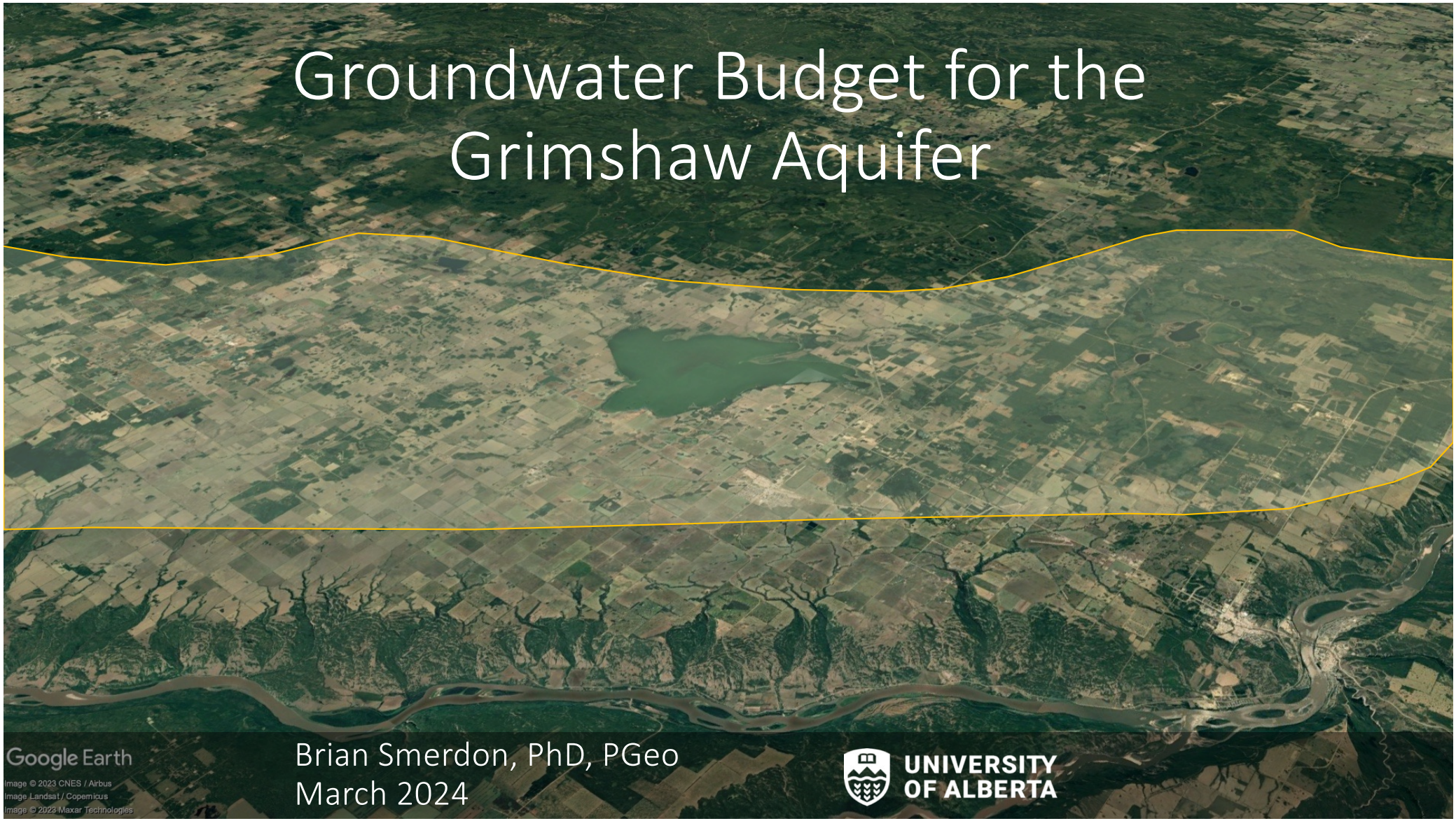
Groundwater Budget for the Grimshaw Aquifer



Brian Smerdon, PhD, PGeo
March 2024

UNIVERSITY OF ALBERTA

Project Objective

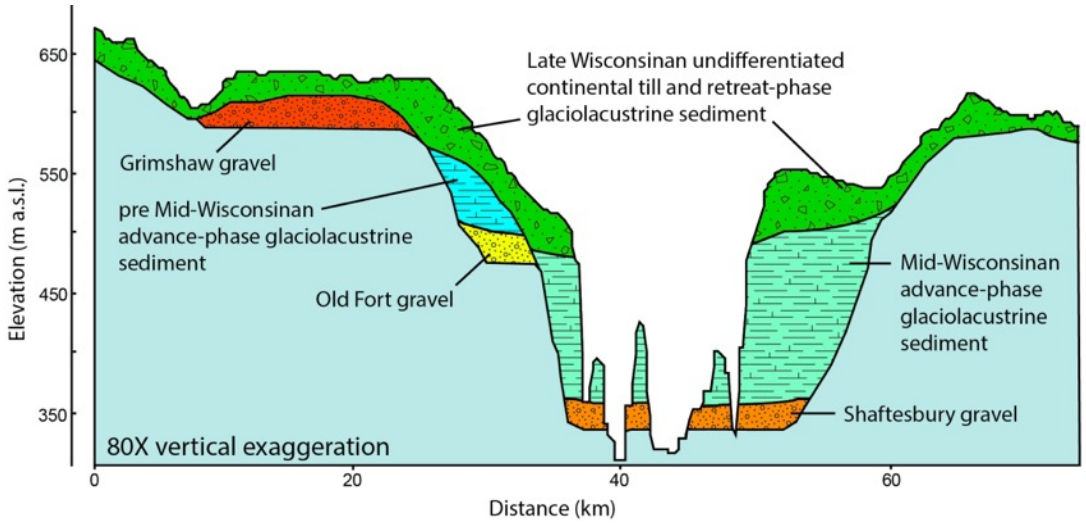
- **Develop a water budget and groundwater model for the Grimshaw Aquifer**
  - A case study for AEPA Lands Planning Branch
  - Investigate groundwater quantity
- **Build on recent work by the Alberta Geological Survey and the Mighty Peace Watershed Alliance**

Presentation Outline

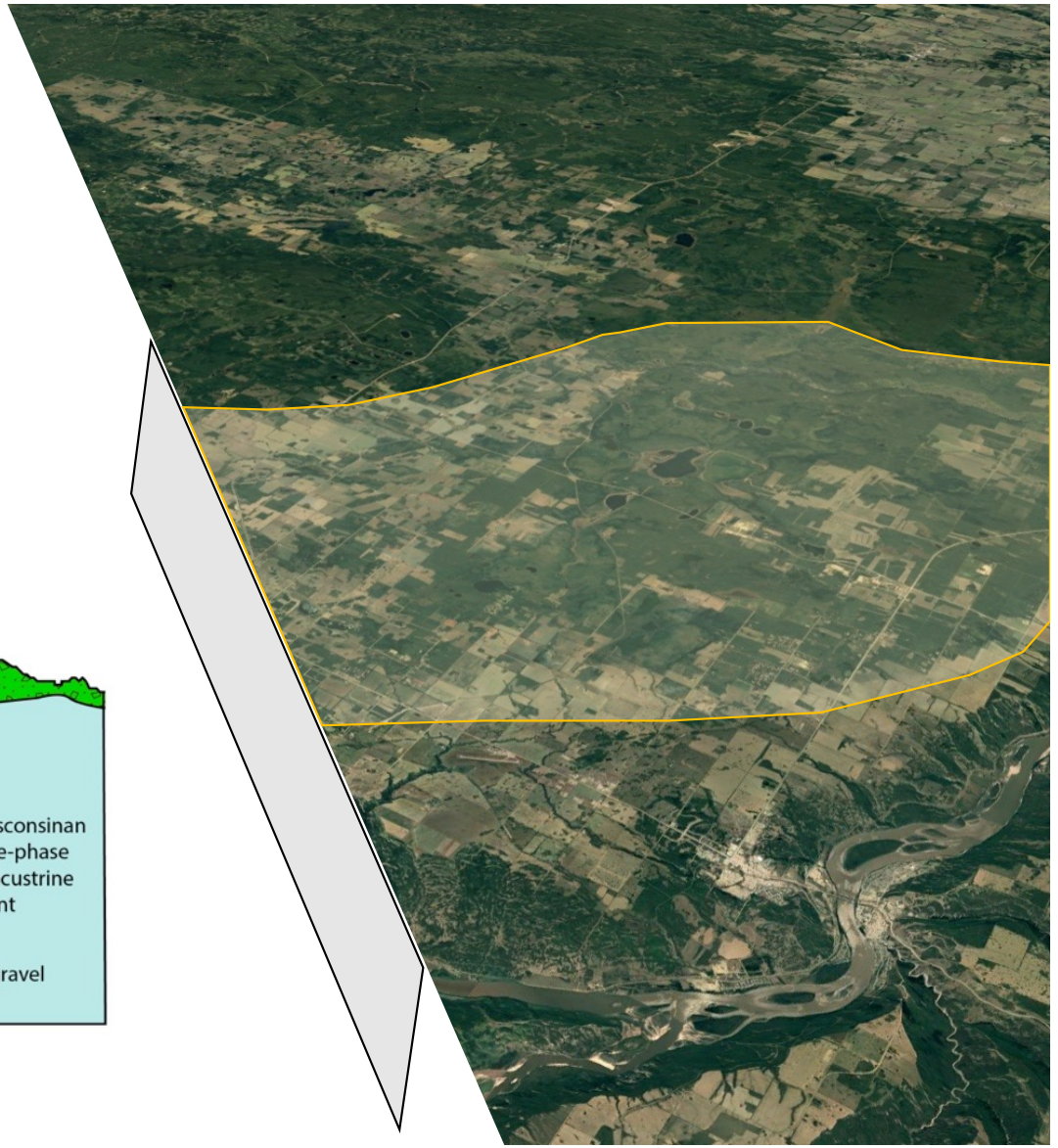
- Define a groundwater budget
- Summary of key findings
- Explore some of the details

Grimshaw Aquifer System

- 3 separate gravel deposits at different elevations
- Long recognized as a productive aquifer system

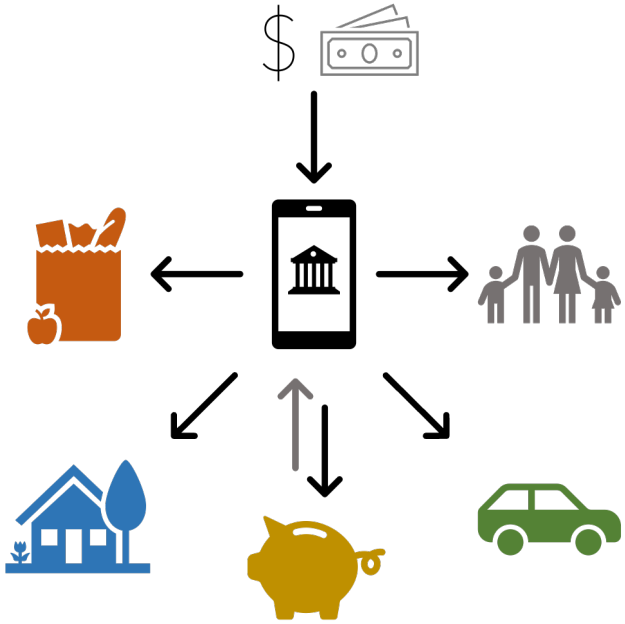


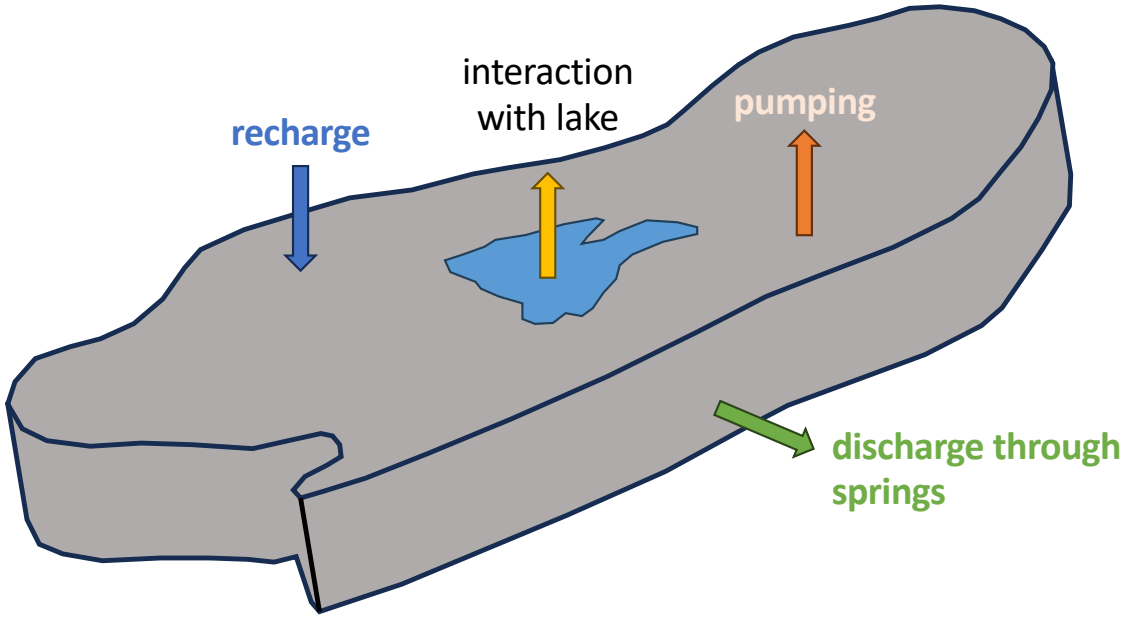
Cross section by Greg Hartman, AGS (2023)



What is a Groundwater Budget?

- Same concept as a financial budget

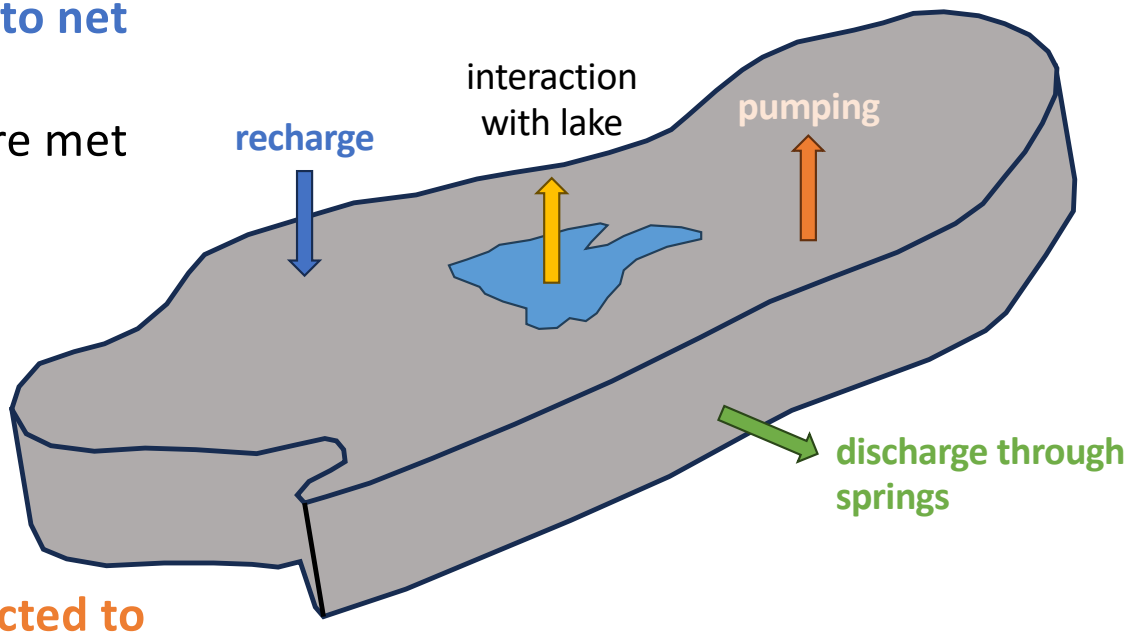




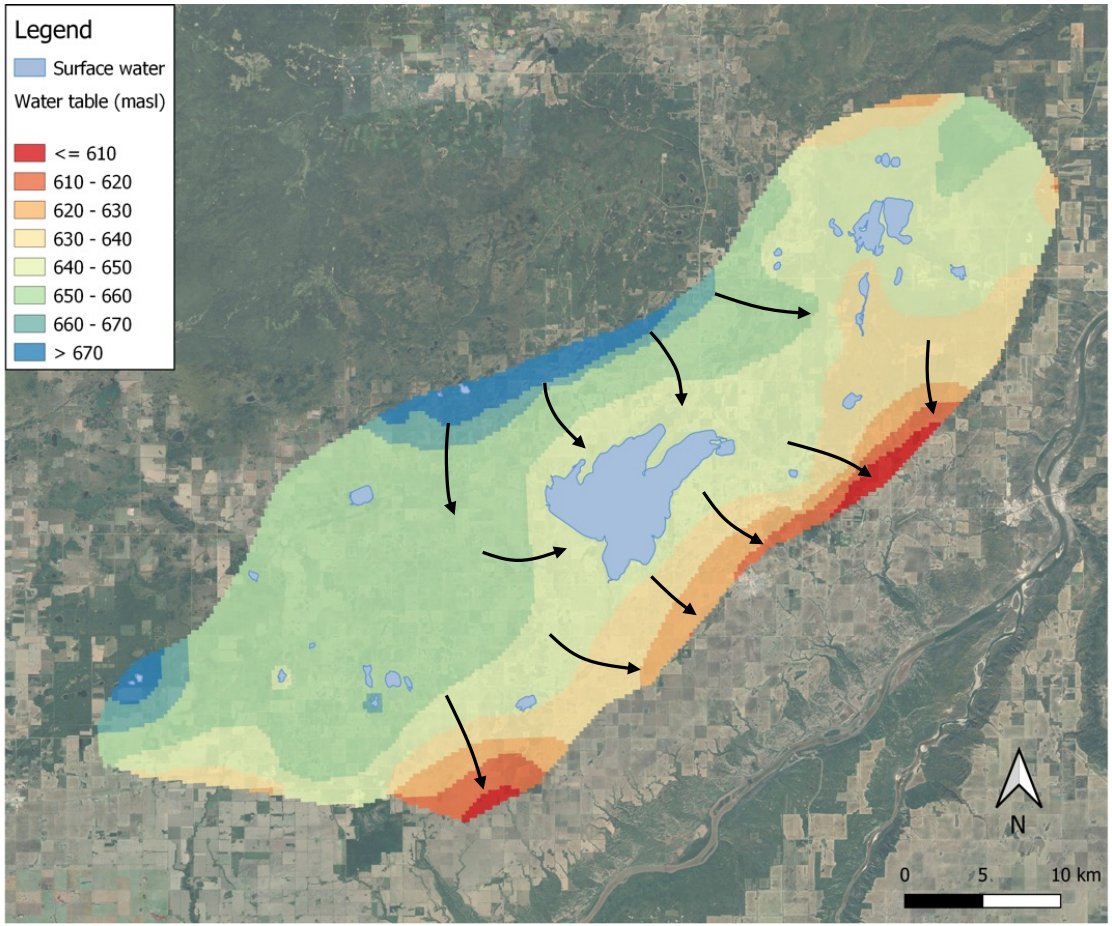
- Requires knowing income and expenses
- For an aquifer, some components are challenging to quantify

Key Findings for the Grimshaw Aquifer

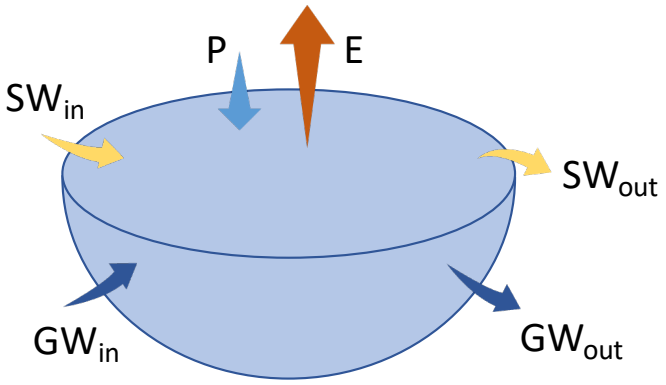
- **Groundwater budget is neutral to net positive**
  - Outflows and withdrawals are met by natural replenishment
  - Aquifer sufficiently supports existing groundwater users
- **Continued pumping is not expected to greatly decrease groundwater levels**



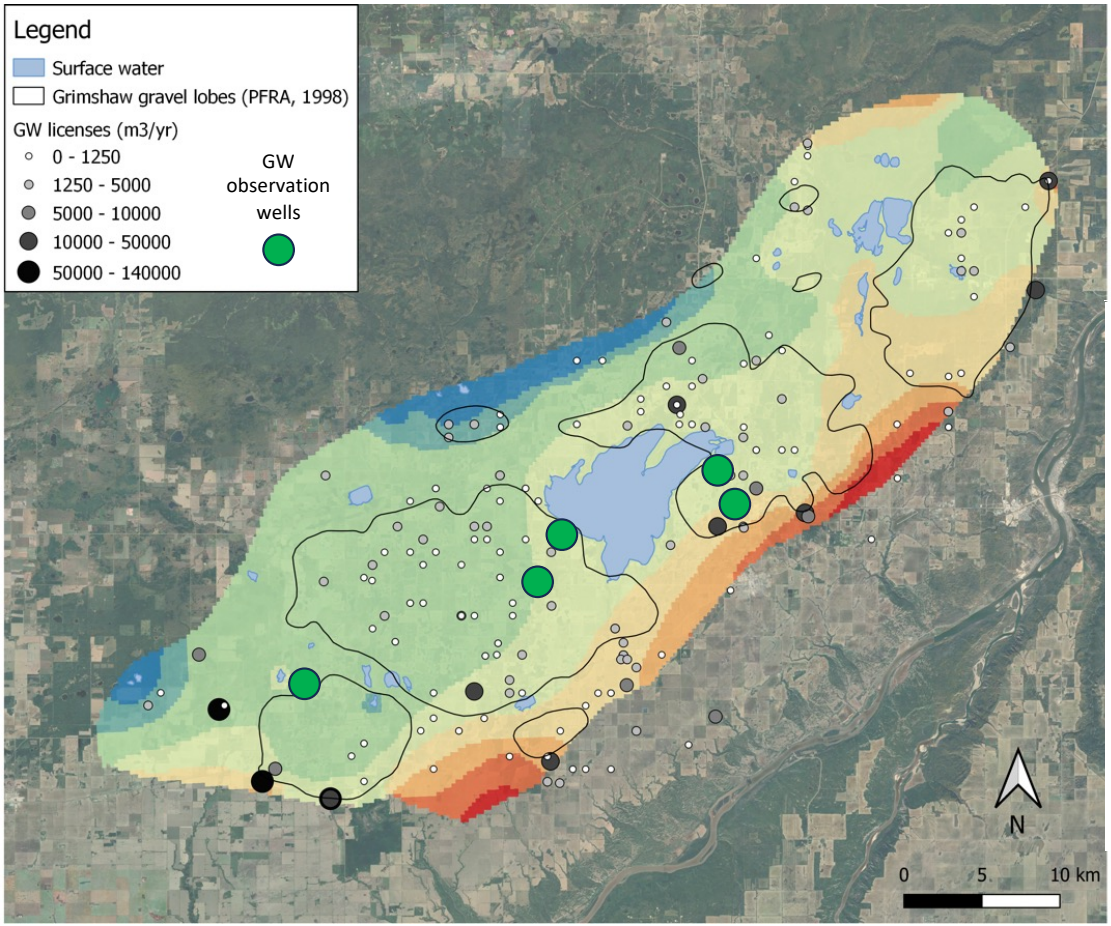
Some other interesting results



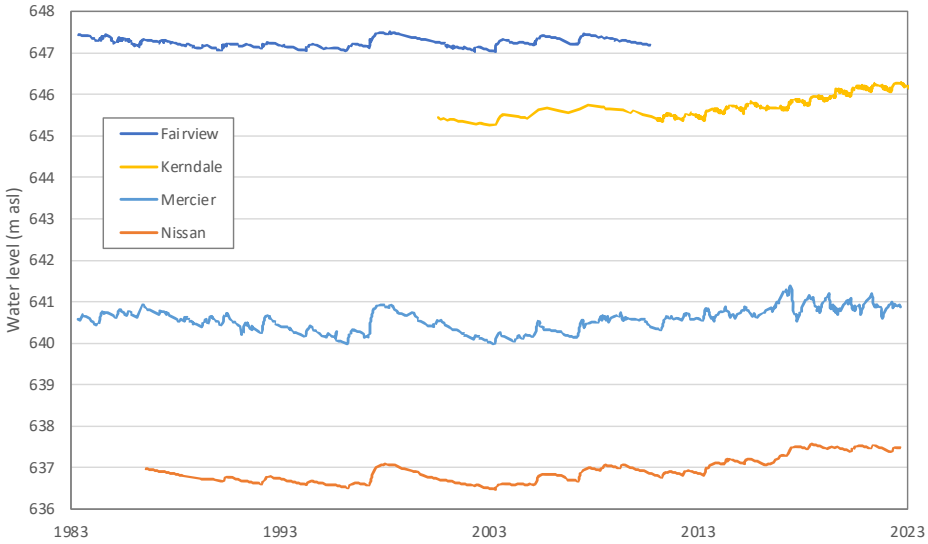
- Groundwater interacts with Cardinal Lake
  - Gain along NW; Loss along SE
  - Groundwater discharges to the lake over the long term
  - Evaporative loss from the aquifer



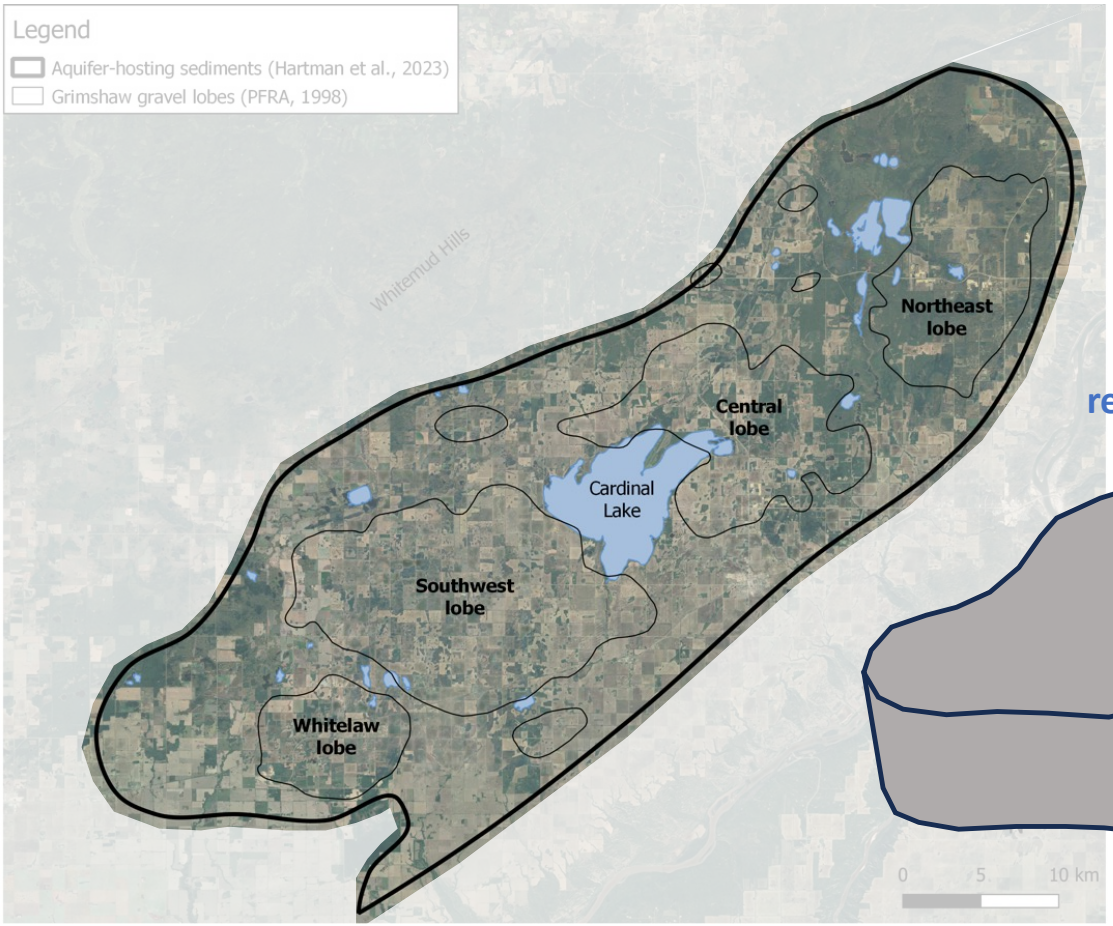
A continued need for groundwater monitoring



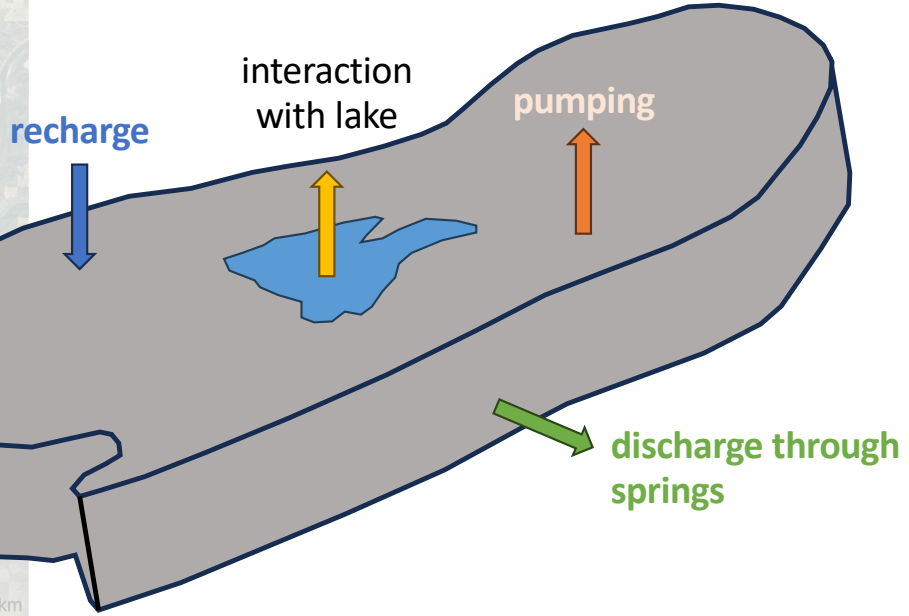
- Groundwater levels have been relatively stable for 40 years
- Monitoring wells are well-positioned compared to pumping locations



A guided tour through the details



- Quantify each major budget component
- Justify choices and acknowledge uncertainty



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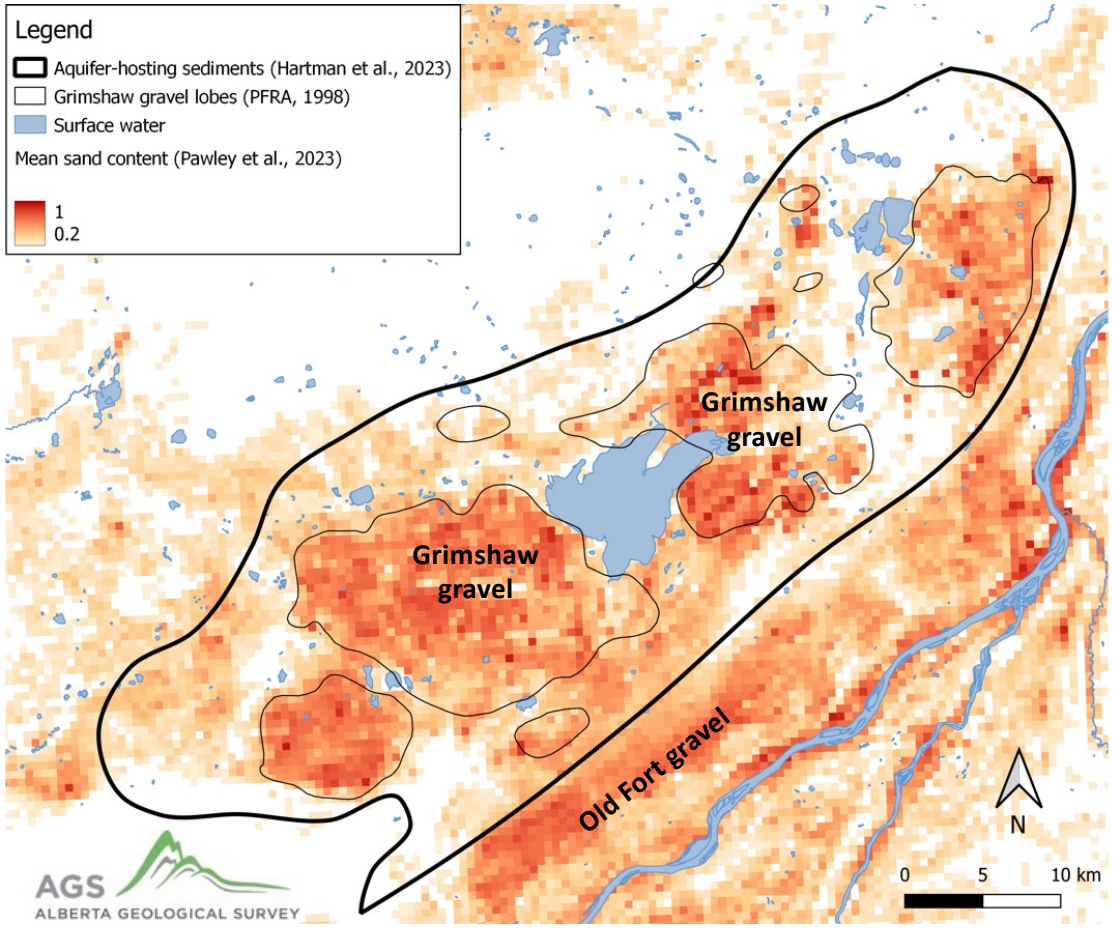


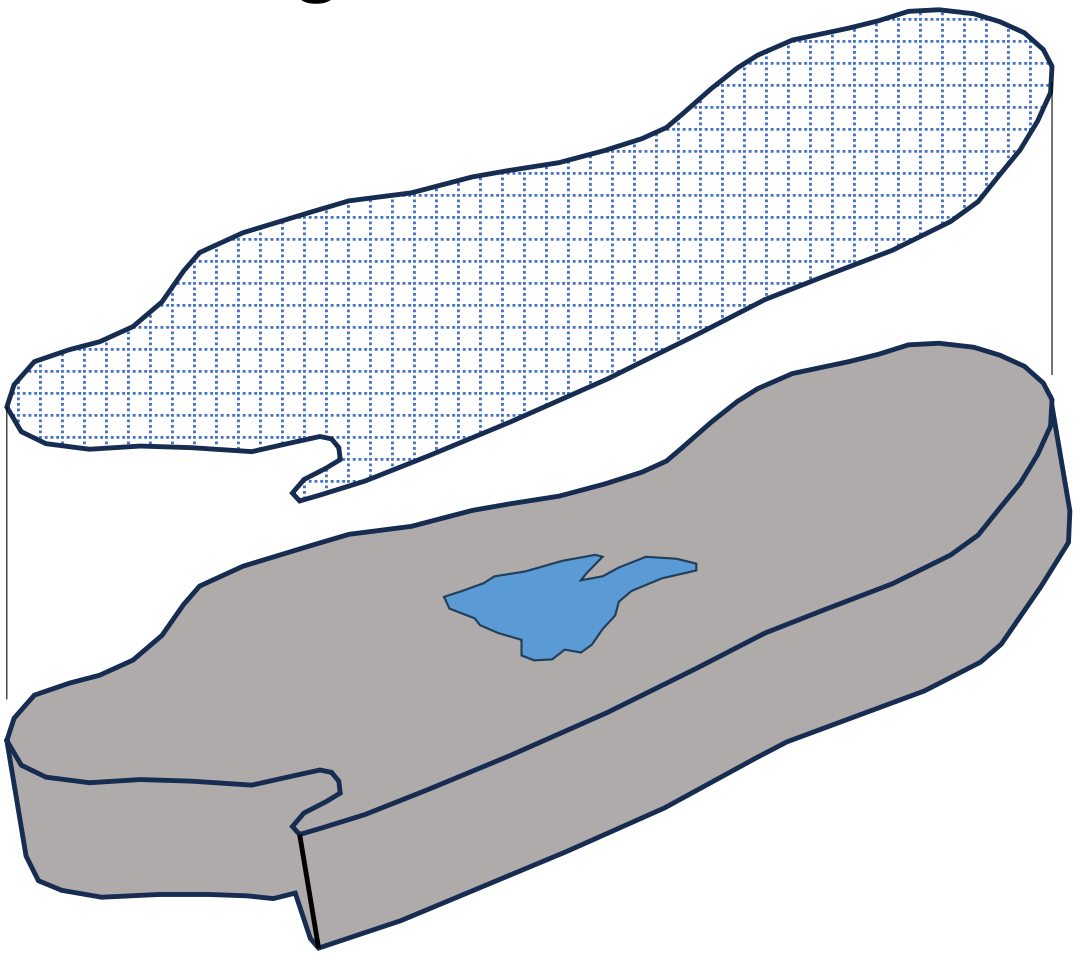
2 new maps from the Alberta Geological Survey:

- Aquifer hosting sediments
- Probability of sand and gravel above bedrock
  - Created using water well records
  - Darker colours expected to have more sand and gravel

- **Confirms location of distinct gravel lobes**
- **Differentiates upper 'Grimshaw' deposit from 'Old Fort' deposit**

A guided tour through the details

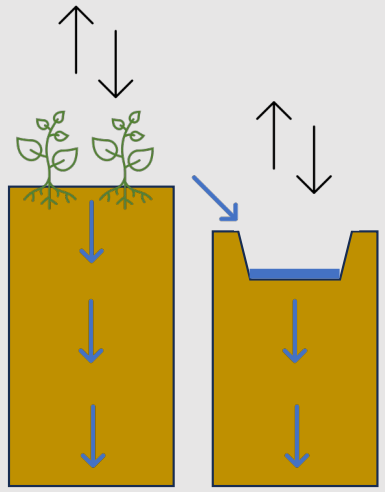
- Water budget units are expressed as **mm/yr**
  - Represents the volume of water for the entire aquifer area
  - Same concept as used for rainfall (mm or inches)
  - Small number across a large area



Groundwater Recharge

Low Estimate

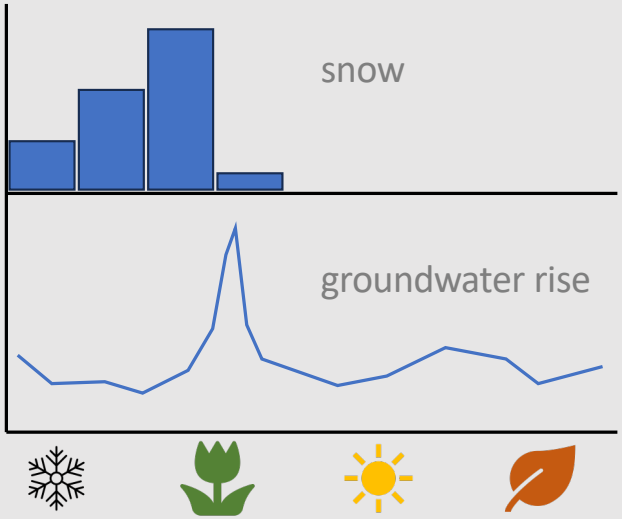
- Determined from VSMB model (Klassen and Liggett, 2019)



5 mm/yr

High Estimate

- Determined from snowmelt and groundwater rise (Klassen and Smerdon, 2020)



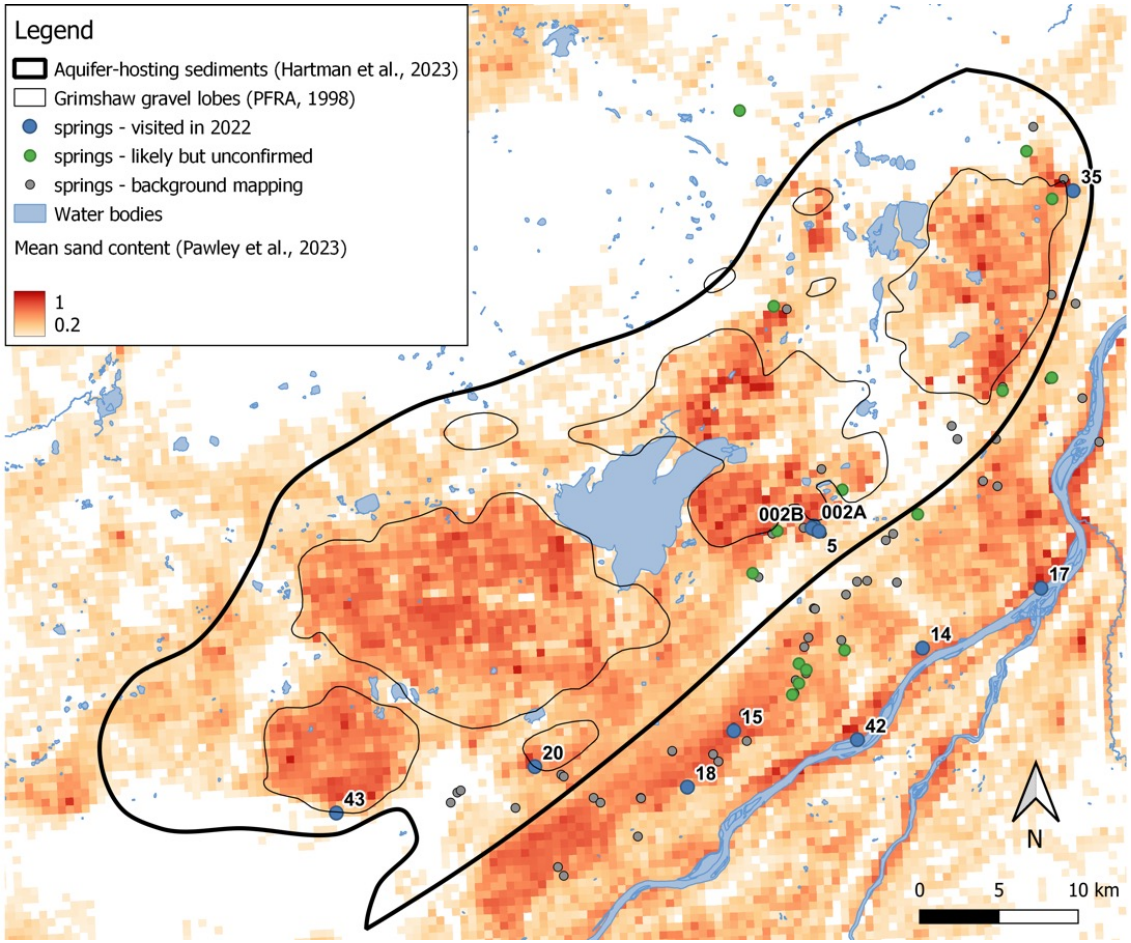
18 mm/yr

Groundwater Discharge: Springs

Led by MPWA

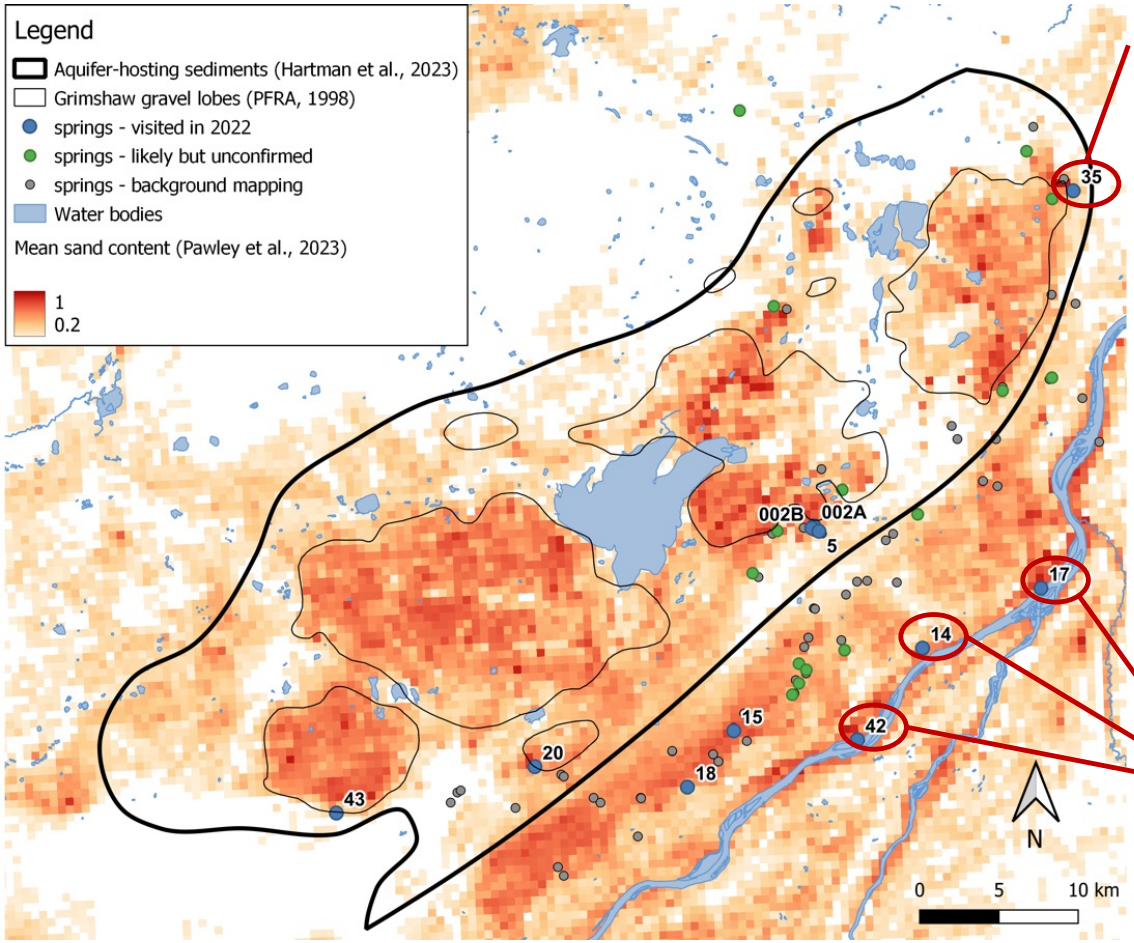
- AGS database
- Google Earth mapping
- Field survey in 2022
  - 11 sites
  - Flow rate
  - Water samples for chemistry and stable isotopes

Groundwater Discharge: Springs

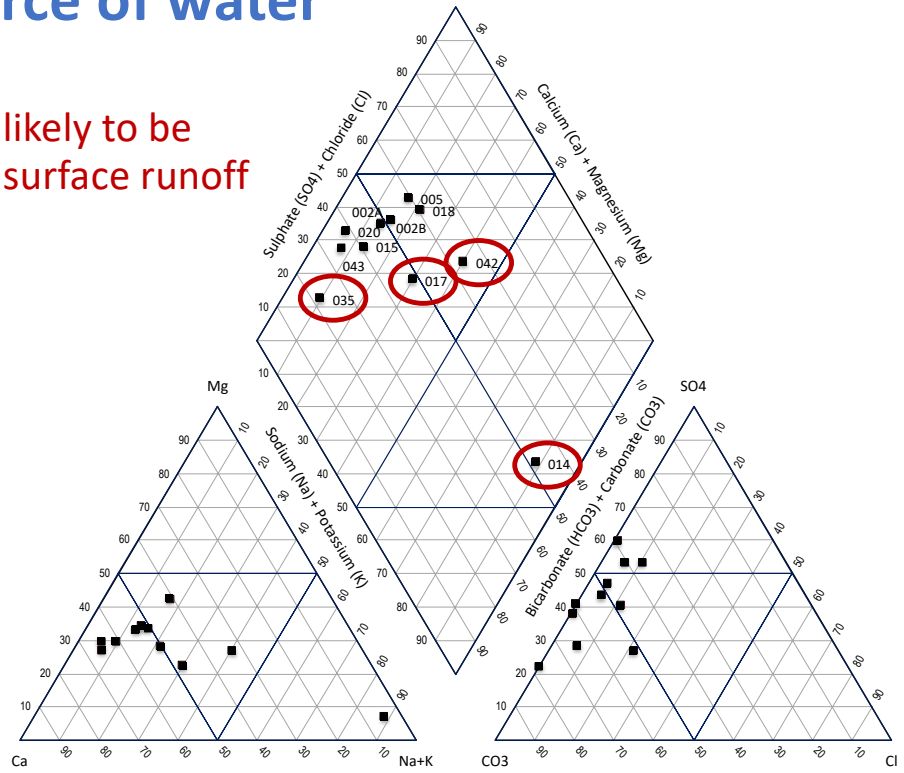


- Some springs are sourced from the Grimshaw deposit
- Some springs are sourced from Old Fort deposit

Chemistry results help confirm the source of water

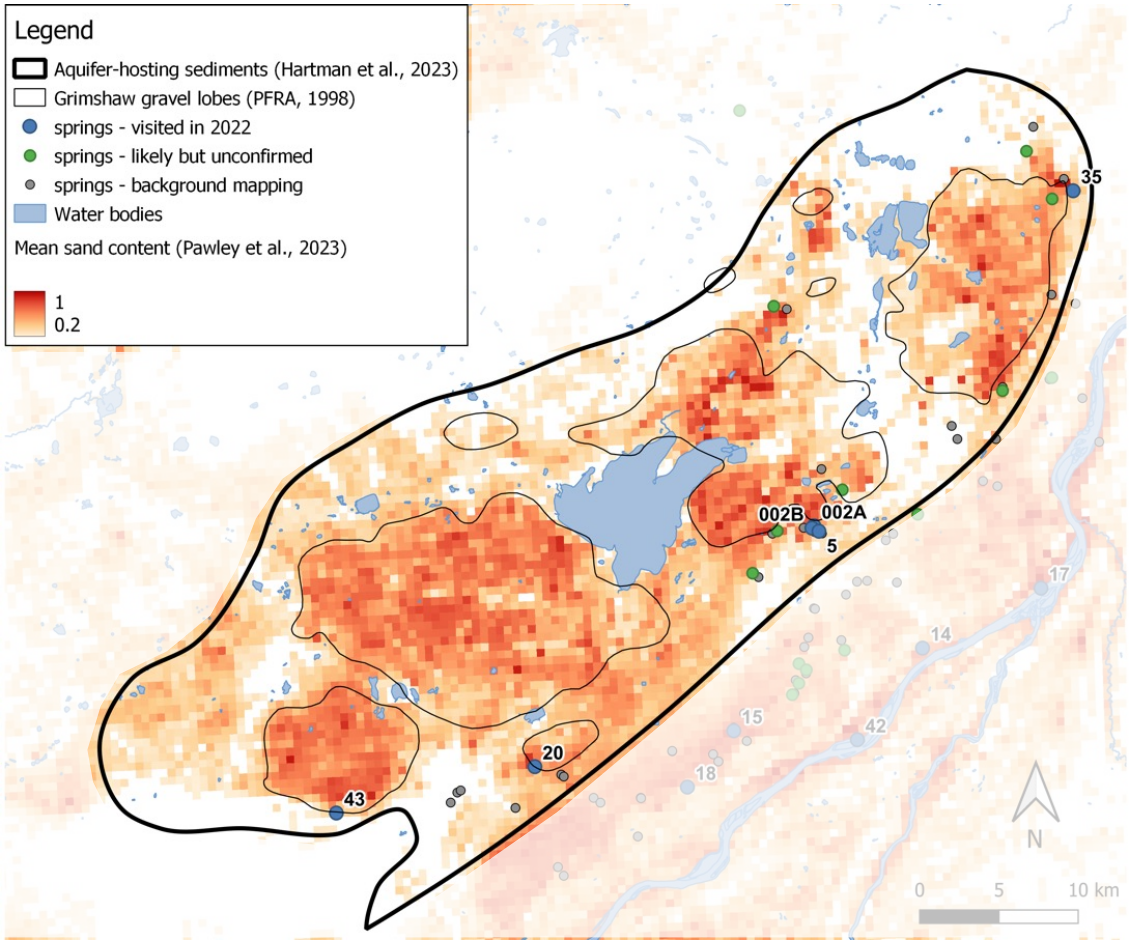


likely to be surface runoff



likely sourced from bedrock formations

Groundwater Discharge: Springs

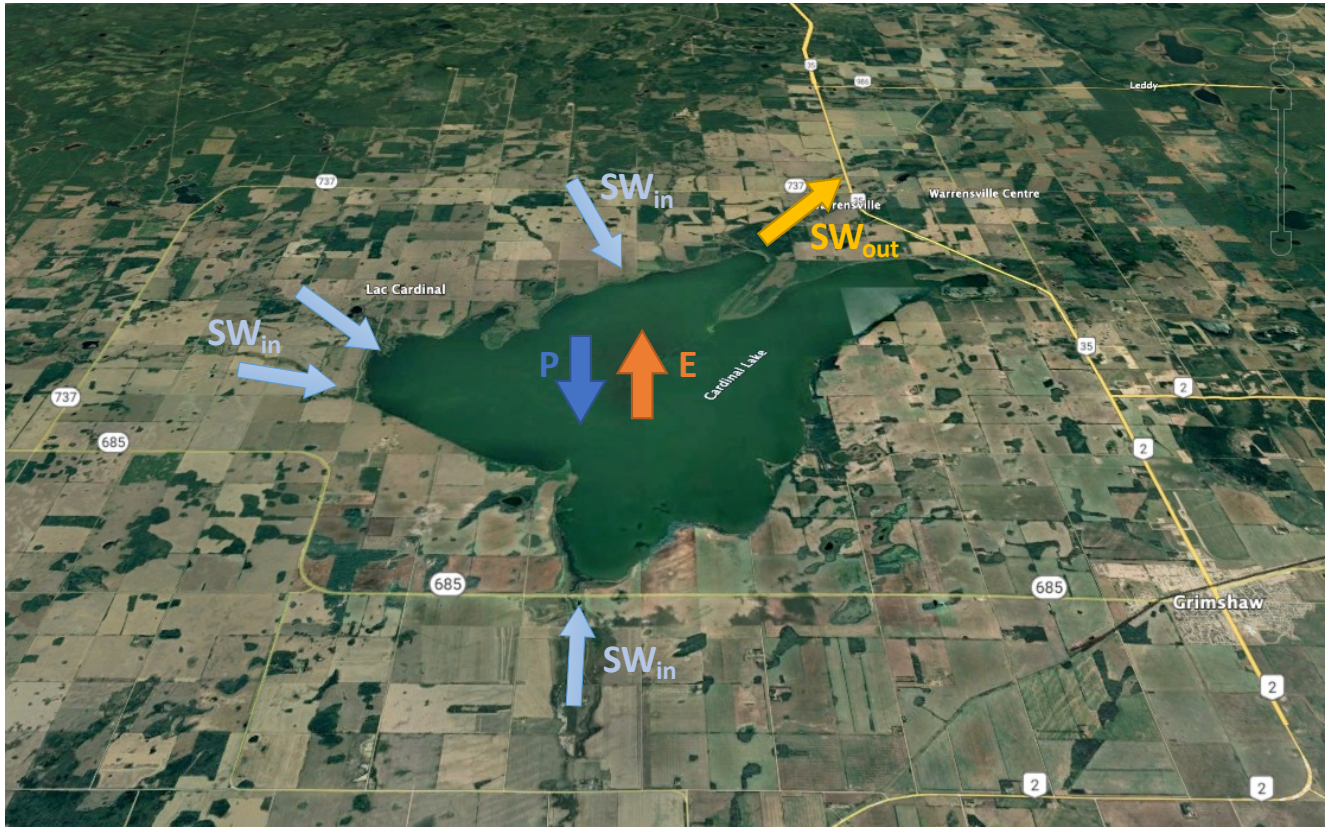


Spring discharge

63 L/s

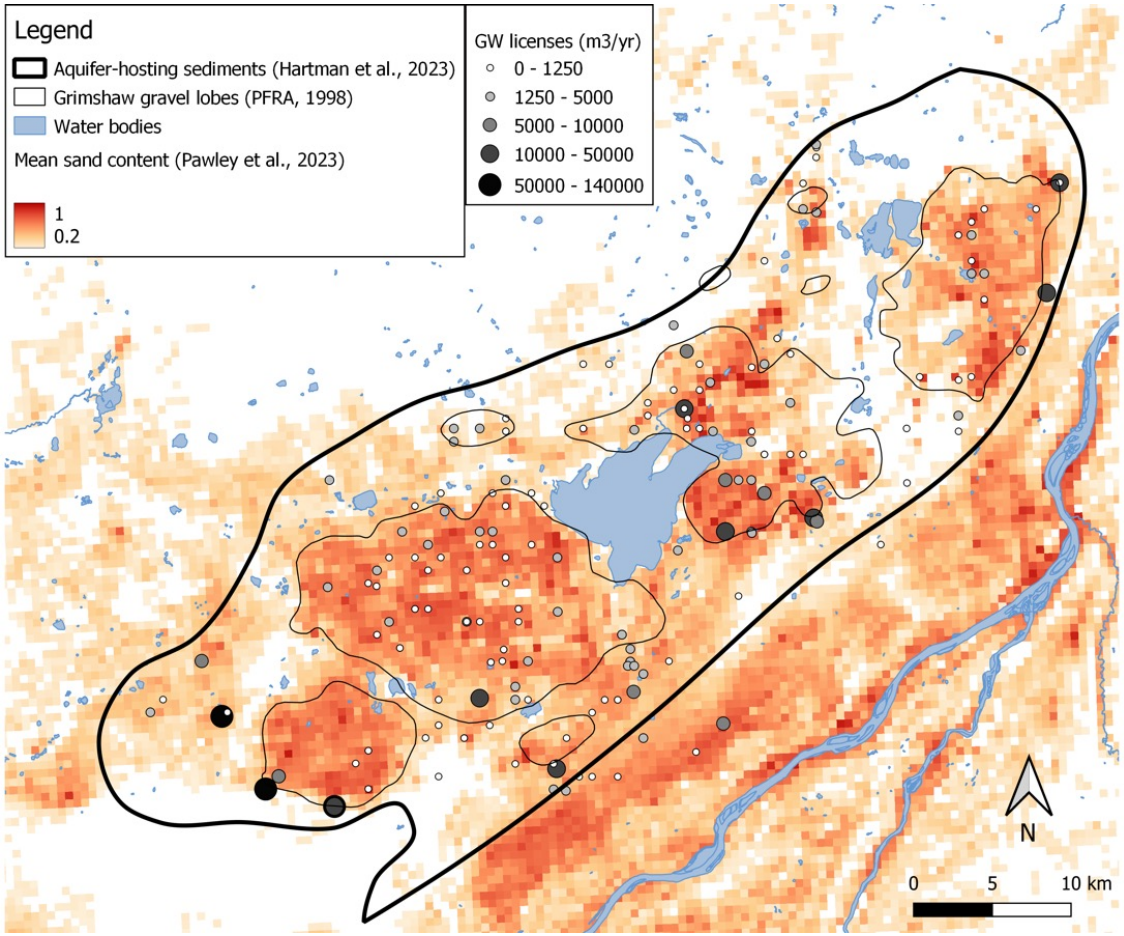
2 mm/yr

Cardinal Lake



- Simple water budget for the lake
  - Climate data
  - Flow estimate for ungauged watersheds
- **Net water loss (74 mm/yr)**
- Could be evaporation and/or groundwater recharge
  - Assume water loss from groundwater system

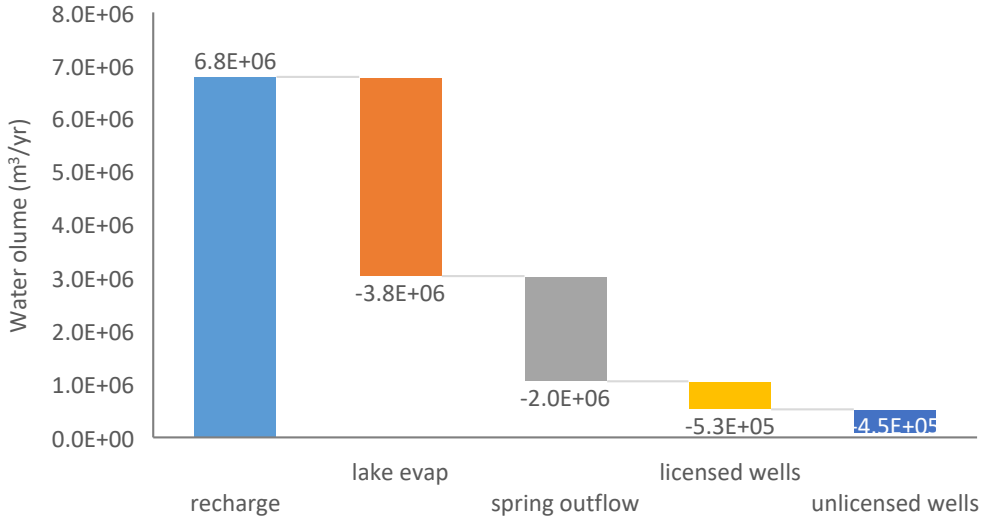
Groundwater Pumping



wells with a water license (consumptive use) + other wells (1250 m^3/yr)

- Actual use is largely unknown
  - MD of Fairview: 14 to 58%
  - MD of Peace: 51%
- Assumed % of allocation for water budget
  - **Low: 30%**
  - **Medium: 50%**
  - **High: 100%**

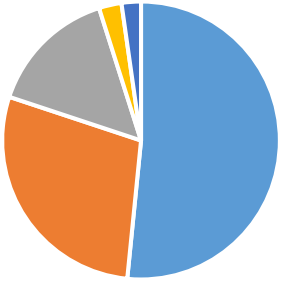
Aquifer Water Budget: *low recharge → neutral*



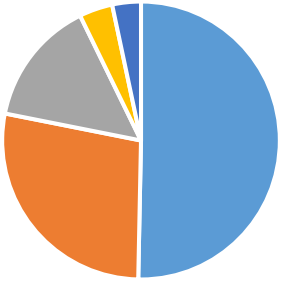
Medium pumping
50% of allocation
8.6E+04 m^3/yr
0.2 mm/yr

Aquifer Water Budget: *low recharge → neutral*

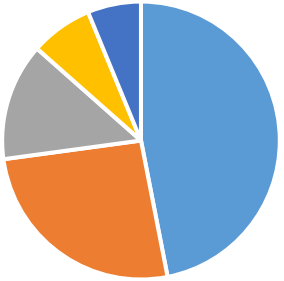
Low well use (30% allocation)

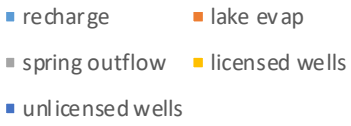


Medium well use (50% allocation)



High well use (100% allocation)



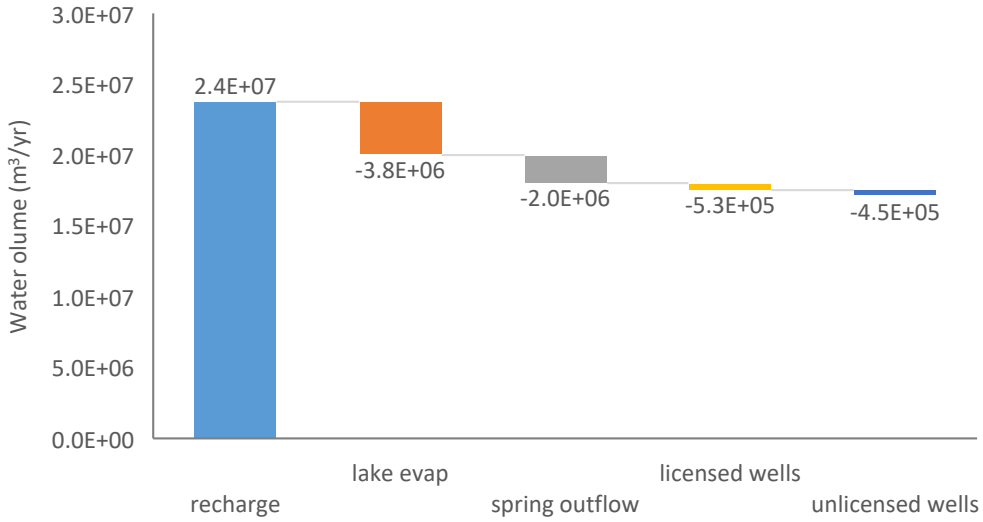


Low pumping
30% of allocation
4.2E+05 m^3/yr
0.3 mm/yr

Medium pumping
50% of allocation
8.6E+04 m^3/yr
0.2 mm/yr

High pumping
100% of allocation
-8.9E+05 m^3/yr
-0.6 mm/yr

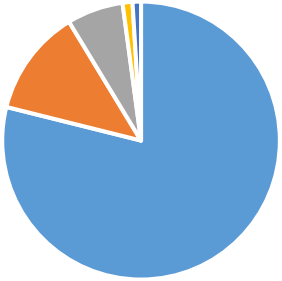
Aquifer Water Budget: *high recharge → net positive*



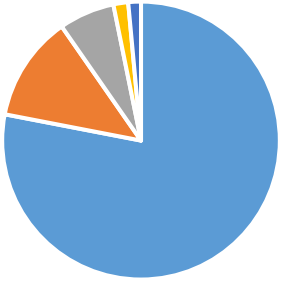
Medium pumping
50% of allocation
1.7E+07 m^3/yr
12.2 mm/yr

Aquifer Water Budget: *high recharge → net positive*

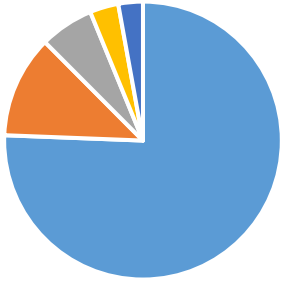
Low well use (30% allocation)

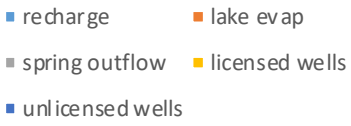


Medium well use (50% allocation)



High well use (100% allocation)



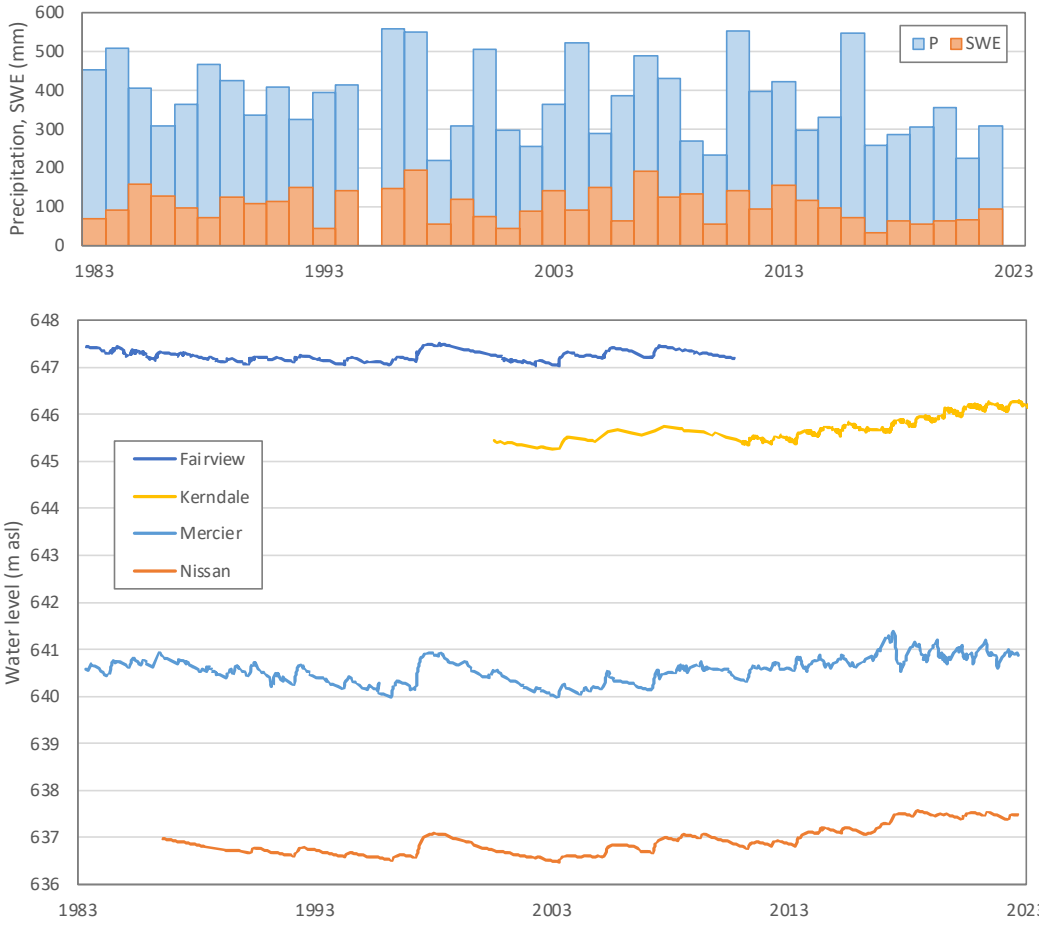


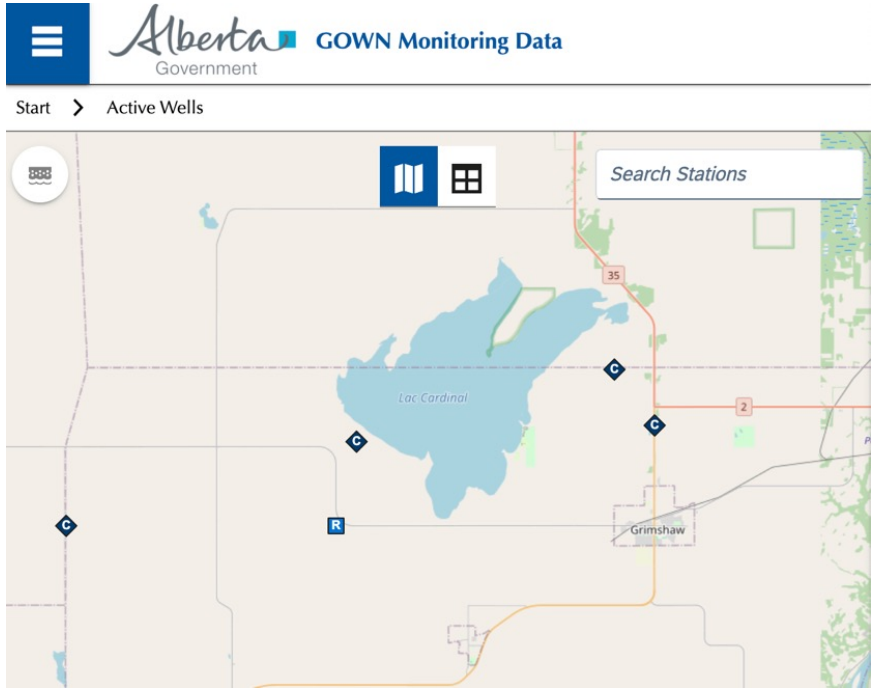
Low pumping
30% of allocation
1.7E+07 m^3/yr
12.5 mm/yr

Medium pumping
50% of allocation
1.7E+07 m^3/yr
12.2 mm/yr

High pumping
100% of allocation
1.6E+07 m^3/yr
11.5 mm/yr

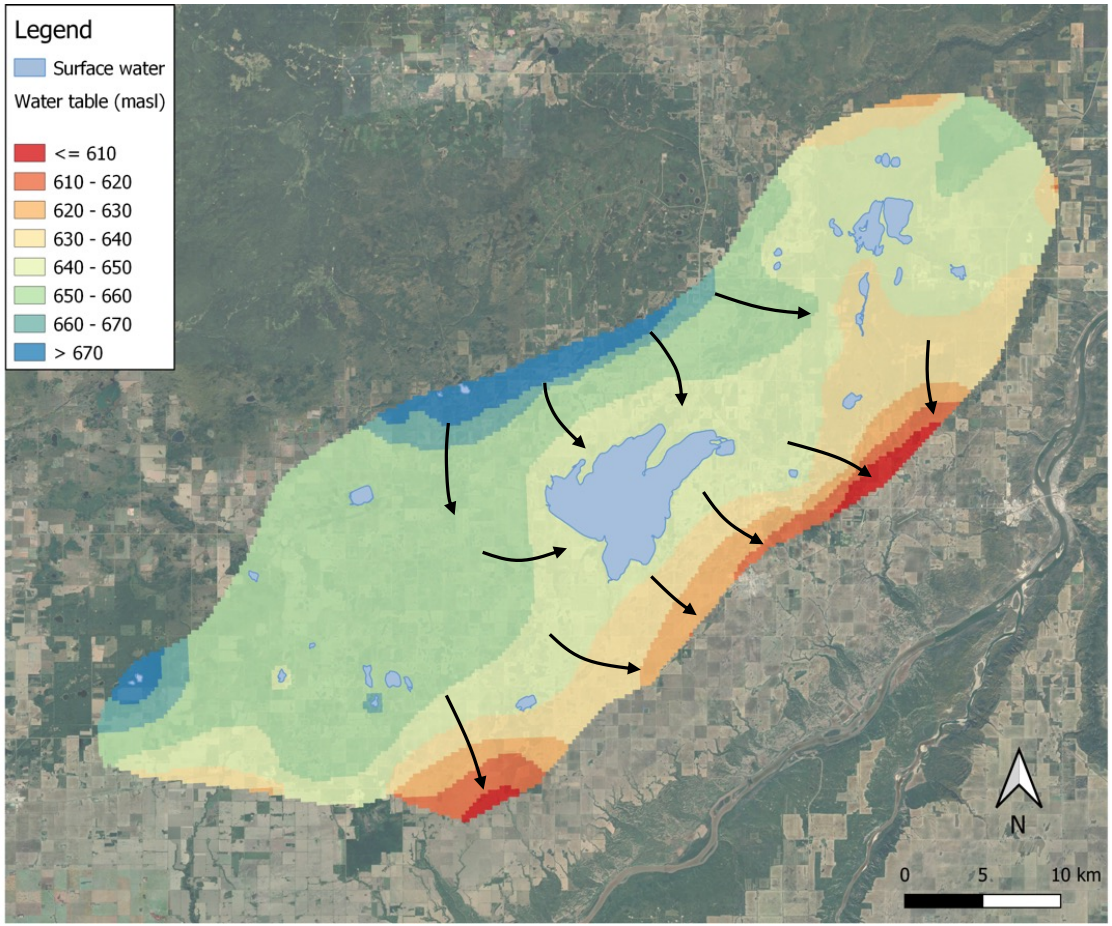
Groundwater Observations





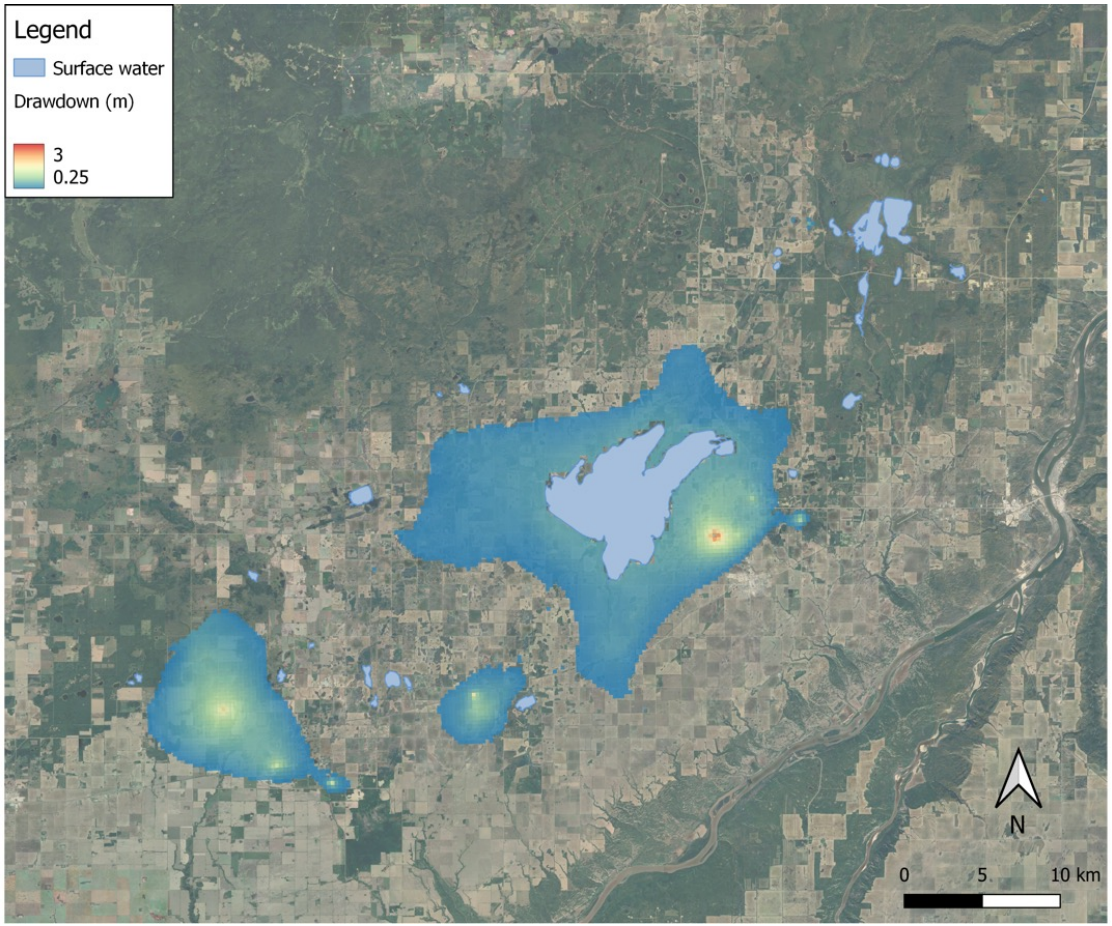
- Groundwater levels respond directly to annual variation in snowmelt
- From 1983 to 2023 fluctuations within 1 m

Groundwater Modelling



- Mimics the distribution of groundwater in the Grimshaw Aquifer
- Provides a check on the water budget estimates
- Confirms groundwater flow direction and interaction with the lake

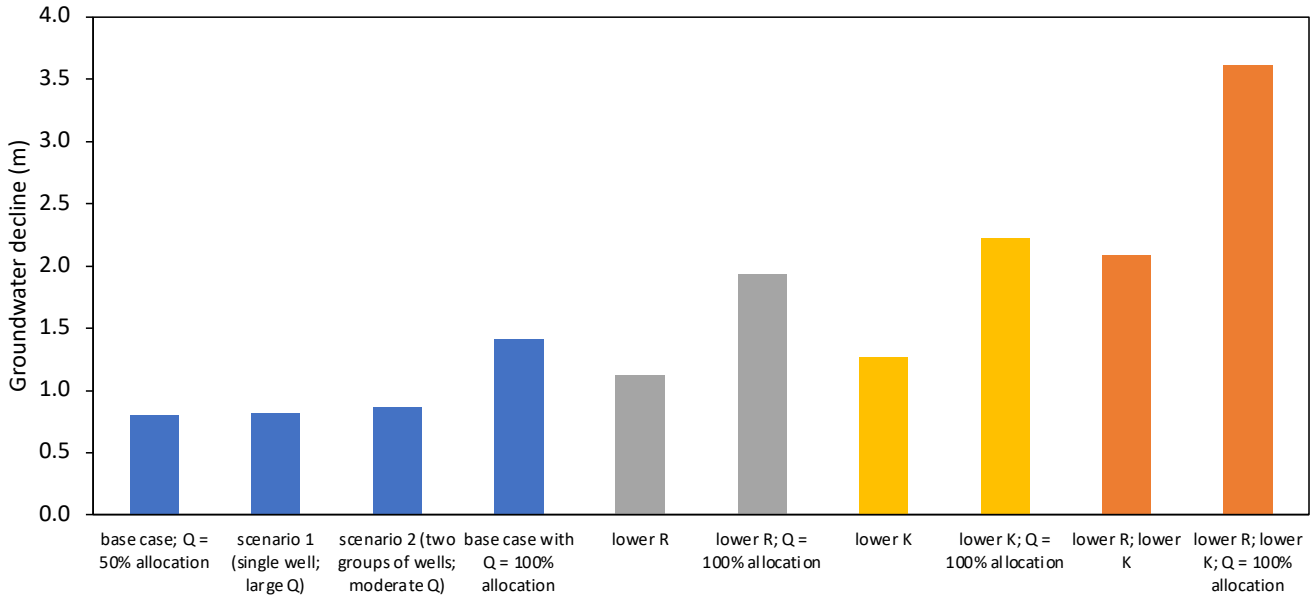
Groundwater Modelling



- Also useful to evaluate the influence of pumping
- For pumping at 30% of allocation groundwater decline is limited
  - < 1 m in the broad area surrounding a well

- Base case
  - 50% allocation
  - 100% allocation
  - Scenario 1: single well; large Q
  - Scenario 2: two groups of wells; moderate Q
- Lower recharge
  - 50% allocation
  - 100% allocation
- Lower hydraulic conductivity
  - 50% allocation
  - 100% allocation
- Lower recharge and lower hydraulic conductivity
  - 50% allocation
  - 100% allocation

Many scenarios can be considered!



Key Findings for the Grimshaw Aquifer

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  - Outflows and withdrawals are met by natural replenishment
  - Aquifer sufficiently supports existing groundwater users
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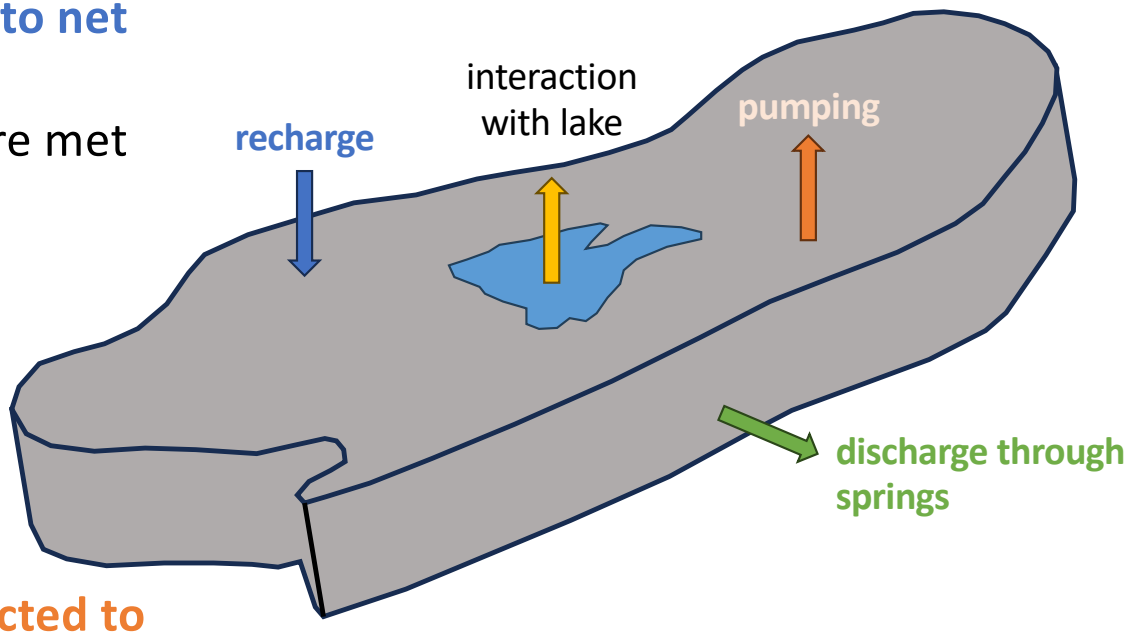
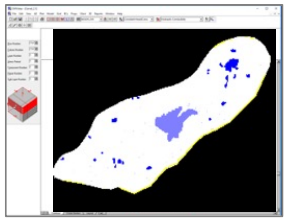


Thank you!

Darby Burns

- Summer Student
- GW modelling



Mighty Peace Watershed Alliance

Alberta
Environment and Protected Areas

Alberta Energy Regulator

AGS
ALBERTA GEOLOGICAL SURVEY