Scottish Sanitary Survey Programme

Sanitary Survey Report

Production Area: Loch Leven: Lower

SIN: HL 170 222 08

March 2012

Report Distribution – Loch Leven: Lower

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I. Executive Summary

The sanitary survey at Loch Leven: Lower was undertaken due to the ranking of the area in a statistical assessment of potential deterioration in *E. coli* results. Loch Leven is located along the northern reaches of Loch Linnhe on the western coast of Scotland, approximately 40 km northwest of Oban. Loch Leven opens to the west via a narrow straight. The Loch Leven: Lower fishery is located close to the narrows. The area surrounding Loch Leven: Lower fishery is moderately populated although this increases between March and October due to tourism.

At the time of the shoreline survey in Spetmber 2011, the Loch Leven: Lower shellfish farm consisted of a group of fourteen mussel rafts, with 6 m dropper lines, located to the east of Eilean Choinneich. Harvesting is not normally undertaken in the months of December, January and February.

Continuous sewage discharges from treatment works at Ballachulish and Glencoe were redirected to the secondary treatment works at North Ballachulish in 2010, thereby markedly reducing sewage contamination in Loch Leven. The remaining principal sources of sewage contamination to the fishery are the remaining intermittent discharges into Lower Loch Leven at Ballachulish and Glencoe. Although the operation of these discharges would be rainfall dependent, when they spill the impact could be significant. There is one septic tank at Glenachulish serving 10 houses; this discharge may impact on the shellfish. The North Ballachulish WWTW, located about 2.6 km west of the fishery, may have residual impact on background levels of contamination in the outer loch.

Only a small number of farms are present and only a few animals were observed during the shoreline survey. A moderate amount of sheep droppings on grazing land on the northwest shoreline of the loch were seen. When present the direct deposition of droppings at the shoreline and in and around watercourses is likely to pose a threat to water quality at the fishery. The impact from wildlife will be moderate. The breeding colony of gulls and terns on the island west of the fishery is likely to contribute to faecal bacteria at the mussel farm. However, impacts from the breeding colony will be higher in early summer during nesting. Limited impacts from geese or deer are most likely to be carried via freshwater runoff to the fishery. There is potential for runoff of animal faecal material from the steep hillsides adjacent to the loch.

The main potential sources of contamination from watercourses are those on the southern and northern shores to the east of the farm although others will contribute to background *E. coli* levels in the area, especially after heavy rainfall. Rainfall varies by season, with September to January being the wettest months and April the driest. It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area will be higher during the autumn and winter months. A particularly high result of 16 000 *E. coli* cfu/100 ml was obtained from a sample taken from a small stream on the northern shore of the loch, which indicates faecal contamination although there was no obvious input in this case. The overall loading

of this stream (based on a spot measurement) was moderate, however, even after heavy rainfall and the highest estimated loadings related to the Rivers Coe and Laroch.

Loch Leven: Lower has had a mixed A/B classification for most years apart from 2005 where the site held a B classification year round. No significant correlation was found between *E. coli* results in shellfish and rainfall in the previous 2 days or previous 7 days.

The currents around the Loch Leven: Lower mussel farm are weak generally but faster through the narrows. Currents at the farm will be complex and estimated transport distances mean that most of the potential source of contamination observed during the shoreline survey could impact at the mussel farm, especially at spring tides. The southern end of the farm is anticipated to be more vulnerable to impact by such contamination than the northern end.

Recommendations

Due to the significant number of both point and diffuse sources of faecal contamination in lower Loch Leven, it is recommended that the production area boundaries be curtailed to exclude the waters near Ballachulish, North Ballachulish, and Glencoe. The recommended boundaries are described as the area bounded by lines drawn between NM 0640 5931 and NM 0659 5884 and between NM 0742 5943 and NM 0727 5840 and extending to MHWS.

It is recommended that the RMP be relocated to NM 0716 5905. This lies at the southeastern end of the mussel farm, which is nearer to sources arising from the southern shore.

II. Sampling Plan

PRODUCTION AREA	Loch Leven: Lower
SITE NAME	Lower
SIN	HL 170 222 08
SPECIES	Common mussels
TYPE OF FISHERY	Suspended aquaculture
NGR OF RMP	NN 0716 5905
EAST	107160
NORTH	759050
TOLERANCE (M)	20
DEPTH (M)	1
METHOD OF SAMPLING	Hand
FREQUENCY OF SAMPLING	Monthly
LOCAL AUTHORITY	Highland Council Lochaber
AUTHORISED SAMPLER(S)	Stephen Lewis
LOCAL AUTHORITY LIAISON OFFICER	Stephen Lewis

III. Report

1. General Description

Loch Leven is located along the northern reaches of Loch Linnhe on the western coast of Scotland, approximately 40 km northwest of Oban. Loch Leven opens to the west via a narrow straight and contains 5 sills. The loch is 13 km in length, 0.09 km at its narrowest point and 1.6 km at its widest point, with a maximum depth of 62 metres. The Loch Leven: Lower fishery is located on the bottom sill close to the opening of the loch.

The sanitary survey at Loch Leven: Lower is being undertaken due to the ranking of the area in a statistical assessment of potential deterioration in *E. coli* results. A map of the area of interest is shown in Figure 2.1.

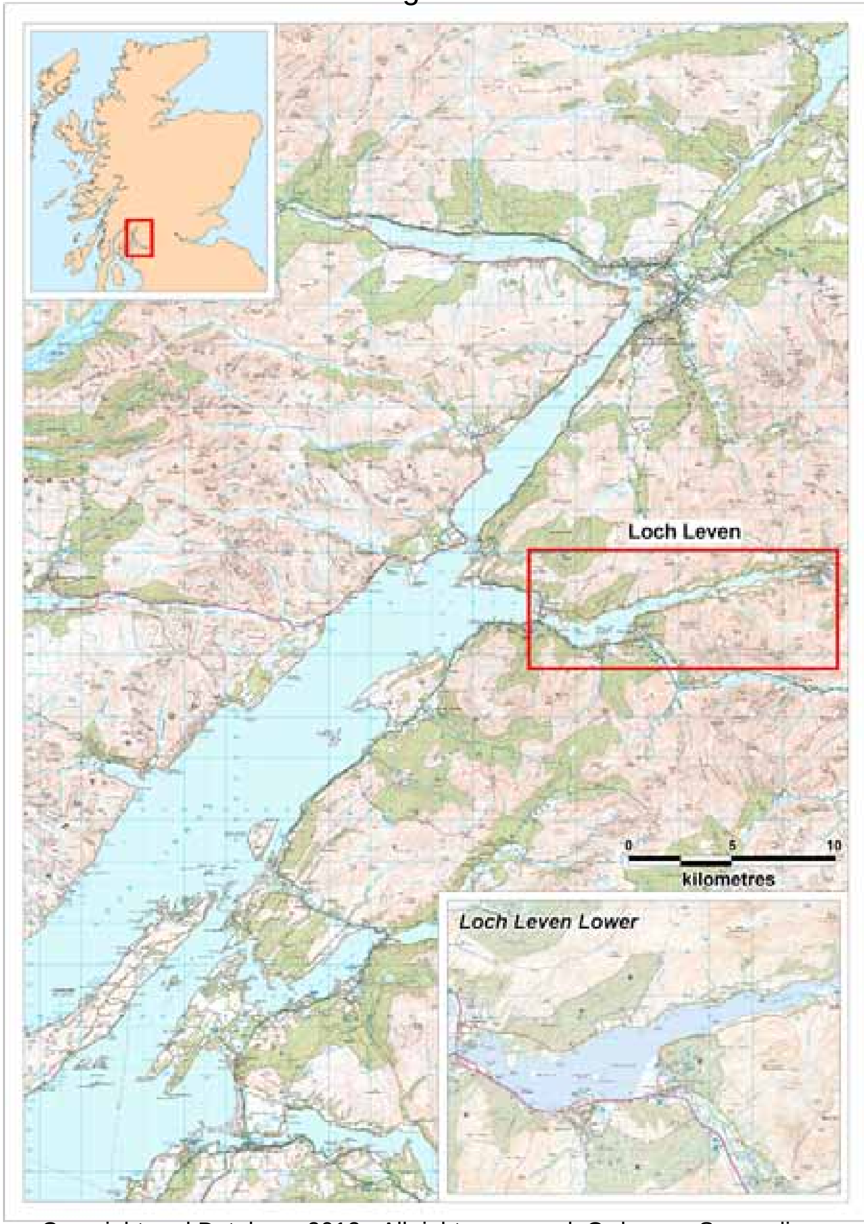


Figure 1.1 Location of Loch Leven: Lower

2. Fishery

At the time of the shoreline survey, the Loch Leven: Lower shellfish farm consisted of a group of fourteen mussel rafts, with 6 m dropper lines, located to the east of Eilean Choinneich. Harvesting is not normally undertaken in the months of December, January and February.

The current production area boundary is defined by lines drawn between NN 0521 5986 and NN 0520 5967 (Ballachulish Bridge) and between NN 1400 6120 and NN 1400 6154. The nominal Representative Monitoring Point (RMP) is reported at NN 07200 59400, which lies 220 m north of the mussel rafts.

The actual location of the mussel farm within the loch was recorded during the shoreline survey and is shown together with the production area boundaries, RMP and lease areas, in Figure 2.1.

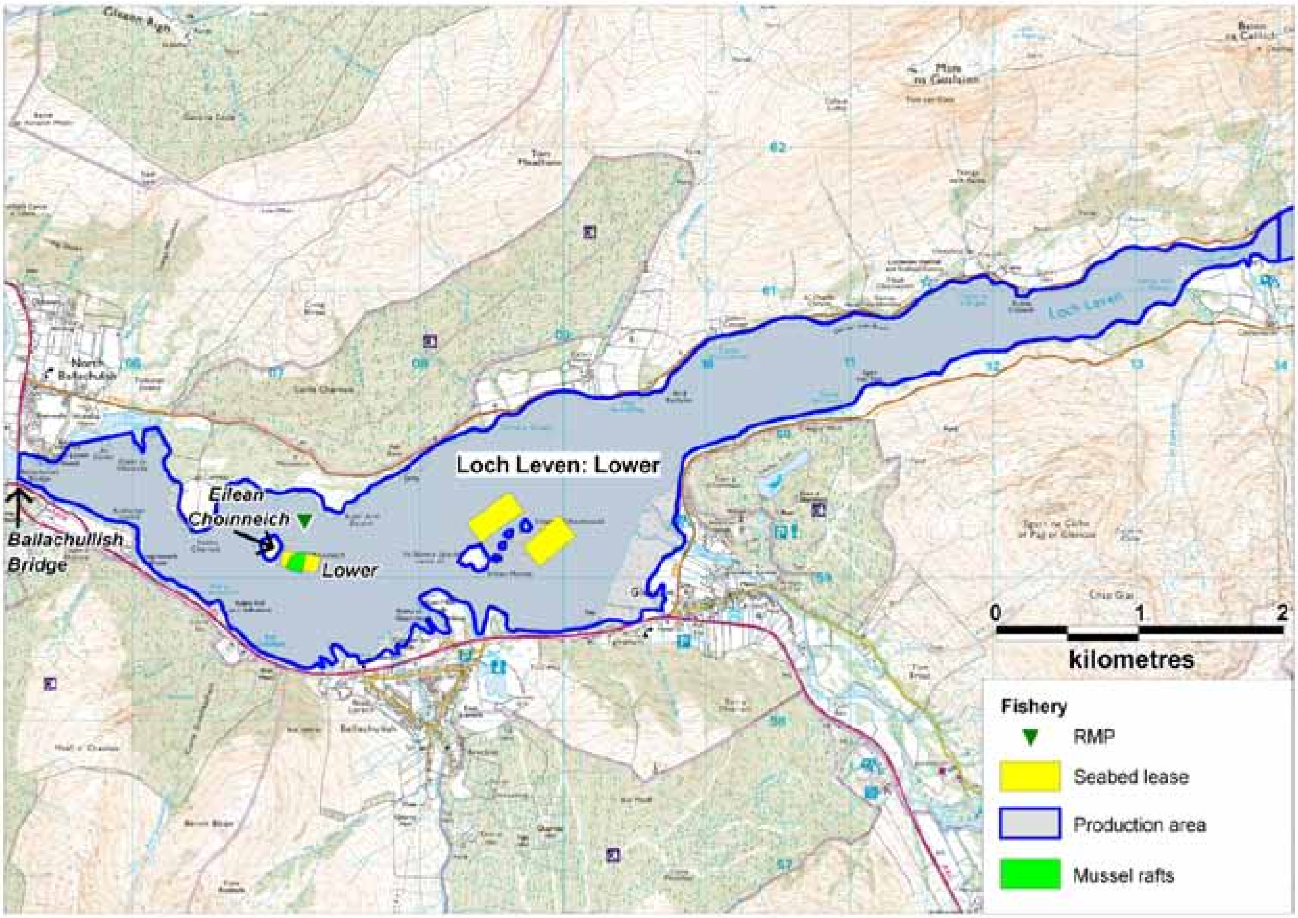


Figure 2.1 Loch Leven: Lower Fishery

3. Human Population

Information on the human population of the area around Loch Leven: Lower was obtained from the General Register Office for Scotland. Data was provided for the 2001 census by output area. The population density for the output areas nearest the fishery is shown thematically mapped in Figure 3.1.

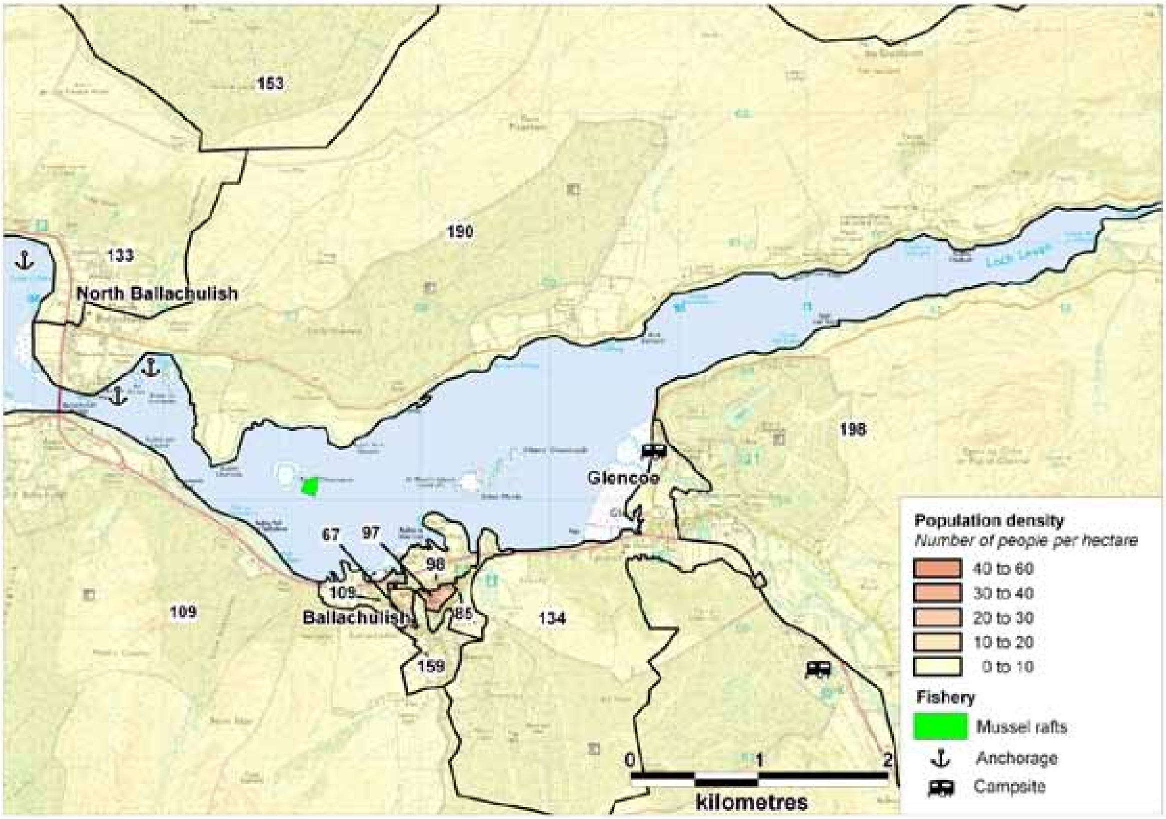


Figure 3.1 Population map of Loch Leven: Lower

The population density for the area surrounding the fishery varies from low to moderate. The majority of the local population is centred around two main areas: Kinlochleven at the head of the loch (11 km east of the fishery) and North Ballachulish, Glencoe and Ballachulish at the western end of the loch. Ballachulish, on the south shore, is the largest area of population in the vicinity of the fishery but is still a relatively small settlement.

Loch Leven is a popular tourist destination and a number of hotels and B&Bs cater for visitors to the area. There is a large caravan and campsite located on the shore at Glencoe. There are three anchorages west of the fishery, two of which are located in a small bay north-west of the bridge and the third of which is located in Ballachulish Bay. Yachts were observed in the former two anchorages during the shoreline survey. Several boats were also observed on moorings between Ballachulish and Glencoe. Recreational boats have been identified as sources of intermittent sewage contamination where they discharge toilet wastes overboard (Guillard-Cottard *et al*, 1998). There is a pier west of Glencoe and a jetty on the shoreline opposite Ballachulish, where a wildlife tour boat operates.

4. Sewage Discharges

Information on sewage discharges to the area was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified community septic tanks and sewage discharges for the area surrounding Loch Leven: Lower. These are detailed in Table 4.1.

Table 4.1 Discharges identified by Scottish Water

Consent Ref No.	NGR of discharge	Discharge Name	Discharge Type	Level of Treatment	Consented flow m^3/day	Consented Design PE
CAR/L/1087888	NN 0312 6132	Onich SPS3 (Manse) CSO/EO	intermittent	6mm screen	-	-
CAR/L/1087888	NN 0404 6116	Onich SPS4 (Onich) CSO/EO	intermittent	6mm screen	-	-
CAR/L/1087888	NN 0465 6098	Onich SPS5 (BMC Hut) CSO/EO	intermittent	6mm screen	-	-
CAR/L/1087888	NN 0506 6096	Onich SPS6 (Marden) CSO/EO	intermittent	6mm screen	-	-
CAR/L/1087888	NN 0577 6024	North Ballachulish SPS1 (Grianan) CSO/EO	intermittent	6mm screen	-	-
CAR/L/1087888	NN 0534 5979	North Ballachulish SPS2 (Columba/Pier) CSO/EO	intermittent	6mm screen	-	-
CAR/L/1087888	NN 0531 6039	North Ballachulish SPS3 (Fern Lea) CSO/EO	intermittent	6mm screen	-	-
CAR/L/1087888	NN 1038 5894	Glencoe Upper SPS (Seaforth Cottage) CSO/EO [1]	intermittent	6mm screen	-	-
CAR/L/1087888	NN 0929 5882	Glencoe SPS (old Works) CSO/EO	intermittent	6mm screen	401	834
CAR/L/1087888	NN 0806 5863	South Ballachulish East SPS CSO/EO	intermittent	-	-	-
CAR/L/1087888	NN 0761 5847	South Ballachulish West SPS CSO/EO	intermittent	-	-	-
CAR/L/1087888	NN 0775 5829	South Ballachulish Croft Road CSO	intermittent	-	-	-
CAR/L/1087888	NN 0787 5836	South Ballachulish SPS CSO/EO	intermittent	6mm screen	1114	2160
CAR/L/1002004	NN 0472 6017	North Ballachulish WWTW	continuous	septic tank and secondary	1503	3101
T/B08/23/94	NN 051 598	North Ballachulish WWTW EO	intermittent	6mm screen	-	-
WPC/N/51353	NN 048 593	Glenachulish ST [2]	continuous	septic tank	-	-
T/B08/97/88	NN 014 586	Kentallen Glengorm ST [3]	continuous	septic tank	-	-
	NN 0232 6281	Inchree WWPS 1 EO [4]	intermittent	-	-	-
	NN 0246 6289	Inchree WWPS 2 EO [4]	intermittent	-	-	-
WPC/N/53463	NN 0215 6270	Inchree WWTW [4]	continuous	secondary	120	600

[1] Discharges to River Coe
[2] Serves 10 houses, discharges to Gleann a Choalais river
[3] Serves 7 houses, discharges to Loch Linnhe
[4] Discharges to Abhainn Righ
- Data not provided

No sanitary or microbiological data were provided for these discharges. Scottish Water recently completed an improvement project which resulted in the relocation of septic tank discharges that were direct to the Shellfish Growing Water, from Glencoe and South Ballachulish villages, to North Ballachulish where they are combined with the effluent from the North Ballachulish Wastewater Treatment Works (WWTW) and discharged to the waters of Ballachulish Bay, outwith the entrance to the loch. This upgrade was completed in 2010. The relatively large (1503 m^3/d flow) discharge at North Ballachulish WWTW receives primary settlement followed by secondary biological treatment. Scottish Water have identified that this has significantly reduced the impact from human sewage to the waters of the loch and on the basis of dispersion modelling undertaken in support of the new discharge project do not believe that the discharges to Loch Linnhe are likely to affect water quality within Loch Leven. The modelling study predicts 90% compliance with the design standard established by SEPA (100 FC/100 ml) at the western boundary of the designated shellfish growing water. It must be noted that this does not bear any direct relation to the shellfish hygiene standards, which are established in shellfish flesh.

In addition to the North Ballachulish continuous discharge there is a continuous discharge at Inchree, located in Loch Linnhe, approximately 5.8 km northwest of Ballachulish Bridge, outside of the production area. Given its distance from the fishery and its relatively small size, this is unlikely to impact on the shellfish in Loch Leven. Kinlochleven WWTW, which receives secondary biological treatment and has a population equivalent of 530, is situated over 10 km east of the shellfish area and as such is not considered to impact on the water quality at the fishery in Loch Leven Lower.

The Glenachulish Septic Tank (ST) was identified as currently serving 10 houses, discharging to the Gleann a Choalais river, approximately 3 km from the shellfish farm. Although this is currently a much smaller discharge than that from North Ballachulish, it receives a much lower level of treatment. Plans to further develop housing in the area may lead to a greater use of this septic tank in the future. However, it is not clear whether it currently contributes to background contamination levels in lower Loch Leven.

The Kentallen Glengorm ST lies well south of the entrance to the loch, and is smaller than the Glenachulish ST and therefore is considered unlikely to affect water quality within the loch.

The previous discharges at South Ballachulish and Glencoe have been converted to pumping stations with the potential for intermittent overflows, in line with SEPA design requirements. Scottish Water predicted spill frequencies of 0 per year for the South Ballachulish Combined Sewer Overflows (CSOs) and 6 per year for Glencoe. South Ballachulish Croft Road CSO and North Ballachulish Sewage Pumping Station (SPS) 3 both discharge to small ditches and while flow in these ditches would be expected to ultimately reach the shore, Scottish Water report that both appear also to work in large part as soakaways.

Eight intermittent emergency (EO) or storm (CSO) overflows remain within the Loch Leven Shellfish Growing Water, in proximity to the shellfish harvesting area. However in a typical combined sewerage system with pumping stations, the EOs would not be expected to spill except in abnormal circumstances. The CSOs would be expected to spill when heavy rainfall leads to higher flows through the storm drains than the sewerage system could handle, resulting in spills of a mixture of rainfall runoff and untreated sewage. These spills would carry a combination of human sewage as well as contamination from animal faeces, garden compost, etc.

Scottish Water predicted a low spill frequency for the Glencoe and South Ballachulish WWPS (6 and 0 spills per year, respectively). No actual spill data was available.

SEPA provided information on a relatively large number of consented discharges. These are listed in Table 4.2. All discharges are shown mapped in Figure 4.1.

Table 4.2 Discharge consents identified by SEPA

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
1	CAR/R/1053561	NN 10060 60690	Continuous	Septic tank	6	soakaway
2	CAR/R/1018537	NN 09970 60670	Continuous	Septic tank	5	land
3	CAR/R/1037881	NN 09471 60711	Continuous	Septic tank	5	soakaway
4	CAR/R/1037882	NN 09208 60416	Continuous	Septic tank	5	soakaway
5	CAR/R/1037880	NN 09173 60468	Continuous	Septic tank	5	soakaway
6	CAR/R/1016372	NN 06520 59940	Continuous	Septic tank	5	soakaway
7	CAR/R/1037129	NN 06430 59910	Continuous	Septic tank	5	soakaway
8	CAR/R/1018236	NN 06400 59880	Continuous	Septic tank	5	land
9	CAR/R/1037883	NN 05704 60119	Continuous	Septic tank	5	soakaway
10	CAR/L/1002004	NN 04721 60175	Continuous	Secondary	not supplied	Loch Linnhe
11	CAR/R/1039426	NN 05320 60930	Continuous	Septic tank	5	land
12	CAR/R/1037615	NN 02855 61432	Continuous	Septic tank	5	unnamed w/c[1]
13	CAR/R/1078547	NN 02780 61420	Continuous	Septic tank	7	soakaway
14	CAR/R/1039571	NN 02661 61386	Continuous	Septic tank	5	land
15	CAR/R/1059361	NN 02560 61470	Continuous	Septic tank	5	soakaway
16	CAR/R/1038711	NN 02400 61390	Continuous	Septic tank	6	U/T of Loch Linnhe[2]
17	CAR/R/1039291	NN 02020 61380	Continuous	Septic tank	6	Loch Linnhe
18	CAR/R/1039425	NN 02430 61620	Continuous	Septic tank	5	land
19	CAR/R/1016119	NN 02460 61706	Continuous	Septic tank	5	land
20	CAR/R/1037903	NN 02087 61627	Continuous	Septic tank	5	soakaway
21	CAR/R/1064973	NN 02139 61695	Continuous	Septic tank	6	soakaway
22	CAR/R/1090036	NN 02206 61700	Continuous	Septic tank	6	soakaway
23	CAR/R/1037695	NN 02200 61720	Continuous	Septic tank	6	soakaway
24	CAR/R/1090037	NN 02200 61720	Continuous	Septic tank	6	soakaway
25	CAR/R/1064982	NN 02185 61744	Continuous	Septic tank	10	soakaway
26	CAR/R/1037682	NN 02259 61734	Continuous	Septic tank	5	soakaway
27	CAR/R/1037696	NN 02219 61761	Continuous	Septic tank	6	soakaway
28	CAR/R/1037697	NN 02239 61793	Continuous	Septic tank	6	soakaway
29	CAR/R/1091669	NN 02273 61838	Continuous	STW FE[3]	5	U/T of Loch Linnhe[2]
30	CAR/R/1039285	NN 02236 61836	Continuous	Septic tank	6	U/T of Loch Linnhe[2]
31	CAR/R/1038485	NN 01611 61728	Continuous	Septic tank	5	soakaway
32	CAR/R/1076075	NN 02083 61863	Continuous	Septic tank	7	soakaway
33	CAR/R/1016303	NN 02350 62030	Continuous	Septic tank	5	soakaway
34	CAR/L/1002100	NN 02100 62700	Continuous	STW		Abhainn Righ
35	CAR/L/1002101	NN 02144 62702	Intermittent	CSO		Abhainn Righ
36	CAR/R/1059574	NN 02791 63269	Continuous	Septic tank	5	U/T of Abhainn Righ[2]
37	CAR/L/1002982	NN 04119 62756	Continuous	Water treatment works effluent	not supplied	Abhainn Righ
38	CAR/R/1021793	NN 02390 59260	Continuous	Septic tank	5	land
39	CAR/R/1040111	NN 02532 59255	Continuous	Septic tank	5	Watercourse
40	CAR/R/1010768	NN 02910 59550	Continuous	Septic tank	5	soakaway
41	CAR/R/1084032	NN 02925 59552	Continuous	STW FE[3]	6	U/T of Loch Linnhe[2]
42	CAR/R/1037045	NN 04500 59500	Continuous	Septic tank	6	Loch Linnhe
43	CAR/R/1034659	NN 04810 59340	Continuous	Septic tank	11	soakaway
44	CAR/R/1084065	NN 04960 59170	Continuous	Septic tank	6	soakaway
45	CAR/R/1037800	NN 05052 59172	Continuous	Septic tank	5	soakaway

No.	Ref No.	NGR of discharge	Discharge Type	Level of Treatment	Consented/ design PE	Discharges to
46	CAR/R/1039760	NN 05359 59418	Continuous	Septic tank	5	soakaway
47	CAR/R/1037963	NN 05360 59530	Continuous	Septic tank	12	soakaway
48	CAR/R/1030975	NN 05260 59570	Continuous	STW FE[3]	5	soakaway
49	CAR/R/1088397	NN 07329 58378	Continuous	Council depot trade effluent	-	Coastal waters
50	CAR/L/1021781	NN 07885 58425	Intermittent	CSO	-	River Laroch
51	CAR/L/1021781	NN 07885 58425	Intermittent	EO	-	River Laroch
52	CAR/L/1002128	NN 07907 58415	Intermittent	CSO	-	River Laroch
53	CAR/R/1034877	NN 08240 57900	Continuous	Septic tank	6	soakaway
54	CAR/R/1080321	NN 09310 58661	Continuous	Septic tank	12	Loch Leven
55	CAR/L/1021780	NN 09290 58810	Intermittent	CSO	-	Loch Leven
56	CAR/L/1021780	NN 09290 58807	Intermittent	EO	-	Loch Leven
57	CAR/L/1002087	NN 0930 5880	Intermittent	EO	-	Loch Leven
58	CAR/R/1040108	NN 10630 58560	Continuous	Septic tank	15	soakaway
59	CAR/R/1081743	NN 10692 58417	Continuous	Septic tank	9	soakaway

[1] w/c = watercourse
[2] U/T = unnamed tributary
[3] STW FE = sewage treatment works final effluent
- Data not supplied

SEPA provided two consents (CAR/L/1004012 and CAR/L/1002146) that pertained to continuous discharges from Ballachulish South and Glencoe WWTW, which are now pumped to North Ballachulish. Therefore, these have not been included in Table 4.2.

A small number of consents were identified as being for sewage treatment works final effluent for private dwellings. These are presumed to be package treatment works providing secondary treatment or better. Two consents related to trade effluents, one from a water treatment works and the other from a council depot. These may have a septic constituent, however no estimate of the amount of septic content in these discharges was provided.

Discharges to either land or to soakaway were from private septic tanks or small treatment works serving private dwellings with population equivalents of between 5 and 15. The total combined population equivalent of all identified private discharges is 297, or approximately 10% of the capacity of the public sewerage system. Unless these private septic tanks are malfunctioning, or inappropriately situated, it is not anticipated that they would comprise a significant source of faecal contamination to the waters of the loch. No attempt was made to ascertain the functional status of the septic tanks identified in the area of the fishery, as this was outside the scope of this survey. Sewage infrastructure recorded during the shoreline survey is listed in Table 4.3.

Table 4.3 Discharges and septic tanks observed during shoreline surveys

No.	Date	NGR	Description
1	06/09/2011	NN 07330 58351	Pipe - flowing. Hydrocarbon smell.
2	06/09/2011	NN 07470 58438	Pipe running out from side of house: then goes under shore.
3	06/09/2011	NN 08376 58602	Old iron pipe emerging from direction of hotel - no flow
4	06/09/2011	NN 08393 58583	Large concrete pipe with flow; no access to sample or measure; seawater sample near end
5	06/09/2011	NN 10355 58928	Upper Carnoch WWPS
6	06/09/2011	NN 10377 58932	Outlet pipe below west side of Coe River
7	06/09/2011	NN 10389 58936	Outlet pipe below east side of Coe River, trickle flowing
8	06/09/2011	NN 09771 58810	Glencoe Waste Water Pumping Station
9	06/09/2011	NN 09681 58799	Two long outfall pipes; one looks newer than the other; seawater sample partway out along pipes
10	07/09/2011	NN 05836 60098	Iron pipe approx 18 cm outer diameter.; newer plastic pipe extends from end out under water
11	07/09/2011	NN 05136 59971	New North Ballachulish WWTW
12	08/09/2011	NN 08188 58537	Ballachulish Waste Water Pumping Station

A seawater sample taken from near the outfall pipes from the Glencoe WWPS returned a result 8900 *E. coli* cfu/100 ml. A water sample taken from the River Coe upstream of the shoreline returned a result of 1000 *E. coli* cfu/100 ml. As the weather was very wet, the CSO may have been operating at the time and so could have been the source of the contamination. The geometric mean faecal coliform concentration reported in the literature for storm sewage overflows is 2.5 x 10^6 cfu/100 ml (Kay *et al*, 2008).

A seawater sample taken from opposite the South Ballachulish East WWPS (approximately 170 metres northeast of the outfall) also contained elevated levels of faecal bacteria, with a result of 1700 *E. coli* cfu/100 ml. However, it is not clear what part of this may have been attributable to any spill at the pumping station.

A freshwater sample taken near an outlet pipe to the Coe River (Table 4.3, No 7) gave a result of 1000 *E. coli* cfu/100 ml which indicates some faecal input, though this would have represented the sum of contamination carried in the river, including the output from the septic tank outlets.

Although the continuous flow of sewage to the Loch Leven: Lower production area from Glencoe and Ballachulish has been eliminated, CSOs associated with these treatment works are likely to significantly impact water quality at the fishery when they spill. Scottish Water report an emergency overflow for the North Ballachulish works just to the west of the bridge.

The North Ballachulish WWTW outfall lies just over 2.6 km to the west of the fishery. Water samples taken on an incoming tide at the mouth of the loch were found to contain <100 *E. coli* cfu/100 ml. While the parameters to which public sewage discharges must adhere are predicted to be met in this case, there is a difference between the water quality identified by SEPA as suitable for meeting the SGW standard and that required to meet shellfish hygiene standards. A recent study examining the relationship between faecal indicator concentrations in shellfish flesh and overlying water in England and Wales predicted compliance with the class B threshold (≤4600 *E. coli*/100g with 90% probability) in common mussels at 33 *E. coli* cfu/100 ml in overlying waters (Campos, et al 2011). This broadly concurs with a study on equivalence between shellfish and water standards, which identified a value of 50 *E. coli*/100 ml in water for 90% compliance with class B (EU Scientific Veterinary Committee Working Group on Faecal Coliforms in Shellfish 1996).

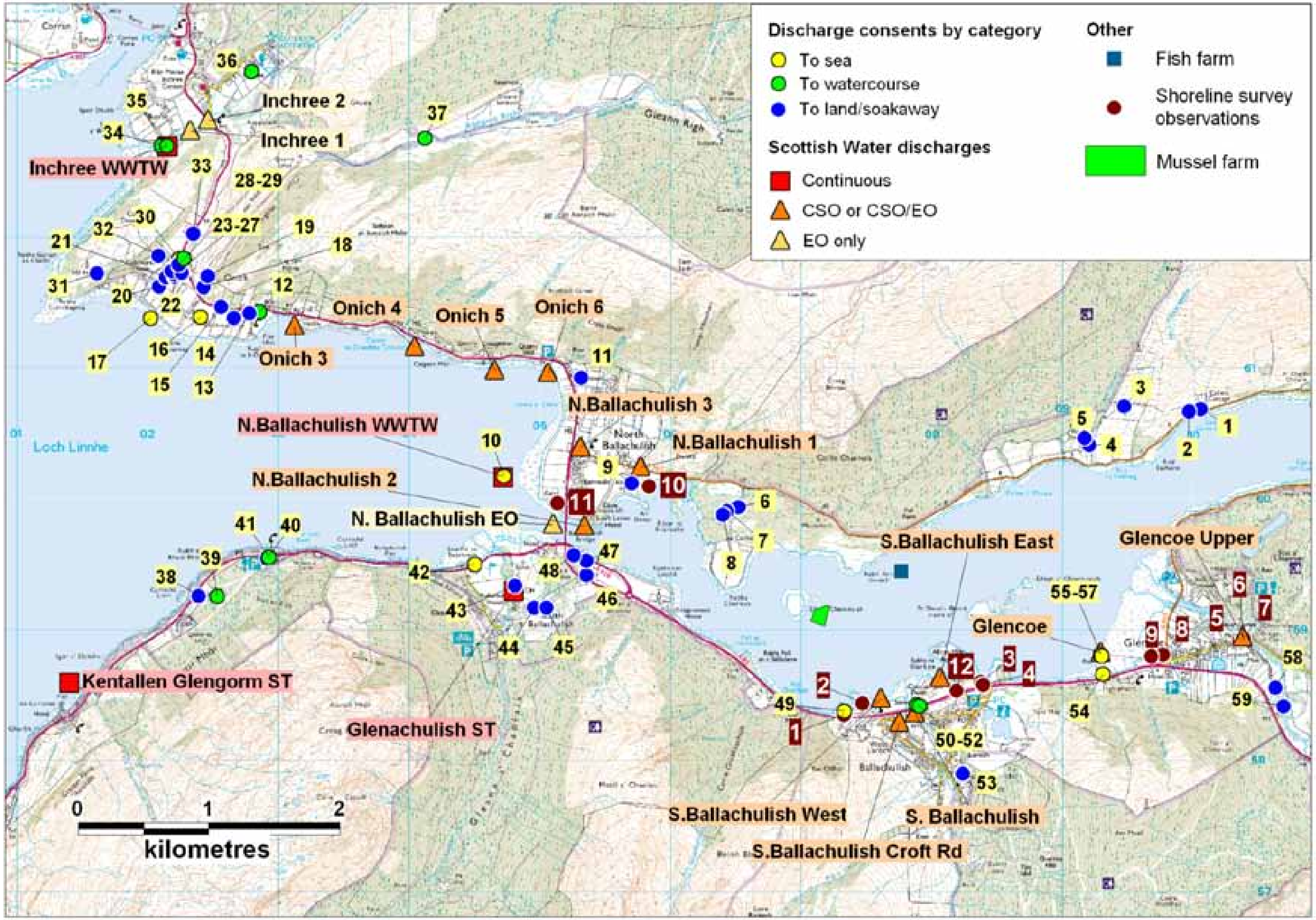


Figure 4.1 Map of discharges for Loch Leven: Lower

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 indicate poorly draining soils while areas shaded blue indicate more freely draining soils. Solid grey areas indicate predominantly impermeable surfaces on built-up areas.

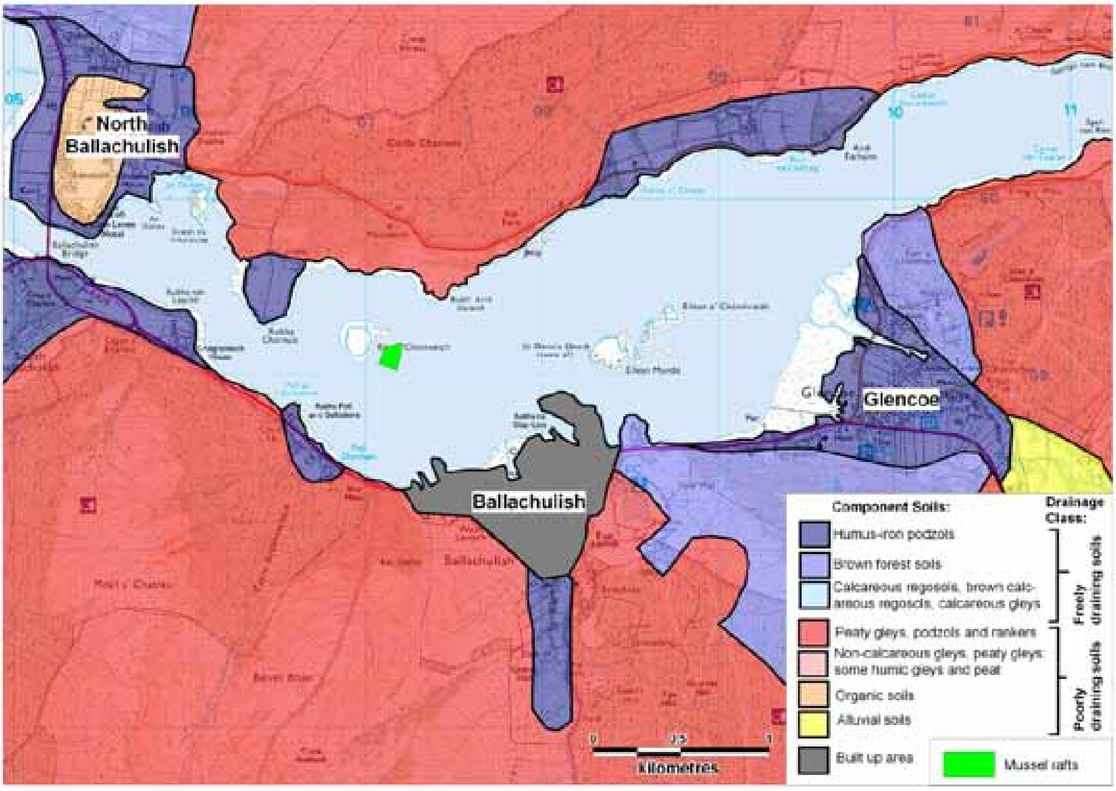


Figure 5.1 Component soils and drainage classes for Loch Leven Lower

There are six main types of component soils found in this area. The predominant soil type is composed of poorly draining peaty gleys, podzols and rankers. This soil type is present on both sides of the loch and is dominant inland east of Glencoe and west of North Ballachulish. Other soil types with poor drainage characteristics, organic soils and alluvial soils, are found in North Ballachulish and stretching southeast from Glencoe.

More freely draining soils composed of brown forest soils and humus iron podzols are found around Glencoe and North Ballachulish, but also in isolated pockets found around the shoreline and south of Ballachulish.

Only Ballachulish was identified as a built up area, however Glencoe and North Ballachulish would also be considered under the same terrain type and are all likely to have a large proportion of impervious covering.

The potential for runoff contaminated with *E. coli* from human and/or animal waste attributable to soil characteristics is highest to the south of the mussel farm, around Ballachulish and along the shore north of the farm.

6. Land Cover

Land Cover Map 2000 data was obtained and thematically mapped for the area around lower Loch Leven. This is shown in Figure 4.1.

The land cover surrounding Loch Leven Lower is varied. Large areas of broadleaf and coniferous woodland are found on both sides of the loch. Small areas of improved grassland are found on both the north and south shores of the loch, though those along the north shore lie nearest to the fishery. Developed areas are shown around the settlements of Ballachulish, North Ballachulish and Glencoe. This is likely to be a more accurate representation of hardened landcover associated with settlement than that provided by the soil profile map data presented in Section 5.

Studies undertaken by Kay et al (2008) found that faecal indicator organism export coefficients for faecal coliform bacteria were highest for urban catchment areas (approx 1.2 – $2.8x10^9$ cfu km^{-2} hr^{-1}) and lower for areas of improved grassland (approximately $8.3x10^8$ cfu km^{-2} hr^{-1}) and rough grazing (approximately $2.5x10^8$ cfu km^{-2} hr^{-1}) areas. Lowest contributions would be expected from areas of woodland (approximately $2.0x10^7$ cfu km^{-2} hr^{-1}). The contributions from all land cover types would be expected to increase significantly after rainfall events, however this effect would be particularly marked from improved grassland areas (roughly 1000-fold) (Kay *et al*. 2008).

The developed areas at Ballachulish are likely to contribute the greatest loads of faecal indicator organisms to the fishery. The areas of improved grassland to the northeast and northwest of the mussel farm will contribute lesser amounts of faecal bacteria, however the contribution from these areas will increase the most after heavy rainfall. The majority of land surrounding Loch Leven falls into the category which is expected to give the lowest contribution. Contamination from forest areas may increase immediately after logging operations.

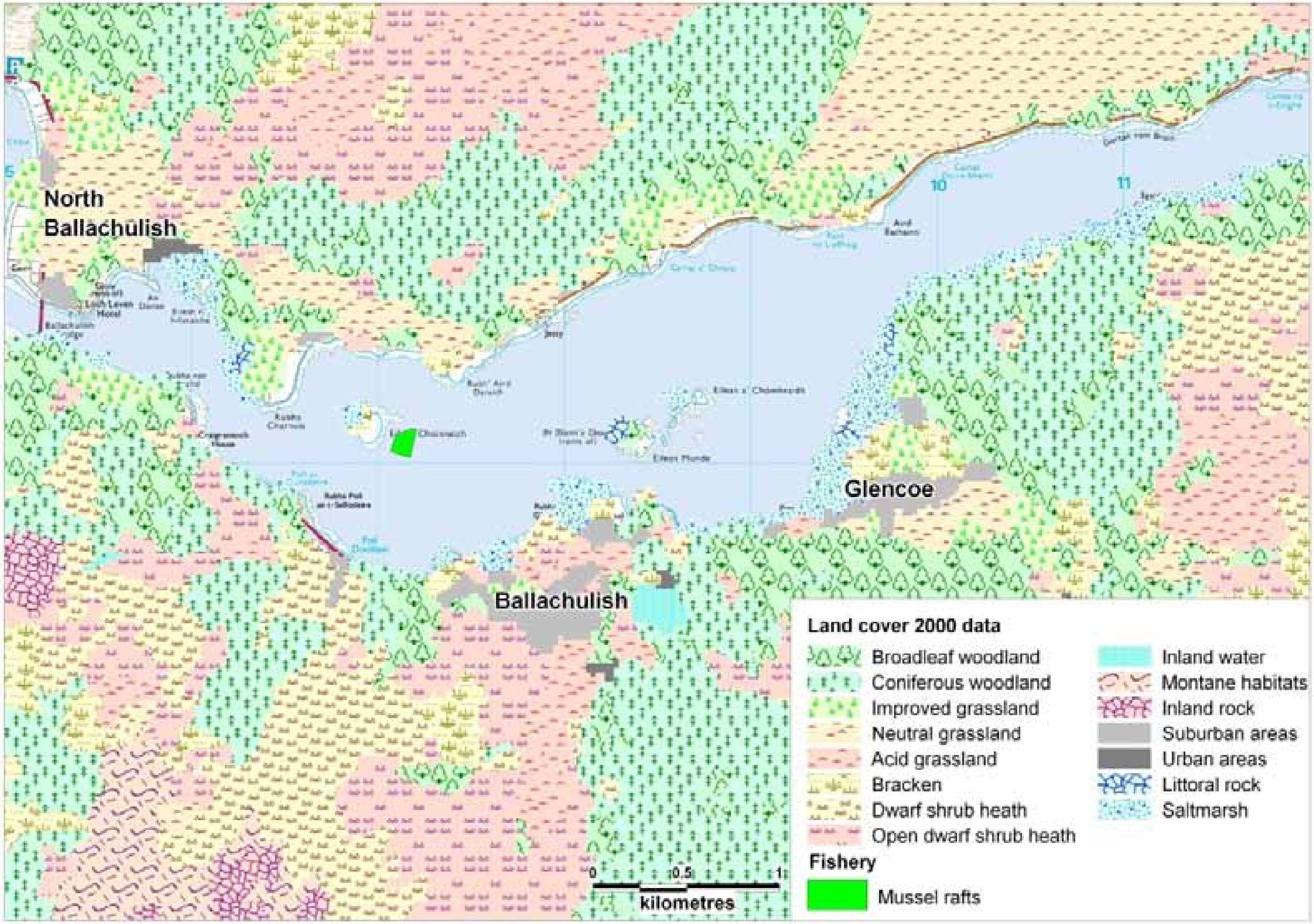


Figure 6.1 LCM2000 class land cover data for Loch Leven Lower

7. Farm Animals

Information on the spatial distribution of animals on land adjacent to or near the fishery can provide an indication of the potential amount of organic pollution from livestock entering the shellfish production area. Agricultural census data to parish level was requested from the Scottish Government Rural Environment, Research and Analysis Directorate (RERAD) for the Kilmallie and Lismore and Appin parishes. Reported livestock populations for the parish in 2009 and 2010 are listed in Table 7.1. RERAD withheld data for reasons of confidentiality where the small number of holdings reporting would have made it possible to discern individual farm data. Any entries which relate to less than five holdings, or where two or fewer holdings account for 85% or more of the information, are replaced with an asterisk.

Table 7.1 Livestock in Kilmallie, Lismore, and Appin parishes 2009-2010

	Kilmallie (870 km^2)				**Lismore and Appin** (378 km^2)			
	2009		2010		2009		2010	
	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers	Holdings	Numbers
Pigs	*	*	0	0	*	*	*	*
Poultry	21	262	25	323	24	225	27	235
Cattle	31	611	32	631	40	1030	43	1099
Sheep	25	11230	25	10902	53	17285	53	17512
Horses used in Agriculture	0	0	0	0	*	*	*	*
Horses and ponies	10	22	10	22	12	73	13	70

Both agricultural parishes are very large, extending well inland. Table 7.1 indicates that there were fewer than five holdings of pigs in the Lismore and Appin parish and no pigs in the Kilmallie agricultural parish in 2010. Both parishes have a large number of both sheep and cattle. Although large numbers of livestock are reported, it is the number of animals kept within the catchment and near shore of the fishery that will be most likely to affect water quality there; such spatial information cannot be obtained from the census data.

The only significant source of spatially relevant information was the shoreline survey (see Appendix 6), which only relates to the time of the site visit during the 7th September 2011. The only evidence of livestock that was seen during the survey was a moderate amount of sheep droppings on grazing land on the north west shoreline of the loch. Much of the land adjacent to the fishery is used for forestry.

The spatial distribution of the shoreline observation and the agricultural parish boundaries are illustrated in Figure 7.1.

The catchment for the area extends on both sides of the loch along a number of large burns, and these areas away from the immediate shoreline were not viewed.

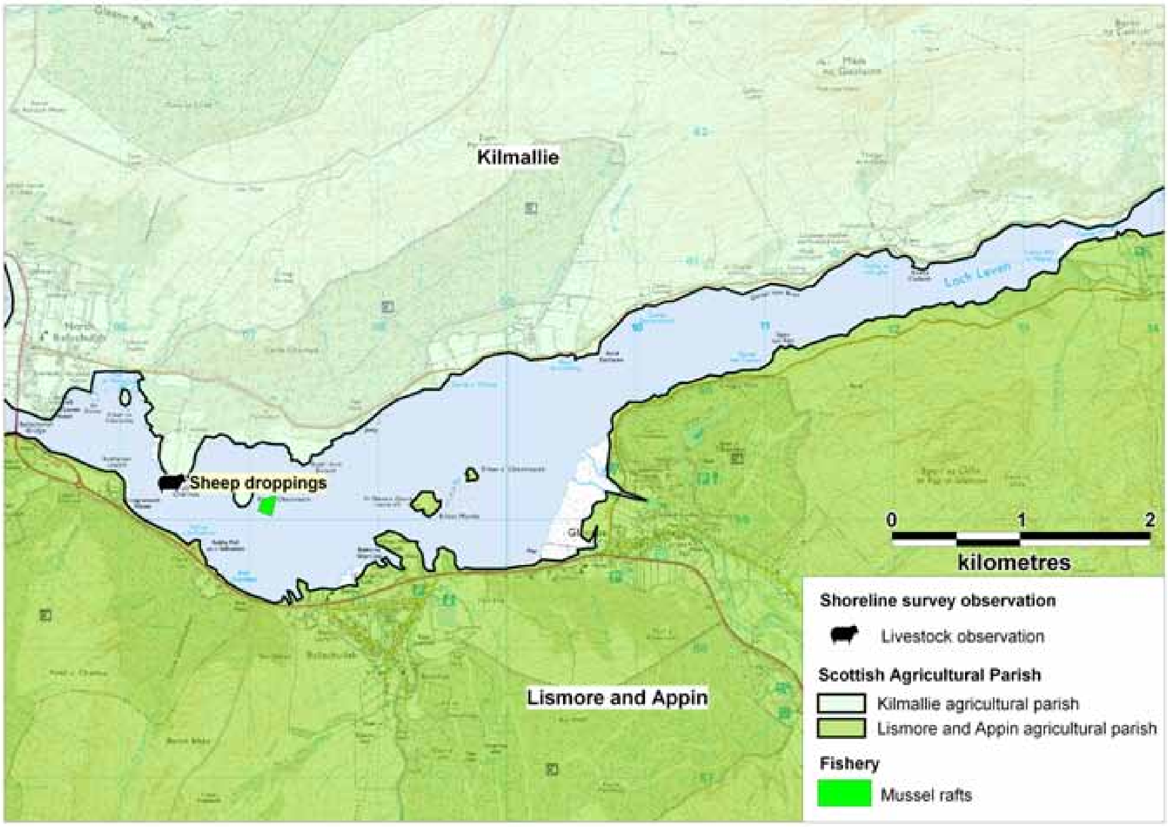


Figure 7.1 Livestock observations at Loch Leven: Lower

8. Wildlife

Wildlife may also contribute to faecal contamination observed at fisheries. General information on the impacts of wildlife species can be found in Appendix 2. Wildlife species most likely to contribute to faecal contamination of the waters of Loch Leven: Lower include seabirds, seals, deer and otters.

There are various designations in the Loch Leven Lower vicinity. Parts of the inland areas south of Ballachulish fall within the Glen Etive and Glen Fyne Special Protected Area (SPA), designated for 28/10/10 for internationally important aggregations of breeding birds – Golden eagle (*Aquila chrysaetos*). An area inland situated between Ballachulish and Glencoe is covered by the Carnach Wood Site of Special Scientific Interest (SSSI) designated for species (flies) and wet woodland. Located inland northwest of North Ballachulish is the Onich to North Ballachulish Woods Special Area of Conservation (SAC) was designated for internationally important habitat. An area inland east of Glen Coe is also an SAC called Glen Coe and was designated for its internationally important habitat.

Birds

Seabird 2000 census data (Mitchell *et al*. 2004) was queried for the area within a 5 km radius of the Loch Leven: Lower production area and is summarised in Table 8.1 below. This census, undertaken between 1998 and 2002, covered the 25 species of seabird that breed regularly in Britain and Ireland.

Table 8.1 Seabird counts within 5km of Loch Leven: Lower

Common name	Species	Count*	Method
Common Tern	*Sterna hirundo*	54	Occupied nests
Herring Gull	*Larus argentatus*	4	Occupied nests
Common Gull	*Larus canus*	206	Occupied territory or nests
Black-headed Gull	*Larus ridibundus*	4	Occupied nests

* Counts for occupied nests were doubled to reflect the number of individuals

Loch Leven Lower is adjacent to the Glen Etive and Glen Fyne Special Protected Area (SPA), which had 19 breeding pairs of Golden eagle (*Aquila chrysaetos*), representing approximately 4.2% of the GB population in 2003 (http://www.snh.org.uk/pdfs/strategy/GEConsult/5.5A-GLENETIVEGLENFYNECASE-B437685.pdf).

During the shoreline survey wild Canadia geese (*Branta canadensis*) were observed on the promontory behind Rubha Charnuis. A small number of ducks and gulls were also seen at the mouth of the Laroch River. The harvesters reported that eider ducks occurred frequently on Eilean Choinneich and feed from the mussel lines.

Birds nesting nearest the fishery are most likely to contribute diffuse faecal contamination to the area, particularly after rainfall. Birds flying over or feeding in waters at the mussel farm may directly deposit droppings near the mussel lines and so would have a greater impact on water quality when this occurs. Some species, such as gulls, are likely to be present year round and may rest on mussel floats. However, the majority of seabirds will only be present near shore during the summer nesting season, which is roughly from May to August and varies by species, with some arriving earlier and others staying later. Guano deposited around nest areas, however, is likely to wash off with rainfall over a longer period of time.

Seals

Both grey seals (*Halichoerus grypus*) and common or harbour seals (*Phoca vitulina vitulina*) are found along the west coast of Scotland, however recent surveys have recorded only harbour seals in Loch Linnhe (Special Committee on Seals, 2009). No seals were observed during the shoreline survey. These animals are likely to be present in and around the fishery from time to time and could potentially leave faeces behind, though any effect would be expected to be minor in comparison with other sources.

Deer

Deer are present throughout much of Scotland in significant numbers and Highland Lochaber has large deer populations. The grower reports that deer occur on hills around the loch, particularly on the southern side and roe deer are managed at Glencoe on behalf of the National Trust for Scotland (http://www.glencoe-nts.org.uk/Dear-Management-g.asp). No specific information on deer numbers was found for lower Loch Leven. Faecal indicator bacteria arising from deer droppings are likely to be carried via rainfall runoff to rivers and streams. No deer or evidence of deer was directly observed during the shoreline survey.

Otters

Otters have been recorded in the area in the past, however no recent records of otter numbers were found. No otters were seen during the shoreline survey. Otters typically defecate in established latrines adjacent to freshwater courses. Loch Leven has a large number of rivers and burns that may host otters, and any faecal contamination from these animals is likely to be carried in the streams. However, typical population densities of coastal otters are low and therefore any impact is expected to be minor.

Conclusions

The wildlife species most likely to contribute faecal pollution to the waters at the fishery include seabirds, particularly those nesting on the nearby island or resting on the rafts, eider ducks, geese and deer. Any impacts from geese or deer are most likely to be carried via freshwater runoff to the fishery. The main sources are likely to be to the west of the fishery.

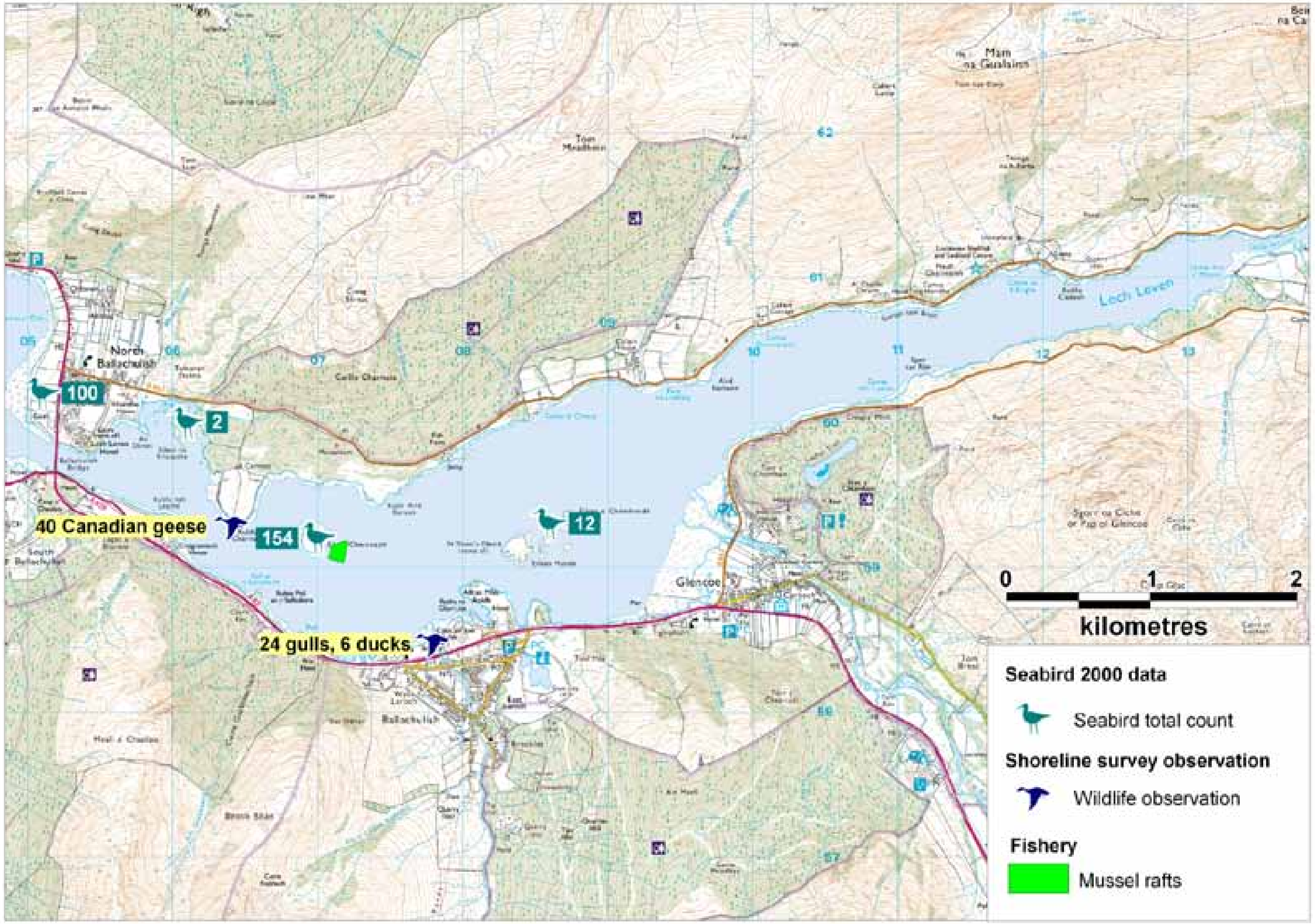


Figure 8.1 Map of seabird distributions at Loch Leven

9. Meteorological data

The nearest weather station is located at Ardgour: Clovullin, approximately 9.4 km to the north west of the production area. Rainfall data was available for 2003 - 2010, however data was missing for September to December 2006 and for April 2007.

Wind data was available for Glasgow Bishopton, which is 95 km south of the fishery. Conditions may differ between this station and the fisheries due to the large distances between them. However, this data is still shown as it can be useful in identifying seasonal variation in wind patterns.

Data from the station was purchased from the Meteorological Office. Unless otherwise identified, the content of this section (e.g. graphs) is based on further analysis of this data undertaken by Cefas. This section aims to describe the local rain and wind patterns in the context of the bacterial quality of shellfish at Loch Leven Lower.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water run-off from land where livestock or other animals are present, and through sewer and waste water treatment plant overflows (e.g. Mallin et al, 2001; Lee & Morgan, 2003). The box and whisker plots in Figures 9.1 and 9.2, present a summary of the distribution of individual daily rainfall values by year and by month. The grey box represents the middle 50% of the observations, with the median at the midline. The whiskers extend to the largest or smallest observations up to 1.5 times the box height above or below the box. Individual observations falling outside the box and whiskers are represented by the symbol *.

Rainfall varied from year to year over the period examined, with 2010 in particularly drier than the other years. Rainfall events greater than 40 mm per day were recorded in all years. For the period considered here, 42% of days had less than 1mm of rainfall and 23% of days had more than 10mm of rainfall.

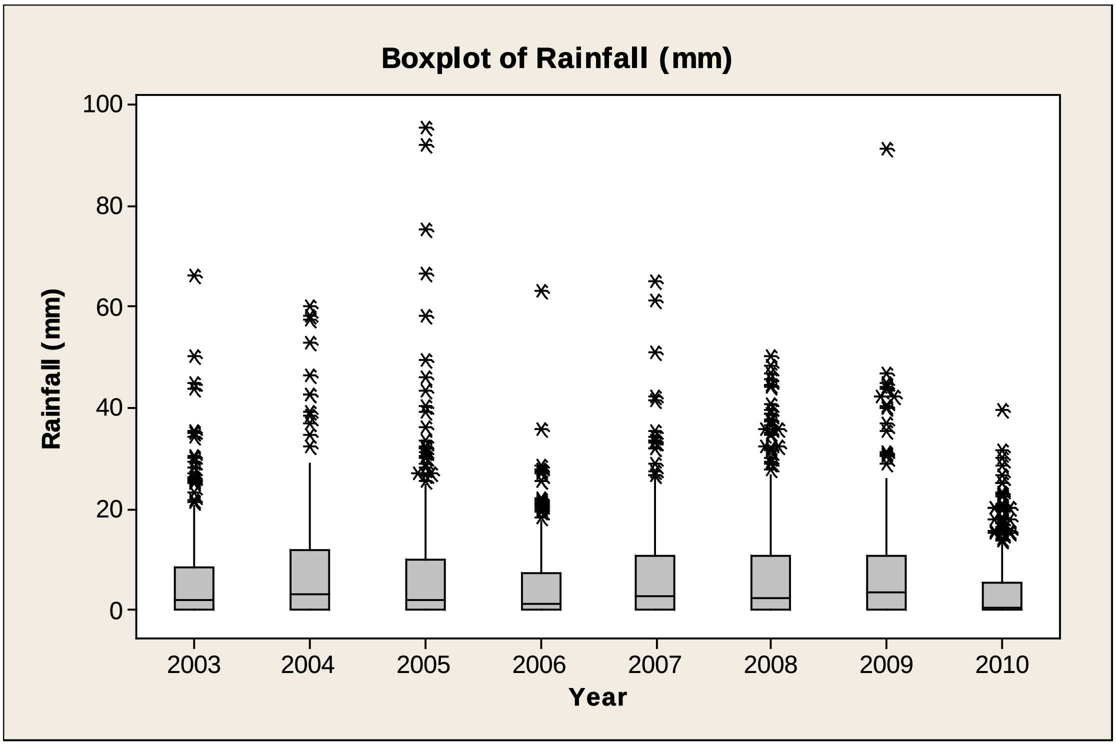


Figure 9.1 Boxplot of daily rainfall values by year at Ardgour: Clovullin (2003 – 2010)

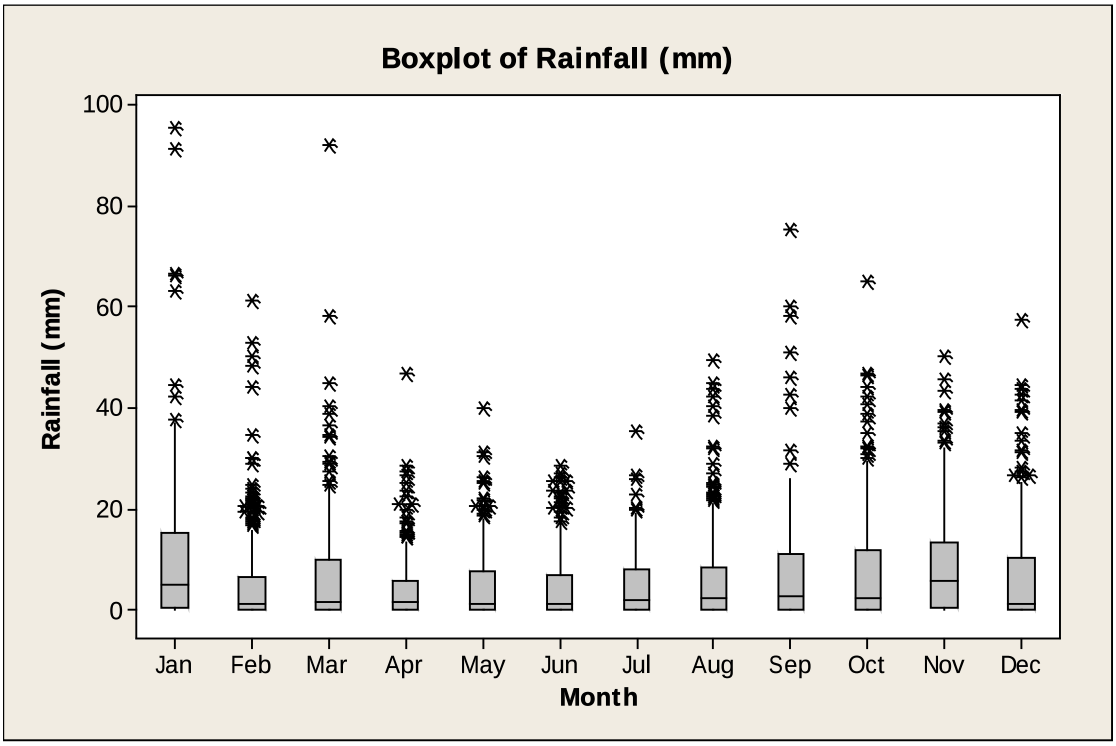


Figure 9.2 Boxplot of daily rainfall values by month at Ardgour: Clovullin (2003 – 2010)

September to January were the wettest months whereas April was the driest, with the remaining months showing similar levels of rainfall. Extreme rainfall events (>20mm) occurred throughout the year, with more extreme events occurring in January.

It can therefore be expected that levels of rainfall dependent faecal contamination entering the production area from these sources will be higher during the autumn and winter months. It is possible that there is a build-up of faecal matter on pastures during the drier summer months when stock levels are at their highest which results in a ‘first flush’ of contaminated runoff following summer storms, or in the autumn at the onset of the wetter months although this could happen at any time of the year.

9.2 Wind

Wind data from Glasgow Bishopton is summarised by seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

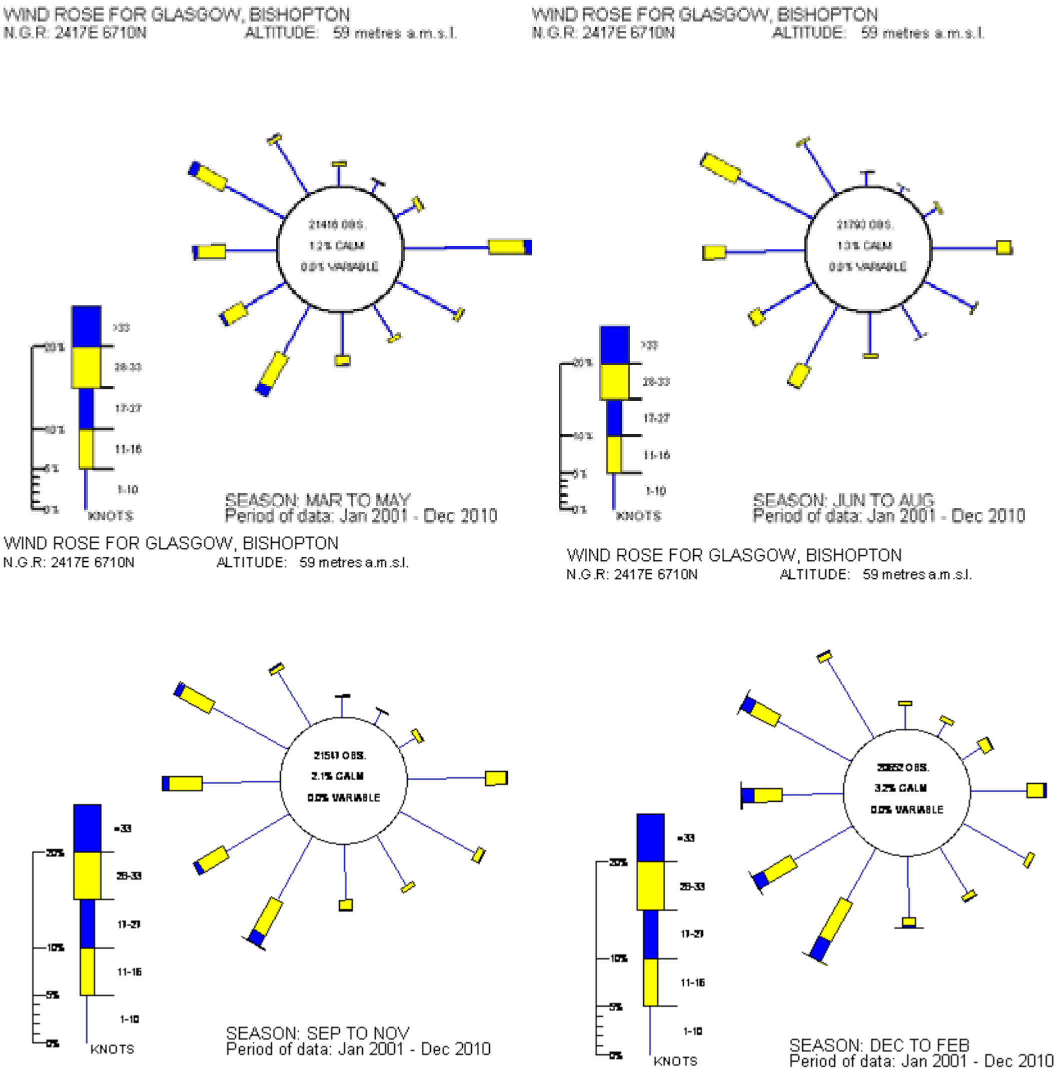


Figure 9.3 Seasonal Wind roses for Glasgow

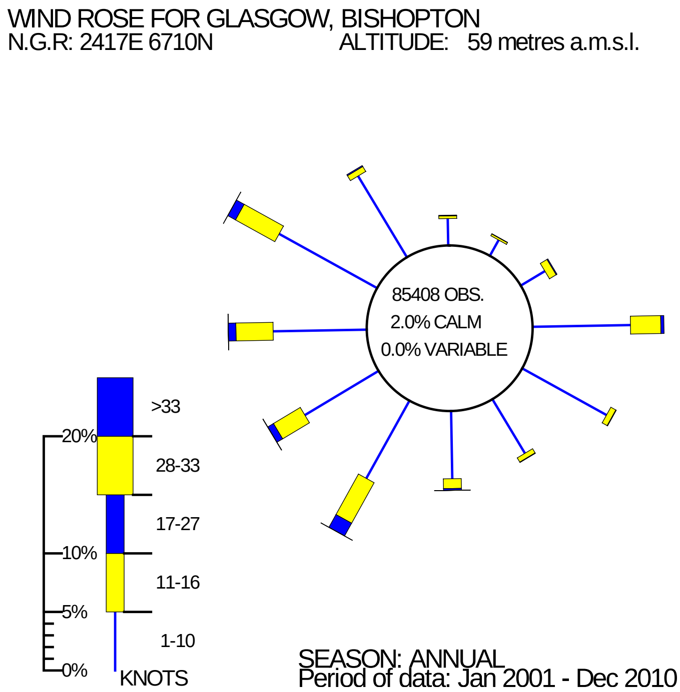


Figure 9.4 Annual wind rose for Glasgow

Overall the prevailing wind is predominantly from the south west. In general winds are stronger in the winter and lighter in the summer; however there is a higher occurrence of easterly winds also in the spring at the Glasgow weather station. It should be noted there may be a difference in conditions at the site compared to the weather station due to the distance and topography of the land between them.

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

10. Current and historical classification status

Loch Leven Lower was first given a classification for common mussels (*Mytilus edulis*) in 2004. The historical and current classifications for the area are shown below in Table 10.1

Table 10.1 Loch Leven Lower, common mussels

	Jan	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*July*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
2004	B	B	B	A	A	A	A	A	A	A	A	A
2005	B	B	B	B	B	B	B	B	B	B	B	B
2006	A	A	A	A	B	B	B	B	B	B	A	A
2007	A	A	A	A	A	B	B	B	B	B	B	A
2008	A	A	A	A	A	A	B	B	B	B	A	A
2009	B	B	B	A	A	A	B	B	B	B	A	A
2010	B	B	B	A	A	A	B	B	B	B	A	A
2011	A	A	A	A	A	A	A	B	B	B	B	B
2012	B	B	A									

Loch Leven Lower has a mixed classification for most years apart from 2005 where the site withheld a B classification year round. There is no real pattern of A or B occurrences but for the most part April, May and December throughout the years were fairly consistent in achieving A classification.

11. Historical *E. coli* data

11.1 Validation of historical data

The results for all samples assigned against Loch Leven: Lower from 1st January 2007 up to the 31st December 2011 were extracted from the FSAS database and validated according to the criteria described in the standard protocol for validation of historical *E. coli* data. The data was extracted from the database in March 2012. All *E. coli* results were reported as most probable number per 100 g of shellfish flesh and intravalvular fluid.

Two samples were recorded on the database as “Rejected” and were deleted. Eight of the remaining samples were received at the laboratory more than 24 hours after collection but none were received more than 48 hours after collection. The reported coolbox temperatures were all <8°C, except for one sample where the coolbox temperature was recorded as 10°C. The location given for one samples fell approximately 17 km outside the production area and approximately 21 km from the mussel farm. No obvious transposition errors could be identified and the record was deleted. Two samples had the result reported as <20, and were assigned a nominal value of 10 for statistical assessment and graphical presentation. No sample had a result reported as >18000.

11.2 Summary of microbiological results

Table 11.1 Summary of historical sampling and results

Sampling Summary	
Production area	Loch Leven: Lower
Site	Lower
Species	Common mussels
SIN	HL-170-222-08
Location	Various
Total no of samples	39
No. 2007	9
No. 2008	9
No. 2009	6
No. 2010	6
No. 2011	9
Results Summary	
Minimum	<20
Maximum	1700
Median	140
Geometric mean	156
90 percentile	1300
95 percentile	1700
No. exceeding 230/100g	12 (31%)
No. exceeding 1000/100g	3 (8%)
No. exceeding 4600/100g	0
No. exceeding 18000/100g	0

11.3 Overall geographical pattern of results

Prior to March 2009, all sampling locations were recorded on the database to 100 m accuracy. All but one of these was recorded against the nominal RMP location which does not lie on the present mussel farm. The location of two samples taken in 2011 were also recorded to 100 m accuracy and identified against that same nominal RMP. One sample taken in 2010 was apparently reported to 10 m accuracy but the location given was that of the nominal RMP. The locations of the other fifteen samples taken since March 2009 were reported to 10 m accuracy: apart from one sample, these all lay within a small area on the western side of the present mussel farm.

The reported sampling locations are plotted on the map shown in Figure 11.1 with the size of the symbols graduated by the *E. coli* result.

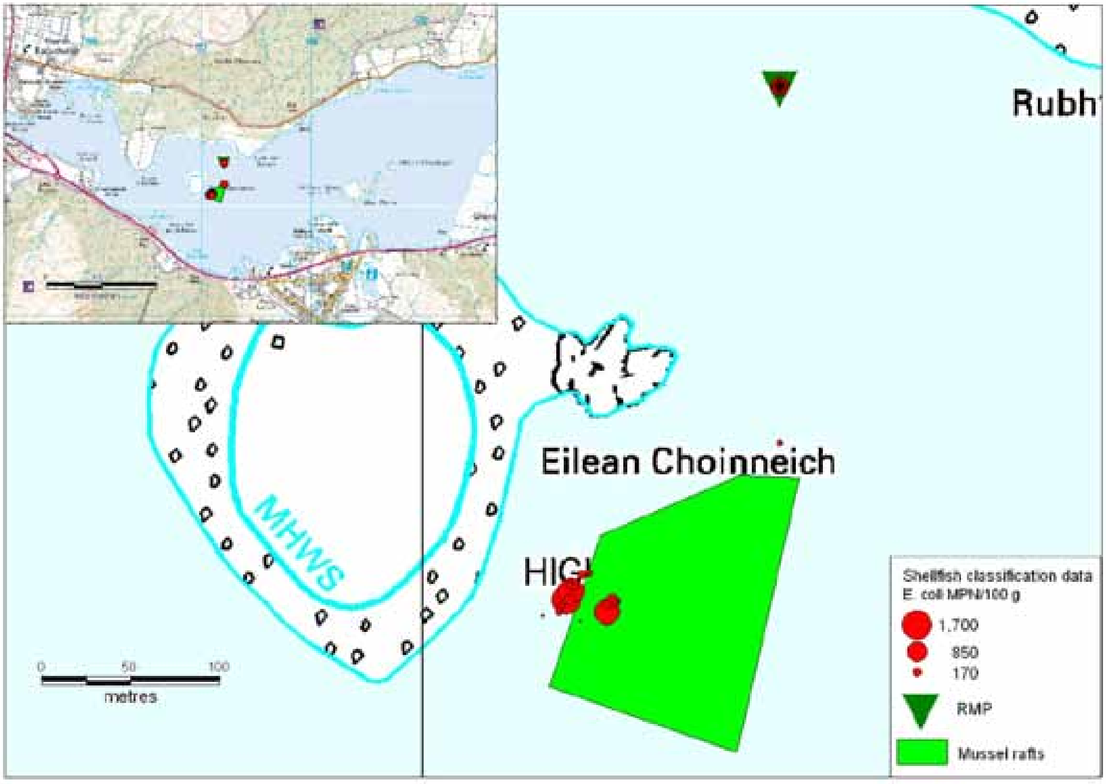


Figure 11.1 Map of reported sampling locations

Given that more than half of the samples were reported against the location of the nominal RMP, it is not possible to make any meaningful assessment of the historical *E. coli* results by location.

11.4 Overall temporal pattern of results

Figure 11.2 presents a scatter plot of individual mussel results against date, fitted with a loess trend line. Loess stands for 'locally weighted regression scatter plot smoothing'. At each point in the data set an estimated value is fit to a subset of the data, using weighted least squares. The approach gives more weight to points near to the x-value where the estimate is being made and less weight to points further away. In terms of the monitoring data, this means that any point on the loess line is influenced more by the data close to it (in time) and less by the data further away. The trend line helps to highlight any apparent underlying trends or cycles.

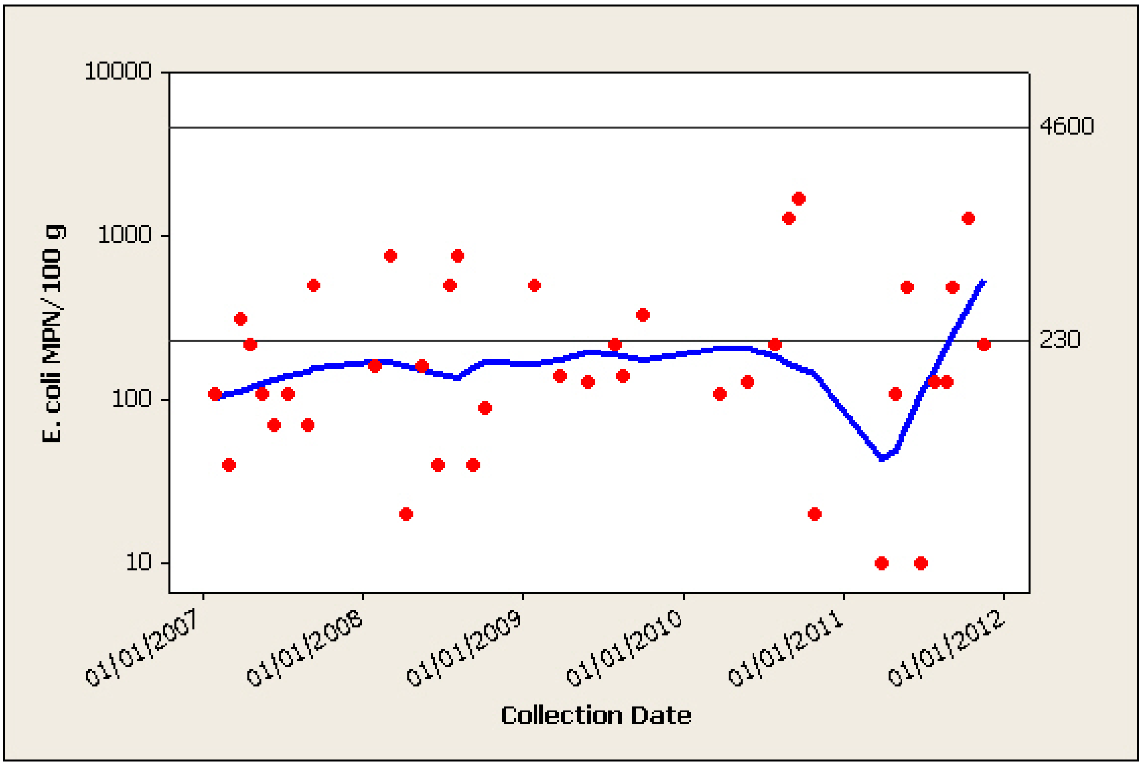


Figure 11.2 Scatterplot of *E. coli* results by date with loess line

The dip in the trend line in early 2011 was associated with the only two <20 *E. coli* MPN/100 g results seen at the site over the period under review. The subsequent sharp rise in the trend line may simply be due to the results returning to their usual level. However, over the period since January 2007, there does appear to have been a slight general increase in the microbiological contamination of the mussels at the site. During the review period, results greater than 1000 *E. coli* MPN/100 g have only been seen since August 2010. However, it should be noted that several results greater than 1000 *E. coli* MPN/100 g were seen in monitoring at this site prior to 2007 and the trend shown in Figure 11.2 should not be taken out of that context.

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. Figure 11.3 presents a scatterplot of *E. coli* result by month, overlaid with a loess line to highlight any trends. It should be noted that the points on the graph have been “jittered” (randomly moved a small distance in the X and Y directions) to allow otherwise superimposed points to be seen separately.

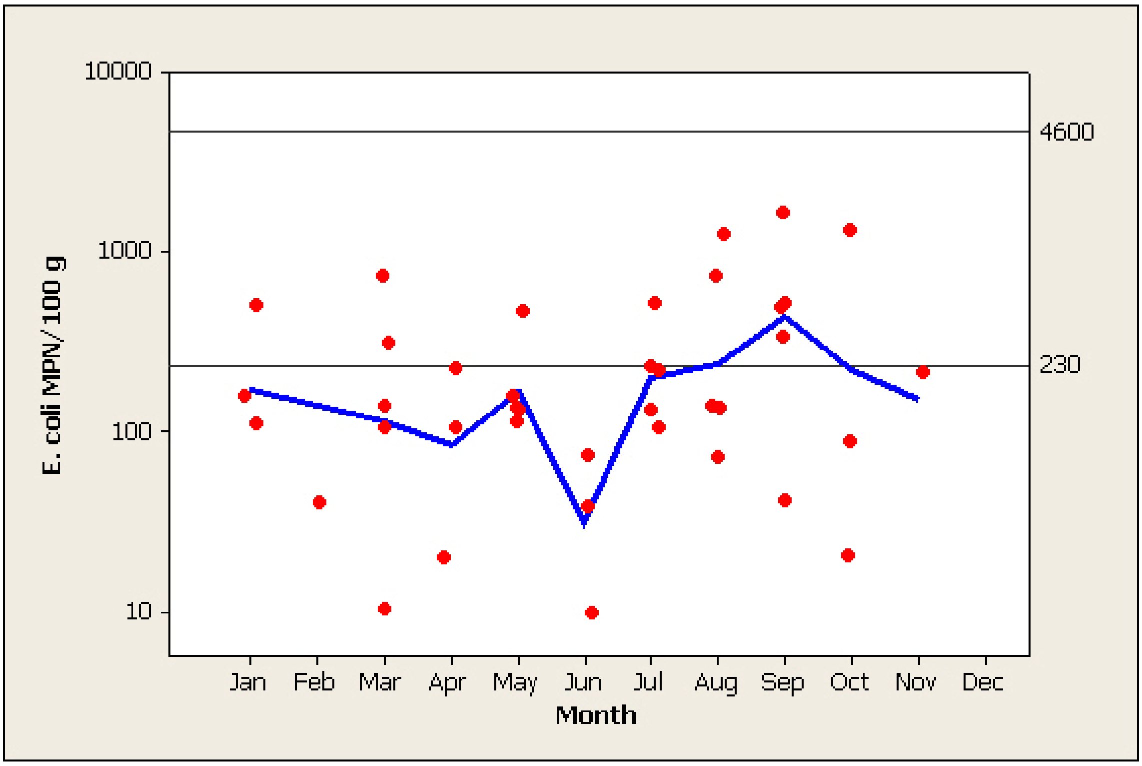


Figure 11.3 Scatterplot of results by month

The results tended to be lower in June and highest between August and October. Only one sample had been taken in February and November and none in December.

For statistical evaluation, seasons were split into spring (March - May), summer (June - August), autumn (September - November) and winter (December - February). Boxplots of results by season are shown in Figure 11.4.

No significant difference was found between results by season (One-way ANOVA, p=0.694, Appendix 4). However, care needs to be taken in placing too much emphasis in the outcome of this analysis due to the uneven distribution of sampling occasions by month.

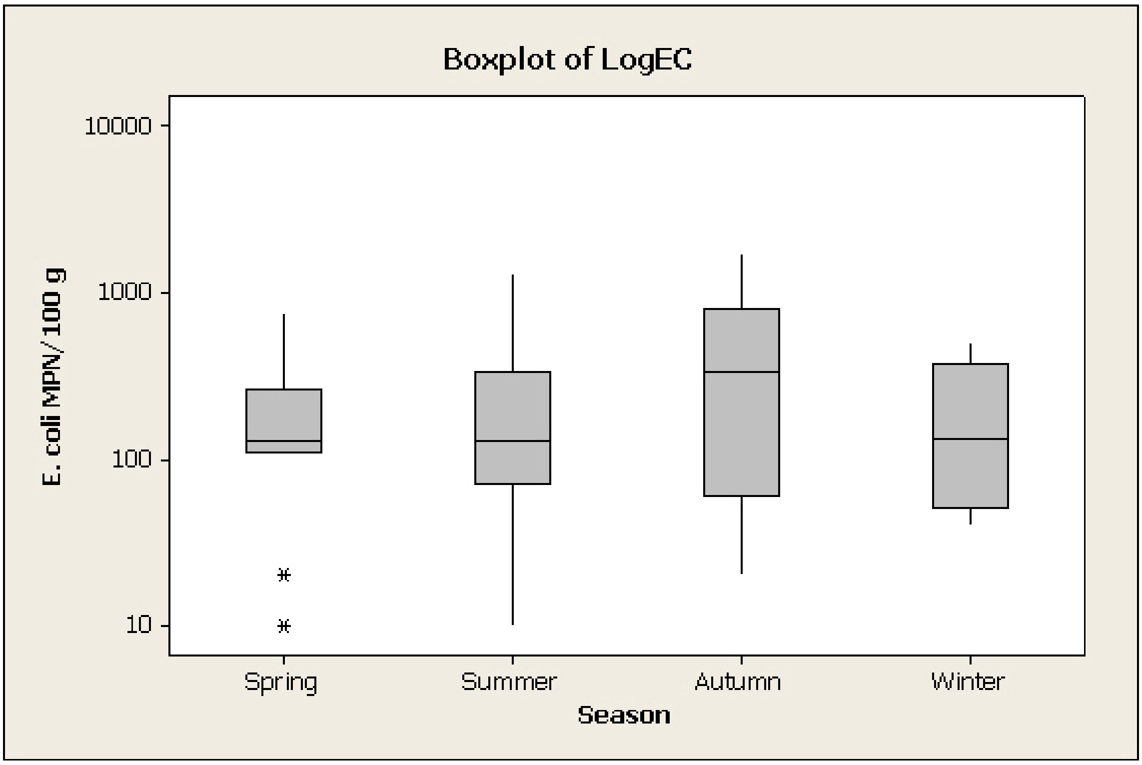


Figure 11.4 Boxplot of result by season

11.6 Analysis of results against environmental factors

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

11.6.1 Analysis of results by recent rainfall

The nearest weather station for which rainfall was available was at Ardgour: Clovullin, approximately 9.4 km to the north west of the production area. Rainfall data was purchased from the Meteorological Office for the period 1/1/2002 to 31/12/2010 (total daily rainfall in mm). Data was extracted from this for the period 1/1/2007 to 31/12/2010.

Two-day antecedent rainfall

Figure 11.5 presents a scatterplot of *E. coli* results against total rainfall recorded on the two days prior to sampling.

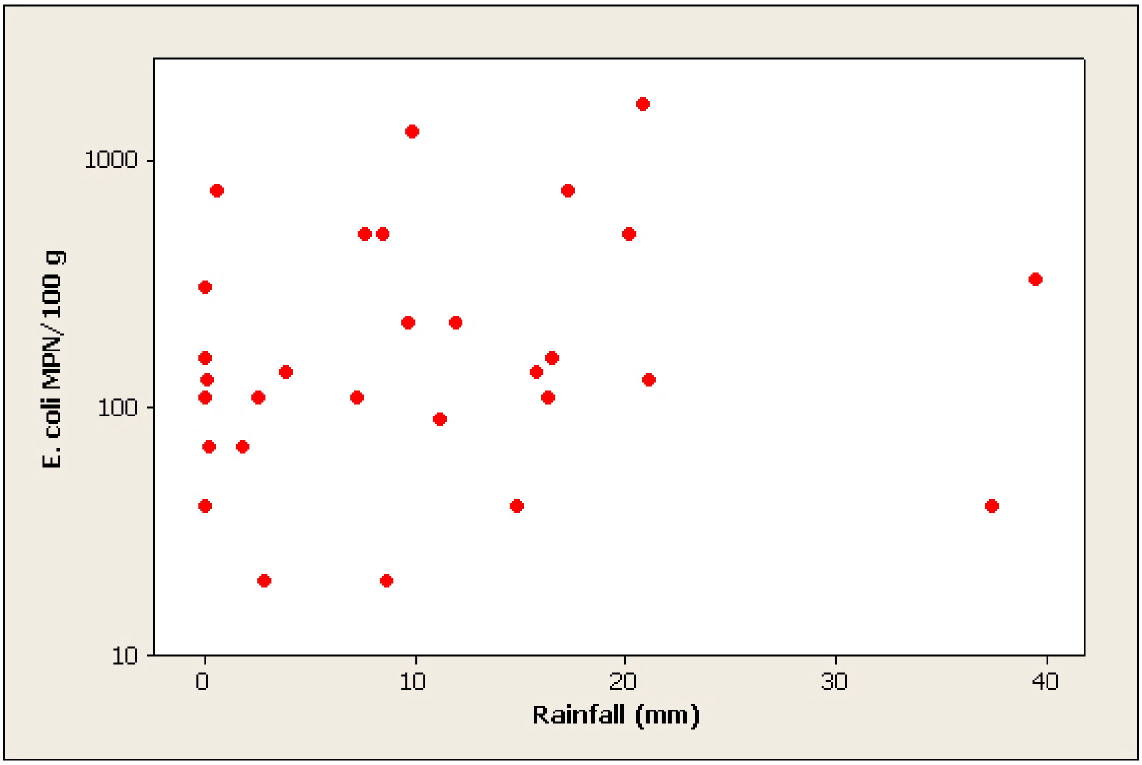


Figure 11.5 Scatterplot of result against rainfall in previous 2 days

A Spearman's Rank correlation was carried out between the results and the two day rainfall. No significant correlation was found between *E. coli* result and rainfall in the previous 2 days (Spearman's rank correlation=0.235, p=0.221).

Seven-day antecedent rainfall

As the effects of heavy rain may take differing amounts of time to be reflected in shellfish sample results in different systems, the relationship between rainfall in the previous 7 days and sample results was investigated in an identical manner to the above. Figure 11.6 presents a scatterplot of *E. coli* results against total rainfall recorded on the seven days prior to sampling.

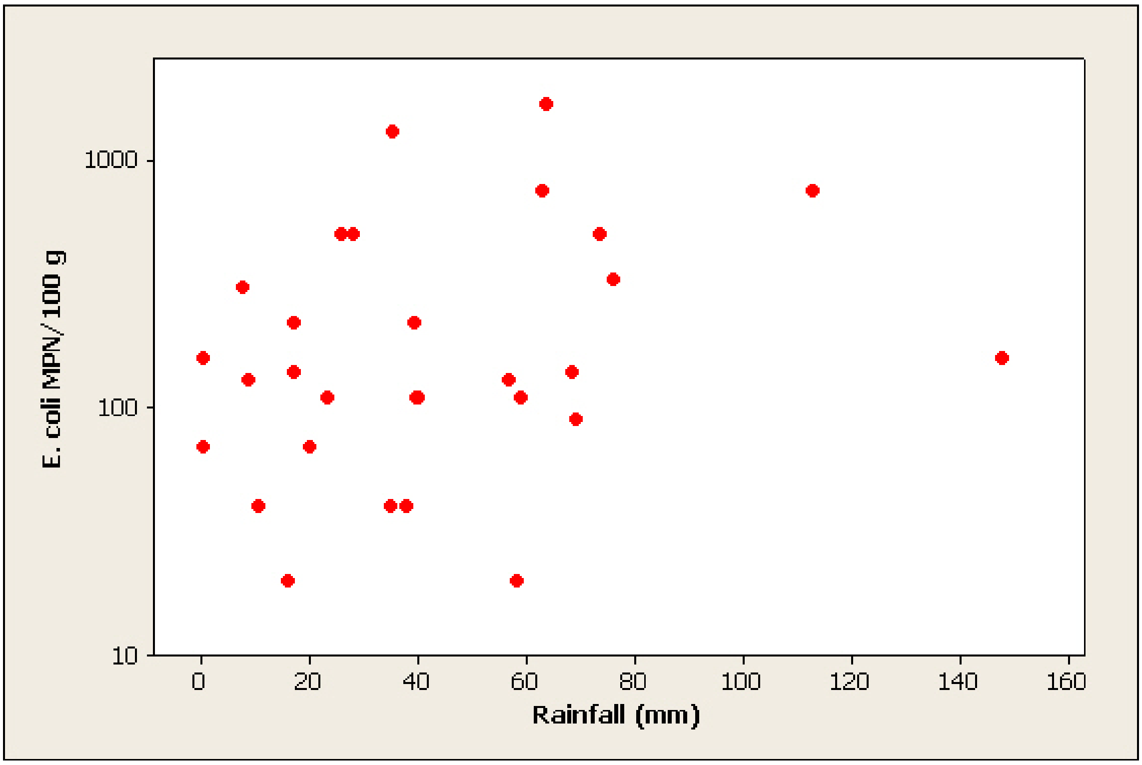


Figure 11.6 Scatterplot of result against rainfall in previous 7 days

No significant correlation was found between *E. coli* result and rainfall in the previous 7 days (Spearman's rank correlation= 0.303, p=0.110).

11.6.2 Analysis of results by tidal height 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 area. Figure 11.7 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar spring/neap tidal cycle. Full/new moons are located at 0º, and half moons at 180º. The largest (spring) tides occur about 2 days after the full/new moon, or at about 45º, then decrease to the smallest (neap tides) at about 225º, then increase back to spring tides. It should be noted that local meteorological conditions such as wind strength and direction can influence the height of tides and this is not taken into account.

No significant correlation was found between $\log_{10}$ *E. coli* results and the spring/neap cycle (circular-linear correlation, r=0.083, p=0.778).

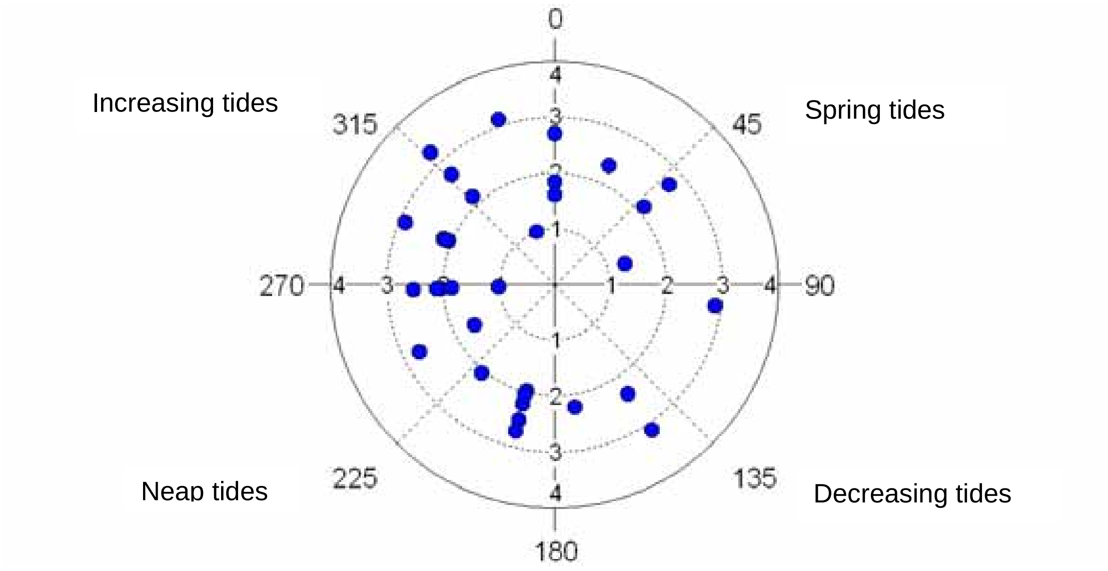


Figure 11.7 Polar plot of $\log_{10}$ *E. coli* results on the spring/neap tidal cycle

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. As *E. coli* levels in some shellfish species can respond within a few hours or less to changes in *E. coli* levels in water, tidal state at time of sampling (hours post high water) was compared with *E. coli* results. Figure 11.8 presents a polar plot of $\log_{10}$ *E. coli* results on the lunar high/low tidal cycle. High water is located at 0º, and low water at 180º.

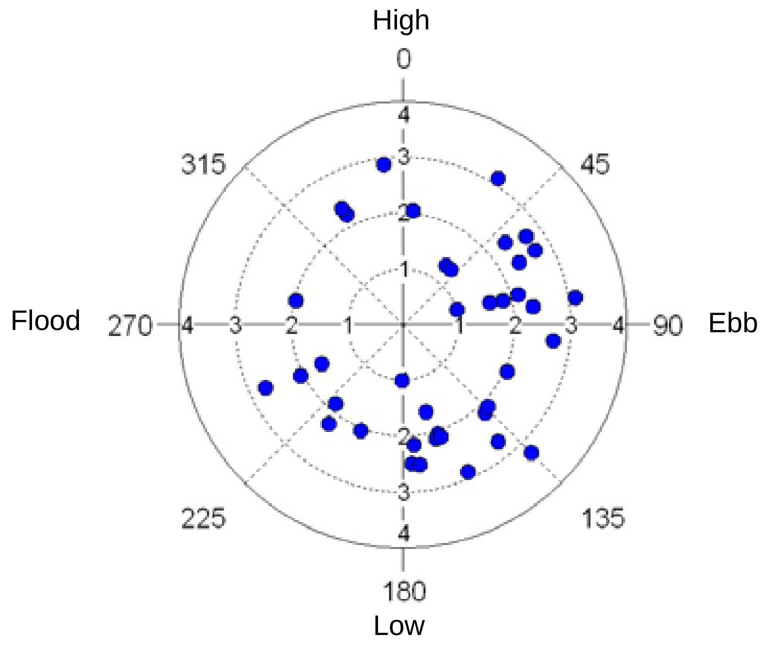


Figure 11.8 Polar plot of $\log_{10}$ *E. coli* results on the high/low tidal cycle

No significant correlation was found between *E. coli* results and the high/low tidal cycle (circular-linear correlation, r=0.11, p=0.648).

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. Water temperature was recorded against 26 of the sampling occasions. Figure 11.9 presents a scatterplot of *E. coli* results against water temperature recorded at the time of sampling.

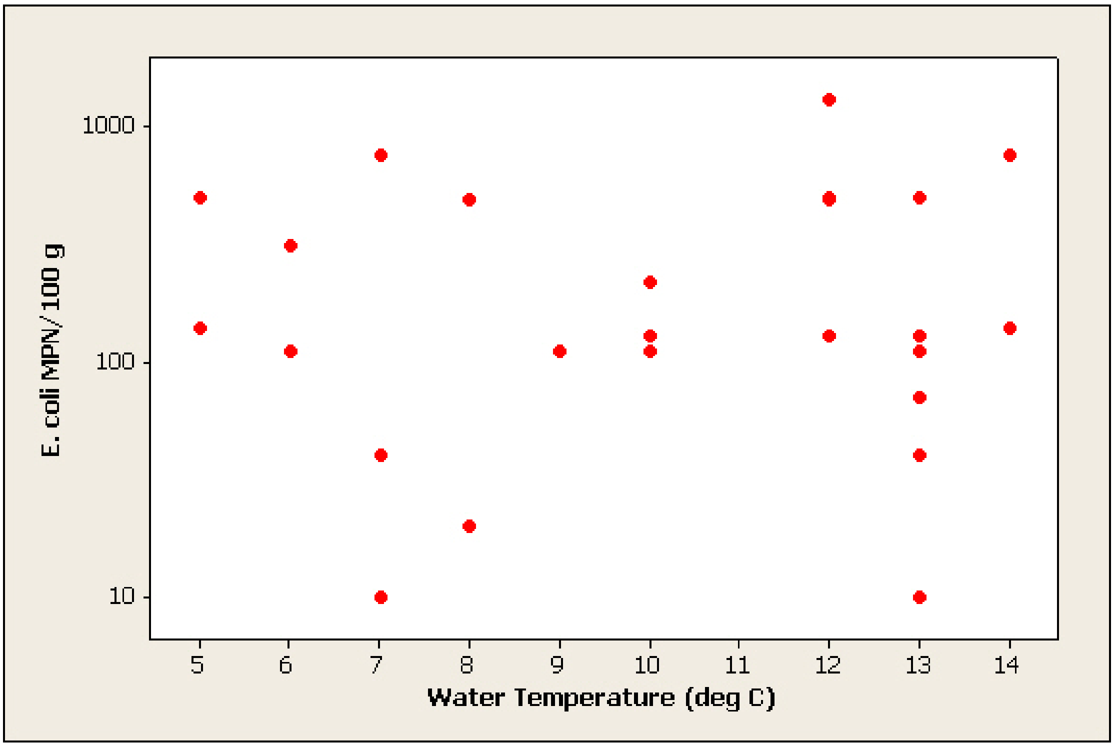


Figure 11.9 Scatterplot of *E. coli* results against water temperature

No significant correlation was found between *E. coli* result and water temperature (Spearman's rank correlation= 0.045, p=0.826).

11.6.4 Analysis of results by salinity

Salinity will give a direct measure of freshwater influence, and hence freshwater borne contamination, at the site. A scatterplot of *E. coli* results against salinity is shown in Figure 11.10.

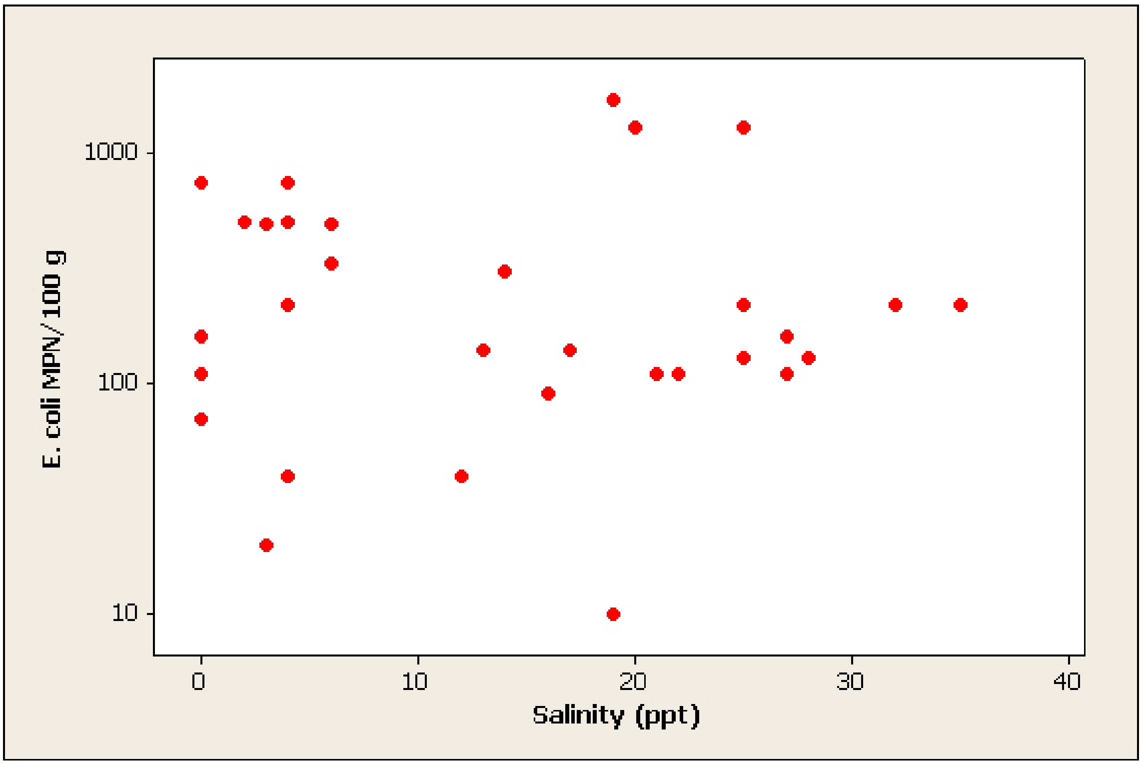


Figure 11.10 Scatterplot of *E. coli* results against salinity

Salinity was recorded for 32 of the mussel sampling occasions for the data analysed. A wide range of salinities was recorded, from 0 to 35 ppt. No significant correlation was found between *E. coli* result and salinity (Spearman's rank correlation = -0.033, p=0.857).

11.7 Evaluation of results over 1000 *E. coli* MPN/100 g

Table 11.2 Historic *E. coli* sampling results over 1000 *E. coli* MPN/100 g

Collection date	*E. coli* (MPN/ 100 g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (ºC)	Salinity (ppt)	Tidal state (high/low)	Tidal state (spring/neap)
30/08/2010	1300	NN 07080 59112	9.8	35.2	*	25	Ebb	Decreasing
21/09/2010	1700	NN 07067 59103	20.8	63.6	*	19	Ebb	Increasing
11/10/2011	1300	NN 07103 59109	*	*	12	20	Ebb	Increasing

*Data not available

The three samples had occurred from August 2010 on (although, as noted above, results >1000 *E. coli* MPN/100 g had been seen prior to 2007). The three samples had been taken between August and November. All three samples had been taken from locations on the western side of the mussel farm. The two samples for which rainfall data were available had been taken after moderate amounts of rainfall. However, the salinity results were in the middle of the range of values recorded at the site. Water temperature had only been recorded for one of the sampling occasions. Two of the three samples had been taken on an increasing tide, and one on a decreasing tide, with respect to the spring/neap cycle. All three samples had been taken on an ebb tide although they had been taken at differing times with respect to high water.

11.8 Summary and conclusions

Most sampling locations had been reported against the nominal RMP which does not lie on the present mussel farm. The three highest results were for samples recorded as having been taken from an area on the western side of the present farm.

More than 30% of samples taken during the review period yielded results greater than 230 *E. coli*/100 g but none had yielded results greater than 4600 *E. coli* MPN/100 g. Results greater than 1000 *E. coli*/100 g had only been seen since August 2010 in the present review period but such values had been seen prior to 2007. Sampling was uneven through the year but it has been identified that harvesting tends not to be undertaken during the winter months. No significant seasonal effect was found with respect to the *E. coli* results.

No significant correlation was found between either rainfall or salinity and the magnitude of the *E. coli* results. The samples that yielded results >1000 *E. coli* MPN/100 g had all been taken after moderate rainfall and at salinities that feel in the middle of the range recorded for the site.

No significant correlation was found between the *E. coli* results and either the spring/neap or high/low tidal cycle. However, the samples that had yielded the highest *E. coli* results were all taken on an ebb tide.

11.9 Sampling frequency

When a production area holds a non-seasonal classification and the geometric mean of the results falls within a certain range, the EURL Good Practice Guide (GPG) recommends that consideration be given to the sampling frequency being decreased from monthly to bimonthly. The recommendations are based on regular sampling having taken place and an initial three year data set of 24 results. As the area currently holds a seasonal classification an assessment was not undertaken.

12. Designated Shellfish Growing Waters Data

The production area at Loch Leven: Lower lies within the Loch Leven designated shellfish growing water. The area was designated under the European Community Shellfish Waters Directive (2006/113/EC) in 2002. SEPA is responsible for ensuring that monitoring is undertaken for a variety of parameters, including faecal coliforms in mussels. The growing water encompasses a larger area than that covered by this report.

Results of shellfish monitoring to 2004 were provided by SEPA and are presented in Table 12.1. The relative positions of the SGW boundaries, the Loch Leven: Lower production area, and both the shellfish hygiene and SGW monitoring points are shown in Figure 12.1.

Table 12.1 SEPA monitoring results for shore mussels – Loch Leven

Year	Quarter	Faecal coliform results (FC/100g)		
		NN 146 616	NN 054 598	NN 08648 60074
2002	Q1	-	-	-
	Q2	-	-	-
	Q3	-	-	-
	Q4	500	-	-
2003	Q1	1300	-	-
	Q2	-	-	-
	Q3	-	110	-
	Q4	-	<20	-
2004	Q1	-	70	-
	Q2	-	160	-
	Q3	-	110	-
	Q4	-	310	-
2005	Q1	-	-	90
	Q2	-	-	90
	Q3	-	-	500
	Q4	-	-	1300
2006	Q1	-	-	925
	Q2	-	-	1100
	Q3	-	-	-
	Q4	-	-	5400
2007	Q1	-	-	54000
	Q2	-	-	-
	Q3	-	-	-
	Q4	-	-	-

- No result reported or not sampled

Mussel samples were taken for faecal coliform analysis from three points within the growing water. The first point sampled corresponds to the RMP for the Loch Leven: Upper production area and was sampled on two occasions. The second sampling point is located in the Loch Leven: Lower production area and was sampled on 6 occasions during 2003 – 2004 with most results containing low levels of faecal coliforms. Sampling was relocated to the third point, at Camas a'Chnaip (1.7 km northeast of the mussel farm), in February 2005 due to a lack of mussels at the previous sampling location. Higher contamination levels were recorded at this location, with the most recent sample taken in 2007 containing extremely high concentrations of faecal coliforms.

Since 2007, SEPA have obtained shellfish classification monitoring results (*E. coli*) under an agreement with FSAS for the purposes of SGW monitoring. Those results have been used in the analysis in Section 11 of this report and so are not repeated here.

Although levels of faecal coliforms are usually correlated to levels of *E. coli* at a ratio of roughly 1:1, the ratio depends on a number of factors, such as environmental conditions and the source of contamination and so caution should be exercised in comparing the SGW results with results shown elsewhere in this report.

As shore mussels were sampled, and these are generally subject to higher levels of contamination than mussels grown in suspended culture away from the shoreline. However, the SGW results do suggest episodically extremely high levels of contamination along the north shoreline of the fishery. It should be noted that all of these samples were taken prior to the improvement scheme undertaken by Scottish Water and therefore may not be fully representative of contamination levels post-2010.

The relative positions of the SGW boundary, mussel farm and SGW monitoring points are shown in Figure 12.1.

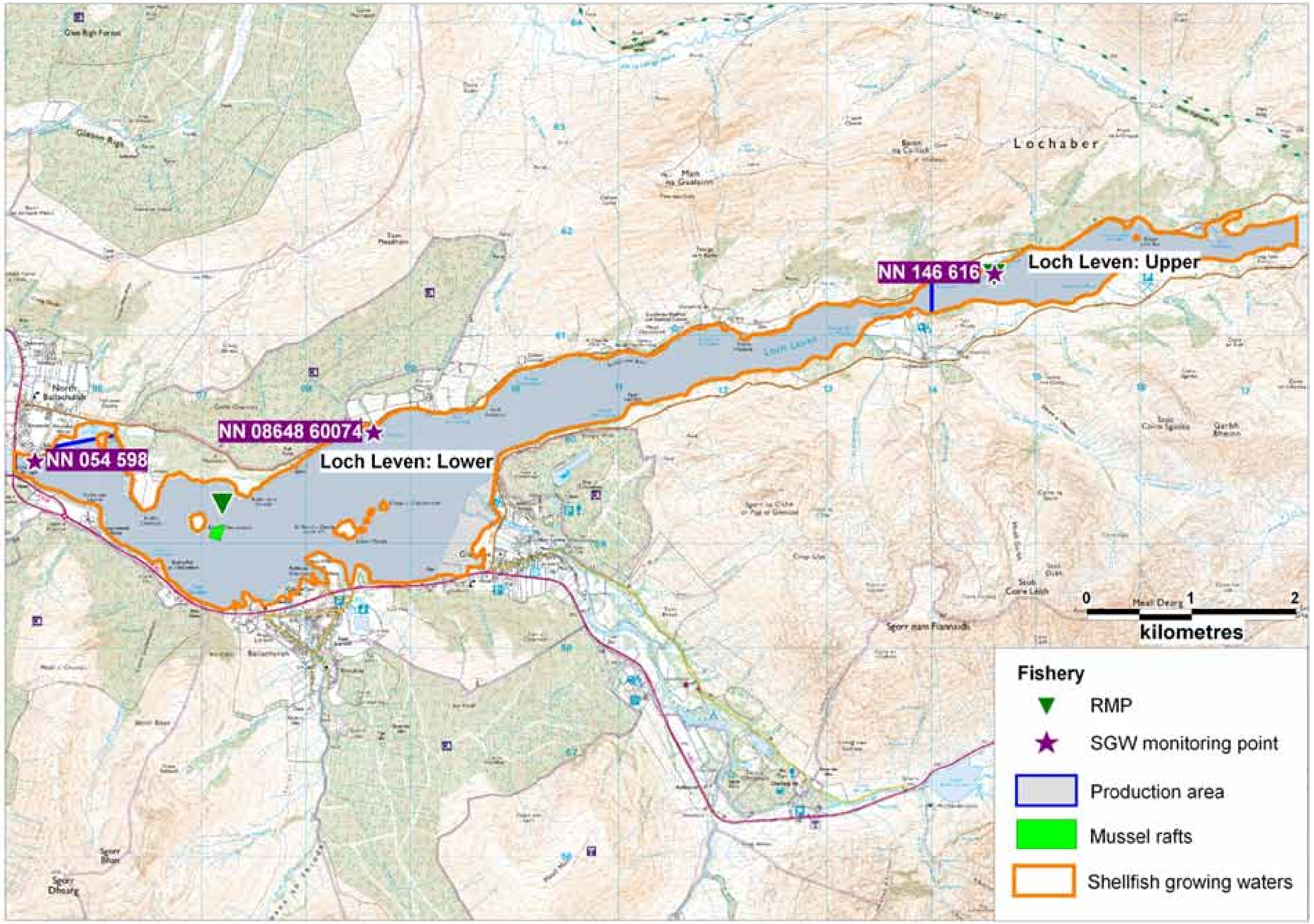


Figure 12.1 Loch Leven Shellfish Growing Water

13. River Flow

There are no public river gauging stations on rivers or burns on Loch Leven. During the Loch Leven Upper sanitary survey, no information could be obtained on flows through the hydro-electric plant at Kinlochleven. An estimated flow of 2,800,000 m^3 per day was used for the River Leven in the Upper Loch Leven sanitary survey report. This is a large flow and so the river may impact on the lower loch, in terms of freshwater influence if not in terms of faecal contamination.

The following rivers and streams were measured and sampled in the Lower Loch Leven area during the shoreline survey. These represent freshwater inputs directly entering the survey area. There was extremely heavy rain on the first day of the shoreline survey, intermittent heavy rain on the second day and showers on the third day.

Table 13.1 Watercourse loadings for Loch Leven Lower

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m/s)	Flow in m^3/day	*E. coli* (cfu/ 100 ml)	Loading (*E. coli* per day)
1	NN 07023 58400	Stream	1.4	0.08	0.014	135	<100	$<1.4 \times 10^8$
2	NN 07091 58379	Stream	0.45	0.05	0.436	848	100	8.5×10^8
3	NN 07145 58362	Stream	0.19	0.01	0.387	64	100	6.4×10^7
4	NN 07846 58395	River Coe	10.5	0.4	0.961	34700	1100	3.8×10^{12}
5	NN 10388 58935	River Laroch	11.3	0.7	1.362	931000	1000	9.3×10^{12}
6	NN 07770 59764	Allt an Daraich	3	0.04	1.234	12800	100	1.3×10^{10}
7	NN 07753 59675	Stream	1	0.07	0.056	339	16000	5.4×10^{10}
8	NN 07520 59508	Stream	0.4	0.03	0.2	207	100	2.1×10^8
9	NN 07332 59517	Stream	0.2	0.02	0.111	38	300	1.2×10^8
10	NN 07244 59590	Stream	Not measured or sampled					Not determined
11	NN 06964 59592	Stream	Not measured or sampled					Not determined
12	NN 06953 59585	Stream	Not measured or sampled					Not determined
13	NN 06331 59642	Stream	Sampled but not measured				<100	Not determined
14	NN 06269 59856	Stream	1.15	0.15	0.09	1340	<100	$<1.3 \times 10^9$
15	NN 06176 60087	Stream	1.1	0.4	0.655	24900	<100	$<2.5 \times 10^{10}$
16	NN 05792 60142	Allt an t-Seilich	3.9	0.25	0.612	51600	<100	$<5.2 \times 10^{10}$
17	NN 05910 59166	Allt na Leachd	0.75	0.09	0.798	4650	<100	$<4.7 \times 10^9$

Three streams were too small to measure or sample. One stream was too small to measure but was sampled as it ran from the direction of a house and could have contained septic tank effluent.

Figure 13.1 Map of watercourse loadings at Loch Leven Lower

The watercourses contributing the largest *E. coli* loadings to the area at the time of the shoreline survey were the Rivers Coe and Laroch, located on the southern shore at Glencoe and Ballachulish respectively. The other watercourses with moderate loadings at the time of the survey were two streams located in the vicinity of the fish farm on the northern shore to the east of the mussel farm. Streams on the northern and southern shores closer to the mussel farm contained relatively low loadings at the time of the survey despite the heavy rain that had fallen. Areas of land seepage were also noted on the shoreline during the survey. Loadings during dry weather would generally be expected to be one-tenth or less of those seen during wet weather.

The main potential sources of contamination at the mussel farm from a watercourse perspective are those on the southern and northern shores to the east of the farm although the others will contribute to background *E. coli* levels in the area, especially after heavy rainfall.

Contamination may also be carried down the loch from the River Leven (see Loch Leven Upper sanitary survey report). Although, given the distance from the head of the loch to the fishery, there is likely to be significant dilution, this source may contribute to background levels of contamination at Loch Leven: Lower.

14. Bathymetry and Hydrodynamics

The hydrographic chart for lower Loch Leven is shown in Figure 14.1.

Loch Leven as a whole is 13.5 km long, with an area at high water of 8.6 km^2 and has 5 sills (Edwards & Sharples, 1986). The approximate locations of the sills are marked on Figure 14.1 (the details of the sills given in the relevant table in the reference do not appear to match the sills marked on the accompanying diagram). The loch has an estimated flushing time of three days. The lower Loch Leven mussel farm is located in the second basin of the loch. The deepest part of that basin, marked at 65 m, lies to the north-north-east of the mussel farm. The farm lies towards the western side of the basin, and immediately to the east of Eilean Choinneich, in approximately 20 m depth of water. Depths to the north and west of the island are considerably less. The two sets of narrows, with associated sills, between this area and the mouth of the loch will constrict water flows and increase current speeds. The narrows used to be dredged to allow the passage of larger vessels but no record could be found of recent dredging.

The extent of drying areas varies around the loch, being greatest in the vicinity of the river mouths and also in some of the bays. There is a drying area around Eilean Choinneich. There are also some rocky islets immediately to the north of the mussel farm.

Upper Loch Leven is considerably influenced by the large input from the River Leven itself, and this results in a significant low salinity layer in the upper basin (see the Lower Loch Leven sanitary survey report). However, this is likely to receive at least some mixing as it moves across the sills between basins. It is likely that this freshwater influence will impact on the lower loch during the ebb tide. In addition, there are significant freshwater inputs to the lower loch, predominantly the Rivers Coe and Laroch and the Allt an t-Seilich.

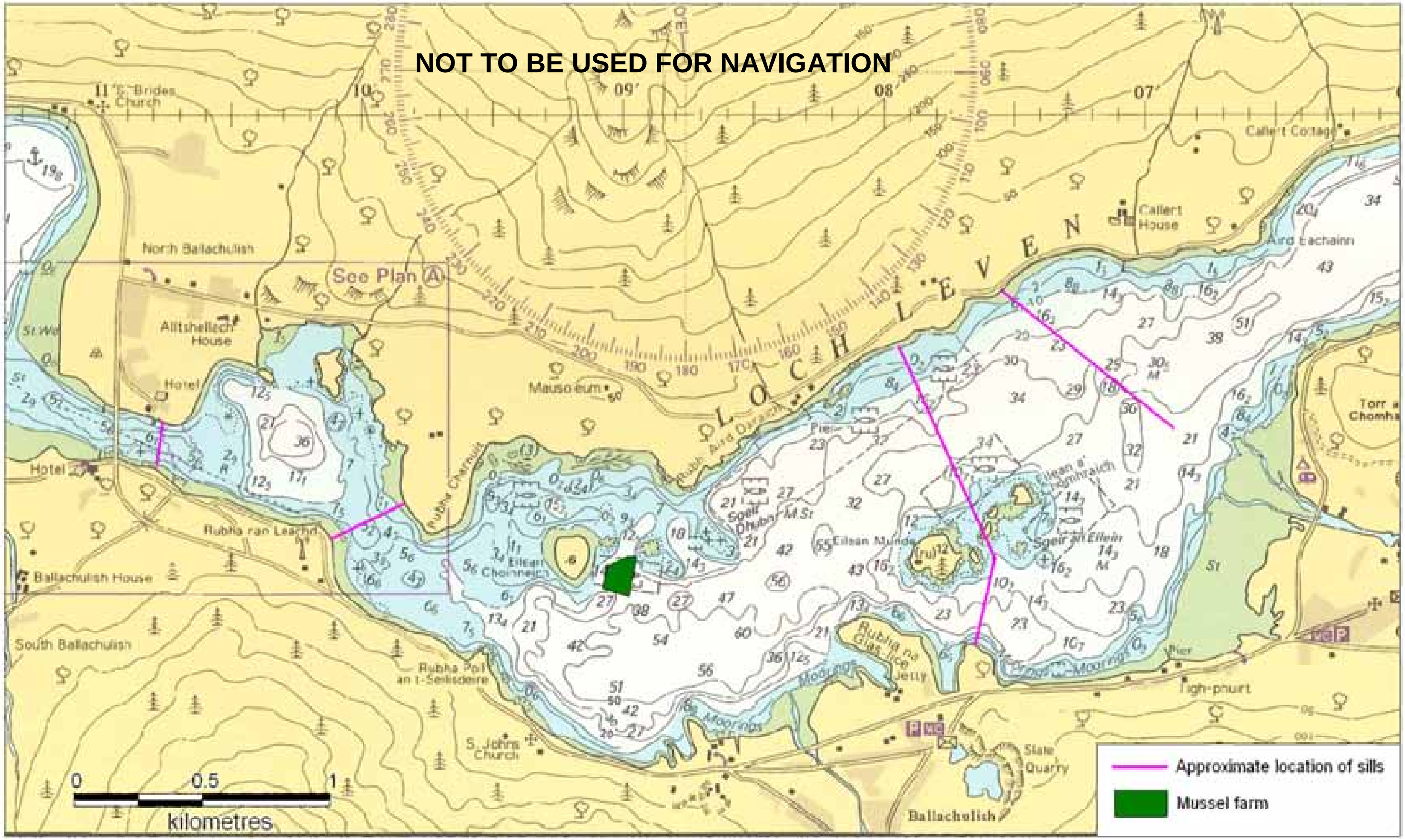


Figure 14.1 Bathymetry at Loch Leven: Lower

14.1 Tidal Curve and Description

The two tidal curves below are for Corran, approximately 6 km from the mussel farm. The tidal curves have been output from UKHO TotalTide. The first is for seven days beginning 00.00 BST on 06/09/11 and the second is for seven days beginning 00.00 BST on 13/09/11. This two-week period covers the dates of the shoreline survey. Together they show the predicted tidal heights over high/low water for a full neap/spring tidal cycle.

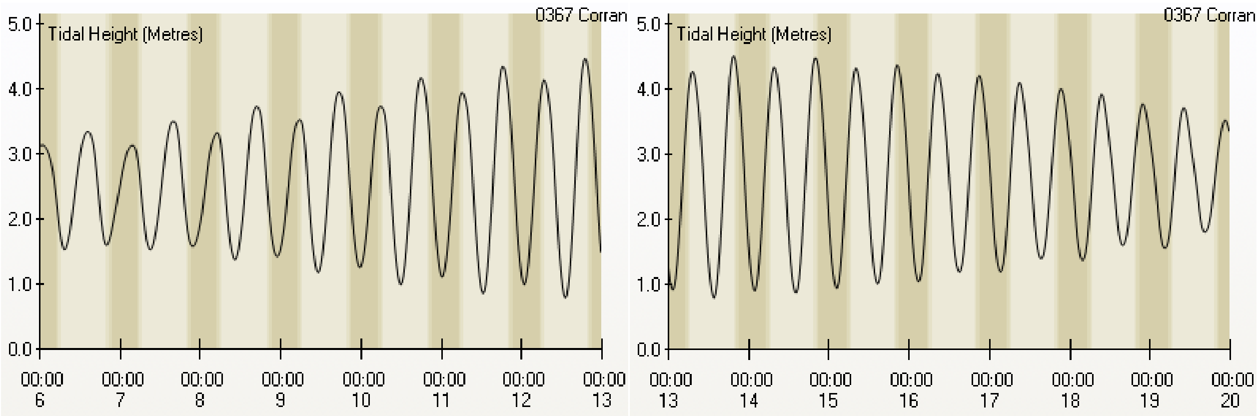


Figure 14.2 Tidal curves for Corran

The following is the summary description for Corran from TotalTide:

0367 Corran is a Secondary Non-Harmonic port.
The tide type is Semi-Diurnal.

HAT	4.9 m
MHWS	4.4 m
MHWN	3.3 m
MLWN	1.7 m
MLWS	0.7 m
LAT	0.1 m

Predicted heights are in metres above chart datum. The mean tidal range at spring tide is 3.7 m and at neap tide it is 1.6 m. The area is therefore mesotidal (moderate tidal range).

14.2 Currents

There is tidal stream information available at Corran, located in Loch Linnhe just to the north of Ballachulish Bay (which lies outside the mouth of Loch Leven). However, Loch Linnhe lies in a different direction to Loch Leven. There is also a significant constriction in Loch Linnhe at Corran and this will affect the current speeds. The tidal stream information at Corran will therefore not be relevant to the assessment of currents within Loch Leven.

SEPA supplied data from a current meter study that had been undertaken at two sites in Lower Loch Leven. Summary information on the sites is given in Table 14.1 and the positions are shown on the map in Figure 14.3. Plots of the current directions and speeds, together with the wind direction and speeds over the relevant period, are shown in Figure 14.4.

Table 14.1 Survey period for the current meter study

Location	NGR	Survey period
Leven East	NN 0807 5956	13/06/05 - 29/06/05
Leven West	NN 0783 5946	11/02/05 - 28/02/05

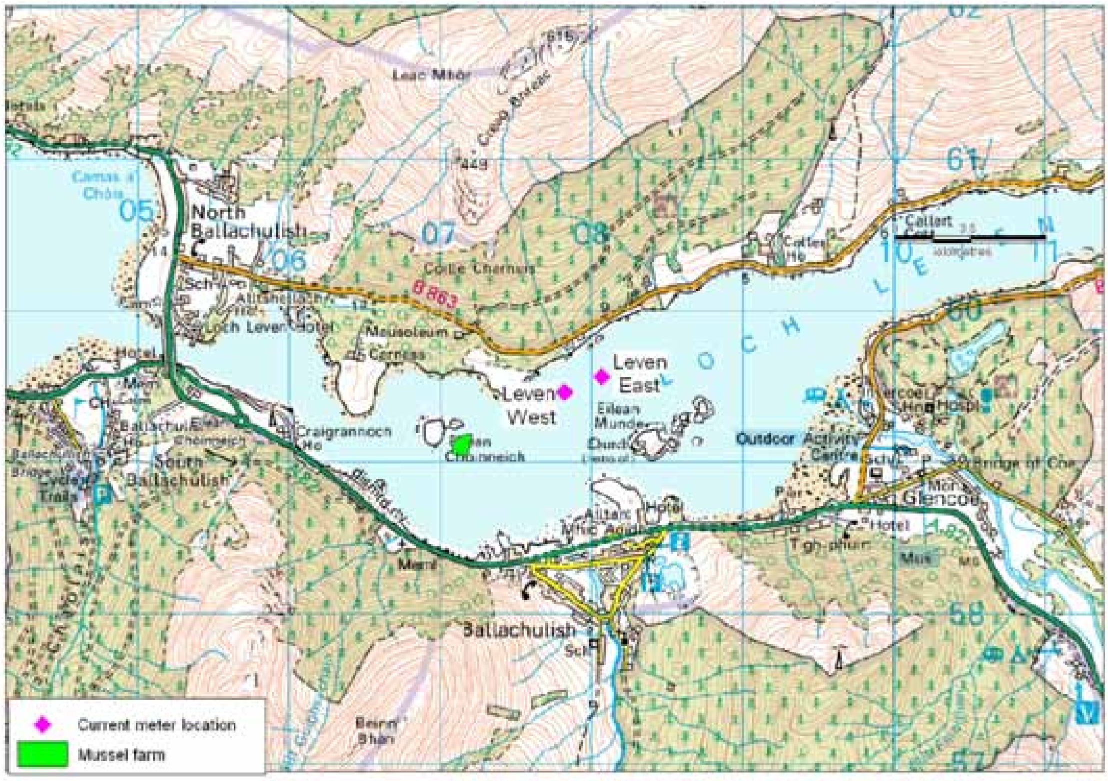


Figure 14.3 Current meter locations

Flows to the south-west near the sea bed at both locations: this is approximately parallel to the northern shore at that point. At Leven East, flows were more variable at mid-depth and near-surface but these were generally in a southerly direction. The predominant wind direction during that study was from the west and therefore does not appear to have influenced the current directions. At Leven West, flows at mid-depth and (especially) near-surface were also more variable than at depth and were mainly towards the east. The wind direction during that study was strongest from the west but there were easterly winds for a proportion for the time. The wind may therefore have affected the currents during that study.

Table 14.2 shows the median and maximum current speeds recorded during the two studies.

Table 14.2 Median and maximum current speeds

Location	Depth	Current speed (cm/s)	
		Median	**Maximum**
Leven East	Near-bottom	4.5	33.9
	Mid-depth	4.1	15.6
	Near-surface	5.5	26.2
Leven West	Near-bottom	3.3	14.8
	Mid-depth	3.7	13.4
	Near-surface	4.4	23.4

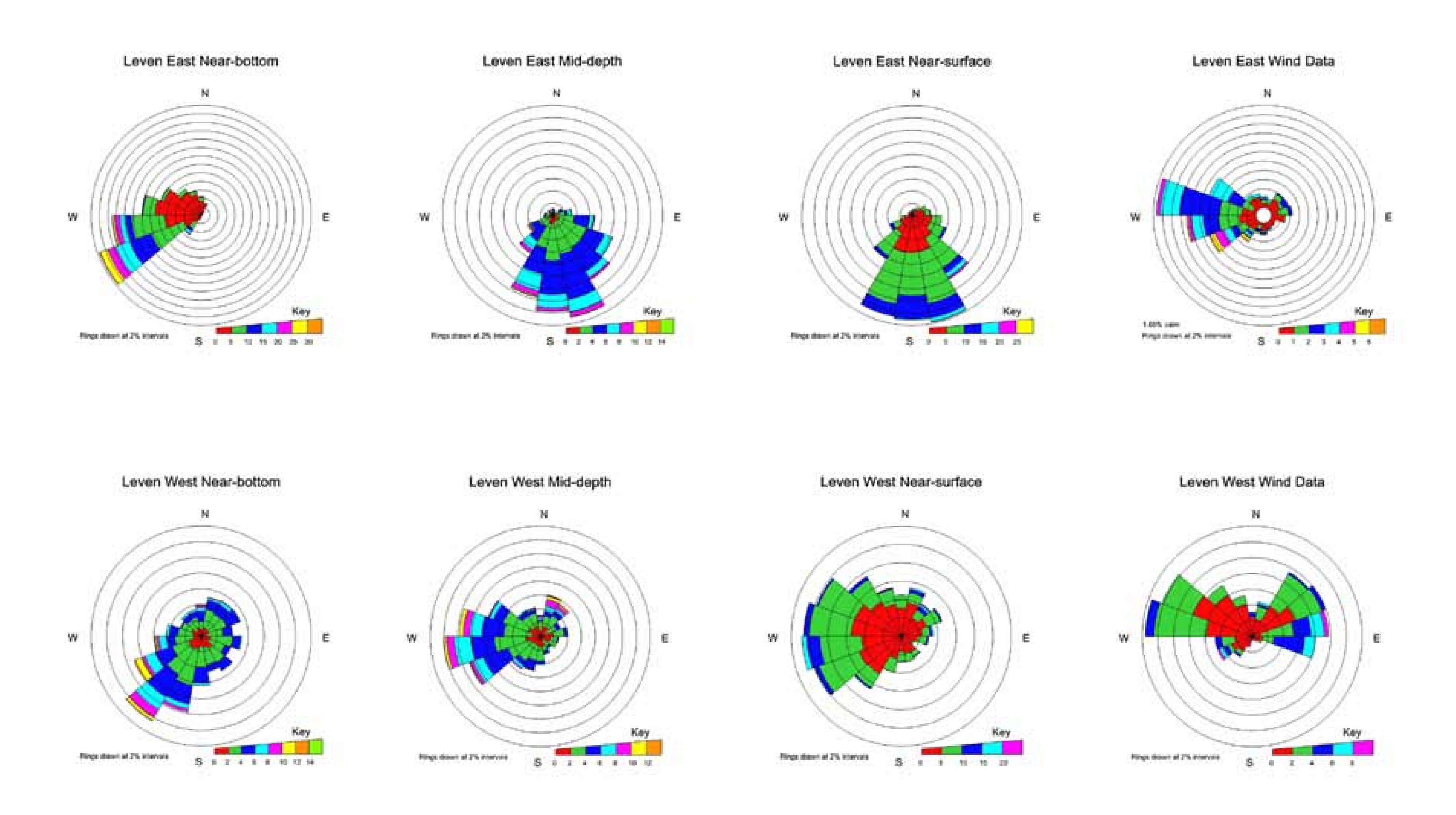
The Clyde Cruising Club guide for the area identifies that streams in Caolas Mhic Phadruig (the outer narrows) reach 4 to 5.5 knots (2.1 to 2.8 m/s; 210 to 280 cm/s) in each direction at spring tide (Clyde Cruising Club, 2007). It also states that spring tide streams in Caolas nan Con, the narrows between lower and upper Loch Leven, probably reach 6 knots (3.1 m/s; 310 cm/s) going towards the head of the loch and 4.5 knots (2.3 m/s; 230 cm/s) in the other direction. As expected, the currents through the narrows are much faster than in the basins.

The current speeds at the mussel farm are likely to be similar to those measured in the current meter studies but the direction will be influenced by three factors:

- the slightly different aspect of the loch at the mussel farm
- the constriction caused by Rubha Charnuis
- the presence of Eilean Choinneich immediately to the west of the mussel farm

The current directions will therefore be more chaotic at the site of the mussel farm. Given the aspect of the loch (including the bathymetry) and island relative to the location of the mussel rafts, it is likely that the southern end of the farm will be impacted to a greater extent by contamination than the northern end.

The mid-depth and near-surface measurements made during the current meter studies are most relevant to the depths of the droppers on the mussel rafts. At a maximum speed of 26 cm/s, contamination would be maximum distance of 3.7 km over a tidal cycle, ignoring any effects of dilution and dispersion. In general, currents, and therefore transport distances, would be expected to be less than this. Given the faster currents through the narrows to the west, contamination from sources within Ballachulish Bay could easily reach the mussel farm within a tidal cycle. To the east, contamination from sources as far as Glencoe could also reach the farm on a spring tide.



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

Figure 14.4 Current and wind plots for the current meter studies

Scottish Water provided a copy of a report on initial dilution and dispersion studies undertaken by Metoc in support of the North Ballachulish sewage treatment scheme. The report used a number of approaches to look at the potential impact of the proposed scheme at the boundary of the designated shellfish growing water. With respect to currents, the report identifies that at the mouth of the loch, surface flows predominate on the ebb tide while flows are more uniform with depth on the flood tide and that there is a net movement out of the loch into Ballachulish Bay. At neap tide, the currents are identified as reaching a maximum of approximately 0.4 m/s (40 cm/s) in the centre of the jet exiting the loch. Average flood tide speeds at the mouth, as determined by a dye study, were determined to be in the order of a few tenths of 1 m/s. Incomplete mixing was seen during the dye study. The maximum probable modelled speed was approximately 0.9 m/s (90 cm/s).

14.3 Salinity effects

Three salinity profiles were recorded during the shoreline survey. The location is shown in Figure 14.5 and the results are given in Table 14.2.

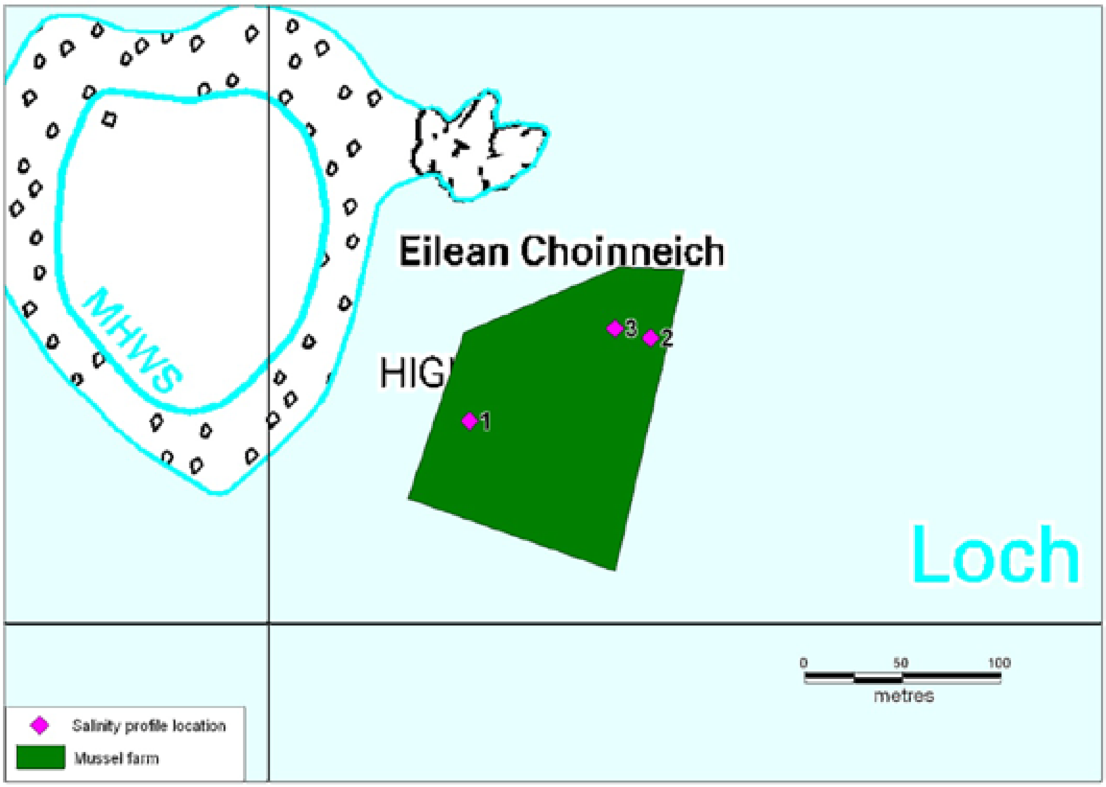


Figure 14.5 Salinity profile locations

Table 14.3 Salinity profile results

Profile	Date	Position	Depth (m)	Salinity (ppt)	Temperature (°C)
1	08/09/11	NN 07102 59103	0	7.0	11.6
			1	10.6	11.7
			3	28.3	13.2
			5	29.6	13.2
2	08/09/11	NN 07194 59145	0	6.7	12.1
			1	9.6	12.0
			3	25.4	13.2
			5	29.8	13.4
3	08/09/11	NN 07176 59150	0	7.0	11.9
			1	9.0	11.9
			3	24.2	12.9
			5	29.9	13.1

The profiles therefore showed a marked difference in salinity with depth with a brackish layer extending down to at least 1 m. The effect is not as extreme as seen previously at Upper Loch Leven where salinity profiles taken during the shoreline survey yielded surface salinities of 1.3 to 1.4 ppt. Salinity results (from laboratory analyses) for spot seawater samples taken during the survey gave results ranging from 2.2 to 32.3 ppt. The lowest result was from a sample taken in the vicinity of Glencoe and the next three lowest results (6.1, 6.8 and 7.5 ppt) were from samples taken at the mussel farm. The temperature profiles taken at the farm also showed an effect of depth.

The stratification will mean that contamination from sources with a freshwater component will tend to be constrained to the upper layer and will be subject to less dilution than if significant mixing occurred. The upper halves of the dropper lines may therefore be impacted to a greater extent than the lower halves.

14.4 Conclusions

Loch Leven is a complex water body with several basins, sills and narrows. Currents within the basin where the Loch Leven: Lower mussel farm is sited are generally weak but they are much faster through the narrows. The ebb tide through the narrows is much faster at the surface and there is a net transport out of the loch. At the mussel farm, currents will be complex, and potentially chaotic, due to the aspect and bathymetry of the loch and the presence of an island immediately to the west. Estimated transport distances mean that many of the potential sources of contamination observed during the shoreline survey could impact at the mussel farm, especially at spring tides. The southern end of the farm is anticipated to be more vulnerable to impact by such contamination than the northern end.

15. Shoreline Survey Overview

The shoreline survey was undertaken from the 6th to the 8th September 2011. There were strong winds and extremely heavy rain on the first day, strong winds and intermittent heavy rain on the second day and light winds and intermittent showers on the third day. Figure 15.1 shows a summary map of the significant findings from the shoreline survey.

The fishery consisted of a group of fourteen mussel rafts to the west of Eilean Choinneich with 6 m dropper lines. Harvesting is not normally undertaken in the months of December, January and February.

Much of the area is on the community sewerage system. The main Ballachulish Waste Water Treatment Works was recorded, as were some of the pumping stations on the southern shore. Very few private septic tank discharges to the marine environment were observed. No livestock were seen during the survey but a moderate amount of sheep droppings was noted on grazing land on the promontory behind Rubha Charnuis. Approximately 50 yachts and other boats were moored at a number of locations around the lower loch. Wild geese were observed on the promontory behind Rubha Charnuis. Ducks and gulls were also seen at the mouth of the Laroch River. The harvesters reported that eider ducks occurred frequently on Eilean Choinneich and took mussels from the lines.

Due to the rainfall, the Coe and Laroch Rivers were high during the survey and apart from other permanent burns and streams, a number of small streams and areas of land run-off were noted that may not be present during dry weather. The highest *E. coli* concentration in fresh water (16000 *E. coli* cfu/100 ml) was seen at a stream located near the fish farm on the northern shore to the east of the mussel farm. The rivers Coe (1000 *E. coli* cfu/100 ml) and Laroch (1100 *E. coli* cfu/100 ml) also contained significant levels of *E. coli*. Salinity profiles taken at the shellfish farm indicate a marked brackish layer down to at least 1 metre.

The highest concentration of *E. coli* in a seawater sample was obtained from a location towards the end of the pipe leading from the Glencoe Waste Water Pumping Station. The concentration was higher than that seen in the nearby Coe River and thus the Pumping Station overflow may have been operating due to the heavy rain. High seawater *E. coli* concentrations were also seen at the mussel farm (between 1800 and 2280 *E. coli* cfu/100 ml) and off the end of Alltan Mhic Aoidh (promontory near the Isles of Glencoe Hotel).

Mussel samples at the farm returned results that ranged from <20 to 3500 *E. coli* MPN/100 g. The lowest result came from the normal classification sampling location. The two highest results came from samples taken at the top of two other dropper lines.

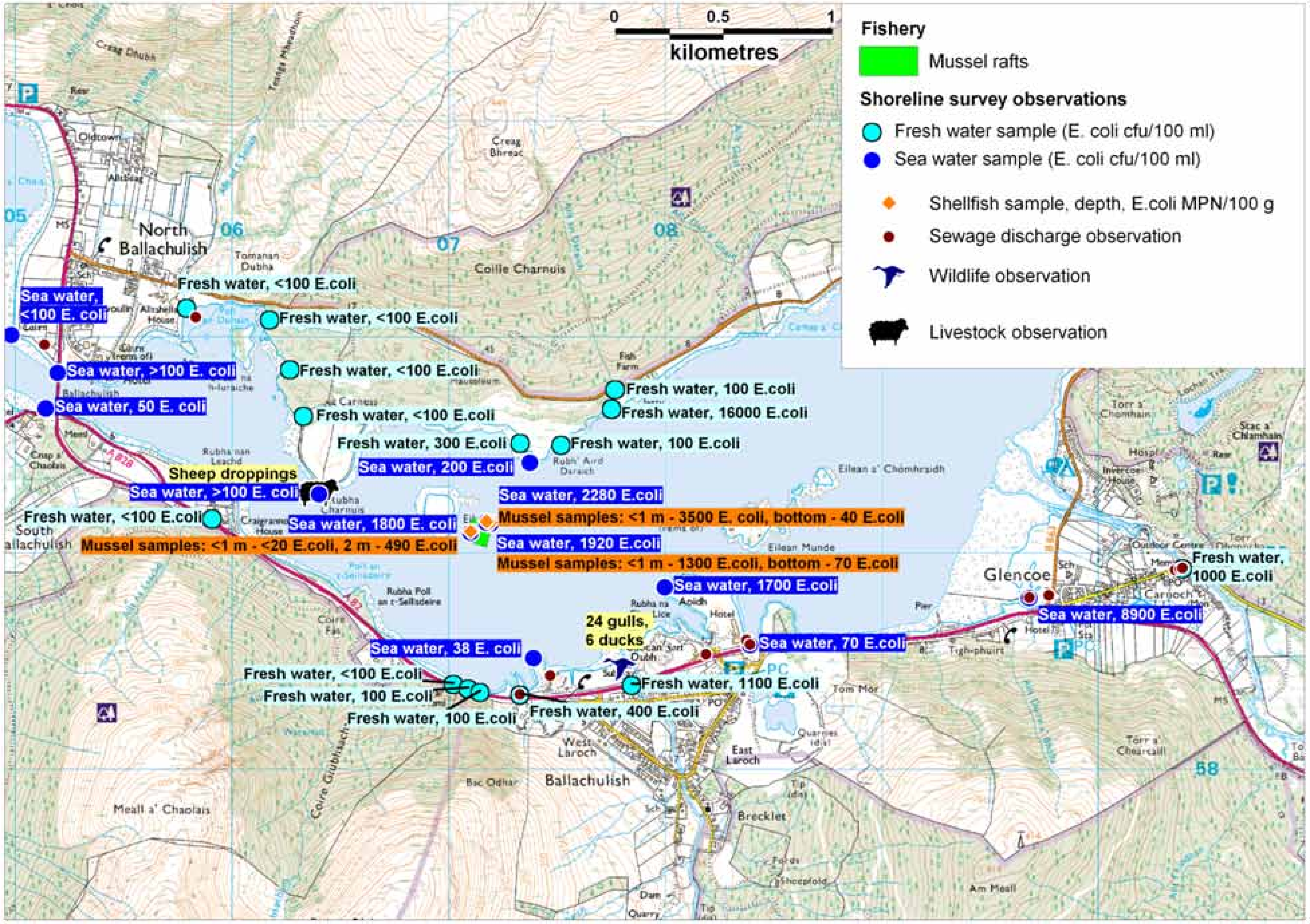


Figure 15.1 Summary of shoreline survey findings for Loch Leven: Lower

16. Overall Assessment

Human sewage impacts

Although the continuous flow of sewage to the Loch Leven: Lower production area from Glencoe and Ballachulish has been eliminated, CSOs associated with these treatment works are likely to significantly impact water quality at the fishery when they spill. Eight intermittent discharges associated with the various works are located east of the Ballachulish bridge and could potentially impact the fishery if any of them were to spill.

The North Ballachulish WWTW outfall lies just over 2.6 km to the west of the fishery. Water samples taken on an incoming tide at the mouth of the loch were found to contain <100 *E. coli* cfu/100 ml, suggesting that at the time of sampling the treatment works outfall was not contributing significant levels of faecal contamination to the flow into the loch at the sampling points.

Agricultural impacts

The catchment for the area extends on both sides of the loch along a number of large burns, and these areas away from the immediate shoreline were not viewed. Few animals were observed during the shoreline survey, and there are limited farm fields around the loch, therefore there is not expected to be much contribution of livestock faecal material to land around the fishery. Much of the land adjacent to the fishery is used for forestry, and although forested areas that have been recently cut are likely to contribute higher levels of rainfall runoff, evidence suggests that these may not necessarily contribute increases in faecal contaminant loads.

Wildlife impacts

While wild animals such as deer, geese, gulls and other birds are known or likely to be present in and around the fishery, their impact on contamination levels there is likely to be moderate. The breeding colony of gulls and terns on the island west of the fishery is the likely to contribute to faecal bacteria to the mussel farm, particularly during the summer when birds and chicks are present. Eider ducks feeding on the mussels may contribute to contamination levels at the fishery when they are present. Deer are likely to be present in significant numbers within the catchment area of the rivers and streams, and these are likely to contribute significantly to loadings of *E. coli* found in streams and rivers discharging to the loch. However, it is not clear what proportion of the overall loading is from wildlife sources in comparison to human or other sources.

Seasonal variation

There is a significant seasonal variation in human population in the area, with the tourist season running from March to October and the largest number of visitors present in July and August. There is a large amount of visitor accommodation in the area, and the loading on the sewage system is likely to be highest in July and August.

Breeding gulls and terns are most likely to be present during their nesting season in early summer, though deposited guano may be washed off the nest area over a longer period of time.

Rainfall varies by season, with September to January being the wettest months and April the driest. Rainfall events >20 mm in a day occurred throughout the year, with more of these tending to occur in January.

The area holds a seasonal classification, with A months tending to occur in spring and sometimes winter. Microbiological monitoring results tended to be lower in June and highest between August and October. However, only one sample had been taken in either February or November and none had been taken in December, therefore contamination levels in winter are not well characterised.

Rivers and streams

Water samples taken during the shoreline survey at several freshwater and seawater locations gave low *E. coli* results in general, with some exceptions. A particularly high result of 16 000 *E. coli* cfu/100 ml was taken from a small stream on the northern shore of the loch. This elevated result would indicate substantial faecal contamination but in this case there was no obvious source of contamination. The overall spot *E. coli* loading for the source was moderate. The highest spot *E. coli* loadings related to the Rivers Coe and Laroch.

No significant variation in monitoring results against rainfall was found, suggesting that contamination levels in the shellfish have not to date been found to vary with rainfall-dependent sources. Further, there was no correlation between monitoring results and salinity.

The main potential sources of contamination at the mussel farm from a watercourse perspective are those on the southern and northern shores to the east of the farm although others will contribute to background *E. coli* levels in the area, especially after heavy rainfall.

Movement of contaminants

Loch Leven is a complex water body with several basins, sills and narrows. Currents within the basin where the Loch Leven: Lower mussel farm is sited are generally weak but they are much faster through the narrows. The ebb tide through the narrows is much faster at the surface than at depth and there is a net transport out of the loch. At the mussel farm, currents will be complex, and potentially chaotic, due to the aspect and bathymetry of the loch and the presence of an island immediately to the west. Estimated transport distances mean that most of the potential sources of contamination observed during the shoreline survey could impact at the mussel farm, especially at spring tides. However, no statistically significant correlation was found between monitoring results and either the spring/neap tidal cycle or the high/low tidal cycle.

The south-eastern end of the farm is anticipated to be more vulnerable than the northern end to impact from sources along the southern shore and arising from outside the entrance to the loch.

Temporal and geographical patterns of sampling results

Although there was a dip and then subsequent rise is the trend of monitoring results in 2011, these appeared to be due to two unusually low results and a return to historically ‘normal’ levels of contamination afterward. Due to these factors, it is not suggested that monitoring results have worsened over the time period studied.

More than half of the samples were reported against the location of the nominal RMP, and therefore it was not possible to assess any variation by geographical location.

Samples taken during the shoreline survey showed higher results in shellfish taken from the northeast of the mussel farm than from the southwest. However, no samples were taken from the southeast part of the farm.

Conclusions

The fishery at Loch Leven: Lower is subject to periodic contamination from both diffuse and point sources of faecal contamination. A concerted effort has been made to reduce the amount of human source contamination discharging into the lower part of the loch, and to this end Scottish Water rerouted waste from treatment works at Ballachulish and Glencoe to the secondary treatment works at North Ballachulish in 2010, thus moving the continuous discharges to waters outside Loch Leven. Intermittent discharges due to combined sewer overflows remain within the loch, and these were the most likely source of faecal contamination observed during the shoreline survey in 2011.

Watercourses discharging to the lower loch also form a significant source of faecal contamination to the loch, and runoff from developed land around Ballachulish is also expected to contribute significantly to faecal contamination in the area. There is little in the way of agriculture in the area, and therefore agricultural sources of diffuse pollution are not expected to significantly impact the area. Wildlife, while present, may contribute to contamination directly at the fishery, however are more likely to contribute to background levels of contamination throughout the year.

Levels of contamination are likely to be higher toward the south-eastern end of the fishery, which lies nearest to the intermittent discharges and river sources arising along the southern shore of the loch. However, spot samples taken during the shoreline survey indicated that contamination levels were higher at the north-eastern end of the mussel farm than at the south-western end. No samples had been taken from the south-eastern part of the farm at that time.

As there are significant identified sources of faecal contamination, it would be prudent to restrict the production area boundaries to exclude to the greatest extent possible those known sources.

17. Recommendations

Production area

Due to the significant number of both point and diffuse sources of faecal contamination in lower Loch Leven, it is recommended that the production area boundaries be curtailed to exclude the waters near Ballachulish, North Ballachulish, and Glencoe. The recommended boundaries are described as the area bounded by lines drawn between NN 0640 5931 and NN 0659 5884 and between NN 0742 5943 and NN 0727 5840 and extending to MHWS.

RMP

It is recommended that the RMP be relocated to NN 0716 5905. This lies at the southeastern end of the mussel farm, which is nearer to sources arising from the southern shore.

Tolerance

A tolerance of 20 metres is recommended to allow for a suitable sampling location to be identified on the raft and to allow for movement on the anchors.

Depth of sampling

Due to the influence of freshwater sources of contamination in the area, and the likelihood that these may be more concentrated in lower salinity water at the surface, the recommended sampling depth is 1 metre or less.

Frequency

The area currently holds a seasonal classification and therefore reduced sampling frequency is not indicated.

However, it is noted that harvesting is not normally undertaken during the months of December, January, and February due to difficulties in accessing the mussel farm. However, due to the proximity of significant sources of human faecal contamination it is recommended that monthly sampling be continued throughout the year.

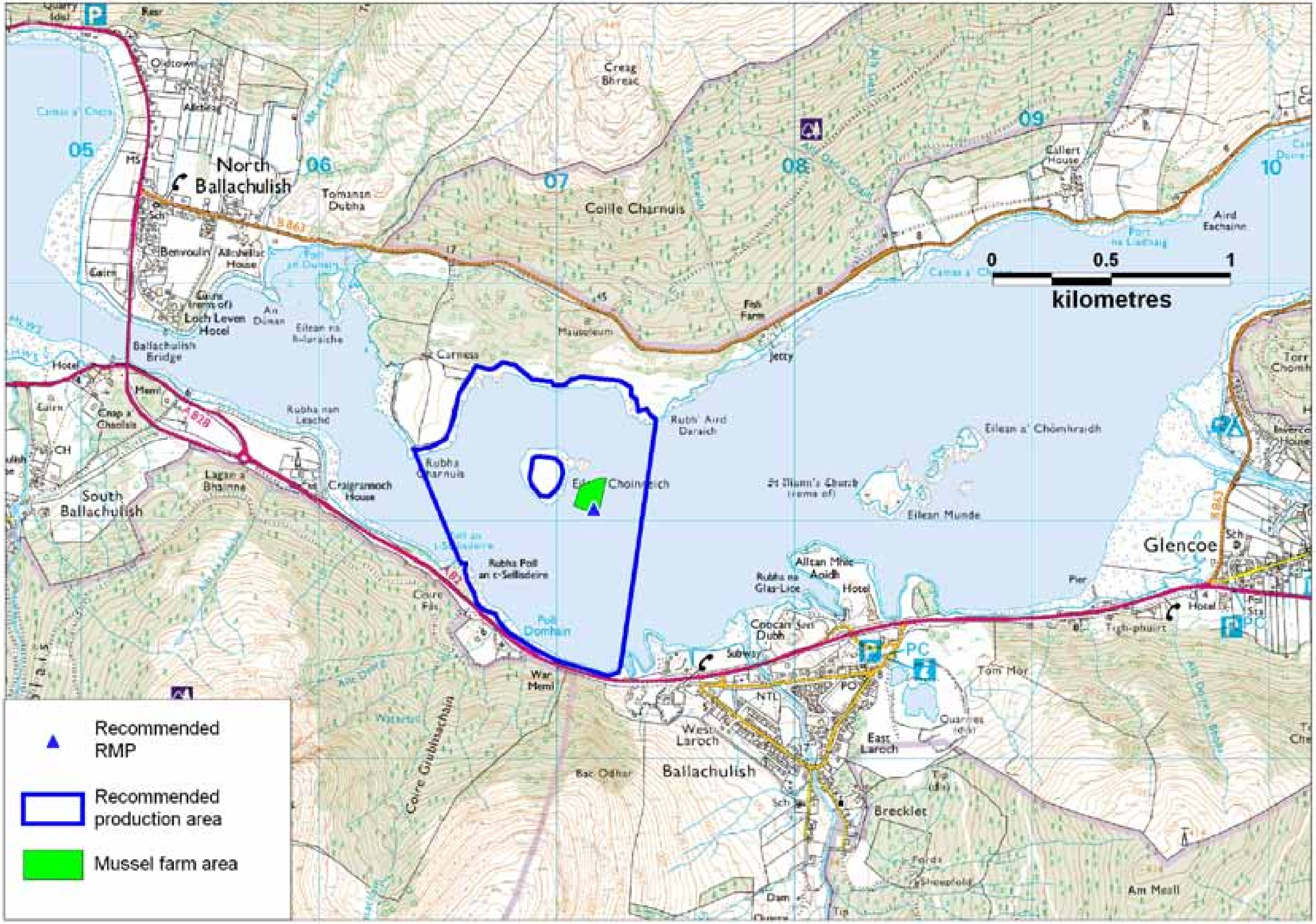


Figure 17.1 Map of recommendations at Loch Leven: Lower

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19. List of Figures and Tables

Appendices

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Geology and Soils Assessment Method

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 x 10^4 CFU (colony forming units) *E. coli* per gram dry weight of faeces (Lisle *et al* 2004).

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

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

Cetaceans

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

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

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

Birds

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

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

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

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

Deer

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

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

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

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

Other

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

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

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Tables of Typical Faecal Bacteria Concentrations

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

Indicator organism	Base-flow conditions				High-flow conditions			
Treatment levels and specific types: Faecal coliforms	n^c	Geometric mean	Lower 95% CI	Upper 95% CI	n^c	Geometric mean	Lower 95% CI	Upper 95% CI
Untreated	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	282	$2.8 \times 10^{6*}$ (-)	2.3×10^6	3.2×10^6
Crude sewage discharges	252	$1.7 \times 10^{7*}$ (+)	1.4×10^7	2.0×10^7	79	$3.5 \times 10^{6*}$ (-)	2.6×10^6	4.7×10^6
Storm sewage overflows					203	2.5×10^6	2.0×10^6	2.9×10^6
Primary	127	$1.0 \times 10^{7*}$ (+)	8.4×10^6	1.3×10^7	14	4.6×10^6 (-)	2.1×10^6	1.0×10^7
Primary settled sewage	60	1.8×10^7	1.4×10^7	2.1×10^7	8	5.7×10^6		
Stored settled sewage	25	5.6×10^6	3.2×10^6	9.7×10^6	1	8.0×10^5		
Settled septic tank	42	7.2×10^6	4.4×10^6	1.1×10^7	5	4.8×10^6		
Secondary	864	$3.3 \times 10^{5*}$ (-)	2.9×10^5	3.7×10^5	184	$5.0 \times 10^{5*}$ (+)	3.7×10^5	6.8×10^5
Trickling filter	477	4.3×10^5	3.6×10^5	5.0×10^5	76	5.5×10^5	3.8×10^5	8.0×10^5
Activated sludge	261	$2.8 \times 10^{5*}$ (-)	2.2×10^5	3.5×10^5	93	$5.1 \times 10^{5*}$ (+)	3.1×10^5	8.5×10^5
Oxidation ditch	35	2.0×10^5	1.1×10^5	3.7×10^5	5	5.6×10^5		
Trickling/sand filter	11	2.1×10^5	9.0×10^4	6.0×10^5	8	1.3×10^5		
Rotating biological contactor	80	1.6×10^5	1.1×10^5	2.3×10^5	2	6.7×10^5		
Tertiary	179	1.3×10^3	7.5×10^2	2.2×10^3	8	9.1×10^2		
Reedbed/grass plot	71	1.3×10^4	5.4×10^3	3.4×10^4	2	1.5×10^4		
Ultraviolet disinfection	108	2.8×10^2	1.7×10^2	4.4×10^2	6	3.6×10^2		

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

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

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

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

Statistical Data

One-way ANOVA: LogEC versus Season

Source	DF	SS	MS	F	P
Season	3	0.448	0.149	0.49	0.694
Error	35	10.731	0.307		
Total	38	11.179			

S = 0.5537   R-Sq = 4.01%   R-Sq(adj) = 0.00%

```
                          Individual 95% CIs For Mean Based on
                          Pooled StDev
Level   N    Mean   StDev  --------+---------+---------+---------+-
1      13  2.1079  0.5027        (---------*----------)
2      13  2.1600  0.5517          (---------*---------)
3       9  2.3835  0.6549              (-----------*------------)
4       4  2.1366  0.4530  (------------------*------------------)
                          --------+---------+---------+---------+-
                               1.80      2.10      2.40      2.70
```

Pooled StDev = 0.5537

Grouping Information Using Tukey Method

Season	N	Mean	Grouping
3	9	2.3835	A
2	13	2.1600	A
4	4	2.1366	A
1	13	2.1079	A

Means that do not share a letter are significantly different.

Hydrographic Methods

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

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

<u>Background processes</u>

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

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

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

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

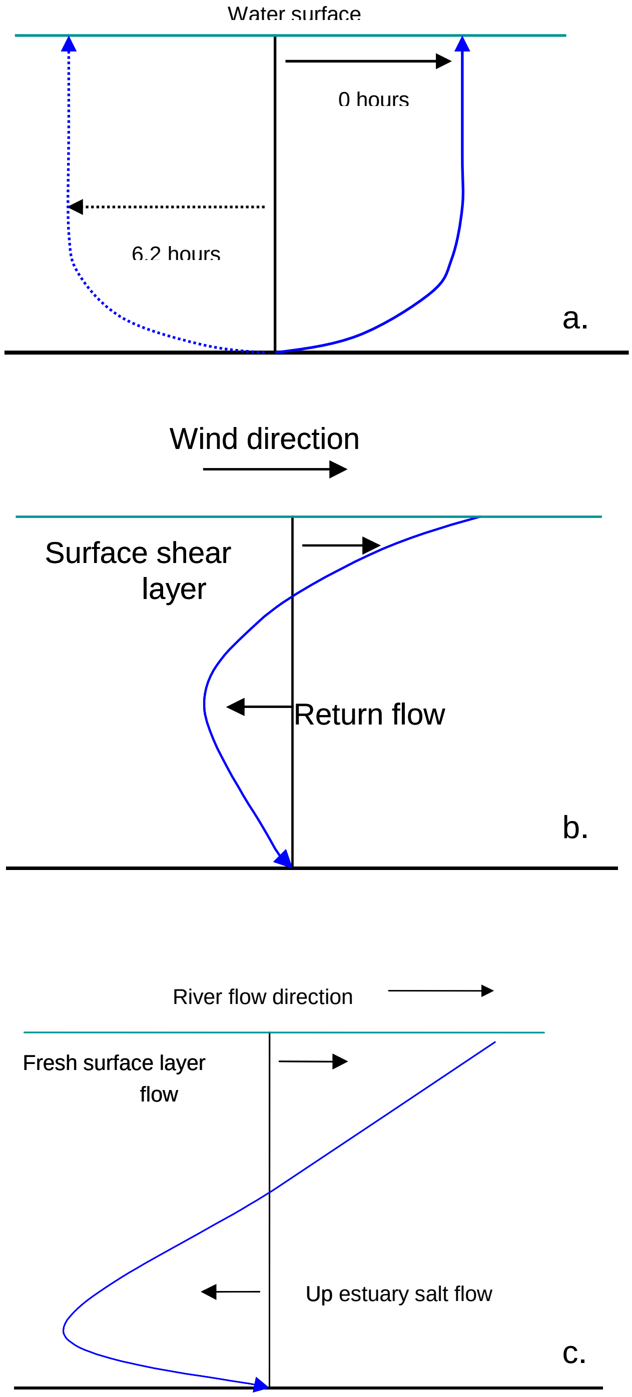

Figure 1. Typical vertical profiles for water currents. The black vertical line indicates zero velocity so portions of the profile to the left and right indicate flow moving in opposite directions. a) Peak tidal flow profiles. Profiles are shown 6.2 hours apart as the main tidal current reverses direction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

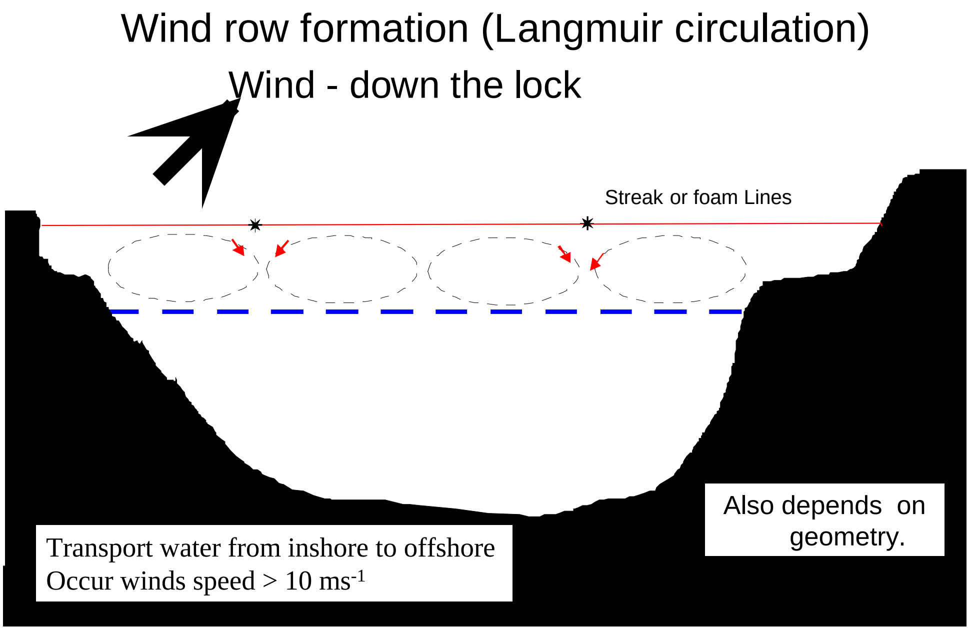

Figure 2. Schematic of wind driven 'wind row' currents. The dotted blue line indicates the depth of the surface fresh(er) water layer usually found in sea lochs.

<u>Non-modelling Assessment</u>

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

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

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

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

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

References

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

Glossary

The following technical terms may appear in the hydrographic assessment.

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

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

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

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

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

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

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

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

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

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

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

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

Shoreline Survey Report

Prod. area:	Loch Leven: Lower
Site name:	Lower
Species:	Common mussel
Harvester:	Mr and Mrs Salvarli (Glencoe Shellfish)
Local Authority:	The Highland Council: Lochaber
Status:	Existing
Date Surveyed:	6-8 September 2011
Surveyed by:	Ron Lee, Steve Lewis
Nominal RMP:	NN 07200 59400
Area Surveyed:	Glencoe to South Ballachulish and from the Marine Harvest site to North Ballachulish

Weather observations

6 September. Strong winds and extremely heavy rain.
7 September. Strong winds and intermittent heavy rain.
8 September. Light winds and intermittent showers.

Fishery

The fishery consists of a group of fourteen mussel rafts to the west of Eilean Choinneich. The dropper lines are 6 m in length. Harvesting had recently been undertaken from some rafts. Normally harvesting is not undertaken in the months of December, January and February.

Sewage/Faecal Sources

Much of the area is on the community sewerage system. The small septic tank works for each community have been replaced by a larger new treatment works at North Ballachulish, with pumping stations remaining at the other locations. Few private septic tank discharges to the marine environment were observed.

Farming and livestock

The only evidence of livestock that was seen during the survey was the moderate amount of sheep droppings on grazing land on the promontory behind Rubha Charnuis.

Seasonal Population

The area is very popular with tourists and there are several hotels and a large number of B&Bs. Peak season for tourism is July to September inclusive.

Boats/Shipping

Approximately 50 yachts and other boats were moored at a number of locations around the lower loch. A few empty moorings were noted during the survey. Boats tend to be taken off the mooring s in the winter. A recount on 14 November 2011 showed the following still on moorings:

North Ballachulish: 5 yachts and 4 small boats
Glencoe: 4 yachts and 6 small boats

Land Use

There are significant urban areas associated with the small communities with some grassland around these. Around most of the rest of the loch there was woodland (mainly deciduous, some mixed) with fern immediately above the shore with coniferous forest stretching up the hills. The tops of the hills were mainly a mixture of heather and rough grassland. There are forested areas that tend to be cropped on a 25 year rotation.

Watercourses

The Coe and Laroch Rivers, some burns and several streams were measured and sampled during the survey. Due to the very heavy rainfall that occurred during the first half of the survey period, a large number of small streams were flowing and several areas of land seepage were evident.

Wildlife/Birds

Wild geese were observed on the promontory behind Rubha Charnuis. Ducks and gulls were also seen at the mouth of the Laroch River. The harvesters reported that eider ducks occurred frequently on Eilean Choinneich and took mussels from the lines.

Observations are listed in Table 1 and mapped in Figure 1.

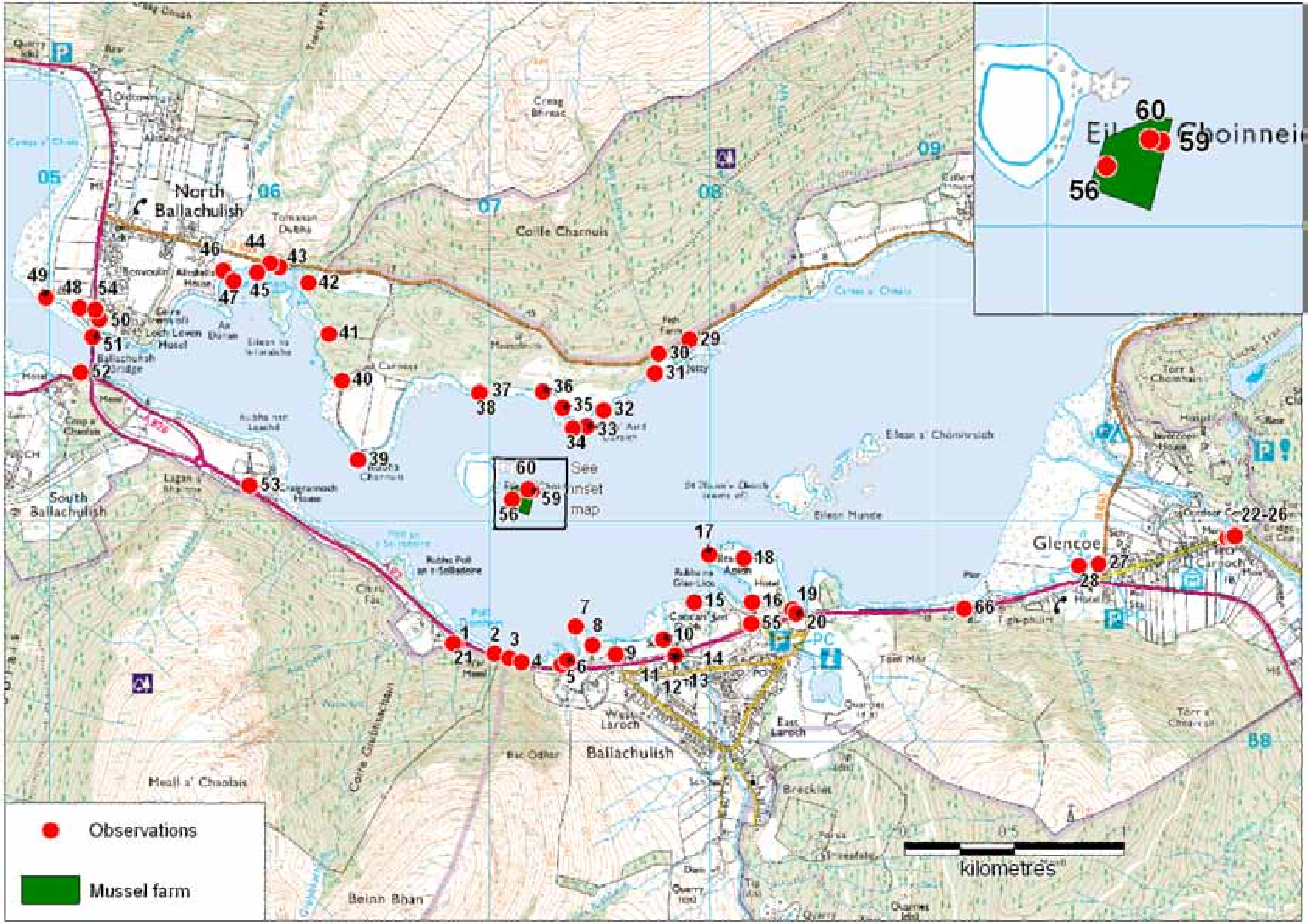

Figure 1. Map of Shoreline Observations
(The observations used to derive the farm polygon have been omitted)

Table 1. Shoreline Observations

No.	Date	Time	NGR	Easting	Northing	Photograph	Sample	Observation
1	06/09/11	09:39:35	NN 06846 58444	206846	758444			Start of survey section
2	06/09/11	09:47:25	NN 07023 58400	207023	758400		LLW01	Stream down hillside from submerged culvert. Width 140 cm; depth 8 cm; flow 0.014 m/s. Width 66cm; depth 3 cm; flow 0.362 m/s.
3	06/09/11	09:55:57	NN 07091 58379	207091	758379		LLW02	Stream flowing through pipe under road. Width 45 cm; depth 5cm; flow 0.436 m/s.
4	06/09/11	10:03:35	NN 07145 58362	207145	758362		LLW03	Minor stream through culvert. Width 19 cm; depth 1 cm; flow 0.387 m/s.
5	06/09/11	10:14:59	NN 07330 58351	207330	758351		LLW04	Pipe - flowing. Hydrocarbon smell.
6	06/09/11	10:21:55	NN 07353 58371	207353	758371			Small bay. 1 motor boat and 2 dinghies on shore. Caravan parked above shore.
7	06/09/11	10:33:43	NN 07392 58523	207392	758523		LLW05	Seawater sample
8	06/09/11	10:38:31	NN 07470 58438	207470	758438	Figure 5		Pipe running out from side of house: then goes under shore.
9	06/09/11	10:44:37	NN 07576 58398	207576	758398			Small inlet by house. Green algae on shore.
10	06/09/11	10:50:06	NN 07790 58467	207790	758467			23 gulls and 6 ducks by river mouth.
11	06/09/11	10:55:58	NN 07846 58395	207846	758395	Figure 6	LLW06	East side of river - 1st reading; width by GPS; depth 40 cm; flow 0.961 m/s
12	06/09/11	10:56:38	NN 07847 58392	207847	758392			East side of river- 2nd reading
13	06/09/11	11:05:25	NN 07836 58389	207836	758389			West side of river - 1st reading
14	06/09/11	11:05:31	NN 07837 58389	207837	758389			West side of river - 2nd reading
15	06/09/11	11:12:15	NN 07929 58637	207929	758637			Five small boats offshore
16	06/09/11	11:22:53	NN 08196 58637	208196	758637			Pier by Isles of Glencoe Hotel; 2 yachts; 5 open boats; 1 disused fishing boat; disused fishermen's huts
17	06/09/11	11:33:19	NN 07999 58850	207999	758850		LLW07	Seawater sample
18	06/09/11	11:39:53	NN 08157 58833	208157	758833			Salmon farm on other side of loch; island just offshore - no animals seen
19	06/09/11	11:47:31	NN 08376 58602	208376	758602	Figure 7		Old iron pipe emerging from direction of hotel - no flow
20	06/09/11	11:49:45	NN 08393 58583	208393	758583	Figure 8	LLW08	Large concrete pipe with flow; no access to sample or measure; seawater sample near end
21	06/09/11	12:17:43	NN 06836 58449	206836	758449			End of survey section
22	06/09/11	12:28:04	NN 10355 58928	210355	758928			Upper Carnoch WWPS
23	06/09/11	12:29:45	NN 10377 58932	210377	758932			West side of Coe River - 1st reading; outlet pipe below
24	06/09/11	12:29:59	NN 10378 58931	210378	758931			West side of Coe River - 2nd reading

No.	Date	Time	NGR	Easting	Northing	Photograph	Sample	Observation
25	06/09/11	12:31:44	NN 10388 58935	210388	758935	Figure 9	LLW09	East side of Coe River - 1st reading; Width from GPS; depth 70 cm; flow 1.362 m/s
26	06/09/11	12:31:53	NN 10389 58936	210389	758936			East side of Coe River - 2nd reading; Outlet pipe on side of bank - trickle flowing
27	06/09/11	12:46:57	NN 09771 58810	209771	758810	Figure 10		Glencoe Waste Water Pumping Station
28	06/09/11	12:50:28	NN 09681 58799	209681	758799	Figure 11	LLW10	Two long outfall pipes; one looks newer than the other; seawater sample partway out along pipes
29	07/09/11	08:46:55	NN 07910 59827	207910	759827			Start of survey section; above fish farm
30	07/09/11	08:56:33	NN 07770 59764	207770	759764		LLW11	Burn; width 3 m; depth 4 cm; flow 1.234 m/s; water sample
31	07/09/11	09:08:12	NN 07753 59675	207753	759675		LLW12	Small stream; width 1m; depth 7 cm; flow 0.056 m/s; some flow bypassing measured width; two photos of fish farm
32	07/09/11	09:24:12	NN 07520 59508	207520	759508		LLW13	Very small stream; width 40 cm; depth 3 cm; flow 0.200 m/s
33	07/09/11	09:33:16	NN 07442 59435	207442	759435	Figure 12		Top of hill overlooking mussel farm
34	07/09/11	09:36:24	NN 07377 59426	207377	759426		LLW14	Seawater sample; land run-off nearby; lots of broken mussel shell on rocks
35	07/09/11	09:45:32	NN 07332 59517	207332	759517		LLW15	Small stream; width 20 cm; depth 2 cm; flow 0.111 m/s; also land seepage nearby
36	07/09/11	09:53:52	NN 07244 59590	207244	759590			Very small stream - too small to measure or sample; lots of broken mussel shell on beach
37	07/09/11	10:05:45	NN 06964 59592	206964	759592			Very small stream - too small to measure or sample
38	07/09/11	10:07:13	NN 06953 59585	206953	759585			Very small stream - too small to measure or sample
39	07/09/11	10:26:58	NN 06403 59279	206403	759279		LLW16	Headland is grazed; no sheep at time but moderate amount of droppings; approx 40 Canada geese; seawater sample
40	07/09/11	10:39:53	NN 06331 59642	206331	759642		LLW17	Very small stream; too small to measure; sampled as it runs from direction of house
41	07/09/11	10:54:42	NN 06269 59856	206269	759856		LLW18	Stream; width 1.15 m; depth 15 cm; flow 0.090 m/s; Deciduous woodland with ferns
42	07/09/11	11:09:12	NN 06176 60087	206176	760087		LLW19	Two streams merge; measured and sampled below junction; width 1.10 m; depth 40 cm; flow 0.655 m/s
43	07/09/11	11:18:28	NN 06046 60158	206046	760158			Land run off
44	07/09/11	11:20:30	NN 06001 60177	206001	760177			Land run off
45	07/09/11	11:24:10	NN 05945 60133	205945	760133			Bay with 14 yachts; 1 fishing boat; 1 launch; several small open boats; tenders on shore; deciduous trees above shore with some conifers to west
46	07/09/11	11:29:41	NN 05792 60142	205792	760142		LLW20	Burn; width 3.90 m; depth 25 cm; flow 0.612 m/s

No.	Date	Time	NGR	Easting	Northing	Photograph	Sample	Observation
47	07/09/11	11:35:56	NN 05836 60098	205836	760098	Figure 13		Iron pipe approx 18 cm O.D.; newer plastic pipe extends from end out under water
48	07/09/11	11:56:36	NN 05136 59971	205136	759971			New North Ballachulish WWTW
49	07/09/11	12:03:19	NN 04983 60018	204983	760018		LLW21	Seawater sample
50	07/09/11	12:10:22	NN 05224 59920	205224	759920			Mobile home above shore; no obvious arrangements for waste disposal
51	07/09/11	12:12:47	NN 05197 59841	205197	759841		LLW22	Seawater sample
52	07/09/11	12:29:32	NN 05141 59678	205141	759678		LLW23	Seawater sample
53	07/09/11	12:52:53	NN 05910 59166	205910	759166		LLW24	Burn and road drain; width 75 cm; depth 9 cm; flow 0.798 m/s
54	07/09/11	15:21:58	NN 05210 59966	205210	759966	Figure 14		Photos of North Ballachulish WWTW from road
55	08/09/11	09:14:08	NN 08188 58537	208188	758537			Ballachulish WW Pumping Station
56	08/09/11	09:35:30	NN 07102 59103	207102	759103		LLM1; LLW25	Classification sampling line; classification sample taken from approx 2 m; SS sample taken from near top of line; salinity profile 5m 29.6 ppt; 13.2C; 3 m 28.3 ppt 13.2C; 1 m 10.6 ppt 11.7 C; surface 7.0 ppt 11.6C: seawater sample
57	08/09/11	09:56:19	NN 07076 59065	207076	759065			Approx 10 m off one corner of rafts
58	08/09/11	09:58:04	NN 07172 59025	207172	759025			Approx 20 m off one corner of rafts
59	08/09/11	10:00:02	NN 07194 59145	207194	759145		LLM2 (top) LLM3 (bottom) LLW26	Line raised from one of easterly rafts; two mussel samples and 1 seawater sample; salinity profile 5 m 29.8 ppt 13.4 C; 3 m 25.4 ppt 13.2 C; 1 m 9.6 ppt 12.0C; surface 6.7 ppt 12.1C
60	08/09/11	10:18:51	NN 07176 59150	207176	759150		LLM4 (top) LLM5 (bottom) LLW27	One of middle rafts; line raised; two mussels samples and seawater sample; salinity profile 5 m 29.9 ppt 13.1C; 3 m 24.2 ppt 12.9C; 1 m 9.0 ppt 11.9C; surface 7.0 ppt 11.9C
61	08/09/11	10:48:50	NN 07215 59186	207215	759186			Approx 20 m off corner of rafts
62	08/09/11	10:49:04	NN 07177 59189	207177	759189			Approx 20 m off corner of rafts
63	08/09/11	10:49:42	NN 07095 59152	207095	759152			Approx 20 m off corner of rafts
64	08/09/11	10:50:02	NN 07086 59097	207086	759097			Approx 20 m off corner of rafts
65	08/09/11	10:50:31	NN 07155 59053	207155	759053			Approx 20 m off corner of rafts
66	08/09/11	12:12:57	NN 09159 58606	209159	758606	Figure 15		Glencoe Boat Club storage area; boats on land; 21 yachts and 6 smaller boats moored between Glencoe and Ballachulish. Some empty moorings.

Photographs referenced in the table can be found attached as Figures 5-15.

Sampling

Water and shellfish samples were collected at sites marked on the maps shown in Figures 2 & 3. Samples were transferred to either Biotherm 25 or Biotherm 10 boxes with ice packs and shipped to Glasgow Scientific Services on the day collected for *E. coli* analysis. In all cases, samples were received and analysed on the day following collection. Sample temperatures on arrival ranged between 2.1 and 4.7°C. The results are presented in Tables 2 and 3.

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

At the fishery, salinity and temperature were recorded at the surface, 1 meter, 3 meters and 5 meters depth at three locations using a YSI ProPlus CT probe. The locations are shown in Figure 4 and the resulting profiles are reported in Table 4.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	06/09/11	LLW01	NN 07023 58400	Fresh	<100	-
2	06/09/11	LLW02	NN 07091 58379	Fresh	100	-
3	06/09/11	LLW03	NN 07145 58362	Fresh	100	-
4	06/09/11	LLW04	NN 07330 58351	Fresh	400	-
5	06/09/11	LLW05	NN 07392 58523	Sea	38	30.7
6	06/09/11	LLW06	NN 07846 58395	Fresh	1100	-
7	06/09/11	LLW07	NN 07999 58850	Sea	1700	25.6
8	06/09/11	LLW08	NN 08393 58583	Sea	70	30.3
9	06/09/11	LLW09	NN 10388 58935	Fresh	1000	-
10	06/09/11	LLW10	NN 09681 58799	Sea	8900	2.2
11	07/09/11	LLW11	NN 07770 59764	Fresh	100	-
12	07/09/11	LLW12	NN 07753 59675	Fresh	16000	-
13	07/09/11	LLW13	NN 07520 59508	Fresh	100	-
14	07/09/11	LLW14	NN 07377 59426	Sea	200	24.3
15	07/09/11	LLW15	NN 07332 59517	Fresh	300	-
16	07/09/11	LLW16	NN 06403 59279	Sea	>100	26.3
17	07/09/11	LLW17	NN 06331 59642	Fresh	<100	-
18	07/09/11	LLW18	NN 06269 59856	Fresh	<100	-
19	07/09/11	LLW19	NN 06176 60087	Fresh	<100	-
20	07/09/11	LLW20	NN 05792 60142	Fresh	<100	-
21	07/09/11	LLW21	NN 04983 60018	Sea	<100	30.7
22	07/09/11	LLW22	NN 05197 59841	Sea	>100	32.0
23	07/09/11	LLW23	NN 05141 59678	Sea	50	32.3
24	07/09/11	LLW24	NN 05910 59166	Fresh	<100	
25	08/09/11	LLW25	NN 07102 59103	Sea	1800	6.8
26	08/09/11	LLW26	NN 07194 59145	Sea	1920	6.1
27	08/09/11	LLW27	NN 07176 59150	Sea	2280	7.5

- not analysed

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	Location on line	E. coli (MPN/100g)
1	08/09/2011	LLM1	NN 07102 59103	Common mussel	Top*	<20
2	08/09/2011	LLM2	NN 07194 59145	Common mussel	Top	3500
3	08/09/2011	LLM3	NN 07194 59145	Common mussel	Bottom	40
4	08/09/2011	LLM4	NN 07176 59150	Common mussel	Top	1300
5	08/09/2011	LLM5	NN 07176 59150	Common mussel	Bottom	70

*The harvesters identified that the sampling line is kept at a depth of 3 m. The classification sample taken at the same time from approximately 2-4 m down the same line, and tested at Veromara, returned a result of 490 *E. coli* MPN/100 g

Table 4. Salinity profiles

Profile	Date and time	Time	Position	Depth (m)	Salinity (ppt)	Temperature (°C)
1	08/09/11	09:35	NN 07102 59103	0	7.0	11.6
				1	10.6	11.7
				3	28.3	13.2
				5	29.6	13.2
2	08/09/11	10:00	NN 07194 59145	0	6.7	12.1
				1	9.6	12.0
				3	25.4	13.2
				5	29.8	13.4
3	08/09/11	10:19	NN 07176 59150	0	7.0	11.9
				1	9.0	11.9
				3	24.2	12.9
				5	29.9	13.1

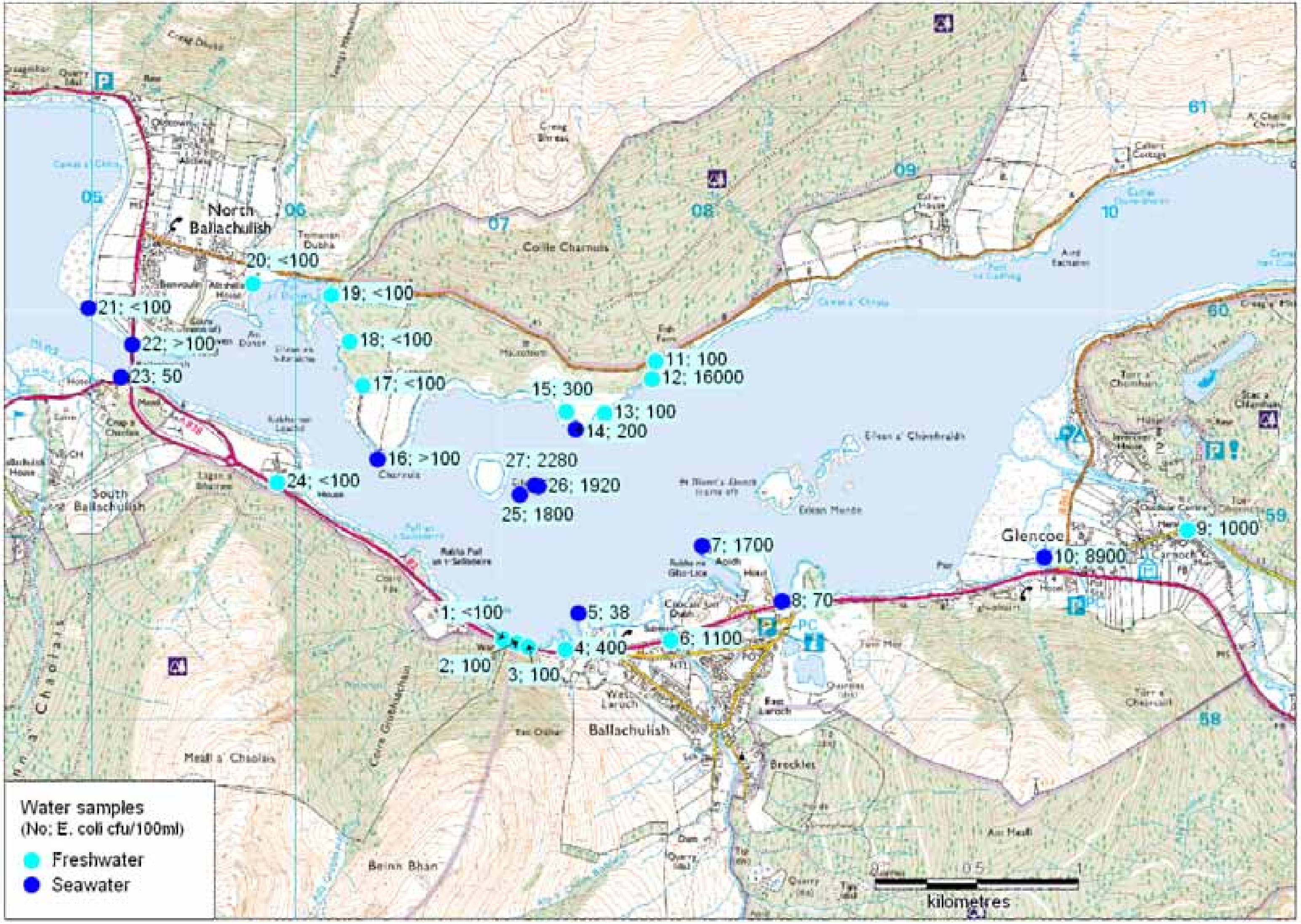

Figure 2. Water sample results map

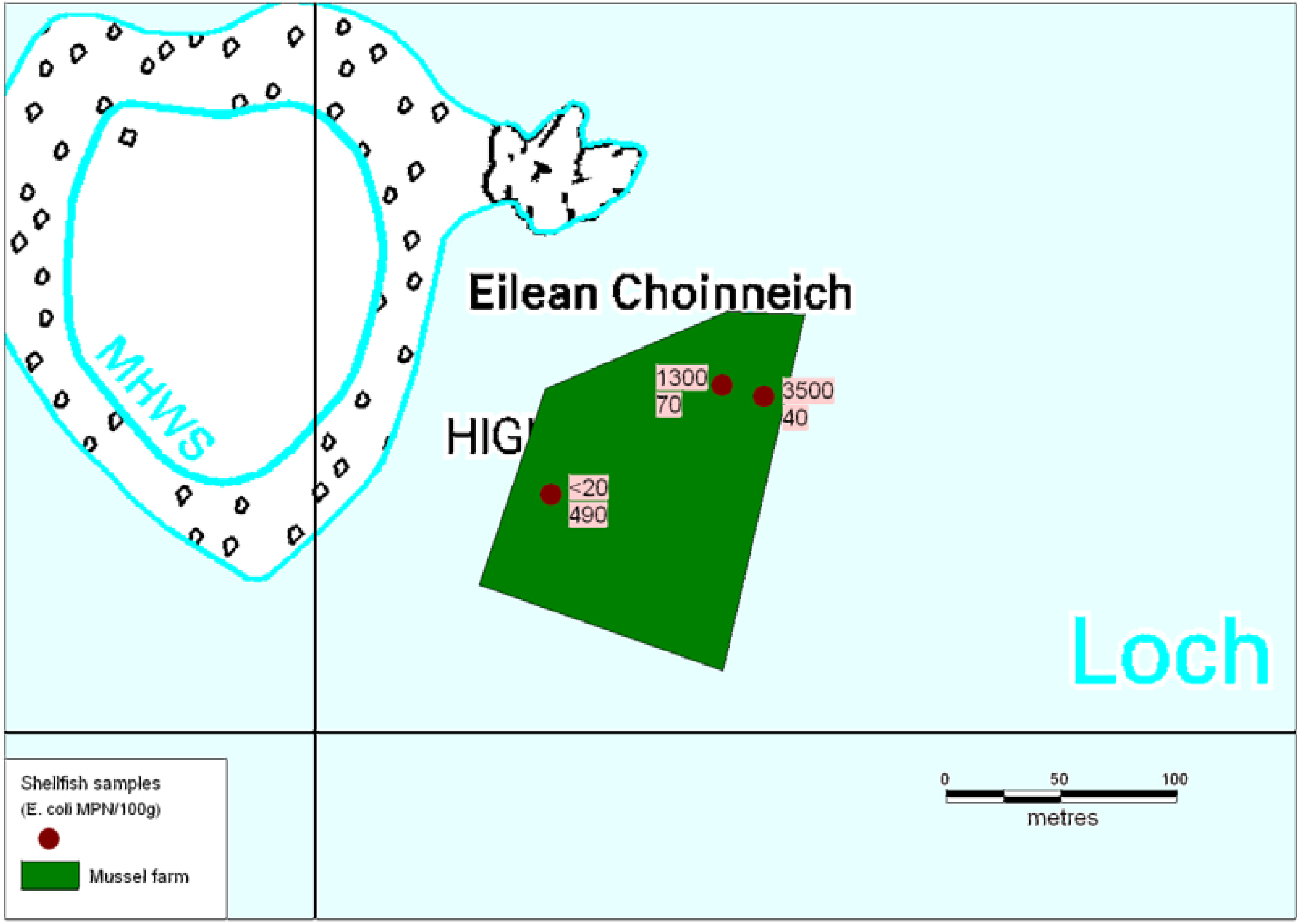

Figure 3. Shellfish sample results map

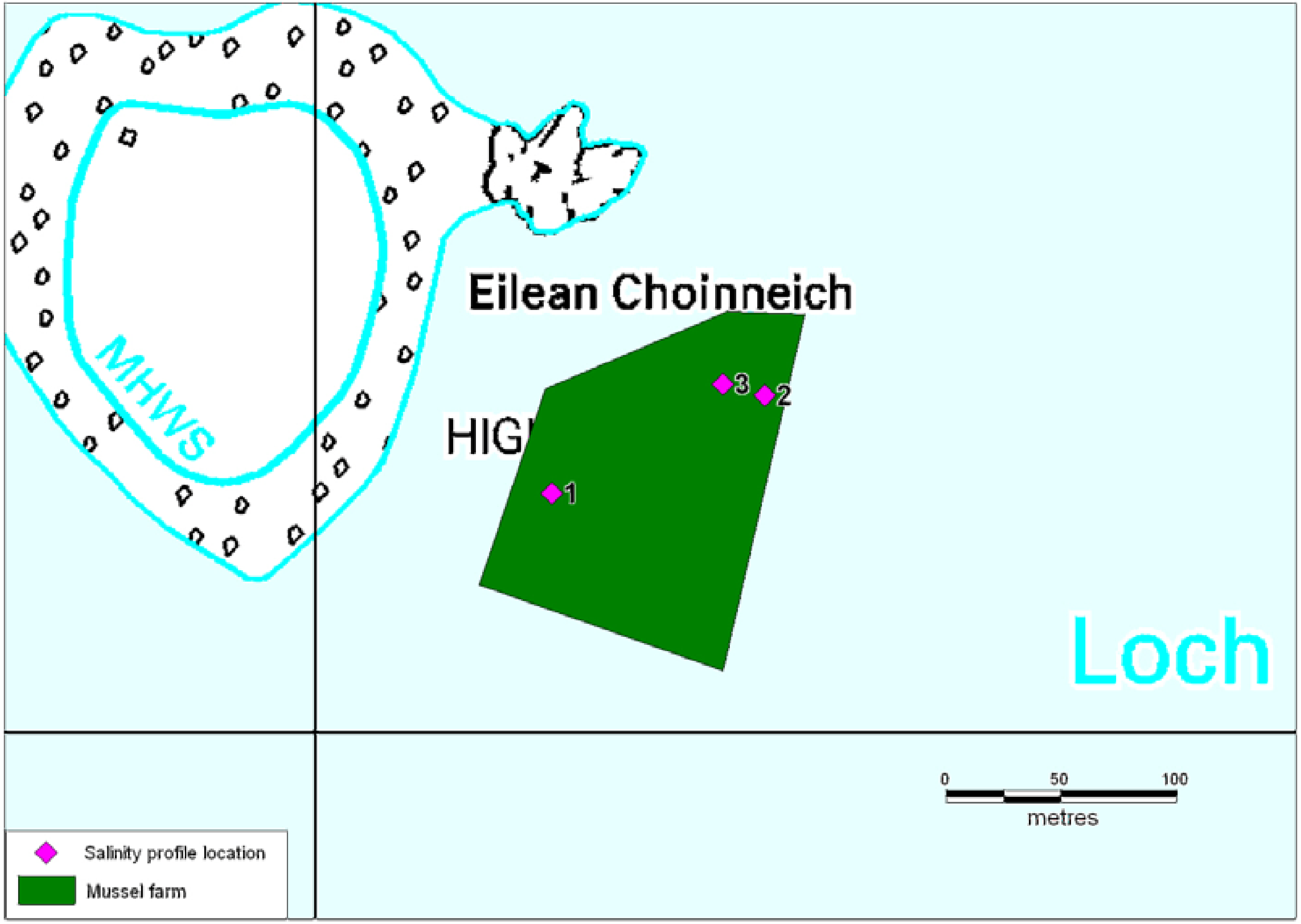

Figure 4. Salinity profile locations

Photographs

Figure 5. Pipe running from property

Figure 6. Laroch River


Figure 7. Possibly disused pipe by hotel


Figure 8. Stream running through concrete pipe

Figure 9. River Coe at road bridge

Figure 10. Part of Glencoe Waste Water Pumping Station site

Figure 11. Pipes running out from Glencoe WWPS

Figure 12. Mussel rafts

Figure 13. Pipe running out into bay from property

Figure 14. North Ballachulish Waste Water Treatment Works

Figure 15. Boats in the vicinity of Glencoe