UTAH GEOLOGICAL SURVEY

Geologic Factors Controlling the Response of Fractured Bedrock, Basin-fill, and Perched Aquifers to Recent Groundwater Development in the Cedar Pass Area, Eagle Mountain City, North-central Utah

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Utah Geological Survey - Groundwater Program

Rocky Mountain/Cordilleran Geological Society of America meeting

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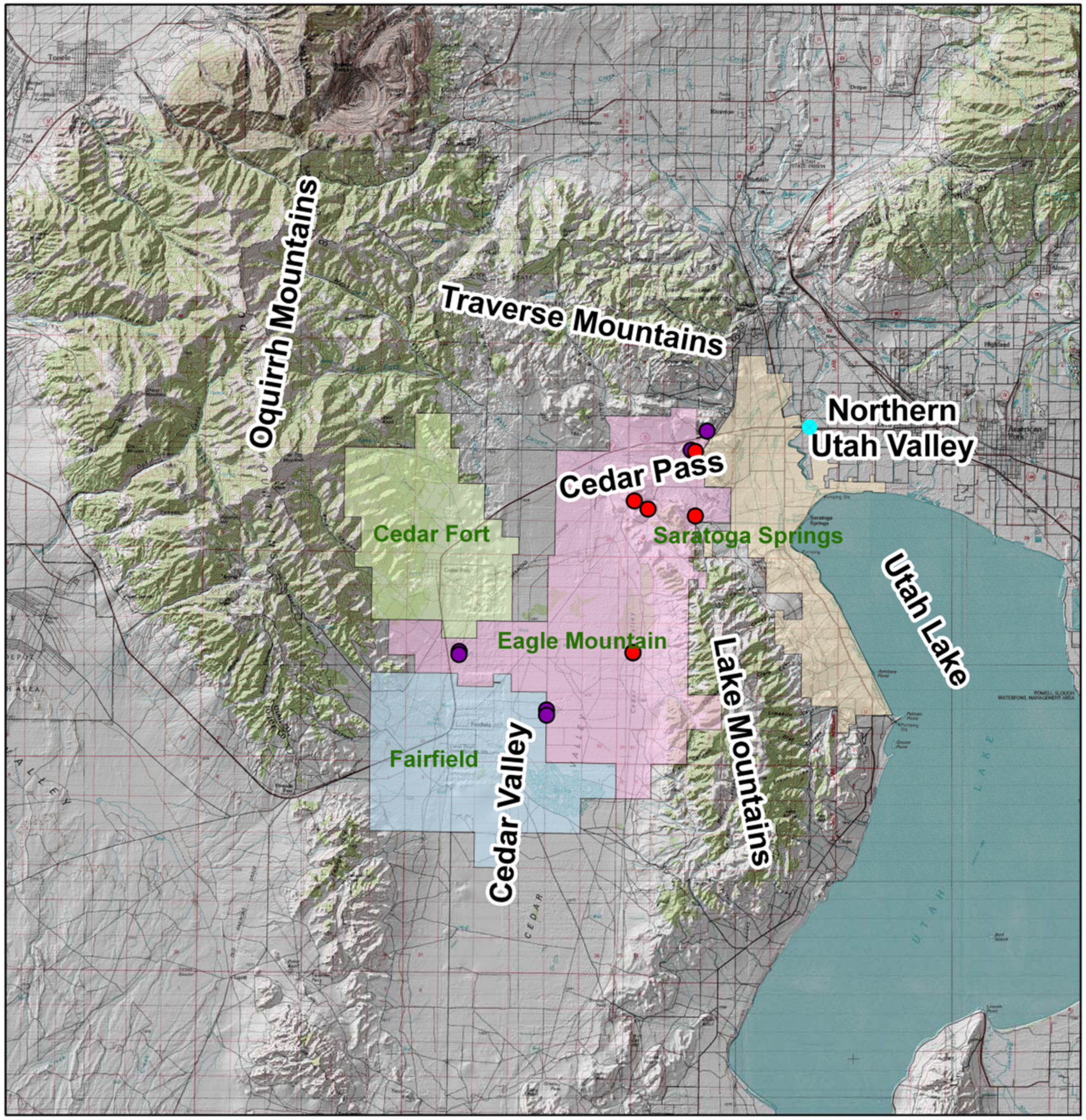
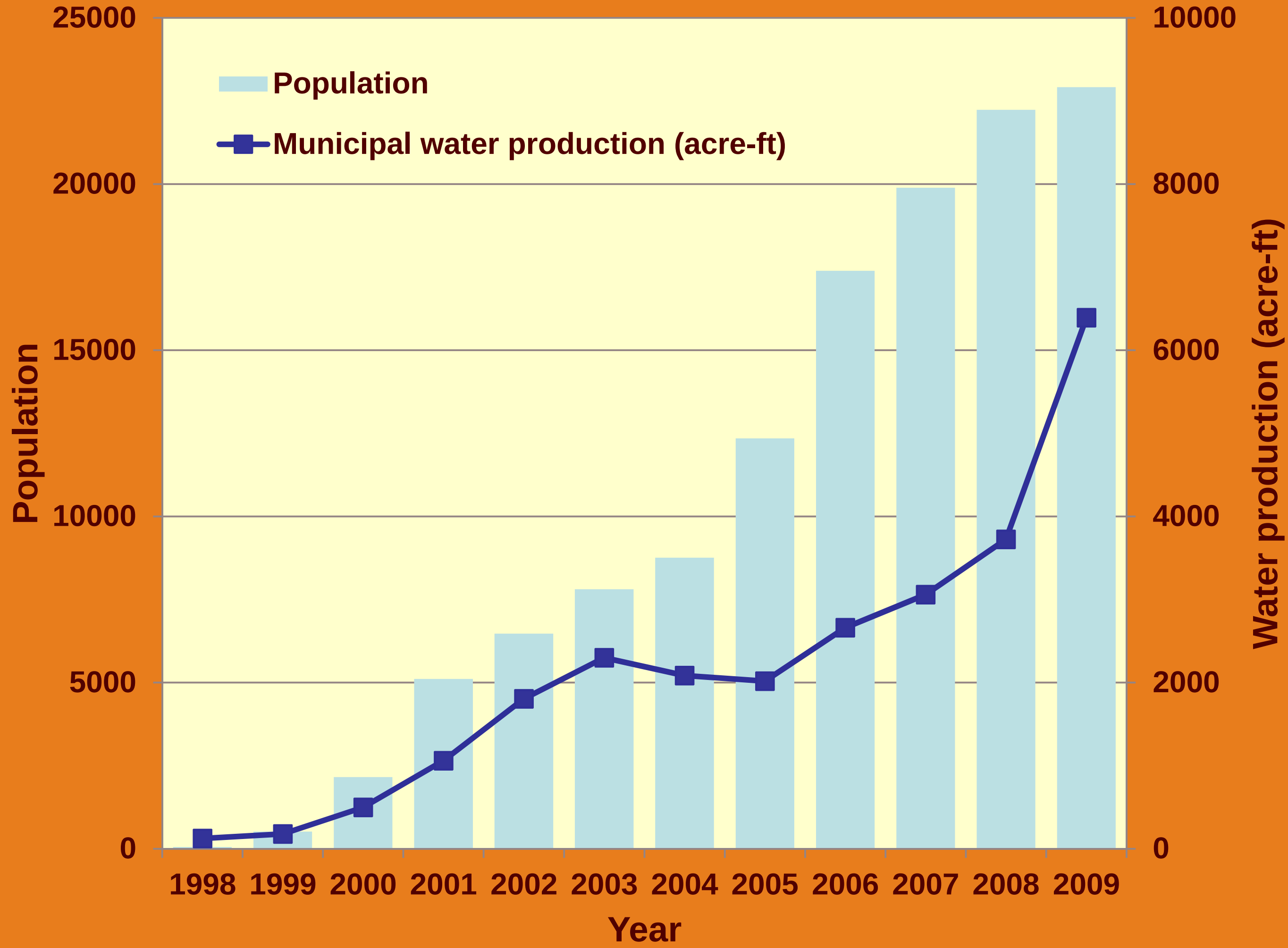


Population Growth and Municipal Groundwater Pumping for Eagle Mountain City



New residential development at Cedar Pass

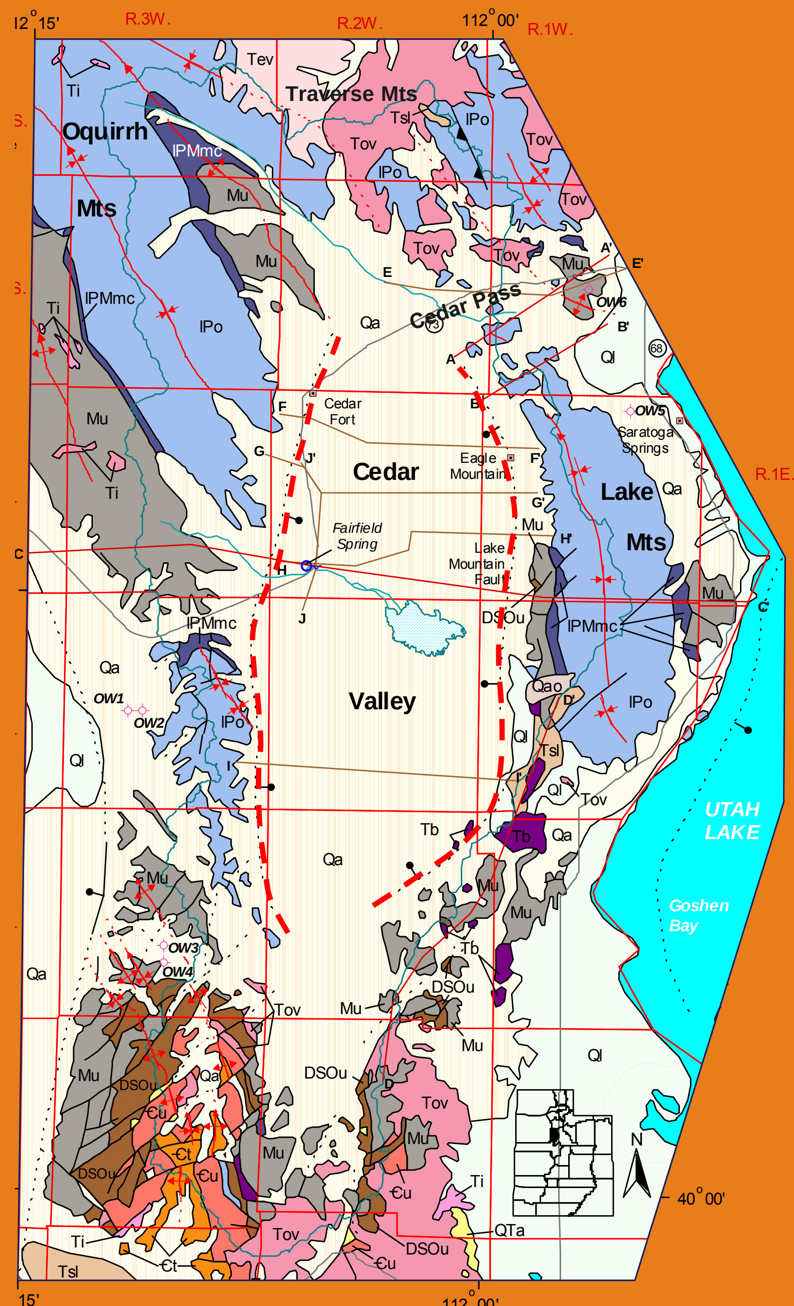
Oquirrh Mountains primary recharge area and Eagle Mountain City

Work Performed

- ✓ Quarterly water-level monitoring 2007-2009 on 18 wells
- ✓ Measured water level in 27 private wells in Cedar Pass area.
- ✓ 3 monitoring wells drilled at 2 locations
- ✓ Long-term aquifer tests on 2 large production wells
- ✓ Water-quality sampling of 12 wells for general chemistry and isotopes

Generalized Geologic Map

From Hurlow, H.A., 2004, The geology of Cedar Valley, Utah County, Utah, and its relation to ground-water conditions, Utah Geological Survey Special Study, Utah Geological Survey 109.



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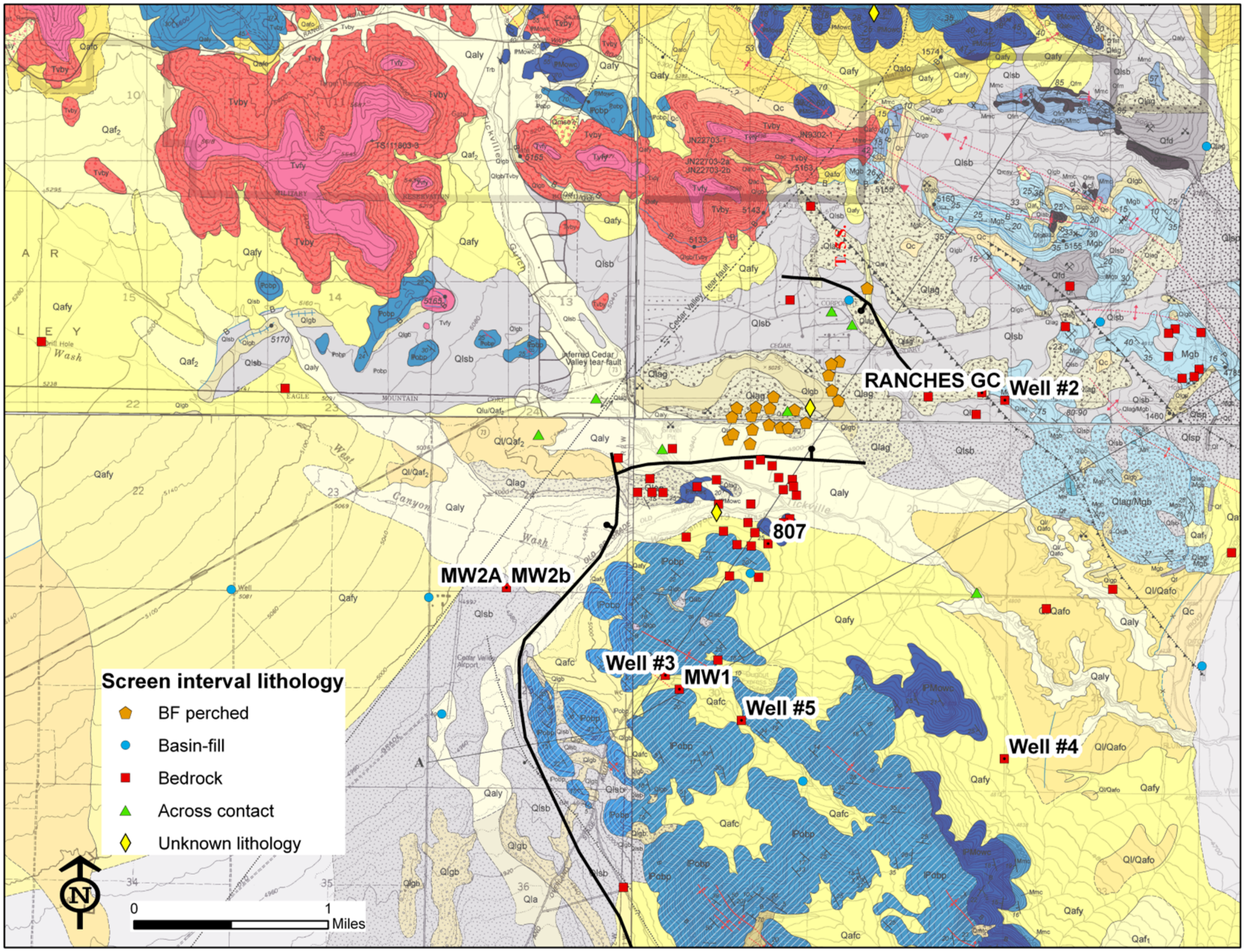
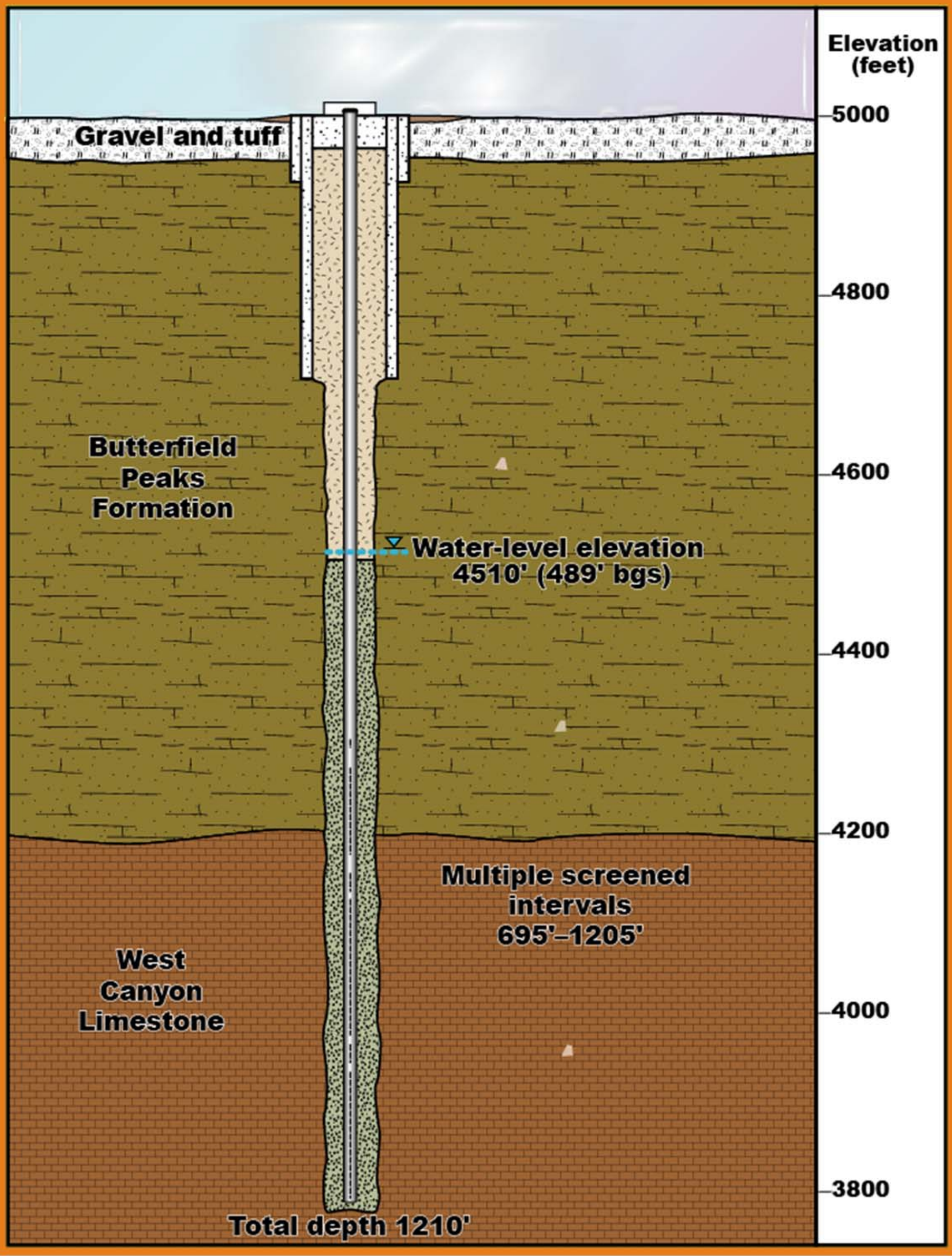
Cedar Pass Geology

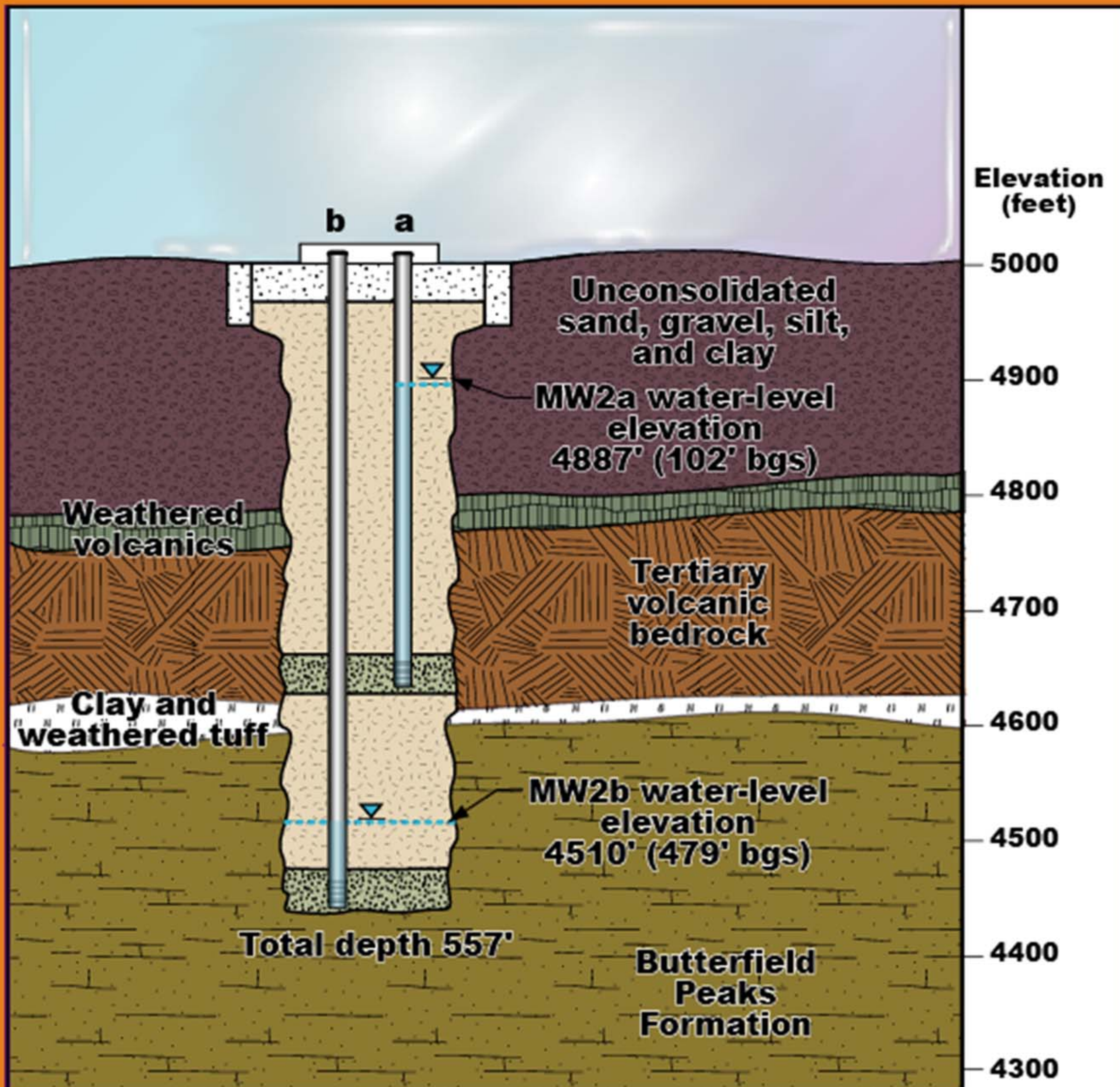


Fault locations refined by this study and Cederberg et al, 2009.



MW1

- Designed to mimic completion interval of Eagle Mountain production well #3
- Well #3 located 500 feet NW along strike of small anticline.



MW2ab

- Double completion well designed to have upper well in basin fill and lower well in Paleozoic aquifer
- Volcanics came in higher than saturated basin fill
- Unsaturated zone below volcanics/above unconfined Paleozoic aquifer

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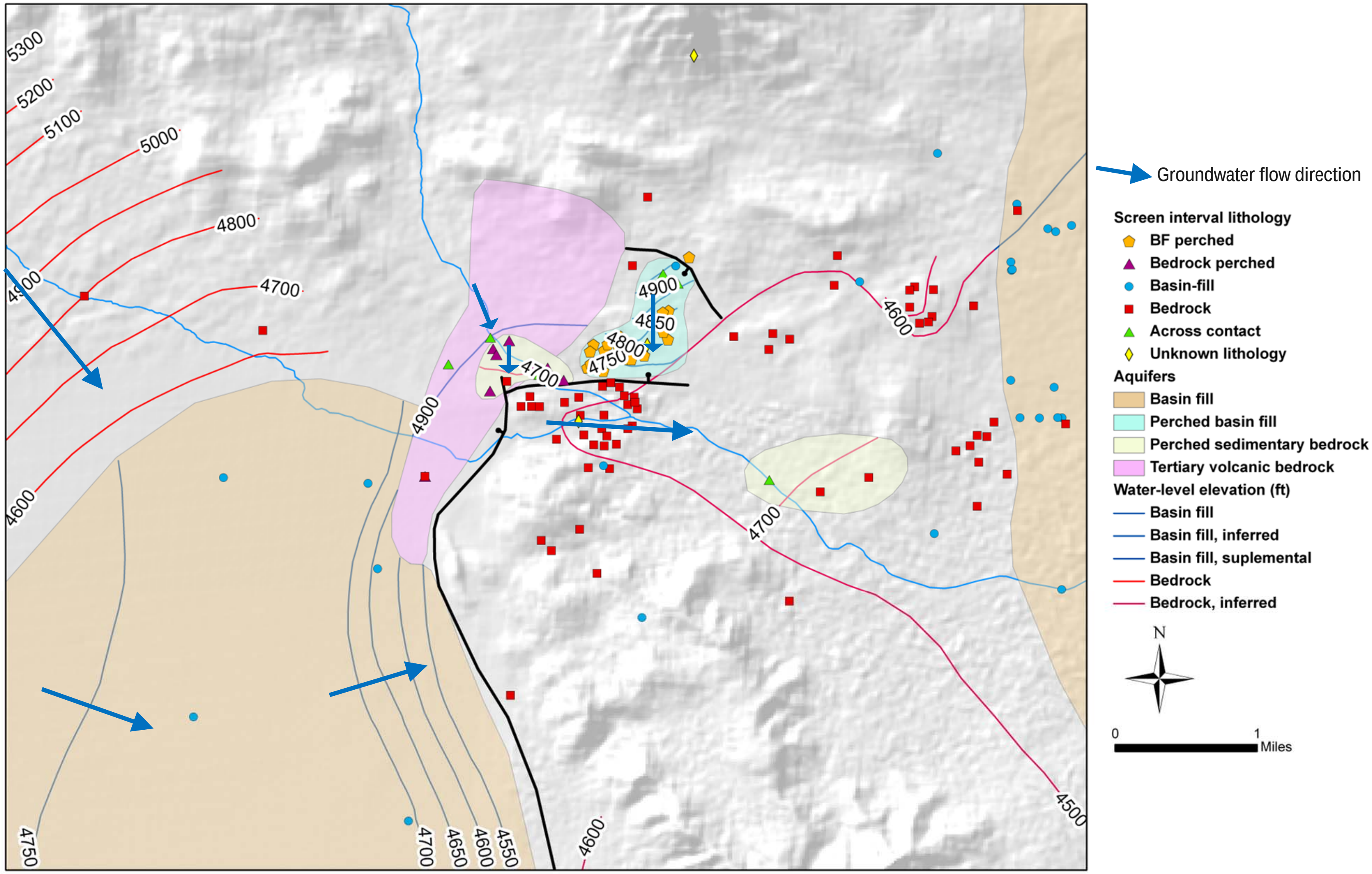
Cedar Pass area aquifers and potentiometric contours



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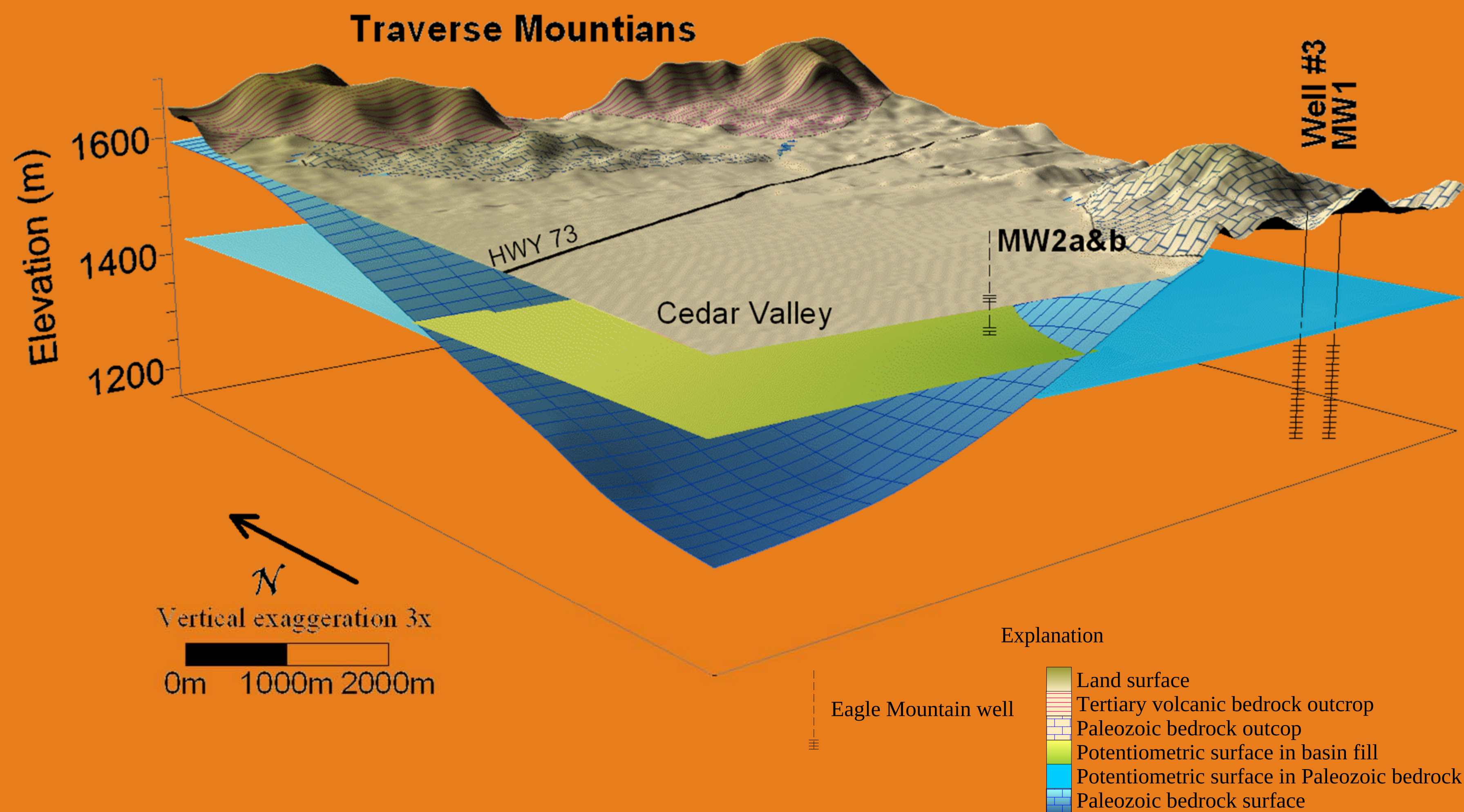
Hyrdrostratigraphy of Cedar Pass area



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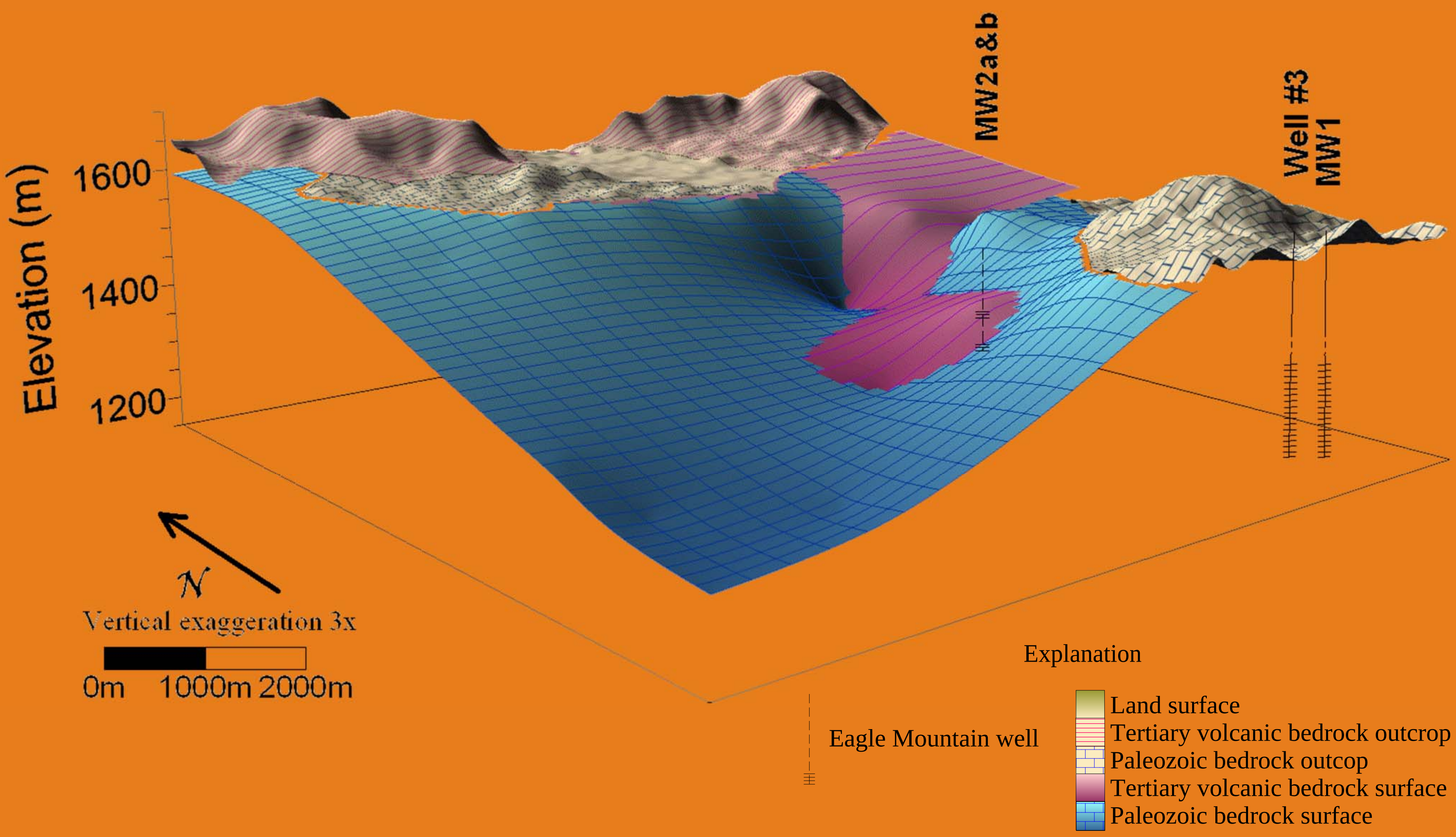
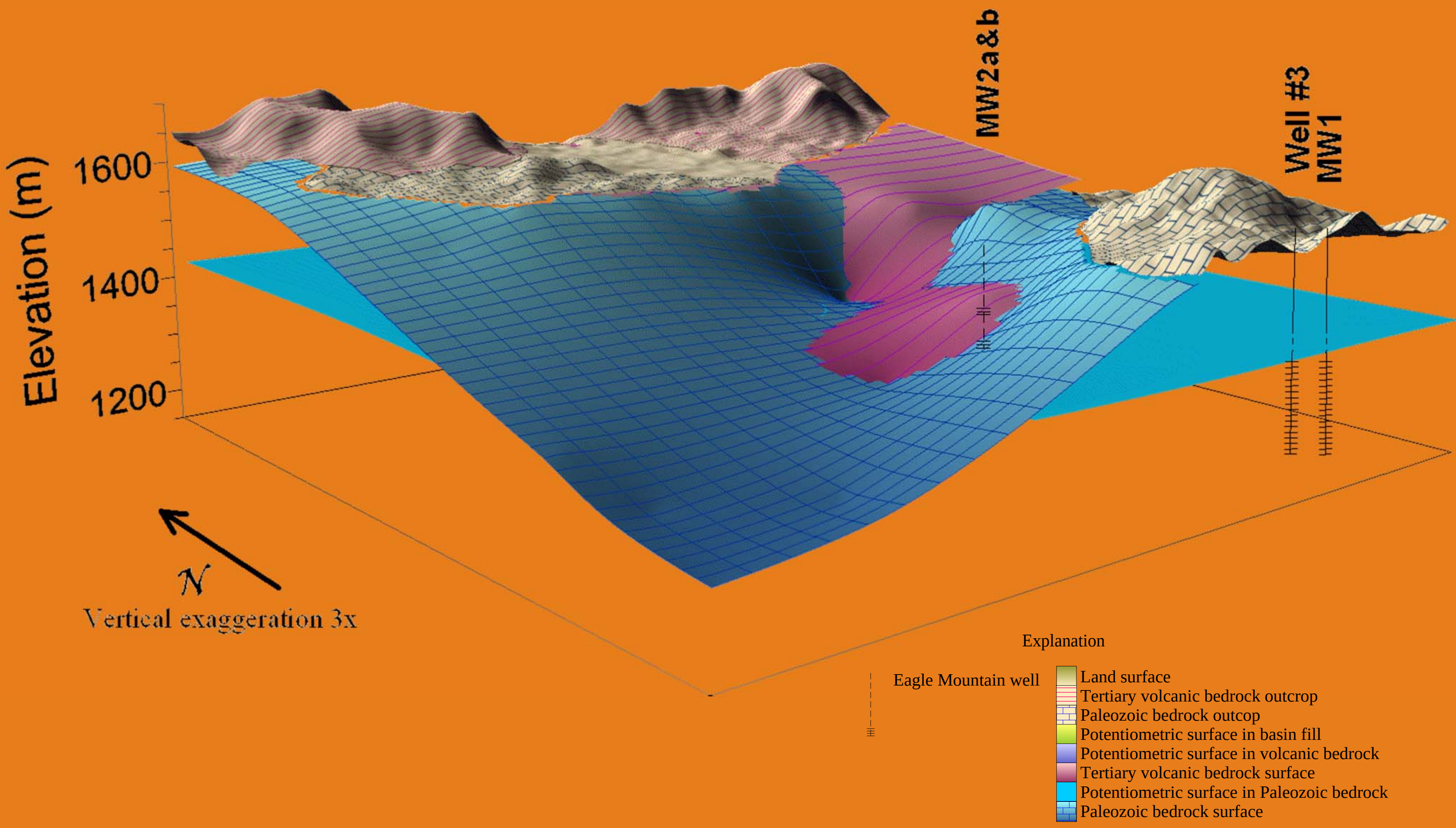
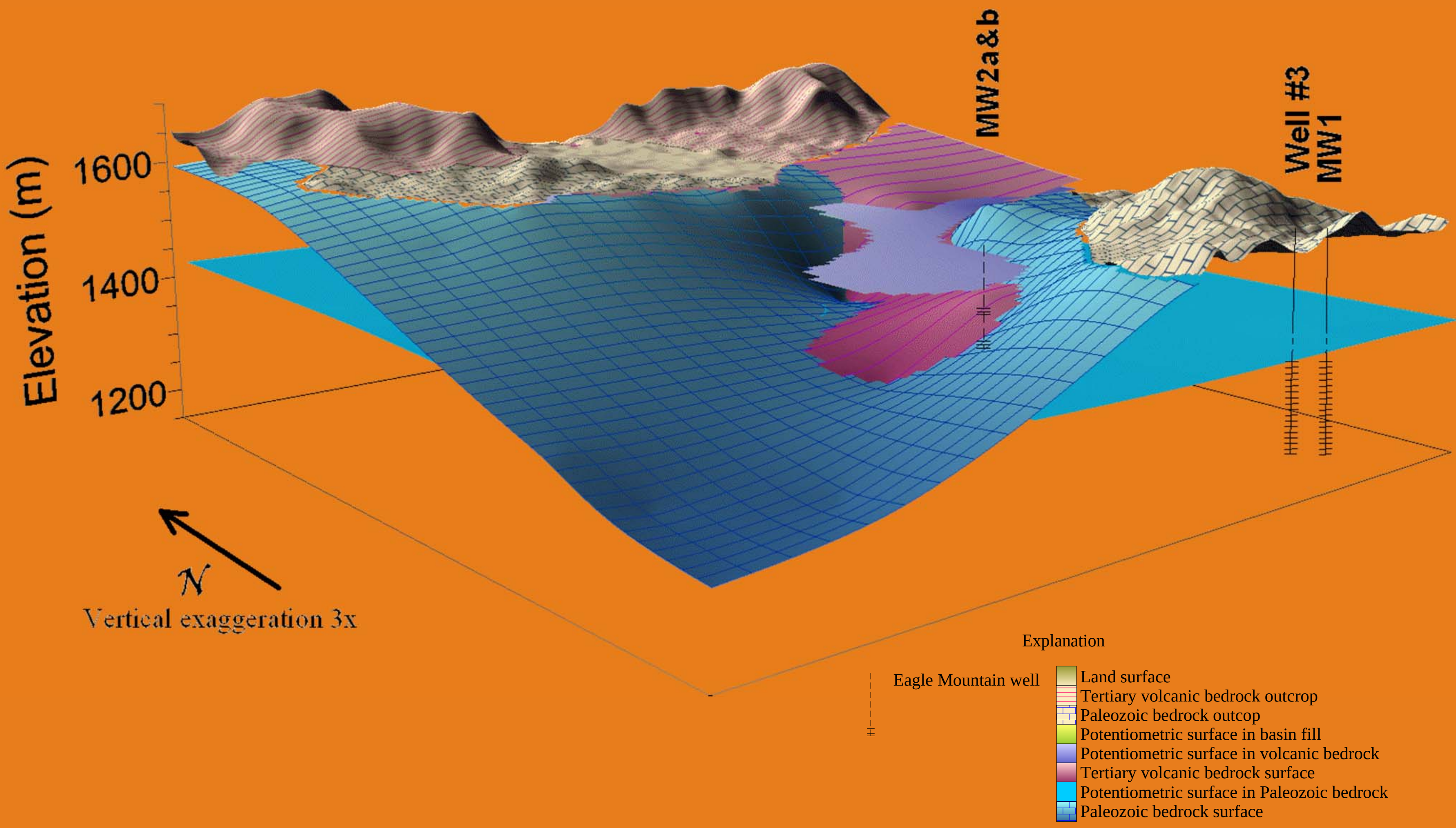
Hydrostratigraphy of Cedar Pass area – geologic units



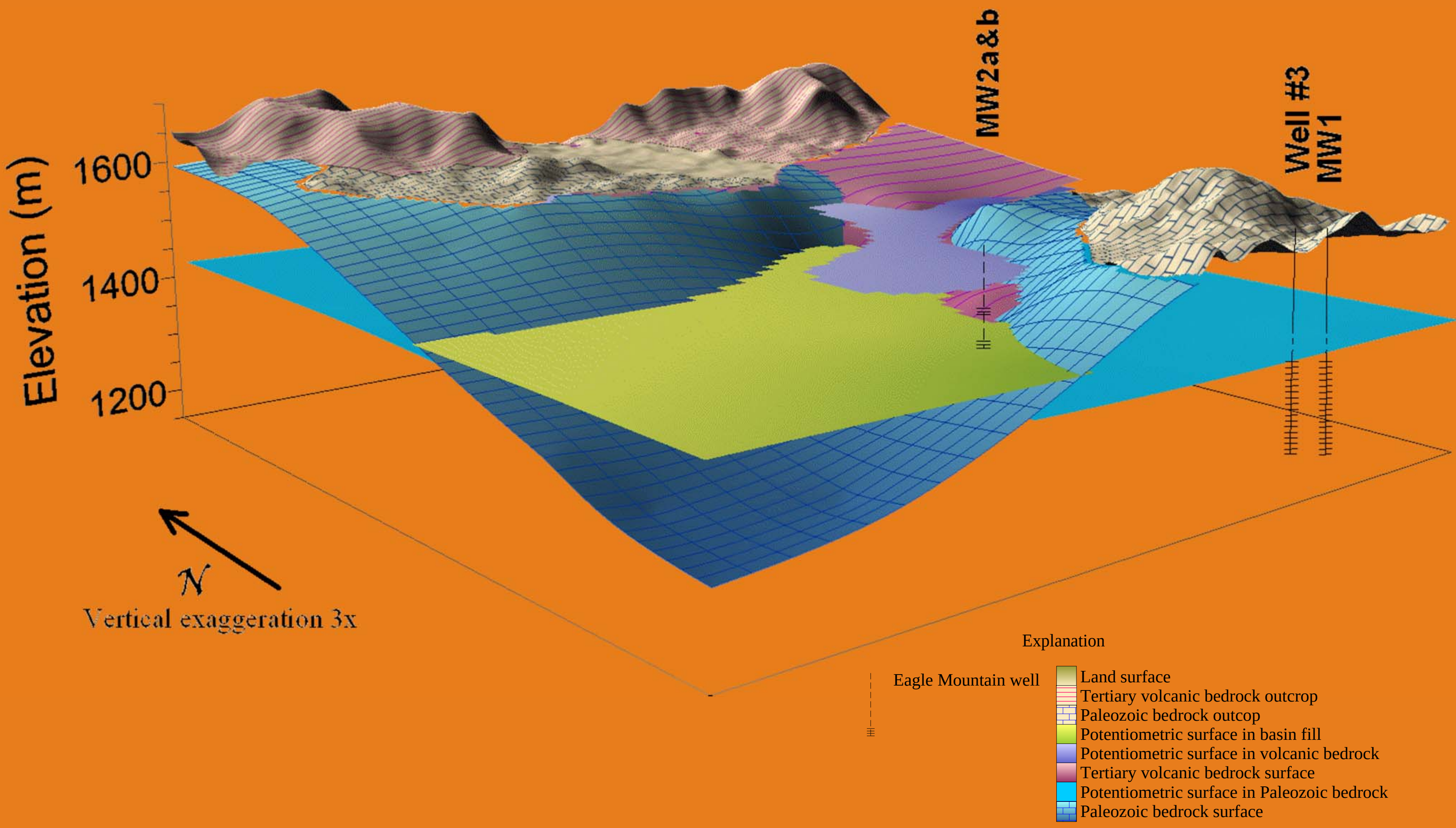
Hydrostratigraphy of Cedar Pass area – geologic units + potentiometric surface in the Paleozoic aquifer



Hydrostratigraphy of Cedar Pass area – geologic units + potentiometric surface in the Paleozoic and volcanic aquifers

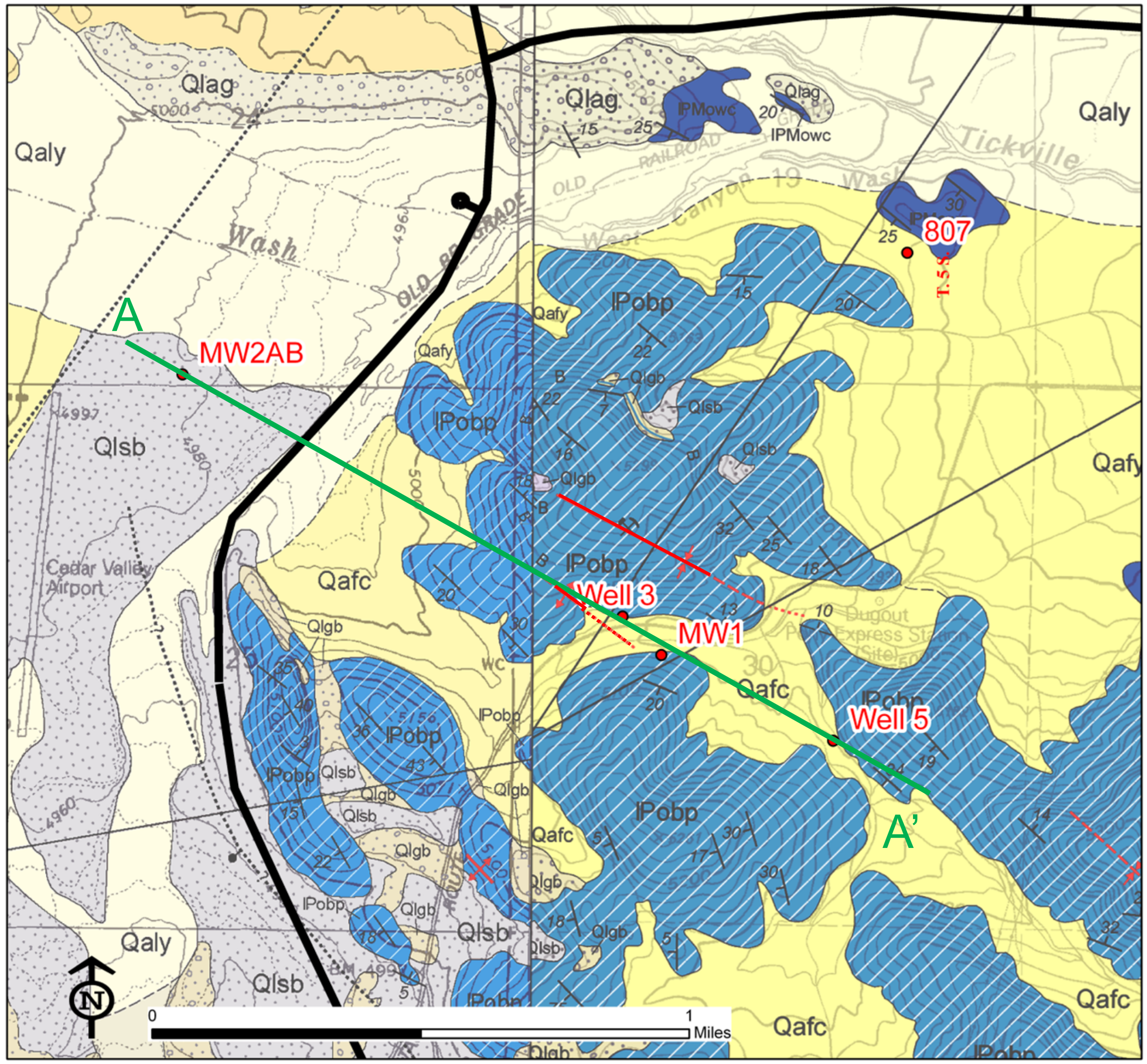


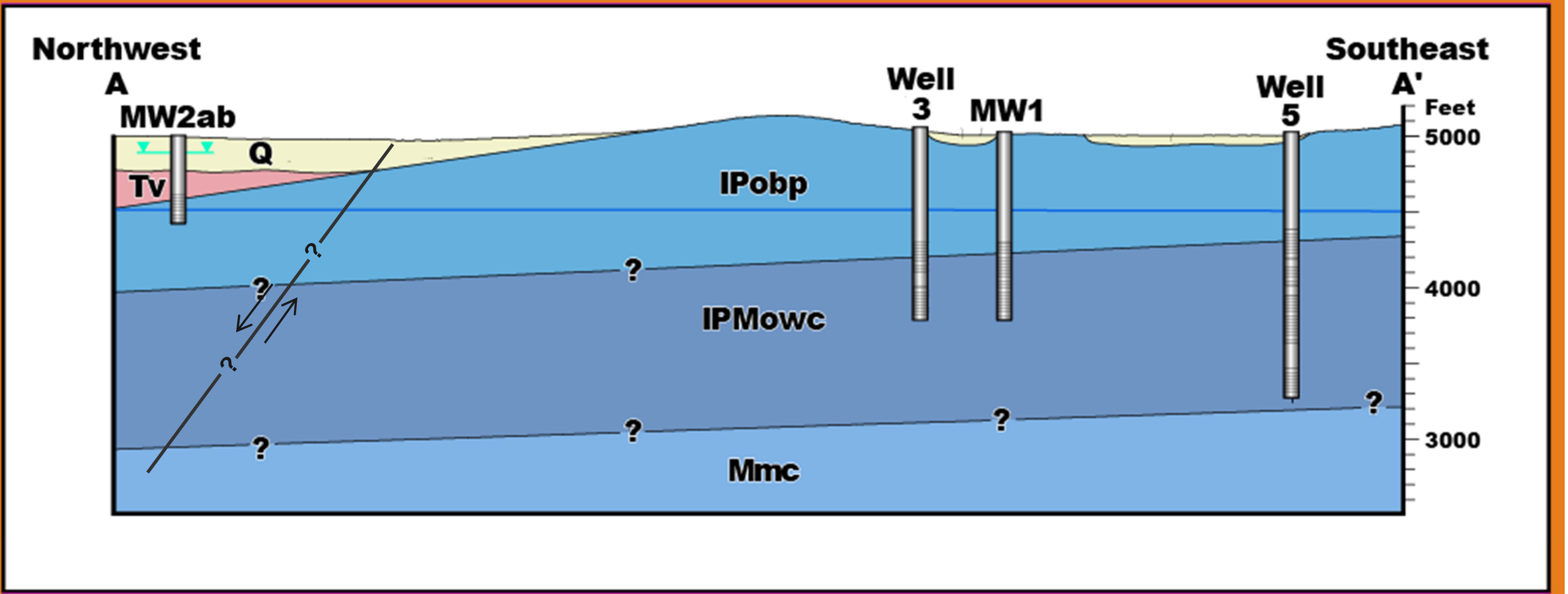
Hydrostratigraphy of Cedar Pass area – geologic units + potentiometric surfaces

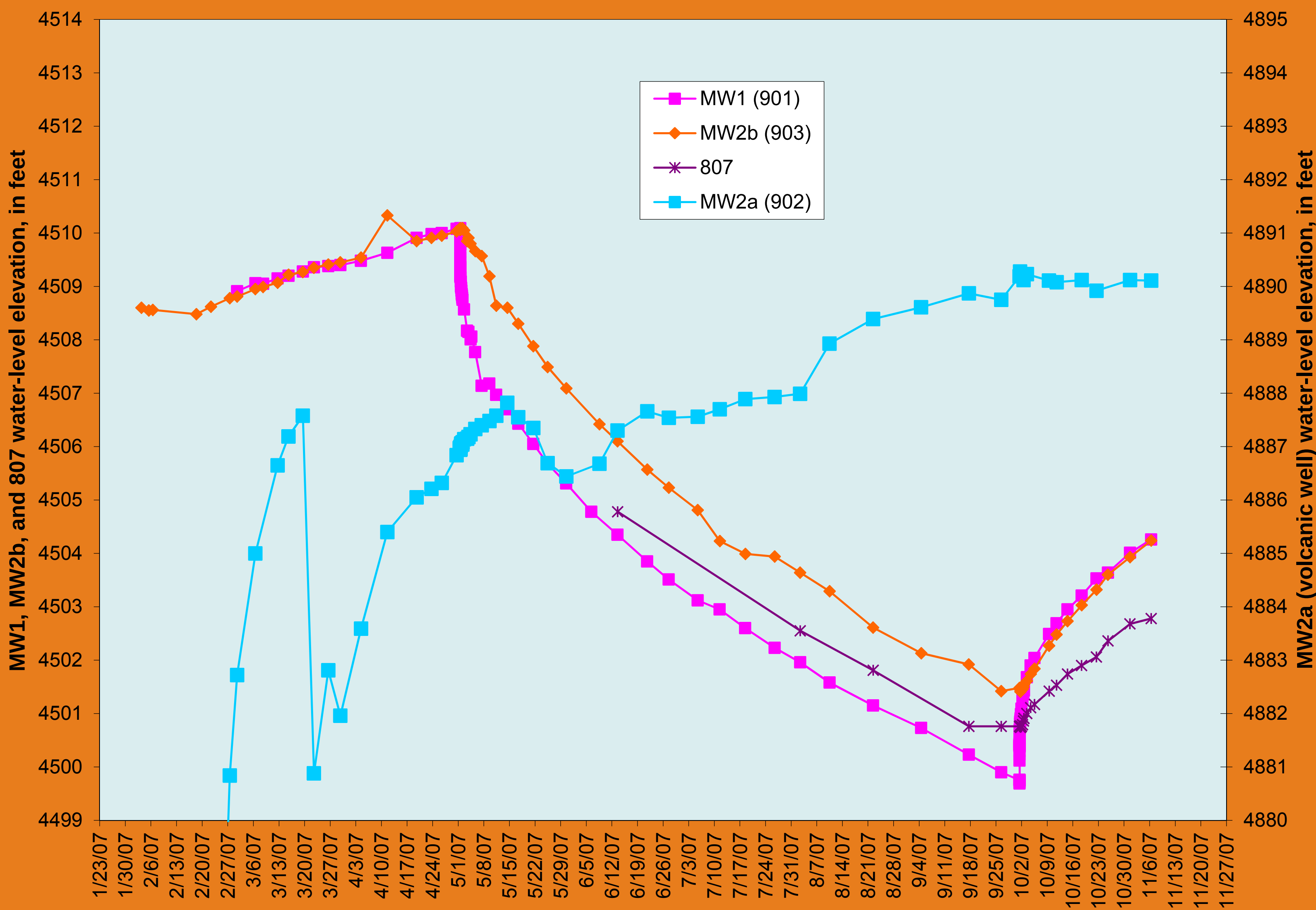


Aquifer test: Eagle Mountain Well #3

- Well #3: 16”-diameter well, screened 700-1200 ft below ground level in Pennsylvanian-Mississipian Oquirrh Group (Butterfield Peaks and West Canyon Limestone Fms)
- 5 months long, 1930 gpm
- MW1 ~500 feet from pumping well and designed to monitor aquifer response over entire thickness of aquifer
- MW2b and 807 ~ 5000 feet distant
- MW1 and MW2b along direction of primary T, 807 perpendicular to primary T




Northwest
A
MW2ab
Q
Tv
IPobp
IPMowc
Mmc
Well
3
MW1
Well
5
Southeast
A'
Feet
5000
4000
3000



MW1, MW2b, and 807 water-level elevation, in feet
MW2a (volcanic well) water-level elevation, in feet
MW1 (901)
MW2b (903)
807
MW2a (902)
4499
4500
4501
4502
4503
4504
4505
4506
4507
4508
4509
4510
4511
4512
4513
4514
4880
4881
4882
4883
4884
4885
4886
4887
4888
4889
4890
4891
4892
4893
4894
4895
1/23/07
1/30/07
2/6/07
2/13/07
2/20/07
2/27/07
3/6/07
3/13/07
3/20/07
3/27/07
4/3/07
4/10/07
4/17/07
4/24/07
5/1/07
5/8/07
5/15/07
5/22/07
5/29/07
6/5/07
6/12/07
6/19/07
6/26/07
7/3/07
7/10/07
7/17/07
7/24/07
7/31/07
8/7/07
8/14/07
8/21/07
8/28/07
9/4/07
9/11/07
9/18/07
9/25/07
10/2/07
10/9/07
10/16/07
10/23/07
10/30/07
11/6/07
11/13/07
11/20/07
11/27/07

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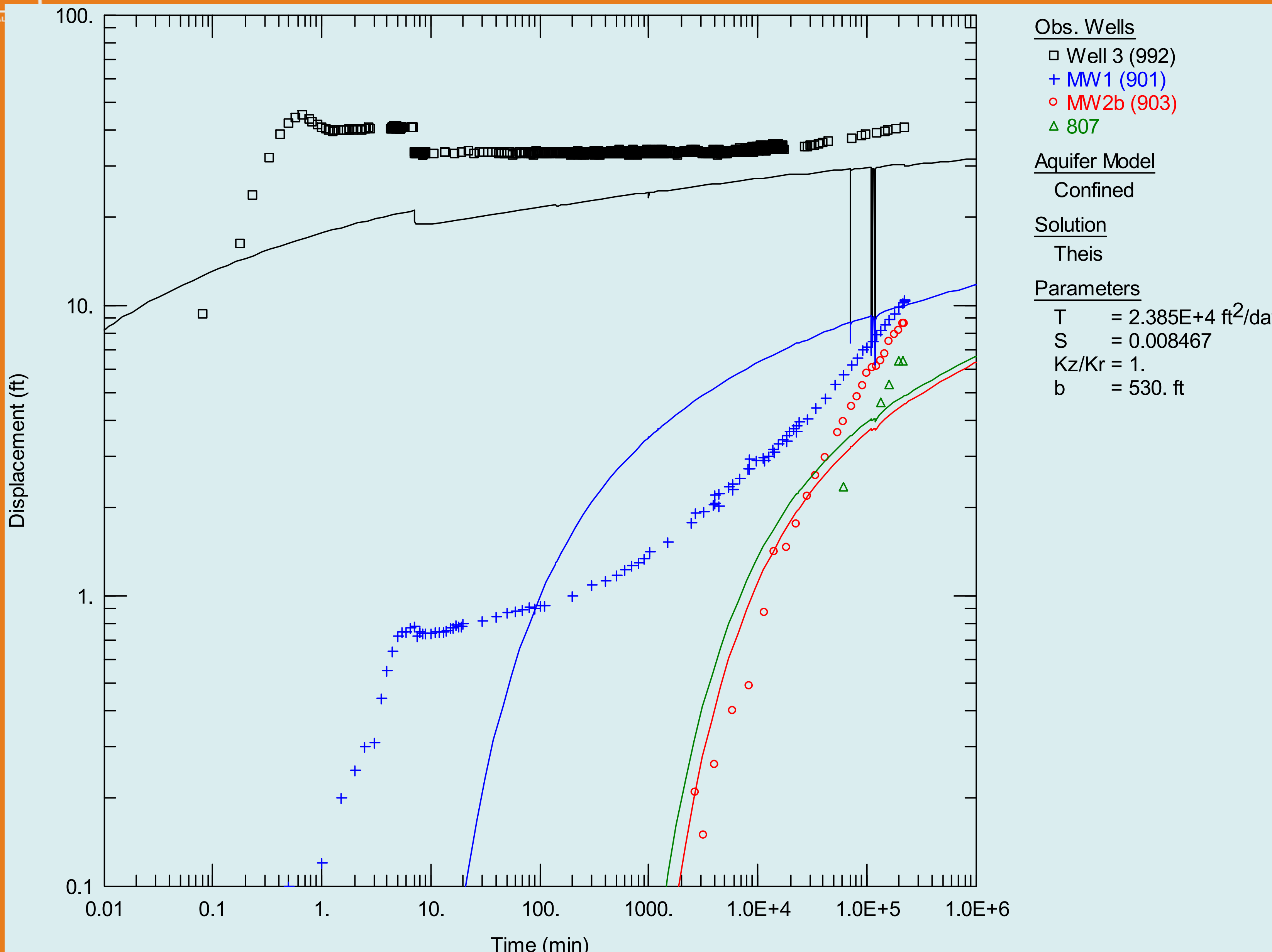

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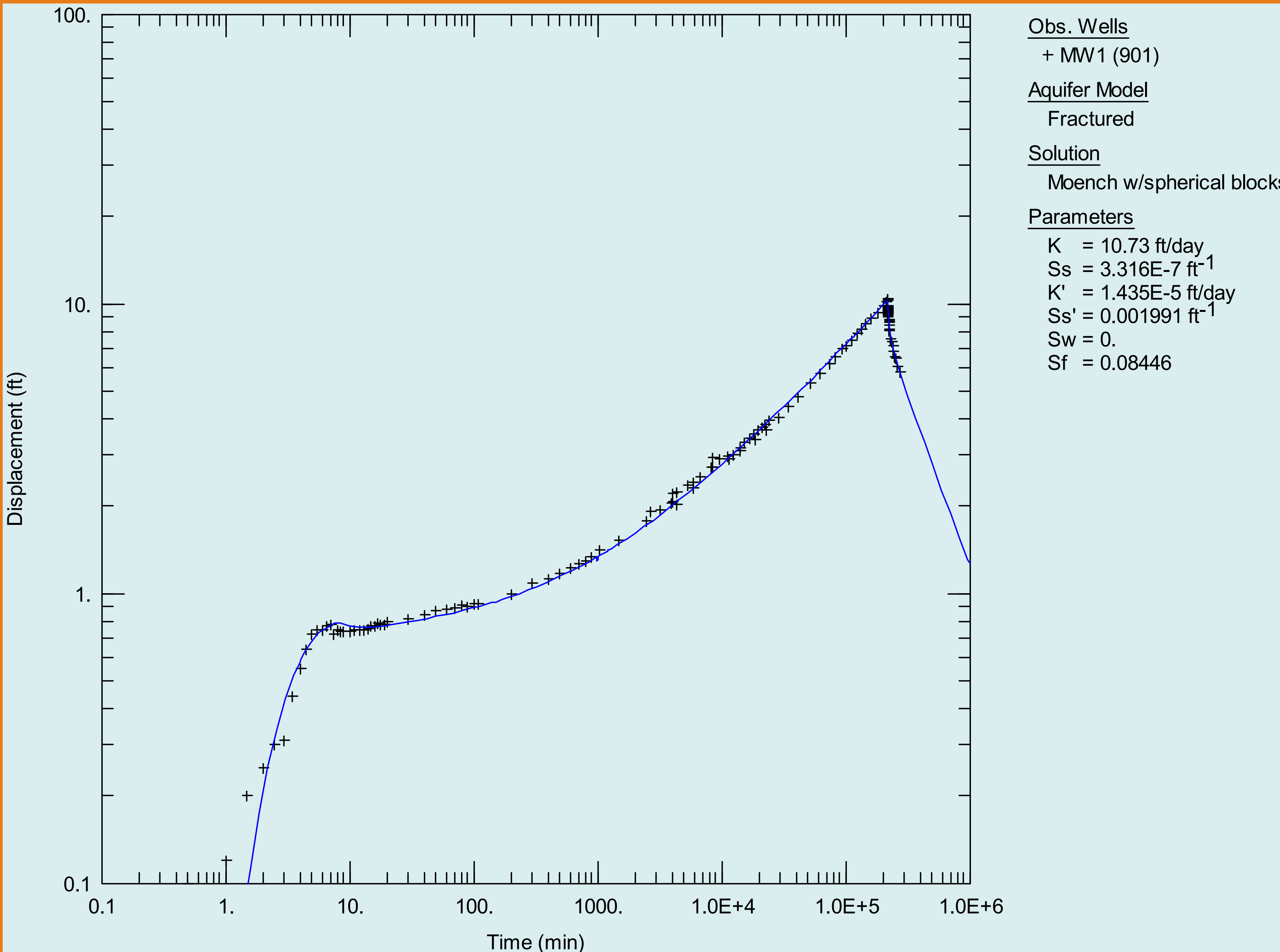

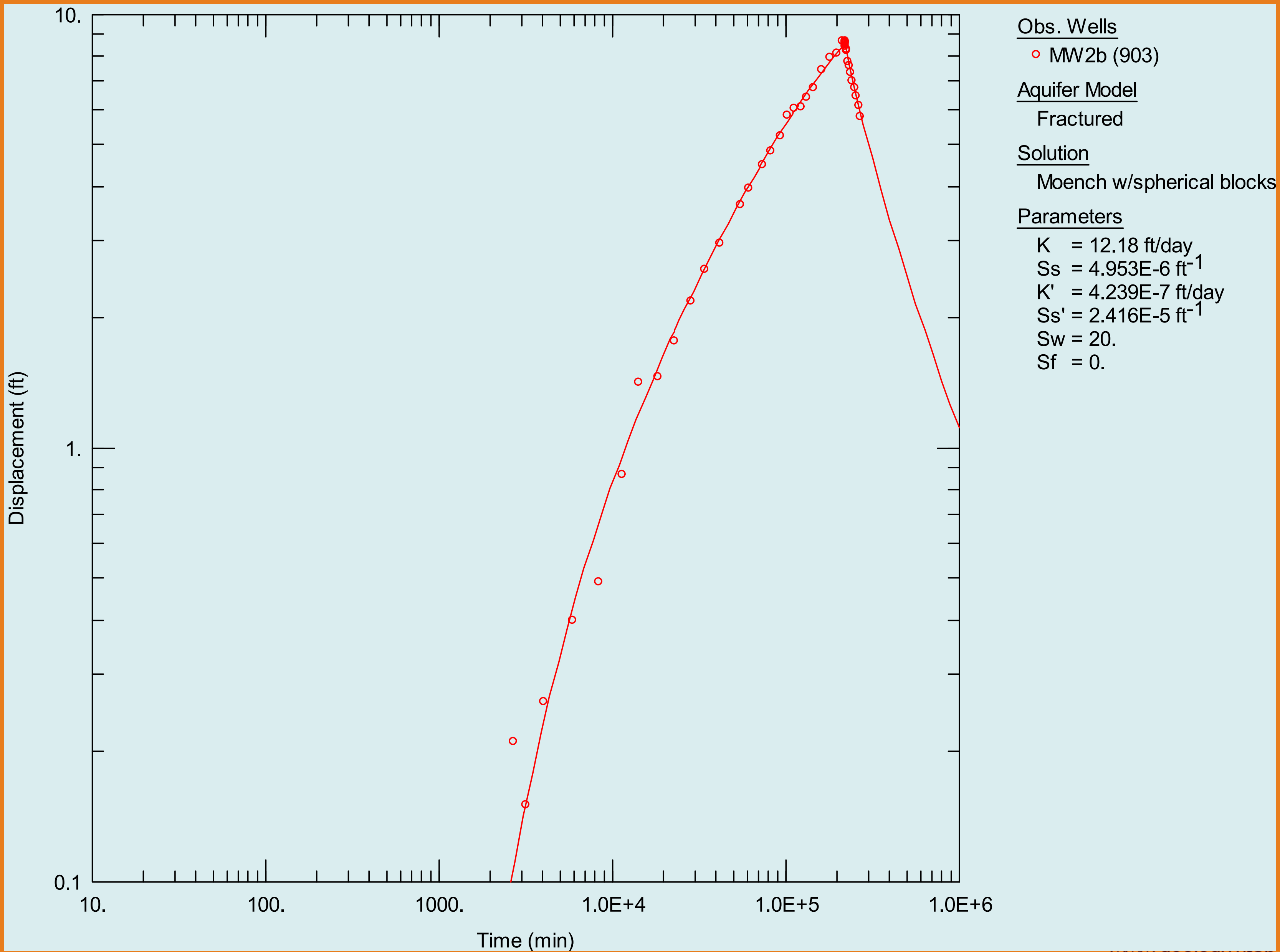
10.
1.
0.1
10.
100.
1000.
1.0E+4
1.0E+5
1.0E+6
Displacement (ft)
Time (min)
Obs. Wells
MW2b (903)
Aquifer Model
Fractured
Solution
Moench w/spherical blocks
Parameters
K = 12.18 ft/day
Ss = 4.953E-6 ft-1
K' = 4.239E-7 ft/day
Ss' = 2.416E-5 ft-1
Sw = 20.
Sf = 0.

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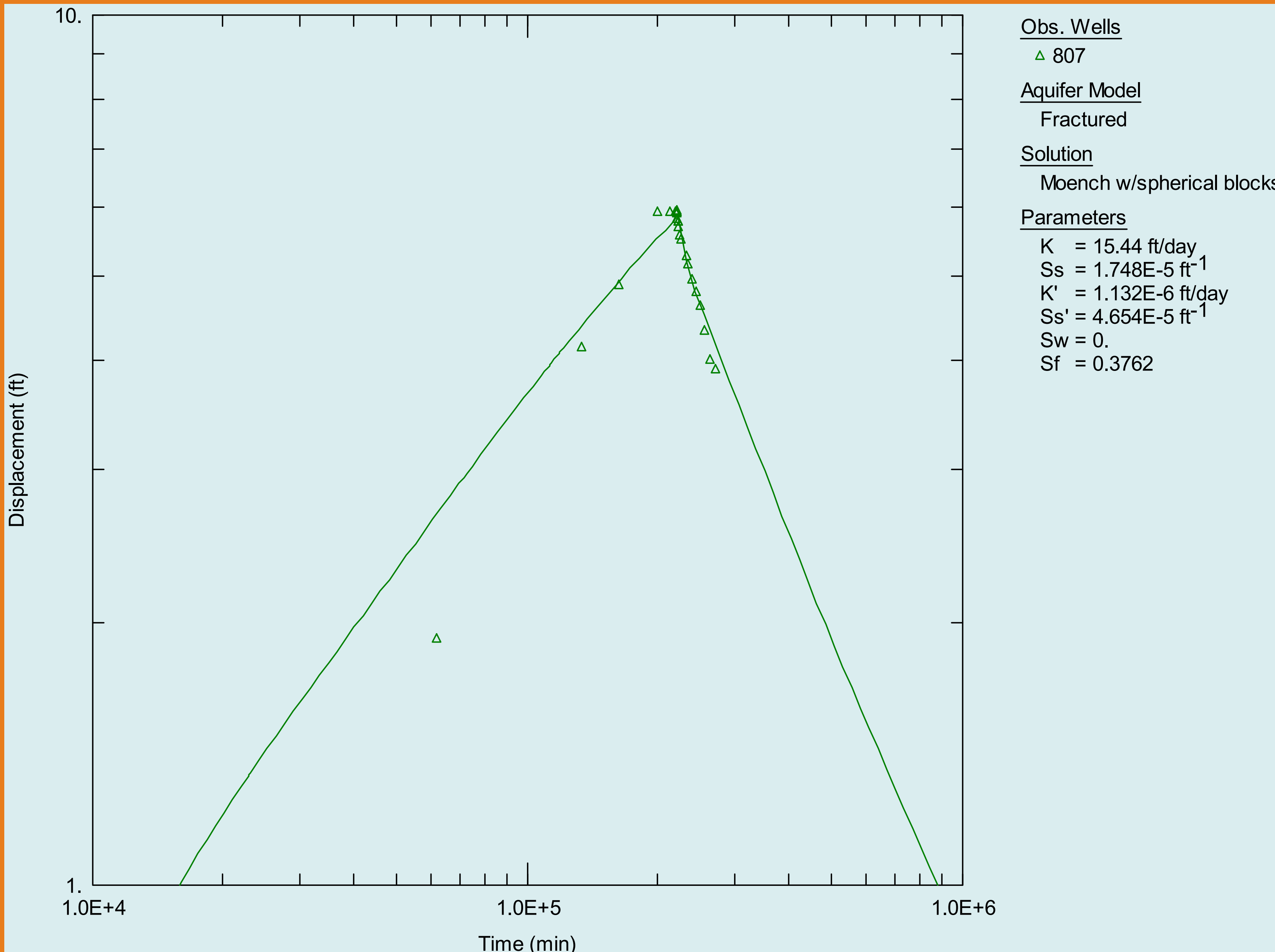

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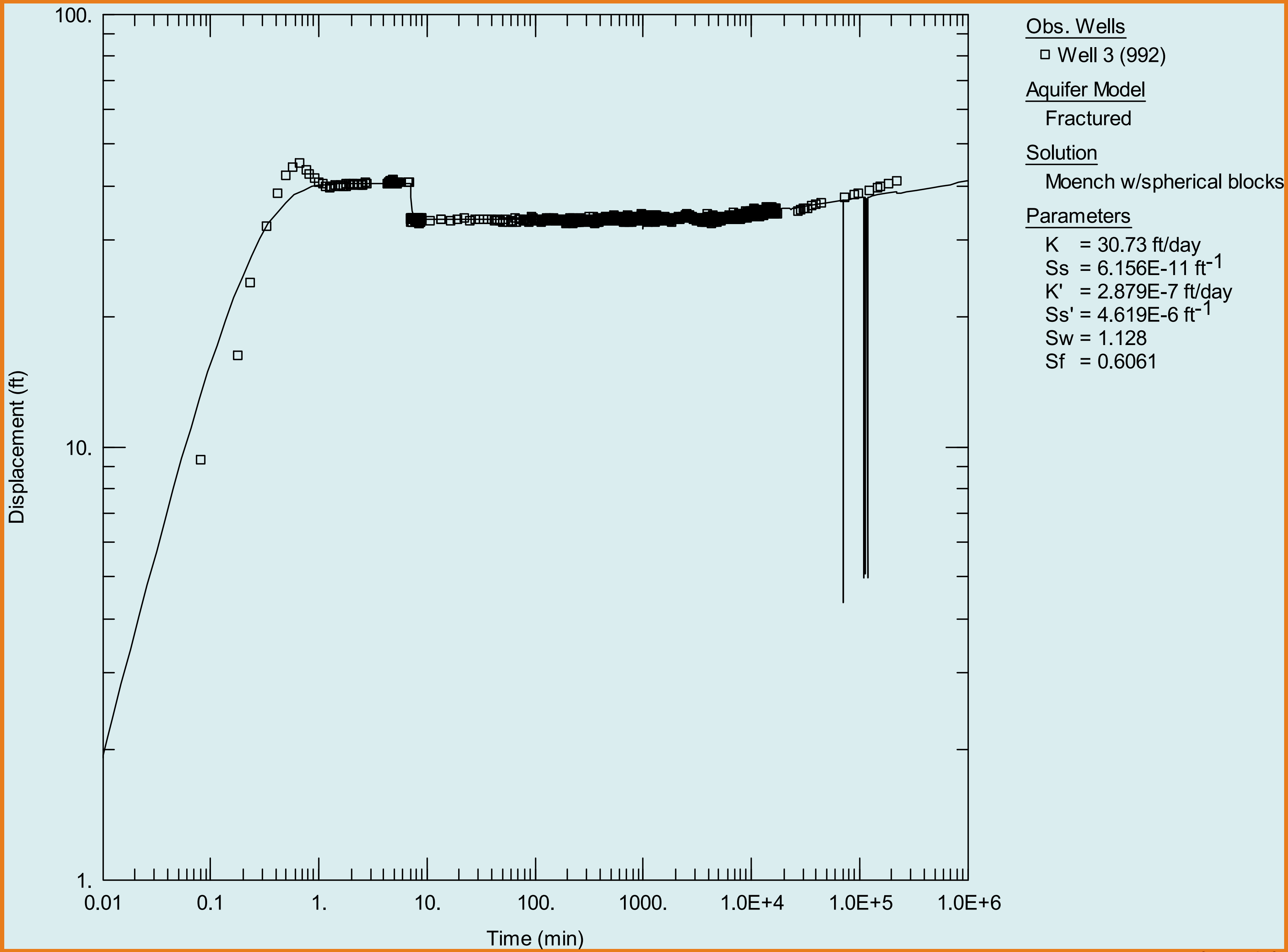


Determining transmissivity anisotropy

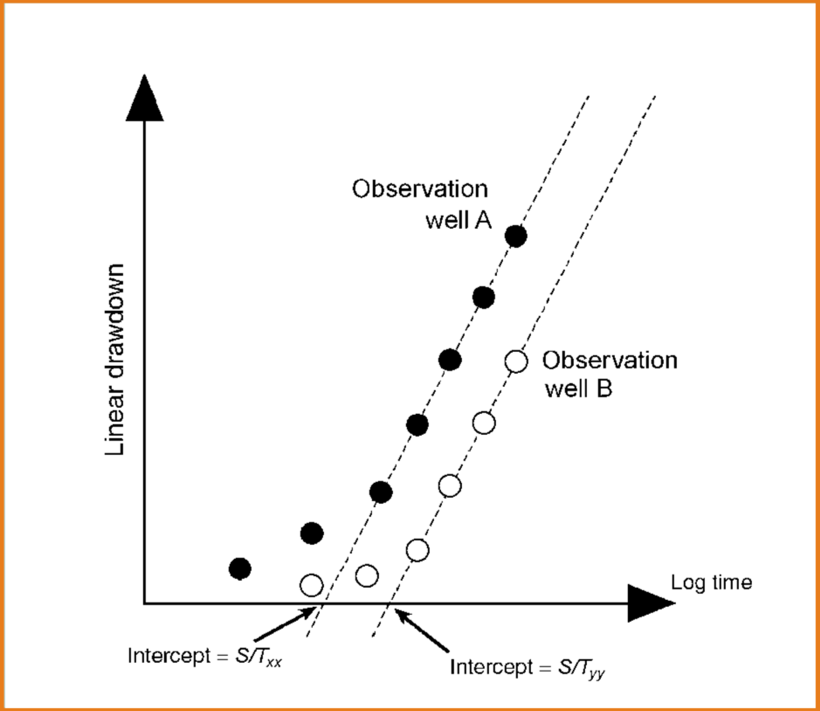
- Method: Heilweil, V.M., and Hsieh, P.A., 2006, Determining anisotropic transmissivity using a simplified Papadopulos method: Ground Water, v. 44, no. 5, p. 749-753.
- Simplification of Papadopulos
- Fractured aquifers in which principal directions of the transmissivity are known
- Assumes that observation wells are drilled along the two principal directions of transmissivity from the pumped well
- Only 2 observation wells needed

Papadopulos, 1965

$$s(x,y,t) = \frac{Q}{4\pi\sqrt{T_{xx}T_{yy}}} W(u_{xy})$$

$$u_{xy} = \frac{S}{4T}\left(\frac{T_{xx}y^2 + T_{yy}x^2}{T_{xx}T_{yy}}\right)$$

✓ Cooper-Jacob method: slope of *late time data* (straight line part) is used to calculate T (Δs over 1 log cycle time into equation) and intercept gives S/T



$$\sqrt{T_{xx}T_{yy}} = \frac{2.3Q}{4\pi\Delta s}$$

$$\frac{S}{T_{yy}} = \frac{2.25t_{0b}}{[y_B]^2}$$

1) Square $\sqrt{T_{xx}T_{yy}}$ to obtain $T_{xx}T_{yy}$
2) Multiply *S/Txx* and *S/Tyy* to obtain $S^2/(T_{xx}T_{yy})$
3) Multiply the result from steps 1 and 2 to get S^2, then take the square root to arrive at S
4) Divide the S obtained from step 3 by S/T_{xx} to get T_{xx}
5) Divide the S obtained from step 3 by S/T_{yy} to get T_{yy}.

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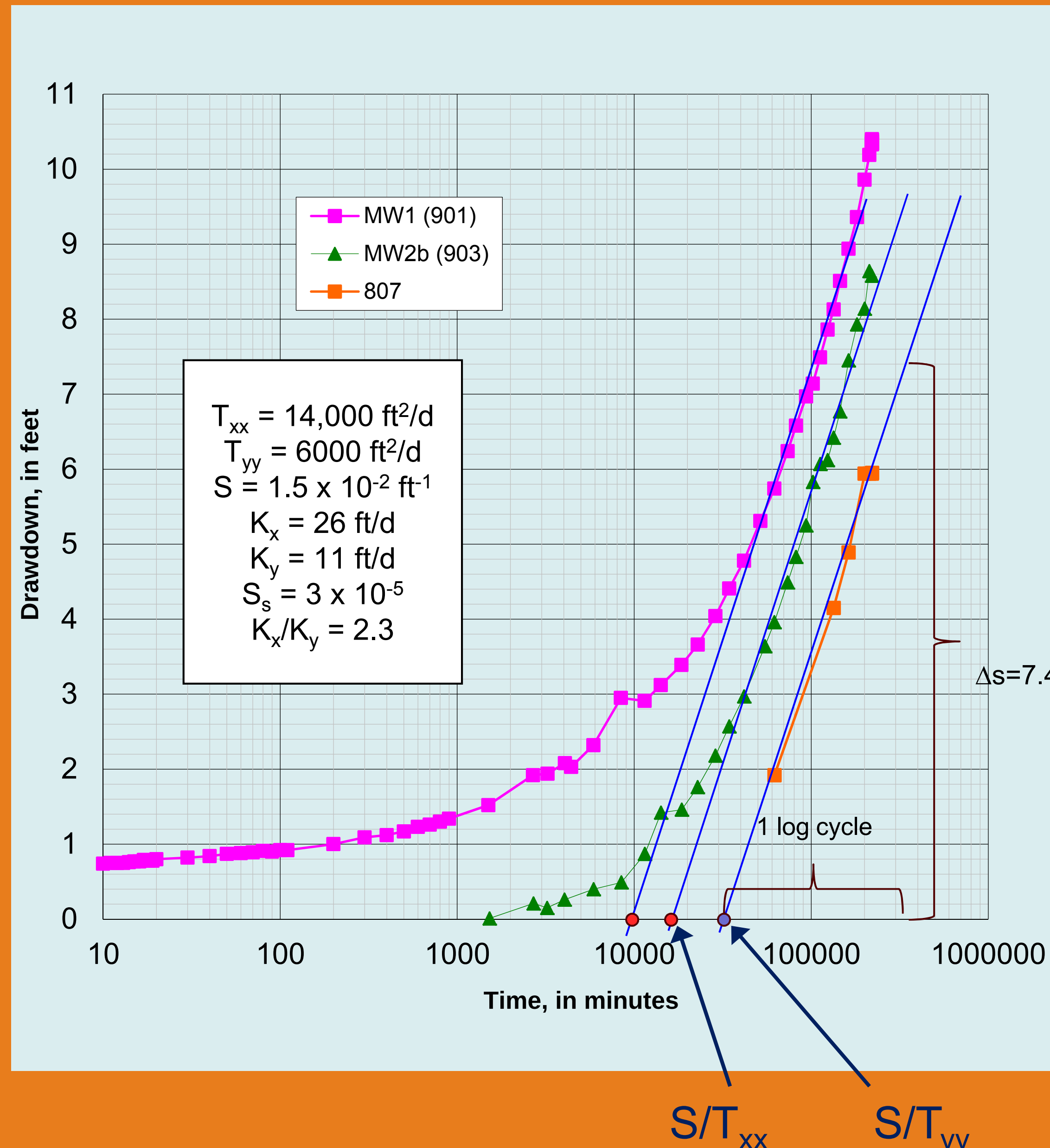
Determine transmissivity anisotropy

Semi-log plot of drawdown versus time in monitoring wells during Well 3 aquifer test. Parallel lines are fitted to the straightest part of the late-time data. The value of drawdown over one log cycle, 7.4 feet, is used as input for determining anisotropic transmissivity in fractured-rock aquifers.



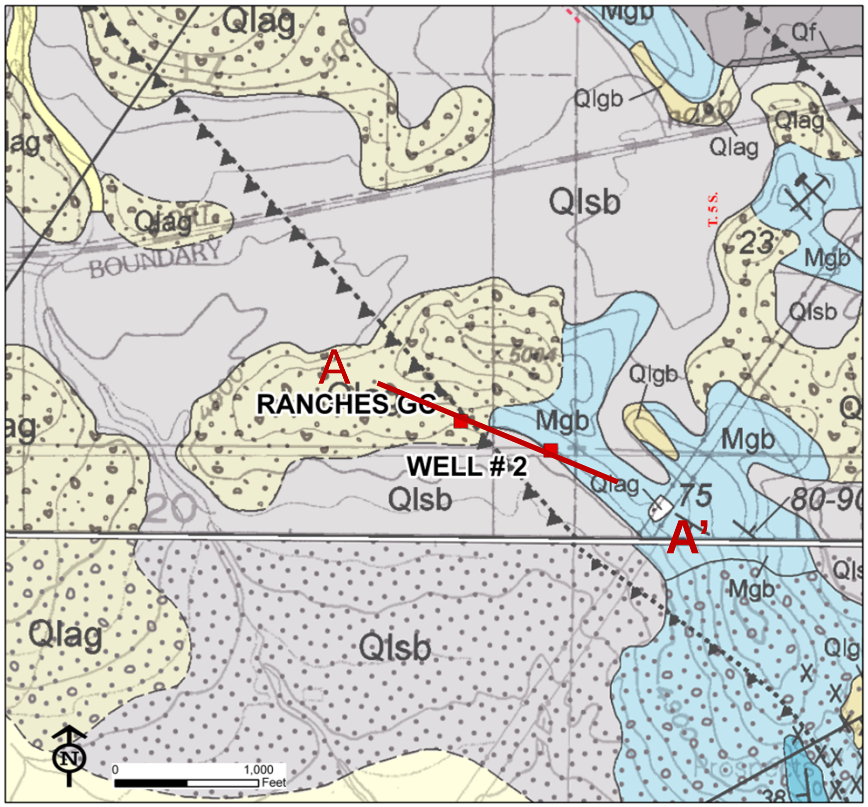
Well #3 test results

- Dual-porosity system: 3-foot spherical blocks
- Anisotropic with principal direction of T 2+ times greater in the direction parallel to structure

Hydraulic conductivity of fractures (K)	11 to 31 ft/d
Hydraulic conductivity of matrix blocks (K')	$3 \cdot 10^{-7}$ to $1 \cdot 10^{-5}$ ft/d
Specific storage of the fractures (Ss)	$3 \cdot 10^{-7}$ to $3 \cdot 10^{-5}$ ft^{-1}
Specific storage of the matrix blocks (Ss')	$2 \cdot 10^{-5}$ to $2 \cdot 10^{-3}$ ft^{-1}
Transmissivity (T)	5800 to 16,000 ft^2/d
Storage capacity or storativity (S)	0.01
Aquifer thickness (b)	530 ft

Aquifer test: Eagle Mountain Well #2

- 35 days, 2500 gpm
- Aquifer thickness ~525 feet
- One observation well 660' distant
- Both wells in Great Blue Limestone



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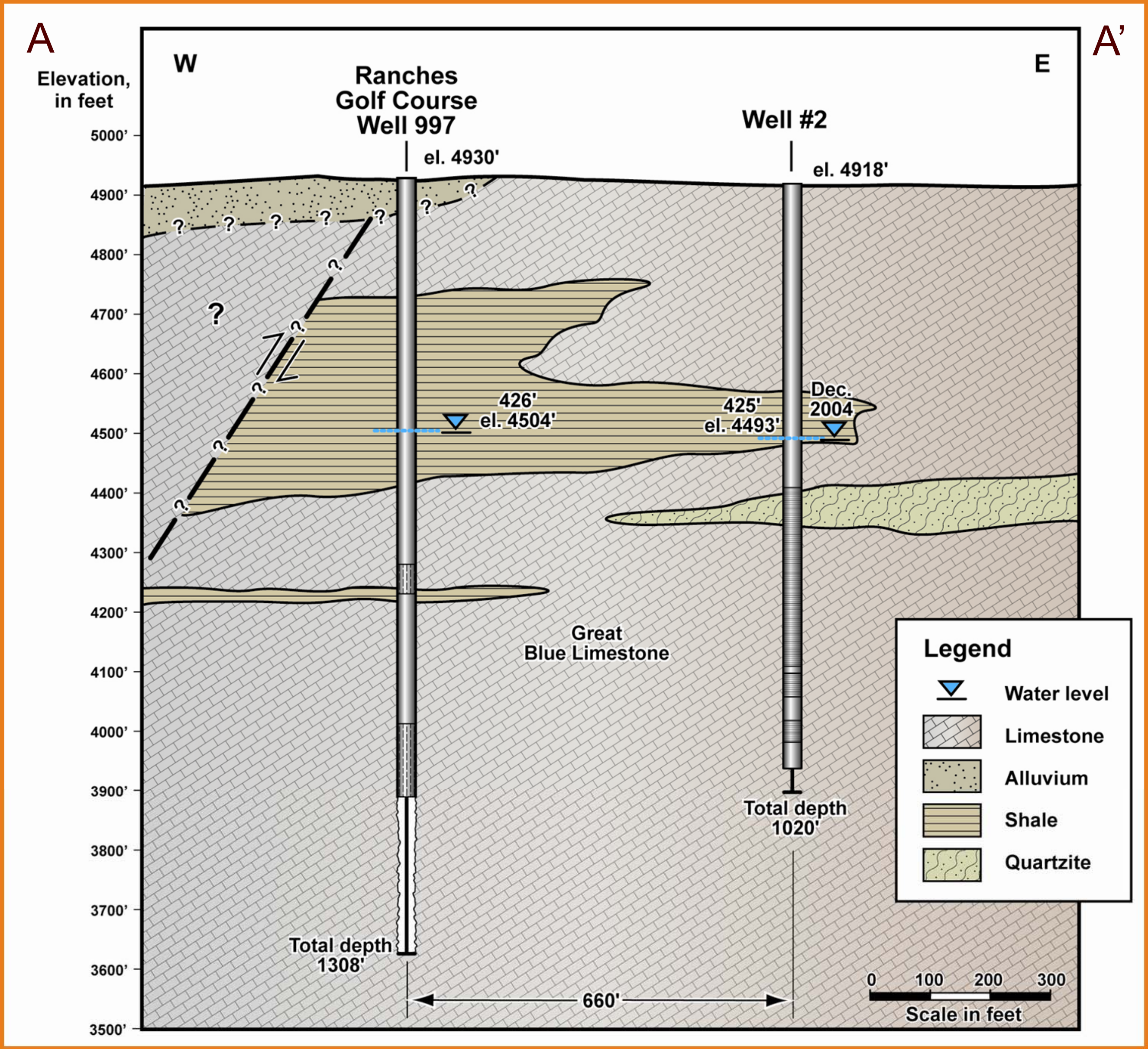

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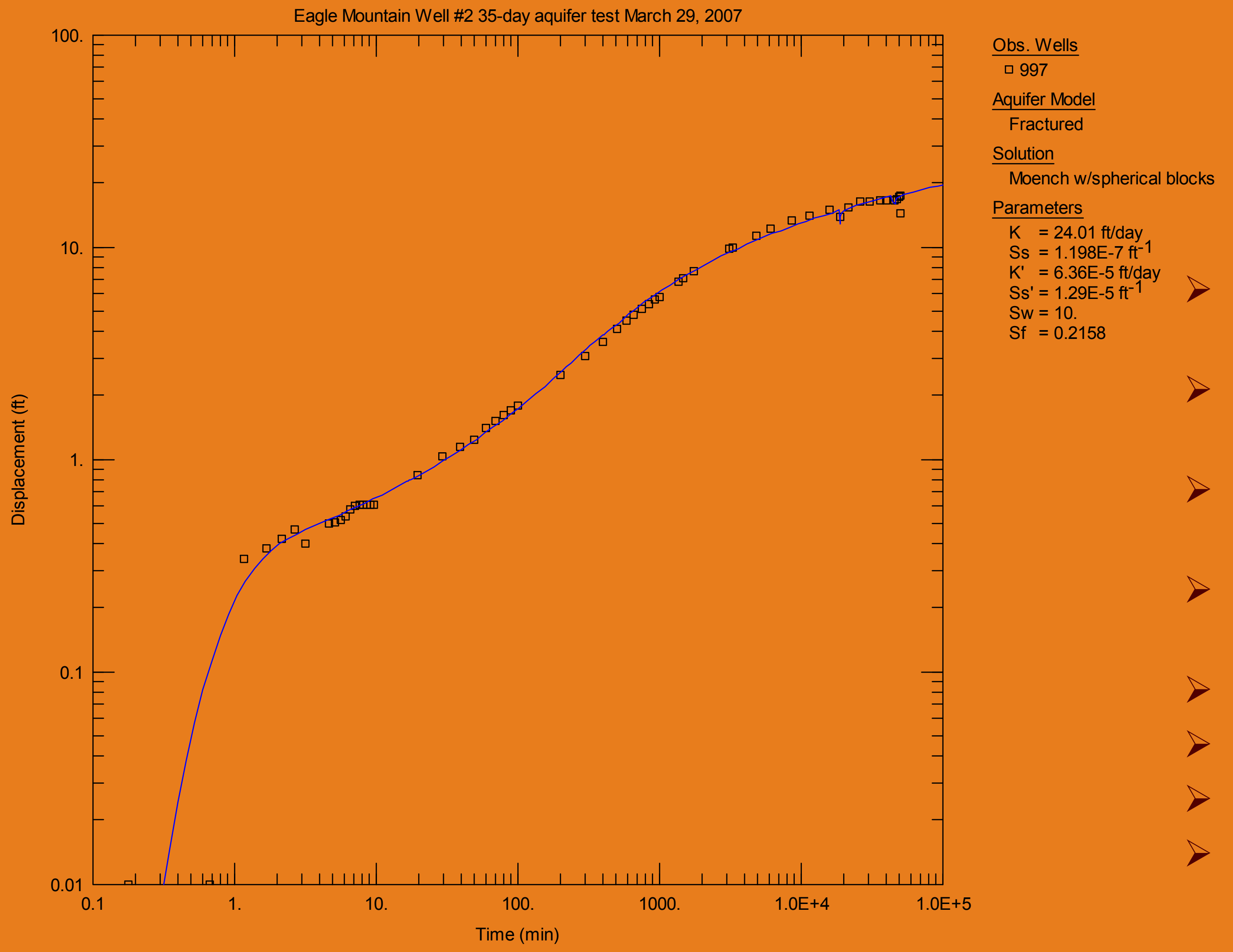
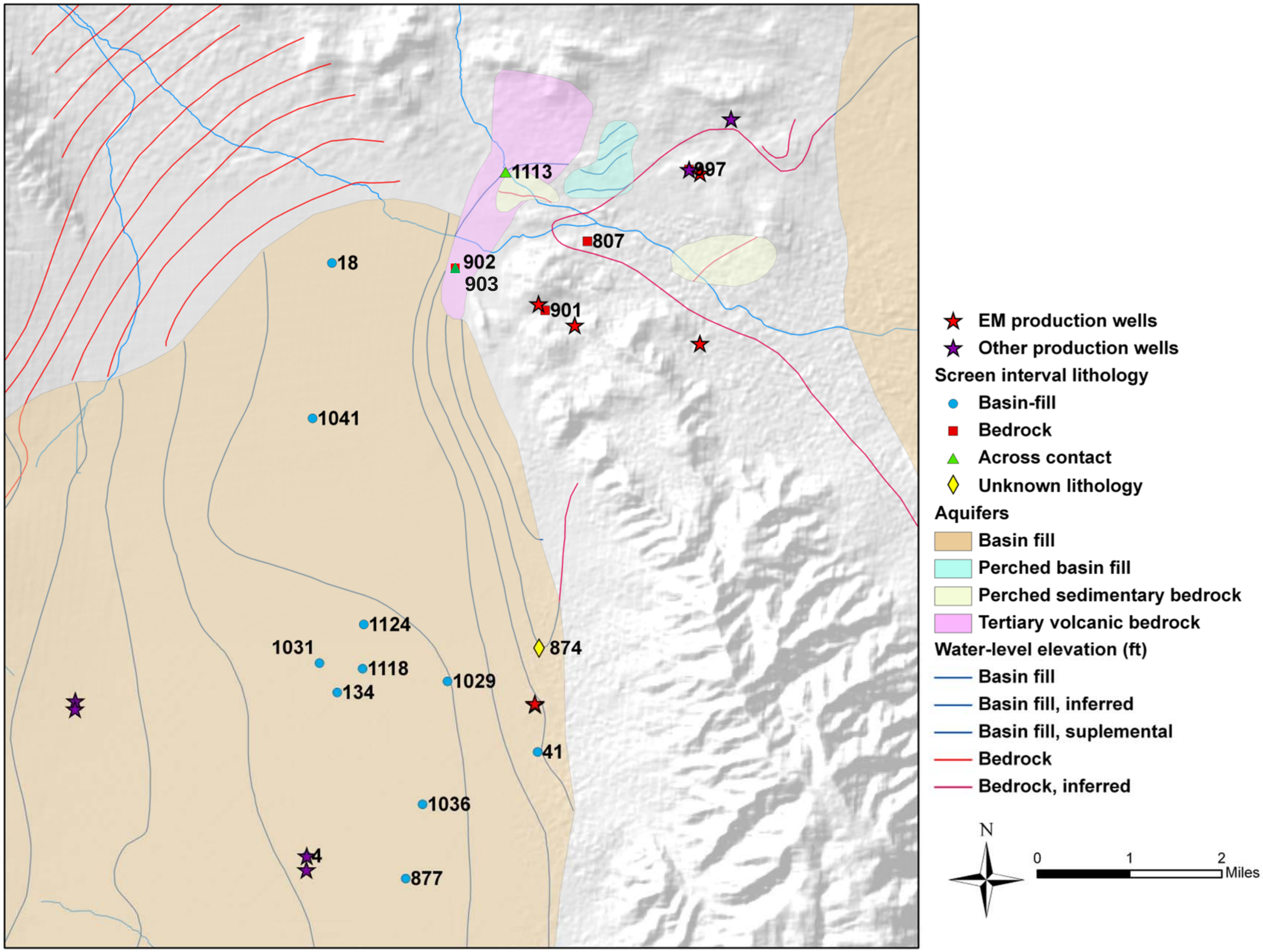
Well #2 test results

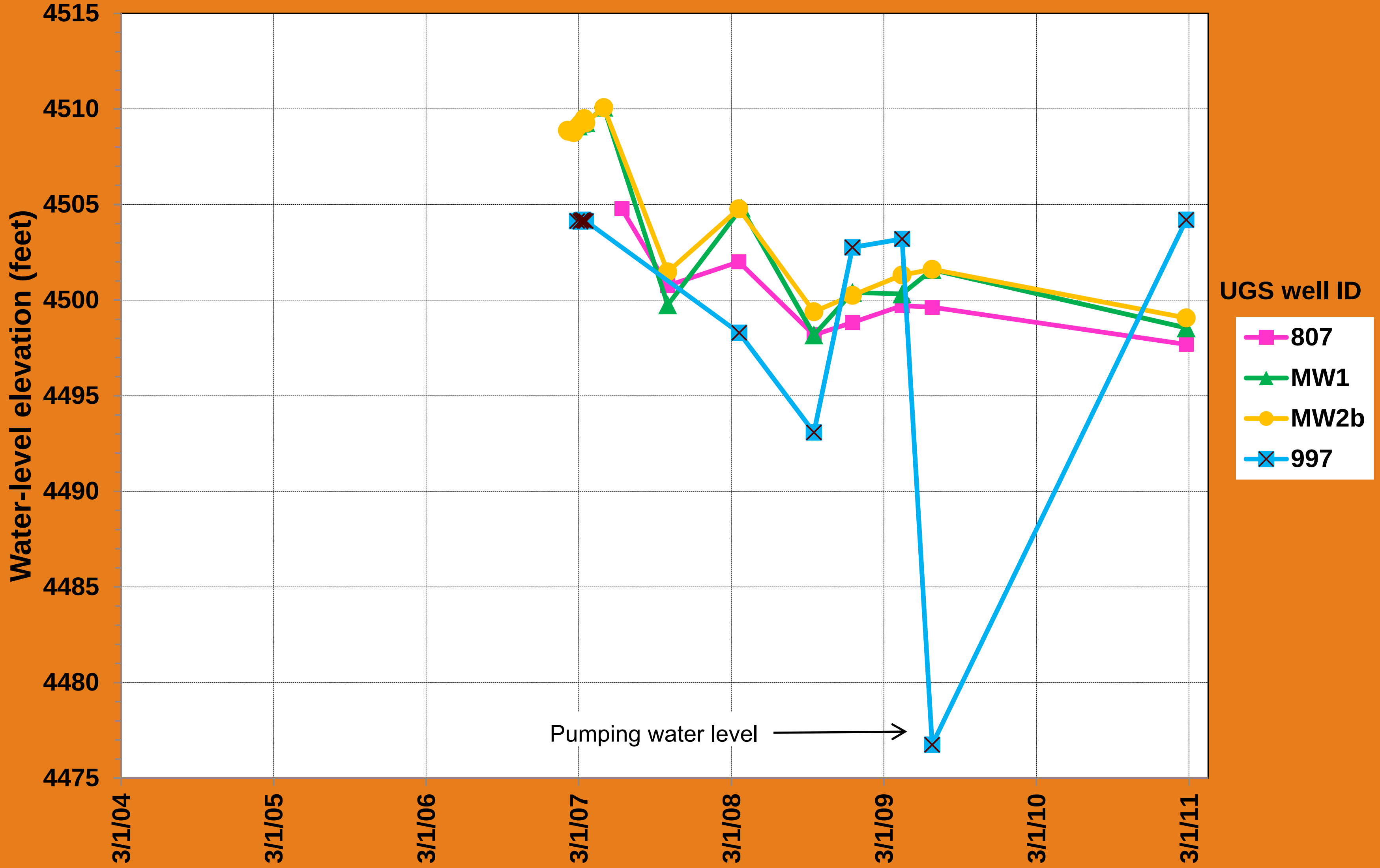


- Max s 660' away = 17.45'
- Good match to fractured solution
- Confined, double porosity system
- K of fractures 10^7 greater than K of blocks
- T = 12,600 ft^2/d
- K = 24 ft/d
- S = $7x10^{-3}$
- No flow boundary at fault

Water-level monitoring locations



Water-level elevation fluctuation in wells monitored for Eagle Mountain: bedrock aquifer at Cedar Pass



Conclusions

- Geologic controls
  - Disposition of geologic units
    - Tv is a “dam”
    - Perched unconsolidated aquifer OK aquifer
    - Basin fill has no outlet other than to move into Paleozoic bedrock aquifer
  - Structure
    - Folds = anisotropy
    - Faults = impediments and conduits
- Slight aquifer depletion?

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Thank you

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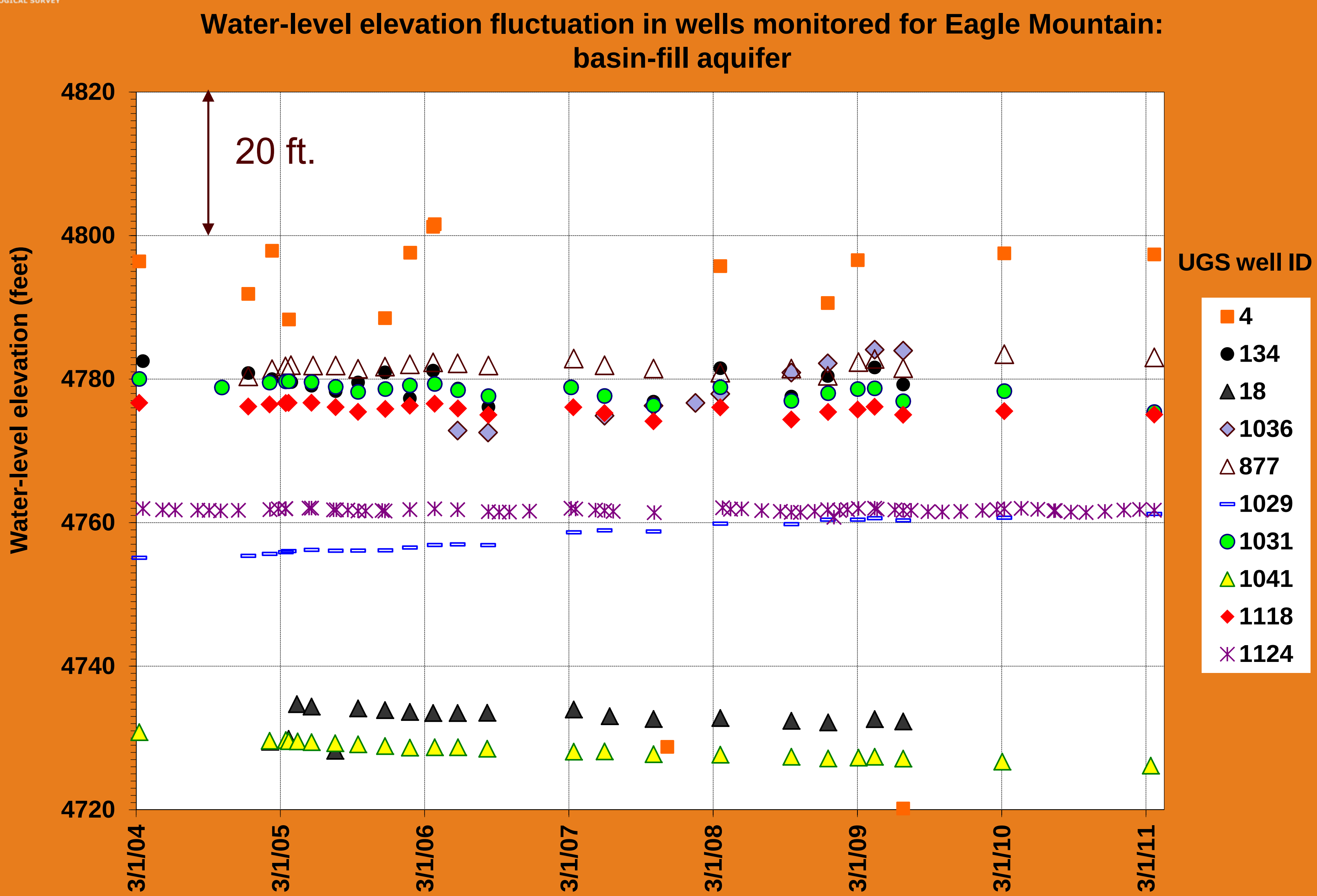

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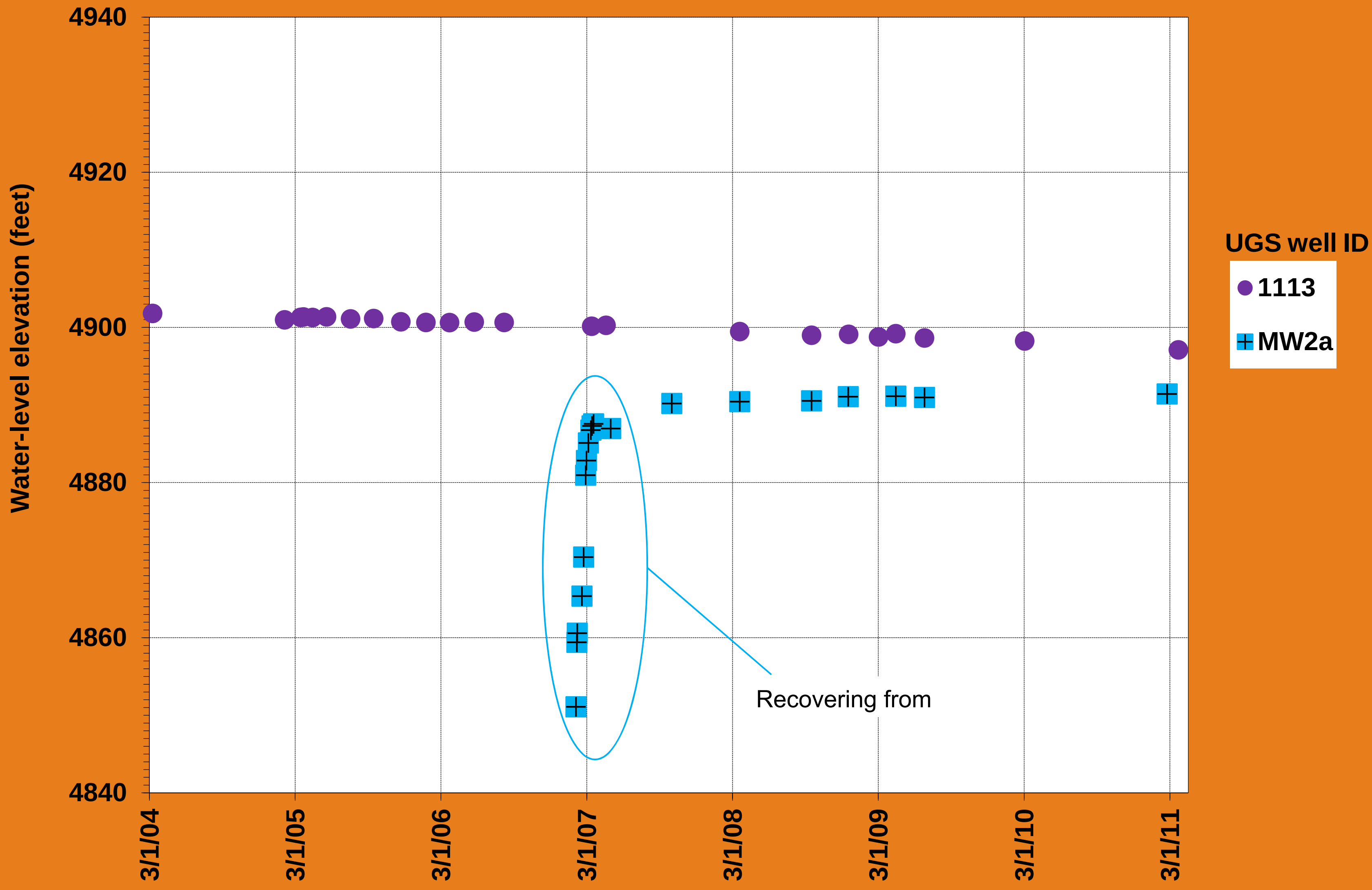
Water-level elevation fluctuation in wells monitored for Eagle Mountain: volcanic rock "aquifer" at Cedar Pass



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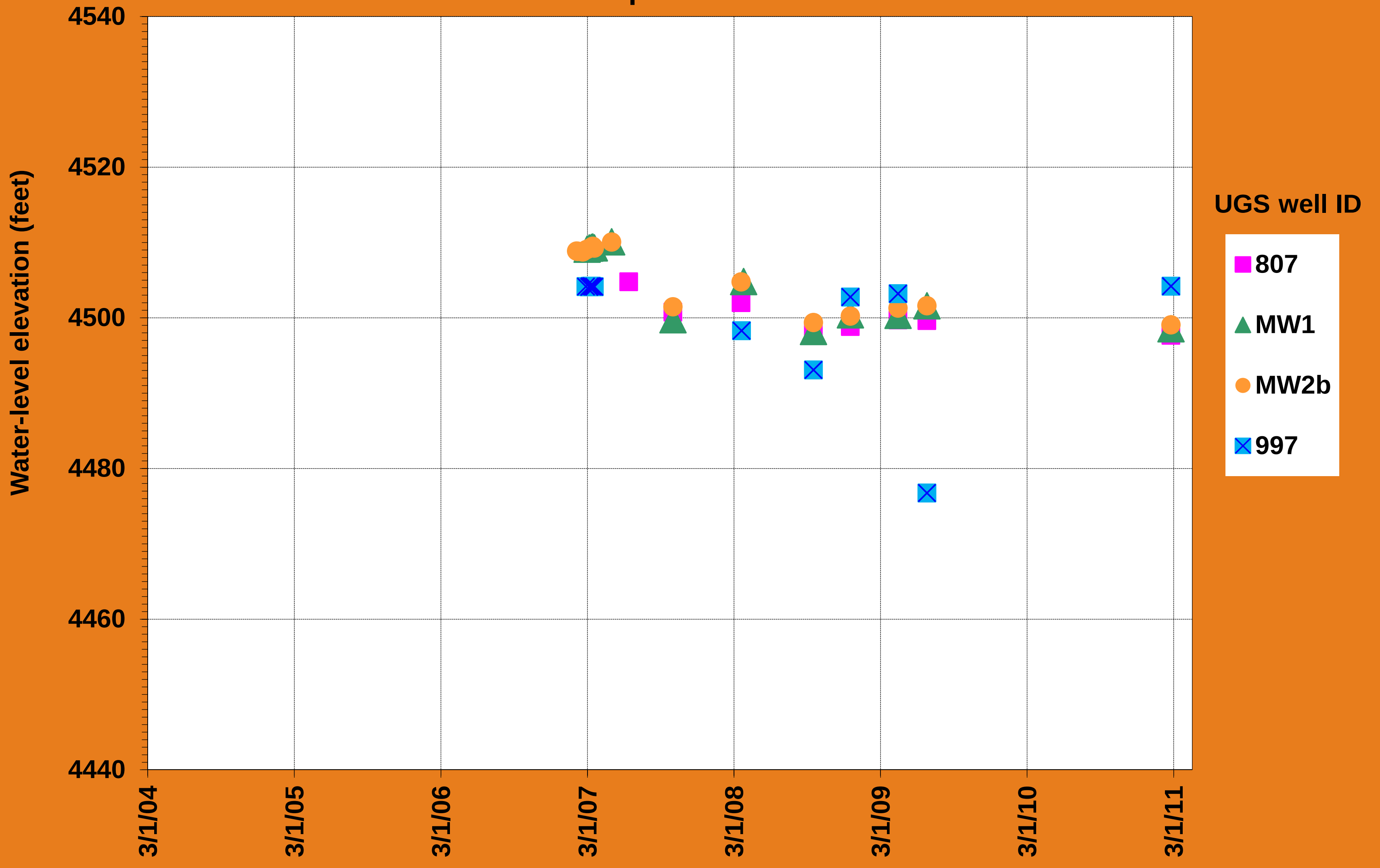

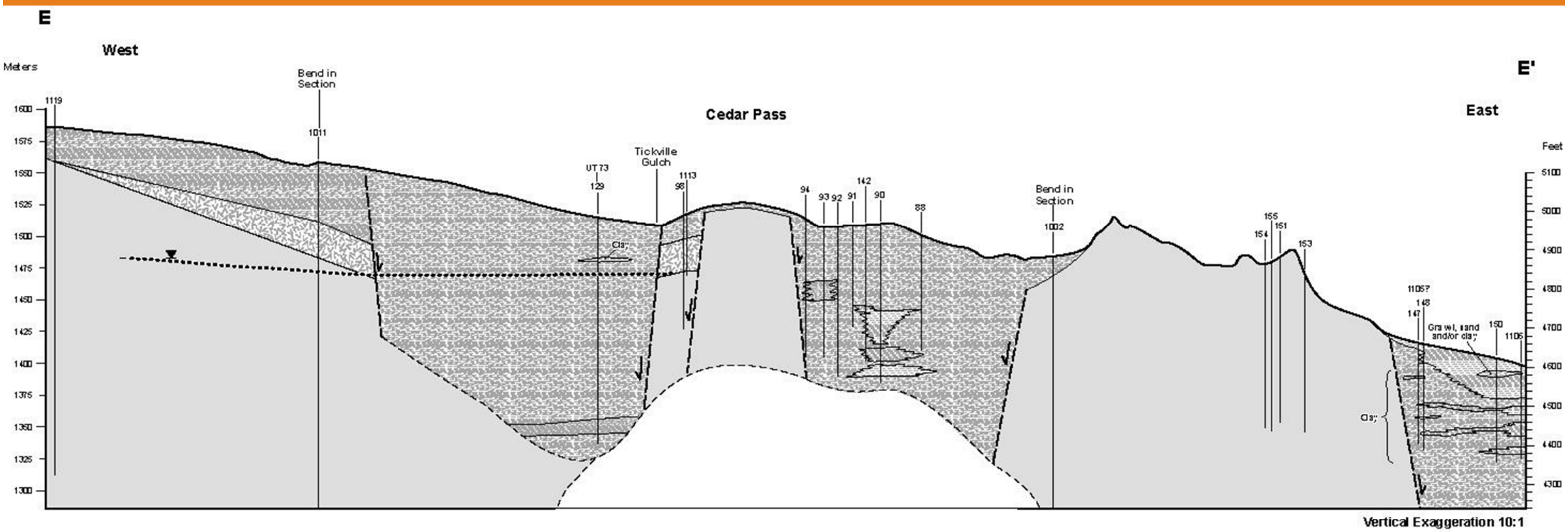

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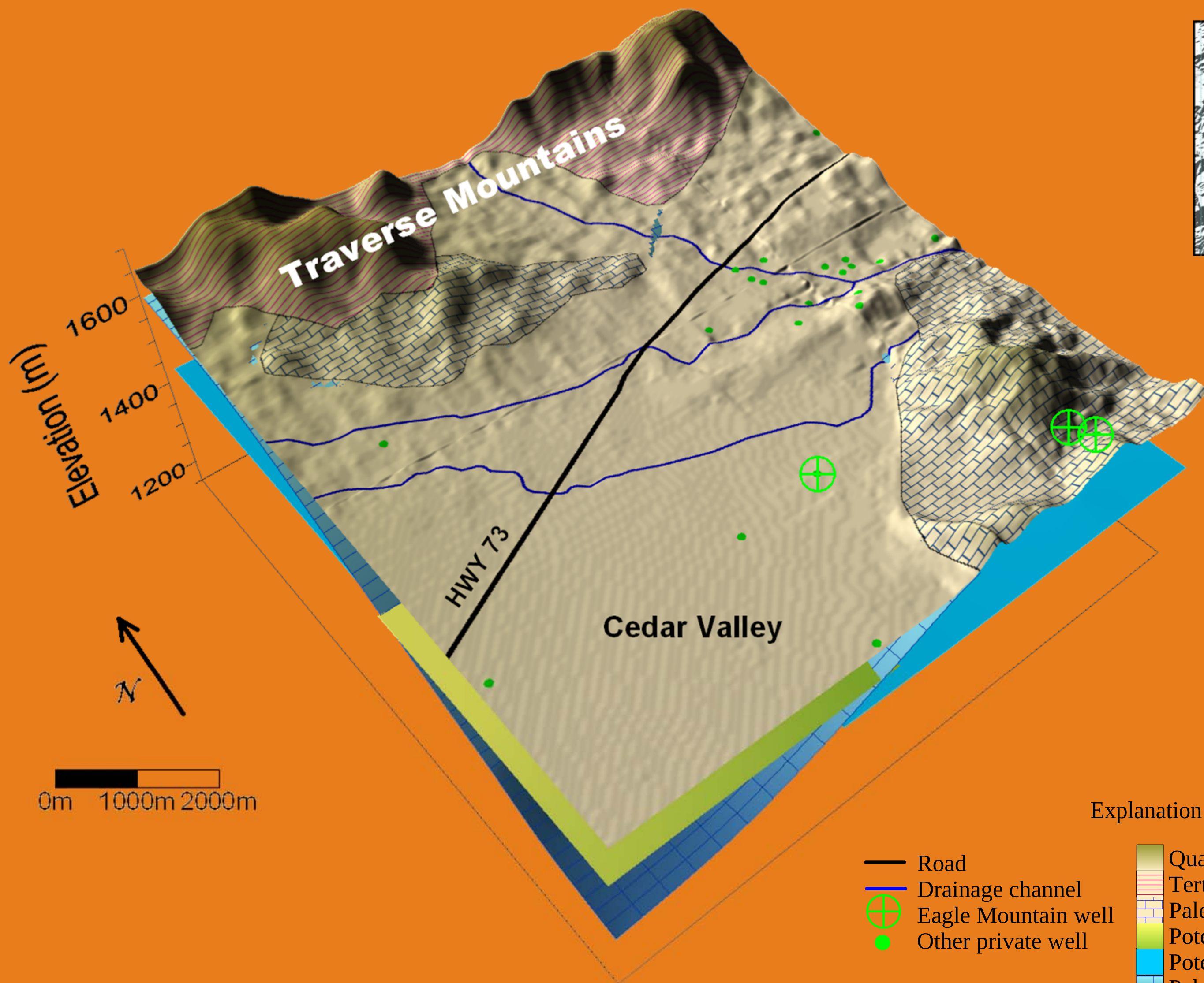
Hyrdrostratigraphy of Cedar Pass area



Explanation

- Road
- Drainage channel
- Eagle Mountain well
- Other private well
- Quaternary basin-fill
- Tertiary volcanic bedrock outcrop
- Paleozoic bedrock outcrop
- Potentiometric surface in basin fill
- Potentiometric surface in Paleozoic bedrock
- Paleozoic bedrock surface

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