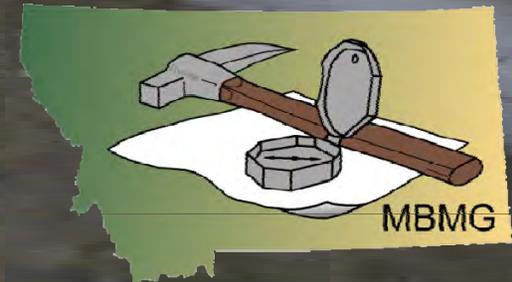


A Hydrologic Study of the North Hills, Helena, Montana

Andrew Bobst, Kirk Waren, James Swierc, and Jane Madison
MBMG Groundwater Investigations Program



12/6/11 - Lewis and Clark County Water Quality Protection District Board

Background

- Groundwater Steering Committee Selected North Hills as #1 priority for groundwater investigation
- Controlled Groundwater Area (CGWA)
 - Increased Subdivisions
 - 1995 – 1,077 homes
 - 2009 – 2,150 homes
 - Observed Water Level Declines
 - Concerns regarding nitrate
- Purpose and Scope of Study
 - Provide a scientific basis for evaluating water availability and water quality.

Study Area

Southern Lewis and Clark County

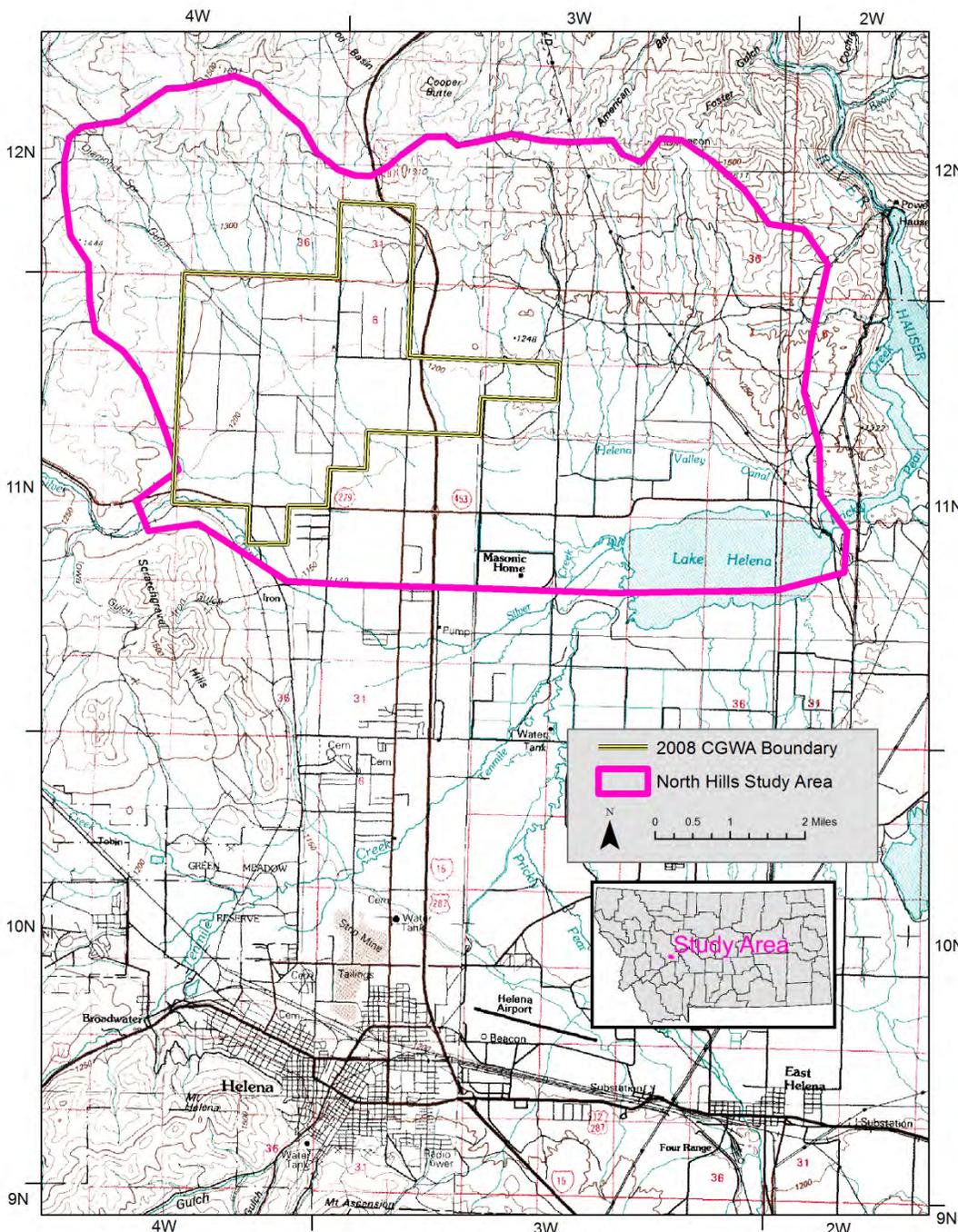
~8 miles north of Helena

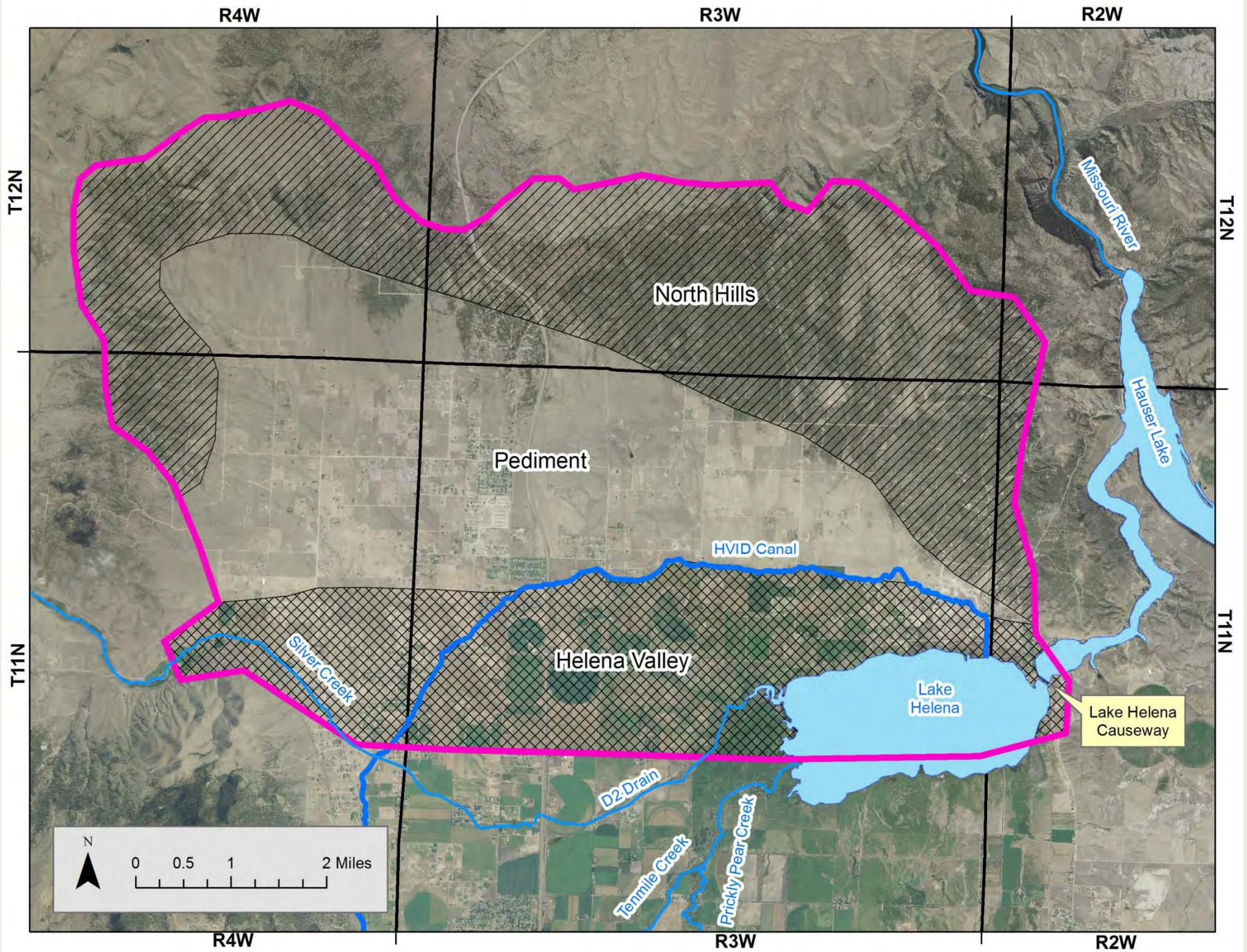
On the northern edge of the Helena Valley

~ 55 square miles

Study area boundary

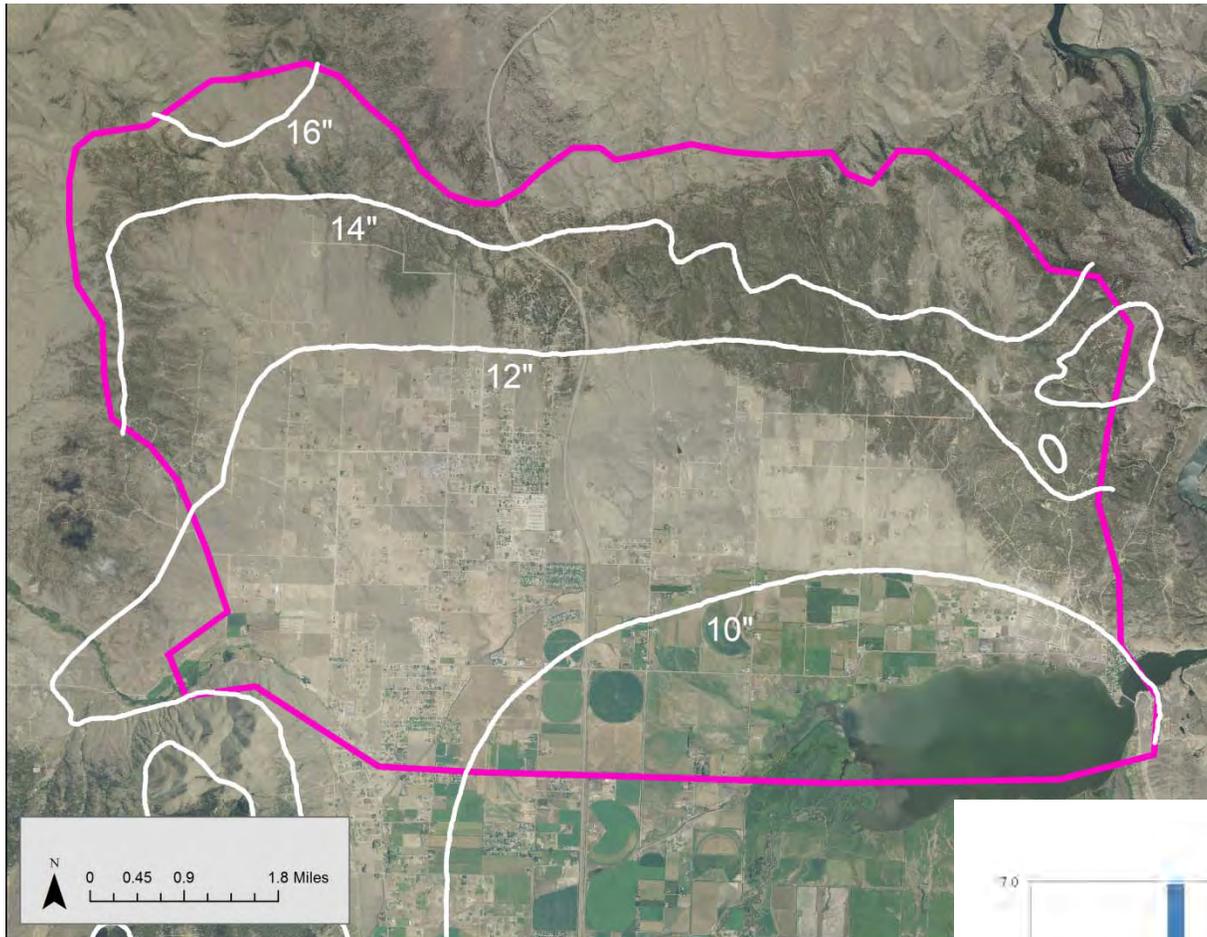
Surface water divides on the west, north and east, and a groundwater flow line on south.





Setting: Climate

Average precipitation ranges from less than 10" in the Valley to over 16" in the hills.

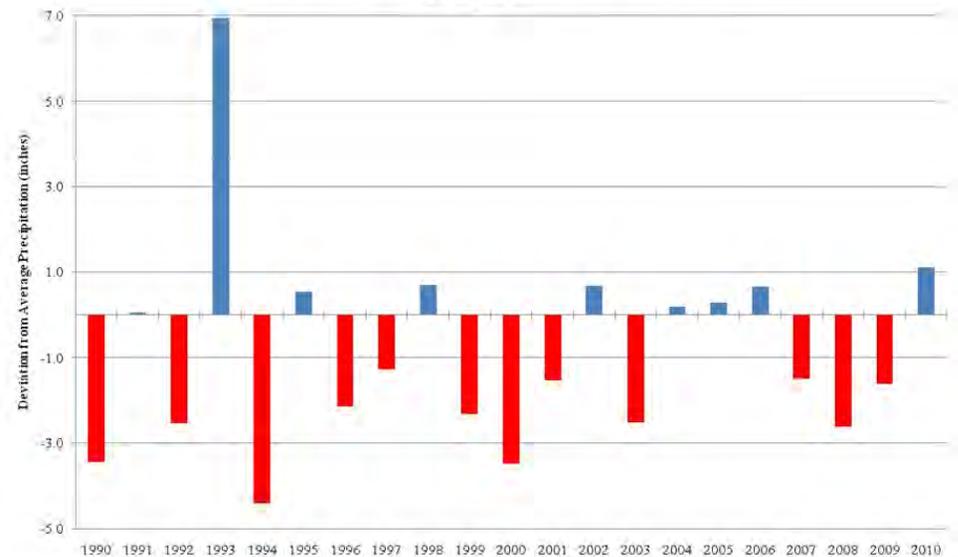


Substantially below average over the last 20 years.

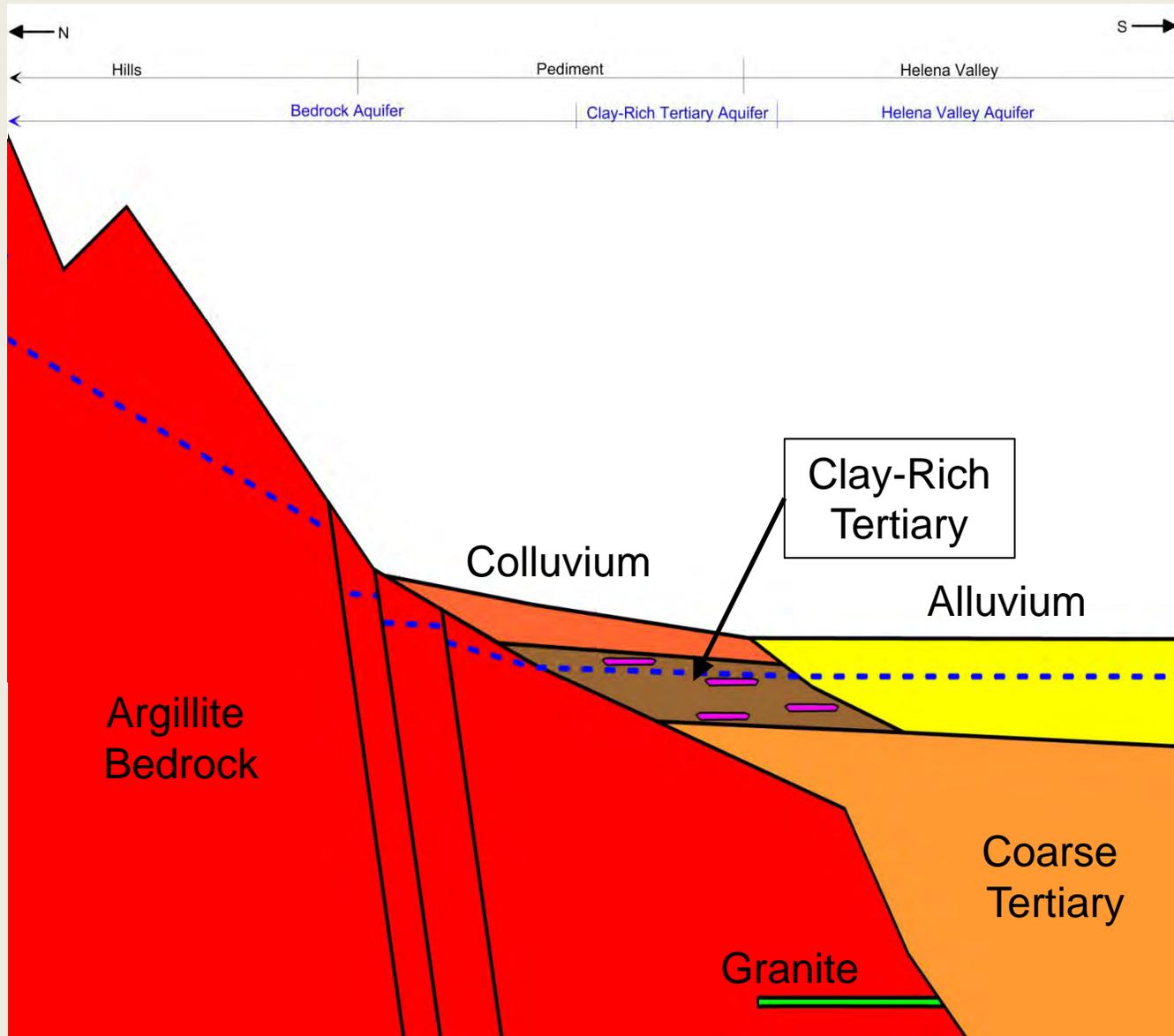
1993 Wet

2010 and 2011 have been wet

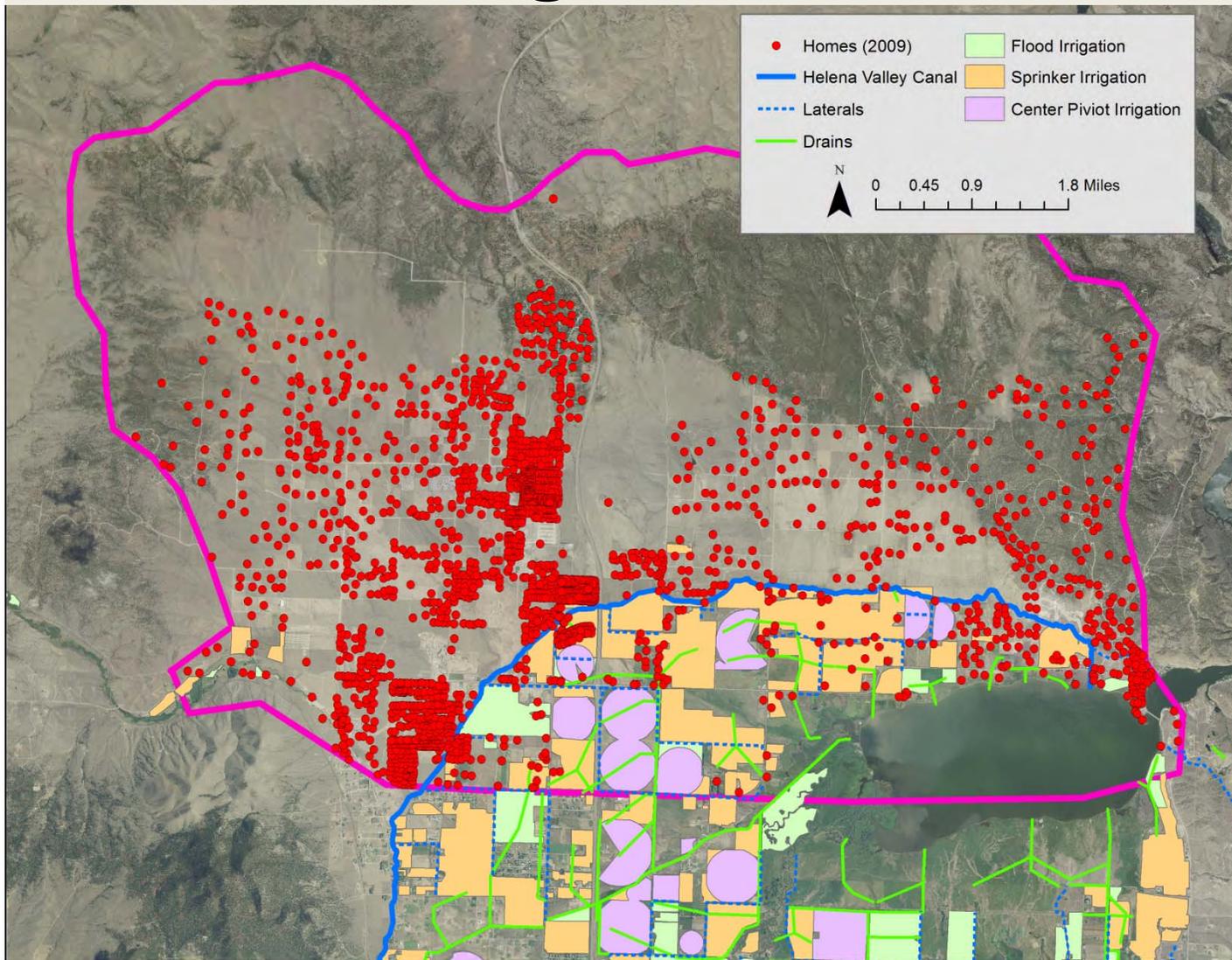
Devation from Average Precipitation
1990-2010



Setting: Geologic Conceptual Cross Section



Setting: Human Influences



Lake Helena & Hauser Lake

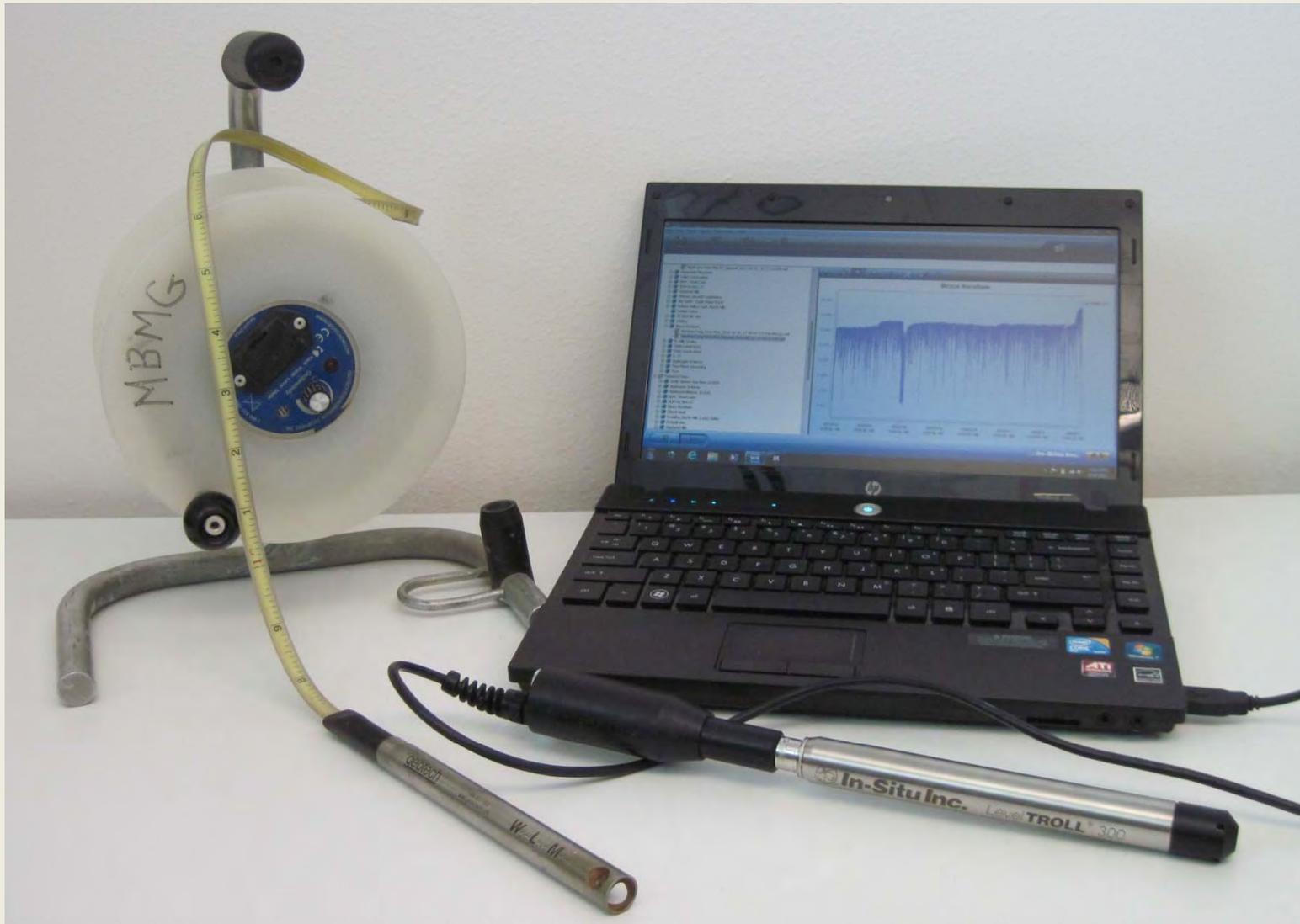
Canal and Laterals Leak to recharge groundwater with surface water from the Missouri River

Irrigation water in excess of crop demand recharges groundwater

Drains installed to prevent water logging

Homes remove water and discharge septic effluent

Methods: Measure Water Levels



Electronic Tapes (e-tapes) and Pressure Transducers; hourly to monthly
Obtain Depth to Water below a Surveyed Measuring Point – Convert to Groundwater Altitude

Methods: Install Wells & Conduct Aquifer Tests

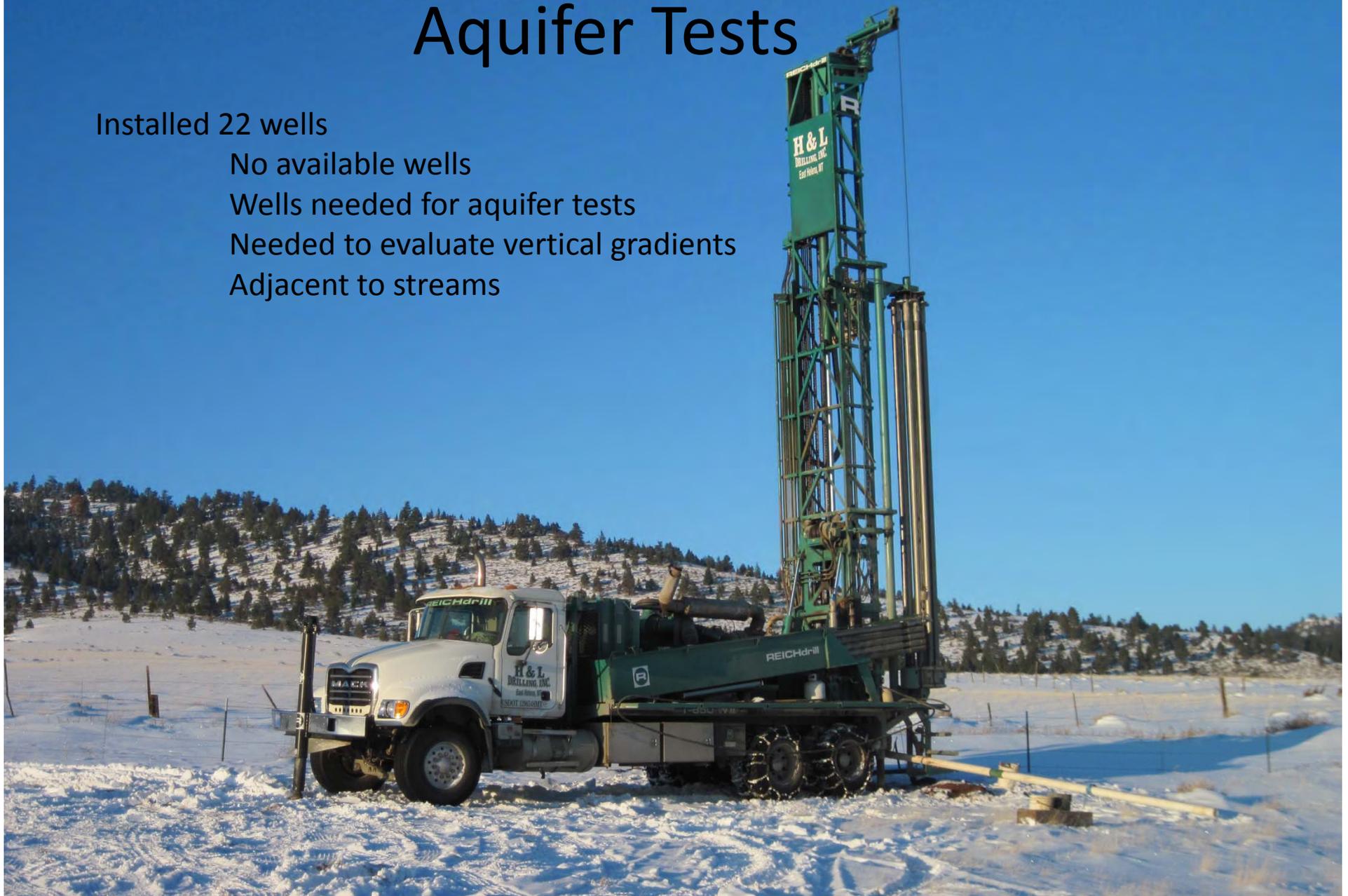
Installed 22 wells

No available wells

Wells needed for aquifer tests

Needed to evaluate vertical gradients

Adjacent to streams



Methods: Surface Water – Groundwater Sites

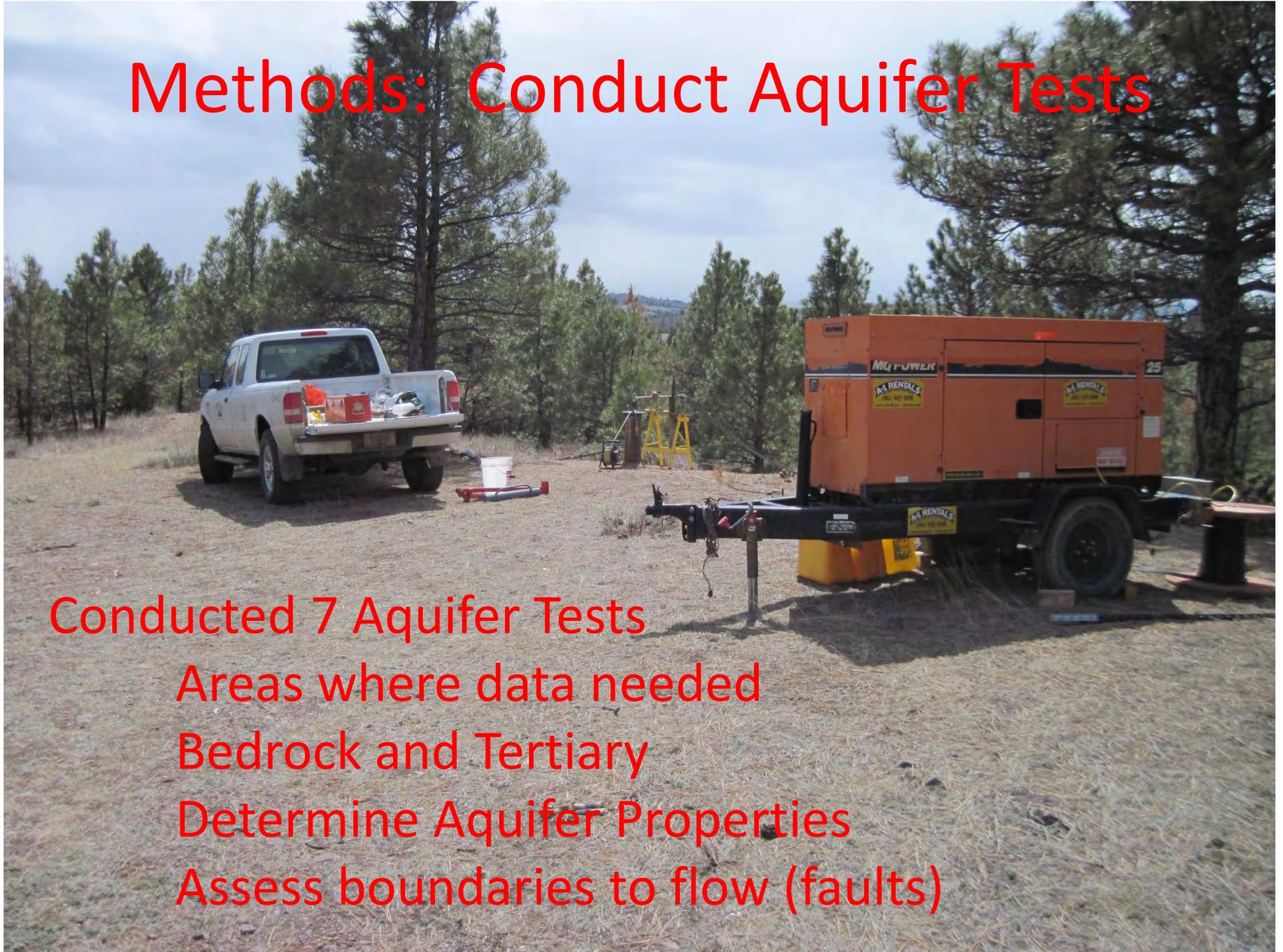


Stilling Well in Stream
Surface Water Altitude
Surface Water Temperature

Well Adjacent to Stream
Groundwater Altitude
Groundwater Temperature

Methods: Conduct Aquifer Tests

Conducted 7 Aquifer Tests
Areas where data needed
Bedrock and Tertiary
Determine Aquifer Properties
Assess boundaries to flow (faults)



Methods: Water Sampling

Three main events

Early April 2010

August 2010

October 2010

87 Groundwater samples from 31 sites

25 Surface Water samples from 12 sites

Standard Suite

Field Parameters

pH, SC, Temp

Major Ions

Ca, Mg, Na, K, Fe, Mn, SiO₂

HCO₃, CO₃, Cl, SO₄

Nutrients

Nitrate, Fluoride, Orthophosphate

Trace Metals

Al, Sb, As, Ba, Be, B, Br, Cd, Ce, Cs,

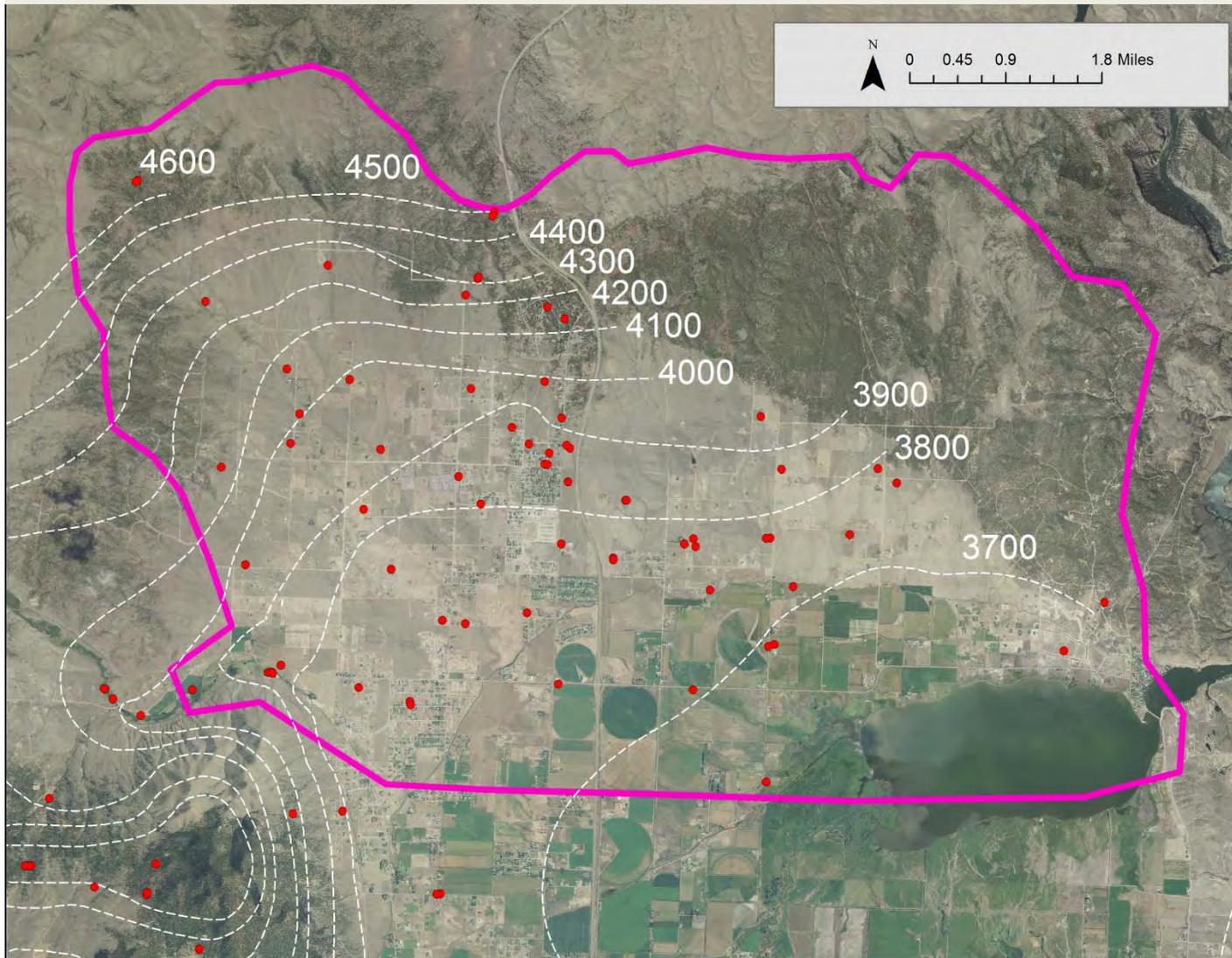
Cr, Co, Cu, Ga, La, Pb, Li, Hg, Mo,

Ni, Nb, Nd, Pd, Pr, Rb, Ag, Se, Sr, Tl,

Th, Sn, Ti, W, U, V, Zn, Zr



Observations & Interpretations: Potentiometric Surface Map (October 2010)



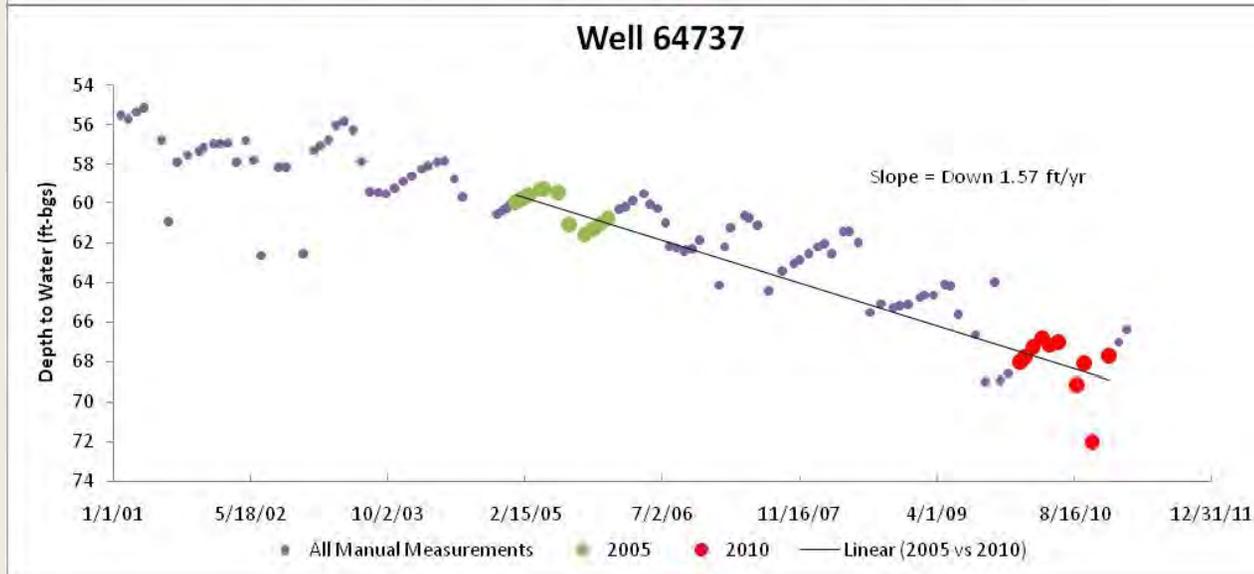
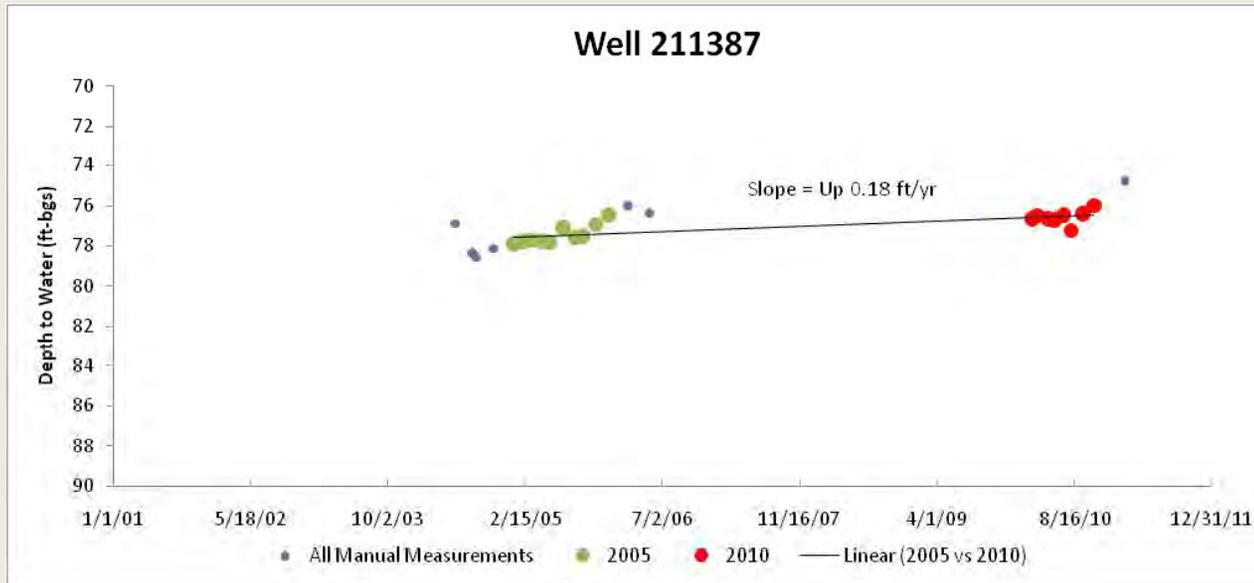
Water Flow from high to low:
From the hills to Lake Helena

Tighter spacing of contours in Hills indicates lower transmissivity

The surface can be contoured, indicating that at this scale the bedrock can be treated as porous media

Supports conceptual model & provides quantitative targets for numerical model calibration

Observations & Interpretations : Hydrographs



Hydrographs are evaluated for overall trend

Best Fit Line of 2005 and 2010 Data used for quantification

Other data is used to evaluate the result

34 Hydrographs Evaluated
11 up; 23 down

Slope Breakdown:

>1'/yr down = 9

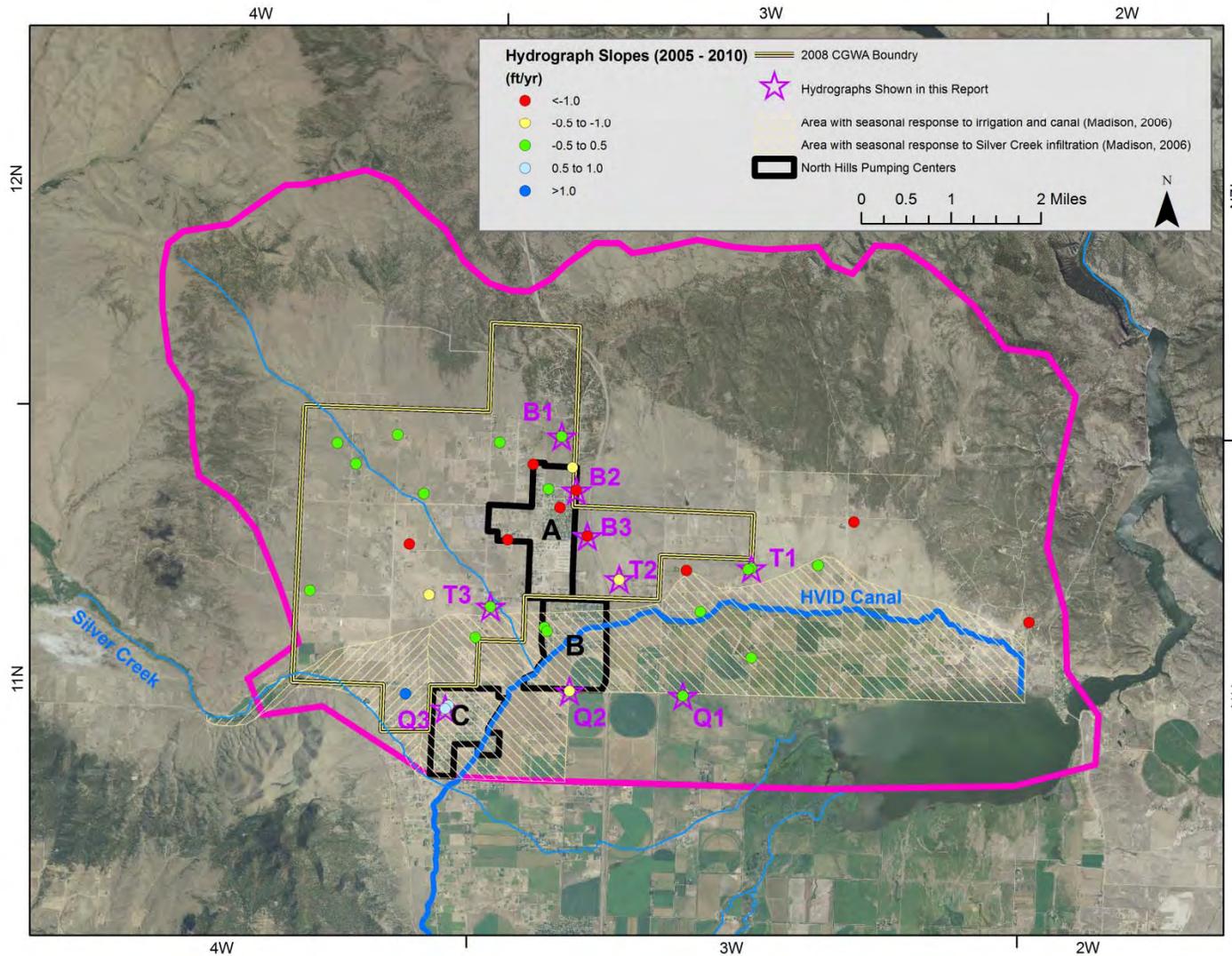
0.5-1'/yr down = 4

±0.5'/yr up or down = 18

0.5-1'/yr up = 2

>1'/yr up = 1

Observations & Interpretations : Hydrograph Slope Geographic Distribution



No change or upward
In the areas identified
by Madison as
influenced by irrigation
or Silver Creek

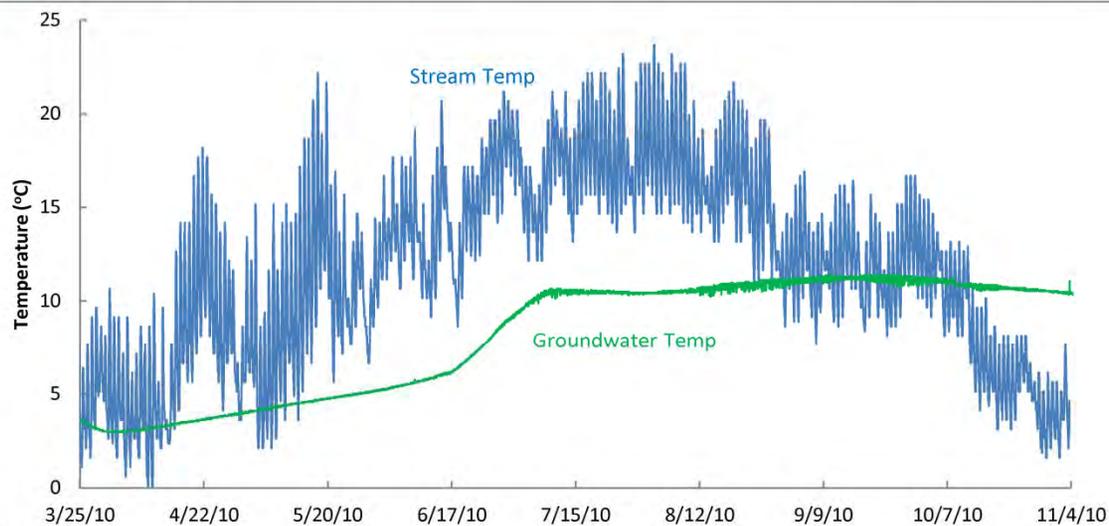
Noticeable declines in
wells in the bedrock
area with highest
development
(Pumping Center A)

Scattered wells with
declines in areas of
lower density
development. Likely a
due to level of use and
aquifer properties at
that location

Observations & Interpretations : Surface Water – Groundwater Interactions



A



B

Silver Creek:
Groundwater levels are consistently below surface water levels.

Changes in surface water elevation is rapidly transmitted to groundwater.

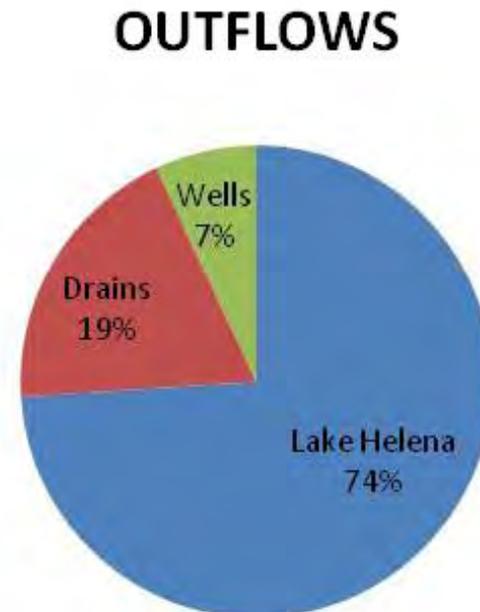
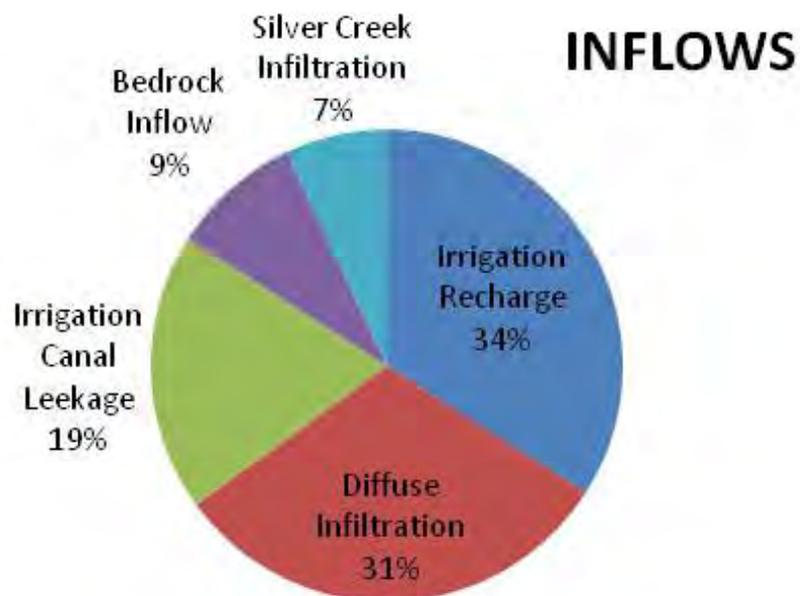
Diurnal temperature variations are not transmitted, however seasonal variation is seen.

This shows that Silver Creek is a contiguous losing stream, but that the amount of loss is relatively small.

The pattern is the same for all sites on Silver Creek.

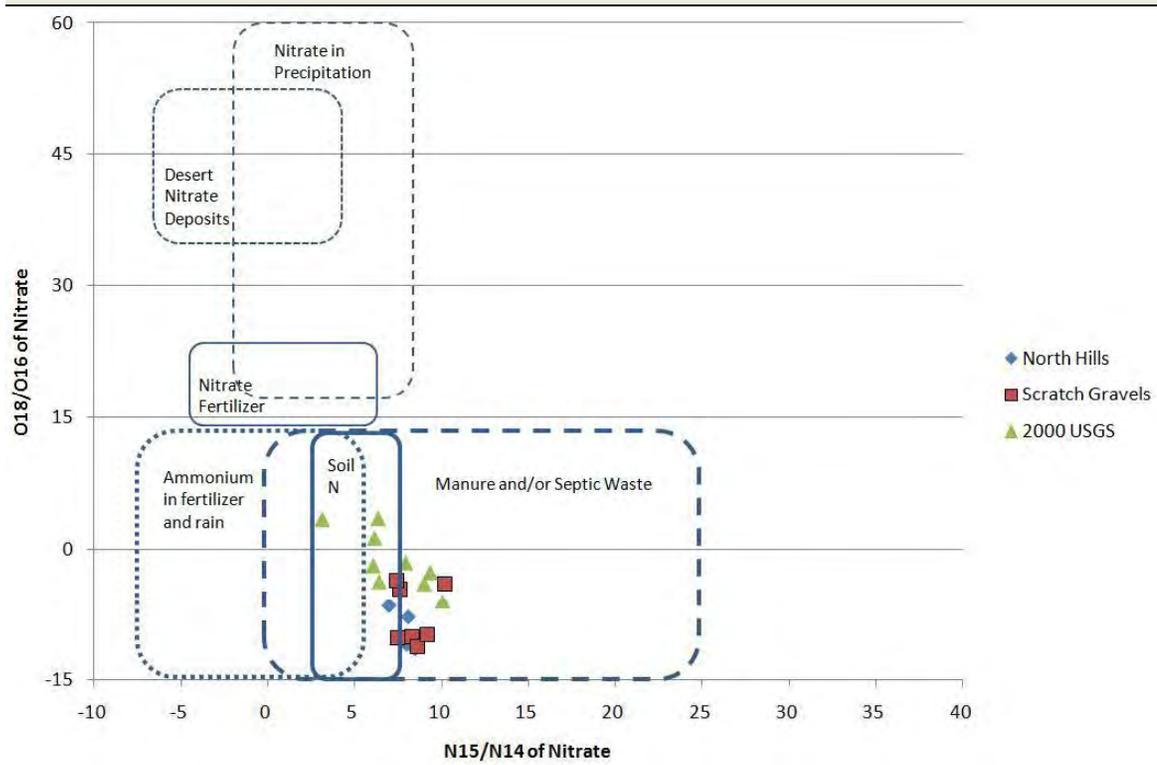
Observations & Interpretations: Water Budget

$$\text{Inflow} = \text{Outflow} \pm \text{Changes in Storage}$$



Analysis shows that ~98% of consumptive use by wells is for the irrigation of lawns and gardens.

Observations & Interpretations: Water Chemistry



Groundwater:

One sample exceeded the drinking water standard for nitrate. All other standards were met.

Natural nitrate is typically less than 2 mg/L (Mueller and Helsel, 1996).

24 of 87 samples had >2 mg/L of Nitrate.

Based on nitrate isotopes, septic systems are the most likely source of the nitrates.

No major livestock operations, but reported past feed lots.

Disturbance relates to release of soil nitrate.

Observations & Interpretations: Water Chemistry

Surface water:

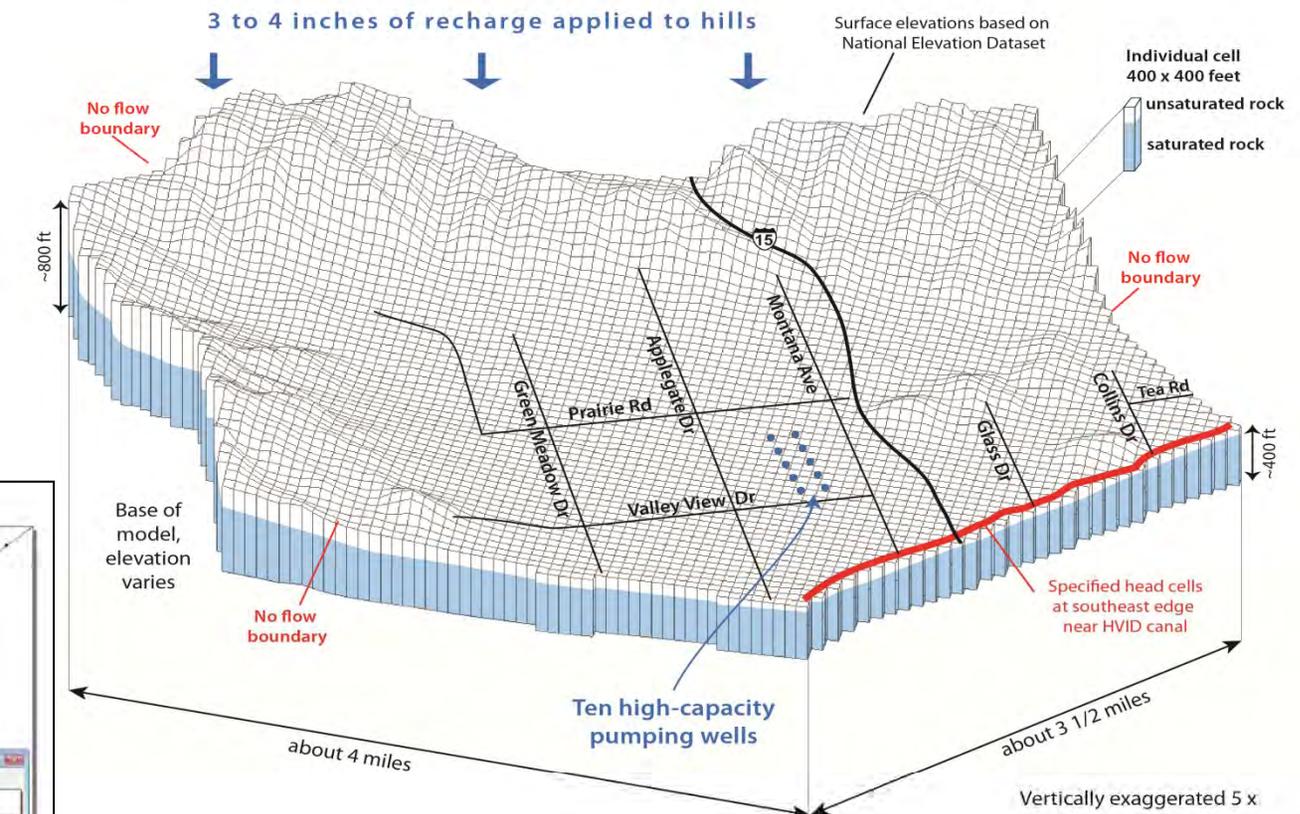
- Arsenic often above drinking water standard
- Cadmium – 2 exceedences of Aquatic Life Standard in Tenmile Creek
- N – Often above Aquatic Life Standard

Data Analysis & Interpretation: Numerical Groundwater Modeling

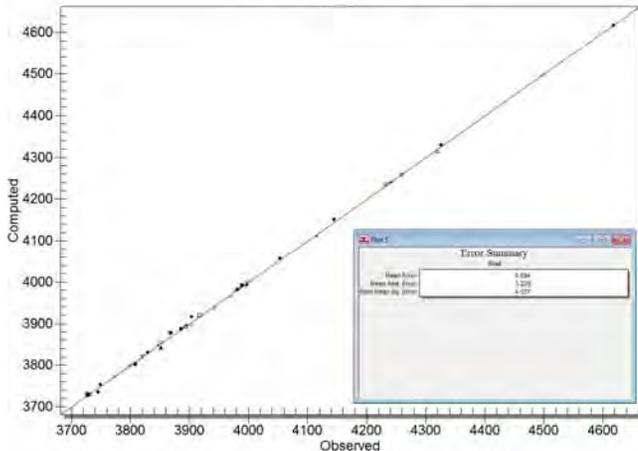
Numerical models quantitatively combine the components of system & allow for predictions to be made concerning potential future scenarios

Kirk will discuss in detail

North Hills Pediment Focus Model
Schematic View



Computed vs. Observed Values
Head



Summary

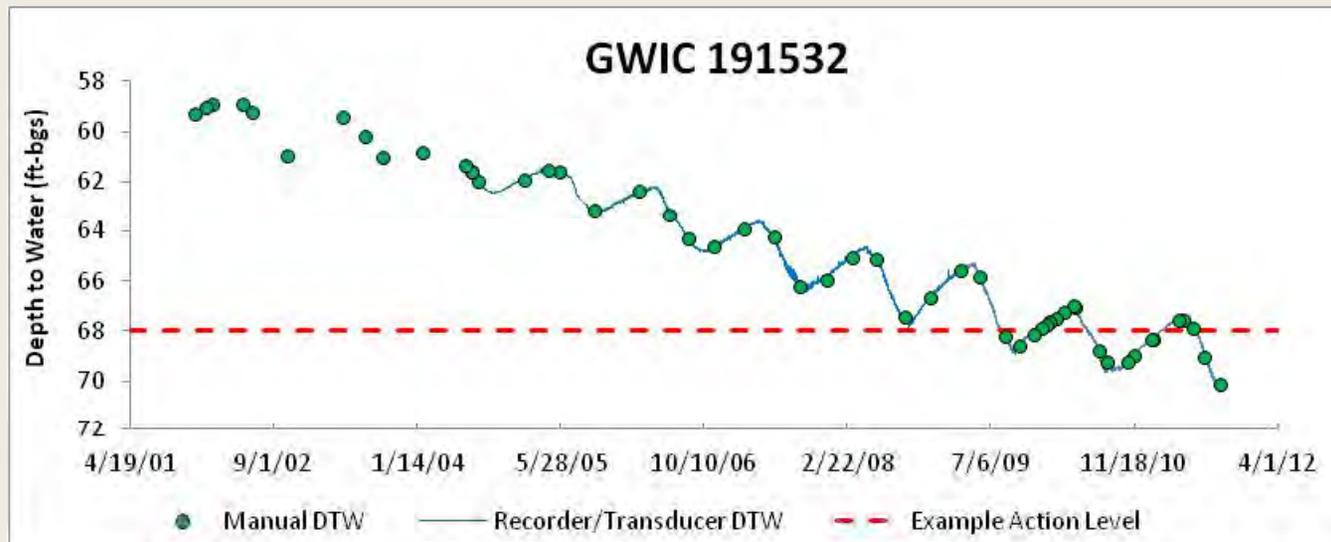
- Groundwater flow is from the hills to Lake Helena and the drains.
- Recharge rarely occurs on the pediment, ET is essentially equal to precipitation.
- Episodic recharge occurs in the hills (3-4 inches per year),
- Recharge from HVID Canal and its laterals, and beneath irrigated fields
 - Only available below canal
- The Bedrock is the least productive aquifer.
 - Fracture Flow (variable)
 - Inhibited by bedrock faults
- The Clay-Rich Tertiary materials are somewhat more productive
 - Depends on gravel layers (west more productive than east)
- Helena Valley Aquifer (sand and gravel) is the most productive aquifer.
- Sustained drawdown is seen north of the HVID canal, and west of the interstate.
- No declines are seen in areas influenced by irrigation or Silver Creek.

Recommendations

- Monitor
 - Existing Dense Development (Pumping Center A)
 - New Development < 10 acre lots where water is from Bedrock
 - Low development density (background patterns)
 - Monitor water use, groundwater levels & water quality
 - document actual timing and magnitude of drawdown
 - allow for Adaptive Management
- Consider PWS wells in the Helena Valley Aquifer
 - Physical Availability vs. Legal Availability
- Consider limits on landscaped area (98% of consumptive use)
- Consider shallow soils, and fractured bedrock when designing septic systems
- Incorporate site specific data as much as possible (faults and fractures) if site specific decisions are needed.

Adaptive Management

1. Specify the objective
2. Establish initial Action Levels based on key indicators (modeling)
3. Establish initial Actions (changes in management) based on Action Levels (modeling)
4. Monitor key indicators, and implement actions as needed.
5. Assess results relative to the objective
6. If needed modify the action levels, actions, indicators, or objective.



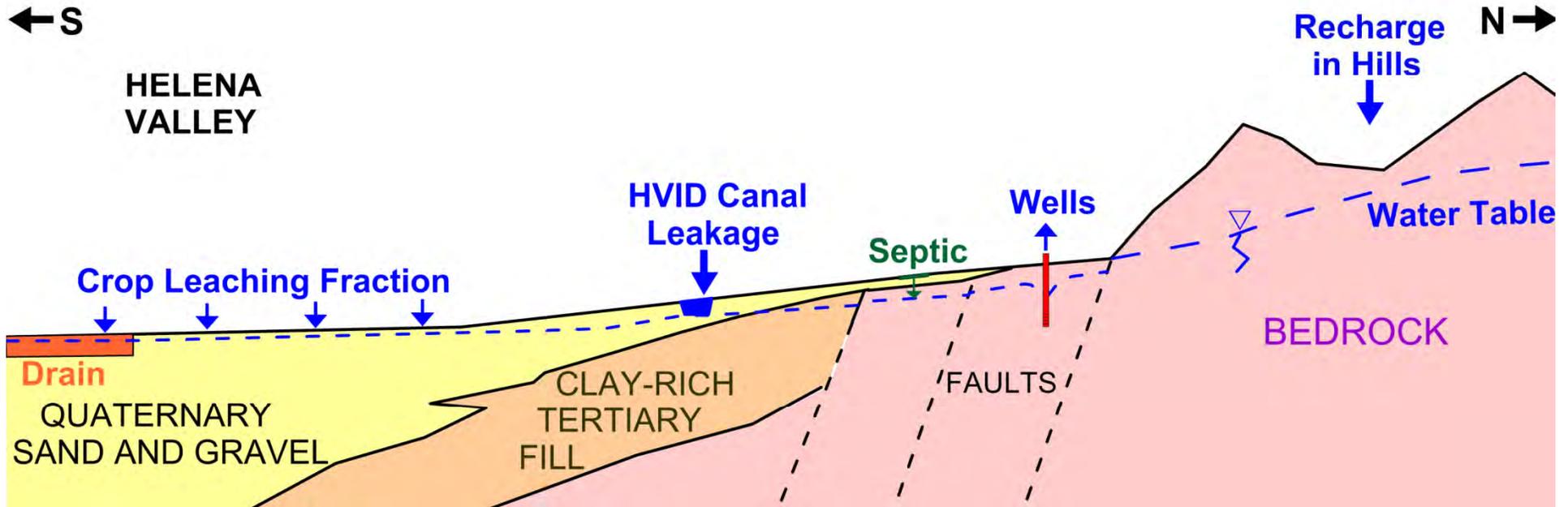
Example:

- Objective:** Stabilize water levels in the area of the North Hills showing drawdown.
- Action Level & Action:** If the static water level in the North Hills well drops below 68' then watering of lawns and gardens in the Northern Lights, North Star and Sky View Subdivisions can only occur every other day.

Questions?



Setting: Conceptual Cross Section with Human Influences



Wells and Drains Remove Water
Septic Systems, Canals and Laterals, and Crop Leaching
Fraction Add Water

Drains installed to remove excess water:
Prevent Waterlogging & Accumulation of Salts

Observations & Interpretations: Water Budget

	Best Estimate		Probable Range	
		%	Minimum	Maximum
INPUTS				
Silver Creek Alluvium Inflow	21	0.1%	14	28
Bedrock Inflow	1,252	9%	834	1,669
Diffuse Infiltration	4,380	31%	3,942	4,818
Silver Creek Infiltration	1,012	7%	876	1,071
Irrigation Canal Leakage	2,701	19%	2,339	2,858
Crop Leaching Fraction	4,778	34%	4,138	5,057
TOTAL INPUTS	14,144	100%	12,143	15,501
OUTPUTS				
Drains	2,894	19%	2,704	3,304
Lake Helena	11,075	74%	10,344	12,643
Wells	1,033	7%	949	1,136
TOTAL OUT	15,001	100%	13,977	17,083