Scottish Sanitary Survey Project

Sanitary Survey Report
Loch Riddon
AB 183
February 2010

Report Distribution – Loch Riddon

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

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Appendices

1. General Description

Loch Riddon is located on the southwest coast of Scotland near the top of the Kyles of Bute. Its fairly sheltered by surrounding islands and the mainland. Loch Riddon is roughly 5 km in length and 0.8 km wide. In the lower reaches of the loch, the depth varies from 10-50 m. The rest of the loch is shallow (<5 m) with an extensive intertidal area. This survey was undertaken on the basis of the score Loch Riddon received on the risk matrix.

Figure 1.1 Location of Loch Riddon

2. Fishery

The fishery at Loch Riddon (AB-183-052) is comprised of six Pacific oyster (*Crassostrea gigas*) trestles.

The Loch Riddon production area is currently described as the area bounded by a line drawn between NS 0011 7700 and NS 0100 7700 extending to MHWS. The Representative Monitoring Point (RMP) is currently located at NS 007 783. The production area boundaries and RMP are mapped in Figure 2.1 overleaf.

The entire loch is a designated shellfish growing water. Planning papers from Argyll and Bute Council indicate that the Crown Estates do not claim ownership of the seabed / foreshore here, so no Crown Estates seabed lease is applicable to the area.

The fishery currently consists of only 6 trestles covering an area of approximately 3 m by 10 m, and is not harvested commercially at present. At the time of shoreline survey, stock on site had been there for about three years, and was of a marketable size. Planning permission to extend the site to 672 trestles had recently been granted, but the grower is awaiting the award of a grant before expanding the operation. The area in which permission for these trestles has been granted, as indicated in planning documents held by Argyll and Bute Council, together with the location of the six trestles at the time of shoreline survey are shown in Figure 2.1.

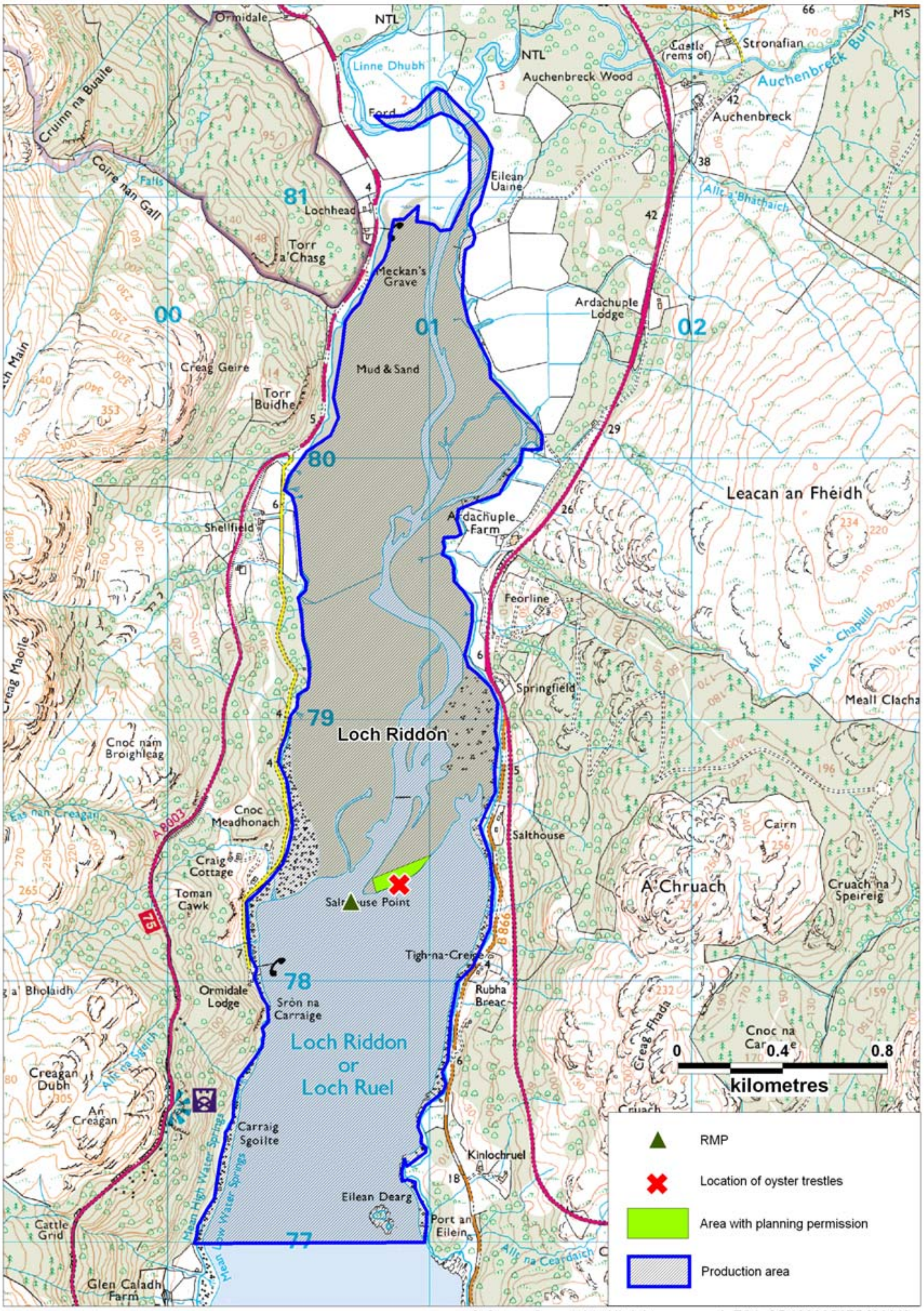

Figure 2.1 Loch Riddon shellfish farm

3. Human Population

The figure below shows information obtained from the General Register Office for Scotland on the population within the census output areas bordering on Loch Riddon. Statistics given are those obtained for the 2001 census.

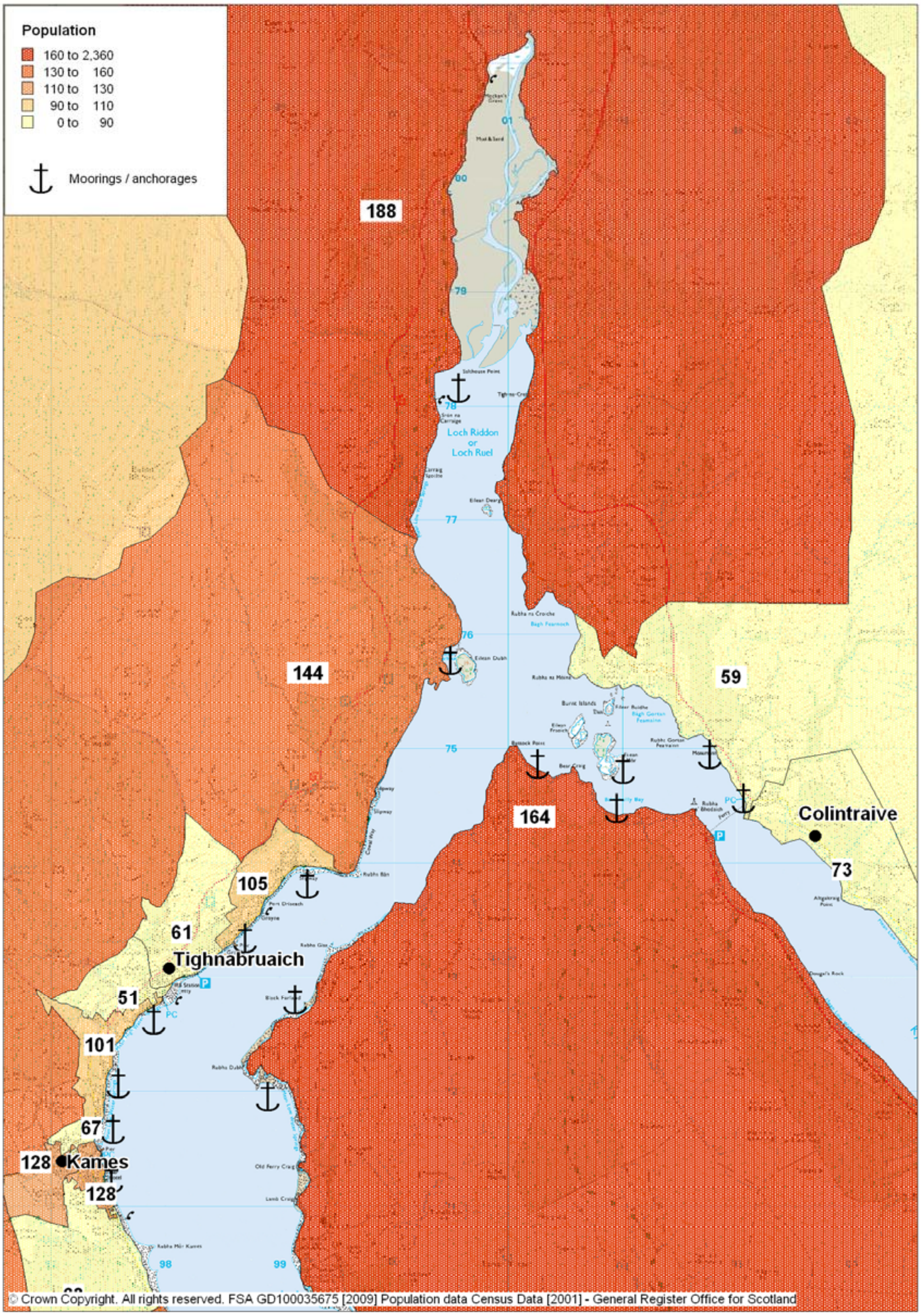

Figure 3.1 Population of Loch Riddon

The population for the three census output areas bordering immediately on the loch are:

60QD000016	188
60QD000014	144
60QD000018	59
Total	391

Population figures for the census output areas encompassing the northern Kyles of Bute, south to Kames on the west side and Colintraive on the east side, including the Isle of Bute are:

60QD000012	105
60QD000010	61
60QD000011	51
60QD000007	101
60QD000008	67
60QD000006	128
60QD000009	128
60QD000013	63
60QD000571	164
60QD000018	59
Total	927

Population in along the shores of Loch Riddon is sparse, with no major settlements, although there are a few scattered dwellings on both the east and west shores. Further south of the loch, along the east and west arms of the Kyles of Bute, the villages of Kames, Tighnabruaich and Colintrave contain significant resident populations.

As, there is tourist accomodation at Colintraive and Tighnabruaich, it is anticipated that the above population figures will be higher during the summer months. A marina, boat yard and sailing club are located at Tignabruaich and The Clyde Cruising Club guide to the Firth of Clyde indicates the area is very popular with cruising yachts with a number of moorings and anchorages both within and just outside Loch Riddon. There is potential for contamination directly to the loch from yachts discharging toilet waste overboard, as well as to the waters flowing into the loch from the south.

A camping and caravan park is situated along the River Ruel approximately 13 km upstream of the estuary at the head of the loch (not shown on map). The Cowal Way walking path runs along the River Ruel and south along the west side of Loch Riddon. This is likely to draw walkers mostly during the summer months.

Therefore, on this basis there is the potenital for direct contamination of the loch with human sewage, and this is likely to be more pronounced during the summer months when the population is expected to increase due to tourism.

4. Sewage Discharges

Scottish Water identified the following discharges within 8 km of the production area. These are listed from north to south in Table 4.1.

Table 4.1 Scottish Water discharges near Loch Riddon

NGR	Discharge Name	Discharge Type	Level of Treatment	Consented flow (DWF) m^3/d	Consented /design PE	SEPA consent ref no.
NS 0287 7462	Colintraive Kyles View ST	continuous	septic tank	8	15	WPC-W-72021
NS 0310 7450	Colintraive Ferry Bank ST	continuous	septic tank	not stated	not stated	Not known
NS 0414 7346	Colintraive South ST	continuous	septic tank	13.3	37	WPC-W-72017
NS 0414 7346	Colintraive South CSO/EO	intermittent	6mm screening		not stated	WPC-W-72017
NR 9815 7295	Tighnabruaich SPS2 CSO/EO	intermittent	storage/6mm screening	131.6	506	WPC-W-30495
NR 9752 7199	Tighnabruaich SPS3 CSO/EO	intermittent	storage/6mm screening	156.6	602	WPC-W-30497
NR 9763 7093	Kames SPS4 CSO/EO	intermittent	storage/6mm screening	194.5	747	WPC-W-30501
NR 9824 7012	Kames & Tighnabruaich STW	continuous	secondary	197	757	CAR/L/1003717
NR 9824 7012	Kames & Tighnabruaich STW CSO/EO	intermittent	septic tank	197	757	CAR/L/1003717
NR 9824 7012	Kames TPS1 CSO/EO	intermittent	storage/6mm screening	197	757	WPC-W-30499 and CAR/L/1003715

The Scottish Environment Protection Agency provided information on the following discharge consents granted within the same area as above, listed from north to south in Table 4.2.

Table 4.2 Discharge consents issued by SEPA

Ref No.	NGR of discharge	Discharge Type	Discharges to	Consented flow (DWF) m^3/d	Consented/ design PE	Comments
CAR/R/1026653	NS 0070 8737	Domestic	Land via soakaway		12	Private discharge at Glendaruel
CAR/R/1020614	NS 0072 8728	Domestic	Unnamed tributary of River Ruel		5	Private discharge at Glendaruel
WPC-W-0011366	NS 001 869	Domestic	Unnamed watercourse		Possibly over 100 at times	Glendaruel Caravan Park ST.
CAR/R/101909	NR 9994 8529	Domestic	Land via soakaway		8	Private discharge near Glendaruel
CAR/R/1022609	NS 0110 8220	Domestic	Unnamed watercourse		5	Private discharge to Ruel tributary
CAR/R/1018092	NS 0132 7935	Domestic	Unnamed watercourse via partial soakaway		5	Private discharge to small watercourse flowing direct into production area
CAR/R/1019026	NS 0117 7808	Domestic	Loch Riddon		5	Private discharge direct to production area. Also observation 1 on Table 4.3
CAR/R/1020521	NS 0169 7648	Domestic	Allt na Fearnoch		5	Private discharge about 2 km south of the trestles
WPC-W-72021	NS 0287 7462	Domestic	Kyles of Bute	8	15	Colintraive Kyles View ST

Ref No.	NGR of discharge	Discharge Type	Discharges to	Consented flow (DWF) m3/d	Consented/ design PE	Comments
CAR/R/1023279	NS 0334 7460	Domestic	Milton Burn via partial soakaway		5	Private discharge at Colintraive
CAR/R/1026006	NR 9974 7455	Domestic	Coastal waters		5	Private discharge at Tighnabruich
CAR/R/1021333	NR 9877 7366	Domestic	Kyles of Bute		5	Private discharge at Tighnabruich
WPC-W-72017	NS 0414 7346	Domestic	Kyles of Bute	13.32	37	Colintraive South ST and CSO/EO
CAR/R/1022469	NR 9872 7345	Domestic	Kyles of Bute		6	Private discharge at Tighnabruich
WPC-W-30495	NR 9815 7295	Storm sewage	Kyles of Bute	131.6	506	Tighnabruaich SPS2 CSO/EO
WPC-W-30497	NR 9752 7199	Storm sewage	Kyles of Bute	156.6	602	Tighnabruaich SPS3 CSO/EO
CAR/R/1025342	NR 9739 7146	Domestic	Land via soakaway		8	Private discharge at Kames
CAR/R/1029160	NR 9743 7139	Domestic	Land via soakaway		5	Private discharge at Kames
CAR/R/1013781	NR 9709 7109	Domestic	Watercourse		5	Private discharge at Kames
CAR/R/1019884	NR 9704 7108	Domestic	Land via soakaway		12	Private discharge at Kames
CAR/R/1015796	NR 9752 7107	Domestic	Kyles of Bute		5	Private discharge at Kames
WPC-W-30501	NR 9763 7093	Domestic	Kyles of Bute	194.5	747	Kames SPS4 CSO/EO
CAR/R/1014558	NR 9576 7070	Domestic	Land		6	Private discharge at Tighnabruich
CAR/R/1021311	NR 9769 7057	Domestic	Coastal waters		5	Private discharge at Kames
CAR/L/1003715	NR 9824 7012	Domestic	Kyles of Bute	196.82	757	Kames Transfer pumping Station 1. Same as WPC-W-30499
WPC-W-30499	NR 9824 7012	Domestic	Kyles of Bute	196.82	757	Kames Transfer pumping Station 1. Same as CAR/L/1003715
CAR/L/1003717	NR 98043 69998	Domestic	Kyles of Bute	197	757	Kames & Tighnabruich STW and CSO/EO
CAR/R/1018585	NS 0050 6848	Domestic	Unnamed watercourse		8	Private discharge on Bute

Four outfall pipes were recorded during the shoreline survey. These are listed in Table 4.3.

Table 4.3 Outfall pipes observed during shoreline survey

No	NGR	Description
1	NS 01178 78092	110mm cast iron outfall pipe, serves 1 or 2 houses (presumably CAR/R/1019026)
2	NS 01251 78449	110mm plastic outfall pipe leading underwater, serves 1 house
3	NS 01220 78602	110m cast iron outfall pipe leading underwater, serves 1 house
4	NS 00351 77984	110m cast iron outfall pipe leading underwater, serves 1 house

The locations of discharges in the vicinity of Loch Riddon are mapped in Figure 4.1. This includes discharges within the Ruel catchment, and at Colintraive and Tighnabruich & Kames.

A total of four small private discharges direct to the production area were noted during the shoreline survey (observations 1-4 in Table 4.3). Of these, three were to the east shore, within 0.4 km of the trestles, and one was to the west shore 0.6 km from the trestles. Consent number CAR/R/1019026 applies to observation 1. Assuming a population equivalent of 5 for each discharge, the total population equivalent discharging direct to the production area is 20.

In addition to the discharges direct to Loch Riddon, consents for 26 further discharges which were not observed during the shoreline survey are listed in Table 4.2. Of these, three discharge to tributaries of the River Ruel, including two at Glendaruel, approximately 13 km upriver from the RMP, one of which serves a caravan park. An internet search revealed the caravan site hosts 30 static pitches, two caravans for hire, 10 camping pitches and 15 mixed pitches for visitors to bring their own tourers and camping equipment, so this could potentially serve over 100 people in peak season. The SEPA consent does not specify the size of the associated discharge. The total population equivalents of the other two discharges is 10. Additionally, there are two small private discharges to soakaway at Glendaruel, but it is not expected that these will be of any significance to the fishery.

Also listed are consents for a private discharge serving a population of 5 to a small watercourse which in turn discharges to Loch Riddon over 2 km to the south of the trestles, and for another small private discharge also serving a population of 5 to a watercourse via a partial soakaway about 1 km north of the trestles.

Further afield, are the settlements of Colintraive and Tighnabruaich and Kames. Tighnabruaich & Kames lies between 6 and 8 km south of the production area in the western Kyle of Bute, and Colintraive which between 3 and 5 km south of the production area on the eastern Kyle of Bute. At Tighnabruaich & Kames there is a discharge of secondary treated effluent from a population of 757, and this system also incorporates 5 intermittent EO/CSO discharges. At Colintraive, there are three septic tank discharges and one EO/CSO discharge, serving a population of at least 52 (no information was available on the size of the Colintraive Ferry Bank ST). No information was available on the spill frequencies of the intermittent discharges. There are also a number of small private discharges with SEPA consents at both these settlements.

As there has historically been no requirement to register septic tanks within Scotland, it is likely that there are additional unregistered discharges within the survey area.

In addition to fixed sewage discharges noted above, the area to the south of the fishery is used by yachts and other pleasure craft. A total of 39 yachts were observed on moorings to the south of the fishery, and many more were seen even further south in the Kyles of Bute. Therefore, contamination from these sources may be expected to be carried towards the fishery as the tide floods, and these impacts are likely to be greater during the summer months.

Oyster samples were collected quarterly between August 2008 and May 2009 and analysed for Norovirus genogroups I and II. All samples were positive for genogroup II, and two (those taken in November 2008 and February 2009) were positive for genogroup I. This indicated that human sewage contamination was impacting the fishery throughout the year.

In summary, though sewage inputs direct to Loch Riddon appear to be relatively minor, and are likely be greater during the summer, evidence of human faecal contamination to the oysters was present throughout the year. It is possible that contamination from Colintraive and Tighnabruaich and Kames may impact on the fishery, but they are a considerable distance away. The most significant sources of human sewage relative to the oyster fishery are those on the east shore, those to the River Ruel and its tributaries, and yachts anchored in the vicinity of the oyster farm. The detection of norovirus in oyster samples from Loch Riddon indicates that human faecal contamination is present throughout the year.

Figure 4.1 Sewage discharges at Loch Riddon

5. Geology and Soils

Geology and soil types were assessed following the method described in Appendix 2. A map of the resulting soil drainage classes is shown in Figure 5.1. Areas shaded red and yellow indicate poorly draining soils while areas shaded blue indicate more freely draining soils.

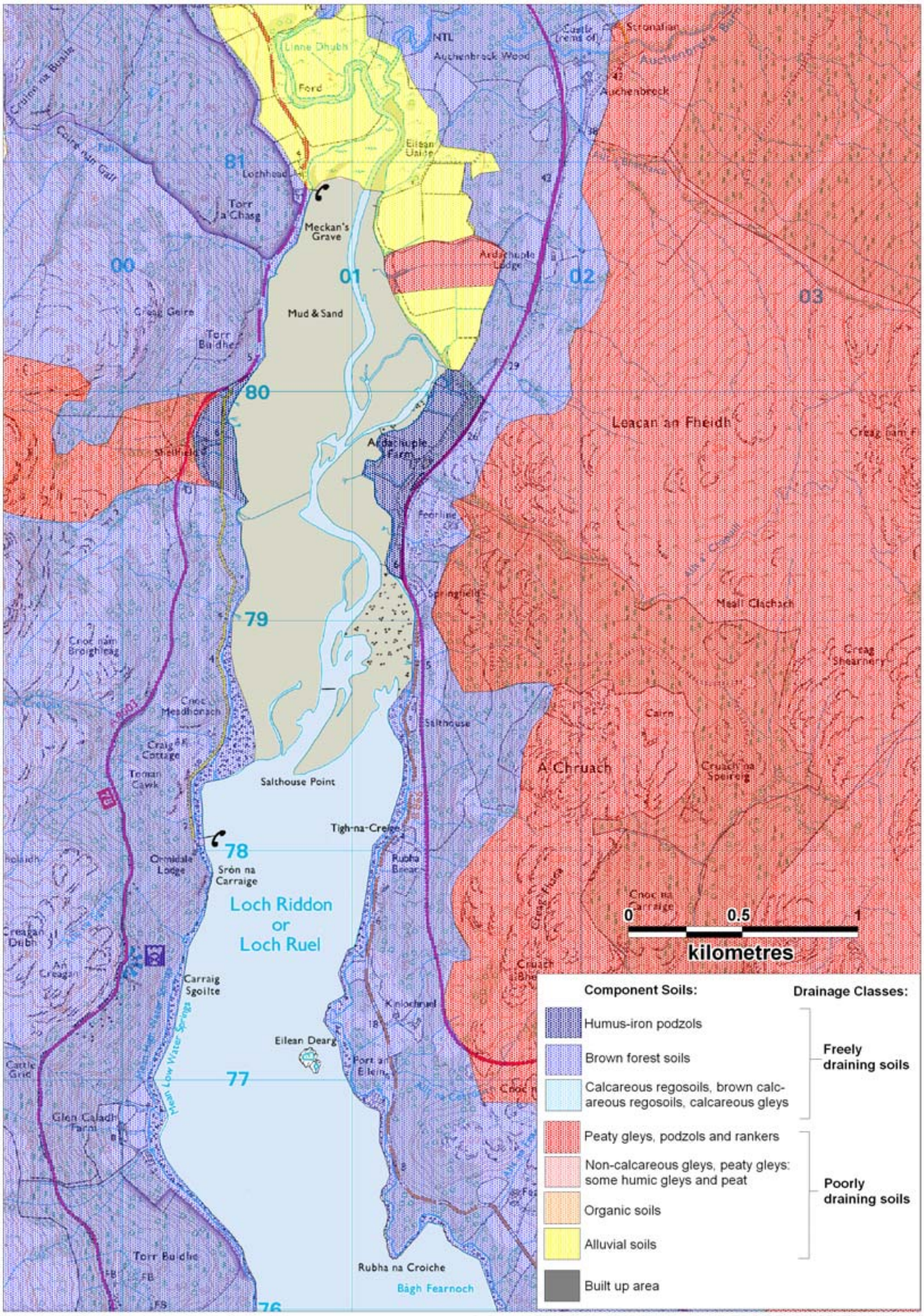

Figure 5.1 Component soils and drainage classes for Loch Riddon.

There are four types of soils found in this area. The most dominant soil type is brown forest soil, which is present along much of the coastline of Loch Riddon. Humus-iron podzols can be found in small patches of coastline, on either side of the loch towards the northern end. Both soil types are classed as freely-draining and as such are less likely to contribute contamination to the loch via rainfall runoff.

Poorly-draining peaty gleys, podzols and rankers are found on the eastern coastline of the loch behind the band of brown forest soils as well as an inland strip on the western coastline. Alluvial soil, also poorly-draining, is found at the northern end of the loch in the floodplain of the River Ruel.

Therefore, the potential for contaminated runoff is greater from the poorly draining soils on the east side of Loch Riddon, and from the alluvial soils found in the floodplain of the River Ruel. Of these, the River Ruel is the most likely to directly impact the fishery.

6. Land Cover

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

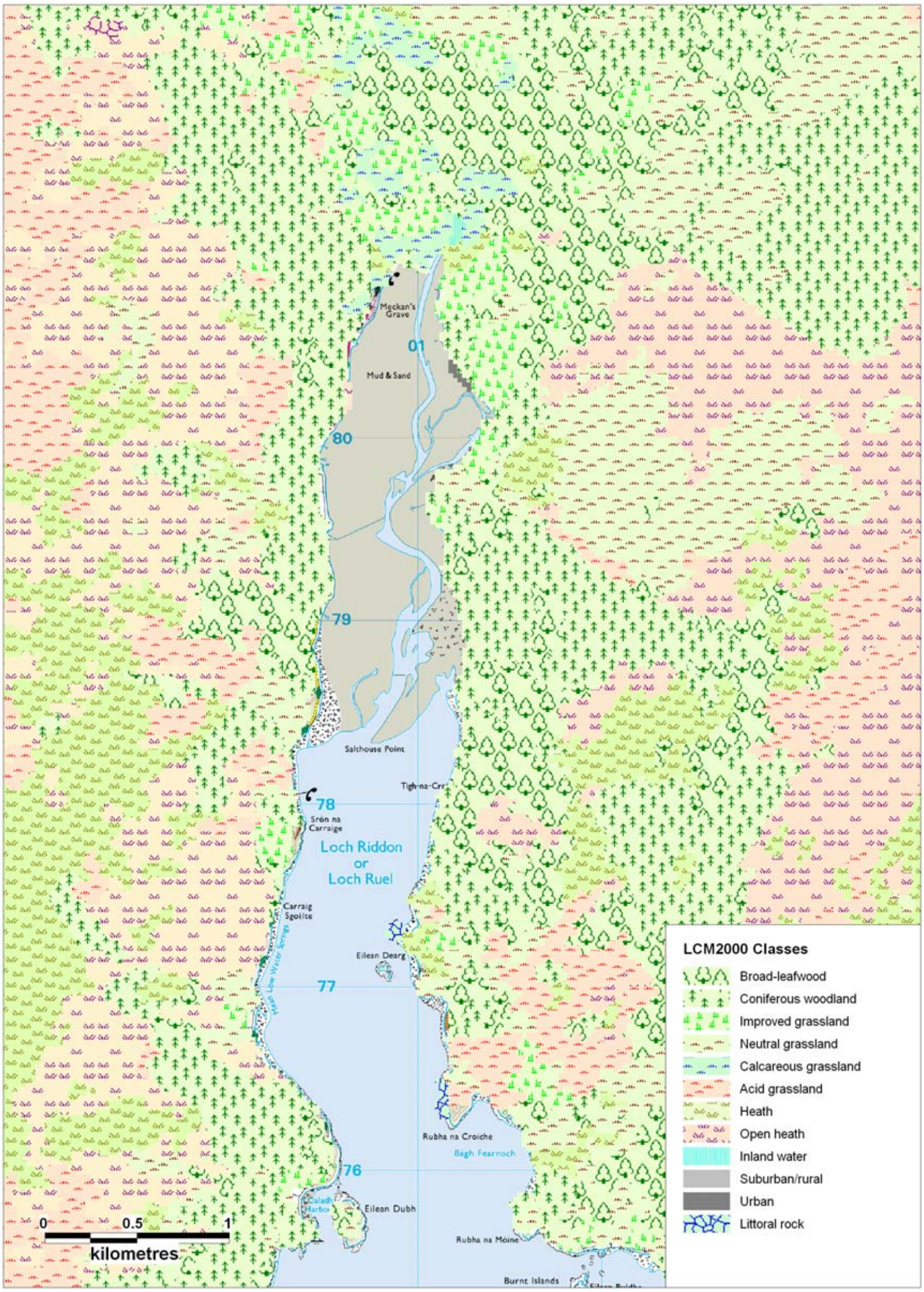

Figure 6.1 LCM2000 class land cover data for Loch Riddon

Much of the land area around Loch Riddon is wooded, with both broadleaf woodland and coniferous plantation present on both sides of the Loch. Areas of improved grassland are found predominantly along the River Ruel floodplain. The remaining area is a mixture of natural grassland and heath.

Faecal coliform contributions would be expected to be higher from the improved grassland (approximately 8.3×10^8 colony forming units (cfu) km^{-2} hr^{-1}) and lower 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.

Therefore, higher contributions from the areas of improved grassland which are mainly found at the head of the loch and along the River Ruel may be expected. The contribution from these areas, and other areas of unimproved grassland may be expected to increase significantly following heavy rainfall.

7. Farm Animals

With regard to potential sources of pollution of animal origin, agricultural census data was requested from the Scottish Government. Agricultural census data was provided by Scottish Government Rural and Environment Research and Analysis Directorate (RERAD) for the parishes of Kilmodan and Inverchaolain. The parish of Kilmodan covers the entire the western coastline of Loch Riddon and also the northern half of the eastern coastline. The parish of Inverchaolain covers the south end of the east coast of Loch Riddon. Reported livestock populations for the parishes in 2007 and 2008 are listed in Table 7.1 and Table 7.2. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data.

Table 7.1 Livestock census data for Kilmodan parish

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	0	-
Total poultry	*	*	*	*
Total cattle	9	804	9	793
Total sheep	9	10858	12	9069
Deer	0	-	0	-
Horses and Ponies	0	-	0	-

* Data withheld on confidentiality basis.

Table 7.2 Livestock census data for Inverchaolain parish

	2007		2008	
	Holdings	Numbers	Holdings	Numbers
Total pigs	*	*	0	-
Total poultry	*	*	*	*
Total cattle	*	*	*	*
Total sheep	6	5448	6	5299
Deer	0	-	0	-
Horses and Ponies	*	*	*	*

* Data withheld on confidentiality basis.

Pigs were no longer farmed in either parish by 2008. Poultry are farmed somewhere within both parishes, however specific data on numbers could not be provided. Specific data numbers concerning horses and ponies were also unavailable for the Inverchaolain parish. Due to the large area of both combined parishes, this data does not provide information on the livestock numbers relevant to the area immediately surrounding Loch Riddon or the River Ruel catchment. The only information specific to the area near the shellfishery was therefore the shoreline survey (Appendix 7), which only relates to the time of the site visit on the 5th and the 6th August 2008. The spatial distribution of animals observed and noted during the shoreline survey is illustrated in Figure 7.1.

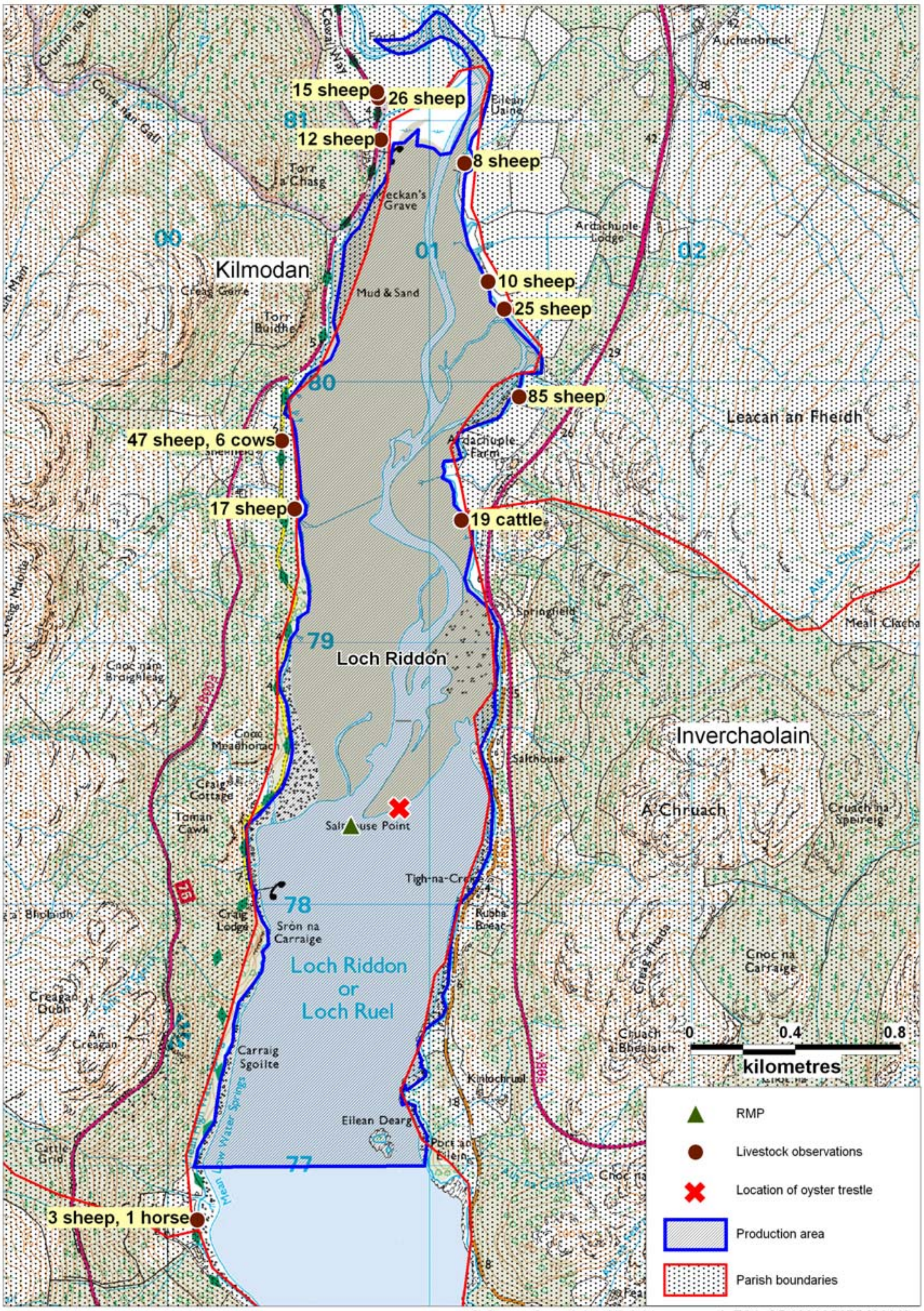

Figure 7.1 Livestock observations at Loch Riddon

These observations confirm that local agriculture is predominately sheep production, with some cattle also present. Livestock were present on fields from around the head of the loch to Ardachuple Farm on the east shore, and on two small areas of pasture on the west shore. Higher levels of contamination in the streams draining these areas may be expected. Much of the floodplain of the River Ruel is improved pasture on which livestock is grazed, so it is likely that the River Ruel is an important pathway for carrying contamination from livestock into the production area, particularly when in spate.

Generally, a seasonal increase in numbers of livestock in the area would be expected with higher numbers beginning in spring, when lambs and calves are born, and a corresponding decrease in autumn when they are sold off or sent for slaughter.

8. Wildlife

General information related to potential risks to water quality by wildlife can be found in Appendix 4. A number of wildlife species present or likely to be present at Loch Riddon could potentially affect water quality around the fishery.

Seals

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*). Scotland hosts significant populations of both species.

A survey conducted by the Sea Mammal Research Unit in 1996 estimated a population of 991 common seals within the area named ‘Clyde Estuary’ (Southend to Loch Ryan). This is large stretch of coastline which includes the east coast of the Kintyre, Loch Fyne, the Clyde estuary and the whole of the Ayrshire coast, so overall densities are low. The exact locations of the haul out sites were not specified, so it is uncertain whether they reside within Loch Riddon. No seals were seen during the course of the shoreline survey.

Seals will hunt widely for food and it is likely that seals will feed near the shellfishery at some point in time. The population is likely to be 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.

Whales/Dolphins

Whales and dolphins are relatively common off the west coast of Scotland and sightings are recorded by the Hebridean Whale and Dolphin trust. These are reported to the trust by ferry skippers, whale watch boats and other observers and are listed in Appendix 4.

Given the shallow, estuarine nature of Loch Riddon, particularly in its upper reaches near the oyster fishery, it is unlikely that whales or dolphins will be present in the near vicinity. It is possible that some of the smaller cetaceans may be present further south within either Loch Riddon or the Kyles of Bute from time to time, but the larger species are unlikely to be seen in this shallow enclosed water body. Any presence, however, is unlikely to impact the fishery in a predictable manner.

Birds

A number of bird species are found in the vicinity of Loch Riddon, but seabirds and waterfowl are most likely to occur around or near the fishery in significant numbers.

Seabird populations were investigated all over Britain as part of the SeaBird 2000 census. The area was surveyed in late spring of 1999. Total counts of all species recorded within 5 km of the production area are presented in Table 8.1. Counts were of occupied nests or territories, so each count represents a breeding pair.

Table 8.1 Seabird counts within 5km of the site

Common name	Species	Count	Method
Herring Gull	*Larus argentatus*	660	Occupied nests/territory
Common Gull	*Larus canus*	21	Occupied nests/territory
Lesser Black-backed Gull	*Larus fuscus*	50	Occupied territory
Great Black-backed Gull	*Larus marinus*	5	Occupied nests/territory

The vast majority of these birds were recorded at Burnt Islands (717 of 736 pairs), which are located just off the northeastern end of Bute, approximately 3.3 km to the south of the trestles. Nesting occurs in early summer and after this many species disperse. However, gulls are likely to be present in the area throughout the year. About 30 gulls were seen at low tide on the mud surrounding the trestles, and their droppings were seen on the oyster bags suggesting that they use the trestles as a perch at certain states of the tide. This direct deposition may be a significant source of contamination as gull faeces have been found to carry high concentrations of faecal bacteria (1.77×10^8 faecal coliforms per faecal deposit, Appendix 3).

Waterfowl (ducks and geese) are likely to be present in the area at various times, primarily to overwinter, or briefly during migration, although some species breed in Argyll and Bute. A total of 33 geese were observed on pastures at the head of the loch during the shoreline survey (August), indicating a presence in the area during the summer months. Geese tend to be found grazing on farm fields and open grassland and so will be mainly be concentrated on the larger areas of pasture around the north and east of the production area and along the River Ruel. Larger numbers of geese may overwinter in the area, and given the faecal coliform content of goose faeces (1.28×10^5 per faecal deposit, Appendix 3), they may have a significant impact at these times if present in large numbers.

Wading birds would be concentrated on intertidal areas, such as the area on which the trestles are located, but none was recorded during the shoreline survey.

Deer

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

Deer will be present particularly in wooded areas where the habitat is best suited for them. The majority of the shoreline of Loch Riddon is wooded. While no population data were available for this specific area, it can be presumed that it host significant populations of deer. However, it is believed that the overall density of deer in the area is likely to be low relative to that of livestock. It is possible that some of the indicator organisms detected in the streams feeding into Loch Riddon will be of deer origin, although this will not materially affect the sampling plans.

Otters

No otters were observed during the course of the shoreline survey, although otters are likely to be present in the area. However, the typical population densities of coastal otters are low and their impacts on the shellfishery are expected to be minor.

Summary

Potential wildlife impacts to the fisheries at Loch Riddon include those from gulls, geese and other waterbirds, deer, seals and otters. Gulls may be a significant source of contamination as there is a breeding colony to the south of the production area, and gulls were observed in the vicinity of the fishery and their droppings were seen on the oyster bags during the shoreline survey. Geese grazing on the pastures may constitute a source of diffuse contamination in the same manner as livestock, but their impacts are likely be minor relative to livestock based on the numbers observed during the shoreline survey, and less predictable as they are free to range more widely. It is however possible that they overwinter in the area in larger numbers, and if this is the case their impacts are likely to be more significant at these times. Impacts from other wildlife species are likely to be of lesser significance. Whilst it is likely that some contamination in the area is of wildlife origin, there is no specific information available to suggest that any particular area is more heavily impacted by wildlife than another.

9. Meteorological data

The nearest weather station is located at Benmore, approximately 13 km to the north east of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). It is likely that the rainfall experienced at Benmore is similar to that experienced at the production area due to their close proximity.

The nearest major weather station where wind is measured is located at Glasgow: Bishopton, approximately 42 km to the east of the production area. Wind direction was recorded at 3 hourly intervals for the majority of the period 1/1/1996 to 31/12/2007. It is likely that there are broad similarities in wind patterns between the production area and the weather station, such as seasonal variations in wind strength. However, given the differences in local topography distance between the two and it is likely that the patterns of wind direction differ, and that the wind strength and direction may differ significantly at any given time.

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 wastewater treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003).

Total annual rainfall and mean monthly rainfall were calculated, and are presented in Figures 9.1 and 9.2.

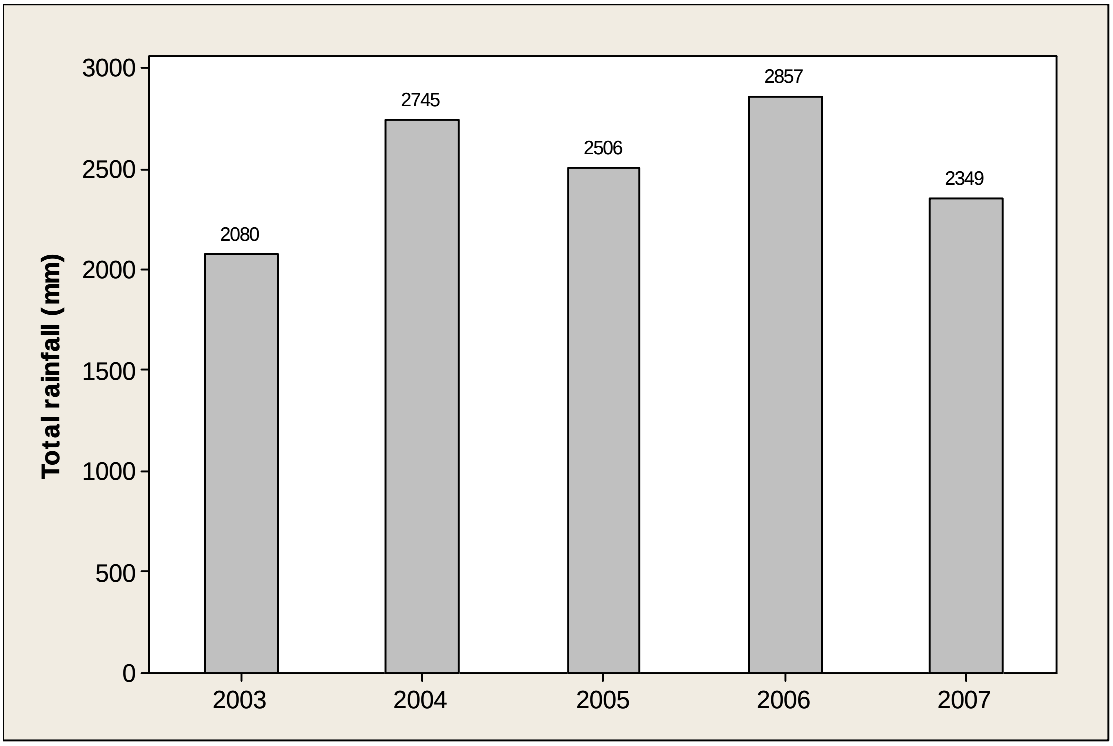

Figure 9.1 Total annual rainfall at Benmore, 2003 – 2007

Variation in annual rainfall was less than the variation between months shown in Figure 9.2.

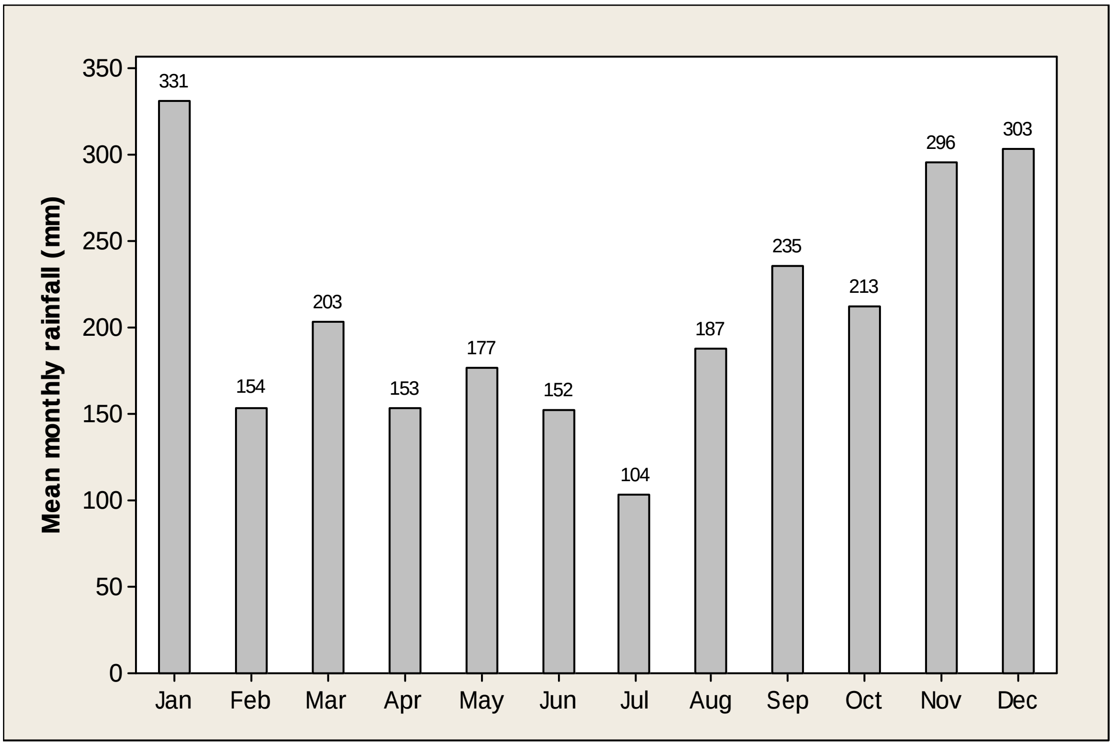

Figure 9.2 Mean total monthly rainfall at Benmore, 2003 - 2007

The wettest months were January, November and December. For the period considered here, 42% of days experienced rainfall of 1 mm or less, and 25% of days experienced rainfall of 10 mm or more. There was marked variation in the mean monthly total rainfall, and large increases in rainfall from July to August, and from October to November.

Faecal matter can build up on pastures during the drier summer months when stock levels are at their highest, potentially leading to more significant faecal contamination of runoff at the onset of the wetter weather in the autumn. 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 early winter months, but episodes of contamination following heavy rain may occur at any time of year. Contamination from livestock kept on pastures in the floodplain of the River Ruel will be washed into the production area when the river is in spate.

9.2 Wind

Wind data collected at the Glasgow: Bishopton weather station is summarised by season and presented in figures 9.3 to 9.7.

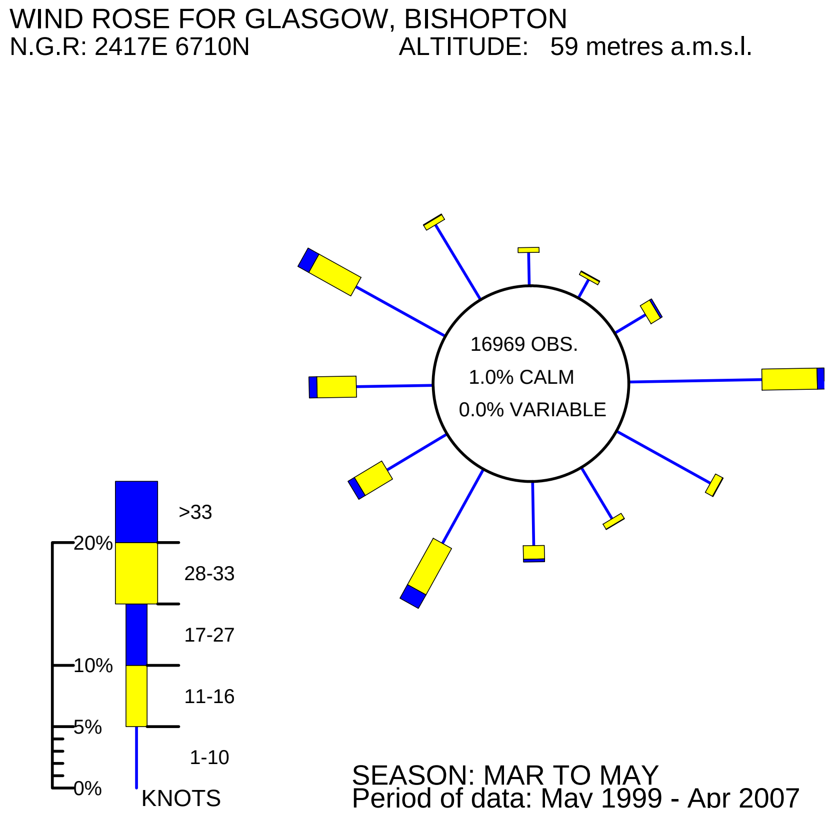

Figure 9.3 Wind rose for Glasgow: Bishopton (March to May)

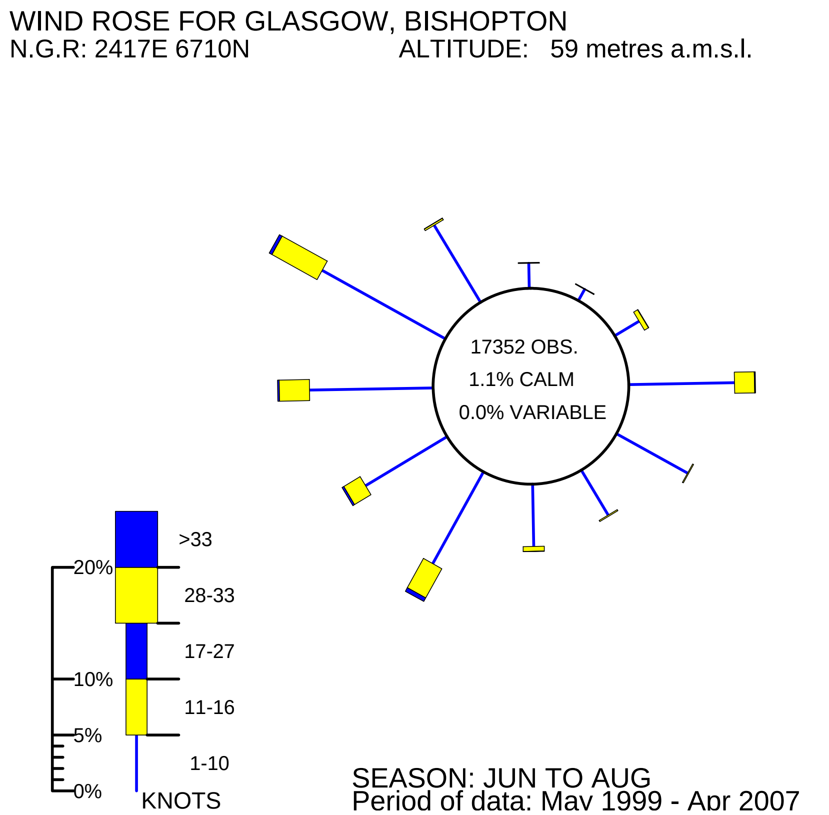

Figure 9.4 Wind rose for Glasgow: Bishopton (June to August)

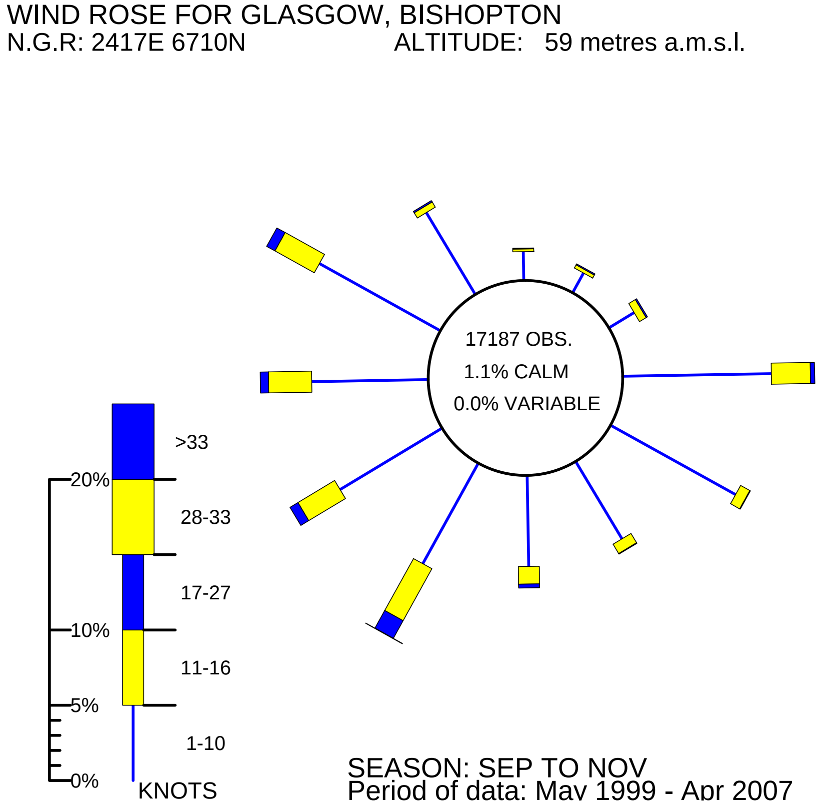

Figure 9.5 Wind rose for Glasgow: Bishopton (September to November)

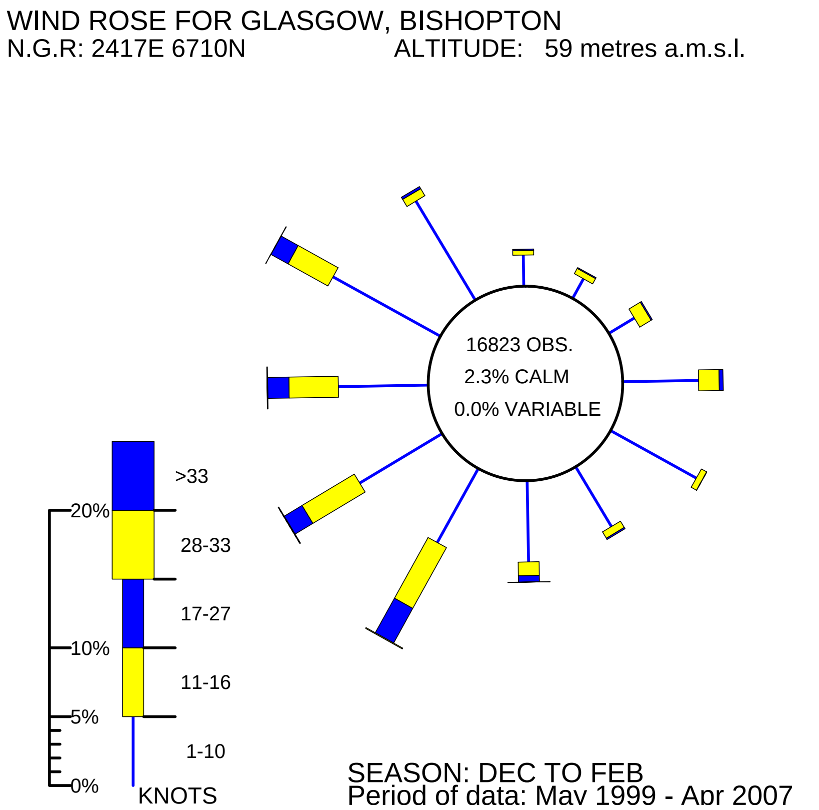

Figure 9.6 Wind rose for Glasgow: Bishopton (December to February)

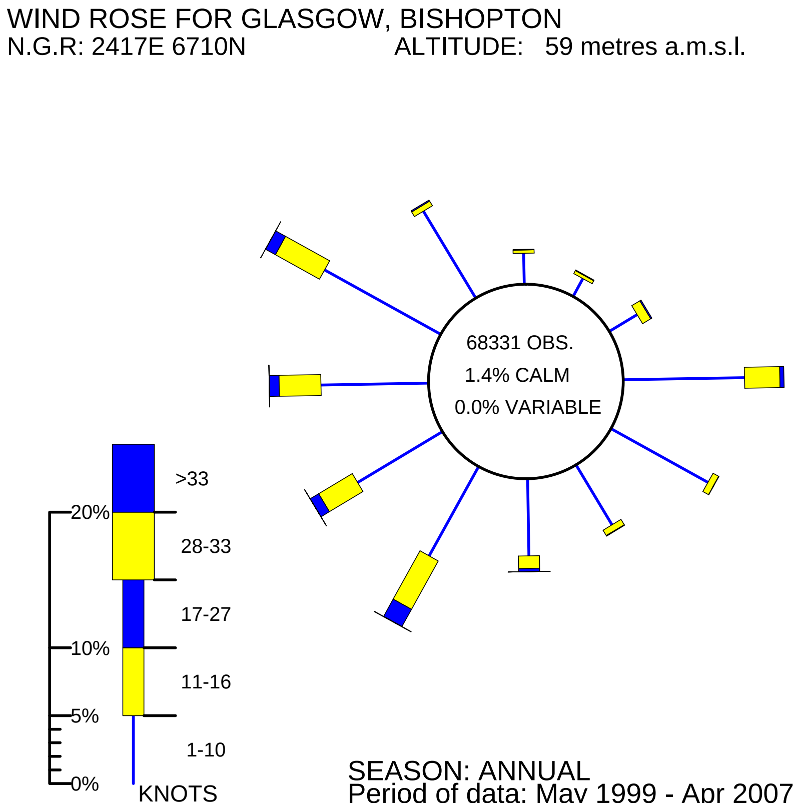

Figure 9.7 Wind rose for Glasgow: Bishopton (All year)

Glasgow is not one of the windier areas of Scotland, with a low frequency of gales compared to places such as the Western Isles and the Shetlands. The wind roses show that the overall prevailing direction of the wind is from the west, and the strongest winds come from this direction. Stronger winds are also experienced from the east, presumably due in part to local topography - Bishopton is in the Clyde Valley, which has a west to east aspect. Winds are generally lighter during the summer months and stronger in the winter, and it is likely that this is also the case at Loch Riddon.

Loch Riddon has a south to north aspect. The Isle of Bute lies at its mouth giving shelter from the open sea. It is about 6 km long and just under 1 km wide, and lies in a steep sided valley surrounded by hills rising to over 400 m in places. The loch will receive shelter from winds from most directions, but is more open to southerly or northerly winds, which would be funnelled up or down the Loch by the surrounding land. Therefore, winds at Loch Riddon are likely to align more along the north-south axis than the east-west axis as they do at Glasgow: Bishopton.

A strong southerly wind combined with a spring tide may result in higher than usual tides that will carry accumulated faecal matter from livestock, above the normal high water mark, into the loch. It would also create wave action on the intertidal areas that may result in resuspension of contamination from the sediment.

Although tidally driven circulation of water in the Loch may is likely to be important in defining circulation patterns within the loch due to its tidal range, and the presence of a large intertidal area, wind effects are likely to cause significant changes in water circulation. 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 in the direction of the wind. These surface water currents create return currents which may travel along the bottom or sides of the loch depending on bathymetry. Either way, strong winds will increase the circulation of water and hence dilution of contamination from point sources within the loch. There may be some instances where contamination from point sources may be carried to production sites by wind driven currents. An example may be a south westerly wind carrying contamination from the point source at Ormidale lodge towards the production site.

10. Current and historical classification status

Loch Riddon has been classified for the production of Pacific oysters since 2005. The classification history is presented in Table 10.1. From 2005-2006, the area was classified B. In 2007 the area was classified as a seasonal A/B, then in 2008 it was classified as a seasonal A/B/C. The nominal RMP lies 200 m away from the oyster trestles from which the classification samples were actually taken. A map of the current production area is presented in Figure 10.1. There is no Crown Estates lease associated with this production area as Crown Estates do not claim ownership of the seabed / foreshore here.

Table 10.1 Classification history, Loch Riddon

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005*	B	B	B	B	B	B	B	B	B	B	B	B
2006	B	B	B	B	B	B	B	B	B	B	B	B
2007	B	B	B	A	A	A	A	A	A	A	A	A
2008	A	A	A	A	A	B	C	B	B	B	B	B
2009	B	A	A									

*Provisional classification

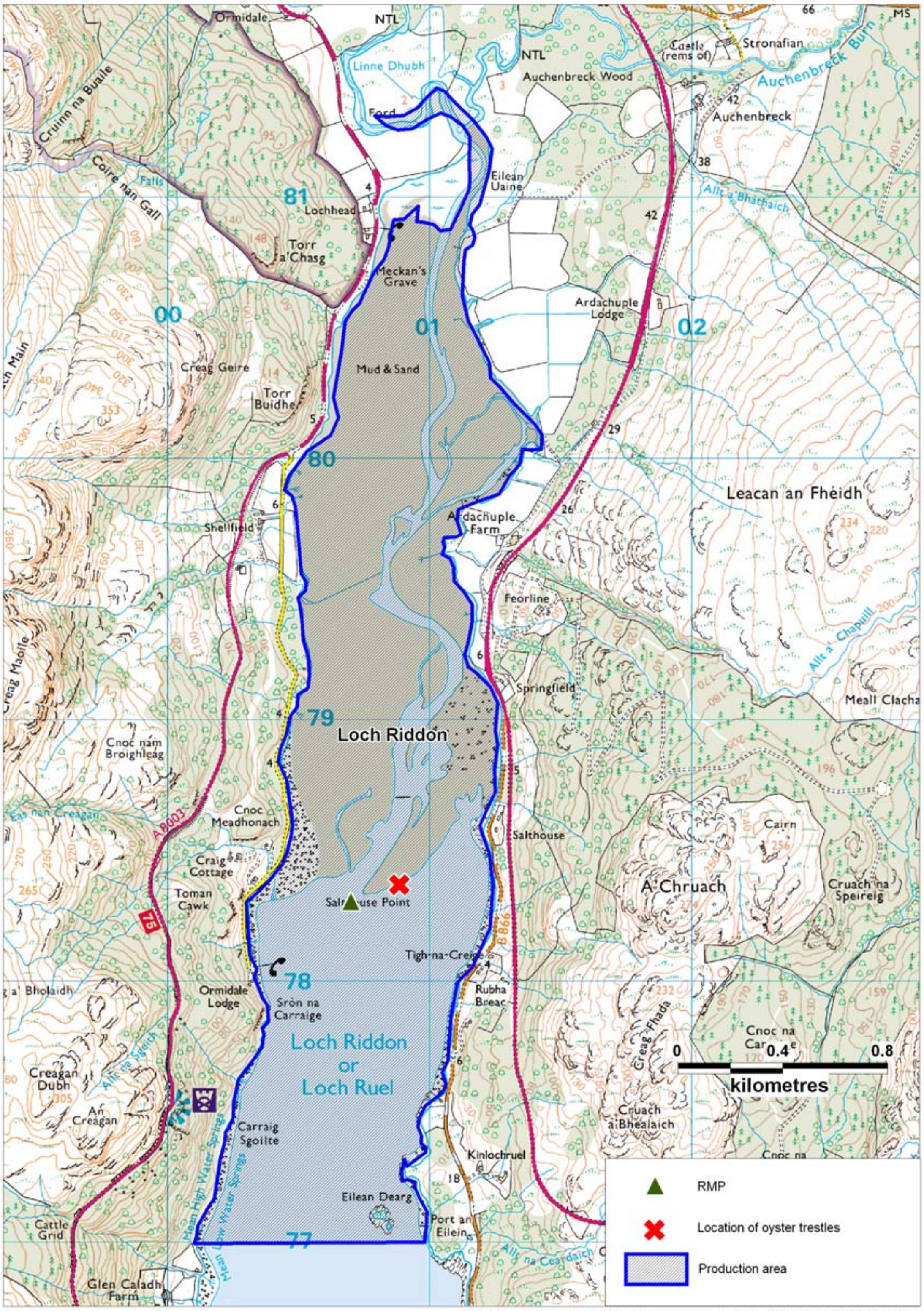

Figure 10.1 Current production area

11. Historical *E. coli* data

11.1 Validation of historical data

All shellfish samples taken from Loch Riddon from the beginning of sampling in 2004 up to the end of 2007 were extracted from the database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data.

No samples were rejected on the basis of major geographical or sampling date discrepancies.

One sample had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. One sample had a reported result of >18000, which was assigned a nominal value of 36000 for statistical assessment and graphical presentation.

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

11.2 Summary of microbiological results by production area

A summary of all sampling and results by is presented in Table 11.1.

Table 11.1 Summary of E. coli classification results from Loch Riddon

Sampling Summary			
Production area	Loch Riddon	Loch Riddon	Loch Riddon
Site	Salthouse Point	Salthouse Point	Salthouse Point
Species	Pacific oysters	Pacific oysters	Pacific oysters
SIN	AB-183-52-13	AB-183-52-13	AB-183-52-13
Location	Both	NS007783	NS008783
Total no of samples	30	22	8
No. 2002	0	0	0
No. 2003	0	0	0
No. 2004	6	6	0
No. 2005	8	8	0
No. 2006	7	7	0
No. 2007	9	1	8
Results Summary			
Minimum	<20	<20	20
Maximum	>18000	5400	>18000
Median	750	750	565
Geometric mean	536	526	566
90 percentile	3500	3500	12000
95 percentile	4550	3500	24000
No. exceeding 230/100g	19 (63%)	13 (59%)	6 (75%)
No. exceeding 1000/100g	13 (43%)	10 (45%)	3 (38%)
No. exceeding 4600/100g	2 (7%)	1 (5%)	1 (13%)
No. exceeding 18000/100g	1 (3%)	0 (0%)	1 (13%)

11.3 Overall geographical pattern of results

Samples taken from July 2004 to October 2006 were reported against one location ,NS007783 (the RMP), approximately 200 m from the present trestles. Samples taken during 2007 were reported against a different location, NS008783, approximately 100 m from the present trestles. Given that neither location is likely to represent the actual location of the sampled oysters, no explicit geographical analysis was undertaken (although the results for the two locations are summarised separately in Table 11.1).

11.4 Overall temporal pattern of results

Figures 11.1 presents a scatter plot of individual results against date for all samples taken from Loch Riddon. It has been fitted with a Loess line to help highlight any apparent underlying trends or cycles.

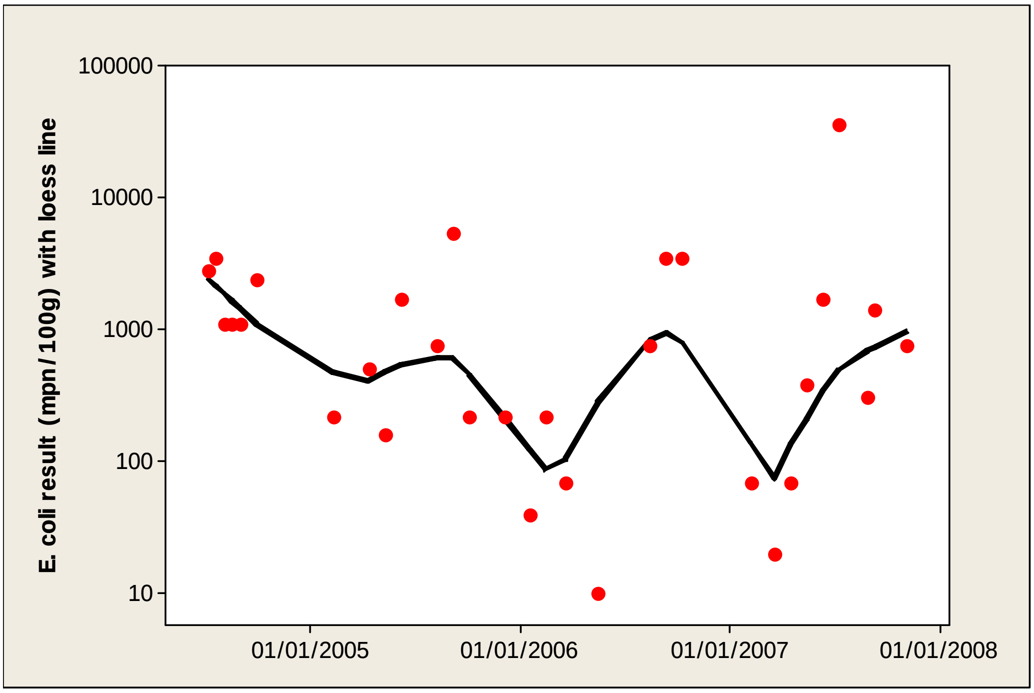

Figure 11.1 Scatterplot of *E. coli* results by date with loess smoother

Figure 11.1 suggests seasonal dips in results during early in 2006 and 2007, as well as a peak occuring in late 2006. Results fall over a wide range of values, though there are relatively few points below 100 MPN/100 g and one greater than 10000 MPN/100 g.

11.5 Seasonal pattern of results

Season dictates not only weather patterns and water temperature, but livestock numbers and movements, presence of wild animals and patterns of human occupation. All of these can affect levels of microbial contamination, and cause seasonal patterns in results. Too few samples were taken to graphically present results by month. Instead, seasons were split into spring (March - May), summer

(June - August), autumn (September - November) and winter (December - February).

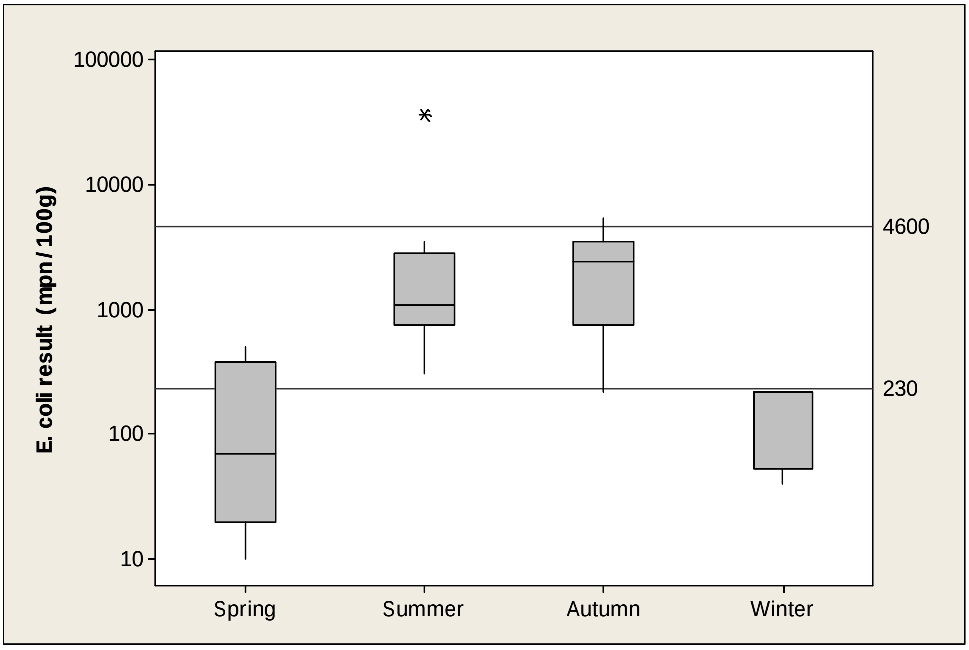

Figure 11.2 Boxplot of *E. coli* result by season

A highly significant difference was found between results by season (One-way ANOVA, p=0.000, Appendix 5). A post ANOVA test (Tukeys comparison, Appendix 5) indicates that results in the summer and autumn were significantly higher than those in the winter and spring.

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest Meteorological Office weather station is Benmore, 13 km NE of area. Rainfall data was purchased from the Met Office for the period 1/1/2003 to 31/12/2007 (total daily rainfall in mm). It should be noted that although this station is somewhat near to the production area, it does not lie within the catchment of the River Ruel. Therefore, there is a chance that rainfall within the catchment may differ from that recorded and used here.

A Spearman's rank correlation of *E. coli* against rainfall during the previous two and seven days prior to sampling was carried out in order to investigate whether monitoring results related to recorded rainfall levels. Scatterplots illustrating E. coli results versus rainfall are presented in Figures 11.3 and 11.4.

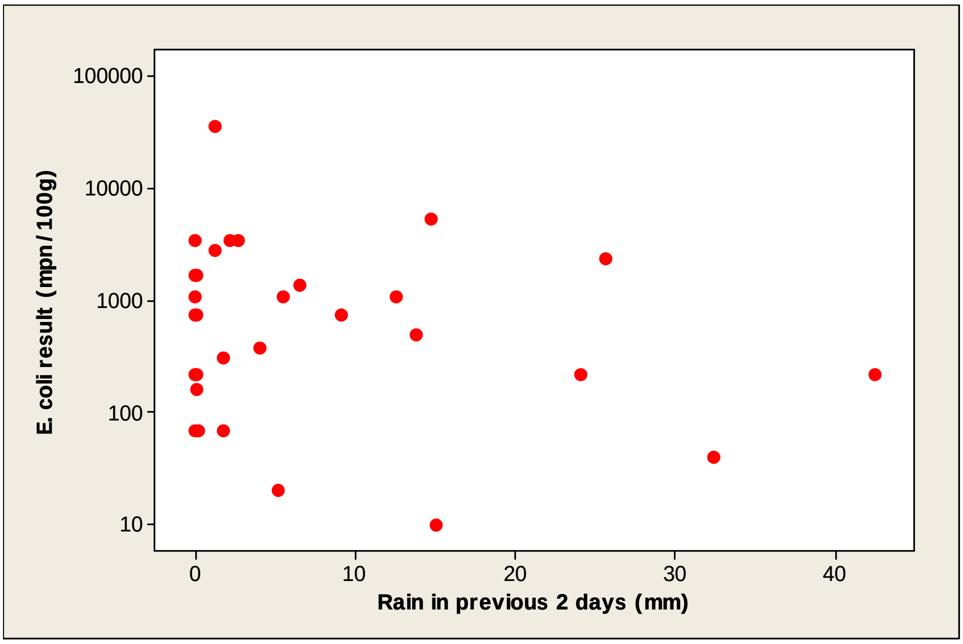

Figure 11.3 Scatterplot of *E. coli* result against rainfall in previous 2 days

In this case, no correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous two days (Spearmans Rank correlation=-0.108, p=0.570, Appendix 5).

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above.

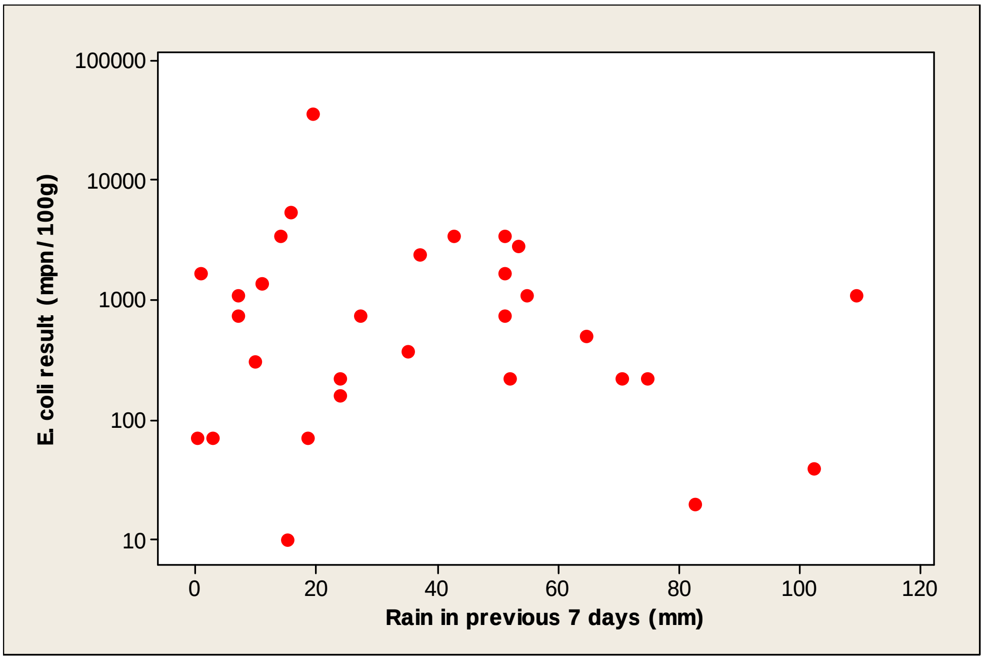

Figure 11.4 Scatterplot of *E. coli* result against rainfall in previous 7 days

No correlation was found between the ranked *E. coli* result and the ranked rainfall in the previous seven days (Spearmans Rank correlation=-0.063, p=0.741,

Appendix 5). Generally higher rainfall is expected to result in greater levels of faecal contamination entering coastal waters via land runoff, and much of the floodplain of the River Ruel is improved pasture. It may be the case that although more contamination is entering Loch Riddon through the River Ruel when it is in spate, this does not actually result in higher levels of contamination in the oysters. Pacific oysters can tolerate salinities as low as 2 ppt for brief periods, but feeding rates slow at salinities of 15 ppt or below, so when the river is in spate, the oysters may accumulate contamination at a slower rate. Also, during spate conditions, although there may be a higher overall *E. coli* loading contributed by the river, it may actually be considerably more diluted than at base flow.

11.6.2 Analysis of results by tidal size and state

When the larger (spring) tides occur every two weeks, circulation of water and particle transport distances will increase, and more of the shoreline will be covered at high water, potentially washing more faecal contamination from livestock into the loch. Also, direction and strength of flow around the production areas will change according to tidal state on the (twice daily) high/low cycle, and, depending on the location of sources of contamination, this may result in marked changes in water quality in the vicinity of the farms during this cycle. However, as the site can only be accessed and sampled at low water during spring tides these factors could not be investigated.

11.6.3 Analysis of results by water temperature

Water temperature is likely to affect the survival time of bacteria in seawater (Burkhardt *et al*, 2000) and the feeding and elimination rates of shellfish and therefore may be an important predictor of *E. coli* levels in shellfish flesh. It is of course closely related to season, and so any correlation between temperatures and *E. coli* levels in shellfish flesh may not be directly attributable to temperature, but to other factors such as seasonal differences in livestock grazing patterns.

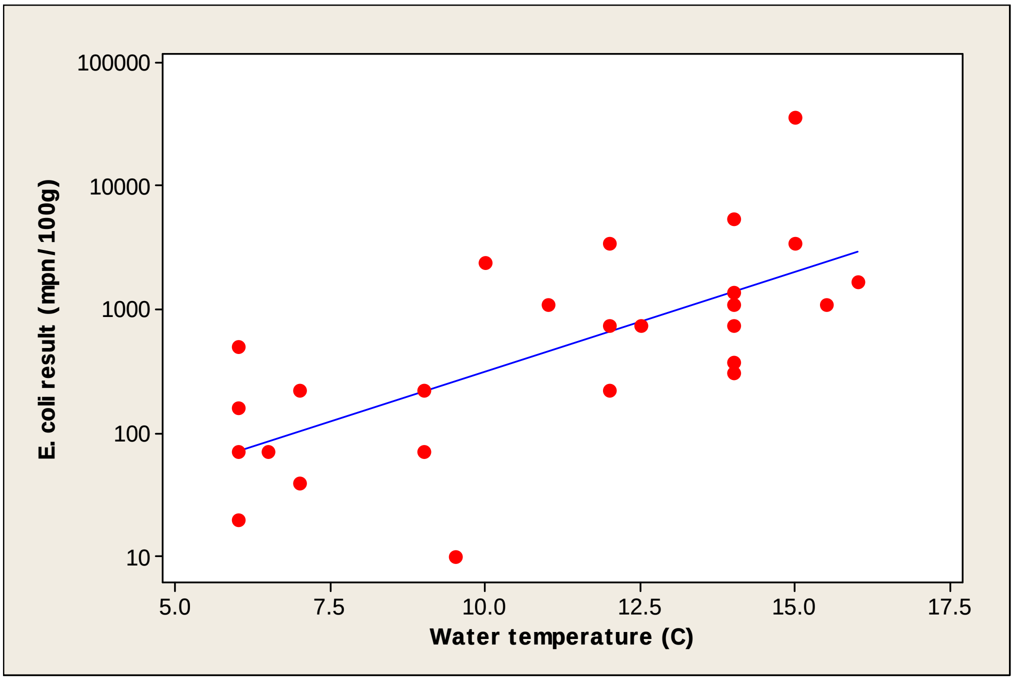

Figure 11.5 Scatterplot of *E. coli* result by water temperature with best fit line

The coefficient of determination indicates that there was a significant positive relationship between the *E. coli* result and water temperature (Adjusted R-sq=46.5%, p=0.000, Appendix 5).

11.6.4 Analysis of results by wind direction

Wind speed and direction are likely to change water circulation patterns in the production area. Mean wind direction for the 7 days prior to each sample being collected was calculated from wind data recorded at the Glasgow: Bishopton weather station 42 km east of the production area, where available. A polar plot of Log_{10} *E. coli* results by wind direction in the previous 7 days is plotted in Figure 11.6. It must be noted that this analysis does not take into account either wind speed or variability, and the weather station used in a considerable distance from the production area.

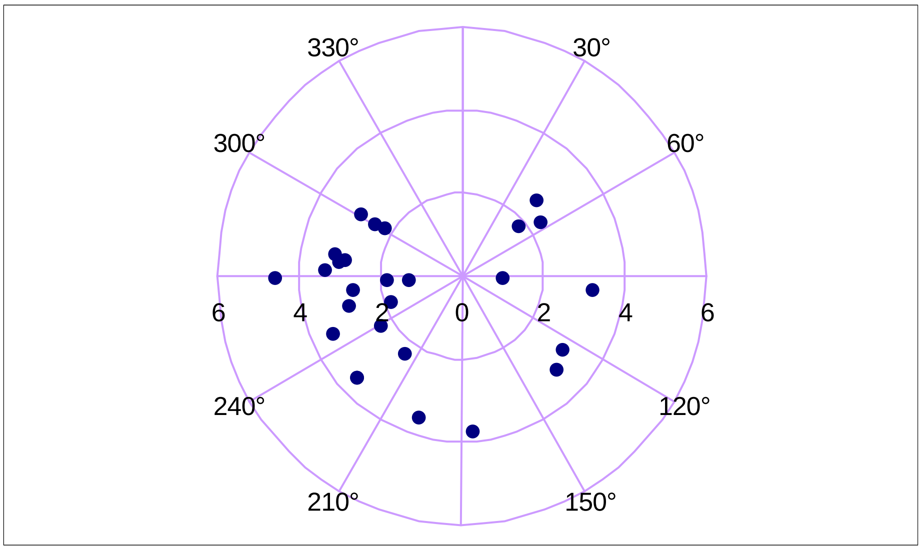

Figure 11.6 Polar plot of Log10 *E. coli* results by wind direction

A significant correlation was found between wind direction and *E. coli* result (circular-linear correlation, r=0.377, p=0.032, Appendix 5), and results appear to be consistently higher when wind was blowing from between 90 and 270° at Glasgow. Winds blowing from this range of directions at Glasgow are likely to be more closely aligned to 180° at Loch Riddon given their relative geometries (Glasgow Bishopton is in a valley with an east west aspect, whereas Loch Riddon has a north south aspect).

11.6.5 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination at the site. Figure 11.7 presents a scatter plot of *E. coli* result against salinity, where salinity readings were available.

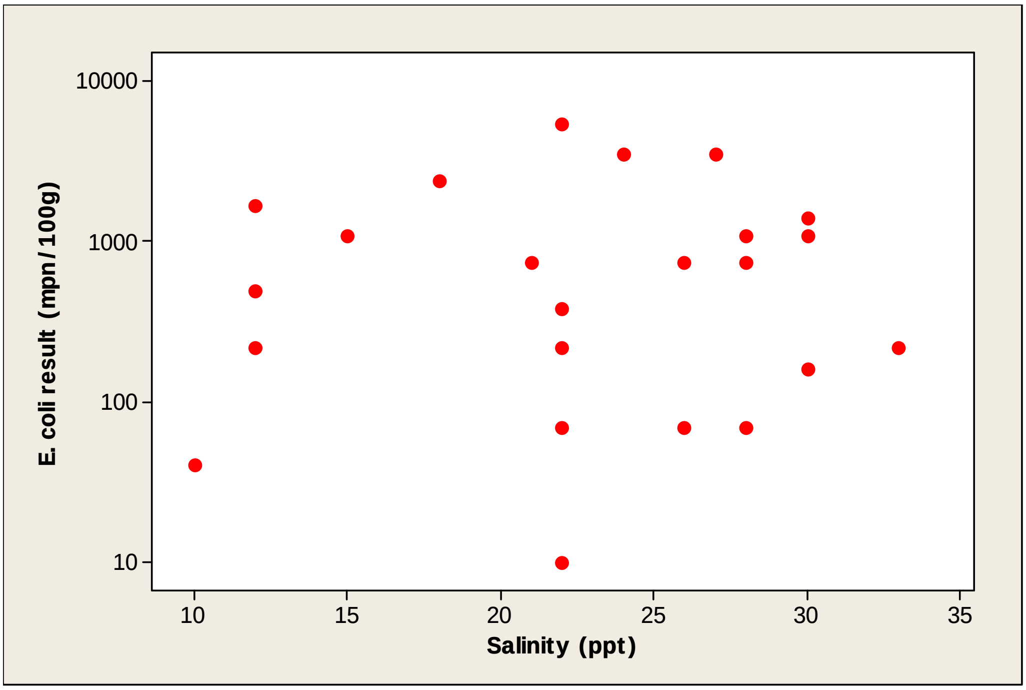

Figure 11.7 Scatterplot of result by salinity

The coefficient of determination indicates that there was no relationship between the *E. coli* result and salinity (Adjusted R-sq=0.0%, p=0.777, Appendix 5). The range of salinities recorded indicates a large freshwater influence at times, which is not unexpected given that the trestles are close to the channel of the River Ruel.

11.7 Evaluation of peak results

The circumstances under which the five highest results occurred are presented in Table 11.2. All samples were taken from the same location, which was the only location ever sampled. They occurred during the summer and autumn months when the water was relatively warm. All occurred following a period of south westerly wind. None occurred following particularly heavy rain or at particularly low salinity, although salinity readings were not available for 2 of the 5 results.

Table 11.2 Historic E. coli sampling peak results

Collection Date	*E. coli* result (mpn/100g)	Location sampled	2 day rain quartile	7 day rain quartile	Water temperature	7 day wind direction	Salinity (ppt)
10/07/2007	36000	NS007783	Q2	Q2	15 ºC	269º	*
06/09/2005	5400	NS007783	Q3	Q2	14 ºC	176º	22
20/07/2004	3500	NS007783	Q2	Q3	*	226º	27
12/09/2006	3500	NS007783	Q2	Q3	15 ºC	197º	*
10/10/2006	3500	NS007783	Q1	Q1	12 ºC	227º	24

* Data not available

11.8 Summary and conclusions

It was not possible to investigate geographic differences in levels of contamination, as all samples were collected from the same grid reference.

Highly significant seasonal differences were found, with higher results in the summer and autumn compared to the spring and winter. A significant positive relationship was also found between water temperature and result, though it isn't clear whether this is only due to higher temperature or due to other factors that coincide with higher water temperatures. It may be due a combination of higher levels of contamination during the summer months and higher feeding rates

No statistically significant relationship between recent rainfall and *E. coli* result was found. No relationship with salinity was found either, with a large range of salinities recorded. This indicates that although there is significant freshwater influence at times, this does not result in higher levels of contamination in the oysters.

A weak correlation with wind direction was found, with higher results generally occurring when the wind was from a southerly direction. It is uncertain how useful this analysis was given the weather station for wind data is over 40 km from the site, and the local topography is very different. However, the loch is most exposed to winds from the south and so a correlation with winds from this direction is expected.

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

11.9 Sampling frequency

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

12. Designated Shellfish Growing Waters Data

The area considered in this report is also part of a shellfish growing water which was designated in 1998. The growing water encompasses a larger area than the two production areas covered by this report and also includes the Kyles of Bute. The extent of the growing water is shown on Figure 12.1.

The monitoring 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

A total of four points within the growing water were sampled for faecal coliforms in shore mussels. Two of these were within the Loch Riddon production area and two were to the south of the production area at Colintrave. Monitoring results for faecal coliforms in shore mussels from 1999 to the end of 2007 have been provided by SEPA (faecal coliforms/100 g). These results are presented in Table 12.1.

Table 12.1 Growing waters monitoring results

	Site	Kyles Of Bute:Colintraive	Kyles Of Bute:Colintraive	Kyles of Bute:Loch Riddon	Kyles of Bute:Loch Riddon
	OS Grid Ref.	NS 028 750	NS 02991 74718	NS 012 790	NS 01014 79688
1999	Q3	3100		700	
	Q4	1100		9100	
2000	Q1	110		110	
	Q2	40		70	
	Q3	9100		70	
	Q4	750		750	
2001	Q1	70		40	
	Q2	700		20	
	Q3	1400		3500	
	Q4	16000		9100	
2002	Q1	310		160	
	Q2	110		310	
	Q3	>18000*		9100	
	Q4	1300		250	
2003	Q1	20		160	
	Q2				
	Q3		1100		3500
	Q4		110		750
2004	Q1		1700		220
	Q2		16000		70
	Q3		24000		9100
	Q4		16000		9100
2005	Q1		250		700
	Q2		13000		1700
	Q3		16000		160
	Q4		750		110
2006	Q1		91000		160
	Q2		3500		>18000*
	Q3		160000		625
	Q4		2800		410
2007	Q1		7000		90
	Q2				
	Q3				
	Q4				
Geometric mean		687	5162	403	732

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

Results were higher on average at the Colintraive monitoring points. For both sample sites, and Colintraive in particular, results were higher at the more recently sampled monitoring points. It is not clear whether these are spatial effects or indicative of worsening water quality.

Results were highest during Quarter 3 and lowest during Quarter 1 at both Colintraive and Loch Riddon, but differences between results by quarter were not statistically significant (One-way ANOVA, p=0.087 for Colintraive, p=0.084 for Loch Riddon, Appendix 5). Nevertheless, this apparent patter agrees with that observed for the classification samples.

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 shellfish species, environmental conditions and the source of contamination and as a consequence the results presented in Table 12.1 are not directly comparable with other shellfish testing results presented in this report.

However, the SGW monitoring results indicate very high levels of faecal contamination in the vicinity of the monitoring points, especially at the more recent Colintraive point where 2 results (13%) were above 46000 FC/100 g and only 1 result (7%) fell below 230 FC/100 g, indicating gross levels of contamination at this point. Even though the results for the same period at the Loch Riddon monitoring point were better, only fewer than half (6 samples or 40%) fell below 230 FC/100 g and three were highly contaminated, with concentrations in excess of 4600 FC/100g.

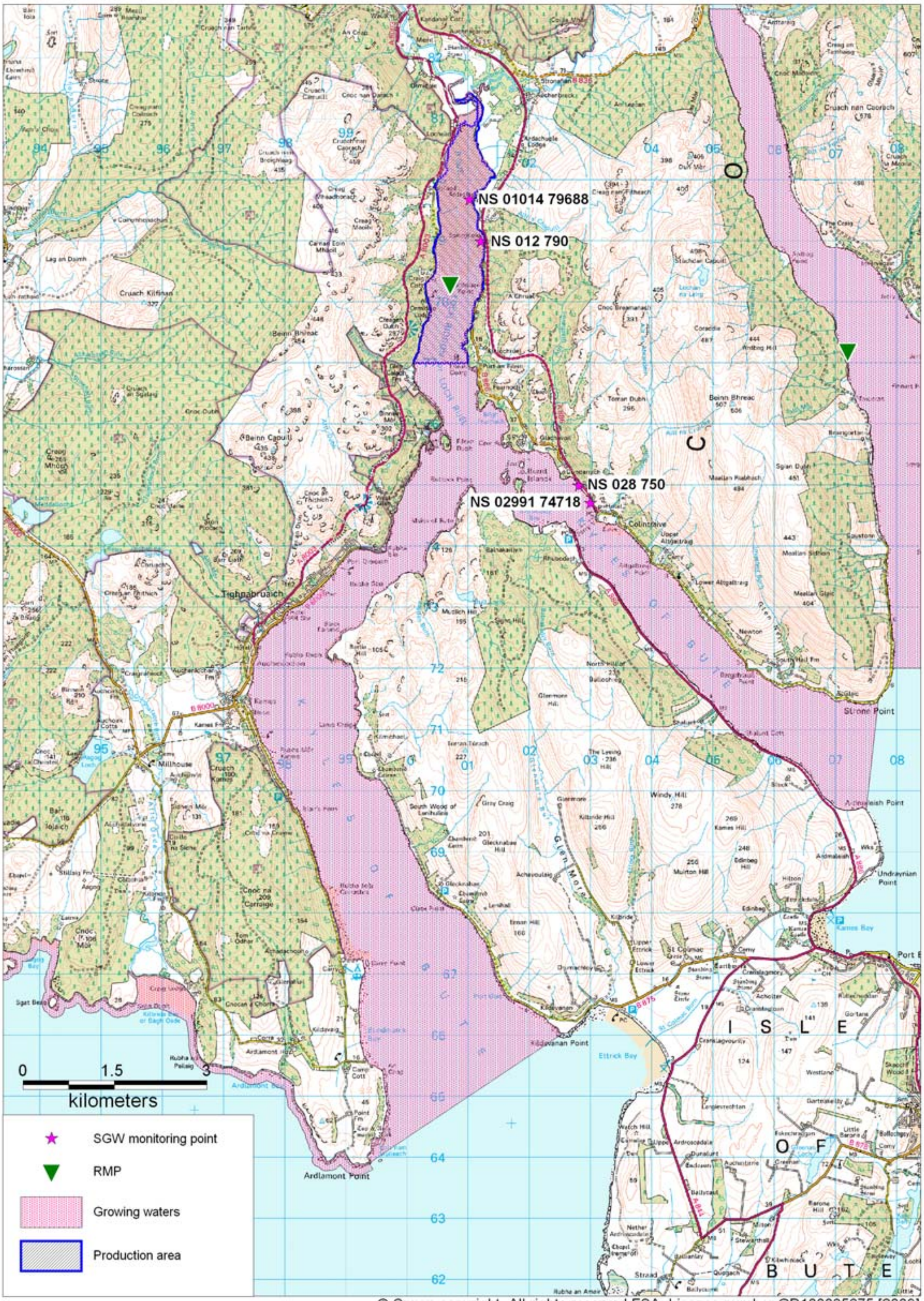

Figure 12.1 Designated shellfish growing waters

13. River Flow

There are no river gauging stations on rivers or burns along the Loch Riddon coastline. The following rivers and streams were measured and sampled during the shoreline survey. These represent the largest freshwater inputs to Loch Riddon.

Table 13.1 River and stream loadings for Loch Riddon

No	Grid Reference	Description	Width (m)	Depth (m)	Flow (m/s)	Flow (m^3/day)	*E.coli* (cfu/ 100 ml)	Loading (*E.coli* per day)
1	NS 01260 78679	Stream	0.50	0.05	0.217	469	100	4.7×10^8
2	NS 01531 76294	Stream	1.08	0.10	0.108	1008	<100*	-
3	NS 01110 76924	Stream	0.85	0.06	0.231	1018	400	4.1×10^9
4	NS 01094 77706	Stream	0.20	0.04	0.071	49	<100*	-
5	NS 01173 78064	Stream	0.38	0.06	0.133	262	<100*	-
6	NS 01263 78146	Stream	0.85	0.05	0.082	301	<100*	-
7	NS 01275 78268	Stream	0.45	0.04	0.162	252	100	2.5×10^8
8	NS 01290 78835	Stream	0.24	0.04	0.458	380	<100*	-
9	NS 01146 80534	Stream	0.95	0.03	0.275	677	1200	8.1×10^9
10	NS 01427 80182	Stream	0.80	0.05	0.177	612	700	4.3×10^9
11	NS 01443 80036	Stream	1.05	0.06	0.278	1513	<100*	-
12	NS 01113 79640	Stream	0.90	0.07	0.116	631	<100*	-
13	NS 01198 79375	Stream	0.53	0.03	0.202	277	100	2.8×10^8
14	NS 01840 81520	Stream	1.15	0.11	0.83	9072	100	9.1×10^9
15	NR 99997 82695	River Ruel	17.40	0.50	0.312	234524	1200	2.8×10^{12}
16	NS 00125 76684	Stream	0.50	0.10	0.284	1227	<100*	-
17	NS 00111 76770	Stream	0.80	0.06	0.214	888	1500	1.3×10^{10}
18	NS 00128 76869	Stream	5.30	0.10	0.043	1969	200	3.9×10^9
19	NS 00263 77654	Stream	0.70	0.05	0.143	432	<100*	-
20	NS 00401 78377	Stream	3.80	0.05	0.329	5401	100	5.4×10^9
21	NS 00437 79778	Stream	1.00	0.05	0.373	1611	400	6.4×10^9
22	NS 00486 79517	Stream	0.85	0.15	0.512	5640	100	5.6×10^9
23	NS 00807 81004	Stream	0.82	0.08	0.012	68	200	1.4×10^8

* Loading not calculated

The *E. coli* loading from the main freshwater discharge (the River Ruel) at time of shoreline survey contributed over 97% of the total loadings calculated on Table 13.1, and was roughly equivalent to the loading that would be contributed by septic tank discharges from a population equivalent of 350. The River Ruel is a spate river, and was running low and clear on day of survey, so discharge and possibly loading may increase significantly during spates. Much of the floodplain is improved grassland used for grazing sheep and cattle, so during a spate contamination from these animals will be washed into the production area by the river, though it may be highly diluted. The river also receives two small private septic tank discharges, and a septic tank discharge from a campsite that may serve up to about 100 people in peak season, and quite probably effluent from other unregistered private septic tanks. The river channel runs immediately adjacent to fishery at Salthouse Point, so the River Ruel is almost certainly the most significant identified source of contamination to the fishery.

Also of some interest was the low level of *E. coli* contamination found in streams 2 and 13 (<100 and 100 cfu/100 ml respectively) both of which are reported to receive inputs from individual private septic tanks as detailed in Section 4 of this report. This suggests that inputs from these septic tanks were very minor at the time of survey.

Other stream sources draining the surrounding hills were distributed fairly evenly around the loch. The land they drained was mainly forested, with some areas of pasture. Measured discharges were low in comparison to the River Ruel, and generally so were *E. coli* levels. The highest levels of *E. coli* were found in two of the streams which run through areas of pasture (streams 9 and 17), but the loadings from these streams, which could both be considered significant sources of contamination, particularly stream 17, were still more than two orders of magnitude smaller than that of the River Ruel.

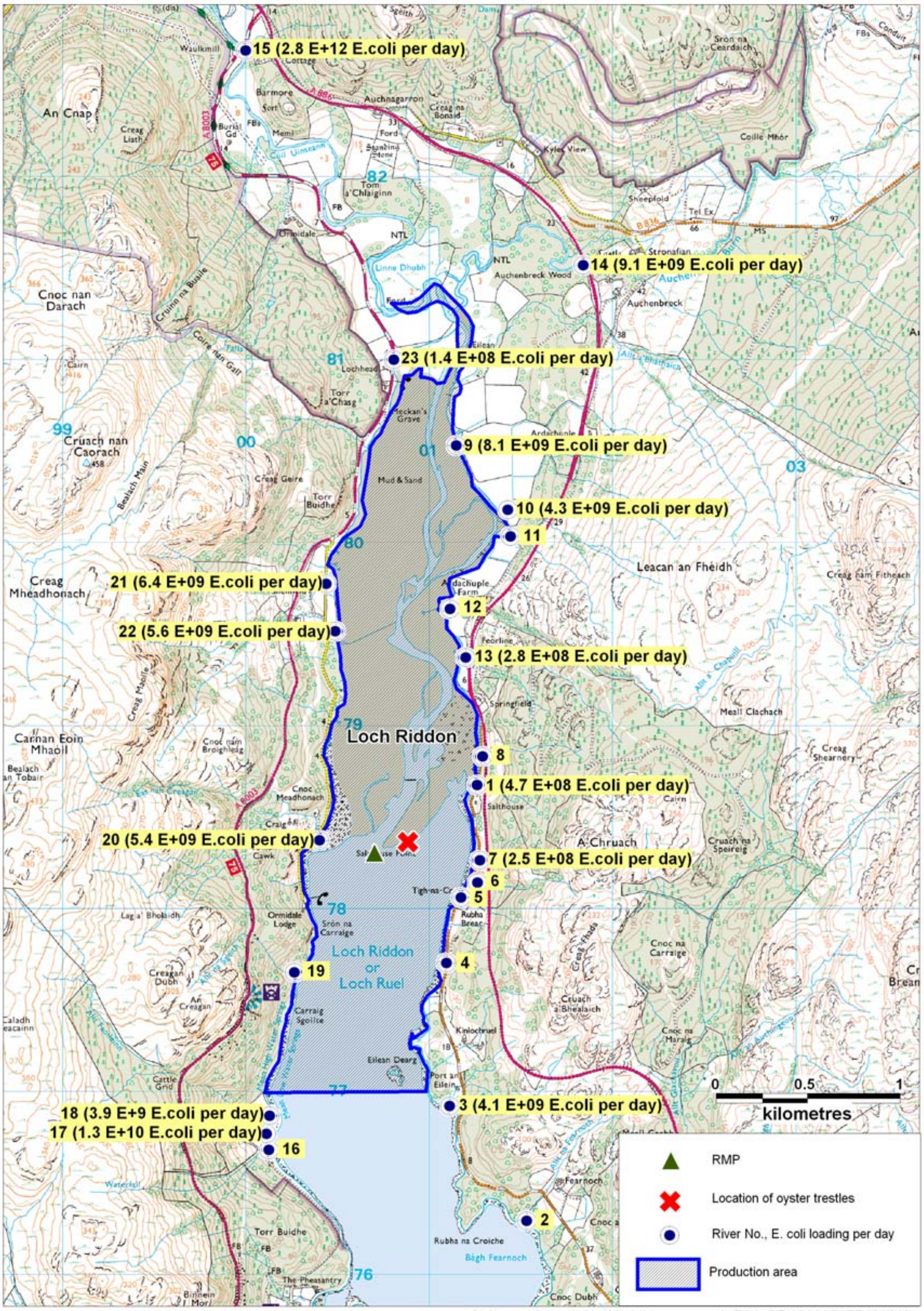

Figure 13.1 Significant streams and loadings

14. Bathymetry and Hydrodynamics

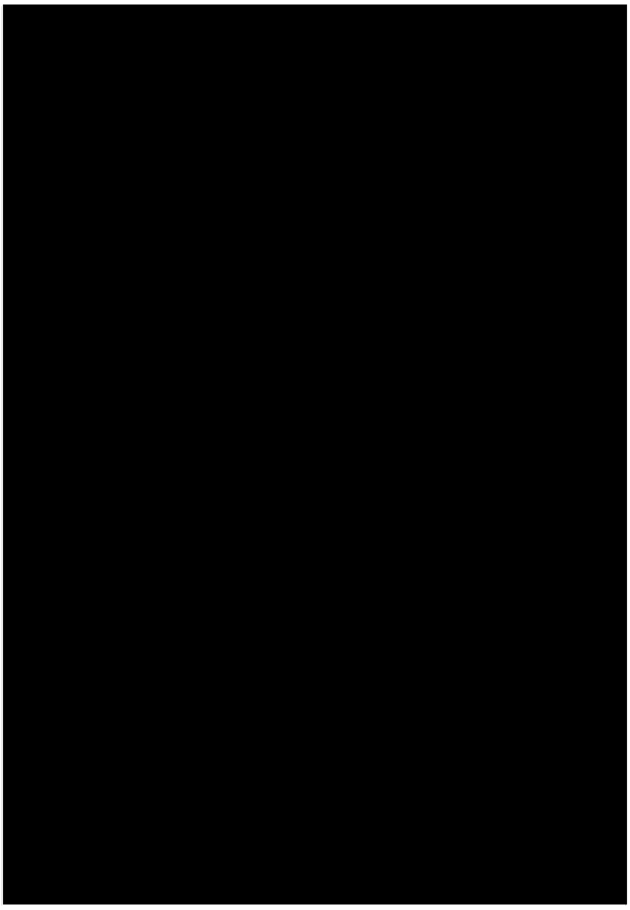

Figure 14.1 Bathymetry of Loch Riddon **Figure 14.2 OS map of Loch Riddon**

The chart above shows that there is a large intertidal area covering the northern half of the production area through which the channel of the River Ruel runs. South of this intertidal area, the loch slopes gently down to a depth of over 30 m at the southern end of the production area. There are no sills within Loch Riddon. Further south, the loch splits into the two Kyles of Bute, which then open out into the Firth of Clyde south of Bute.

Tidal Curve and Description

The two tidal curves below are for Tighnabruaich, 7.5 km to the SSW of the fishery. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 GMT on 29/07/08 and the second is for seven days beginning 00.00 GMT on 05/08/08. This two-week period covers the date of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

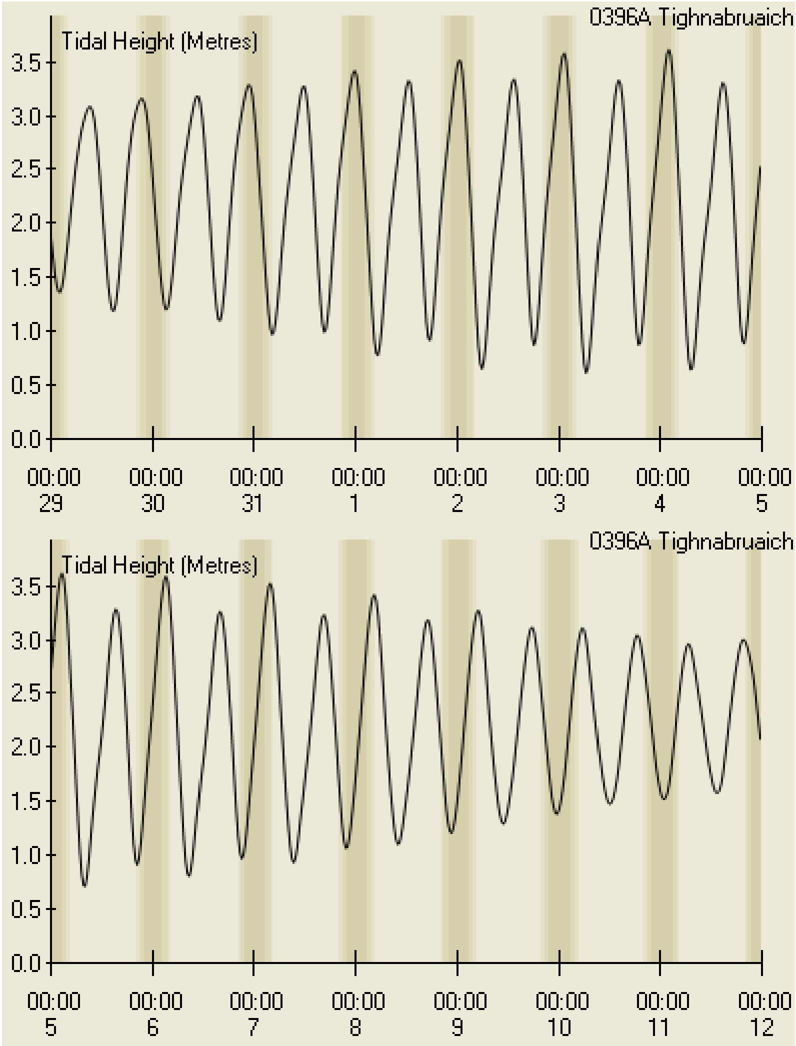

Figure 14.3 Tidal curves for Tighnabruaich

The following is the summary description for Tighnabruaich from TotalTide:

Tighnabruaich is a Secondary Non-Harmonic port. The tide type is Semi-Diurnal. Predicted heights are in metres above Chart Datum.

MHWS	3.4 m
MHWN	3.0 m
MLWN	1.4 m
MLWS	0.8 m

The tidal range at spring tide is therefore approximately 2.6 m and at neap tide 1.6 m.

Currents

Currents in coastal waters are predominantly driven by a combination of tide, wind and freshwater inputs. The tidal range here is fairly large, and there is an extensive intertidal area where the fishery is located, so tidally driven exchange of water is important, with water in the upper loch from the trestles northwards almost completely exchanged each tidal cycle. This is reflected in the relatively short flushing time of 3 days for the Loch Riddon as a whole (Edwards & Sharples, 1986). Tidally driven currents within the loch would be expected to move in a generally northerly direction on the flood tide, and a southerly direction on the ebb tide in the waters south of the intertidal area. Water is expected to move up the river channel running through the intertidal area, flooding over the intertidal area from here as the tide rises, with the reverse happening on the ebb tide. Contamination from yachts and other minor sewage sources to the south of the trestles would be carried in on the flooding tide in this manner.

Immediately south of the loch, tidal streams in the Kyles of Bute are reported to be much stronger in the west Kyle, where tidal streams of 5 knots can occur on spring tides around the Burnt Isles, than in the east Kyle. The two arms of the flood tide meet in the east Kyle south of Colintraive, with the exact meeting point depending on meteorological conditions. Therefore, it is assumed that sources in the west Kyle may be of more importance to water quality in Loch Riddon than those in the east Kyle.

The loch is located in a steep sided glacial valley with a north-south aspect with the surrounding hills rising to over 400 m in places. Therefore, it will receive shelter from winds from most directions, but is more open to southerly or northerly winds, which would be funnelled up or down the Loch by the surrounding land. Wind driven currents have the potential to significantly alter flows around the production area, creating surface currents which flow in the same direction as the wind. However, these are probably less important than tidally driven circulation, particularly over the intertidal area. A strong southerly wind may push contamination from sources to the south towards the fishery, which is located at the southern end of the estuary. It may also result in higher than usual tides, allowing contamination from the foreshore to be washed into the loch. Also, it is likely to result in wave action in the intertidal area possibly causing resuspension of any contamination within the sediment.

The catchment area of Loch Riddon is about 110 km^2, most of which is drained by the River Ruel, which discharges at the head of the loch. An average salinity reduction of 2.1 ppt was calculated on the basis of tidal and freshwater inflows (Edwards and Sharples, 1986) although this is likely to fluctuate greatly depending on rainfall. Salinitiy measurements taken at the trestles during *E. coli* classification monitoring averaged 22.6 ppt and ranged from 10 to 31 ppt indicating significant but variable freshwater influence here. A strong negative correlation was found between these salinity measurements and rainfall recorded in the previous 2 (Spearmans Rank correlation=-0.593, p=0.003, Appendix 5) and 7 days (Spearmans Rank correlation=-0.602, p=0.002, Appendix 5), as would be expected. Given that the loch is fairly shallow and enclosed with a relatively large river discharging at its head, freshwater (density) driven currents are likely to be of significance in Loch Riddon, particularly following heavy rainfall. Simplistically, a net seaward flow of fresh water will occur at the surface of the Loch, possibly with return currents of more saline water at depth. This is likely to apply to the lower loch, and may to some extent constrain the movement of contamination from sources to the south of the production area towards the fishery. The situation in the intertidal area is likely to be more complex. At low tide, the river will flow through the main channel, but when the intertidal area is covered, the plume is likely to spread out somewhat and float over the surface of the denser seawater brought in by the tide.

Conclusions

Tidally driven currents within the loch would be expected to move in a generally northerly direction on the flood tide, and a southerly direction on the ebb tide in the waters south of the intertidal area. As the tide comes in it is likely to travel first up the deeper channels and then fan out from there - so local flow across the oyster trestles is more likely to be northwesterly on the incoming tide as the water bends around and flows toward the shore as well as along it. This may carry any contamination from boats anchored east of the fishery, as well as that carried via the river, to the oyster farm.

Contamination from yachts and other sources to the south of the trestles would also be carried in on the flooding tide in this manner. As the two arms of the flood tide meet in the east Kyle around Rothesay Sound, it is assumed that sources in the west Kyle may be of more importance to water quality in Loch Riddon than those in the east Kyle. Tidal influences will result in a broadly north - south flow of water in the loch as the tide floods and ebbs.

Freshwater inputs will result in a net southerly flow of less saline water on the surface. This may carry relatively high levels of contamination, and may to some extent constrain the movement of contamination from sources to the south towards the fishery. Superimposed on this, wind driven currents can create a surface flow in the direction of the wind. A southerly wind will generate wave action which may resuspend contamination in intertidal sediments, it may have the effect of backing up the seaward flow of more contaminated freshwater, and carry contamination from yachts and possibly even other sources further to the south towards the fishery.

15. Shoreline Survey Overview

The shoreline survey was conducted on the 5th and 6th August 2008. The grower reported that the River Ruel had recently been in spate, but at the time of survey it was flowing low and clear.

There were only six trestles covering an area of approximately 3 m by 10 m in place at the time of survey, however there is planning permission to extend the site. Oysters were mature stock of a marketable size. The site was not in commercial production at the time, but expansion is planned providing a grant application is successful.

There were three discharges on the western coastline of Loch Riddon that were within 0.4 km of the oyster trestle. One of these discharges entered Loch Riddon via a soakaway. There was a single outfall pipe identified on the western coastline of Loch Riddon serving Ormidale Lodge, discharging approximately 0.6 km from the oyster trestle. There were 8 static caravans located on the east shore of the loch.

Loch Riddon is situated in a steep-sided glacial valley and the majority of the land in the valley was woodland, mainly deciduous with some conifer plantations in places. There were relatively small areas of pasture on the shores of the Loch. The floodplain of the River Ruel was pasture. The largest area of pasture was around Ardachuple Farm, on the north eastern shore of the Loch, where 19 cows and 128 sheep were observed. Significant numbers of livestock (64 sheep and 6 cows) were also seen at a farm at Shellfield on the west shore. The floodplain of the River Ruel Valley is grazed by sheep and cattle and extends about 12 km from the head of tide. Approximately 30 geese were grazing on the pasture at the head of the loch. An aggregation of 30 gulls was also seen at low tide on the mud surrounding the trestles, and bird droppings were seen on one of the oyster bags.

Boating activity in the immediate vicinity of the oyster trestles was limited. At the southern end of the loch there were several areas of moorings, where a total of 39 boats were moored. Some of these were of sufficient size for people to live on board, and most were pleasure craft so it is likely that impacts from these are highest during the summer months.

Seawater sample results varied from 31 to 700 *E. coli* (cfu/100 ml). The highest two results were in samples taken from near the oyster trestle when the tide was out (260 cfu/100 ml) and towards the head of the loch (700 cfu/100 ml). An oyster sample taken from the site gave a result of 9100 *E. coli* MPN/100 g, which falls within the class C range. When tested for norovirus it proved positive at limit of detection for norovirus genogroup II and negative for norovirus genogroup I, indicating some level of contamination of human origin.

All larger streams were measured and sampled. *E. coli* levels in the streams sampled ranged from 100 to 1500 cfu/100ml. The largest fresh water input, the River Ruel, also contributed the highest loading by two orders of magnitude in terms of *E. coli* per day.

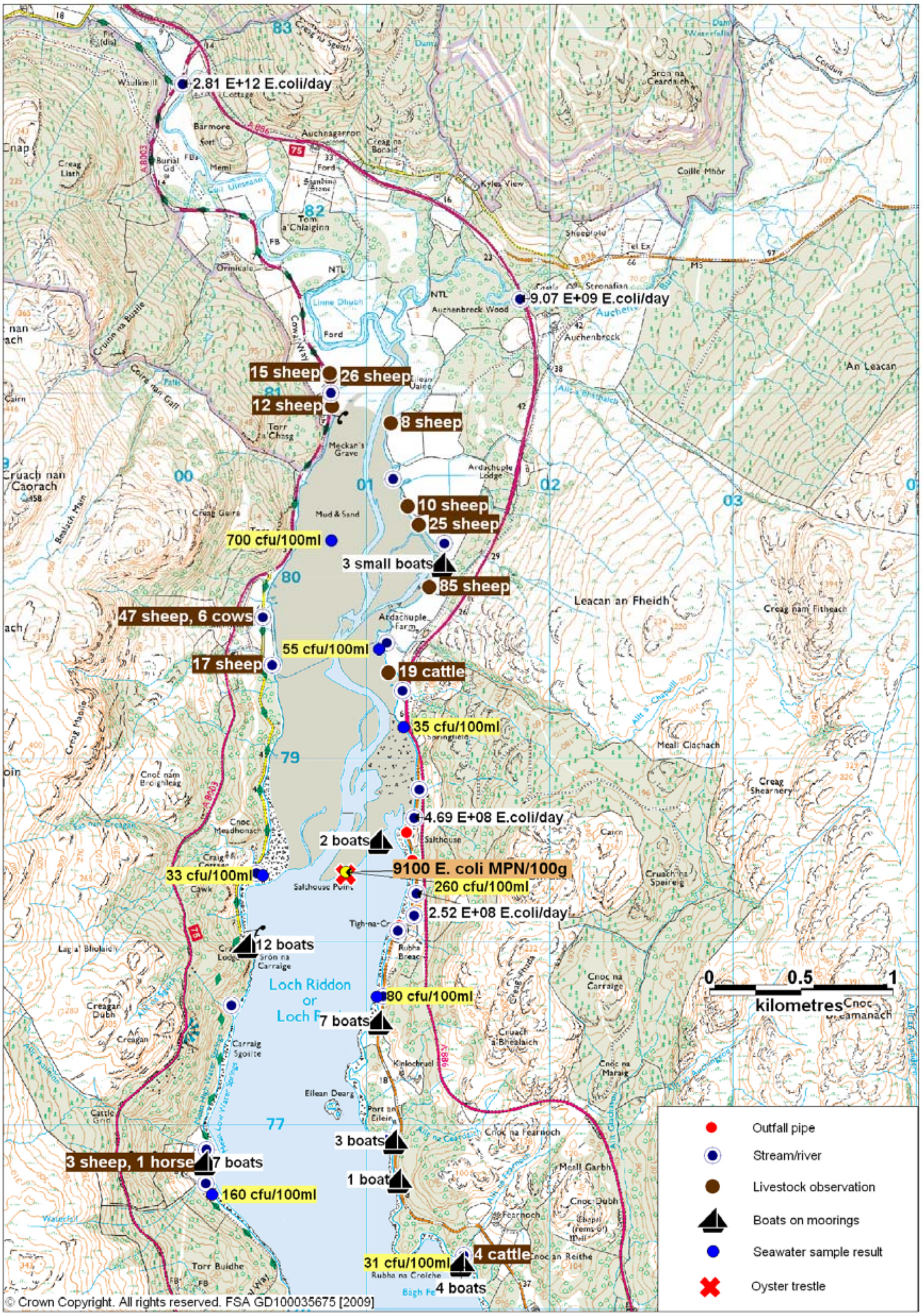

Figure 15.1 Summary of shoreline observations

16. Overall Assessment

Human sewage impacts

Sewage inputs directly to Loch Riddon are few and small, consisting of four septic tank discharges from a total population of about 20. Three of these were to the east shore, within 0.4 km of the trestles. Further sewage inputs carried to the production area via the River Ruel consisted of three private septic tanks, one of which serves a campsite which could potentially cater for over 100 people. There are also two private septic tanks discharging indirectly to the east shore of Loch Riddon via other watercourses, although when these watercourses were sampled during the shoreline survey levels of contamination were low.

It is likely that there are further, unregistered small private discharges to the River Ruel and other watercourses feeding into Loch Riddon. It is also possible that contamination from Scottish Water discharges at Tighnabruaich and Kames (757 people) may impact on the fishery, though these are about 7.5 km south-southwest of the fishery.

The area to the south of the oyster trestles is heavily used by yachts and other pleasure craft, with yachts were observed on moorings between 0.5 and 2.5 km from the trestles. Many more were seen a few kilometers further south in the Kyles of Bute. Contamination from these sources may be carried towards the fishery on the flood tide, and these impacts are also likely to be greater during the summer months when yachting activity in the area is highest.

Although there were no large sewage discharges to the area, norovirus was detected all samples submitted for analysis indicating that human faecal contamination affects the oyster farm year-round.

Agricultural impacts

Agricultural census data indicated that local agriculture is dominated by sheep production, with some cattle also present, and this was confirmed by shoreline survey observations. The majority of the land surrounding Loch Riddon is forested with some areas of pasture around the head of the loch and along the west shore, where livestock were present. Higher levels of contamination in the streams draining these areas may be expected.

Much of the floodplain of the River Ruel is improved pasture on which livestock is grazed, so it is likely that the River Ruel is an important pathway for carrying diffuse contamination from livestock into the production area.

Livestock numbers are expected to be highest in summer, when lambs and calves are present, and lower after they have been sent to market in the autumn.

Wildlife impacts

Most likely sources of wildlife-source faecal contamination in Loch Riddon include gulls, geese and other waterbirds and deer. Gulls may be a significant source of contamination as there is a breeding colony 3.3 km to the south of the trestles, and gulls were observed in the vicinity of the fishery and their droppings were seen on the oyster bags during the shoreline survey. This could occur at any time of the year, and on any of the trestles.

Geese grazing on the pastures may constitute a source of diffuse contamination in the same manner as livestock, and any mpacts from geese may be higher during the winter if significant numbers overwinter here. Deer are a likely source of diffuse contamination reaching the fishery via streams and rainfall runoff from wooded areas surrounding the shoreline.

Although it is likely that some of the faecal contamination present in the area is of wildlife origin, there is no clear spatial pattern to their impacts which would affect placement of a monitoring point or points.

Seasonal variation

The area is popular with tourists, and as a consequence the population on the shores of Loch Riddon and in the Ruel valley is likely to increase significantly during the summer months, leading to increased levels of human sewage input into the area during this time. The Kyles of Bute and the southern end of Loch Riddon are popular with yachts and pleasure craft, and any inputs from these are also likely to be greater during the summer months.

Livestock numbers are likely to be higher in the summer, so inputs from livestock may be higher during the summer, particularly following high rainfall events. Livestock are likely to access watercourses to drink more frequently during warmer weather, leading to direct contamination of watercourses most likely during the summer.

Weather is wetter and windier during the winter months, so more rainfall dependent contamination such as runoff from pastures may be expected during these times.

An analysis of historic *E. coli* monitoring data showed a very strong seasonal effect, with results in the summer and autumn significantly higher than those in the winter and spring. Peak results occurred from July to October. A strong positive relationship between *E. coli* results and water temperature was also found, suggesting that contamination levels are higher when the water is warmer and/or the uptake of bacteria by the oysters is higher in warmer water. A similar, though not statistically significant, seasonal pattern in levels of faecal contamination was observed in shore mussels sampled as part of the shellfish growing waters monitoring programme.

In conclusion, there is likely to be more contamination of both human and livestock origin during the summer months as the area is popular with tourists, and livestock numbers will be higher during summer, and this is strongly supported by the analysis of historical *E. coli* monitoring data.

Rivers and streams

The *E. coli* loading from the River Ruel at the time of shoreline survey contributed over 97% of the total loadings from streams sampled, and was roughly equivalent to the loading that would be contributed by septic tank discharges from a population equivalent of 350. The River Ruel is a spate river, and was running low and clear on day of survey. Discharge and possibly loading may increase during spates, particularly if they occur during the summer or autumn. Much of the floodplain is improved grassland used for grazing sheep and cattle, so during a spate contamination from these animals will be washed into the production area by the river.

The river receives three registered septic tank discharges (and possibly other unregistered ones), two of which are minor, but one of which is from a campsite that may serve up to about 100 people in peak season. As the river channel runs immediately adjacent to fishery at Salthouse Point, the River Ruel is the most significant identified source of contamination to the fishery.

Other stream sources draining the surrounding hills were distributed fairly evenly around the loch. Measured discharges were low in comparison to the River Ruel, and generally so were *E. coli* levels. The highest levels of *E. coli* were found in two of the streams which run through areas of pasture, but the loadings from these streams were still more than two orders of magnitude smaller than that of the River Ruel.

Meteorology, hydrology, and movement of contaminants

The tidal range in Loch Riddon is fairly large, and there is an extensive intertidal area where the fishery is located, so tidally driven exchange of water will be the most significant factor affecting movement of contaminants, with water in the upper loch from the trestles northwards almost completely exchanged each tidal cycle. Contamination from yachts and other sources to the south of the trestles would be carried in on the flooding tide. Just south of the entrance to the loch, the two arms of the flood tide flowing around the Isle of Bute meet in the east Kyle southeast of Loch Riddon, so it is assumed that sources in the west Kyle may be of more importance to water quality in Loch Riddon than those in the east Kyle.

A significant correlation between wind direction and historic *E. coli* monitoring results was found, with a tendency for higher results when the wind was blowing from the south. Strong southerly winds may result in higher than usual tides, cause resuspension of contaminants in intertidal sediments, generate surface currents which push contamination from the south towards the fishery, and may also slow the seaward flow of any fresh water on the surface.

When historic *E. coli* sampling results were compared with recent rainfall and salinity at the time of sampling, no statistically significant relationship was found. The nearest rainfall station for which records were available was located some distance away and fell outside the catchment for the River Ruel, so it may not accurately reflect rainfall experienced within the river catchment. While higher rainfall can result in more faecal contamination entering coastal waters via land runoff, this may be counterbalanced by increased dilution of contaminants. Finally, Pacific oysters can tolerate salinities as low as 2 ppt for brief periods, but feeding rates slow at salinities of 15 ppt or below. Therefore, when the river is in spate the oysters may accumulate contamination at a slower rate.

Temporal and geographical patterns of sampling results

No spatial pattern in historic *E. coli* oyster sampling results could be investigated, as all samples were reported from the same location. No overall temporal trends were identified in the historic sampling results, aside from the seasonal effect already discussed.

Only one oyster sample was taken during the shoreline survey as the fishery only covered a few square meters, so geographic trends in levels of contamination in shellfish could not be investigated.

A number of seawater samples were taken from various locations around the loch during this survey. The highest two results were in samples taken from near the trestle and towards the head of the loch, and these contained 260 and 700 *E. coli* (cfu/100 ml) respectively. The latter had the lowest salinity of all seawater samples (13.8 ppt), with all other samples having a salinity of around 30 ppt. This indicates that higher levels of contamination were found in the less saline areas of the loch, which in turn highlights the importance of the River Ruel as a source of contamination.

17. Recommendations

The current boundaries of the Loch Riddon production area encompass the entire loch. However, the sanitary survey has shown that levels of contamination may differ markedly across the loch, with significant sources of contamination being the River Ruel to the north and east of the Pacific oyster farm and areas of yacht moorings located to the south. It is therefore recommended that the production area boundaries be curtailed to the area immediately surrounding the oyster farm.

The recommended production area boundaries for Pacific oysters are the area bounded by lines drawn between NS 0124 7850 and NS 0085 7850 and between NS 0085 7850 and NS 0075 7835 and between NS 0075 7835 and NS 0075 7821 and between NS 0075 7821 and NS 0125 7836 extending to MHWS. This includes the entire area for which the fishery has planning permission but excludes most of the loch.

As the main source of contamination in the area is the River Ruel, the RMP should be located as close to the river channel as possible. The trestles presently only cover a small area, but are likely to be expanded and could possibly fill the entire area for which planning permission has been granted. However, as this area lies on a sand spit along the current river channel, it is also likely that area may shift over time as the river bed moves. Argyll & Bute council have advised the area between the existing trestle and the river channel is inaccessible by foot due to soft sediment conditions and that the nearest accessible point to the river channel is where the trestles are currently located.

Therefore, it is recommended that the RMP be set at NS 0089 7838, where the existing trestles are located. Should the fishery expand in the future, this recommendation could be reviewed in light of any changes and a determination made as to whether the RMP should be relocated. No sampling depth is applicable, and a standard sampling tolerance of 10 m should be applied.

As strong seasonal fluctuations in *E. coli* results have been found for this site, the sampling frequency should remain monthly.

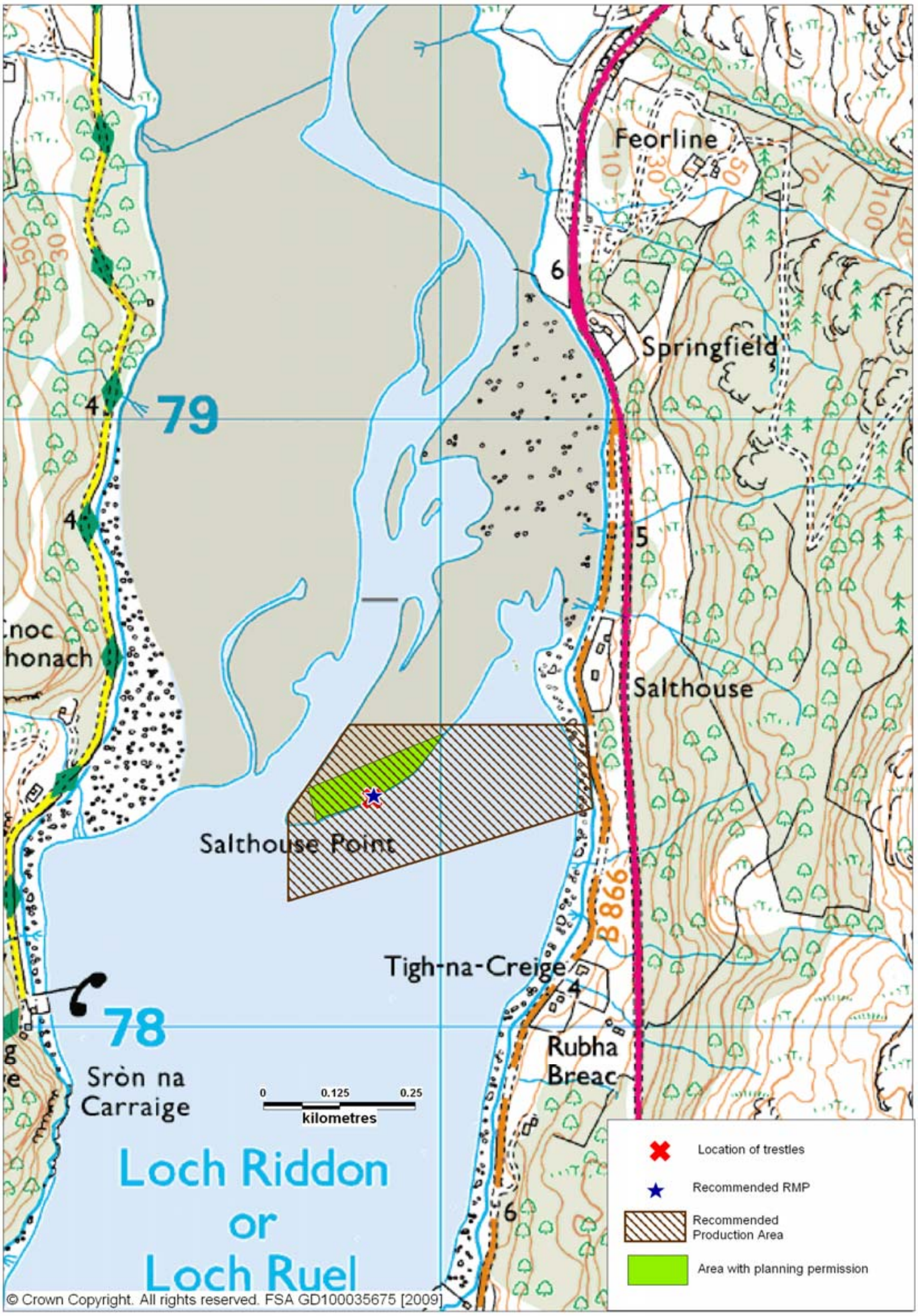

Figure 17.1 Recommendations for Loch Riddon

18. References

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Sampling Plan for Loch Riddon

PRODUC-TION AREA	SITE NAME	SIN	SPECIES	TYPE OF FISH-ERY	NGR OF RMP	EAST	NORTH	TOLER-ANCE (M)	DEPTH (M)	METHOD OF SAMPLING	FREQ OF SAMPLING	LOCAL AUTHORITY	AUTHORISED SAMPLER(S)	LOCAL AUTHORITY LIAISON OFFICER
Loch Riddon	Salthouse Point	AB 183 052 13	Pacific oyster	Trestle	NS 0089 7838	200890	678380	10	N/A	Hand	Monthly	Argyll & Bute	Christine McLachlan William MacQuarrie Ewan McDougall Donald Campbell	Christine McLachlan

Table of Proposed Boundaries and RMPs – Loch Riddon

Production Area	Species	SIN	Existing Boundary	Existing RMP	New Boundary	New RMP	Comments
Loch Riddon	Pacific oyster	AB 183 052 13	Area bounded by a line drawn between NS 0011 7700 and NS 0100 7700 extending to MHWS.	NS 007 783	Area bounded by lines drawn between NS 0124 7850 and NS 0085 7850 and between NS 0085 7850 and NS 0075 7835 and between NS 0075 7835 and NS 0075 7821 and between NS 0075 7821 and NS 0125 7836 extending to MHWS	NS 0089 7838	Boundaries reduced to exclude other areas of the loch where levels of contamination may be higher.

Geology and Soils Assessment

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

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

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

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

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

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

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

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

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

Glossary of Soil Terminology

Calcareous: Containing free calcium carbonate.

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

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

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

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

General Information on Wildlife Impacts

Pinnipeds

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

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

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

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

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

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

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

Cetaceans

A variety of cetacean species are routinely observed around the west coast of Scotland.

Table 8.1 Cetacean sightings in 2007 – Western Scotland.

Common name	Scientific name	No. sighted*
Minke whale	*Balaenoptera acutorostrata*	28
Killer whale	*Orcinus orca*	183
Long finned pilot whale	*Globicephala melas*	14
Bottlenose dolphin	*Tursiops truncatus*	369
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. Source: Hebridean Whale and Dolphin Trust.

Birds

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

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

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms per faecal deposit and ring-billedgulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio and DeLuca, 1999). Waterfowl can be a significant source of pathogens as well as indicator organisms. Gulls frequently feed in human waste bins and it is likely that they carry some human pathogens and birds are known to carry *Salmonella*.

Deer

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

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

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

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

Other

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

Otters leave faeces (also known as spraint) along the shoreline or along streams.

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.

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

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		

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

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

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

Statistical Data

All *E. coli* results were log transformed prior to analysis.

Section 11.5. ANOVA comparison of *E. coli* results by season

```
Source  DF      SS     MS      F      P
Season   3  10.855  3.618  13.34  0.000
Error   26   7.052  0.271
Total   29  17.908

S = 0.5208   R-Sq = 60.62%   R-Sq(adj) = 56.08%

                           Individual 95% CIs For Mean Based on
                           Pooled StDev
Level   N    Mean   StDev  -----+---------+---------+---------+----
1       7  1.9249  0.6276  (------*------)
2      11  3.2158  0.5298                       (-----*----)
3       7  3.2235  0.4818                      (------*-----)
4       5  2.0949  0.3497    (-------*-------)
                           -----+---------+---------+---------+----
                              1.80      2.40      3.00      3.60
Pooled StDev = 0.5208

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

Individual confidence level = 98.91%

Season = 1 subtracted from:

Season    Lower  Center   Upper  ------+---------+---------+---------+---
2        0.6001  1.2910  1.9818                      (-----*-----)
3        0.5348  1.2986  2.0624                     (------*-----)
4       -0.6666  0.1700  1.0067            (------*------)
                                 ------+---------+---------+---------+---
                                    -1.2       0.0       1.2       2.4

Season = 2 subtracted from:

Season    Lower   Center    Upper  ------+---------+---------+---------+---
3       -0.6832   0.0077   0.6985            (-----*-----)
4       -1.8916  -1.1209  -0.3503  (------*-----)
                                   ------+---------+---------+---------+---
                                      -1.2       0.0       1.2       2.4

Season = 3 subtracted from:

Season    Lower   Center    Upper  ------+---------+---------+---------+---
4       -1.9653  -1.1286  -0.2919  (------*------)
                                   ------+---------+---------+---------+---
                                      -1.2       0.0       1.2       2.4
```

Section 11.6.1 Spearmans rank correlation of *E. coli* results and rainfall in the previous 2 days.

```
Pearson correlation of result ranked and 2 day rain ranked = -0.108
P-Value = 0.570
```

Section 11.6.1 Spearmans rank correlation of *E. coli* results and rainfall in the previous 7 days.

```
Pearson correlation of result ranked and 7 day rain ranked = -0.063
P-Value = 0.741
```

Section 11.6.3 Regression analysis for *E. coli* result vs water temperature

The regression equation is
logres water temp = 0.875 + 0.162 WaterTemp

Predictor	Coef	SE Coef	T	P
Constant	0.8754	0.3928	2.23	0.035
WaterTemp	0.16223	0.03401	4.77	0.000

S = 0.589115 R-Sq = 48.7% R-Sq(adj) = 46.5%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	7.8950	7.8950	22.75	0.000
Residual Error	24	8.3293	0.3471		
Total	25	16.2243			

Unusual Observations

Obs	WaterTemp	logres water temp	Fit	SE Fit	Residual	St Resid
14	9.5	1.000	2.417	0.127	-1.417	-2.46R
23	15.0	4.556	3.309	0.177	1.247	2.22R

R denotes an observation with a large standardized residual.

Section 11.6.4 Circular-linear correlation of *E. coli* results and wind direction

CIRCULAR-LINEAR CORRELATION
Analysis begun: 26 September 2008 09:10:57

Variables (& observations)	r	p
Angles & Linear (27)	0.377	0.032

Section 11.6.5 Regression analysis for *E. coli* result vs salinity

The regression equation is
logres salinity = 2.50 + 0.0065 Salinity

Predictor	Coef	SE Coef	T	P
Constant	2.5036	0.5360	4.67	0.000
Salinity	0.00652	0.02277	0.29	0.777

S = 0.714158 R-Sq = 0.4% R-Sq(adj) = 0.0%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0418	0.0418	0.08	0.777
Residual Error	21	10.7105	0.5100		
Total	22	10.7523			

Unusual Observations

Obs	Salinity	logres salinity	Fit	SE Fit	Residual	St Resid
16	22.0	1.000	2.647	0.150	-1.647	-2.36R

R denotes an observation with a large standardized residual.

Section 12 ANOVA comparison of SEPA faecal coliform results by season at Loch Riddon

```
Source   DF      SS     MS     F      P
Quarter   3   4.699  1.566  2.47  0.084
Error    26  16.488  0.634
Total    29  21.187

S = 0.7963   R-Sq = 22.18%   R-Sq(adj) = 13.20%

                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level  N    Mean   StDev  ---+---------+---------+---------+------
Q1     8  2.1747  0.3534  (--------*---------)
Q2     6  2.5449  1.1870      (----------*-----------)
Q3     8  3.0871  0.7932                 (--------*---------)
Q4     8  3.0849  0.7713                 (--------*---------)
                          ---+---------+---------+---------+------
                           1.80      2.40      3.00      3.60

Pooled StDev = 0.7963
```

Section 12 ANOVA comparison of SEPA faecal coliform results by season at Colintraive

```
Source   DF      SS     MS     F      P
Quarter   3   6.571  2.190  2.44  0.087
Error    26  23.296  0.896
Total    29  29.866

S = 0.9466   R-Sq = 22.00%   R-Sq(adj) = 13.00%


                          Individual 95% CIs For Mean Based on Pooled StDev
Level  N    Mean   StDev    +---------+---------+---------+---------
Q1     8  2.7639  1.1904    (--------*---------)
Q2     6  3.0584  1.0829      (-----------*----------)
Q3     8  3.9978  0.7420                     (---------*---------)
Q4     8  3.2253  0.7229          (---------*---------)
                            +---------+---------+---------+---------
                          2.10      2.80      3.50      4.20

Pooled StDev = 0.9466
```

Section 14 Spearmans rank correlation of rainfall in the previous 2 days and salinity at the time of sampling

```
Pearson correlation of 2day rain ranked and salinity ranked = -0.593
P-Value = 0.003
```

Section 14 Spearmans rank correlation of rainfall in the previous 7 days and salinity at the time of sampling

```
Pearson correlation of 7 day rain ranked and salinity ranked = -0.602
P-Value = 0.002
```

Hydrographic Methods Document

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.

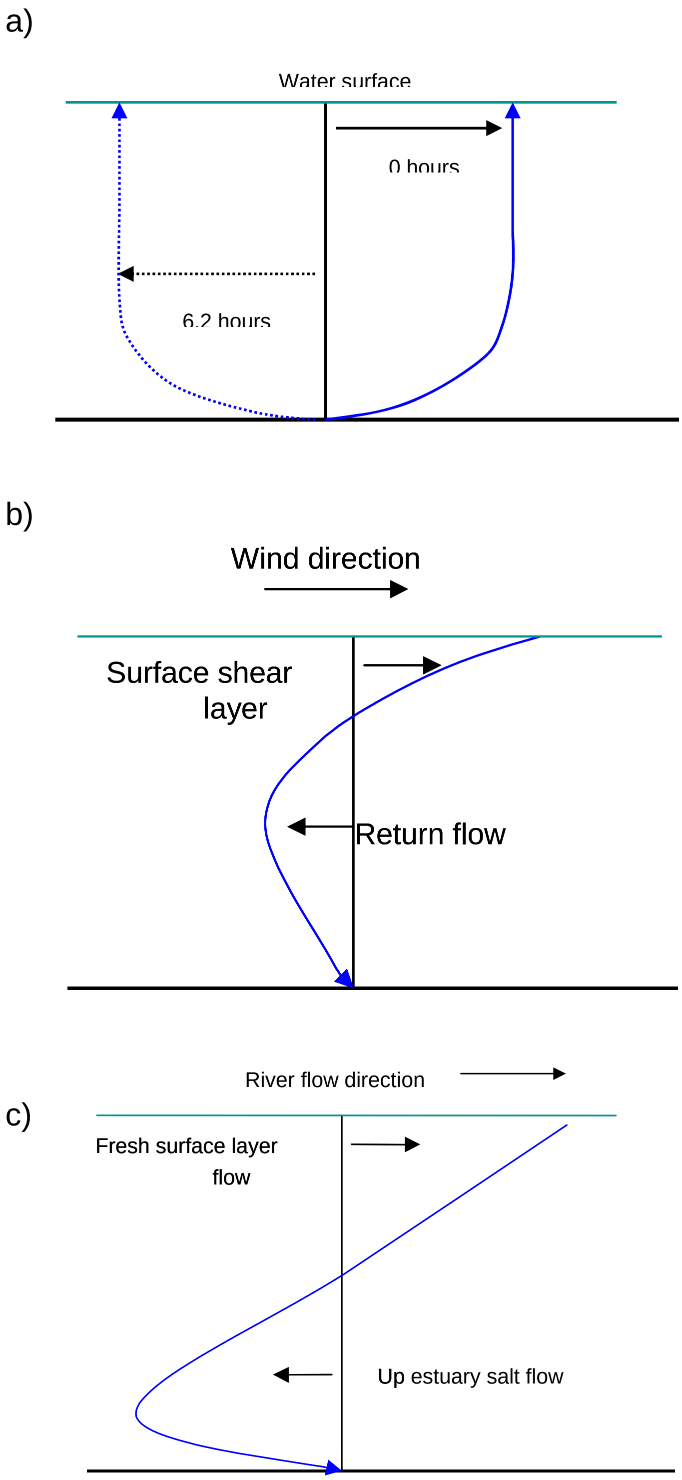

Figure 1 Typical vertical profiles for water currents.
The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

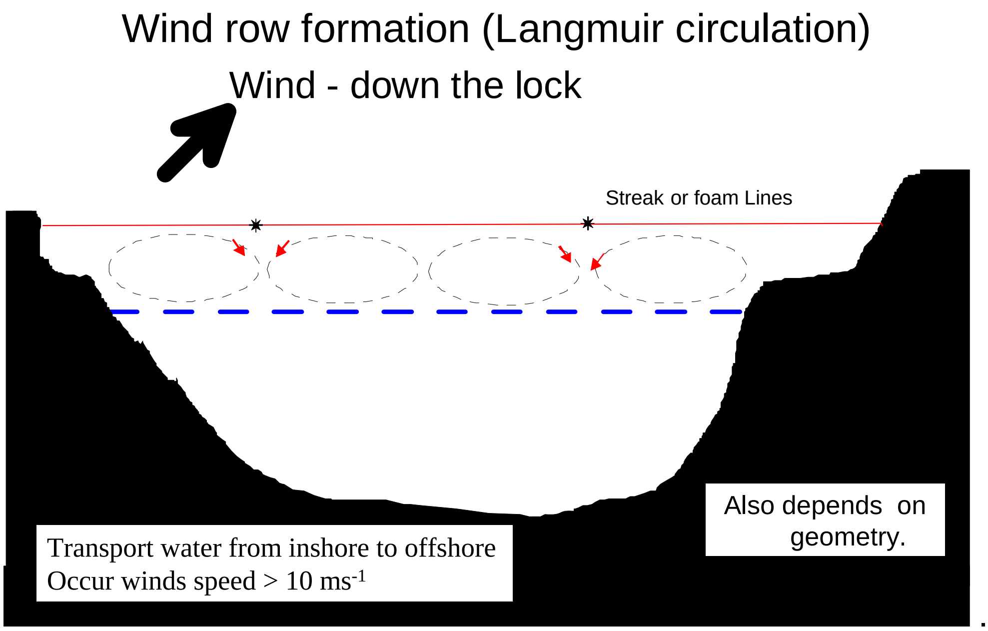

Figure 2 Schematic of wind driven 'wind row' currents.
The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

Shoreline Survey Report

Loch Riddon
(AB 183)

Scottish Sanitary Survey Project

Shoreline Survey Report

Production Area:

Production Area	Site	SIN	Species
Loch Riddon	Salthouse Point	AB 183 052 13	Pacific oysters

Harvester: Mr John McNaughton
Status: Currently classified for harvest.
Date Surveyed: 5/8/08 to 6/8/08.
Surveyed by: Christine McLachlan, William McQuarrie, Alastair Cook
Existing RMP: NS 007783
Area Surveyed: See Figure 1.

Weather observations

5/8/08 – No wind, sunny, 13 ºC at 08:00
6/8/08 – Wind 13 Km/h NNE, rain, 13 ºC at 09:00.

Heavy rain had been experienced several days before the survey, and the grower reported that the River Ruel had recently been in spate.

Site Observations

Specific observations made on site are mapped in Figure 1 and listed in Table 1. Water and shellfish samples were collected at sites marked on Figures 2 and 3. Bacteriology results are given in Tables 2 and 3. Norovirus testing results are presented in Table 4. Photographs are presented in Figures 4-7.

Fishery

The fishery currently consists of only 6 trestles covering an area of approximately 3 m by 10 m, and is not harvested commercially at present. Stock on site had been there for about three years, and was of a marketable size. Planning permission to extend the site to 100 trestles has recently been granted, but the grower is awaiting the award of a grant before expanding the operation.

Sewage/Faecal Sources

Human – There are no major settlements on the shores of the production area. There are a few houses here, but only four of these had visible sewage pipes discharging directly into the loch. A large number of pleasure yachts frequent the moorings to the south of the production area, and these represent a potential source of contamination.

Livestock – There are several areas of pasture on the shores of Loch Riddon. The largest is the area around Ardachuple Farm, on the north eastern shore of the Loch, where 19 cows and 128 sheep were observed. Significant numbers of livestock (64 sheep and 6 cows) were also seen at a farm at Shellfield on the west shore. 12 sheep were seen grazing on salt grassland at the head of the estuary. Also of significance to the production area, but not actually surveyed, is the River Ruel Valley. The floodplain of this river is pasture grazed by sheep and cattle, extending about 12 km from the head of tide. The river was measured and sampled and the results of this are taken to reflect any inputs further upstream.

A few streams discharge into the loch, mainly draining forested areas. Water samples were taken, and discharge estimated where the streams were of sufficient size for flow to be measured. Stream inputs had levels of *E. coli* of from <100 to 1500 cfu/100ml. Of more significance is the River Ruel, a relatively large river which discharges to the head of the loch. Flow measured during the survey was 2.7 cumecs (m^3/s), and a water sample contained *E. coli* concentrations of 1200 cfu/100ml.

E. coli levels in seawater taken from the shore ranged from 31 to 700 cfu/100ml. Salinities ranged from 13.8 to 31.1 parts per thousand. The sample with the lowest salinity also had the highest level of *E. coli*, and was taken near the head of the loch.

An oyster sample taken from the trestles returned an *E. coli* result of 9100 mpn/100g, and tested positive at the limit of detection for norovirus genogroup II, and negative for norovirus genogroup I

Seasonal Population
A number of the dwellings seen on the shoreline survey are likely to be holiday homes. A total of 8 static caravans were seen on the east shore. The area is picturesque and popular with tourists, and as a consequence the population on the shores of Loch Riddon and in the Ruel valley is likely to increase during the summer months.

Boats/Shipping
Several areas of moorings were seen in the southern end of the production area, where a total of 39 boats were moored. Some of these were of sufficient size for people to live on board, and most were pleasure craft so it is likely that impacts from these are highest during the summer months.

Land Use
Loch Riddon lies in a steep sided glacial valley. The majority of the land surrounding the loch is wooded, mainly deciduous with some conifer plantations in places. There are some relatively small areas of pasture on the shores of the Loch. The floodplain of the River Ruel is pasture.

Wildlife/Birds
30 seagulls were seen at low tide on the mud surrounding the trestles, and their droppings were seen on the oyster bags suggesting that they use the trestles as a perch at certain states of the tide. 33 geese were seen grazing on pasture at the head of the loch. Aside from these, no significant aggregations of wildlife were seen during the survey.

General observations

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

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

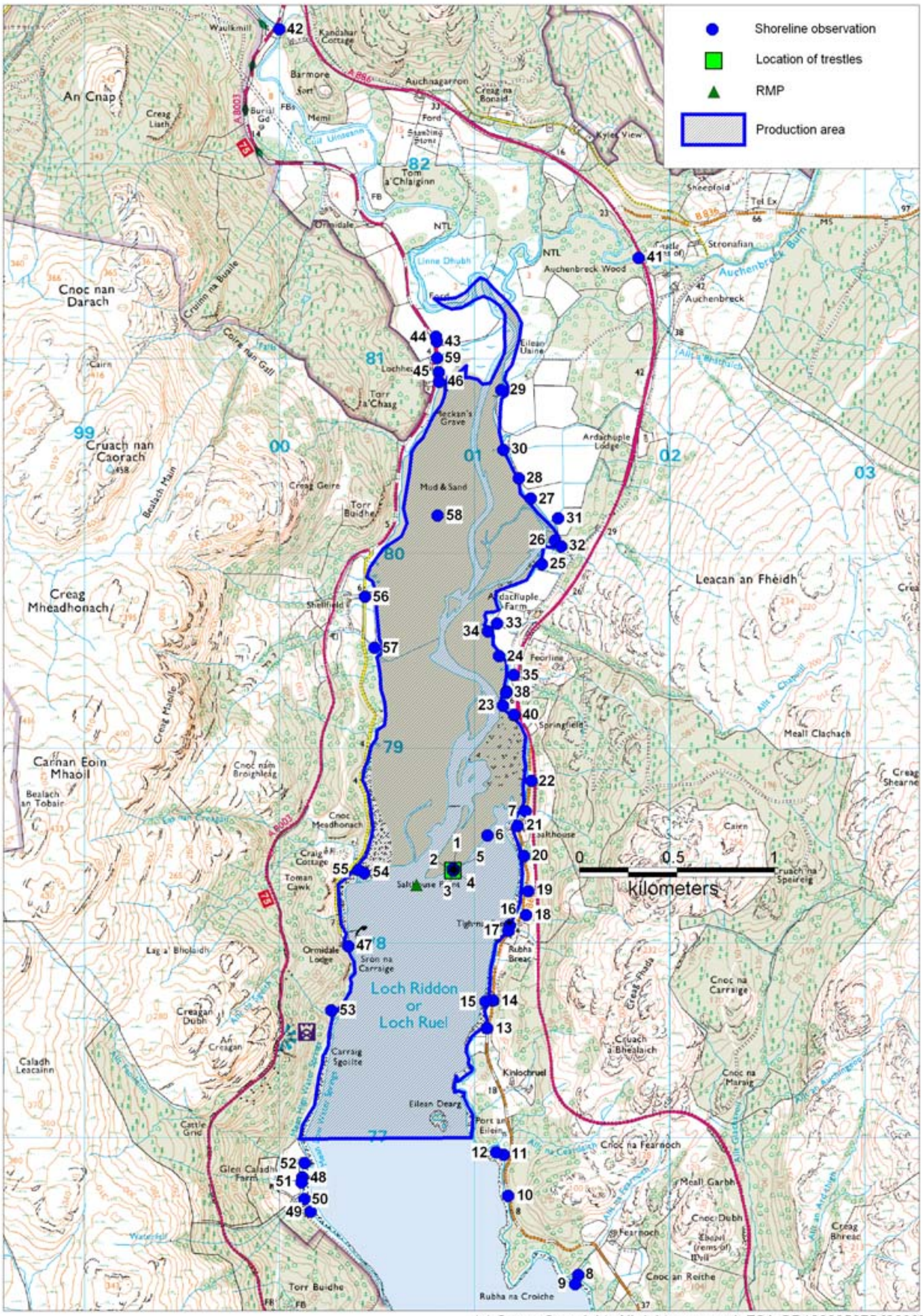

Figure 1 Map of Shoreline Observations

Table 1 Shoreline observations

Name	Date & time	Position	Photograph	Description
1	05-AUG-08 8:38:28AM	NS 00887 78373	Figure 4	Corner of trestles.
2	05-AUG-08 8:38:34AM	NS 00890 78374		Corner of trestles.
3	05-AUG-08 8:38:42AM	NS 00891 78381		Corner of trestles.
4	05-AUG-08 8:38:48AM	NS 00888 78382		Corner of trestles.
5	05-AUG-08 8:38:53AM	NS 00886 78382		LR1 Oyster sample (submitted as classification sample), LRNoro Oyster sample, LR Seawater sample 1. 30 seagulls on surrounding mud. Bird droppings on one of the oyster bags.
6	05-AUG-08 9:00:52AM	NS 01065 78553		2 moorings with small boats on.
7	05-AUG-08 9:27:57AM	NS 01260 78679		Stream 50cmxx5cmx0.217m/s. LR freshwater sample 2.
8	05-AUG-08 10:03:38AM	NS 01531 76294		Stream 108cmx10cmx0.108m/s. LR freshwater sample 3. 4 cattle
9	05-AUG-08 10:08:51AM	NS 01514 76247		4 boats on moorings. LR seawater sample 4.
10	05-AUG-08 10:20:37AM	NS 01170 76702		Boat on mooring just offshore.
11	05-AUG-08 10:25:38AM	NS 01148 76913		3 static caravans, 1 house. 3 boats moored and 6 empty moorings.
12	05-AUG-08 10:27:04AM	NS 01110 76924		Stream 85cmx6cmx0.231m/s, LR freshwater sample 5
13	05-AUG-08 10:39:03AM	NS 01063 77563		7 boats on moorings, 15 empty moorings, boathouse.
14	05-AUG-08 10:46:18AM	NS 01094 77706		Stream 20cmx4cmx0.071m/s. LR freshwater sample 6.
15	05-AUG-08 10:50:44AM	NS 01055 77699		LR seawater sample 7.
16	05-AUG-08 11:00:15AM	NS 01178 78092	Figure 5	110mm cast iron sewage pipe, serves 1 or 2 houses.
17	05-AUG-08 11:05:55AM	NS 01173 78064		Stream 38cmx6cmx0.133m/s. LR freshwater sample 8.
18	05-AUG-08 11:14:07AM	NS 01263 78146		Stream 85cmx5cmx0.082m/s. LR freshwater sample 9.
19	05-AUG-08 11:23:20AM	NS 01275 78268		Stream 45cmx4cmx0.162m/s. LR freshwater sample 10.
20	05-AUG-08 11:31:07AM	NS 01251 78449		110mm orange plastic sewer pipe to underwater. (1 house).
21	05-AUG-08 11:35:42AM	NS 01220 78602		110mm cast iron sewer pipe to underwater (1 house).
22	05-AUG-08 11:42:00AM	NS 01290 78835		Stream 24cmx4cmx0.458m/s. LR freshwater sample11.
23	05-AUG-08 11:56:14AM	NS 01144 79221		2 static caravans 200m back from this point.
24	05-AUG-08 12:01:12PM	NS 01123 79473	Figure 6	19 cattle on shore. Area of pasture around farm along shore to north of here to head of loch.
25	05-AUG-08 12:12:48PM	NS 01343 79946		85 sheep.
26	05-AUG-08 12:17:06PM	NS 01410 80068		3 static caravans, 1 house. 3 boats moored and 6 empty moorings.

Name	Date & time	Position	Photograph	Description
27	05-AUG-08 12:25:55PM	NS 01286 80283		25 sheep (no fence to shore).
28	05-AUG-08 12:28:22PM	NS 01225 80387		10 sheep.
29	05-AUG-08 12:38:15PM	NS 01135 80841		8 sheep about 300m north of here on far bank.
30	05-AUG-08 12:45:36PM	NS 01146 80534		Stream 95cmx3cmx0.275m/s. LR freshwater sample12.
31	05-AUG-08 12:56:16PM	NS 01427 80182		Stream 80cmx5cmx0.177m/s. LR freshwater sample13.
32	05-AUG-08 1:02:28PM	NS 01443 80036		Stream 105cmx6cmx0.278m/s. LR freshwater sample14.
33	05-AUG-08 1:19:05PM	NS 01113 79640		Stream 90cmx7cmx0.116m/s. LR freshwater sample15.
34	05-AUG-08 1:23:50PM	NS 01067 79600		LR Seawater sample16.
35	05-AUG-08 1:31:52PM	NS 01198 79375		Stream 53cmx3cmx0.202m/s. LR freshwater sample17.
36	05-AUG-08 1:36:21PM	NS 01163 79291		No specific observation.
37	05-AUG-08 1:36:23PM	NS 01162 79290		No specific observation.
38	05-AUG-08 1:36:28PM	NS 01160 79286		No specific observation.
39	05-AUG-08 1:40:17PM	NS 01203 79173		No specific observation.
40	05-AUG-08 1:40:30PM	NS 01202 79174		LR seawater sample 19.
41	05-AUG-08 2:03:18PM	NS 01840 81520		Stream 115cmx11cmx0.830m/s. LR freshwater sample 20.
42	05-AUG-08 2:15:33PM	NR 99997 82695		River 1740cmx50cmx0.312m/s. LR freshwater sample 18.
43	06-AUG-08 9:32:09AM	NS 00805 81091		Field of 26 sheep.
44	06-AUG-08 9:32:50AM	NS 00800 81114		33 geese and 15 sheep on pasture to east.
45	06-AUG-08 9:36:14AM	NS 00814 80931		12 sheep on salt grass about 100m east of here.
46	06-AUG-08 9:37:47AM	NS 00817 80883		3 houses.
47	06-AUG-08 10:55:13AM	NS 00351 77984		110 mm cast iron septic pipe to underwater (Ormadale house). 12 boats on moorings.
48	06-AUG-08 11:35:31AM	NS 00114 76796		3 sheep, 1 horse, farm, 3 cottages, 7 boats on moorings.
49	06-AUG-08 11:39:05AM	NS 00157 76620		LR seawater sample 21.
50	06-AUG-08 11:41:28AM	NS 00125 76684		Stream 50cmx10cmx0.284m/s. LR freshwater sample 22.
51	06-AUG-08 11:46:39AM	NS 00111 76770		Stream 80cmx6cmx0.214m/s. LR freshwater sample 23.
52	06-AUG-08 11:51:06AM	NS 00128 76869		Stream 530cmx10cmx0.043m/s. LR freshwater sample 24.
53	06-AUG-08 12:11:38PM	NS 00263 77654		Stream 70cmx5cmx0.143m/s. LR freshwater sample 25.
54	06-AUG-08 12:41:31PM	NS 00433 78361		LR seawater sample 26.
55	06-AUG-08 12:44:01PM	NS 00401 78377		Stream 380cmx5cmx0.329+m/s. LR freshwater sample 27. 4 houses on hill behind.
56	06-AUG-08 12:56:43PM	NS 00437 79778		Stream 100cmx5cmx0.373m/s. LR freshwater sample 28. 6 cows, 47 sheep, farm.

Name	Date & time	Position	Photograph	Description
57	06-AUG-08 1:04:17PM	NS 00486 79517		Stream 85cmx15cmx0.512m/s. LR freshwater sample 29. 17 sheep on shore.
58	06-AUG-08 1:19:07PM	NS 00808 80196		LR seawater sample30.
59	06-AUG-08 1:32:59PM	NS 00807 81004		Stream 82cmx8cmx0.012m/s. LR freshwater sample 31.

Table 2 Water sample E. coli results

Name	Date & time	Position	Type	*E. coli* (cfu/100ml)	Salinity (ppt)
LR 1	05-AUG-08 8:38:53AM	NS 00886 78382	Seawater	260	30.2
LR 2	05-AUG-08 9:27:57AM	NS 01260 78679	Freshwater	100	
LR 3	05-AUG-08 10:03:38AM	NS 01531 76294	Freshwater	<100	
LR 4	05-AUG-08 10:08:51AM	NS 01514 76247	Seawater	31	30.0
LR 5	05-AUG-08 10:27:04AM	NS 01110 76924	Freshwater	400	
LR 6	05-AUG-08 10:46:18AM	NS 01094 77706	Freshwater	<100	
LR 7	05-AUG-08 10:50:44AM	NS 01055 77699	Seawater	80	28.7
LR 8	05-AUG-08 11:05:55AM	NS 01173 78064	Freshwater	<100	
LR 9	05-AUG-08 11:14:07AM	NS 01263 78146	Freshwater	<100	
LR 10	05-AUG-08 11:23:20AM	NS 01275 78268	Freshwater	100	
LR 11	05-AUG-08 11:42:00AM	NS 01290 78835	Freshwater	<100	
LR 12	05-AUG-08 12:45:36PM	NS 01146 80534	Freshwater	1200	
LR 13	05-AUG-08 12:56:16PM	NS 01427 80182	Freshwater	700	
LR 14	05-AUG-08 1:02:28PM	NS 01443 80036	Freshwater	<100	
LR 15	05-AUG-08 1:19:05PM	NS 01113 79640	Freshwater	<100	
LR 16	05-AUG-08 1:23:50PM	NS 01067 79600	Seawater	55	28.7
LR 17	05-AUG-08 1:31:52PM	NS 01198 79375	Freshwater	100	
LR 18	05-AUG-08 2:15:33PM	NR 99997 82695	Freshwater	1200	
LR 19	05-AUG-08 1:40:30PM	NS 01202 79174	Seawater	35	30.9
LR 20	05-AUG-08 2:03:18PM	NS 01840 81520	Freshwater	100	
LR 21	06-AUG-08 11:39:05AM	NS 00157 76620	Seawater	160	29.1
LR 22	06-AUG-08 11:41:28AM	NS 00125 76684	Freshwater	<100	
LR 23	06-AUG-08 11:46:39AM	NS 00111 76770	Freshwater	1500	
LR 24	06-AUG-08 11:51:06AM	NS 00128 76869	Freshwater	200	
LR 25	06-AUG-08 12:11:38PM	NS 00263 77654	Freshwater	<100	
LR 26	06-AUG-08 12:41:31PM	NS 00433 78361	Seawater	33	31.1
LR 27	06-AUG-08 12:44:01PM	NS 00401 78377	Freshwater	100	
LR 28	06-AUG-08 12:56:43PM	NS 00437 79778	Freshwater	400	
LR 29	06-AUG-08 1:04:17PM	NS 00486 79517	Freshwater	100	
LR 30	06-AUG-08 1:19:07PM	NS 00808 80196	Seawater	700	13.8
LR 31	06-AUG-08 1:32:59PM	NS 00807 81004	Freshwater	200	

Table 3 Shellfish sample E. coli testing results

Name	Date & time	Position	Species	*E. coli* (mpn/100ml)
LR 1	05-AUG-08 8:38:53AM	NS 00886 78382	Pacific Oyster	9100

Table 4 Shellfish sample norovirus testing results

Name	Date & time	Position	Species	Norovirus Genogroup I	Norovirus Genogroup II
LR Noro	05-AUG-08 8:38:53AM	NS 00886 78382	Pacific Oyster	Negative	Positive at limit of detection

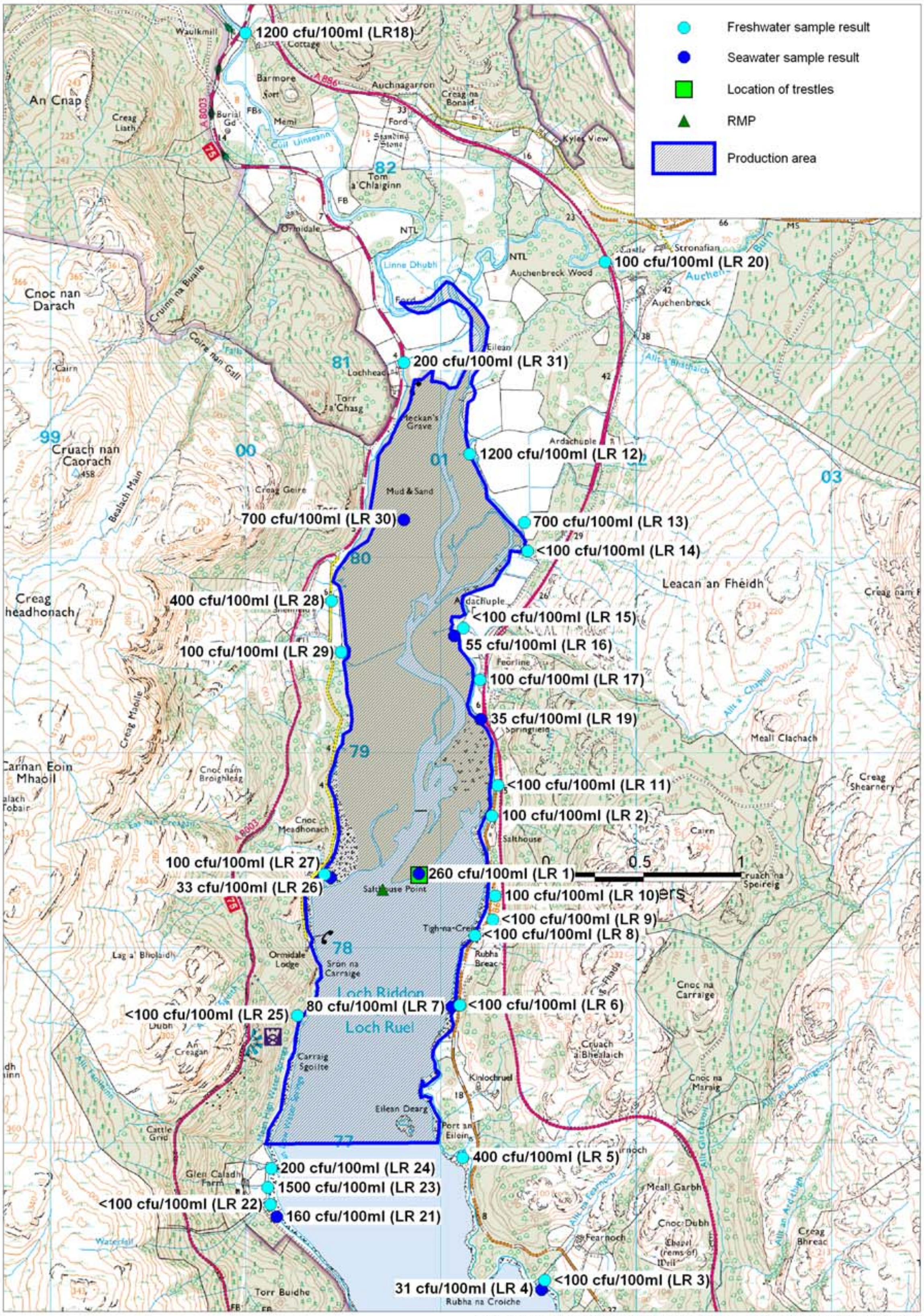

Figure 2 Water sample results map

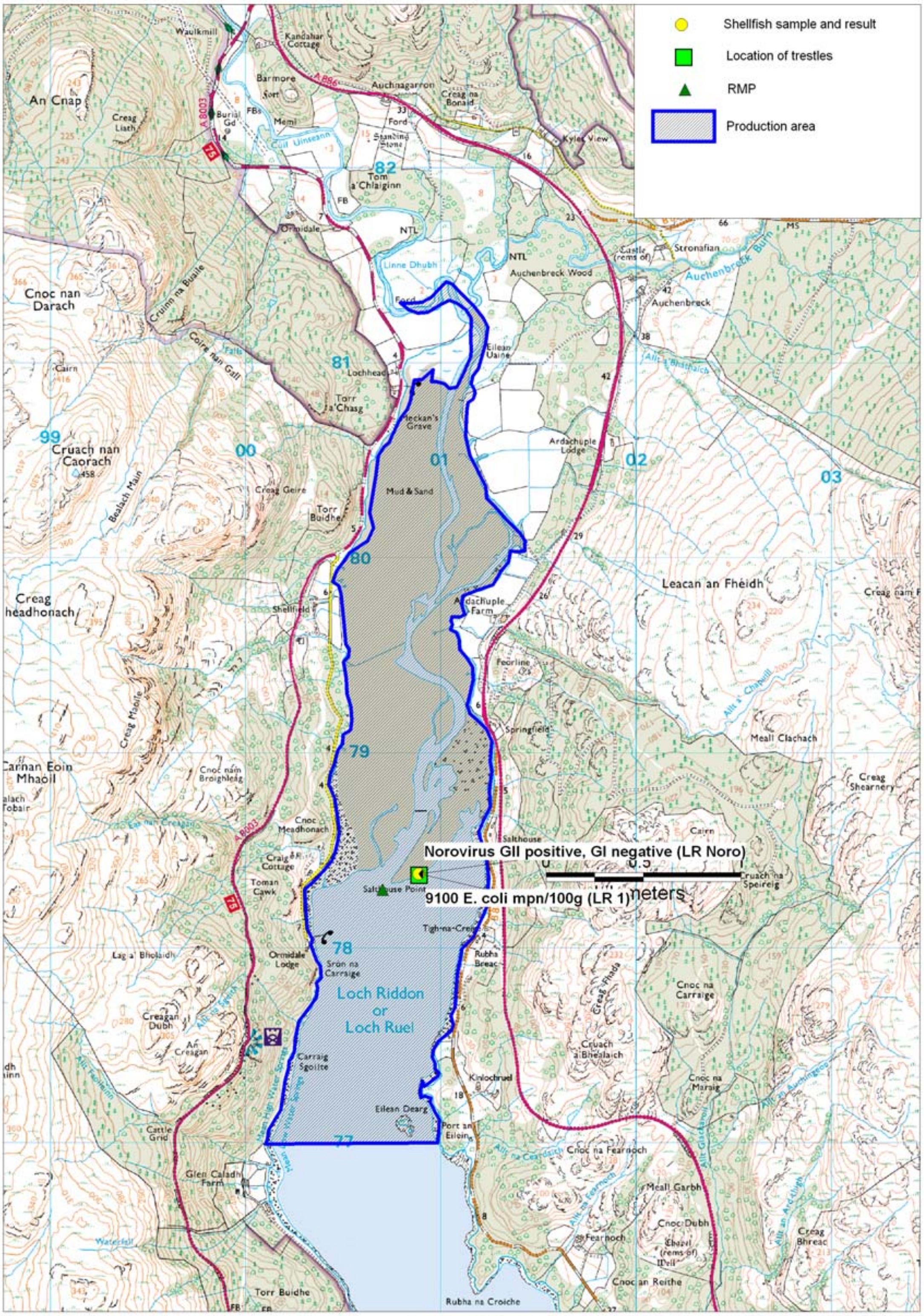

Figure 3 Shellfish sample results map

Figure 4 Oyster trestles at Salthouse point

Figure 5 Sewer pipe

Figure 6 Cattle on shoreline

Norovirus Testing Summary
Loch Riddon

Oyster samples taken from the oyster trestles at Loch Riddon were submitted for Norovirus analysis quarterly from August 2008. Results are summarised in the table below.

Ref No.	Date rec'd	NGR	GI	GII
08/160	06/08/08	NS 00886 78382	Not detected	Positive at limit of detection
08/269	19/11/08	NS 00886 78379	Positive	Positive
09/015	13/02/09	NS 00888 78381	Positive	Positive
09/093	12/5/09	NS 00892 78381	Not detected	Positive