Technical report advising Proposed Plan Change 6A Officer's Report of Decisions Requested

Assessment of Nitrogen Sensitive Zone loading limits

Modelling of Kakanui – Kauru, Ettrick, and Lower Taieri nitrogen accumulation sensitivity

Background

Plan Change 6A of the Otago Regional Plan: Water contains nitrogen discharge limits in proposed clause 12.C.1.3:

3. *"The discharge of nitrogen from land to groundwater, is a **permitted** activity, providing:*
    i) *From 31 March 2019, calculated nitrogen leaching by the Council using OVERSEER version 6.0 does not exceed:*
        (a) 10 kilograms nitrogen per hectare per year over any nitrogen sensitive zone identified in Maps I1-I6; and
        (b) 30 kilograms nitrogen per hectare per year elsewhere in Otago; and
    ii) *Upon request ...."*

Nitrogen Sensitive Zones

In this manner, the plan change is proposed to make a distinction between "*nitrogen sensitive zones"* and rural land elsewhere in the region. Maps I-1 to I-6 detail the six areas or zones considered to have additional sensitivity to nitrogen contamination:

- I-1 Kakanui – Kauru Aquifer (the northern Groundwater Protection Zone A is pictured).
- I-2 Shag Alluvium Aquifer.
- I-3 Lower Taieri Aquifer - East, (the Groundwater Protection zones A & B surrounding Mosgiel are pictured).
- I-4 Ettrick Basin Aquifer and Roxburgh Basin Aquifer (the respective A Groundwater Protection zones in each aquifer are pictured).
- I-5 Wakatipu Basin Aquifer, and catchment of lakes Wakatipu and Wanaka.
- I-6 Catchment of lakes Wanaka and Hawea.

The aquifer components of the "*nitrogen sensitive zones"* are subject of this report. The major lake catchment of maps I-5 and I-6 are not included in the discussions of this report, although the Wakatipu Basin Aquifer on map I-5 is.

Hydro-Dynamic Conditions favouring Nitrogen Accumulation

The sub-text of the distinction made between "*nitrogen sensitive zones"* and rural land elsewhere in the region is that the specified zones are considered to be more sensitive to nitrogen accumulation than elsewhere. Dissolved inorganic nitrogen species, such as nitrate, nitrite and ammonia, are naturally occurring and occur pervasively in groundwater within 500 m of the land surface. All groundwater systems experience some degree of nitrogen accumulation unless they are confined or if the *in situ* geochemical environment reduces incoming nitrogen from soil drainage. Some groundwater systems or aquifers have particular conditions that favour the compounding accumulation of dissolved inorganic nitrogen over long time frames. These conditions increase the probability of nutrient levels rising towards the drinking water guidelines for nitrate, nitrite or ammonia nitrogen. The most readily definable special conditions are what can be described as hydro-dynamic. Hydro-dynamic conditions that favour nitrogen accumulation are as follow:

- Unconfined aquifer setting, open to soil drainage drizzling through the unsaturated zone above.
- Thin aquifers, containing a relatively small volume of groundwater within the saturated zone.
- Soil drainage dominated recharge.
- Lack of dilution from other sources of recharge having low nitrogen content, such as surface water infiltration directly from a water body.
- Low permeability and/or groundwater flow velocity (flux).

Other risk factors are whether the aquifer has also displayed an accumulation in nitrogen concentration already or the known lack of geochemical conditions that would otherwise suppress the accumulation of nitrate nitrogen.

Nitrogen Guideline Values

The dissolved inorganic nitrogen species of health significance, if taken for water supplies are nitrate and nitrite. The respective drinking water guideline concentrations are as follow:

- Nitrate (short term exposure) 50 gNO_3/m^3 or 11.3 gN/m^3
- Nitrite (short term exposure) 3 gNO_2/m^3 or 0.91 gN/m^3
- Nitrite (long term exposure) 0.2 gNO_2/m^3 or 0.061 gN/m^3

Ammonia has a Maximum Acceptable Value (MAV or guideline value) of aesthetic significance. That is to say, if ammonia in raw water exceeds 1.5 gNH_3/m^3, then there is an odour that reduces palatability, but health significance is not triggered. The associated ammonia nitrogen value is not much less at 1.16 gN/m^3. All forms of nitrogen, including "*organic nitrogen, ammoniacal nitrogen, nitrite nitrogen and nitrate nitrogen"* are referenced in Plan Change 6A, clause 12.C.1.3 for management of soil zone discharges to groundwater.

The water quality of groundwater has long been difficult to classify or provide standards or guidelines for. Since groundwater is commonly used as a source of domestic water in rural communities, without water treatment or ongoing monitoring, it has become customary for authorities to refer to the drinking water standard MAVs when setting water quality guidelines. The most stringent drinking water MAV is that of <u>nitrite</u> nitrogen with a concentration of 0.061 gN/m^3 for long-term exposure. Given that long-term exposure to water from a water bore is an entirely feasible eventuality for long-term members of a rural residential population, the long-term MAV is the most appropriate guideline. Unfortunately, there is little information available from groundwater monitoring to differentiate between nitrate and nitrite despite the large difference in MAV.

The processes of soil nutrient cycling and soil drainage have the effect of *nitrifying* the entrained nitrogen dissolved in any soil leachate. This process is mediated by *Nitrobacter sp.* bacteria in the soil / subsoil and has nitrite as a transitional species with nitrate as the end member. Most nitrogen transiting the subsoil and unsaturated zone is thus nitrate nitrogen. Therefore, most attention on environmental management of groundwater nitrogen goes on the nitrate species of the element. The substantial water quality management programme practised in the European Union, termed the Nitrates

Directive of 2001 and confirmed in the Groundwater Directive of 2006, seeks to limit groundwater nitrate nitrogen concentrations to 11.3 gN/m^3 (European Union, 2012).

Modelling

Ettrick Unconfined Aquifer

Appendix A outlines the process of modelling the Ettrick Aquifer, termed the *Ettrick Unconfined Aquifer* by Bekesi (2006), in order to assess the sensitivity of the groundwater to nitrogen accumulation. Modelling showed a tendency to accumulate nitrogen on the down-gradient side of the flow system, especially adjacent to an area of flow stagnation against a basement margin. Modelling suggested that if uniform rate of nitrogen discharge to the aquifer was practised, then a rate of 20 kgN/ha/y would still maintain the aquifer substantially within the 11.3 gN/m^3 MAV concentration. It should be noted that the hydro-dynamic model using Rushton soil-moisture modelling for recharge, MODFLOW for flow simulation and MT3D for advection / dispersion modelling of nitrogen movement through the aquifer was highly conservative to employ the zero nitrogen inflows of Benger Burn and range-front recharge which diluted nitrogenous soil drainage.

North Taieri – Mosgiel groundwater protection zones

Reporting of Modelling of the North Taieri groundwater System around Mosgiel is given in Appendix B. Modelling of recharge, groundwater flow and nitrogen movement in the multi-layered North Taieri compartment of the Lower Taieri groundwater system strongly suggested that the system was relatively insensitive to changes in nitrogen discharge in the range of 10 to 30 kgN/ha/y, which is also the difference in loading rates proposed between sensitive zones and anywhere else in Otago. The model had a relatively small area in which nitrate could affect groundwater quality (without geochemical reduction) and affect the Mosgiel public water supply. The infiltration losses of the Silver Stream of up to 40 litres per second, which were confirmed by field gauging (Rekker & Houlbrooke, 2010), contributed greatly to the groundwater system's resilience against nitrogen accumulation. The contrasting soil retention properties of the soil classes in the recharge zone were also important.

Kakanui – Kauru Alluvium

The Kakanui – Kauru zone is reported in Appendix C. The northern groundwater protection zone A within the Kakanui – Kauru Alluvium was proposed in the notification of RPW Plan Change 6A as a nitrogen sensitive zone. This zone perhaps stands apart from the foregoing aquifer modelling exercises because the water quality values to be protected are in-stream surface water quality of the Kakanui River rather than groundwater nitrate.

A study of the groundwater – surface water interaction between the alluvium and river was carried out. The study showed that up to 25% of the aquifer could be replenished by peak flow events. The limited groundwater storage available in the riparian gravels makes for a highly responsive aquifer that will not tend to accrue nutrients from year to year. In this way, the Kakanui – Kauru alluvium differs from other aquifers in Otago, which have a much greater storage to annual recharge ratio.

The available data indicates that nitrate concentrations in the river are peaking well above the 0.08 mg/l nitrate-N threshold during winter and spring. This makes sense because there is very little nutrient use within the soil profile during this time. Much of the nutrient – enriched groundwater is flushed into the aquifer by rainfall, and discharged into the river during winter and spring. However, a residual of elevated nitrate continues to discharge to the river during the critical summer period. The gain in river flow from groundwater storage is typically over 10% during a flow recession, so residual nitrate in the aquifer continues to be added to the river during summer. The nitrate concentrations increase during periods of flow recession because the proportion of groundwater contribution to river flow increases as flow decreases.

The conceptual model outlined above suggests that to control river water quality requires controlling nutrient discharge through the soil, particularly during the critical winter leaching period. The ECAN lookup tables for nitrate leaching indicate that wintering of cows contributes an additional 10 to 15 kgN/ha/yr[1]. This implies that winter leaching rates are at least 30% higher than the annual values specified in the lookup tables. Furthermore, the area of greatest groundwater gain from the river has very light soils which are prone to high rates of leaching. This leaching will continue into the summer period on irrigated pasture.

Our recommendation is that the Kakanui – Kauru aquifer remains a sensitive aquifer, with a 20 kgN/ha/y leaching limit.

Re-Evaluation of Nitrogen Sensitive Zones

The following re-evaluation of the six proposed nitrogen sensitive zones that are aquifers was undertaken in the knowledge submissions received in response to Plan Change 6A notification and subsequent modelling of nitrogen accumulation.
Table 1 lists the loading limits within the proposed plan change alongside the suggested new loadings following a re-evaluation, including some nitrogen accumulation modelling.

[1] The majority of the area consists of extra light soils. These soils are predicted to leach between 38 and 65 kgN/ha/y depending on herd density and wintering (Lilburne et al. 2010).

Table 1: Schedule of Notified and Re-Evaluated Nitrogen Loadings.

	Notified Loading Limit (kgN/ha/y)	New Recommended Loading Limit (kgN/ha/y)	Comment
Kakanui – Kauru Alluvium	10	20	Surface water quality controlled
Shag Alluvium	10	20	Surface water quality controlled
Mosgiel – N Taieri GPZ A & B	10	30	Remove from PC 6A map I-3
Ettrick Aquifer	10	20	
Roxburgh Aquifer	10	20	
Wakatipu Basin	10	20	A series of sub-basins couched in schist

It is suggested that the Mosgiel – North Taieri groundwater protections zones can be removed from the initial list of nitrogen sensitive zones on the basis of the conceptual understanding of the stratified aquifer and groundwater modelling results.

Nothing in the foregoing analysis indicates that current land practices can conform to the discharge limits discussed, or otherwise. The analysis has instead focused on the ability of the underlying groundwater system to assimilate soil discharges at the nitrogen limits discussed.

References

Bekesi, G. 2006: Groundwater allocation of the Ettrick Basin. Prepared by Resource Science Unit for Otago Regional Council, December 2006, Dunedin. ISBN 1-877265-42-X.

European Union. 2012: http://ec.europa.eu/environment/water/water-nitrates/index_en.html

Lilburne, L., Webb, T., Ford, R., and Bidwell, V. 2010. Estimating nitrate-Nitrogen leaching rates under rural land uses in Canterbury. Environment Canterbury technical report R10/127

Rekker, J H; and Houlbrooke, C. 2010: Lower Taieri Groundwater Allocation Study. Prepared by Resource Science Unit for Otago Regional Council, December 2006, Dunedin. ISBN 1-877265-42-X.