Scottish Sanitary Survey Programme

Sanitary Survey Report

Tong Sands

LH-605-1100-04

August 2013

Cefas

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Buidheann Inbhe-Bìdhe

Report Distribution – Tong Sands

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Partner Organisations

The hydrographic assessment and the shoreline survey and its associated report were undertaken by SRSL, Oban.

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I. Executive Summary

A sanitary survey was undertaken at Tong Sands as it had been the subject of a new standard track classification application. Tong Sands is located on the northeast side of the Isle of Lewis in the Western Isles. It is a brackish lagoon which lies adjacent to the northeastern outskirts of the town of Stornoway. The lagoon opens to the east through a narrow mouth. The shellfishery consists of a wild cockle bed that covers most of the area of the lagoon. The cockle bed was first classified in March 2013 and currently has a C classification from June to December and a B classification outside this period.

The lagoon in which the Tong Sands cockle bed is situated is subject to significant faecal contamination from both continuous and intermittent sewage discharges associated with both the outskirts of Stornoway and the smaller communities in the area. During the shoreline survey, areas of crofted land were found to the north and east and to the southeast of the cockle bed and livestock were observed near the southwest and southern shores. Wildlife, including seabirds and seals will add to the contamination in the area but no significant overall spatial element has been identified. Watercourse loadings estimated from shoreline survey observations indicate that most contamination from these sources will be at the northwestern and southwestern parts of the cockle bed.

The harvester plans to harvest primarily during the summer tourist season, for local sale to consumers. The restricted number of monitoring results available indicates that contamination levels are highest during summer and autumn.

Within the lagoon itself, the ebb and flood tides are likely to follow the deeper channel of the river which will carry contaminants around the end of the sandspit at Teanga Tunga. Freshwater flow to the lagoon is likely to carry contaminants outward over the cockle bed. On the flood tide, contaminants discharged from the Tong ST outfall may enter Tong Sands and be taken across the cockle bed.

It is recommended that the previously defined production area be reduced in size to exclude some of the main sources of contamination on the northwestern, southwestern and southern sides of the lagoon. This will not exclude any parts of the estimated location of the present cockle bed. It is recommended that the RMP be relocated to the southwestern side of the bed in order to reflect contamination arising from the Stornoway sewerage network and diffuse pollution transported by the watercourses in that location. It is recommended that monitoring be undertaken on a monthly basis, due to the seasonal trend seen in the available classification data. However, such monitoring may not fully reflect the risk from the intermittent discharges in the area.

II. Sampling Plan

Production Area	Tong Sands
Site Name	Tong Sands Cockles
SIN	LH-605-1100-04
Species	Common cockles
Type of Fishery	Hand raked
NGR of RMP	NB 4380 3440
East	143800
North	934400
Tolerance (m)	100
Depth (M)	Not applicable
Method of Sampling	Hand
Frequency of Sampling	Monthly
Local Authority	Comhairle nan Eilean Siar
Authorised Sampler(s)	Paul Tyler
Local Authority Liaison Officer	Colm Fraser

III. Report

1. General Description

Tong Sands, known variously as Tong Saltings, Tong Beach or Cockle Ebb is a shallow brackish lagoon (Scottish Natural Heritage, 2013), at the confluence of Abhainn Lacasdail, Abhainn a' Ghlinne Dhuibh and several smaller streams, which drain to Broad Bay (Loch a Tuath) on the northeastern side of the Isle of Lewis. The flats are sheltered from the sea by a shingle ridge, Teanga Tunga, which extends from north to south separating Tong Sands from Melbost Sands (Traigh Mhealaboist) beach.

The land to the west of the lagoon is wetland, but the north and south is agricultural land. The outskirts of Stornoway, the largest town in the Western Isles, bound the southern shore of the lagoon together with the smaller settlement of Steinish.

The sanitary survey at Tong Sands is being undertaken due to the submission of a standard application for classification of the area for the harvest of common cockles. An overview map of the survey area is shown in Figure 1.1.

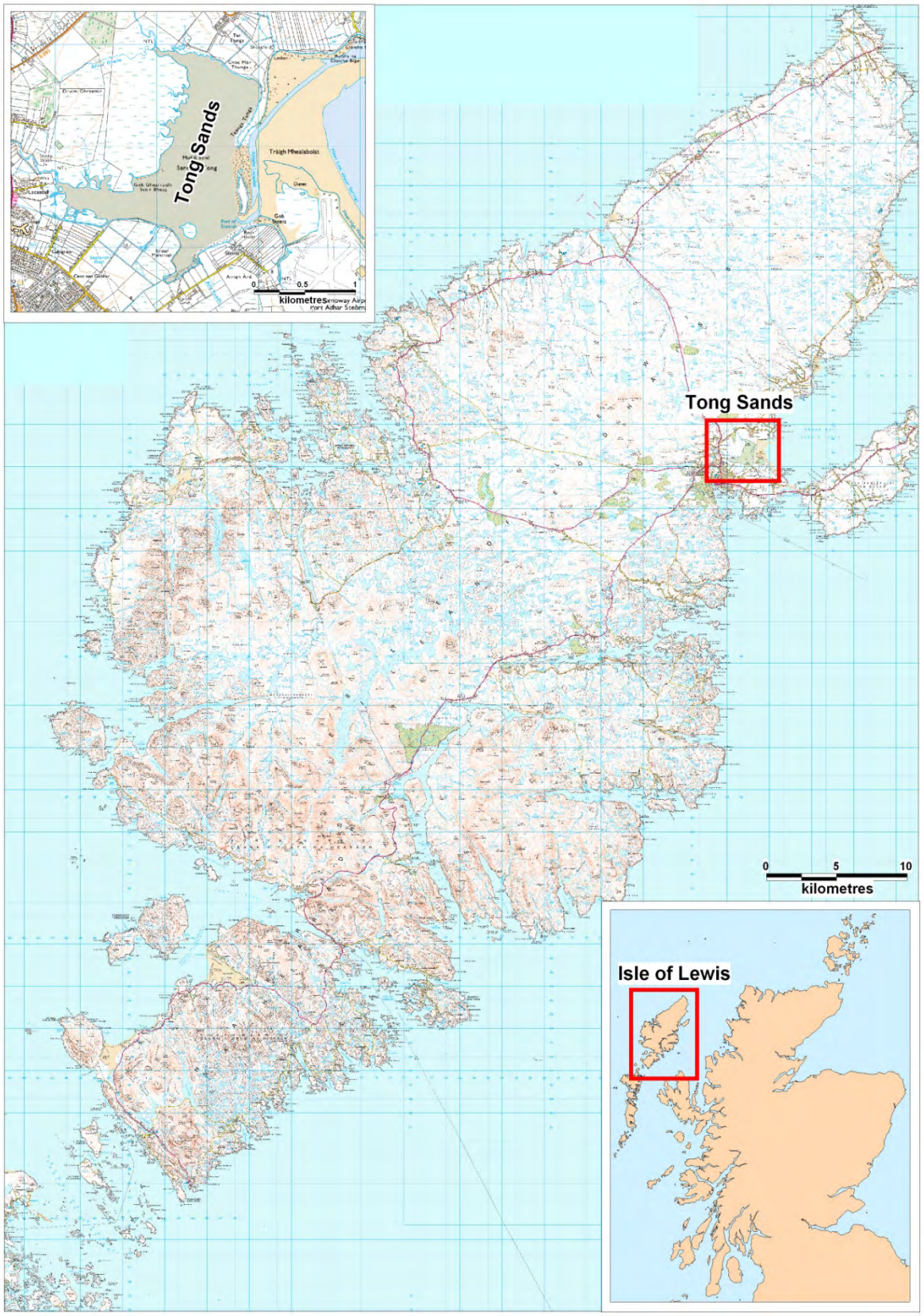

Figure 1.1 Location of survey area

2. Fishery

The fishery at Tong Sands is comprised of a single site; Tong Sands Cockles (LH-605-1100-04), harvesting wild common cockles (*Cerastoderma edule*)

The area was first classified in March 2013, with an RMP at NB 4461 3523. Sampling has been undertaken since February 2012 from the vicinity of NB 445 355.

On the 25th January 2010 a regulation was put in place by the Scottish Government prohibiting the fishing for cockles less than 30 mm in size within inshore areas throughout the Western Isles (Scottish Government, 2009). This includes Lewis.

The extent of the cockle bed had been identified in a survey of Western Isles cockle grounds in 2000 (Howell, et al., 2001) and is mapped in Figure 2.1.

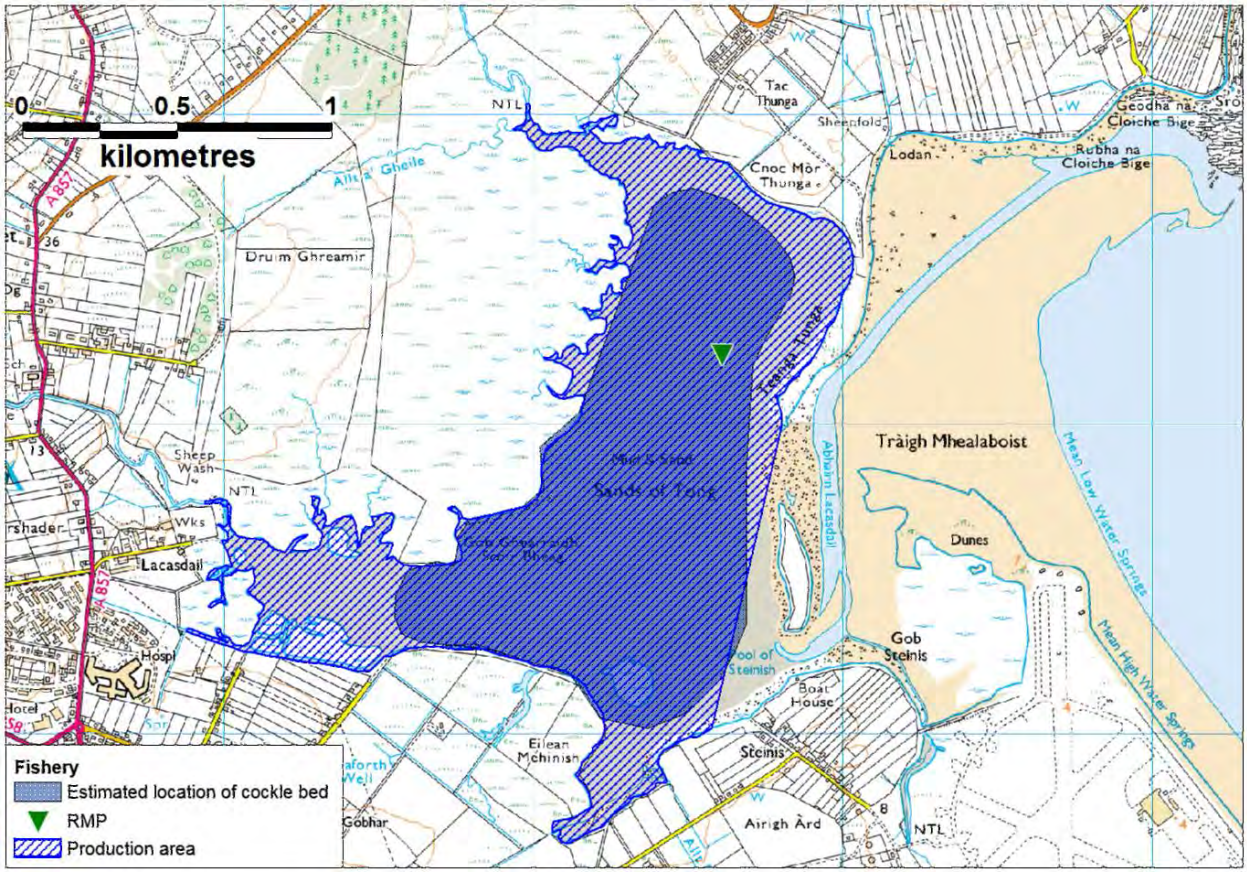

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Figure 2.1 Tong Sands fishery

3. Human Population

Information was obtained from the General Register Office for Scotland on the population within the census output areas in the vicinity of Tong Sands. The last census was undertaken in 2011. However, this 2011 census data was unavailable at the time of writing this report and therefore data from the 2001 census was used.

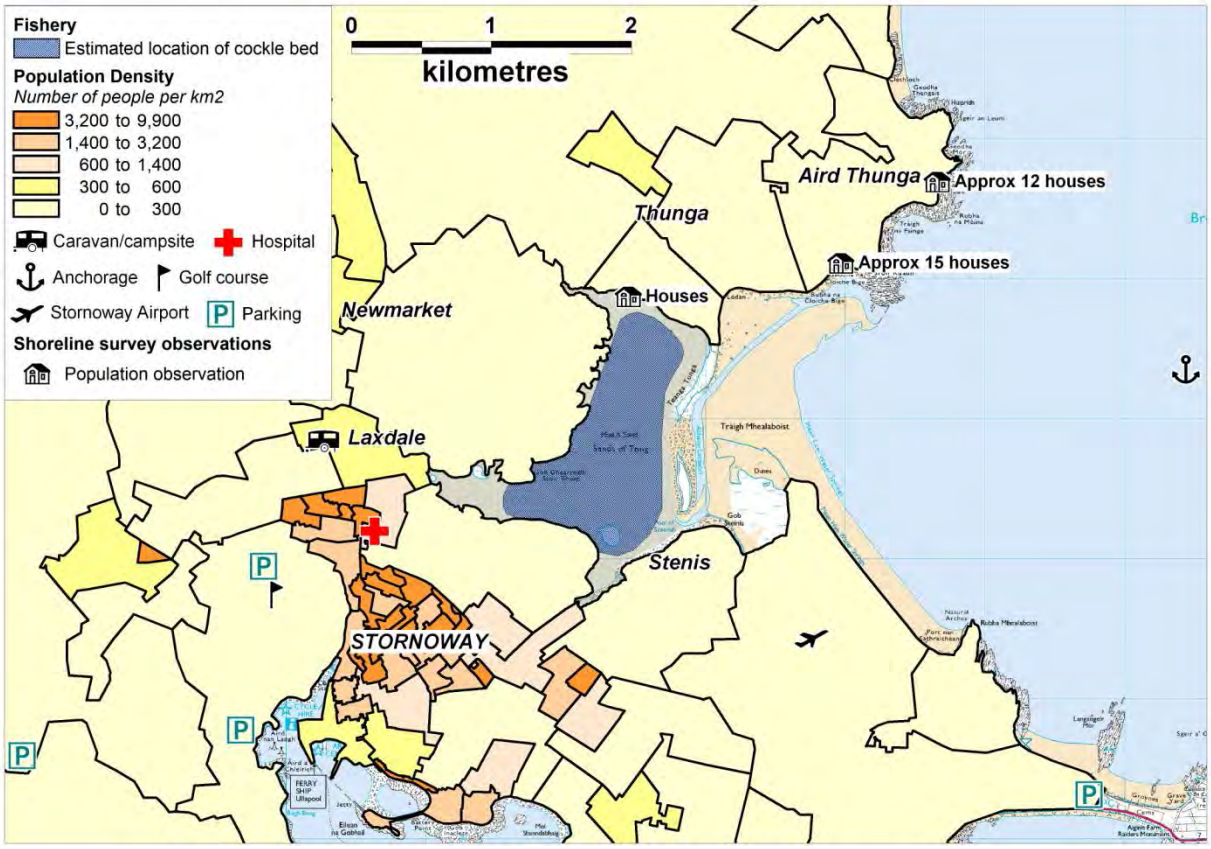


Figure 3.1 Population map of Tong Sands

Figure 3.1 shows that population density is high for the census output areas representing the town of Stornoway and low elsewhere along the coastline. The large majority of the population for the area is located in the town of Stornoway, on the southwest shore of Tong Sands. An updated estimate for the population of Stornoway only was obtained via the internet from Comhairle Nan Eilean Sar Council (Comhairle nan Eilean Siar, 2012). This identified a 2011 estimated population of 5,660, however did not provide a breakdown by census area.

Stornoway is the largest settlement in the Outer Hebrides, with local amenities including schools, an airport, hospital, lifeboat station and a ferry port/harbour. The town also has a large number of bed and breakfasts, self catering accommodation, a few hotels and a caravan/campsite is located on the northern outskirts of town. There is a golf course west of Stornoway. There is a ferry service from Ullapool to

Stornoway which runs a daily service, with an increased timetable in the summer months.

Passenger numbers reported at Stornoway airport for 2012 show seasonal dips in passenger numbers in December-January and July-August with the highest numbers of passengers in September and October, suggesting that seasonal increases in visitors may not strictly coincide with the traditional peak tourist season of June-August (http://www.airportpartners.co.uk/graphics/Stornoway_ms.pdf)

The smaller settlements of Steinis, Laxdale, Newmarket, Thunga and Aird Thunga lie close to the shoreline of Tong Sands. During the shoreline survey, houses were observed along the shoreline north of the fishery.

An anchoring area is provided in Broad Bay, approximately 4 km north east of Tong Sands.

Due to the large permanent settlements around the area, impacts from human sources to the water quality at Tong Sands are likely to be relatively stable year round. There is tourist accommodation in the area, and therefore there may be seasonal increases in population due to tourism. However, there is some evidence to suggest that this may not strictly coincide with the traditional summer school holiday months of July and August.

4. Sewage Discharges

Information on sewage discharges to Tong Sands was sought from Scottish Water and the Scottish Environment Protection Agency (SEPA). Scottish Water identified 35 community septic tanks and sewage discharges for the area surrounding Tong Sands. Only discharges within a 3 km radius were included in this analysis and excluded discharges from Stornoway, which will not impact Tong Sands due to the nature of the coastline. Eight Scottish Water discharges were extracted and they are detailed below in Table 4.1

Table 4.1 Discharges identified by Scottish Water

Consent No.	Discharge Name	NGR	Discharge Type	Level of Treatment	Flow (m^3d)	PE	Overflow Setting (l/sec)
CAR/L/1002949	Steinish ST	NB 4470 3410	Continuous	Septic tank	31.5	-	-
CAR/L/1002949	Steinish ST PS CSO+EO	NB 4470 3410	Intermittent	6 mm screen	31.5		6
CAR/L/1026181	Simons Rd CSO	NB 4440 3360	Intermittent	-	-	-	-
CAR/L/1001872	Tong ST	NB 4610 3610	Continuous	Septic tank	310.5	1035	-
CAR/L/1001872	Tong ST CSO	NB 4610 3610	Intermittent	6 mm screen	310.5	-	20
CAR/L/1026181	Sandwick CSO	NB 4400 3200	Intermittent	-	-	-	-
WPC/N/62145	Tong Road ST	NB 4370 3640	Continuous	Septic tank	4	13	-
CAR/L/1026181	Stornoway (Bayhead Rd) CSO	NB 4245 3340	Intermittent	6 mm screen		-	-

-No data provided, ST – Septic Tank, PS – pumping station, CSO – combined sewage overflow

Information on design/consented population equivalent, predicted spill frequency, microbiological data and planned improvements was also sought from Scottish Water for the eight listed discharges in Table 4.1. Population equivalent data was provided for two continuous discharges and overflow setting information was also given for two intermittent discharges. The remaining requested information was not provided.

SEPA provided information on 39 consented discharges in the general vicinity of Tong Sands. Of these, 19 discharge are located within the immediate vicinity of the fishery. These are listed below in Table 4.2 and shown in Figure 4.1.

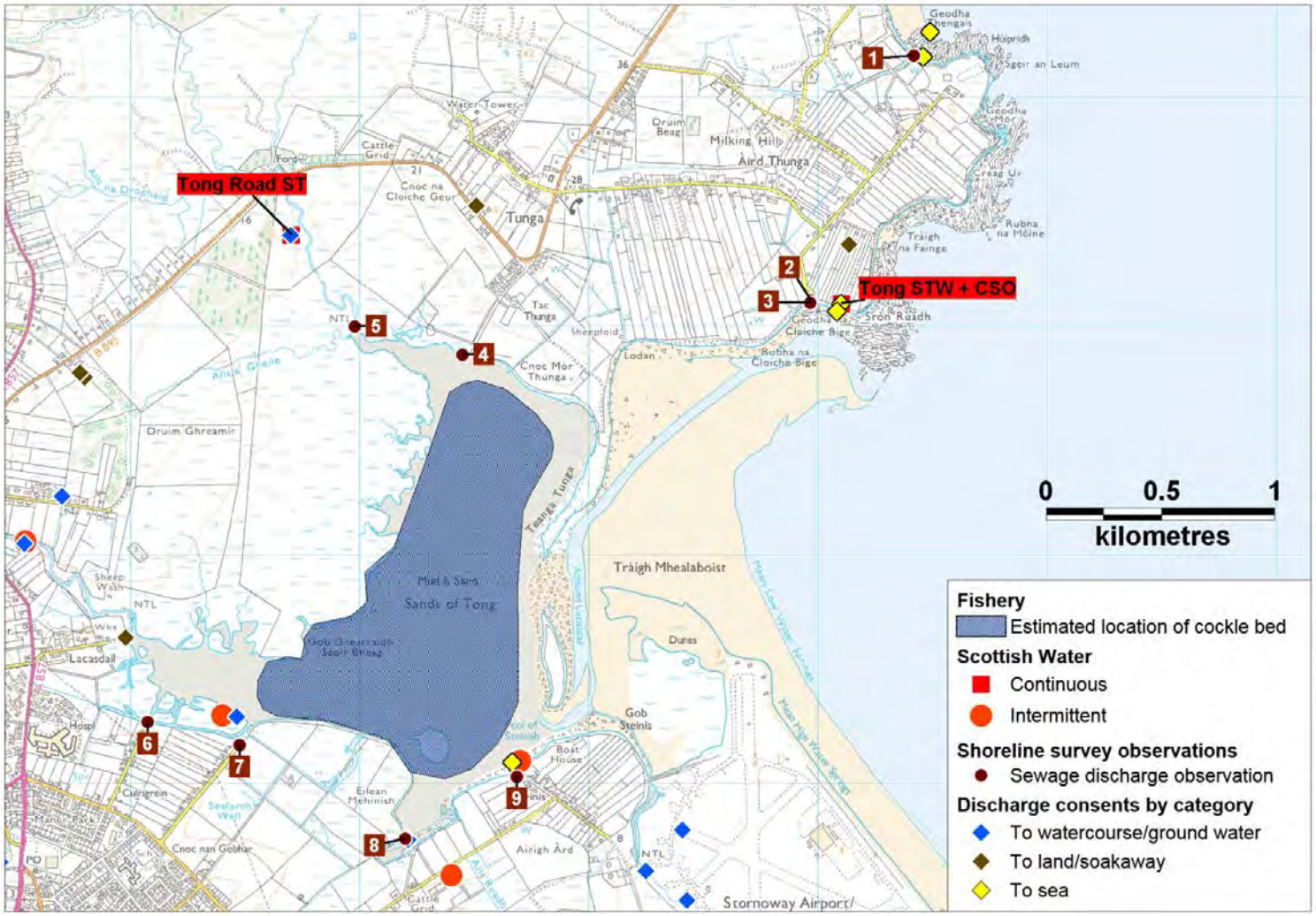


Figure 4.1 Map of consented and observed sewage discharges to Tong Sands

Table 4.2 Discharge consents identified by SEPA in the immediate vicinity of Tong Sands

No	Consent No.	NGR	Discharge Type	Level of Treatment	Flow (m^3/d)	PE	Discharges to
1	CAR/L/1001872	NB 46084 36066	Continuous	Septic tank	310.5	1035	Broad Bay
2	CAR/L/1001872	NB 46100 36100	Intermittent	CSO	-	-	Broad Bay
3	CAR/L/1026181	NB 44212 33756	Intermittent	EO	-	-	Abhainn Lacasdail
4	CAR/L/1026181	NB 42538 35051	Intermittent	CSO	-	-	Abhainn Lacasdail
5	CAR/L/1026181	NB 43465 34293	Intermittent	CSO/EO	-	-	Abhainn Lacasdail
6	CAR/L/1026181	NB 44667 34095	Intermittent	CSO/EO	-	-	Pool of Tong
7	WPC/N/62145	NB 4370 3640	Continuous	Unspecified sewage	-	-	Unspecified
8	CAR/L/1089168	NB 46490 37290	Intermittent	CSO/EO	-	-	Loch a Tuath (Broad Bay)
9	CAR/L/1089168	NB 46460 37180	Intermittent	EO	-	-	Loch a Tuath (Broad Bay)
10	CAR/R/1040036	NB 46136 36361	Continuous	Septic tank	-	7	Soakaway
11	CAR/R/1051311	NB 45487 33189	Continuous	Septic tank	-	5	Land
12	CAR/R/1041261	NB 42980 34640	Continuous	Septic tank	-	5	Soakaway
13	CAR/R/1055763	NB 42800 35780	Continuous	Septic tank	-	6	Soakaway
14	CAR/R/1041228	NB 42780 35800	Continuous	Septic Tank	-	5	Soakaway
15	CAR/R/1057200	NB 42702 35258	Continuous	Septic Tank	-	5	Unnamed tributary of Abhainn Lacasdail
16	CAR/R/1022445	NB 44510 36530	Continuous	Septic Tank	-	5	Soakaway
17	I/B19/079/98	NB 4525 3362	Trade/runway	Interceptors	-	-	Surface water
18	I/B19/080/98	NB 4543 3349	Trade/runway	Interceptors	-	-	Surface water
19	CAR/L/1003095	NB 45410 33800	Trade effluent	Unspecified	-	-	Ground water

-No data provided, OE – other effluent, EO – Emergency Overflow, CSO – Combined sewage overflow

The majority of discharge consents identified by SEPA related to parts of the public sewerage network in the area. SEPA identified that one of the discharges reported by Scottish Water as continuous, CAR/L/1002949 Steinish ST, had been revoked as the septic tank had been removed and replaced with a pumping station and associated CSO/EO under CAR/L/1026181. This has been amended in Figure 4.1 to show the discharge as intermittent rather than continuous.

There were a small number of identified discharges from private septic septic tanks, most of which discharge to soakaway. One of these (No. 12, Table 4.2) is identified within 25 m of MHWS, near an area of marshy ground and therefore may contribute to faecal contamination of ground water in the near vicinity. One private septic tank discharges to a small stream that joins the Abhainn Lacasdail upstream of Tong Sands.

Three trade discharges associated with Stornoway Airport were identified by SEPA. One relates to discharge of effluent associated with the fire training ground and the other two relate to surface water discharge that may contain chemical de-icing compounds, particularly during the winter months.

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	Descriptions
1	11/03/2013	NB 4642 3718	Discharge pipe encased in concrete, no discharge visible.
2	11/03/2013	NB 4597 3611	Pipe running under road onto the shore. Discharge coming from pipe.
3	11/03/2013	NB 4596 3610	Possible storm overflow, not flowing. Possible septic tanks / storage tanks with houses behind.
4	11/03/2013	NB 4445 3587	Discharge pipe flowing. Houses behind. Freshwater sample taken returned result of 1000 *E. coli* cfu/ 100 ml.
5	11/03/2013	NB 4398 3600	Cast iron discharge pipe enclosed in concrete. Looks contaminated. Village behind. Diameter - 15 cm. Sample 2200000 *E. coli* cfu/ 100 ml.
6	11/03/2013	NB 4307 3427	Open man-hole cover with pump.
7	11/03/2013	NB 4348 3417	Scottish Water Station, Sand Street Pumping Station.
8	12/03/2013	NB 4420 3376	Discharge pipe. Large cast iron pipe with storm valve on end. Approx. 30 cm diameter.
9	12/03/2013	NB 4468 3403	Scottish Water sewage compound storage chamber - green kiosk (Steinish). Discharge pipe onto shore.

Observation 5 relates to a cast iron outfall pipe discharging to the upper part of the lagoon roughly in a line with reported location of the Tong Road ST. The end of the pipe was submerged at the time of survey, though a greyish discharge plume could be seen. A water sample taken from this plume returned a result of 2.2×10^6 *E. coli* cfu/ 100 ml, which is consistent with settled septic tank sewage (Appendix 2). Therefore, this outfall is presumed to be from the Tong Road ST.

Another discharge suspected to be from a house was sampled (observation 4), but returned a moderate result of 1000 *E. coli* cfu/ 100 ml. The contents were therefore unlikely to represent raw sewage, though the result was still indicative of significant faecal input.

Overall Tong Sands cockle bed is exposed to both continuous and intermittent sewage discharges from community and private sources. The largest public continuous contamination source is Tong ST, though both final effluent and intermittent discharges from the CSO are identified as discharging to Broad Bay, the location plots to the channel representing the mouth of the Abhainn Lacasdail.

Contamination from this source may be carried into the cockle bed as it follows the incoming tide up the river channel.

The discharge pipe from the Tong Road ST was found to discharge approximately 500 m to the north of the cockle bed. Although the reported flow for this discharge is relatively small, it represents the largest continuous input directly to the upper lagoon and is likely to impact water quality particularly at the northern end of the cockle bed. The discharge from the house along the north shore will also contribute to contamination levels at the north end of the bed.

Intermittent discharges from the CSOs are likely to significantly impact the southern end of the cockle bed when they discharge.

5. Agriculture

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 Stornoway parish. Reported livestock populations for the parish in 2012 are listed in Table 5.1. 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 5.1 Livestock numbers in the Stornoway parish 2012

	Stornoway	
	254 km^2	
	2012	
	Holdings	Numbers
Pigs	23	93
Poultry	97	1578
Cattle	51	507
Sheep	376	17058
Other horses and ponies	44	92

The Stornoway parish covers the north eastern side of the Isle of Lewis and the Eye Peninsula, encompassing a land area of over 250 km^2 (shown in the inset of Figure 5.1). Because the livestock census numbers relate to such a large parish area, it is not possible to determine the spatial distribution of the livestock in relation to the Broad Bay area or identify how many animals are likely to impact the catchment around Tong Sands. Therefore the figures are of little use in assessing the potential impact of livestock contamination to the fishery; however they do give an idea of the total numbers of livestock over the broader area.

There is a dairy farm inland to the south of Tong Sands. Any farm-related runoff would be carried via the unnamed watercourse running parallel to the farm towards Tong Sands. There is also a poultry farm inland to the west of Tong Sands and any farm-related runoff would be carried via the river Abhainn Lacasdail running east into the fishery. Exact numbers of animals at each of these farms were not available.

The only significant source of spatially relevant information on livestock population in the area was the shoreline survey (see Appendix 5) which only relates to the time of the site visit during 11th – 12th March 2013 (see Table 5.1). Observations made during the survey are dependent upon the viewpoint of the observer some animals may have been obscured by the terrain. The spatial distribution of animals observed

and noted during the shoreline survey is illustrated in Figure 5.1. This shows that the greatest impact from farm animals would be expected to be on the southern end of the cockle bed, although the extent of this impact would be expected to be low to moderate on the basis of the small number of animals observed.

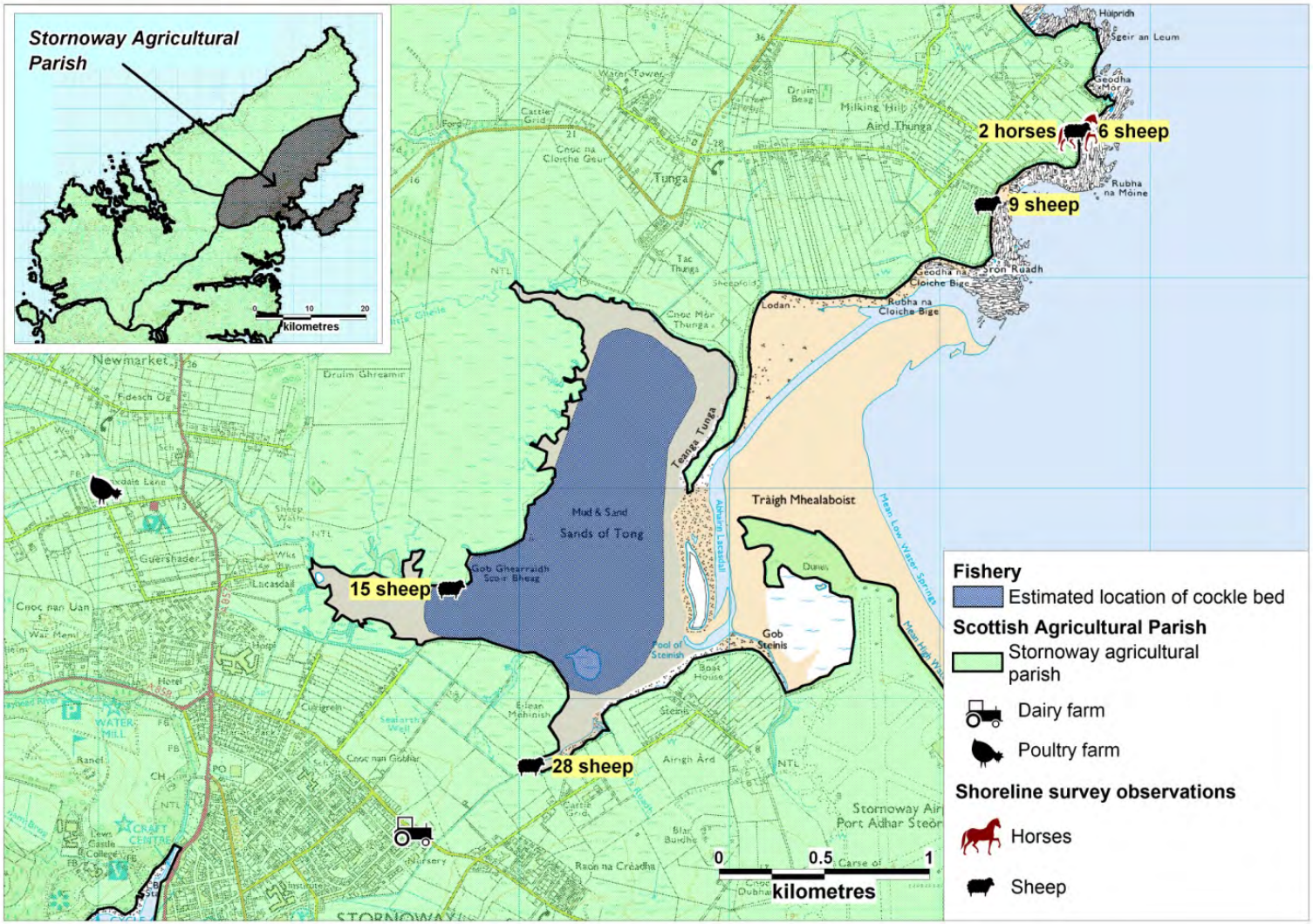


Figure 5.1 Agricultural parish boundary and livestock observations at Tong Sands

6. Wildlife

The cockle bed at Tong Sands lies within an lagoon that has salt marsh, tidal mud flat, sand dune and sand/shingle bank habitats likely to be used by a number of species, including breeding seabirds, migrating waders and waterfowl, seals, and otters.

Pinnipeds

The common/harbour seal (*Phoca vitulina*) and the grey seal (*Halichoerus grypus*) are commonly found around Tong Sands.

The Outer Hebrides is an important area for grey seal populations, with the majority of the UK population concentrated here. These populations have increased over recent years (Special Committee on Seals, 2011) with 12,857 pups born in 2010, a 2.9% increase since 2005.

Common seals are also widespread in the Outer Hebrides, though populations are estimated to be declining at a rate of 3% per annum since 1996, with a total decrease of 38% since 2000 (Special Committee on Seals, 2011).

In a report by the Sea Mammal Research Unit (Special Committee on Seals, 2009) numbers of common seals at Tong Sands were estimated at 200-250 and grey seals 31-50. The sheltered sand banks at Tong Sands are the preferred habitat for common seals, with grey seals likely to be more prevalent on the exposed western shorelines of the Outer Hebrides.

Grey seals have been reported to travel great distances, between the Outer Hebrides, Orkney Islands, Shetland Islands and North Sea (Special Committee on Seals, 2011). Both adults and pups have large foraging patterns and it is likely that grey seals around Tong Sands are constantly in transit and therefore impacting the fishery sporadically. Common seals are shown to have smaller foraging distances and therefore may have a greater faecal contamination impact at Tong Sands compared to grey seals. In addition, the sheltered sand banks at Tong Sands are also ideal habitat for common seals, with grey seals more commonly associated with exposed shorelines. No seals were observed during the shoreline survey.

Cetaceans

The Minch is the water body adjacent to Tong Sands, separating western mainland Scotland and the Outer Hebrides. It is a key feeding area for whales and dolphins, including the white beaked dolphin (*Lagenorhynchus albirostris*) and common dolphin (*Delphinus Delphis*). However, there are no sightings recorded for cetaceans around Tong Sands (Hebridean Whale and Dolphin Trust, 2013) and the

shallowness of the area would suggest it is an unsuitable habitat for these species. No cetaceans were observed during the shoreline survey.

Seabirds

No RSPB reserves are situated at Tong Sands or nearby, and therefore bird population data was unavailable from that source. Seabird 2000 census data (Mitchell, et al., 2004) was queried for the area within a 5 km radius of the estimated cockle bed at Tong Sands and is summarised in Table 6.1 below. This census undertaken between 1998 and 2002 covered the 25 species of seabird that breed regularly in Britain and Ireland.

Table 6.1 Seabird species found at Tong Sands, from the Seabird Census 2000.

Common Name	Species	Count	Qualifier
Northern Fulmar	*Fulmarus glacialis*	4	Occupied sites
Little Tern	*Sterna albifrons*	20	Occupied nests
Arctic Tern	*Sterna paradisaea*	1300	Occupied nests

The Arctic Tern and Little Tern colonies are located on the sand dune system southeast of the Tong Sands cockle bed. The Northern Fulmar colony is located 2.5 km southeast of the cockle bed, and is therefore unlikely to represent a direct contamination source. All three species of birds are likely to use the cockle bed and surrounding tidal flats and salt marshes from time to time, for resting and/foraging, creating a sporadic contamination source to the cockle bed.

The tidal flats and the salt marsh habitats at Tong Sands are also important for birds such as waders and waterfowl, and for wintering populations of Slavonian grebes and eider ducks (Comhairle nan Eilean Siar; Environmental and Protective Services Comittee, 2011).

During the shoreline survey gulls, geese and a pigeon were all noted around Tong Sands, with duck droppings also observed on salt marsh northwest of the estimated cockle bed area (Figure 6.1). The large majority of sightings were made on habitats surrounding the cockle bed, confirming that these areas are used by seabirds and waterfowl.

Otters

There are anecdotal accounts of the Eurasian otter (*Lutra lutra*) around Tong Sands, particularly close to watercourses (Lewis Wind Power, 2011) but at the time of this report no population data was available. No otters were observed during the shoreline survey.

Overview

Species potentially impacting on Tong Sands include seabirds, waterfowl such as geese and seals. Impacts from breeding seabirds and seals would be expected to be higher along the southern and eastern sides of the cockle bed, while direct impacts from birds feeding on the intertidal mud and sand flats would be spread widely throughout.

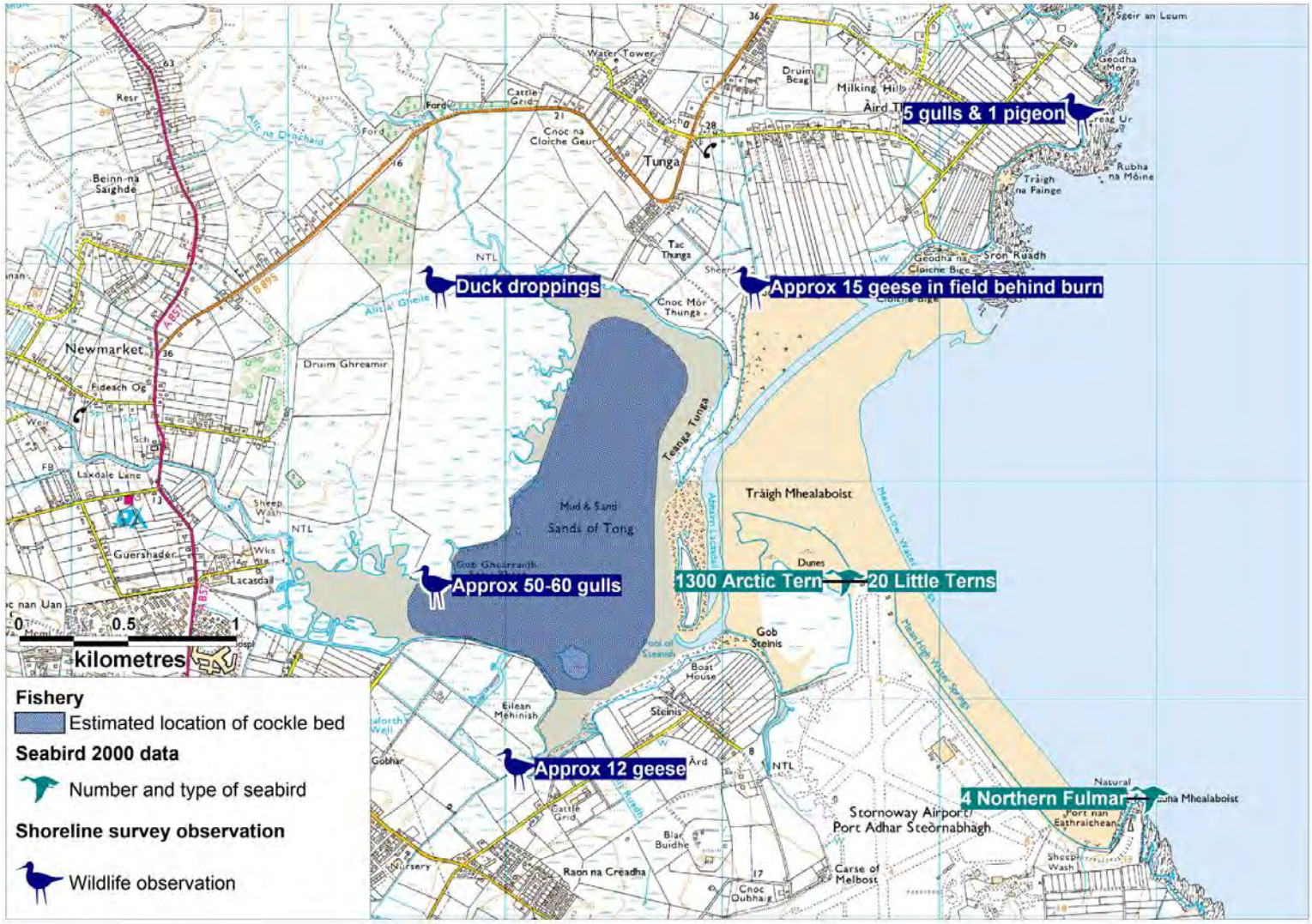


Figure 6.1 Wildlife around Tong Sands

7. Land Cover

The Land Cover Map 2007 data for the area is shown in Figure 7.1. Improved grassland, rough grassland, bog, neutral grassland and dwarf shrub heath are the predominant land cover types on the shoreline surrounding Tong Sands. Stornoway is shown as a suburban and urban area, surrounded by improved grassland and small patches of arable land and coniferous and broad leaved woodland. There is a large area of improved grassland southwest of the fishery and neutral grassland and supra-littoral sediment to the west. Further inland the land cover is a mixture of bog, rough grassland, improved grassland and neutral grassland. Improved grassland to the west of Stornoway coincides with the location of the golf course.

Faecal indicator organism export coefficients for faecal coliform bacteria have been found to be approximately 1.2 – $2.8x10^9$ cfu/km^2/hr for urban catchment areas, approximately $8.3x10^8$ cfu cfu/km^2/hr for areas of improved grassland and approximately $2.5x10^8$ cfu/km^2/hr for rough grazing (Kay, et al., 2008). 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 highest potential contribution of contaminated runoff to the Tong Sands shellfish bed is from the areas of improved grassland west and south west of the fishery. The areas utilised for rough grazing to the north and southeast of the fishery would be expected to contribute significantly to faecal contaminant loading carried in watercourses and overland flow draining the area during rainfall.

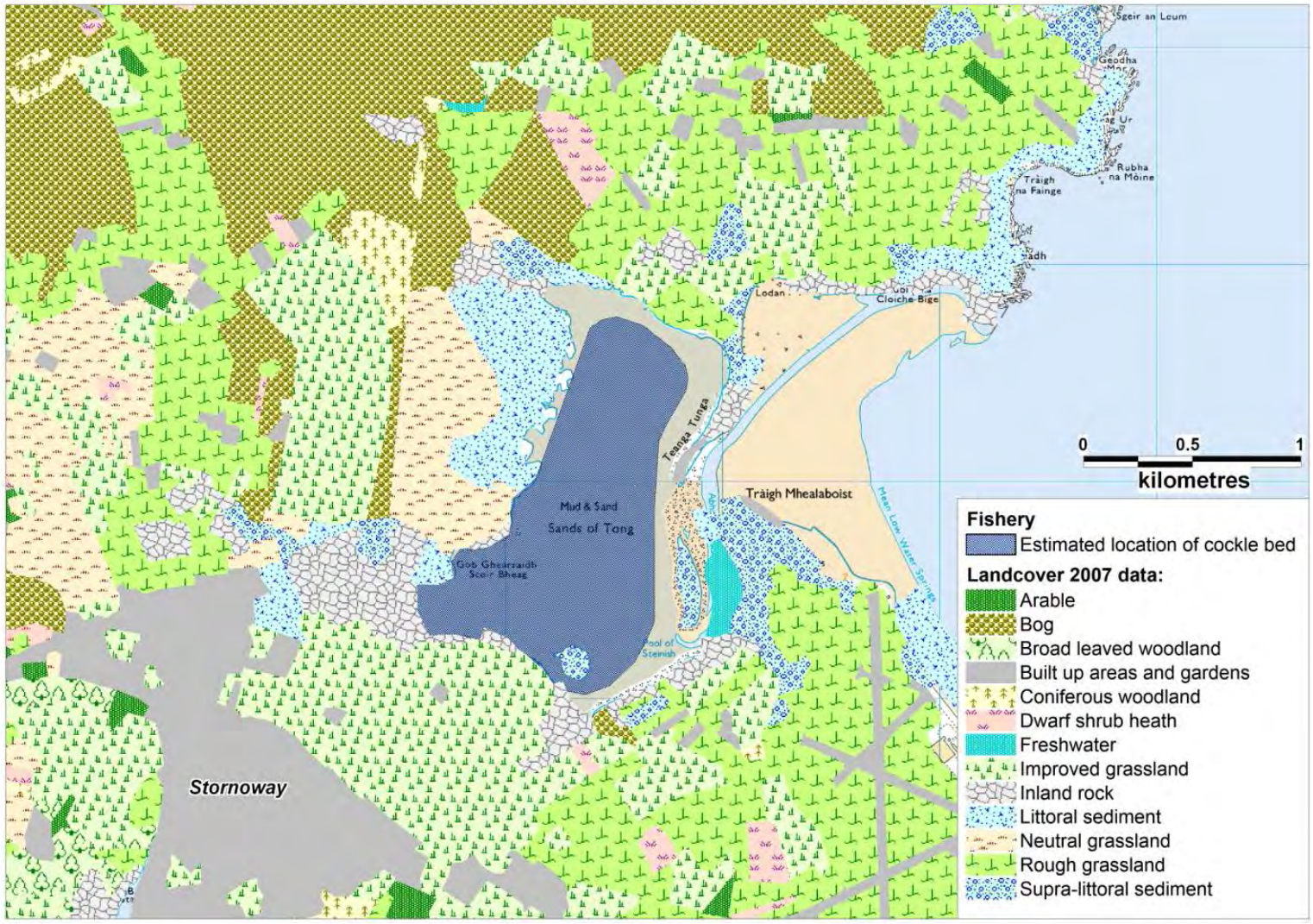


Figure 7.1 LCM2007 land cover data for Tong Sands

8. Watercourses

There are no river gauging stations on watercourses discharging around Tong Sands. The following six watercourses listed in Table 8.1 were measured and sampled during the shoreline survey and represent the largest freshwater inputs into the survey area. No precipitation fell in the 48 hours prior to this survey and it was noted that the last previous 3-4 weeks had been very dry. No precipitation fell on the first survey day (11th March 2013), though snow/sleet/showers fell intermittently on the second day of sampling (12th March 2013).

Table 8.1 Watercourse loadings for Tong Sands

No	Grid Ref	Description	Width (m)	Depth (m)	Flow (m^3/d)	*E. coli* (cfu/ 100 ml)	Loading (*E. coli* per day)
1	NB 4515 3590	Burn	0.70	0.06	620	100	6.2×10^8
2	NB 4393 3613	Abhainn a' Ghlinne Dhuibh	1.70	0.11	1280	400	5.1×10^9
3	NB 4370 3590	Allt a' Gheile	0.33	0.05	360	<100*	3.6×10^8
4	NB 4298 3475	Abhainn Lacasdail	3.70	0.13	10600	<100*	1.1×10^{10}
5	NB 4307 3427	Land drainage	1.50	0.08	280	200	5.6×10^8
6	NB 4442 3385	Allt Ruadh	1.07	0.08	620	<100*	6.2×10^8

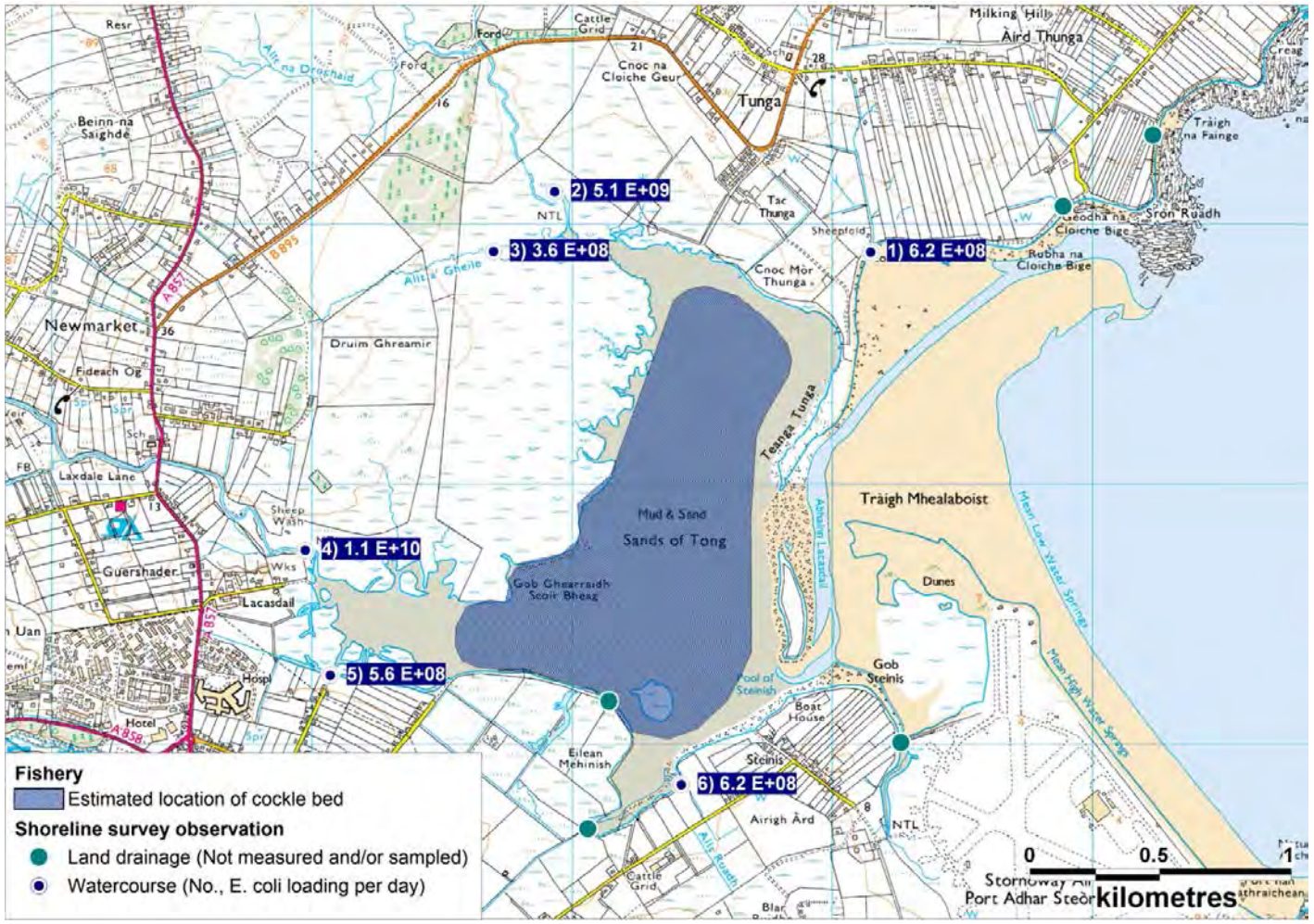
*A nominal assumed value of 100 *E. coli CFU*/100 ml was used to calculate a 'less than' potential loading. NGRs rounded to 10 m, full NGRs found in Appendix 1.

Overall, contamination from freshwater input appears to be moderate. Five out of the six measured watercourses discharge into the estimated cockle bed area at Tong sands, entering at the northwest, southwest and southern sides of the harvest area (Figure 8.1). Watercourse 1 discharges to the northeast and outside the harvest area to Broad Bay. Watercourse 1 loading was calculated at 6.2×10^8 *E. coli*/ day. Due to its location close to the entrance to Tong Sands, contamination is likely to be washed into the harvest area during incoming tides and will spread across the extent of the cockle bed.

Five additional freshwater inputs were noted during the survey. These represented areas of land drainage that were unable to be sampled and/or measured at the time of the survey. These were located to the northeast, south and southeast of the harvest area (Figure 8.1). Contamination from the two land drainage areas to the south of Tong Sands will impact the cockle bed directly adjacent to the discharges. Land drainage from the two areas outside of Tong Sands (northeast and southeast) is likely to be washed into the harvest area during an incoming tide, though this excludes land drainage from the far northeast.

The highest *E. coli* loading entering the harvest area came from Abhainn Lacasdail (No 4 in Table 8.1) to the southwest corner of Tong Sands. Loading was moderately high, calculated at 1.1×10^{10} *E. coli*/ day. Land drainage (No. 5) was observed near to Abhainn Lacasdail and and Alt Ruadh (No. 6) enters at the southeastern extent of the cockle bed. In addition, two other land drainage locations were recorded on the

southern side of the cockle bed but these could not be measured/sampled. All of those inputs would add to the extent of contamination in the area. At the northwestern end of the lagoon, Abhainn a' Ghlinne Dhuibh (No. 2) showed a moderate estimated loading at $5.1x10^9$ E. coli/ day while Allt a' Gheile had a much lower estimated loading at $3.6x10^8$ *E. coli*/day. Overall freshwater contamination inputs to Tong Sands cockle bed are moderate. However, this may reflect the un-seasonally dry weather experienced in the weeks leading up to the survey, which will have reduced flows and possibly the amount of faecal material entering the watercourses. On the basis of the observations and subsequent loading calculations, the main impacts from the watercourses will be at the southwestern and northwestern parts of the cockle bed. Contamination at these locations is likely to be significantly higher during and after periods of wet weather.



Where the bacterial loading is labelled on the map, the scientific notation is written in digital format, as this is the only format recognised by the mapping software. So where normal scientific notation for 1000 is $1x10^3$, in digital format it is written as 1E+3

Figure 8.1 Map of river/stream loadings at Tong Sands

9. Meteorological Data

The nearest weather station for which rainfall data was available is located at Stornoway Airport, situated approximately 2 km to the south east of the fishery. Rainfall data was available for January 2007 – August 2012. At the time of writing this report rainfall data was only available up until August 2012. The nearest wind station is Stornoway Airport, at the same location. Conditions at the wind station and the fishery should be similar and the data can be useful in identifying seasonal variation in wind patterns.

Data for these stations 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 Tong Sands.

9.1 Rainfall

High rainfall and storm events are commonly associated with increased faecal contamination of coastal waters through surface water runoff 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 *.

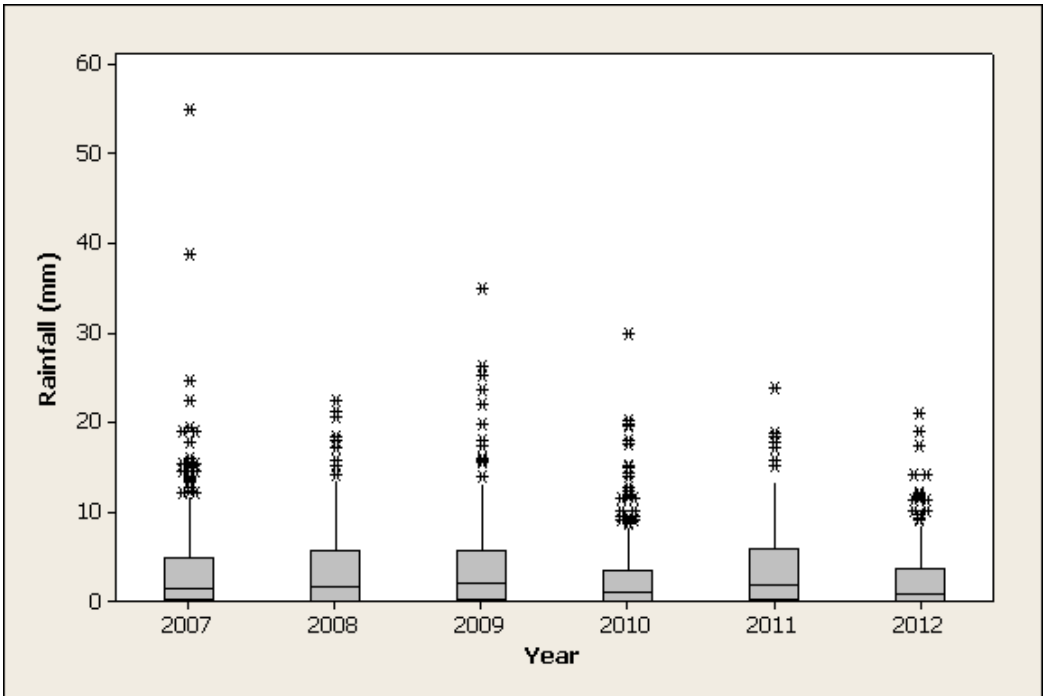


Figure 9.1 Box plot of daily rainfall values by year at Stornoway Airport (2007 – 2012)

Daily rainfall values varied from year to year, with 2010 being the driest year. The wettest year was 2011. High rainfall values of more than 30 mm/d occurred in 2007, 2009 and 2010 and an extreme rainfall event of nearly 60 mm/d was seen in 2007. The missing data for 2012 will affect the appearance of the boxplot.

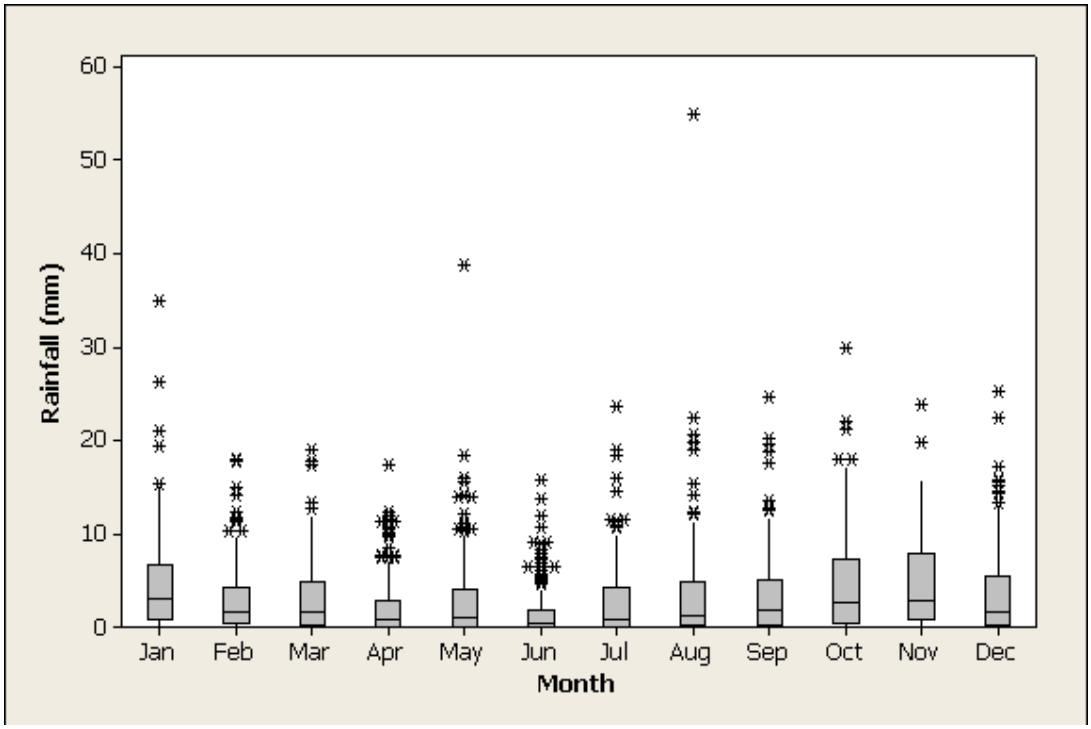


Figure 9.2 Box plot of daily rainfall values by month at Stornoway Airport (2007 – 2012)

Daily rainfall values were higher during the autumn and winter. Rainfall increased from July onward and was highest in October and November. Weather was drier from April to June. Rainfall values exceeding 30 mm/d were seen in January, May and August. The 2007 extreme event occurred in August.

For the period considered here (2007 – 2012) 43 % of days received daily rainfall of less than 1 mm and 8 % of days received rainfall of over 10 mm.

It is therefore expected that runoff due to rainfall will be higher during the autumn and winter months. However, extreme rainfall events leading to episodes of high runoff can occur in most months and when these occur during generally drier periods in summer and early autumn, they are likely to carry higher loadings of faecal material that has accumulated on pastures when greater numbers of livestock were present.

9.2 Wind

Wind data was collected from Stornoway Airport and summarised in seasonal wind roses in Figure 9.3 and annually in Figure 9.4.

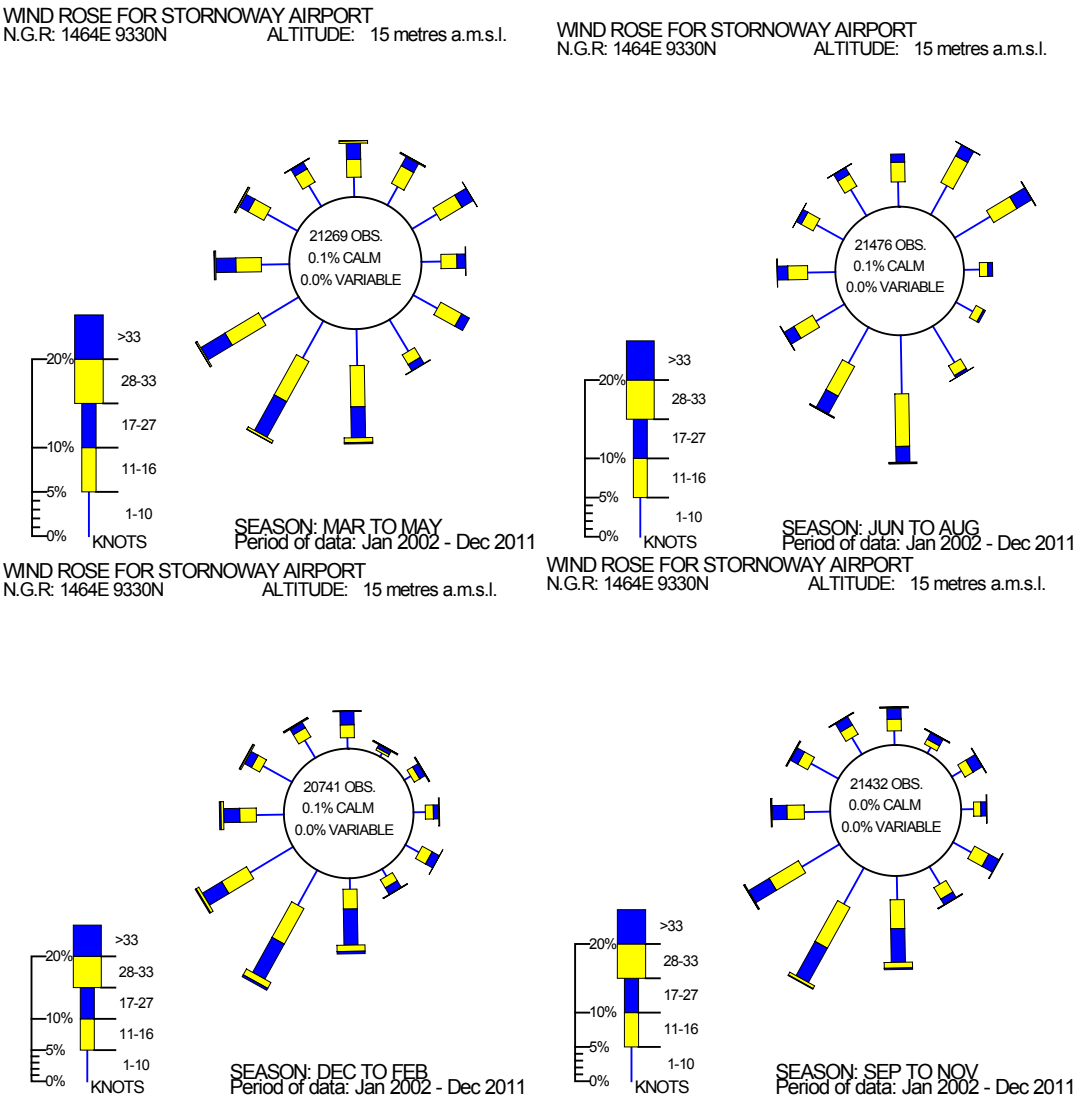


Figure reproduced under license from Meteorological Office. Crown Copyright 2012.

Figure 9.3 Seasonal wind roses for Stornoway Airport

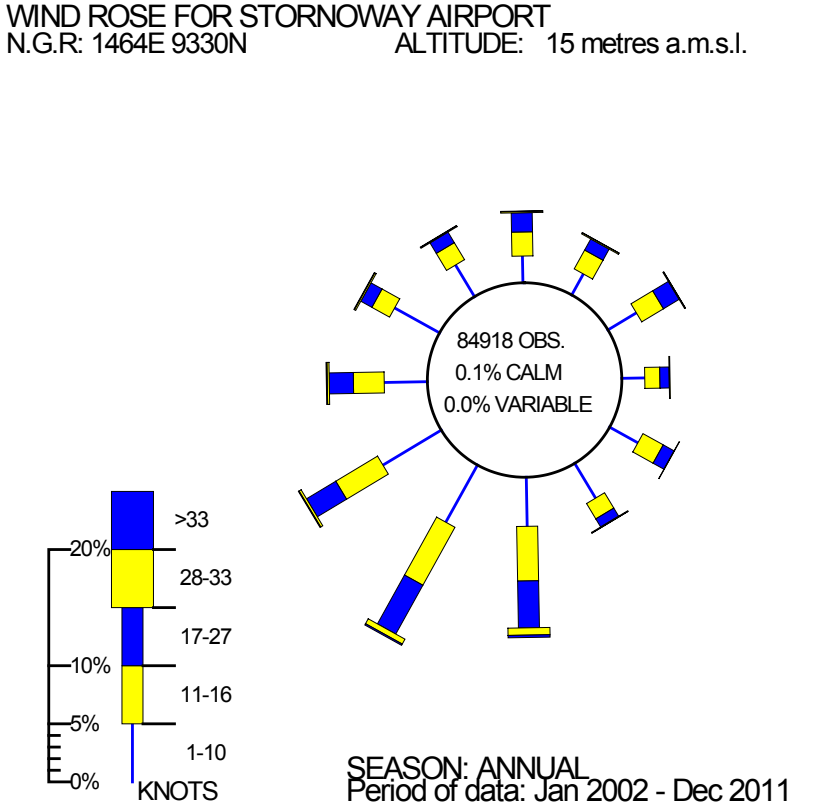


Figure 9.4 Annual wind rose for Stornoway Airport

Overall, winds were predominantly from the southwest. However, during summer, southerly winds predominated and there were also relatively strong winds from the north-west. Wind is an important factor in the spread of contamination as it has 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 can significantly alter the pattern of surface currents. Strong winds also have the potential to affect tide height depending on wind direction and local hydrodynamics of the site. A strong wind combined with a spring tide may result in higher than usual tides, which will carry any accumulated faecal matter at and above the normal high water mark into the fishery area.

10. Classification Information

The area was classified in March 2013. The current classification is shown in Table 10.1

Table 10.1 Tong Sands classification – common cockles

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013				B	B	C	C	C	C	C	C	C
2014	B	B	B									

11. Historical *E. coli* Data

11.1 Validation of historical data

Results for all samples assigned against the Tong Sands production area up to 25/02/2013 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 on 25/02/2013. All *E. coli* results were reported as most probable number per 100 g of shellfish flesh and intravalvular fluid (MPN/100 g FIL).

Results were only available for years 2012 and 2013. One record [CEFAS_12/540] did not have an *E. coli* result assigned to it and was therefore deleted. All samples were collected and delivered to the laboratory within the allowed 48 hr window. All samples had a box temperature of <8^{o} C. One sample had an *E. coli* level of >18000 and was reassigned a nominal value of 36000 *E. coli* MPN/100 g for the purposes of statistical analysis and graphical representation. A summary of microbiological results is presented below in Table 11.1.

Table 11.1 Summary of historical *E. coli* sampling and results at Tong Sands.

Sampling Summary	
Production area	Tong Sands
Site	Tong Sands
Species	Common cockles
SIN	LH-605-1100-04
Location	NB 445 355
Total no. of samples	13
No. 2012	12
No. 2013	1
Results Summary	
Minimum	330
Maximum	> 18000
Median	4450
Geometric mean	2780
90 percentile	17400
95 percentile	18000
No. exceeding 230/100g	13 (100%)
No. exceeding 1000/100g	9 (69%)
No. exceeding 4600/100g	6 (46%)
No. exceeding 18000/100g	1 (8%)

As only 13 results were available, further analysis was limited to simple temporal and spatial assessment and tabulation of the samples yielding results greater than 4600

E. coli MPN/100 g. Assessment of the effect of environmental variables has not been undertaken.

11.2 Overall geographical pattern of results

All sampling locations of common cockles at Tong Sands were recorded within a 1 km radius of one another. Figure 11.1 illustrates that samples were taken to the north of Tong Sands, with the highest results closer to the mouth of the lagoon area and smaller results closer to the mouth of the river mouth entering to the NNW.

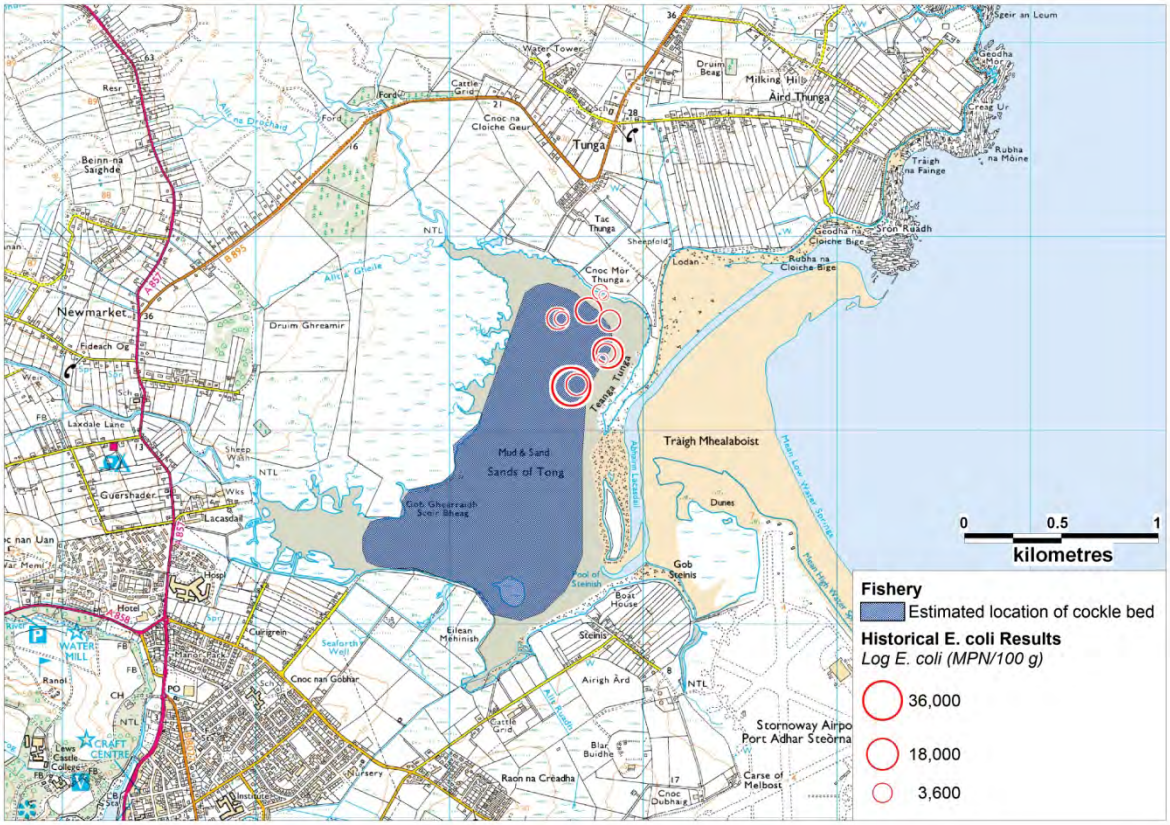


Figure 11.1 Map of reported sampling locations for common cockles at Tong Sands.

11.3 Overall temporal pattern of results

Figure 11.2 shows a scatterplot of the cockle *E. coli* results against sampling date.

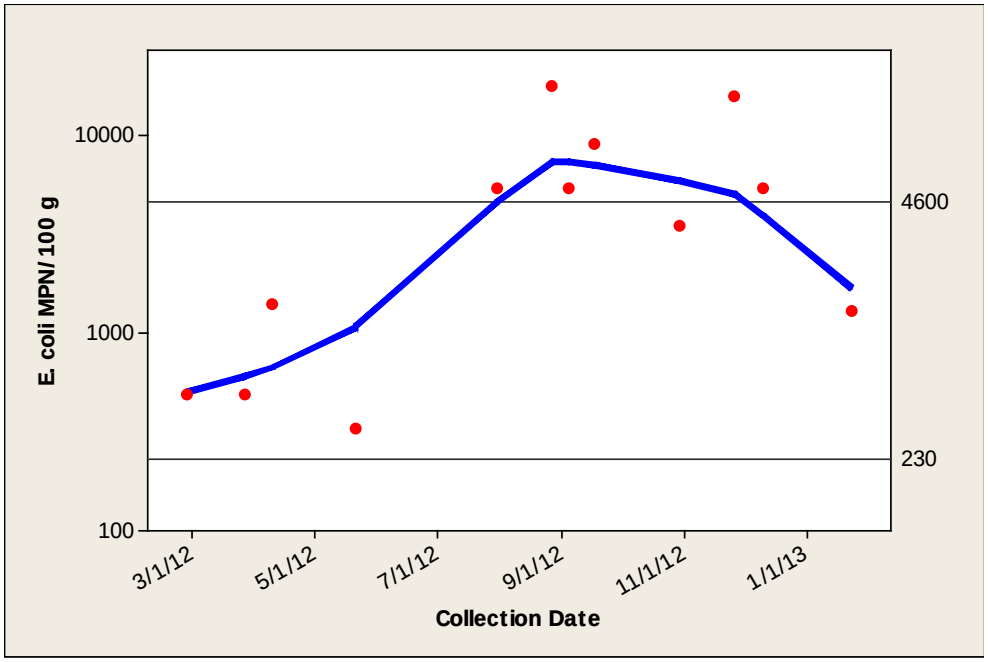


Figure 11.2 Tong Sands *E. coli* results by collection date, fitted with a lowess line

The dataset is fitted with a lowess trend line. Lowess trendlines allow for locally weighted regression scatter plot smoothing. At each point in the dataset an estimated value is fitted 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 lowess 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.

The scatterplot shows a trend towards higher values during the summer/autumn period. However, data over a more extended period would need to be analysed to determine whether this trend occurs each year.

11.4 Evaluation of results over 4600 *E. coli* MPN/100 g

Of the common cockle samples, six had results >4600 *E. coli* MPN/100 g. These are presented in Table 11.3.

Table 11.2 Historic common cockle *E. coli* sampling results over 4600 *E. coli* MPN/100 g.

Collection Date	*E. coli* (MPN/ 100 g)	Location	2 day rainfall (mm)	7 day rainfall (mm)	Water Temp (^{o}C)	Salinity (ppt)	Tidal State (high/low)	Tidal state (spring/neap)
30/07/2012	5400	NB 4466 3524	1.6	19.2	12	-	Low	Neap
27/08/2012	18000	NB 4463 3523	4.6	29.0	14	-	Low	Decreasing
04/09/2012	5400	NB 4483 3557	-	-	13	-	High	Decreasing
17/09/2012	9200	NB 4472 3562	-	-	12	-	High	Neap
26/11/2012	16000	NB 4482 3540	-	-	6	-	Flood	Decreasing
10/12/2012	5400	NB 4456 3558	-	-	4	-	Flood	Neap

(-) No data available

All of the results in Table 11.3 are from 2012, as this was the only year sufficient samples were recorded. Elevated results were taken between the months of July and December, with two results taken in September. Sample location varied slightly. Salnity was not recorded for any of the samples. Rainfall was recorded for two of the elevated samples, and although the initial rainfall over the two days prior to sampling was low, rainfall levels seven days prior to sampling was moderate for both results. Water temperature varied between 4-14^{o}C with the majority ≥12^{o}C. There was no significant trend in tidal state with respect to high/low tidal cycles but all of these high results were from samples taken on decreasing or neap tides.

11.5 Summary and conclusions

Due to the small amount of samples available for analysis, conclusions drawn here only relate to the trends observed for the year 2012, with one sample in 2013.

All samples were taken to the north of Tong Sands, within a 1 km proximity to one another. Higher results were seen in the samples taken further south in the limited sampled area.Forty-six percent of results were >4600 *E. coli* MPN/100 g, with no results <230 *E. coli* MPN/100 g. One sample had a result of >18000 *E. coli* MPN/100 g. There was an upward trend in *E. coli* results across the year, with highest results in the summer and autumn months.

12. Designated Shellfish Growing Waters

The Tong Sands fishery does not lie within a designated shellfish growing water.

13. Bathymetry and Hydrodynamics

13.1 Introduction

13.1.1 The Study Area

Tong Sands is situated on the southwest of the area of Broad Bay (Loch a Tuath) which itself is situated on the east of the Isle of Lewis. Two small settlements are located to the northeast of the area, the closest being Tunga and then further north, Aird Thunga. The largest main town near Tong Sands is Stornoway which is roughly 2 km to the southwest. Stornoway airport is adjacent to the lagoon and situated to the southeast. Tong Sands is unique in comparison to other beaches within Broad Bay because it is a split feature rather than the typical bow shaped beaches. The split continues southwards for approximately 1 km from Tunga village and forms a natural barrier at the head of Broad Bay composed of a large area of northward-facing sand and mudflats. These natural conditions lead to a complex cross between marine and estuarine systems. Broad Bay stretches from Tolsta Head which is roughly 13 km north of Stornoway, southeast to Tiumpan Head situated on the Eye Peninsula, and reaches as far inland as Laxdale. For the purposes of this report, the study area starts just south of Tolsta Head near Creag Fhraoch. There is net landward sand movement enabled by the gentle gradient offshore of ratio 1:1.176 (Ritchie & Mather, 1970). The study area is shown in Figure 13.1 and the assessment area is contained within the purple line.

Coordinates for the middle of Tong Sands (Tràigh Mhealaboist):

58° 13.77’ N 006° 20.7’ W

NB 45000 35000

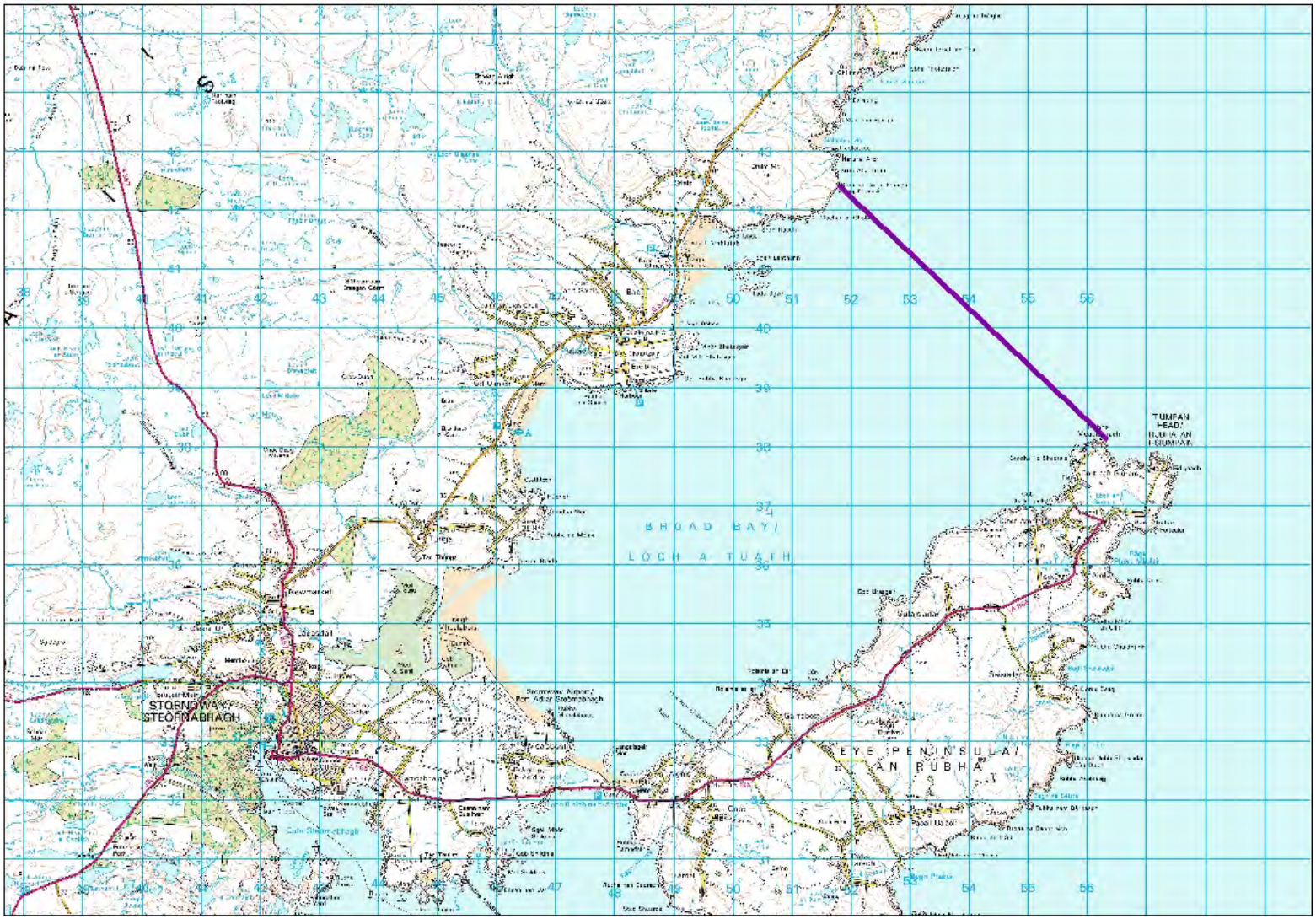


Figure 13.1 Extent of hydrographic study area

13.2 Bathymetry and Hydrodynamics

13.2.1 Bathymetry

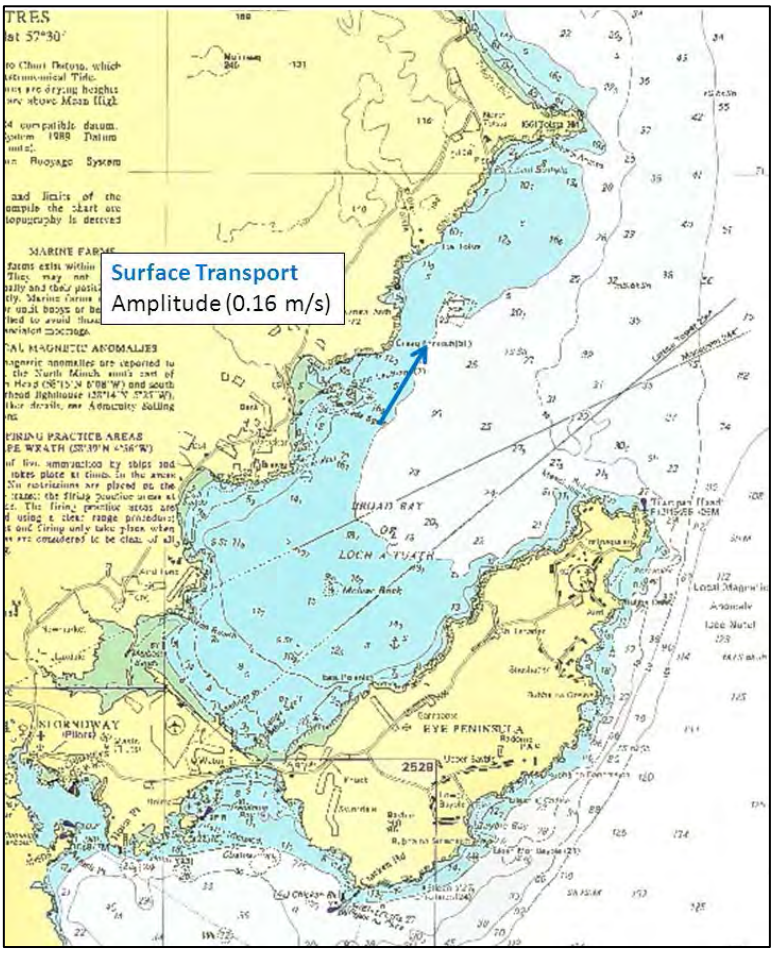


Figure 13.2 Admiralty chart extract for Broad Bay. Note that the length of the flow arrow approximately equates with the cumulative transport distance during the ebb phases of the tide.

Figure 13.2 shows the bathymetry of Broad Bay which contains Tong Sands. The length of the Bay is approximately 14 km; width of 6 km and the total area is around 82.5 km^2 and is open to the north east. The charted depths of Broad Bay show a gradual shoaling from 30 m at the entrance towards the flats at the head of the Bay. There is no sill. The estimated volume is 1.36 x 10^9 m^3 (Marine Scotland, 2012).

The study area defined in Figure 13.1 is really the inner part of Broad Bay, with a length of about 9 km, giving an effective area of 54 km^2.

13.2.2 Tides

The nearest location for tidal predictions is Stornoway [http://easytide.ukho.gov.uk] which shows a typical semi-diurnal tidal characteristic. Data on tidal information is given from charted information.

Standard tidal data for Stornoway are given below (from Admiralty Surveys) and the spring/neap cycle of tidal height around the time of the planned survey (March 2013) is shown in figure 13.3:

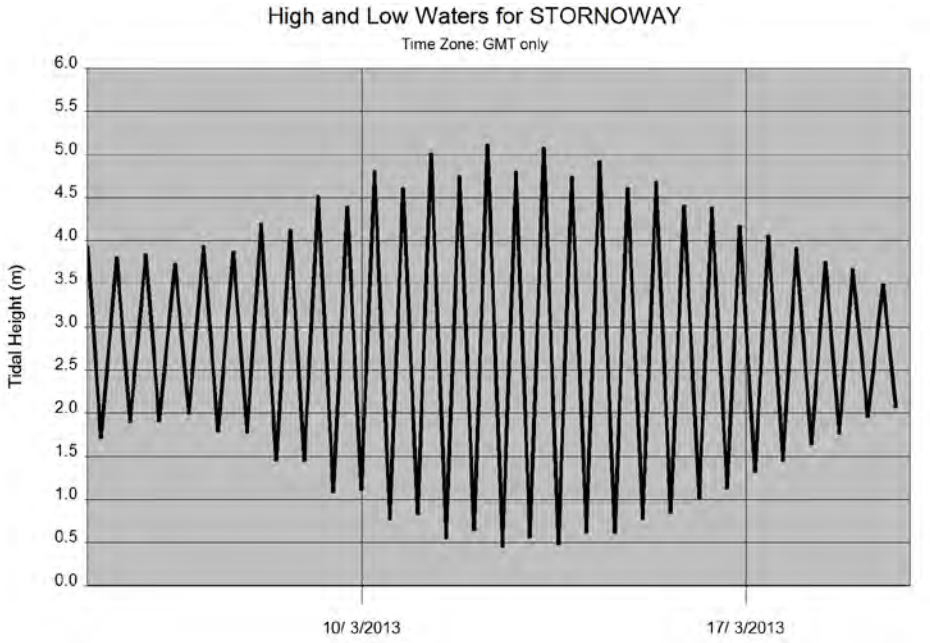


Figure 13.3 Two week tidal curve for Stornoway. Reproduced from Poltips3 [www.pol.ac.uk/appl/poltips3]

Tidal Heights at Stornoway (from Admiralty Chart 1794):

Mean High Water Springs = 4.8 m
Mean Low Water Springs = 0.7 m
Mean High Water Neaps = 3.7 m
Mean Low Water Neaps = 2.0 m

Tidal Ranges averaged for Stornoway:

Mean Spring Range = 4.1 m
Mean Neap Range = 1.7 m

However it is noted that the mean spring range for Broad Bay is given as 3.5 to 4.0 m by Ramsay and Brampton (2000), but these values are not attributed to any specific source.

The stated values for Stornoway give a tidal volume of water for the entire Broad Bay area during each tidal cycle of approximately:

Springs: 3.4×10^8 m^3
Neaps: 1.4×10^8 m^3

13.2.3 Tidal Streams and Currents

The flood stream travels northwards up the Minch, the ebb flowing south past Tolsta Head. In general around the east of Lewis, the maximum tidal currents during mean spring tide will range from 0.5 to 1.0 m/s. The tidal current speeds will generally be larger when flowing through narrow channels and around headlands and promontories which are numerous in this area. North of the study area in the northern Minch, between Cape Wrath on the mainland and the Butt of Lewis, current speeds at spring tides are recorded as 0.4 m/s and at neap tides 0.15 m/s (Barne, et al., 1997)

There is limited specific hydrographic and meteorological data concerning Tong Sands however, there are some data available for different parts of Broad Bay. The mouth of Broad Bay opens out into the Minch and the tidal flow in the Minch across the mouth is < 0.3 m/s, even at peak spring rates. Therefore the tidal stream can be described as generally weak, even within the Bay (Ramsay & Brampton, 2000). During the ebb tide (travelling south in the Minch) a weak, anti-clockwise rotation occurs in the Bay. The only significant tidal stream reported for the Bay is on the north coast where a weak NNE stream gradually gets stronger on the flood as it travels towards Tolsta Head (Ramsay & Brampton, 2000). However, these streams are poorly quantified.

There are no current meter data available from the British Oceanographic Data Centre for this location. Current meter data are available from a previous survey by SEPA from a site in the north of Broad Bay, Toa Tolsta (Anderson, 2009). The survey period spanned 15 days; being the half-lunar period to capture a spring-neap cycle. In the report, sub-surface refers to the depth of approximately 7 m, mid-depth is approximately 14 m and near-bottom is approximately 2 m above the seabed.

Data from Toa Tolsta were collected in 2009, summarised in Table 13.1. Clear semi-diurnal periodicity along with spring-neap variation was displayed throughout the velocity readings. In general, the currents were of a moderate speed. Whilst the tabulated mean and maximum velocities are greatest in the sub-surface measurements, the report states that overall there was “similarity of current velocity and direction throughout the water column” (Anderson, 2009). The report also notes that the directions of the currents in all depths were asymmetric with currents at each level aligned in the NE-SW direction following the coast. Overall, the 2009 survey

suggested that the Toa Tolsta site in north Broad Bay was a “moderately-flushed” site.

Table 13.1 Toa Tolsta current data measured in 2009.

	Near-Bed	Mid	Sub-Surface
Mean Speed (ms^{-1})	0.064	0.082	0.099
Maximum Speed (ms^{-1})	0.192	0.208	0.338
Principal Axis Amp & Dir (ms^{-1}) & (^{o}M)	0.092 (205)	0.113 (035)	0.164 (035)
Eccentricity Ratio	1.6	2.0	2.2
Residual speed (ms^{-1})	0.003	0.018	0.025

It is important to note that the principal directions show an approximately 180° shift between the near bed and the mid and sub-surface levels. Given the nature of tidal forcing this is rather unlikely as the dominant tidal flow will tend to align in broadly the same direction at the same time. It is possibly indicative of a 180° switch in the reporting of the direction of the principal axis.

There are no tidal diamonds in the area bounded by the study site. One tidal diamond is reported to the east of the Eye Peninsula but its location in deep water (> 100m) renders it of little value to this assessment other than confirming the ‘offshore’ direction of flood and ebb tides.

Based upon a measured surface principal current amplitude of 0.16 m/s (Table 13.1) and the assumption of a uniform sinusoidal tide, the cumulative transport that might be expected in the surface during each phase of the tide has been estimated as approximately 2.1 km. No distinction is made here for springs and neaps, nor has any estimate been made for any seasonal variation.

Dispersion is an important property of a water body with respect to redistribution of contaminants over time. There are no measurements or published data relating to dispersion in Broad Bay. Without such data it is difficult to judge what the dispersive environment might be like, but the occurrence of small promontories on the west side of the bay, and the reported tidal flow along this coast may enhance dispersion in that location.

Dispersion of surface contaminants may be enhanced by wave energy within Broad Bay. Sources of wave energy are from both short period waves that are created within the Bay itself and the Minch and also from swell conditions that have a much larger period originating in the North Atlantic and Norwegian Sea (Ramsay & Brampton, 2000) Long fetch lengths occur in the north east direction and the biggest wind generated waves are produced from this narrow wave window. However, overall within Broad Bay itself, the waves produced are usually small because of the short fetch duration from the south and east and therefore the size of wind-generated waves are restricted (Ritchie & Mather, 1970; Ramsay & Brampton, 2000).

13.2.4 River/Freshwater Inflow

There are several small watercourses around Broad Bay. The two main rivers are Abhainn a Ghlinne Dhuibh and Abhainn Lacasdail and they both enter Broad Bay directly through the Tong Sands area. These two large watercourses have the potential for high discharge particularly on the ebb tide (Ritchie & Mather, 1970). There are other smaller watercourses that enter Broad Bay to the northeast of Tong Sands, namely Abhainn Aonghais, Abhainn Chuil and Abhainn Ghriais. There are other unnamed rivers shown on the OS map which may or may not flow depending on the season.

The nearest record of annual rainfall in the eastern part of the Isle of Lewis is for Stornoway which displays moderate levels averaging at nearly 1000 mm (39.5 inches) (Ritchie & Mather, 1970).

Salinity levels are most likely liable to fluctuate due to the inter-annual changes of the input of Atlantic water (Ellett, 1979; Barne, et al., 1997). What can be surmised is that salinity levels will decrease from the west to the east of the Hebrides due to mixing of high salinity Atlantic water together with fresher coastal water which originates from land runoff. On the eastern side of the Isle of Lewis and encompassing the study area in Broad Bay, the salinity is generally around 34.5 psu but there will be seasonal variation (Barne, et al., 1997).

The estuarine discharge into Broad Bay will, under calm conditions, produce a stratified water column with a fresher surface layer overlying a denser (more saline) lower layer. The effect of stratification is that the surface layer becomes more susceptible to influence from the wind and can lead to enhanced wind-driven surface flow.

13.2.5 Meteorology

All coastal zones on the Isle of Lewis can be affected by very strong winds which originate from different directions. Along with Orkney and Shetland, the Western Isles are amongst the windiest in the UK (Barne, et al., 1997). In the outer headlands and islands, the wind speed was recorded as surpassing 4 m/s (8 knots, Force 3) for 75% of the time and 20 m/s (40 knots, Force 9) 0.1% of the time. Throughout the whole area, for 75% of the time, speeds were recorded as 3 m/s (6 knots) and for 0.1% of the time they were 19 m/s (Barne, et al., 1997). From this it can be deduced that the island and especially coastal areas can experience significant wind forcing on hydrographic processes.

Topography in this region is very influential, not just on the wind speed but also the direction. The eastern side of the island is comparatively more sheltered from the wind due to landforms that provide protection, for example, by hilly areas and

hinterland. The exposed western side therefore in general, has wind speeds that are larger. It is notable that although the winds can originate from any direction, it is most probable that winds will blow from a southerly direction. Stornoway tends to experience winds originating from the south. More precisely, winds from southeast to southwest blew 50.6% of the sampled time with north and northeast winds also having a large input. The winds that come from the west and northwest have the least influence in the area and constitute only 15.4% of the combined total (Ritchie & Mather, 1970)

13.2.6 Model Assessment

The location of Tong Sands is relatively data sparse compared to other locations, such that there is little information to either set up or validate a sophisticated box model.

A simple exchange model has been set-up by Marine Scotland Science (Marine Scotland, 2012) to estimate the environmental sensitivity of a variety of sea lochs. Output from this model for the location of Broad Bay produces a flushing time of 3 days and a volume exchange rate of 165188 Mm^3yr^{-1}. Given the tidal and bathymetric characteristics of the site it is likely that the underlying mechanism is one of tidally dominated exchange.

13.3 Hydrographic Assessment

13.3.1 Surface flow

The site and the meteorological data indicate that there is likely to be a rather steady freshwater discharge into the surface waters of the loch, though the absolute value of discharge would be seasonally varying. The distribution of fresh water sources is concentrated at the head and the north side of the Bay.

Any estuarine flow to the NE would be concentrated on the north side and possibly enhanced by the prevailing winds from the south quadrant. Therefore one would anticipate a long term net residual flow to the NE. The weak current shear that is reported (Anderson, 2009) also implies a weak estuarine flow.

The dominance of the southerly winds is likely to enhance the surface flow during periods of strong winds. However, under those conditions, the loch is likely to become more uniformly mixed, breaking down surface stratification. Further, any enhancement of flow will be relaxed as the wind decreases. This will give rise to non-steady estuarine circulation in the Loch.

Wind from the NE would tend to set up a large fetch causing significant mixing of the surface waters through probably the full depth.

Underlying the estuarine flow is the tidal flow along the northern coast of the Bay that aligns with the coastline, running NNE on the flood and SSW on the ebb creating a generally anticlockwise circulation on the ebb. The principal current direction of the surface water has, from rather short surveys of currents, been shown to flow in alignment with the shoreline. Cumulative transport during each phase of the tide is estimated to be around 2.0 km.

It is likely that any surface contaminant would be transported primarily along the axis of the loch but with the potential for dispersion as the flow encounters promontories, particularly on the north side of the Bay.

Net transport of contaminants is related to the residual flow presented in Figure 13.2. The residual surface flow measured in the surface waters (Anderson, 2009) is towards the NW which may be related to the shape of the coastline at the survey location or dominating meteorological conditions during the survey period. Nevertheless, this can be interpreted as a weak outflow of the surface waters. With the measured surface residuals of order 0.02 m/s, the transport over a tidal cycle of approximately 12 hours would be less than 1 km. It is therefore likely that any surface contaminant would follow the contours of the loch and disperse effectively via the surface estuarine flow.

Comparing the size and tidal characteristics of Broad Bay to other sites, one might anticipate that the rate of dispersion in the surface waters would be rather high. Dispersion could be further enhanced by strong prevailing winds.

13.3.2 Exchange Properties

An important assessment for Broad Bay in terms of the exchange is that the tidal volume flux will dominate the estuarine volume flux. This means that exchange of waters in Broad Bay will be principally a tidally driven process. Hence, while there may be seasonal variation in the surface flow, there is likely to be rather little seasonal variation in the overall flushing time of the Loch.

Exchange modelling predicts a mean flushing time of 3 days (Marine Scotland, 2012) which implies a well flushed system. Indeed, Broad Bay has been categorised as a location with minimal hydrodynamic impact on nutrient or benthic conditions (Marine Scotland, 2012).

The lack of a shallow sill within this system implies that there is effective exchange between the waters within the Bay and the coastal waters within the Minch and Broad Bay has variously been described as either moderately flushed (Anderson, 2009)or “strongly flushed” EPSC (2011). Therefore, one can judge with some confidence that surface contamination would be short-lived in this location.

There is rather little data available from current meters for Broad Bay and there is a paucity of any measured hydrographic data. However, there is a simple model assessment of exchange available. Therefore the confidence level of this assessment is MEDIUM.

14. Shoreline Survey Overview

The shoreline survey was conducted between the 11th and 12th March 2013. Prevailing weather conditions were cold, but largely dry with showers/snow falling intermittently on the second survey day. No precipitation fell in the 48 hrs prior to the survey and it was noted that during the 3-4 weeks prior to the survey the weather had been very dry. The most significant observations from the shoreline survey are shown mapped in Figure 14.1.

The fishery at Tong Sands was new and consisted of a common cockle bed, which was harvested by hand. No fixed facilities for harvest handling (i.e. shore bases) were noted on the survey. The harvester's short term plan was to sell to the local market in the tourist season from April to October. He also planned to make customers aware of the classification of his stock and the need to cook the product to prescribed temperature and duration prior to consumption. The harvester did not yet have any long term plans for the fishery.

The area immediately surrounding Tong Sands was found to be heavily inhabited. Human population to the northeast consisted mostly of detached private dwellings. The highest human population concentration was found to the south in the town of Stornoway.

There were several B&Bs present in the survey area, with one campsite present north at Traigh Chuill beach. Three moorings were located at NB 455 358, though no boats were on the moorings at the time of the survey.

Sewage discharges were found on the northern shoreline as well as at Steinis. At Sand Street there were tanks and associated pumping facilities, but no discharge pipe was visible.

Small scale crofting agriculture and small areas of forest/woodland were found on the northwest shoreline. Along the rest of the northern part of Tong Sands there was a mixture of rough and improved grassland along with heath. The large area immediately west of the bay was a mix of unimproved heath, grassland and marsh, with some plantation woodland 500 m back from the shore. The area to the south of the sands was a mixture of rough/improved grassland, with Stornoway Airport and associated industry to the southeast.

Livestock were noted on crofts at Aird Thunga (2 horses and 15 sheep), Lacasdail (15 sheep) and Steinis (28 sheep). Moorland to the west of the harvest area was noted to be presumably used to graze livestock though at the time of the survey, no livestock were present. No arable fields were noted during the survey.

Gulls were seen around the area, with up to 50 birds seen at the mouth of the Abhainn Lacasail. Duck droppings were also noted on the northwestern shoreline. No other wildlife was observed during the survey.

Two major watercourses were noted in the survey area; Abhainn a Ghlinne Dhuibh and Abhainn Lacasail. The Abhainn a Ghlinne Dhuibh disappeared underground into the grassland/marsh in several places, and was braided, making accurate measurement difficult. Freshwater samples had low contamination levels varying between <100 to 400 *E. coli* cfu/ 100 ml. Three other smaller watercourses and numerous small land seeps were observed but not sampled or measured during the survey.

Samples taken from discharge pipes varied hugely between <100 to 2200000 *E. coli* cfu/ 100 ml, with the highest result associated with a cast iron pipe discharging to shore to the north west of Tong Sands. Seawater samples also had varying levels of contamination between 2 and 56 *E. coli* cfu/ 100 ml. The highest seawater sample was taken adjacent to Tong ST. Four cockle samples were taken, with contamination levels ranging from 70 and 1400 *E. coli* MPN/ 100 g, with the highest contamination levels found in a cockle sample taken from the northwest extent of the cockle bed.

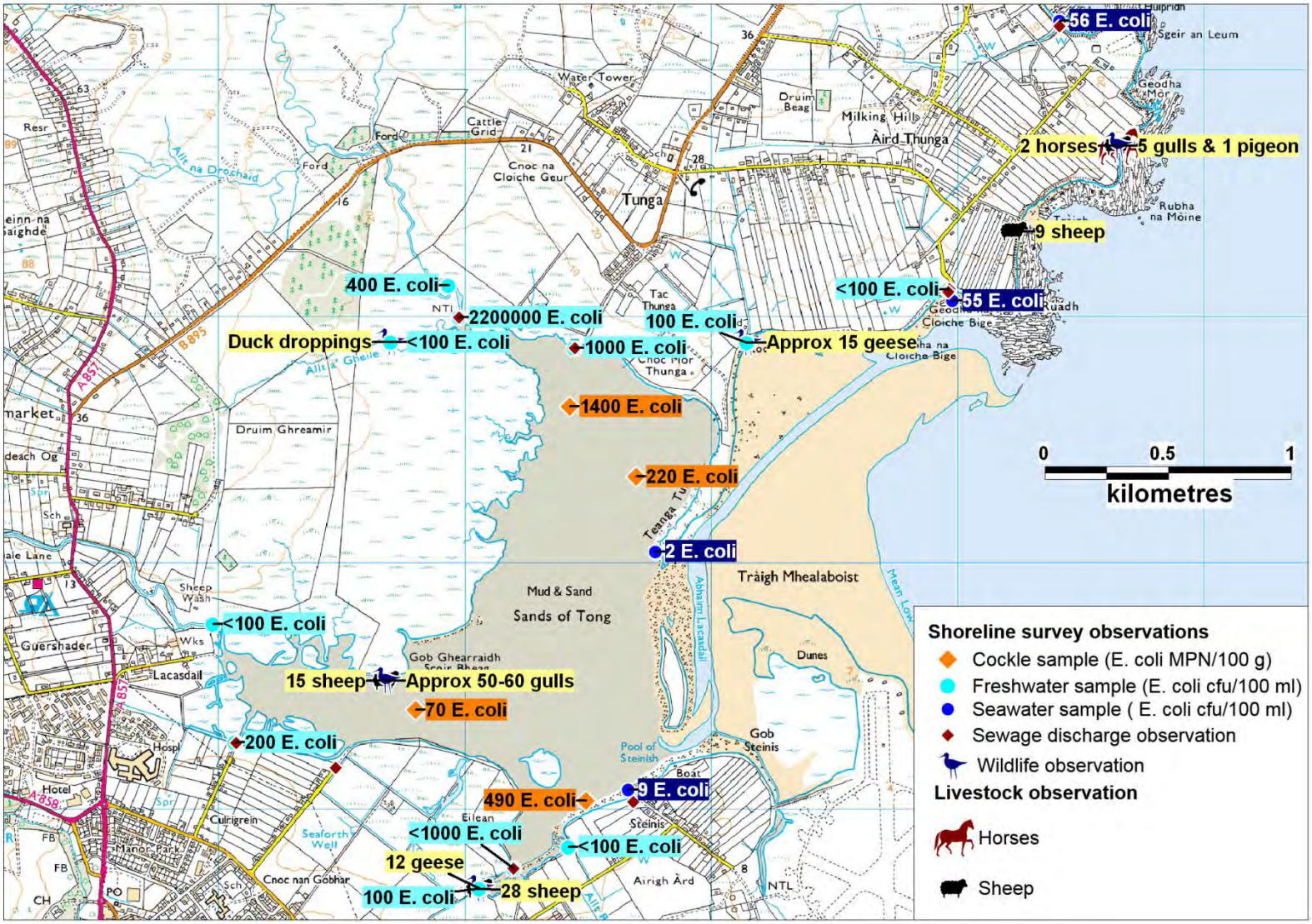


Figure 14.1 Summary of shoreline survey findings for Tong Sands

15. Bacteriological Survey

A bacteriological survey was undertaken at Tong Sands between 25 March and 9 May 2013. Three locations were sampled on three separate occasions, with results shown below in Table 15.1 and mapped in Figure 15.1.

Table 15.1 Bacteriological survey results for Tong Sands

Date	Site 1	Site 2	Site 3
25/03/2013	330	230	
26/03/2013			<20
22/04/2013	1100	3500	490
08/05/2013	5400	5400	1300
Geometric mean	1250	1630	185

Results showed increasing levels of contamination over the period surveyed, with highest results occurring on the May sampling date. Sample results from two of the sites exceeded 4600 *E. coli* MPN/100 g on that date, indicating that the shellfish were severely impacted by faecal contamination on that date.

Average levels of contamination at Sites 1 and 2 were markedly higher than at Site 3. Results were highest overall at Site 2, on the southwestern side of the cockle bed and lowest at Site 3 near the southeastern extent of the bed. Site 2 was located nearest the main freshwater input to the lagoon, Abhainn Lacasdail, which carried the highest calculated loading based on sampling undertaken during the shoreline survey. This location is therefore likely to be impacted by agricultural pollution, urban surface runoff, as well sewage discharges.

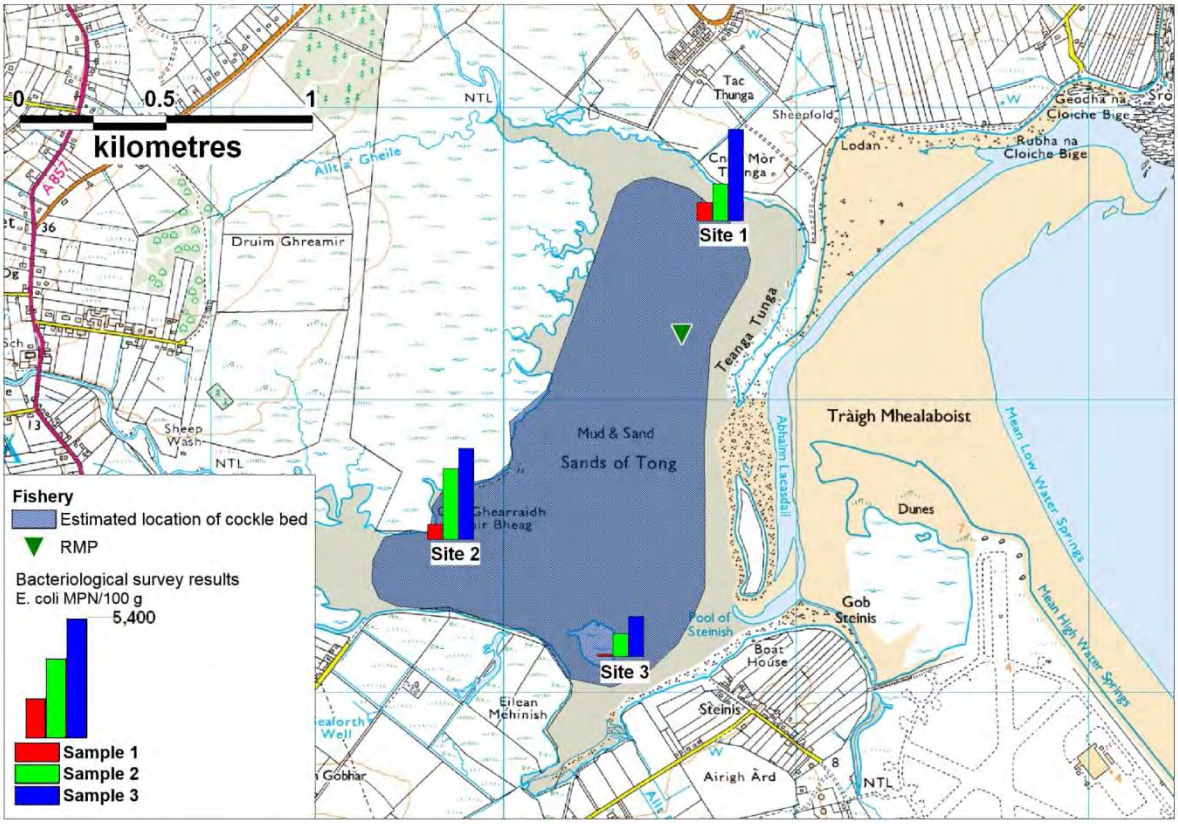


Figure 15.1 Summary of bacteriological survey results for Tong Sands

16. Overall Assessment

Human sewage impacts

The lagoon in which the Tong Sands cockle bed is situated is subject to significant faecal contamination from both continuous and intermittent sewage discharges. The area is located adjacent to the largest town in the Western Isles, Stornoway, and receives continuous discharges from septic tanks serving smaller communities and outer fringes of Stornoway to the north and south of the production area. A larger continuous outfall discharges east of the cockle bed into the mouth of the Abhainn Lacasdail. Although not directly addressed by the hydrographic assessment, it is postulated that the flood tide will flow along the deeper channel of the river carrying contaminants discharged from the Tong ST outfall inland and across the cockle bed.

Further discharges within the lagoon would add to the load of faecal contaminants over the bed, particularly when the CSOs are discharging. No information was provided regarding the frequency of overflows. If the overflows are considered to be infrequent, it is unlikely that a monthly monitoring programme will adequately reflect risk posed by these intermittent discharges.

Agricultural impacts

Areas of crofted land were found to the north and east and to the southeast of the cockle bed. Livestock were observed near the southwest and southern shores, and may also be grazed more extensively around the area during the summer months. It is therefore likely that a portion of the faecal contamination found in the lagoon around Tong Sands will come from diffuse livestock sources.

Wildlife impacts

Wildlife are likely to be present across the intertidal area, with impacts from seals and breeding seabirds more likely along the eastern side of the fishery and from migratory wading birds and geese over much of the intertidal area and along the western shores. There is likely to be a seasonal turnover in species, with some wading birds only present during spring and autumn migrations and seabirds such as terns only present during the summer nesting season. However, compared to other sources in the area, contributions of faecal contamination from wildlife species are expected to be relatively minor. There was insufficient information on which to develop an overall spatial assessment of the contamination from wildlife sources to the fishery.

Seasonal variation

The harvester planned to harvest primarily during the summer tourist season, for local sale to consumers. Early monitoring results indicate that contamination levels are highest during summer and autumn, though a longer period of monitoring would be required to confirm this trend. Overall, there is more rainfall from October to January, however extreme rainfall exceeding 20 mm per day occurred in most months over the period examined, excepting February, March, April and June. This may be of particular significance for the fishery considering the number of CSOs discharging to the southern end of the lagoon.

Although there is likely to be tourism in the area, the majority of the area is permanently settled and therefore any change in population is likely to be relatively minor.

Rivers and streams

The Tong Sands cockle bed is situated within the Lacasdail lagoon, and therefore subject to significant freshwater input. The highest *E. coli* loading entering the harvest area came from Abhainn Lacasdail, to the southwest of the cockle bed. Loading was moderately high, calculated at 1.1×10^{10} *E. coli*/ day. This watercourse receives outflow from the Sandwick CSO, and is also likely to carry urban surface water runoff and some diffuse agricultural pollution. Further areas of land drainage, and Alt Ruadh at the southeastern extent of the cockle bed, would add to the contamination loads across the southern end of the bed.

Overall freshwater contamination inputs to Tong Sands cockle bed were estimated to be moderate based on shoreline survey sampling. However, this may reflect the un-seasonally dry weather experienced in the weeks leading up to the survey, which will have reduced flows and possibly the amount of faecal material entering the watercourses.

On the basis of the observations and subsequent loading calculations, the main impacts from the watercourses will be at the southwestern and northwestern parts of the cockle bed. Contamination at these locations is likely to be significantly higher during and after periods of wet weather.

Movement of contaminants

Little information was found on water movement within the lagoon, therefore the hydrographic assessment focused largely on contaminants circulating within Broad Bay, which receives outflow from the lagoon. Within the lagoon

itself, the ebb and flood tides are likely to follow the deeper channel of the river which will carry contaminants around the end of the sandspit at Teanga Tunga. The area dries almost completely at low tide, when freshwater flow will follow channels across the seabed.

Temporal and geographical patterns of sampling results

There is insufficient sampling history to date to suggest any temporal variation in sampling results. Monitoring samples have been taken from the north end of the cockle bed, where results have been highest along the eastern edge of the bed. However, it is not clear whether this is due to spatial variation or changes in contamination levels between sampling dates.

During the shoreline survey, highest cockle sample results came from the northwestern extent of the fishery and lowest from the southwestern extent. However, a subsequent bacteriological survey showed consistently higher results at the southern end of the fishery, with highest results nearer the outflow from Abhainn Lacasdail. This is consistent with the river being a significant source of both diffuse and point source faecal contamination.

Conclusions

Overall, the area is subject to significant faecal contamination from point and diffuse source contamination in particular from continuous and intermittent sewage discharges and urban runoff. Four separate CSOs discharge to the southern end of the fishery, and the impacts from these may not be adequately captured in monthly monitoring data. The Abhainn Lacasdail is also likely to carry diffuse faecal contamination from agricultural sources and from urban runoff. While there are continuous discharges from septic tanks at the northern end of the fishery, only the smaller of these (4 m^3/day) discharges to the lagoon itself. The larger discharges to the outer channel of Abhainn Lacasdail and is likely to be carried toward the southern end of the fishery along the river channel on the flood tide, where it would be most likely to impact the southern end of the fishery.

The majority of sources appear to be rainfall dependent, and therefore it is anticipated that contamination levels at the fishery will be higher during and immediately after rainfall.

17. Recommendations

Production area

It is recommended that the production area boundaries be amended to the area bounded by lines drawn between NB 4480 3500 and NB 4458 3402 and between NB 4454 3400 and NB 4423 3400 and between NB 4352 3425 and NB 4352 3456 and between NB 4432 3561 and NB 4447 3589 and extending to MHWS.

This excludes areas nearest to significant freshwater input and CSOs and the septic tank outfall at Tong Rd.

RMP

Due to the abundance of sources at the southern end of the fishery, and contamination associated with Abhainn Lacasdail, it is recommended that the monitoring point be amended to NB 4380 3440, at the southwestern end of the cockle bed.

Tolerance

As the shellfishery is a wild cockle bed, a tolerance of radius 100 m is recommended to allow for variation in density of stocks in the vicinity of the recommended RMP.

Frequency

As there is limited monitoring data from the area, and the classification results to date have shown some evidence of a difference in the extent of contamination across the year, it is recommended that monitoring is undertaken monthly. As some of the significant sources in the area are intermittent sewage discharges, this frequency may not fully represent the risk of contamination.

Depth of sampling

This is not relevant as the samples will be hand-raked at low tide.

The locations of the recommended monitoring point, tolerance area, and production area boundaries are shown in Figure 17.1.

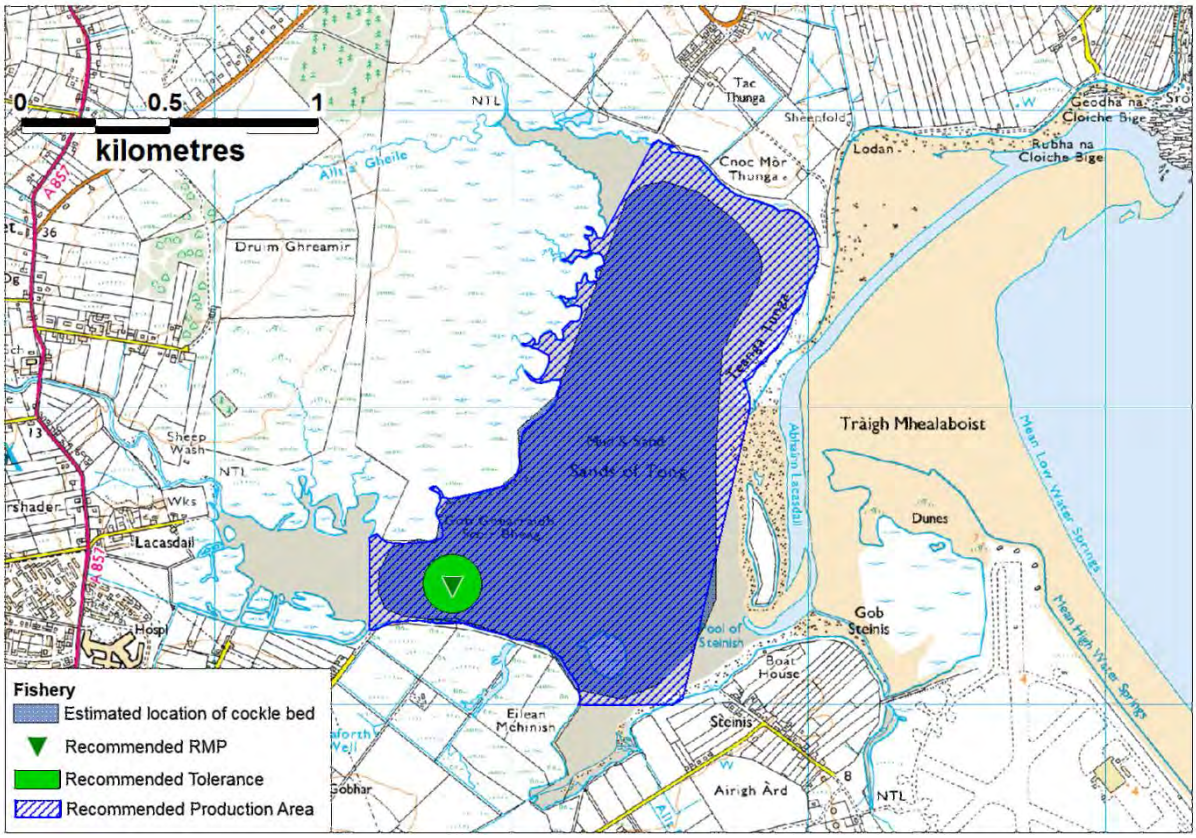


Figure 17.1 Map of recommendations at Tong Sands

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19. List of Figures and Tables

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1. **General Information on Wildlife Impacts**
2. **Tables of Typical Faecal Bacteria Concentrations**
3. **Hydrographic Section Glossary**
4. **Shoreline Survey Report**

1. 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 50-170 kg. They are estimated to consume between 4 and 8% of their body weight per day in fish, squid, molluscs and crustaceans. No estimates of the volume of seal faeces passed per day were available, though it is reasonable to assume that what is ingested and not assimilated in the gut must also pass. Assuming 6% of a median body weight for harbour seals of 110kg, that would equate to 6.6kg consumed per day and probably very nearly that defecated.

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

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

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

Cetaceans

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

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

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

Birds

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

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

A study conducted on both gulls and geese in the northeast United States found that Canada geese (*Branta canadiensis*) contributed approximately 1.28×10^5 faecal coliforms (FC) per faecal deposit and ring-billed gulls (*Larus delawarensis*) approximately 1.77×10^8 FC per faecal deposit to a local reservoir (Alderisio & 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 (Gauthier & Bedard, 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 National Heritage, n.d.). 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 treams, which may be washed into the water during periods of rain.

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2. 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}		
Reed bed/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, et al., 2008)

Geometric mean (GM) and 95% confidence intervals (CIs) of the GM faecal indicator organism (FIO) concentrations (cfu 100ml$_{-1}$) under base- and high-flow conditions at the 205 sampling points and for various subsets, and results of paired t-tests to establish whether there are significant elevations at high flow compared with base flow

FIO	*n*	Base Flow			High Flow		
Subcatchment land use		Geometric mean	Lower 95% CI	Upper 95% CI	Geometric mean[a]	Lower 95% CI	Upper 95% CI
Total coliforms							
All subcatchments	205	5.8×10^{3}	4.5×10^{3}	7.4×10^{3}	7.3×10^{4}**	5.9×10^{4}	9.1×10^{4}
Degree of urbanisation							
Urban	20	3.0×10^{4}	1.4×10^{4}	6.4×10^{4}	3.2×10^{5}**	1.7×10^{5}	5.9×10^{5}
Semi-urban	60	1.6×10^{4}	1.1×10^{4}	2.2×10^{4}	1.4×10^{5}**	1.0×10^{5}	2.0×10^{5}
Rural	125	2.8×10^{3}	2.1×10^{3}	3.7×10^{3}	4.2×10^{4}**	3.2×10^{4}	5.4×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	6.6×10^{3}	3.7×10^{3}	1.2×10^{4}	1.3×10^{5}**	1.0×10^{5}	1.7×10^{5}
≥75% Rough Grazing	13	1.0×10^{3}	4.8×10^{2}	2.1×10^{3}	1.8×10^{4}**	1.1×10^{4}	3.1×10^{4}
≥75% Woodland	6	5.8×10^{2}	2.2×10^{2}	1.5×10^{3}	6.3×10^{3}*	4.0×10^{3}	9.9×10^{3}
Faecal coliform							
All subcatchments	205	1.8×10^{3}	1.4×10^{3}	2.3×10^{3}	2.8×10^{4}**	2.2×10^{4}	3.4×10^{4}
Degree of urbanisation							
Urban	20	9.7×10^{3}	4.6×10^{3}	2.0×10^{4}	1.0×10^{5}**	5.3×10^{4}	2.0×10^{5}
Semi-urban	60	4.4×10^{3}	3.2×10^{3}	6.1×10^{3}	4.5×10^{4}**	3.2×10^{4}	6.3×10^{4}
Rural	125	8.7×10^{2}	6.3×10^{2}	1.2×10^{3}	1.8×10^{4}**	1.3×10^{4}	2.3×10^{4}
Rural subcatchments with different dominant land uses							
≥75% Imp pasture	15	1.9×10^{3}	1.1×10^{3}	3.2×10^{3}	5.7×10^{4}**	4.1×10^{4}	7.9×10^{4}
≥75% Rough Grazing	13	3.6×10^{2}	1.6×10^{2}	7.8×10^{2}	8.6×10^{3}**	5.0×10^{3}	1.5×10^{4}
≥75% Woodland	6	3.7×10	1.2×10	1.2×10^{2}	1.5×10^{3}**	6.3×10^{2}	3.4×10^{3}
Enterococci							
All subcatchments	205	2.7×10^{2}	2.2×10^{2}	3.3×10^{2}	5.5×10^{3}**	4.4×10^{3}	6.8×10^{3}
Degree of urbanisation							
Urban	20	1.4×10^{3}	9.1×10^{2}	2.1×10^{3}	2.1×10^{4}**	1.3×10^{4}	3.3×10^{4}
Semi-urban	60	5.5×10^{2}	4.1×10^{2}	7.3×10^{2}	1.0×10^{4}**	7.6×10^{3}	1.4×10^{4}
Rural	125	1.5×10^{2}	1.1×10^{2}	1.9×10^{2}	3.3×10^{3}**	2.4×10^{3}	4.3×10^{3}
Rural subcatchments with different dominant land uses							
≥75% Imp. pasture	15	2.2×10^{2}	1.4×10^{2}	3.5×10^{2}	1.0×10^{4}**	7.9×10^{3}	1.4×10^{4}
≥75% Rough Grazing	13	4.7×10	1.7×10	1.3×10^{2}	1.2×10^{3}**	5.8×10^{2}	2.7×10^{3}
≥75% Woodland	6	1.6×10	7.4	3.5×10	1.7×10^{2}**	5.5×10	5.2×10^{2}
[a] Significant elevations in concentrations at high flow are indicated: **po0.001, *po0.05.							
[b] Degree of urbanisation categorised according to percentage built-up land: 'Urban' (X10.0%), 'Semi-urban' (2.5–9.9%) and 'Rural' (o2.5%).							

Source: (Kay, et al., 2008a)

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 x 108
Cow	230,000	23,600	5.4 x 109
Duck	33,000,000	336	1.1 x 1010
Horse	12,600	20,000	2.5 x 108
Pig	3,300,000	2,700	8.9 x 108
Sheep	16,000,000	1,130	1.8 x 1010
Turkey	290,000	448	1.3 x 108
Human	13,000,000	150	1.9 x 109

Source: (Gauthier & Bedard, 1986)

3. Hydrographic Assessment 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.

MHW. Mean High Water, The highest level that tides reach on average.

MHWN. Mean High Water Neep, The highest level that tides reach on average during neep tides.

MHWS. Mean High Water Spring, The highest level that tides reach on average during spring tides

MLW. Mean Low Water, The lowest level that tides reach on average.

MLWN. Mean Low Water Neep, The lowest level that tides reach on average during neep tides.

MLWS. Mean Low Water Spring, The lowest level that tides reach on average during spring tides.

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 lagoon or sea loch during half a tidal cycle. Equal to the difference in lagoon/sea loch volume at high and low water.

Spring/Neap Tides. Spring tides occur during or just after new moon and full moon when the tide-generating force of the sun acts in the same direction as that of the moon, reinforcing it. The tidal range is greatest and tidal currents strongest during spring tides.

Neep tides occur during the first or last quarter of the moon when the tide-generating forces of the sun and moon oppose each other. The tidal range is smallest and tidal currents are weakest during neep 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. A surface flow at the surface may be accompanied by a compensating flow in the opposite direction at the bed.

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.

4. Shoreline Survey Report

Report Title	Tong Sands Shoreline Survey Report
Project Name	Shellfish Sanitary Surveys
Client/Customer	Cefas
SRSL Project Reference	00561_B0067

Document Number	B0067_Shoreline 0007
Revision	Issue 02
Date	16/04/13

Revision History

Revision	Changes	Date
A	Issue for internal review	27/03/2013
01	First formal issue to CEFAS	04/04/2013
02	Second issue to CEFAS incorporating comments at Rev 01.	16/04/2013

	Name & Position	Date
Author	Eilidh Cole, Lars Brunner	16/04/2013
Checked	John Hausrath	16/04/2013
Approved	John Hausrath	16/04/2013

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Shoreline Survey Report

Production area:	Tong Sands Cockles
Site name:	Tong Sands
SIN:	LH-605-1100-04
Species:	Common Cockles
Harvester:	Gavin Dillon
Local Authority:	Comhairle nan Eilean Siar
Status:	New application
Date Surveyed:	11th – 12th March 2013
Surveyed by:	Eilidh Cole, Lars Brunner
Existing RMP:	none
Area Surveyed:	Southern end of Traigh Chuil beach to immediately south of Gob Steinis

Weather

No precipitation over the previous 48hrs. Survey period had also been preceded by approximately 3-4 weeks of very dry weather.

Monday 11th March 2013 – Dry, wind Easterly 11.3mph, gusting slightly. Temperate 4.6°C, cloud cover 5%.

Tuesday 12th March 2013 – largely dry with intermittent blustery showers/snow. Wind Easterly 4.5mph with strong gusts preceding showers. Temperature 2.4°C, cloud cover 95%.

Stakeholder engagement during the survey

Both the harvester and local sampling authority were contacted prior to the survey in order to plan to meet on location and gather information. Neither the harvester nor sampling officer could make time to meet on site, although both provided assistance prior to the survey with information on the site.

Fishery

The fishery at Tong Sands consists of hand harvest of common cockles from the sands at the centre of the bay. No fixed facilities for harvest handling (i.e. shore base) were noted on the survey.

The fishery is new, and the harvester's short term plan is to sell to the local market in the tourist season from April to October and he is planning to make all customers aware of the classification of his stock and the need to cook the product to prescribed temperature and duration. The harvester was not able to provide additional information on plans for the long term at the time of writing/survey.

Sewage Sources

The entire area around Tong Sands is inhabited. To the north of the bay the villages of Aird Thunga and Tunga consist of detached private dwellings with Scottish Water septic tanks and associated overflow discharges located at the southern end of Traigh Chuill beach, Tong and Tong Road.

The western edge of the bay fringes the edges of Stornoway as well as the villages of Newmarket and Lacasdail. The latter two villages consist of similar style housing to the villages to the north, whereas Stornoway consists of a higher density of residential dwellings with a small mix of industrial facilities as well as schools and a hospital. Scottish Water septic tanks and associated discharge pipes exist at Steinis (where the settlement returns to detached private dwelling houses), and at Sand Street there are tanks and associated pumping facilities, but no discharge pipe was visible.

Seasonal Population

There are no campsites or caravan parks noted in the vicinity of Tong Sands, the nearest being to the north at Traigh Chuill beach. There are several B&Bs present in the survey area and a larger number, including hotels, in the greater Stornoway area.

Boats/Shipping

There are no permanent piers or anchorages around Tong Sands. The only moorings noted were three running moorings located at NB 455 358, although no boats were on the moorings at the time.

Farming and Livestock

Farming is present around most of the survey area. The majority is undertaken on small crofts, revolving around sheep and is concentrated on the Aird Thunga (2 horses, 15 sheep), Lacasdail (15 sheep) and Steinis (28 sheep) areas. It is likely that these observations are an underestimate of the actual number present.

Land Use

Land use around Tong Sands is mixed, with the northern part of the bay consisting of detached private dwellings and mixed habitation, with small scale crofting agriculture and some small areas of forest/woodland to the north-west. To the west lies an expanse of moor, presumably grazed although no livestock was seen at the time of survey, with habitation from the villages of Newmarket and Lacasdail. To the south-west the town of Stornoway provides a mix of habitation and industry, while the south shore of the bay has small scale habitation of detached private dwellings mixed with agriculture/crofting. Finally the far south-eastern corner of the bay has industrial use with the footprint of Stornoway Airport.

There was no evidence of forestry activity observed during the survey.

Land Cover

In the northern part of Tong Sands there is a mixture of rough and improved grassland along with heath. The large area immediately west of the bay is a mix of unimproved heath, grassland and marsh, with some plantation woodland 500m back from the shore. The area to the south of the sands is a mixture of rough/improved grassland.

Watercourses

There are two major watercourses in the survey area, the Abhainn a Ghlinne Dhuibh, which discharges at NB 4400 3600, and the Abhainn Lacasail, which discharges at NB 4300 3470. The Abhainn a Ghlinne Dhuibh disappears underground into the grassland/marsh at several sections on its entry to the bay, and also splits flow, making accurate flow measurement difficult. As such, the largest and main tributary was sampled downstream, so as to try and incorporate all of the smaller tributaries flowing into it to allow the most representative measurement.

There were several smaller watercourses, some of which had little flow due to the dry weather prior to the survey. These include a small unnamed stream discharging onto the beach at NB 4640 3717, a drainage ditch (unnamed) at

NB 4600 3610, and a combined drainage ditch/stream (unnamed) at NB 4406 3367.

There are numerous small freshwater land seeps immediately above the high tide mark.

Wildlife/Birds

Birdlife seen included seagulls, pigeons, mallard ducks and geese. The most frequent of these were seagulls, with up to 50 birds seen at the discharge of the Abhainn Lacasail.

Shoreline Survey Maps

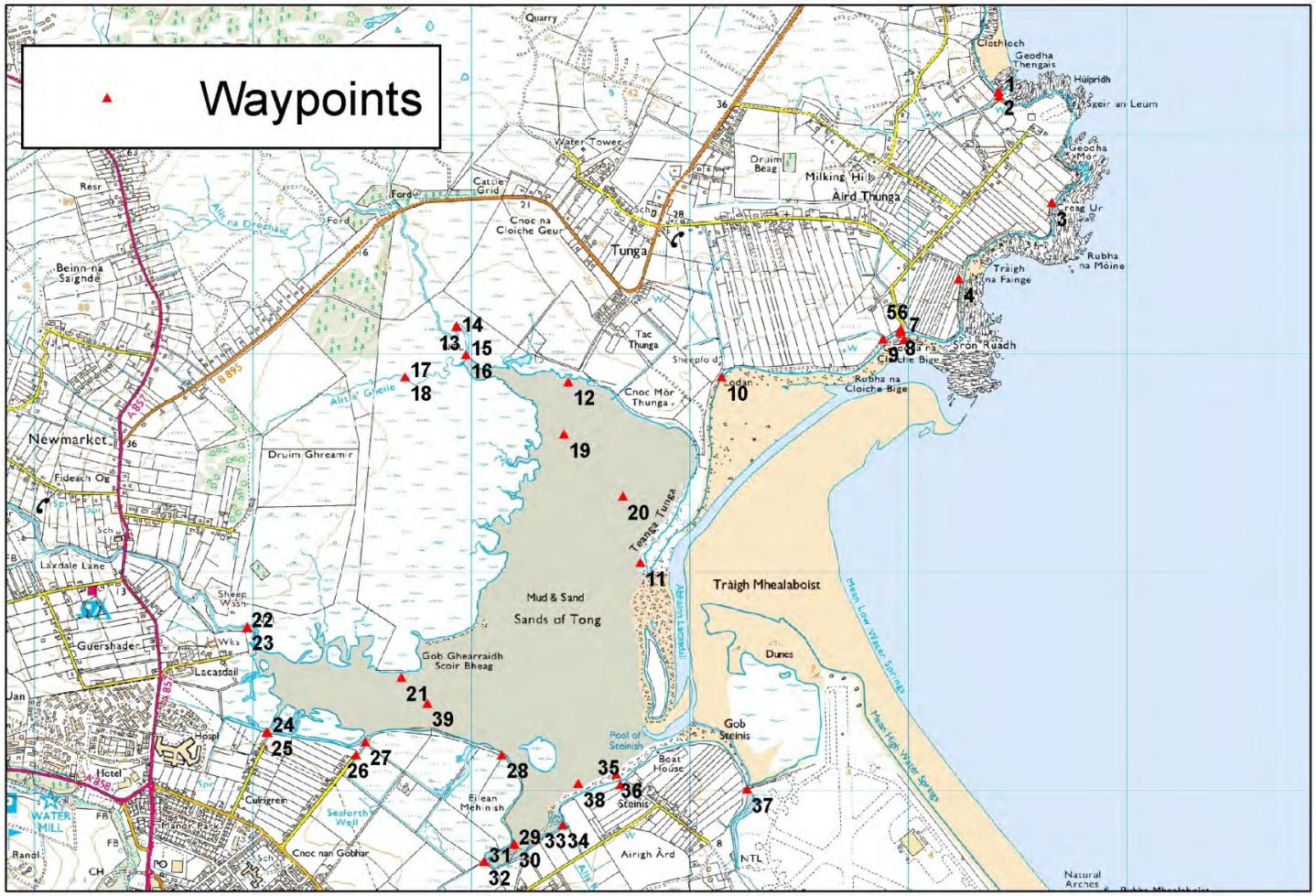

Figure 1. Tong Sands Waypoints

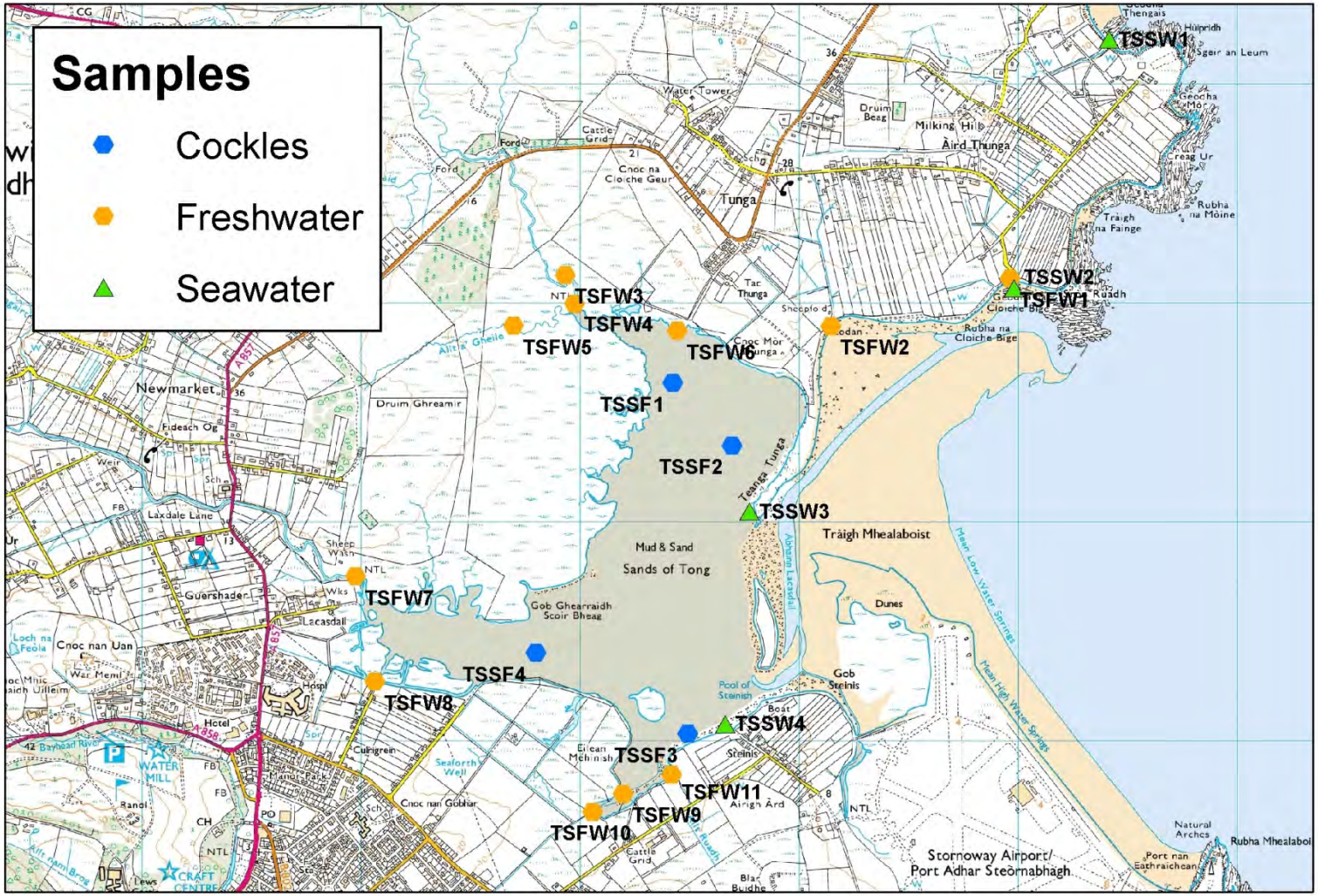

Figure 2. Tong Sands samples

Table 1 Shoreline Observations

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
1	11/03/2013	8:54	NB 46416 37181	146417	937182	Fig.3		Start of survey at Aird Thunga. Discharge pipe encased in concrete, no discharge visible.
2	11/03/2013	8:57	NB 46415 37203	146415	937203		TSSW1	Planned seawater sample taken north of Aird Thunga.
3	11/03/2013	9:19	NB 46657 36694	146657	936694	Fig.4		Two horses in field next to shore. Six sheep in adjacent field. Approximately twelve houses behind these fields. Sheep droppings along the cliff tops. Five seagulls and one pigeon on the shore.
4	11/03/2013	9:31	NB 46231 36344	146232	936345			Nine sheep in field along the cliff top. Drainage furrows all along the cliff top.
5	11/03/2013	9:40	NB 45967 36112	145968	936113	Fig.5		Approximately fifteen houses behind shore. Pipe running under road onto the shore. Discharge coming from pipe. Diameter - 52 cm; Depth - 4 cm; Flow - 0.549 m/s; SD - 0.017.
6	11/03/2013	9:41	NB 45966 36112	145967	936113	Fig.5	TSFW1	Freshwater sample taken. Sample associated with Waypoint 5.
7	11/03/2013	9:46	NB 45982 36066	145982	936067		TSSW2	Planned seawater sample taken at Geodha na Cloiche Bige.
8	11/03/2013	9:49	NB 45964 36102	145964	936102			Storm overflow, not flowing. Possible septic tanks / storage tanks with houses behind.
9	11/03/2013	9:54	NB 45887 36070	145887	936071			Burn running off croftland. Burn runs under road onto shore. Stream runs into valve which is badly blocked therefore no measurements or sample taken. No animals visible.
10	11/03/2013	10:15	NB 45147 35895	145148	935895	Fig.6	TSFW2	Burn running from fields onto shore. Width - 70 cm; Depth - 6 cm; Flow - 0.170 m/s; SD - 0.002. Approximately fifteen geese in field behind burn. Freshwater sample taken.
11	11/03/2013	10:35	NB 44775 35046	144775	935047		TSSW3	Planned seawater sample taken at Teanga Tunga.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
12	11/03/2013	10:57	NB 44446 35874	144447	935874		TSFW6	Discharge pipe flowing. Houses behind. Freshwater sample taken.
13	11/03/2013	11:15	NB 43934 36126	143934	936127			Abhainn a Ghlinne Dhuibh, very slow flow. Ground soft and rivers splits underground in several places. Sample taken downstream from largest visible tributary of the river, in an attempt to get most representative flow. Width - 1.7 m; Depth - 11 cm; Flow - 0.079 m/s; SD - 0.002.
14	11/03/2013	11:16	NB 43934 36128	143934	936128		TSFW3	Freshwater sample taken. Sample associated with Waypoint 13.
15	11/03/2013	11:23	NB 43976 35998	143976	935998	Fig.7		Cast iron discharge pipe enclosed in concrete. Looks contaminated. Village behind. Diameter - 15 cm. Flow measurement not possible as the pipe exit was completely submerged in water (see Fig. 7).
16	11/03/2013	11:27	NB 43977 35997	143977	935998	Fig.7	TSFW4	Freshwater sample taken. Sample associated with Waypoint 15.
17	11/03/2013	11:37	NB 43699 35896	143699	935897	Fig.8		Smaller stream with many tributaries possibly due to the ground being very soft. Width - 33 cm; Depth - 5 cm; Flow - 0.251 m/s; SD - 0.001. Duck droppings next to stream.
18	11/03/2013	11:40	NB 43699 35896	143700	935897	Fig.8	TSFW5	Freshwater sample taken. Sample associated with Waypoint 17.
19	11/03/2013	12:08	NB 44427 35635	144427	935635		TSSF1	Planned shellfish sample taken in Sands of Tong south of Tunga.
20	11/03/2013	12:42	NB 44696 35350	144696	935350		TSSF2	Planned shellfish sample taken further southeast of Waypoint 19.
21	11/03/2013	13:48	NB 43682 34520	143682	934520			Three sheep on shore, no fence separating them from shore

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
								line. Note: could not find stream marked on map for sampling next to the Abhainn Lacasail, this is possibly due to the dry weather. Approximately fifty to sixty gulls on the shore. Twelve sheep in field above. No fence on the shore.
22	11/03/2013	14:07	NB 42975 34748	142975	934749	Fig.9		Abhainn Lacasail. Width - 3.7 m; Depth a - 13 cm; Flow a - 0.395 m/s; SD a - 0.029. Depth b - 15 cm; Flow b - 0.135 m/s; SD b - 0.010. Depth c - 10 cm; Flow c - 0.234 m/s; SD c - 0.004.
23	11/03/2013	14:07	NB 42977 34752	142977	934753	Fig.9	TSFW7	Freshwater sample taken. Sample associated with Waypoint 22.
24	11/03/2013	14:30	NB 43071 34268	143072	934268	Fig.10		Land drainage and open man-hole cover with pump. Width - 1.5 m; Depth - 8 cm; Flow - 0.027 m/s; SD - 0.002.
25	11/03/2013	14:30	NB 43066 34271	143067	934272	Fig.10	TSFW8	Freshwater sample taken. Sample associated with Waypoint 24.
26	11/03/2013	14:42	NB 43475 34167	143475	934167	Fig.11		Scottish Water Station, Sand Street Pumping Station.
27	12/03/2013	10:10	NB 43515 34227	143516	934227			Start of second day of survey at Sand Street.
28	12/03/2013	10:23	NB 44141 34167	144142	934168			Land drain - perforated plastic pipe. No discharge. No sign of stream discharge as noted. Some mixed freshwater/seawater seepage from low lying marsh pools but nothing worth sampling.
29	12/03/2013	10:35	NB 44197 33758	144198	933759	Fig.12		Discharge pipe. Large cast iron pipe with storm valve on end. Approx. 30 cm diameter. Sample (waypoint 30) was taken after the tide had gone down. Flow measurement was very difficult due to the presence of the storm valve and as such flow was estimated instead (using the sample vial [30mL]which was filled in 2 seconds) at 15mL/s.

No.	Date	Time	NGR	East	North	Associated photograph	Associated sample	Description
30	12/03/2013	10:36	NB 44197 33759	144198	933760	Fig.12	TSFW9	Freshwater sample taken. Sample associated with Waypoint 29.
31	12/03/2013	10:41	NB 44061 33676	144061	933677	Fig.13		Storm culvert draining land area behind. No obvious contamination other than approximately 28 sheep and 12 geese in field.
32	12/03/2013	10:41	NB 44060 33677	144061	933677	Fig.13	TSFW10	Freshwater sample taken (associated with Waypoint 31), but impossible to give accurate measurements for flow etc. as storm drain is backed up.
33	12/03/2013	10:53	NB 44421 33846	144421	933847			Stream running off farmland and moor. Width - 1.07 m; Depth - 8 cm; Flow - 0.084 m/s; SD - 0.002.
34	12/03/2013	10:53	NB 44421 33846	144421	933847		TSFW11	Freshwater sample taken. Sample associated with Waypoint 33.
35	12/03/2013	11:05	NB 44684 34029	144685	934029			Scottish Water sewage compound storage chamber - green kiosk (Steinish Street). Discharge pipe onto shore.
36	12/03/2013	11:10	NB 44663 34078	144664	934078		TSSW4	Planned seawater sample taken at Steinis, near Waypoint 35.
37	12/03/2013	11:24	NB 45262 34010	145263	934010			End of survey path. Large tidal pond outflowing into bay. Airport boundary.
38	12/03/2013	11:56	NB 44492 34034	144493	934034		TSSF3	Planned shellfish sample taken at the Steinis end of production area.
39	12/03/2013	12:29	NB 43800 34403	143800	934403		TSSF4	Planned shellfish sample taken at the southwest region of production area.

Photographs referenced in the table can be found attached in separate document as Figures 3 – 13.

Sampling

Water samples were collected at sites marked on the map shown in Figure 1. Samples were transferred to either Biotherm 10 or Biotherm 25 boxes with ice packs and shipped to Glasgow Scientific Services (GSS) for *E.coli* analysis. All samples were shipped on the day of collection and all of them were received and analysed the following day. The sample temperatures on arrival to the laboratory ranged between 4.7 ˚C and 5.2 ˚C.

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

$$\text{Salinity (ppt)} = 0.0018066 \times Cl^{-}\ (\text{mg/L})$$

At Tong Sands, cockle samples were collected. These were taken at low tide in the intertidal zone. No salinity profiles were taken.

Table 2. Water Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (cfu/100ml)	Salinity (ppt)
1	11/03/2013	TSSW1	NB 46415 37203	Seawater	56	36.3
2	11/03/2013	TSFW1	NB 45966 36112	Freshwater	<100	
3	11/03/2013	TSSW2	NB 45982 36066	Seawater	55	35.8
4	11/03/2013	TSFW2	NB 45147 35895	Freshwater	100	
5	11/03/2013	TSSW3	NB 44775 35046	Seawater	2	35.2
6	11/03/2013	TSFW3	NB 43934 36128	Freshwater	400	
7	11/03/2013	TSFW4	NB 43977 35997	Freshwater	2200000	
8	11/03/2013	TSFW5	NB 43699 35896	Freshwater	<100	
9	11/03/2013	TSFW6	NB 44446 35874	Freshwater	1000	
10	11/03/2013	TSFW7	NB 42977 34752	Freshwater	<100	
11	11/03/2013	TSFW8	NB 43066 34271	Freshwater	200	
12	12/03/2013	TSFW9	NB 44197 33759	Freshwater	<1000	
13	12/03/2013	TSFW10	NB 44060 33677	Freshwater	100	
14	12/03/2013	TSFW11	NB 44421 33846	Freshwater	<100	
15	12/03/2013	TSSW4	NB 44663 34078	Seawater	9	34.3

Table 3. Shellfish Sample Results

No.	Date	Sample	Grid Ref	Type	E. coli (MPN/100g)
1	11/03/2013	TSSF1	NB 44427 35635	Cockles	1400
2	11/03/2013	TSSF2	NB 44696 35350	Cockles	220
3	12/03/2013	TSSF3	NB 44492 34034	Cockles	490
4	12/03/2013	TSSF4	NB 43800 34403	Cockles	70

Photographs – Tong Sands Sanitary Survey.

Figure 3. Waypoint 1. Discharge pipe encased in concrete, no discharge visible.

Figure 4. Waypoint 3. Two horses in field next to shore.

Figure 5. Waypoint 5 & 6. Pipe running under road onto the shore with discharge coming from pipe. Site of sample TSFW1.

Figure 6. Waypoint 10. Burn running from fields onto shore. Site of sample TSFW2.

Figure 7. Waypoint 15 & 16. Cast iron discharge pipe enclosed in concrete. Looks contaminated. Site of sample TSFW4.

Figure 8. Waypoint 17 & 18. Duck droppings next to stream. Site of sample TSFW5.

Figure 9. Waypoint 22 & 23. River Laxdale. Site of sample TSFW7.

Figure 10. Waypoint 24 & 25. Land drainage and open man-hole cover with pump. Site of sample TSFW8.

Figure 11. Waypoint 26. Scottish Water Station, Sand Street Pumping Station.

Figure 12. Waypoint 29 & 30. Large cast iron discharge pipe with storm valve on end. Site of sample TSFW9.

Figure 13. Waypoint 31 & 32. Storm culvert draining land area behind. Site of sample TSFW10.