Groundwater Supply Management

Prepared for the Idaho-Washington Aquifer Collaborative (IWAC)

August 10, 2021

GSI Water Solutions, Inc.

Water Supply Management/Planning Topics

- Groundwater model readiness for modern-day needs
  - Wellfield operations
  - Long-term groundwater supply planning
- Well performance, maintenance, rehabilitation
- Coordinated water conservation planning

Why Use Groundwater Models?

- Wellfield operations and management
  - Optimizing operations amongst multiple wells
  - Siting and designing new wells
  - Understanding aquifer effects on well/wellfield performance
- Operational effects of changing water demands
  - Amount and/or timing
- Effects of climate change on aquifer and river
- Pumping effects on river (water rights, instream flows)

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- Groundwater model readiness for modern-day needs
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Models in the SVRP (USGS, 1983)

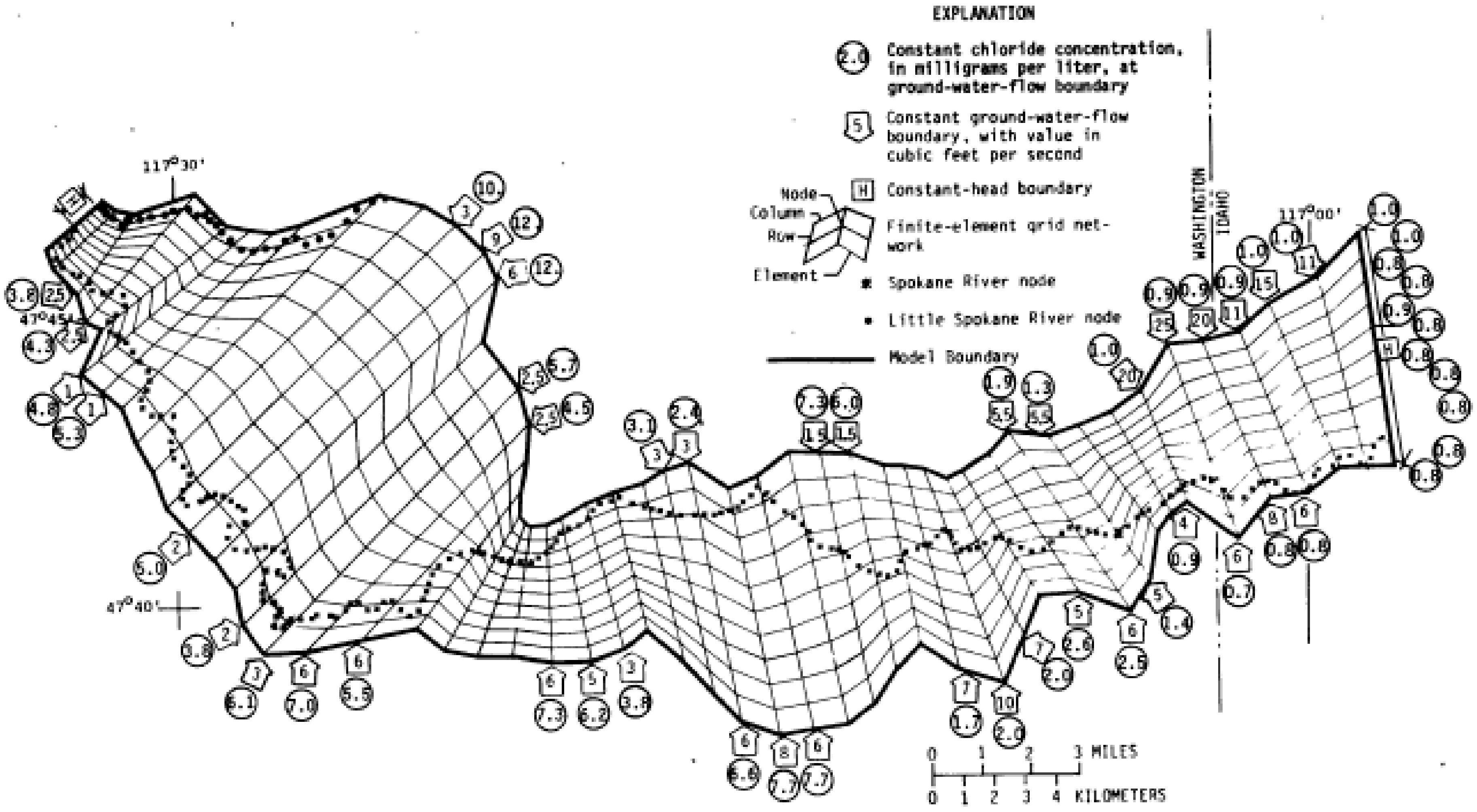
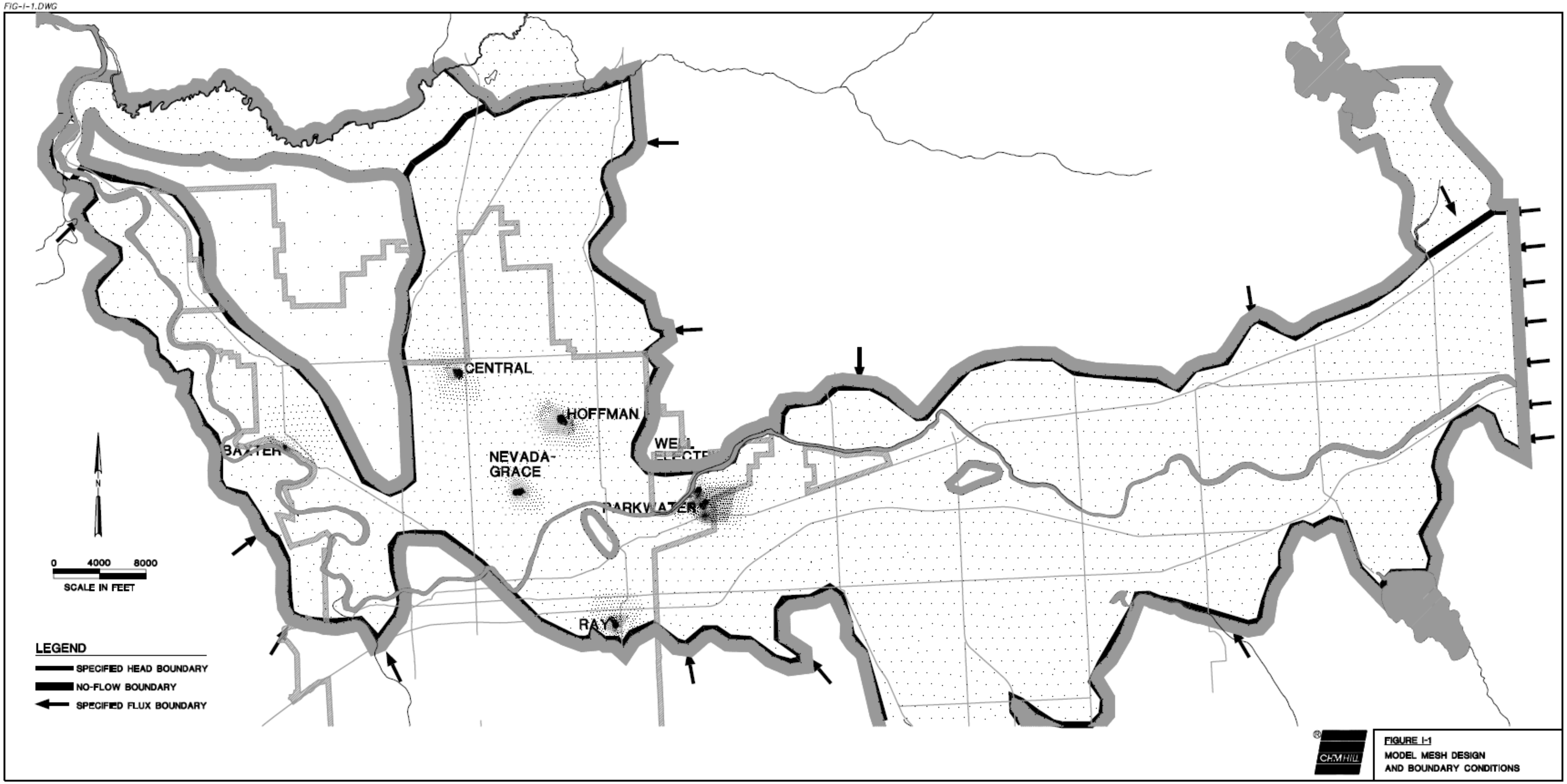
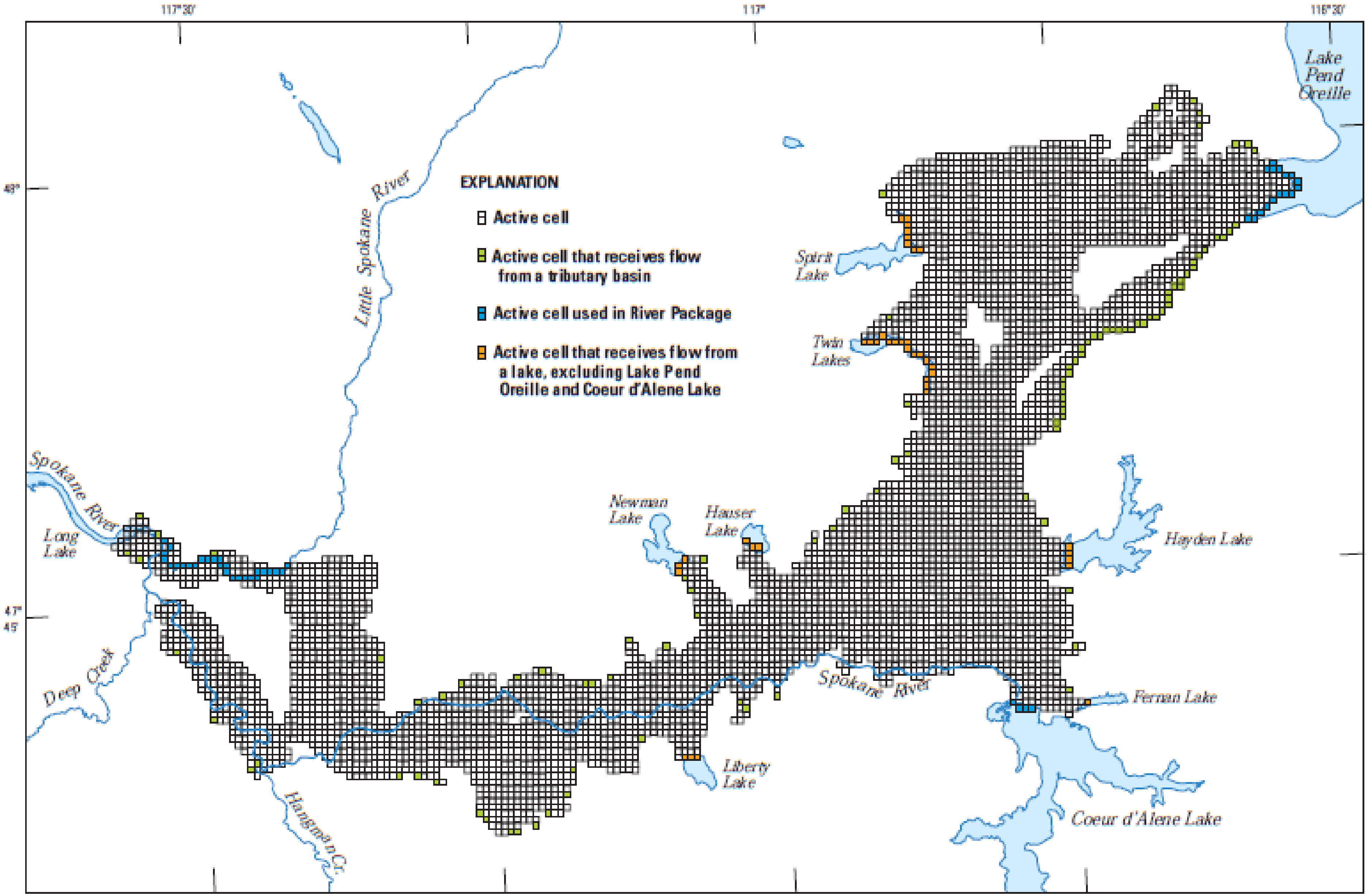


FIGURE 22.--Model-grid network and boundary conditions used in the model.

Models in the SVRP (City of Spokane, 1998)



Models in the SVRP (USGS Bi-State Model, 2007)



Models in the SVRP (City/ SAJB Model, 2012)

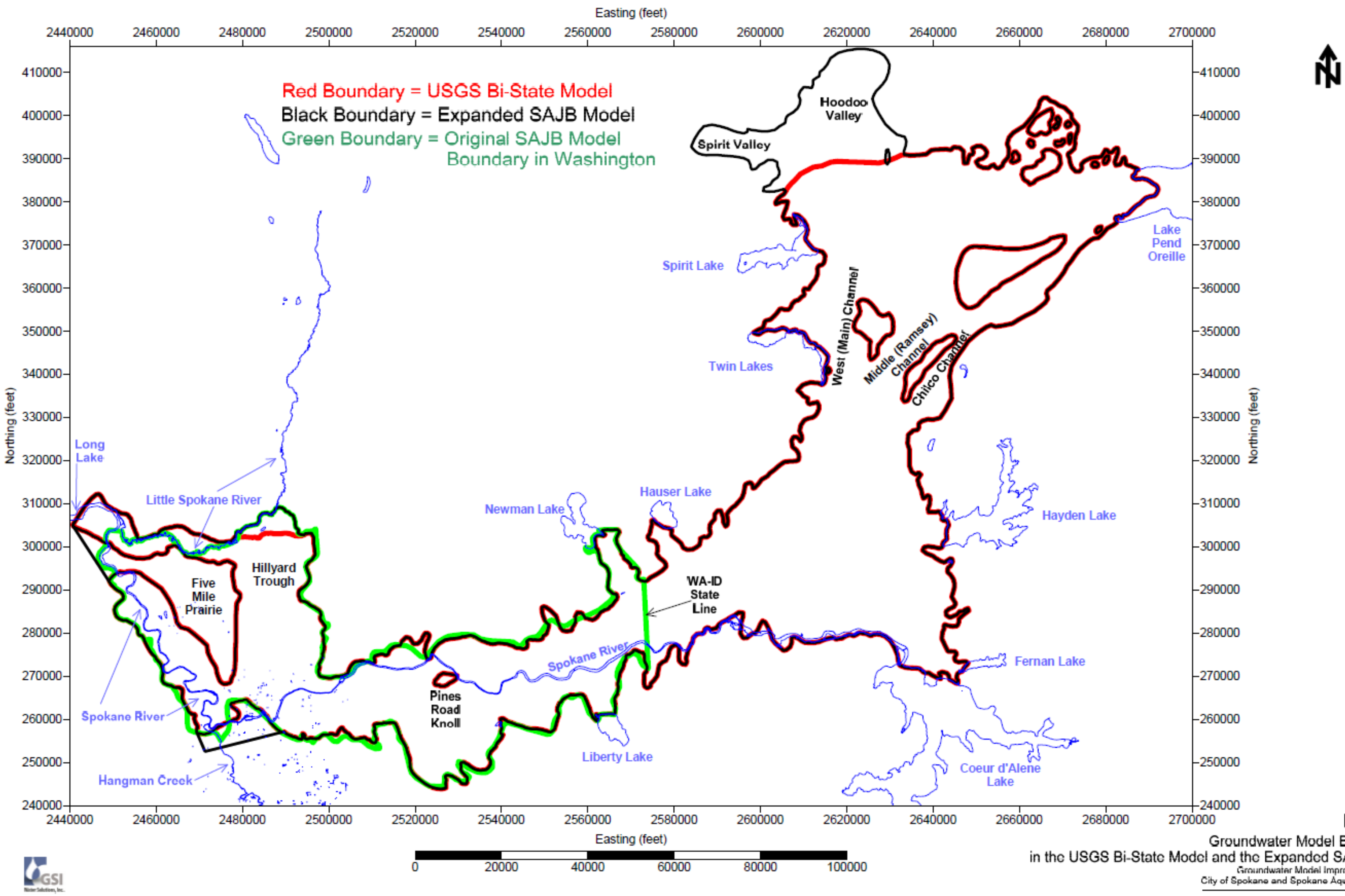
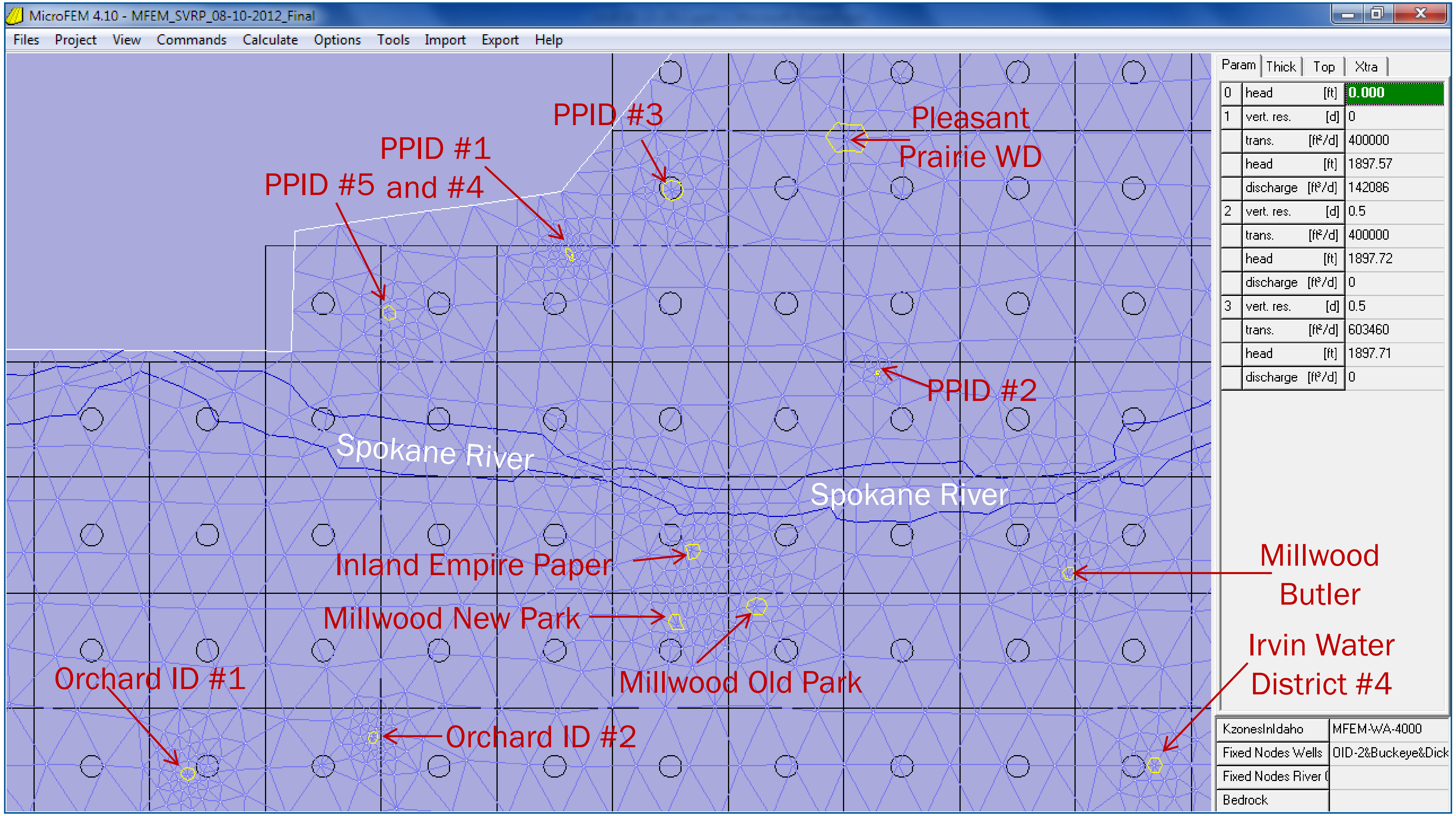


Figure 1
Groundwater Model Boundaries in the USGS Bi-State Model and the Expanded SAJB Model
Groundwater Model Improvement Project
City of Spokane and Spokane Aquifer Joint Board

Grids (USGS Bi-State Model & City/SAJB Model)



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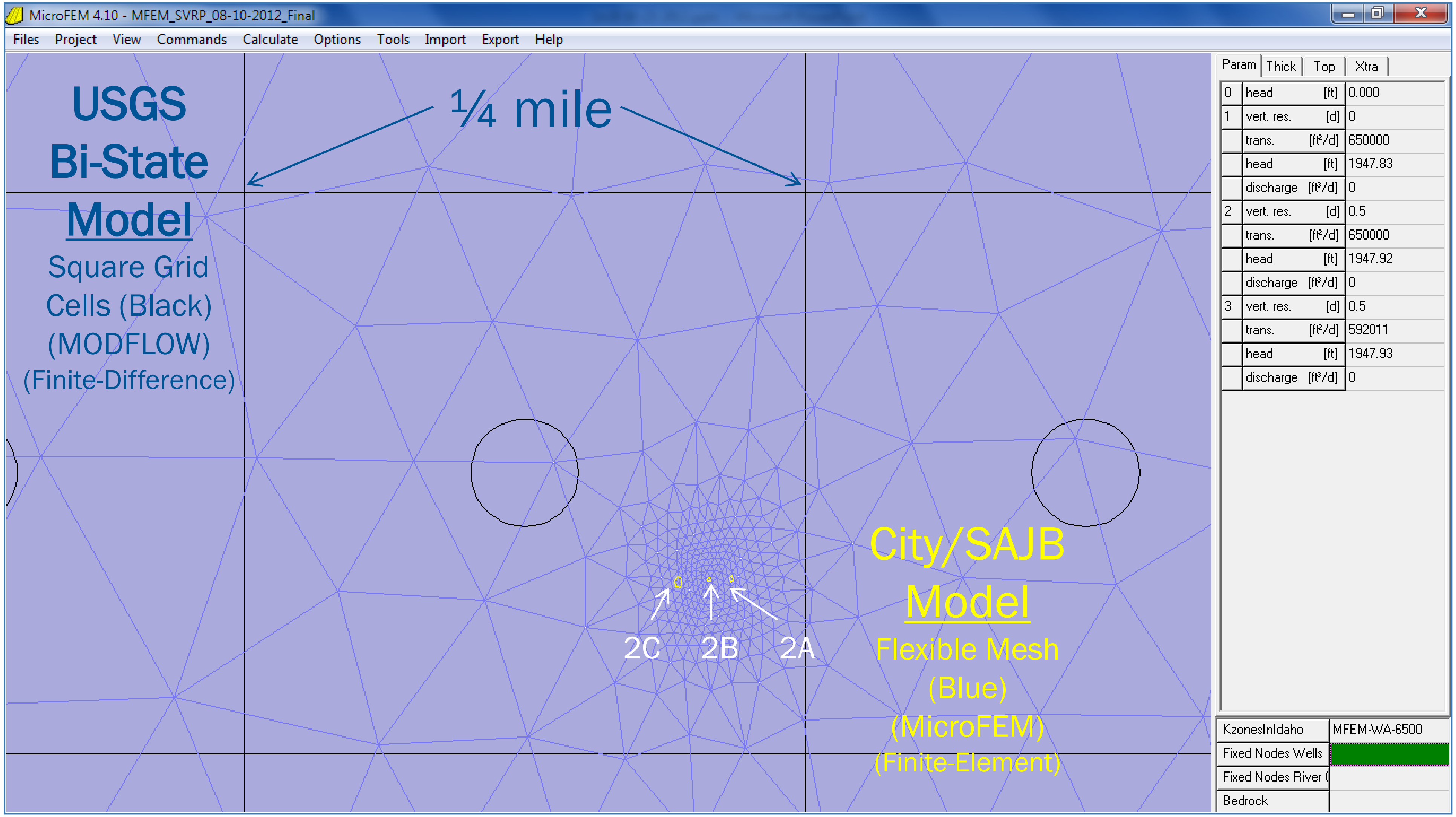
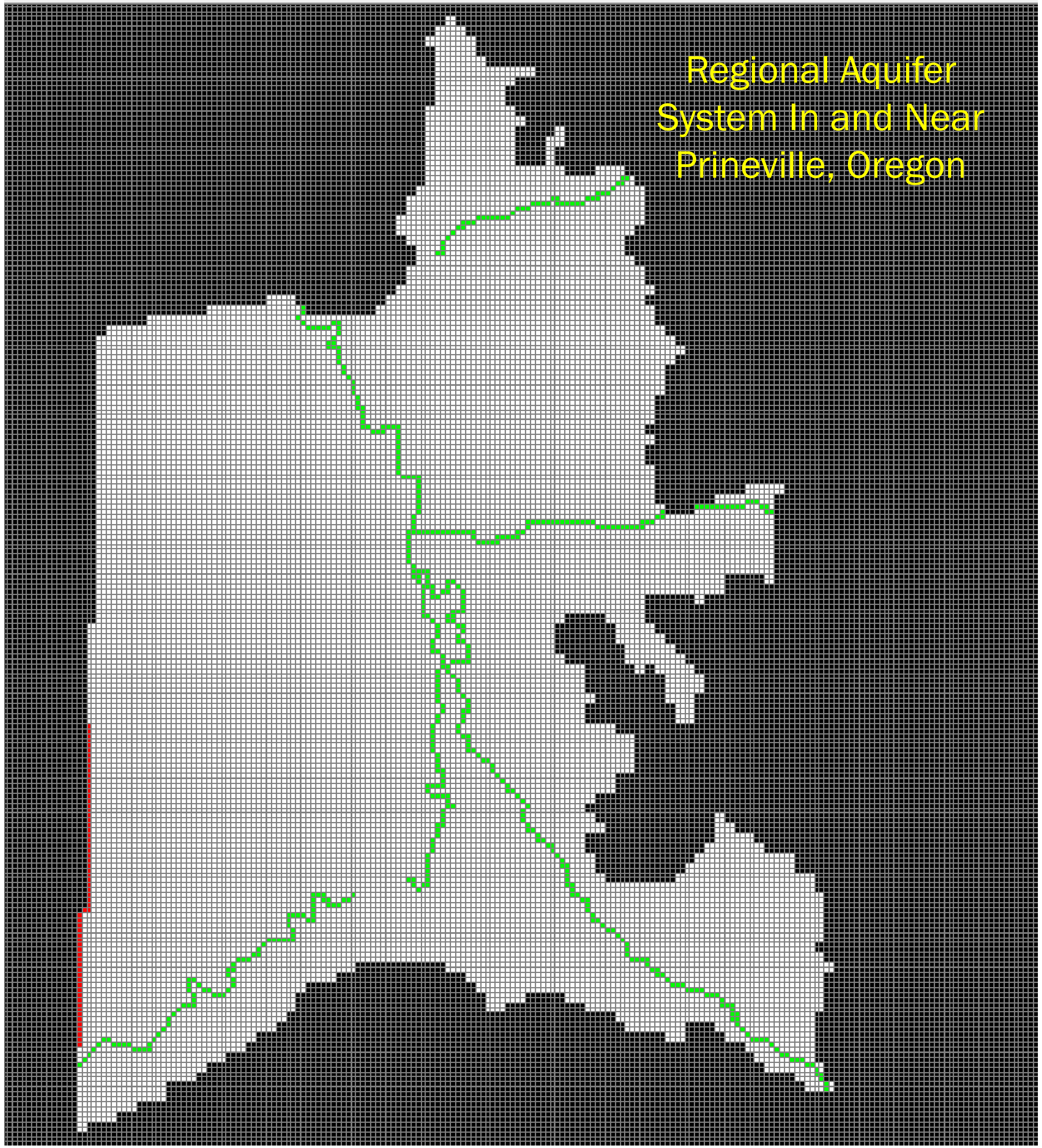
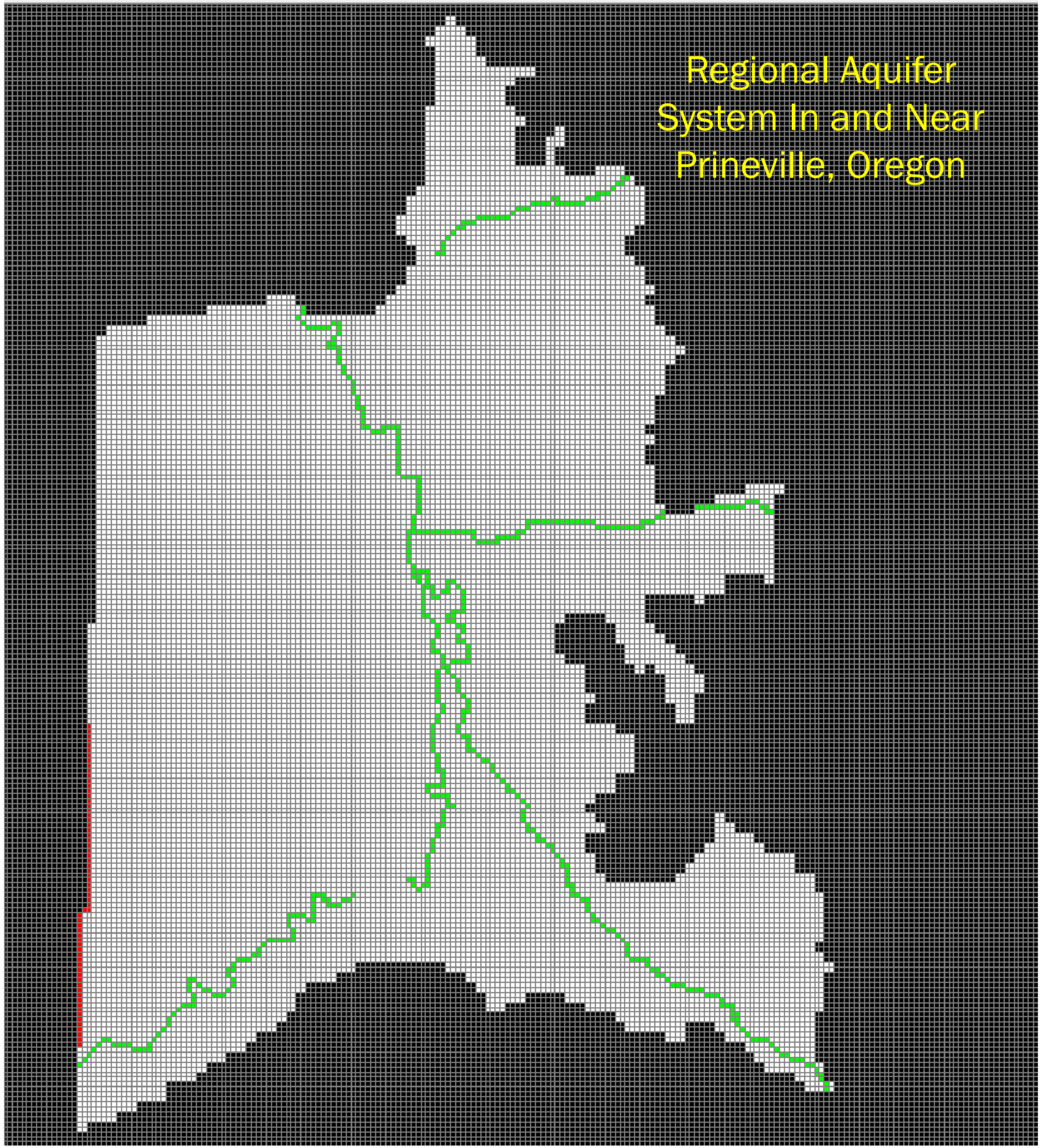


Reasons to Migrate to New Model Software

- Current models are showing their age
  - Bi-State model: coarse grid, only 1 layer in most areas
  - City/SAJB model: software has not kept up, developer retired
- Much better tools have become available recently
  - USGS software developed in partnership with private sector
    - Can imbed detailed grids inside regional models
    - Local detail without losing the regional flow and system drivers (which accounts for aquifer-wide and watershed-scale influences)


Regional Aquifer
System In and Near
Prineville, Oregon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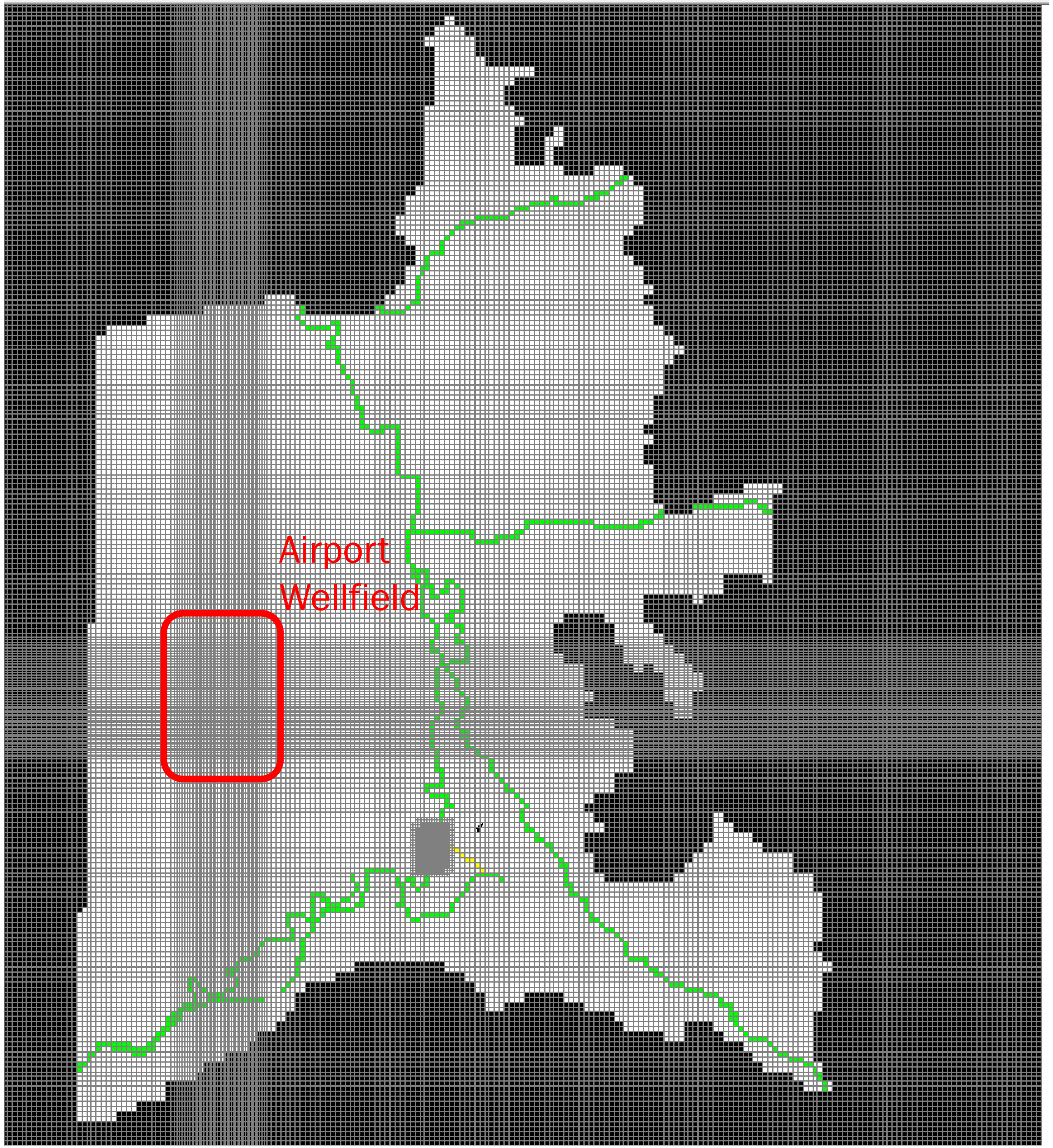
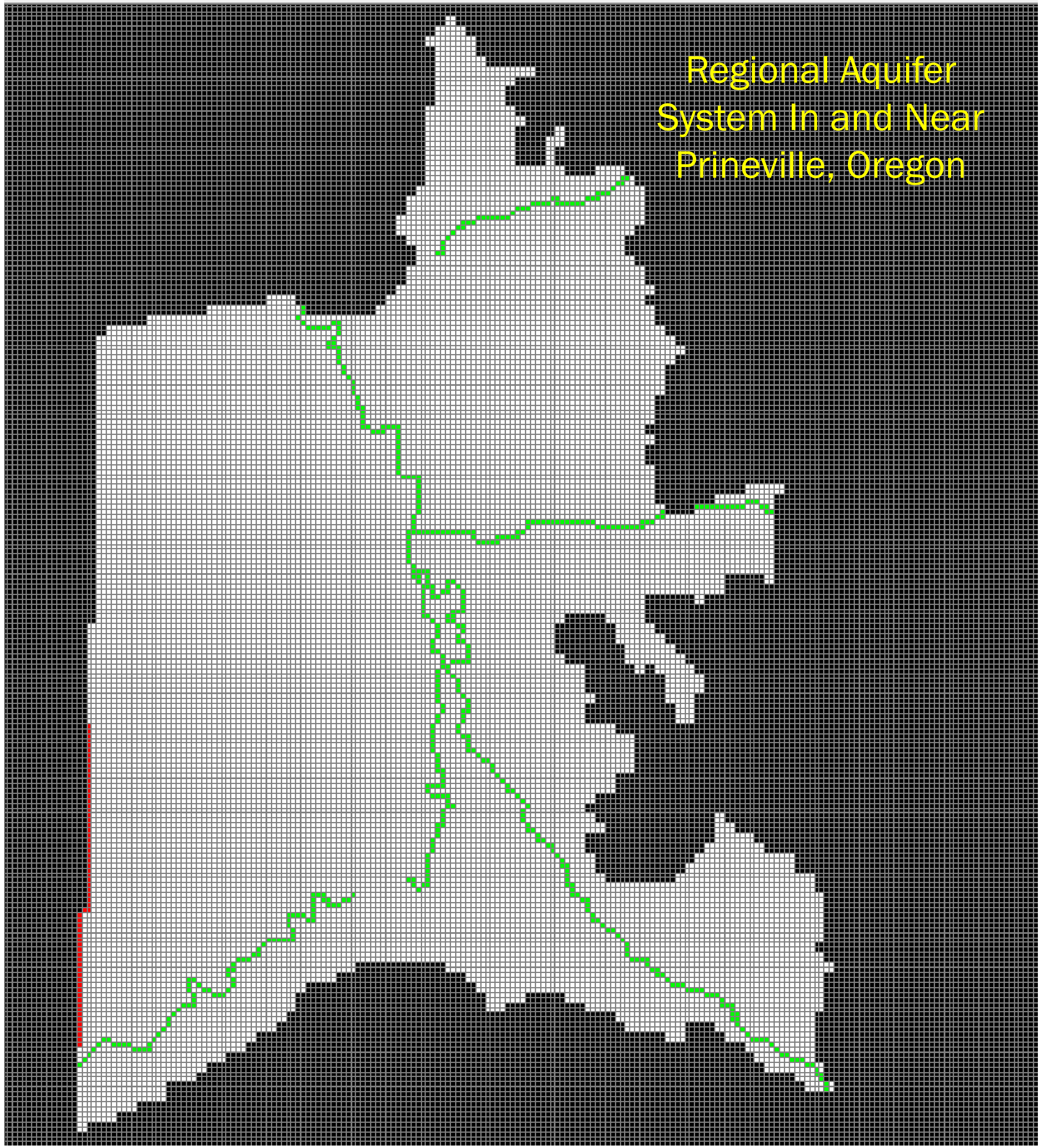

Airport
Wellfield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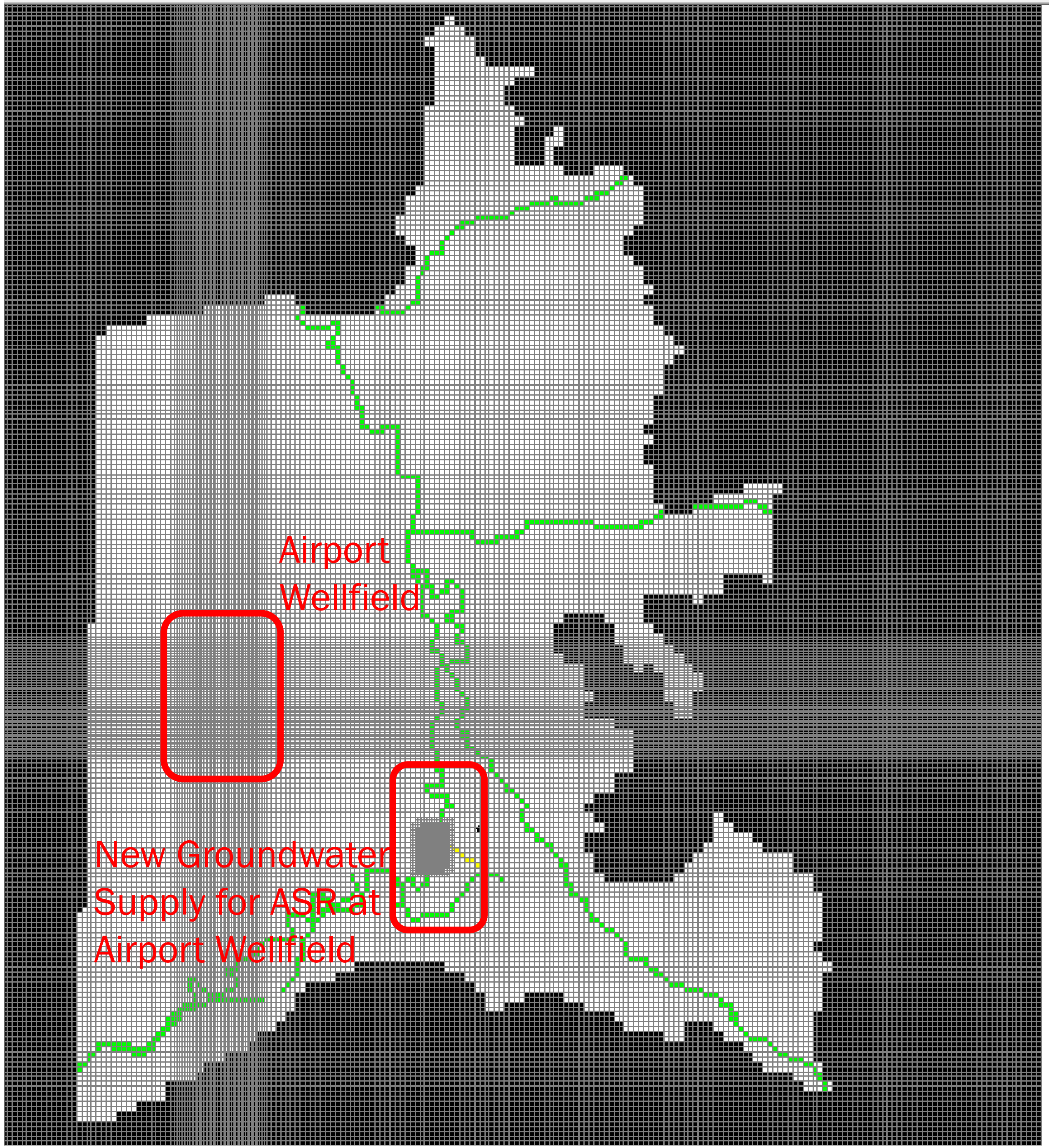
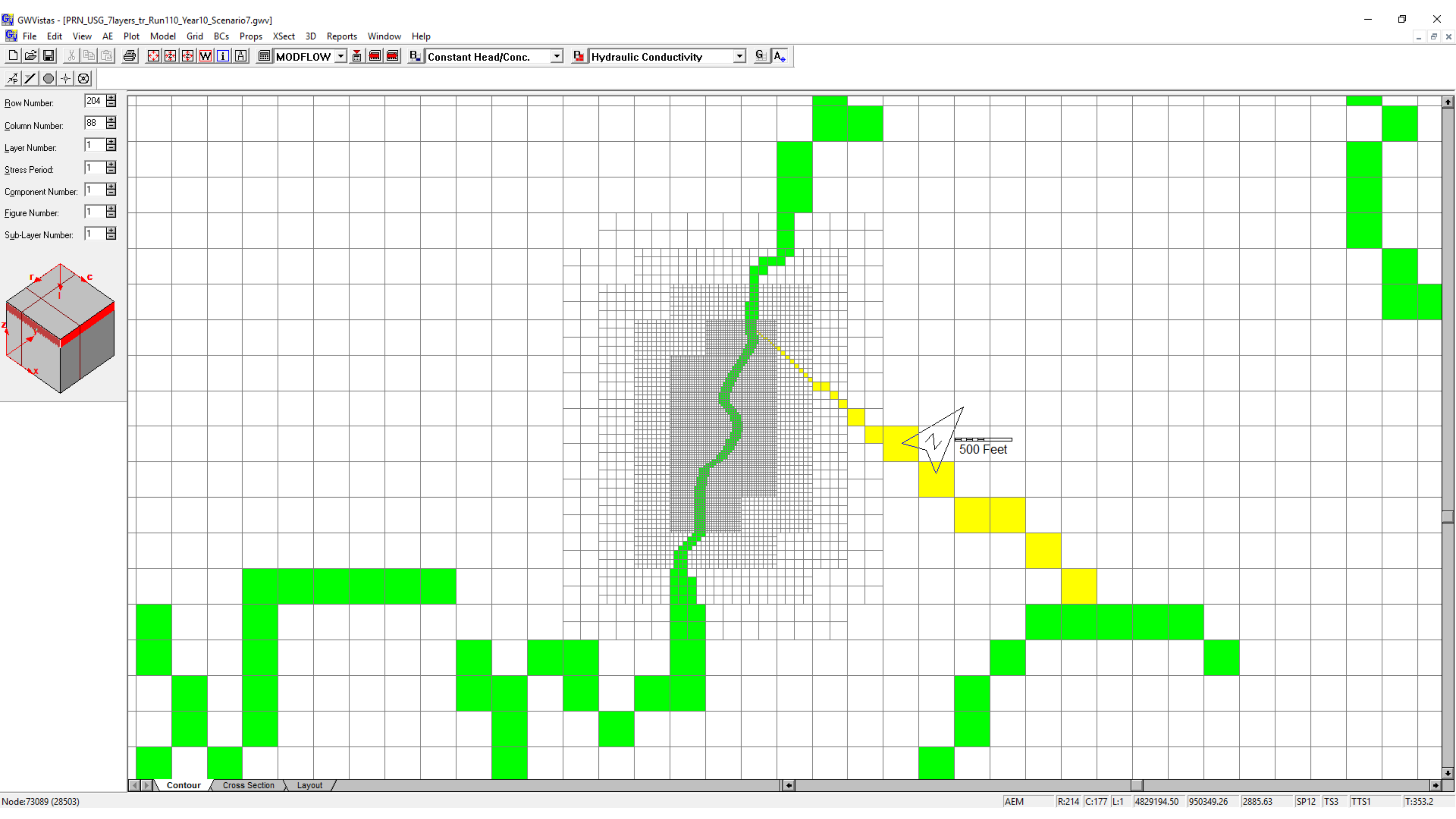

Airport
Wellfield
New Groundwater
Supply for ASR at
Airport Wellfield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Hydraulic Conductivity
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Column Number: 88
Layer Number: 1
Stress Period: 1
Component Number: 1
Figure Number: 1
Sub-Layer Number: 1
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Contour
Cross Section
Layout
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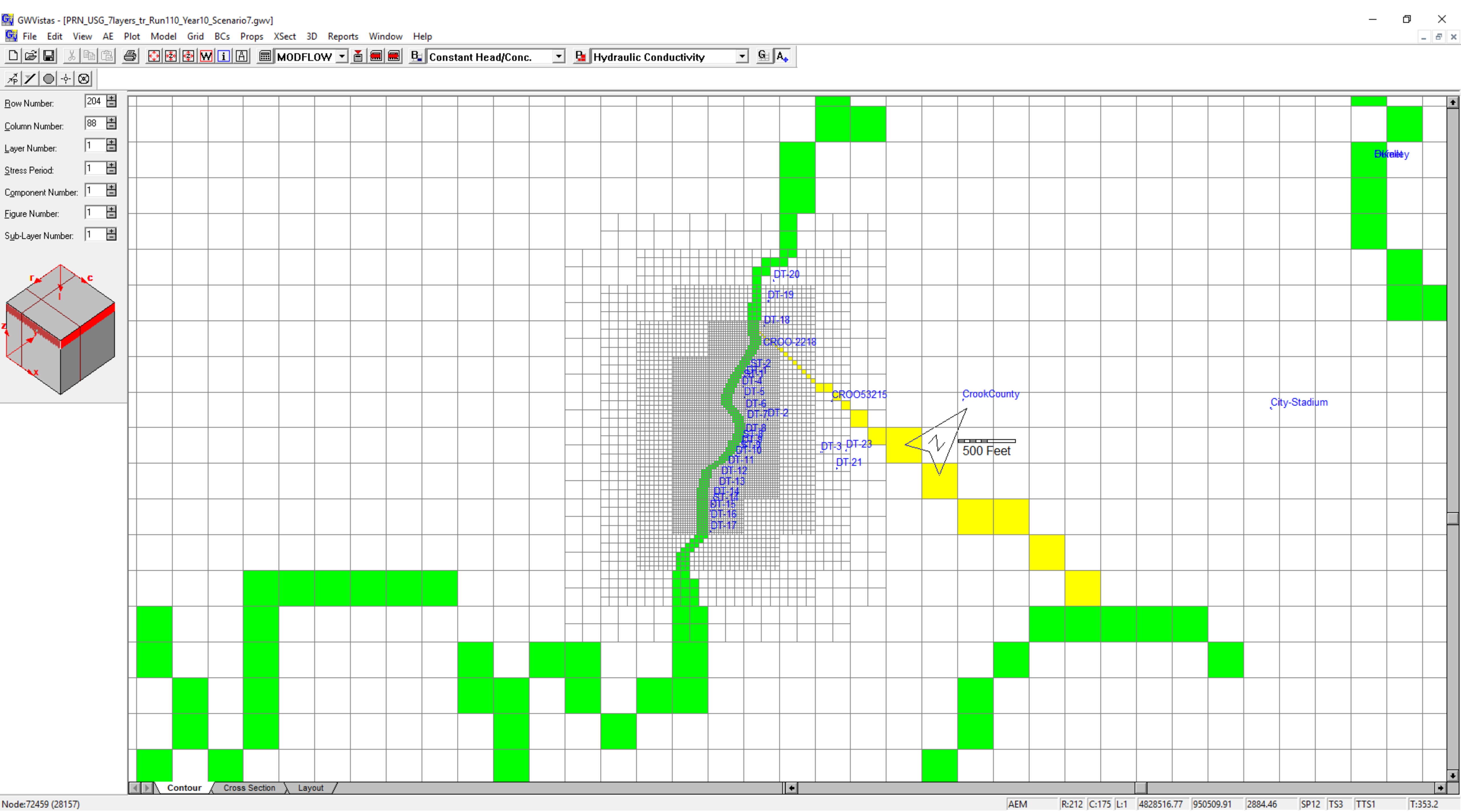
TS3
TTS1
T:353.2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Hydraulic Conductivity
Row Number:
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Column Number:
88
Layer Number:
1
Stress Period:
1
Component Number:
1
Figure Number:
1
Sub-Layer Number:
1
DT-20
DT-19
DT-18
CROO-2218
CROO53215
CrookCounty
City-Stadium
DT-3
DT-23
DT-21
DT-11
DT-12
DT-13
DT-15
DT-16
DT-17
500 Feet
Contour
Cross Section
Layout
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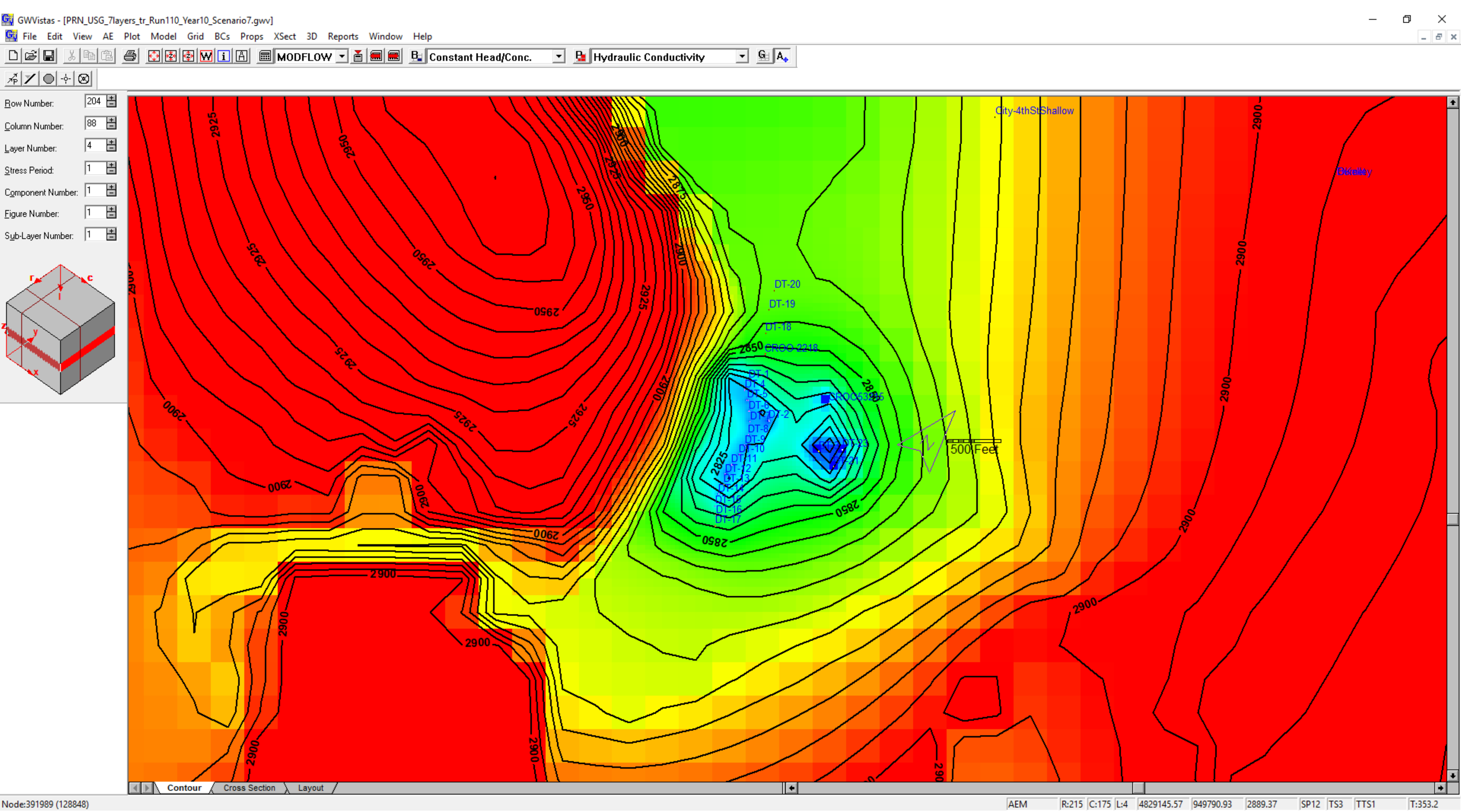
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Hydraulic Conductivity
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Component Number: 1
Figure Number: 1
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City-4thStShallow
DT-20
DT-19
DT-18
CROO-2218
DT-1
DT-2
DT-8
DT-9
DT-10
DT-11
DT-12
DT-13
DT-14
DT-16
DT-17
500 Feet
2950
2925
2900
2875
2850
2825
Contour
Cross Section
Layout
Node:391989 (128848)
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C:175
L:4
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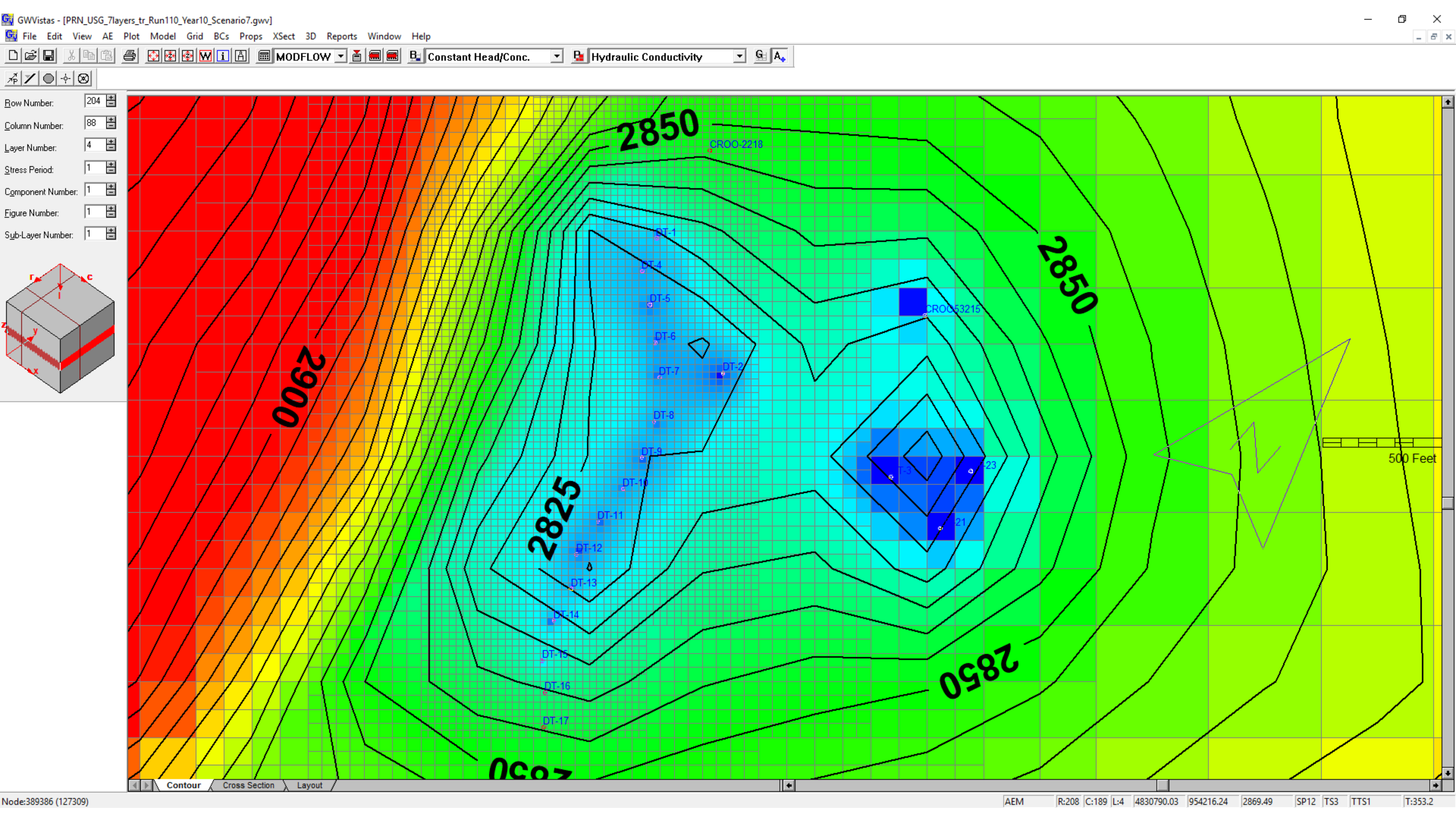
TS3
TTS1
T:353.2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2850
2900
2825
2850
2850
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CROO-2218
CROO53215
DT-1
DT-4
DT-5
DT-6
DT-7
DT-2
DT-8
DT-9
DT-10
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DT-12
DT-13
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DT-15
DT-16
DT-17
500 Feet
Contour
Cross Section
Layout
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L:4
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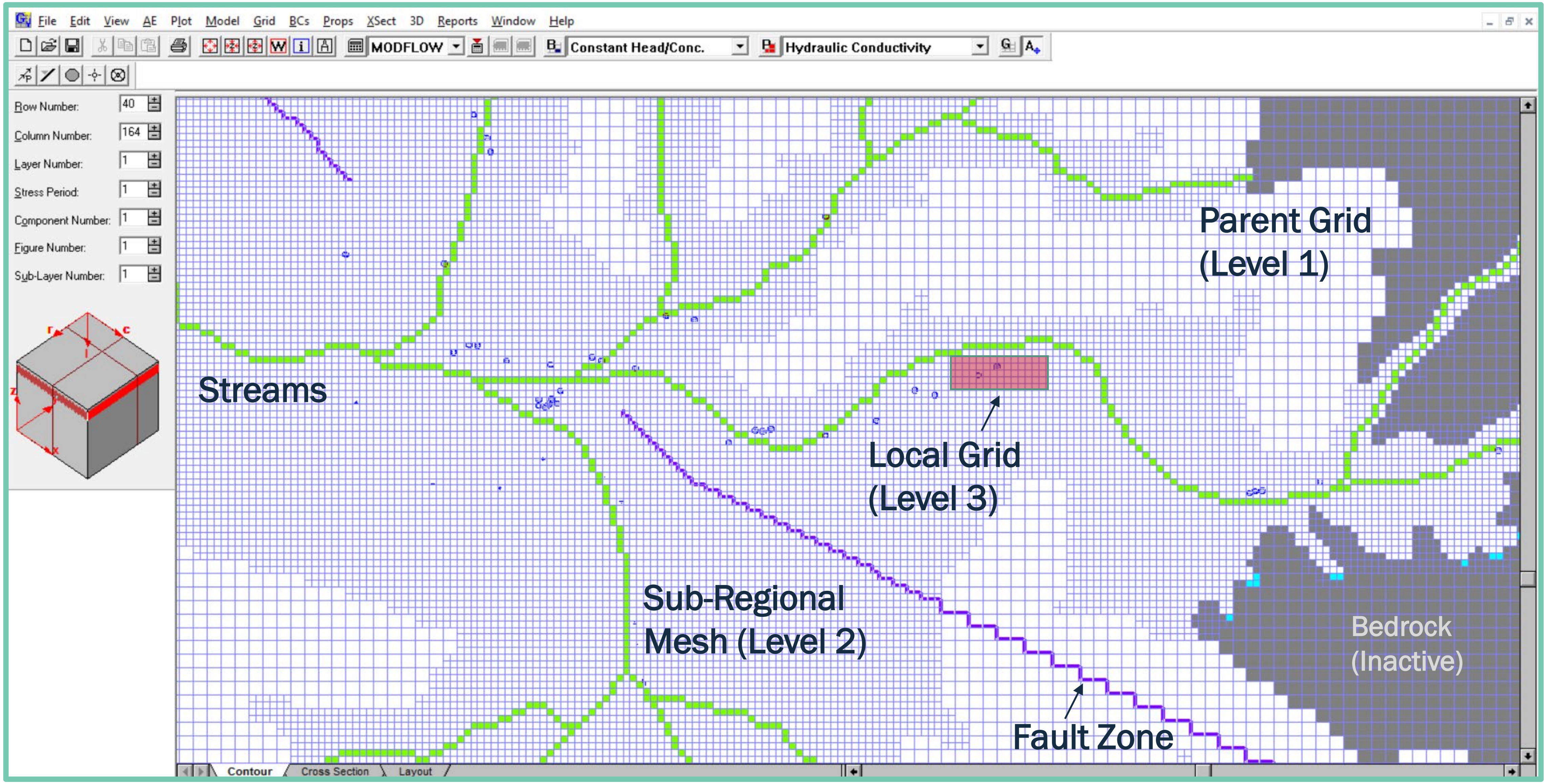
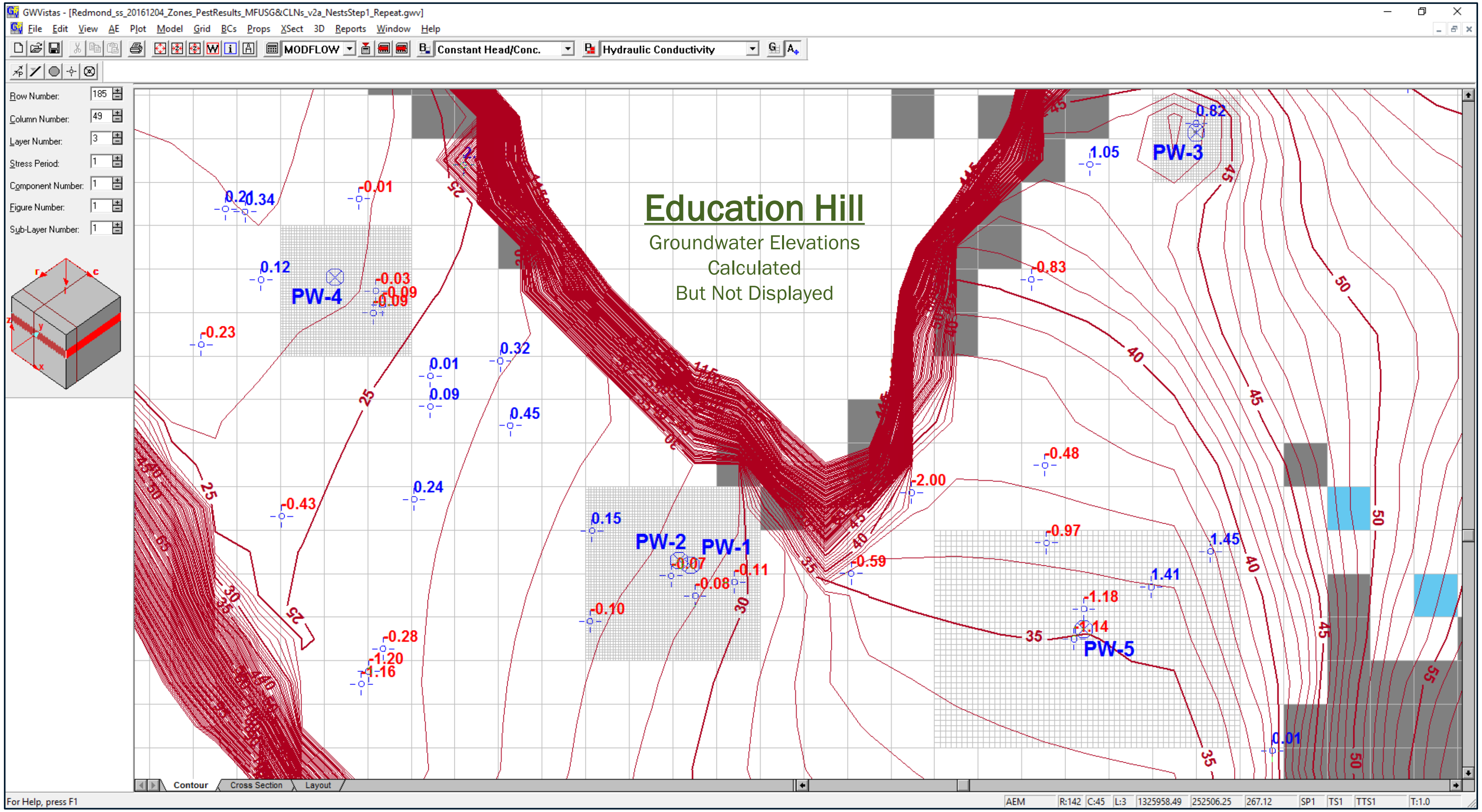
2869.49
SP12
TS3
TTS1
T:353.2

Imbedding a Local Grid Inside a Sub-Regional Mesh

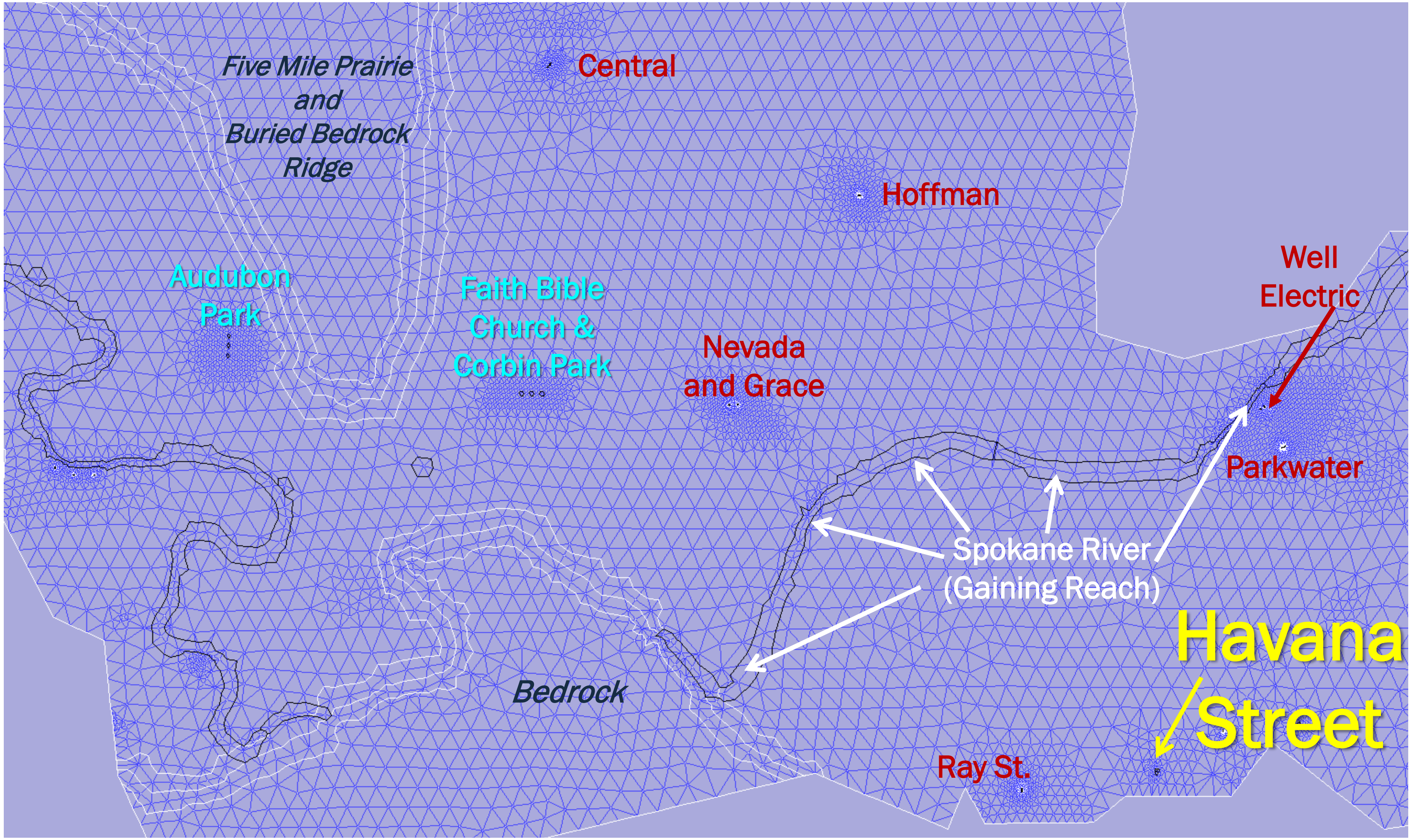


Grids Imbedded at Municipal Production Well Sites

(City of Redmond, WA)

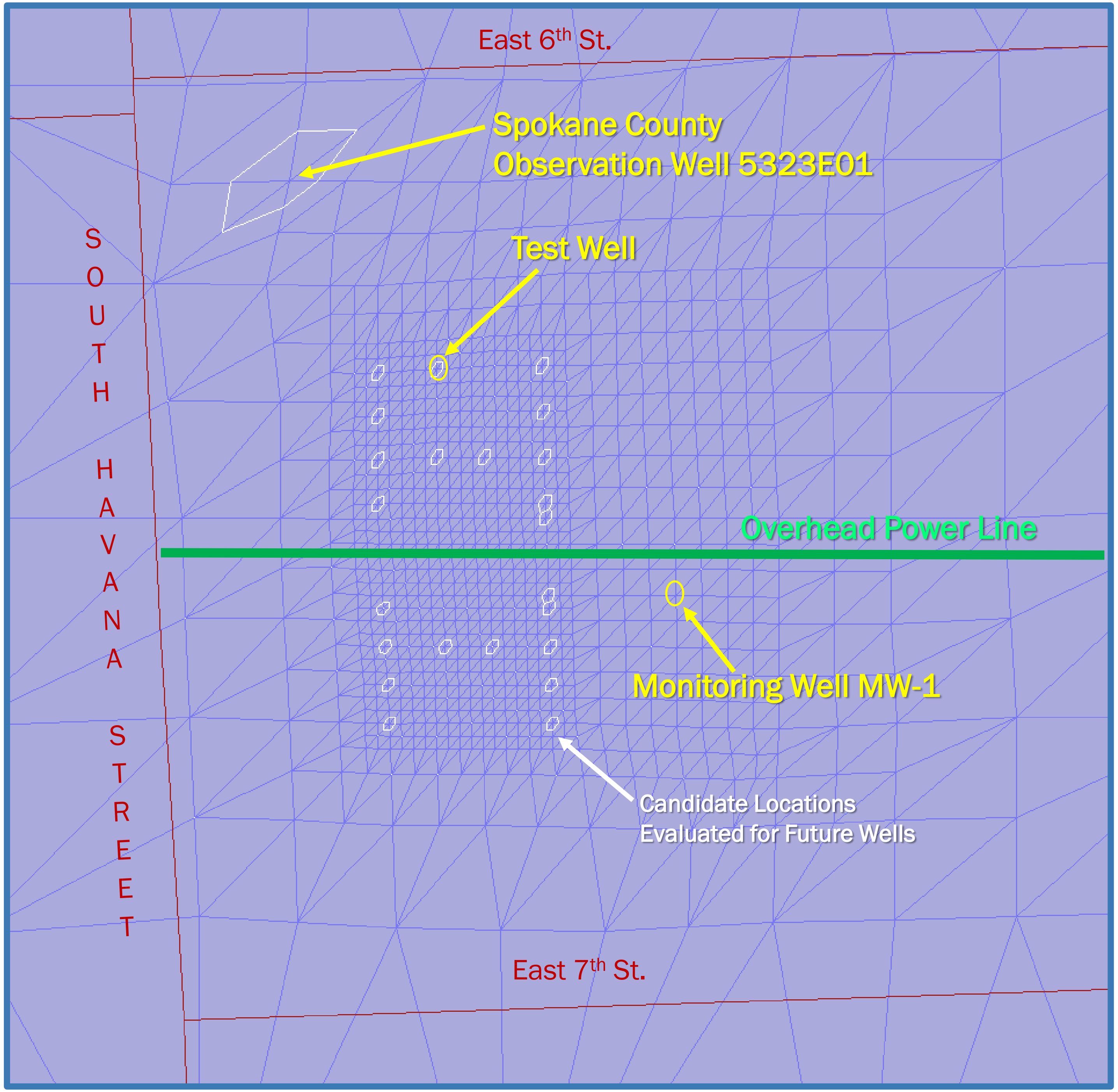


City of Spokane Well Locations



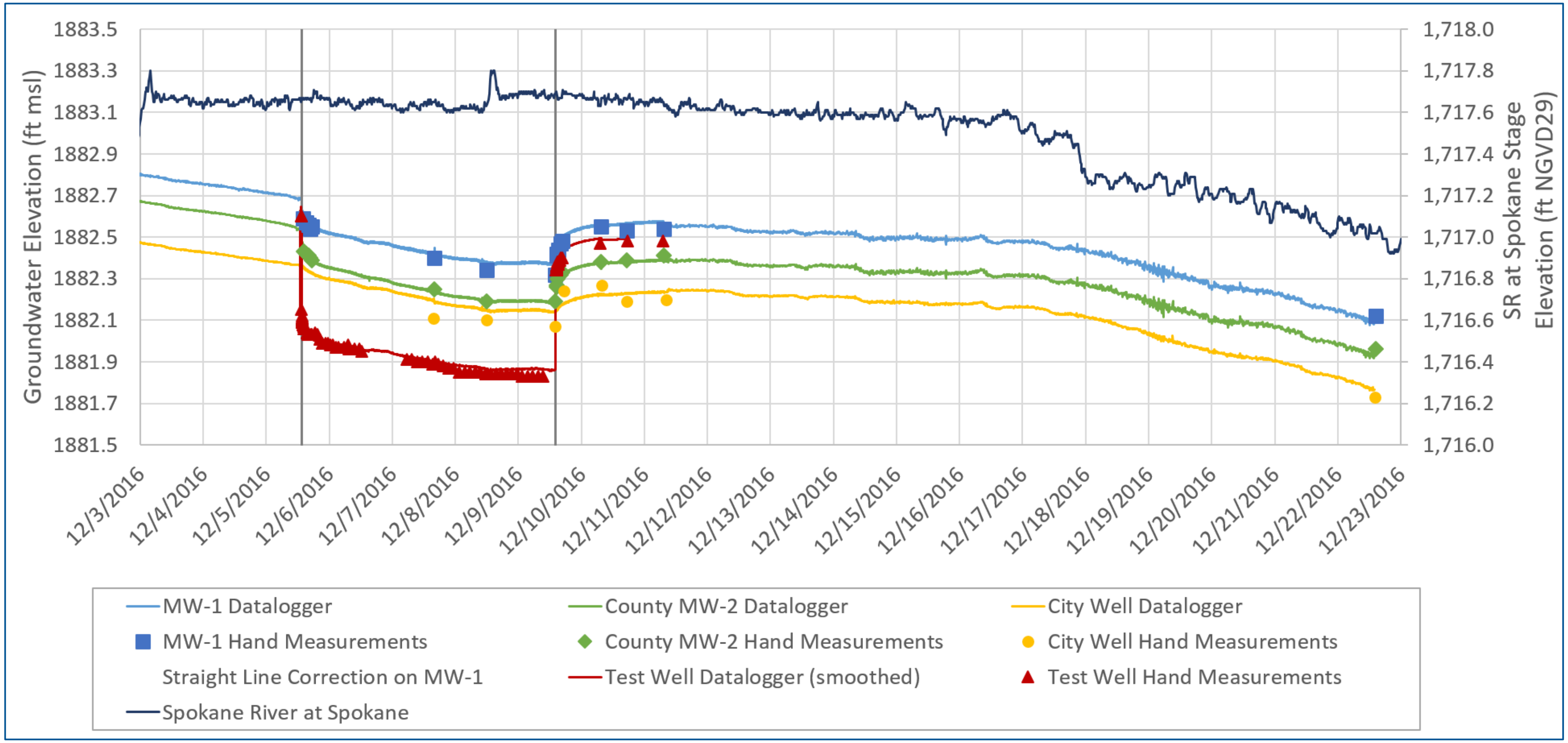
City/SAJB Model: Existing Wells in Red, New Authorized Sites in Yellow and Blue

Spatially Refined Model Grid at the City of Spokane's New Havana Wellfield

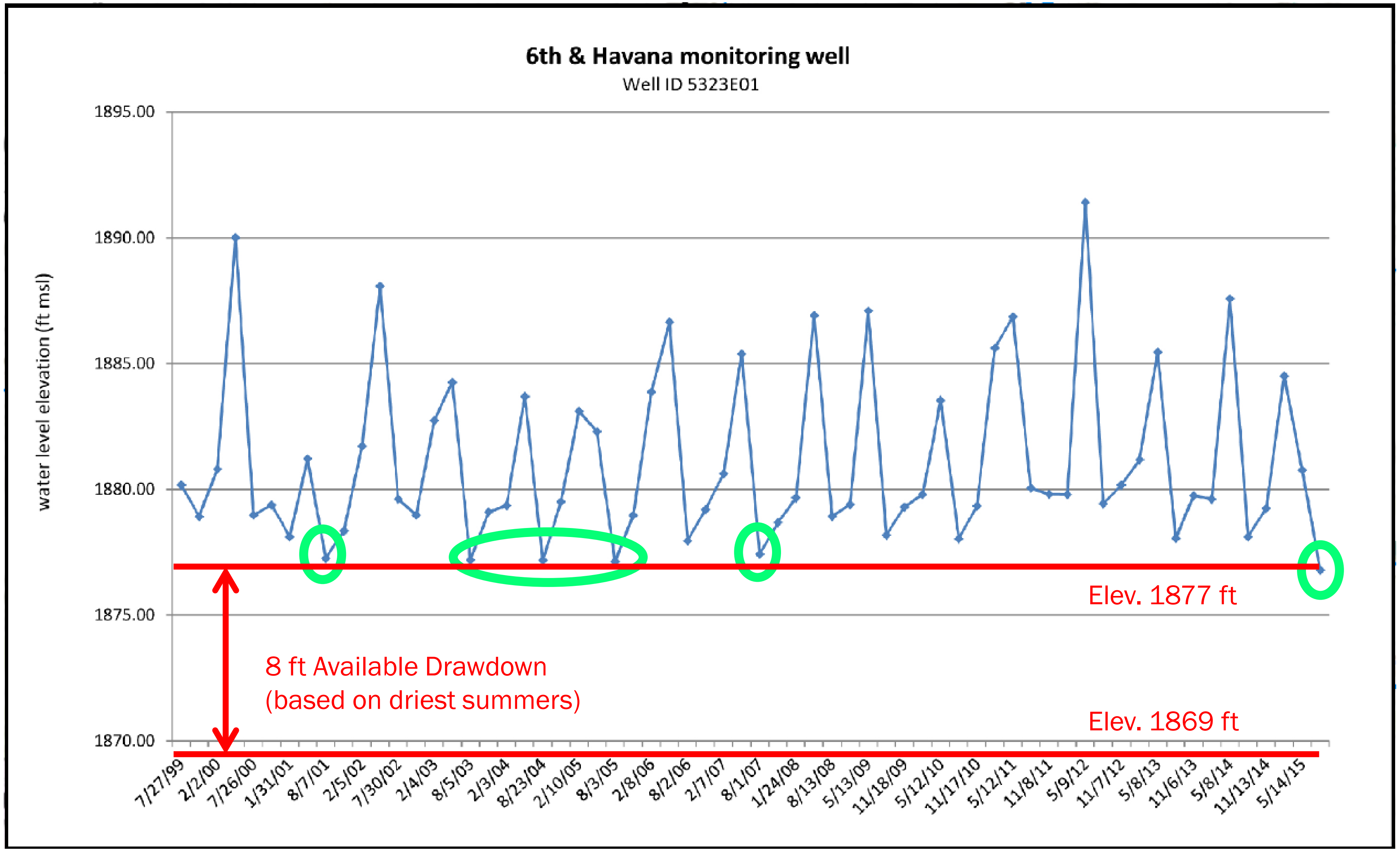


Conduct 5–Day Aquifer Test in Test Well

Pumping Rate Held Constant at 1,600 gpm



Incorporate Long-Term Historical Data and Proposed Well Design into the Model



Results from Modeling and Field Aquifer Testing

Layout No.	No. of Wells	Target Wellfield Production Rate (gpm)	Estimated Drawdown (feet) inside Well Casings Under Best-Case Scenario	Sustainable in Summer Under Best-Case Scenario?	Sustainable in Summer Under a Plausibly Less Optimistic Scenario?
1	4	15,000	5.0	Yes	Yes
2	8	30,000	8.5	Yes	Maybe
3a	6	22,500	6.5	Yes	Yes
3b	8	30,000	8.7	Yes	Maybe
4	12	45,000	12.0	Yes	No
FINAL	6	22,500	6.5	Yes	Yes

Final Design Concept

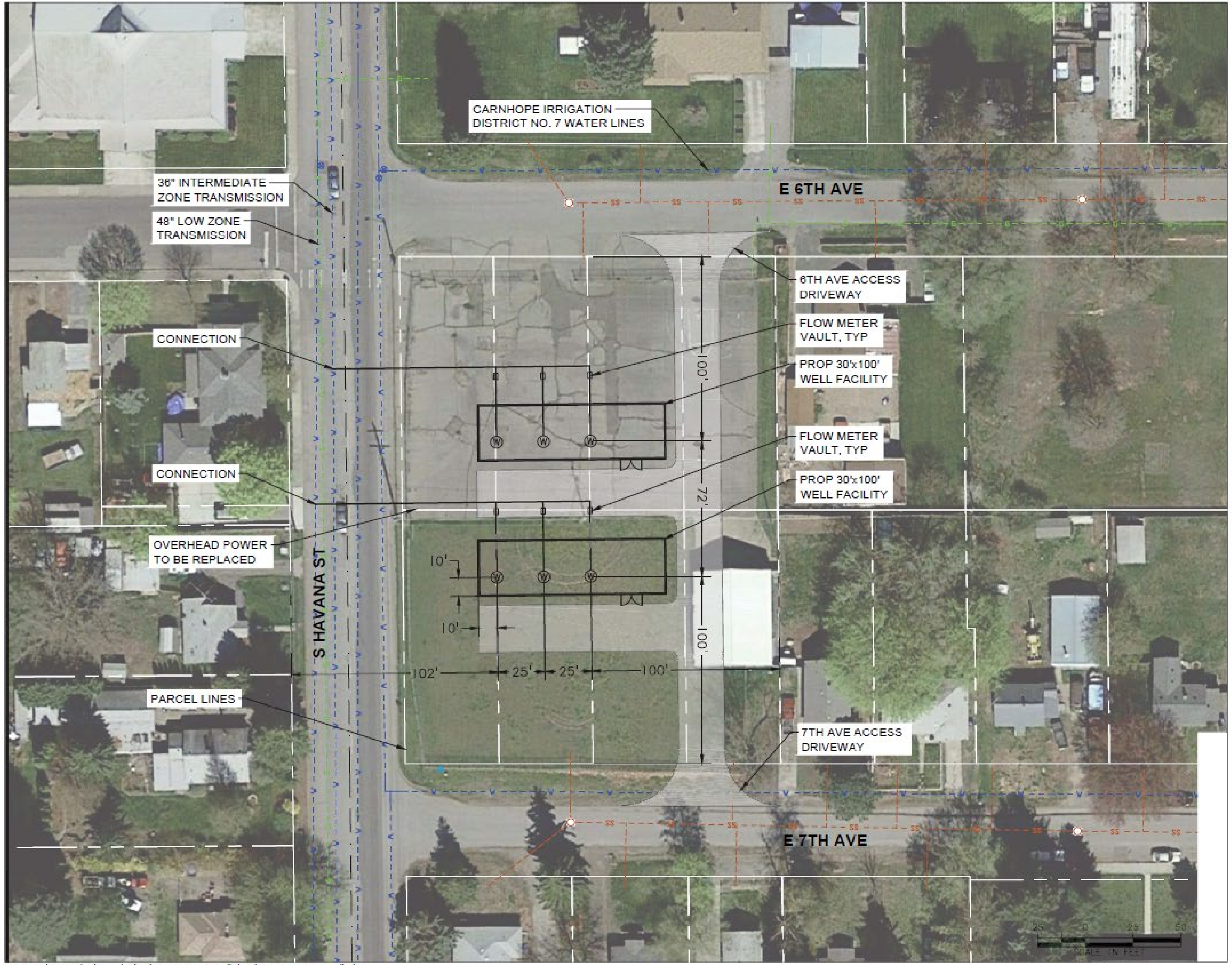


FIGURE 5-1
Conceptual Site Plan for a Future Wellfield
Havana Street Well Site Evaluation and Test Well Development
City of Spokane Water Department, Spokane, Washington
March 2017

MSA

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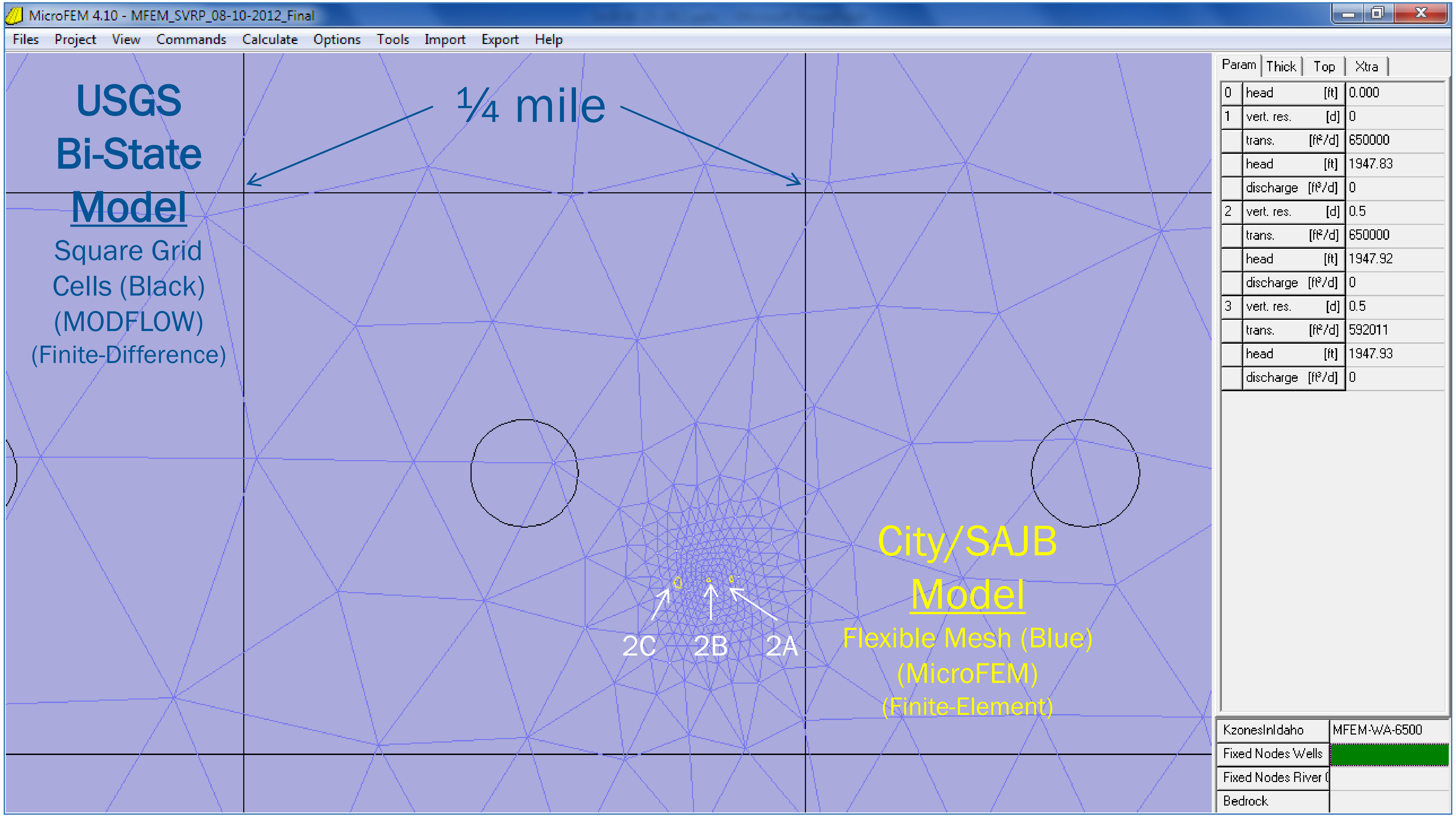
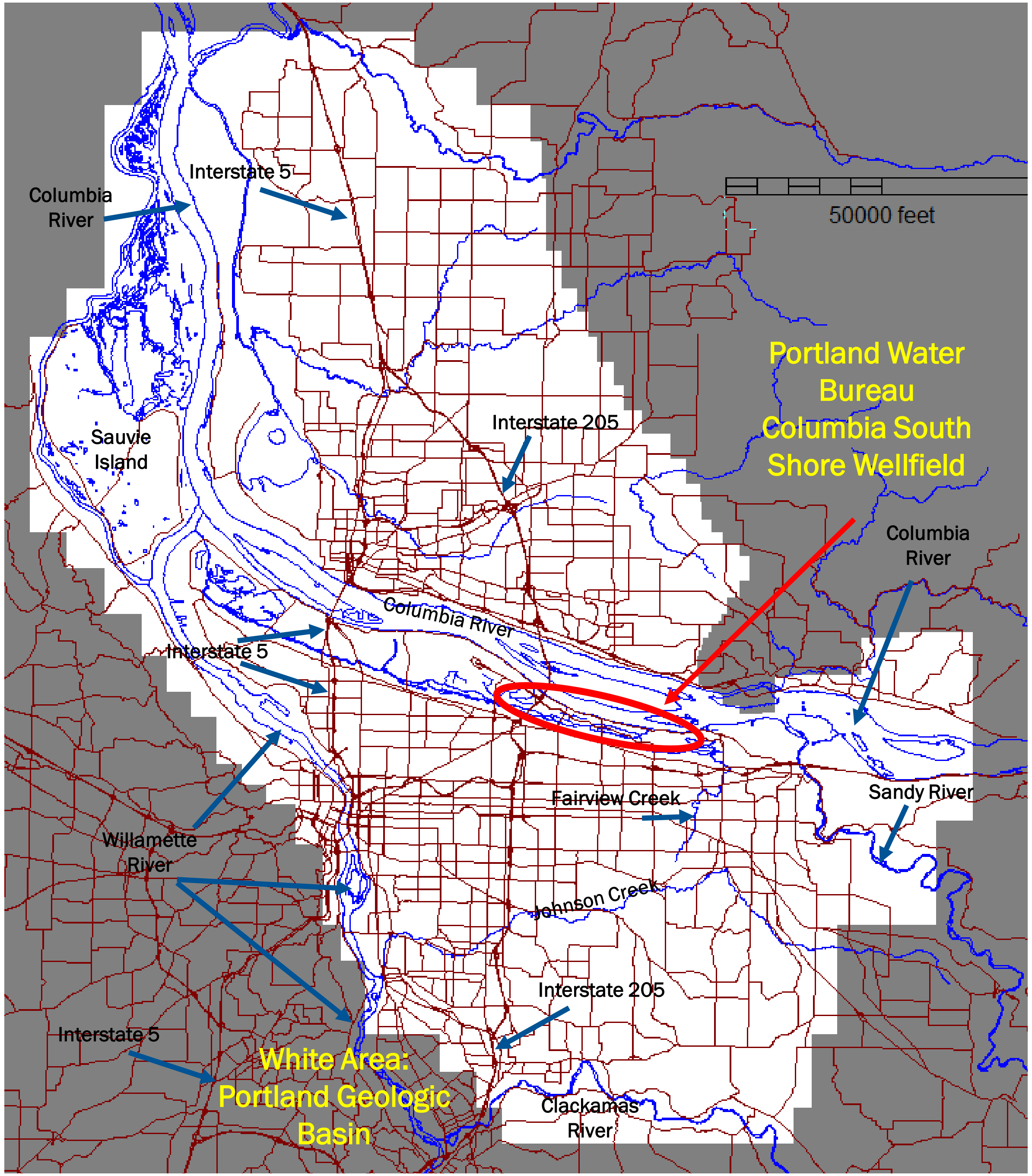
Wellfield Studies: Impossible with a Coarse Grid

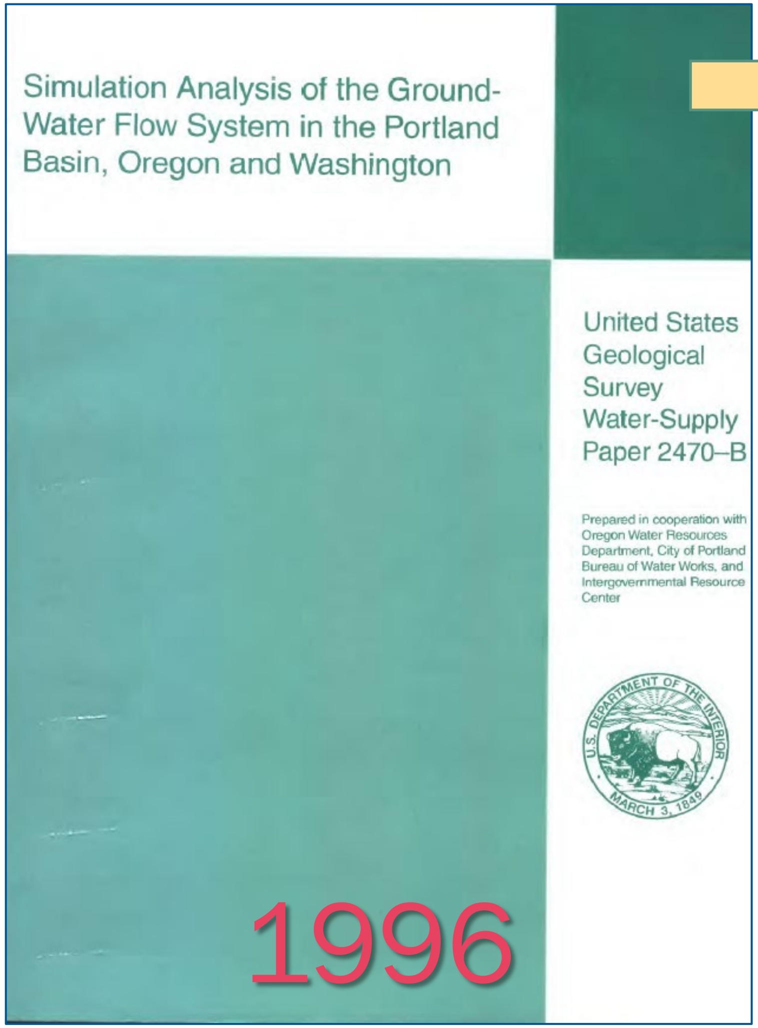


Groundwater Modeling to Support Supply System Master Planning

Portland Water Bureau



Building Upon a USGS Basin Model (Portland)

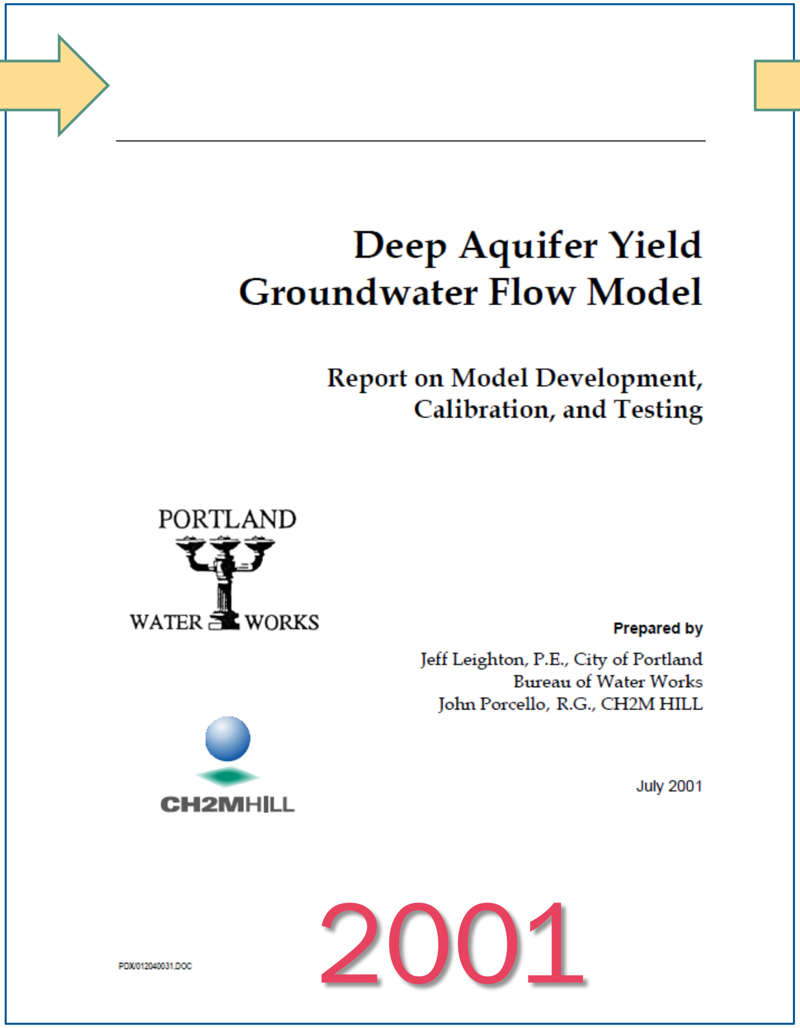


Simulation Analysis of the Ground-Water Flow System in the Portland Basin, Oregon and Washington

United States Geological Survey Water-Supply Paper 2470–B

Prepared in cooperation with Oregon Water Resources Department, City of Portland Bureau of Water Works, and Intergovernmental Resource Center

1996



Deep Aquifer Yield Groundwater Flow Model

Report on Model Development, Calibration, and Testing

PORTLAND WATER WORKS

Prepared by

Jeff Leighton, P.E., City of Portland Bureau of Water Works
John Porcello, R.G., CH2M HILL

CH2MHILL

July 2001

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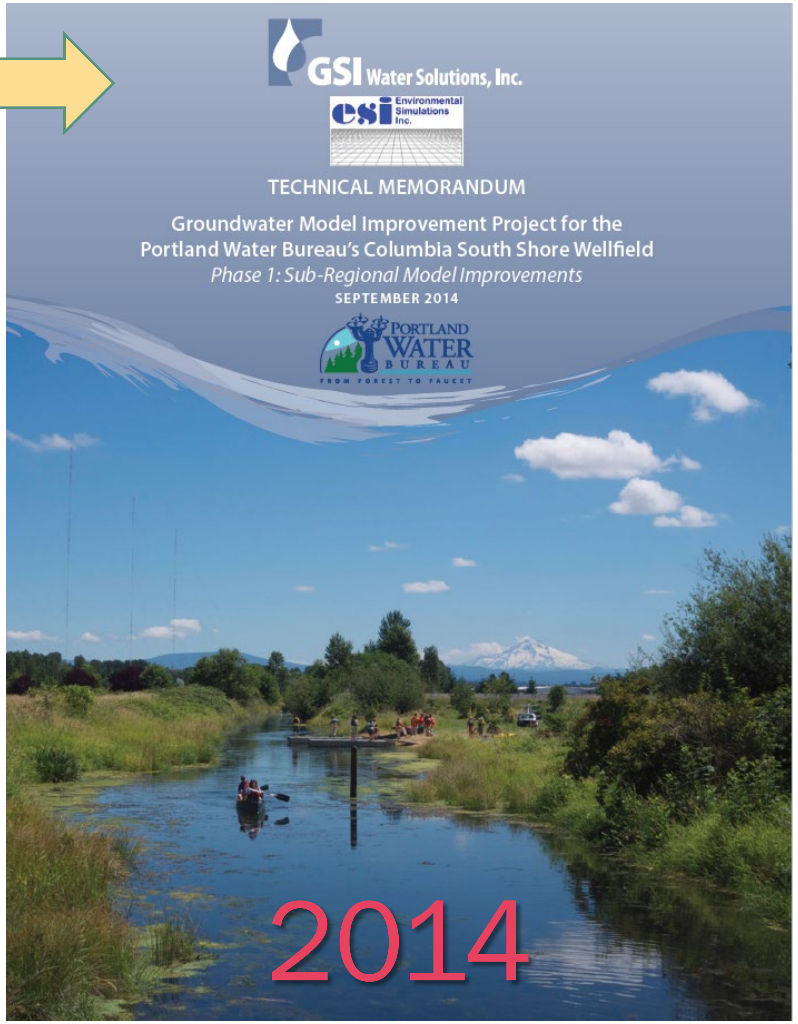
2001



GSI Water Solutions, Inc.

esi Environmental Simulations Inc.

TECHNICAL MEMORANDUM

Groundwater Model Improvement Project for the Portland Water Bureau's Columbia South Shore Wellfield

Phase 1: Sub-Regional Model Improvements

SEPTEMBER 2014

PORTLAND WATER BUREAU

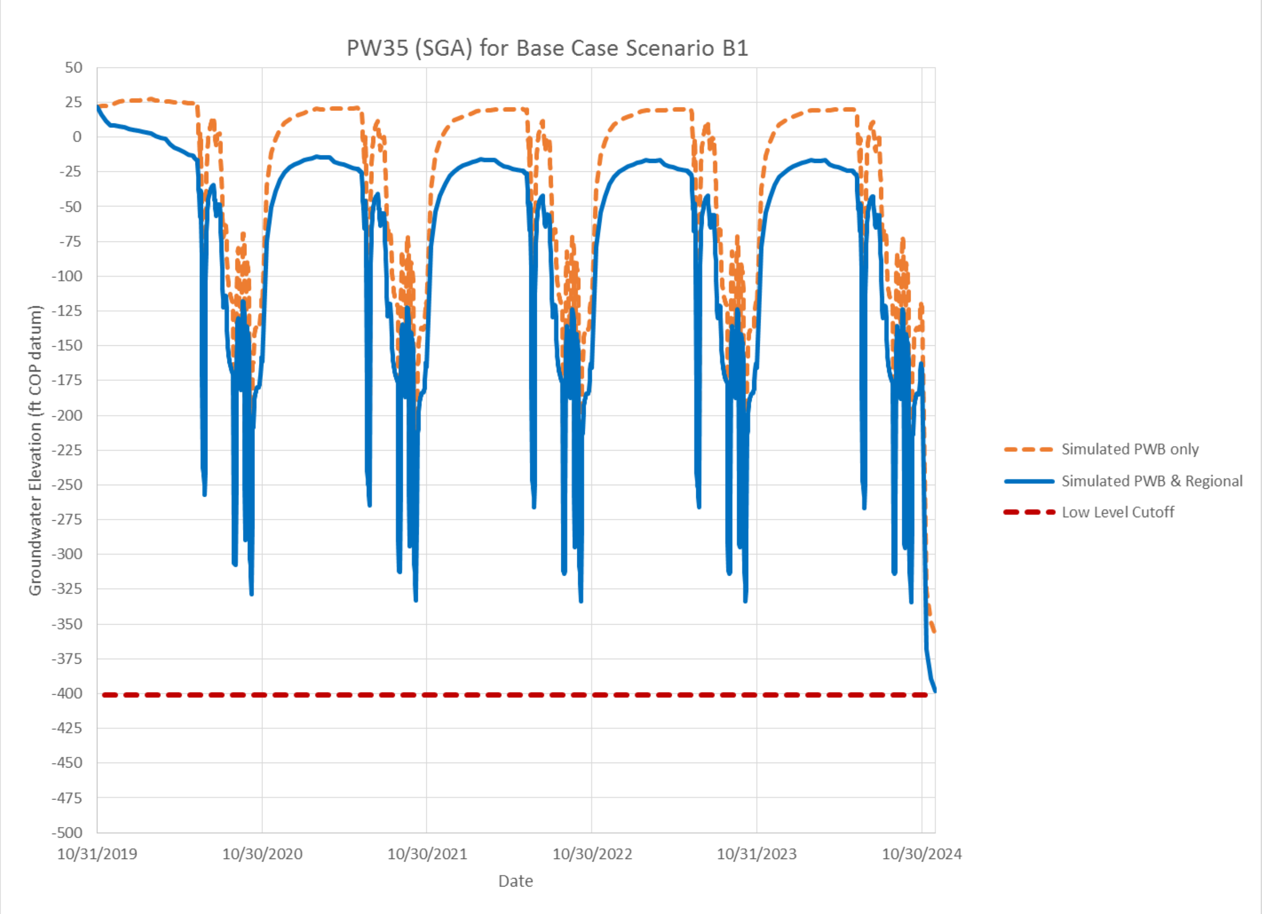
FROM FOREST TO FAUCET

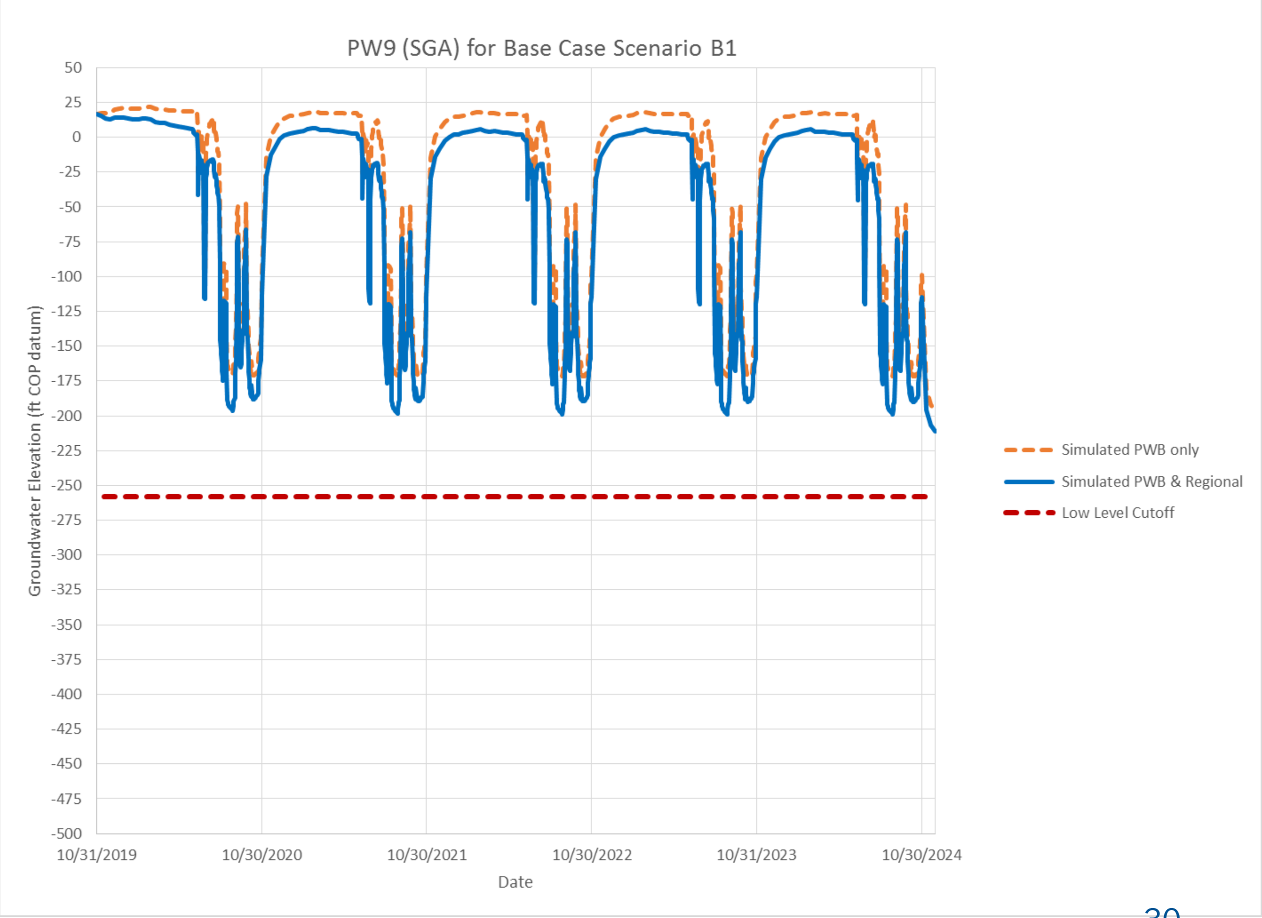
2014

Base-Case Demand Scenario

2018 Supply System Master Plan

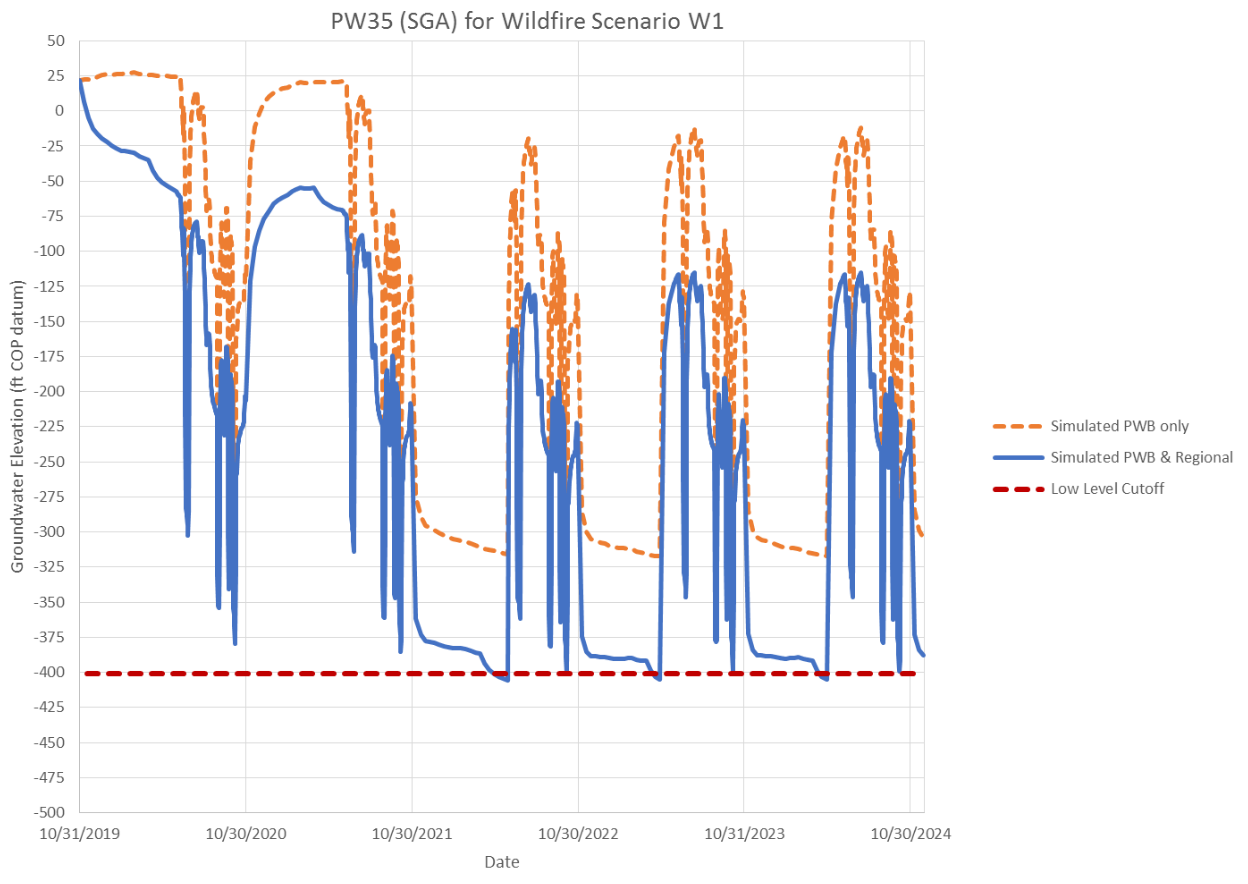
Seasonal Use Plus 1-Month-Long Emergency Use Due to Flood-Related Interruption of Surface Water Supply Source

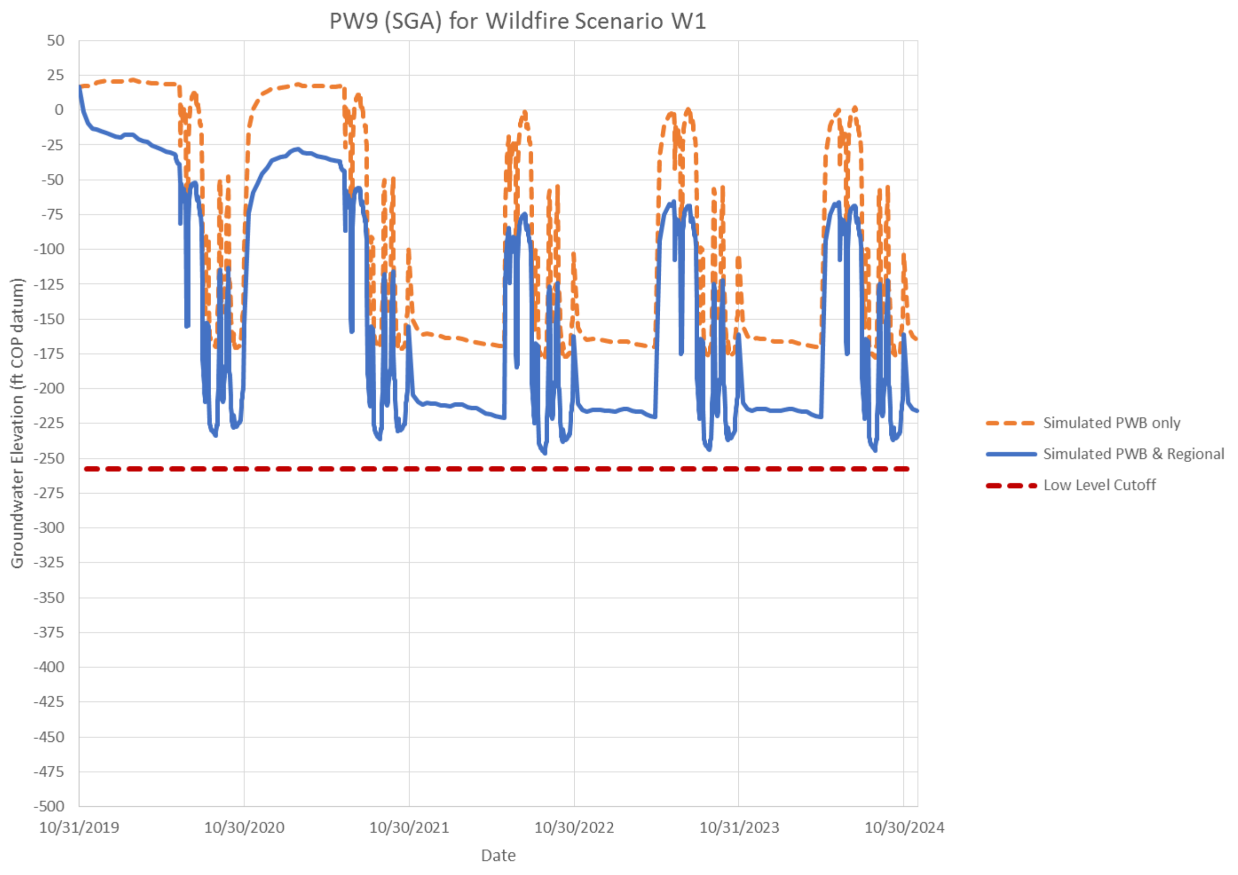




Emergency Demand Scenario
2018 Supply System Master Plan

Seasonal Use Plus 3-Year-Long Emergency Use Due to Wildfire-Related Interruption of Surface Water Supply Source





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- Well performance, maintenance, rehabilitation
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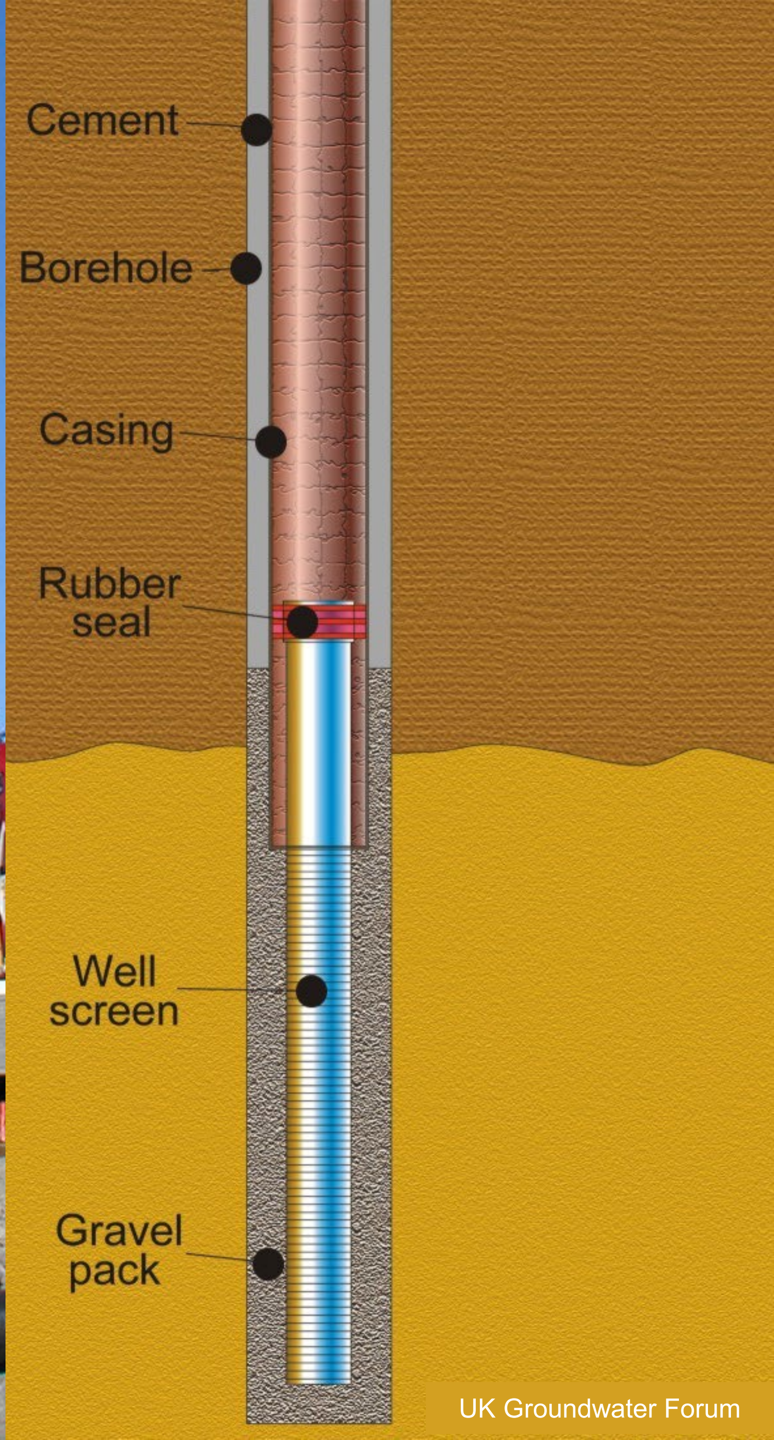
Well Maintenance/ Rehabilitation

Wells are…

- …NOT simply steel pipes stuck in holes in the ground



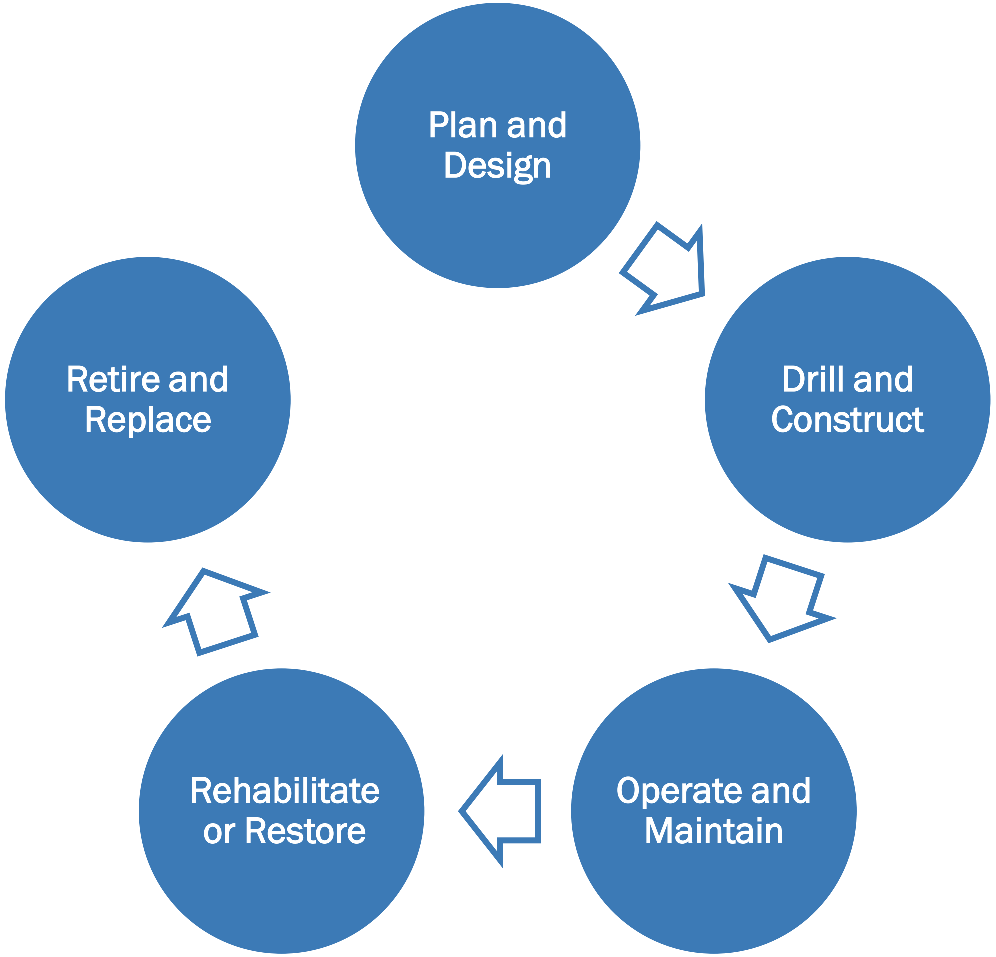
Wells are…

- …NOT simply steel pipes stuck in holes in the ground
- …Engineered structures

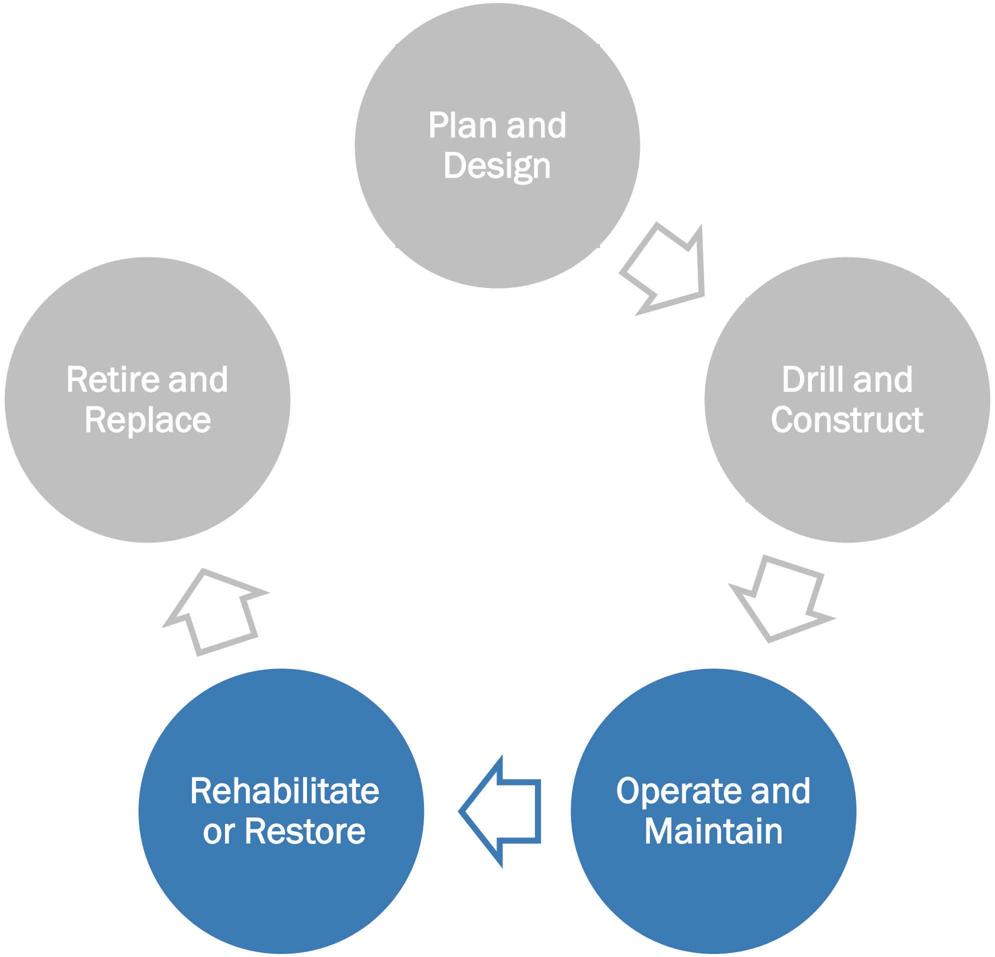
Wells are…

- …NOT simply steel pipes stuck in holes in the ground
- …Engineered structures
- …NOT passive structures

Life Cycle Stages of a Production Well



Life Cycle Stages of a Production Well



Types of Problems

Is it the pumping system?

- Worn or damaged impellers, or holes in pump column

Is it the aquifer?

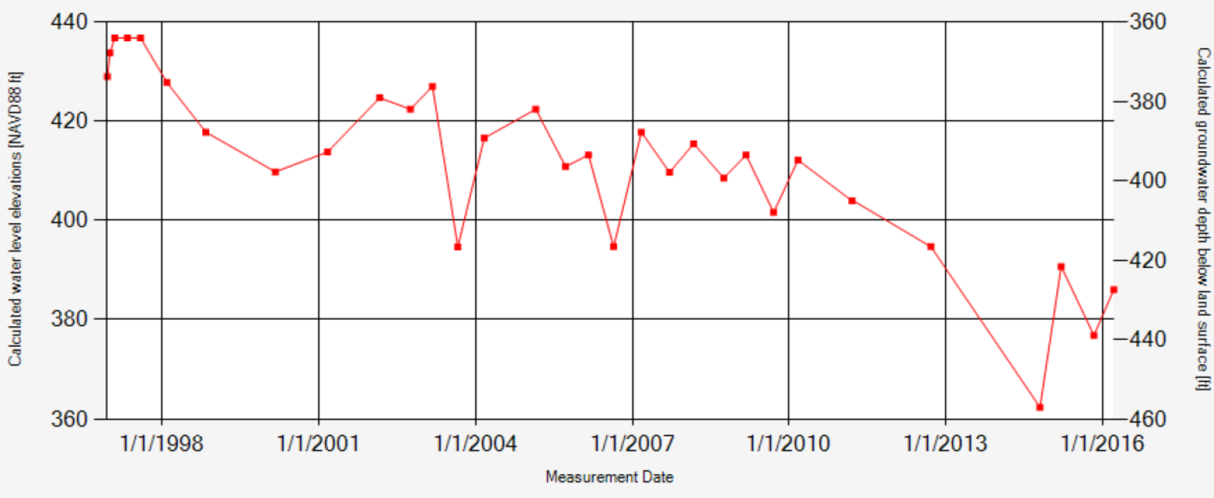
- Declining or seasonally changing groundwater levels

Is it the well?

- Screen plugged → more drawdown → less efficient → less yield

Compounding problems?

- Rupture in casing or well screen → pumping sand and damaging pump



Examples of Symptoms

Is it the **pumping system**?

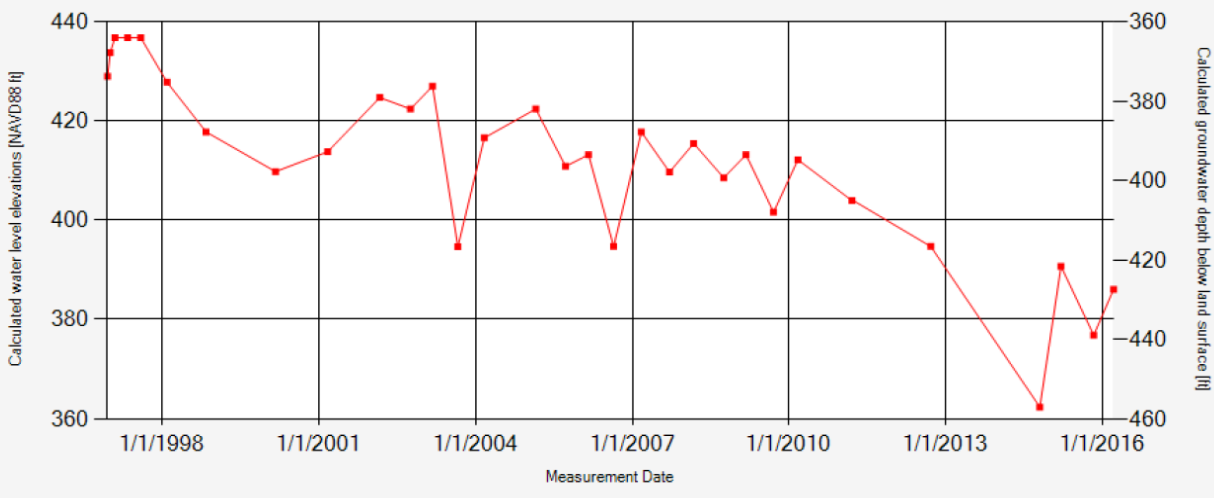
- Decrease wire-to-water efficiency

Is it the **aquifer**?

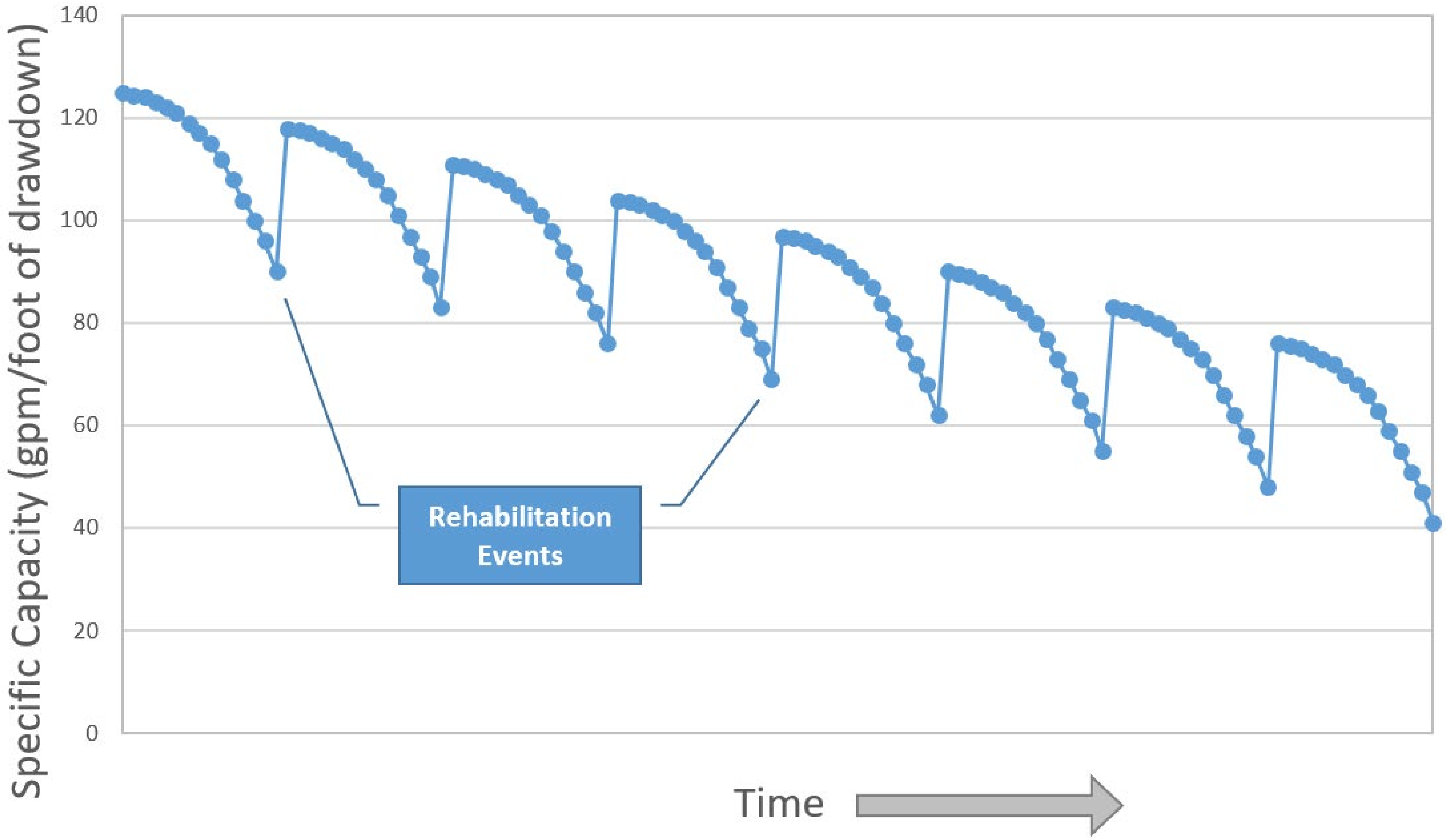
- Deeper static water level→ less available drawdown → cavitation despite same pumping rate

Is it the **well**?

- Changes in odor, taste, water quality
- Slimes or biofilms on equipment
- Decrease in performance (i.e., specific capacity)



Declining Specific Capacity Trend



Specific capacity (*Q*/s) is a measure of well performance

Specific capacity = pumping rate (*Q*) divided by drawdown (s):

- *Q* = 500 gpm
- *s* = 10 feet
- ***Q*/*s* = 50 gpm/foot of drawdown**

Performance Monitoring

Proactive approach:

- Monitor and track performance regularly
- Perform routine inspections (i.e., video and pumping system surveys)
- Conduct microbial assessments

Reactive approach:

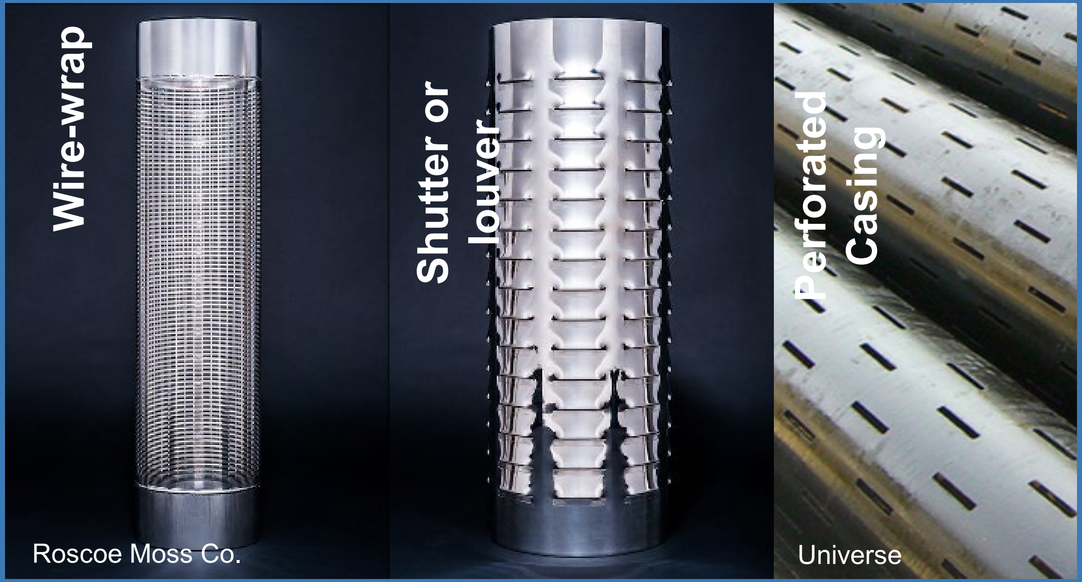
- Pump is damaged
- Well is failing
- Too little, too late

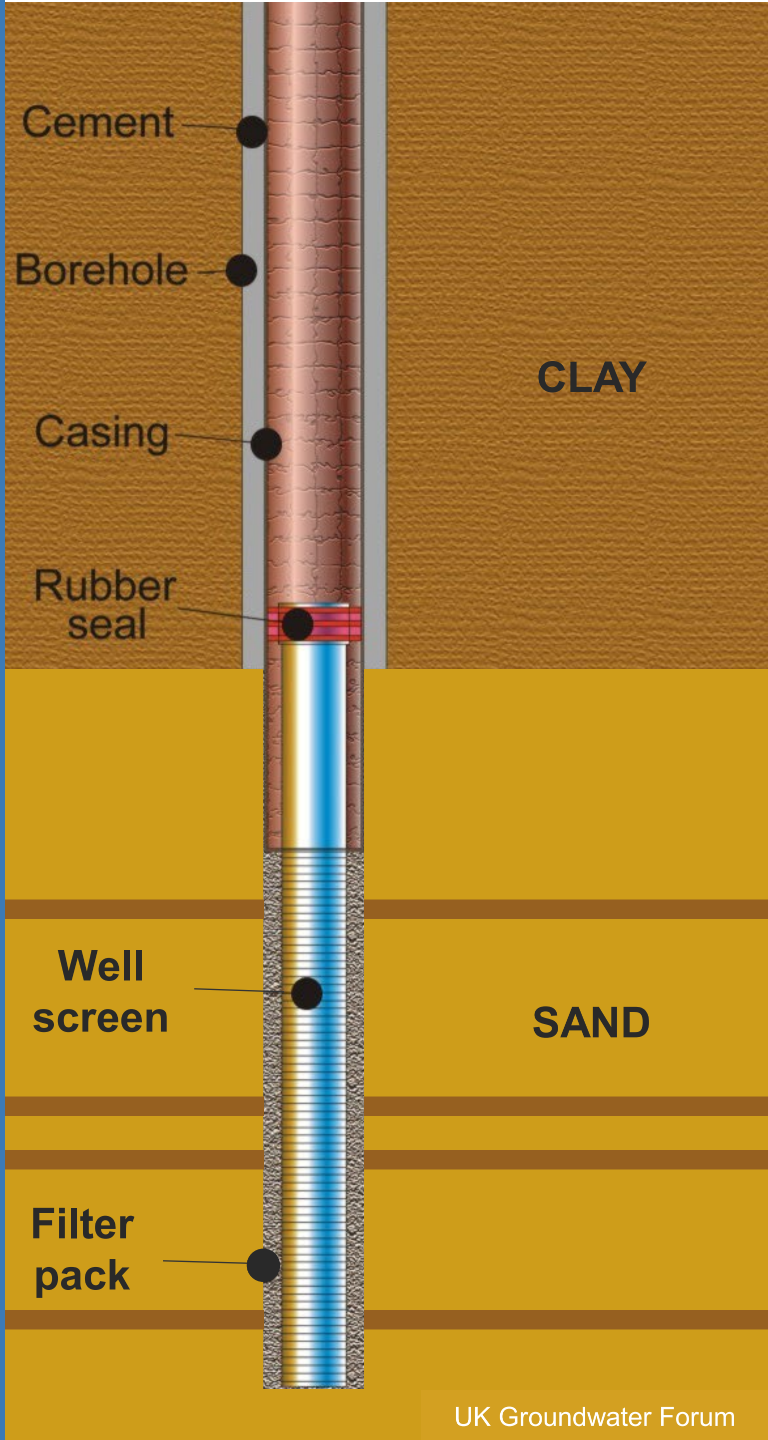
Every well is different:

- Geologic environment
- Age
- Construction materials
- Operations
- Historical maintenance
- Groundwater quality

Well Types

- Filter pack
  - Common screen types:





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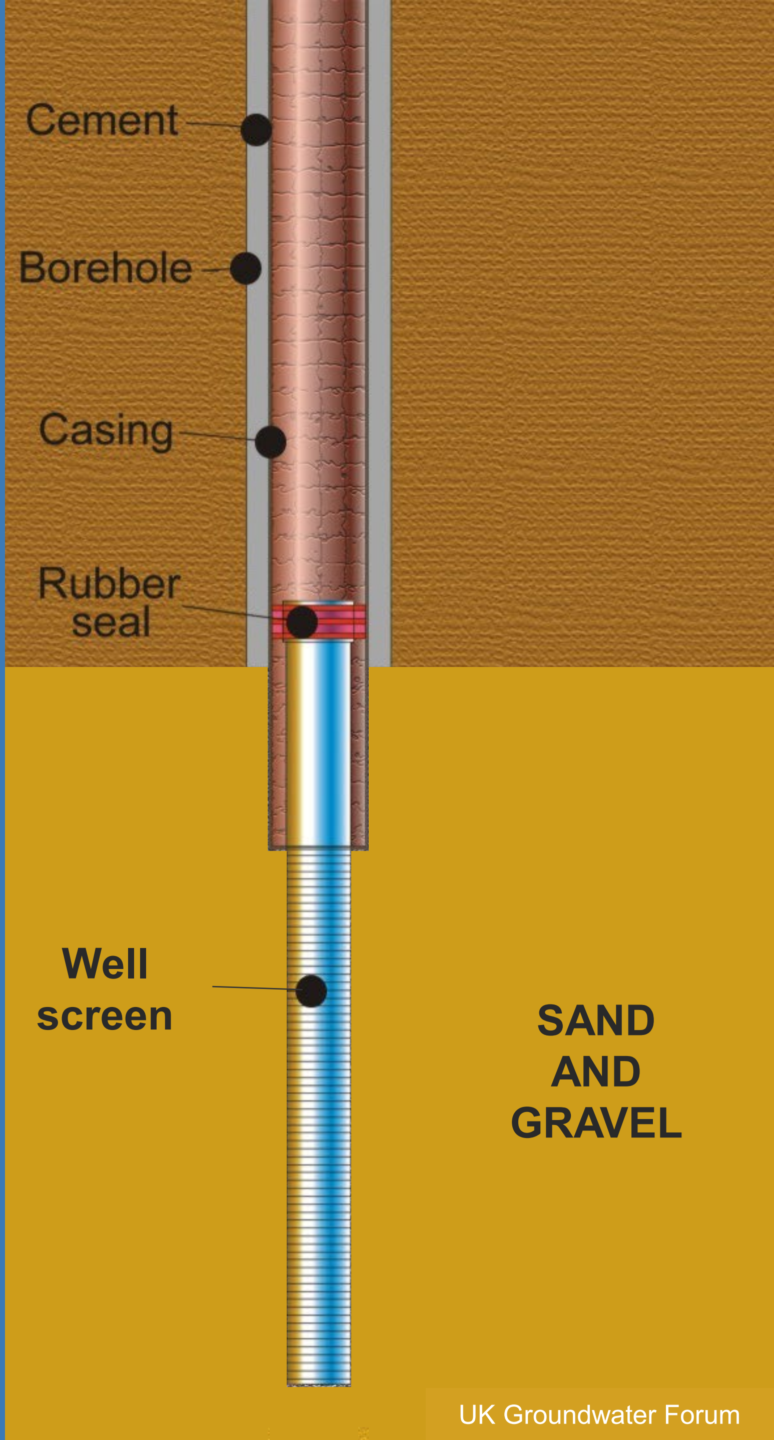
  - Well-graded aquifer
  - Sand and gravel formations



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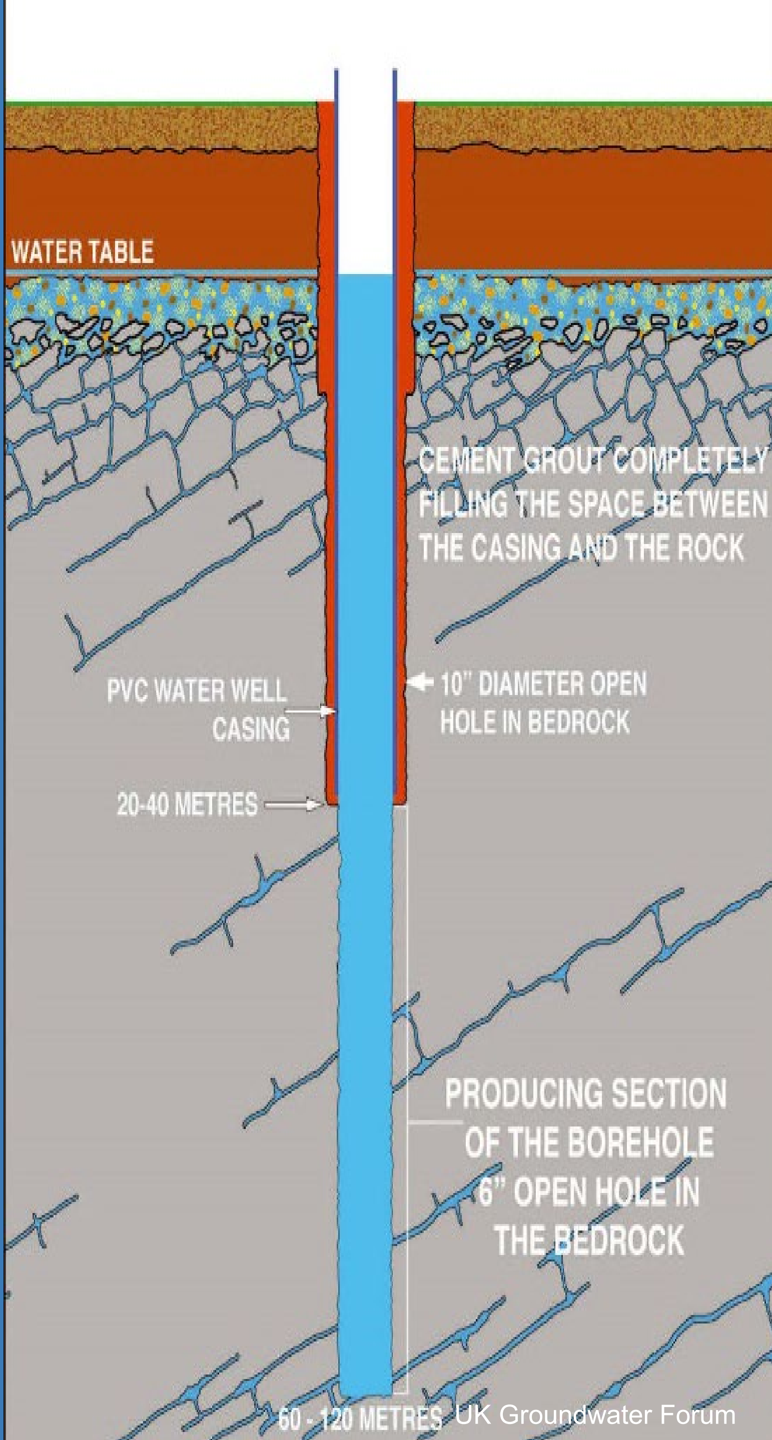
  - Fractured or porous bedrock
  - CRBG wells



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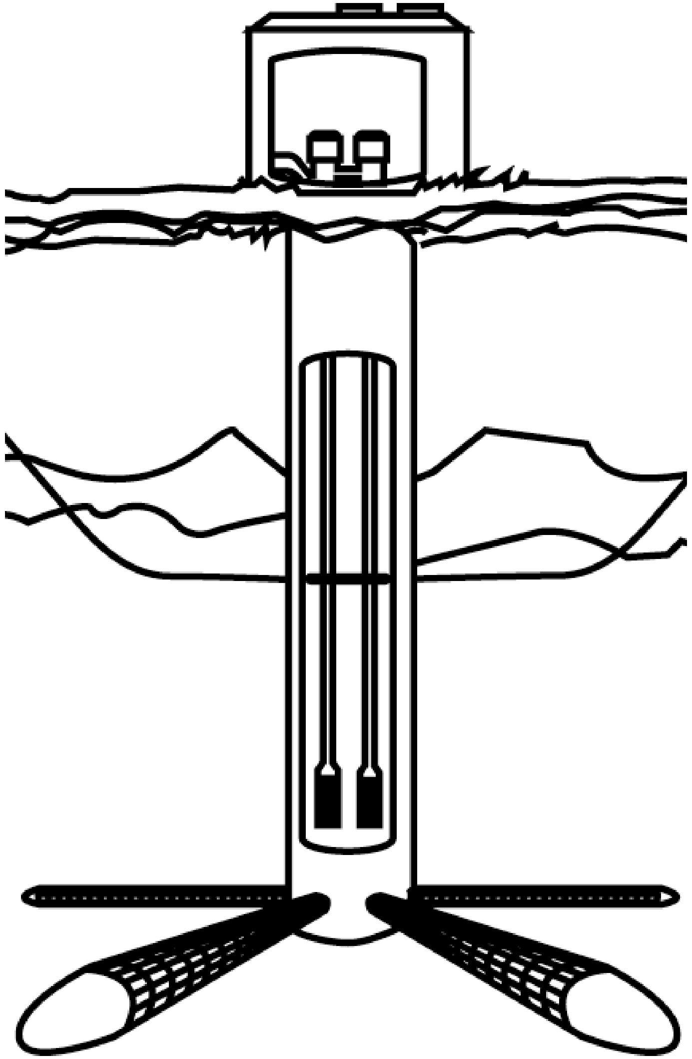
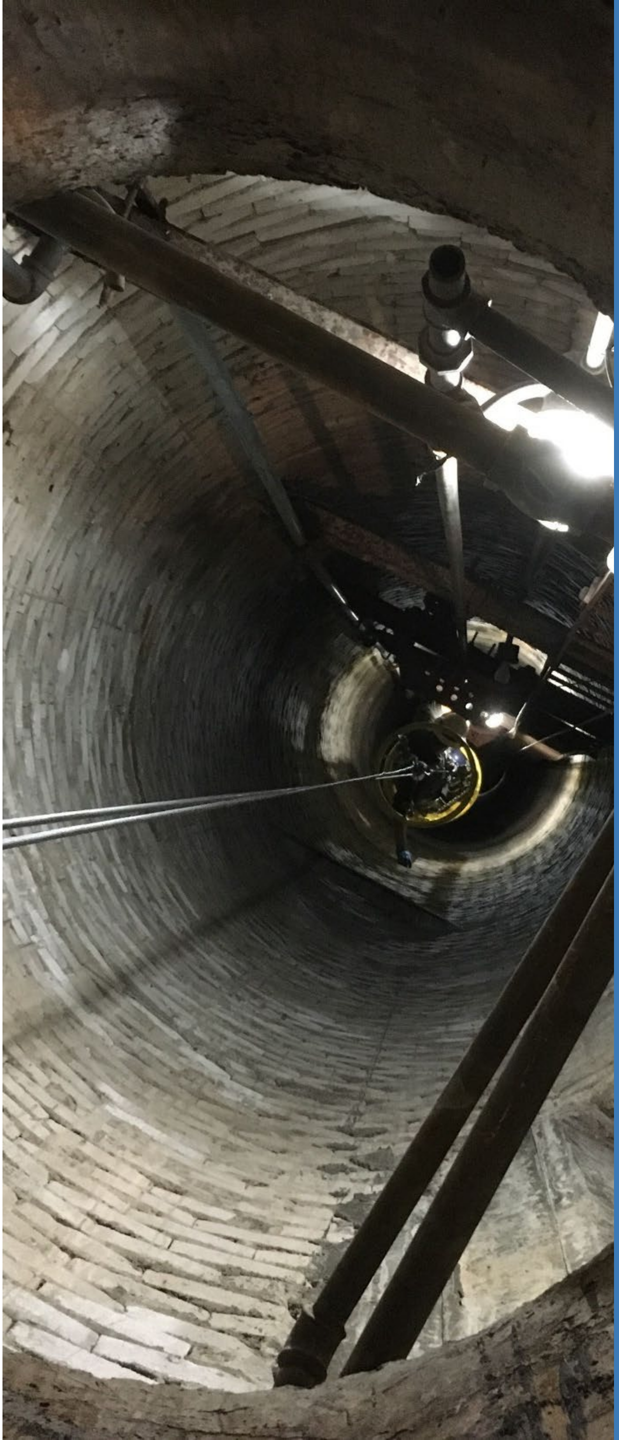
- Collectors (e.g., Ranney)
  - Reinforced concrete caisson; 10-20+ feet dia.
  - Lateral/radial well screens
  - Single well yields 2 to 50+ mgd





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- Collectors (e.g., Ranney)
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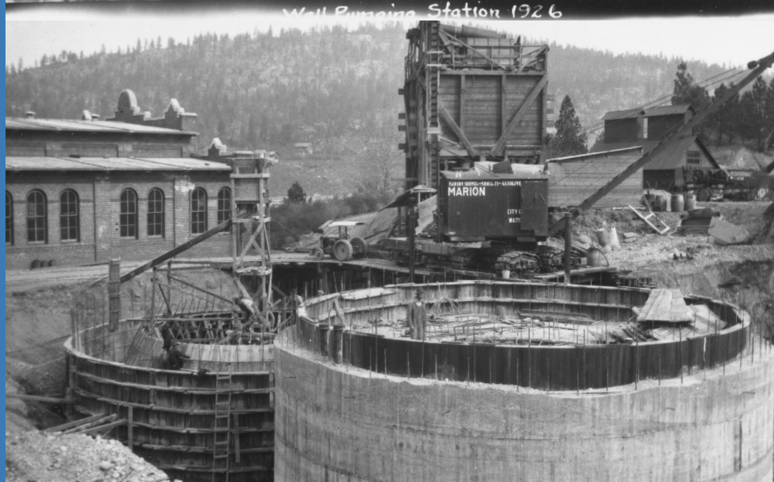
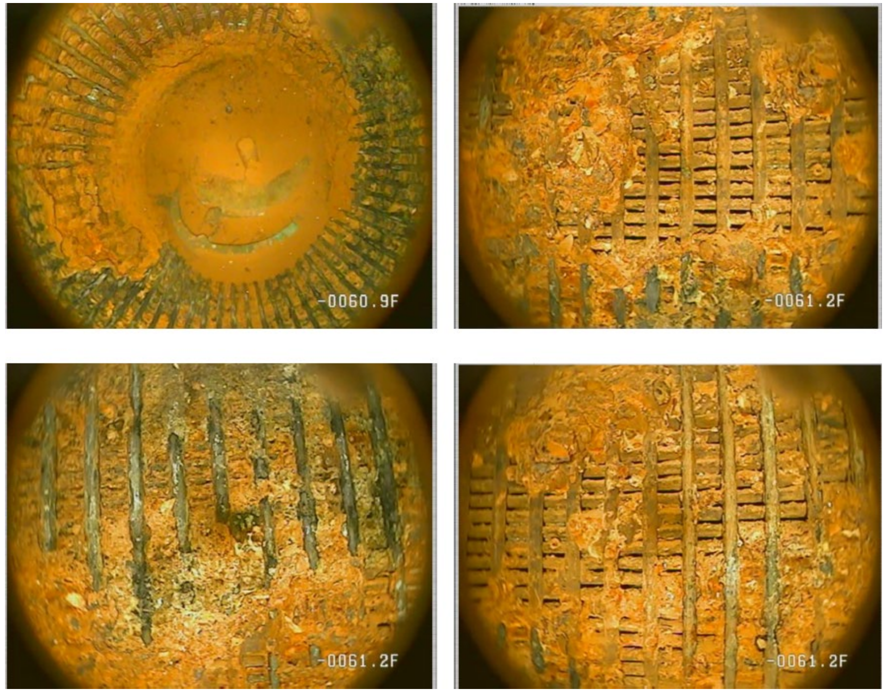
  - Lateral/radial well screens
  - Single well yields 2 to 50+ mgd
- Caissons
  - Concrete or brick-lined

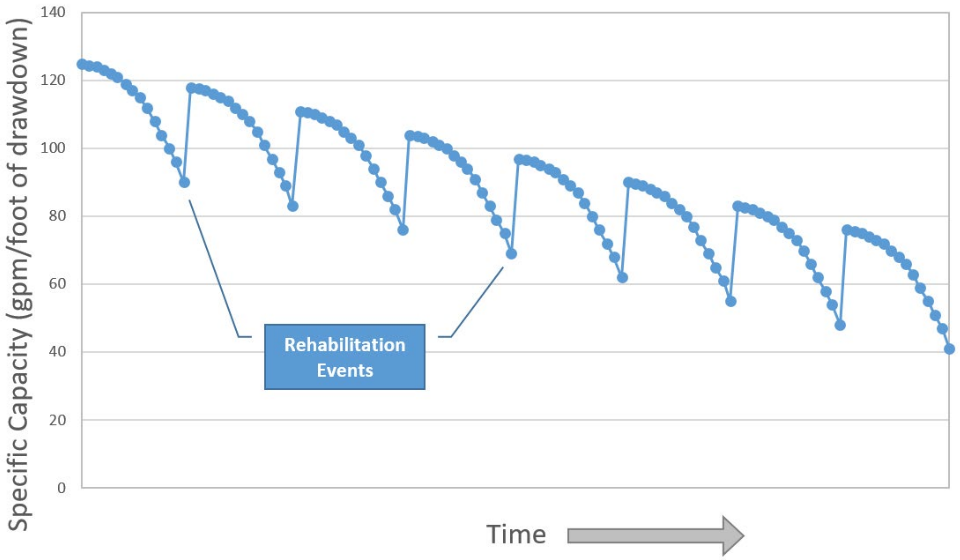


Well Rehabilitation

- Well not performing as expected: **now what?**
  - Do nothing and hope for the best
  - Diagnose and prepare a targeted plan to repair or restore
  - Drill and construct new replacement well

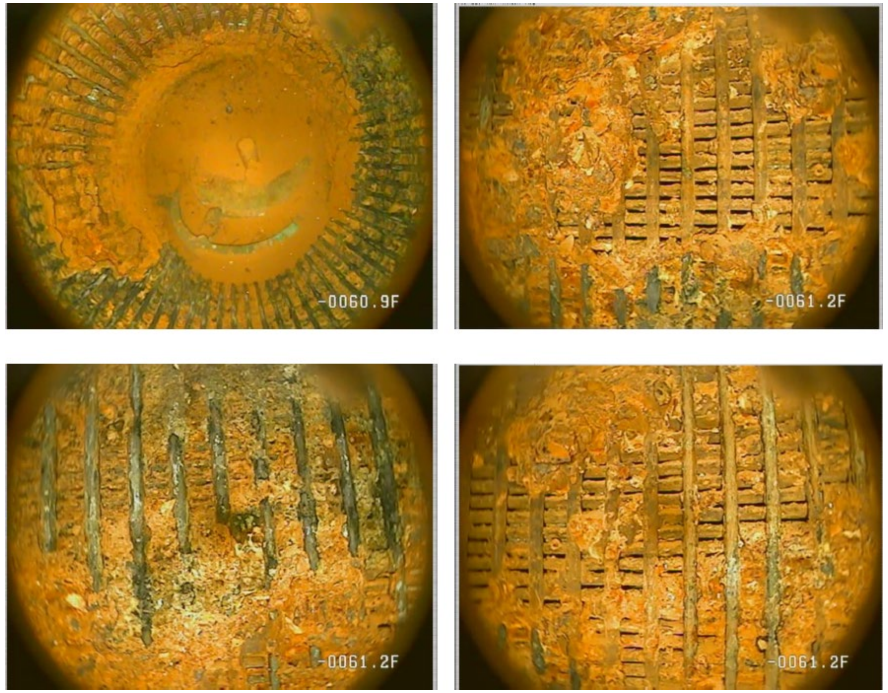
- Well rehabilitation vs. new construction
  - Cost 10 to 100% of a new well
  - May not ever regain lost performance

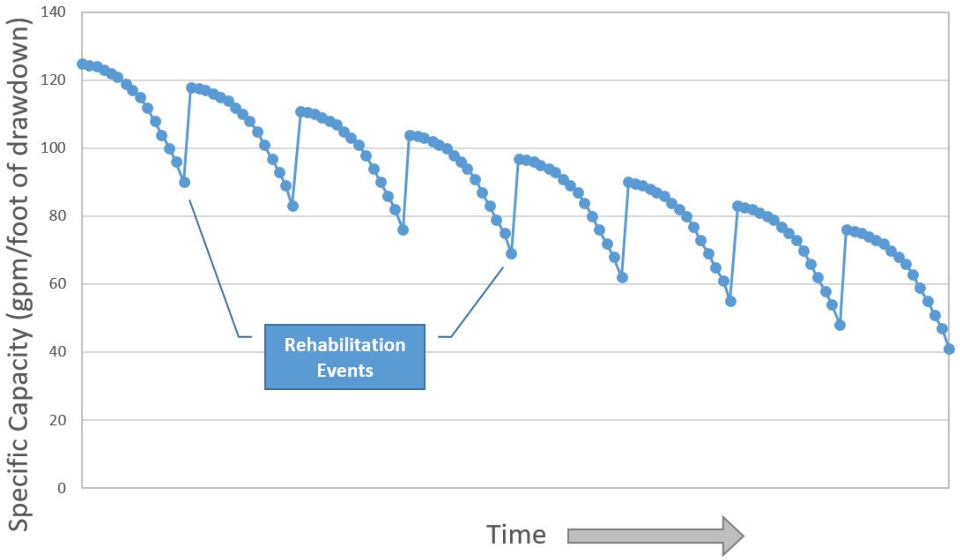




Well Rehabilitation

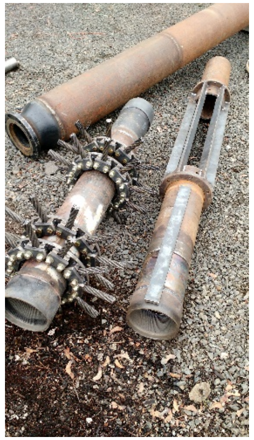
- Diagnose
  - Maintenance/operations history
  - Poor well construction or development
  - Pumping/well performance test
  - Remove pumping system and video survey well
    - Ruptured casing? Damaged or plugged screen?
  - Collect and analyze groundwater quality samples
    - Physical or biological plugging?

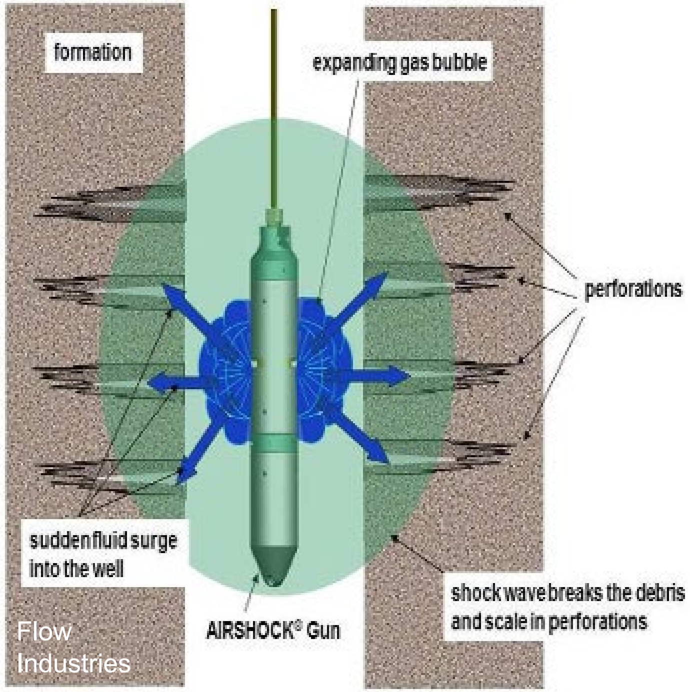


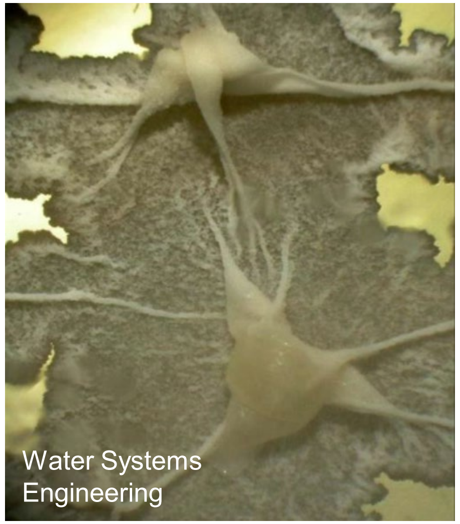


Well Rehabilitation

- Develop a plan
  - Well type and condition
  - Mechanical rehabilitation
    - Brushing, swabbing, surging, bailing, air- or water-jetting, rawhiding
  - Impulse generation
    - Hydropulse® or AIRSHOCK®
    - Typically used in combination with mechanical methods
  - Chemical rehabilitation
    - Chlorine, disinfectants, biodispersants, biocides
    - Design to address microbiology in well
    - Typically used in combination with other methods
    - Proper disposal is essential
  - Expect and plan for change

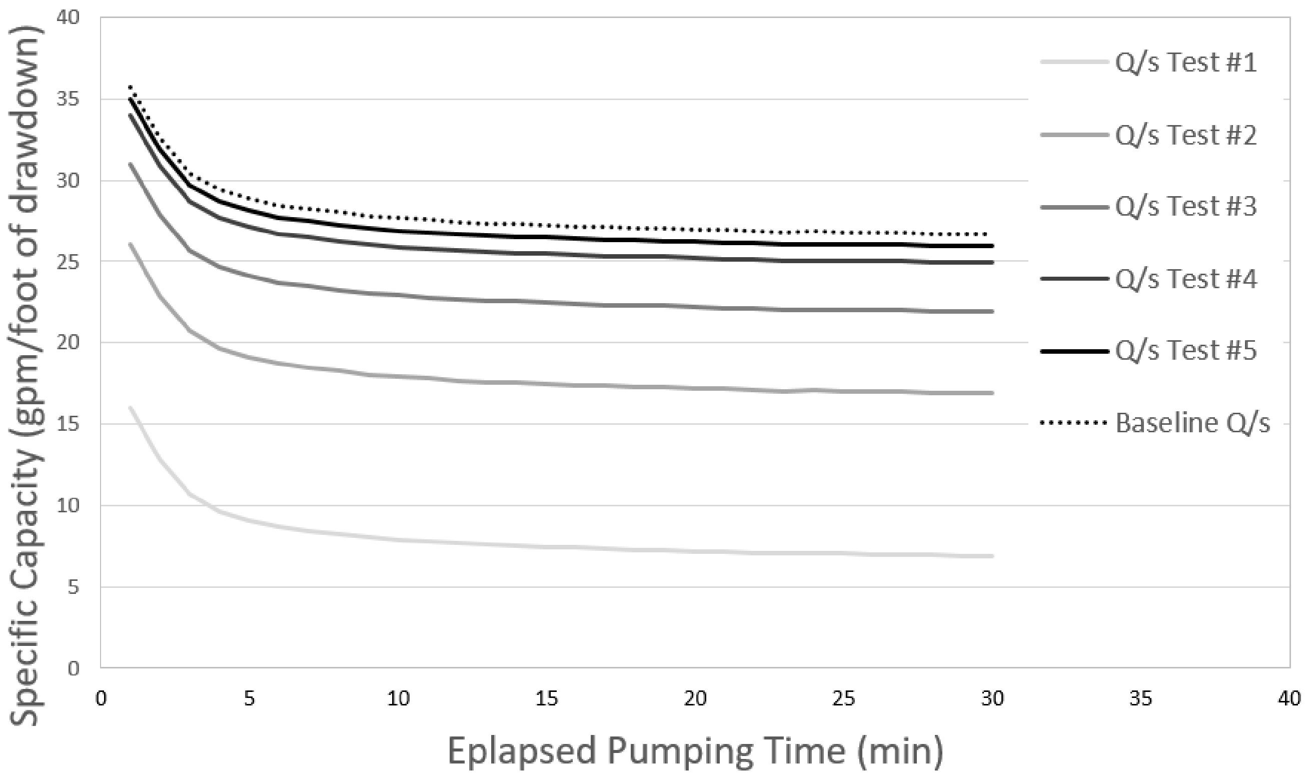






Well Rehabilitation

- Monitor performance
  - Evaluate relative improvements
  - Evaluate effectiveness of method(s)
  - Q/s varies based on pumping rate and duration
  - Compare against baseline performance
  - Document and reference
  - Use as baseline threshold to inform future rehabilitation needs



Well Maintenance/Rehabilitation

- Recommendations
  - Know your well and pumping system
  - Conduct routine inspections
  - Monitor well and pumping system performance regularly
    - Once per year – great!
    - Twice per year seasonally – even better!
    - Consistent and systematic approach
  - Monitor groundwater and pumping water levels
  - Consider age, condition, and water quality of well when developing plan
  - Avoid idling wells too long; keep active
  - Avoid pumping water level below top of screen

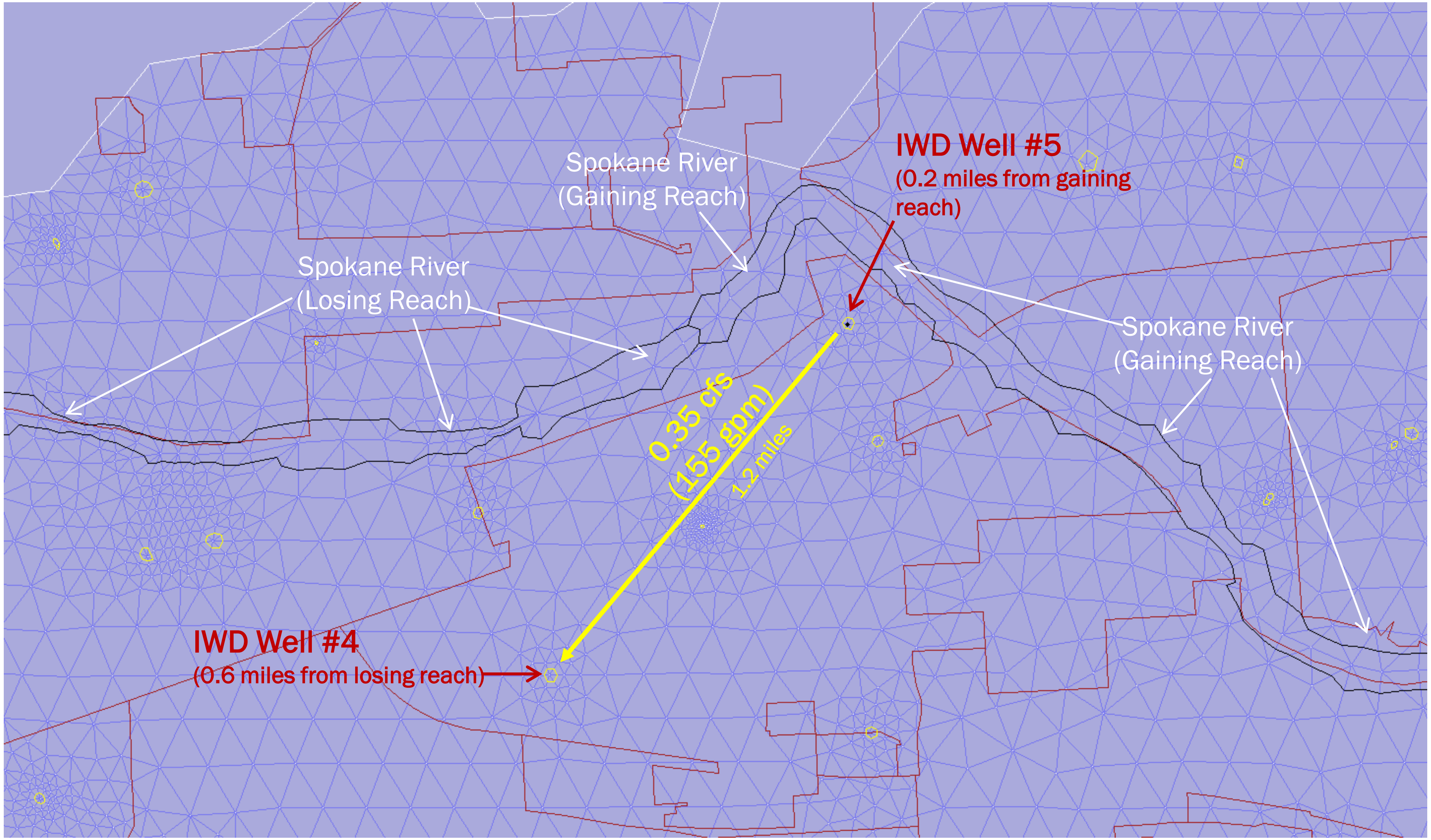
Water Supply Management/Planning Topics

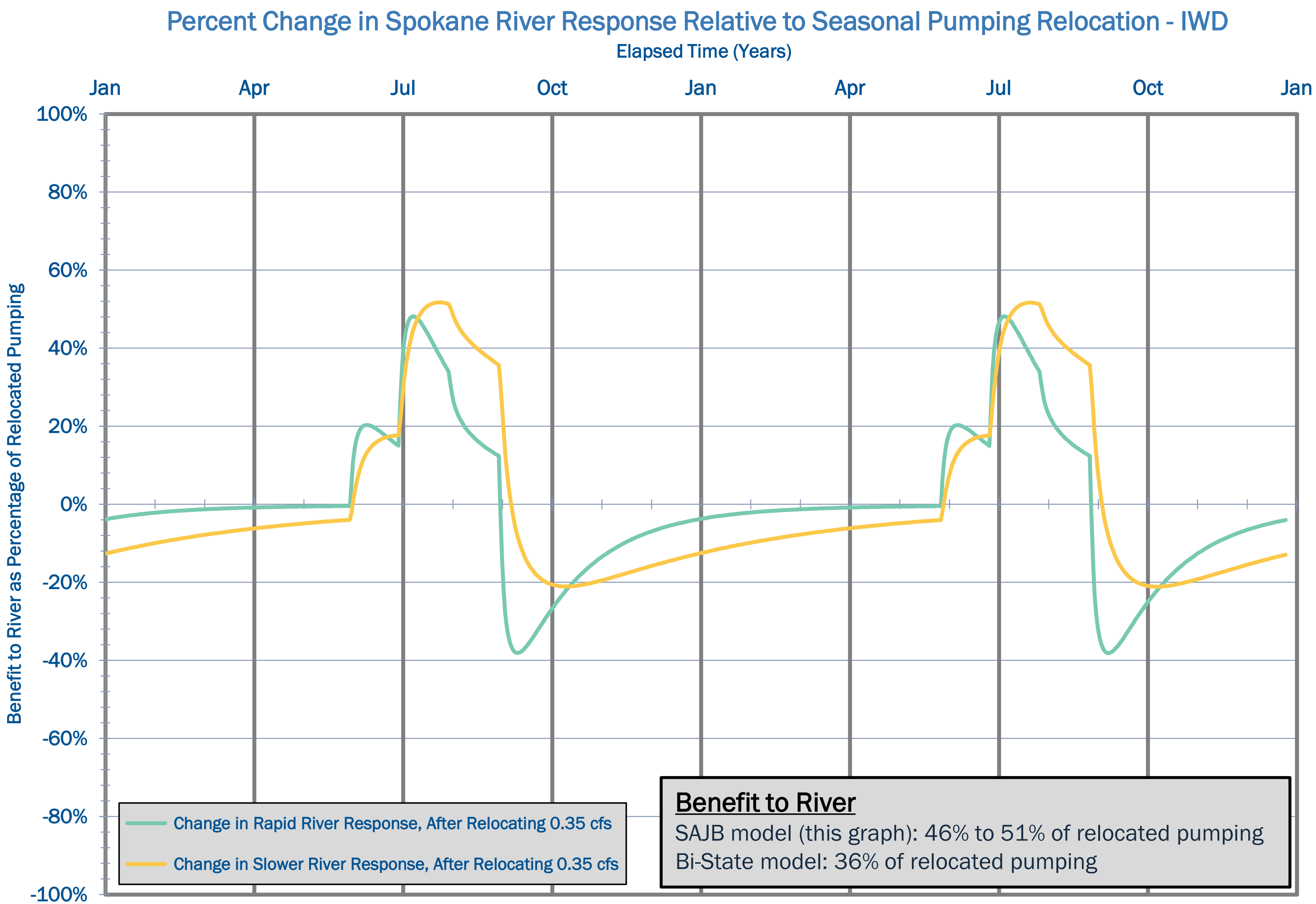
- Groundwater model readiness for modern-day needs
  - Wellfield operations
  - Long-term groundwater supply planning
- Well performance, maintenance, rehabilitation
- Coordinated water conservation planning

Modeling to Guide Groundwater Supply Planning

- Accounting for the effects of external forces on groundwater levels (under static and pumping conditions)
  - Climate-change influences
    - Changes in timing of rainfall, snowmelt, and streamflow on ambient aquifer conditions (which affect timing and amounts of recharge)
    - Effect of changing temperature on customer water demands
  - Growth influences (demands, conservation, supply needs)
- Minimizing effects on the river during its low-flow season

Effect on River of a Hypothetical Summer-Season Redistribution of Groundwater Pumping Between 2 Wells





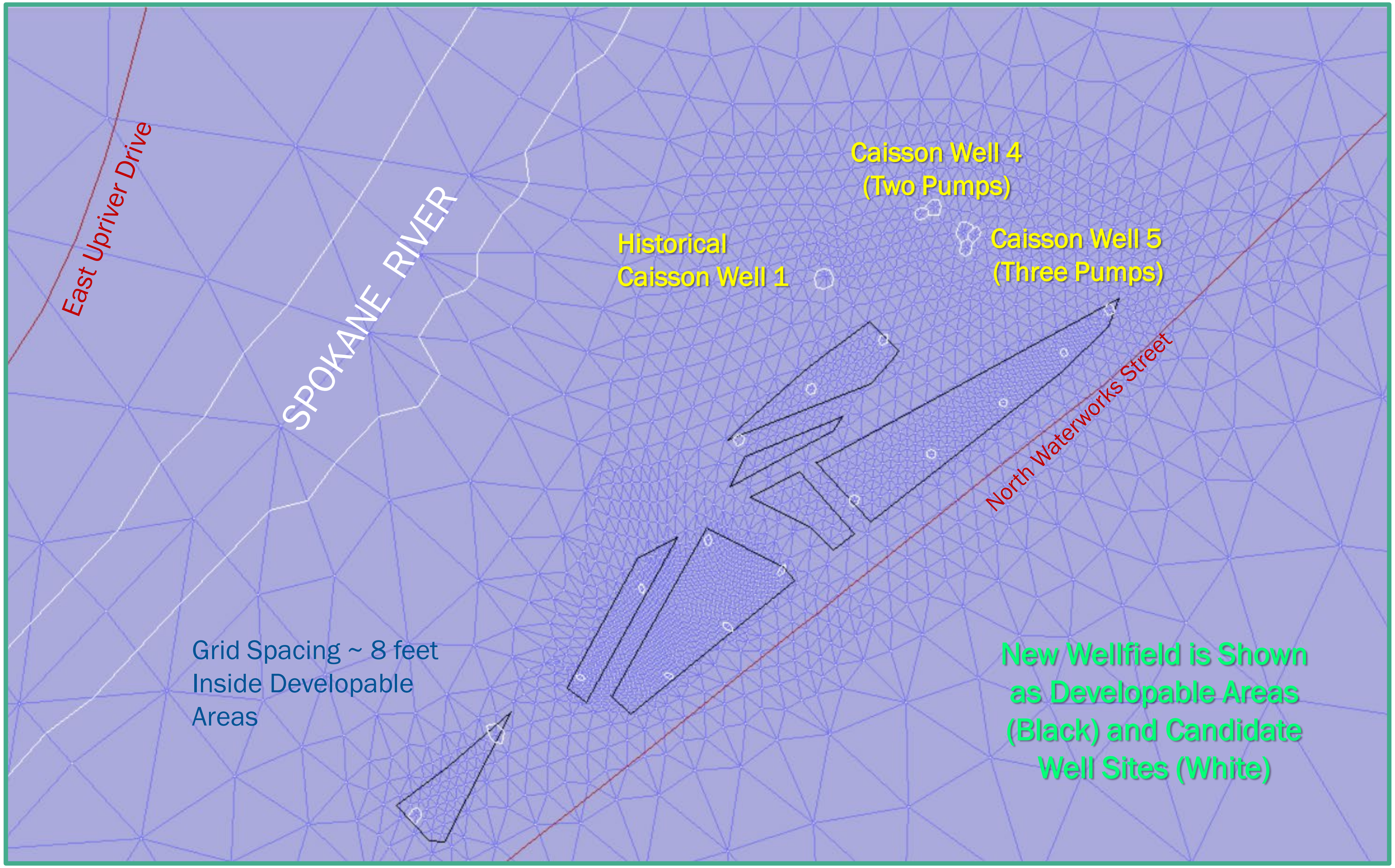
Benefit to River

SAJB model (this graph): 46% to 51% of relocated pumping

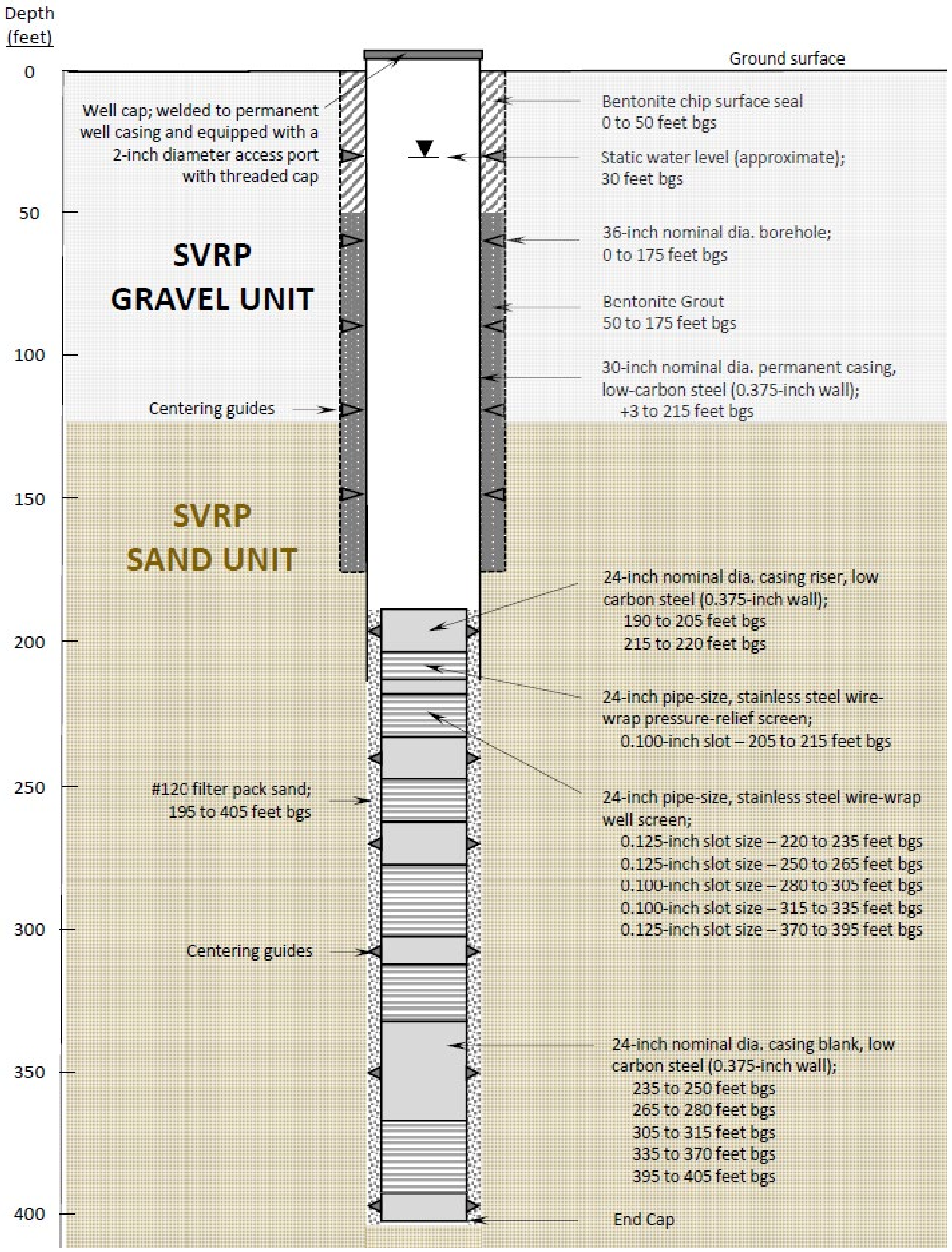
Bi-State model: 36% of relocated pumping

City of Spokane Concept:

Switch from Shallow to Deep Wells

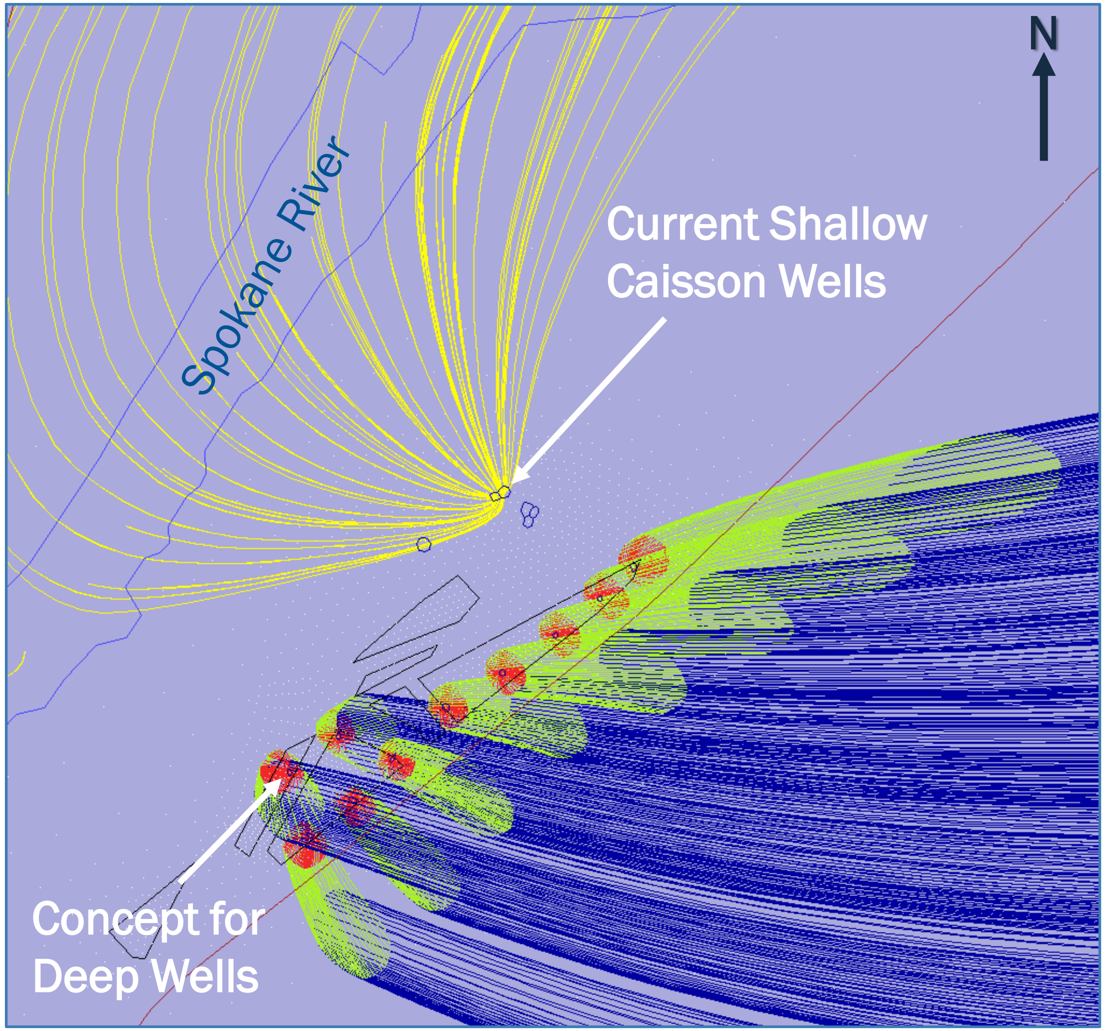


Concept Design for Deep Wells

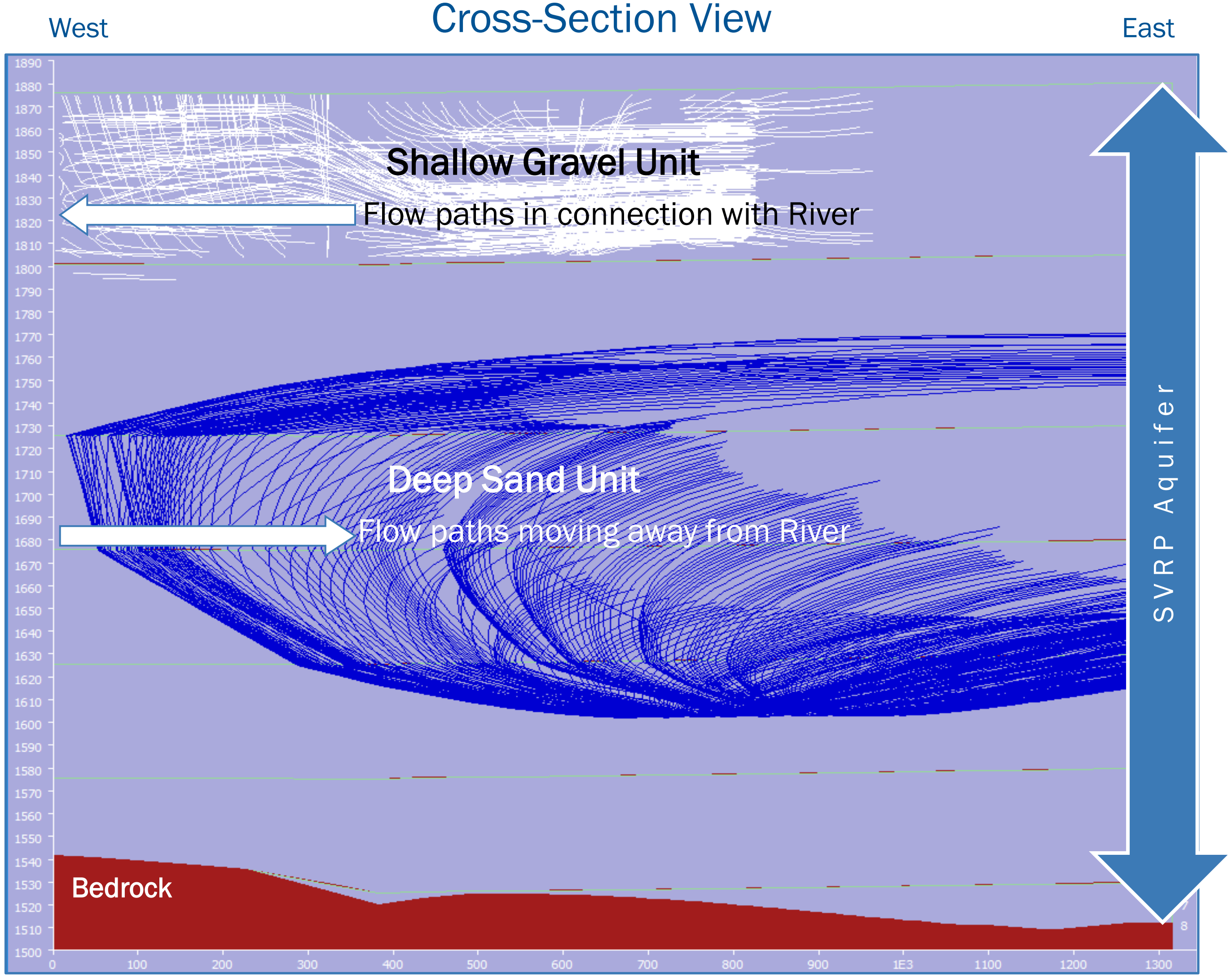


3D Flowpaths to Shallow vs. Deep Wells

Map View



Cross-Section View



Different Flowpath Colors Represent Different Depth Zones in the Aquifer

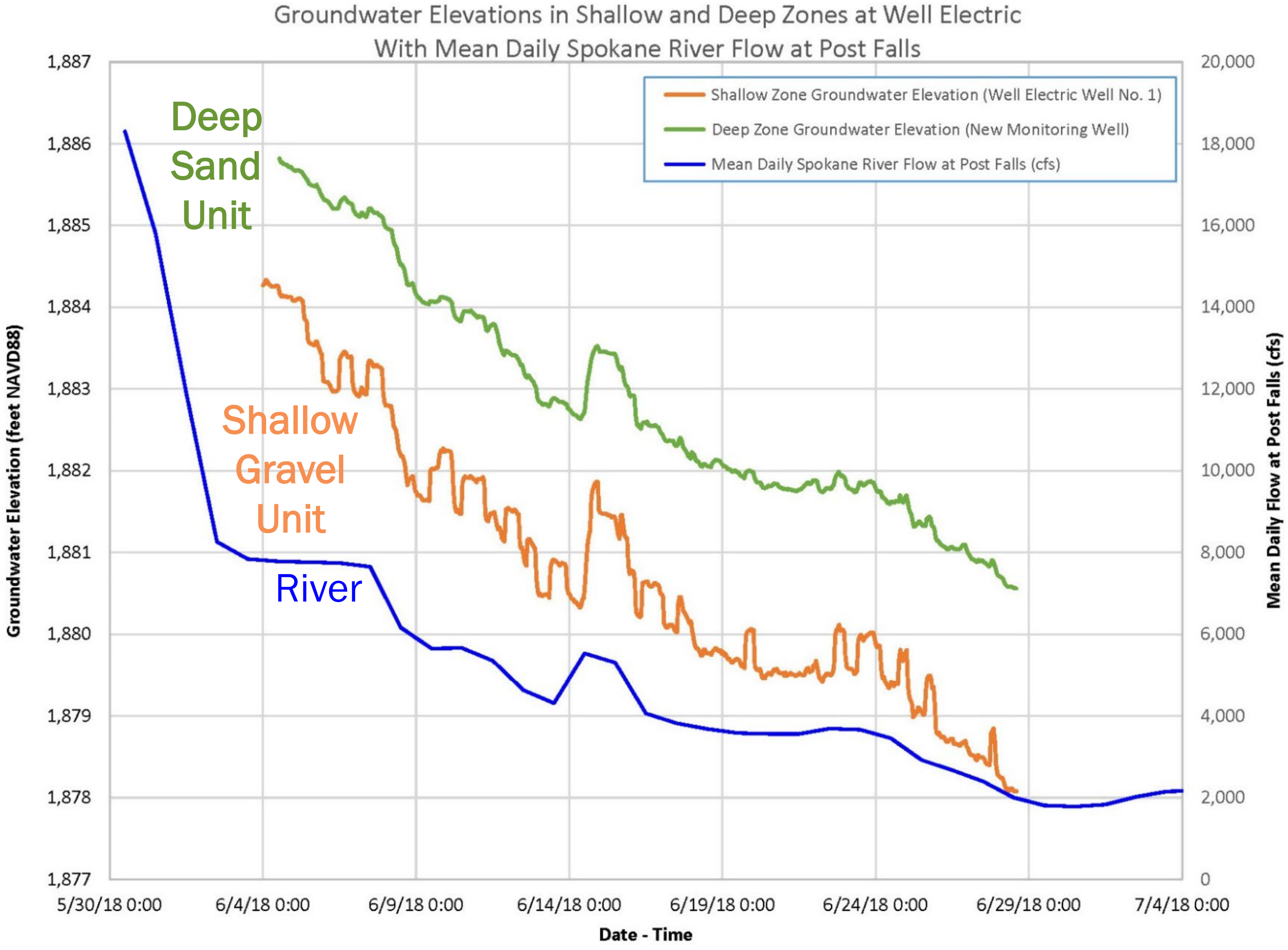
Supporting Field Evidence

Groundwater elevation is higher in the deep sand unit than in the shallow gravel unit.

Upward gradient (from deep sand unit to shallow gravel unit).

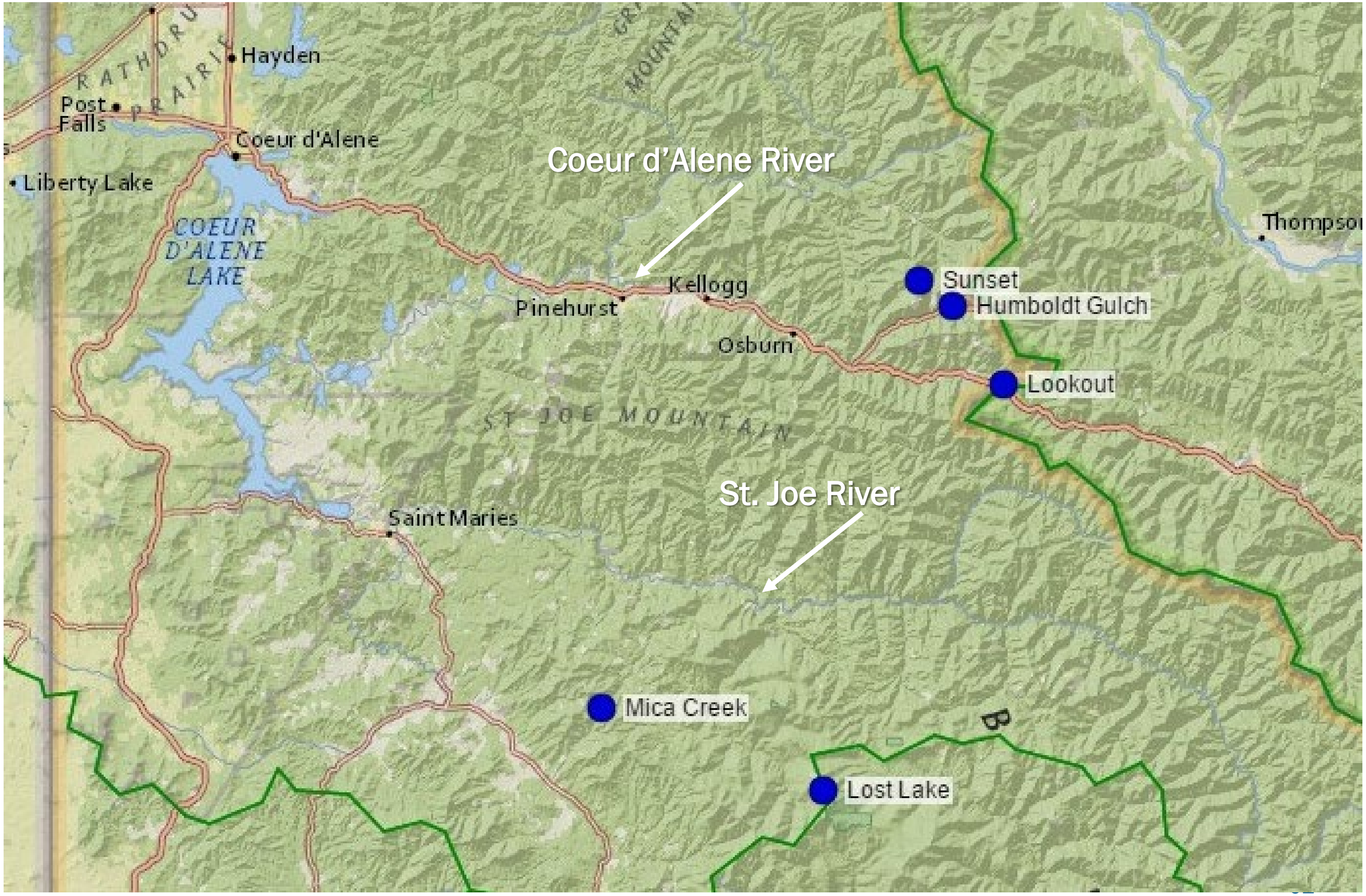
Less daily fluctuation in deep sand than in shallow gravel unit.

These observations together tell us that the recharge source is distant (not nearby river recharge).



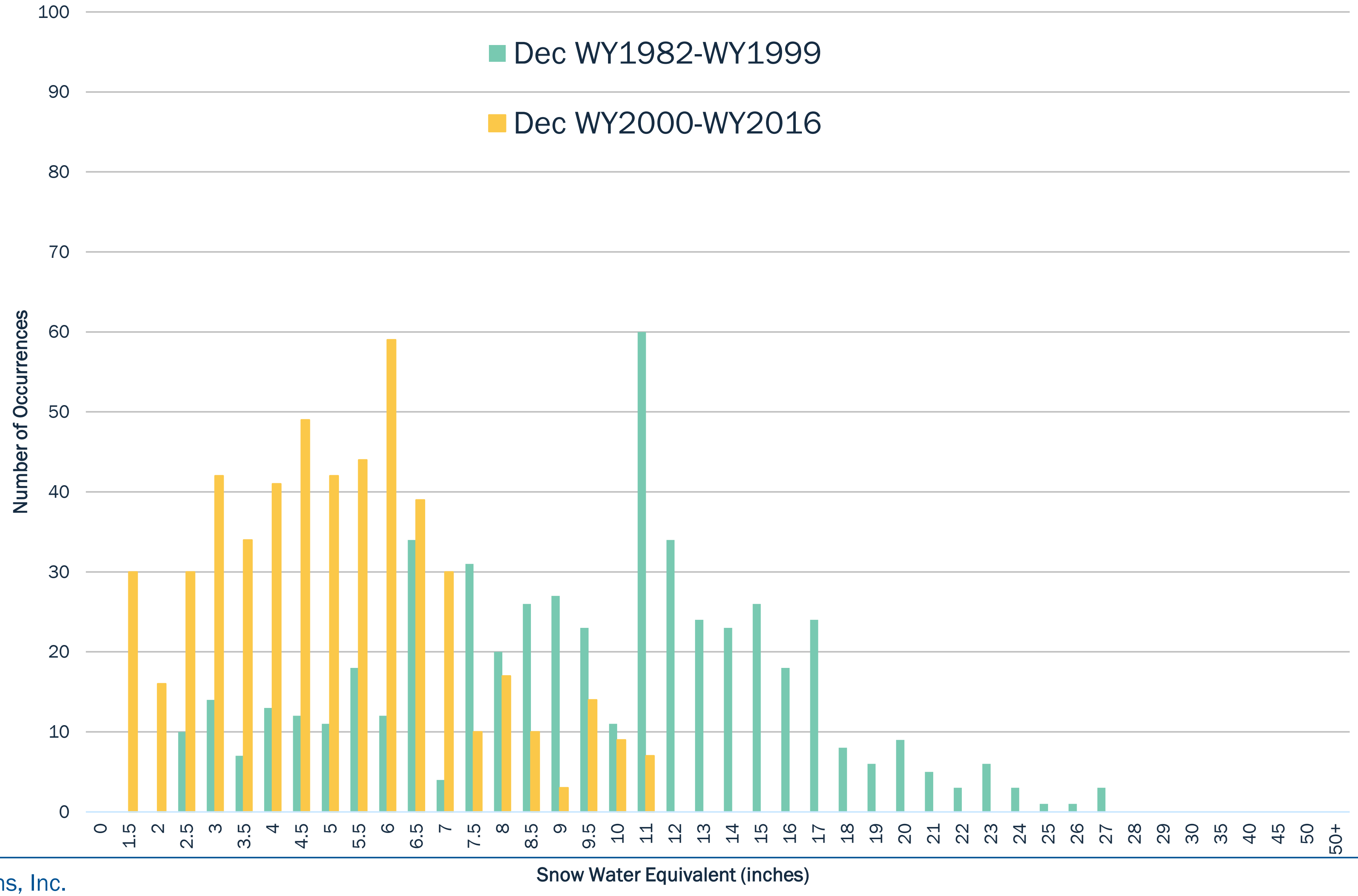
Historical Snowmelt and Streamflow Trends

Locations of Snotel Sites



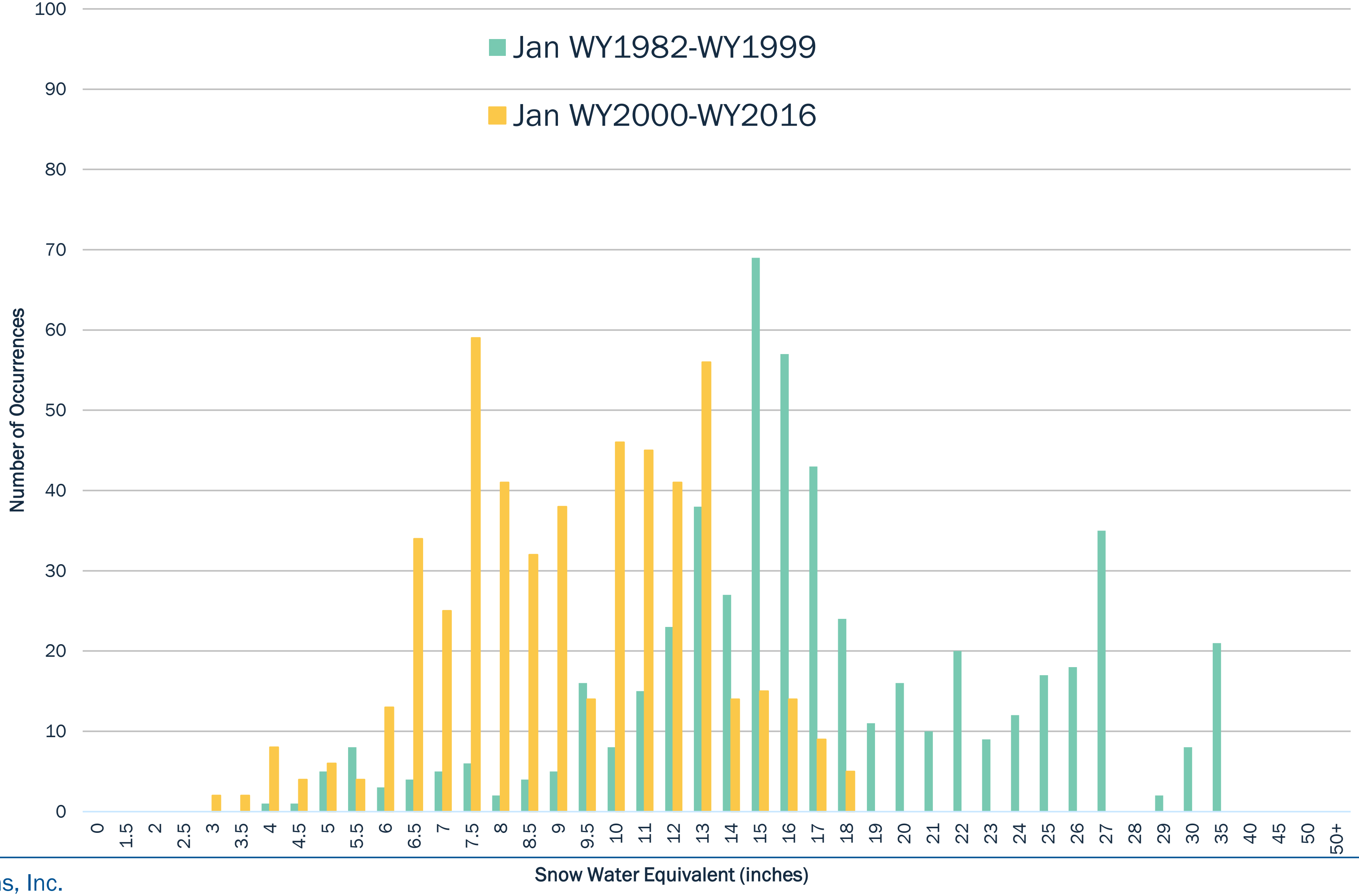
Binned Frequency of Occurrences of Snow Water Equivalent, Sunset SNOTEL Station,

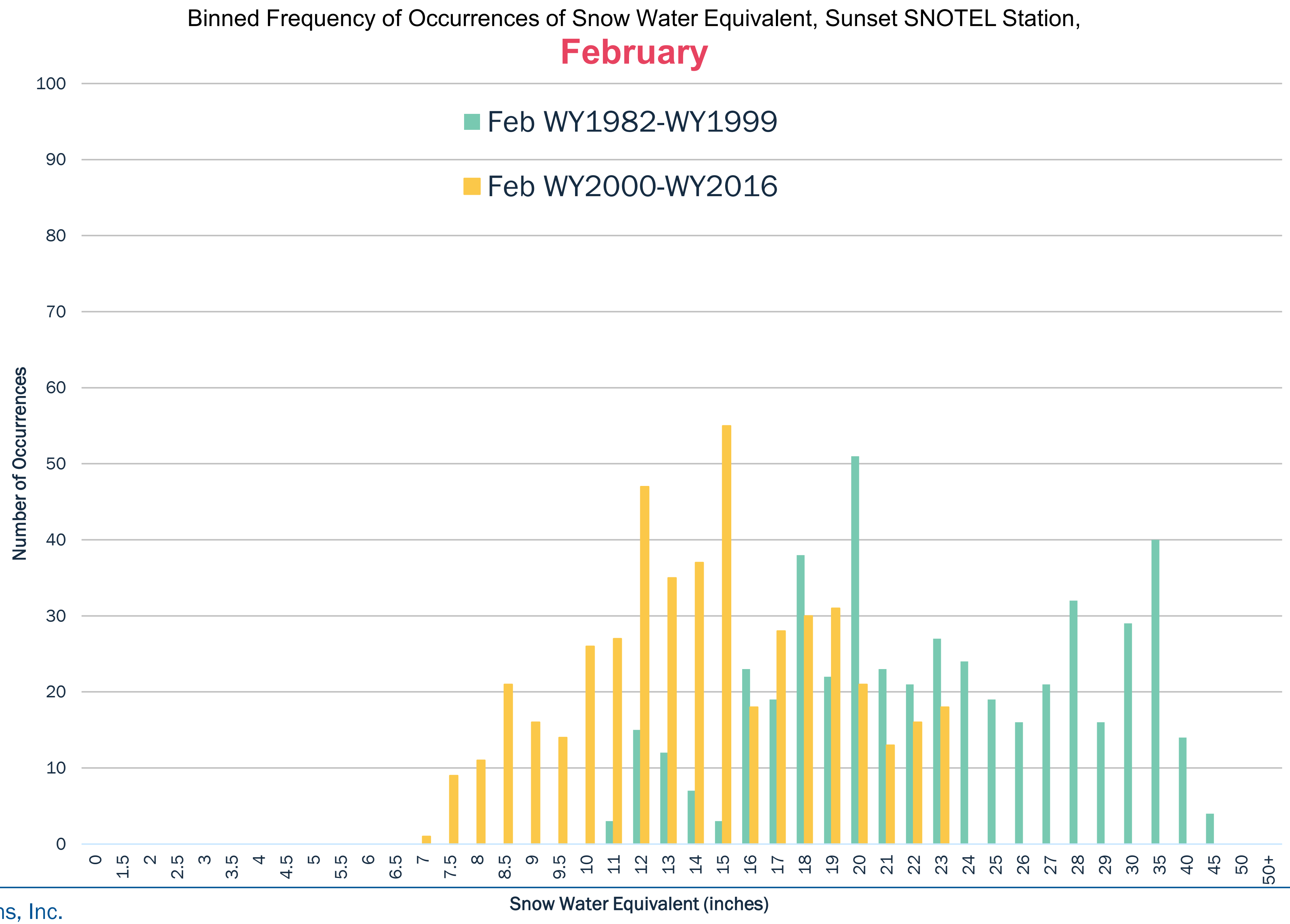
December



Binned Frequency of Occurrences of Snow Water Equivalent, Sunset SNOTEL Station,

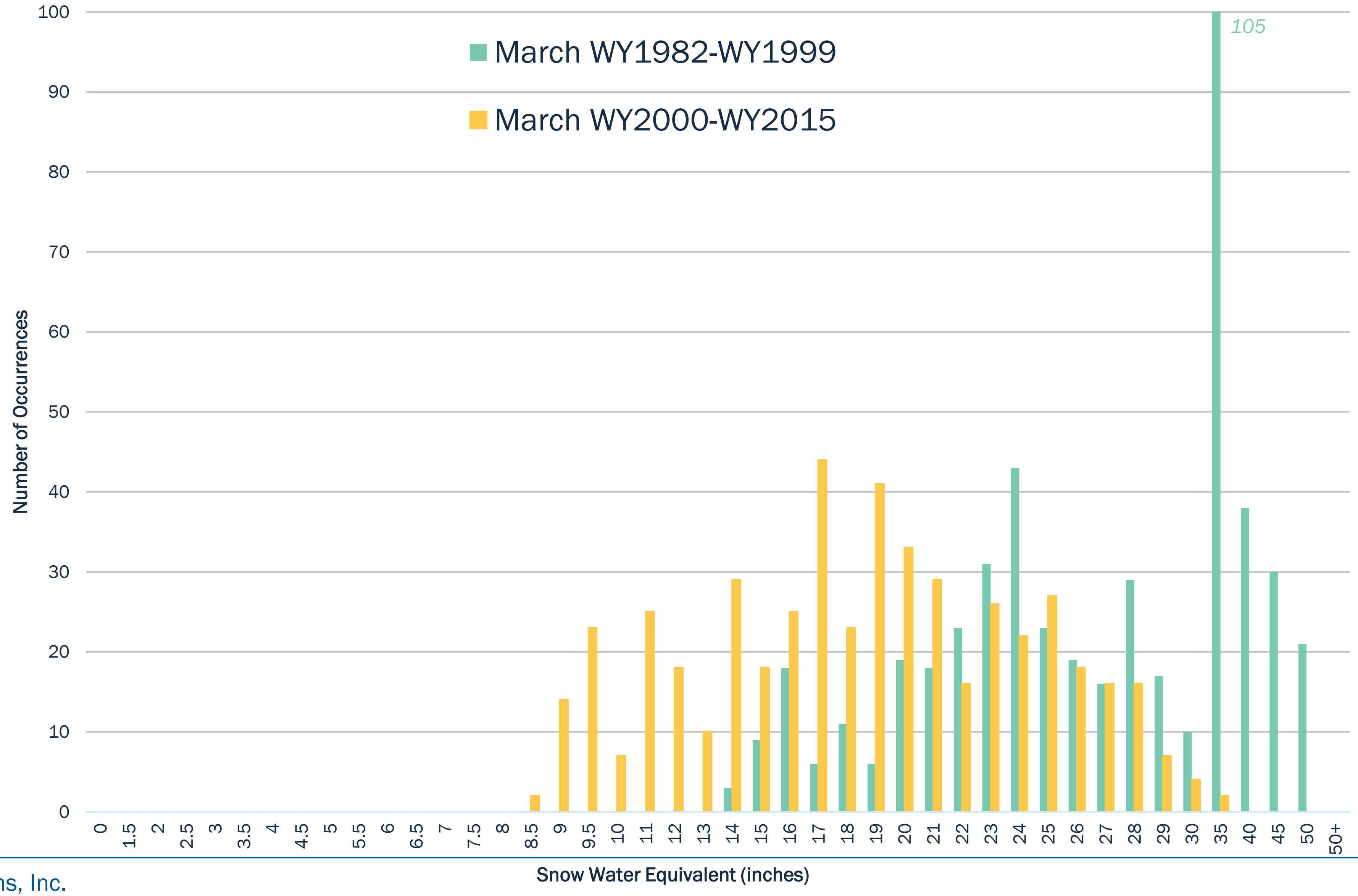
January




Binned Frequency of Occurrences of Snow Water Equivalent, Sunset SNOTEL Station,
February
Feb WY1982-WY1999
Feb WY2000-WY2016
Number of Occurrences
100
90
80
70
60
50
40
30
20
10
0
0
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
35
40
45
50
50+
Snow Water Equivalent (inches)

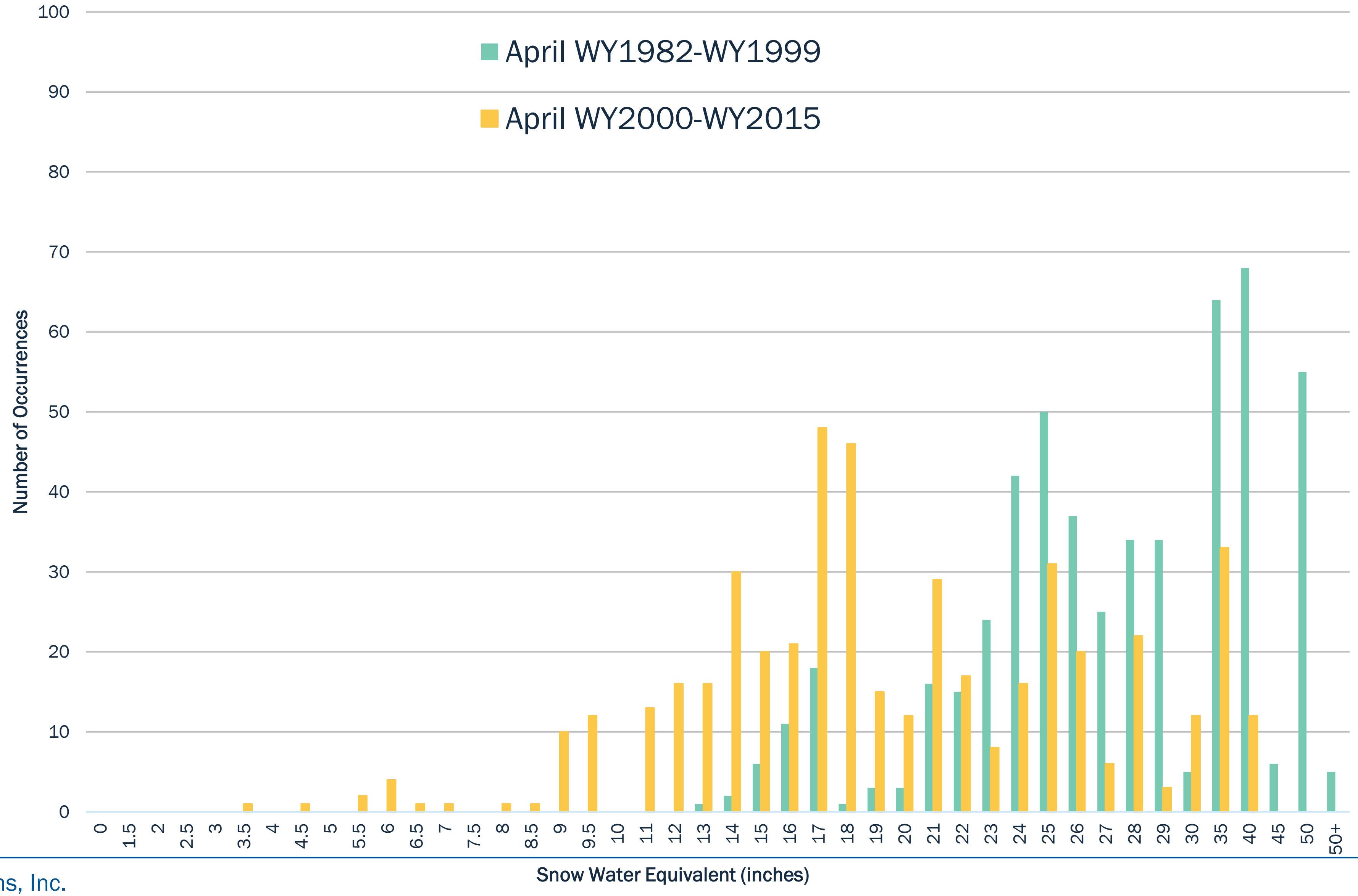
Binned Frequency of Occurrences of Snow Water Equivalent, Sunset SNOTEL Station,

March



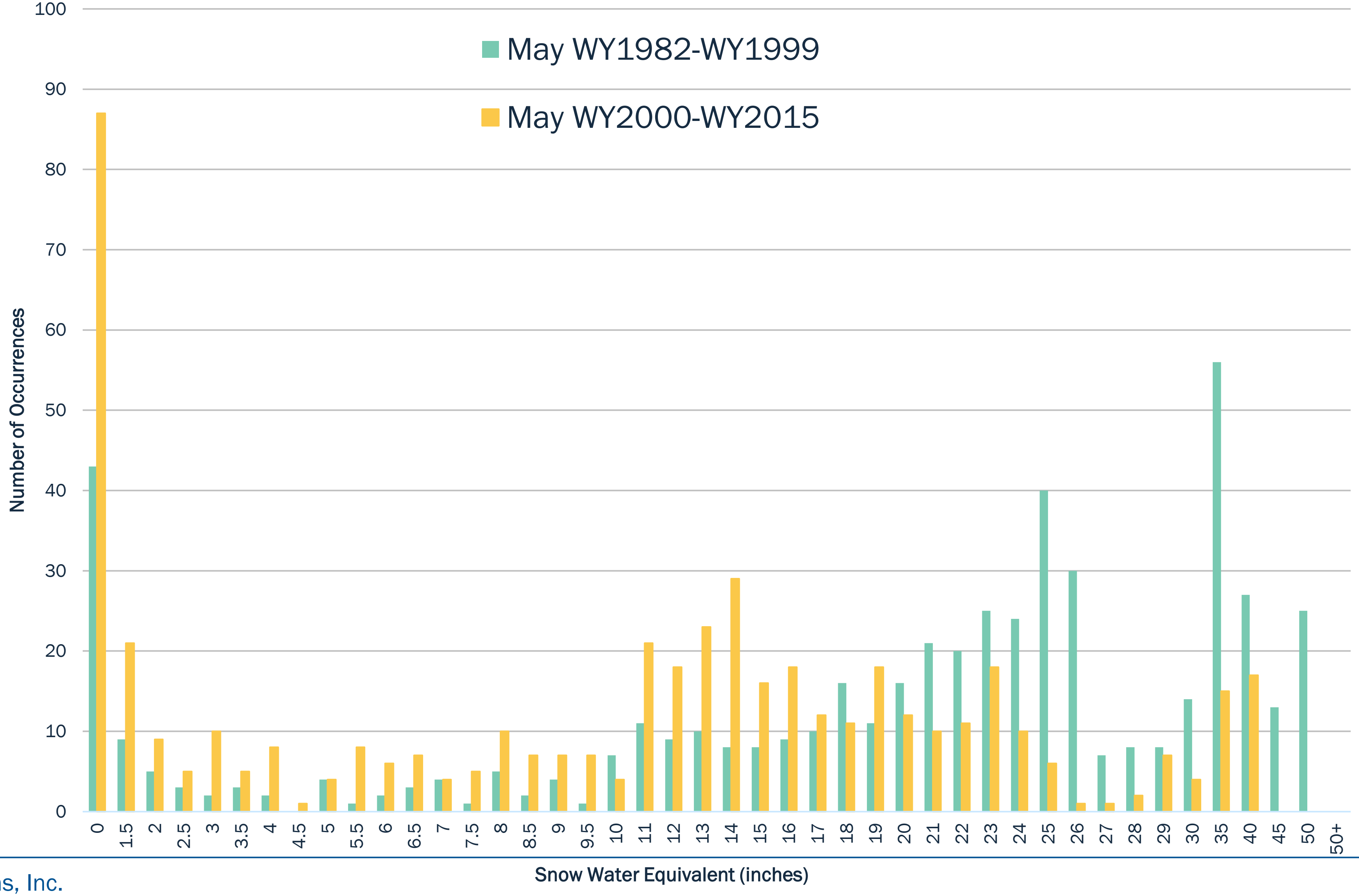
Binned Frequency of Occurrences of Snow Water Equivalent, Sunset SNOTEL Station,

April

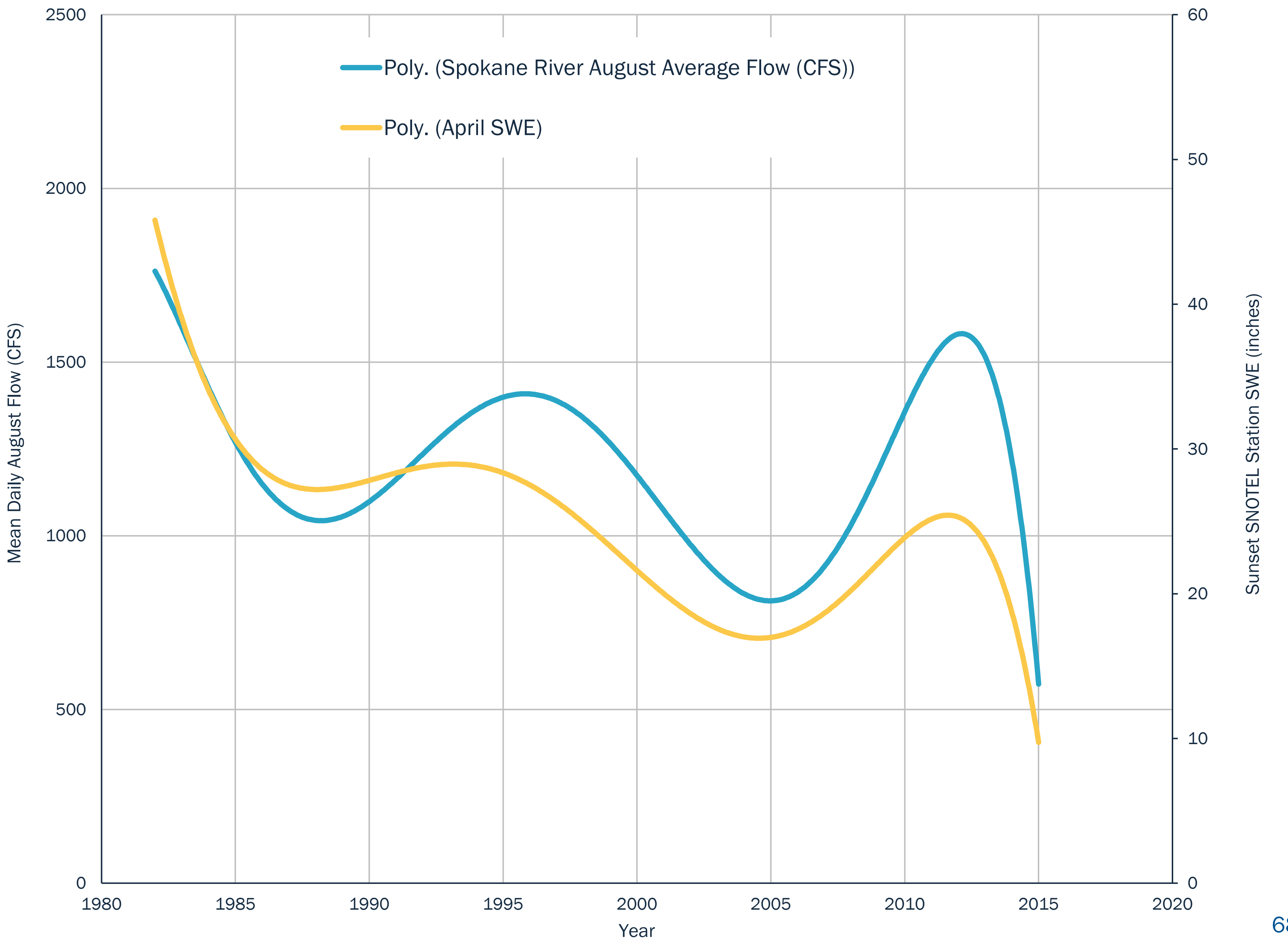


Binned Frequency of Occurrences of Snow Water Equivalent, Sunset SNOTEL Station,

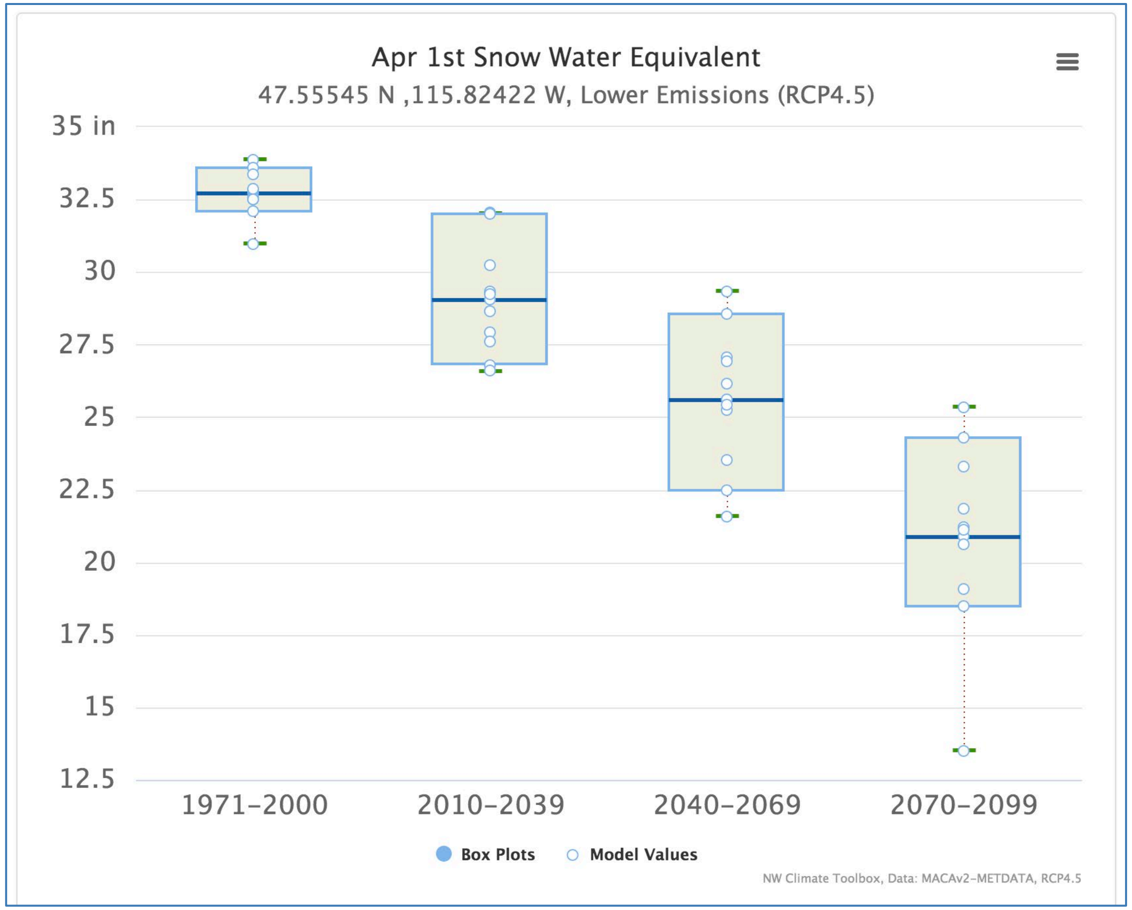
May

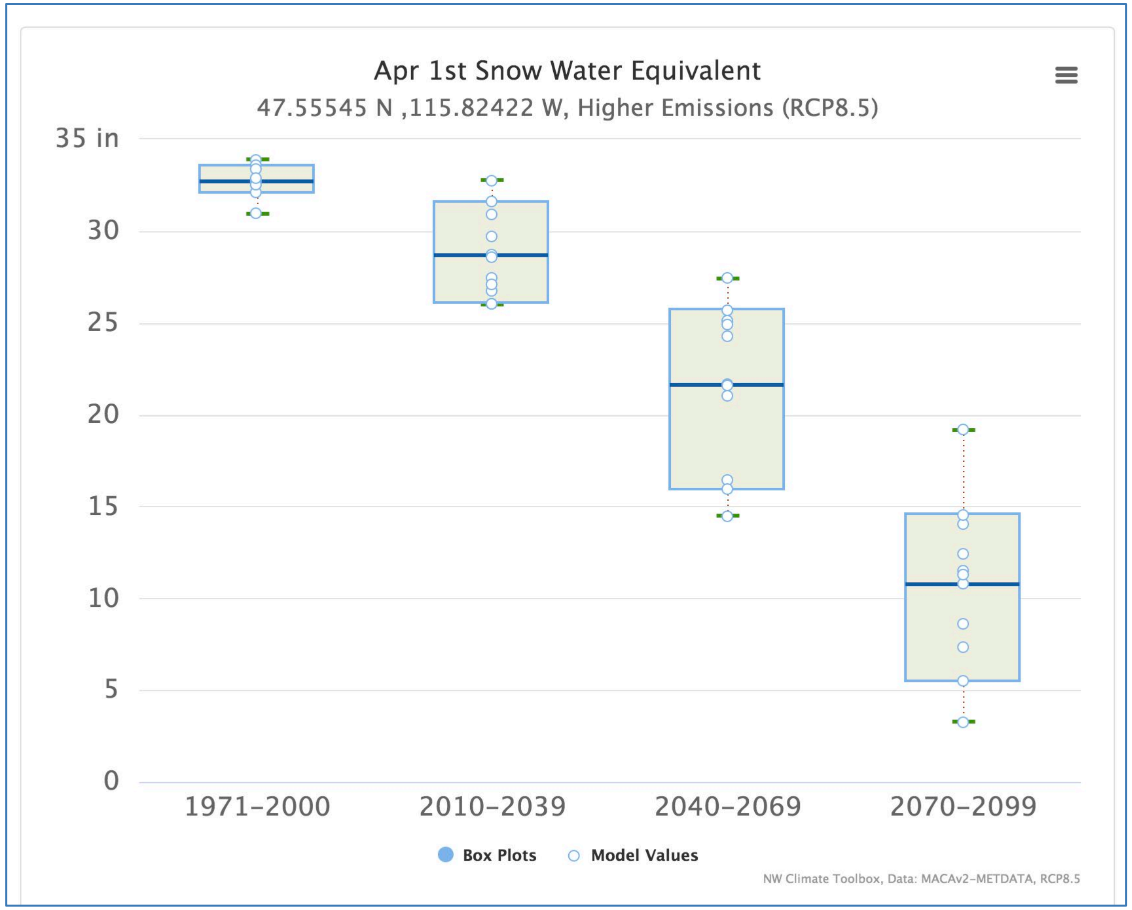


August Daily Streamflow versus April SWE



April 1 SWE at Sunset Snotel Station



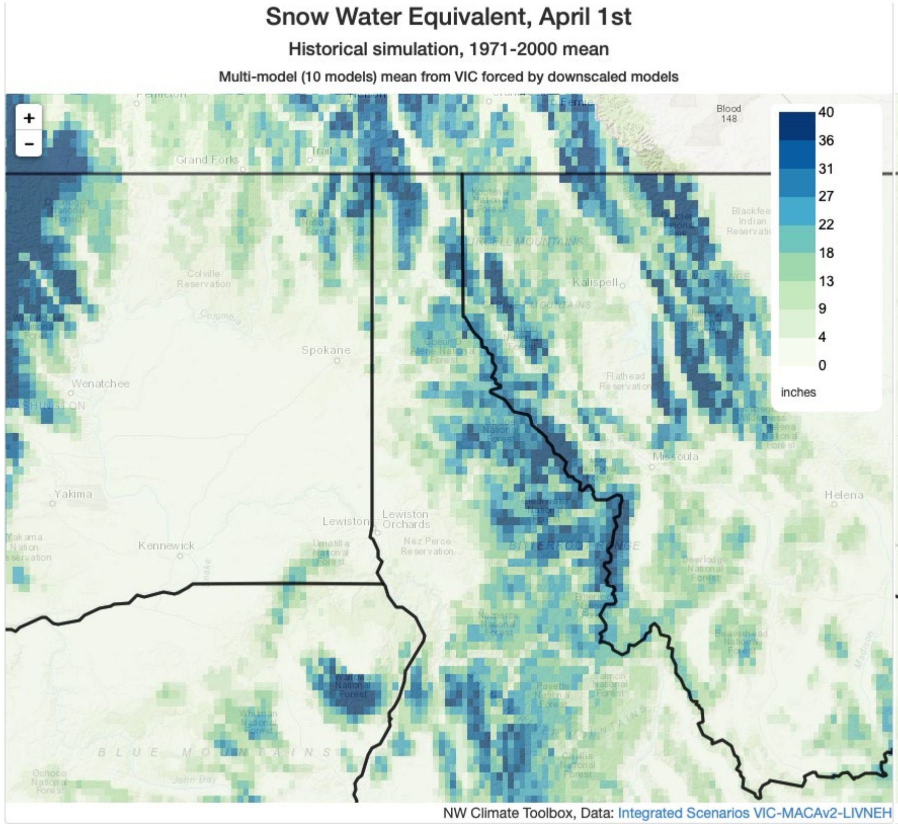


Low Future Emissions (RCP 4.5)

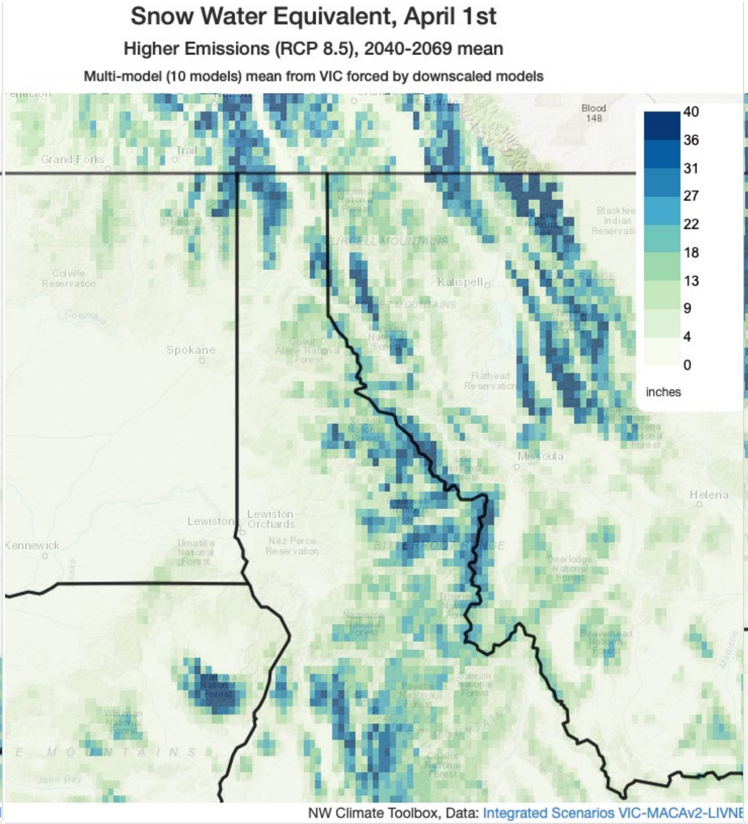
High Future Emissions (RCP 8.5)

Source: Climate Mapper Tool (https://climatetoolbox.org/tool/Climate-Mapper), Climate Toolbox (formerly the Northwest Climate Toolbox), Accessed March 2019

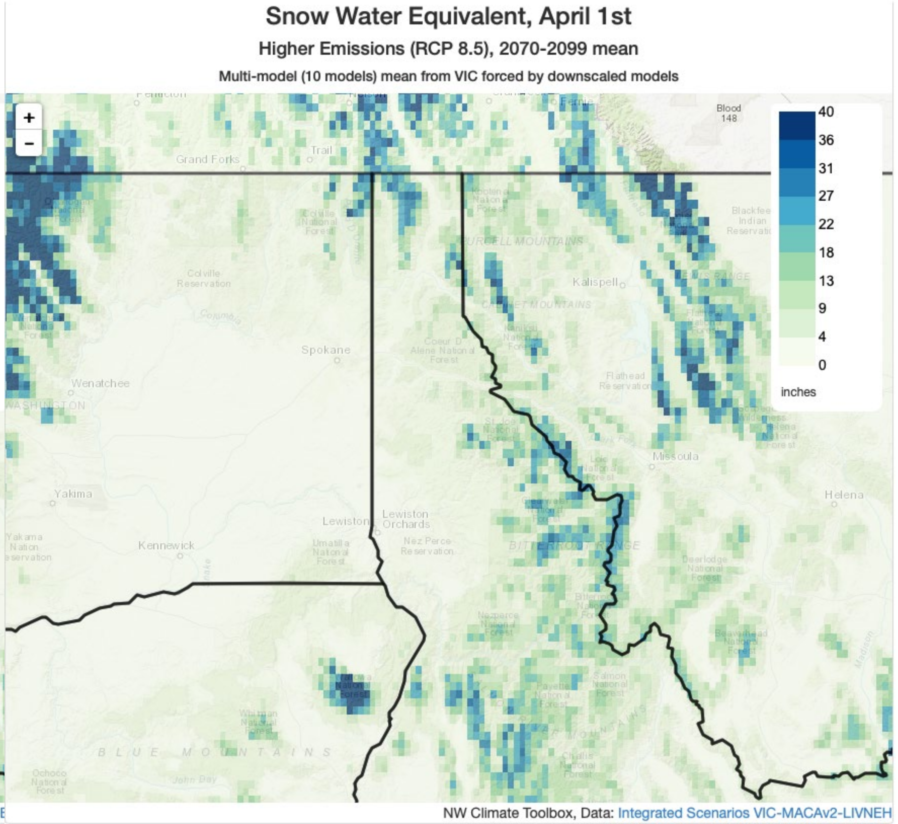
April 1 SWE (Historical and Future RCP 8.5)



1971-2000



2040-2069



2070-2099

Source: Climate Mapper Tool (https://climatetoolbox.org/tool/Climate-Mapper), Climate Toolbox (formerly the Northwest Climate Toolbox), Accessed March 2019

Water Supply Management/Planning Topics

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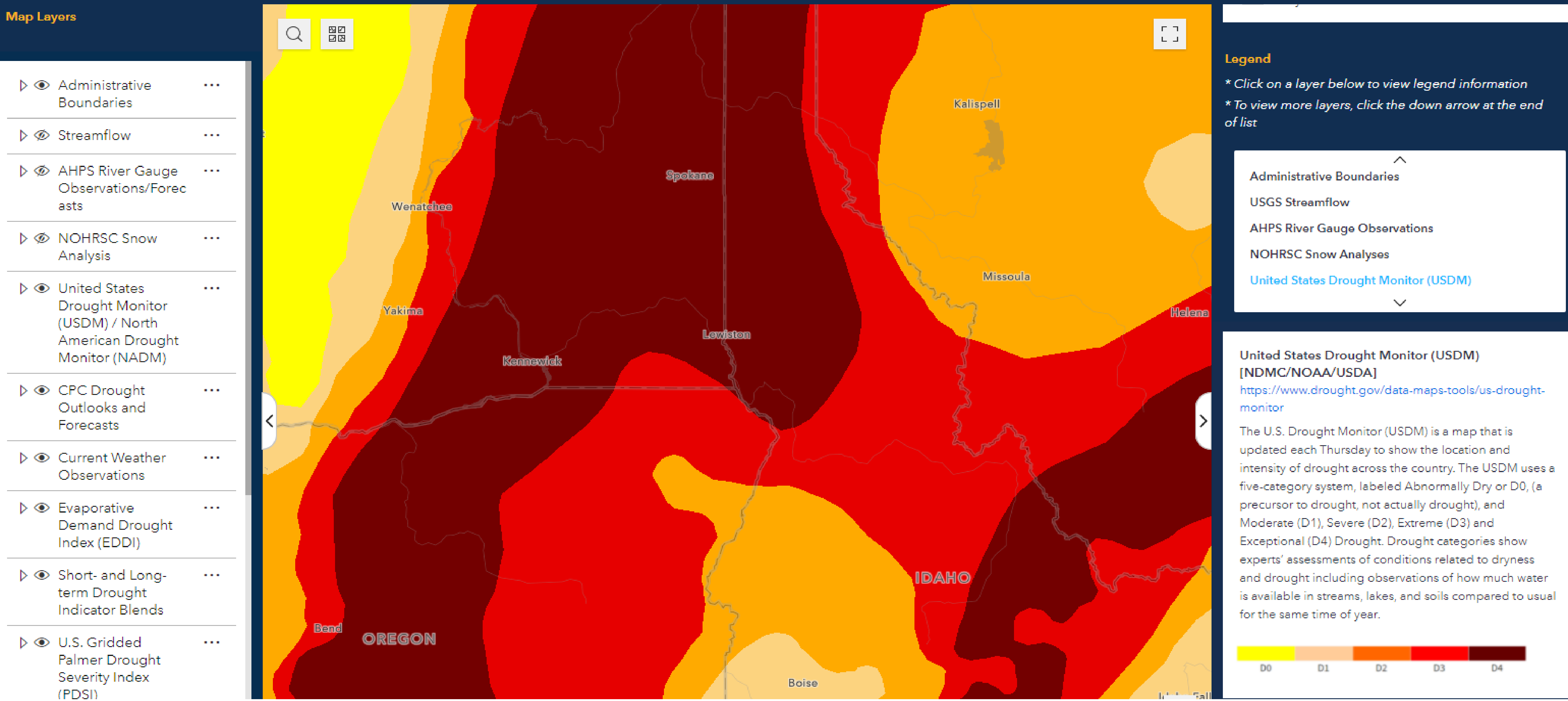
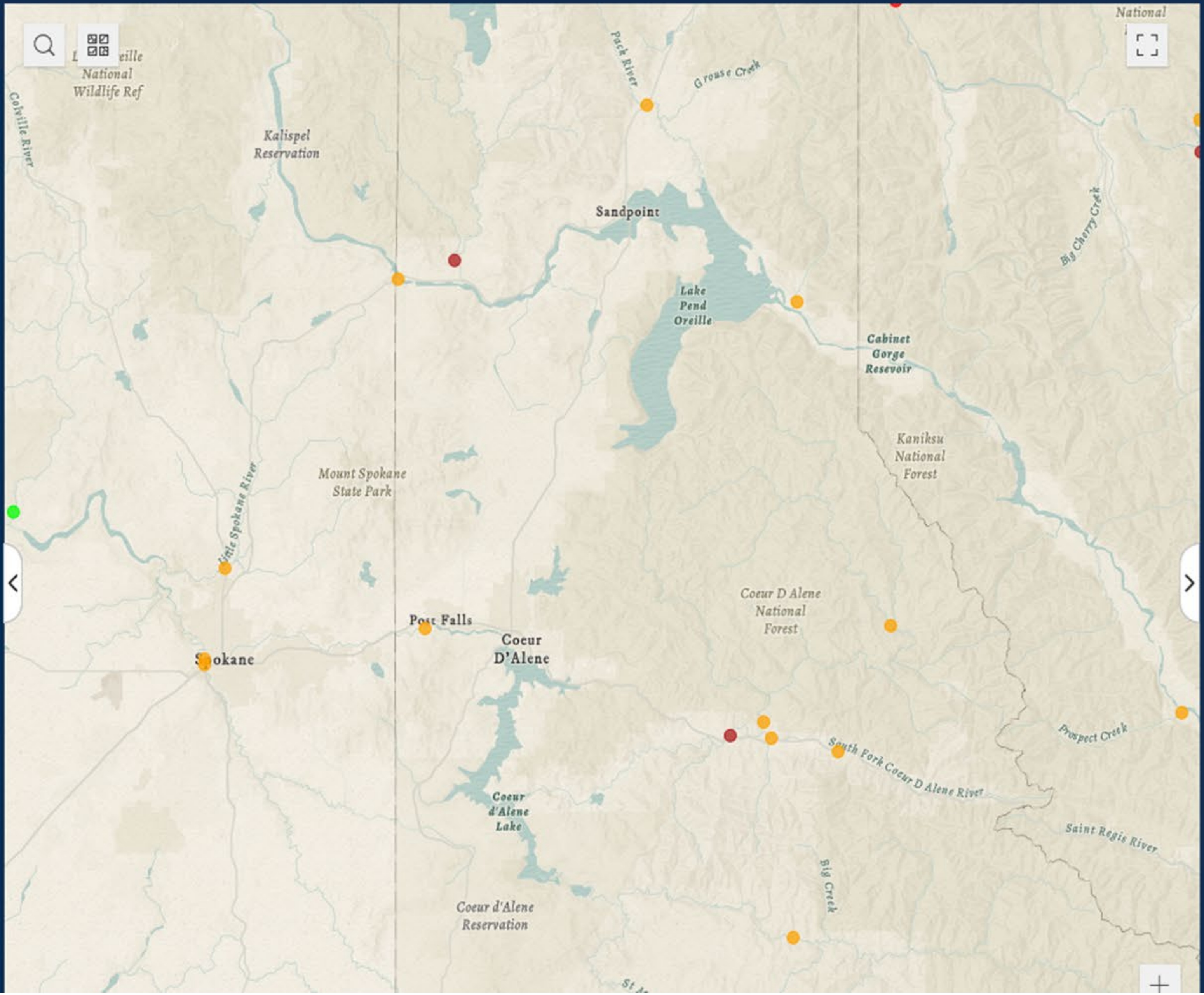
  - Wellfield operations
  - Long-term groundwater supply planning
- Well performance, maintenance, rehabilitation
- Coordinated water conservation planning

NOAA United States Drought Monitor (Drought.gov)



Map Layers

- Administrative Boundaries
- Streamflow
  - Streamflow - Current Conditions [USGS]
  - Streamflow - 1 day [USGS]
  - Streamflow - 7 day [USGS]
  - Streamflow -14 day [USGS]
  - Streamflow - 28 day [USGS]
- AHPS River Gauge Observations/Forecasts
- NOHRSC Snow Analysis
- United States Drought Monitor (USDM) / North American Drought Monitor (NADM)
- CPC Drought Outlooks and Forecasts
- Current Weather Observations



Click on a layer below to view legend information

** To view more layers, click the down arrow at the end of list*

- Administrative Boundaries
- USGS Streamflow
- AHPS River Gauge Observations
- NOHRSC Snow Analyses
- United States Drought Monitor (USDM)

Streamflow [USGS]

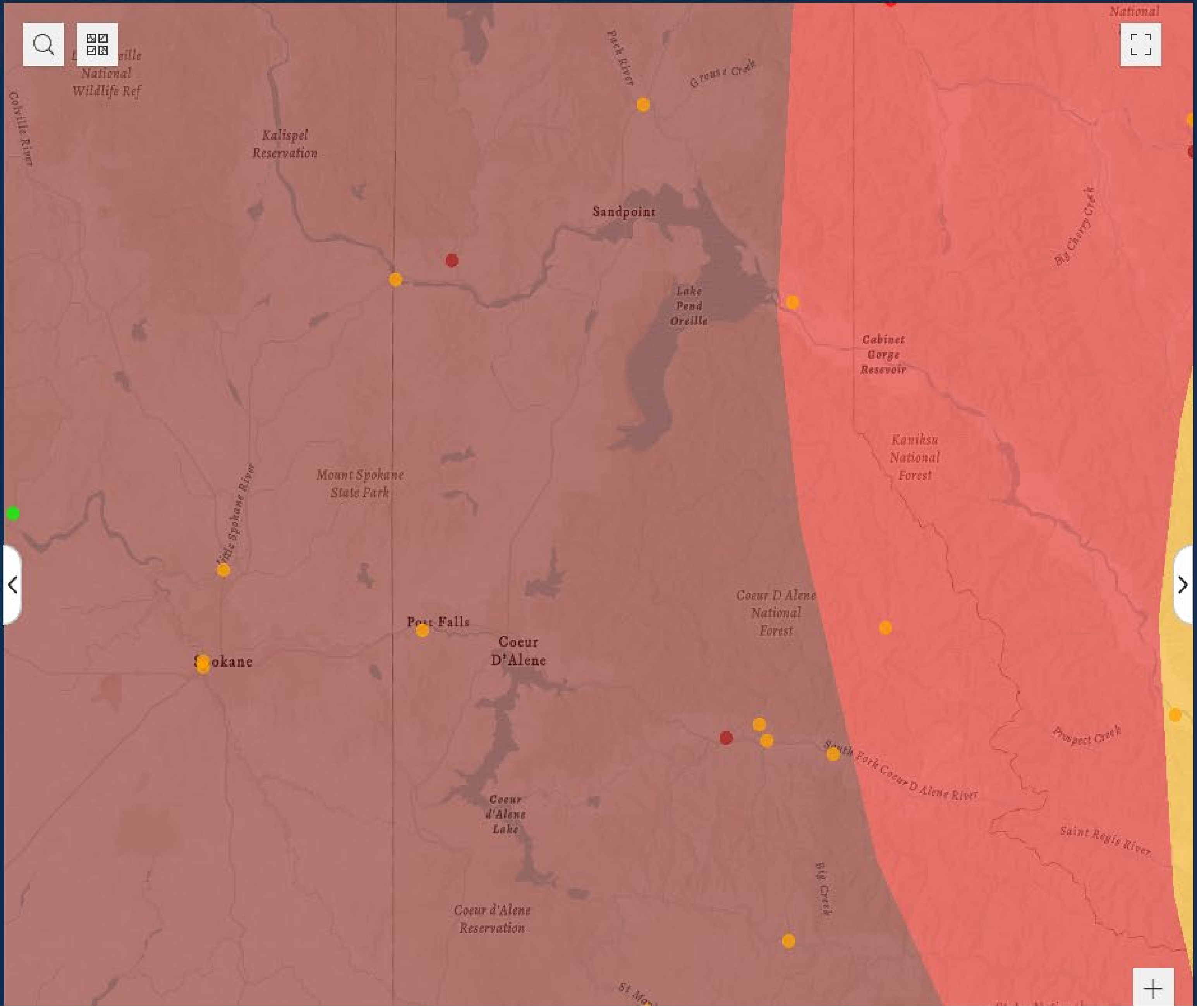
https://www.drought.gov/data-maps-tools/usgs-waterwatch

USGS provides streamflow data for 3,000 long-term (30 years or more) streamgauges. Colors represent streamflow conditions compared to historical streamflow. Data is available for current conditions and for 1-, 7-, 14-, and 28-day periods.

- Low
- Much below normal
- Below normal
- Normal
- Above normal
- Much above normal
- High

Map Layers

- Administrative Boundaries
- Streamflow
- AHPS River Gauge Observations/Forecasts
- NOHRSC Snow Analysis
- United States Drought Monitor (USDM) / North American Drought Monitor (NADM)
- CPC Drought Outlooks and Forecasts
- Current Weather Observations
- Evaporative Demand Drought Index (EDDI)
- Short- and Long-term Drought Indicator Blends
- U.S. Gridded Palmer Drought Severity Index (PDSI)



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To view more layers, click the down arrow at the end of list

- Administrative Boundaries
- USGS Streamflow
- AHPS River Gauge Observations
- NOHRSC Snow Analyses
- United States Drought Monitor (USDM)

United States Drought Monitor (USDM) [NDMC/NOAA/USDA]

https://www.drought.gov/data-maps-tools/us-drought-monitor

The U.S. Drought Monitor (USDM) is a map that is updated each Thursday to show the location and intensity of drought across the country. The USDM uses a five-category system, labeled Abnormally Dry or D0, (a precursor to drought, not actually drought), and Moderate (D1), Severe (D2), Extreme (D3) and Exceptional (D4) Drought. Drought categories show experts' assessments of conditions related to dryness and drought including observations of how much water is available in streams, lakes, and soils compared to usual for the same time of year.

D0 D1 D2 D3 D4

Current Soil Moisture Conditions

0–100 cm Soil Moisture Percentile **5 cm Soil Moisture Percentile**

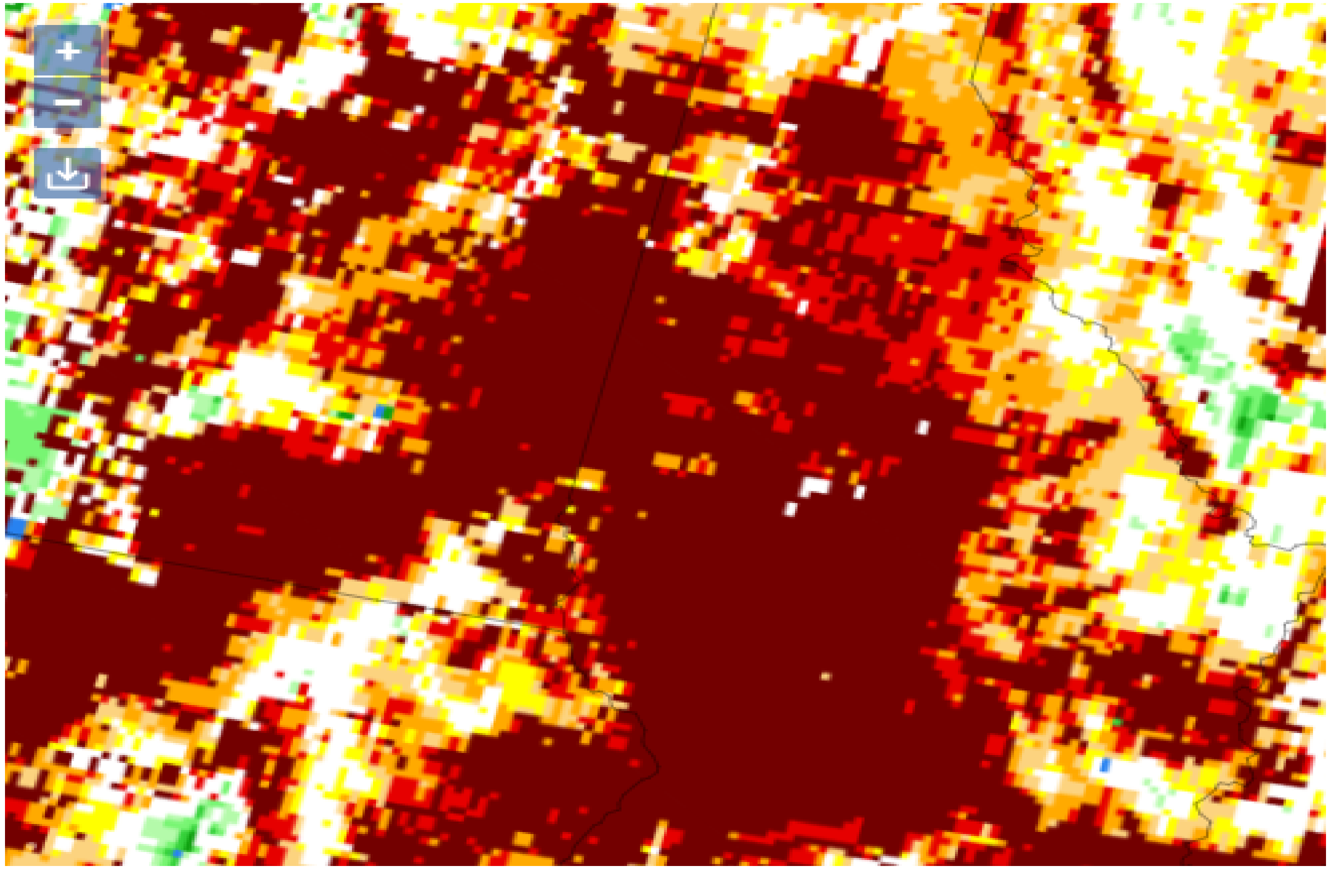
NASA's Short-term Prediction and Transition Center – Land Information System (SPoRT-LIS) provides high-resolution (about 3-km) gridded soil moisture products in real-time to support regional and local modeling and improve situational awareness. The 0–100 cm soil moisture percentile data has shown to be a utility for drought monitoring. The near-surface (0–10 cm) layer responds quickly to heavy precipitation and rapidly drying events. In deeper layers, soil moisture evolves more slowly and has demonstrated greater utility overall for drought monitoring purposes since drought evolves typically on timescales of weeks to years. Learn more.

0–100 cm Soil Moisture Percentile

< 2	2 – 5	5 – 10	10 – 20	30 – 70
70 – 80	80 – 90	90 – 95	95 – 98	> 98

***Currently, data are only available for the contiguous U.S.**

Source(s): NASA



Updates Daily - 08/05/21

Socially Acceptable
Net Ecological Benefit
Capital Cost Avoidance
Regional Approach
Maximize Effort and Approach
Emergency Response and Resiliency
Customer Outreach