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Nitrates in Groundwater: Impacts of Climate Change

Aqualinc Research Ltd

water NEW ZEALAND
The New Zealand Water & Wastes Association Waiora Aotearoa

water NEW ZEALAND CONFERENCE & EXPO
17-19 OCTOBER 2023
Tākina, Te Whanganui-a-Tara Wellington

Introduction

Climate change

- Warming climate, rising sea level
- More drought
- More extreme rainfall events

How does this affect nitrates in groundwater?

- Complex issue
- More questions than answers?

Nitrates

Essential for plant growth

Excess nitrogen is a problem

Nitrogen losses adversely

- Affect groundwater and surface water quality
  - Drinking water issues
  - Ecosystem health
- Affect plant growth
  - Cost of lost production
- Cost the economy
  - Effects on human health and ecosystems

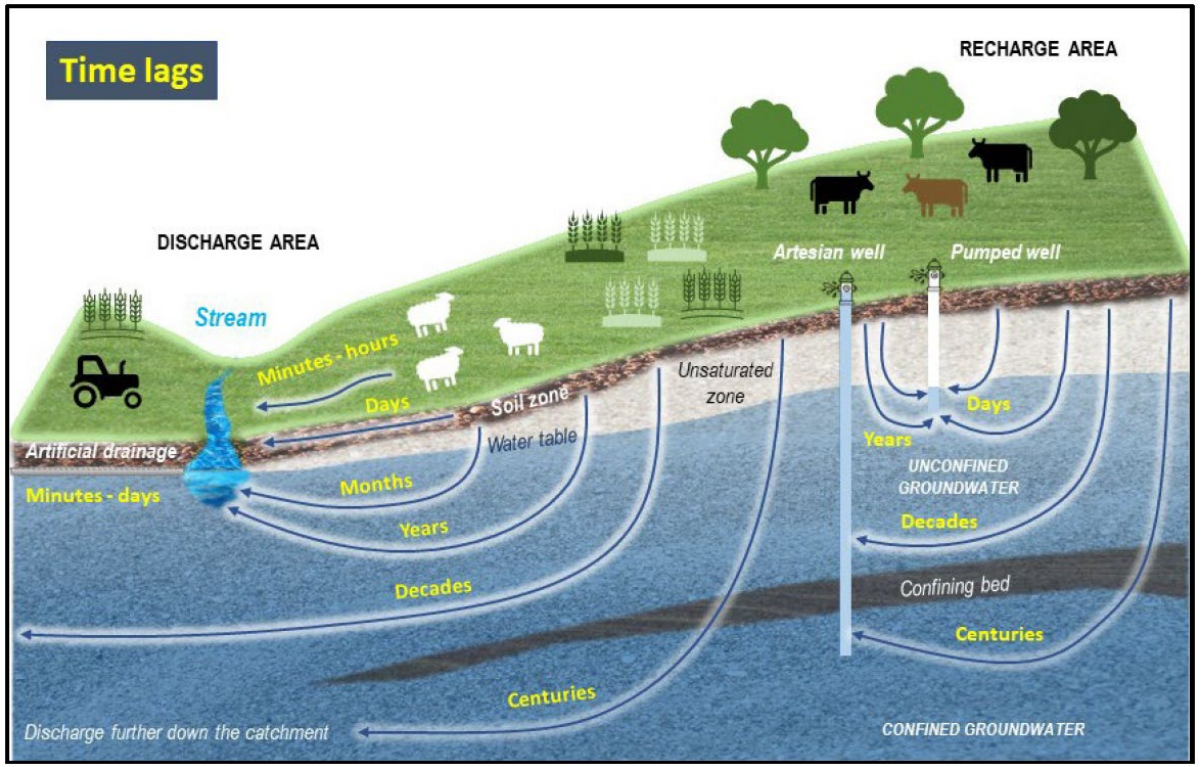
Contributor to climate change

- Nitrous oxide and ammonia

Understanding nitrates

- Source
- Pathway
- Receptor

- Predicting changes with climate need to take all of these into account



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Source

Inputs dominated by fertiliser and animal excreta

- Both organic and inorganic forms of nitrogen

Organic nitrogen insoluble

- Converted by mineralisation to inorganic nitrate

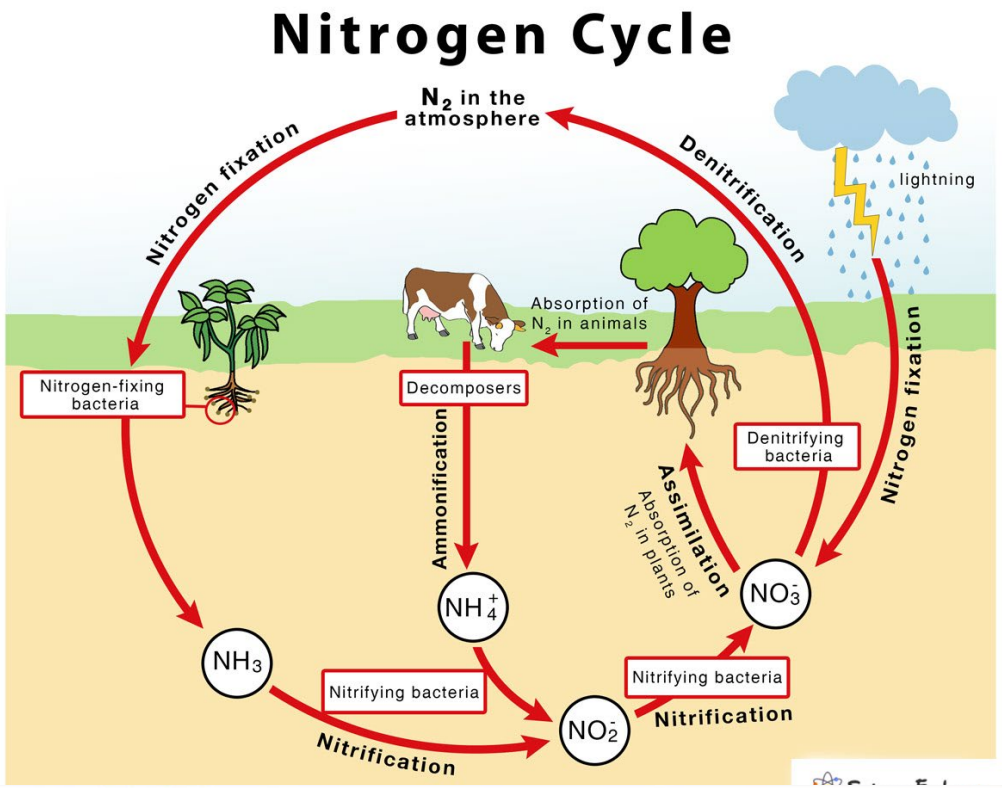
Source

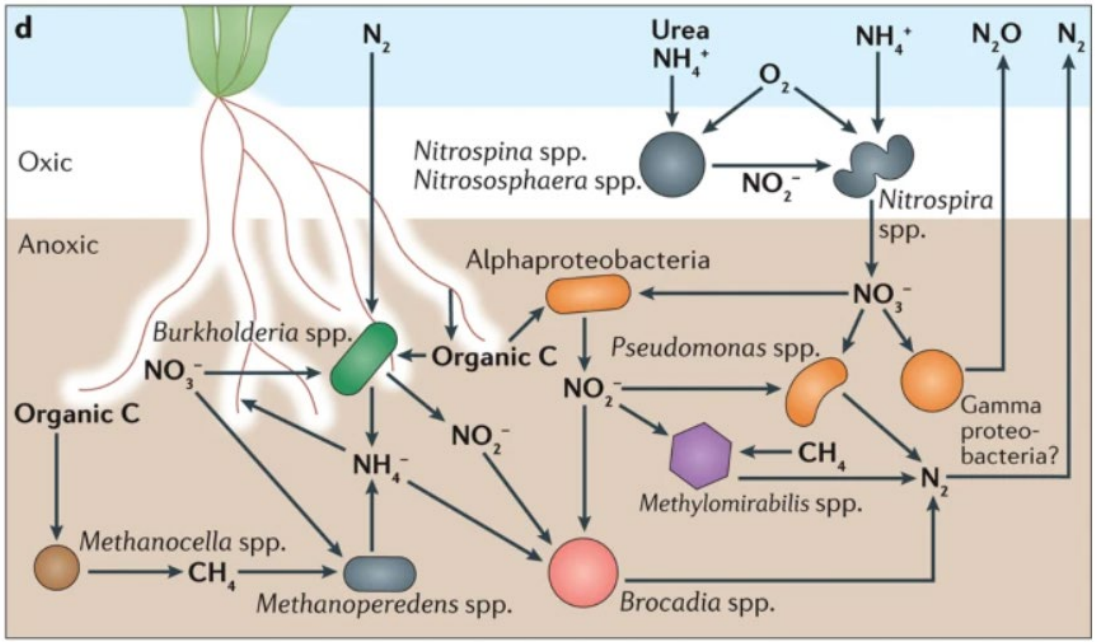
Understanding the nitrogen cycle

- Driven by microbial transformations
- Anything that affects microbial ecology will disrupt processes

Classical nitrogen cycle consisting of distinct processes that follow each other in an orderly fashion does not exist

- Microorganisms form complex networks that link nitrogen-transforming reactions





Source

Prolonged drought reduces viability of soil biology

- Organic nitrogen accumulates due to lack of mineralisation
- Biota can be reactivated when conditions change
- Research suggests this can result in very high concentrations of soluble nitrate

Soil wetting and recurrence of recharge may be accompanied by exceptionally high nitrogen concentrations

- “Hot moments”

Pathways

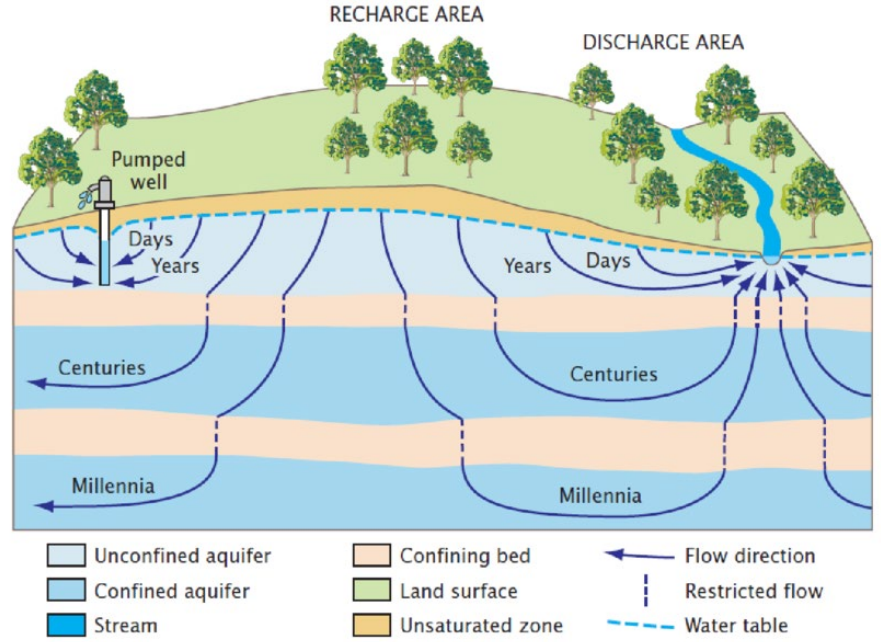
Transport of nitrogen from the land surface to a receptor

Nitrate is a solute – moves with the water

Many different possible flow paths

Transport processes are not well understood

- Multiple flow/transport pathways?
  - Some nitrate is transported rapidly
  - Some follows much slower flow path



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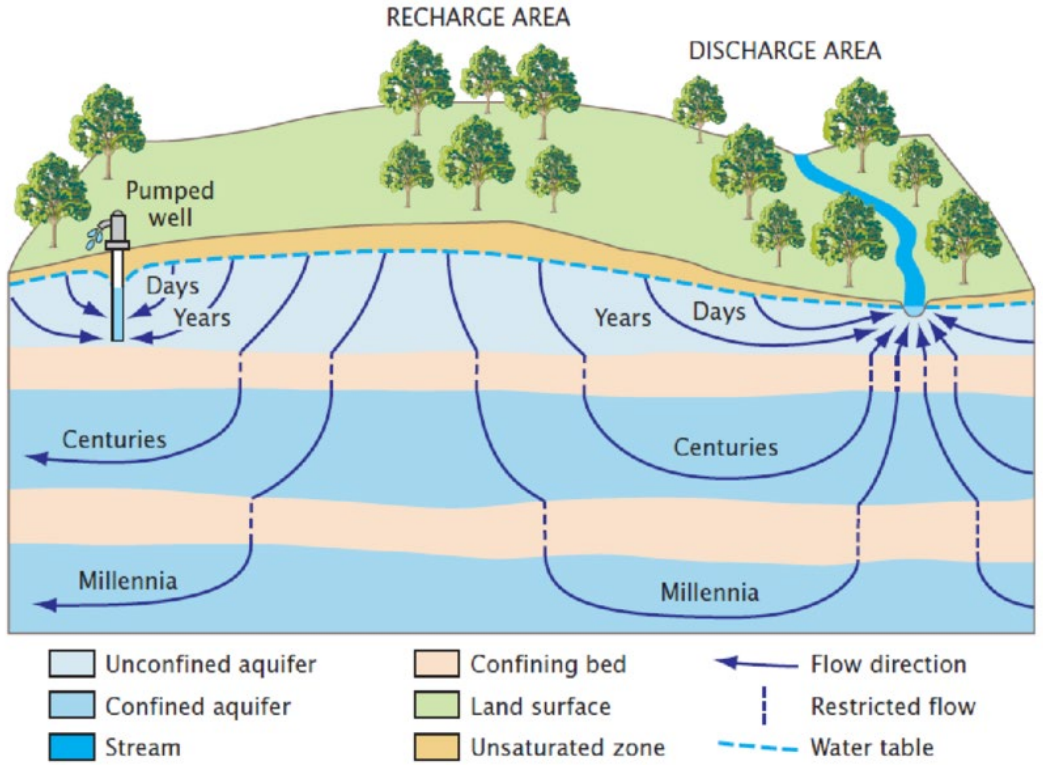
Receptor

What we measure at receptor affected by source and pathway

Complex in space and time

Different concerns depending on receptor

- Surface water
  - Biodiversity, eutrophication
  - Aesthetic factors
- Drinking water
  - Health implications
  - Aquifer ecology



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Impacts of climate change

Literature suggests impacts could be positive or negative

- Complex subject

Effects on groundwater systems in general

- Possibly greater contrast between summer and winter

Drier conditions

- Less leaching, more accumulation, large pulses exported during rainfall events
- Less uptake by vegetation
- Soil processes
  - Denitrification decrease, accumulation of nitrogen
  - Less mineralisation

Wetter conditions

- Leaching increases with recharge
- Soil processes
  - Denitrification increase in wetter areas
  - Increased mineralisation

Impacts of climate change

Effects on nitrates in groundwater

- Possibility of "hot moments" caused by accumulation of nitrogen, lack of uptake, re-wetting of soils and recharge
- Greater frequency of large precipitation events leading to more recharge
- Greater transport through preferential flow paths with increased rainfall
- More opportunity for preferential flow where soils are prone to cracking

Impacts of climate change - irrigation

Greater need for irrigation

Results of irrigation

- Maintaining high levels of soil moisture
- Soil biota continue to thrive
- Plants uptake more nitrate
- Greater opportunity for leaching when major precipitation events do occur
    - But less opportunity for nitrates to accumulate in soils?

Evidence for climate-driven changes in nitrate concentrations

Nitrate concentration isn't a constant

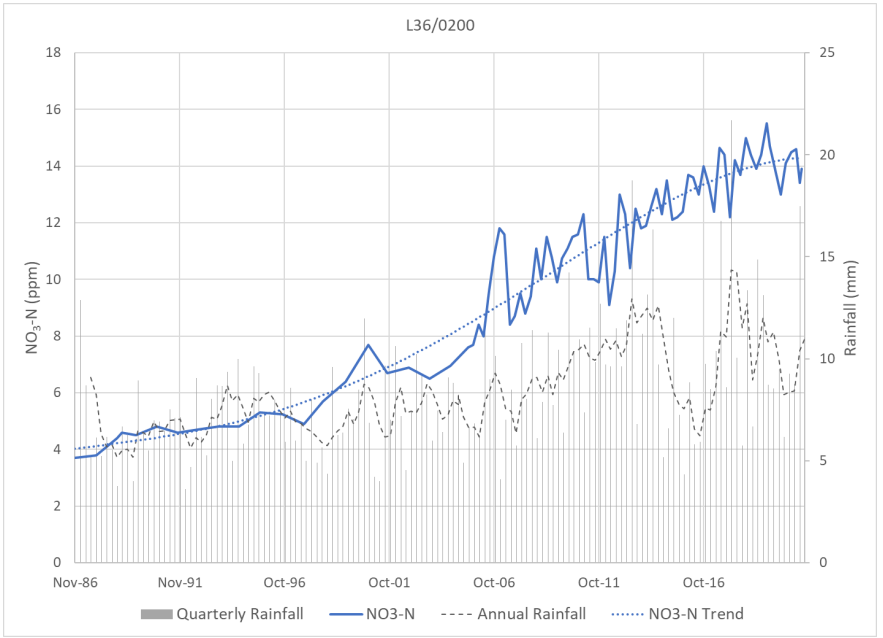
Trends

Also

- Seasonal fluctuations
- Patterns in high resolution data
    - Evidence for "hot moments"

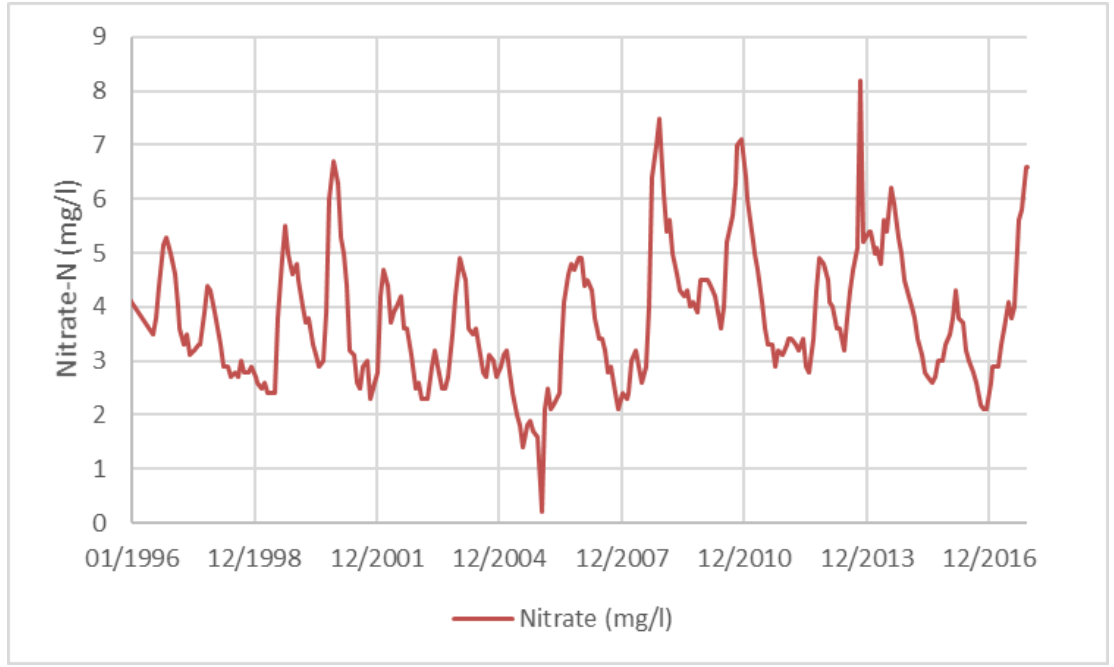
Complicated by other drivers/issues

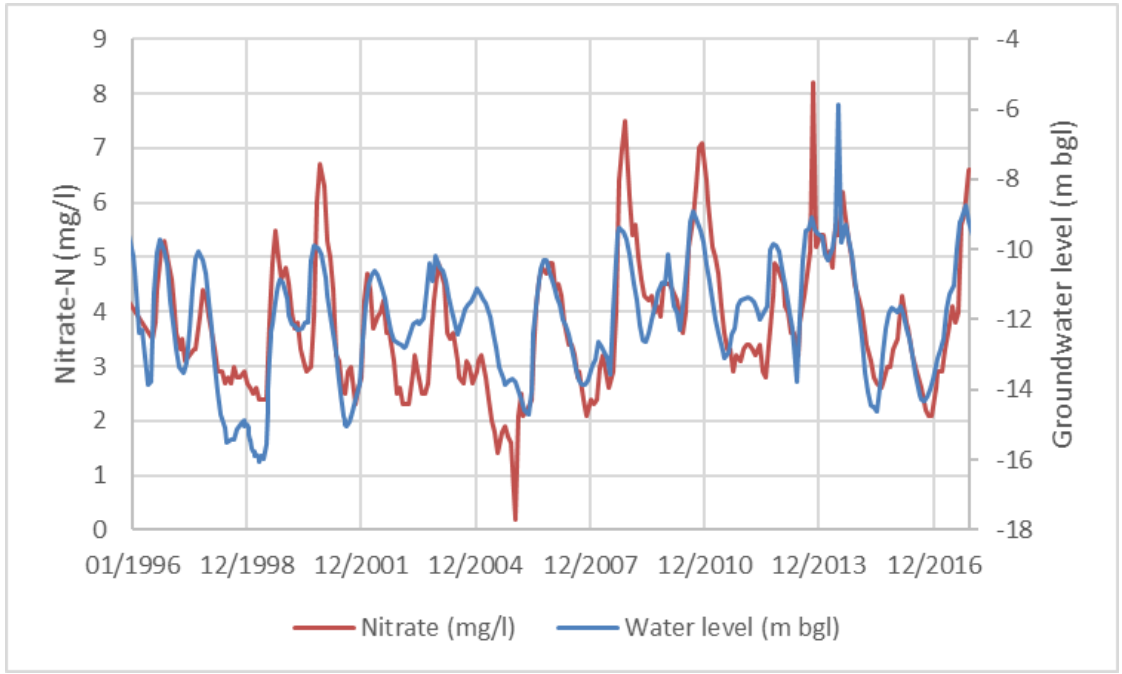
- Time lags
- Understanding transport processes
- Land use change



Seasonal fluctuations in nitrate concentrations

Have observed seasonal fluctuations in many bores





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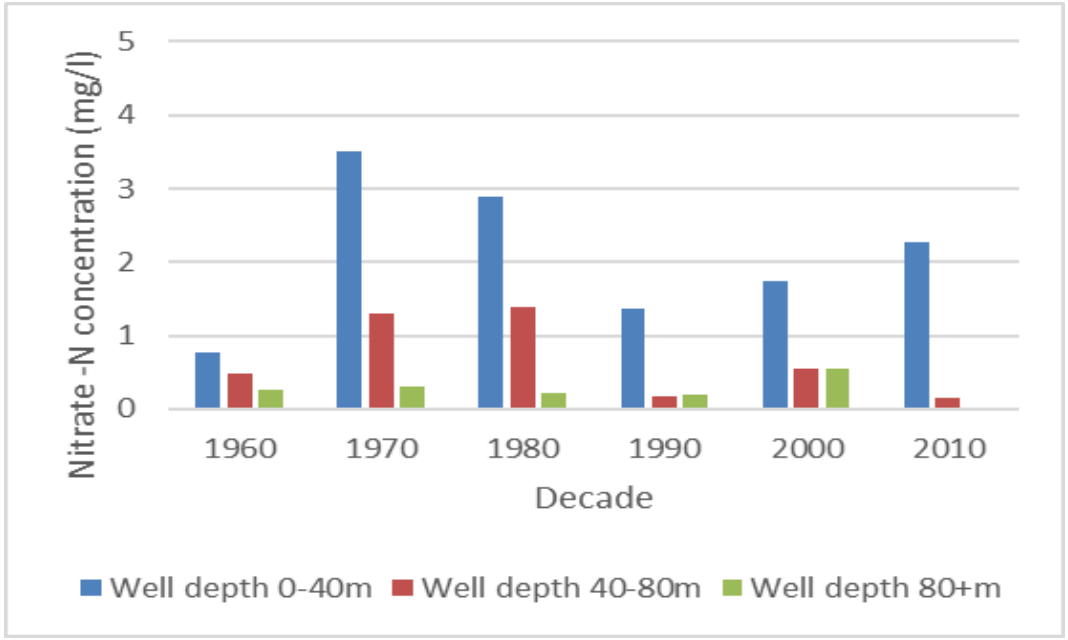
Long term trends

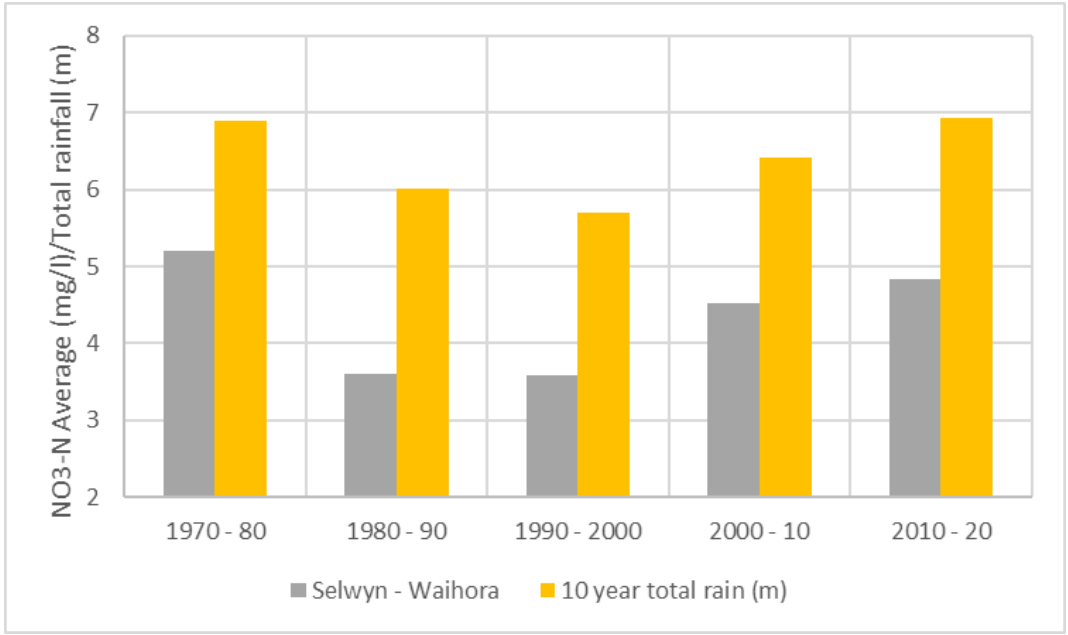
Observation that average nitrate-N concentrations in 1970s were higher than now

Due to high rainfall in the mid-late 1970s

Nitrate concentrations appear to follow rainfall trends



Selwyn-Waihora Groundwater Zone

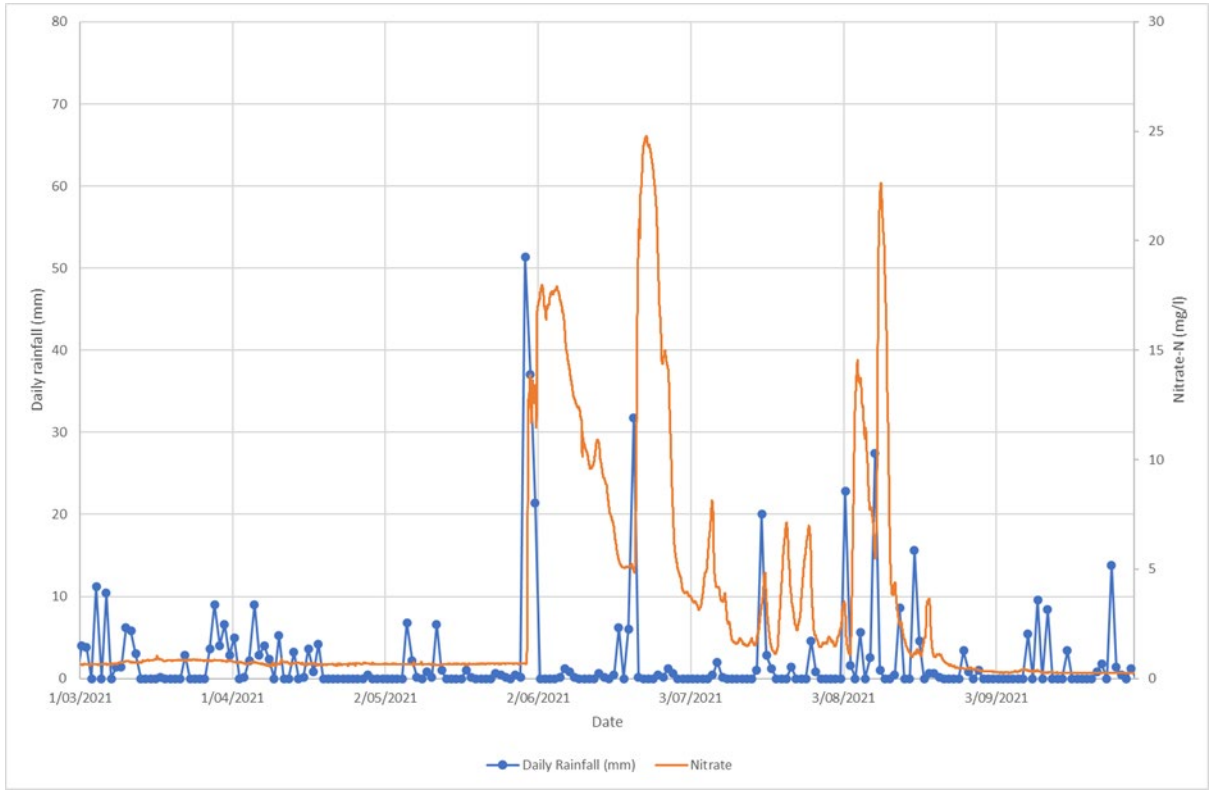


High resolution data

Peaks in nitrate concentration driven by rainfall events

- Repeated leaching events
- Not all nitrate is lost during first flushing event
- Subsequent ones (with lower rainfall) resulted in larger peaks

Evidence for “hot moments”?



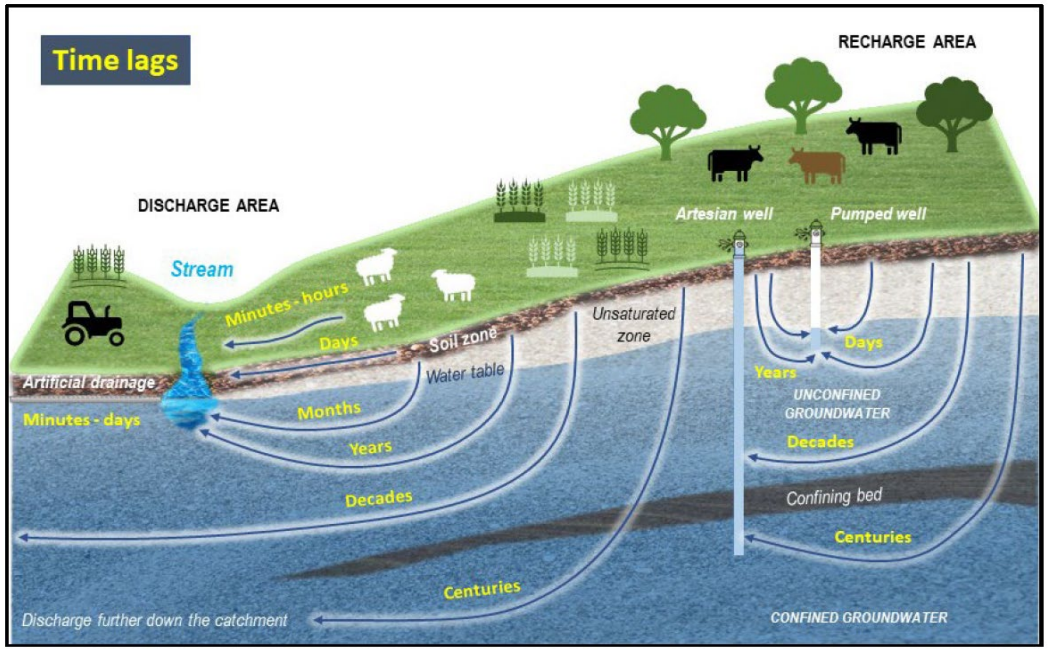
Confounding issues

Nitrate time lags

Source (contributing land use) and pathway (position in catchment, sample depth), all add to complexity

Transport processes are poorly characterised

- Transport through preferential flow paths



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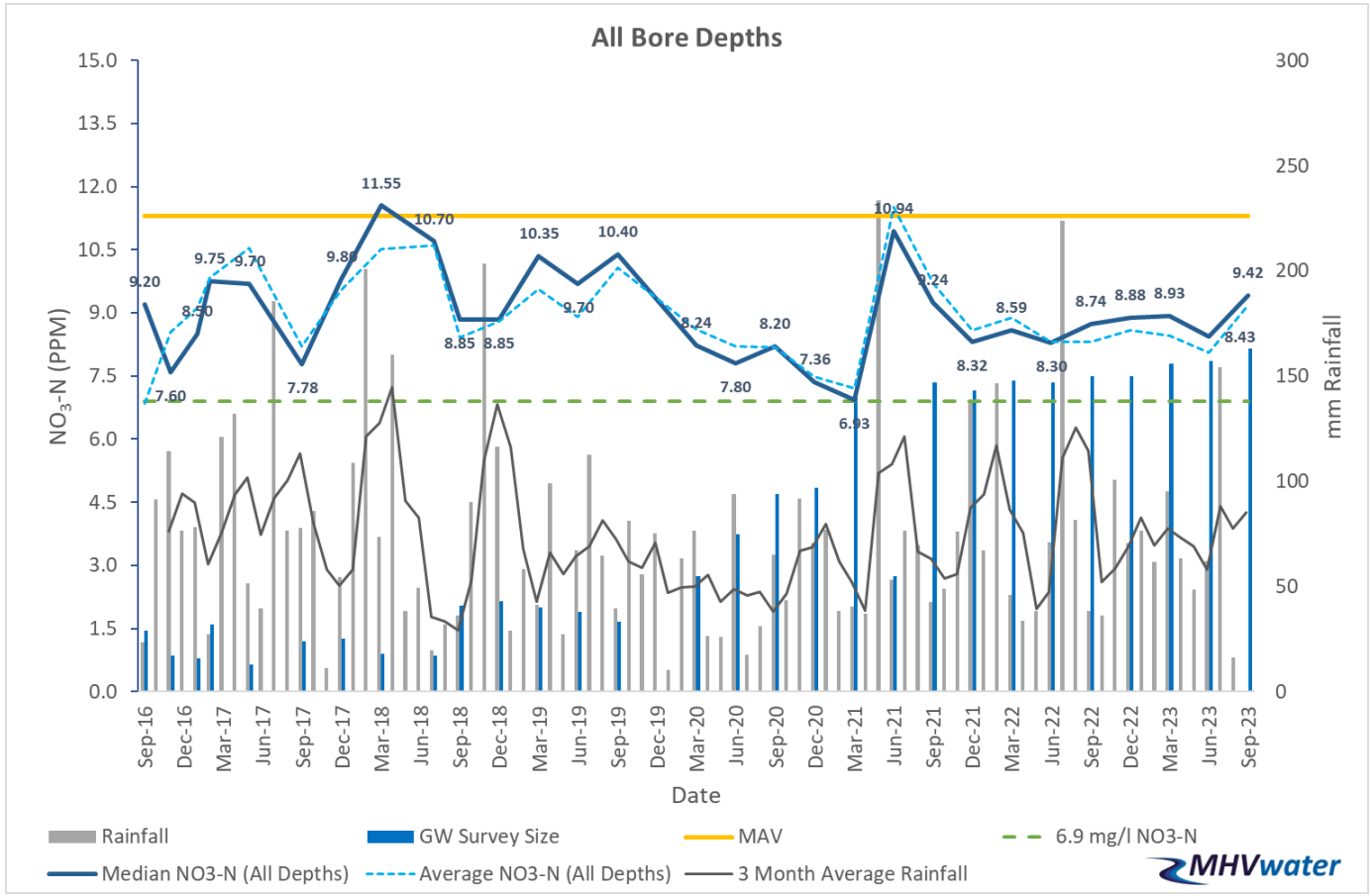
Confounding issues

Land management change

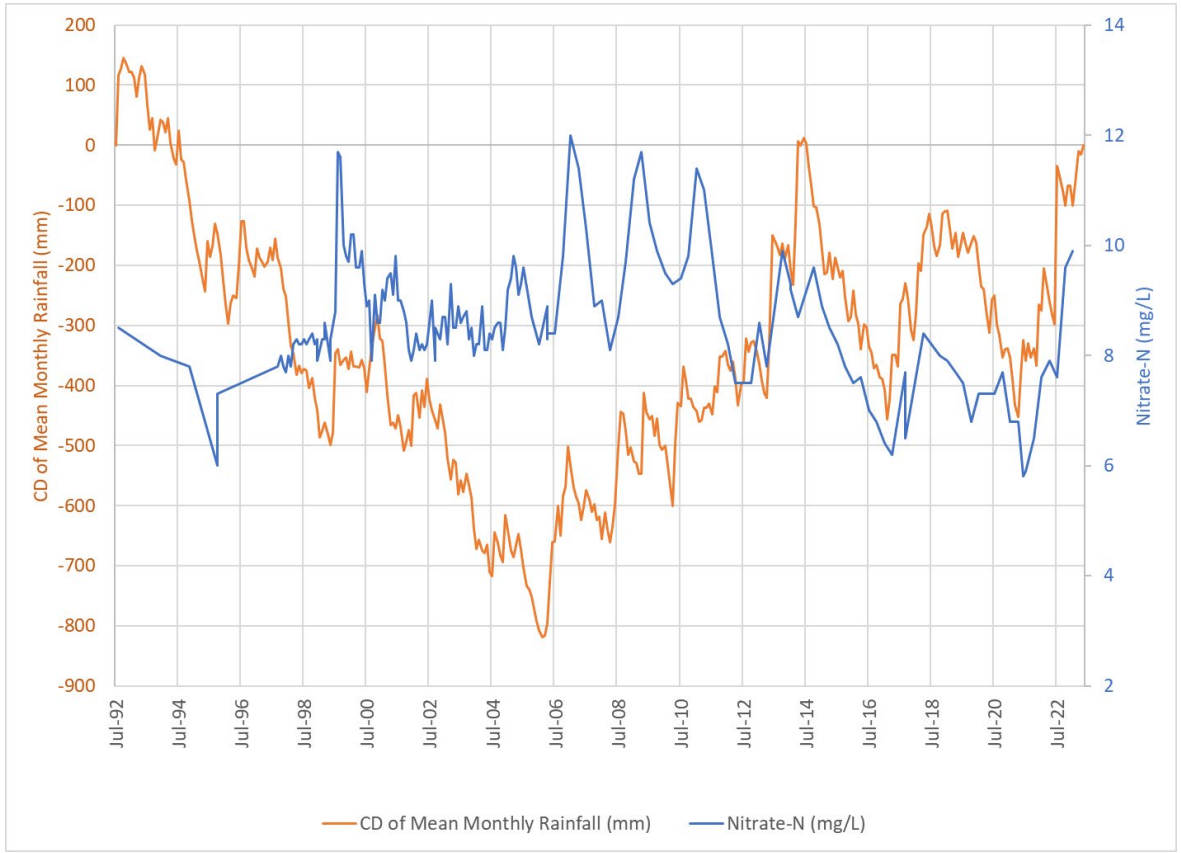
- Introduction of farm environment management plans
- Downward trend in nitrate concentrations
  - Improvement in land management
  - Impact of rainfall recharge



Confounding issues

Land use change

- Long term elevated nitrate concentrations due to septic tank discharges?
  - Late 1990s started change to reticulated wastewater
- Decline in nitrate concentrations thought to be due to removal of discharge
- When compared with cumulative departure from the mean rainfall, potentially climate-driven



Summary

Two main aspects of climate change to consider:

- Biological soil processes
- Physical leaching

More extremes in climate likely to lead to more extremes in hydrological responses and ultimately in nitrate concentrations

Consequences

- Impacts on human health and ecology?

Hugely complex

Thank you

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