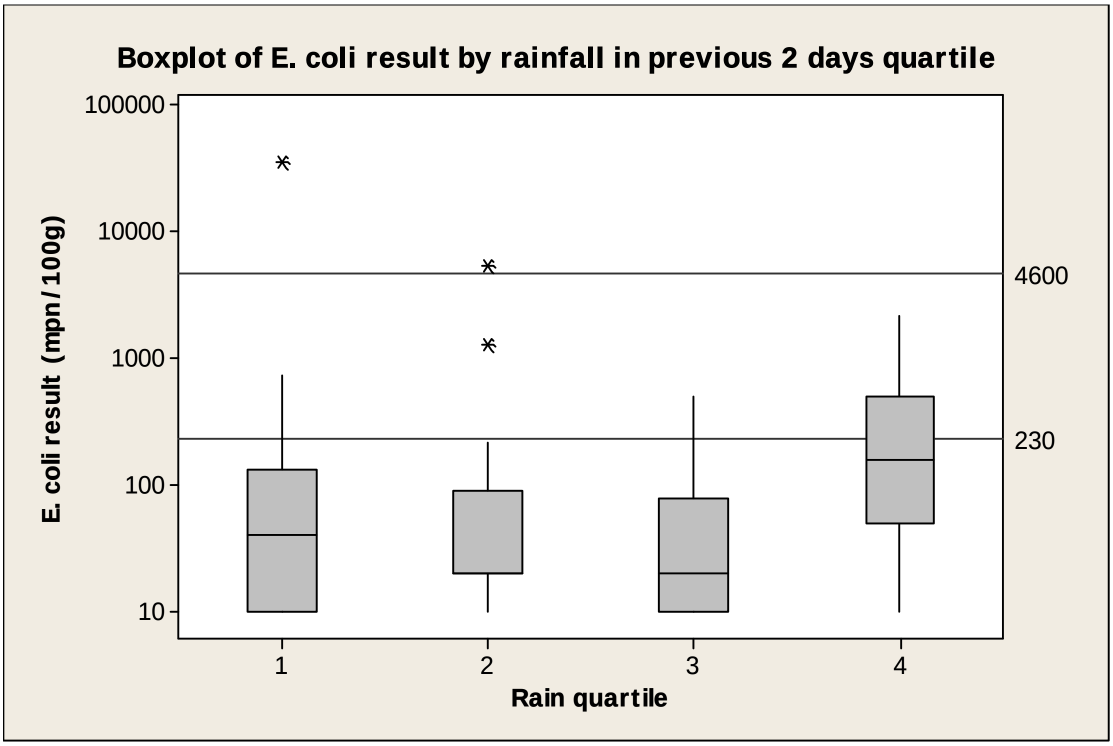


Figure 11.8 Boxplot of shellfish *E.coli* result by rainfall in previous 2 days quartile

A statistically significant difference was found between the results for each rain quartile (One way ANOVA, p=0.001, Appendix) with the highest results occurring for quartile 4 compared to quartiles 1 and 3.

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 Busta Voe Lee North 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.

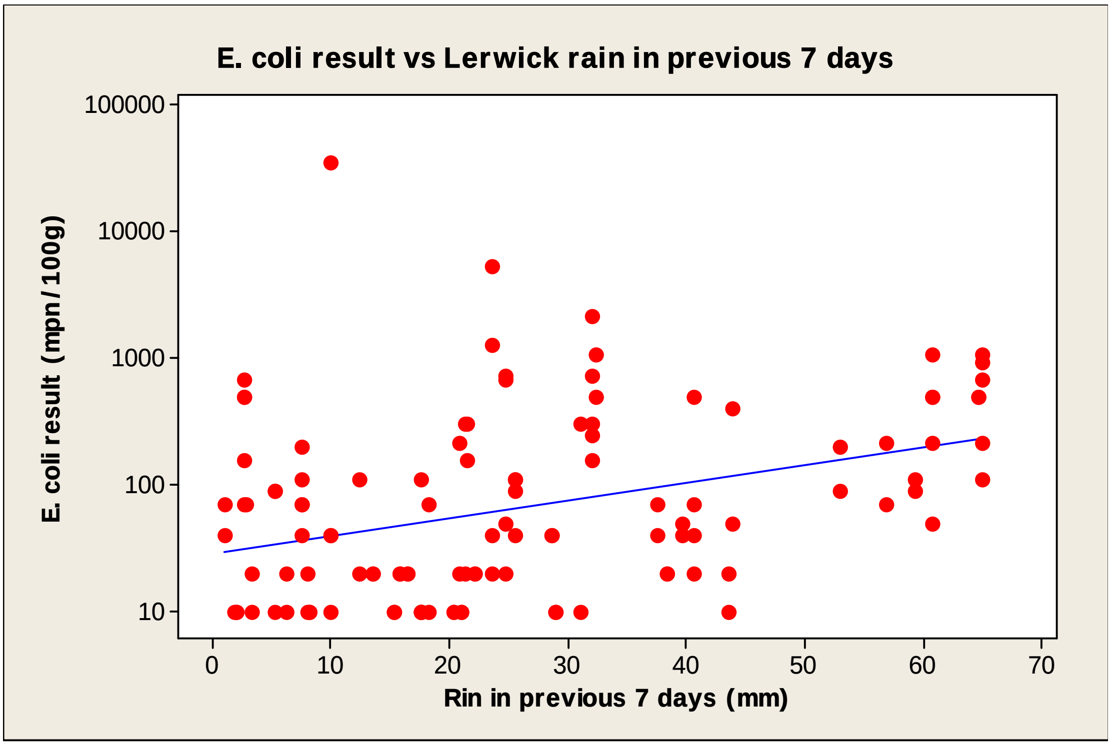


Figure 11.9 Scatterplot of shellfish *E.coli* result against rainfall in previous 7 days

The coefficient of determination indicates that there is a weak positive relationship between the *E. coli* result and the rainfall in the previous seven days (Adjusted R-sq=12.5%, p=0.000, Appendix).

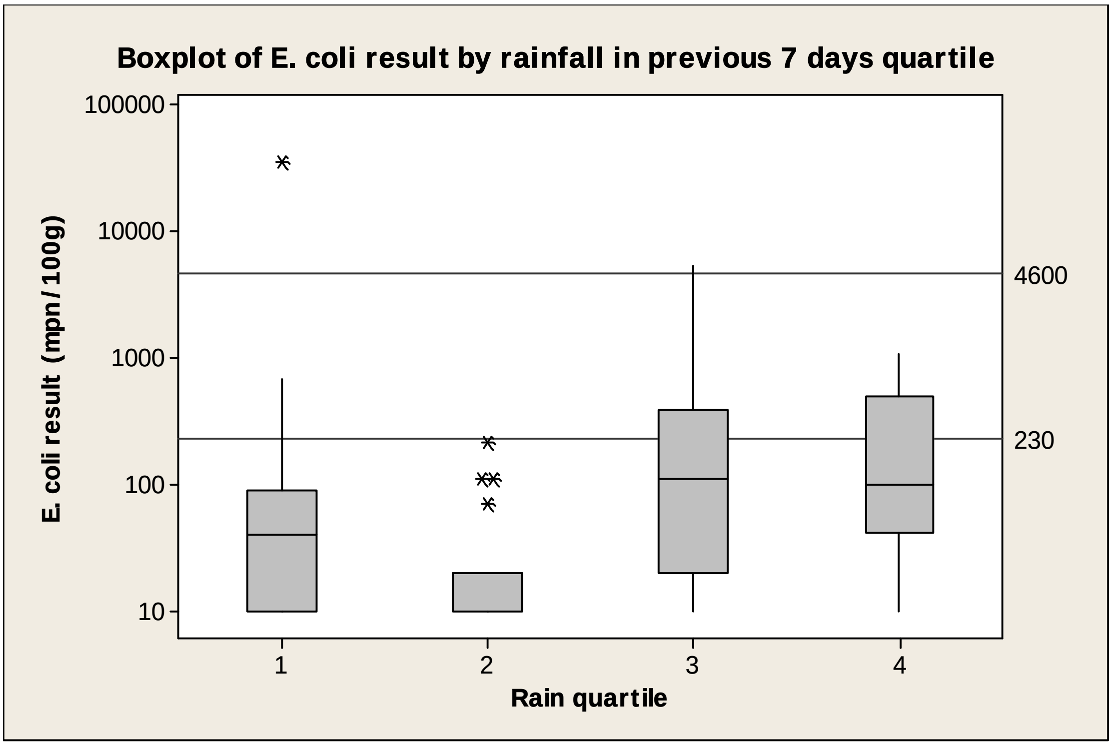


Figure 11.10 Boxplot of result by rainfall in previous 7 days quartile

There was a significant difference between results for each quartile (One way ANOVA, p=0.000, Appendix) with quartile 2 having lower results than the other quartiles.

Overall, higher recent rainfall is associated with higher contamination of shellfish in the Voe. Any rainfall related effects might be expected to be at their greatest in the autumn and winter months when rainfall is at its' highest (see section 9). The influence of rainfall on microbiological quality will depend on factors such as local geology, topography and land use.

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 voe (as described in section 12) 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.

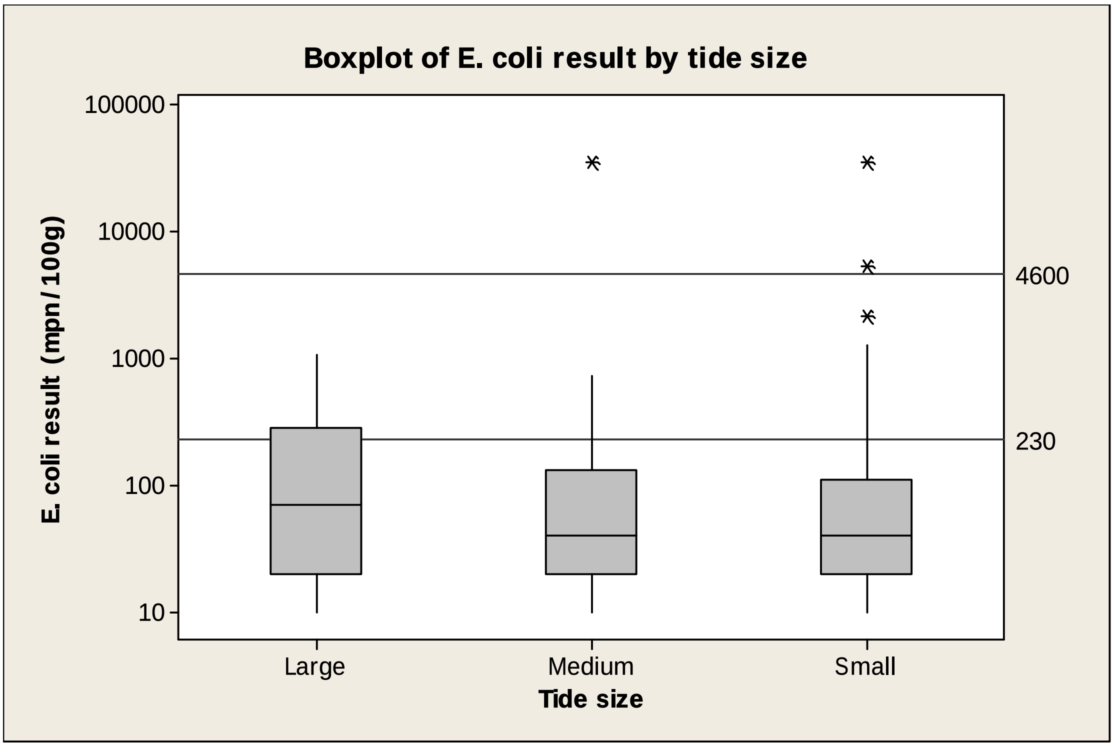


Figure 11.11 Boxplot of shellfish *E.coli* result by tide size

There was no statistically significant influence of tide size detected by this analysis (One way ANOVA, p=0.246, Appendix). This may be expected, as the tidal range is small and the voe is large and deep.

<u>11.4.4 Water temperature</u>

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

Water temperature at the time of sample collection was only recorded in one instance, so no analysis was possible.

<u>11.4.5 Wind direction</u>

Wind speed and direction is likely to significantly change water circulation patterns in Busta Voe. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Lerwick weather station (where data was available), and mean result by mean wind direction in the previous 7 days is plotted in Figure 11.12.

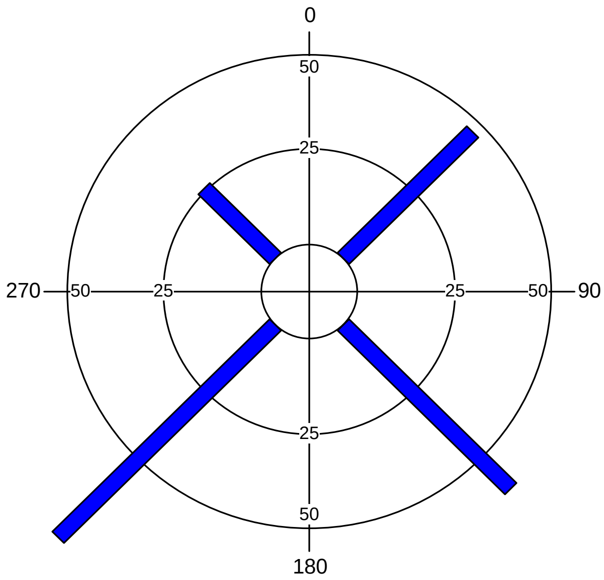


Figure 11.12 Circular histogram of geometric mean *E. coli* result by wind direction

A relatively weak correlation between wind direction and *E. coli* result was found (circular-linear correlation, r=0.27, p<0.001, Appendix). Results were highest 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. It must be noted however that this is the prevailing wind direction, and when it is blowing in this direction it is likely to be stronger than when blowing from other directions.

11.4.6 Discussion of environmental effects

A strong seasonal effect was found, with results in the spring being significantly lower than in other seasons. Higher results were associated with higher recent rainfall. No influence of tide size was apparent. South westerly winds were associated with increased contamination. Early autumn is the period when livestock densities are highest, and the onset of the wetter and windier autumn/winter period so it is to be expected that contamination from livestock is at its highest during the autumn.

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 for Busta Voe Lee North, as the area had a seasonal classification in 2004. When data to the end of 2007 is available, this assessment will be required.

12. Designated Shellfish Growing Waters Data

The area considered in this report is part of a SEPA shellfish growing water (Busta and Linga Voe) that was designated in 2002. The extent of the designated area and the SEPA designated monitoring point are shown on figure 12.1.

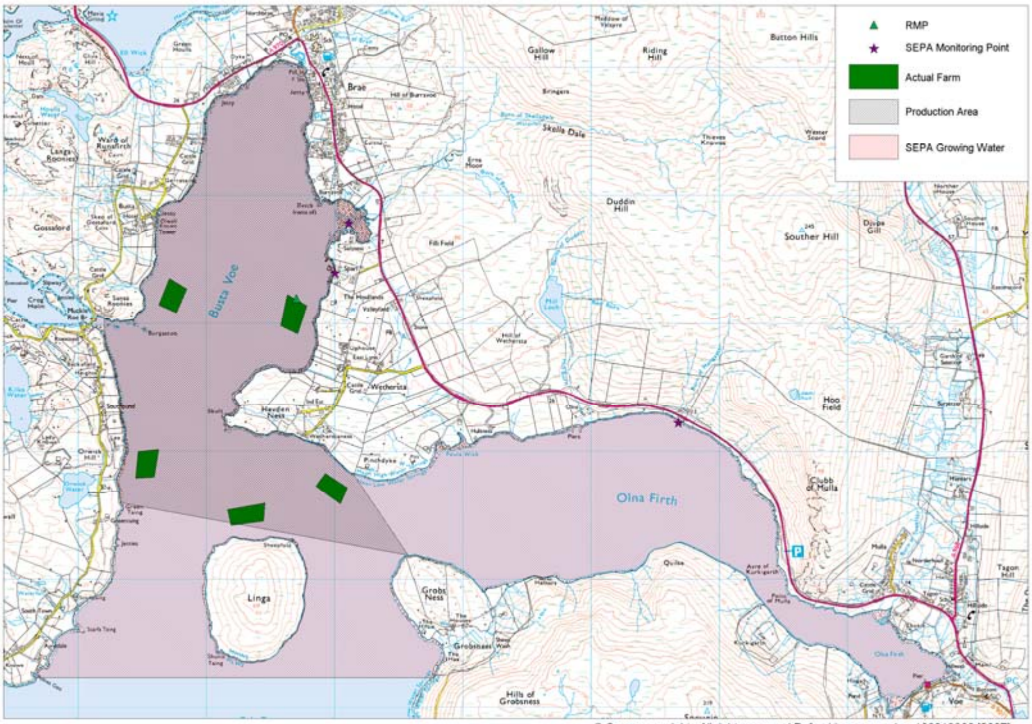


Figure 12.1 SEPA designated growing water and monitoring points

The monitoring regime requires the following testing:

- Quarterly for salinity, dissolved oxygen, pH, temperature, visible oil.
- Twice yearly for metals in water.
- Annually for metals and organohalogens in mussels.
- Quarterly for faecal coliforms in mussels.

Monitoring started in 2002, and results to the end of 2005 have been provided by SEPA. Monitoring results for faecal coliforms are presented in Table 12.1.

Table 12.1. SEPA faecal coliform results (fc/100 g) for shore mussels gathered from Busta Voe and Linga Voe.

	Site NGR	Busta and Linga Voe HU 360 664	Busta and Linga Voe HU 347 667	Busta and Linga Voe HU 3611 6679
2002	Q4	-	90	-
	Q1	750	40	-
	Q2	-	-	-
	Q3	-	-	5400
2003	Q4	-	-	90
	Q1	-	-	40
	Q2	-	-	70
	Q3	-	-	9100
2004	Q4	-	-	1100
	Q1	-	-	310
	Q2	-	-	70
	Q3	-	-	750
2005	Q4	-	-	1400

The majority of these samples were gathered from a shallow bay immediately to the south of the settlement of Brae. The geometric mean result of the samples taken from NGR HU 3611 6679 is 446 faecal coliforms / 100g. Levels of Faecal coliforms are usually closely correlated to levels of *E. coli* often at a ratio of approximately 1:1. The ratio depends on a number of factors, such as environmental conditions and the source of contamination. Assuming rough equivalence, the level of contamination in shore mussels taken from the current SEPA monitoring point appears higher than that observed in rope mussels in the voe, possibly due to lower dilution of faecal contaminants deposited directly at the shoreline.

Results of tests for chemical parameters were not considered in this assessment as they do not directly affect the microbiological quality of shellfish.

13. Bathymetry and Hydrodynamics

This site was chosen for a full hydrodynamic modelling. It is recommended that the Hydrography Methods Document be consulted for background information on the methods applied.

Physical Characteristics
Busta Voe is located on the north island of Shetland and comprises a northern embayment within a larger inlet (figure 12.1). Primary data comes from the Sea Loch Catalogue (SLC) produced by the SMBA. A brief summary of this data is provided below.

Chart Number	3295
Chart Scale	1:25000
Length:	3.0 km
Tidal range:	1.7 m
Max depth:	39 m
Ave depth at LW:	16.8m
HW Area	3.2 sq.km
Watershed	12 sq.km
Sill Data	No basins or sills
Salinity reduction:	0.1 ppt
Flushing time:	7 days

While no quantitative information on turbidity was available at the time of writing, informal observations made during the shoreline survey suggests relatively clear water.

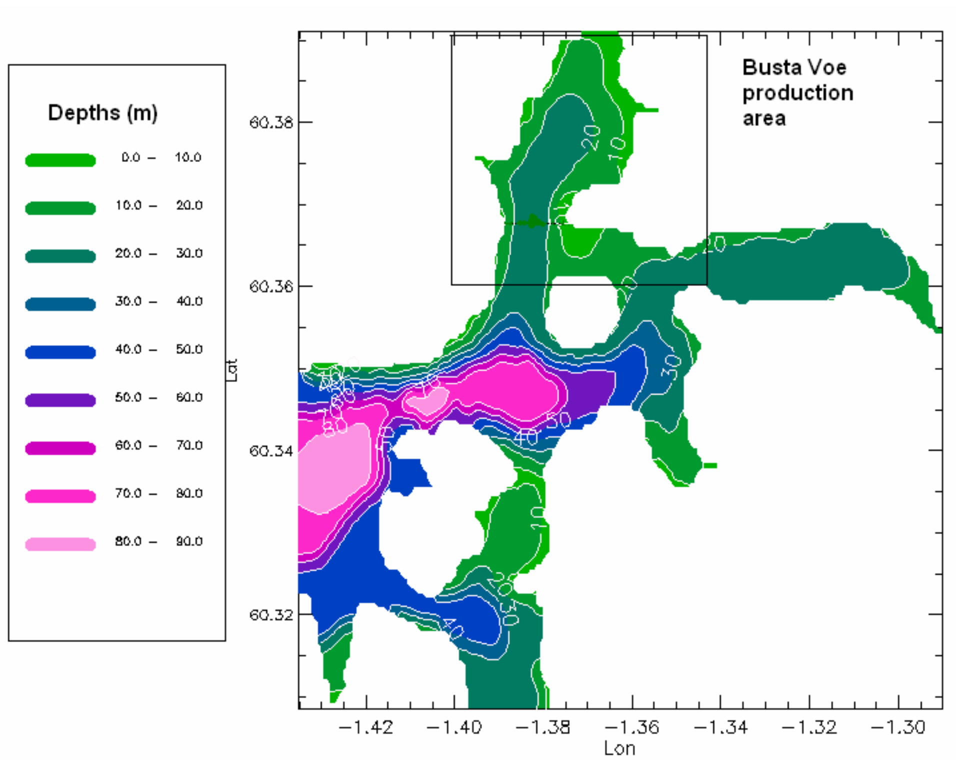


Figure 13.1: Complete model domain with depths (m).

Tides

Spring tidal range is given as 1.7m, with the area at high and low water being 3.2 km^2 and 3.1 km^2 respectively. The low water volume of the loch is 51.6 M m^3. There are no sills within Busta Voe itself, although there are a number in the surrounding embayment.

Wind driven flows

Winds measured at Lerwick (figure 12.2) should be closely representative of the wind speed and directions experienced at the Busta Voe. There is a clear predominance of winds from a southwesterly direction and these are generally rather strong, being above 17 knots (8 ms^{-1}) for about 60% of the time.

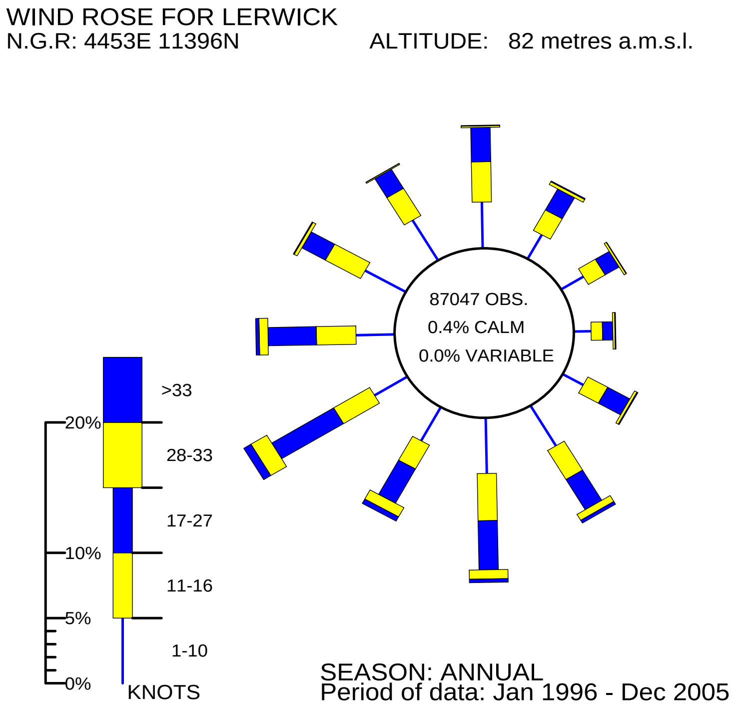


Figure 13.2: Annual wind rose for Lerwick.

Density driven flows

There are two burns that flow into or near the crown estate lease areas, there is no gauging data, but they do not drain a large catchment area. The sea loch catalogue gives the ratio of runoff to tidal exchange as 1:256, which is low implying annual freshwater inputs are small compared to tidal exchange. Nevertheless, because the tides are still relatively weak, there is the possibility of thermal stratification in summer. If this occurs, a layer of warm water on top of colder dense water will form generating a density driven current. For the purposes of modelling, we consider only wind and tide driven flows.

Related studies

At the time of development of this model, no other hydrodynamic modelling or hydrographic measurements carried out in the area were available for consultation and so were not considered.

Model study

Set-up

The area covered by the model is shown in figure 12.1. The resolution of the model (the grid spacing) was around 50m so that features down to this length can be represented. The tidal forcing was set to reproduce the observed spring tidal range of approximately 1.7 metres, as given in the Scottish Sea Loch Catalogue. No flow measurements through the Roe Sound were available. Rather than applying an arbitrary value, water inputs via the Roe sound were neglected. This appears reasonable given the shallow and narrow nature of this input compared with the main entrance to the south. Nevertheless there may be a small local modification to the tidal flows in the immediate vicinity of Roe sound not captured by the model. We do expect this to change significantly any conclusions about the particles paths described later.

In addition to tidal flows, the response to constant winds blowing from the north, south, east and west directions at a speed of 5 ms^{-1} (gentle to moderate breeze) was calculated. The effect of the (predominant) south-westerly wind can be analysed by considering by the average of the separate south and west cases. In each wind scenario, winds were applied for 48 hours so that a constant (equilibrium) current pattern was reached. Particles were released into the combined tidal and equilibrium wind generated currents from locations identified as potential sources by the shoreline survey. The paths of these particles were followed for 48 hours.

Limitations of using a simple depth integrated model are discussed in the hydrography methods document. These concern the inability of the model to describe vertical structure within the water column and will effect the modelling of wind and density driven flows in particular.

Results

Modelled tidal currents were found to be very weak in Busta Voe, with speeds generally much less than 10 cms^{-1}. Stronger tidal currents were associated with narrow constrictions and sills such as that between Linga and Hevden Ness. Even here peak tidal current speeds were generally less than 15 cms^{-1}. The tidal residual flow was predicted to be very weak and generally of the order of a few millimetres per second. Consequently tidal currents lead to very small transport distances (figure 12.3). Imposing even a modest wind was found to have a large the effect on water movement and particle paths as discussed below.

Figure 13.3: Particle paths for tide only. The black circle shows the start location. Two paths are shown representing particles released on flood and ebb tides. (about 6.2 hours apart).

Shoreline surveys indicated most significant point sources of contamination within Busta Voe to be associated with the settlement of Brae. The septic tank outfall at ‘Sunnyside’ (HU 35706750) was assumed as the source of particles for model simulations. A second potential source in the Olna Firth at ‘Voe’ (HU 403636) was assumed not to impact the production areas in and around Busta Voe and was therefore not considered further.

Particle movements for tide only and for the different wind driven runs are shown in figure 12.4. In summary the results were:

- For tides only, transport distances are very small (less than 250m), and particles stay within the vicinity of the release point with a small northwards residual drift.
- For an imposed north wind, particles move to the south, potentially impacting the leased production area on the east shore.
- For an imposed south wind, particles move to the north and are predicted to impact the northern shore and then have the potential to move around in an anticlockwise direction, although not impacting any leased site.

- For an imposed east wind, particles move north and impact the northern shore and then have the potential to move around in an anticlockwise direction, although not impacting any leased site.
- For an imposed west wind, particles move to the south then become trapped within a circular pattern away from production areas.

For wind runs the state of the tide at which particles were released (particles released 6.2 hours apart) had little effect - consistent with the relatively weak tidal influence.

The particle paths for the wind driven runs can be explained by reference to the underlying water circulation patterns in each case (figure 12.5). Visual inspection confirms that particles move in a way consistent with these patterns. However, it should be emphasised that these patterns are set up as a consequence of persistent winds from a given direction. At any particular time winds will vary dynamically and so the results shown correspond to somewhat idealised situations. They are nevertheless indicative of the response that might be expected.

The case of winds from the southwest (the predominant wind direction) is best analysed by superimposing the south and westerly patterns shown in figure 12.4. In the vicinity of the source at Sunnyside these give opposing transport directions (flows to the north for wind blowing from the south, and flows to the south for wind blowing from the west). However, the currents generated by the south wind are slightly stronger so that a pure south-westerly wind is likely to move material slowly to the north. Winds from the prevailing south westerly direction thus have the effect of keeping contaminants released from the Brae region confined to the north east of the Voe and away from production areas.

Bacterial concentrations in the water measured near the main settlement at Brae are generally well above the 100 *E.coli* per 100 ml that correlates roughly with a B classification. Movement of material south (due to a northerly wind, say) is likely to bring this water into the leased production area just north of Hevden Ness. As dilution in the Voe is expected to be relatively weak, this is likely to expose the area to concentrations around 100 *E.coli* per 100 ml. The duration of the exposure will however depend on the particular wind conditions and how quickly they change.

Summary

In general tidal flows appear to be weak, and wind generated currents have a major influence. The prevailing south-westerly wind direction seems likely to act to confine inputs from sources near Brae to the north eastern corner of the Voe and generally away from leased areas. However contamination is likely to impact production areas under some wind conditions, with northerly winds most likely to cause this. On average, winds with a significant northerly component occur for about 20% of the time.

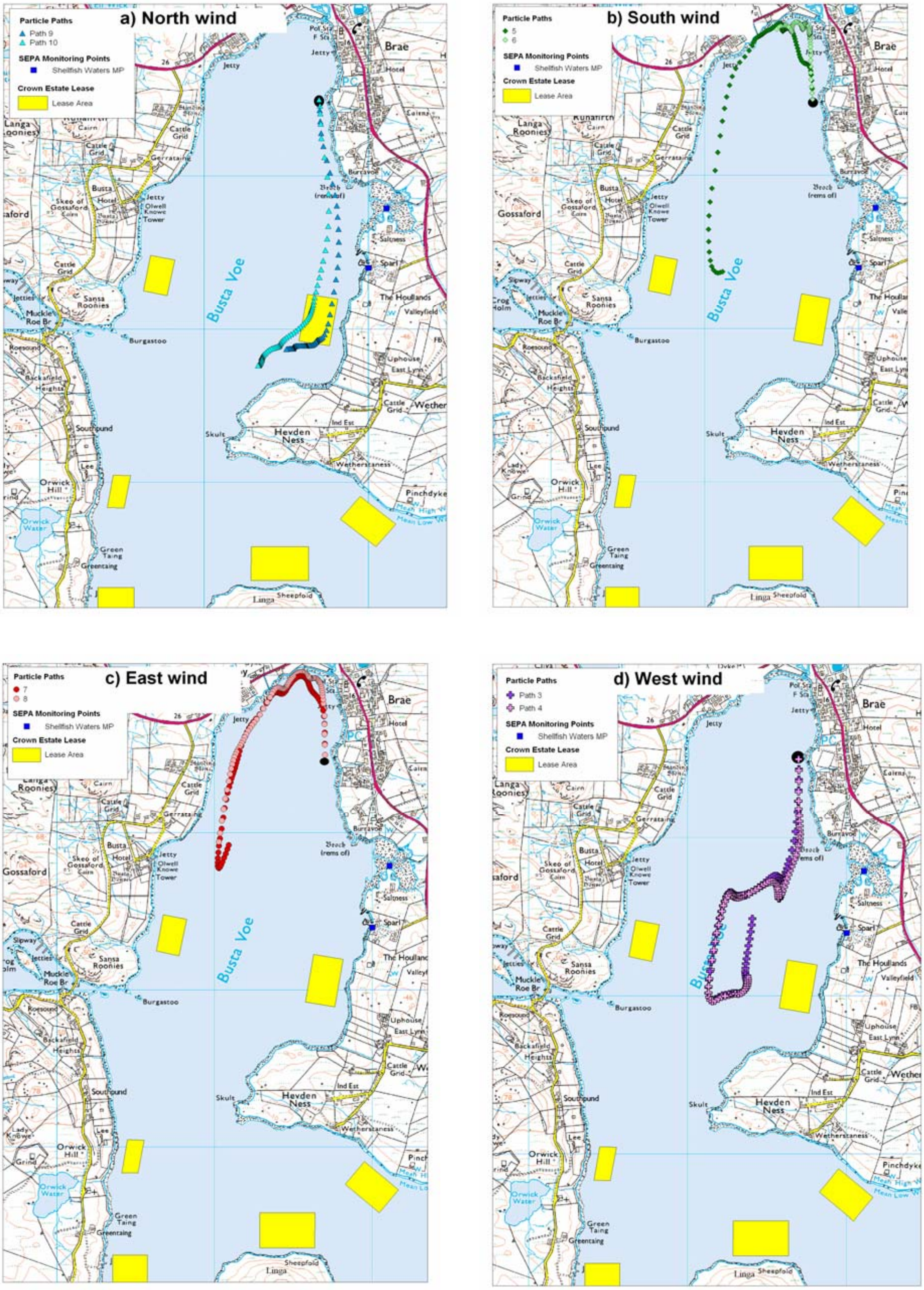


Figure 13.4: Particle paths for tide with superimposed wind driven flows for south, north, east and west winds. The black circle shows the start location. For each wind condition, two paths are shown representing particles released on flood and ebb tides. (about 6.2 hours apart).

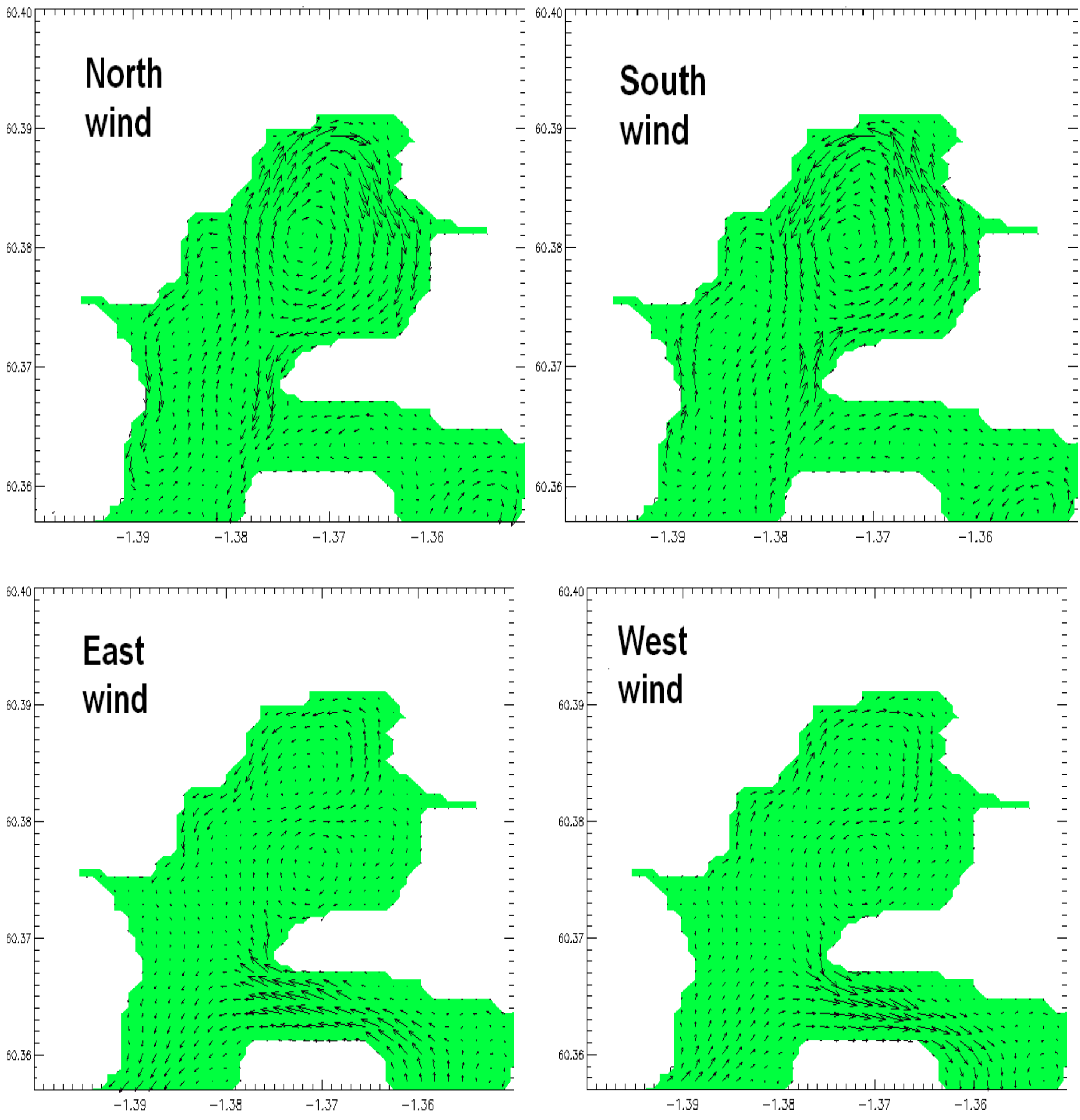


Figure13.5: Wind driven residual currents. Peak speeds around 5 cms^{-1} (north and south winds), 10 cms^{-1} (east and west winds)

14. River Flow

Busta Voe has a low input from fresh water sources, with a salinity reduction of 0.1 parts per thousand and a watershed area of just 12 sq.km. There are no river gauging stations on streams or burns feeding into Busta Voe.

The most significant of the streams flowing into the voe were sampled and measured during the shoreline survey so that loadings could be determined.

These showed that loadings were higher toward the southern end of the voe, with a loading of 6×10^{10} *E. coli* per day entering the loch near the Busta Voe Lee mussel site. The lowest loading came from the Burn of Brae, which discharges into the head of the voe and lies most distant to the five sites.

The Burn of Erns Moor and another small stream both flow into the voe 700 m to the northeast of the Hevden Ness site. A further unnamed stream flows into the voe on the western shore at Busta and approximately 0.5km northwest of the Busta Voe site.

Measurements and loadings apply only to the day of sampling and are not necessarily representative of flows and loadings throughout the year.

Table 14.1 River flows and loadings – Busta Voe 03-06 September 2007

No	Grid Ref	Description	Width (m)	Depth (m)	Meas. Flow (m/s)	Flow in m3/day	*E.coli* (cfu/ 100ml)	Loading (*E.coli*/ day)
1	HU 36278 66621	Stream	0.7	0.09	0.4	2000	130	3×10^{9}
2	HU 36212 66820	Burn of Erns Moor	2.5	0.35	0.3	20000	410	9×10^{10}
3	HU 35748 67943	Burn of Brae	1.7	0.07	0.4	4000	20	8×10^{8}
4	HU 34608 66886	Stream	0.6	0.11	0.2	1000	900	1×10^{10}
5	HU 34246 64765	Stream from Orwick	0.9	0.11	0.6	5000	1100	6×10^{10}

The stream and loadings are illustrated in Figure 14.1. Streams are labelled with the number assigned in Table 14.1. Loadings are displayed in digital scientific format on the map, where 1E+10 is equal to 1×10^{10}.

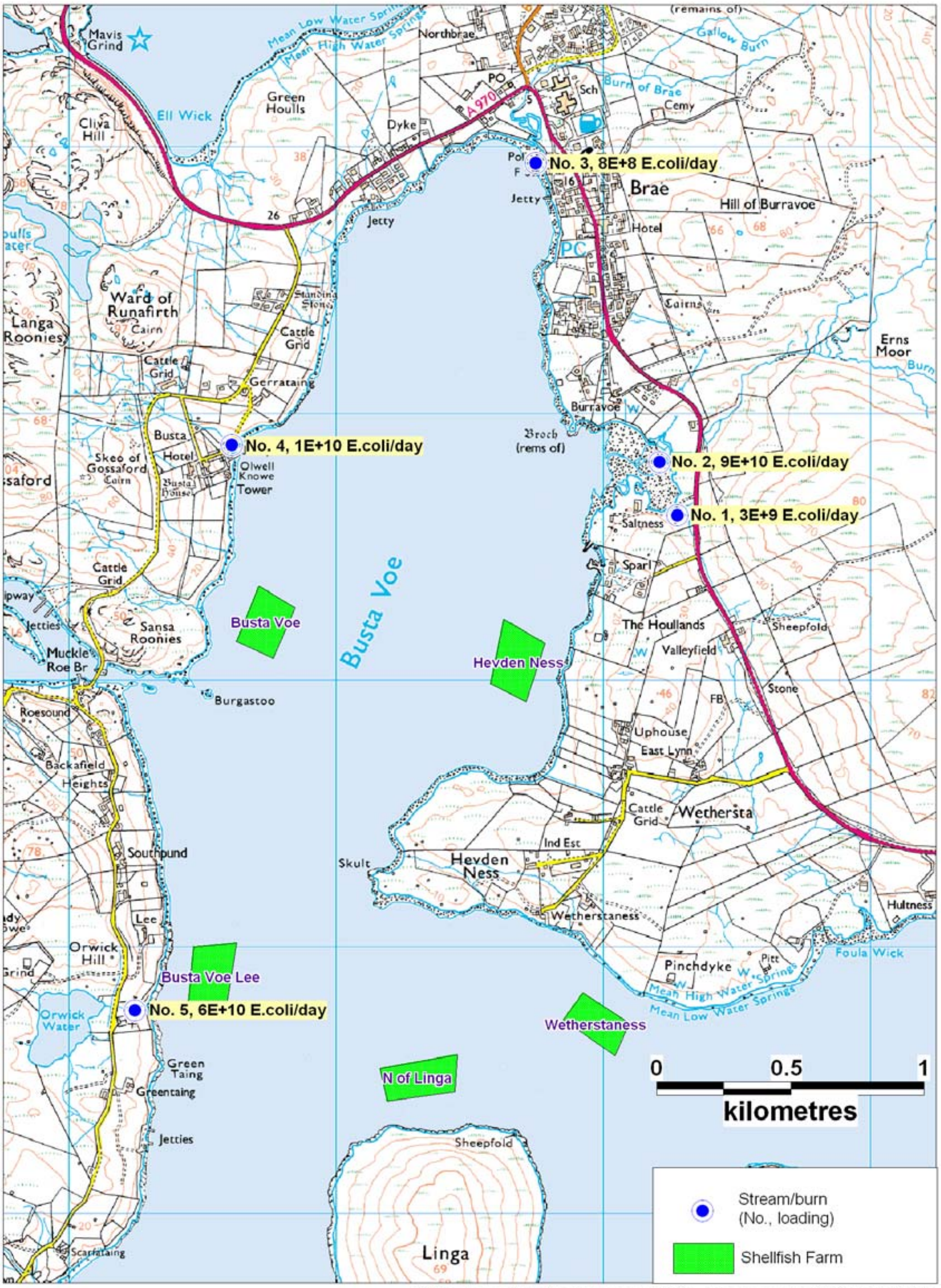


Figure 14.1 Significant streams and loadings

15. Shoreline Survey Overview

The survey at Busta Voe was triggered by its placement on the risk matrix used to prioritise existing production areas for sanitary survey. Placement toward the top of the priority list was due to monitoring results obtained outwith its classification.

There was development around the northern end of the Voe, and the one public septic tank at Brae. Twelve septic tanks and/or outfalls were identified during the shoreline survey. Development of new housing areas was underway along the northwestern shore of the voe and these appeared to be on a community septic system. Repairs appeared to be underway on the sewage pipe leading from one of the homes along the A970 and the untreated discharge appeared to be carried along through a field drain in the interim.

Water samples were collected from both freshwater sources and from seawater around the voe. The most contaminated came from around the settlement of Brae. An *E. coli* concentration of >5400 cfu/100 ml was found in a seawater sample collected from near the outfall of the Brae septic tank. A concentration of 5400 cfu/100ml was recorded from a seawater sample taken at an outfall pipe leading from a house to the shore just to the north of the Brae tank.

A number of small streams, field drains and burns fed into the voe. Five of these were measured and sampled. Of these, the highest levels of *E. coli* were found in the stream draining Orwick water. This empties into the voe very near the Busta Voe Lee mussel farm and may be a source of contamination levels seen in the mussel sample taken from there.

Sanitary-related debris was recorded in the vicinity of these two samples, further indicating the presence of sewage in the water.

Mussel samples were also collected from each of the farms located within the production area. Where possible, samples were collected from three depths. The highest sample results were recorded from the Busta Voe Lee site, where a sample taken from the top of the mussel line contained 1100 *E. coli* (MPN/100 g). A surface mussel sample taken from the Wetherstaness site contained a concentration of 290 *E. coli* (MPN/100g). All other mussel samples collected on the day of survey had *E. coli* concentrations below the A classification threshold of 230 per 100g.

Livestock, mainly sheep, were observed around the voe and near the shoreline is some areas. Some cattle and a small number of other livestock were observed.

Two marinas and jetties with workboats were noted during the survey. The marinas contained mainly day boats. Work boats were observed servicing one of the salmon farms in the voe.

No campsites or other concentrations of seasonal visitors were observed during the survey.

Wildlife were observed, including a seal and an assortment of seabirds. Greylag geese were seen in a field near the shore. The harvester reported that an otter was resident in the area, though this was not directly observed on the day. Overall, no significant concentrations of wildlife were seen in the voe. The cormorants observed resting on the mussel floats constituted the most significant potential source of faecal bacteria from wildlife. The most significant noted observations are mapped in Figure 15.1 below.

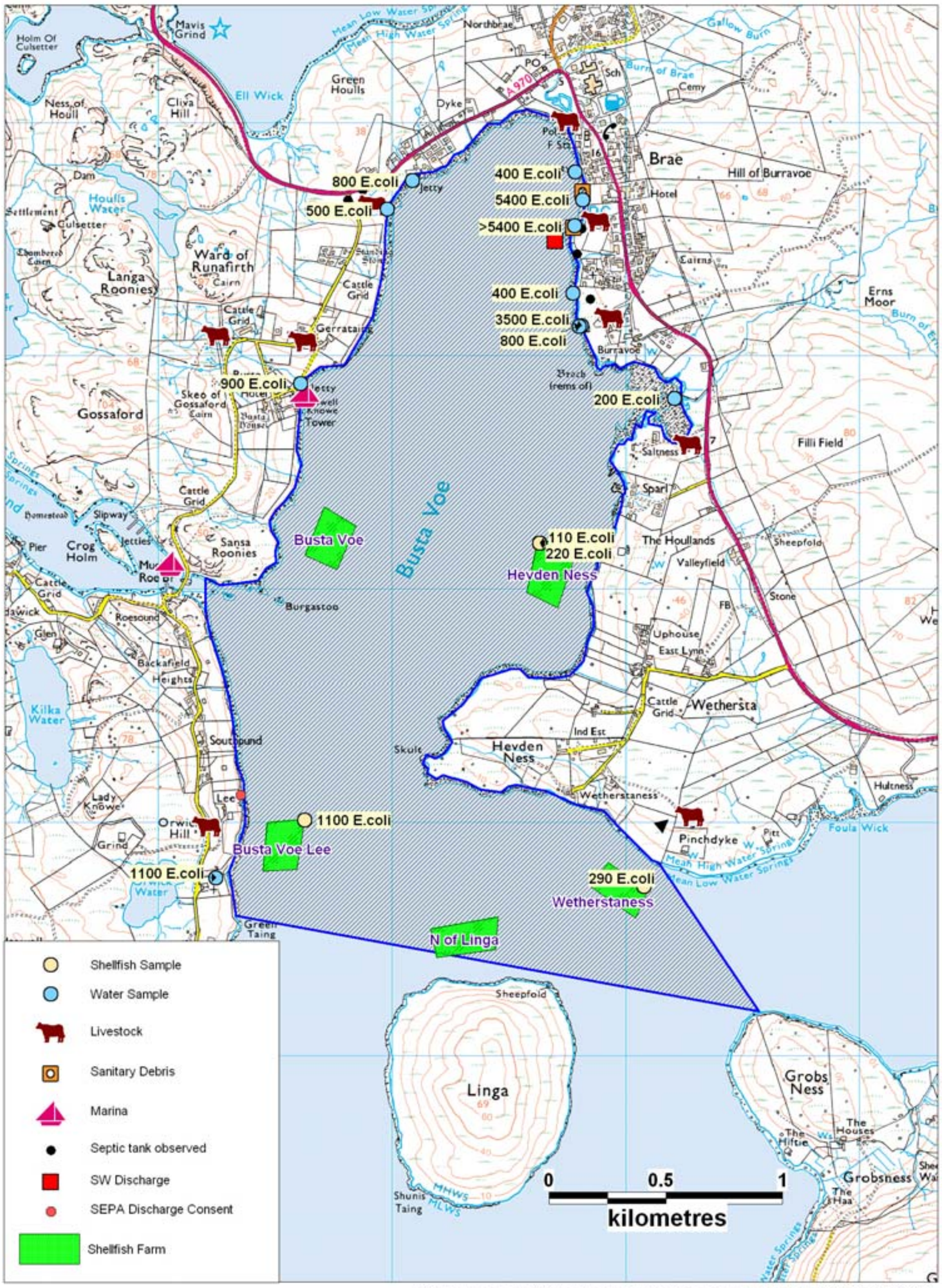


Figure 15.1 Significant findings from shoreline survey

16. Overall Assessment

Busta Voe has a human population concentrated along the northern shores of the voe while the southern half of the voe is sparsely populated. Crofts and rough grazing make up the majority of the shoreline, with livestock present around the voe.

Of the five mussel farms located in the production area, the three easternmost were brought on line in 2006. The sampling results from these sites appear to show higher levels of contamination in these sites, though samples taken from all five sites on the same date showed no significant differences between them. Of the five, only Hevden Ness was had significantly worse results than the others. As there were relatively few samples on which to base this assessment, it was decided not to recommend splitting the production area into Eastern and Western sections at this time.

Human Sewage Impacts

Busta Voe is impacted by human sources of faecal contamination in its upper reaches. The community septic tank at the settlement of Brae is the largest source of sewage but other sources are also present along the northeastern and northwestern shores of the Voe. This is where the human population is concentrated. The remainder of the shoreline around the voe is sparsely populated.

As shown in Figure 5.1, there is a small domestic discharge (population equivalent 5) in close proximity to the Busta Voe mussel farm. As long as the treatment plant stipulated in the SEPA consent is operating properly, this discharge should not negatively impact on the shellfishery. If the plant were to fail, the discharge would be intermittent and while it would impact the fishery it is difficult to predict the extent of impact.

While there would certainly have been septic tanks in place for the dwellings at Wetherstaness and along the eastern shore of the voe, none were directly observed during the shoreline survey.

The geology in Shetland generally is not suitable to the proper function of soakaway systems due to the thin soils over bedrock that are prevalent. The soils around Busta Voe specifically are classed as poorly draining and so any soakaway systems present would be unlikely to function optimally, leading to a greater risk of faecal contamination with runoff. Contamination of this variety could impact any one or all of the sites in the voe.

A further potential source of human sewage are the two marinas located to the north and south of the Busta Voe site on the western shore of the voe. While mostly these contained day boats, the types of boats present may vary over time and the possibility of sewage discharge from some of the boats cannot be completely discounted.

Agricultural Impacts
Livestock and farming activities are an important factor in the use of land around Busta Voe. Much of the area is used for grazing and there is some arable agriculture. Silage is grown in some of the fields along the western shore and a cut was in progress during the shoreline survey visit. Crofts are present along both shores of the voe. The predominant livestock present was sheep, followed by cattle. Livestock observations were mapped in section 7.

Land cover bordering the voe is predominantly improved pasture with some rough grassland, moorland and bog. Developed areas are limited to the northern end of the voe. Both developed land and improved pasture can contribute significant concentrations of bacteria in rainfall runoff. This would have the most acute impact on the Hevden Ness site.

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.

Wildlife Impacts
Wildlife impact, as discussed in section 8, is unpredictable. While large wild mammals such as seals and dolphins can and do enter the voe, 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 some species of gulls and fulmars breeding in the area. Seabirds will rest on the mussel floats, including cormorants, terns, and gulls and these are the most likely to directly impact the fishery. While these impacts may be very significant locally (directly under the birds) the impact to the wider fishery is unpredictable.

Geese were present in the area during the shoreline survey and their droppings would contribute to the *E. coli* loading of any water runoff from the land. However, they are not expected to have a substantial impact on the fisheries particularly in light of the larger human and livestock impacts.

River/Stream Inputs
The most significant of the streams contributing to the risk of faecal pollution in the voe was the discharge from Orwick Water, a small lake. This flows into the voe 150m from the southern end of the Busta Voe Lee site. Contamination from this source would most strongly affect the southern end of the mussel lines when winds were blowing from the South or West, based on the prediction of wind driven residual currents provided in section 13.

Other significant inputs come from the Burn of Erns Moor and an adjacent stream which flow into the voe approximately 700 m to the north of the

Hevden Ness site. These contribute 9 x 10^{10} and 3 x 10^{9} *E.coli* per day respectively and though they are more than 0.5 km away may still contribute significant concentrations of *E. coli* to the mussel farm, particularly if winds are blowing from the North.

Seasonal Variation
There was little seasonal variation apparent in the monitoring results, though results were higher in autumn, winter and spring compared to summer. This tends to coincide with higher average rainfall seen during that time. The Busta Voe Lee North production area has not historically held a seasonal classification.

While there may be a small increase in human population and boating activity during the summer months, this is not expected to significantly impact the fishery here and monitoring results have been lowest during the summer months.

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 local 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 from observations at Lerwick.

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. Particle tracking models of the discharge from Brae indicate that only winds from the North would drive contamination from the Brae outfall directly across any of the fisheries, and then only at Hevden Ness. This would seem to indicate that any high results obtained at other sites within the production area were due to other influences, possibly diffuse pollution from land runoff or point sources closer to the fisheries.

It should be noted that the modelling and particle paths used in this analysis were based on the location of the outfall as it existed in 2007. The proposed shifting of the outfall to a position further south and to a discharge point further into the loch may to some extent affect the movement of contaminants.

Further information provided by Scottish Water pertaining to the proposed new discharge from the Brae septic tank confirmed that wind driven flows were likely to dominate mixing and the movement of the plume from the outfall and that the Shellfish Growing Water standard of 100FC/100 ml would likely be achieved approximately 0.5 km north of the Busta Voe and Hevden Ness sites. The Shellfish Growing Water standard in water roughly equates to the upper Class B limit in shellfish. No inference can be made as to whether the data support Class A compliance levels (<3 FC/100 ml) at the fishery.

The correlation found between historical *E. coli* results and rainfall would tend to indicate that diffuse pollution carried via direct land runoff and in streams would be an important source of contamination at all five sites.

Analysis of Results

The current SEPA shellfish monitoring point lies on the sands to the north of Saltness, near the Burn of Erns Moor on the eastern shoreline. The nearest shellfish farm is Hevden Ness. Hevden Ness has only been monitored since 2006 and SEPA microbiological results were only available through 2005, leaving no overlap between results. Additionally, the SEPA shellfish were tested for faecal coliforms, of which *E. coli* is a subset. While this means that direct comparisons are not possible, the range of results obtained by SEPA falls within that seen since 2006 at Hevden Ness even though they are higher than those reported at the two older sites of Busta Voe and Busta Voe Lee.

Although statistically there was no significant difference observed between results among the sites, there did appear to be a split between the eastern and western sites, with results at Busta Voe and Busta Voe Lee appearing to be lower than those observed at Hevden Ness, North of Linga and to a lesser extent Wetherstaness.

Water samples taken during the shoreline survey also showed higher concentrations of *E. coli* along the eastern side of the voe, though admittedly a greater number of samples were taken from there. Water samples taken from on the mussel farms themselves showed very low counts, with results from <1 cfu/100 ml at Busta Voe and Busta Voe Lee to 4 cfu/100 ml at Hevden Ness. These water samples showed higher *E. coli* concentrations on the Hevden Ness, North of Linga and Wetherstaness sites.

Results of both sampling done on the day of the shoreline survey and historical monitoring results, as well as those obtained by SEPA, indicate that higher levels of contamination are seen at the Hevden Ness site when compared to other sites within the production area.

17. Recommendations

This production area is not recommended for reduced sampling due to stability. While it has held an A classification for three years, monitoring samples have only been taken from the current RMP at Hevden Ness since 2006. An analysis of historical monitoring by site shows that greater than 10% of samples collected across all sites exceeded 230 E. coli per 100 g, thereby exceeding the 90% compliance limit for Class A waters. It is therefore recommended that monthly sampling be continued.

The production area boundaries as currently drawn do not fully encompass all the shellfish farms within it. Current boundaries are given as the area bounded by lines drawn between HU 3614 6483 to HU 3657 6419 and from HU 3657 6419 to HU 3433 6460 and from HU 3420 6590 to HU 3420 6605 extending to MHWS.

It is recommended that the boundaries be adjusted to the area bounded by lines drawn between HU 3597 6634 to HU 3459 6660 and from HU 3420 6590 to HU 3420 6605 and from HU 3430 6450 to HU 3520 6432 and HU 3568 6428 to HU 3657 6419 to HU 3614 6483 extending to MHWS.

This would expand the production area slightly to the south in order to cover the full extent of the existing shellfish farms and would remove the northernmost section of the area as it receives the most contamination and is not currently used for shellfish production. The proposed boundary is illustrated in Figure 17.1.

It is recommended that microbiological sampling be conducted at one RMP. It is recommended that the Hevden Ness location be retained as it lies nearest the largest source of contamination and within the site that has shown the highest results and therefore is most protective of public health. The existing monitoring point at Hevden Ness is recorded at HU 357 662, which plots 12.2 m north of the recorded boundary of the shellfish farm, but within the seabed lease area. It is recommended that this point be described at HU 3570 6616, which places it well within the boundaries of the mussel farm and allows for a 20 m tolerance to also fall within the recorded farm. The tolerance of 20m is suggested as it allows for samples to be taken from lines with mature stock.

The recommended sampling depth is between 1 and 3 metres depth as contamination in this production area is likely to be found near the surface.

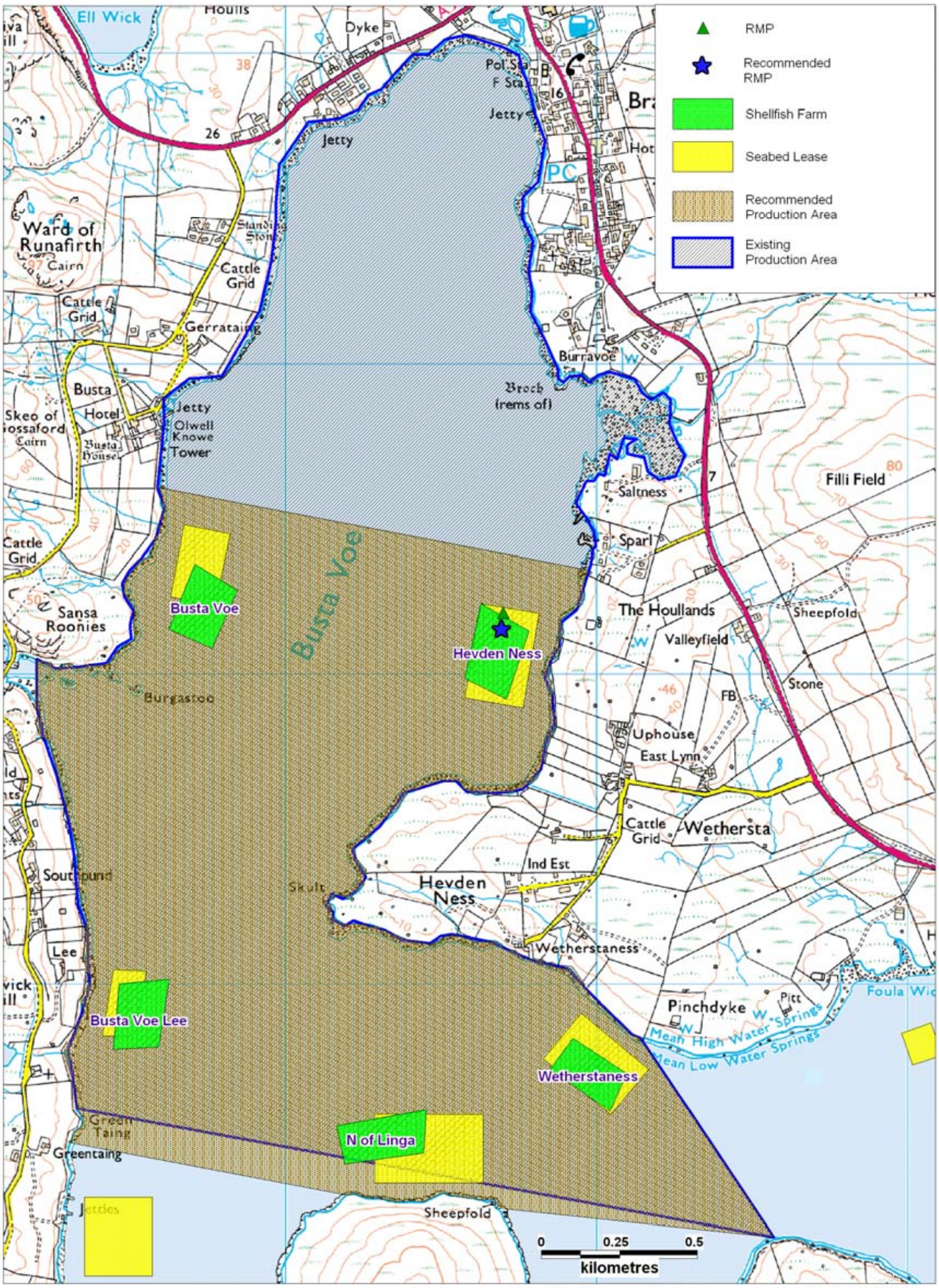


Figure 17.1 Recommendations for Busta Voe

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Shoreline Survey Report

Busta Voe Lee North

SI 327

Scottish Sanitary Survey Project

Cefas

Shoreline Survey Report

Prod. area:	Busta Voe Lee North
Site name:	Hevden Ness (755), Wetherstaness (754), North of Linga (753), Busta Voe (409) and Busta Voe Lee (410).
Species:	Common mussels
Harvester:	Blueshell Ltd. Michael Laurenson
Local Authority:	Shetland Islands Council
Status:	Existing production area
Date Surveyed:	3-6 September 2007
Surveyed by:	Michelle Price-Hayward, Sean Williamson
Existing RMP:	HU 354 645
Area Surveyed:	See Map in Figure 1

Weather observations

Rain over 48 hours prior to 3 September:
Winds force 5-6. Partly cloudy with spells of sunshine. Scattered showers. Max air temp 12C. Water temp 12C.

The voe is relatively sheltered and does not seem to be greatly affected by sea swells.

Fishery

At all 5 sites, mussels are grown on double-headed longlines to 10m depths. All of the sites are currently owned by Blueshell Ltd.

The RMP for the production area is currently located on the Busta Voe Lee site. Coordinates taken by GPS on the day of survey placed the RMP at grid reference HU 34845 66272. A sampling bag is hung at this location to a depth of 5 metres. Sampling bags are also in place on other sites.

Busta Voe Lee (currently called Busta Voe Lee South by the harvester) had 10 long lines in place.

New lines and anchors had recently been placed at the Busta Voe site, however there were other lines on site that had stock of suitable size for sampling.

The Wetherstaness site had 6 long lines in place.

Hevden Ness currently has 10 lines, with a further two removed from Busta Voe site and temporarily placed just offshore of the Hevden Ness anchors.

The lines on the Hevden Ness site were too heavy to bring up to sample more than just the top metre, so a further sample was taken from the bag to represent conditions at mid line depth. The production area was closed for harvest due to biotoxin levels at the time of survey and as soon as it is reopenened these lines were to be harvested and removed. There was a workboat on the site on the day of sampling releasing lines with settled spat.

As the settlement rate on site had been greater at the top half of the lines last year, the new lines on the site were tied up to keep the full length of the lines at the top 5 metres of water to allow better settlement along the full line. These were being cut to allow full extension to 10 metres for the growth of the settled spat.

The harvester at Busta Voe will harvest year round when possible due to customer demand.

Sewage/Faecal Sources

Scottish Water reported one community septic tank discharge located at the settlement of Brae. The discharge itself is located along the northeastern shore of the voe, near the head.

The North Brae wastewater pumping station overflow discharges into Sullom Voe to the north and does not directly impact Busta Voe. The septic tank at Voe discharges into Olna Firth 5km East of the nearest mussel farm at Wetherstaness. It is not expected to significantly impact the Busta Voe Lee North production area and so was not surveyed.

Table 1. Scottish Water Discharges

Discharge name	Type	Treatment	Consented flow (m3/d)	NGR
Sunnyside, Brae	continuous	Septic Tank	242	HU 35706750
North Brae WWPS	intermittent	6mm screen on overflow	127	HU 35706864
Voe	continuous	Septic Tank	80	HU 403636

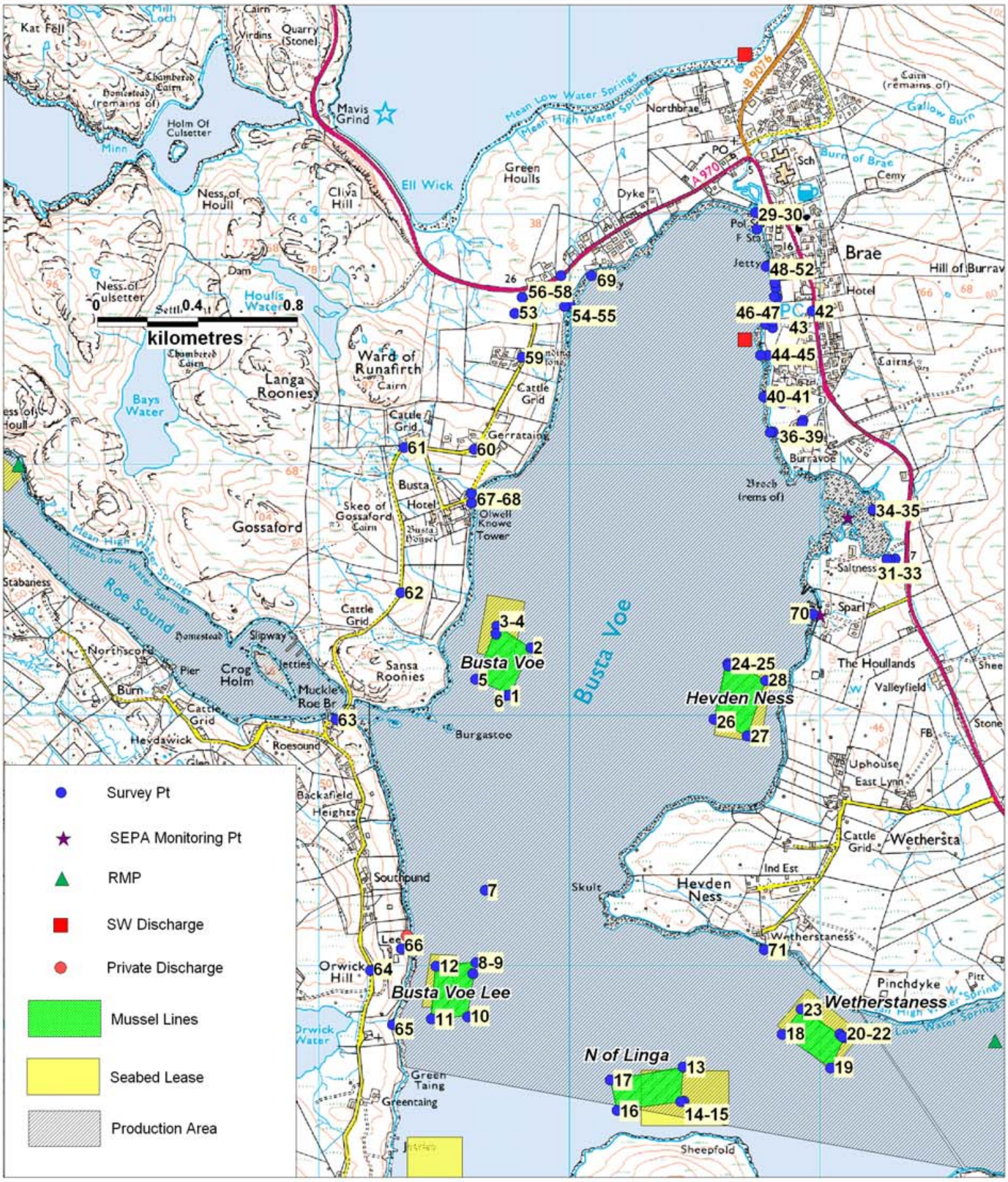
In addition, SEPA have one recorded domestic discharge permit for a septic tank (permit CAR/R/1018415, NGR HU 34350 65120, population equivalent of 5).
These discharges are plotted on the map in Figure 1.

Additional private septic systems were observed on the day. These are noted in Table 2. Some of the observed tanks were large and would presumably serve a group of dwellings. Permits for these were not located through the SEPA office, so nothing is known about their age, condition or number of households served.

Seasonal Population
There is a seasonal peak in population during the school holidays running from July to mid-August. There are several hotels in Brae and guest houses located along the A970 which skirts the northern shore of the voe.

Figure 1. Map of shoreline observations for Busta Voe

Busta Voe Lee North Survey



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Boats/Shipping
Two workboats were observed on site, one as mentioned previously working on the Hevden Ness mussel site and one servicing a nearby salmon farm. There were a further two workboats tied up at the harvester's shore base.

There is a small marina near the Muckle Roe bridge that contained 15 boats on the day of survey.

A further 28 small boats were observed in a new marina that has been installed along the northwestern edge of the voe. The docks had adjustable finger piers so the total number of berths available would be variable depending upon the sizes of boats in residence. The marine appeared to be approximately 50% occupied.

Land Use
Land use around the voe is primarily grazing of both sheep and cattle, as well as some silage production. Hay for silage is generally cut twice per year, with the second cut underway during the survey. Sheep had been gathered onto the crofts for shipment to the mainland beginning the week of survey. Due to foot and mouth restrictions, some of the hill sheep had not been brought down yet, however this was anticipated to take place during the following two weeks.

While there are crofts and settlements in the area, the land is mainly sparsely populated and much of the shoreline inaccessible by foot.

Wildlife/Birds
One seal and no otters were observed at the time of survey. The boat skipper reported an otter living near the harvesters shore operations just to the north of the Hevden Ness site.

General Observations

Outside Brae and the developments around the northern end of the voe, 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.

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

Sampling

Water and shellfish samples were collected at sites as illustrated in Figures 2 and 3. 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 3, given in units of grams salt per litre of water. This is the same as ppt.

Bacteriology results follow in Tables 3 and 4.

Table 2. Shoreline Observations

No.	Date	NGR	East	North	Associated photograph	Description
1	03/09/2007 09:25	HU 34749 66081	434749	1166081	Figure 4	Corner of Busta Voe lines
2	03/09/2007 09:27	HU 34845 66272	434845	1166272		RMP
3	03/09/2007 09:39	HU 34709 66355	434709	1166355		Corner of Busta Voe lines
4	03/09/2007 09:53	HU 34706 66326	434706	1166326		Busta Voe mussel samples 1, 2 and 3 and water sample
5	03/09/2007 09:54	HU 34625 66146	434625	1166146		Corner of Busta Voe lines
6	03/09/2007 09:57	HU 34763 66084	434763	1166084	Figure 5	Corner of Busta Voe lines
7	03/09/2007 10:00	HU 34664 65303	434664	1165303	Figure 6	2 workboats, salmon farm, silage cutting on shore behind salmon farm
8	03/09/2007 10:01	HU 34626 65014	434626	1165014		Busta Voe Lee water sample 1
9	03/09/2007 10:04	HU 34613 64970	434613	1164970		Mussel lines - 10 long lines
10	03/09/2007 10:15	HU 34594 64797	434594	1164797		Busta Voe Lee mussel lines -corner
11	03/09/2007 10:16	HU 34448 64789	434448	1164789		Busta Voe Lee mussel lines -corner
12	03/09/2007 10:17	HU 34467 64999	434467	1164999		Busta Voe Lee mussel lines -corner
13	03/09/2007 11:28	HU 35453 64596	435453	1164596		North of Linga mussel lines - corner
14	03/09/2007 11:30	HU 35457 64460	435457	1164460		North of Linga mussel lines - corner
15	03/09/2007 11:32	HU 35444 64457	435444	1164457		North of Linga samples taken here
16	03/09/2007 11:48	HU 35190 64422	435190	1164422		North of Linga mussel lines - corner
17	03/09/2007 11:50	HU 35163 64544	435163	1164544		Corner of North of Linga mussel lines. 3 cormorants. 4 long lines in place, no stock on outer 2. Bagged mussels on sampling point
18	03/09/2007 11:55	HU 35850 64727	435850	1164727		Corner of Wetherstaness mussel lines - 6 lines. 18 cows and 60 sheep, 4 houses on shore.
19	03/09/2007 11:57	HU 36043 64592	436043	1164592		Wetherstaness mussel lines - corner
20	03/09/2007 11:59	HU 36097 64714	436097	1164714		Wetherstaness mussel lines - corner
21	03/09/2007 12:13	HU 36079 64729	436079	1164729		Wetherstaness water sample and 3 shellfish samples top, mid and bottom. Salinity 34.7ppt, water t. 12.0C
22	03/09/2007 12:15	HU 36089 64718	436089	1164718		Wetherstaness mussel lines - corner
23	03/09/2007 12:17	HU 35924 64828	435924	1164828		Wetherstaness mussel lines - corner
24	03/09/2007 12:57	HU 35632 66209	435632	1166209		Corner of Hevden Ness mussel lines - 10 lines plus 2 lying offshore

No.	Date	NGR	East	North	Associated photograph	Description
						which had been moved there and would be harvested as soon as open.
25	03/09/2007 13:04	HU 35633 66199	435633	1166199		Hevden Ness samples
26	03/09/2007 13:12	HU 35577 65986	435577	1165986		Hevden Ness mussel lines -corner
27	03/09/2007 13:14	HU 35710 65920	435710	1165920		Hevden Ness mussel lines -corner
28	03/09/2007 13:16	HU 35782 66140	435782	1166140		Hevden Ness mussel lines -corner
29	03/09/2007 17:13	HU 35748 67943	435748	1167943	Figure 7	Stream sample Busta 7, Burn of Brae. 165 cm x 7 cm, flow 0.4 m/s. Photo.
30	03/09/2007 17:22	HU 35743 68009	435743	1168009		12 domestic geese
31	05/09/2007 14:43	HU 36301 66625	436301	1166625	Figure 8, 9	Pipe and water inspection covers. Small discharge pipe, 5cm diameter, not discharging. Photo.
32	05/09/2007 14:46	HU 36278 66621	436278	1166621	Figure 10	70cm wide, 9cm deep. Flow 0.4 m/s. Sample Busta 8.
33	05/09/2007 14:52	HU 36267 66623	436267	1166623		Fields with 12 sheep, in view.
34	05/09/2007 15:03	HU 36212 66820	436212	1166820		Burn 2.5m wide, 35cm deep, flow 0.3 m/s. Sample Busta 9.
35	05/09/2007 15:08	HU 36211 66822	436211	1166822	Figure 11	Seawater sample, Busta 10. Pipe from shed under gravel drive, no flow. 9cm diameter .
36	05/09/2007 15:43	HU 35929 67166	435929	1167166		7 sheep, 2 goats in the field SE of the road, approx 30 sheep on other side.
37	05/09/2007 15:46	HU 35932 67178	435932	1167178	Figure 12, 14	Septic tank discharging at shore. 9cm diameter. Flow 0.5L/min
38	05/09/2007 15:50	HU 35812 67132	435812	1167132		Sample Busta 11
39	05/09/2007 15:55	HU 35802 67130	435802	1167130		Sample Busta 12, seawater.
40	05/09/2007 16:02	HU 35776 67273	435776	1167273	Figure 13, 15	Sample Busta 13. Septic tank, 24 sheep in field above tank.
41	05/09/2007 16:04	HU 35849 67247	435849	1167247	Figure 16	Concrete tank cover.
42	06/09/2007 10:51	HU 35968 67615	435968	1167615		35 sheep.
43	06/09/2007 10:57	HU 35811 67548	435811	1167548	Figure 17	Septic tank – large, odour apparent. 12 x 9m.
44	06/09/2007 11:01	HU 35792 67439	435792	1167439	Figure 19	Another large septic tank and outfall. 5 chickens.
45	06/09/2007 11:08	HU 35763 67439	435763	1167439	Figure 18	Sample Busta 14, end of outfall.
46	06/09/2007 11:16	HU 35782 67563	435782	1167563	Figure 20,21	Sample Busta 15, end of outfall, very big tank, very smelly, some sanitary debris including wet wipes.
47	06/09/2007 11:21	HU 35811 67575	435811	1167575		Surface water seeping across the beach 4m wide <1 cm deep.
48	06/09/2007 11:30	HU 35829 67668	435829	1167668	Figure 22	Pipe from house across shoreline

No.	Date	NGR	East	North	Associated photograph	Description
49	06/09/2007 11:32	HU 35818 67673	435818	1167673		Busta 16 sample.
50	06/09/2007 11:38	HU 35824 67709	435824	1167709	Figure 23, 24	Sanitary towel, adjacent to pipe, second pipe broken.
51	06/09/2007 11:44	HU 35820 67729	435820	1167729	Figure 25	Land runoff across beach, very shallow, 1.5m width. Large pipe 20m diameter, dripping across the rocks, not enough to sample.
52	06/09/2007 11:52	HU 35784 67794	435784	1167794		Sample Busta 17, adjacent pier,New housing development, currently 8 being constructed.
53	06/09/2007 12:07	HU 34782 67606	434782	1167606	Figure 26	Marina, adjustable slips, mostly day boats, about 28 of them.
54	06/09/2007 12:16	HU 35001 67645	435001	1167645		Sample Busta 18 taken from corner of marina.
55	06/09/2007 12:24	HU 34980 67634	434980	1167634	Figure 27	Field drain, 19 sheep. Sample Busta 19, freshwater.
56	06/09/2007 12:36	HU 34811 67670	434811	1167670	Figure 28	Septic tank with dropping. Photo. 2 covers at the top of the hill above the marina.
57	06/09/2007 12:39	HU 34873 67714	434873	1167714	Figure 29	Foul line uncovered, in work tank with broken/uncovered lid, runs under road, out black pipe and down a hill towards marina, along a field drain. Sample 20. Marina parking lot drain under road, white pipe into surface runoff, towards parking. Cover in car park, in line with drain.
58	06/09/2007 12:49	HU 34965 67756	434965	1167756		Septic tank outside housing development.
59	06/09/2007 12:55	HU 34811 67430	434811	1167430		8 houses.
60	06/09/2007 12:59	HU 34619 67063	434619	1167063		3 houses, 40 sheep, Busta House Hotel.
61	06/09/2007 13:00	HU 34340 67070	434340	1167070		Agricultural shed and silage pit. 100 sheep down road in fields on both sides. 39 greylag geese and 32 sheep, 2 goose droppings collected.
62	06/09/2007 13:09	HU 34327 66490	434327	1166490		Air Temp 13C, overcast and foggy, wind 4-5.
63	06/09/2007 13:16	HU 34067 65985	434067	1165985		Muckle Roe bridge, Sample 21. Pier - used to be harvester shore
64	06/09/2007 13:22	HU 34205 64983	434205	1164983		Stream 80cm width and 4cm depth. Flow, 3m in 5 seconds. Water sample Busta 22. 26 cattle, 110 sheep. Marina with 15 boats across the sound under Muckle Roe bridge.
65	06/09/2007 13:38	HU 34293 64766	434293	1164766	Figure 30	Mussel floats, 13 cormorants, I juv. Guilemot, 1 seal. House on hill, flag iris, surface water runoff.
66	06/09/2007 13:59	HU 34329 65069	434329	1165069		Bigger surface runoff, 10cm width and 1cm depth - no suitable run to gauge flow, sample Busta 23. Arable field, fenced down to the water, no evidence of pipes, 4 houses.

No.	Date	NGR	East	North	Associated photograph	Description
67	06/09/2007 15:10	HU 34609 66850	434609	1166850		Sample Busta 24, seawater.
68	06/09/2007 15:14	HU 34608 66886	434608	1166886		Stream culvert, 60cm width, 11cm depth . Fow 0.2 m/s. Sample Busta 25.
69	06/09/2007 15:30	HU 35087 67757	435087	1167757		Inspection cover at marina mark, outfall in rocks, surface water sample Busta 26 approx 2.5m from inspection cover..
70	06/09/2007 15:43	HU 35972 66404	435972	1166404		water sample Busta 27, left side of jetty
71	06/09/2007 16:14	HU 35778 65065	435778	1165065		Sample Busta 28, house, cant see a pipe.
72	05/12/2007 14:15	HU 34246 64765	434246	1164765		Stream 90cmx11cm, flow 0.588 m/s. Water sample Busta Voe 1 fresh.
73	05/12/2007 14:22	HU 34178 64762	434178	1164762		Point where road crosses stream

Photos referenced in the table can be found attached as Figures 4-30.

Table 3. Water Sample Results

No.	Date	Sample	Type	NGR	*E. coli* (cfu/ 100ml)	Salinity (g/L)
1	03/09/2007	Busta Voe Lee N 1	Sea	HU 34749 66081	1	28.91
2	03/09/2007	Busta Voe Lee N 2	Sea	HU 34709 66355	<1	28.57
3	03/09/2007	Busta Voe Lee S 1	Sea	HU 34626 65014	<1	28.88
4	03/09/2007	N Linga	Sea	HU 35444 64457	2	28.76
5	03/09/2007	Wether	Sea	HU 36079 64729	1	28.84
6	03/09/2007	Hevd Ness	Sea	HU 35633 66199	4	28.94
7	05/09/2007	Busta Voe Lee 7	Fresh	HU 35748 67943	20	0.077
8	05/09/2007	Busta Voe Lee 8	Fresh	HU 36278 66621	130	0.068
9	05/09/2007	Busta Voe Lee 9	Fresh	HU 36212 66820	410	0.102
10	05/09/2007	Busta Voe Lee 10	Sea	HU 36211 66822	200	6.787
11	05/09/2007	Busta Voe Lee 11	Fresh	HU 35812 67132	3500	0.142
12	05/09/2007	Busta Voe Lee 12	Sea	HU 35802 67130	800	0.108
13	05/09/2007	Busta Voe Lee 13	Sea	HU 35776 67273	400	23.16
14	06/09/2007	Busta Voe Lee 14	Sea	HU 35763 67439	200	19.54
15	06/09/2007	Busta Voe Lee 15	Sea	HU 35782 67563	>5400	18.4
16	06/09/2007	Busta Voe Lee 16	Sea	HU 35818 67673	5400	22.96
17	06/09/2007	Busta Voe Lee 17	Sea	HU 35784 67794	400	21.82
18	06/09/2007	Busta Voe Lee 18	Sea	HU 35001 67645	20	29.38
19	06/09/2007	Busta Voe Lee 19	Fresh	HU 34980 67634	500	na
20	06/09/2007	Busta Voe Lee 21	Sea	HU 34067 65985	<1	29.99
21	06/09/2007	Busta Voe Lee 22	Fresh	HU 34205 64983	400	na
22	06/09/2007	Busta Voe Lee 23	Fresh	HU 34329 65069	120	na
23	06/09/2007	Busta Voe Lee 24	Sea	HU 34609 66850	100	30.88
24	06/09/2007	Busta Voe Lee 25	Fresh	HU 34608 66886	900	na
25	06/09/2007	Busta Voe Lee 26	Fresh	HU 35087 67757	800	na
26	06/09/2007	Busta Voe Lee 27	Sea	HU 35972 66404	190	23.83
27	06/09/2007	Busta Voe Lee 28	Sea	HU 35778 65065	<1	41.33
28	05/12/2007	Busta Voe 1	Fresh	HU 34246 64765	1,100	na

Table 4. Shellfish Sample Results

No.	Date	Sample	Type	NGR	*E. coli* (mpn/ 100g)	Depth
1	03/09/2007	Busta Voe Lee 1	Mussels	HU 34706 66326	50	<1
2	03/09/2007	Busta Voe Lee 2	Mussels	HU 34706 66326	110	4
3	03/09/2007	Busta Voe Lee 3	Mussels	HU 34706 66326	110	8
4	03/09/2007	Busta Voe Lee S 1	Mussels	HU 34626 65014	1100	<1
5	03/09/2007	Busta Voe Lee S 2	Mussels	HU 34626 65014	70	4
6	03/09/2007	Busta Voe Lee S 3	Mussels	HU 34626 65014	70	8
7	03/09/2007	N Linga	Mussels	HU 35444 64457	70	<1
8	03/09/2007	N Linga 2	Mussels	HU 35444 64457	70	4
9	03/09/2007	Wether 1	Mussels	HU 36079 64729	290	<1
10	03/09/2007	Wether 2	Mussels	HU 36079 64729	70	4
11	03/09/2007	Wether 3	Mussels	HU 36079 64729	160	8
12	03/09/2007	Hev 1	Mussels	HU 35633 66199	110	<1
13	03/09/2007	Hev 2	Mussels	HU 35633 66199	220	3

Figure 2. Water sample results map

Busta Voe Lee North Water Samples

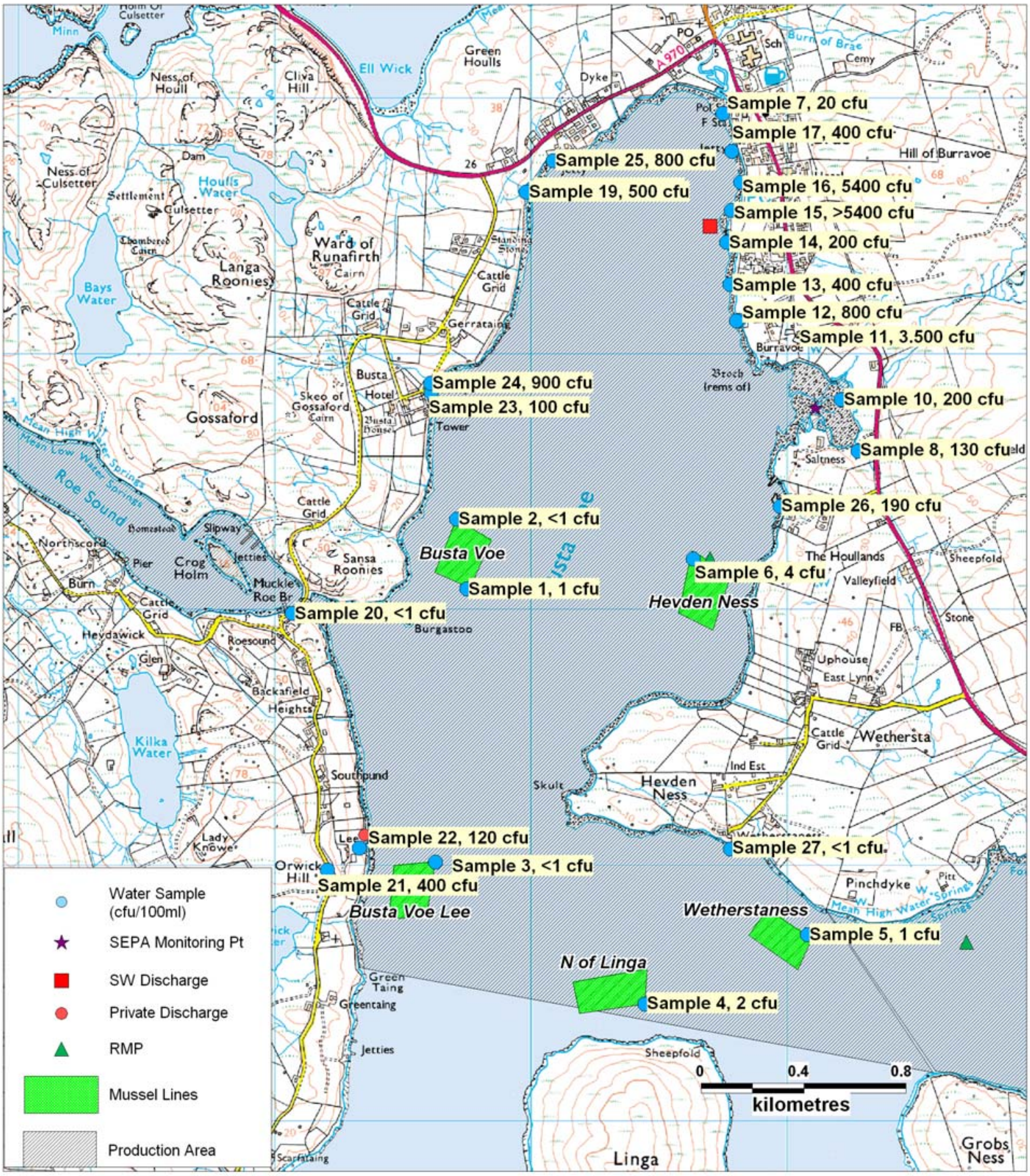

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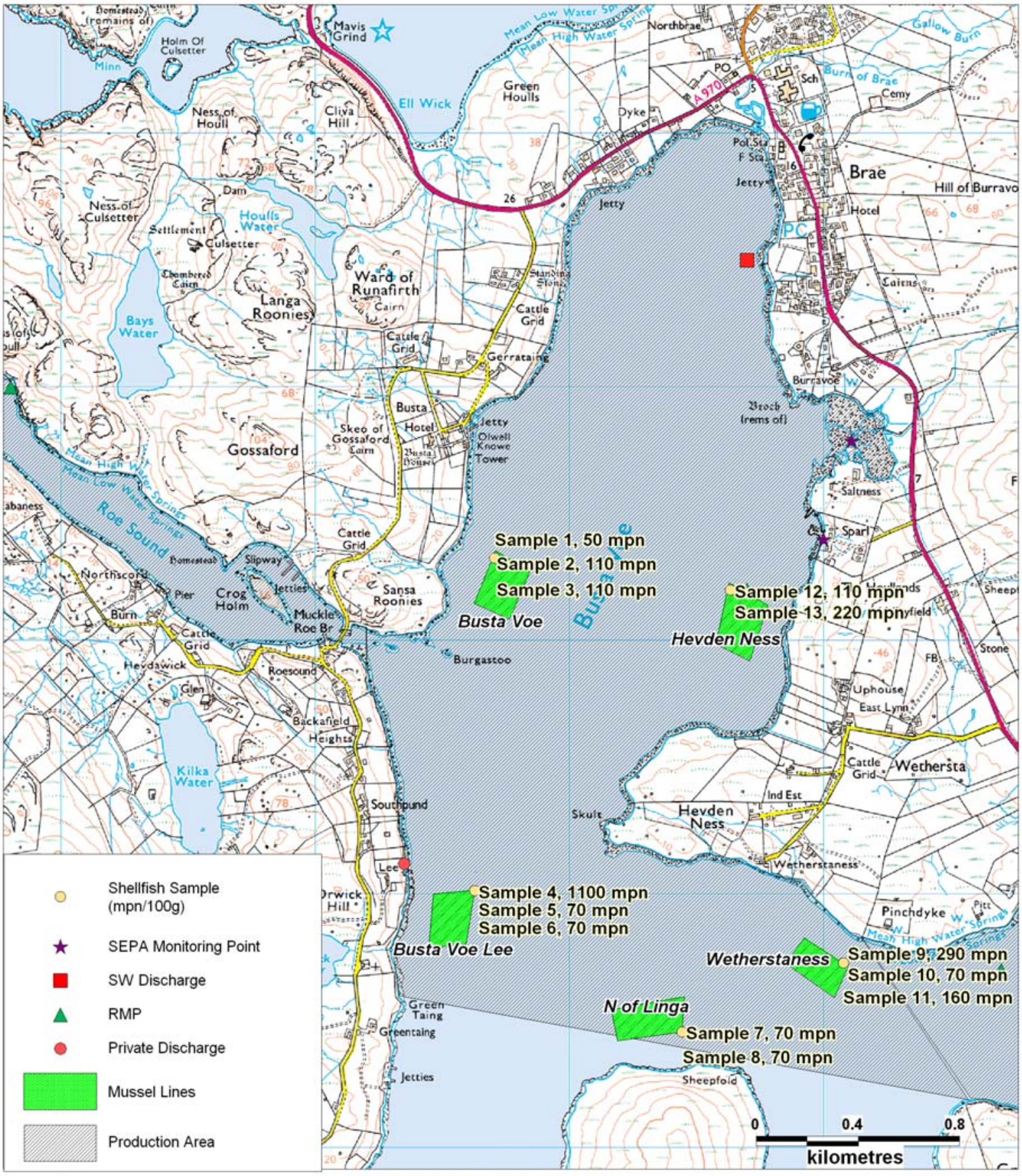
Figure 3. Shellfish sample results map

Busta Voe Lee North Shellfish Samples



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Photos

Figure 4. Busta030901. Mussel farm at Busta Voe

Figure 5. Busta030903. View toward Muckle Roe bridge.

Figure 6. Busta030904. Silage cutting on shore behind salmon farm.

Figure 7. Busta030913.
Burn of Brae.

Figure 8. Busta050901.
Plastic pipe and inspection covers.

Figure 9. Busta050902.
Pipe discharge at stream.

Figure 10. Busta050903.

Figure 11. Busta0509005.
Shed and discharge pipe.

Figure 12. Busta050909. Septic tank cover.

Figure 13. Busta050910.
Septic tank cover.

Figure 14. Busta050912. Discharge pipe.

Figure 15. Busta050913. Discharge pipe.

Figure 16. Busta050911. Concrete septic tank cover.

Figure 17. Busta060901. Large septic tank cover.

Figure 18. Busta060902.
Discharge pipe for tank.

Figure 19. Busta060903.
Another big septic tank.

Figure 20. Busta060904. Discharge pipe for tank in Figure 20.

Figure 21. Busta0609005.
Sampling at discharge.

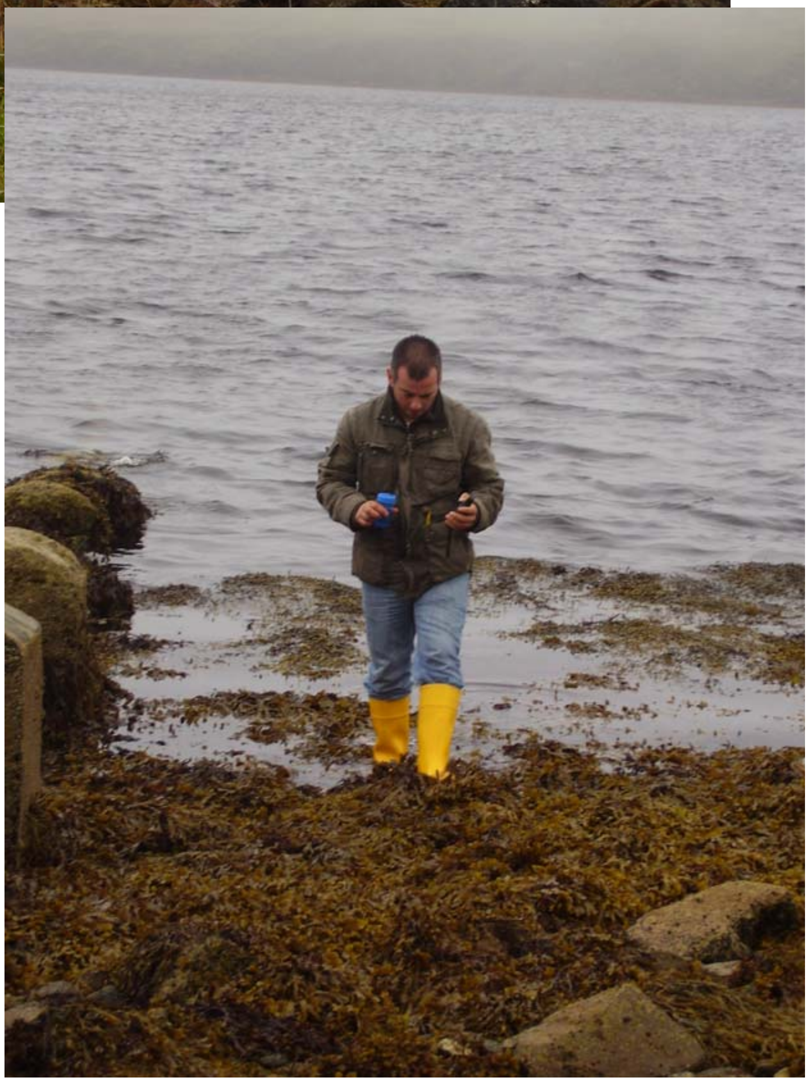


Figure 22. Busta060909. Pipe across shoreline.

Figure 23. Busta060910. Broken pipe on shore.

Figure 24. Busta060911. Sanitary debris.

Figure 25. Busta060914. Large pipe, dripping.

Figure 26. Busta060917. New marina.

Figure 27. Busta060918. Field drainage.

Figure 28. Busta060920. Septic tank cover.

Figure 29. Busta060921. Exposed septic pipe under repair.

Figure 30. Busta060925. Mussel lines.

Sampling Plan for Busta Voe

PRODUCTION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISHERY	NGR OF RMP	EAST	NORTH	TOLERANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Busta Voe Lee North	Hevden Ness	SI 327 755 08	Common mussels	Long line	HU 3570 6616	43570	11616	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

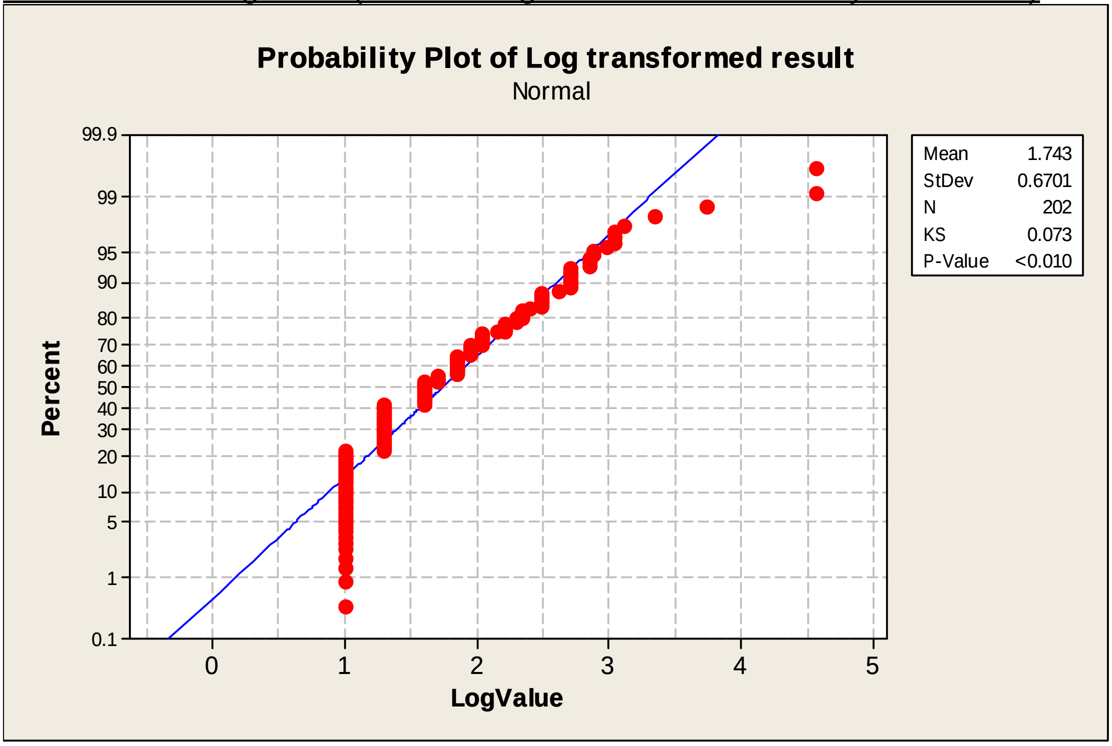
Animal	Faecal coliforms (FC) number	Excretion (g/day)	FC Load (numbers /day)
Chicken	1,300,000	182	2.3×10^8
Cow	230,000	23,600	5.4×10^9
Duck	33,000,000	336	1.1×10^{10}
Horse	12,600	20,000	2.5×10^8
Pig	3,300,000	2,700	8.9×10^8
Sheep	16,000,000	1,130	1.8×10^{10}
Turkey	290,000	448	1.3×10^8
Human	13,000,000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

<u>Distribution on log scale (with Kolmogorov-Smirnov normality test results)</u>



<u>Section 11.2 ANOVA comparison of results by site</u>

```
Source    DF      SS     MS     F      P
Site       4   6.295  1.574  3.69  0.006
Error    197  83.972  0.426
Total    201  90.268

S = 0.6529   R-Sq = 6.97%   R-Sq(adj) = 5.09%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level              N    Mean   StDev  ------+---------+---------+---------+---
Busta Voe         90  1.7040  0.5772   (---*---)
Busta Voe Lee     90  1.6651  0.6541  (---*--)
Hevden Ness        8  2.4157  1.1132              (------------*------------)
North of Linga     7  2.1956  0.7621       (-------------*-------------)
Wetherstaness      7  2.0252  0.8252  (-------------*-------------)
                                      ------+---------+---------+---------+---
                                          1.75      2.10      2.45      2.80

Pooled StDev = 0.6529

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

Individual confidence level = 99.35%
```

```
Site = Busta Voe subtracted from:

Site                Lower   Center   Upper
Busta Voe Lee     -0.3066  -0.0389  0.2288
Hevden Ness        0.0492   0.7117  1.3743
North of Linga    -0.2130   0.4916  1.1963
Wetherstaness     -0.3835   0.3212  1.0259

Site              --------+---------+---------+---------+-
Busta Voe Lee                  (---*--)
Hevden Ness                         (-------*-------)
North of Linga                  (--------*--------)
Wetherstaness                 (--------*--------)
                  --------+---------+---------+---------+-
                       -0.80      0.00      0.80      1.60


Site = Busta Voe Lee subtracted from:

Site                Lower  Center   Upper
Hevden Ness        0.0881  0.7506  1.4132
North of Linga    -0.1741  0.5305  1.2352
Wetherstaness     -0.3446  0.3601  1.0648

Site              --------+---------+---------+---------+-
Hevden Ness                         (-------*--------)
North of Linga                   (--------*-------)
Wetherstaness                  (--------*-------)
                  --------+---------+---------+---------+-
                       -0.80      0.00      0.80      1.60


Site = Hevden Ness subtracted from:

Site                Lower   Center   Upper
North of Linga    -1.1495  -0.2201  0.7094
Wetherstaness     -1.3200  -0.3905  0.5389

Site              --------+---------+---------+---------+-
North of Linga        (----------*-----------)
Wetherstaness       (----------*-----------)
                  --------+---------+---------+---------+-
                       -0.80      0.00      0.80      1.60


Site = North of Linga subtracted from:

Site               Lower   Center   Upper
Wetherstaness    -1.1304  -0.1705  0.7895

Site             --------+---------+---------+---------+-
Wetherstaness        (-----------*----------)
                 --------+---------+---------+---------+-
                      -0.80      0.00      0.80      1.60
```

Section 11.2 ANOVA comparison of results where all 5 sites were sampled on the same day

Source	DF	SS	MS	F	P
Site (all on same day)	4	0.8276	0.20689	1.49	0.242
day of coll (all5)	5	10.4241	2.08481	15.05	0.000
Error	20	2.7697	0.13849		
Total	29	14.0213			

S = 0.3721   R-Sq = 80.25%   R-Sq(adj) = 71.36%

Section 11.4.1 ANOVA comparison of results by season

```
Source   DF      SS     MS     F      P
Season    3   9.500  3.167  7.76  0.000
Error   198  80.767  0.408
Total   201  90.268

S = 0.6387   R-Sq = 10.52%   R-Sq(adj) = 9.17%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  ---+---------+---------+---------+------
1      45  1.3704  0.4598  (-------*------)
2      57  1.7603  0.7094                 (-----*------)
3      55  1.9790  0.7636                         (------*------)
4      45  1.8053  0.5179                  (------*-------)
                           ---+---------+---------+---------+------
                            1.25      1.50      1.75      2.00

Pooled StDev = 0.6387


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

Individual confidence level = 98.96%


Season = 1 subtracted from:

Season   Lower  Center   Upper  ---+---------+---------+---------+------
2       0.0602  0.3898  0.7194                (-------*-------)
3       0.2763  0.6085  0.9408                     (-------*--------)
4       0.0864  0.4349  0.7833                (--------*--------)
                                ---+---------+---------+---------+------
                                -0.40      0.00      0.40      0.80


Season = 2 subtracted from:

Season    Lower  Center   Upper  ---+---------+---------+---------+------
3       -0.0937  0.2187  0.5311            (------*-------)
4       -0.2846  0.0450  0.3747       (-------*-------)
                                 ---+---------+---------+---------+------
                                 -0.40      0.00      0.40      0.80


Season = 3 subtracted from:

Season    Lower   Center   Upper  ---+---------+---------+---------+------
4       -0.5059  -0.1737  0.1586  (--------*-------)
                                  ---+---------+---------+---------+------
                                  -0.40      0.00      0.40      0.80
```

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

```
The regression equation is
2dayrainres = 1.61 + 0.0302 2dayrainmm

Predictor        Coef   SE Coef      T      P
Constant      1.61261   0.09264  17.41  0.000
2dayrainmm   0.030250  0.009831   3.08  0.003

S = 0.699247   R-Sq = 7.5%   R-Sq(adj) = 6.7%
```

```
Analysis of Variance

Source           DF       SS      MS     F      P
Regression        1   4.6288  4.6288  9.47  0.003
Residual Error  117  57.2067  0.4889
Total           118  61.8355


Unusual Observations

Obs  2dayrainmm  2dayrainres     Fit  SE Fit  Residual  St Resid
 11         1.6       3.1139  1.6610  0.0820    1.4529     2.09R
 12         1.6       3.7324  1.6610  0.0820    2.0714     2.98R
 68        22.4       3.0414  2.2902  0.1662    0.7512     1.11 X
 69        22.4       2.6990  2.2902  0.1662    0.4088     0.60 X
104         0.0       4.5563  1.6126  0.0926    2.9437     4.25R

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 2 days).

```
Source       DF      SS     MS     F      P
2dayrainq     3   8.097  2.699  5.78  0.001
Error       115  53.739  0.467
Total       118  61.835

S = 0.6836   R-Sq = 13.09%   R-Sq(adj) = 10.83%


                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
q1     37  1.7470  0.7771           (------*-------)
q2     16  1.6942  0.7639     (----------*-----------)
q3     29  1.5119  0.5820  (-------*--------)
q4     37  2.1837  0.6182                       (-------*------)
                           --------+---------+---------+---------+-
                                1.50      1.80      2.10      2.40

Pooled StDev = 0.6836


Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of 2dayrainq

Individual confidence level = 98.97%


2dayrainq = q1 subtracted from:

2dayrainq    Lower   Center   Upper  ---------+---------+---------+---------
+
q2         -0.5865  -0.0528  0.4809           (--------*--------)
q3         -0.6775  -0.2351  0.2072          (------*------)
q4          0.0220   0.4367  0.8513                     (------*------)
                                     ---------+---------+---------+---------

+
                                           -0.60      0.00      0.60
1.20
```

```
2dayrainq = q2 subtracted from:

2dayrainq    Lower   Center   Upper  --------+---------+---------+---------+
q3         -0.7378  -0.1823  0.3731         (--------*--------)
q4         -0.0442   0.4895  1.0232                    (--------*--------)
                                     --------+---------+---------+---------+
                                         -0.60      0.00      0.60      1.20

2dayrainq = q3 subtracted from:

2dayrainq   Lower  Center   Upper  ---------+---------+---------+---------+
q4         0.2294  0.6718  1.1142                           (------*-------)
                                   ---------+---------+---------+---------+
                                         -0.60      0.00      0.60      1.20
Pooled StDev = 0.6836
```

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

```
The regression equation is
7dayrainres = 1.45 + 0.0141 7dayrainmm

Predictor       Coef   SE Coef      T      P
Constant      1.4516    0.1067  13.61  0.000
7dayrainmm  0.014116  0.003337   4.23  0.000

S = 0.677062   R-Sq = 13.3%   R-Sq(adj) = 12.5%

Analysis of Variance

Source           DF       SS      MS      F      P
Regression        1   8.2012  8.2012  17.89  0.000
Residual Error  117  53.6343  0.4584
Total           118  61.8355

Unusual Observations

Obs  7dayrainmm  7dayrainres     Fit  SE Fit  Residual  St Resid
 12        23.6       3.7324  1.7847  0.0626    1.9477      2.89R
 85        32.0       3.3424  1.9033  0.0652    1.4392      2.14R
 97         2.6       2.8451  1.4883  0.0997    1.3568      2.03R
104        10.0       4.5563  1.5927  0.0818    2.9636      4.41R

R denotes an observation with a large standardized residual.
```

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

```
Source      DF      SS     MS     F      P
7dayrainq    3  10.697  3.566  8.02  0.000
Error      115  51.138  0.445
Total      118  61.835

S = 0.6668   R-Sq = 17.30%   R-Sq(adj) = 15.14%

Individual 95% CIs For Mean Based on Pooled StDev
Level   N    Mean   StDev   -+---------+---------+---------+--------
q1     31  1.7029  0.7713               (------*-----)
q2     23  1.2904  0.3972   (-------*-------)
q3     33  2.0286  0.7749                          (------*------)
q4     32  2.0930  0.5849                            (------*-----)
                            -+---------+---------+---------+--------
                           1.05      1.40      1.75      2.10

Pooled StDev = 0.6668
```

```
Tukey 95% Simultaneous Confidence Intervals
All Pairwise Comparisons among Levels of 7dayrainq

Individual confidence level = 98.97%


7dayrainq = q1 subtracted from:

7dayrainq    Lower   Center   Upper  --------+---------+---------+---------
+-
q2         -0.8914  -0.4126  0.0663       (------*------)
q3         -0.1095   0.3257  0.7609                  (------*-----)
q4         -0.0484   0.3900  0.8285                   (------*-----)
                                     --------+---------+---------+---------
+-
                                          -0.70      0.00      0.70
1.40


7dayrainq = q2 subtracted from:

7dayrainq   Lower  Center   Upper  --------+---------+---------+---------+-
q3         0.2657  0.7383  1.2109                       (------*-----)
q4         0.3270  0.8026  1.2782                        (-----*------)
                                   --------+---------+---------+---------+-
                                        -0.70      0.00      0.70      1.40


7dayrainq = q3 subtracted from:

7dayrainq    Lower  Center   Upper  --------+---------+---------+---------+-
q4         -0.3673  0.0643  0.4960              (-----*-----)
                                    --------+---------+---------+---------+-
                                         -0.70      0.00      0.70      1.40
```

Section 11.4.3 ANOVA comparison of results by tide size

```
Source      DF      SS     MS     F      P
Tide size    2   1.263  0.632  1.41  0.246
Error      199  89.004  0.447
Total      201  90.268

S = 0.6688   R-Sq = 1.40%   R-Sq(adj) = 0.41%


                            Individual 95% CIs For Mean Based on
                            Pooled StDev
Level    N    Mean   StDev  ---------+---------+---------+---------+
Large   56  1.8530  0.6339             (-----------*----------)
Medium  84  1.6602  0.6380  (---------*--------)
Small   62  1.7558  0.7369       (----------*----------)
                            ---------+---------+---------+---------+
                                   1.65      1.80      1.95      2.10

Pooled StDev = 0.6688
```

Section 11.4.5 Circular-linear correlation of wind direction and result

CIRCULAR-LINEAR CORRELATION

Busta Voe

Analysis begun: 18 December 2007 10:58:02

Variables (& observations)	r	p
Angles & Linear (103)	0.27	6.81E-4

Hydrographic Methods

1.0 Introduction

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. This document collects together information common to all hydrographic assessments avoiding the repetition of information in each individual report.

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.

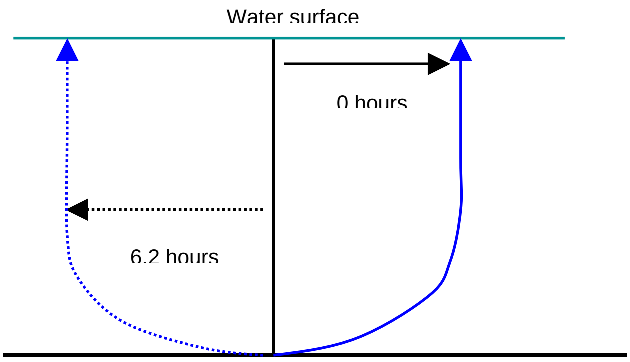
The regulations require an appreciation of the hydrography and currents within a region classified for shellfish production.

2.0 Background processes

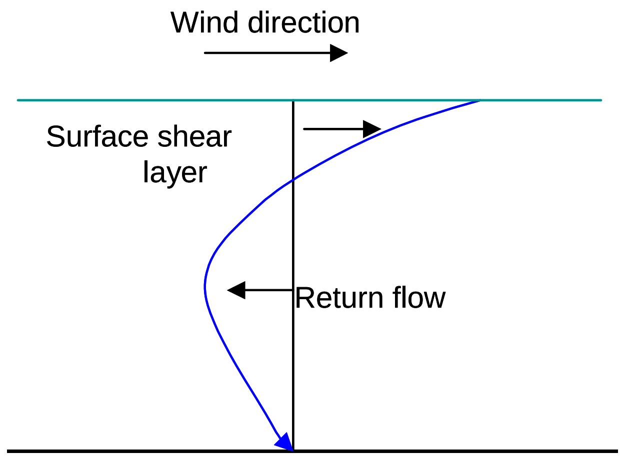
This section gives an overview of the hydrographic processes relevant to sanitary surveys.

Movement in the estuarine and coastal waters is generally driven by one of three mechanisms: 1) Tides, 2) Winds, 3) Density differences. Unless tidal flows are weak they usually dominate over the short term (~12 hours) and move material over the length of the tidal excursion. The tidal residual flow acts over longer time scales to give a net direction of transport. 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)



b)



c)

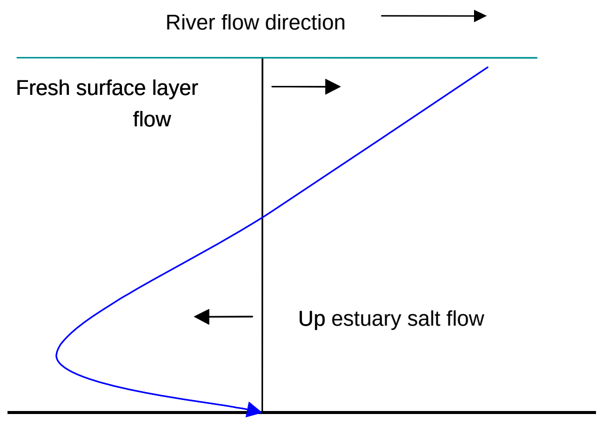


Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

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

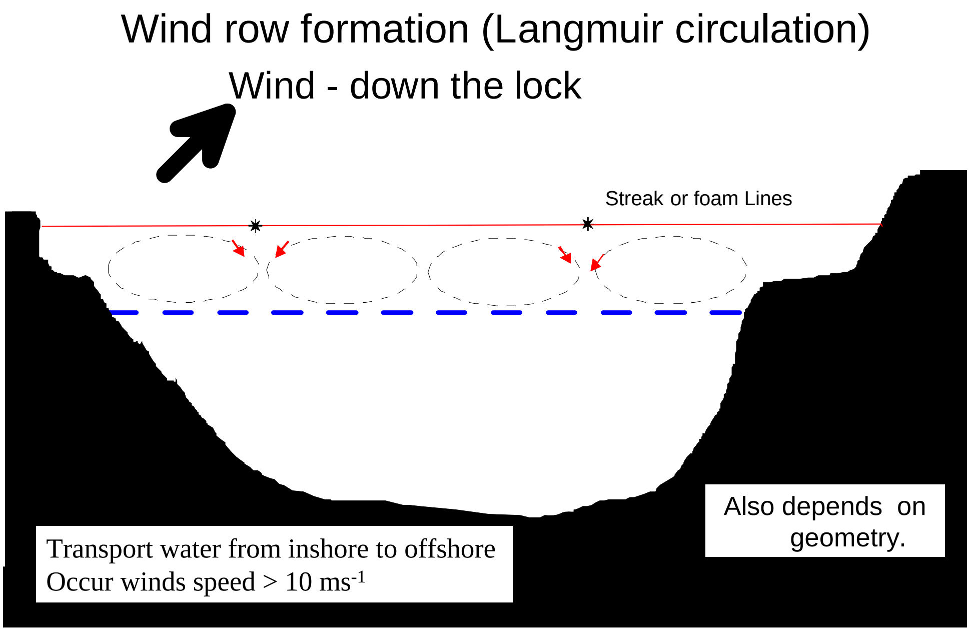


Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

2.0 Basic Assessment

This will be applied to most sites and consists of a description of bathymetry and the tidal regime obtained from admiralty charts and tidal diamonds and is not described in detail here.

3.0 More Detailed Assessment

This is applied at the request of the regulator (FSAS) when particular circumstances apply. Typically this will be at sites where production areas regular fail or where unusual results have been reported.

3.1 Modelling approach

The Hydrotrack computer model is used. This is able to simulate depth averaged tidal currents and give some indication of wind driven currents. Model output from the model is analysed to provide information on:

- Particle paths due to tides and winds.
- Residual current patterns due to tide and winds.

Tidal forcing is a simple sinusoidal current applied at the model boundary. Where possible the assumption is made that the change in tidal phase across the boundary is negligible. Basic checking of the model is limited to the available data. In most cases this is limited to reproducing the observed tidal range. If tidal diamond or current meter observations are available, model results are checked against these.

Model calculations are carried out for five cases: tides only and tides plus winds from north, south east and west directions. The resulting winds patterns are for winds blowing constantly for 48 hours so that a steady current pattern is produced. In reality of course winds are highly variable. For each of these cases the results over the last two tidal periods are analysed to provide tidal phase and amplitude and the residual current. The paths of particles moving with the water and starting from known sources of contamination are calculated using the analysed currents. For point sources very near the shore, model release points may be moved slightly offshore out to ensure particles are caught by the prevailing current and not trapped at the release point.

For a given water body, the strength of the applied wind is chosen to ensure wind driven currents are large relative to the tidal currents so that particle paths clearly show the wind driven movement.

Although Hydrotrack calculates currents over the spatial area of a water body, it cannot calculate the vertical profile of currents. Although adequate for tidal flows this has limitations for wind and density driven systems characteristic of many sea lochs. Therefore the modelling approach is more usefully applied to tidally dominated systems or shallow regions where vertical structure may be less significant.

3.2 Non-modelling approach

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

1. Near-shore flows will generally align parallel to the shore.
2. Tidal flows are bi-directional, thus sources on either side of a production area are potentially polluting.
3. For tidal flows, the tidal excursion gives an idea of the likely main ‘region of influence’ around an identified pollutant source.
4. Wind driven flows can drive material from any direction depending on the wind direction. Wind driven current speeds are usually at a maximum when the wind direction is aligned with the principle axis of the loch.
5. Density driven flows generally have a preferred direction.
6. Material will be drawn out in the direction of current, often forming long thin ‘plumes’.
7. Estimates of flow speed combined with T_{90} will give a ‘region of influence’.
8. The ratio of river run-off to tidal prism gives an indication of the importance of density effects.

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

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

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

Dilution calculations in regions with steep and variable bathymetry typical of sea lochs are extremely difficult. The following methods are applied.

For class A and B classifications, correlation with data (European Commission 1996) suggest the following water concentration need to be achieved:

Class A: 1 bacterium per 100 ml = 10^4 m^{-3}
Class B: 100 bacterium per 100 ml = 10^6 m^{-3}

3.2.1 Integrated inputs

Given *E. coli* loadings and estimates of water body volume and flushing time, the E. coli concentration averaged over the entire water body can be estimated from

$$C = S T_f / V$$

C = number *e-coli* m^{-3}
S = Sum of all loadings (number of *e-coli* per day)
T_f = Flushing time (days)
V = Water body volume (m^3)

This can then be compared with the Class A and B requirements.

3.2.2 Individual inputs

For a source with a loading M *E. coli* per second, discharging into water flowing at speed u (ms^{-1}), the number of *E. coli* per meter in the flow direction is given by M/u (*E. coli* m^{-1}). To achieve a target concentration of T, the cross sectional area that the material needs to be mixed over is given by

$$A = M/(u\ T)$$

Assuming an average depth for the water body this can be converted to a distance offshore. A subjective judgement can then made as to whether this is likely to occur over the relevant time scales (< 3 days). That is, will the required dilution occur quickly enough that only localised impacts would be expected? For sea lochs the assumption is made that away from the sills, mixing is likely to be quite weak.

References

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

Glossary of terms

The following technical terms appear in the hydrographic assessment.

Bathymetry. The underwater topography given as depths relative to some fixed reference level e.g. mean sea level.
Hydrography. Study of the movement of water in navigable waters e.g. along coasts, rivers, lochs, estuaries.
Tidal period. The dominant tide around the UK is the twice daily one generated by the moon. It has a period of 12.42 hours. For nearshore so-called rectilinear tidal currents then roughly speaking water will flow one way for 6.2 hours then back the other way for 6.2 hours.
Tidal range. The difference in height between low and high water. Will change over a month.
Tidal excursion. The distance travelled by a particle over one half of a tidal cycle (roughly~6.2 hours). Over the other half of the tidal cycle the particle will move in the opposite direction leading to a small net movement related to the tidal residual. The excursion will be largest at Spring tides.
Tidal residual. For the purposes of these documents it is taken to be the tidal current averaged over a complete tidal cycle. Very roughly it gives an idea of the general speed and direction of travel due to tides for a particle over a period of several days.
Tidal prism. The volume of water brought into an estuary or sea loch during half a tidal cycle. Equal to the difference in estuary/sea loch volume at high and low water.
Spring/Neap Tides. The strongest tides in a month are called spring tides and the weakest are called neap tides. Spring tides occur every 14 days with neaps tides occurring 7 days after springs. Both tidal range and tidal currents are strongest at Spring tides.
Tidal diamonds. The tidal velocities measured and printed on admiralty charts at specific locations are called tidal diamonds.
Wind driven shear/surface layer. The top metre or so of the surface that generally moves in the rough direction of the wind typically at a speed that is a few percent (~3%)of the wind speed.
Return flow. Often a surface flow at the surface is accompanied by a compensating flow in the opposite direction at the bed (see figure 1).
Stratification. The splitting of the water into two layers of different density with the less dense layer on top of the denser one. Due to either temperature or salinity differences or a combination of both.