Water quality assessments

Woldwide One Limited and Woldwide Two Limited
&
Woldwide Four Limited and Woldwide Five Limited

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LIST OF ATTACHMENTS

ATTACHMENT A – Groundwater Well and/or Bore Assessment – Heddon Bush

1 Background

1.1 This report has been prepared to assess the water quality effects of the proposed changes for Woldwide One and Two (WW1&2) and Woldwide Four and Five (WW4&5). One report has been prepared for all the resource consent applications because of the close proximity of the properties, the commonality of existing environment information (e.g., the same river water quality monitoring sites) the largely common receiving environments and to endeavour to provide assessments in the most cost-effective and informative manner.

1.2 The detailed backgrounds to the applications are covered in detail in the primary assessments of environmental effects (AEEs) prepared by Dairy Green Limited and Landpro. Those AEEs also includes a significant amount of information related to the existing environment and potential adverse effects. This report has been prepared to provide a more detailed assessment of key aspects of the existing environment and the potential effects of the proposed activities on both groundwater quality and surface water quality.

2 Soil and physiographic environment

2.1 The soils and physiographic zones have also been described in detail in the primary AEEs together with the implications for contaminant loss and are not repeated here.

3 Receiving water bodies

3.1 The WW1&2 dairy platforms and the Horner Block (HB) are spread across the catchments of the Aparima River, the Waimatuku Stream and the Oreti River as indicated in Figure 1. There are long-term water quality monitoring sites for these rivers at Thornbury, near Waimatuku and Wallacetown respectively.

3.2 The WW4&5 dairy platforms and the Gladfield Block are further south and east from the WW1&2 blocks and are spread across the Aparima River and Waimatuku Stream catchments, with the majority of WW5 in the Aparima River catchment.

3.3 The surface water catchments are illustrated in figures 1 & 2 together with the Environment Southland GIS system's approximate catchment boundaries.

3.4 The runoff blocks are in the catchment of the Orauea River and there is a long-term water quality monitoring site at the Orawia Pukemaori Road, as indicated in more detail in Figure 3.

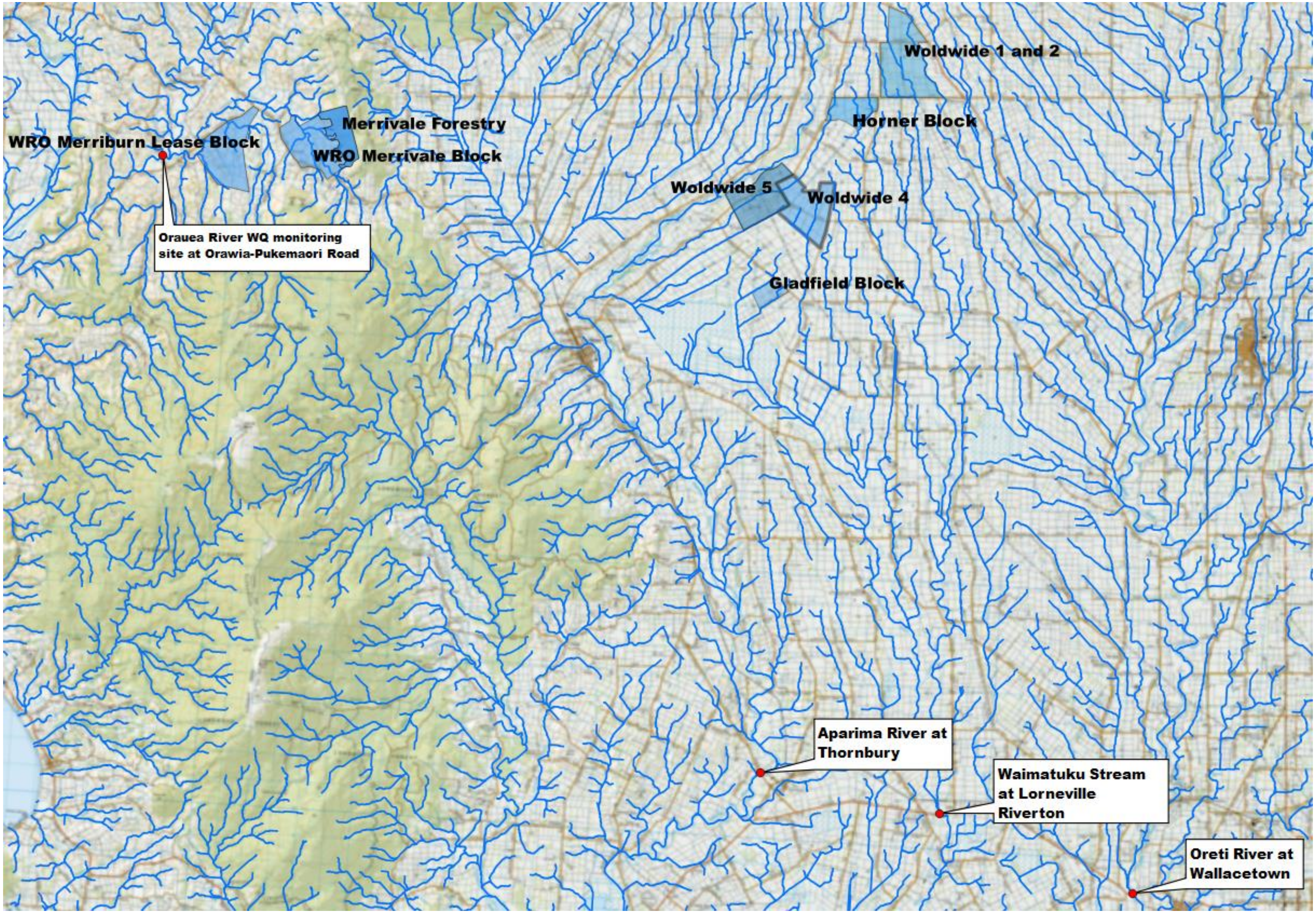

Figure 1: Location of all properties and catchments above the Orauea River, Aparima River, Waimatuku Stream and Oreti River monitoring sites

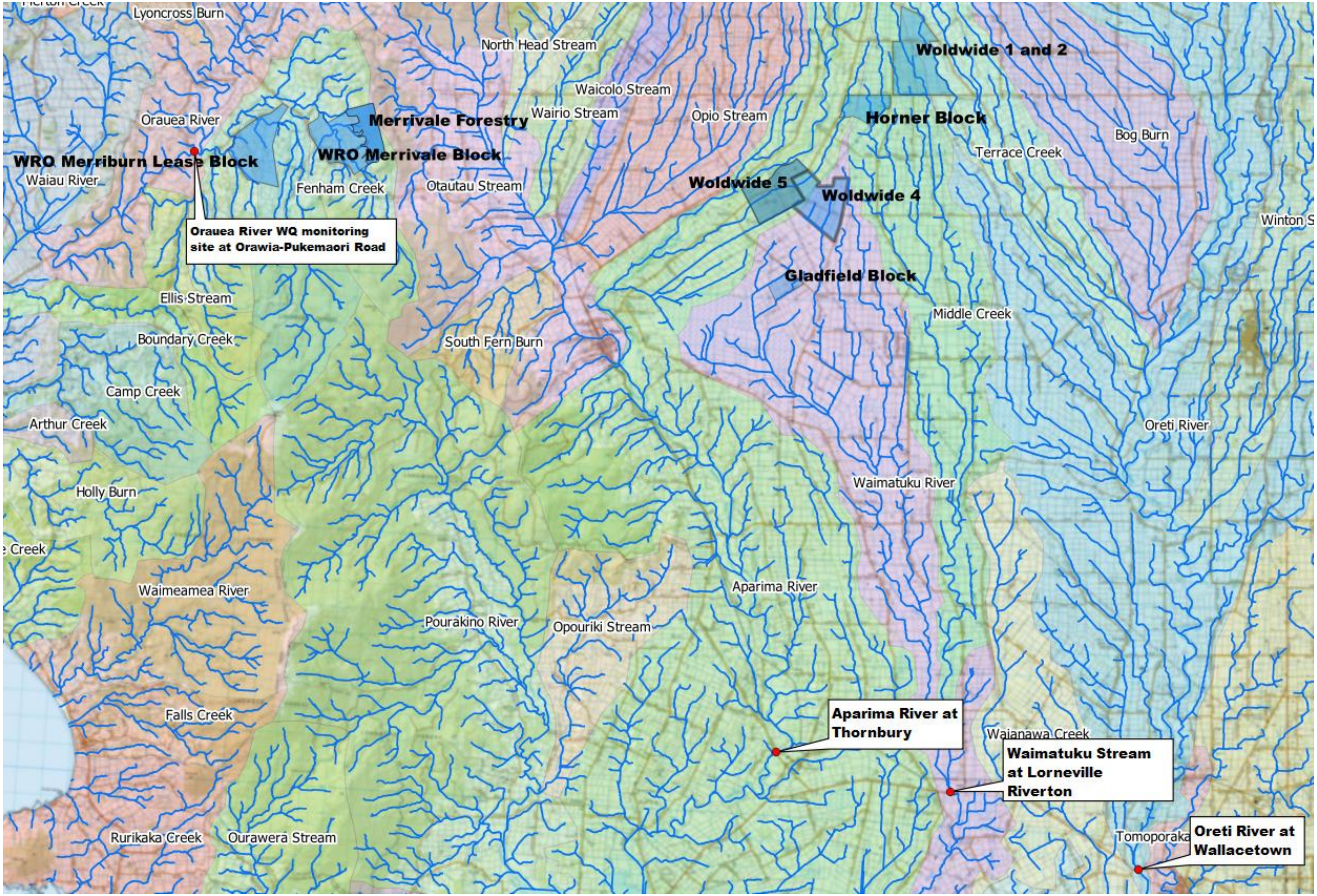

Figure 2: Location of properties and catchment above the Aparima River and Waimatuku Stream river monitoring sites, shaded areas showing Environment Southland GIS surface catchment areas

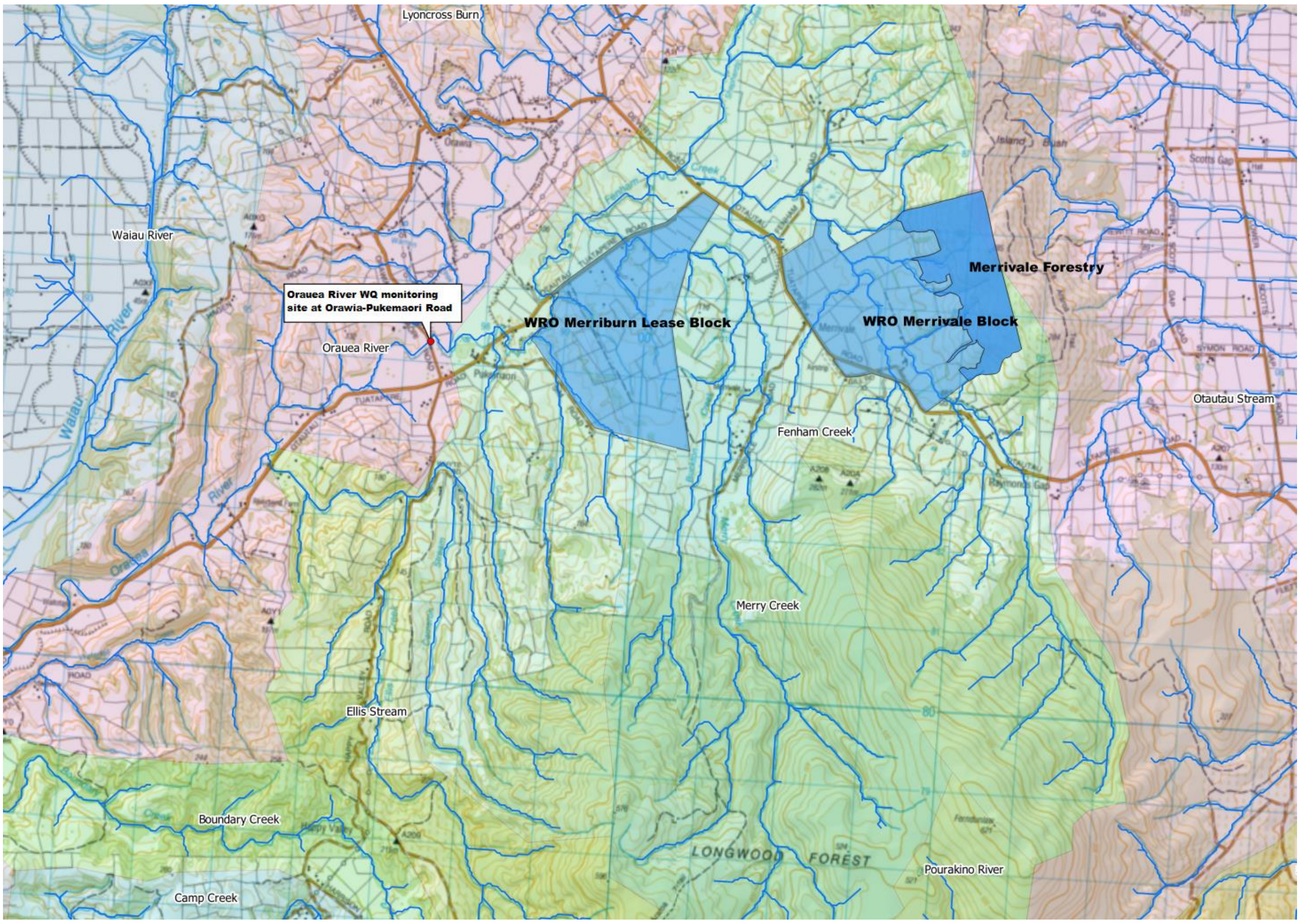

Figure 3: Location of the WRO properties and catchment above the Orauea River monitoring site, shaded areas showing Environment Southland GIS surface catchment areas

3.5 The land use in the catchments is predominantly sheep and beef, dairying and some grain growing. The primary AEE summarises the results of on-site soil investigations. In addition to these assessments, the Landcare Research S-map database[1] has been assessed and supports the conclusions that the WW1&2& HB properties have both deep poorly drained soils (Braxton) and shallow well-drained soils (Glenelg). This is illustrated in Figure 4 and the primary AEEs have a more detailed discussion on the results of a field investigation of soil characteristics and the implications of soils for contaminant loss to water. The WW5 land has a greater proportion on the well-drained soils.

3.6 The heavier soils provide for significant run-off during rainfall events and artificial drainage provides an important transport route. The free-draining soils provide a primary contaminant transport route to groundwater.

[1] https://smap.landcareresearch.co.nz/app#

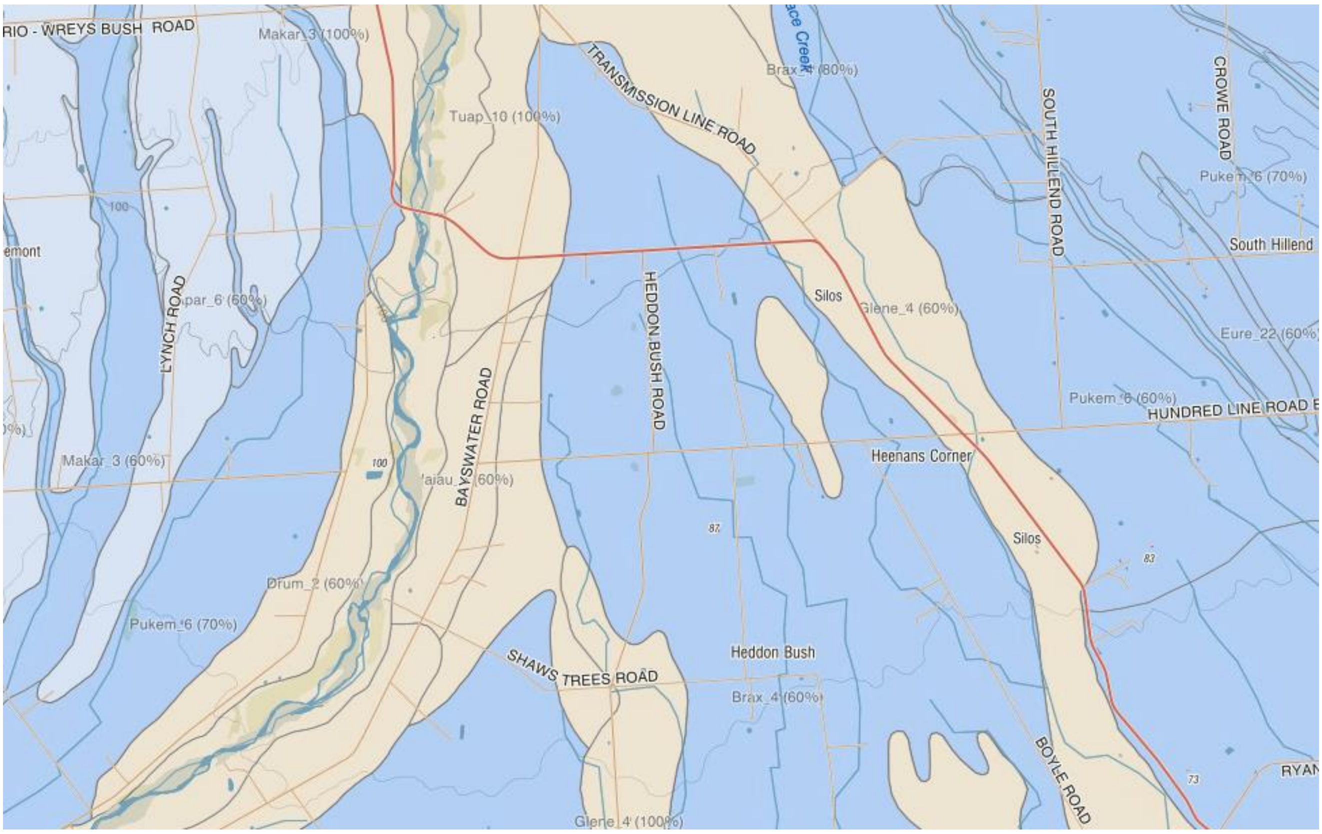

Figure 4: S-map representation of soils in the area of the dairy platforms and the Horner Block (blue = heavy poorly drained soils, cream/yellow = relatively shallow well-drained soils)

3.7 Excluding WRO, the properties are underlain by groundwater that is part of the Upper Aparima, Waimatuku, and Central Plains groundwater management zones (as specified in the PSWLP). Information used to inform the PSWLP process (LWP 2017[2]) strongly indicates that the groundwater in this general area is primarily recharged via rainfall and some infiltration of runoff from surrounding hills. Groundwater discharge is primarily to drains and streams in the area, and the general direction of groundwater flow is southerly.

3.8 There is little piezometric contour information available for the wider area with the exception of an MSc thesis[3] undertaken in the upper catchment of the Waimatuku Stream. A figure from that thesis helps to clarify the direction of groundwater flow in the upper reaches of the Waimatuku Stream and is reproduced as Figure 5.

[2] Landwaterpeople (2017) Groundwater Provisions of the Proposed Southland Water and Land Plan, Technical Background, Report for Environment Southland

[3] Hitchcock MK (2014) *Characterising the surface and groundwater interactions in the Waimatuku Stream, Southland*, MSc Thesis

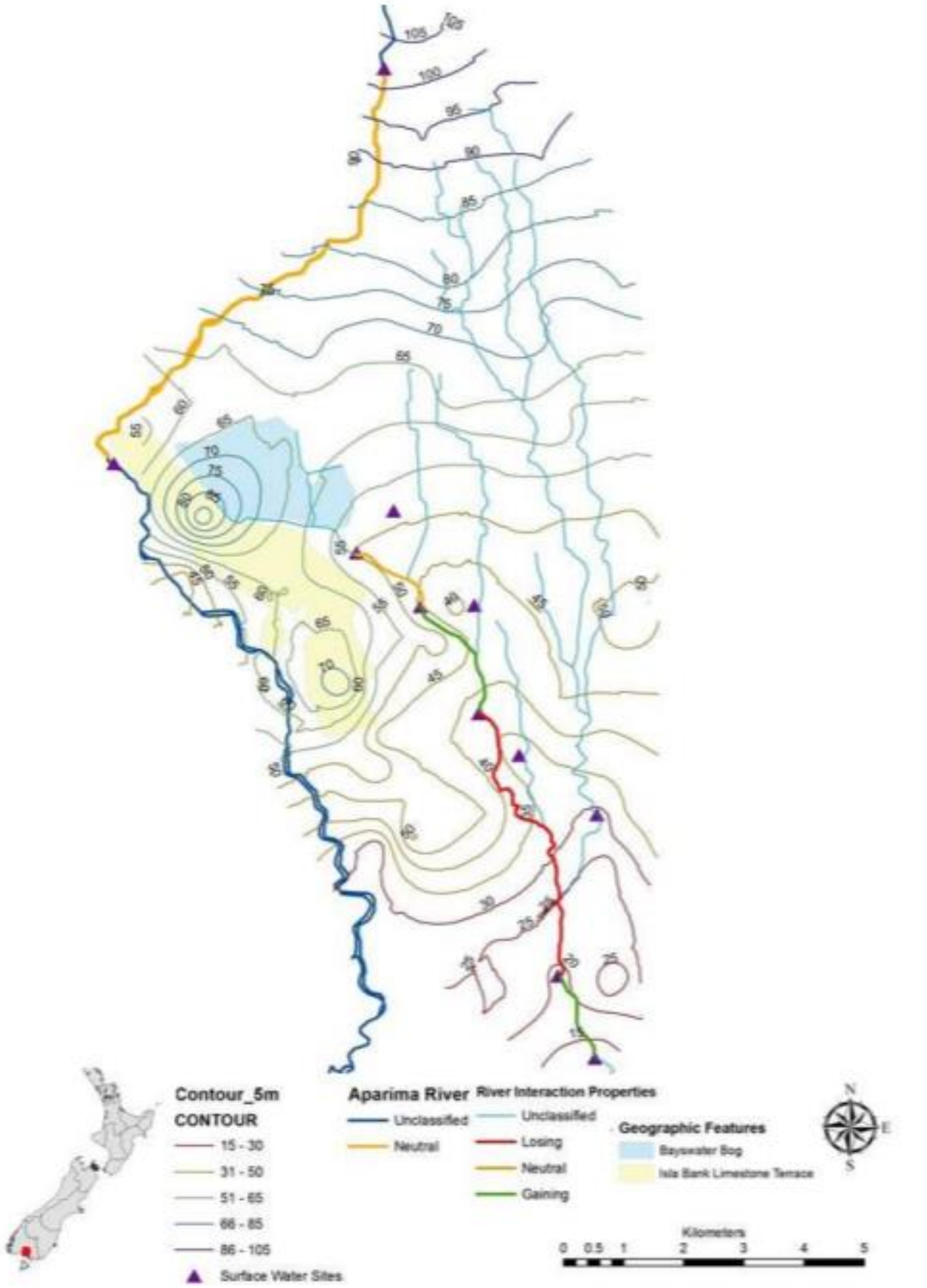

Figure 5: Piezometric contour diagram from Hitchcock thesis showing groundwater flow direction and some stream sections losing/gaining flows to/from groundwater

3.9 This groundwater contour information strongly indicates that groundwater flow direction is generally southerly and depending on groundwater levels would recharge tributaries of the Waimatuku Stream, Aparima River and Oreti River depending on location. Some drainage water will enter groundwater and recharge surface waters some distance down-gradient and some drainage water will discharge more quickly and directly into surface waters via artificial/natural drainage.

3.10 To assist in identifying the direction of groundwater flow relative to each of the properties the diagram from Ms Hitchcock's thesis has been georeferenced to Google earth and the location of the Woldwide properties to more clearly indicate the direction of groundwater flow relative to the properties. This is illustrated in the following figure.

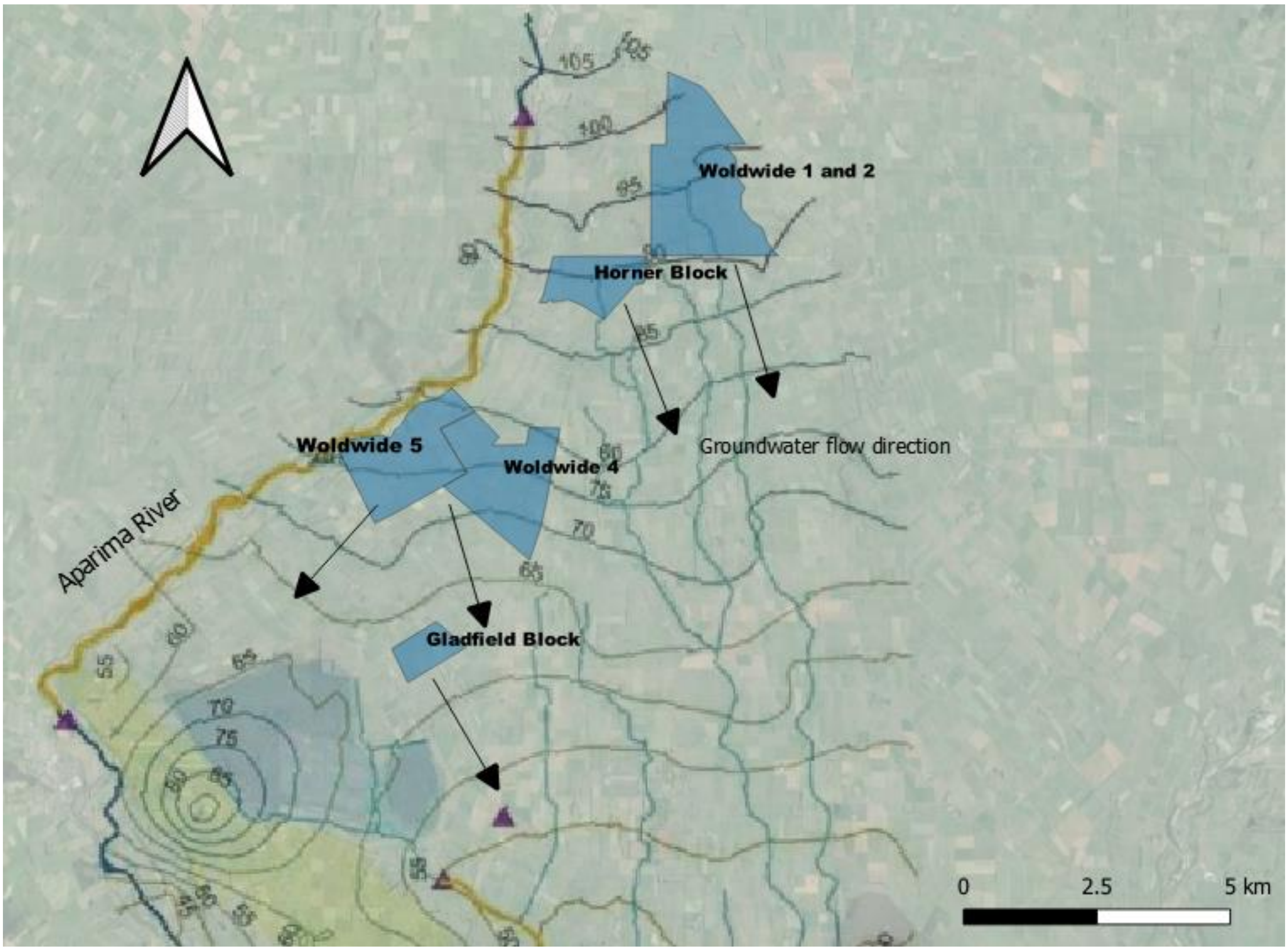

Figure 6: Piezometric contour diagram from Hitchcock thesis georeferenced showing groundwater flow paths relative the location of Woldwide properties

4 Statutory water quality objectives and standards

4.1 The most directly relevant planning documents are the Regional Water Plan for Southland (RWPS) and the Proposed Southland Water and Land Plan (PSWLP). These specify the values, objectives, policies and 'standards' for water in the Southland region.

4.2 Under the RWPS and the PSWLP, surface water bodies at downstream monitoring sites appear to be classified as Lowland Soft Bed (Orauea River) and Lowland Hard Bed (Aparima River, Waimatuku Stream and Oreti River). Table 1 summarises the values associated with these water body 'classifications' as specified in the RWPS. The PSWLP does not establish values for rivers and streams. However, the relevant regional objectives in the PSWLP are also provided in Table 1.

4.3 The relevant numerical water quality standards and guidelines are included in Section 5 of this evidence along with the results from water quality monitoring.

4.4 The Southland Regional Coastal Plan also contains a diverse suite of objectives and values that apply to the Jacobs River Estuary. Those are not repeated here but it is important to appreciate that there is a relationship between regional plans and the overarching Southland Regional Policy Statement.

Table 1: Summary of key regional plan surface water values & objectives for water in this location

Regional Plan	Classification	Values/objectives specified in the relevant plan
Southland Regional Water Plan 2010 Objective 3	Lowland hard & soft bed	- Bathing in those sites where bathing is popular; - Trout where present, otherwise native fish; - Stock drinking water; - Ngāi Tahu cultural values, including mahinga kai; - Natural character including aesthetics.
Proposed Southland Water and Land Plan Objectives 3, 6, 7, & 8	Region-wide	3 The mauri (inherent health) of waterbodies provide for te hauora o te tangata (health of the people), te hauora o te taiao (health of the environment) and te hauora o te wai (health of the waterbody). 6 There is no reduction in the quality of freshwater and water in estuaries and coastal lagoons by, (a) maintaining the quality of water in waterbodies, estuaries and coastal lagoons, where the water quality is not degraded; and (b) improving the quality of water in waterbodies, estuaries and coastal lagoons, that have been degraded by human activities. 7 Any further over-allocation of freshwater (water quality and quantity) is avoided and any existing over-allocation is phased out in accordance with freshwater objectives, freshwater quality limits and timeframes established under Freshwater Management Unit processes. 8 (a) The quality of groundwater that meets both the Drinking Water Standards for New Zealand 2005 (revised 2008) and any freshwater objectives, including for connected surface waterbodies, established under Freshwater Management Unit processes is maintained; and (b) The quality of groundwater that does not meet Objective 8(a) because of the effects of land use or discharge activities is progressively improved so that: (1) groundwater (excluding aquifers where the ambient water quality is naturally less than the Drinking Water Standards for New Zealand 2005 (revised 2008)) meets the Drinking Water Standards for New Zealand 2005 (revised 2008); and

Regional Plan	Classification	Values/objectives specified in the relevant plan
		(2) groundwater meets any freshwater objectives and freshwater quality limits established under Freshwater Management Unit processes

4.5 These values and objectives are relevant reference points here to understand the implications of existing water quality particularly where that quality is not consistent with relevant objective and values specified in relevant regional plans.

4.6 The detailed policy assessment is contained in the AEEs and in the planning evidence.

5 Existing water quality in the vicinity and downstream of the property

Surface water quality

5.1 The following tables and figures provide summary information on the quality of surface water and groundwater in the vicinity of the properties. The water quality data has been provided by Environment Southland via the LAWA (Land Air Water Aotearoa) website[4] or more recent data directly. This water quality information is compared to the most relevant guidelines, specifically the National Objective Framework (NOF) attributes (e.g., *E. coli*, clarity (black disc), dissolved reactive phosphorus, ammonia, etc.) contained within the National Policy Statement Freshwater Management (2017)(NPSFM), the PSWLP Appendix E Water Quality 'Standards' (referenced primarily via Policy 16 of the PSWLP), and the Australia New Zealand Environment and Conservation Council (ANZECC) water quality 'trigger values'[5].

5.2 The interpretation of the data in the following four tables is challenging for a number of reasons including because there is often a disconnection between the sampling methodology and the NPSFW NOF specified attribute states and some of the PSWLP Appendix E Water Quality 'Standards'. For example, the monthly river sampling does not enable an assessment against the dissolved oxygen numeric attribute states ('standards') which effectively require daily

[4] https://www.lawa.org.nz/

[5] Water quality that exceeds an ANZECC trigger value indicates marginal water quality for supporting ecosystem health. If the median value of a water quality variable for a particular site exceeds the trigger value, then it is intended to 'trigger' an investigation response to identify the cause and significance of the degraded water quality. (Hart, B.T., Maher, B., & Lawrence, I. (1999) New generation water quality guidelines for ecosystem protection. Freshwater biology 41: 347-359).

sampling between 1 November and 30 April, the PSWLP clarity standard requires concurrent flow monitoring but this information is not always available.

5.3 The stream water quality definitions and locations (Lowland Hard and Soft Bed) appear[6] to provide direction for the PSWLP water quality standards and do provide some indication of the likely natural background water quality. However, regardless of the legal status of the PSWLP water quality standards, they are generally specified as absolute maxima so that even one observed breach is counted as non-compliance with that standard. In recent decades surface water quality management has moved towards more complex and meaningful water quality standards and guidelines such as those in the NPSFM that focus more on a statistical description against specific targets that relate more directly with specific uses and values of that water. For example, the PSWLP sets a faecal coliform standard of <1,000/100ml while the NPSFM focuses on medians and 95th percentiles combined with various states that describe the level of infection risk.

[6] There does not appear to be an explicit linkage from the PSWLP Appendix E water quality standards to the maps contained in the separate Maps volume of the PSWLP. Environment Southland Planning staff have been made aware of this issue.

Table 2: Summary of State and Trend of the Orauea River at Orawia Pukemaori Road water quality monitoring site (LAWA/Environment Southland data)

Primary WQ indicators	State	LAWA National Objective Framework (NOF) Band, Annual Median (2008 – 2017) PSWLP Maximum (2009 -18)	Trend	PSWLP water quality standard (Lowland Soft Bed) & ANZECC[∞] trigger values
E. Coli	In the worst 25% of all lowland rural sites	**E** – For more than 30% of the time, the estimated risk is >=50 in 1000 (>5% risk). The predicted average infection risk is >7%. 5-year median = **315 n/100ml** Maximum = **21,000 cfu/100ml**	Likely Improving	≤1,000/100ml Faecal coliforms[#] Highly unlikely to meet standard
Clarity (Black Disc)	In the worst 25% of all lowland rural sites	No NOF attribute band set 5-year median = **1.13 metres**	Not assessed	≥ 1.6 m when flow below median flow (~1.46 m3/s), Unlikely to meet standard
Total Oxidised N	In the worst 50% of all lowland rural sites	**A** – High conservation values system. Unlikely to be effects on even sensitive species. 5-year median = **0.415 g/m^3** Maximum = **7.8 g/m^3**	Very likely improving	≤0.444 g/m^3 (ANZECC, 2000)* Greater than this trigger value
Ammoniacal N	In the best 25% of all lowland rural sites	**A** – 99% species protection level. No observed effect on any species tested. 5-year median = **0.005 g/m^3** Maximum = **0.16 g/m^3**	Not assessed	<2.5-0.9 (pH 6.0-8.0) Meets standard
Dissolved Reactive P	In the worst 50% of all lowland rural sites	No NOF attribute set 5-year median = **0.011 g/m^3** Maximum = **0.04 g/m^3**	Indeterminate	≤0.01 g/m^3 (ANZECC, 2000)* Greater than this trigger value
Macroinvertebrate Community Index	Fair	MCI 5-year median = **93.** Range 88 – 109 (2012 – 2018) Fair ecological condition. Indicative of only fair water quality and/or habitat condition.	Not assessed.	>80 Meets standard
Additional PSWLP Water Quality Stds		**Observed WQ range Jan 2009 – Dec 2018**		**PSWLP water quality standard (Lowland Soft Bed)**
Temperature		1.8 – 20.3°C		≤23°C Meets standard
pH		7 – 8.7		6.5 – 9.0 Meets standard
Sediment cover		Not assessed by ES		
Dissolved oxygen		77% - 152% (8.3 – 16.2 g/m^3) NOF Attribute **B**		> 80 % sat. Does not meet standard
Bacterial/fungal slime		Not assessed by ES		
Periphyton		0.0 – 129.6 mg chl *a*/m^2 (2014 – 2019) 83%ile = 49 mg chl *a*/m^2 NOF Attribute potentially **A**		<120 mg chl *a* /m^2 filam. algae < 200 mg/m^2 diatom/cyanob. Likely to meet standard
Fish		Not assessed by ES		

[∞]Australian and New Zealand Environment and Conservation Council, 2000, Australian and New Zealand guidelines for fresh and marine water quality.
[#] PSWLP standard is ≤1,000 faecal coliforms/100 ml. However, *E. coli* is monitored. *E coli* are a subset of faecal coliforms.
* ANZECC trigger values for investigation. These have no legal status in NZ and are included as a reference point only.

Table 3: Summary of state and trend at the Aparima River at Thornbury water quality monitoring site (LAWA/Environment Southland data)

Primary WQ indicators	State	LAWA National Objective Framework (NOF) Band, Annual Median (2008 – 2017) PSWLP Maximum (2009 -18)	Trend	PSWLP water quality standard (Lowland Hard Bed) & ANZECC[∞] trigger values
E. Coli	In the worst 50% of all lowland rural sites	**D** – 20-30% of the time, the estimated risk is >=50 in 1000 (>5% risk). The predicted average infection risk is >3%*. 5-year median = **130 n/100ml** Maximum = **68,000 cfu/100ml**	Very likely Improving	≤1,000/100ml Faecal coliforms[#] Highly unlikely to meet standard
Clarity (Black Disc)	In the best 50% of all lowland rural sites	No NOF attribute band set 5-year median = **2.305 metres** Maximum = **5.72 meters**	Likely improving	≥ 1.6 m when flow below median flow (27.4 m3/s), Does not meet standard
Total Oxidised N	In the worst 50% of all lowland rural sites	**B** – Some growth effect on up to 5% of species. 5-year median = **0.665 g/m^3** Maximum = **1.78 g/m^3**	Very likely improving	≤0.444 g/m^3 (ANZECC, 2000)* Greater than this trigger value
Ammoniacal N	In the best 25% of all lowland rural sites	**A** – 99% species protection level. No observed effect on any species tested. 5-year median = **0.005 g/m^3** Maximum = **0.12 g/m^3**	Not assessed	<2.5-0.9 (pH 6.0-8.0) Meets standard
Dissolved Reactive P	In the best 50% of all lowland rural sites	No NOF attribute set 5-year median = **0.006 g/m^3** Maximum = **0.05 g/m^3**	Likely improving	≤0.01 g/m^3 (ANZECC, 2000)* Greater than this trigger value
Macroinvertebrate Community Index	Good	MCI 5-year median = **100**. Good ecological condition. Streams in good ecological condition. Indicative of good water quality and/or habitat conditions.	Indeterminate	>90 Meets standard
Additional PSWLP Water Quality Stds		**Observed WQ range Jan 2009 – Dec 2018**		**PSWLP water quality standard (Lowland Hard Bed)**
Temperature		3.0 – 20.8 °C		≤23°C Meets standard
pH		6.6 – 8.0		6.5 – 9.0 Meets standard
Sediment cover		Not assessed by ES		
Dissolved oxygen		74.8 – 134% (7.45 – 15.3 g/m^3) NOF Attribute **B**		> 80 % sat. Meets standard
Bacterial/fungal slime		Not assessed by ES		
Periphyton		0.0 – 301 mg chl *a*/m^2 (2014 - 2018) NOF Attribute potentially **C** 92%ile = 181 mg chl *a*/m^2		<120 mg chl *a* /m^2 filam. algae < 200 mg/m^2 diatom/cyanob. Unlikely to meet standard
Fish		Not assessed by ES		

[∞]Australian and New Zealand Environment and Conservation Council, 2000, Australian and New Zealand guidelines for fresh and marine water quality.
[#] PSWLP standard is ≤1,000 faecal coliforms/100 ml. However, *E. coli* is monitored. *E coli* are a subset of faecal coliforms.
* ANZECC trigger values for investigation. These have no legal status in NZ and are included as a reference point only.

Table 4: Summary of state and trend of the Waimatuku Stream at Lorneville Riverton Highway water quality monitoring site (LAWA/Environment Southland data)

Primary WQ indicators	State	LAWA National Objective Framework (NOF) Band, Annual Median (2008 – 2017) PSWLP Maximum (2009 -18)	Trend	PSWLP water quality standard (Lowland Hard Bed) & ANZECC∞ trigger values
E. Coli	In the worst 25% of all lowland rural sites	**E** – For more than 30% of the time, the estimated risk is >=50 in 1000 (>5% risk). The predicted average infection risk is >7%. 5-year median = **450 n/100ml** Maximum = **21,000 cfu/100ml**	Very likely Improving	≤1,000/100ml Faecal coliforms# Highly unlikely to meet standard
Clarity (Black Disc)	In the worst 50% of all lowland rural sites	No NOF attribute band set 5-year median = **1.22 metres** Maximum **= N/A**	Very likely Improving	≥ 1.6 m when flow below median flow (~1.46 m3/s), Unlikely to meet standard Flows not measured at this site. Measured at a site approx. 2 km downstream.
Total Oxidised N	In the worst 25% of all lowland rural sites	**C** – Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects 5-year median = **3.0 g/m^3** Maximum = **7.8 g/m^3**	Very likely improving (pre 2018 data)	≤0.444 g/m^3 (ANZECC, 2000)* Greater than this trigger value
Ammoniacal N	In the worst 50% of all lowland rural sites	**A** – 99% species protection level. No observed effect on any species tested. 5-year median = **0.01 g/m^3** Maximum = **0.16 g/m^3**	Very likely Improving	<2.5-0.9 (pH 6.0-8.0) Meets standard
Dissolved Reactive P	In the worst 25% of all lowland rural sites	No NOF attribute set 5-year median = **0.0425 g/m^3** Maximum = **0.1 g/m^3**	Very likely degrading	≤0.01 g/m^3 (ANZECC, 2000)* Greater than this trigger value
Macroinvertebrate Community Index	Fair	MCI 5-year median = 83- 91. Fair ecological condition. Indicative of only fair water quality and/or habitat condition.	Not assessed. Only two results for past five years	>90 Does not meet standard
Additional PSWLP Water Quality Stds		**Observed WQ range Jan 2009 – Dec 2018**		**PSWLP water quality standard (Lowland Hard Bed)**
Temperature		3.8- 21.0°C		≤23°C Meets standard
pH		6.9 - 9.0		6.5 – 9.0 Meets standard
Sediment cover		Not assessed by ES		
Dissolved oxygen		82 – 132% (7.4 – 14.2 g/m^3) NOF Attribute **B** band		> 80 % sat. Meets standard
Bacterial/fungal slime		Not assessed by ES		
Periphyton		**<1 – 124 mg chl *a*/m^2** (annual sampling, 2014 - 2018) 92%ile = 88 mg chl *a*/m^2 NOF Attribute potentially **B**	Periphyton monitoring site 2 km downstream	<120 mg chl *a* /m^2 filam. algae < 200 mg/m^2 diatom/cyanob. Does not meet standard
Fish		Not assessed by ES		

∞Australian and New Zealand Environment and Conservation Council, 2000, Australian and New Zealand guidelines for fresh and marine water quality.
PSWLP standard is ≤1,000 faecal coliforms/100 ml. However, *E. coli* is monitored. *E coli* are a subset of faecal coliforms.
* ANZECC trigger values for investigation. These have no legal status in NZ and are included as a reference point only.

Table 5: Summary of state and trend at the Oreti River Wallacetown water quality monitoring site (LAWA/Environment Southland data)

Primary WQ indicators	State	LAWA National Objective Framework (NOF) Band, Annual Median (2008 – 2017) PSWLP Maximum (2009 -18)	Trend	PSWLP water quality standard (Lowland Hard Bed) & ANZECC∞ trigger values
E. Coli	In the worst 50% of all lowland rural sites	**D** – 20-30% of the time, the estimated risk is >=50 in 1000 (>5% risk). The predicted average infection risk is >3%*. 5-year median = **130 n/100ml** Maximum = **10,000 cfu/100ml**	Likely Improving	≤1,000/100ml Faecal coliforms# Highly unlikely to meet standard
Clarity (Black Disc)	In the best 50% of all lowland rural sites	No NOF attribute band set 5-year median = **1.815 metres** Maximum = **6.2 meters** Seven results during 2009 – 2018 did not comply with PSWLP WQ standard	Indeterminate	≥ 1.6 m when flow below median flow (27.4 m3/s), Does not meet standard
Total Oxidised N	In the worst 25% of all lowland rural sites	**B** – Some growth effect on up to 5% of species. 5-year median = **0.94 g/m^3** Maximum = **2.5 g/m^3**	Not assessed	≤0.444 g/m^3 (ANZECC, 2000)* Greater than this trigger value
Ammoniacal N	In the best 25% of all lowland rural sites	**A** – 99% species protection level. No observed effect on any species tested. 5-year median = **0.005 g/m^3** Maximum = **0.04 g/m^3**	Not assessed	<2.5-0.9 (pH 6.0-8.0) Meets standard
Dissolved Reactive P	In the best 50% of all lowland rural sites	No NOF attribute set 5-year median = **0.006 g/m^3** Maximum = **0.04 g/m^3**	Not assessed	≤0.01 g/m^3 (ANZECC, 2000)* Greater than this trigger value
Macroinvertebrate Community Index	Fair	MCI 5-year median = 95. Fair ecological condition. Indicative of only fair water quality and/or habitat condition.	Likely degrading	>90 Meets standard
Additional PSWLP Water Quality Stds		**Observed WQ range Jan 2009 – Dec 2018**		**PSWLP water quality standard (Lowland Hard Bed)**
Temperature		4.2 – 21 °C		≤23°C Meets standard
pH		7.0 – 7.8		6.5 – 9.0 Meets standard
Sediment cover		Not assessed by ES		
Dissolved oxygen		82 – 130% (7.4 – 14.4 g/m^3) NOF Attribute **B** band		> 80 % sat. Meets standard
Bacterial/fungal slime		Not assessed by ES		
Periphyton		4.5 – 361 mg chl *a*/m^2 (annual sampling, 2004 - 2018) 92%ile = 158 mg chl *a*/m^2 NOF Attribute potentially **C**		<120 mg chl *a* /m^2 filam. algae < 200 mg/m^2 diatom/cyanob. Does not meet standard
Fish		Not assessed by ES		

∞Australian and New Zealand Environment and Conservation Council, 2000, Australian and New Zealand guidelines for fresh and marine water quality.
PSWLP standard is ≤1,000 faecal coliforms/100 ml. However, *E. coli* is monitored. *E coli* are a subset of faecal coliforms.
* ANZECC trigger values for investigation. These have no legal status in NZ and are included as a reference point only.

5.4 These data indicate that water quality in all four major surface water bodies that receive drainage from these properties is degraded to a greater or lesser extent, and does not, or is currently unlikely to, meet all the relevant numerical standards or guidelines. This is generally the situation for all rivers in Southland that have the majority of their recharge coming from drainage through extensive agricultural land.

5.5 The water quality data has been compared with the PSWLP standards on the basis of simple maximum because those standards are specified as maximum values, not medians.

5.6 It is not possible to provide a comprehensive and definitive assessment of water quality in the context of all of the PSWLP water quality standards because not all the water quality standards appear to be monitored (sediment cover, bacterial/fungal slime and fish) and determining compliance with the water clarity standard effectively requires concurrent flow gauging. Flows are monitored on three of these rivers but a detailed analysis of hydrology information would be required to estimate or extract the flow at the time of sampling and flows are not measured at the Waimatuku Stream site. In addition, there are notes that accompany the sampling results that state that because of safety concerns clarity measurements have not been taken at very high flows, so a small number of high results are not included.

5.7 It is not of any significant benefit to undertake a detailed comparison of all water quality variables for each river/stream. Instead it useful to appreciate that while there are some significant differences there are three significant common broad water quality-related issues:

1. High concentrations of faecal indicator microorganisms;
2. Raised nutrient concentrations leading to plant growth in the stream and further downstream; and
3. Generally poor water clarity at times.

5.8 It is also useful to compare some key water quality variables to appreciate some significant apparent differences between the four rivers. This is outlined in the following table.

Table 6 Summary of some key water quality variables for the four rivers (Five year medians, 2012-2017)

	Orauea River	Aparima River	Waimatuku Stream	Oreti River
E. coli (n/100ml)	315	130	450	130
Clarity (BD) (m)	1.13	2.305	1.22	1.815
Total oxidised N (g/m^3)	0.415	0.665	3.0	0.94
Dissolved reactive P (g/m^3)	0.011	0.006	0.0425	0.006
Periphyton (mg chl-*a* /m^2) (83 & 92%iles)	49 (83 %ile)	181 (92 %ile)	88 (92 %ile)	143 (92 %ile)
MCI	93	100	87*	95

* Estimate

5.9 One key feature of the above summary table is that the Waimatuku Stream stands out as significantly degraded when compared to the other three rivers and with the exception of periphyton biomass, this is generally consistent across these key variables.

5.10 The LAWA water quality monitoring information only goes up to December 2017 (as at mid-August 2019). Additional information was provided separately from Environment Southland for the sites in Excel files. A comprehensive statistical comparison of this dataset with the LAWA statistical summaries has not been undertaken. However, more recent data has been compiled and presented along with the older data dataset, primarily to obtain a general understanding of recent water quality. One feature of the more recent data has been to illustrate the challenges in establishing meaningful statistical assessments. For example, the recent peaks in nitrate nitrogen has abruptly ended the apparent earlier five year trends of decreasing concentrations in all rivers except the Oreti River.

5.11 For the purposes of this report, it is not necessary to provide detailed comparisons of all key variables for all rivers over time.

Nitrate nitrogen concentrations

5.12 An example of the differences in water quality and the nature of the annual changes in nutrient concentrations is illustrated in the following diagram that compares the changes in total oxidised nitrogen in the four rivers over recent years.

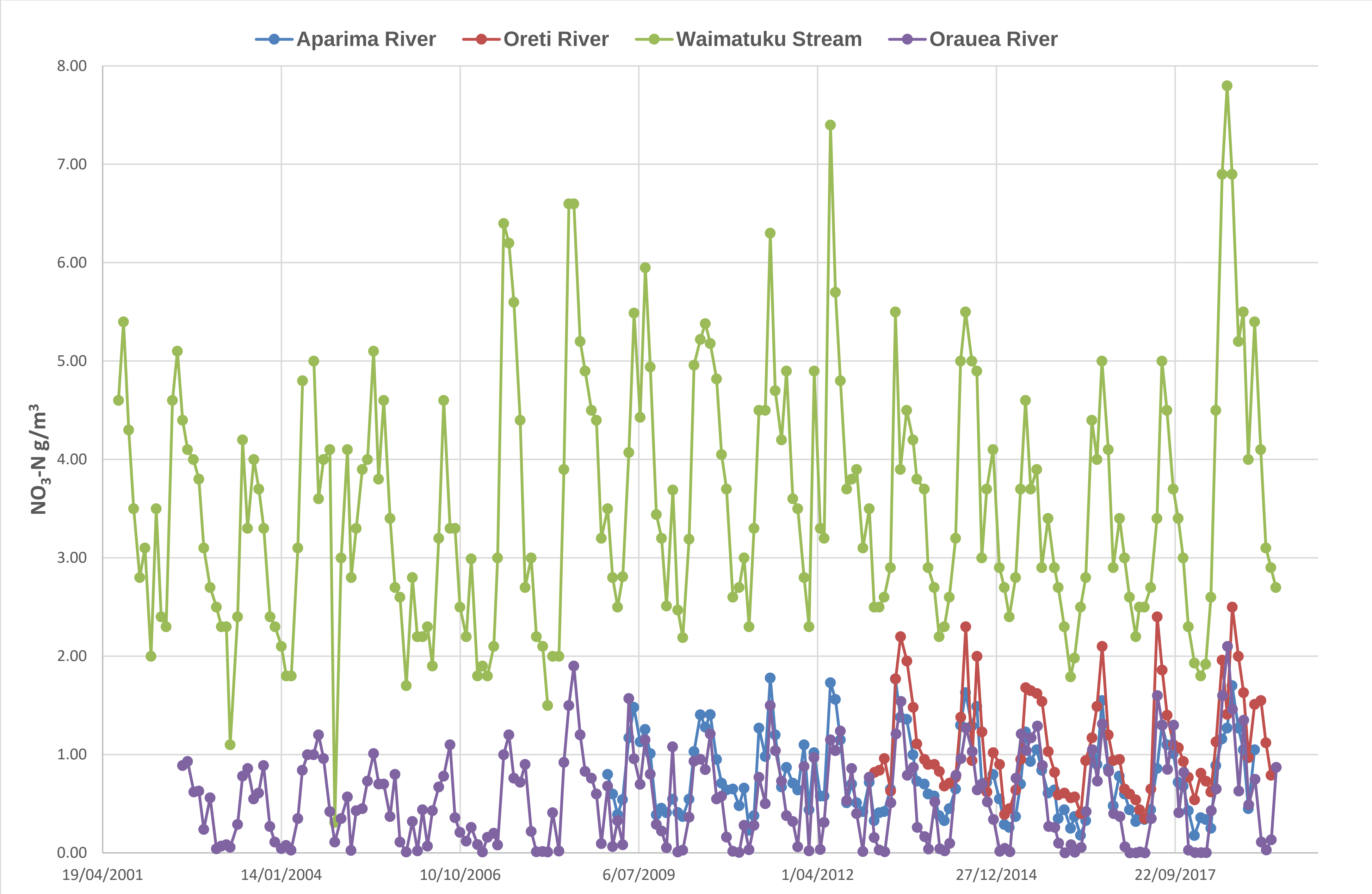

Figure 7 Total oxidised nitrogen changes over the last ~20 years in the four rivers/streams

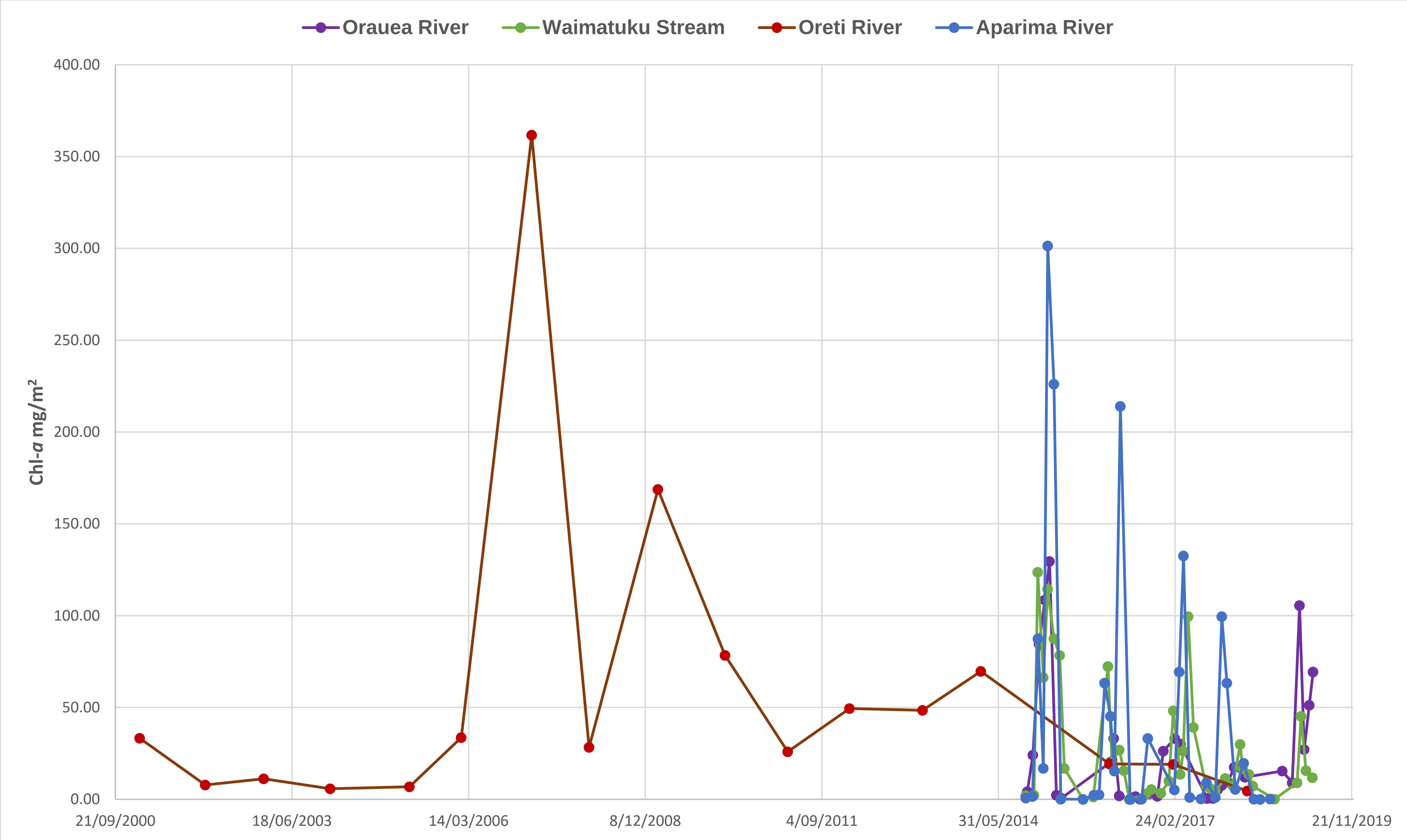

Figure 8: Periphyton chlorophyll-a biomass at four sites on the four rivers/streams

5.13 The nitrate nitrogen data illustrate the annual rise and fall in nitrate nitrogen concentrations that happens; generally during/after the winter period when surplus nitrogen in the soil profile drains through to groundwater and then moves through to surface water. In addition, the data highlights the significantly higher nitrate nitrogen concentrations in the Waimatuku Stream with annual winter high concentrations recently peaking at 7.8 g/m^3.

Periphyton biomass

5.14 The long-term data on periphyton for all four rivers are illustrated in Figure 7 above.

5.15 The nature of the sampling methodology and the range of factors controlling periphyton growth (e.g., substrate suitability) and biomass removal (e.g., in freshes and flood events) means that it is challenging to interpret both changes over time in one river and particularly in comparing one river with another. One feature that does stand out from Figure 7 is the apparently relatively low periphyton biomass in recent years. However, because this is not matched by similar reductions in river nutrient concentrations it would be inappropriate to assume that this reflects a reduction in nutrient sources.

5.16 It is also challenging to interpret periphyton data in terms of the NPSFM NOF attribute because of the methodology (including sampling frequency required) used in the NPSFM to define attribute state and the sampling frequency adopted by Environment Southland. The NPSFM indicates that monthly sampling for a minimum of three years is needed. However, Environment Southland has generally sampled approximately seven to nine times per year. Environment Southland also has an annual periphyton sampling programme.

5.17 The NPSFM requires that the River Environment Classification (REC) be used to distinguish between a “Productive” and “Default” category. In this situation, the Orauea River is defined as “Productive” because the REC Geology bed is defined as “Soft Sedimentary”. The Waimatuku Stream and the Oreti River are both defined as “Default” (Geology is “AL” or Alluvium). Similarly, the Aparima River at the Thornbury site has a REC geology class of “HS” or Hard Sedimentary Rock. This means that the States are defined in terms of these categories using a percentile attribute assuming monthly sampling for a minimum of three years.

5.18 Using the available data the periphyton information is included in tables 2 – 6 and figure 7. These calculations have been done to give an indication of the extent of periphyton biomass and because the data does not comply with the NPSFM requirements is not a complete assessment against the NPSFM periphyton attributes.

Additional sources of contaminants.

5.19 In addition to loss of contaminants to water from pastoral agriculture there are a range of other activities that result in contaminants entering these rivers such as arable land use, treated wastewater and stormwater from small settlements, septic tank discharges and stormwater discharges from roading and other settlements/activities.

Conclusions on current surface water quality

5.20 The available data indicate that the rivers/streams in this area have raised concentrations of faecal indicator bacteria, reduced clarity and raised concentrations of dissolved N and P, and as with probably all lowland rivers in Southland are likely to not comply with all the PSWLP water quality standards, specifically the faecal coliform and water clarity standards. The primary cause of reduced water quality is most likely contaminant losses from agricultural land use with minor contributions from other sources e.g., treated sewage and stormwater discharges, septic tank effluent discharges, and roading run-off.

5.21 There are some significant methodological issues involved in assessing water quality against standards, guidelines and attributes when the sampling of water quality has not always been consistent with the methodology prescribed for the standard and/or attribute.

5.22 The long-term water quality monitoring data indicate that agricultural land use activities in the catchment are having adverse effects on water quality and that long-term catchment-scale mitigation of a broad range of land uses and discharges are needed to reduce the concentrations of contaminants in surface waters to be consistent with national and regional statutory standards and relevant guidelines. However, it is unlikely that the current PSWLP faecal coliform standard could always be achieved in pastoral agricultural catchments.

5.23 A detailed assessment of water quality trends is beyond the scope of this report. However, it appears that peak concentrations of nitrate nitrogen in the Waimatuku Stream and the Orauea River are higher than they were 15 – 20 years ago. The concentrations of key contaminants in these rivers/streams are almost certainly greater than they were 35 years ago prior to the significant expansion of dairying in Southland[7].

Groundwater Quality

5.24 The results of Environment Southland's survey of regional nitrate nitrogen concentrations are provided as a layer within the Beacon public GIS system (Figure 9) and indicate that the WW1&2& HB properties are in an area where the underlying unconfined groundwater was likely to have been generally between 1.0 – 8.5 mg/l of nitrate nitrogen between 2007 – 2012, or indicative of "minor to high land use impacts". The 2007 – 2012 survey also indicated that a 'nitrate hotspot' exists to the south west of the WW1&2 property.

5.25 Similarly, the 2007-2012 survey indicates that the WW4&5 properties are primarily in an area of groundwater with nitrate nitrogen concentrations between 3.5 – 8.5 g/m^3. However, the amount of information that supports this contour map may not always be sufficient to justify making significant conclusions about the differences in groundwater quality in different locations.

5.26 Interpretation of the contour data should be done with great care because there are a limited number of results that have been used as the basis for developing these groundwater quality contours, and the source data includes results from a very wide range of bores. Many of these bores, particularly those that have been installed in recent years as a requirement of resource consent conditions are relatively shallow (<8 m depth) and some do not appear to have been installed with appropriate well head protection (in spite of bore land use consent conditions apparently requiring compliance with NZS 4411:2001 (Environmental standard for drilling of soil and rock).

5.27 A recent observation assessment (Attachment A) of six shallow bores used as part of the Environment Southland groundwater quality monitoring in this area indicated that most of them had a combination of poor wellhead protection and nearby potential surface contaminant sources that together potentially provide conduits for contaminated surface water to enter groundwater. Therefore it appears that it is likely that the data illustrated in Figure 9 may include some results that are caused by contaminated surface water entering groundwater via a

[7] Hamil K & McBride K (2003) River water quality trends and increased dairying in Southland, New Zealand, New Zealand Journal of Marine and Freshwater Research, 2003, Vol. 37: 323-332.

bore/well. If bores with poor wellhead protection were rectified it is possible that groundwater quality in this area could be improved.

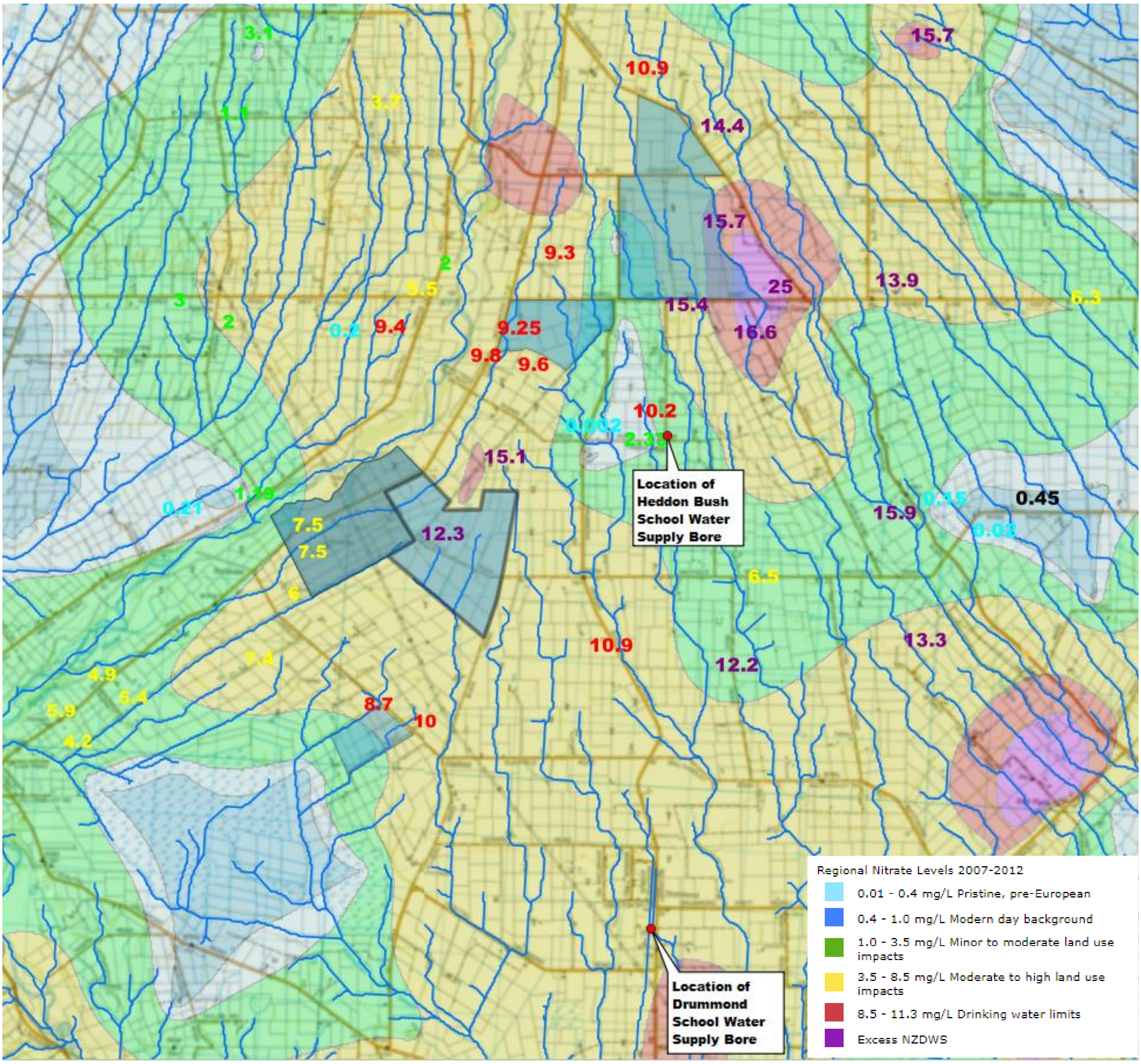

Figure 9: Environment Southland groundwater nitrate nitrogen concentration contour estimates for the period 2007 – 2012 with location of property overlaid, and more recent peak nitrate nitrogen results

5.28 A combination of a wide range of bore depths, timing of sampling, and poor wellhead protection means that interpretation of groundwater quality data is very difficult. Therefore there is some uncertainty about the extent that the reported groundwater quality data accurately represents groundwater quality, and the extent to which some data represents the effects of land use on groundwater quality or the effects of contaminated surface water entering groundwater via bores and/or bore casings. For example, the survey data include results from bores between 3 m and 20 m deep, and at least one Southland study has shown that nitrate nitrogen concentrations in deeper groundwater can have lower concentrations than found in shallow bores[8].

5.29 To further complicate the understanding of groundwater quality there is some indication from the reported measurements of water levels (i.e., significantly deeper than found in shallower bores) that some bores in this area may be tapping a lower confined or semi-confined aquifer that may be separated in part from the overlying unconfined groundwater.

5.30 The highest nitrate nitrogen results for groundwater samples taken from each bore post-2012 is also indicated as spot results on the above figure. All the data provided by Environment Southland has been mapped even though there are challenges involved in interpreting some data. For example, there is not enough information about the wellhead protection, topography, nearby contaminant sources, or depth of bore/screen depth to be able to confidently remove for example, bores that are too shallow, located in an effluent disposal location or currently at risk of contamination from surface runoff (e.g., bore E45/0622)

5.31 There are quite a few bores in the general area that have had nitrate nitrogen monitored over a significant period of time up to 2018. The results from these have been included in this report as ones that appear to provide some useful information on the characteristics of nitrate nitrogen in groundwater in this area. The following bores have been included: E45/0081 (2008 – 2018, reported but unverified depth of 6.5 m deep, no information on screen depth) and E45/0610 (2012 – 2018, reported but unverified 7.3 m deep, no information on screen depth), and

[8] Hughes B (2009) Review of groundwater quality monitoring results from the Heenans Corner nested piezometer site, 20p.

E45/0458 (verified 8.5 m deep with no screen depth information). All of these bores are relatively close to the properties.

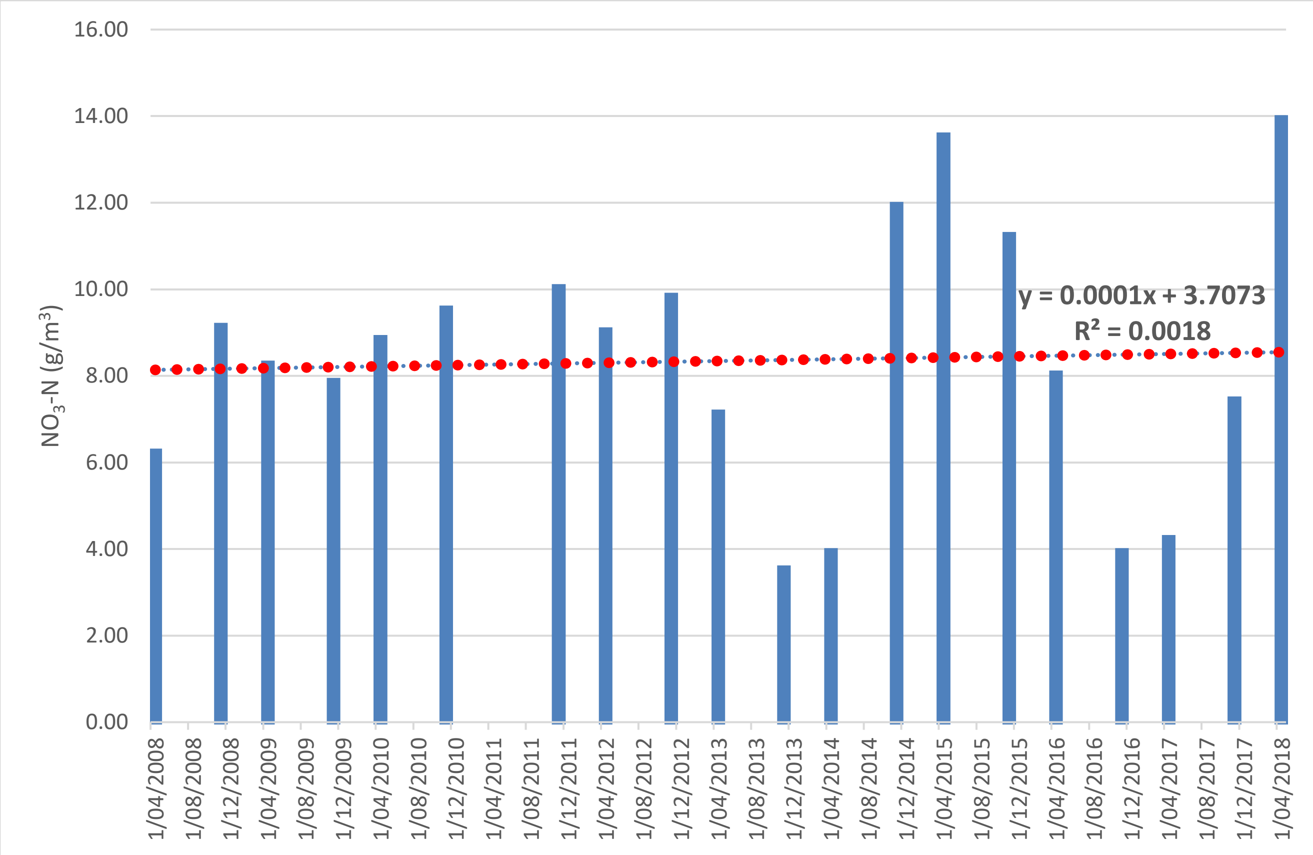

Figure 10: Nitrate nitrogen concentrations in groundwater from bore E45/0081, 2008-2018 (showing as a purple '13.9' east of the property in Figure 9)

5.32 The results from this bore (E45/0081, Figure 13) indicate some significant variability over time that may reflect real changes in regional groundwater quality, for example, the responses to increased drainage after a winter period with significant drainage and the possible decrease in nitrate nitrogen in response to the relatively dry period in 2017, with a significant increase in very recent years that possibly reflects an increase in drainage. However, the use code for the bore is noted in the Environment Southland system as a groundwater quality monitoring which is likely to indicate that it has been established to monitor the localised effects of dairy shed effluent disposal rather than regional groundwater quality. The low R^2 value of 0.0018 and the obvious peaks and troughs indicate that an overall trend is not obvious.

5.33 This bore was included in the observational assessment and was identified as having poor wellhead protection, close to contaminant sources, surface water flow path and stock access, indicating a potential for localised groundwater contamination via the bore.

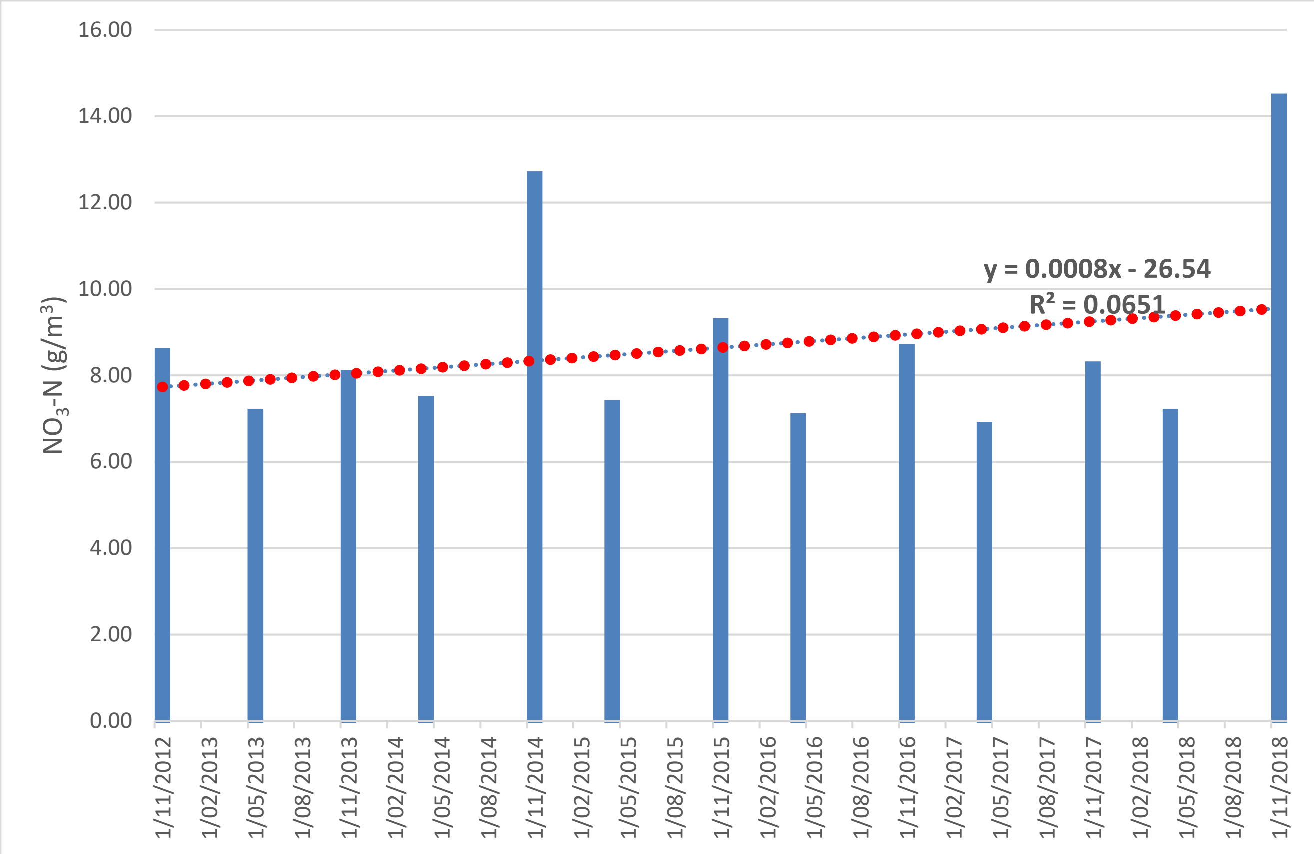

Figure 11: Nitrate nitrogen concentrations in groundwater from bore E45/0610, 2009-2018 (showing as a purple '14.4' north east of the property in Figure 9)

5.34 The data from bore E45/0610 potentially indicate similar summer and winter lows and highs in nitrate nitrogen concentrations. There is an apparent small increasing trend but the very low R^2 value indicates that there is little confidence that this indicates a real trend in groundwater nitrate nitrogen concentrations.

5.35 The use code for this bore is noted as dairy use rather than groundwater quality monitoring so it is less likely that groundwater from this bore is directly influenced by dairy shed effluent discharges. This bore was not inspected as part of the bore observation assessment.

5.36 The results from bore E45/0458 down-gradient from the Horner block are illustrated in the following figure. However, as noted for bore E45/0081, the use code for this bore is also noted in the Environment Southland system as a groundwater quality monitoring which is likely to indicate that it has been established to monitor the localised effects of dairy shed effluent disposal rather than regional groundwater quality. This bore was not inspected as part of the bore observation assessment.

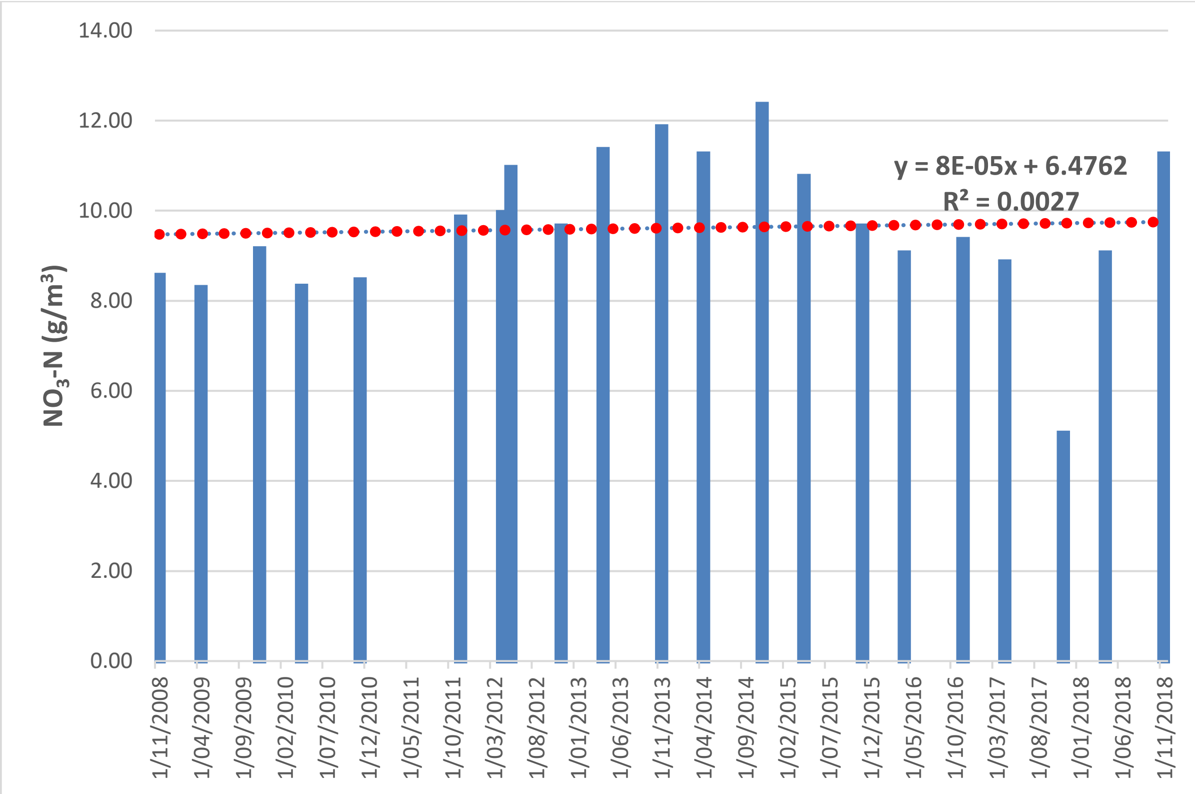

Figure 12: Nitrate nitrogen concentrations in groundwater from bore E45/0458, 2008-2018 (showing as a purple '12.3' south west of the property in Figure 9)

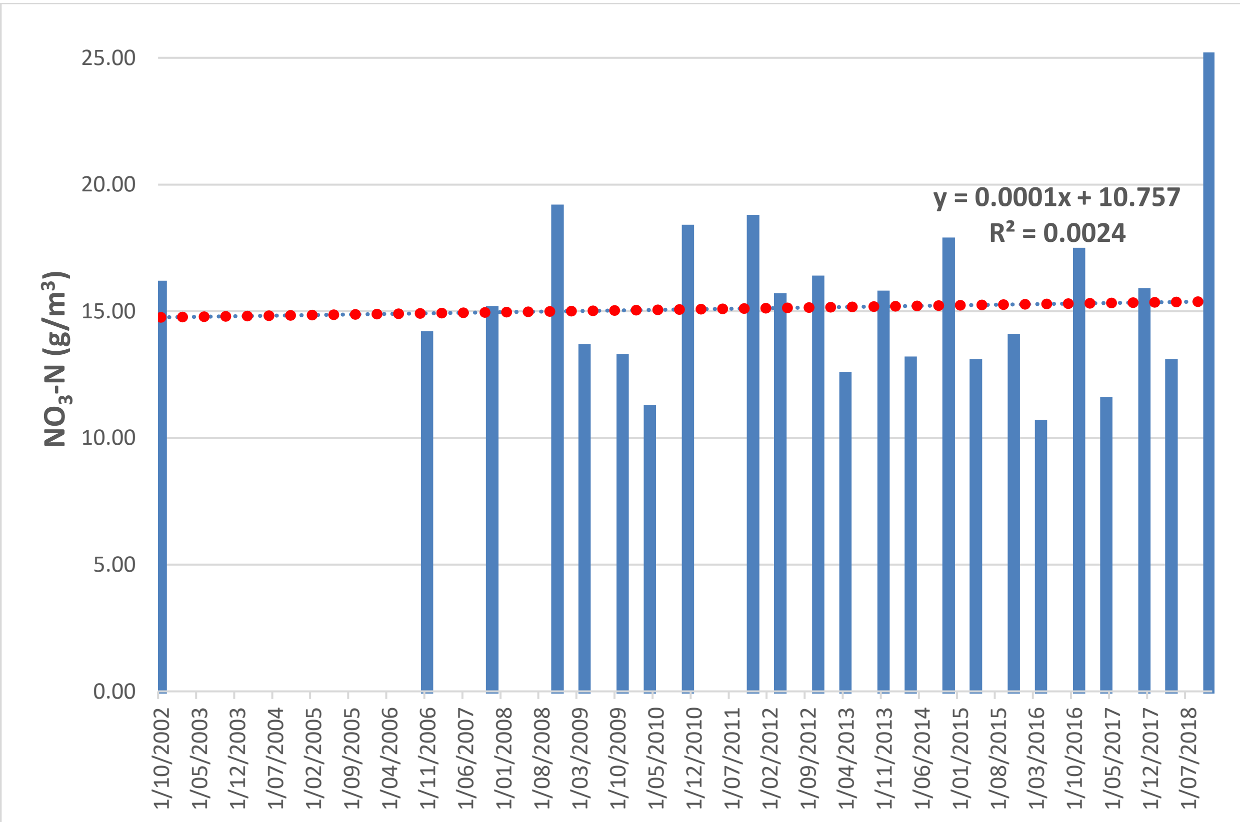

Figure 13: Nitrate nitrogen concentrations in groundwater from bore E45/0060, 2002-2018 (showing as a purple '25' south east of the property in Figure 9)

5.37 The very high concentrations found in groundwater from bore E45/0060 are likely to be related to the proximity to a dairy shed and effluent pond immediately upgradient from the bore of unverified depth. These concentrations are consistently high but with some peaks indicating a possible local source of contamination.

5.38 This bore was included in the observational assessment and was identified as having poor wellhead protection, close to contaminant sources, surface water flow path and close but not immediate stock access, indicating a potential for localised groundwater contamination via the bore.

5.39 The potential limitations of some of the groundwater data are particularly apparent from the results of sampling from bore E45/0622 which is referred to in the main AEE. The results for this bore from 2013 to 2018 are illustrated below. The peak nitrate nitrogen result for 2016 appears to highlight the pitfalls with very shallow (3 m deep, unverified) well/bore without adequate wellhead protection for groundwater quality monitoring. The peak is highly unlikely to represent the quality of the underlying groundwater which is more likely to be represented by the other results that appear to range between 2 – 6 g/m^3 of nitrate nitrogen.

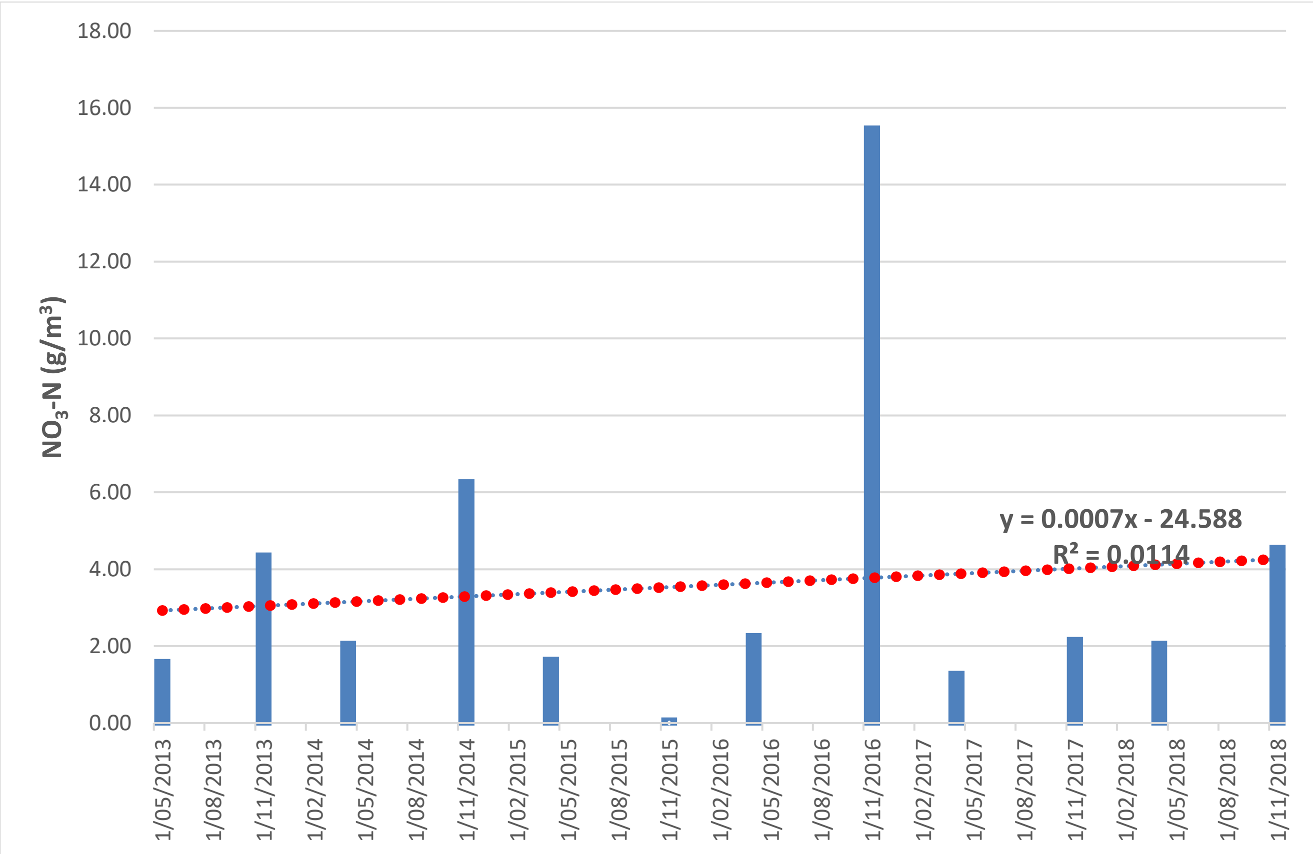

Figure 14: Nitrate nitrogen concentrations in groundwater from bore E45/0622, 2013-2018 (showing as a purple '15.4' south of the property in Figure 9)

Figure 15: Bore E45/0622 in early 2019, showing the lack of wellhead protection and potential for surface water runoff entry

5.40 Bore E45/0622 is scheduled to be modified in late August/early September to raise the well significantly above ground level and a concrete apron will also be installed to ensure that this well meets the requirements of NZS 4411:2001.

5.41 The bore at the Heddon Bush School (E45/0718) has been sampled by Environment Southland in 2017 and is included in Figure 9. However, additional sampling has been undertaken by Dairy Green Limited and analysed at the Watercare (IANZ accredited for nitrate nitrogen testing) and all these results are listed in the following table.

Table 7 Summary of groundwater sample results for bore E45/0718

Date	Nitrate nitrogen (g/m^3)	E. coli (MPN/100ml)
2/6/17 (ES sample)	2.33	<1.0
2/11/17[9]		<1
18/12/17	2.0	<1.0
12/1/18	1.8	<1.0
15/2/18[8]		<1
14/3/18	1.8	<1.0

[9] Analysed by Invercargill Water Testing Laboratory, Ministry of Health approved laboratory.

Conclusions on groundwater quality

5.42 In general, much groundwater quality data reflects the predominant rural land use in the catchment contributing to nitrate nitrogen leaching through to groundwater. A key potential effect is the discharge of groundwater with elevated nitrate nitrogen concentrations to surface waters i.e., the contribution of nitrogen to surface waters contributes to plant growth in streams, and the subsequent rivers, and at the bottom of the catchment in the Jacobs River Estuary. However, the number of groundwater quality samples that appear to have relatively high nitrate nitrogen concentrations are also a potential concern because of the use of groundwater as a source of drinking water (drinking water nitrate nitrogen standard (maximum acceptable value) is 11.3 g/m^3).

5.43 The locations of many groundwater monitoring bores and the many examples of poor wellhead protection mean that it is very challenging to interpret results.

5.44 A 2014 study on a bore near Heenans corner just south west of WW1&2 strongly indicated that groundwater at a depth of approximately 16 m had a significantly lower (~5 g NO_3-N/m^3) concentration of nitrate nitrogen than found in the shallower bores (~12 g NO_3-N/m^3) at the same location. This does indicate that some deeper groundwater in this area may be older groundwater less affected by the affects of the recent decades of land use[10].

5.45 Notwithstanding the significant limitations and difficulties in interpreting the available groundwater nitrate nitrogen data, there are some conclusions that can be tentatively drawn:

- Compared to the 2007 – 2012 survey, groundwater nitrate nitrogen concentrations appear to be generally higher, this is particularly evident with the large number of relatively high results in areas where concentrations may have been lower. However, it is also possible that this may not be a result of more intensive land use and may in part at least be a consequence of other factors relating to monitoring bore locations and wellhead protection.
- Some high nitrate nitrogen results reflect localised effects of dairy shed effluent disposal rather than more regional groundwater quality. However, if a large number of effluent disposal applications are causing significant deterioration of localised groundwater quality this could eventually give rise to a more extensive impact on groundwater quality.

[10] Hughes B (2009) Review of groundwater quality monitoring results from the Heenans Corner nested piezometer site, 20p.

Conversely, it is also possible that very localised high results are being extrapolated beyond their actual affected area to indicate a larger area than actually exists.

- It is highly likely that some high nitrate nitrogen results have been caused by contaminated surface water entering bores with inadequate wellhead protection.
- The number and extent of very high nitrate nitrogen groundwater quality results provided from Environment Southland sampling are not reflected in the same very high concentrations in downgradient surface water quality indicating that: the high nitrate nitrogen groundwater is diluted by lower concentration groundwater; there is a significant lag in travel time to surface water; surface water quality sampling may be missing peak surface water nitrate nitrogen concentrations; the contribution of groundwater recharge to flows is minimal; the groundwater sample results are not indicative of regional groundwater quality; or a combination of all of these potential factors.
- To obtain a more comprehensive understanding of the state of groundwater quality and the activities that may be affecting local and regional groundwater quality would need a detailed assessment of each bore and its setting which is beyond the scope of this report.

Assessment of effects on drinking water supplies sourced from groundwater

5.46 There are many individual property drinking water supplies as well as the Heddon Bush School water supply downgradient from the properties associated with both the land use consent applications and the discharge permit application.

5.47 The WW1/2 and HB properties are spread over two main soil types that differ significantly in terms of the predominant contaminant pathways. The predominant Braxton and Pukemutu soils are poorly drained and the predominant pathway is via runoff and artificial drainage. Conversely, the Glenelg soils are well drained providing a transport route to groundwater. The greatest risk to shallow bores used to supply drinking water is in areas with well-drained soils in locations with activities that can result in contaminants leaching through soils into groundwater.

5.48 The two primary issues for groundwater-sourced drinking water supplies in areas are nitrate nitrogen and faecal indicator organisms (indicators of pathogens, disease-causing organisms). The difficulties involved in understanding current factors influencing nitrate nitrogen concentrations have been outlined above. The factors involved in influencing the transport of faecal indicator organisms are similarly complex, but with the added complexity of a range of complex attenuation factors apply to microorganisms that do not apply to dissolved nitrate nitrogen.

5.49 It has been recognised for many decades that shallow groundwater in those parts of Southland (and other parts of New Zealand) with pastoral catchment land use is vulnerable to microbiological contamination[11]. This 1998 study showed that 75% of the wells sampled and 25% of the bores sampled had faecal coliforms detected. This and other studies around New Zealand have demonstrated that shallow bores/well in areas with well-drained soils and pastoral agriculture are vulnerable to microbiological contamination.

5.50 The good management practices and mitigation measures that are proposed will result in a significant reduction in N loss to groundwater and in P loss to surface water. It is noted elsewhere in this report that it has been generally accepted that the significant reduction in P loss to surface water will also result in a reduction in the risk of microbiological loss to surface water. While there does not appear to be any New Zealand specific research into the consequences for microbiological groundwater quality of mitigation measures designed to reduce N loss to groundwater and P/sediment/microbiological loss to surface water. It is conceivably possible that some mitigation measures could theoretically result in a small increased risk of microorganisms entering soils then eventually entering the underlying groundwater. For example, recontouring laneways and installing culvert cut-offs to ensure that contaminated surface water doesn't enter surface water means that that water is redirected onto soils to allow it to slowly drain into soils.

5.51 However, it would be a complex process to then assess the extent to which a small potential occasional increase in microorganism application to soils could then eventually move into groundwater and then migrate through an aquifer towards drinking water supplies. The scope of this report does not allow a quantitative assessment of the potential risks. In the context of the existing relatively high risk of microbiological contamination of shallow groundwater supplies, it is highly likely that the increased risk posed by these mitigation measures would be insignificant.

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[11] Hamil K (1998) Groundwater Quality in Southland" A Regional Overview, Southland Regional Council Publication No 96, 51p.

Estuary water quality

5.52 The four rivers/streams that are relevant to this report have four separate estuary systems:

- The Orauea River discharges int the Waiau River which discharges into the Waiau Lagoon
- The Aparima River discharges into the Jacobs River Estuary
- The Waimatuku Stream discharges into the Waimatuku Lagoon
- The Oreti River discharges into the New River Estuary

5.53 The key water quality issues in all these locations are eutrophication and sedimentation that appears to be driven by N, P and sediment loads to the estuary from the main surface water inputs. Broad-scale mapping has been undertaken by Wriggle Coastal Management for all of these locations at various times including recent (2018) surveys of the Waimatuku Estuary, Jacobs River Estuary[12] and the New River Estuary[13]. The Waiau Lagoon appears to have been surveyed most recently in 2009.

5.54 Generally, the Jacobs River Estuary and New River Estuary have shown evidence over the past 20 years of increased eutrophication with increased coverage by opportunistic macroalgae, combined with soft, poorly oxygenated mud, and decreasing seagrass and saltmarsh. Conversely, the Waiau Lagoon and the Waimatuku Estuary appear to be significantly different estuaries with comparatively well flushed environments. The Waiau Lagoon has been described[14] as in "*Stage 2 (Moderate) condition*" based on biological observations of plant species and predominantly muddy bottom with available bare habitat. The Waimatuku Estuary has been described[15] as follows: "*…low-moderate state overall in relation to subtidal channel condition and trophic status, indicating conditions have deteriorated slightly since 2012. Given its above threshold catchment nutrient load coupled with potential further eastward mouth migration and consequent constriction, eutrophication (presently expressed as*

[12] Stevens, L.M. 2018. Jacobs River Estuary: Broad Scale Habitat mapping 2018. Report prepared by Wriggle Coastal Management for Environment Southland.

[13] Robertson, B.M., Stevens, L.M., and Dudley, B. 2017. New River Estuary - review of water quality data in relation to eutrophication 1991-2015. Report prepared by NIWA and Wriggle Coastal Management for Environment Southland. 33p.

[14] Robertson, B.M. and Stevens, L.M. 2009. Waiau Lagoon 2009 Synoptic survey, macrophyte mapping and vulnerability assessment. 22p.

[15] Robertson, B.P. and Robertson, B.M. 2018. Waimatuku Estuary: Fine Scale Monitoring and Macrophyte Mapping 2018. Report prepared by Wriggle Coastal Management for Environment Southland. 29p.

nuisance macroalgal production and reduced sediment oxygenation in the upper-middle estuary) and to a lesser extent sedimentation are expected to be ongoing issues in the estuary."

5.55 Nutrient loads to the main estuaries in Southland have been estimated by Aqualinc[16]. These are outlined in the following table.

Table 8: Summary of estimated N and P loads to eight Southland catchments

Catchment	Current catchment agricultural source loads (t/year)		Total catchment source nitrogen load (t/yr)	Estimated realised nitrogen loads (t/yr)	Estimated attenuation (%)
	Nitrogen	Phosphorus			
Bluff_Harbour	19	1	36	29	20
Haldane_Estuary	23	0	39	26	33
Jacobs_River_Estuary	1958	53	2133	1300	39
Lake_Brunton	20	0	20	14	30
New_River_Estuary	4969	139	5513	3718	33
Toetoes_Harbour	6256	142	6617	4392	34
Waiau_River	2714	35	4970	1864	62
Waikawa_Harbour	144	4	176	180	-2
Total/average	16,102	374	19, 404	11,524	31 (average)

5.56 The Aqualinc report further identified the potential nutrient load reductions that could result from various levels of mitigation. These are summarised in the following two tables.

[16] Aqualinc, Assessment of farm mitigation options and land use change on catchment nutrient contamination loads in the Southland region, 2014

Table 9: Estimated reductions in the agricultural source loads under three levels of mitigation for all dairy farms in each Southland catchment

Catchment	M1			M2			M3		
	Nitrogen	Phosphorus	Overall[1]	N	P	Overall[1]	N	P	Overall[1]
Bluff_Harbour	4	26	2	4	29	2	12	29	6
Haldane_Estuary	0	0	0	0	0	0	0	0	0
Jacobs_River_Estuary	6	28	5	8	31	6	18	31	15
Lake_Brunton	0	0	0	0	0	0	0	0	0
New_River_Estuary	6	29	5	8	32	7	18	32	15
Toetoes_Harbour	3	17	3	4	19	4	10	18	9
Waiau_River	1	9	0	1	9	1	4	9	2
Waikawa_Harbour	1	4	1	1	5	1	2	5	2

5.57 The full suite of mitigations assessed by Aqualinc includes the following measures.

Table 10: Description of mitigations assumed to apply under each mitigation level

Mitigation level	Name	Sheep & Beef	Dairy
Mitigation level 1	M1	• Optimised nutrient inputs • Low solubility P • Wetlands	• Stock exclusion from streams • Improved nutrient management • Improved farm dairy effluent (FDE) management
Mitigation level 2	M2	• Stock exclusion from streams • Reduced stocking rates, improved productivity	• Wetlands • Improved FDE management • Reduced stocking rates, improved per animal productivity.
Mitigation level 3	M3	• Grass buffer strips • Feed pad for beef cattle	• Restricted grazing strategies • Grass buffer strips • Improved FDE management

5.58 The proposal provides for all the relevant mitigation measures suggested by the Aqualinc report, with the exception of wetlands. It has not been possible to determine exactly what stocking rate was envisaged in the Aqualinc report or the NZIER report that it was partly based on. However, the winter barn systems proposed as part of the WW4&5 applications are likely to be significantly different from the systems modelled in the Aqualinc report.

6 Implications of water quality for targeting of mitigation

6.1 The water quality results indicate that priorities for contaminant loss mitigation should be faecal indicator organisms, sediment, N, and P. This is largely reflected in the assessment of the physiographic zones (see main AEE) that indicate risks from both artificial drainage and surface runoff because of the generally heavy soils in both areas.

6.2 The primary contribution to the observed water quality issues presented earlier in this report will be from land use activities upstream and downstream in the catchment, with only a relatively tiny contribution from the individual properties.

7 Contaminant loss mitigation proposals, modelling and water quality

Existing and proposed good management practices and mitigation

7.1 The AEEs, the nutrient loss modelling and the Farm Environmental Management Plans (FEMPs) detail the existing good management practices (GMPs) that are currently being implemented on the property and the additional mitigation practices that will be implemented to mitigate nutrient losses from the properties. The following assessments build on that work, particularly the estimates of contaminant losses to water to estimate the effects on water quality.

Overseer and uncertainty

7.2 The nutrient loss modelling undertaken by Mr Duncan and Mr Crawford has primarily been undertaken using OverseerFM (Overseer). Overseer is a complex model that involves combining a model of a farm system together with information on soil characteristics and the long-term climate to estimate the average annual loss of nitrogen and phosphorus to water. Overseer like any complex model of a biological system has inherent uncertainties. The implications of this and other considerations for the use of Overseer as a regulatory tool have been detailed in a report by Freeman *et al*[17].

7.3 The Overseer estimates and effects on water quality have all been undertaken in the light of the inherent uncertainties involved in the application of Overseer.

[17] Freeman, M, Robson, M, Lilburne L, McCallum-Clark, M, Cooke, A, & McNae, D. (2016) Using OVERSEER in regulation - technical resources and guidance for the appropriate and consistent use of OVERSEER by regional councils, August 2016. Report prepared by Freeman Environmental Ltd for the OVERSEER Guidance Project Board.

Overseer modelling and water quality effects

7.4 The evidence prepared by Mr Duncan and Mr Crawford details the Overseer and other modelling undertaken to estimate the N and P loss to water associated with the proposed developments. The following tables provide summaries of current and estimated N and P losses to water.

Table 11 Summary of the N and P loss estimates for the WW1&2 current and proposed scenarios

Woldwide One & Two			
	Current Farm System	Proposed Farm system	Reduction
N (kg/yr)	20,427	18,932	-7.3%
P (kg/yr)	360	338*	-6.1%

* Includes non OverseerFM modelling of P loss mitigation. Refer to Cain Duncan, Tiaki reports

Horner Block			
	Current Total Farm System	Proposed Total Farm system	Reduction
N (kg/yr)	3,155	3,107	-1.5%
P (kg/yr)	24	22	-8%

Combined Woldwide One & Two & Horner Block			
	Current Total Farm System	Proposed Total Farm system	Reduction
N (kg/yr)	23,582	22,039	-6.5%
P (kg/yr)	384	360	-6.3%

Table 12 Summary of the N and P loss estimates for the WW4 (including Gladfield) current and proposed final farm system

Woldwide Four Current & Final Proposed			
	Current Farm System	Proposed Farm system	Reduction
N (kg/yr)	11,792	9,550	-19%
P (kg/yr)	340	337	-0.9%

* Includes non OverseerFM modelling of P loss mitigation. Refer to Mark Crawford, Ravensdown reports

Table 13 Summary of the N and P loss estimates for the WW5 current and proposed final farm system

Woldwide Five Current & Final Proposed			
	Current Farm System	Proposed Farm system	Reduction
N (kg/yr)	15,978	14,378	-10.0%
P (kg/yr)	239	231	-3.3%

* Includes non OverseerFM modelling of P loss mitigation. Refer to Mark Crawford, Ravensdown reports

Table 14 Summary of the N and P loss estimates for WRO current and proposed

Woldwide Five Current & Final Proposed			
	Current Farm System	Proposed Farm system	Reduction
N (kg/yr)	23,033	22,603	-1.9%
P (kg/yr)	516	454	-12%

* Includes non OverseerFM modelling of P loss mitigation. Refer to Cain Duncan, Tiaki reports

7.5 A critical consideration in the context of the estimated nutrient losses is what the implications are of the inherent uncertainties in Overseer and other modelling. The absolute uncertainties involved with Overseer modelling have been commented on extensively and are referred to in the previous reference. However, it is important in this situation to appreciate that that Overseer is not being used to assess compliance with a catchment-based N loss property target. Overseer is being used to estimate losses compared to baseline for one farm system. Many of the concerns about uncertainties involved in Overseer estimates are focused particularly on the former situation i.e., comparing a farm nutrient loss estimate with an absolute N loss target prescribed in a regional plan and/or resource consent. That is a very different situation than the relative comparison that is the focus of these applications. Here the reference point is one existing property, particularly one that is located in a situation that is similar to those used to calibrate key components (or sub-models) of Overseer, the uncertainties are significantly reduced[18]. Indeed, comparisons of modelled and measured nitrate losses for dairy farms in Southland found[19]:

- *"Given the inherent uncertainty associated with measuring and modelling N leaching, there was good agreement between Overseer estimates and measured values reported for 3 key experimental sites in Southland.*
- *Estimates of drainage volumes, based on annual rainfall inputs to the model also agreed reasonably well with those derived from a daily soil water balance model.*
- *The agreement between measured and modelled values indicates that the Overseer model is performing well for this combination of soil-climate-management factors."*

[18] Shepherd M *et al* (2013) Overseer: accuracy, precision, error and uncertainty, FLRC workshop proceedings
[19] Smith, C & Monaghan R (2013) Comparing OVERSEER estimates of N leaching from grazed winter forage crops with results from Southland trial sites, Report for Environment Southland, RE500/2013/123

7.6 This investigation was done with Overseer version 6.1 in 2013 prior to a major change to the hydrological model that would likely have significantly improved drainage estimates.

7.7 Therefore, given that the Overseer N and P loss estimates are being used to compare losses for one property on a relative and not absolute basis, there will be a very low level of uncertainty about the extent to which estimated reductions or increases reflect real reductions or increases.

7.8 All modelling of long-term annual average estimates of N and P loss to water involve uncertainties, i.e., limitations in parts of the modelling process that is a result of incomplete knowledge. Uncertainty is the most relevant term to use for annual average estimates of N and P loss from a whole farm system[20]. However, the uncertainties involved in Overseer modelling are not currently able to be quantified. They are probably greater than 30% for both N and P modelling[21].

7.9 There are two significant implications of this:

- The estimated differences between the current and proposed farm system nutrient loss estimates is significantly less than the likely uncertainties involved in Overseer modelling.
- Overseer modelling should be considered in conjunction with the specific farm systems and mitigation measures that are proposed, to provide a reasonable level of certainty about the relativities of nutrient loss estimates.

7.10 This means that while there may be a relatively high level of uncertainty about nutrient loss estimates, if there are clear, measurable and verifiable changes to one farm system there will be a high level of certainty about the relative changes to long-tern annual average nutrient loss estimates[22]. Therefore, provided that there is assurance that the farm system changes have occurred there will be a high level of certainty there will be relative reduction in long-term annual average N and P losses to water.

7.11 It is difficult of course to model the resultant changes in water quality that would result from decreased nutrient losses to water. At one level it could be sufficient to simply assume that a significant reduction in nutrient losses will be reflected in a reduction in the loading to the

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[20] Shepherd M *et al* (2013) Overseer: accuracy, precision, error and uncertainty, FLRC workshop proceedings
[21] Wheeler D & Shepherd M (2013) Overseer: Answers to commonly asked questions, RE500/2012/027
[22] Freeman, M, Robson, M, Lilburne L, McCallum-Clark, M, Cooke, A, & McNae, D. (2016) Using OVERSEER in regulation - technical resources and guidance for the appropriate and consistent use of OVERSEER by regional councils, August 2016. Report prepared by Freeman Environmental Ltd for the OVERSEER Guidance Project Board.

relevant receiving water body. However, given the importance an assessment of that is undertaken in the context of the specific receiving environment.

Surface water and groundwater catchments

7.12 The specific surface water catchments for WW1&2 and the Horner Block are illustrated in the following figure:

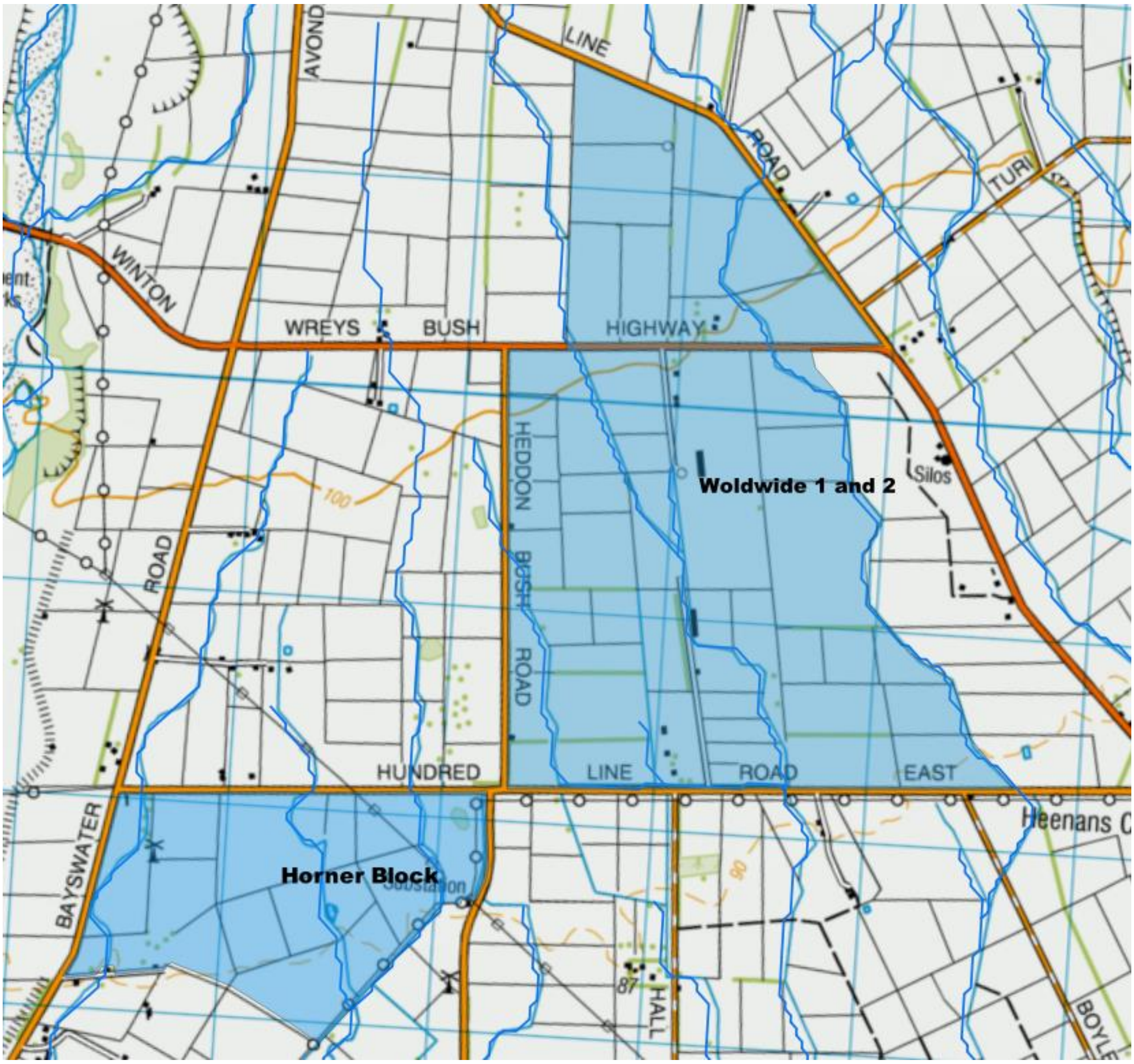


Figure 16: Woldwide 1 & 2 and the Horner Block and key streams/drains

7.13 As noted earlier in this report, the information in the above figure illustrates the locations of the key streams/drains on the properties with the easternmost stream in the Oreti River catchment and the westernmost stream in the Aparima River catchment, with the streams in between draining to the Waimatuku Stream. The nutrient loss modelling has not been 'blocked' on the basis of surface water catchments and the information available, for example, for effluent application on the Horner Block indicates that it is valid to assume that no individual stream would be subject to an increase in nutrient loss. Therefore there is strong evidence to justify a conclusion that all streams that leave the properties would have small reductions in the nutrient losses entering those streams, both in terms of P losses via overland flow and N losses that would occur via artificial drainage to those streams and via recharge further downstream in the catchments.

7.14 The groundwater contour mapping illustrated in Figure 6 strongly indicates that the majority of groundwater that receives drainage from the WW1&2 and Horner Block properties will move in a southerly direction and is likely to eventually recharge the Waimatuku Stream further down the catchment. Nitrogen loading reductions will contribute to a very small loading to groundwater that moves down-gradient in the Waimatuku catchment.

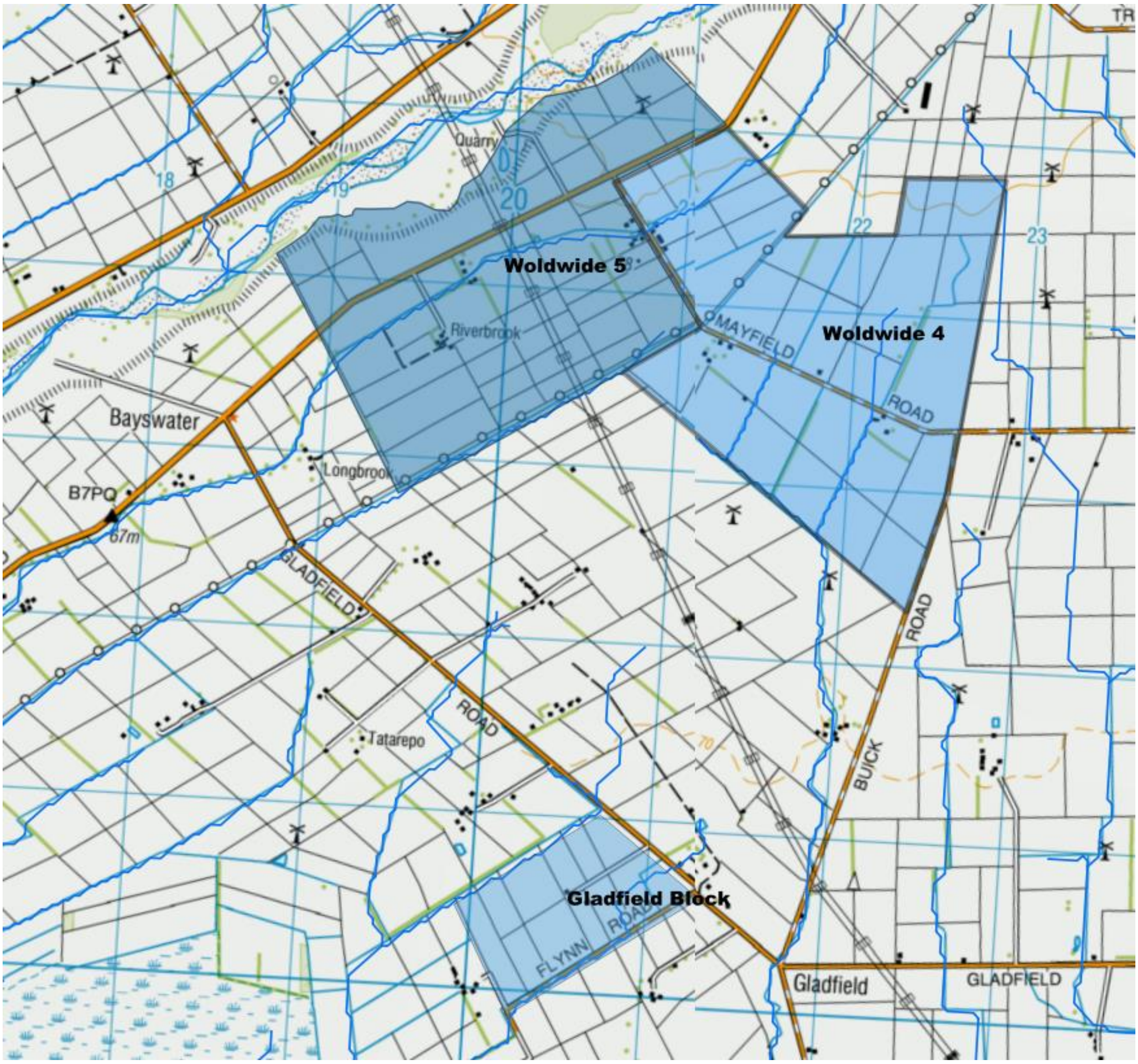


Figure 17: Woldwide 4 & 5 and the Gladfield Block and key streams/drains

7.15 Figure 16 illustrates that the primary surface water catchment for the Woldwide 5 property is the Aparima River while the majority of the WW4 property is in the upper reaches of the Waimatuku Stream catchment. Similarly, Figure 6 indicates that the majority of drainage from WW5 moves parallel to the Aparima River and is likely to eventually recharge that river further downstream. Conversely, the majority of drainage from WW4 is likely to drain away from the Aparima River following the Waimatuku catchment.

7.16 Similar to WW1&2 there does not appear to be any specific high nutrient loss activity occurring on individual blocks in one sub-catchment that would result in an increase in nutrient losses to any individual creek or drain. Therefore it can be concluded that the reduction in losses would contribute to small decreases in nutrient loadings to all surface water bodies as well as groundwater.

7.17 It is possible to develop assumptions that would enable some very crude estimates of the potential consequences in nutrient loss reductions for receiving water quality, e.g., for P loss to estimate the number of significant rainfall events on average per year and by using a simple mass balance approach estimate the effect of this on short-term water quality. However, this would involve some significant assumptions (e.g., mean stream flows) and the resultant estimates have significant uncertainties. In this situation, it is more useful to simply recognise that the combination of modelling together with a high level of confidence that the proposed mitigations will be implemented will mean that there will be an extremely small improvement in both groundwater and surface water quality. However, it is also important to recognise that nutrient loss reductions for these properties in the context of four fairly large surface water catchments and a relatively large groundwater system will not result in measurable improvements in the receiving water bodies in the absence of a coordinated catchment approach.

Water quality effects on estuaries

7.18 There are effectively three estuary/lagoons downstream of these properties: the Jacobs River Estuary (Aparima River), the mouth of the Waimatuku Stream and the New River Estuary (Oreti River). The information summarised in Table 5 does not include a load estimate for the Waimatuku Stream.

7.19 As a proportion of the estimated catchment loads for the Jacobs River Estuary and the New River Estuary, the overall loads from these properties are understandably relatively very small.

For example, if contrary to the hydrological/hydrogeological information all the nutrient load from WW1&2 and the Horner Block was applied to the Aparima River catchment, on a modelled catchment source load basis, using the 2014 Aqualinc data (which is highly likely to need updating) the overall current loads would amount to currently approximately 23.6/1,958 or 1.2% (N) and 0.38/53 or 0.7% (P) of the modelled catchment loads. These figures should be treated with great caution because the catchment load estimates appear to be low based on current dairy farm nutrient loss estimates.

7.20 This calculation is useful to get a very rough appreciation of the potential scale of the overall current contributions to N and P catchment loads. However, it can't be used in any meaningful way to estimate contributions to nutrient concentrations in the relevant estuaries/river mouth because of the complex hydrogeological, physical, chemical and biological processes that operate in the contributing catchments.

8 Faecal indicator organisms and sediment losses before and after development

8.1 It is very difficult to develop quantitative estimates of the loss of faecal indicator organisms or sediment loss. There are no equivalent readily available farm-scale models that can be used. Some sediment loss models such as SedNetNZ, NZeem and HEL have been tested and applied in New Zealand[23]. However, none are currently widely used in RMA planning or regulatory processes. One common current approach[24] is to use Overseer modelled P loss as a surrogate for both. This is because a key component of Overseer P loss modelling is based on an assessment of soil loss which will include faecal indicator organisms as well as sediment. Therefore, the modelled P loss indicating a small reduction in P loss provides a clear indication that there is highly likely to be similar small reductions in both sediment and faecal indicator loss to water as a consequence of the proposed changes.

8.2 Therefore, there is a very high level of certainty that there will be very small improvements in sediment and microbiological water quality for all surface water bodies leaving all the properties.

[23] Palmer D, Dymond J & Basher L (2013) Assessing erosion in the Waipa catchment using the New Zealand Empirical Erosion Model (NZeem®), Highly Erodible Land (HEL), and SedNetNZ models David Palmer, John Dymond, and Les Basher, Landcare Research Report LCR1685.

[24] It was accepted at a 2018 ES consultant meeting that phosphorus loss modelling can be used as an approximate proxy for sediment and microbiological contaminant losses.

However, these changes are unlikely to be measurable unless they are accompanied by similar catchment-wide mitigation measures.

9 Water quality issues raised by submitters

Heddon Bush Primary School

9.1 The Ministry of Education has made a submission in opposition to the resource consent applications made by WW 1 & 2. The main concerns expressed in the submission are as follows:

- Elevated nitrate nitrogen concentrations near to or above the NZ Drinking water Standards at E45/0060 and E45/0330.
- Lag time between application of nutrients to land and reaching groundwater and an implied concern that the relatively low concentrations of nitrate nitrogen at the school bore could increase over time.

9.2 The submission requests that the 'application' be refused unless it is established that the "...Heddon Bush School bore is not adversely affected by the discharge of contaminants.... If a monitoring bore is proposed as part of the operation the proposed location, proposed depth and frequency of sampling and testing and the proposed trigger levels need to be specified by the applicant.".

9.3 As noted earlier in this report, some groundwater quality results may not accurately indicate regional groundwater quality and in some locations groundwater quality is likely to be affected by contaminated surface water entering groundwater because of poor well head protection and proximity to contaminant sources. For example, bore E45/0060 was inspected as part of the survey of six bores. The location of this bore is illustrated in the following figure.

Figure 18: Location of monitoring bore E45/0060 relative to adjacent contamination sources

9.4 Bore E45/0060 is located extremely close to a dairy shed and associated lane and underpass, the wellhead protection is poor and there is a surface water flow path to the well. The results of sampling of this well are illustrated in Figure 11 and indicate that the results are likely to have been affected by these factors.

9.5 Bore E45/0330 does not currently exist. It was previously the bore number for a multilevel piezometer system that provided for sampling groundwater at five depths from approximately 3 m depth to 16 m depth[25]. It appears that the results for these bores (E45/0768-0772) were

[25] Hughes B (2009) Review of groundwater quality monitoring results from the Heenans Corner nested piezometer site, 20p.

recorded as E45/0330 when data was supplied to the Ministry of Education representative. That report did identify that groundwater nitrate nitrogen from the deepest bore had a significantly lower nitrate nitrogen concentration than the shallower bores. The data illustrated in Figure 9 shows the results from the 3 m deep bore E45/0768 with a high of 16.6 g NO_3-N/m^3.

9.6 The concerns expressed by the Ministry of Education based on those two specific bores does not appear to be a robust basis for concern about the nitrate nitrogen concentrations at the Heddon Bush School water supply bore where all the recent sampling results show relatively low concentrations of nitrate nitrogen.

9.7 However, the groundwater quality data do indicate that it is likely that there are broad areas of groundwater with significantly raised concentrations of nitrate nitrogen. This indicates that land use activities in some locations are resulting in high nitrate nitrogen concentrations in shallow groundwater. However, the changes proposed as part of these applications will result in significant reductions in the loss of nitrogen to groundwater from this landholding and if such measures are adopted more broadly across the groundwater catchment there would be measurable improvements in groundwater quality. Therefore the combination of the proposed significant mitigations and the existing relatively low concentrations of nitrate nitrogen mean that it is highly unlikely that the concentrations of nitrate nitrogen in the Heddon Bush School groundwater supply would increase.

9.8 The existing groundwater quality found at the school bore which is a verified depth of 14.9 metres indicates that it is not currently being significantly affected by land use activities, with nitrate nitrogen concentrations in the range of 1.8 – 2.3 g/m3. With the reduction in contaminant loss that will occur at the properties the proposal will not result in any additional risk to the existing quality of the current water supply.

9.9 As noted in Section 5 shallow unconfined groundwater in this and similar locations is already at significant risk of microbiological contamination. Which is one of the reasons why self-supplying schools are recommended to treat such supplied with some form of disinfection[26]. The activities proposed at WW1&2 would not result in a significant increase in the existing level of microbiological risk to this water supply.

[26] https://www.education.govt.nz/school/property-and-transport/school-facilities/energy-water-and-waste-management/drinking-water-quality/self-supplying-schools/

10 Conclusions on the effects of the proposal on water quality

Local and cumulative surface water quality

10.1 The information outlined in this report on the existing quality of surface water downstream of these properties combined with the estimates of the current and likely futures losses of sediment, faecal indicator organisms, N and P from the proposed changes provide strong evidence for a real but extremely small overall improvement in the quality of the surface waters leaving these properties.

10.2 The improvements in water quality are unlikely to be measurable with the current Environment Southland surface water quality monitoring programmes. However, if other properties in the wider catchments implemented equivalent good management practices/mitigation measures there would be significant and measurable improvements particularly for the water quality variables that currently do not comply with the relevant standards or guidelines. The nature of some water quality issues such as deposition of sediment in slow-flowing reaches (which may take many years to move downstream) means that some water quality improvements would take a long time to be realised.

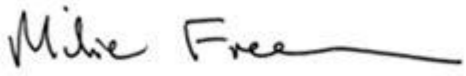
Local and cumulative groundwater quality

10.3 The information from the Overseer and additional modelling combined with the specific good management practices/mitigation measures provide strong evidence for a real but small reduction in the N loading to groundwater and associated artificial drainage from all properties. If this occurs across enough properties in the wider area there would be an improvement in both the underlying groundwater nitrate N concentrations and the concentrations in drainage water discharging to, and/or recharging, streams. Because of the complexity of groundwater systems including the inherent heterogeneity of alluvial aquifers, and travel times for drainage water and groundwater it may be many years[27] before reductions in N concentrations are observed in bores used to monitor groundwater quality and in surface water recharged by that groundwater.

[27] A 2014 study by Environment Southland concluded that the 'transit time' (time from soil to downgradient groundwater) would be less than five years for the majority of the region. Wilson S *et al* (2014) Estimating Time Lags for Nitrate Response in Shallow Southland Groundwater, Environment Southland Technical Report 2014-03

Estuaries and lagoon water quality

10.4 The key water quality issues in the Jacobs River Estuary and the New River Estuary and likely to be an issue in the Waimatuku Stream lagoon, appear to be sediment and nutrient loading. Contaminant losses from this property will be making an almost negligible contribution to these loadings. The good management practices/additional mitigation measures that would be implemented would reduce this contribution by extremely small amounts. By itself this would be insignificant but combined with similar initiatives across the relevant catchments would result in significant reductions in the nutrient and sediment loadings which have the potential to contribute to a significant improvement to the significant estuary/lagoon eutrophication issues.



Mike Freeman, BSc, PhD
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Landpro Limited
5 September 2019

Attachment A

Dairy Green Ltd

Practical Engineering Solutions Consents,
Effluent, Stock water, Irrigation Design
through to Installation
Irrigation NZ Accredited Designer

Groundwater Well and/or Bore Assessment – Heddon Bush; Central Southland

A visual assessment of 6 shallow groundwater wells/bores was carried out by Quinton Scandrett of Dairy Green Ltd on the 25th July 2019. Wells/bores across the Heddon Bush area of Central Southland were assessed. The assessment targeted shallow wells that have demonstrated high groundwater nitrate concentrations and have been used by Environment Southland to report on the state of groundwater quality in this area of the Southland Region. The same assessment criteria was used for each well site, photos of the site were also taken.

Assessment Criteria:

- Primary use of bore/well
- Well head protection; poor (no protection), moderate (some protection), high (adequate protection)
- Proximity to potential contaminate source; close (<200 m), moderate (200 m – 500 m), distant (>500 m)
- Potential flow path of surface runoff to well; clear route, possible route, no likely route.
- Stock access to bore/well site; yes or no
- Distance to surface waterway; close (<100 m), moderate (100 m – 500 m), distant >500 m
- Suitability for groundwater monitoring; low, medium, high

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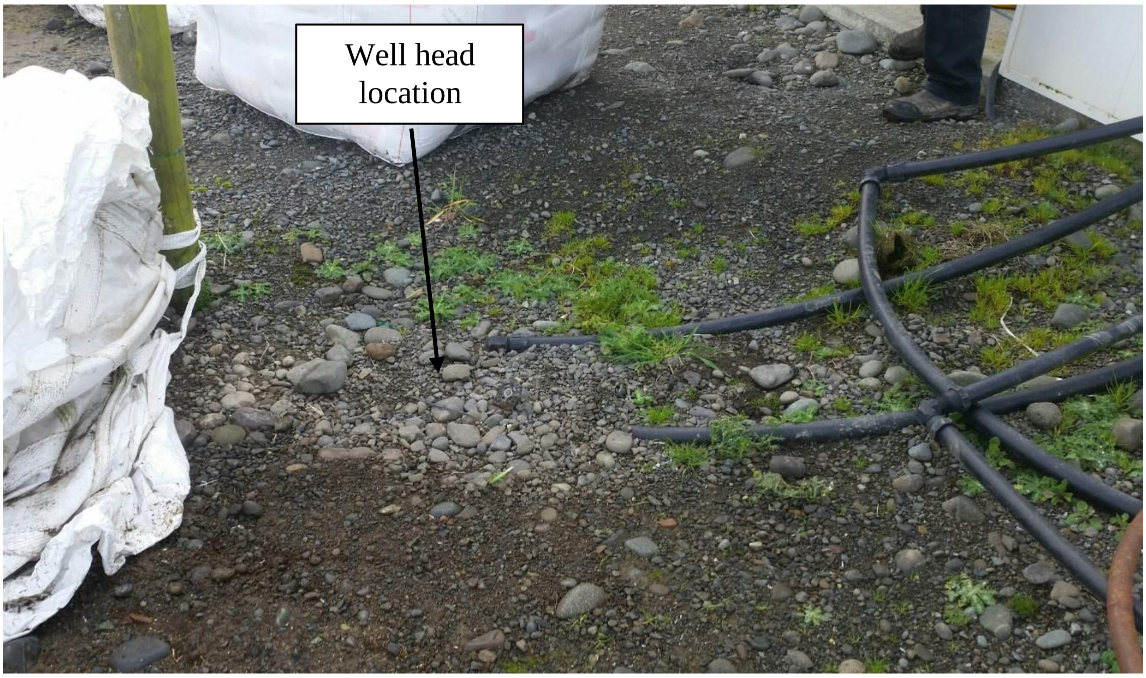
Well E45/XXXX: Located 2 m from the dairy shed

- Primary Use; Dairy
- Well head protection; Poor
- Proximity to contaminate sources; Close <200 m – Dairy Shed, Stock Lanes, Septic system
- Surface water flow path; Possible route to well
- Stock access; No
- Distance to surface water way; Close <100 m
- Suitability for groundwater monitoring; Low

Photos:



Well E45/XXXX: A well adjacent to a pump shed and 6 m from a stock underpass

- Primary Use; Dairy
- Well head protection; Poor
- Proximity to contaminate sources; Close <200 m – Dairy Shed, Stock Lanes, Underpass
- Surface water flow path; Clear route to well
- Stock access; No, however stock can access within 1 m of the well.
- Distance to surface water way; Close <100 m
- Suitability for groundwater monitoring; Low

Photos:

Well E45/XXXX: A bore adjacent to a shelter belt within a paddock

- Primary Use; Environment Southland Ground Water Monitoring
- Well head protection; Moderate
- Proximity to contaminate sources; Close <200 m – Shelter Belt/Stock Camp, Stock Lane, Water Trough
- Surface water flow path; No likely route to well
- Stock access; Yes
- Distance to surface water way; Moderate 100 m - 500 m
- Suitability for groundwater monitoring; Medium

Photos:

Well E45/XXXX: A well adjacent to a water tank within a paddock

- Primary Use; Environment Southland Ground Water Monitoring
- Well head protection; Poor
- Proximity to contaminate sources; Close <200 m – Stock Camp, Silage Pits
- Surface water flow path; Clear route to well (clear route to inside well pipe due to a hole at ground level)
- Stock access; Yes
- Distance to surface water way; Moderate 100 m - 500 m
- Suitability for groundwater monitoring; Low

Photos:

Well E45/XXXX: A bore adjacent to a fence line within a paddock

- Primary Use; Environment Southland Ground Water Monitoring
- Well head protection; Poor
- Proximity to contaminate sources; Close <200 m – Intensive winter grazing, stock lane
- Surface water flow path; No likely route to bore
- Stock access; Yes
- Distance to surface water way; Moderate 100 m - 500 m
- Suitability for groundwater monitoring; Medium

Photos:

Well E45/XXXX: A well adjacent to a fence within a paddock (close to a house)

- Primary Use; Environment Southland Ground Water Monitoring
- Well head protection; Poor
- Proximity to contaminate sources; Close <200 m – Stock camp, Calf Sheds, Gateway, Septic Tank System
- Surface water flow path; Clear route to bore
- Stock access; Yes
- Distance to surface water way; Moderate 100 m - 500 m
- Suitability for groundwater monitoring; Low

Photos:

Summary of Assessment:

Overall the small number of bores/wells assessed in the Heddon Bush area indicated a significant risk of direct contamination of groundwater via the bore/well from surface contaminates. Well head protection in particular was poor with one well having a hole at ground level allowing direct flow of surface water and or contaminates into the well.

………………………

Author
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