MONITORING EFFECTS OF SOUTHLAND DEMONSTRATION FARM ON STREAM WATER NITRATE

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Abstract

The objective of this research work was to monitor the effects of the Southland Demonstration Farm on the concentration and amount of nitrate in the Tomoporakau Creek. The creek runs through the central area of the farm and drainage outfalls discharge directly into this stream.

A detailed GPS topographical survey was conducted to confirm the drainage catchment area and hydrology of the site. Groundwater piezometers were established adjacent to the stream in order to monitor groundwater levels and compare those to stream water levels. Detailed surveys of the stream bed, stream surface, groundwater levels, and stream bank geometry were also conducted. Stream flow rate measurements were continuously monitored using "Sontek" Doppler flow equipment installed in concrete box culverts at 'up-stream' and 'down-stream' monitoring sites. Stream water was pumped continuously from the monitoring sites using submerged samplers that sent water to an instrument base-station at the dairy shed. The water nitrate concentration from each site was monitored in real-time using flow-through UV absorption spectrometer sensors. This system does not require any reagents as it measures the water nitrate concentration by detecting the UV light absorption by nitrate**.** These sensors also measure a full spectrum adsorption in order to automatically 'correct' for light absorption due to particulate material and/or other chemicals in the water.

Introduction

Nitrate leaching losses from soil into water represents a threat to aquatic environments and to human health (Wild and Cameron, 1980; Addiscott, 1996; Di and Cameron, 2002; Goulding *et al*., 2008; Cameron *et al*., 2013). Agriculture is a major source of nitrate leaching in New Zealand which has led to community concerns about water quality deterioration (Monaghan *et al.*, 2007; Holland and Doole, 2014). However, it is difficult to accurately measure the effect of farming on nitrate leaching into rivers or lakes (Powlson, 1993). This is because nitrate is extremely difficult to capture and measure continuously either from a representative sample of water draining from the soil, or changes within a fluctuating dynamic river water system flowing across farmland.

The establishment of the Southland Demonstration Farm provided an opportunity to make direct measurements of the effects of dairying on the concentration and amount of nitrate in the Tomoporakau Creek that runs through the central area of the farm. The farm is located NW of Wallacetown (about 20 km from Invercargill). The farm milks 790-800 cows grazing on a ryegrass/white clover pasture milking platform of approximately 260 ha. Milk production is approximately 1228 kg MS/ha or 422kg MS/cow. Nitrogen fertiliser is applied at rate of 190 to 250 kg N/ha/y, depending on the season. The cows are wintered on farm grazing brassicas and fodder beet. Most of the farm (80%) has poorly drained soils (Makarewa Gley Soils, Northope Soils, Tomoporakau Soils) with a network of tile drains and pipe drains.

Methodology

A detailed topographical and hydrological survey was conducted to confirm the drainage catchment area and hydrology of the site. The detailed topographical survey involved measurements of over 5,000 individual GPS survey points across the farm. The survey identified that 138 ha of the farm potentially contributed drainage water into the stream.

To establish how much stream water was being lost into ground water (since this could limit the usefulness of stream water monitoring) and the likelihood of groundwater diluting the stream water; groundwater piezometers were established at selected sites. The piezometers were located adjacent to the stream in order to monitor groundwater levels and compare those to stream water levels. Following piezometer installation, a further detailed survey of the stream bed, stream surface, groundwater levels, and stream bank geometry was conducted. This information enabled us to quantify the surface water-groundwater interaction and gave us confidence that the monitoring would capture the farm's impact on stream water quality (i.e. excessive amounts of stream water were not being lost to groundwater, or the stream was not being excessively diluted by groundwater).

Stream flow rate measurements were continuously monitored using "Sontek" flow equipment installed in concrete box culverts at an 'up-stream' site and at a 'down-stream' site. These sensors are used routinely for this purpose and provide a measure of water flow rate within the box section. The data is collected on a data logger and sent by telemetry to a central 'base-station' located at the dairy shed.

Stream water was collected using submerged samplers and pumped to the instrument base-station at the dairy shed. The nitrate concentration in the water was monitored in real-time using flow-through UV absorption spectrometer sensors. The system does not need any reagents and measures the nitrate concentration by detecting UV light absorption at 220 nm**.** These state-of-the-art UV absorption spectrometer sensors also measure a full spectrum adsorption in order to automatically 'correct' for light absorption caused by particulate material and/or other chemicals in the water. This system enabled measurement of nitrate concentration at the 'up-stream' site and the 'down-stream' site every hour.

Results

Water balance over farm catchment

Based on the cumulative differences in measured flows between the up-stream and down-stream sites, the total amount of drainage water entering the stream from the 137.96 ha farm catchment approximately matched the total amount of rainfall minus evapotranspiration over the period January to December 2012 (Figure 1). This confirmed that the detailed topographical survey correctly identified the stream catchment area of the farm.

The agreement between rainfall minus evapotranspiration and stream-measured drainage further confirms that most of the rainfall that falls on the catchment drains into the stream (via the farm drainage system or surface runoff).Therefore the stream can be used to quantify the amount of N that is leached from the farm (i.e. there is no major loss to deep groundwater).

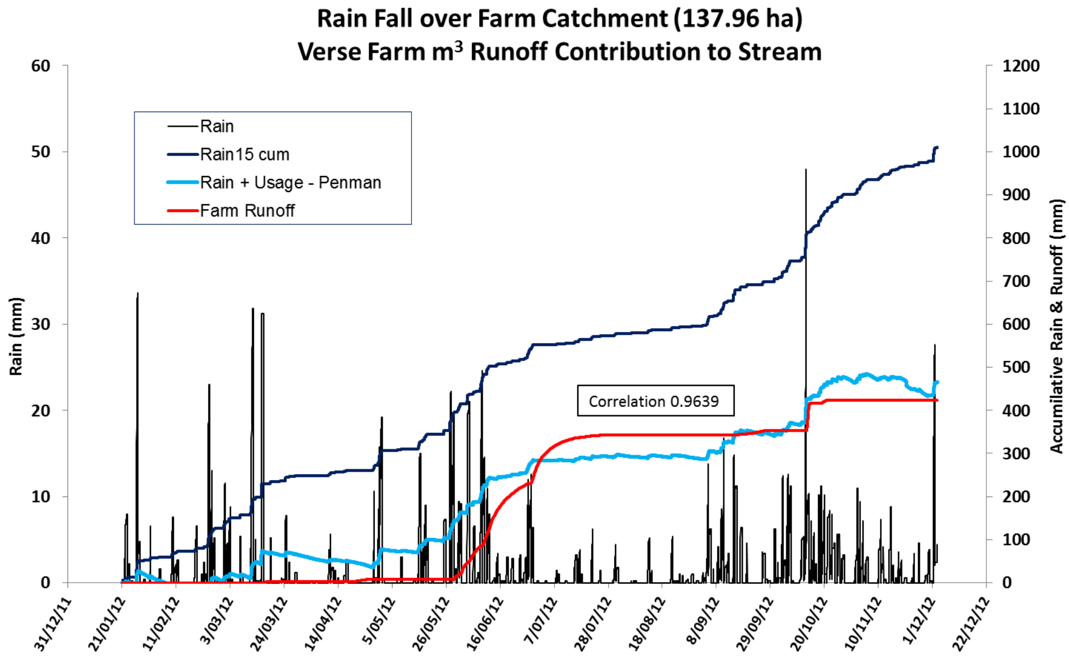

Figure 1 Water balance for farm catchment.

Stream water flow rate

Over the period of measurement the stream water flow rate ranged from 0.1 to 3.4 m^3/s. This wide range in flows resulted in a wide range of stream flow transit times across the farm; from 100 hours (almost stationary) during dry periods to as fast as 2 hours during rainfall and drainage flow events. It is during these rapid transit times, when the farm drains are running, that most of the N leaching losses occur from the farm into the stream.

Nitrate concentration in the stream

Stream water nitrate concentrations varied, ranging between 0.1 and 12.9 mg N/L (Figure 2). During periods of low stream flow rates the water nitrate concentration at the 'up-stream' monitoring site exceeded the water nitrate concentration at the 'down-stream' monitoring site (Figure 2). This was unexpected and indicates that there must have been significant sources of nitrate entering the stream up-gradient of the Southland Demonstration Farm. The reduction in nitrate concentration from 'up stream' to 'down-stream' monitoring sites occurred during periods of slow flow. Some of this may be due to within stream denitrification and/or nitrogen uptake by weeds growing in the stream. However 'down-stream' measurements during these low flow periods typically showed greater water volumes than the 'up-stream' measurements, and piezometer bore level measurements showed that the lower reach of the creek had ground levels higher than water levels. This indicates that ground water sources were diluting the nitrate levels during low flow periods and probably account for the majority of the difference between the two sites during these periods. In contrast, at periods of high stream flow (i.e. when the farm drains were discharging water into the stream) the nitrate concentration at the 'down-stream' site exceeded the concentration at the 'up-stream' site (Figure 2). This can be attributed to nitrate leaching loss from the farm and represents the farm's contribution to the nitrate in the stream.

Simply taking nitrate spot readings, rather than continuous recording, could have led to inaccurate conclusions about the effect of the farm on the stream. For example, taking a single water sample in February would have detected a very low nitrate concentration; whist taking a single sample in June would have detected a very high nitrate concentration (Figure 2).

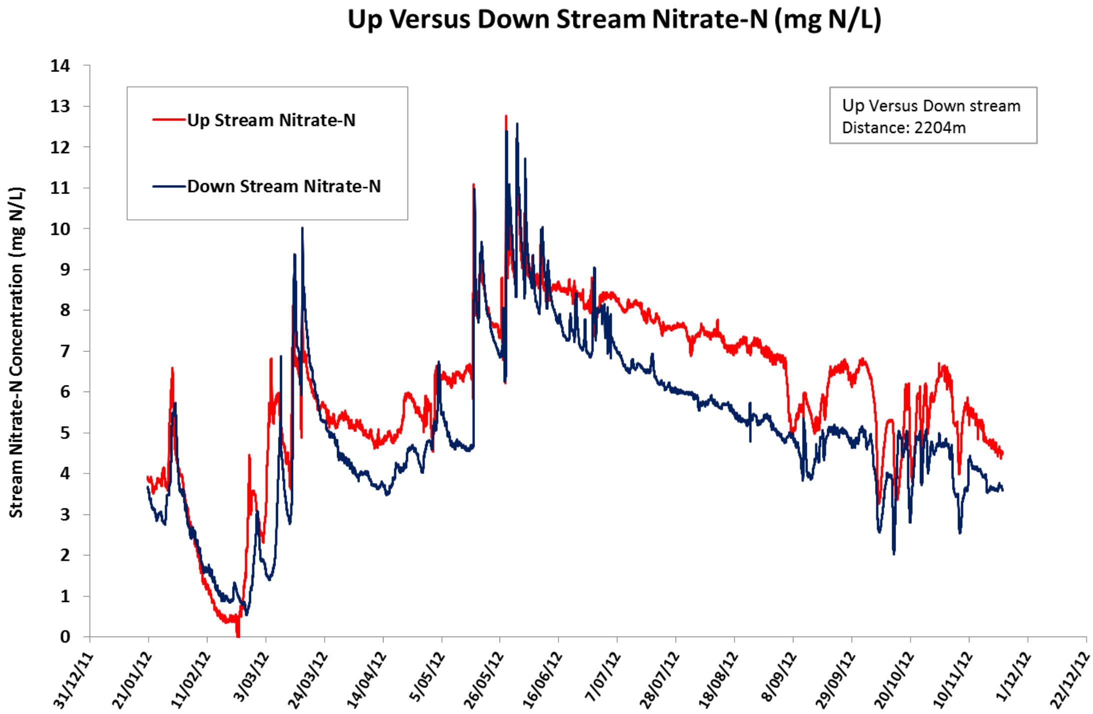

Figure 2 Stream water nitrate-N concentrations.

The majority of leaching loss occurred during spasmodic events when the farm drains were running and stream was flowing fast (Figure 3). At other periods there was little interaction between the farm and the stream.

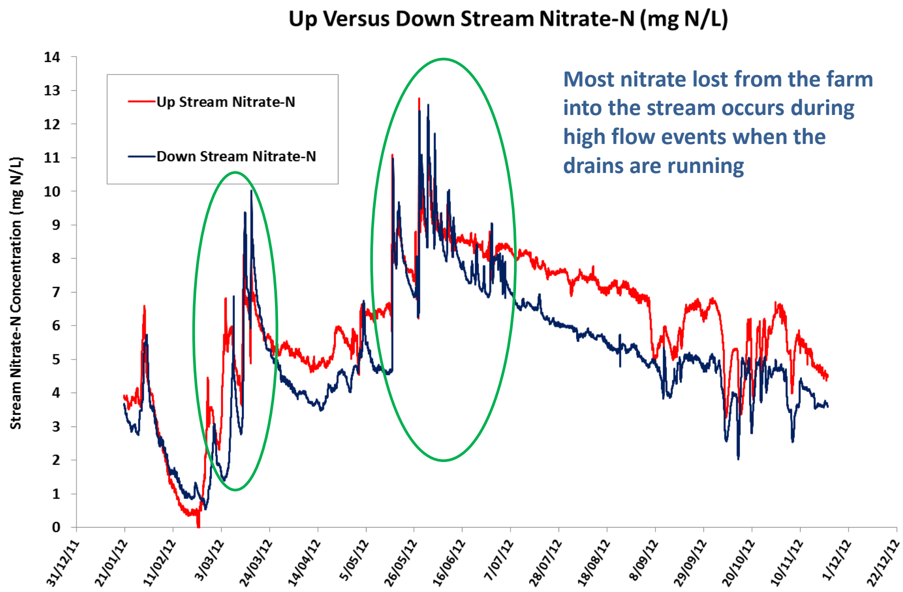

Figure 3. Up-stream and down-stream nitrate concentrations showing periods of nitrate leaching loss from the farm.

Amounts of nitrate in the stream

From January to December 2012 the amount of nitrate-N leached from the farm into the stream was calculated to be equivalent to approximately 43 kg N/ha (Figure 4). However these are interim results for one year only and more data is required before definitive conclusions can be drawn about the effects of the farm on stream water nitrate.

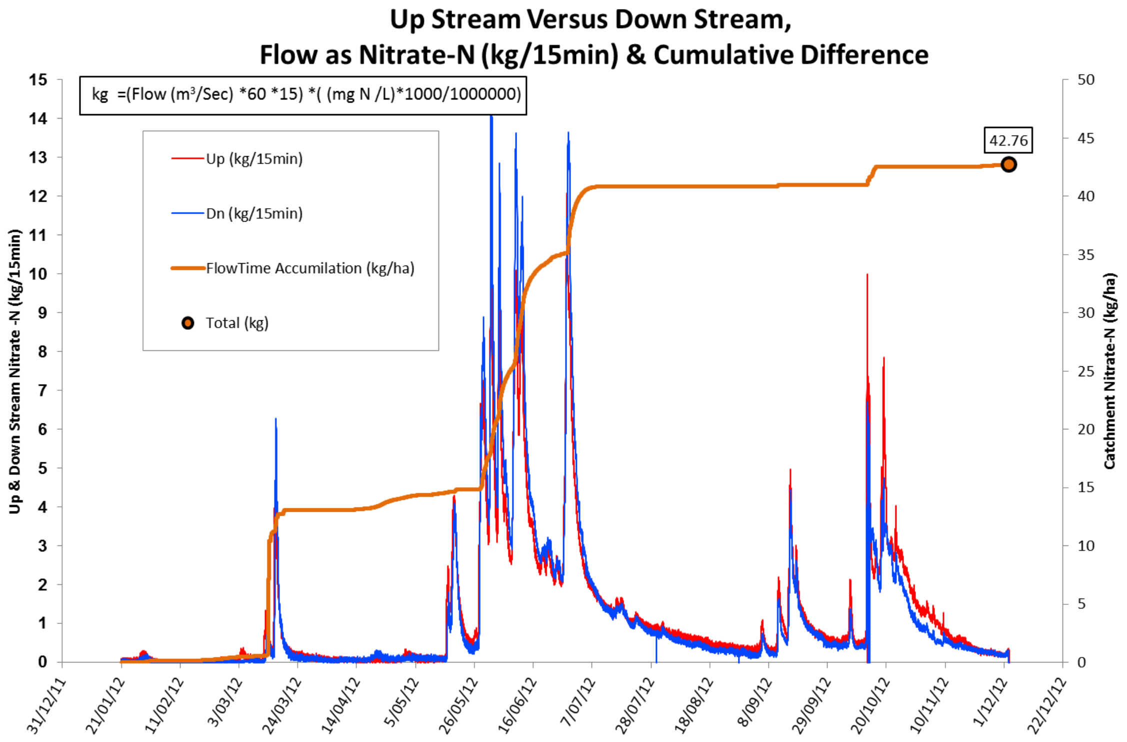

Figure 4 Amounts of nitrate-N carried in the stream at the up-stream versus down-stream sampling sites and the cumulative amount of nitrate-N leached from the farm into the stream.

Conclusions

The conclusions from the first year of the study are that:

- It is very difficult and expensive to measure the amount of nitrate-N draining from the farm into the stream.
- The majority of the leaching loss occurred during spasmodic events when the farm drains are running.
- During the period from January – December 2012, most leaching losses occurred between May and the end of July.
- Between January – December 2012, the annual nitrate leaching loss from the farm was calculated to be equivalent to 43 kg N/ha (NB. results are for one year only).
- Simply taking nitrate spot readings and not measuring full water dynamics could have led to inaccurate conclusions about the effect of the farm on the stream.

Acknowledgements

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