DEVON AREA
INTERNAL REPORT

ENVIRONMENT
AGENCY

THE ENVIRONMENTAL IMPACT OF SEWAGE DISCHARGES TO THE SALCOMBE ESTUARY, SOUTH DEVON, FROM *ANCHOR WATCH*, CLIFF ROAD, SALCOMBE

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All times GMT

1.0 INTRODUCTION

Anchor Watch is multiple-occupancy property situated at the southern end of Salcombe Town. The property has an unconsented sewage discharge to Salcombe Harbour at NGR SX 73472 38149. The outfall lies within a small bay (subsequently referred to as Woodville Bay) and is situated some 5m beyond Mean Low Water Springs (MLWS). The discharge is not treated.

The property owners have applied for connection to the main under Section 101A (the so-called 'first time sewerage' section) of the 1991 Water Industry Act. To assist in determining the application Devon Area Investigations Team (DAIT) were asked by Environment Protection (South) to assess the environmental impact of the current discharge.

The principal impact from the discharge will be bacteriological and in order to quantify it's magnitude we need to use some sort of standard against which we can assess water quality. The most appropriate bacteriological standards are those already used by the Agency in this area to determine (i) bathing water quality at North and South Sands (Bathing Water Directive) (**Reference1**.) and (ii) water quality in relation to the trial shellfishery at Geese Quarry (Shellfish Directive) (**References 2 and 3** and **Figure 1**.).

In addition to the sites above there are 4 floating crab pens some 150m from the outfall (**Figure 1**). The effect of the discharge on these will also be considered.

2.0 METHOD

An initial visit was made to the property to inspect the sewerage and to identify the position of the outfall.

A **Preliminary Dye Study** was then carried out to gauge the dispersion behaviour of the discharge over a full tide cycle (High Water 1 (HW1) to High Water 2 (HW2)). A continuous discharge was simulated by introducing freshwater to the discharge chamber using a hose. Discrete doses of fluoroscein (green) and rhodamine (red) dye were added to the discharge via this chamber. Dye was used in 1 litre quantities. Behaviour of the plume was recorded visually using sketches and photography. The survey was conducted over Spring tides when plume dispersion was likely to be greatest.

Using information obtained during the study above a second survey (**Principal Survey**) was undertaken, again on Spring tides. Dye releases were made via a simulated discharge as previously. In addition a continuous dose of Bacillus globigii tracer was made to the discharge. Records were made throughout the survey of (i) flow rates via the hose, (ii) flow rates of globigii solution and (iii) the concentrations of globigii being released.

The extent and rates of dispersion were assessed from tracer concentration in samples taken by boat at various points in the estuary, and from samples collected at the designated sampling points at North and South Sands. Drogues were also used to record the plume's direction and rate of travel. Sample points and drogue positions were determined using uncorrected GPS positions obtained from on board the boat. As in the preliminary survey, behaviour of the plume was recorded visually using sketches and photography. Meteorological observations were also made.

Tracer concentration was used to quantify the potential bacteriological impact of the discharge on the sites mentioned above.

3.0 RESULTS AND DISCUSSION

3.1 INITIAL VISIT

The initial visit, made on 22/06/01, showed that sewage from the property seems to receive no treatment and that discharges are made via a metal pipe running down the cliff and across the foreshore (**Photograph 1**.). The original metal pipe, which ends just below MLWS, appears to have been extended with the addition of a 5m approx. white plastic section.

3.2 PRELIMINARY DYE STUDY

The study was carried out on 23/07/01 when the times of high water were 07:43 (HW1) and 19:58 (HW2). Low water was at 13:56. The weather was dry with a light to moderate W to SW wind. Dye was introduced to the discharge between High Water and 1 hour 20 minutes following High Water (HW1 to HW1+01:20). Movement of the discharge is shown in **Figure 2.**

Dye was seen to issue from both the intended outfall position and from the joint between the metal and plastic pipes (**Photograph 2**.).

Over the first half of the ebb tide (HW1 to HW1+03:00 approx.) dye moved towards the estuary mouth (**Figure 2** and **Photograph 4**). The maximum rate of travel was >300 m in 30 minutes (>0.16 ms^{-1})(08:45 to 09:15). Within approx. 400m of the discharge point the plume had largely dispersed and dye was difficult to discern. No visible impact at the Bathing Beaches was observed.

During the second half of the ebb the dye tended to pond around the outfall and then to move in a NE direction along the shore of Woodville Bay. This latter movement may have been the result of a clockwise eddy set up within Woodville Bay by the ebb current in the main channel.

From HW1 + 02:00 to HW1 + 06:10 the plume was impacting at the crab pens. At LW1 dye at the northernmost point of Woodville Bay was being carried round the small headland and on up the estuary (**Photograph 3**).

3.3 PRINCIPAL DYE AND TRACER SURVEY

The survey was carried out on 06/09/01 between HW1 and HW2 -02:28. The times of High Water were 07:45 (HW1) and 19:57 (HW2) and Low Water was at 13:51. The weather was dry with light NW winds. A risk assessment had been completed beforehand (**Appendix 1**.).

Positions were acquired using an on-board GPS system. Corrections of 0.03'S, 0.07'E were applied as per Imray Chart Y48. Comparison of GPS and known positions indicated that sample points were reported with an accuracy of 20 m.

Results of sample analysis are given in **Table 1** and the movement of dye is shown in **Figures 3 and 4. Figure 5** shows the behaviour of the surface drogue. Discharge and globigii dosing rates are given in **Appendix 2**.

Prior to the release of globigii tracer from the outfall background samples were taken from the boat at point 'upstream' of the *Anchor Watch* outfall and from positions just off the beaches at South Sands and North Sands. The sample 'upstream' of *Anchor Watch* showed a positive globigii result of 18 100ml^{-1} (**Table 1**.) but succeeding samples taken outside the dye plume contained no globigii. Was the positive result genuine, we would have expected to find globigii in at least one of the subsequent samples that were taken from outside the plume. It seems likely, therefore, that the positive result in the background sample was an aberration (possibly the result of cross-contamination) and will be ignored in what follows.

Using a calculated B. globigii concentration value for the discharge (**Appendix 2**.) and an assumed faecal coliform concentration (**Appendix 3**.) we can predict the bacteria concentrations that are likely to derive from the *Anchor Watch* discharge for any sampled point in the estuary. Data so calculated are termed bacterial *equivalents* and are included in **Table 1**.

As a result of alterations that were made at 08:30 to the flow rates of tracer and freshwater, two flow regimes were identified; regime A which was effective from 07:30 to 08:30 and regime B which applied for the rest of the survey. Mean flow rates were 0.33 ls^{-1} for Regime A and 0.15 ls^{-1} for Regime B (**Appendix 2**.)[1]. Because we cannot confidently ascribe the globigii concentration in a particular sample to one flow regime as opposed to the other, the bacterial *equivalent* calculations shown in **Table 1**. necessarily include predictions based on both regimes. However, subsequent reference to bacterial *equivalent* concentrations will be based on regime A which gave higher tracer concentrations and thus represents the greater impact.

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[1] These flows are likely to exceed real discharge rates over extended periods but underestimate instantaneous discharge rates.

In **Figures 6-12** sample globigii concentrations have been combined with observed dye movement to produce possible synopses for plume behaviour (it should be noted when interpreting these Figures that each covers a time frame and so does not represent a 'snapshot' of the situation at a specific time).

As in the Preliminary Dye Study dye was seen to be issuing from the outfall at two points.

Generally, plumes tended to be carried towards the mouth of estuary on the ebb tide, when the discharge has the potential to impact at the bathing beaches of North and South Sands, whilst on the flood they were carried 'up' the estuary, where they have the potential to impact at the shellfshery, or tended to 'pond' at the outfall. In considering the results in more detail it is convenient to deal with the flood and ebb tides separately.

(i) Impacts of the Ebb tide on the bathing beaches at North and South Sands.

When fully established the ebb current was observed to follow the main channel. By comparison, the bodies of water overlying North and South Sands beaches appeared to be relatively static (although circulatory currents may well be present). At HW1+01:53 considerable disturbances of the water surface were noted at the interface between these 'static' areas and the main channel flow (**Figure 5**.). Maximum flow velocities 'downstream' of the outfall (measured from plume and drogue movement) were in the order of 0.49 ms^{-1} at HW1+01:23 to 01:36 (in comparison with 0.17 ms^{-1} maximum during the Preliminary Dye Study, **Section 3.2**).

Dye and tracer work indicated that the effluent plume tended to follow the main channel towards the estuary mouth throughout the ebb. From HW1+02:40 to 05:11 the plume was also carried into North Sands but it was not until LW1+01:00 approx. before an impact at South Sands was found (**Figures 6-10**).

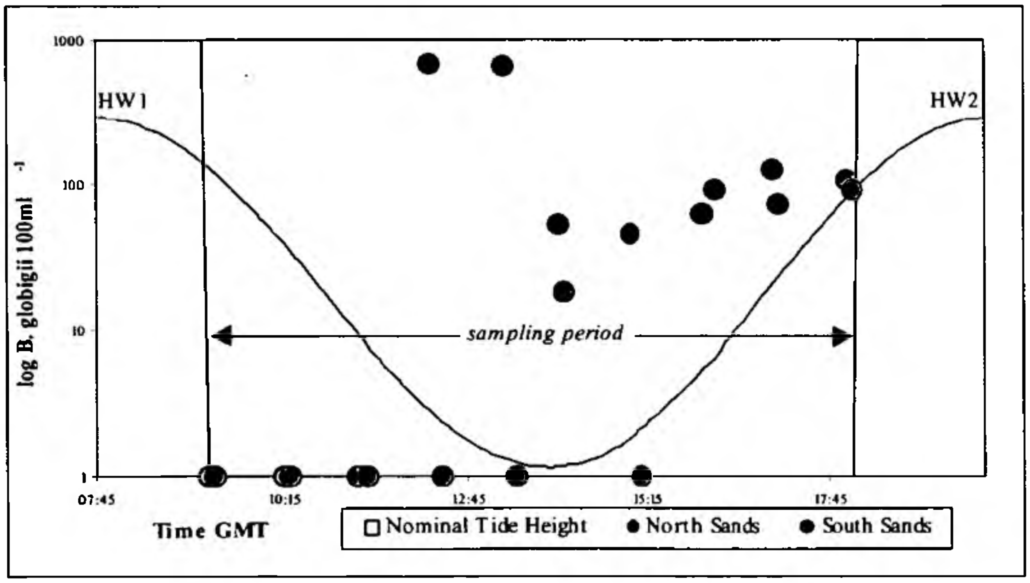

FIGURE 13. Principal Survey: B. globigii concentration and tide state at North and South Sands.

Figure 13. shows the relationship between tide state and B. globigii concentration at North and South Sands throughout the survey. B. globigii was first detected at North Sands at HW1+04:30 and at South Sands at HW2-05:49. The greatest impact at North Sands was 67 faecal coliform *equivalent* (at HW1+ 04:30) whilst at South Sands the value was 9 faecal coliform *equivalent* (between HW2–03: 49 and HW2–01:53). A sample was taken at both beaches the following day and these showed faecal coliform *equivalent* concentrations of 3 100ml^{-1} in each case.

The impacts identified under survey conditions, therefore, were insufficient to cause beaches to fail. However, the *Anchor Watch* discharge may serve to augment other sources of bacteria.

(ii) Impacts of the Flood tide on the trial shellfishery at Geese Quarries.

Dye and tracer work indicated that, for the initial part of the flood, the effluent plume moved north-east from the outfall, against the shore, and then out towards the crab pens (**Photographs 5 and 6** and **Figure 11**). The plume then receded before spilling out to the south of the outfall and filling the southern end of Woodville Bay.

The alignment of weed in the vicinity of the outfall between HW1 and HW1+04:50 suggested that there was a steady circa southerly current and this may have been part of a general anticlockwise eddy within Woodville Bay. At LW1+02:53 a drogue was placed at what appeared to be an interface between the south-eastern extremity of this eddy and the flood current. The drogue was carried rapidly up the channel (**Figure 5**.) suggesting that contaminated water within the eddy is 'stripped off' by the flood current. This is supported by the globigii counts found in samples taken further up the channel between LW1+03:15 and LW1+03:36. Nevertheless, faecal coliform equivalent concentrations had reduced to a maximum of 66 100 ml^{-1} within 500m of the discharge point.

No impact was found at Mill Bay bathing water (**Figure 12.**).

Under the Shellfish Directive Geese Quarries was classed as C in 2000. In order for improvements to be made to the *Anchor Watch* (or any other) discharge under the Directive we would have to demonstrate that the impact of the discharge at the shellfishery is sufficient to contribute to the fishery failing to achieve class B. In addition the Agency considers faecal coliform concentrations in excess of 1500 100 ml^{-1} to be unacceptable at a shellfishery (**Reference 4**.). The fishery is some 4 km from the discharge point. Further dilution and die-off will take place over the remaining 3.5 km and concentrations at the shellfishery are likely to be very low. It is unlikely that the discharge can either influence classification of the shellfishery or result in faecal coliform concentrations of >1500 100ml^{-1} so far up the estuary. It is feasible that faecal coliforms from the discharge are not carried as far as the shellfishery in any event. It had been hoped that shellfish flesh could have been analysed following the survey for the presence/absence of B. globigii but this was technically not possible.

(iv) Other Impacts

The small private beach adjacent to the outfall was substantially affected by dye for the greater part of both surveys and is thus liable to be heavily contaminated with bacteria at any state of tide.

The maximum *equivalent* total and faecal coliform concentrations at the crab pens were 1423 and 398 100ml^{-1} respectively (adjacent to pen 3) at 14:05 (LW+00:14). It is not known whether this poses a health risk when the crabs are subsequently used - this will inevitably depend on the treatment they receive and way in which they are used and, moreover, the evaluation of such a risk is outside the scope of the Agency. South Hams District Council Environmental Health Department were unable to establish the risk when contacted because the surveys provide insufficient information (**Appendix 4**.).

Transects made across the effluent plume in Woodville Bay included a total and faecal coliform *equivalent* concentration of 28107 and 7857 100ml^{-1} respectively (LW1+02:37). This was the most concentrated of all samples taken during the survey.

Rock pools in the area of the Fort Charles ruin are exposed on the ebb tide and have the potential to contain residual effluent. A sample was taken from one of these pools adjacent to the NW side of the ruin at LW1+00:44. The total and faecal coliform *equivalents* were 18 100ml^{-1} and 5 100ml^{-1} respectively which probably represents a low risk to anyone coming into contact with such water.

One sample was taken at the mouth of the estuary (HW1+03:02) which showed no contamination.

3.4 CONCLUSION

As we would expect discharges from *Anchor Watch* are carried towards the estuary mouth on the ebb tide and inland on the flood.

Impact at the Bathing Waters

Impact at North and South Sands was low. No contamination at Mill Bay beach was found.

North and South Sands are liable to contamination on the ebb tide and, although the contamination may persist at least 14 hours, the levels of contamination are not high. Generally, the effect of dilution was to reduce total and faecal coliform concentrations at North and South Sands by log5.6.

Impact at the crab pens

Impact at the crab pens was high.

Eddies appear to form in the bay around the outfall: clockwise on the ebb tide, anticlockwise on the flood. The clockwise eddy lags behind the tide state so that it 'overruns' low water and continues to operate at the start of the flood. The anticlockwise eddy may exhibit the same behaviour. Bacterial contamination of the Woodville Bay area is likely to be high so that there is a considerable impact at the crab pens and along the foreshore. Bacterial concentrations were reduced at the crab pens by log4.8.

Impact at Geese Quarries

The level of contamination at Geese Quarries is believe to be very low if not absent.

Field work was undertaken on Spring Tides. It is believed that the effect of Neap Tides would be to reduce dispersion resulting in less contamination of the bathing beaches and probably no effect at the shell fishery. Bacteria concentrations close to the outfall, however, are likely to be higher so that impacts at the crab pens and along the foreshore would be greater.

The predicted levels of contamination suggested above are likely to represent 'worst case' conditions for three reasons: we have used the globigii flow regime that gave the greatest impact, we employed a continuous simulated discharge whereas, in reality, discharges will be intermittent, and no account has been taken of bacterial die-off/mortality rates which would result in a circa 90% faecal coliform reduction over 10 hours (*Gould and Munro*, 1981, and others).

Faecal coliform bacteria (and, in the case of this document, their *equivalents*) are used as indicators of faecal pollution: their presence may mean that other intestinal pathogens are also present.

3.5 RECOMMENDATIONS

The following are recommended:

3.5.1 The appropriate Environmental Health Office is made aware of the potential bacteria concentrations at the crab pens in order that they can further advise the crab fishermen if required.

ACTION: **DAIT** (This Action has been completed)

3.5.2 Untreated discharges to the estuary are undesirable. If this discharge cannot be treated or connected to the main an extension to the outfall pipe is recommended (when repairs to the faulty joint would also be required). The surveys suggest that a 70m extension laid in a south-easterly direction would enable dispersion to main channel flows at all states of the tide.

ACTION: **ENVIRONMENT PROTECTION OFFICER**

3.5.3 Owners of *Anchor Watch* are advised that water at the private beach is liable to considerable bacterial contamination.

ACTION: DAIT

3.6 REFERENCES

1.	European Union	Council Directive 76/160/EEC of 8 December 1975 concerning the quality of bathing water.
2.	European Union	Council Directive 79/923/EEC of 30 October 1979 on the quality required of shellfish waters.
3.	European Union	Council Directive 91/492/EEC of 15 July 1991 laying down the health conditions for the production and the placing on the market of live bivalve molluscs.
4.	Environment Agency	Wright. C., 2001. Consenting discharges to achieve the requirements of the Shellfish Waters Directive (Microbial Quality).

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DEVON AREA INVESTIGATIONS TEAM
NOVEMBER 2001

TABLE 1. *ANCHOR WATCH* SURVEY 06/09/01: BACILLUS GLOBIGII ANALYSIS

BEACH SAMPLES

Time (GMT)	wrt HW1/ HW2	Sample Site Description/Notes		Glob No/100ml	Flow Regime A		Flow Regime B	
					Total coliform *equivalent*	Faecal coliform *equivalent*	Total coliform *equivalent*	Faecal coliform *equivalent*
09:15	01:30	Salcombe North Sands		< 10	3.47	0.97	1.61	0.45
10 15	02:30	Salcombe North Sands		< 10	3 47	0.97	1.61	0.45
11:15	03 30	Salcombe North Sands		< 10	3.47	0.97	1.61	0 45
12:15	04:30	Salcombe North Sands		690	239 43	66.93	111.09	31.05
13:16	05:31	Salcombe North Sands		660	229 02	64 02	106 26	29.7
13:57	-06 00	Salcombe North Sands		54	18.738	5.238	8 694	2.43
14:58	-04 59	Salcombe North Sands		45	15 615	4 365	7.245	2 025
15:57	-04 00	Salcombe North Sands		63	21.861	6.111	10 143	2 835
16:57	-03 00	Salcombe North Sands		126	43.722	12.222	20 286	5.67
17:58	-01 59	Salcombe North Sands		108	37.476	10 476	17.388	4.86
10:00		Salcombe North Sands	Taken 07/09/01	27	9.369	2.619	4.347	1.215
09:22	01:37	Salcombe South Sands		< 10	3.47	0.97	1.61	0.45
10:22	02:37	Salcombe South Sands		< 10	3.47	0.97	1.61	0 45
11:27	03 42	Salcombe South Sands		< 10	3.47	0.97	1.61	0.45
12:26	04.41	Salcombe South Sands		< 10	3.47	0.97	1.61	0.45
13:27	05 42	Salcombe South Sands		< 10	3.47	0.97	1.61	0 45
14:08	-5 49	Salcombe South Sands		18	6 246	1.746	2.898	0.81
15:08	-4 49	Salcombe South Sands		< 10	3 47	0.97	1.61	0 45
16:08	-3 49	Salcombe South Sands		90	31.23	8.73	14.49	4.05
17.05	-2 52	Salcombe South Sands		72	24.984	6.984	11.592	3.24
18.04	-1 53	Salcombe South Sands		90	31.23	8.73	14.49	4.05
10:10		Salcombe South Sands	Taken 07/09/01	36	12.492	3.492	5.796	1.62

BOAT SAMPLES

Symbol used for Figures	Time (GMT)	wrt HW1/ LW1	Sample Site Description/Notes	GPS North	GPS East	corrected as per Imray (-0.03'S;0.07'E) North	corrected as per Imray (-0.03'S;0.07'E) East	Glob No/100ml	Flow Regime A		Flow Regime B	
									Total coliform *equivalent*	Faecal coliform *equivalent*	Total coliform *equivalent*	Faecal coliform *equivalent*
	07:00	-00:45	Background 'U/S' Anchor Watch	50 13.78	-3 46 409	50 13.750	-3 46.339	18				
	07:08	-00:37	Background South Sands	50 13.529	-3 46.988	50 13.499	-3 46 918	< 10				
	07:15	-00 30	Background North Sands	50 13.757	-3 46.786	50 13.727	-3 46.716	< 10				
	07:57	00 12	centre plume	50 13.781	-3 46.523	50 13.751	-3 46.453	25000	8675	2425	4025	1125
	07 58		met obs: virtually no wind	50 13.702	-3 46.544	50 13 672	-3 46.474					
			leading edge of plume	50 13.715	-3 46.541	50 13 685	-3 46 471					
	08 02		drogue recovered	50 13.73	-3 46.59	50 13.700	-3 46.520					
	08:04		drogue repositioned at centre leading edge of plume	50 13.699	-3 45.51	50 13.669	-3 45.440					
●	08 05	00 20	outside	50 13.699	-3 46.528	50 13.669	-3 46 458	< 10	3 47	0.97	1.61	0.45
●	08 06	00 21	edge	50 13.708	-3 46.545	50 13.678	-3 46.475	7300	2533.1	708.1	1175.3	328 5
●	08 07	00 22	centre plume	50 13.712	-3 46.55	50 13.682	-3 46.480	2200	763.4	213.4	354.2	99
●	08:08	00 23	edge	50 13.719	-3 46 557	50 13 689	-3 46 487	162	56.214	15.714	26 082	7.29
●	08:10	00 25	outside	50 13.724	-3 46 564	50 13 694	-3 46 494	< 10	3.47	0 97	1.61	0 45

TABLE 1.(Cont.) *ANCHOR WATCH* SURVEY 06/09/01: BACILLUS GLOBIGII ANALYSIS

Symbol used for Figures	Time (GMT)	wrt HW1/ LW1	Sample Site Description/Notes	GPS North	GPS East	corrected as per Imray (-0.03'S:0.07'E) North	corrected as per Imray (-0.03'S:0.07'E) East	Glob No/100ml	Flow Regime A Total coliform *equivalent*	Flow Regime A Faecal coliform *equivalent*	Flow Regime B Total coliform *equivalent*	Flow Regime B Faecal coliform *equivalent*
	08:12		drogue fix	50 13.679	-3 46.592	50 13.649	-3 46.522					
●	08:23	00:38	outside	50 13.624	-3 46.555	50 13.594	-3 46.485	< 10	3.47	0.97	1.61	0.45
●	08:26	00:41	outside	50 13.65	-3 46.586	50 13.620	-3 46.516	< 10	3.47	0.97	1.61	0.45
●	08:27	00:42	edge	50 13.65	-3 46.616	50 13.620	-3 46.546	< 10	3.47	0.97	1.61	0.45
●	08:29	00:44	centre	50 13.662	-3 46.625	50 13.632	-3 46.555	1081	375.107	104.857	174.041	48.645
●	08:30	00:45	edge	50 13.684	-3 46.659	50 13.654	-3 46.589	18	6.246	1.746	2.898	0.81
●	08:31	00:46	outside	50 13.709	-3 46.701	50 13.679	-3 46.631	< 10	3.47	0.97	1.61	0.45
	08:33		drogue fix	50 13.671	-3 46.687	50 13.641	-3 46.617					
	09:08	01:23	centre plume	50 13.785	-3 46.526	50 13.755	-3 46.456	160000	55520	15520	25760	7200
X	09:14	01:29	out	50 13.611	-3 46.586	50 13.581	-3 46.516	< 10	3.47	0.97	1.61	0.45
X	09:15	01:30	?out	50 13.647	-3 46.625	50 13.617	-3 46.555	117	40.599	11.349	18.837	5.265
X	09:16	01:31	?in	50 13.685	-3 46.661	50 13.655	-3 46.591	18	6.246	1.746	2.898	0.81
X	09:17	01:32	?in	50 13.715	-3 46.726	50 13.685	-3 46.656	< 10	3.47	0.97	1.61	0.45
X	09:20	01:35	near ECBW	50 13.741	-3 46.77	50 13.711	-3 46.700	< 10	3.47	0.97	1.61	0.45
	09:21		drogue fix	50 13.647	-3 46.732	50 13.617	-3 46.662					
\	09:22	01:37		50 13.616	-3 46.672	50 13.586	-3 46.602	171	59.337	16.587	27.531	7.695
\	09:24	01:39		50 13.594	-3 46.701	50 13.564	-3 46.631	270	93.69	26.19	43.47	12.15
\	09:26	01:41		50 13.567	-3 46.783	50 13.537	-3 46.713	108	37.476	10.476	17.388	4.86
	09:29	01:44	between N and S Sands	50 13.593	-3 46.815	50 13.563	-3 46.745	< 10	3.47	0.97	1.61	0.45
+	09:53	02:08		50 13.55	-3 46.607	50 13.520	-3 46.537	< 10	3.47	0.97	1.61	0.45
+	09:56	02:11		50 13.537	-3 46.678	50 13.507	-3 46.608	63	21.861	6.111	10.143	2.835
+	09:58	02:13		50 13.534	-3 46.769	50 13.504	-3 46.699	153	53.091	14.841	24.633	6.885
+	10:00	02:15		50 13.533	-3 46.848	50 13.503	-3 46.778	< 10	3.47	0.97	1.61	0.45
+	10:02	02:17	off S Sands	50 13.521	-3 46.906	50 13.491	-3 46.836	< 10	3.47	0.97	1.61	0.45
	10:05		drogue fix	50 13.346	-3 46.721	50 13.316	-3 46.651					
+	10:25	02:40		50 13.577	-3 46.603	50 13.547	-3 46.533	< 10	3.47	0.97	1.61	0.45
+	10:26	02:41		50 13.607	-3 46.65	50 13.577	-3 46.580	< 10	3.47	0.97	1.61	0.45
+	10:28	02:43		50 13.652	-3 46.713	50 13.622	-3 46.643	640	222.08	62.08	103.04	28.8
+	10:29	02:44		50 13.704	-3 46.751	50 13.674	-3 46.681	210	72.87	20.37	33.81	9.45
+	10:31	02:46	N end beach	50 13.749	-3 46.748	50 13.719	-3 46.678	< 10	3.47	0.97	1.61	0.45
+	10:32	02:47	centre beach	50 13.738	-3 46.77	50 13.708	-3 46.700	< 10	3.47	0.97	1.61	0.45
+	10:33	02:48	S end beach	50 13.732	-3 46.824	50 13.702	-3 46.754	< 10	3.47	0.97	1.61	0.45
	10:47	03:02	estuary mouth	50 12.674	-3 46.763	50 12.644	-3 46.693	< 10	3.47	0.97	1.61	0.45

TABLE 1.(Cont.) *ANCHOR WATCH* SURVEY 06/09/01: BACILLUS GLOBIGII ANALYSIS

Symbol used for Figures	Time (GMT)	wrt HW1/ LW1	Sample Site Description/Notes	GPS		corrected as per Imray (-0.03'S:0.07'E)		Glob No/100ml	Flow Regime A		Flow Regime B	
				North	East	North	East		Total coliform *equivalent*	Faecal coliform *equivalent*	Total coliform *equivalent*	Faecal coliform *equivalent*
△	10:56	03:11		50 13.554	-3 46.624	50 13.524	-3 46.554	< 10	3.47	0.97	1.61	0.45
△	10:58	03:13		50 13.536	-3 46.697	50 13.506	-3 46.627	< 10	3.47	0.97	1.61	0.45
△	11.00	03:15		50 13 523	-3 46 816	50 13.493	-3 46.746	81	28.107	7.857	13 041	3.645
△	11:01	03:16		50 13.52	-3 46.926	50 13.490	-3 46.856	< 10	3.47	0.97	1.61	0 45
△	11:05	03:20		50 13.555	-3 46 612	50 13.525	-3 46.542	< 10	3.47	0.97	1 61	0.45
△	11:06	03:21		50 13.568	-3 46 654	50 13.538	-3 46.584	< 10	3.47	0.97	1.61	0.45
△	11.07	03:22		50 13.608	-3 46.703	50 13.578	-3 46.633	380	131.86	36.86	61.18	17.1
△	11.08	03:23		50 13.666	-3 46.73	50 13 636	-3 46.660	210	72.87	20.37	33 81	9 45
△	11:10	03:25	N end beach	50 13.725	-3 46.74	50 13 695	-3 46.670	18	6 246	1.746	2 898	0 81
△	11:11	03:26	centre beach	50 13.72	-3 46.764	50 13.690	-3 46.694	135	46.845	13 095	21.735	6 075
△	11:13	03:28	S end beach	50 13.704	-3 46 822	50 13 674	-3 46.752	< 10	3 47	0.97	1 61	0 45
⊙	12:15	04:30		50 13.554	-3 46 613	50 13.524	-3 46.543	< 10	3.47	0.97	1.61	0 45
⊙	12.16	04:31		50 13.56	-3 46 687	50 13.530	-3 46.617	99	34.353	9.603	15.939	4.455
⊙	12:17	04:32		50 13.551	-3 46.763	50 13.521	-3 46.693	54	18.738	5.238	8 694	2.43
⊙	12:19	04:34		50 13.531	-3 46 866	50 13.501	-3 46.796	45	15 615	4 365	7.245	2.025
⊙	12:21	04:36		50 13.523	-3 46.909	50 13.493	-3 46 839	< 10	3.47	0 97	1.61	0 45
⊙	12:38	04:53		50 13.561	-3 46.607	50 13.531	-3 46.537	< 10	3.47	0.97	1.61	0 45
⊙	12:39	04:54		50 13.595	-3 46.693	50 13.565	-3 46.623	54	18.738	5 238	8 694	2.43
⊙	12:40	04:55		50 13.655	-3 46.731	50 13.625	-3 46.661	99	34 353	9 603	15.939	4.455
⊙	12.49	05.04		50 13.687	-3 46.794	50 13.657	-3 46.724	< 10	3.47	0.97	1.61	0.45
⊙	12:55	05:10		50 13.707	-3 46.74	50 13.677	-3 46.670	590	204.73	57.23	94.99	26.55
⊙	12:56	05:11		50 13.721	-3 46 691	50 13.691	-3 46.621	300	104.1	29.1	48 3	13 5
✱	14 00	00 09	at first crab pen	50 13 808	-3 46 446	50 13.778	-3 46.376	1153	400 091	111.841	185.633	51.885
✱	14 01	00 10	at second crab pen	50 13 824	-3 46 432	50 13.794	-3 46.362	3000	1041	291	483	135
✱	14:05	00 14	at third crab pen	50 13 843	-3 46.143	50 13.813	-3 46.073	4100	1422.7	397.7	660.1	184.5
✱	14 07	00 16	at fourth crab pen	50 13.862	-3 46.93	50 13.832	-3 46.860	45	15.615	4.365	7.245	2.025
✱	14:11	00 20	s end plume	50 13.804	-3 46.485	50 13.774	-3 46.415	31000	10757	3007	4991	1395
✱	14:12	00 21	centre plume	50 13.818	-3 46.467	50 13.788	-3 46.397	16000	5552	1552	2576	720
✱	14 13	00 22	n end plume	50 13.838	-3 46 431	50 13 808	-3 46.361	19000	6593	1843	3059	855

TABLE 1.(Cont.) *ANCHOR WATCH* SURVEY 06/09/01: BACILLUS GLOBIGII ANALYSIS

Symbol used for Figures	Time (GMT)	wrt HWl/ LWl	Sample Site Description/Notes	GPS		corrected as per Imray (-0.03'S:0.07'E)		Glob No/100ml	Flow Regime A		Flow Regime B	
				North	East	North	East		Total coliform *equivalent*	Faecal coliform *equivalent*	Total coliform *equivalent*	Faecal coliform *equivalent*
★	14:17	00:26		50 13.557	-3 46.6	50 13.527	-3 46.530	< 10	3.47	0.97	1.61	0.45
★	14:19	00:28		50 13.603	-3 46.643	50 13.573	-3 46.573	72	24.984	6.984	11.592	3.24
★	14:23	00:32		50 13.653	-3 46.722	50 13.623	-3 46.652	153	53.091	14.841	24.633	6.885
★	14:27	00:36	S end beach	50 13.684	-3 46.807	50 13.654	-3 46.737	18	6.246	1.746	2.898	0.81
★	14:29	00:38	centre beach	50 13.696	-3 46.761	50 13.666	-3 46.691	< 10	3.47	0.97	1.61	0.45
★	14:30	00:39	N end beach	50 13.724	-3 46.681	50 13.694	-3 46.611	162	56.214	15.714	26.082	7.29
	14:35	00:44	rock pool adjacent NW side Fort Charles					54	18.738	5.238	8.694	2.43
★	14:44	00:53	N end beach	50 13.576	-3 46.389	50 13.546	-3 46.319	< 10	3.47	0.97	1.61	0.45
★	14:47	00:56	S end beach	50 13.51	-3 46.916	50 13.480	-3 46.846	45	15.615	4.365	7.245	2.025
★	14:50	00:59		50 13.515	-3 46.83	50 13.485	-3 46.760	81	28.107	7.857	13.041	3.645
★	14:52	01:01		50 13.537	-3 46.731	50 13.507	-3 46.661	< 10	3.47	0.97	1.61	0.45
★	14:54	01:03	at green buoy	50 13.556	-3 46.605	50 13.526	-3 46.535	< 10	3.47	0.97	1.61	0.45
□	16:09	02:18	Mill Bay Beach	50 13.84	-3 46.105	50 13.810	-3 46.035	< 10	3.47	0.97	1.61	0.45
□	16:11	02:20		50 13.858	-3 46.132	50 13.828	-3 46.062	< 10	3.47	0.97	1.61	0.45
□	16:13	02:22		50 13.914	-3 46.196	50 13.884	-3 46.126	18	6.246	1.746	2.898	0.81
□	16:14	02:23		50 13.925	-3 46.271	50 13.895	-3 46.201	153	53.091	14.841	24.633	6.885
□	16:26	02:35		50 13.729	-3 46.471	50 13.699	-3 46.401	18	6.246	1.746	2.898	0.81
□	16:27	02:36		50 13.75	-3 46.48	50 13.720	-3 46.410	< 10	3.47	0.97	1.61	0.45
□	16:28	02:37		50 13.759	-3 46.502	50 13.729	-3 46.432	81000	28107	7857	13041	3645
□	16:30	02:39		50 13.849	-3 46.454	50 13.819	-3 46.384	189	65.583	18.333	30.429	8.505
□	16:32	02:41		50 13.837	-3 46.433	50 13.807	-3 46.363	290	100.63	28.13	46.69	13.05
□	16:33	02:42		50 13.818	-3 46.39	50 13.788	-3 46.320	240	83.28	23.28	38.64	10.8
□	16:34	02:43		50 13.813	-3 46.313	50 13.783	-3 46.243	< 10	3.47	0.97	1.61	0.45
	16:44		drogue #3 redeployed at plume/flood interface	50 13.751	-3 46.159	50 13.721	-3 46.089					
	16:35		drogue fix	50 13.822	-3 46.388	50 13.792	-3 46.318					
	17:00		drogue fix	50 13.877	-3 46.323	50 13.847	-3 46.253					
◆	17:06	03:15		50 14.042	-3 46.142	50 14.012	-3 46.072	220	76.34	21.34	35.42	9.9
◆	17:08	03:17		50 14.033	-3 46.113	50 14.003	-3 46.043	380	131.86	36.86	61.18	17.1
◆	17:09	03:18		50 14.014	-3 46.072	50 13.884	-3 46.002	< 10	3.47	0.97	1.61	0.45
◆	17:11	03:20		50 13.987	-3 45.989	50 13.957	-3 45.919	< 10	3.47	0.97	1.61	0.45
	17:22		drogue fix	50 14.14	-3 45.983	50 14.110	-3 45.913					
●	17:24	03:33		50 14.156	-3 45.996	50 14.126	-3 45.926	510	176.97	49.47	82.11	22.95
●	17:25	03:34		50 14.145	-3 45.971	50 14.115	-3 45.901	430	149.21	41.71	69.23	19.35
●	17:27	03:36		50 14.133	-3 45.95	50 14.103	-3 45.880	680	235.96	65.96	109.48	30.6
	17:29		drogue fix	50 14.18	-3 45.91	50 14.150	-3 45.840					

FIGURE 1. SALCOMBE ESTUARY

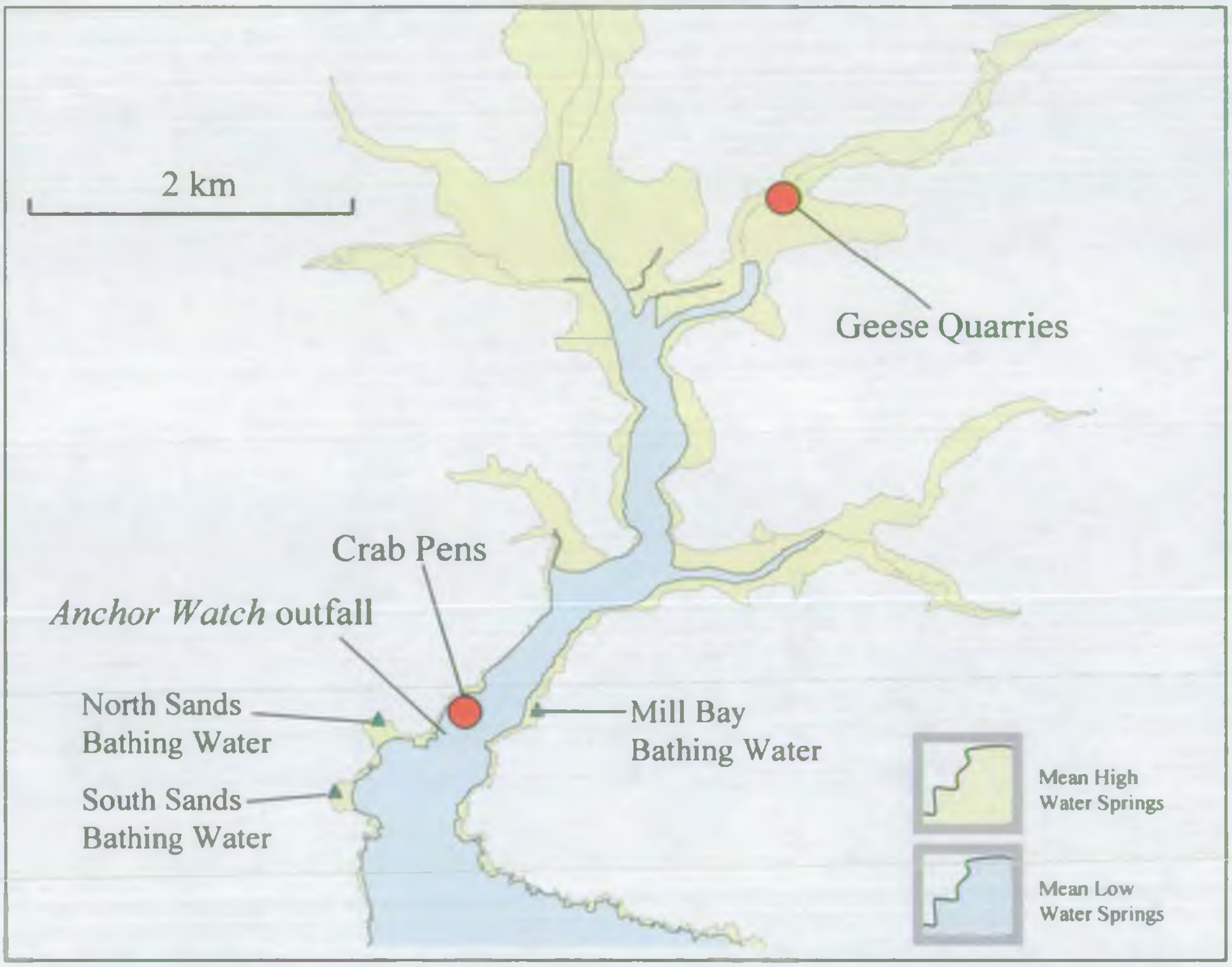


FIGURE 2. PRELIMINARY DYE STUDY 23/07/01: PLUME BEHAVIOUR WITH REFERENCE TO TIDE STATE

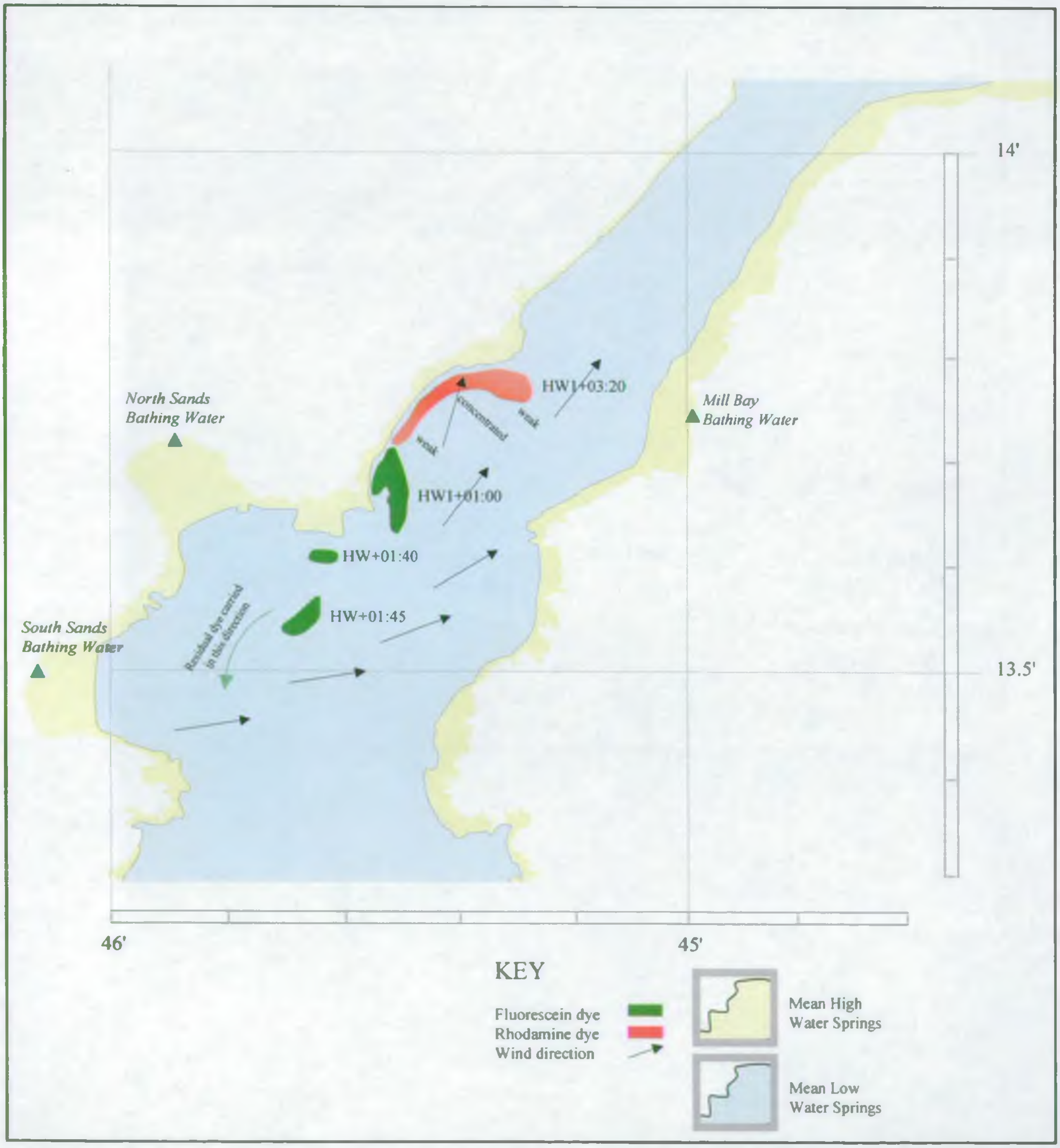


FIGURE 3. PRINCIPAL SURVEY 06/09/01: PLUME BEHAVIOUR WITH REFERENCE TO TIDE STATE

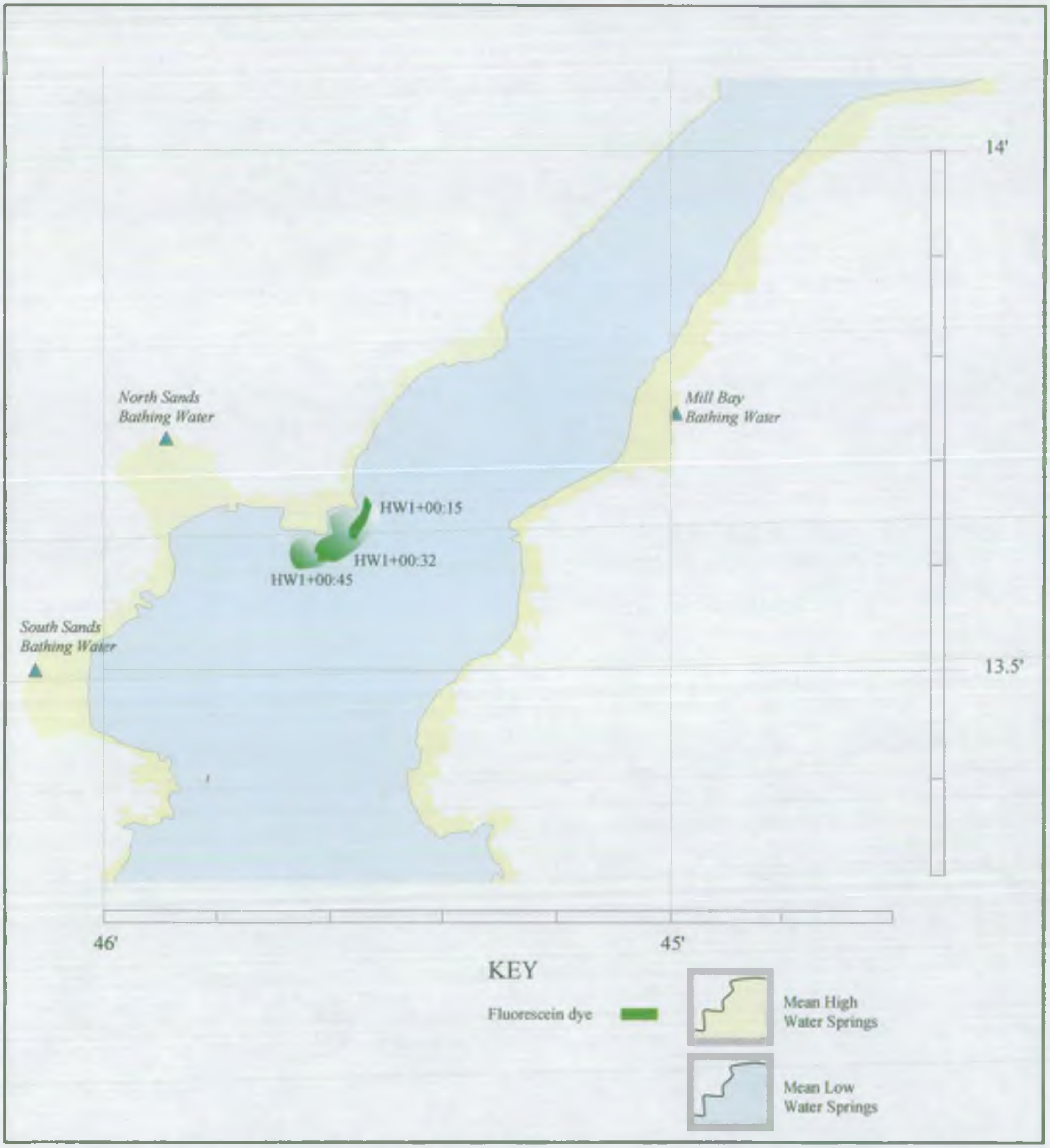


FIGURE 4. PRINCIPAL SURVEY 06/09/01: PLUME BEHAVIOUR WITH REFERENCE TO TIDE STATE

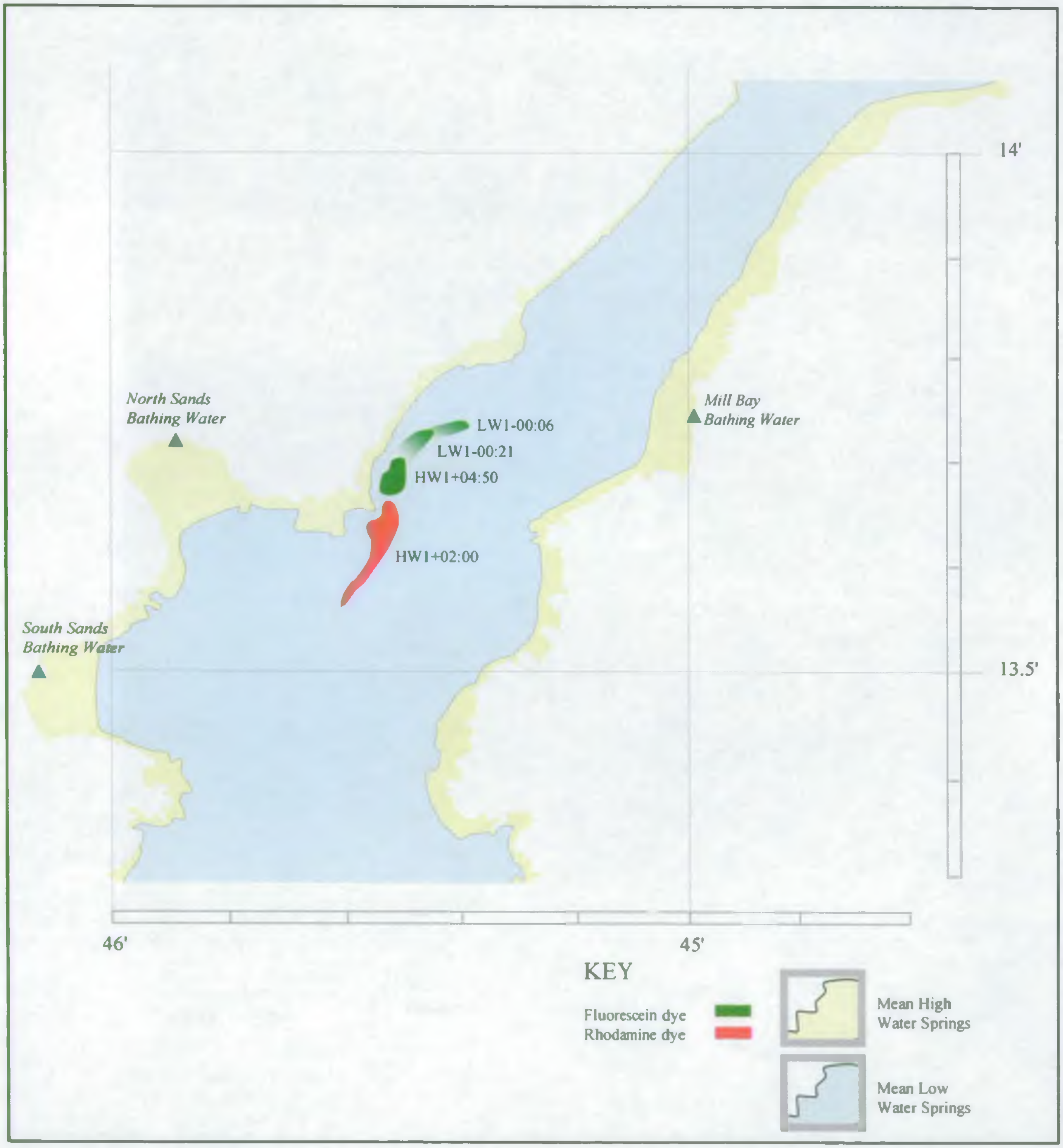


FIGURE 5. PRINCIPAL SURVEY 06/09/01: DROGUE POSITIONS WITH REFERENCE TO TIDE STATE

FIGURE 6: HW1+00:20-HW1+02:17

FIGURE 7: HW1+02:40-HW1+03:16

FIGURE 8: HW1+03:20-HW1+04:36

FIGURE 9: HW1+04:53-HW1+05:11

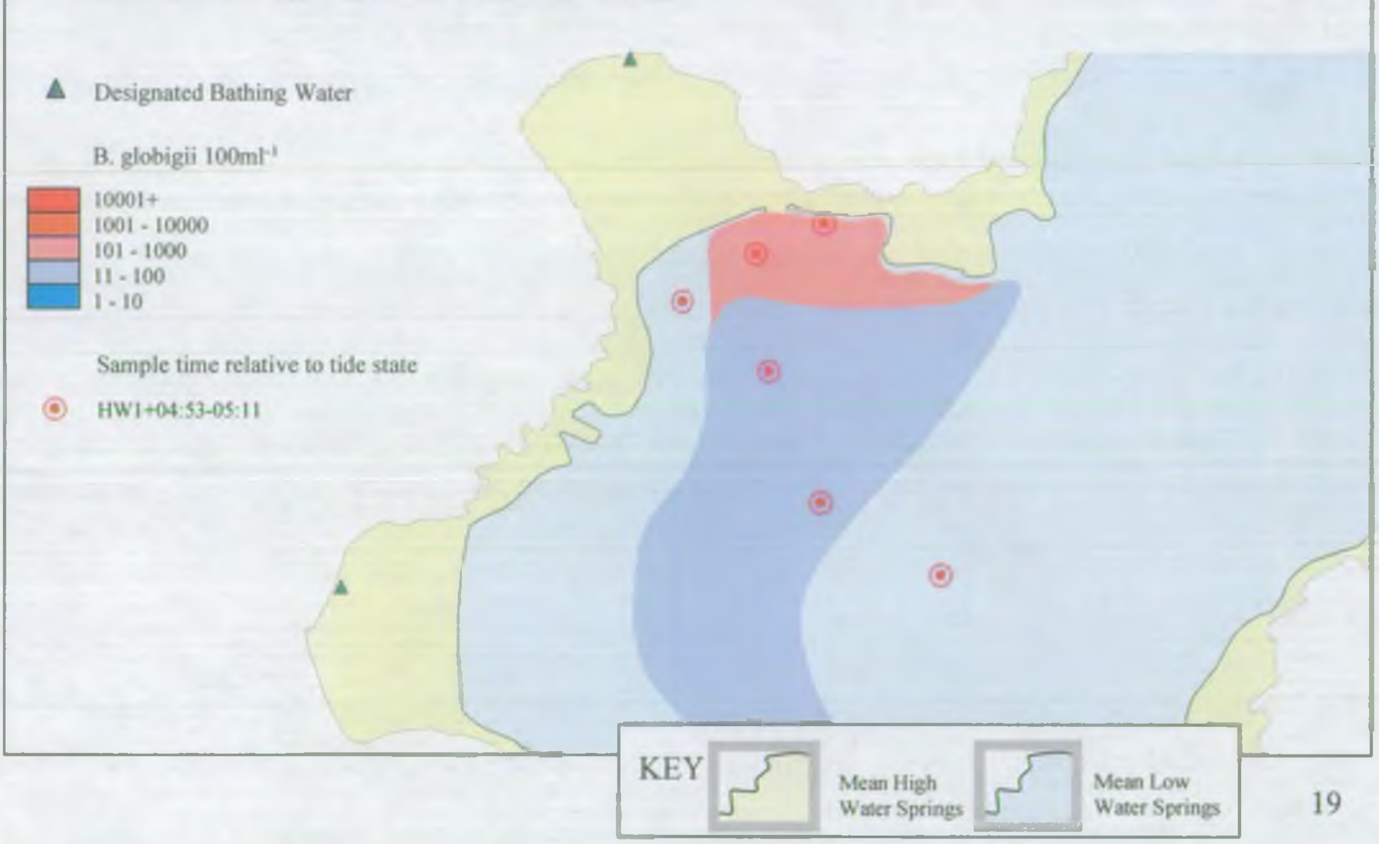
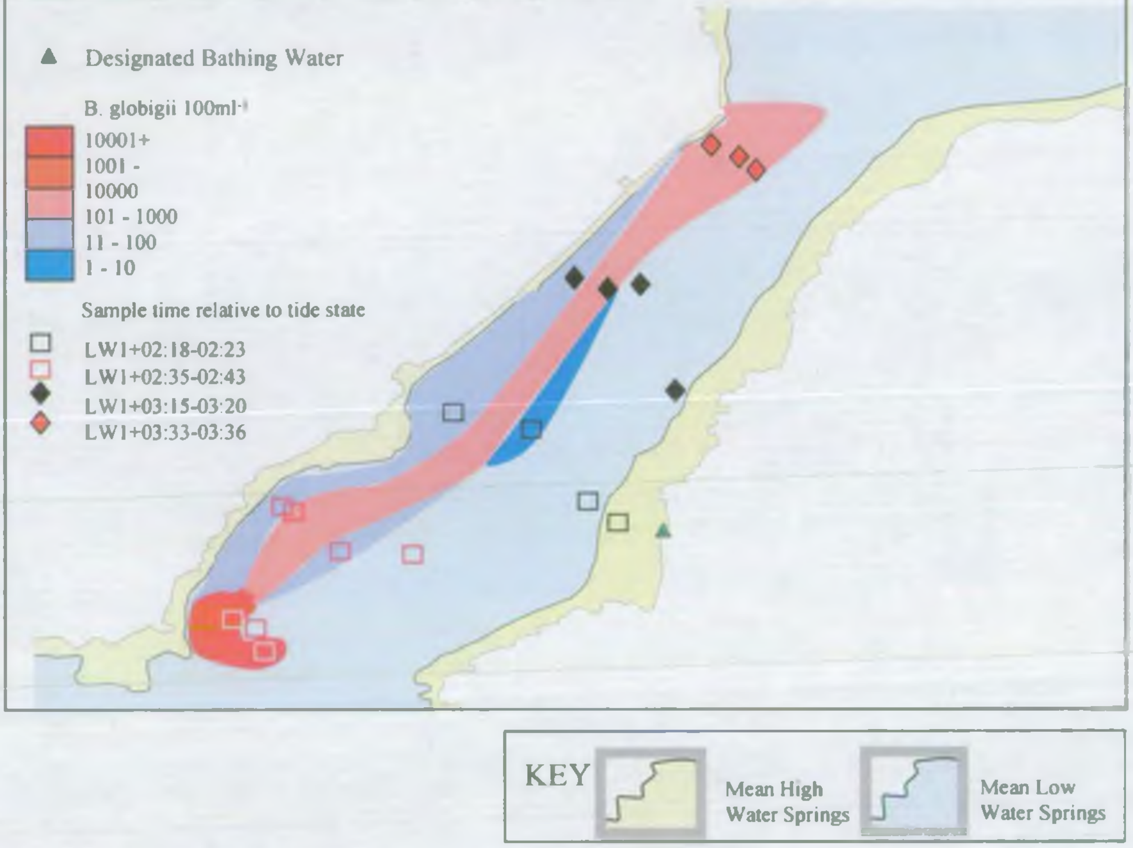


FIGURE 10: LW1+00:26-LW1+01:03

FIGURE 11: LW1+00:09-LW1+00:22

FIGURE 12: LW1+02:18-LW1+03:36



Photograph 1

Anchor Watch outfall pipe
(22/06/01)

Photograph 2

Dye issuing from two points in outfall during Preliminary Dye Study (HW+00:48)
(23/07/01)

Photograph 3

Impact at crab pens using rhodamine (red) dye (crabs being put into pens from boat at right of picture). Also visible is transport of dye around 'Woodville Point' at top of picture (HW1+06:10) Preliminary Dye Study.
(23/07/01)

Photograph 4

Plume transport towards estuary mouth on ebb tide. Outfall is outside photograph to bottom left (HW1+00:19).
Principal Survey.
(06/09/01)

Photograph 5

Transport of plume across 'Woodville Bay' towards crab pens (HW1+05:02)
Principal Survey.
(06/09/01)

Photograph 6

Transport of plume across 'Woodville Bay' towards crab pens (LW1+00:42)
Principal Survey.
(06/09/01)

APPENDIX 1.

DEVON AREA H&S SITE RISK ASSESSMENT

ver 1.1
14/02/00

TRADE / FARMS / INVESTIGATIONS / STW / FRESHWATER / MARINE

SITE: 'ANCHOR WATCH' PRIVATE PROPERTY + SALCOMBE N ~~+ SOUTH SANDS ECBW's~~

CATCHMENT / NGR: 08A

Is this a routine inspection?			
YES	NO	If no specify reason / activity	
	✓		PLANNED INVESTIGATION

Mobile phone reception: [✓ Good] / Poor

Date of Assessment: 5/9/01

Name of Officer: R PEARSON

URN:

CONSIDERATION

ACTIONS REQUIRED

(A) GENERAL	YES	NO	RISK H/M/L	
1. Do you need to notify site manager/ landowner of Agency presence?	✓		L	'ANCHOR WATCH' OWNER CONTACTED, APPROPRIATE HARBOUR AUTHORITIES NOTIFIED
2. Do you need to be accompanied by site staff?		✓	L	
3. Does task require more than one person?	✓		L	
4. Are you working outside daylight hours?		✓	L	ONLY DRIVING DURING DARKNESS
5. Do you need to employ Lone Worker procedures?		✓		
6. Is protective clothing required?	✓		L	PPE FOR DOSING / BEACH / BOAT
7. Will seasonal factors affect site safety?		✓		

8. Are there dangers from the following	YES	NO	RISK H/M/L	
chemicals		✓		
biological hazard / infection from animals / pathogens	✓		L	AVOID DIRECT CONTACT WITH [illegible] SPORES. BOAT / BEACH SAMPLING REQUIRES GLOVES
explosive / noxious gases		✓		
inhalation of fumes/dust/asbestos		✓		
moving vehicles	✓		L	BEACH SAMPLING - CARE NEEDED WHEN CROSSING ROAD
machinery		✓		
falling objects		✓		
electricity sources		✓		
open tanks / lagoons / catch pits		✓		
ladders / steps / scaffolding		✓		

	YES	NO	RISK H/M/L	
9. Are overhead power supplies present?		✓		
10. Is site secure for equipment installation? N/A				

APPENDIX 1. (cont.)

(B) VEHICLE ACCESS

	YES	NO	RISK H/M/L	
1. Is there safe vehicle access to site?	☑	☐	L	
2. Can vehicles be parked/left safely?	☑	☐	L	

(C) FOOT ACCESS

	YES	NO	RISK H/M/L	
1. Is there safe foot access to the site?	☑	☐	L	
2. Are there fences/ditches etc. to cross?	☐	☑		

(D) BANK SITES N/A

	YES	NO	RISK H/M/L	
1. Are banks steep or slippery?	☐	☐		
2. Might banks be undercut?	☐	☐		
3. Is water deep/strong currents?	☐	☐		

(E) CLIFF OR SIMILAR SITES

	YES	NO	RISK H/M/L	
1. Are there dangers from falling?	☐	☑	L	
2. Is the terrain steep/slippery?	☐	☑	L	
3. Might the cliff be overhanging?	☐	☑	L	
4. Are ropes required?	☐	☑	L	

(F) CONFINED SPACES

	YES	NO	RISK H/M/L	
1. Are confined spaces involved? IF *YES* YOU MUST COMPLETE THE CONFINED SPACE FORM HELD IN OFFICE	☐	☑		

(G) BOAT WORK

	YES	NO	RISK H/M/L	
1. Is boat work involved? IF *YES* YOU MUST COMPLETE THE BOAT WORK FORM HELD IN OFFICE	☑	☐	L	

(H) MANHOLES

	YES	NO	RISK H/M/L	
1. Is the area around the manhole safe?	☑	☐	L	
2. Are bollards/cones required?	☐	☑		
3. Can cover be lifted safely?	☑	☐	L	
4. Are cover keys/other equipment needed?	☑	☐	L	CAN BE LIFTED SINGLE HANDED

(I) AGGRESSIVE BEHAVIOUR

	YES	NO	RISK H/M/L	
1. Are people likely to be aggressive?	☐	☑	L	
2. Are guard dogs/farm dogs/other livestock a risk?	☐	☑	L	

(J) OTHER

	RISK H/M/L	
SIGNAGE FOR PUBLIC INFO REQD	L	

APPENDIX 1. (cont.)

DEVON AREA LAUNCHING AND RECOVERY OF BOATS.

ver 1.0
09/02/00

SITE: KINGSBRIDGE LOWER ESTUARY

CATCHMENT
08A

Date of Assessment 5/9/01

Name of Officer R PEARSON

Mobile phone reception [✓ Good] Poor

CONSIDERATION				ACTIONS REQUIRED
(A) GENERAL	**YES**	**NO**	RISK H/M/L	
1. All crew adequately trained?	☑	☐	L	
2. All crew aware of routes and tasks to be completed?	☑	☐	L	
3. Have emergency procedures been agreed?	☑	☐	L	
4. Base personnel aware of routes, tasks, times, communications etc?	☑	☐	L	
5. RCC personnel aware of routes, tasks, times, communications etc?	☑	☐	L	

6. Are there dangers from the following

	YES	NO	RISK H/M/L	
Boat passage to and from site	☑	☐		BUSY BOAT TRAFFIC AT FIRST HALF PASSAGE
weather conditions	☐	☑		FORECAST OBTAINED
State of tide	☐	☑		
Risk of grounding	☑	☐		AREAS IDENTIFIED - BOAT TO AVOID
Daylight constraints	☑	☐		SURVEY ONLY DURING DAYLIGHT

(B) LAUNCHING	**YES**	**NO**	RISK H/M/L	
1. Can the boat be prepared on level ground?	☑	☐		
2. Has boat been secured to trailer by two means i.e. winch strap and painter?	☑	☐		
3. Has winch strap been checked for signs of damage?	☑	☐		

(C) VEHICLE ACCESS	**YES**	**NO**	RISK H/M/L	
1. Is there safe vehicle access to site?	☑	☐		
2. Can vehicles be parked/left safely?	☑	☐		

APPENDIX 1. (cont.)

(D) BOAT CHECK LIST	YES	NO	RISK H/M/L	ACTIONS REQUIRED
Fuel in boat?	☑	☐		
Spare fuel? N/A	☐	☐		
Auxillary engine and fuel?	☑	☐		
Charts?	☑	☐		
VHF working?	☑	☐		
GPS working?	☑	☐		
Navigation lights?	☑	☐		
Engine oil?	☑	☐		
Air pump?	☑	☐		
Basic tool kit?	☑	☐		
Flares?	☑	☐		
Rope?	☑	☐		
Ignition keys?	☑	☐		
Trailer tyres ok?	☑	☐		
Trailer board lights?	☑	☐		
Trailer keys? N/A	☐	☐		
Lifejackets?	☑	☐		
PPE?	☑	☐		
Water / Food?	☑	☐		
Spare clothing?	☑	☐		

(E) OTHER

RISK H/M/L	

APPENDIX 2.

Measured flow rate of simulated discharge, **a**:	0735	5 litres per 15 seconds = 0.33 ls^{-1}
	0830	5 litres per 33 seconds = 0.15 ls^{-1}
Globigii solution flow rate, **b**:	0735	3.0 l h^{-1} = 8.33x10^{-4} ls^{-1}
	0830	2.5 l h^{-1} = 6.94x10^{-4} ls^{-1}
Globigii concentration, **c**:	0735	1.04x10^{12} l^{-1}
	0830	1.21x10^{12} l^{-1}

Bacterial equivalent calculations are made as follows:

b x **c** = globigii flow rate,**d**
d x 1 litre / **a** = glob l^{-1} / 10 = glob 100ml^{-1}

07:30 to 08:30 Regime A

Glob flow rate   3l in 1 hour so 8.33x10^{-4} l s^{-1}

1.04x10^{12}globl^{-1} x 8.33x10^{-4} l s^{-1}
= 8.66x10^{8} glob s^{-1}

8.66x10^{8} glob per 0.33 l water
2.59x10^{9} glob l^{-1} = 2.59x10^{8} glob 100ml^{-1}

if   Tcol is 9x10^{7}
and   Fcol is 2.7x10^{7} (say 2.5x10^{7})

then   1 glob = 0.347 TCol
    1 glob = 0.0965 FCol

08:30 onwards Regime B

Glob flow rate   2.5l in 1 hour so 6.94x10^{-4} l s^{-1}

1.21x10^{12}glob l^{-1} x 6.94x10^{-4} l s^{-1}
= 8.4x10^{8} glob s^{-1}

8.4x10^{8} glob per 0.15 l water
5.6x10^{9} glob l^{-1} = 5.6x10^{8} glob 100ml^{-1}

if   Tcol is 9x10^{7}
and   Fcol is 2.7x10^{7} (say 2.5x10^{7})

then   1 glob = 0.161 TCol
    1 glob = 0.045 Fcol

APPENDIX 3.

2.5×10^7 bacti $100ml^{-1}$ used from observations made of influent to sites at Hope Cove by DAIT. This agrees well with value of 2×10^7 given in Catherine Wright's document **(Reference 4.)**.

APPENDIX 4.

Email sent to Peter Wearden, Environmental Health Department, South Hams District Council (13/11/01).

Peter

In connection with an application for 'first time sewerage' we have been carrying out studies into the possible bacterial contamination resulting from sewage discharges to the Salcombe Estuary from a multiple-occupancy property called Anchor Watch at Cliff Road, Salcombe. The outfall is at NGR SX 73472 38149.

There are four moored crab holding pens some 150m from the outfall position. Our studies have modelled maximum bacterial impacts from the discharge at these pens of total coliforms 1423 100ml-1 and faecal coliforms 398 100ml-1.

We have been asked to conduct an impact assessment report and would like to quantify the impact at the crab pens. In this connection we would be interested to know whether you consider such concentrations to pose any risk to this crab business.

Thanking you in advance,

……………………………………………………………………………………………………

Reply (13/11/01):

Robin

This is a difficult one to answer. Can I assume that this level of organisms is constant ? There are a number of factors to take into account here .ie crabs are scavengers by nature and the quality of crab bait ingested by them would probably also be pretty 'high', they'll probably feed around outfalls anyway and the product is cooked prior to consumption.

I don't like the idea of taking food sources from known discharge waters and it would be useful if there we were able to access any research done from sampling crab flesh from recognised 'clean' and 'dirty 'waters. Any ideas on this one or could it be done on a local trial?
