REPORT No. 1835
August 2010

Coastal Water Quality and Mixing Zone Studies for the Silver Fern Farms Meat Processing Plant: Pareora

RESEARCH BASED SOLUTIONS

Coastal Water Quality And Mixing Zone Studies For The Silver Fern Farms Meat Processing Plant: Pareora

Paul Barter

Prepared for

Silver Fern Farms Ltd.

Cawthron Institute
98 Halifax Street East, Private Bag 2
Nelson, New Zealand
Ph. +64 3 548 2319
Fax. + 64 3 546 9464
www.cawthron.org.nz

Reviewed by: ______________________ Approved for release by: ______________________

Ross Sneddon Rowan Strickland

Recommended citation:
Barter, P. 2010. Coastal Water Quality and Mixing Zone Studies for the Silver Fern Farms Meat Processing Plant: Pareora . Prepared for Silver Fern Farms. REPORT No. 1835. 20 p. plus appendices

Executive Summary

Silver Fern Farms NZ Ltd, holds a resource consent (CRC071504) issued by Environment Canterbury (ECAN) to discharge meatworks processing effluent to the coastal marine area immediately offshore of Pareora, south of Timaru. Under this consent, an interim water quality mixing zone of 1500 m radius from the discharge point was established for the coastal receiving waters, subject to revision under Condition 11 of the Consent.

In 2008, Silver Fern Farms personnel conducted water quality sampling as stipulated in Condition 11 and a short data report was prepared. This 2008 report recommended that the interim 1500 m mixing zone be established as the defined mixing zone for the duration of the consent and that additional water quality sampling was un-necessary. It us understood that ECAN was not fully satisfied with the recommendations of the 2008 Silver Fern Farms report and external consultation was sought. In 2010, the Cawthron Institute (Cawthron) was engaged by Silver Fern Farms to review the monitoring conducted to date along with the wording in Condition 11 and help liaise with ECAN as to the best solution to defining a mixing zone for this discharge.

Meetings were held between Silver Fern Farms, Cawthron, and ECAN, and it was mutually agreed that two additional water quality monitoring rounds be conducted but with a modified approach. This report presents the findings of the additional water quality monitoring rounds as well as some discussion and recommendations on the determination of the mixing zone extent.

A review of all the water quality results collected to date shows that, with the exception of the bacterial indicator *Enterococci*, there do not appear to be any clear water quality trends, with increasing distance from the outfall, which are attributable to the discharge. Identified spatial trends not attributable to the Silver Fern Farms discharge include where some offshore salinity results showed a marked reduction south of the outfall as a result of the Pareora River plume discharge. This highlights a concern that data collected further south than the river will likely be influenced more by the river plume than the outfall plume.

Additional studies on water clarity effects showed that a 75:1 dilution of the effluent is required to meet the current ECAN guideline for assessing conspicuous changes in clarity. Steps have been taken to document potential conspicuous changes in colour through the use of a web camera mounted to the main boiler stack. This system is expected to be implemented for the 2010/2011 season.

With regard to the mixing zone extent, an evaluation of whether the mixing zone could be expanded, reduced, or stay the same was conducted. The results of this assessment concluded that there appears little reason to recommend a change to the status quo of a 1500 m radius mixing zone.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

1. INTRODUCTION AND BACKGROUND

Silver Fern Farms NZ Ltd (Silver Fern Farms) holds a resource consent (CRC071504) issued by Environment Canterbury (ECAN) to discharge meatworks processing effluent to the coastal marine area immediately offshore of Pareora. This Consent was granted in 2007 and has a ten year term (Appendix 1).

Under this consent, an interim water quality mixing zone of 1500 m radius from the discharge point was established for the coastal receiving waters (Condition 8). This interim mixing zone was subject to revision under Condition 11 of the Consent as follows:

A water quality investigation shall be carried out to determine the extent of the mixing zone of the discharge in the coastal marine area. The investigation shall be undertaken firstly, between February and May within the 12-month period following the issue of this consent, and secondly, 5 years later or other time interval agreed with Canterbury Regional Council, at times when the discharge is at or near the expected maximum daily volume for the months in which the investigation is undertaken. The investigation shall include the following:

(a) On three separate occasions:
Surface water samples shall be collected at the water's edge at 0 metres, 500 metres, 1000 metres, 1500 metres and 2000 metres north or south of the discharge point in the direction of the plume flow;

(i) Surface water samples shall be collected at 250, 500, 1000, 1500, 2000 and 3000 m metres from the outfall within the plume;
(ii) Surface water samples shall be collected at the water's edge at 500 metres and 1500 metres north or south of the discharge point in the opposite direction to the plume flow and;
(iii) each sample shall be analysed for the following determinands:

(1) For shoreline samples between 0m and including 1500m

- *Colour*
- *Temperature*
- *pH*
- *Ammonia nitrogen*
- *Total nitrogen or Total Kjeldahl nitrogen*
- *Total phosphorus*
- *Dissolved Oxygen (DO)*
- *Dissolved Reactive Phosphorus (DRP)*
- *Fat, Oil and Grease (FOG)*
- *Faecal coliforms*
- *Enterococci*

Except that at 1500m, Chlorophyll a shall be additionally tested.

(2) For shoreline samples greater than 1500m

- *Ammonia nitrogen*
- *Total nitrogen or Total Kjeldahl nitrogen*
- *Total phosphorus*
- *Dissolved Reactive Phosphorus (DRP)*
- *Chlorophyll-a*
- *Enterococci*

(3) For offshore samples at 250, 500, 1000, 1500, 2000 and 3000m from the outfall and within the plume

- *Ammonia nitrogen*
- *Dissolved Reactive Phosphorus (DRP)*
- *Enterococci*

(b) The direction of the plume, state of the tide, sea and weather conditions must be recorded at the time of sampling

(c) If the data obtained during this sampling programme does not provide sufficient information to enable the mixing zone to be defined, the consent holder shall liaise with Canterbury Regional Council and modify, if necessary, the location of the sampling stations and then undertake further sampling until adequate information for defining the mixing zone is obtained.

On two different occasions in 2008 (26 May and 23 June), Silver Fern Farms personnel conducted sampling as stipulated in Condition 11 and a short data report was prepared (Appendix 2). Among other things, this report (Schepers 2008) recommended that the interim 1500 m mixing zone be established as the defined mixing zone for the duration of the consent and that a third sampling round was un-necessary. The water quality stations, assuming a northerly alongshore current, and interim mixing zone are presented in Figure 1.

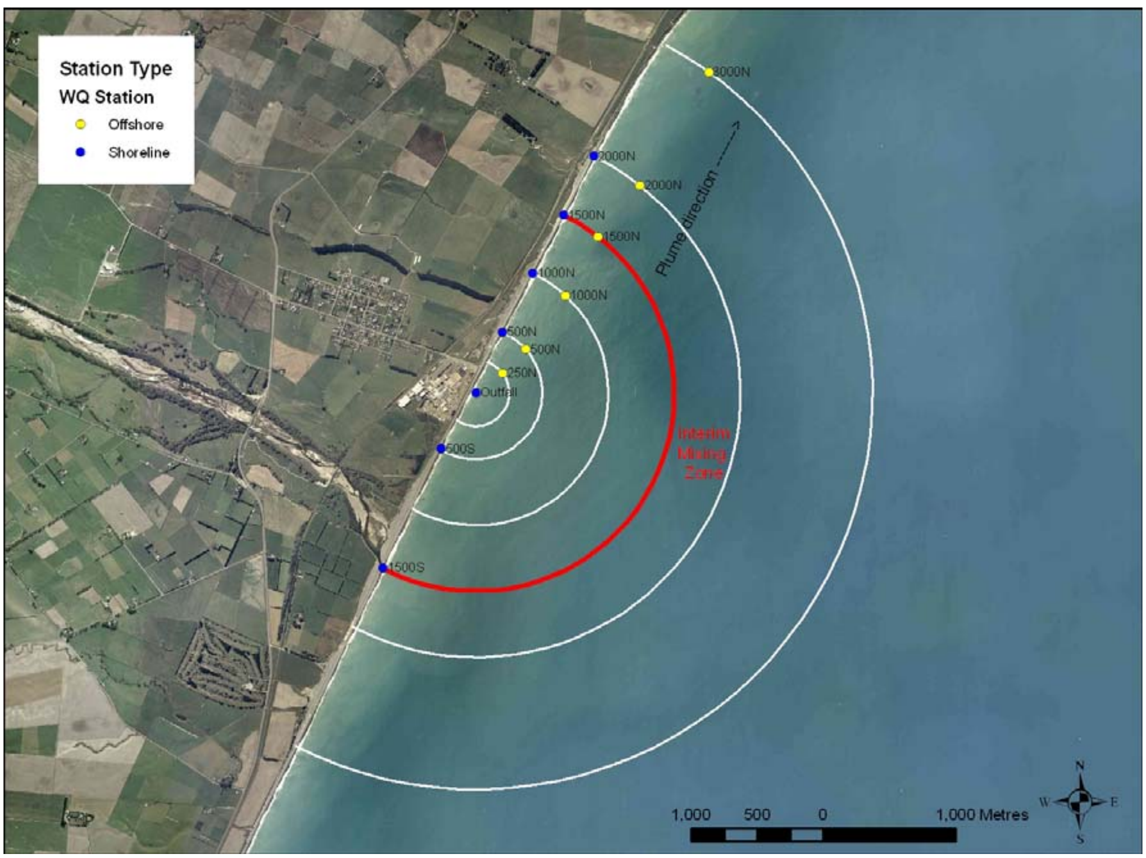

Figure 1. Shoreline and offshore station locations and the 1500 m mixing zone at the Silver Fern Farms Pareora plant.

It us understood that ECAN was not fully satisfied with the findings or recommendations of the 2008 Silver Fern Farms report and external consultation was sought. In February 2010, the Cawthron Institute (Cawthron) was engaged by Silver Fern Farms to review the monitoring conducted to date along with the wording in Consent Condition 11 and help liaise with ECAN as to the best solution to defining a mixing zone for this discharge.

A cursory review of Condition 11 raised several questions and concerns as to the ability of the sampling to actually meet the objective of the Consent Condition; namely to determine the extent of the mixing zone. Based on these questions, a meeting was held between all parties (*i.e.* Silver Fern Farms, ECAN and Cawthron) on 10 March 2010 to discuss the overall sampling programme and the requirements for any additional sampling. The outcome of this meeting was that the collection of field data, will continue to be undertaken largely in accordance with Condition 11 of the resource consent; however, the following changes were agreed upon:

- Drogues will be used, when sampling, to determine the direction of the plume. The drogue will only be deployed on a day when swell and wind conditions are unlikely to affect the direction of its travel.

- Receiving water pH, colour, salinity and Fat, Oil and Grease (FOG) concentrations will not be measured, for the following reasons:

  - pH in the effluent flow prior to discharge will continue to be measured and the data supplied to Environment Canterbury. However, the chemicals originally used for cleaning purposes by Silver Fern Farms and discharged via the outfall are no longer being used, hence the pH of the discharge is no longer seen as a pivotal issue.

  - Water colour will now be measured via the use of RGB hue methodology rather than a Munsell Colour Chart

  - Salinity is not considered necessary due to the effects of fresh water being no greater than that expected from a riverine discharge.

  - Fats Oil and Grease will continue to be measured via visual inspections undertaken as per Condition 9 of resource consent CRC071504.

Two additional sets of water quality measurements were undertaken in 2010 (02 June and 24 June) which incorporated the agreed upon changes. This short report presents the findings of these 2010 water quality monitoring rounds as well as the 2008 monitoring, followed by some discussion on the determination of mixing zone extent.

2. WATER QUALITY INVESTIGATIONS

Prior to conducting the receiving water sampling stipulated in Condition 11, a benchtop dilution series was conducted with Silver Fern Farms Pareora Effluent to determine the amount of dilution required to meet relevant clarity guidelines/standards.

2.1. Benchtop clarity study

Guideline documents concerning water clarity and colour aim to provide criteria that, if met, will avoid 'conspicuous' visual changes to receiving waters (after reasonable mixing) following wastewater discharge or other disturbances. Such quantitative criteria relevant to the Pareora outfall are available from several sources as follows:

- ANZECC (2000) Guideline for Slightly to Moderately Disturbed Ecosystems: Low risk Trigger Values (TVs) for clarity should be determined as the 80th percentile of the reference system(s) distribution.
- MFE (1994) Water Quality Guidelines No. 2: A detailed review of colour, clarity and fine suspended solids criteria from various countries has been presented in this document. For Class A waters, where visual clarity is an important characteristic of the water body, clarity should not be changed by more than 20%. For more general waters, the visual clarity should not be changed by more than 33 to 50% depending on site conditions.
- ECAN (2005) Regional Coastal Environment Plan, Rule 7.1 a (ii): Within areas classified as Coastal AE (aquatic ecosystems) or Coastal CR (contact recreation), the colour of the receiving water shall not be changed by greater than ten points, as measured using the Munsell Scale, and the visual clarity of the receiving water shall not be reduced by greater than 33%.

For the clarity investigations described here, we adopted a more liberal approach; that potential effects should be assessed relative to receiving water trigger levels of 50% clarity change after reasonable mixing. The rationale for the 50% change criterion is that the discharge is into a surf zone where frequent and significant changes in clarity are the norm.

Seawater/wastewater dilution series were conducted using a 24-hour composite sample of Pareora wastewater (collected on 19 Feb 2010), along with 'clean' reference seawater from Tasman Bay. This Tasman bay water is known to have The laboratory dilution series was run in a PVC trough (730 x 260 x 210 mm) specifically designed for laboratory-based transmissivity studies. Each series involved 36 dilution steps, ranging from 0% to approximately 8% wastewater.

Results of the dilution series carried out are shown graphically in Figure 2. To attain a 50% change in water clarity, a 75:1 dilution of seawater to Pareora effluent was required, whereas for the more stringent 33% change in clarity, this dilution increases to 140:1. In terms of the

MFE (1994) guidelines, a mixing zone would have to offer 75:1 dilution in order to meet the criteria.

It is worth noting that this dilution series represents a pseudo 'worst-case' situation since Tasman Bay seawater was used which is generally far clearer than the receiving waters off the coast of Pareora.

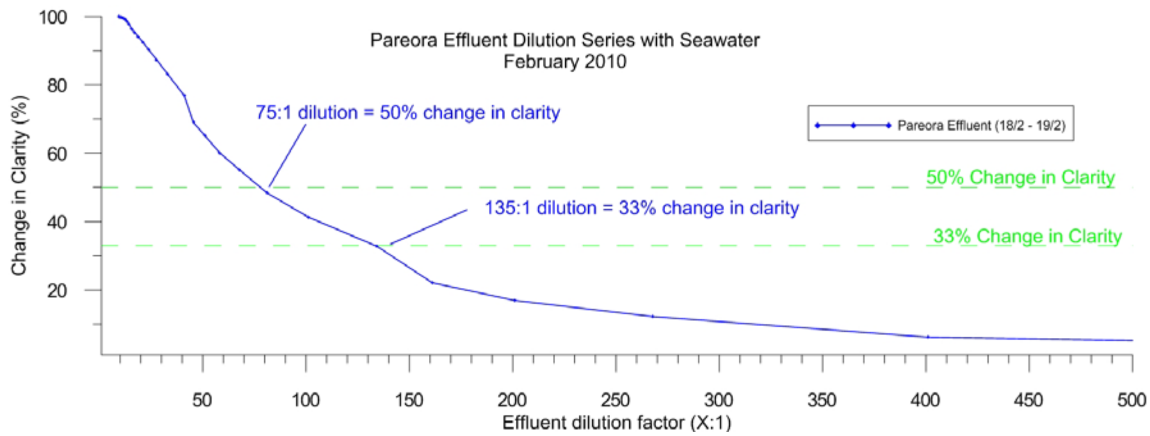

Figure 2. Changes in clarity with dilution of Pareora effluent and reference seawater**.**

2.2. GPS drifters

The direction and speed of effluent dispersion from the Pareora outfall was determined using self-logging GPS drogues released during each of the 2010 water quality rounds. A drogue (also called a drifter) is a device which drifts with water current without being influenced by surface winds. It provides a measure of the direction and speed of water movement (in this case the effluent plume) in the vicinity of the outfall. This information allowed positioning of the water quality stations within the effluent plume even where it was less visible.

In this study, a holey-sock drogue was used, consisting of a 425 mm cylindrical polyethylene tube reinforced with spiral steel rings (
Figure 3). Each drogue was attached at the top, via a bridle, to a small cylindrical closed cell foam float which held a Garmin® Foretrex 101 GPS.

The holey-sock drogue was preferred over the window-shade style outlined in the New Zealand Water and Soil Conservation Authority's Ocean Outfall Handbook (Williams 1985). Studies have shown that current flow around a window-shade drogue may cause lift, similar to air flow for a sail boat, and that the cylindrical drogue designs that enclose a parcel of water (such as the holey-sock) more accurately follow the ambient current patterns (Sombardier & Niiler 1994).

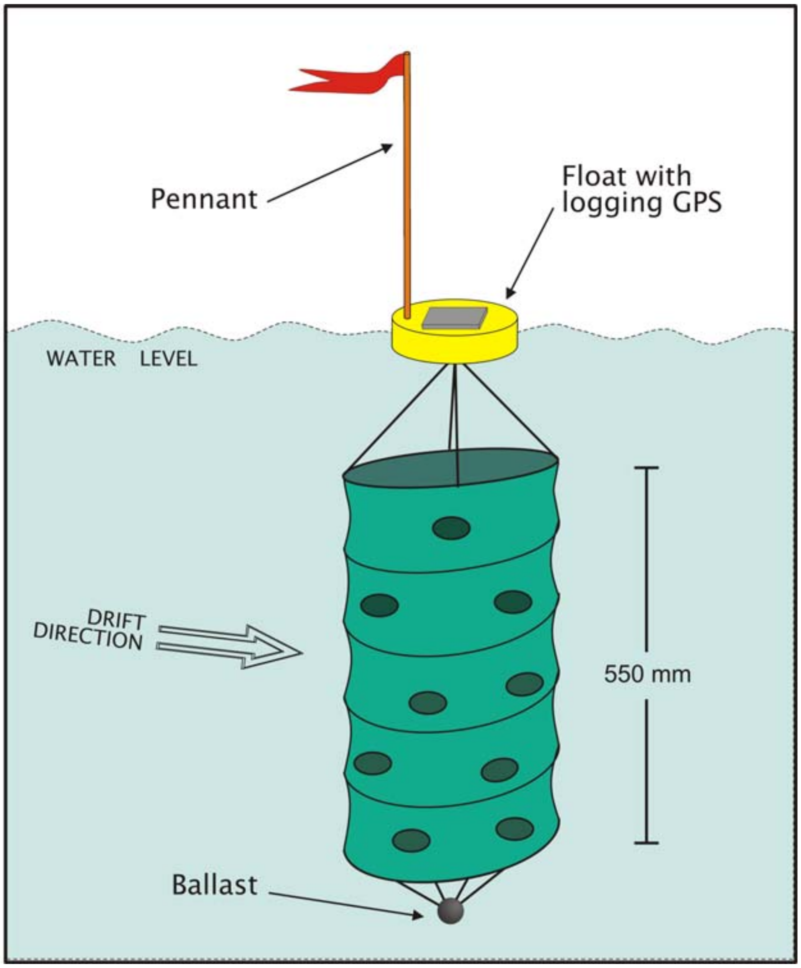

Figure 3. Schematic drawing of a self-logging GPS drifter

The drogues were released at a point directly offshore of the outfall and as close to shore as was safe/possible for the boat to reach. Drogue positions were logged internally at 15 second intervals, via the GPS tracklog function. Each drogue was tracked for up to 2 hours before retrieval.

Following retrieval, the tracklog from each drogue GPS was downloaded to a PC and each track was converted to a GIS-compatible set of waypoints.

Results of the GPS tracks are presented in Figure 4 and summarised in Table 1. What is clearly evident in the GPS drifter data is the alongshore reversing nature of the flow field surrounding the outfall. The drifters released during the June 2 survey headed south at a speed of 10 cm/sec whilst those in the 24 June survey headed north at a much faster rate of 50 cm/sec. While the difference in direction is likely from tidally reversing currents, the difference in speed cannot be attributed solely to tidal reversal and other factors like wave induced longhsore drift, wind induced currents and the southland current could all have an influence. In both sets of drifter data, the plume stayed very close to shore (*i.e.* within 100 m of the breakers).

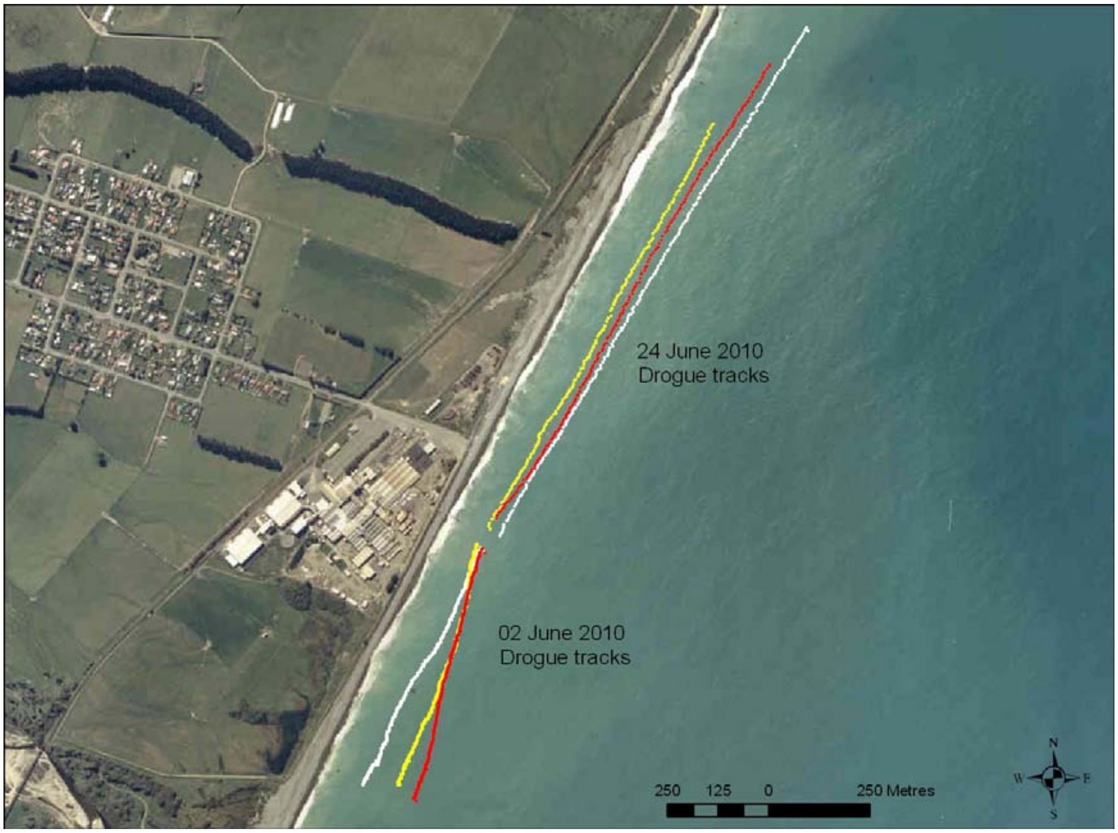

Figure 4. GPS drifter tracks for the 2010 water quality sampling rounds.

Table 1. Results of GPS drifter releases on 2 June and 24 June 2010.

Drifter ID	Date	Start Time	Duration (secs)	Data points	Distance travelled (m)	Average Velocity (cm/sec)
BQ-1		08:46:59	7055	977	472	10
AA-1	2 June 2010	08:55:13	6611	901	442	10
BB-1		08:51:32	6892	868	461	10
BQ-2		09:38:05	3250	1521	218	50
AA-2	24 June 2010	09:51:36	2535	1191	170	50
BB-2		09:43:50	2955	1358	198	50

These alongshore speeds are much greater than the average current speeds used in the 2005 NIWA modelling (Fenwick & Spigel 2005) which estimated an alongshore velocity of 5 cm/sec; however, the NIWA (2005) report does recognise that there could be considerable variation in these speeds and that the 5 cm/sec is a conservative value.

2.3. Water Quality results

A total of four rounds of water quality monitoring, as stipulated under Condition 11 of the Silver Fern Farms Consent, have now been undertaken. The first two rounds were 26 May and 23 June 2008 and the final two were completed on 02 June and 24 June 2010. For all four sets of samples, surface water grabs were collected from either the shoreline or from a boat directly into the laboratory-supplied sample bottles. In addition, several *in-situ* measurements were carried-out including temperature, salinity, and dissolved oxygen.

A full set of the analytical results from the 2010 sampling are included in Appendix A and a summary of the nutrient and bacteriological results from all four rounds are presented in Figure 5. A full set of all laboratory and *in-situ* parameters are presented in Table 2 .

The station locations in Figure 5 are depicted as being either downcurrent, or upcurrent (*i.e.* away from the plume) but do not necessarily represent a specific direction along the coast given that the plume travels in either direction. For example, in rounds one, two and three the effluent plume travelled in a southerly direction with only round four heading in a northerly direction along the coast. The distances along the coast are in metres and the shoreline and offshore sites have been plotted separately to aid in interpretation.

A review of the water quality results presented in Figure 5, shows that, with the exception of *Enterococci*, there does not appear to be any obvious trend (*i.e.* reduction) with increasing distance from the outfall. In the case of *Enterococci* where there was a clear trend in relation to the outfall, the MfE guideline values of 140 and 280 cfu/00ml were met within 1500 m but not always at 1000 m downcurrent of the outfall.

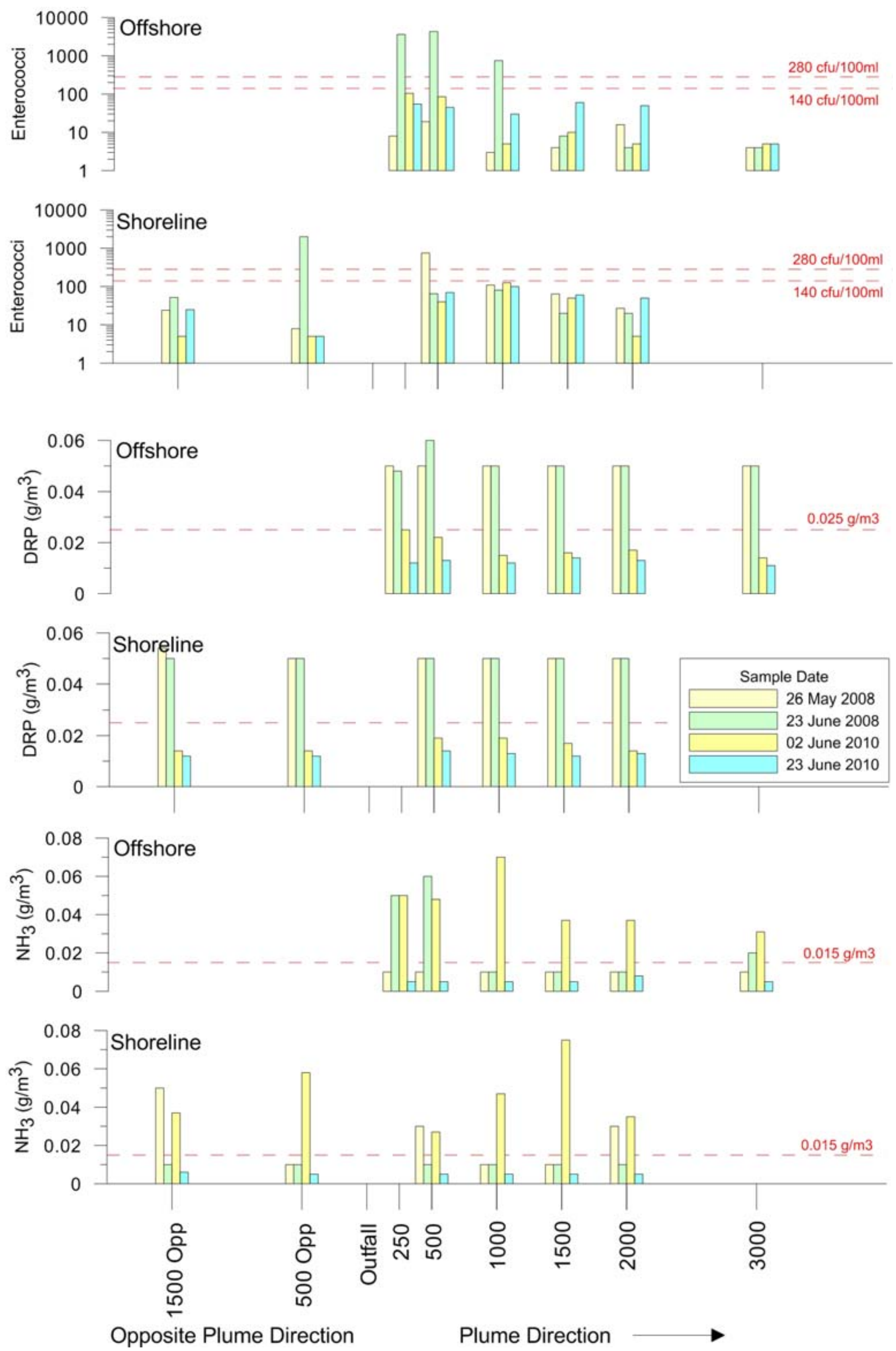

Figure 5. Shoreline and offshore nutrient and bacteriological results from water quality sampling in 2008 and 2010. Grid-lines are used for comparison against relavant guidelines; ANZECC(2000) for NH_3 & DRP, MfE (2003) for Enterococci.

Table 2. Water Quality results from all four rounds of sampling.

Parameter (Units)	Date	Shoreline Sampling Stations							Offshore Sampling Stations					
		Outfall	500	1000	1500	2000	500-O	1500-O	250	500	1000	1500	2000	3000
Enterococci (cfu/100ml)	26/5/08	140	750	110	64	27	8	24	8	19	3	4	16	4
	23/6/08	160	65	80	20	20	2000	52	3600	4300	750	8	<4	<4
	02/6/10	<5	40	125	50	<5	<5	5	105	85	5	10	<5	<5
	24/6/10	5	70	100	60	50	5	25	55	45	30	60	50	5
Dissolved Reactive P (g/m^3)	26/5/08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.054	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
	23/6/08	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.048	0.06	<0.05	<0.05	<0.05	<0.05
	02/6/10	0.013	0.019	0.019	0.017	0.014	0.014	0.014	0.025	0.022	0.015	0.016	0.017	0.014
	24/6/10	0.012	0.014	0.013	0.012	0.013	0.012	0.012	0.012	0.013	0.012	0.014	0.013	0.011
NH3-N (g/m^3)	26/5/08	<0.01	0.03	<0.01	<0.01	0.03	<0.01	0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	23/6/08	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.05	0.06	<0.01	<0.01	<0.01	0.02
	02/6/10	0.036	0.027	0.047	0.075	0.035	0.058	0.037	0.05	0.048	0.07	0.037	0.037	0.031
	24/6/10	0.007	0.005	0.005	0.005	0.005	0.005	0.006	0.005	0.005	0.005	0.005	0.008	0.005
Faecal Coliforms (cfu/100ml)	26/5/08	40	470	140	68		12	12						
	23/6/08	150	62	64	20		610	12						
	02/6/10	25	2400	2300	400		25	45						
	24/6/10	30	1500	230	470		5	10						
TKN (g/m^3)	26/5/08	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8						
	23/6/08	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8	<0.8						
Total N (g/m^3)	02/6/10	0.33	0.36	0.42	0.83	0.32	0.29	0.32						
	24/6/10	0.36	0.48	0.37	0.35	0.31	0.39	0.4						
Total P (g/m^3)	26/5/08	0.05	0.05	0.05	0.05	0.05	0.05	0.05						
	23/6/08	0.079	0.068	0.063	0.051	0.049	0.055	0.051						
	02/6/10	0.040	0.055	0.050	0.032	0.030	0.034	0.028						
	24/6/10	0.067	0.200	0.063	0.061	0.055	0.079	0.058						
Chlorophyll-a (mg/m^3)	26/5/08				<3.8	<3.8		<3.8						
	23/6/08				<3.8	<3.8		<3.8						
	02/6/10				0.66	0.66		0.54						
	24/6/10				0.92	0.92		0.75						
Colour (units)	26/5/08	0.5	0.6	0.5	0.4	0.5	0.5	0.5						
	23/6/08	0.5	0.6	0.6	0.7	0.6	0.6	0.7						
FOG (g/m^3)	26/5/08	<5	<5	<4	<6	<5	<4							
	23/6/08	<5	<5	<5	<5	<5	<5							
Temp (°C)	26/5/08	9.7	9.6	9.6	9.7	9.6	9.5	9.5	9.5	9.5	9.5	9.5	9.6	9.4
	23/6/08	10.1	10	10	10	10.1	10.2	10	9.8	10	10	10.2	10.3	10.2
	2/6/10	11.5	10.4	10.4	---	10.1	10.5	10.3	9.98	10.07	9.74	9.49	9.85	10.01
	24/6/10	9.4	8.4	8.6	8.9	8.6	8.9	9.4	8.6	8.5	8.5	8.6	8.6	8.5
Dissolved Oxygen (% Sat)	26/5/08	129.8	130.8	141.2	132.1	141.6	139.8	127.4	156.3	159.5	155.1	157.4	151.8	158.3
	23/6/08	103.9	107.7	106.1	116.2	102.7	101.8	101.4	116.7	117.1	118.3	118.5	117	116.7
	02/6/10	102.2	103.8	102	---	104	103.9	103.7	113	107.9	108.8	109.7	109.8	110.6
	24/6/10	101.5	105	105.2	103.7	104.4	101.8	99.6	103.7	103.3	103.1	103.5	103.4	101.8
pH	26/5/08	8.1	8.1	8.1	8.1	8.1	8.1	8	7.9	8.1	8.1	8.1	8.1	8.1
	23/6/08	8.2	8.1	8	8.1	8.1	8	8.1	8.1	8.1	8	8	8.1	8.2
Salinity (ppt)	26/5/08	30	30	30	30	30	30	30						
	23/6/08	31	31	31	31	31	31	31						
	02/6/10								32.02	31.97	30.88	23.97	26.28	29.97
	24/6/10													

Similarly, there were no clear trends in the other water quality parameters monitored to date that can be directly attributed to the outfall. Where exceptions were noted, they often had nothing to do with the Silver Fern Farms discharge. For example, the offshore salinity results in Round 3 (2 June 2010) show a marked reduction for those sites 1500 m and beyond as a result of the Pareora River plume discharge. This result highlights that data collected further than 1500 m south of the river will likely be influenced more by the river plume than the outfall plume.

2.4. Change in colour (hue)

Several digital images of the sea surface were taken during the 2010 sampling. These images were used to assess conspicuous visual effects from the outfall by determining the change in colour (Red Green Blue [RGB] hue) between the plume and surrounding water (Barter & Apperley 2005). This approach was based on an RGB model developed by the World Wide Web Consortium (W3C 2000) for ensuring readability of web pages by specifying a minimum colour (hue) difference. The formula is that hue change is the sum of the absolute value of the difference in Red, Green and Blue channels, where RGB is on a 0-255 scale (*e.g.* Blue = 0,0,255):

$$\Delta_{\text{Hue}} = \text{ABS}\ (R_1 - R_2) + \text{ABS}\ (G_1 - G_2) + \text{ABS}\ (B_1 - B_2)$$

This approach has an advantage over the Munsell Scale for comparison of hues because it can be used on digital photos. The MFE (1994) guidelines state that a 10 point change in hue based on the Munsell Scale is considered to be a conspicuous visual effect, and this equates to a 10% change in hue for the approach used in this study.

Immediately adjacent to the outfall, there was a distinct difference in the colour of the plume compared to the receiving waters (Figure 6), however, at distances of greater than 500 m it was difficult to discern the outfall plume from the surrounding waters. For example, in Figure 6 there are two distinct squares that have been highlighted and their respective RGB values calculated. Using the formula presented above, the difference is 38 % and would be considered conspicuous. Note, however that this difference is within the mixing zone where such a change would be considered acceptable, and merely indicates that the method could work for this outfall.

During a site visit in June 2010, the main boiler stack was identified as a location for a webcam where regular photos could be taken of the outfall for comparative purposes. This webcam was not installed in time to be used during the 2010 season but it is still planned for next season. An example panorama photograph taken from the boiler stack on 1 June 2010 is presented in Figure 7 and clearly shows that, while the plume was visible to the south of the outfall, it was far less conspicuous than Figure 6 and would certainly be undetectable from background waters well within the existing mixing zone. The example in Figure 7 demonstrates that photos collected from the boiler stack on a regular basis would be an effective way of documenting the relative conspicuousness of the plume.

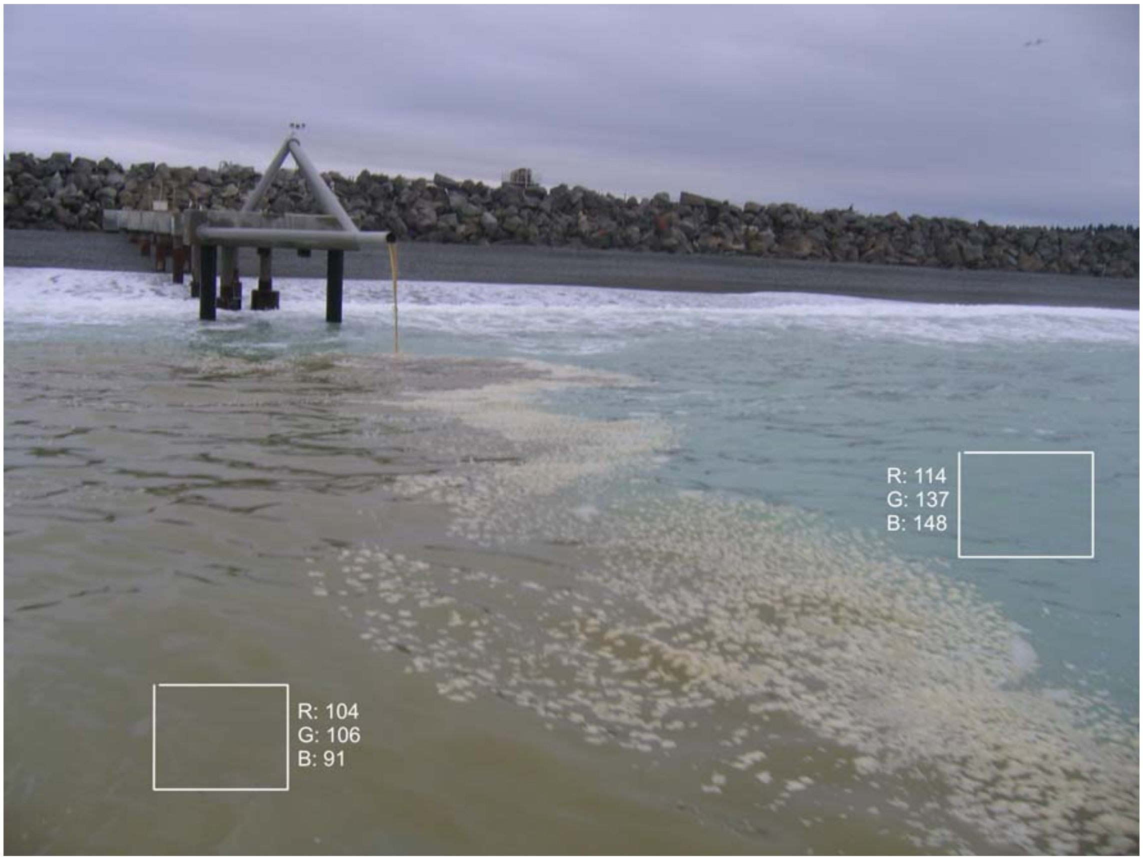

Figure 6. Photo of discharge on 2 June 2010 showing difference in colour between the plume and the surrounding coastal waters.

Figure 7. Panorama photograph of the outfall and plume taken from the Silver Fern Farms boiler stack on 1 June 2010.

3. DETERMINATION OF THE EXTENT OF THE MIXING ZONE

The determination of the size of a mixing zone for Resource Consent purposes is often contentious for several reasons, but mostly because setting the length and width of a mixing zone can be subjective and is often based on best professional judgement with a limited amount of underpinning information. This is certainly the case with the Silver Fern Farms Pareora outfall where the discharge takes place into a highly variable, high energy coastal surf break and the use of traditional modelling and dilution methods are neither practicable nor cost-effective.

The NIWA 2005 report (Fenwick & Spigel 2005) suggested an interim mixing zone of 4000 m radius from the outfall based largely on desktop modelling of nutrients. This value was not adopted and, during the resource consent hearing, an interim mixing zone of 1500 m was established in the hopes that additional monitoring (specifically that required by Condition 11 of the existing Consent) would help refine and/or define this more fully.

As mentioned in Section 1, Cawthron raised some concerns that the design of Condition 11 (*i.e.* the collection of several down-current/down-coast water quality samples) might not be sufficient to 'determine the extent of the mixing zone'. These concerns were due to a number of factors, but primarily the fact that water quality results are inherently variable and additional data may or may not answer the fundamental questions at hand; namely, what mixing/dispersion is available and what are the limiting parameters in the effluent? For example, adoption of the SE Australian nutrient guidelines as outlined in ANZECC (2000) and used in the NIWA (2005) report may be far too conservative for the South Canterbury Bight coastal waters, particularly given the degree of nutrient inputs from the various riverine sources.

Results from the four rounds of receiving water sampling have shown that, with the exception of bacteriological parameters, there is no obvious pattern in water quality parameters that can be attributed to the discharge. While Enterococci results have shown an outfall-related trend, this appears to be reducing over time and may reflect the ongoing efforts by Silver Fern Farms to improve their effluent quality.

Consequently, in the absence of definitive water quality data and/or guidelines that can be used to establish the mixing zone, the following questions are raised and each of these questions is briefly discussed:

- Can the existing 1500 m mixing zone be expanded?
- Can the existing 1500 m mixing zone be reduced?
- Is there a rationale to keep the status quo?

Can the existing 1500 m mixing zone be expanded?

General guidance for the zone of reasonable mixing is outlined in "Resource Management Ideas No 10 – A discussion on reasonable mixing in water quality management." (Rutherford, *et al*. 1994) and among other things states that:

- *the size of the zone of reasonable mixing should be minimised;*
- *any adverse effects should be confined to within the zone of reasonable mixing; and*
- *any adverse effects within the zone of reasonable mixing should be no more than minor*

In the case of the Silver Fern Farms discharge, expanding the interim 1500 m mixing zone generally goes against this guidance, even when the original NIWA modelling suggested a much larger 4000 m mixing zone. Another reason for not expanding the zone is that the ECAN coastal water quality class (ECAN RCEP Map Ref 1.11) changes 1600 m north of the outfall from Aquatic Ecosystem (AE) to Contact Recreation (CR) and having a mixing zone that overlaps two different coastal water quality classes is generally discouraged. This water quality class changes again approximately 5 km north of the outfall (near Ellis Road) from CR to Shellfish Gathering (SG).

Can the existing 1500 m mixing zone be reduced?

In trying to determine the minimum size of a mixing zone, there needs to be a clear understanding of which effluent constituents have the greatest potential to cause adverse ecological effects and/or breaches of RMA (s107) with regard to conspicuous changes in colour clarity or odour.

The NIWA 2005 report (Fenwick & Spigel 2005) essentially performed this exercise and concluded that nutrients would be the limiting parameter. However, this conclusion was based, rightly or wrongly, on the assumption that the ANZECC (2000) SE Australian nutrient guidelines were applicable to Canterbury Bight coastal waters. Given that the coastal waters (out to a distance of 500 m offshore) of the South Canterbury Bight often exceed these ANZECC (2000) guidelines (Bolton-Ritchie 2006), there is a strong argument that incorporating the SE Australian guidelines for a discharge might be far too conservative. It is beyond the scope of this report to discuss guideline development, so for the time being, nutrients are not being considered.

In the absence of nutrients, clarity effects are likely to be one of the primary limiting parameters in the effluent. The benchtop dilution series outlined in Section 2.1, showed that a dilution of 75:1 was required to meet the 50% change in clarity guideline stipulated in the ECAN coastal plan. The modelling work from Fenwick & Spigel (2005) showed that dilution of 67:1 (*i.e.* a concentration of 0.015 g/m^3) was not achieved until a down-current distance of about 1200 m was reached. This would put the 75:1 dilution distance at, or near, the existing 1500 m mixing zone boundary. While the 2005 modelling work was admittedly conservative, it still serves as a reasonable 'worst-case' assessment of dilution along this stretch of coast.

Using these modelling results, in conjunction with the benchtop clarity dilution series, there is no clear rationale for reducing the size of the existing interim mixing zone.

Is the status quo mixing zone size acceptable?

Based on a comparison of the benchtop clarity dilution series and the 2005 modelling work, the 1500 m mixing zone appears to be set at about the right size, but is this size acceptable? Certainly 1500 m is one of the larger coastal mixing zones presently consented nationally, particularly given that it is essentially an intertidal discharge; however, the remote location has to be considered as well. While this discharge would clearly be unacceptable in an area of high recreational, customary, and/or commercial use, the stretch of coastline near Pareora is particularly remote. For example, since the granting of the Consent in 2007, there has only been one documented complaint to ECAN on visual effects or odour associated with the coastal discharge, and no complaints lodged directly with Silver Fern Farms (F. Schepers *pers comm.*). By implication, this general lack of objection represents an inherent acceptance of the status quo by local users of the coastal region.

Taking this into account, and considering also the continued commitment by Silver Fern Farms to both reduce the quantity and improve the effluent quality, along with the long-term goal to remove the coastal discharge entirely by 2017, there appears little reason to recommend a change to the status quo.

4. REFERENCES

ANZECC. 2000: Australian and New Zealand Guidelines for Fresh and Marine Water Quality - 2000.

Barter P, Apperley B 2005. Assessing conspicuous visual effects from a coastal outfall using a webcam and automated image analysis. Conference proceedings, NZWWA annual conference.

Bolton-Ritchie, L. 2006. Coastal Water Quality Lake Ellesmere/Te Waihora to the Waitaki River Mouth. ECAN Technical Report No U06/36. 70 p.

ECAN 2005. Regional Coastal Environment Plan for the Canterbury Region. Volume 1. Report No. R04/13/1. Environment Canterbury November 2005.

Fenwick, G. and B. Spigel 2005. PPCS Ltd's Pareora ocean discharge: Section 41 request for additional information. Prepared for PPCS Ltd. NIWA Client Report: CHC2005-155. 15 p.

MFE. 1994: Water Quality guidelines No. 2. Anonymous. Guidelines for the Management of Water Colour and Clarity.: 1-77.

MFE; MOH. 2003: Bacteriological Water Quality Guidelines for Marine and Freshwater. Guidelines for the Management of recreational and Marine Shellfish-Gathering Waters.: 1-16.

Rutherford,K.; Zuur,B.; Race,P. 1994: Resource Management Ideas No 10: Reasonable Mixing - A discussion of reasonable mixing in water quality management. 15p.

Schepers 2008. Sea water quality investigation: Consent CRC071504, Condition 11. Silver Fern Farms Report Prepared for ECAN. 3 p. plus appendices.

Sombardier L, Niiler PP 1994. Global surface circulation measured by lagrangian drifters. Sea Technology 35(10): 21-24.

W3C 2000. Techniques for Accessibility Evaluation and Repair Tools. World Wide Web Consortium. http://www.w3.org/TR/AERT#color-contrast

5. APPENDICES

Appendix 1. Resource Consent for Silver Fern Farms Coastal Discharge

Appendix 2. Laboratory data