

**BEFORE THE HEARING PANEL OF SOUTHLAND REGIONAL COUNCIL**

**In the matter** of sections 88 to 115 of the Resource Management Act 1991

**And**

**In the matter** Applications for resource consents by:

**WORLDWIDE ONE LIMITED, WORLDWIDE TWO LIMITED,**  
Applicants

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**BRIEF OF EVIDENCE OF DR. MICHAEL FREEMAN**

**16 September 2019**

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## QUALIFICATIONS AND EXPERIENCE

- 1 My full name is Michael Conrad Freeman. I am a Senior Scientist and Planner at Landpro Limited a firm of consulting planners, scientists, surveyors and engineers. I have been in this role since January 2018.
- 2 I have approximately 35 years' experience in environmental science and regulatory processes. My previous relevant work experience includes roles as a water quality research scientist, water quality scientist, pollution control manager, regional council director, environmental consultant, and soil and water impact leader. A significant proportion of my current work relates to providing technical input to the preparation of applications for land use consents, discharge permits and water permits relating to dairy farms in Southland. I have prepared a significant number of reports on water quality and related contaminant loss mitigation in Southland as well as reports on water resources including stream depletion and groundwater interference effects.
- 3 I hold the qualification of BSc (Environmental Science, University of Warwick) and PhD (Periphyton and Water Quality, Massey University). I have both the Intermediate and Advanced Sustainable Nutrient Management Certificates from Massey University.
- 4 I have authored or co-authored scientific and technical papers on the role of nutrients in the growth of periphyton and aspects of Overseer Nutrient Budgets (Overseer), particularly as it can be used in water quality management under the Resource Management Act.
- 5 I have read, and agree to comply with, the Code of Conduct for expert witnesses contained in the Environment Court Practice Note 2014. Other than where I state that I am relying on the evidence of another person, I confirm that the issues addressed in this evidence are within my area of expertise. I have not omitted to consider material facts known to me that alter or detract from the opinions that I express. In addition, I go further than this expert witness code of conduct requires in that I make "... clear the sources and extent of uncertainty, including assumptions, and alternative scenarios and data interpretation<sup>1</sup>."

## SCOPE OF EVIDENCE

- 6 This evidence addresses the following issues:
  - 6.1 Existing groundwater quality and surface water quality in the vicinity of the properties.

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<sup>1</sup> United Kingdom Office of Science and Technology's "Code of Practice for Scientific Advisory Committees, December 2007. Refer: Freeman (2011) The resource consent process: Environmental models and uncertainty, RMLA, August 2011.

6.2 Effects of the proposal on groundwater and surface water quality.

6.3 Responses to concerns raised in Section 42A reports.

7 The evidence that I will give on these issues is within my area of expertise.

## BACKGROUND

### Site visit

8 On 20 June 2019, I visited the site and discussed the proposal with Abe and Anita de Wolde. We visited all the relevant properties and in particular saw the specific infrastructure associated with the farms, the location and orientation of the properties and in particular the creeks and topography associated with the land to obtain a first-hand understanding of the direction of surface water flows.

### Other sources of information

9 I have viewed the Section 42A reports (1,542 pages) provided on Monday 9 September 2019.

## EXISTING REPORTS

10 My evidence does not repeat the information provided in the Water Quality Assessment report that I provided in August 2019. A copy of that report is attached as Attachment 1 to this report. I consider that that report is an informative summary of existing water quality, the implications of overseer and other modelling uncertainty, and the likely implications of small reductions in contaminant loss for receiving environment water quality.

## COMMENTS ON S42A REPORTS

11 I have endeavoured to identify all the significant concerns identified in the S42A reports and provide a response to each specific concern. I have only responded to points raised that appear to be used as a basis for recommending decline. Minor matters are not responded to e.g., why line graphs were used in part of my earlier report rather than the more scientifically robust but very challenging for many people to interpret when multiple data sets are represented (e.g., Figure 3.11 on page 22 of Ms Lovett's initial review report dated July 2019).

**Table 1 List of specific concerns raised in S42A report and responses**

Concern identified in S42A reports	Response to those concerns
<b>Aurora Grant/Alex Erceg Executive Summary points from report</b>	
(a) <i>"The effects arising from an increase in cow numbers on the dairy platforms and</i>	The comments indicate that the reporting officers don't accept the ability of Overseer modelling to

Concern identified in S42A reports	Response to those concerns
<p><i>support blocks, in particular from the operational block of the WW1 platform ...</i></p> <p><i>I consider that there is a high probability that adverse effects on surface and groundwater from the operation will increase, especially from specific blocks. While the overall losses from the proposed landholding may stay neutral or decrease in some areas, in others such as WW1 platform and Horner Block there will be an increase in losses. Effects arising from this are likely to be increased algal growth, nuisance plant growth, turbidity and deposition of sediment in in downstream waterbodies, which are already degraded. There will likely be an increased risk to the health of aquatic ecology from high N concentrations, and a risk to human health from exposure to pathogens via surface water.”</i></p>	<p>provide an adequate assessment of a whole farm system/whole property nutrient losses. The focus on cow numbers does not recognise that cow numbers alone will not determine the losses of nutrients and other contaminants.</p> <p>Similarly, the fact that nutrient losses from one blocked area may increase does not necessarily mean that significant adverse effects will occur. An adequate assessment of effects requires both a catchment, block and property assessment. This has been undertaken as far as practicable in the attached water quality report, and no potential for localised adverse effects were identified.</p> <p>While there may be some blocks that have increased or decreased nutrient losses for N and/or P losses generally such ‘pluses and minus’ should be considered as secondary to the overall property losses unless there is a specific sub-catchment that is affected by a increase or decrease in nutrient loss. Given the size of the properties involved in these consent applications and the hydrogeological and surface water runoff characteristics there does not appear to be any significant risk that any creek or drain would have a significant increase in contaminant loss.</p> <p>Similarly, given the size and complexity of the blocks on the properties it appears highly unlikely that there would be any significant localised increase in nitrate nitrogen concentrations that would not be significantly countered by the overall reduction in N loss to groundwater.</p> <p>Ms Lovett has not raised any concerns that an increase in nutrient losses from any one block will result in specific adverse effects on a specific creek or localised groundwater area. Ms Lovett does note (paragraph 7.6 of her supplementary report) that: “Given the complexity of local</p>

Concern identified in S42A reports	Response to those concerns
	<p>hydrology including shallow drainage and surface water routing and a shallow groundwater table, it is extremely difficult to predict the routes of water flow with any certainty to the point that they might be considered closed to assumptions rather than observed pathways.”</p> <p>Ms Grant contends that there will be an increase in nutrient losses from WW1 platform and Horner Block. However, this does not appear to be supported with specific evidence. Ms Lovett’s Supplementary report does not raise any concerns. Ms Lovett’s July report does raise concerns about the areal N loss rates on WW1, WW2 and the Horner Block. However, this was not compared with baseline figures. Mr Duncan addresses this in more detail in his evidence. Very briefly, Mr Duncan’s most recent assessment of the Horner Block strongly indicates that N and P losses would reduce by 1.5 % and 8 % respectively. See table 2 below.</p>
<p>(b) <i>“The proposed intensification on the WW1 side of the proposed platform is likely lead to an increase in contaminants lost to the groundwater used for drinking water supply by the Heddon Bush School”</i></p>	<p>This conclusion does not appear to be supported by specific evidence. The existing vulnerability of shallow groundwater to contamination was discussed in the attached water quality report and the conclusion was that the proposal is highly unlikely to increase the risk (see comments below in response to Ms Lovett’s report).</p> <p>The update report by Ms Lovett did not conclude that it is likely that there would be an increase in contaminant loss to groundwater. Therefore it is not clear on what basis this statement is made.</p>
<p>(c) <i>“The increased stocking rate and the associated feed demand, through pasture or supplementation, has the potential to increase the nitrogen surplus in the soil, especially within the oxidising</i></p>	<p>The nitrogen content of the soil and other aspects of the nitrogen cycle are modelled with Overseer. It is not clear what specific adverse effects are of concern in terms of volatilisation and “gaseous loss”. If this is a reference to greenhouse gases,</p>

Concern identified in S42A reports	Response to those concerns
<p><i>physiographic zone, and loss to the wider environment through leaching, volatilisation and gaseous loss. There is also a high risk to the soil structure from intensive winter grazing, and sediment loss to surface water during intensive winter grazing, that will continue to occur (and increase in area) on the WRO.”</i></p>	<p>the Supreme Court<sup>2</sup> has stated ““we are satisfied that it in s 104(1)(a), the words “actual or potential effects on the environment” in relation to an activity which is under consideration by a local authority do not extend to the impact on climate change of the discharge into air of greenhouse gases that result indirectly for that activity”.</p> <p>It is generally accepted that there are risks to soil structure<sup>3</sup> and loss of contaminants<sup>4</sup> from intensive winter grazing (IWG). One of the central objectives of the proposed development is to reduce dependence on IWG.</p>
<p>(d) <i>“The surface waterbodies in the receiving environments, including the Waimatuku Stream, Oreti River, Waiau River, and Aparima River show impacts from land use processes and are already significantly degraded.”</i></p>	<p>The term “significantly degraded” is not applicable to all of these water bodies. Table six and Figure 7 in my attached report highlight the fact that the Waimatuku Stream is significantly degraded while the other rivers have significantly lower concentrations of contaminants.</p>
<p>(e) <i>“The cumulative effects of the proposal are significant due to the already degraded nature of waterbodies and estuaries that will be affected”</i></p>	<p>It does not follow that because a receiving water is degraded that any development will cause significant adverse effects, cumulative or otherwise. It is more appropriate to examine the specific proposal and assess the likelihood that the proposed reductions in contaminant loss will occur.</p>
<p>(f) <i>“The dairy platform is located partly on the Central Plains physiographic zone with Braxton soils that have ‘swell-crack’ characteristics. Overseer does not accurately model nutrient losses from</i></p>	<p>All overseer modelling involves uncertainties. These uncertainties are significantly reduced when comparing similar farm systems at one location. The nutrient loss modelling undertaken by Mr Duncan in combination with the specific</p>

<sup>2</sup> West Coast Ent Inc v Buller Coal Ltd [2013] NZSC 87

<sup>3</sup> T Styles , S Laurenson, R Monaghan, D Dalley & J Chrystal (2013) Seasonal changes in soil structure under winter grazing in southern New Zealand. In: Accurate and efficient use of nutrients on farms. (Eds L.D. Currie and C L. Christensen). <http://flrc.massey.ac.nz/publications.html>. Occasional Report No. 26. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 7 pages.

<sup>4</sup> Monaghan R (2012) The impacts of animal wintering on water and soil quality, Report prepared for Environment Southland.

Concern identified in S42A reports	Response to those concerns
<p><i>cracked soils, which adds uncertainty to the accuracy of the Overseer modelling results and may mean calculated nutrient losses are underestimated. Furthermore, the Overseer modelling provided by the applicant does not include the most recent farming season and the “baseline” and “future” scenarios have been modelled in different versions of Overseer”</i></p>	<p>good management practices and mitigation that the applicant agrees to be bound by provide a reasonable level of certainty that the modelled nutrient loss reductions will occur and the consequential small contribution to improving water quality is highly likely to occur.</p> <p>More detailed evidence on this matter has been provided by Dr Roberts.</p>
<p>(g) <i>“Uncertainty regarding the effectiveness and appropriateness of the proposed good management practices and mitigations”</i></p>	<p>Mr Duncan and Dr Roberts have provided evidence that gives a high level of certainty about the effectiveness of the proposed good management practices and mitigations.</p> <p>Therefore, my conclusions about the likely effects of these reductions in contaminant loss on water quality are valid.</p>
<p>(h) Groundwater availability, stream depletion, groundwater interference</p> <p><i>“The applicants propose to increase their groundwater take, however they have not assessed the current status of the aquifer they propose to increase the take from, nor have they provided a stream depletion assessment or aquifer test assessment. While there is no contention that the allocation is available “on paper”, the applicants have not adequately assessed the existing environment for this part of the proposal.”</i></p>	<p>A response was provided in mid-August 2019 when these matters were raised in a Section 92 request for further information.</p> <p>Drawdown and stream depletion assessments were undertaken by Aqualinc using the Environment Canterbury hosted Excel calculators developed by Dr Bruce Hunt.</p> <p>Those assessments concluded that there would be no significant adverse effects on stream flows or groundwater availability in neighbouring bores.</p> <p>The response to the S92 request and the Aqualinc assessments are appended as Attachment 2.</p> <p>The S42A report notes that the groundwater zone(s) is less than 10% allocated using the PSWLP discretionary allocation guide.</p>
<p>(i) “Consent is required under Rule 53(d) of the pSWALP and Rule 22(d) of the RWP</p>	<p>Bore E45/0622 was remediated in early September. It now complies with the requirements of PSWLP Rule 53(c) <i>“The use, maintenance or</i></p>



Concern identified in S42A reports	Response to those concerns
<p>for the use and maintenance (or decommissioning) of a bore.”</p> <p><i>“The permitted activity rules of both plans for the use and maintenance (or decommissioning) of a bore requires that the headworks prevent the infiltration of contaminants, which in regards to Bore E45/0622, the headworks is not adequate and do allow for contaminants to enter the bore and subsequently the groundwater.”</i></p>	<p><i>decommissioning of any bore or well is a permitted activity provided the following conditions are met:</i></p> <p><i>(i) the bore or well design and headworks prevent:</i></p> <p><i>(1) the infiltration of contaminants;...”</i></p> <p><i>Rule 22(c) of the RWP has equivalent wording.</i></p> <p>Photos attached as Attachment 3.</p>
<p><b>Abigail Lovett S42 supplementary report (after receipt of water quality report)</b></p>	
<p>(a) No significant disagreements on the state of existing surface water quality</p>	<p>There does not appear to be any significant disagreement on the state of existing surface water quality.</p>
<p>(b) “It is agreed that a catchment-wide effort to reduce contaminant losses would likely be required to considerably reduce losses to surface water and groundwater bracket and therefore result in a meaningful improvement in water quality). However, it is also recognised that the area covered by WW1/WW2, WW4, WW5, and WRO farms and the actual losses from these properties to play an important role in overall loading to the local and regional groundwater and surface water catchments.” (paragraph 10.2)</p>	<p>I don’t consider that there is any fundamental difference between Ms Lovett’s view and mine in that the raised concentrations of nutrients in these streams and rivers are primarily caused by agricultural activities. However, where we do appear to differ is our opinions on the relative contribution of the Woldwide farms.</p> <p>Ms Hitchcock’s thesis states that the Waimatuku Stream catchment area is 150 km<sup>2</sup>. She also states that the catchment area above the Lorneville Riverton monitoring site is 94 km<sup>2</sup>. The total area of WW1/2, the Horner Block and WW4 is approximately 1,042 ha (with a portion of WW4 and the Horner Block draining to the Aparima River). This does indicate that these properties could potentially be approximately 9% of the lowland area above the Lorneville Riverton monitoring site. Ms Lovett and I agree that the hydrogeology, drainage systems and hydrology in this area can be complex making it difficult to define surface catchments accurately. It is</p>

Concern identified in S42A reports	Response to those concerns
	<p>acknowledged that these properties form a small but significant component of this lowland catchment area. The same is not true for the Aparima River (1,537 km<sup>2</sup> catchment area) or the Oreti River where the relative areas are tiny in proportion to the total catchment areas.</p> <p>The location of the properties relative to specific surface water catchments are illustrated in figures 1, 2, 5 &amp; 6 of my original report. As indicated in that report it is likely that the majority of the N loss reduction will be reflected in groundwater that moves in a southerly direction (Figure 6 in my original report) from the properties that will contribute to recharging the tributaries of the Waimatuku Stream. Similarly figures 1 and 2 in my original report indicate that it is likely that the majority of P loss reduction would be reflected in the Waimatuku Stream because of the majority of surface runoff appearing to be to the tributaries of the Waimatuku Stream.</p> <p>The key difference in our opinions appears to be the relative importance of the contributions. I consider it would be accurate to say that these farms are likely to be “relatively significant” sources of nutrients to the Waimatuku Stream catchment, but only “relatively insignificant” for other surface water catchments.</p>
<p>(c) “Based on information provided in the entirety of application documents, it is agreed that there is <u>potential</u> for the proposed activities and mitigation measures to slightly reduce the losses of sediment nutrients and bacterial contaminants from WW1/WW2, WW4, WW5, and WR0 farms. However, this reduction in nutrient loss is not guaranteed, largely due to a combination</p>	<p>This is a potentially important concern. Ms Lovett says that the reduction is not guaranteed. Neither Mr Duncan nor Dr Roberts are guaranteeing these reductions.</p> <p>My report is based on independently reviewed nutrient loss modelling where the estimated level of nutrient loss reduction is sufficiently large to provide a high level of reassurance that the significant reductions in nutrient loss are highly likely to occur. In addition, the modelling is based</p>

Concern identified in S42A reports	Response to those concerns
<p>of natural complexity in the hydrological system and inherent uncertainties and modelling. Key limitations include: reliance on estimates from overseer; that the estimate is based on the assumption the best management practices and the highest level of mitigation measures will be undertaken at all times (which may not be possible operationally); and since the proposed increase in number of cows will result in (an overall) increased effluent application to land there is a considerably higher probability that a reduction in nutrient losses would occur if all mitigation measures were employed and cow numbers remained the same as they are currently.” (paragraph 10.1)</p>	<p>on specific good management practices and mitigations that are in addition to those practices that have been currently occurring and the applicant would be bound to implement those measures via resource consent conditions.</p> <p>I agree that there would be a greater reduction in nutrient loss if cow numbers remained the same. However, that is not what has been applied for.</p>
<p>(d) Comments on the report by Dairy Green Limited on well head protection in the Heddon Bush area. For example, “Therefore, even though there may be potential contamination of the bores as described in the Scandrett report, it is likely that the water quality results should still be representative of the actual groundwater quality of the aquifer from which the sample was taken.” (paragraphs 11.1 – 11.8)</p>	<p>While I largely agree with the technical conclusions of Miss Lovett, there is an important point that Miss Lovett appears to not recognise. That is that while the report by Mr Scandrett is not a detailed scientific report it does highlight an issue that has been recognised in Southland for over 20 years, that many bores/wells including bores that have been put down to comply with resource consent conditions are being put in place with clearly inadequate well head protection and inappropriately close to sources of surface water contamination that can wash down well head casings. I have seen photographs of many of these bores. Environment Southland reports from the late 1990s have highlighted this issue. It is accepted that the owners of these bores have a responsibility to bring the bores up to the standard specified in NZ S: 4411:2001. However, clearly over the best 20 years the issue does not appear to have been resolved. Putting aside issues about</p>

Concern identified in S42A reports	Response to those concerns
	<p>landholder responsibilities and the implementation of rules I am concerned that it is not possible for me to clearly distinguish between these potential sources of groundwater contamination and other land use effects on groundwater quality.</p>
<p>(e) Heddon Bush School</p> <p>“It is not useful to deflect attention here to ‘potential’ contaminant sources caused by well head security...”</p> <p>“...a more appropriate statement would be “...is unlikely to...””</p> <p>(paragraphs 9.1 &amp; 9.3)</p>	<p>It has certainly not been my intention to deflect attention from the real risks that apply to shallow groundwater source drinking water supplies. The specific bore referred to was identified in the submission by the Ministry of Education as a reason for concern. That is why the discussion was included in this part of the report. I have not yet personally visited the well but it was included in the survey undertaken by Mr Quinton Scandrett and does appear to be at risk of contamination from surface water entering the casing and then underlying groundwater. As noted in my original report this is a wider issue but does have implications for interpreting land use groundwater quality relationships.</p> <p>I agree with Ms Lovett that my conclusion “..will not result in any additional risk..” was inappropriately certain and a more appropriate conclusion should be “...highly unlikely to result in any additional risk...”</p>
<p>(f) In reference to Overseer modelling – (paragraph 7.4) “Only total estimated nutrient losses are provided and the previously reported nutrient loss per hectare of land has been omitted from these tables.”</p>	<p>I don’t consider that per hectare comparisons are particularly useful for specific resource consent applications. For phosphorus in particular, they frequently mask any small changes. I consider that it is more transparent to provide the actual total property loss figures. I think the earlier report that Ms Lovett is referring to is the original AEE report that I was not involved in.</p> <p>Losses per hectare can be useful for making general comparisons e.g., for comparing nutrient</p>

Concern identified in S42A reports	Response to those concerns
	losses to water for sheep and beef, arable farms, dairy farms, etc.

## SUMMARY OF UPDATED NUTRIENT LOSS TO WATER ESTIMATES

- 12 The following tables summarise the most recent nutrient loss to water modelling undertaken by Mr Duncan

### Overseer modelling and water quality effects

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

**Table 2 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)	20,756	19,378	-6.6%
P (kg/yr)	366	344*	-6.0%

\* Includes non OverseerFM modelling of P loss mitigation. Refer to Cain Duncan evidence

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	-8.3%

Combined Woldwide One & Two & Horner Block			
	Current Total Farm System	Proposed Total Farm system	Reduction
N (kg/yr)	23,911	22,485	-6.0%
P (kg/yr)	390	366	-6.1%

**Table 3 Summary of the N and P loss estimates for WRO current and proposed**

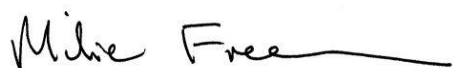
Woldwide Five Current & Final Proposed			
	Current Farm System	Proposed Farm system	Reduction
N (kg/yr)	23,033	22,603	-1.9%
P (kg/yr)	516	454	-12%

\* Includes non OverseerFM modelling of P loss mitigation. Refer to Cain Duncan evidence

## CONCLUSIONS

- 14 I have carefully considered the Section 42A report comments made by Ms Lovett and Ms Grant/Mr Erceg. I respectfully consider that when the bases for those concerns are examined carefully they are addressed by the measures that the applicant has proposed.
- 15 I acknowledge that when considering the effects of farm system changes and new mitigation practices there will always be some uncertainty about the level of effectiveness. However, I am confident with the evidence provided by Mr Duncan and Dr Roberts, the research that I am familiar with and my knowledge of the specific measures that the applicant has agreed to be bound to via resource consent conditions that it is highly likely that they will result in a significant reduction in contaminant loss to groundwater and surface water.
- 16 The evidence of Mr Duncan and Dr Roberts together with my attached report and this evidence provides sufficient evidence for me to conclude that the proposal would make a real but small contribution to improving water quality in these catchments, particularly in the Waimatuku Stream catchment.
- 17 As noted in my earlier report, I consider that measurable improvements in water quality in these catchments will only occur through comprehensive catchment management plans that require appropriate contaminant loss reduction measures across the catchments.

Dated 16 September 2019

A handwritten signature in black ink that reads "Mike Freeman". The signature is written in a cursive style with a long horizontal flourish extending to the right.

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Dr Michael Freeman

# **Attachment 1**

## **Copy of Water Quality Report**



**LANDPRO**

Make the most of your land

## Water quality assessments

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Woldwide Two Limited  
&  
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**QUALITY INFORMATION**

**Reference:** 19180

**Date:** 5 September 2019

**Prepared by:** Mike Freeman

**Reviewed by:** Matilda Ballinger, Landpro & Nessa Legg, Dairy Green

**Client Review:** Abe and Anita de Wolde

**Version Number:** Final

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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.

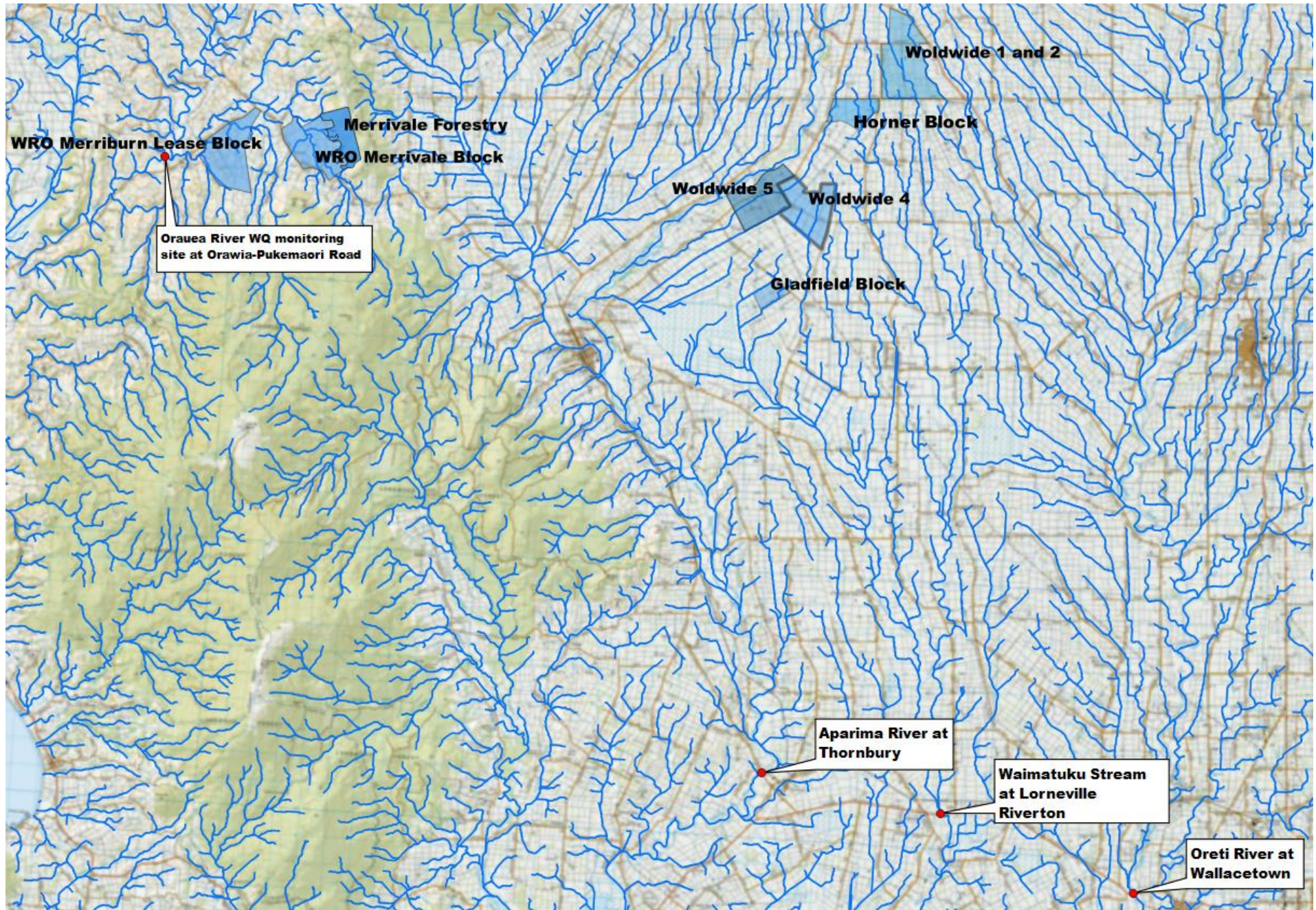


Figure 1: Location of all properties and catchments above the Orauea River, Aparima River, Waimatuku Stream and Oreti River monitoring sites

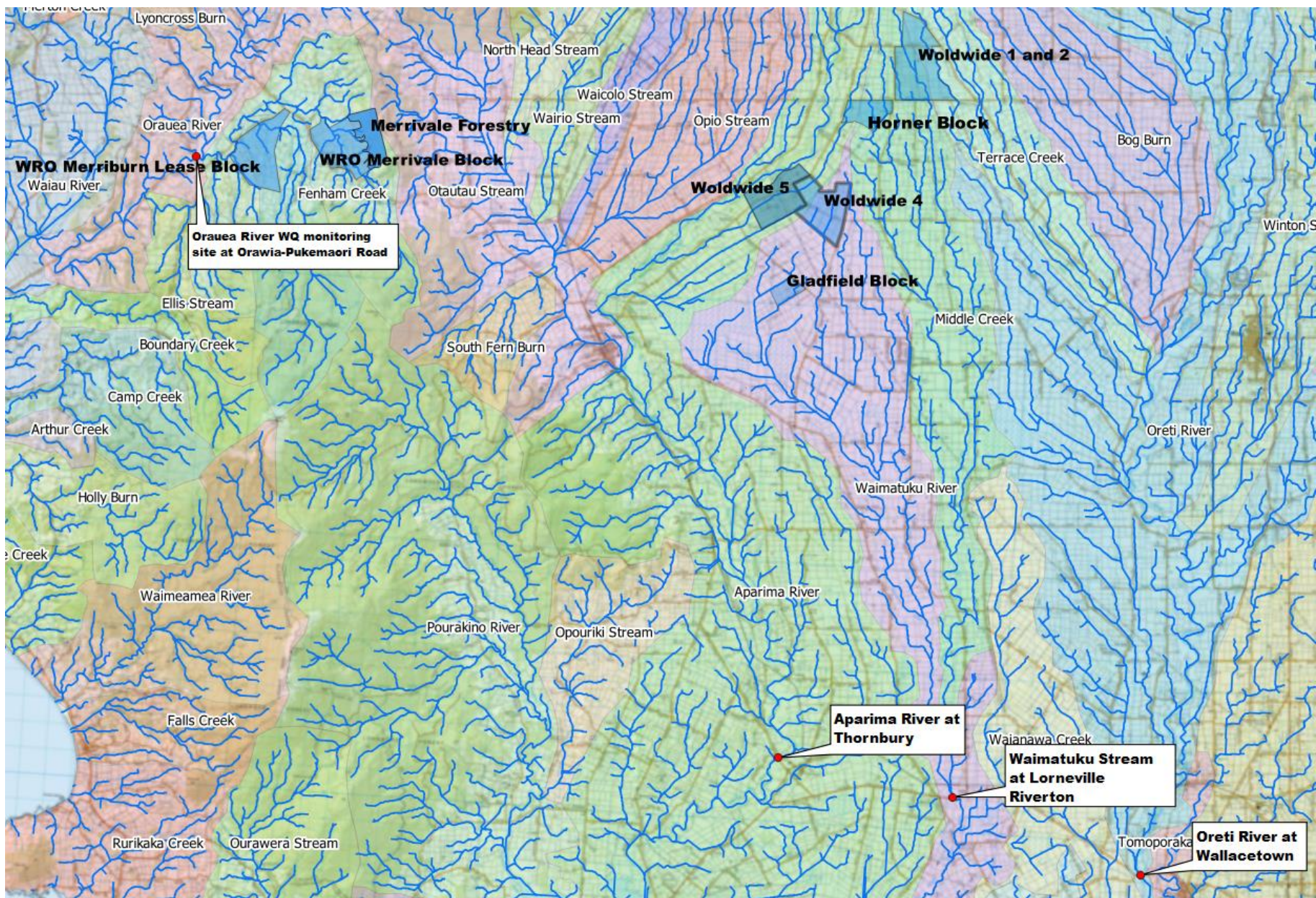
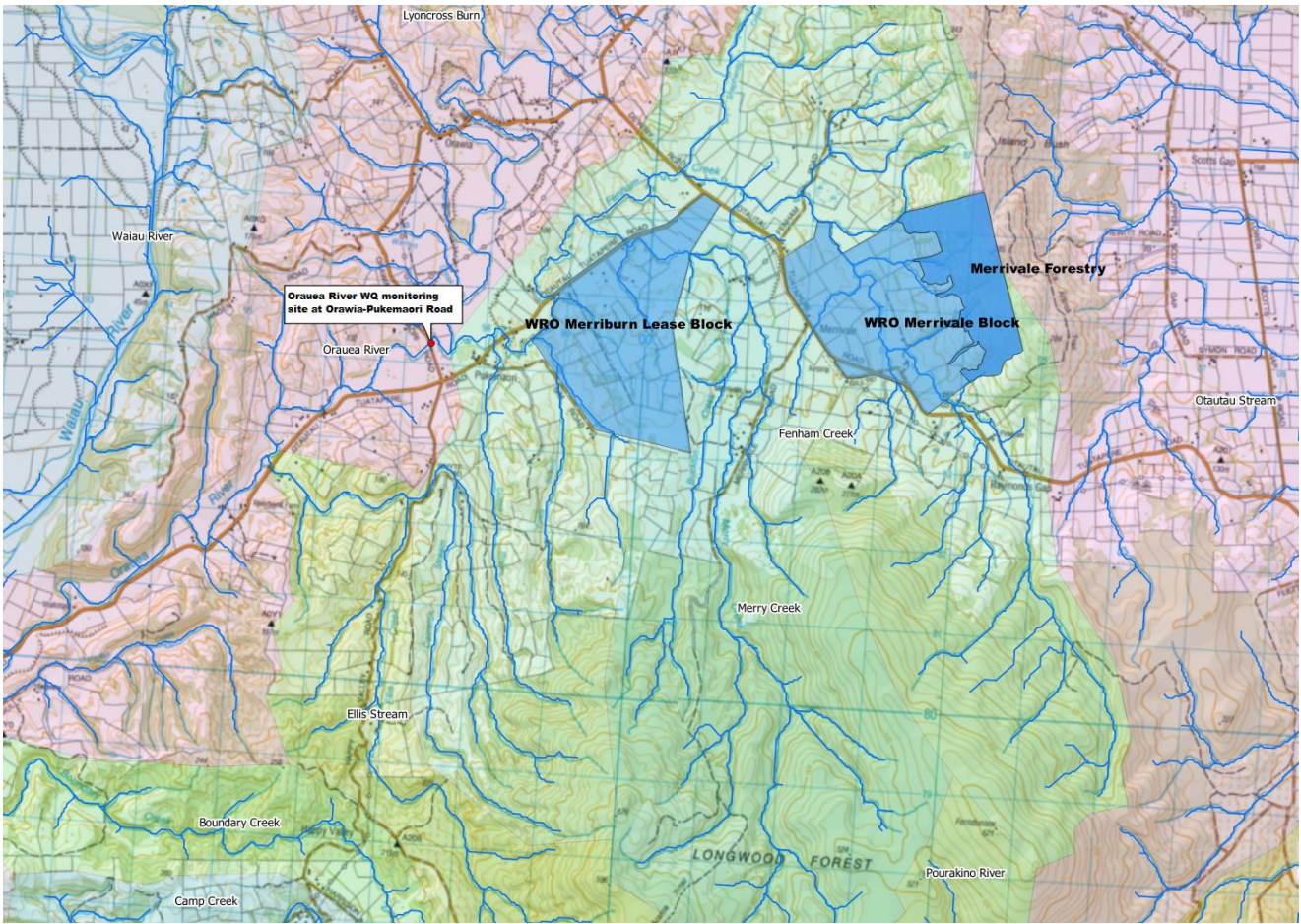


Figure 2: Location of properties and catchment above the Aparima River and Waimatuku Stream river monitoring sites, shaded areas showing Environment Southland GIS surface catchment areas

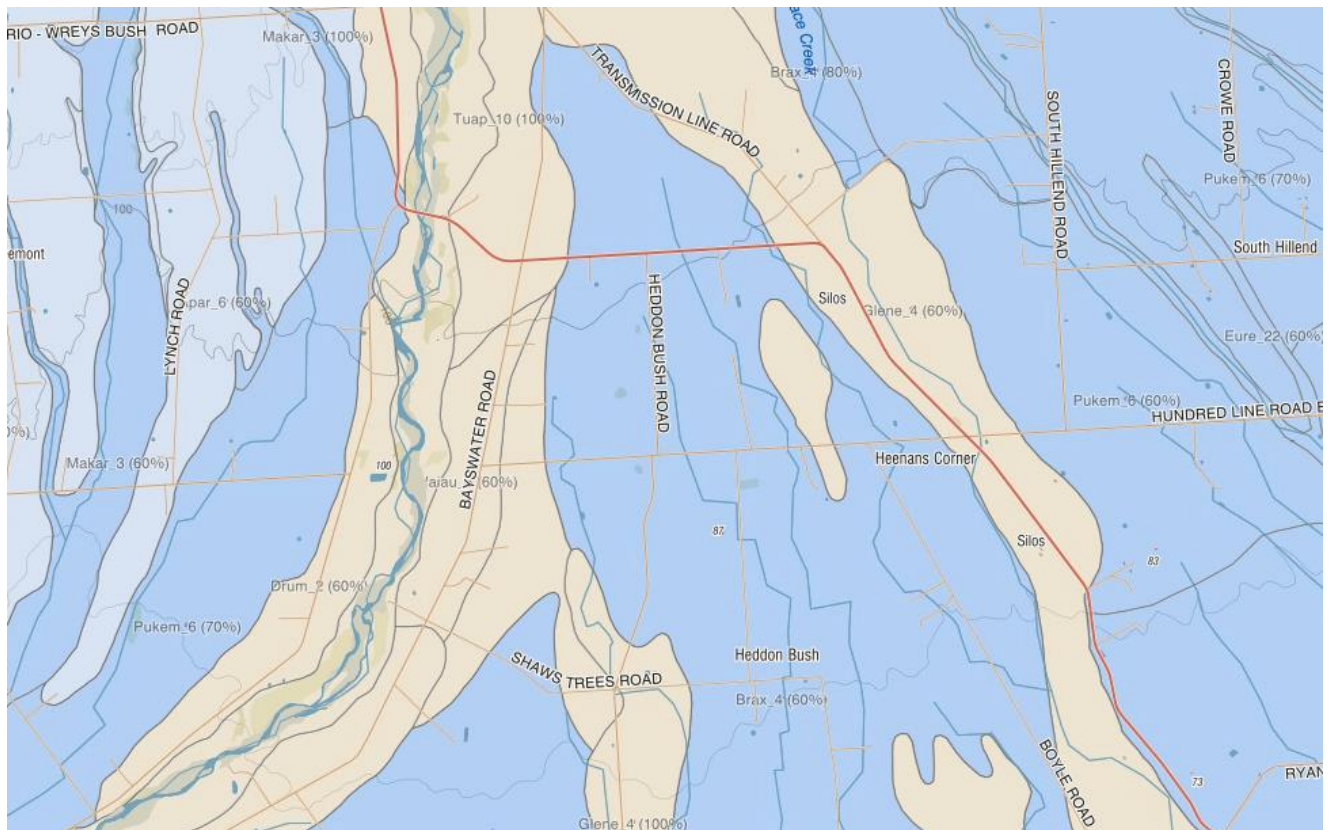


**Figure 3: Location of the WRO properties and catchment above the Orauea River monitoring site, shaded areas showing Environment Southland GIS surface catchment areas**

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<sup>1</sup> 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.

<sup>1</sup> <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)**

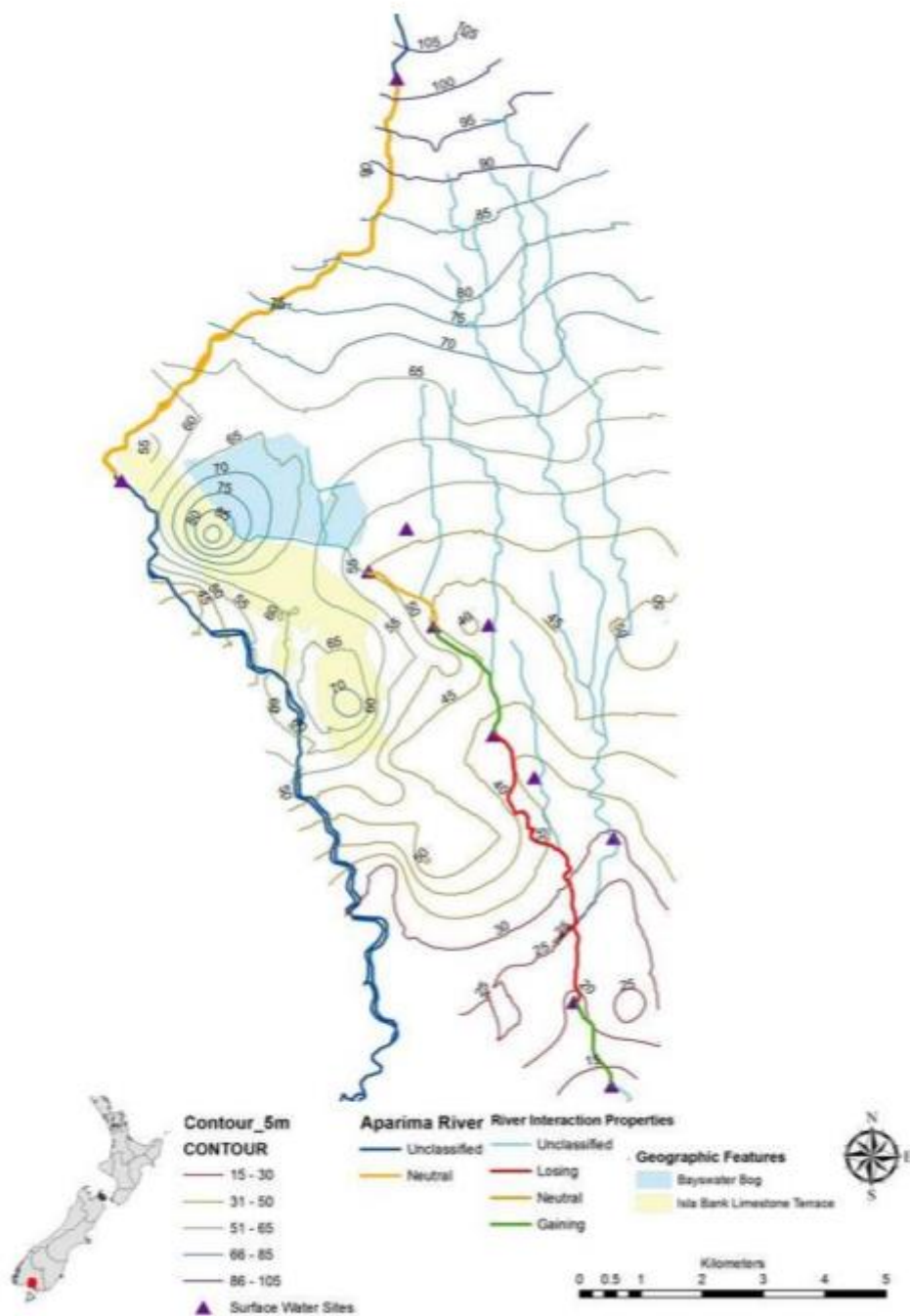
**3.7** Excluding WRO, the properties are underlain by groundwater that is part of the Upper Aparima, Waimatuku, and Central Plains groundwater management zones (as specified in the PSWLP). Information used to inform the PSWLP process (LWP 2017<sup>2</sup>) strongly indicates that the groundwater in 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<sup>3</sup> 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.

<sup>2</sup> Landwaterpeople (2017) Groundwater Provisions of the Proposed Southland Water and Land Plan, Technical Background, Report for Environment Southland

<sup>3</sup> Hitchcock MK (2014) *Characterising the surface and groundwater interactions in the Waimatuku Stream, Southland*, MSc Thesis



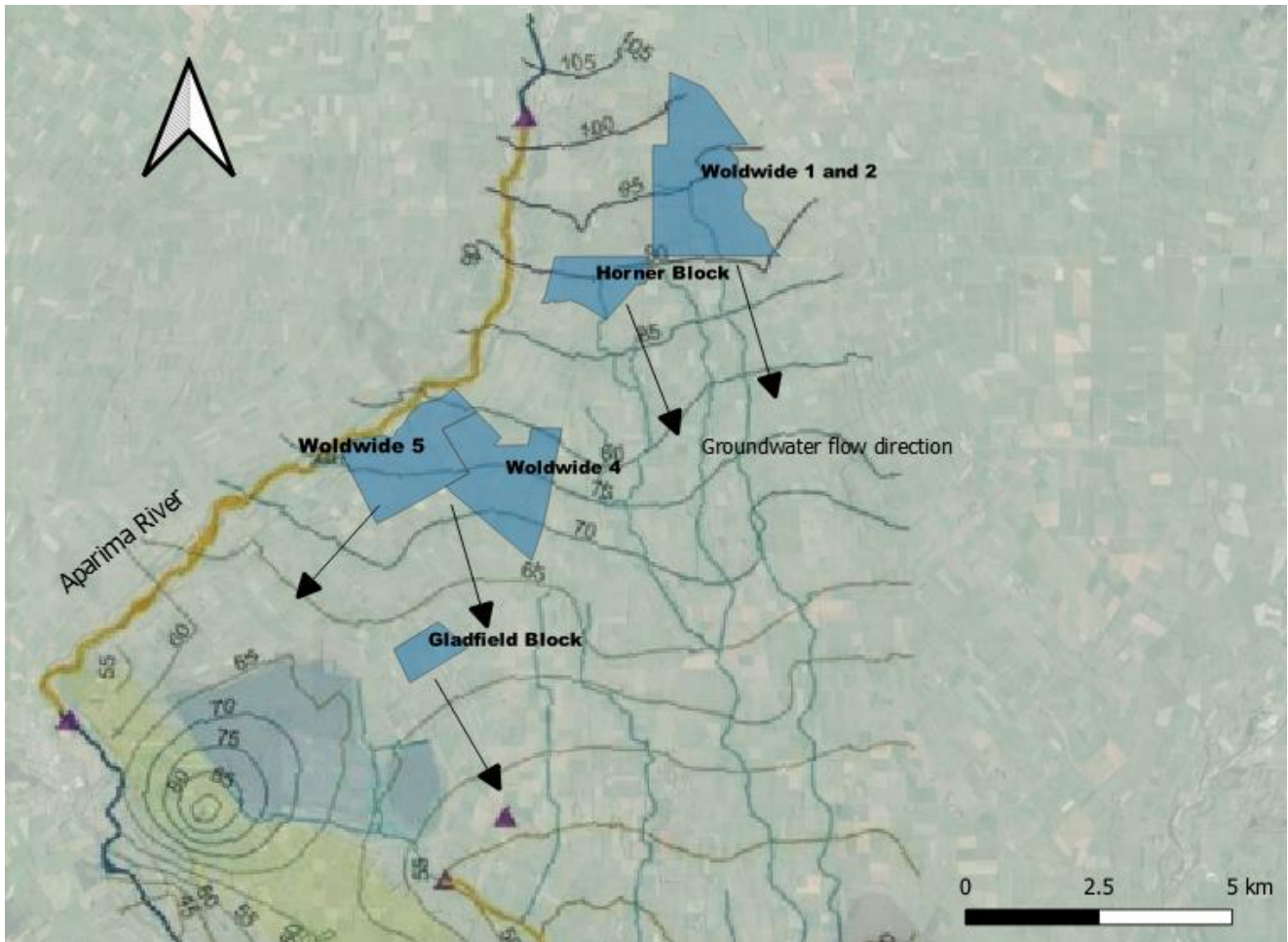


**Figure 5: Piezometric contour diagram from Hitchcock thesis showing groundwater flow direction and some stream sections losing/gaining flows to/from groundwater**

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	<ul style="list-style-type: none"> <li>- Bathing in those sites where bathing is popular;</li> <li>- Trout where present, otherwise native fish;</li> <li>- Stock drinking water;</li> <li>- Ngāi Tahu cultural values, including mahinga kai;</li> <li>- Natural character including aesthetics.</li> </ul>
Proposed Southland Water and Land Plan Objectives 3, 6, 7, & 8	Region-wide	<p>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).</p> <p>6 There is no reduction in the quality of freshwater and water in estuaries and coastal lagoons by,</p> <p>(a) maintaining the quality of water in waterbodies, estuaries and coastal lagoons, where the water quality is not degraded; and</p> <p>(b) improving the quality of water in waterbodies, estuaries and coastal lagoons, that have been degraded by human activities.</p> <p>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.</p> <p>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</p> <p>(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:</p> <p>(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</p>

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<sup>4</sup> 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'<sup>5</sup>.
- 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

<sup>4</sup> <https://www.lawa.org.nz/>

<sup>5</sup> 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<sup>6</sup> 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 95<sup>th</sup> percentiles combined with various states that describe the level of infection risk.

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<sup>6</sup> 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 <sup>∞</sup> trigger values
<i>E. Coli</i>	In the worst 25% of all lowland rural sites	<b>E</b> – For more than 30% of the time, the estimated risk is $\geq 50$ in 1000 ( $>5\%$ risk). The predicted average infection risk is $>7\%$ . 5-year median = <b>315 n/100ml</b> Maximum = <b>21,000 cfu/100ml</b>	Likely Improving	$\leq 1,000/100\text{ml}$ Faecal coliforms <sup>#</sup> 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 = <b>1.13 metres</b>	Not assessed	$\geq 1.6$ m when flow below median flow ( $\sim 1.46$ m <sup>3</sup> /s), Unlikely to meet standard
Total Oxidised N	In the worst 50% of all lowland rural sites	<b>A</b> – High conservation values system. Unlikely to be effects on even sensitive species. 5-year median = <b>0.415 g/m<sup>3</sup></b> Maximum = <b>7.8 g/m<sup>3</sup></b>	Very likely improving	$\leq 0.444$ g/m <sup>3</sup> (ANZECC, 2000)* Greater than this trigger value
Ammoniacal N	In the best 25% of all lowland rural sites	<b>A</b> – 99% species protection level. No observed effect on any species tested. 5-year median = <b>0.005 g/m<sup>3</sup></b> Maximum = <b>0.16 g/m<sup>3</sup></b>	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 = <b>0.011 g/m<sup>3</sup></b> Maximum = <b>0.04 g/m<sup>3</sup></b>	Indeterminate	$\leq 0.01$ g/m <sup>3</sup> (ANZECC, 2000)* Greater than this trigger value
Macroinvertebrate Community Index	Fair	MCI 5-year median = <b>93</b> . 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		$\leq 23^\circ\text{C}$ 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 <sup>3</sup> ) NOF Attribute <b>B</b>		$> 80\%$ sat. Does not meet standard
Bacterial/fungal slime		Not assessed by ES		
Periphyton		0.0 – 129.6 mg chl <i>a</i> /m <sup>2</sup> (2014 – 2019) 83 <sup>rd</sup> ile = 49 mg chl <i>a</i> /m <sup>2</sup> NOF Attribute potentially <b>A</b>		$< 120$ mg chl <i>a</i> /m <sup>2</sup> filam. algae $< 200$ mg/m <sup>2</sup> diatom/cyanob. Likely to meet standard
Fish		Not assessed by ES		

<sup>∞</sup>Australian and New Zealand Environment and Conservation Council, 2000, Australian and New Zealand guidelines for fresh and marine water quality.

<sup>#</sup> PSWLP standard is  $\leq 1,000$  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 <sup>∞</sup> trigger values
<i>E. Coli</i>	In the worst 50% of all lowland rural sites	<b>D</b> – 20-30% of the time, the estimated risk is $\geq 50$ in 1000 ( $>5\%$ risk). The predicted average infection risk is $>3\%$ *. 5-year median = <b>130 n/100ml</b> Maximum = <b>68,000 cfu/100ml</b>	Very likely Improving	$\leq 1,000/100\text{ml}$ Faecal coliforms <sup>#</sup> 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 = <b>2.305 metres</b> Maximum = <b>5.72 metres</b>	Likely improving	$\geq 1.6$ m when flow below median flow (27.4 m <sup>3</sup> /s), Does not meet standard
Total Oxidised N	In the worst 50% of all lowland rural sites	<b>B</b> – Some growth effect on up to 5% of species. 5-year median = <b>0.665 g/m<sup>3</sup></b> Maximum = <b>1.78 g/m<sup>3</sup></b>	Very likely improving	$\leq 0.444$ g/m <sup>3</sup> (ANZECC, 2000)* Greater than this trigger value
Ammoniacal N	In the best 25% of all lowland rural sites	<b>A</b> – 99% species protection level. No observed effect on any species tested. 5-year median = <b>0.005 g/m<sup>3</sup></b> Maximum = <b>0.12 g/m<sup>3</sup></b>	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 = <b>0.006 g/m<sup>3</sup></b> Maximum = <b>0.05 g/m<sup>3</sup></b>	Likely improving	$\leq 0.01$ g/m <sup>3</sup> (ANZECC, 2000)* Greater than this trigger value
Macroinvertebrate Community Index	Good	MCI 5-year median = <b>100</b> . 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		$\leq 23^\circ\text{C}$ 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 <sup>3</sup> ) NOF Attribute <b>B</b>		$> 80\%$ sat. Meets standard
Bacterial/fungal slime		Not assessed by ES		
Periphyton		0.0 – 301 mg chl <i>a</i> /m <sup>2</sup> (2014 - 2018) NOF Attribute potentially <b>C</b> 92%ile = 181 mg chl <i>a</i> /m <sup>2</sup>		$< 120$ mg chl <i>a</i> /m <sup>2</sup> filam. algae $< 200$ mg/m <sup>2</sup> diatom/cyanob. Unlikely to meet standard
Fish		Not assessed by ES		

<sup>∞</sup>Australian and New Zealand Environment and Conservation Council, 2000, Australian and New Zealand guidelines for fresh and marine water quality.

<sup>#</sup> PSWLP standard is  $\leq 1,000$  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 <sup>∞</sup> trigger values
<i>E. Coli</i>	In the worst 25% of all lowland rural sites	<b>E</b> – For more than 30% of the time, the estimated risk is $\geq 50$ in 1000 ( $>5\%$ risk). The predicted average infection risk is $>7\%$ . 5-year median = <b>450 n/100ml</b> Maximum = <b>21,000 cfu/100ml</b>	Very likely Improving	$\leq 1,000/100\text{ml}$ Faecal coliforms <sup>#</sup> 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 = <b>1.22 metres</b> Maximum = <b>N/A</b>	Very likely Improving	$\geq 1.6$ m when flow below median flow ( $\sim 1.46$ m <sup>3</sup> /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	<b>C</b> – Growth effects on up to 20% of species (mainly sensitive species such as fish). No acute effects 5-year median = <b>3.0 g/m<sup>3</sup></b> Maximum = <b>7.8 g/m<sup>3</sup></b>	Very likely improving (pre 2018 data)	$\leq 0.444$ g/m <sup>3</sup> (ANZECC, 2000)* Greater than this trigger value
Ammoniacal N	In the worst 50% of all lowland rural sites	<b>A</b> – 99% species protection level. No observed effect on any species tested. 5-year median = <b>0.01 g/m<sup>3</sup></b> Maximum = <b>0.16 g/m<sup>3</sup></b>	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 = <b>0.0425 g/m<sup>3</sup></b> Maximum = <b>0.1 g/m<sup>3</sup></b>	Very likely degrading	$\leq 0.01$ g/m <sup>3</sup> (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		$\leq 23^\circ\text{C}$ 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 <sup>3</sup> ) NOF Attribute <b>B</b> band		$> 80\%$ sat. Meets standard
Bacterial/fungal slime		Not assessed by ES		
Periphyton		<b><math>&lt; 1 - 124</math> mg chl <i>a</i>/m<sup>2</sup></b> (annual sampling, 2014 - 2018) 92%ile = 88 mg chl <i>a</i> /m <sup>2</sup> NOF Attribute potentially <b>B</b>	Periphyton monitoring site 2 km downstream	$< 120$ mg chl <i>a</i> /m <sup>2</sup> filam. algae $< 200$ mg/m <sup>2</sup> diatom/cyanob. Does not meet standard
Fish		Not assessed by ES		

<sup>∞</sup>Australian and New Zealand Environment and Conservation Council, 2000, Australian and New Zealand guidelines for fresh and marine water quality.

<sup>#</sup> PSWLP standard is  $\leq 1,000$  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 <sup>∞</sup> trigger values
<i>E. Coli</i>	In the worst 50% of all lowland rural sites	<b>D</b> – 20-30% of the time, the estimated risk is $\geq 50$ in 1000 ( $>5\%$ risk). The predicted average infection risk is $>3\%$ *. 5-year median = <b>130 n/100ml</b> Maximum = <b>10,000 cfu/100ml</b>	Likely Improving	$\leq 1,000/100\text{ml}$ Faecal coliforms <sup>#</sup> 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 = <b>1.815 metres</b> Maximum = <b>6.2 metres</b> Seven results during 2009 – 2018 did not comply with PSWLP WQ standard	Indeterminate	$\geq 1.6$ m when flow below median flow (27.4 m <sup>3</sup> /s), Does not meet standard
Total Oxidised N	In the worst 25% of all lowland rural sites	<b>B</b> – Some growth effect on up to 5% of species. 5-year median = <b>0.94 g/m<sup>3</sup></b> Maximum = <b>2.5 g/m<sup>3</sup></b>	Not assessed	$\leq 0.444$ g/m <sup>3</sup> (ANZECC, 2000)* Greater than this trigger value
Ammoniacal N	In the best 25% of all lowland rural sites	<b>A</b> – 99% species protection level. No observed effect on any species tested. 5-year median = <b>0.005 g/m<sup>3</sup></b> Maximum = <b>0.04 g/m<sup>3</sup></b>	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 = <b>0.006 g/m<sup>3</sup></b> Maximum = <b>0.04 g/m<sup>3</sup></b>	Not assessed	$\leq 0.01$ g/m <sup>3</sup> (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		$\leq 23^\circ\text{C}$ 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 <sup>3</sup> ) NOF Attribute <b>B</b> band		$> 80\%$ sat. Meets standard
Bacterial/fungal slime		Not assessed by ES		
Periphyton		4.5 – 361 mg chl <i>a</i> /m <sup>2</sup> (annual sampling, 2004 - 2018) 92%ile = 158 mg chl <i>a</i> /m <sup>2</sup> NOF Attribute potentially <b>C</b>		$<120$ mg chl <i>a</i> /m <sup>2</sup> filam. algae $< 200$ mg/m <sup>2</sup> diatom/cyanob. Does not meet standard
Fish		Not assessed by ES		

<sup>∞</sup>Australian and New Zealand Environment and Conservation Council, 2000, Australian and New Zealand guidelines for fresh and marine water quality.

<sup>#</sup> PSWLP standard is  $\leq 1,000$  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
<i>E. coli</i> (n/100ml)	315	130	450	130
Clarity (BD) (m)	1.13	2.305	1.22	1.815
Total oxidised N (g/m <sup>3</sup> )	0.415	0.665	3.0	0.94
Dissolved reactive P (g/m <sup>3</sup> )	0.011	0.006	0.0425	0.006
Periphyton (mg chl- <i>a</i> /m <sup>2</sup> ) (83 & 92%iles)	49 (83 %ile)	181 (92 %ile)	88 (92 %ile)	143 (92 %ile)
MCI	93	100	87*	95

\* Estimate

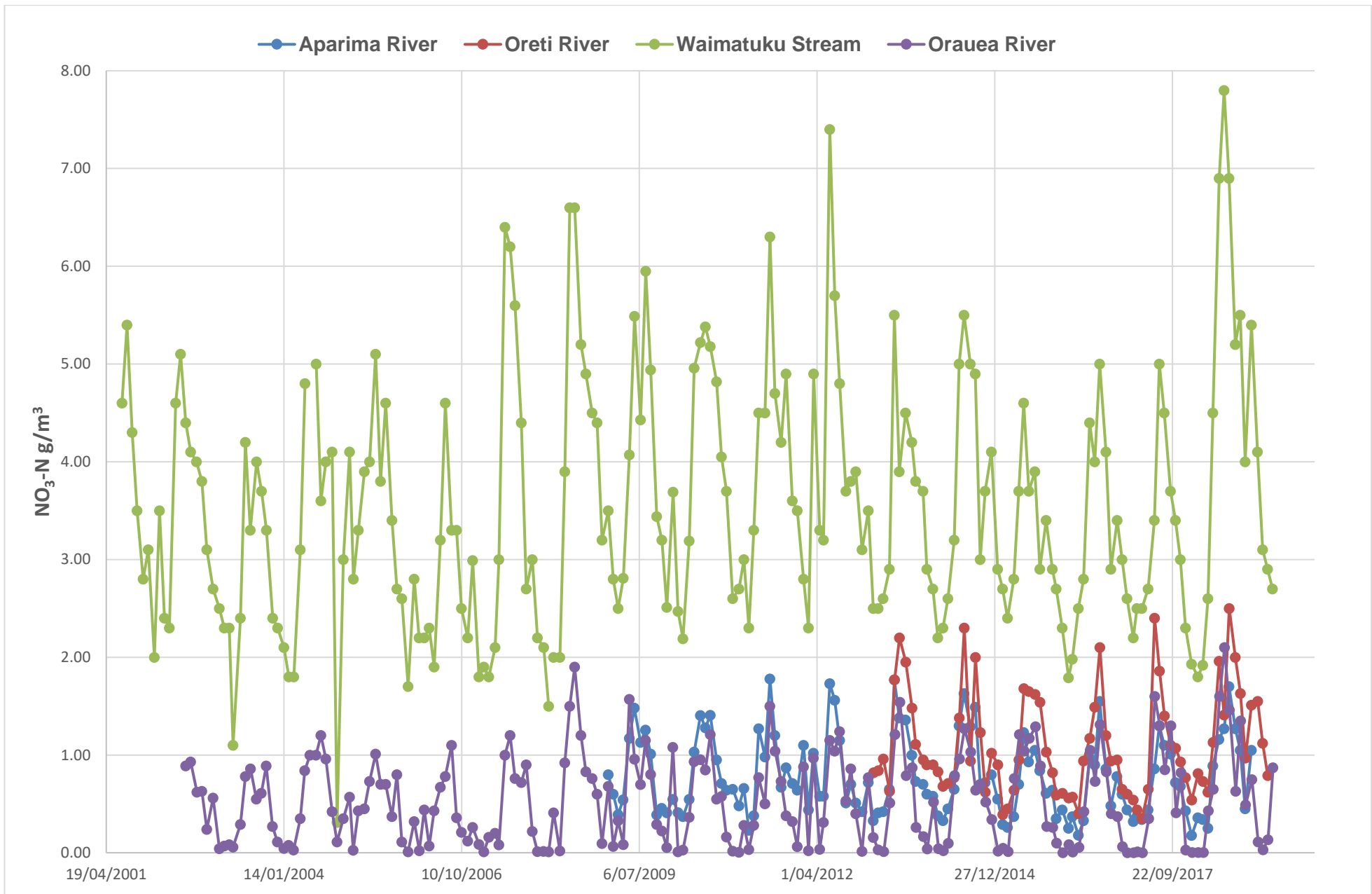
5.9 One key feature of the above summary table is that the Waimatuku Stream stands out as significantly degraded when compared to the other three rivers and with the exception of periphyton biomass, this is generally consistent across these key variables.

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**

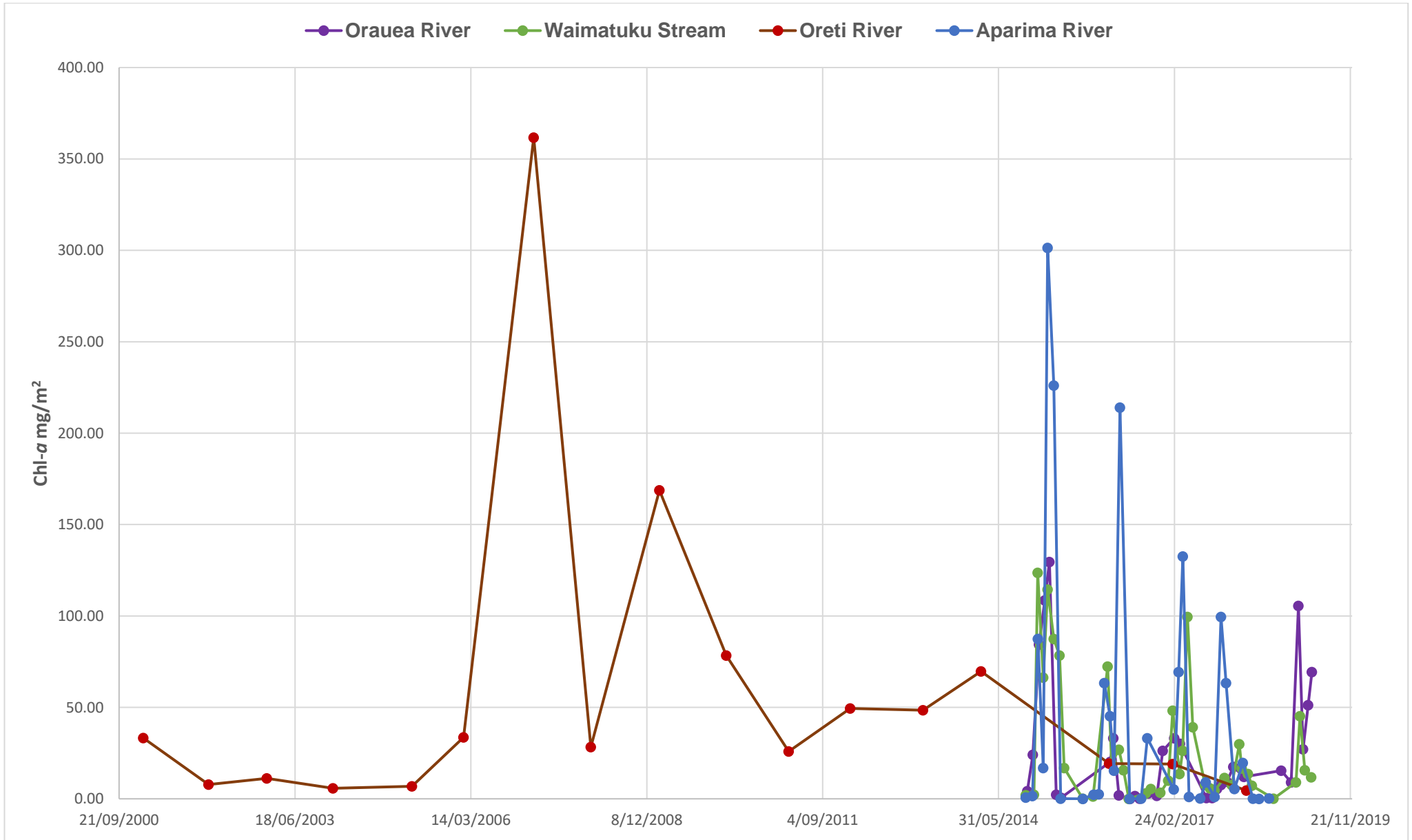


Figure 8: Periphyton chlorophyll-a biomass at four sites on the four rivers/streams

- 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<sup>3</sup>.

### **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<sup>7</sup>.

### **Groundwater Quality**

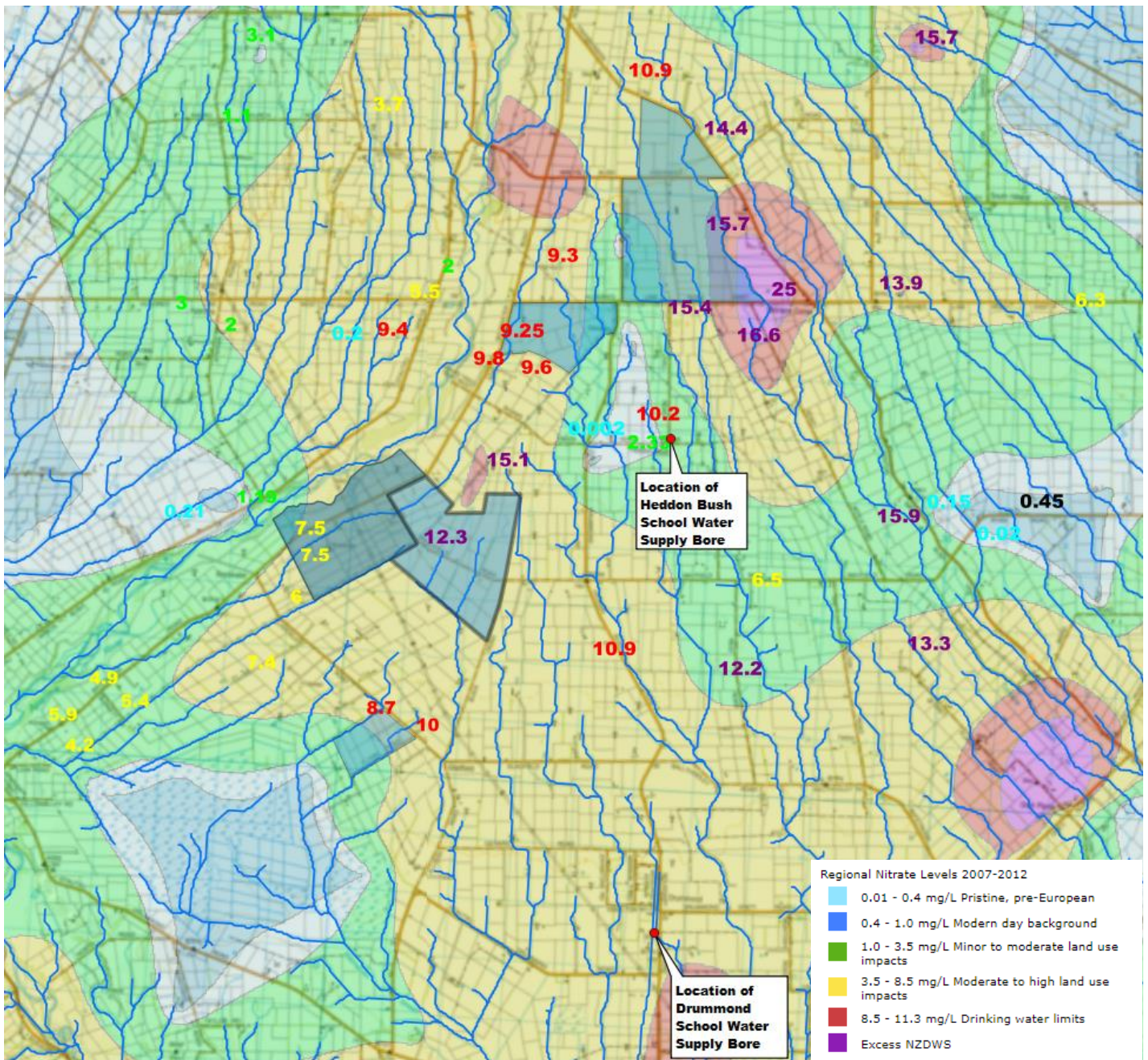
- 5.24 The results of Environment Southland's survey of regional nitrate nitrogen concentrations are provided as a layer within the Beacon public GIS system (Figure 9) and indicate that the WW1&2& HB properties are in an area where the underlying unconfined groundwater was likely to have been generally 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<sup>3</sup>. 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

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<sup>7</sup> 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

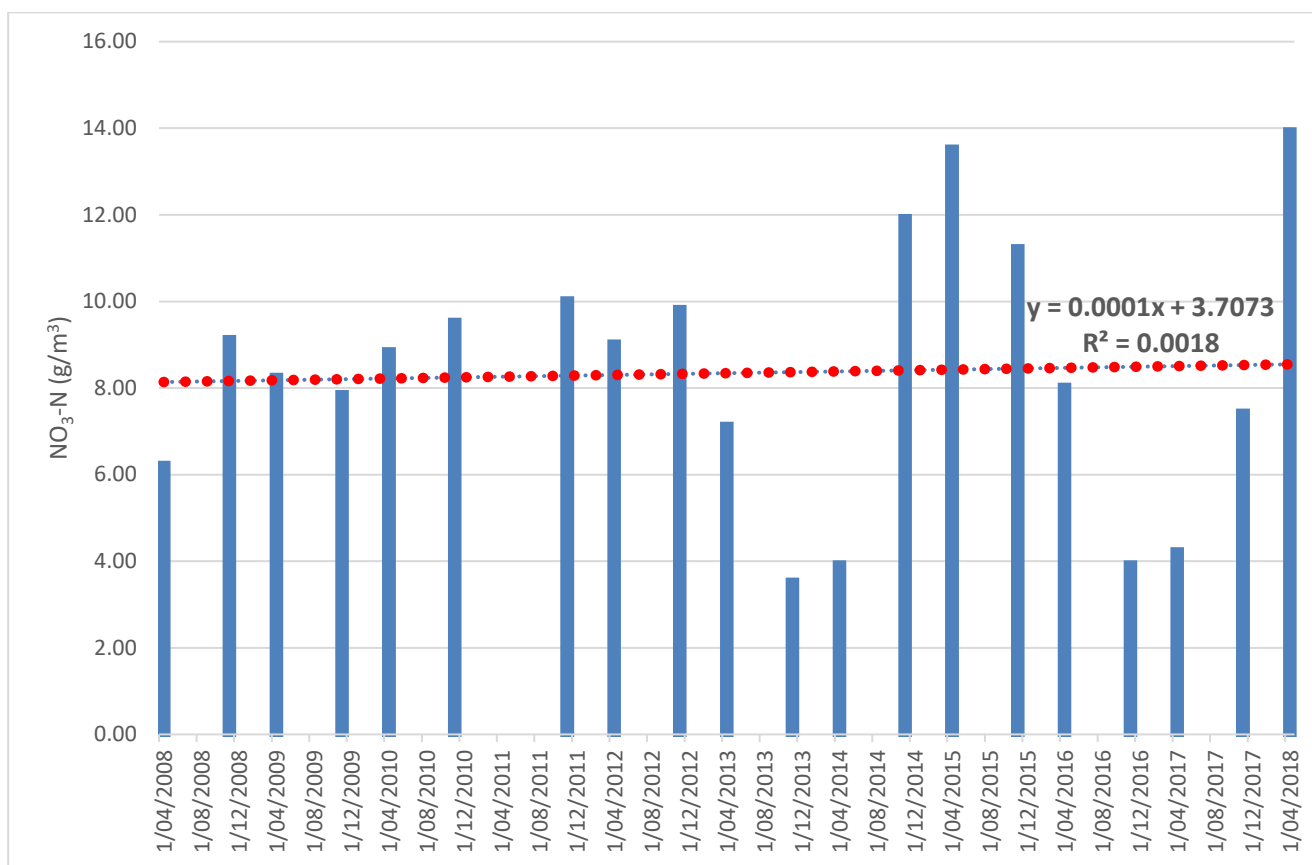
concentrations in deeper groundwater can have lower concentrations than found in shallow bores<sup>8</sup>.

- 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

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<sup>8</sup> Hughes B (2009) Review of groundwater quality monitoring results from the Heenans Corner nested piezometer site, 20p.

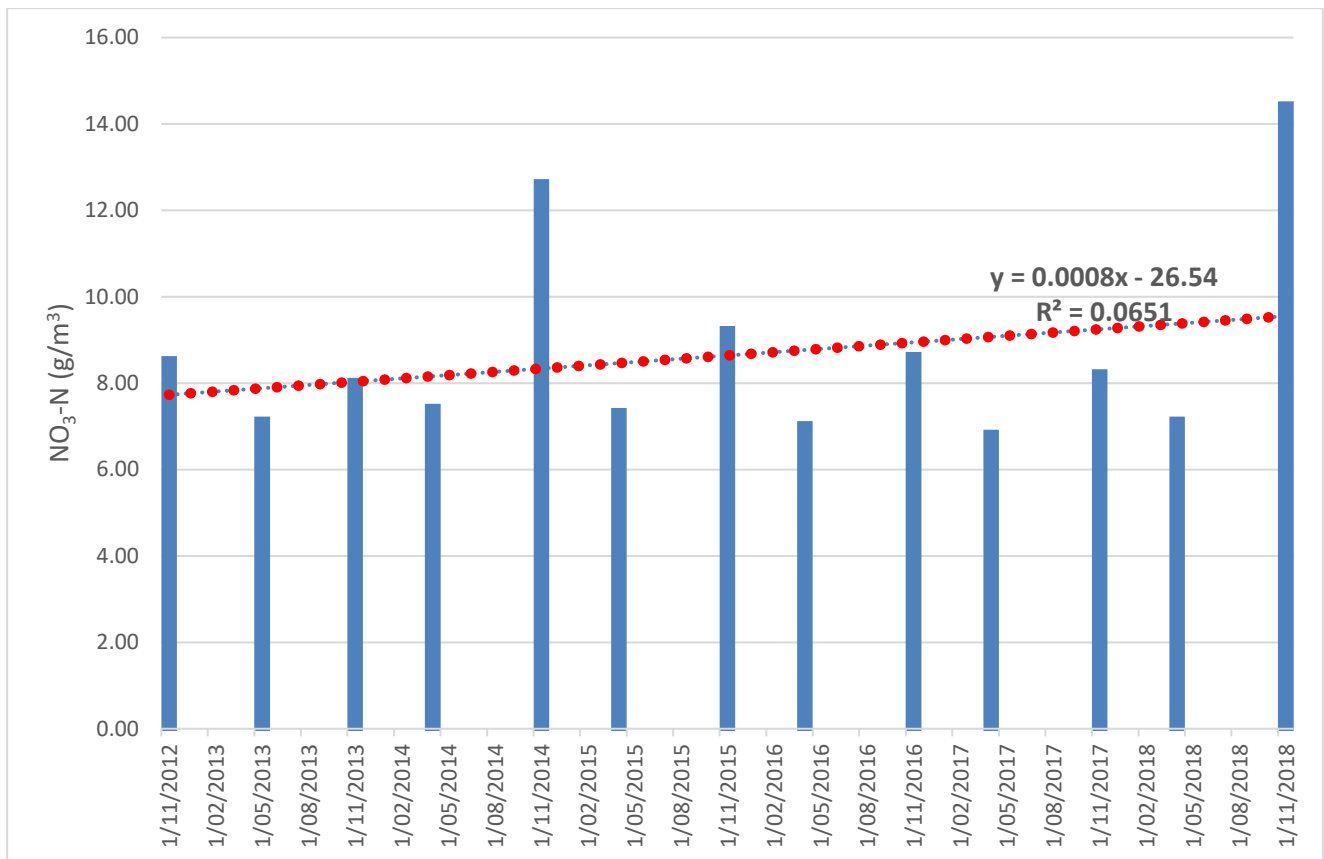
E45/0458 (verified 8.5 m deep with no screen depth information). All of these bores are relatively close to the properties.



**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<sup>2</sup> 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.



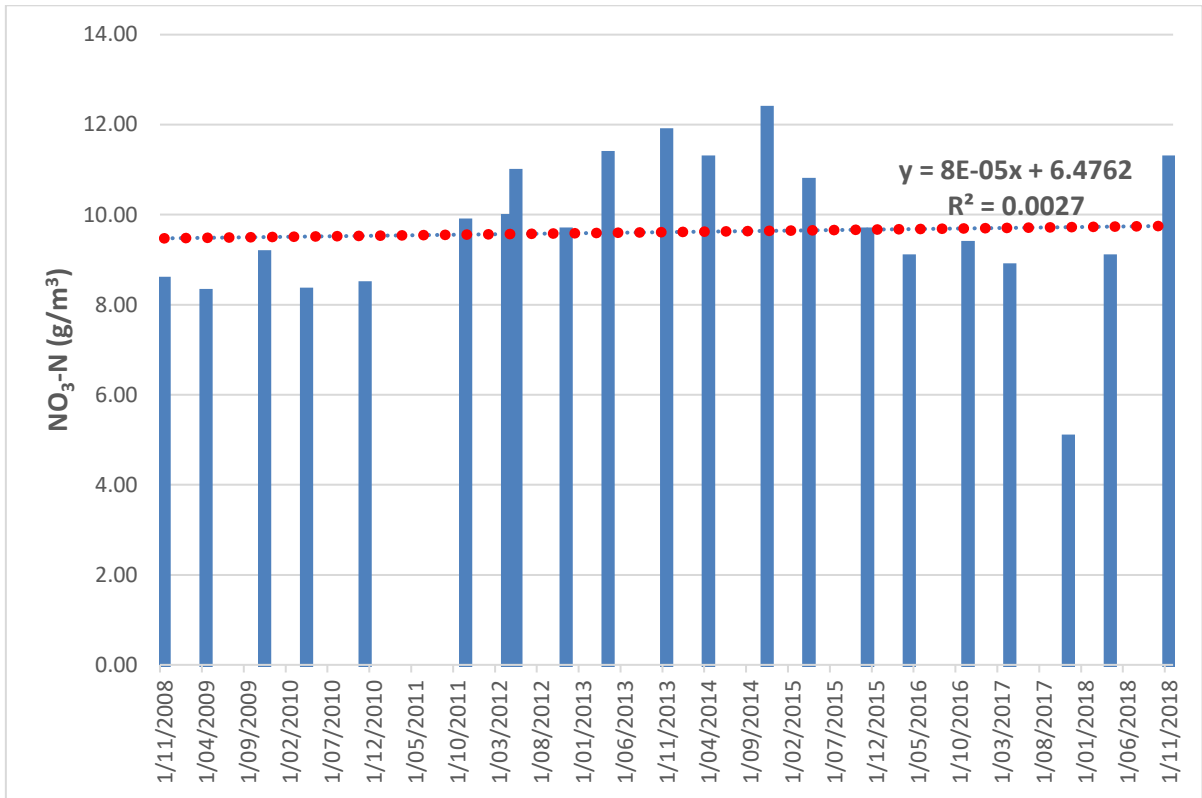
**Figure 11: Nitrate nitrogen concentrations in groundwater from bore E45/0610, 2009-2018 (showing as a purple '14.4' north east of the property in Figure 9)**

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<sup>2</sup> value indicates that there is little confidence that this indicates a real trend in groundwater nitrate nitrogen concentrations.

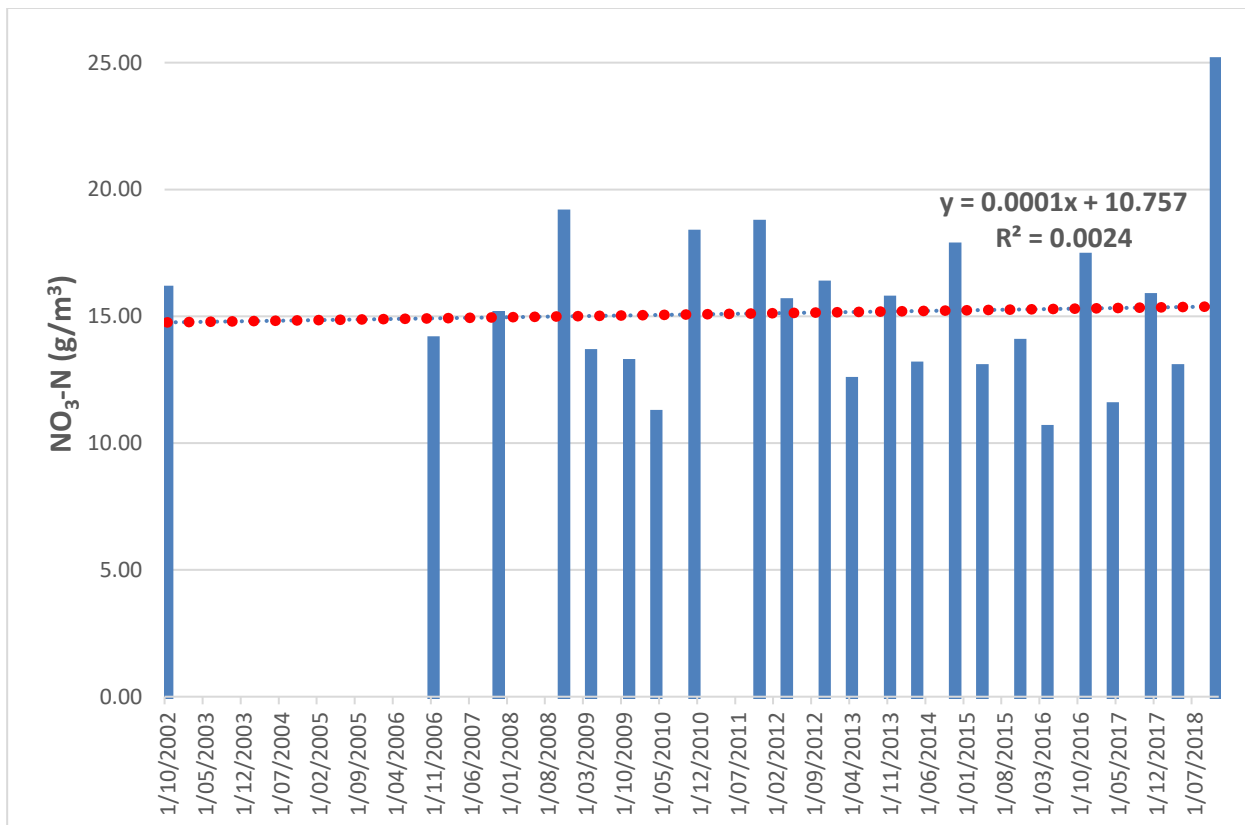
5.35 The use code for this bore is noted as dairy use rather than groundwater quality monitoring so it is less likely that groundwater from this bore is directly influenced by dairy shed effluent discharges. This bore was not inspected as part of the bore observation assessment.

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.

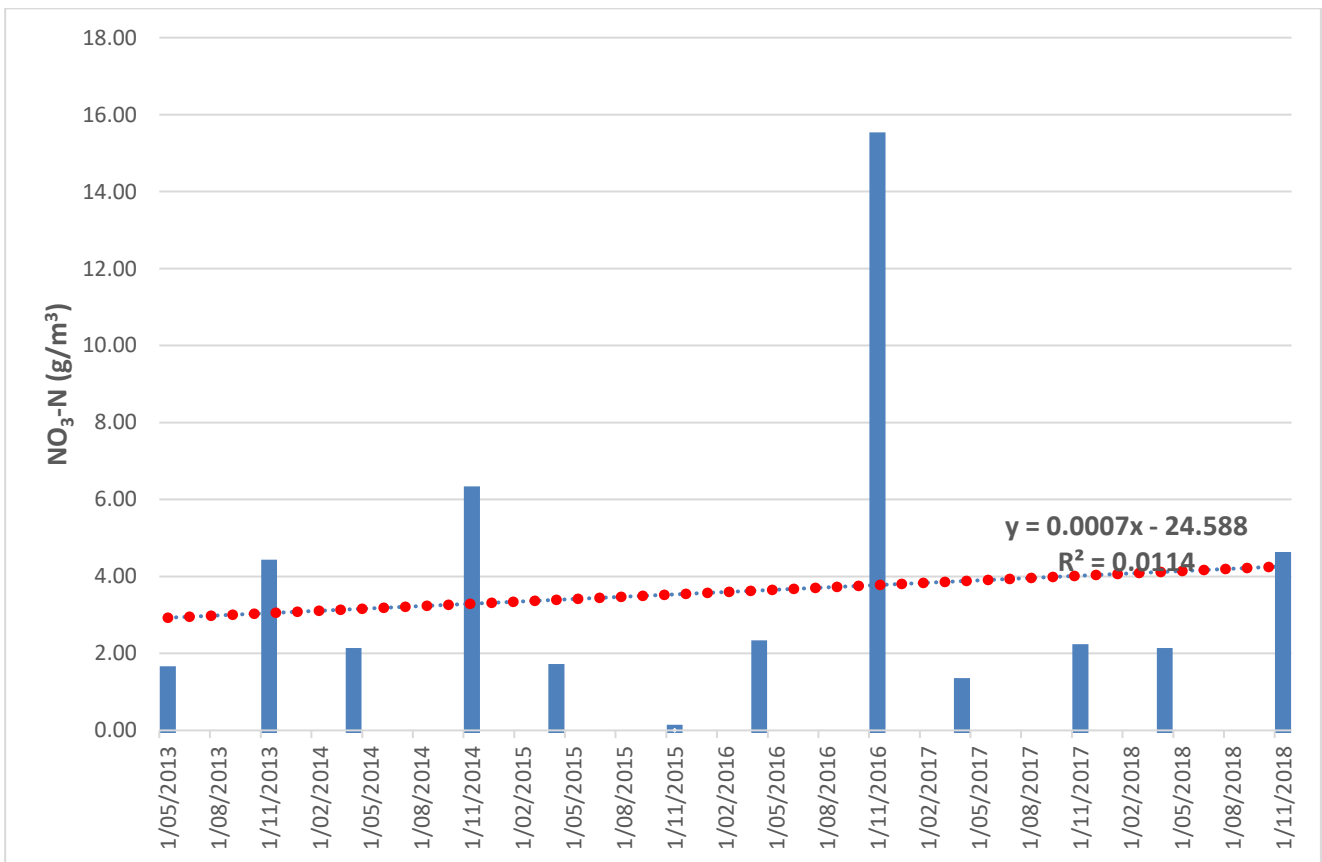


**Figure 12: Nitrate nitrogen concentrations in groundwater from bore E45/0458, 2008-2018 (showing as a purple '12.3' south west of the property in Figure 9)**



**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<sup>3</sup> 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 <sup>3</sup> )	E. coli (MPN/100ml)
2/6/17 (ES sample)	2.33	<1.0
2/11/17 <sup>9</sup>		<1
18/12/17	2.0	<1.0
12/1/18	1.8	<1.0
15/2/18 <sup>8</sup>		<1
14/3/18	1.8	<1.0

<sup>9</sup> 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<sup>3</sup>).
- 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<sub>3</sub>-N/m<sup>3</sup>) concentration of nitrate nitrogen than found in the shallower bores (~12 g NO<sub>3</sub>-N/m<sup>3</sup>) 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<sup>10</sup>.
- 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.

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<sup>10</sup> 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<sup>11</sup>. 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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<sup>11</sup> 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 into 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<sup>12</sup> and the New River Estuary<sup>13</sup>. 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<sup>14</sup> 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<sup>15</sup> 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*

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

<sup>13</sup> 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.

<sup>14</sup> Robertson, B.M. and Stevens, L.M. 2009. Waiau Lagoon 2009 Synoptic survey, macrophyte mapping and vulnerability assessment. 22p.

<sup>15</sup> 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<sup>16</sup>. 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.

<sup>16</sup> 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 <sup>1</sup>	N	P	Overall <sup>1</sup>	N	P	Overall <sup>1</sup>
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	<ul style="list-style-type: none"> <li>Optimised nutrient inputs</li> <li>Low solubility P</li> <li>Wetlands</li> </ul>	<ul style="list-style-type: none"> <li>Stock exclusion from streams</li> <li>Improved nutrient management</li> <li>Improved farm dairy effluent (FDE) management</li> </ul>
Mitigation level 2	M2	<ul style="list-style-type: none"> <li>Stock exclusion from streams</li> <li>Reduced stocking rates, improved productivity</li> </ul>	<ul style="list-style-type: none"> <li>Wetlands</li> <li>Improved FDE management</li> <li>Reduced stocking rates, improved per animal productivity.</li> </ul>
Mitigation level 3	M3	<ul style="list-style-type: none"> <li>Grass buffer strips</li> <li>Feed pad for beef cattle</li> </ul>	<ul style="list-style-type: none"> <li>Restricted grazing strategies</li> <li>Grass buffer strips</li> <li>Improved FDE management</li> </ul>

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*<sup>17</sup>.
- 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.

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<sup>17</sup> 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**

<b>Woldwide One &amp; Two</b>			
	<b>Current Farm System</b>	<b>Proposed Farm system</b>	<b>Reduction</b>
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

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

<b>Combined Woldwide One &amp; Two &amp; Horner Block</b>			
	<b>Current Total Farm System</b>	<b>Proposed Total Farm system</b>	<b>Reduction</b>
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**

<b>Woldwide Four Current &amp; Final Proposed</b>			
	<b>Current Farm System</b>	<b>Proposed Farm system</b>	<b>Reduction</b>
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**

<b>Woldwide Five Current &amp; Final Proposed</b>			
	<b>Current Farm System</b>	<b>Proposed Farm system</b>	<b>Reduction</b>
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<sup>18</sup>. Indeed, comparisons of modelled and measured nitrate losses for dairy farms in Southland found<sup>19</sup>:

- *“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.”*

<sup>18</sup> Shepherd M *et al* (2013) Overseer: accuracy, precision, error and uncertainty, FLRC workshop proceedings

<sup>19</sup> 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<sup>20</sup>. 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<sup>21</sup>.
- 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-term annual average nutrient loss estimates<sup>22</sup>. 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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<sup>20</sup> Shepherd M *et al* (2013) Overseer: accuracy, precision, error and uncertainty, FLRC workshop proceedings

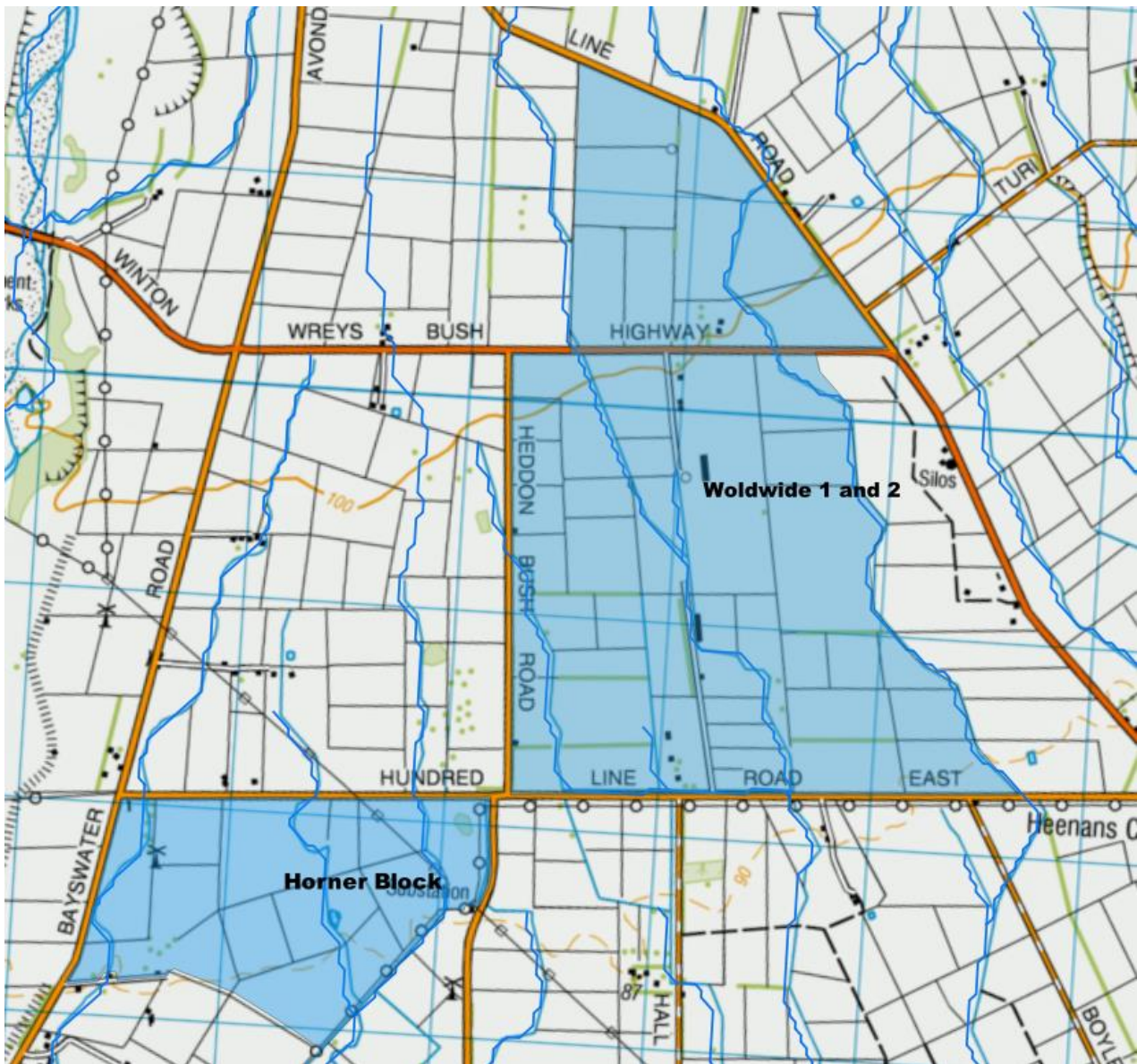
<sup>21</sup> Wheeler D & Shepherd M (2013) Overseer: Answers to commonly asked questions, RE500/2012/027

<sup>22</sup> 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.

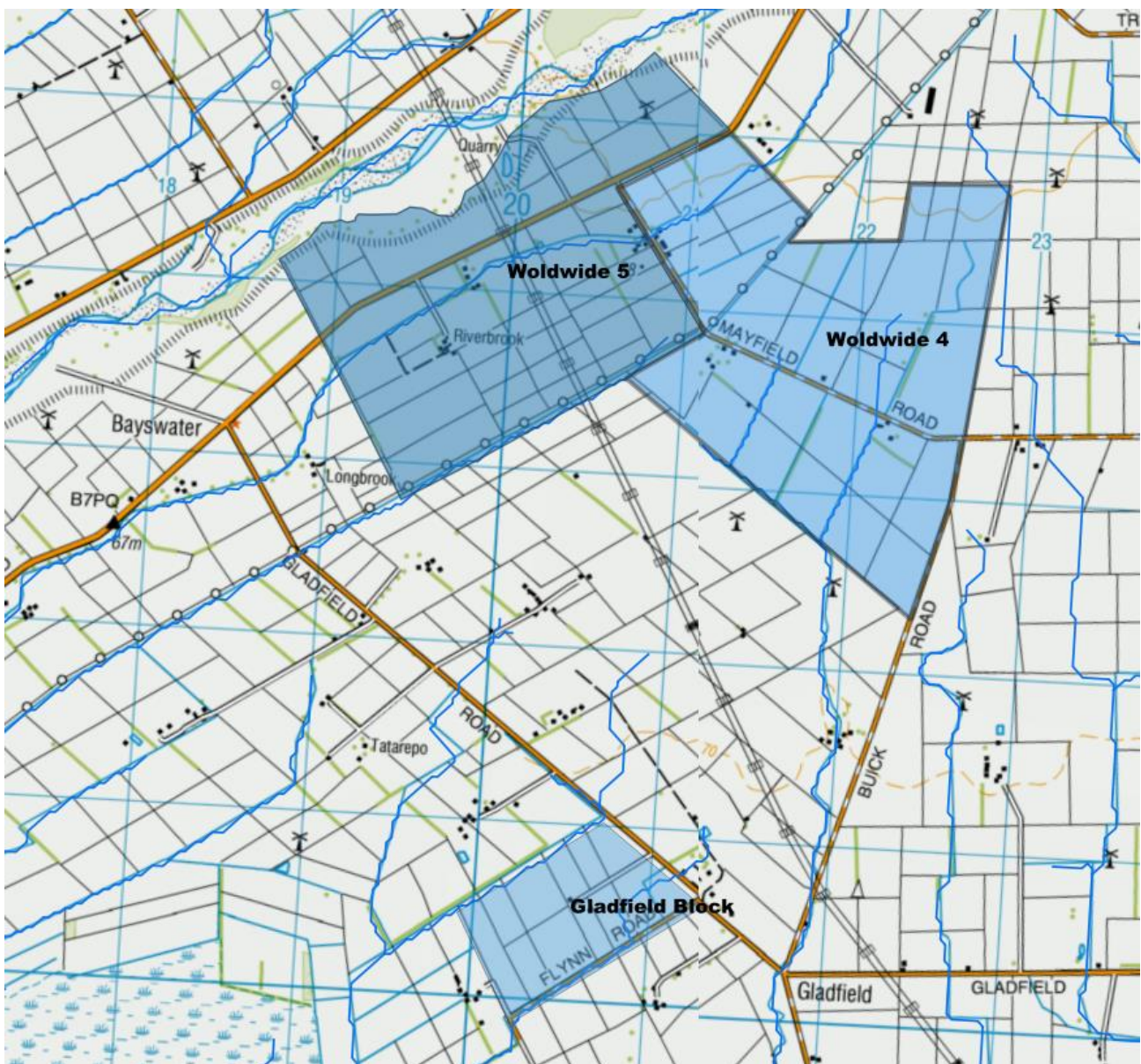


Figure 17: Woldwide 4 & 5 and the Gladfield Block and key streams/drains

- 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<sup>23</sup>. However, none are currently widely used in RMA planning or regulatory processes. One common current approach<sup>24</sup> 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.

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<sup>23</sup> 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.

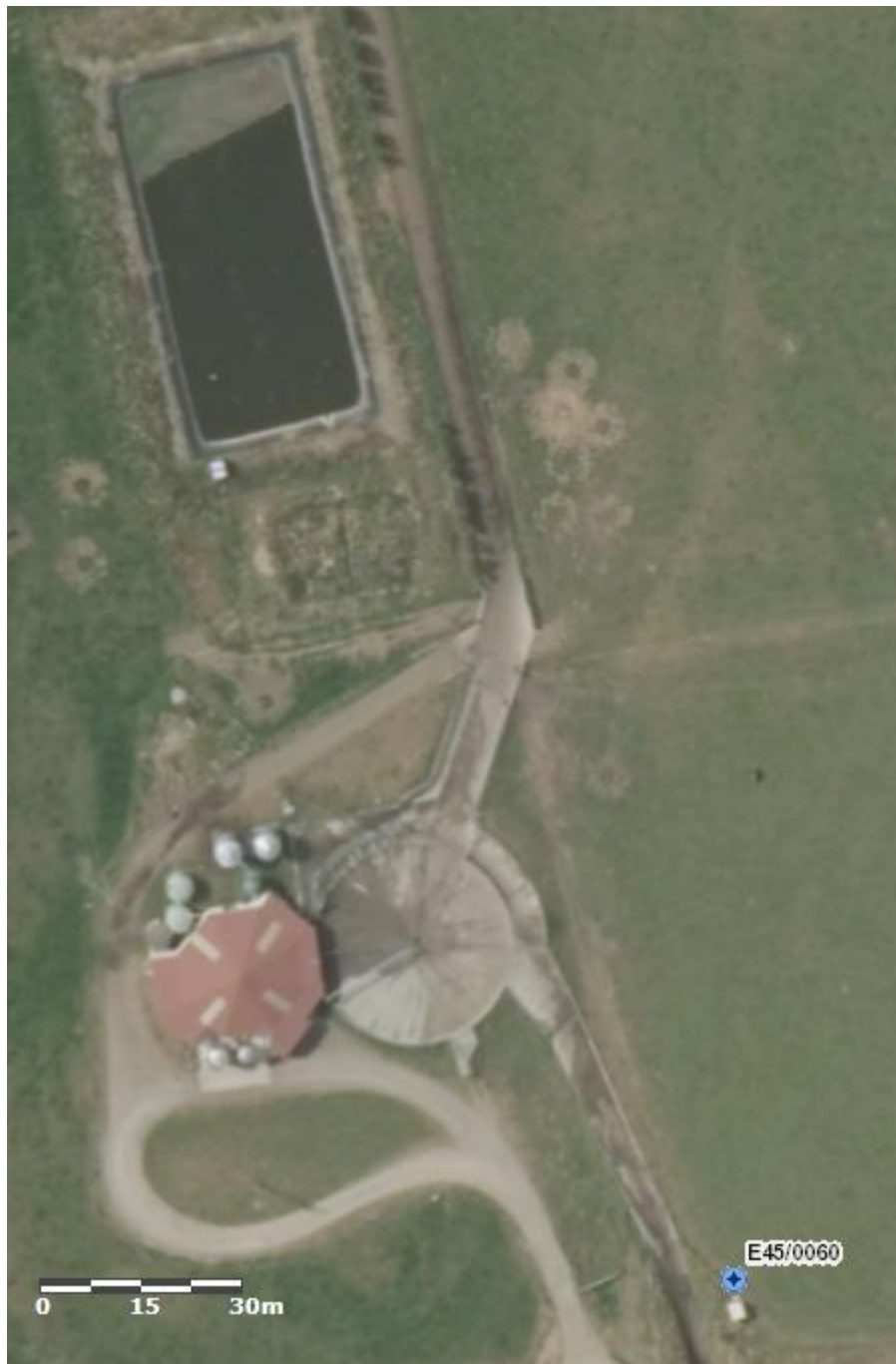
<sup>24</sup> It was accepted at a 2018 ES consultant meeting that phosphorus loss modelling can be used as an approximate proxy for sediment and microbiological contaminant losses.

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<sup>25</sup>. It appears that the results for these bores (E45/0768-0772) were

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<sup>25</sup> 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<sub>3</sub>-N/m<sup>3</sup>.

- 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/m<sup>3</sup>. 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<sup>26</sup>. The activities proposed at WW1&2 would not result in a significant increase in the existing level of microbiological risk to this water supply.

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<sup>26</sup> <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 future 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

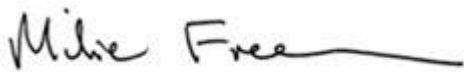
- 10.3 The information from the Overseer and additional modelling combined with the specific good management practices/mitigation measures provide strong evidence for a real but small reduction in the N loading to groundwater and associated artificial drainage from all properties. If this occurs across 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<sup>27</sup> before reductions in N concentrations are observed in bores used to monitor groundwater quality and in surface water recharged by that groundwater.

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<sup>27</sup> 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.

A handwritten signature in black ink that reads "Mike Freeman". The signature is written in a cursive style with a long horizontal line extending to the right.

Mike Freeman, BSc, PhD  
Senior Scientist/Planner  
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 25<sup>th</sup> 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

**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*

Q Scandrett

**Agricultural & Engineering Consultant**

**Dairy Green Ltd**

# **Attachment 2**

Response to S92 request for information on groundwater abstraction effects

# Dairy Green Ltd

Practical Engineering Solutions

Consents, Effluent, Stock water, Irrigation

Design through to Installation

15 August 2019

Environment Southland  
Private Bag 90116  
Invercargill 9348

Our ref:  
ES ref: APP- 20191052

Attn: Aurora Grant

Dear Aurora,

***RE: Request for Further Information under Section 92(1) of the Resource Management Act 1991 – APP 20191052.***

Please find below our response to your request for further information dated 15 July 2019.

Please let me know if you have any further questions or require any further explanations.

Yours sincerely,

Nessa Legg

Consultant for *Woldwide 1 Limited and Woldwide 2 Limited*

## **Assessment of effects on the freshwater resources associated with the proposed abstraction of groundwater.**

Please see responses to questions 2 – 5, noting that technical analyses have been provided by Aqualinc Research Limited.

### **Response to Question 2:**

As clarified via email on 15/7/19, the proposed abstraction is 180 m<sup>3</sup>/day, which aligns with the Environment Southland Guideline of 120 l/cow/day. This is the figure stated in the proposal and AEE. There is an error on page 21 of the application, where 180 m<sup>3</sup>/day is correctly stated but erroneously 91,000 litres is stated for WW1. This should be 84,000 litres as is stated in the proposal (pages 105/106) and AEE. A maximum daily take of 84,000 litres represents an increase of 24,000 litres relative to the current consented maximum daily take.

### **Responses to questions 3 – 5**

No change in maximum daily abstraction (96 m<sup>3</sup>/day) is proposed for bores E45/0083 and E45/0727 combined and the maximum rate will not exceed 2 l/s. The maximum daily take from bore E45/0071 is proposed to increase by 24 m<sup>3</sup> to 84 m<sup>3</sup>/day although the maximum rate will not exceed 2 l/s.

## **Environmental Setting**

To accurately assess the stream depletion effects it is important to look at the environmental setting of the aquifer and provide a conceptual model as per the requirements of Appendix L.2.

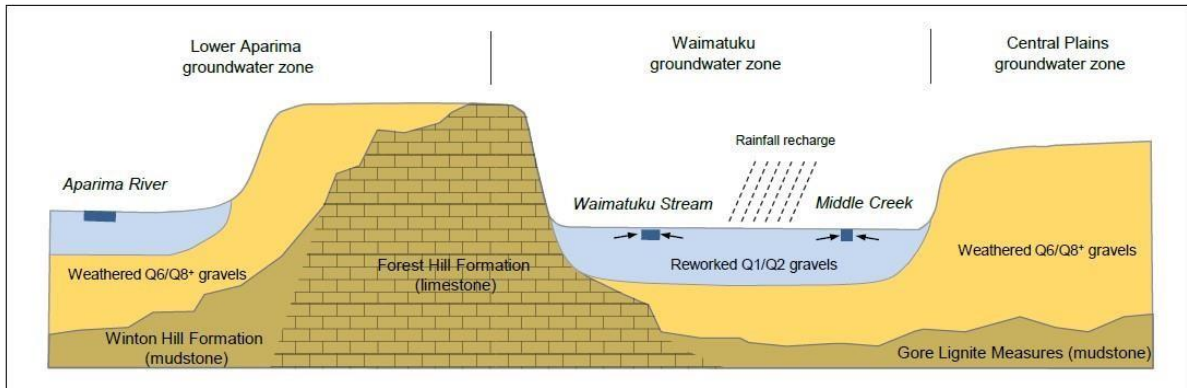
The subsurface geology of the wider Central Plains area consists of a variable thickness of alluvial gravels (between 20 and 100+ metres thick) which overlie Tertiary mudstone and limestone of the East Southland Group (i.e. the limestone deposits of the Winton Hill and Forest Hill Formations and the mudstone and lignite deposits of the Gore Lignite Measures). Outcrops of the Forest Hill Formation form a prominent limestone ridge running from Otautau to Isla Bank that hosts an extensive unconfined aquifer system with significant secondary permeability developed through jointing. The limestone sediments of the Winton Hill formation are much thinner and are interspersed with sand, lignite and mudstone sediments.

The alluvial deposits of the Upper and Lower Aparima groundwater management zones comprise remnant mid-Quaternary alluvial terraces bisected by recent (Q1) gravel deposits of the Aparima River floodplain. The late Quaternary (Q2) alluvial deposits are moderately weathered and form an extensive low yield unconfined aquifer which is typically less than 20 metres thick.

Bore yields increase with proximity to the Aparima River reflecting the reworking of the gravel deposits during river entrenchment. Recent drilling investigations near Drummond and Gladvale also indicated the presence of semi-confined water-bearing layers in the older (Q6-Q8+) alluvial deposits that overlie the Tertiary sediments.

Figure 1 below shows a simple conceptual model of the hydrogeological setting in the vicinity of the proposed take. The figure shows a narrow band of reworked Q1 alluvium along the margins of the Aparima River. While these recent alluvial deposits are hydraulically connected to the Aparima River,

the river itself appears to have limited interaction with the groundwater system in the adjacent Waimatuku groundwater zone which is primarily recharged by local rainfall.



**Figure 1:** Waimatuku groundwater zone schematic.

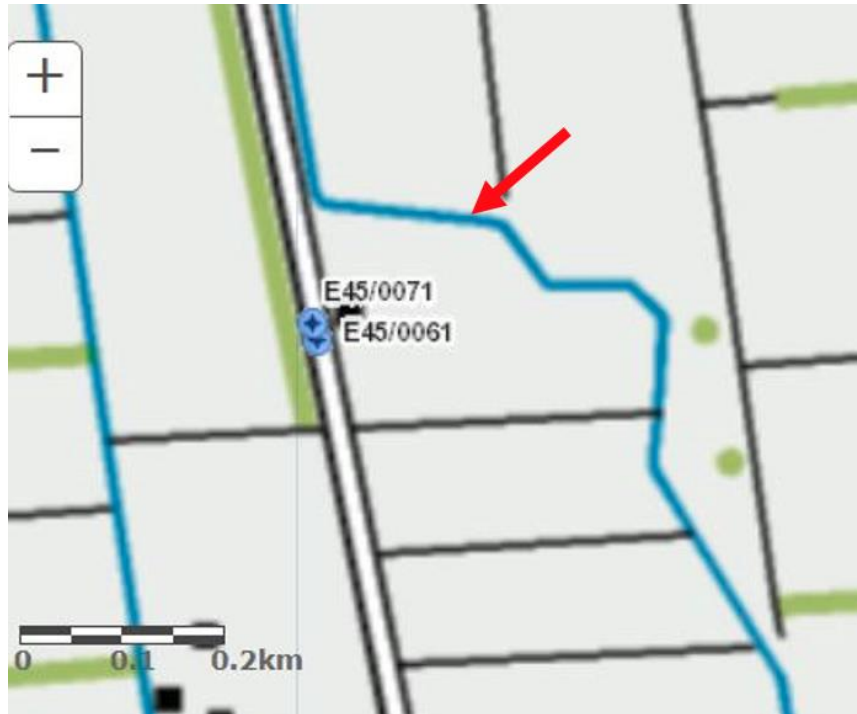
### Stream depletion

Pumping water from a well has the potential to reduce the flow of nearby streams which are connected to groundwater. We have undertaken a preliminary stream depletion assessment using the Hunt (1999) equation.

Please note that the methodology and parameters used in this assessment is based on the recent RFI response for the application APP-20191140. This methodology has been reviewed and approved by Environment Southland.

As such, this assessment assumes a 100% irrigation efficiency (to take account of the water not being used for irrigation). We have used a range of transmissivity and specific yield values. A stream bed conductance of 2 m/day and specific yields between 0.001 and 0.0001 have been used as the typical/default specific yield value for unconfined clay-bound gravel aquifers.

The nearest possible waterway is a stream that discharges into Middle Creek and then into the Waimatuku Stream. This stream, at its closest point, is 130 m from bore E45/0071 (see Figure 2). All of the assessment parameters have been chosen based on advice provided by Brydon Hughes (Liquid Earth) for this specific waterway. Mr Hughes advised that a transmissivity value of 200 m<sup>2</sup>/dy and a storativity value of 0.01 would be appropriate for the assessments. To be conservative we have also assessed the effects using parameters higher and lower than those which were recommended.



1  
Figure 2: Closest waterway to bore E45/0071.

**Table 1:** Stream depletion effects on the tributary of the Waimatuku Stream from pumping bore E45/0071 for 7 days.

Stream depletion effect (% and rate) on the stream at a distance of 130 m after 7 continuous days pumping of 86 m <sup>3</sup> /day (1.0 L/s).		Transmissivity (m <sup>2</sup> /day)		
		100	200	400
Specific yield	0.01	85%; 0.8 L/s	85%; 0.8 L/s	83%; 0.8 L/s
	0.001	85%; 0.8 L/s	85%; 0.8 L/s	83%; 0.8 L/s
	0.0001	95%; 1.0 L/s	95%; 1.0 L/s	95%; 1.0 L/s

**Table 2:** Stream depletion effects on the tributary of the Waimatuku Stream from pumping bore E45/0071 for 300 days.

Stream depletion effect (% and rate) on the stream at a distance of 130 m after 300 continuous days pumping of 86 m <sup>3</sup> /day (1.0 L/s).		Transmissivity (m <sup>2</sup> /day)		
		100	200	400
Specific yield	0.01	98%; 1.0 L/s	98%; 1.0 L/s	98%; 1.0 L/s
	0.001	98%; 1.0 L/s	98%; 1.0 L/s	98%; 1.0 L/s
	0.0001	99%; 1.0 L/s	99%; 1.0 L/s	99%; 1.0 L/s

**Table 3:** Stream depletion effects on the tributary of the Waimatuku Stream from pumping bores E45/0083 and E45/0727 for 7 days.

Stream depletion effect (% and rate) on the stream at a distance of <b>210 m</b> after <b>7</b> continuous days pumping of <b>96 m<sup>3</sup>/day (1.1 L/s)</b> (assumes all water is being taken from the closest bore (E45/0083))		Transmissivity (m <sup>2</sup> /day)		
		100	200	400
Specific yield	0.01	42%; 0.5 L/s	47%; 0.5 L/s	48%; 0.5L/s
	0.001	79%; 0.8 L/s	80%; 0.8 L/s	81%; 0.9L/s
	0.0001	93%; 0.9 L/s	94%; 0.9 L/s	95%; 1.0 L/s

**Table 4:** Stream depletion effects on the tributary of the Waimatuku Stream from pumping bores E45/0083 and E45/0727 for 300 days.

Stream depletion effect (% and rate) on the stream at a distance of <b>210 m</b> after <b>300</b> continuous days pumping of <b>96 m<sup>3</sup>/day (1.1 L/s)</b> (assumes all water is being taken from the closest bore (E45/0083))		Transmissivity (m <sup>2</sup> /day)		
		100	200	400
Specific yield	0.01	91%; 1.0 L/s	93%; 1.0 L/s	93%; 1.0 L/s
	0.001	97%; 1.1 L/s	97%; 1.0 L/s	97%; 1.0 L/s
	0.0001	99%; 1.1 L/s	99%; 1.1 L/s	99%; 1.1 L/s

In accordance with Appendix L.2 it appears that the take can be classified as Direct or Low Hydraulic Connection depending on how Table L.2 is interpreted. Therefore, the groundwater take could be considered an equivalent surface water take for flow and allocation purposes and therefore subject to any relevant minimum flow regime (Waimatuku Stream). However, it is very unlikely that the combined absolute effect from all three bores exceeds 2 L/s. Given that the effects of such a take are likely to be less than minor, we conclude that consideration of PSWLP policies 20 and 23 should result in a take of this scale **not** being subject to minimum flow provisions.

#### Interference Assessment and Effects on Neighbouring Bores

For the neighbouring bore interference assessment we have used the same conservative T and S values for drawdown calculations. The closest neighbouring bore is E45/0605, located 1,220 m to the



SE of bore E45/0071. This bore is used for stock supply. The other two bores (E45/0083 and E45/0727) are more than 2 km away from E45/0605, and hence are unlikely to be affecting it.

**Table 5: Drawdown effects on bore E45/0605 from pumping bore E45/0071 for 7 days.**

Drawdown at <b>1,220m</b> distance under a range of T & S values after <b>7</b> days of continuous pumping at <b>1.0 L/s</b> .		Transmissivity (m <sup>2</sup> /day)		
		<b>100</b>	<b>200</b>	<b>400</b>
Storativity	<b>0.01</b>	0.00 m	0.00 m	0.00 m
	<b>0.001</b>	0.04 m	0.03 m	0.03 m
	<b>0.0001</b>	0.16 m	0.10 m	0.06 m

**Table 6: Drawdown effects on bore E45/0605 from pumping bore E45/0071 for 300 days.**

Drawdown at <b>1,220m</b> distance under a range of T & S values after <b>300</b> days of continuous pumping at <b>1.0 L/s</b> .		Transmissivity (m <sup>2</sup> /day)		
		<b>100</b>	<b>200</b>	<b>400</b>
Storativity	<b>0.01</b>	0.11 m	0.08 m	0.05 m
	<b>0.001</b>	0.26 m	0.15 m	0.09 m
	<b>0.0001</b>	0.41 m	0.23 m	0.13 m

Based on an aquifer thickness of 10 m the drawdown in bore E45/0605 for 7-days pumping is approximately 1.6%, and 300-days pumping is 4.1% of the aquifer thickness, which is within the 20% percent available drawdown recommended by Policy 31 of the RWP, and Policy 22, Rule 54 and Appendix L.3 in the pSWLP (Decisions Version).

As such, the assessment demonstrates that even with a worst-case combination of T and S values and continuous pumping at the maximum daily rate of take the estimated drawdown at bore E45/0605 would be considered 'acceptable' under Appendix L.3 of the pSWLP.

Please note that this neighbouring bore interference assessment assumes no connection to surface water. However, as demonstrated in the stream depletion assessment, the take is considered to be strongly connected to a nearby waterway, which is much closer to the applicant's bore than any neighbouring bores, and therefore it is very unlikely that drawdown effects would propagate beyond the distance to the stream.

Question 4 states that an aquifer test "may" be required. However, given the scale of the proposed take, the stream depletion and interference assessments provided above, in addition to significant cost, it is considered unnecessary to carry out an aquifer test at this time.

**Effects of increased abstraction from the aquifer considered in context of effects on other users and effects on the groundwater system.**

Given the very small proposed increase in the rate of abstraction compared to the scale of the existing inputs and outputs to the groundwater system, the effects of this proposal will be so minor that they would not be able to be measured or even estimated.

**1 Effects of abstraction on surface water quality and quantity of the Waimatuku Stream**

**2** The effects of the proposed take on the Waimatuku Stream have been assessed above (stream depletion). We conclude that given the scale of the abstraction and minimal effects on water resources, no adverse effects on water quality or quantity of the Waimatuku Stream are expected.



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## Memorandum

To: Nessa Legg Of: Dairy Green  
From: John Knight Date: 22 May 2019  
Subject: Woldwide Interference Assessment

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### Introduction

Dairy Green has requested that Aqualinc provide a quantitative interference assessment for the proposed dairymed groundwater take by Woldwide Limited on the Heddon Bush School bore (E45/0718).

Groundwater is abstracted from three bores at WW1 and WW2 properties for use at two dairy sheds and to supply stock drinking water to 1,500 cows. The maximum daily volume of groundwater abstracted to meet the needs of 1,500 cows is 180,000 litres.

At the WW2 unit, two bores supply groundwater. One bore (E45/0083) is located to the west of the dairy shed with a second bore (E45/0727) at the north of the block, close to Wreys Bush Highway. The proposed maximum daily volume supplied to WW2 is 96,000 litres.

At the WW1 unit, the bore (E45/0071) is located to the west of the dairy shed and the proposed maximum daily volume supplied to WW1 is 84,000 litres.

### Methodology

Policy 31 of the RWP states that the interference effect of any new groundwater abstraction should be limited to no more than 20 percent of the available drawdown in any neighbouring bore, provided the neighbouring bore is lawfully established and adequately penetrates the aquifer.

Due to a lack of information regarding the drawdown in bores and water levels in this area, it is not possible to accurately determine 20 percent of available drawdown in neighbouring bores. Because of this, 20 percent of the aquifer thickness has been assumed as an alternative threshold. This approach has been adopted in other groundwater take applications within the Southland region.

The potential effects of pumping the applicant's bores on bore E45/0718 have been assessed using the Theis (1935) drawdown assessment. This method of assessment provides a conservative estimate of the drawdown effects of the proposed groundwater abstraction and often provides an over-estimate of the effects on neighbouring bores.

## Aquifer parameters

Brydon Hughes advised that a maximum transmissivity value of 200 m<sup>2</sup>/day is appropriate for the Waimatuku Groundwater Allocation Zone in the vicinity of the Woldwide One property (email dated 14/02/2017). For this assessment a transmissivity of 200 m<sup>2</sup>/day has been used. Brydon Hughes also advised that a Storativity value of 0.001 would be an appropriate storativity value for aquifers in the Oreti Plains (email dated 16/02/2017).

The worst case scenario has been modelled in which all of the water at WW2 unit (96 m<sup>3</sup>/day) has been abstracted from the closest bore (E45/0083). The WW1 unit is supplied by bore E45/0071 (84 m<sup>3</sup>/day)

Transmissivity = 200 m<sup>2</sup>/day

Storativity = 0.001

E45/0083 7-day pumping rate = 1.11 L/s

E45/00741 7-day pumping rate = 0.97 L/s

## Results

As shown in the attached spreadsheet *Woldwide Interference Assessment.xlsx*, and in Table 1, the combined maximum drawdown in the Heddon Bush School bore (E45/0718) after 7 days is 0.004 m and after 300 days is 0.182 m.

**Table 1:** Drawdown in the Heddon Bush School bore (E45/0718)

	Bore E45/0071	Bore 45/0083	Total DD in bore E45/0718 (m)
Radius (m)	2866	3798	
Time (days)	Drawdown	Drawdown	
1	0.000	0.000	0.000
7	0.004	0.001	0.004
10	0.007	0.002	0.009
20	0.018	0.010	0.028
30	0.027	0.017	0.044
100	0.060	0.050	0.110
150	0.073	0.063	0.136
300	0.095	0.088	0.182

Based on an aquifer thickness of 10 m the drawdown of 0.004 m in bore E45/0718 for 7 days pumping is approximately 0.04%, and 300 days pumping is 1.8% of the aquifer thickness, which is within the 20% percent available drawdown recommended by Policy 31 of the RWP, and Policy 22, Rule 54 and Appendix L.3 in the pSWLP (Decisions Version).

## Summary

The modelled drawdown in the Heddon Bush School bore (E45/0718) using conservative parameters is compliant with the requirements of the RWP and the pSWLP (Decisions Version).

# Attachment 3

Bore E45/0622 before and after remediation by Southdrill

