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5 April 2019

Silver Fern Farms - Irrigation of Meat Processing Wastewater at the Mossburn Plant

Silver Fern Farms Ltd hold an existing consent (AUTH-95498) authorising discharge of wastewater generated in their Mossburn processing plant to land. The current consent is due to expire on the 15th of April 2019. Silver Fern Farms Ltd submitted an application with Environment Southland in late 2018 to replace the existing consent to enable future wastewater disposal from the Mossburn plant. In February 2019, Environment Southland requested further information to enable assessment of the application including:

An assessment of cumulative effects of the discharge to land on water quality. This should include:

a) *A description of the current water quality in the wider receiving environment, beyond the area immediately surrounding the discharge area. The description should including groundwater quality, water quality in the Oreti River and the current state of the New River Estuary;*

b) *An assessment of cumulative effects on groundwater quality downgradient of the discharge area;*

c) *An assessment of cumulative effects on water quality in the Oreti River, through the discharge of groundwater to surface water; and*

d) *An assessment of cumulative effects on the state of the New River Estuary.*

The following report provides an assessment of the potential cumulative effects on water quality associated with the proposed discharge.

1. Characteristics of the discharge

As outlined in Liquid Earth (2018)[1], characteristics of the discharge include:

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[1] Liquid Earth (2018); *Silver Fern Farms - Irrigation of Meat Processing Wastewater at the Mossburn Plant*. Letter report prepared for Silver Fern Farms Ltd, 13 December 2018.

- The composition of the discharge is largely organic in nature, containing very little material that is not fully degradable by biological means. Wastewater composition generally comprises settleable and suspended solids derived from blood, paunch content liquids, stockyard washings and fat/protein from meat tissue;
- Wastewater analyses results as required under the current consent indicate the discharge has a mean TKN concentration of approximately 160 g/m^3, a total phosphorus concentration of 6.6 g/m^3 and a Faecal Coliform loading of 2.0 x 10^6 cfu/100mL;
- Samples undertaken to support the original 1997 consent application suggest similar pH (7.9), BOD (520 g/m^3) and TKN (110 g/ m^3) to those measured at other similar processing operations, and indicate low concentrations of trace metals (including Copper, Cobalt, Selenium, Cadmium, Chromium, Nickel, Zinc and Mercury) consistent with the primarily organic nature of the wastewater;
- Wastewater is discharged at a rate of up to 1,400 m^3/week via spray irrigation to land;
- Typical N loading rates vary between 80 to 140 kg N/ha/year, with maximum application rates of up to 185 kg N/ha/year on individual irrigation blocks in some years. The proposed maximum allowable N application rate is 250 kg N/ha/year, consistent with that specified in consent conditions for the existing discharge.

Characteristics of the land/subsurface in the discharge area include:

- Oreti soils are the dominant soil type of the irrigation area. These soils are characterised as highly permeable and well drained (sometimes excessively) and are assessed as exhibiting very severe nutrient leaching vulnerability reflecting the good profile drainage, low total available water and rapid permeability (TopoClimate South, 2002);
- The potential for overland flow from the discharge area to nearby surface water ways is low due to well drained characteristics of the Oreti soils, relatively flat terrain and set-back from the nearest surface water way (Murray Creek) which is located approximately 500m distant from the irrigated area at its closest point;
- Available hydrogeological information indicates the discharge area is underlain by a shallow aquifer hosted in recent (Q2) alluvium up to 10 metres deep (interpreted to be an unconfined aquifer). The surficial aquifer is underlain by a further water-bearing layer occurring around 30 metres below ground (interpreted to be a semi-confined aquifer);
- The data indicate the water table in the vicinity of the irrigation area is relatively shallow (<5 m bgl) with a typical seasonal variation of around 1.5 metres; and
- The shallow unconfined aquifer is interpreted to be recharged by infiltration of local rainfall, hence loss of nutrients from the discharge into shallow groundwater is possible.

As described above, wastewater of the Mossburn Meat Processing Plant contain elevated concentrations of nitrogen, phosphorus and microbial contaminates that have the potential to adversely affect water quality in downstream receiving environments. However, as outlined in Liquid Earth (2018):

- Given the relatively small Total Phosphorus load from wastewater application (estimated 8.8 kg P/ha/yr), removal of significant quantities of P via cut and carry operations (reflected in low soil Olsen P values) and the limited potential for soil erosion or particulate transport to surface water, it is considered unlikely that Phosphorus in wastewater applied to the irrigation area will result in adverse effects on the environment;
- The limited potential for overland flow combined with the likely attenuation of microbial contaminants associated with movement through porous media, and the significant distance (>600 m) to the nearest down gradient receptor mean the discharge of wastewater to land at the Silver Fern Farms Mossburn plant has limited potential to result in adverse effects on the microbial quality of down-gradient groundwater or Murray Creek; and
- Concentrations of trace metals and other contaminants are typically low to very low and unlikely to result in more than minor effects on the quality of receiving waters, particularly given the potential for adsorption and ion exchange within the soil zone.

Given the above, only possible effects of nitrogen on the wider downstream environment are further assessed in this report.

2. Existing water quality in the wider receiving environment

2.1 Groundwater

The current discharge area is located above a shallow aquifer which is defined as the Castlerock groundwater zone.

There is currently no long-term state of the environment (SoE) groundwater quality monitoring in the Castlerock GWMZ. However, long-term water quality data are available from one former SOE site (E44/0045) and four compliance monitoring bores (E44/0396, E44/0463, E44/0467 and E44/0476). One-off groundwater quality monitoring data is also available from a further 12 bores located in the Castlerock GMZ which have been sampled since 2000. Figure 1 shows the spatial distribution of observed nitrate concentrations (median values at sites with multiple samples). Results indicate groundwater nitrate concentrations are low to moderate across a majority of the zone, but may be significantly elevated in areas adjacent to intensive agriculture. This is consistent with the occurrence of localised groundwater nitrate 'hotspots' elsewhere in the Oxidising physiographic zone (e.g., Hughes *et al*., 2016[2]). Groundwater nitrate concentrations to the west of Sutherland Road are generally less than 4 mg/L.

It is noted that one bore (E44/0262) exhibits very low nitrate (0.002 mg/L) and dissolved oxygen (0.01 mg/L) concentrations along with elevated Fe(II) concentrations (0.3 mg/L) indicative of reducing conditions in the aquifer. Under such conditions denitrification is likely to occur, significantly reducing groundwater nitrate concentrations. However, it is inferred that the reducing conditions observed in this bore reflect the proximity of the screened interval to underlying Gore Lignite Measure sediments do not

[2] Hughes, B., Wilson, K., Rissmann, C., Rodway, E., 2016; *Physiographics of Southland: Development and application of a classification system for managing land use effects on water quality in Southland*. November 2016.

directly underlie the unconfined aquifer across a majority of the Castlerock Terrace. Other sites exhibiting low nitrate concentrations generally show oxic groundwater, suggesting low nitrate levels elsewhere in the aquifer are likely to reflect low nitrate inputs rather than denitrification.

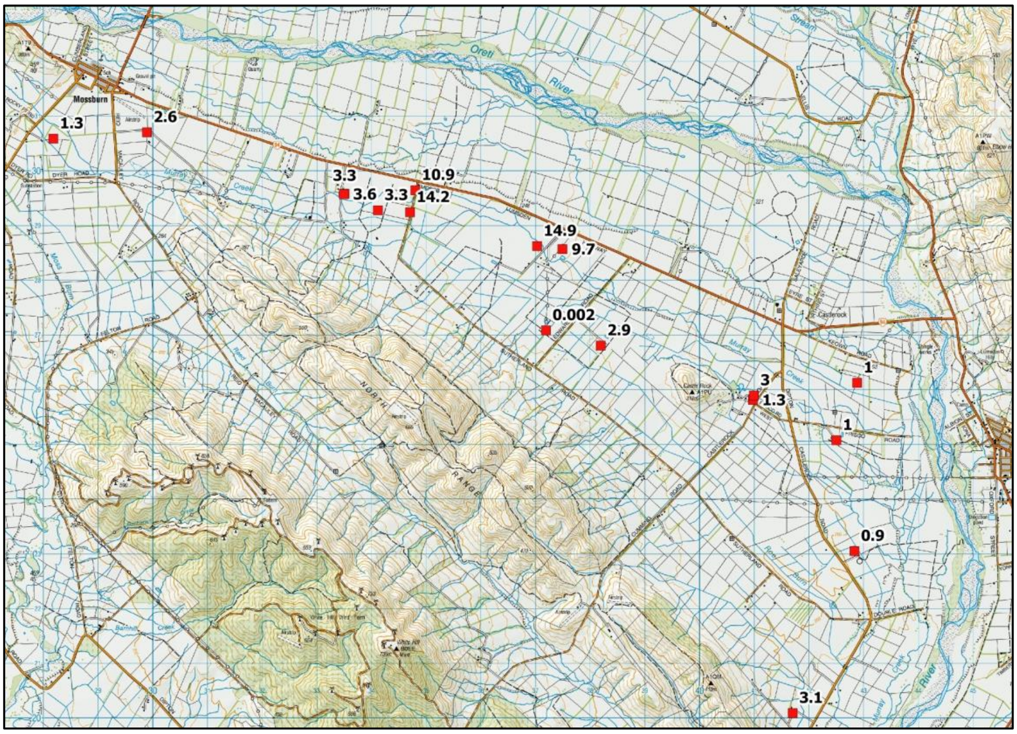

Figure 1. *Spatial distribution of groundwater nitrate concentrations in the Castlerock groundwater zone (median values for sites with multiple samples)*

As illustrated in Figure 2 below, monitoring results from E44/0045, the longest monitored bore in the Castlerock groundwater zone, indicate a clear increasing trend in groundwater nitrate concentrations between 2002 and 2016.

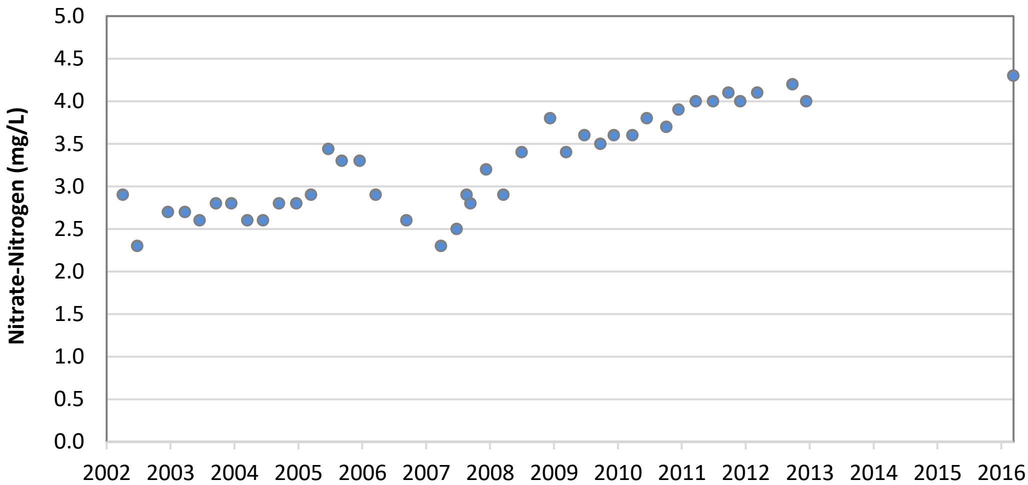

Figure 2. *Groundwater nitrate concentrations in E44/0045, 2002 to 2016.*

Other Environment Southland groundwater compliance monitoring bores in the Castlerock groundwater zone exhibit elevated, but temporally variable groundwater nitrate concentrations. As shown on Figure 3 below, in three of the four bores sampled, episodic nitrate concentrations in excess of 20 mg/L suggest proximity to, or influence by, localised contaminant sources.

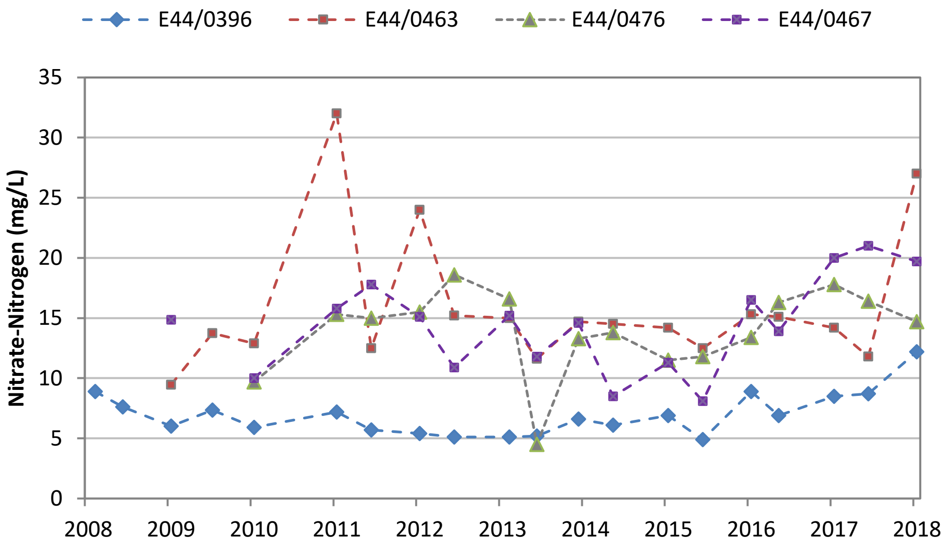

Figure 3. *Temporal variations in groundwater nitrate concentrations in Environment Southland compliance monitoring bores in the Castlerock groundwater zone, 2008 to 2018.*

Overall, available groundwater quality data from the Castlerock groundwater zone indicates background groundwater nitrate concentrations are generally low to moderate (< 4 mg/L), but may be strongly influenced by localised contaminant inputs to the aquifer system, particularly down-gradient of intensive land use. This is consistent with the observation of localised groundwater nitrate 'hotspots' in the Oxidising physiographic zone elsewhere in Southland. Although data is limited, available groundwater monitoring information does not indicate departure from background concentrations in the area west of Sutherland Road that would indicate a significant impact on nitrate concentrations associated with wastewater discharge from the Mossburn plant.

2.2 Oreti River

Hodson *et al.* (2017)[3] report on water quality state and trends of Southland's freshwater at long-term monitoring sites including State of the Environment Monitoring (SoE), National River Water Quality Network (NRWQN) and National Groundwater Monitoring Programme (NGMP) sites for the period 2000 to 2016. This analysis indicated median Nitrate Nitrite Nitrogen (NNN) concentrations in the Oreti River at the three SoE and two NRWQN monitoring sites are generally low (<1 mg/L), with maximum

[3] Hodson, R., Dare, J., Merg, M.L., and Couldrey, M. (2017) Water Quality in Southland: Current State and Trends, Technical Report April 2017, Publication No 2017-04.

concentrations up to 3.3 mg/L observed in the lower catchment. Trends in NNN concentrations were significantly decreasing for 3 of the 5 assessed Oreti River monitoring sites suggesting water quality of the Oreti River is slightly improving. Table 1 provides a summary of the analysis undertaken by Hodson *et al*., 2017.

Table 1. *Summary of Nitrate Nitrite Nitrogen (NNN) concentrations and trends at available Oreti River monitoring sites (Hodson et al., 2017).*

Site Name	**NNN concentration (mg/L) data from 2012-2016**				**Trend in NNN**	
	number of samples	**max**	**median**	**95th percentile**	**significant trend**	**magnitude (mg/L/year)**
Oreti River at Three Kings)	60	0.098	0.034	0.084	decreasing (2012-2016) decreasing (2007-2007)	-0.0076 to -0.0037 -0.0019 to -0.0001
Oreti River at Lumsden Bridge	47	1.24	0.61	1.173	n/a	n/a
Oreti at Lumsden	49	1.265	0.602	1.2458	decreasing (2007-2016)	-0.0227 to 0.0156
Oreti River at Wallacetown	47	2.3	0.94	2.115	n/a *	n/a *
Oreti at Riverton HW Br	49	3.349	0.932	2.1934	deceasing (2007-2016)	-0.0311 to 0.0060

* Plew (2017) reported a statistically significant increase in NNN occurring at the Oreti River at Wallacetown site of 0.0275 mg/L/year between 1989 and 2014

As summarised in Table 2 below, concentrations of Nitrate and Ammonia in the Oreti River are within the A or B bands specified in the National Objectives Framework indicating current water quality is unlikely to result in significant ecological effects.

***Table 2**. Toxicity NOF (National Objectives Framework) bands at available Oreti River monitoring sites (Hodson et al., 2017).*

Site	**NO_3-N - Toxicity (median)**	**NO_3-N - Toxicity (95%ile)**	**NO_3-N - Toxicity**	**NH_4-N - Toxicity (median)**	**NH_4-N - Toxicity (95%ile**	**NH_4-N - Toxicity**	**NH_4-N (median)**	**NO_3-N (median)**	**TN (median)**
Oreti River at Three Kings	A	A	A	A	A	A	<0.01	<0.167	<0.295
Oreti River at Lumsden Bridge	A	A	A	A	A	A	<0.01	>0.167	>0.295
Oreti at Lumsden	A	A	A	A	A	A	<0.01	>0.167	>0.295
Oreti River at Wallacetown	A	B	B	A	A	A	<0.01	>0.167	>0.295
Oreti at Riverton HW Br	A	B	B	A	A	A	<0.01	>0.167	>0.295

2.3 New River Estuary

Generally, nitrogen levels in the tributaries of the New River Estuary (NRE) have been increasing for the period 2000 to 2016 (Plew, 2017[4]; Robertson *et al*., 2017[5]). The increase in N areal loads to the estuary (from tributaries) are consistent with the small but ecologically important increase in Nitrogen levels in the estuary (Plew, 2017; Robertson *et al*., 2017). Of particular significance is the dominance of winter nitrate and DIN concentrations as the main driver of the positive trends at most New River Estuary monitoring sites (Robertson *et al*., 2017).

The CSIRO (2011)[6] suggests appropriate annual mean TN concentration for the ocean boundary of the NRE is likely to be around 0.070 mg/L. Masures (2016)[7] estimated potential TN concentrations in the estuary of 1.05 (winter) to 0.34 mg/L (summer) based on conservative tracer modelling.

3. Assessment of cumulative effects of the Silver Fern Farms Mossburn discharge on the wider environment

3.1 Castlerock groundwater zone

As outlined in Liquid Earth (2018), the current consent allows a maximum nitrogen loading of 250 kg N/year to the 34 ha irrigation area. However, given the composition of the wastewater, only a proportion of the applied nitrate load occurs in the mobile nitrate phase at any given time, with the balance in the relatively immobile organic form or removed from the soil via volatilisation or plant uptake. The predominantly organic form of nitrogen in the wastewater also reduces the potential sensitivity of nutrient losses due to weather-related events.

On average, 100 kg of nitrogen is removed from the irrigated area each year under the cut and carry system (range 77 to 126 kgs, 2008-09 to 2015-16, SoilWork, 2016[8]). Of the remaining loading, a major loss of nitrogen in the land treatment system occurs via volatilisation. Assuming volatilisation accounts for 25% of the applied nitrogen loading on the Silver Fern Farms Mossburn irrigation area, the proposed maximum nitrogen loading of 250 kg N/year effectively reduces to 187.5 kg N/year potentially available for plant uptake or conversion to oxidisable nitrogen (e.g. nitrate). Based on the resulting surplus of 110.5 and 61.5 kg N/ha/year across the land disposal area and an estimated soil moisture surplus of 248 and 480 mm across the irrigation area, median nitrate concentration in soil drainage water under

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[4] Plew, D., 2012; *New River Estuary - CLUES Estuary analysis* Prepared for Environment Southland January 2017.

[5] Robertson, B.M., Stevens, L.M., Ward, N., and Robertson, B.P., 2017. *Condition of Southland's Shallow, Intertidal Dominated Estuaries in Relation to Eutrophication and Sedimentation: Output 1: Data Analysis and Technical Assessment - Habitat Mapping, Vulnerability Assessment and Monitoring Recommendations Related to Issues of Eutrophication and Sedimentation.* Report prepared by Wriggle Coastal Management for Environment Southland. 172p.

[6] CSIRO (2011) CSIRO Atlas of Regional Seas (CARS), www.cmar.csiro.au/cars

[7] Masures, R. (2016) New River Estuary Hydrodynamic Modelling Model build, calibration and tracer simulations Prepared for Environment Southland September 2016.

[8] SoilWork, 2016; *Silver Fern Farms Ltd, Mossburn Plant. Wastewater Irrigation Annual Monitoring and Performance Report 2015-16*, October 2016.

the irrigation area were estimated to be 28.6 g/m^3 assuming wastewater application at the maximum rate of 250 kg N/ha.

A simple mass balance model incorporating estimates of annual average nitrogen excess, drainage volume from the land disposal area and aquifer throughflow was utilised to provide a conservative estimate of potential groundwater nitrate concentrations down-gradient of the land disposal area. Results of this assessment indicated a potential down-gradient nitrate concentration ranging between 4.7 and 6.8 mg/L (it is noted these concentrations are between 15 to 40 percent higher than observed in the area west of Sutherland Road (see Figure 1 above)).

For assessment of cumulative effects of the proposed discharge on the wider environment, the mass balance estimate outlined in Liquid Earth (2018) has been extended to include the entire Castlerock groundwater zone. Land surface recharge estimates utilised for the Proposed Southland Water and Land Plan (LWP, 2018[9]) indicate annual average recharge of 267mm/year to the Castlerock groundwater zone. Across the 6,558 Ha surface area this equates to an annual average recharge volume of 17.49 million m^3/year. At an aquifer-scale, the annual average nitrogen excess on the Silver Fern Farms land disposal area (87 kgN/year/ha or 2,958 kg/year across the 34 Ha wastewater irrigation area) equates to a 0.17 mg/L increase in aquifer-scale groundwater nitrate concentration.

For context, the conservative estimate of average Nitrogen loss of 2,958 kg N/year from the Silver Fern Farms wastewater irrigation area (assuming an annual wastewater application rate equivalent to a nitrogen loading of 250 kgN/ha/yr) equates to the average annual losses from 98 Ha of Dairying (wintering off), 66 Ha of arable cropping or 54 Ha of Dairy support (wintering) based on average N loss figures quoted in Ledgard (2013)[10].

3.2 Oreti River and New River Estuary

The Castlerock groundwater zone is drained by a series of spring-fed streams that originate along the eastern terrace margin. These streams, of which Murray Creek and the Roe Burn are the largest, carry appreciable discharge from areas of poorly drained soils on the Castlerock Terrace and runoff from the North Range during winter and spring. However, during the spring and autumn, runoff from the Castlerock Terrace recedes and flow in the lower reaches of these waterways is largely maintained by spring discharge from the Castlerock groundwater zone. During low flow periods the combined discharge in these waterways of ~300 L/s (representing groundwater inflow) equates to around 50 to 60% of the annual average recharge volume to the to the Castlerock groundwater zone.

[9] LWP, 2018; Groundwater Provisions of the Proposed Southland Water and Land Plan. Recommendations for Policy Development. Report to Environment Southland, June 2018.

[10] Ledgard, 2013; *Nitrogen, Phosphorus and Sediment losses from rural land uses in Southland*. Environment Southland Technical Report, August 2013.

Assuming discharge to these waterways accounts for approximately 60% of the throughflow in the Castlerock groundwater zone[11], this discharge may carry a cumulative load of approximately 1,770 kg N/year originating from the Silver Fern Farms discharge to the Oreti River. Assuming no attenuation within the groundwater system or spring-fed streams draining the Castlerock groundwater zone, this load will eventually reach the Oreti River and ultimately the New River Estuary. Hence, under a worst-case scenario (i.e. no denitrification or attenuation within the soil zone, groundwater, or surface water network) discharge to the Silver Fern Farms wastewater disposal area at the maximum N loading of 250 kgN/ha/year could contribute an estimated 1.77 tonnes of N per year to the Oreti River and downstream New River Estuary.

As outlined in Table 3 below, Robertson and Stevens (2013) estimated cumulative loads of N (P and sediment) to the Oreti River and New River Estuary. Using these estimates, worst-case nitrogen losses from the Silver Fern Farms Mossburn wastewater discharge (1,770 kg/year) represent 0.1% of the cumulative nitrogen load in the Oreti River (1,815 t/year). Based on the mean flow of 28.44 m^3/s the Lumsden Cableway monitoring site, the worst-case N load from the Mossburn wastewater discharge to the Oreti River (equivalent to 4.85 kg/day) via Murray Creek and the Roe Burn would equate to an increase of 0.002 mg/L in the concentration of dissolved inorganic nitrogen (DIN) in the Oreti River. Under low flow conditions (Q_{95} = 5.523 m^3/s), this discharge would potentially increase instream DIN concentrations by 0.01 mg/L.

Assuming no attenuation within the Oreti River system, the estimated worst-case loss from the Mossburn wastewater discharge (1,770 kg/year) equates to 0.04% of the cumulative nitrogen load to the New River Estuary estimated by Robertson and Stevens (2013). More recent estimates of the cumulative nitrogen load to the New River Estuary range from 3,617 t/year (NIWA, 2017[12]) to 3,736 t/year (Aqualinc, 2014[13]). Worst-case losses from the Silver Fern Farms Mossburn discharge represent 0.05% of these revised cumulative load estimates.

3.3 Cumulative losses allowing for attenuation

Attenuation of nitrate in aerobic aquifers, such as the Castlerock groundwater zone, has been shown to be negligible in New Zealand (Sarris *et al*., 2018[14]). However, instream attenuation processes such

[11] Concurrent gaugings from the Oreti River at Lumsden Cableway and Ram Hill do not show a consistent gain over the intervening reach larger in magnitude that cumulative inflow from Murray Creek and the Roe Burn. As a consequence, it appears that the balance of groundwater throughflow in the Castlerock groundwater zone (i.e. that which does not discharge via spring-fed streams) does not make a major contribution to Oreti River baseflow at Ram Hill.

[12] NIWA, 2017; New River Estuary - CLUES Estuary Analysis. Report prepared for Environment Southland, January 2017.

[13] Aqualinc, 2014; *Regional Scale Stratification of Southland's Water Quality - Guidance for Water and Land Management.* Report prepared for Environment Southland, March 2014.

[14] Sarris, Theo; Burbery, Lee and Close, Murray, 2018; *Denitrification rate inputs to groundwater models*. SAM Programme. GNS Science Report 2018/43. December 2018.

as plant uptake and denitrification can reduce nitrate levels in streams, particularly in small (low order) streams which have the greatest attenuation capability (Howard-Williams *et al*., 2010[15]).

Nutrients and instream plants (periphyton and macrophytes) interact dynamically in rivers with nutrients stimulating plant growth that in turn reduces downstream nutrient concentrations, eventually to levels that limit further growth. Furthermore, plant metabolism influences dissolved oxygen and pH that can alter nutrient fluxes between the sediment and water column. A large number of physical and modelling studies have been undertaken in New Zealand to characterise the potential magnitude of in-stream attenuation of nitrogen. Results of these investigations indicate attenuation rates of dissolved inorganic N are influenced by a range of factors influenced including nutrient concentrations, flow rate, periphyton biomass, ecosystem metabolism, gross primary production and diel lighting and may exhibit appreciable seasonality.

For example, in smaller streams such as Murray Creek and the Roe Burn, extensive macrophyte growth during the spring and summer months may result in significant attenuation of nitrate inputs contained in baseflow discharge. However, during the cooler winter months, periphyton growth is much reduced and a significant amount of nitrogen attenuated during the warmer months can be remobilised (NIWA, 2014[16]).

While estimates of attenuation vary between individual catchments, a number of reports indicate attenuation equal to around 50% of cumulative nitrogen inputs to rivers and streams can be expected between source areas and the coastal environment in New Zealand (e.g., Elliott et al. (2005)[17], NIWA

[15] Howard-Williams C. and Pickmere S. (2010). Thirty years of stream protection: Long-term nutrient and vegetation changes in a retired pasture stream. Science for Conservation 300, Department of Conservation, Wellington, New Zealand.

[16] NIWA, 2014; *Catchment models for nutrients and microbial indicators. Modelling application to the upper Waikato River catchment.* Report prepared for Ministry for the Environment, July 2014.

[17] Elliott, A.H., Alexander, R.B., Schwartz, G.E., Shankar, Ude, Sukias, J.P.S., McBride, G.B., 2005: *Estimation of nutrient sources and transport for New Zealand using the hybrid mechanistic-statistical model SPARROW*. Journal of Hydrology (NZ) 44 (1): 1-27.

(2009)[18], Howard-Williams *et al*. (2010)[19], NIWA (2012)[20], NIWA (2014), Elwan *et al*. (2015)[21], Singh et al. (2018)[22], Jacobs (2018)[23]).

Table 3. *Estimated total Nitrogen, Total Phosphorus, and total suspended solids loads to the New River Estuary (from Robertson and Stevens, 2013)*

Discharge	Location	Mean N Load (t/y)	Mean P Load (t/y)	Mean SS Load (t/y)	N % Contribution	P % Contribution	TSS % Contribution
Non-Point Source Discharges Only (i.e. no point sources to these catchments included)	Oreti River	1815	133	115555	40.7%	37.6%	75.7%
	Waikiwi Stream	20	4	1131	0.5%	1.1%	0.7%
	Makarewa River	980	68	32609	22.0%	19.2%	21.4%
	Otatara (5 Streams)	15	1	103	0.3%	0.3%	0.07%
	Waihopai River	359	16	1634	8.1%	4.5%	1.1%
	Otepuni Creek	23	1	259	0.5%	0.3%	0.2%
	Kingswell Creek	13	1	115	0.3%	0.3%	0.1%
	Waimatua (Duck Creek)	76	3	638	1.7%	0.9%	0.4%
	Mokotua Stream	284	13	130	6.4%	3.7%	0.1%
	Mokomoko tributaries	5	1	152	0.1%	0.3%	0.1%
	Whalers Bay	1	0	52	0.02%	0.0%	0.03%
Point Source Discharges	ICC Clifton	181	37.4	0.15	4.1%	10.6%	0.00%
	Prime Range Meats	29.3	4	3.4	0.7%	1.1%	0.00%
	Blue Sky Meats	360	39	0	8.1%	11.0%	0.00%
	Alliance Lorneville*	270	27	203	6.1%	7.6%	0.13%
	Alliance Makarewa	15.3	1.9	7.9	0.3%	0.5%	0.01%
	Mossburn	0.7	0.2	2	0.02%	0.1%	0.00%
	Woodlands	0.8	0.3	2.4	0.02%	0.1%	0.00%
	Winton	6.8	2.4	20.1	0.15%	0.7%	0.01%
	Lumsden	1.4	0.5	4	0.03%	0.1%	0.00%
	Browns	0.5	0.2	1.6	0.01%	0.1%	0.00%
	Whitehouse Hotel	0.5	0.2	1.6	0.01%	0.1%	0.00%
TOTAL		**4456**	**354**	**152624**	**100%**	**100%**	**100%**

* Used HIGH LOAD YEAR (2009/10) for Alliance Lorneville.

Assuming 50% instream attenuation of the nitrogen input from the Castlerock groundwater zone to the Oreti River and tributaries, the effect on downstream DIN concentrations reduce to between 0.005 and 0.001 mg/L. The cumulative load reaching the New River Estuary would reduce to around 880 kg

[18] NIWA, 2009; *Catchment Sensitivity, Nutrient Limits and Nutrient Spiralling & Forecasting Future Landuse Impacts in Hawke's Bay*. Report for Hawke's Bay Regional Council, January 2009.

[19] Howard-Williams, C., Davis-Colley, R., Rutherford, K., Wilcox, R., 2010; *Diffuse pollution and freshwater degradation: New Zealand Perspectives*. In van Bochove, Vanrolleghem, Chambers, Theriauly, Novotna and Burkert (eds) Selected papers from the 14th International Conference of the IWA Diffuse Pollution Specialist Group.

[20] NIWA, 2012; *Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision making framework: Phases 1 and 2 final report.* Prepared for the Ministry of Science & Innovation Envirolink Fund

[21] Elwan, A., Singh, R., Horne, D., Roygard, J., Clothier, B., 2015; *Nitrogen attenuation factor: can it tell a story about the journey of nutrients in different subsurface environments?* In: Moving farm systems to improved attenuation (Eds L.C. Currie and L.L. Burkitt). http://flrc.massey.ac.nz/publications.html. Occasional report No. 28. Fertiliser and Lime Research Centre, Massy University, Palmerston North, New Zealand.

[22] Singh, R., Horne, D., Hedley, M., 2018; *Variable nitrogen attenuation capacity for targeted and effective water quality management in New Zealand agricultural catchments*. In: Farm environment planning - Science, policy and practice. (Eds L. D. Currie and C.L. Christensen. http://flrc.massey.ac.nz/publications.html. Occasional Report No. 31. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.

[23] Jacobs, 2018; *Ruamahanga Catchment Modelling. Water quality freshwater objectives and load setting.* Report for Greater Wellington Regional Council, May 2018

N/year representing around 0.02% of the various cumulative load estimates listed in the previous section.

4. Summary

Meat processing wastewater has been discharged to land from the Silver Fern Farms Mossburn plant for an extended period so the discharge forms part of the existing environment. Historical monitoring of this discharge indicates nitrogen loading rates have been relatively modest, particularly when forage removed via cut and carry operations is accounted for. Historical wastewater disposal is also observed to have resulted in moderate improvements in soil conditions.

Mass balance calculations indicate that discharge of wastewater up to the maximum proposed nitrogen loading of 250 kg N/ha are unlikely to result in elevated nitrate concentrations (i.e. >50% MAV) in groundwater immediately down gradient of the irrigation area (assuming continuation of cut and carry operations).

A review of available groundwater quality data indicates nitrate concentrations in the Castlerock groundwater zone are generally low (in the Southland context). However, as is characteristic of the Oxidising physiographic zone, localised nitrate 'hotspots' are observed in the vicinity of intensive land use. While current nitrate concentrations down-gradient of the Mossburn land disposal area are generally less than 4 mg/L (i.e. <40% MAV), monitoring undertaken by Environment Southland indicates an increasing trend in groundwater nitrate concentrations, with concentrations exceeding MAV observed in several dairy compliance monitoring bores. Assuming no attenuation within the soil zone or underlying groundwater, mass balance calculations indicate that nitrogen loss from the Mossburn land disposal area (operating at the maximum loading rate of 250 kg N/ha/year) may contribute slightly less than 0.2 mg/L to groundwater nitrate concentrations across the wider Castlerock groundwater zone.

Approximately 60 percent of groundwater throughflow in the Castlerock groundwater zone is discharged to the Oreti River via spring-fed streams that originate along the eastern margin of the Castlerock Terrace. This implies a similar proportion of N loss from the Mossburn wastewater irrigation area may ultimately discharge to the Oreti River. Current concentrations of nitrate and ammonia in the Oreti River are within the A and B bands of the NOF indicating current water quality is unlikely to result in significant ecological effects. Assuming no attenuation, N losses from the Mossburn discharge may contribute to an increase in DIN concentrations in the Oreti River ranging between 0.002 mg/L at mean flow to 0.01 mg/L at low flow. The maximum annual load associated with the discharge equates to approximately 0.1% of the cumulative nitrogen load in the Oreti River.

Increasing DIN concentrations (and N loads) in the New River Estuary are associated with declining trends observed in several estuarine health indicators. Assuming no attenuation, the Mossburn discharge may contribute between 0.04 and 0.05% of the cumulative nitrogen loading to the estuary.

Given the oxic state of the unconfined aquifer, it is reasonable to assume there will be little attenuation of DIN within the Castlerock groundwater zone. Attenuation of DIN within surface water systems is complex and time variant however, based on studies undertaken elsewhere in New Zealand, it is not unreasonable to assume that 50% of the total nitrogen load discharged to surface water will be attenuated by instream processes. Applying this assumption to the Oreti catchment, would halve estimates of the potential contribution of the Silver Fern Farms Mossburn wastewater discharge to the instream DIN concentrations and loads listed above.

Overall, it is reasonable to conclude the potential contribution of Silver Fern Farms Mossburn wastewater irrigation to land at the maximum proposed nutrient loading of 250 kg N/ha/year is likely to result in a minor effect on water quality in the Castlerock groundwater zone, Oreti River and New River Estuary. Utilising a conservative estimate of potential N losses (assuming minimal attenuation), the estimated magnitude of effect is likely to be of the order of:

- Castlerock groundwater zone - an increase average aquifer-scale groundwater nitrate concentration of approximately 0.17 mg/L;
- Oreti River - an increase in DIN ranging from 0.002 mg/L at mean flow to 0.01 mg/L at low flow
- New River Estuary - between 0.04 and 0.05% of the cumulative nitrogen loading to the estuary.

Assuming instream attenuation equivalent to 50% of the influent N load, potential water quality effects associated with the Silver Fern Farms Mossburn wastewater discharge (operating at the maximum proposed N application rate) would be an increase of between 0.001 and 0.005 mg/L in downstream DIN concentrations in the Oreti River, and a contribution equivalent to approximately 0.025% of the cumulative annual N loading to the New River Estuary.

Yours Sincerely

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