Groundwater Resource Monitoring and Characterization in Northern Virginia: A summary of recent and ongoing projects.

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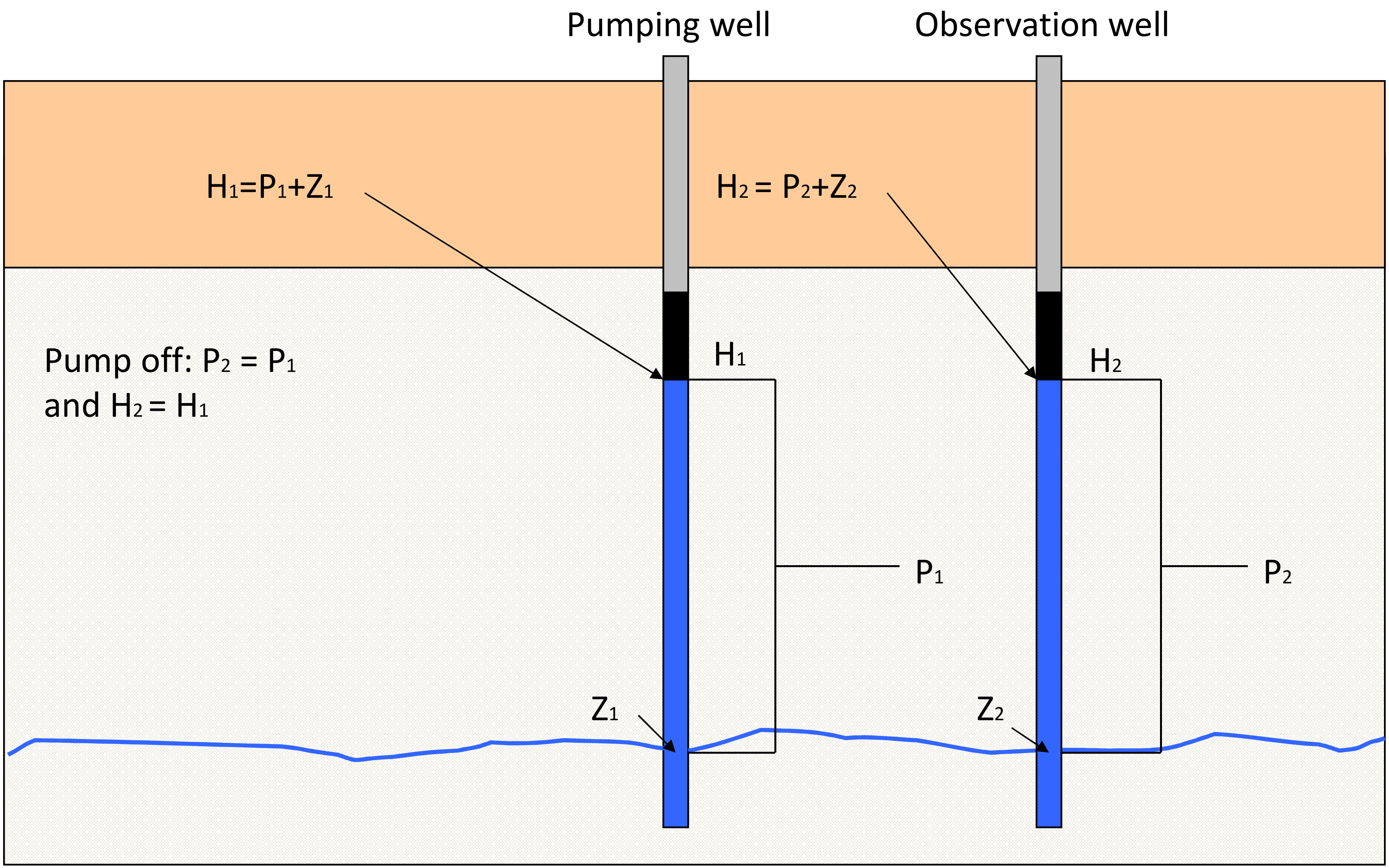
Virginia DEQ Groundwater Characterization Program
January 5, 2018

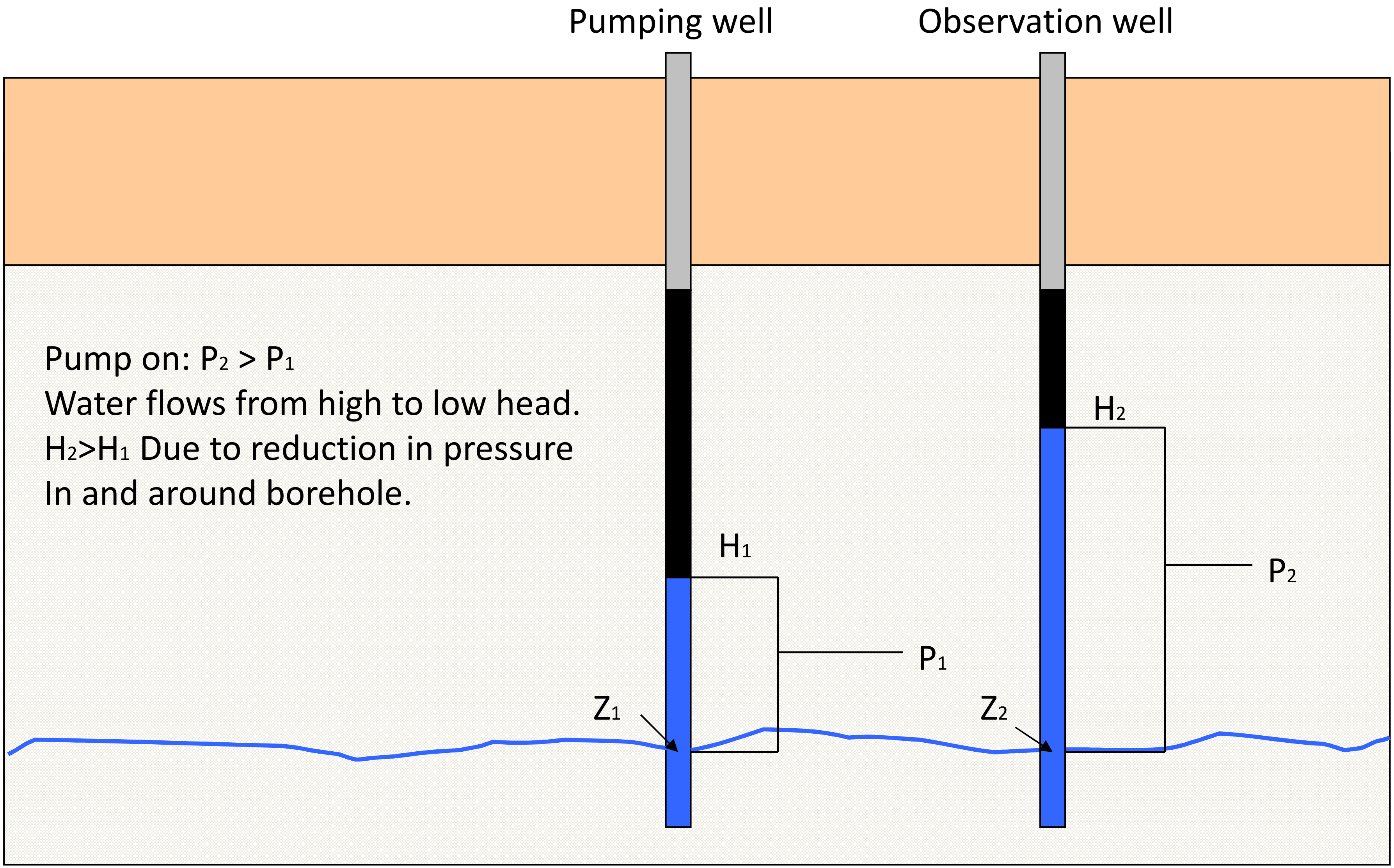
Outline:

- Groundwater 101
- State-Wide Observation Well Network
    - Capabilities
    - Benefits of Historical Data
- A Question of Scale
    - Watershed studies
    - Site studies

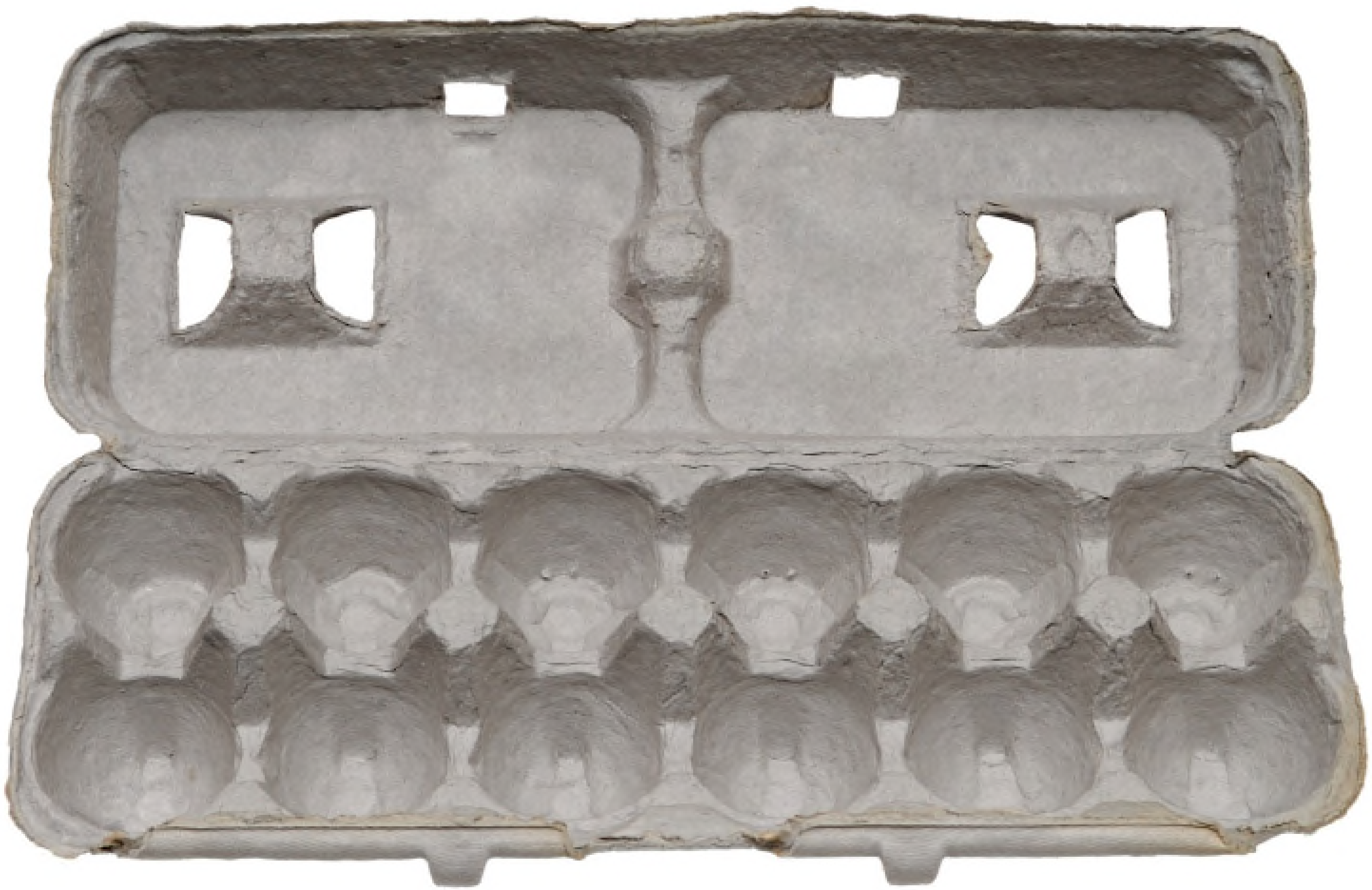
Drilled Wells

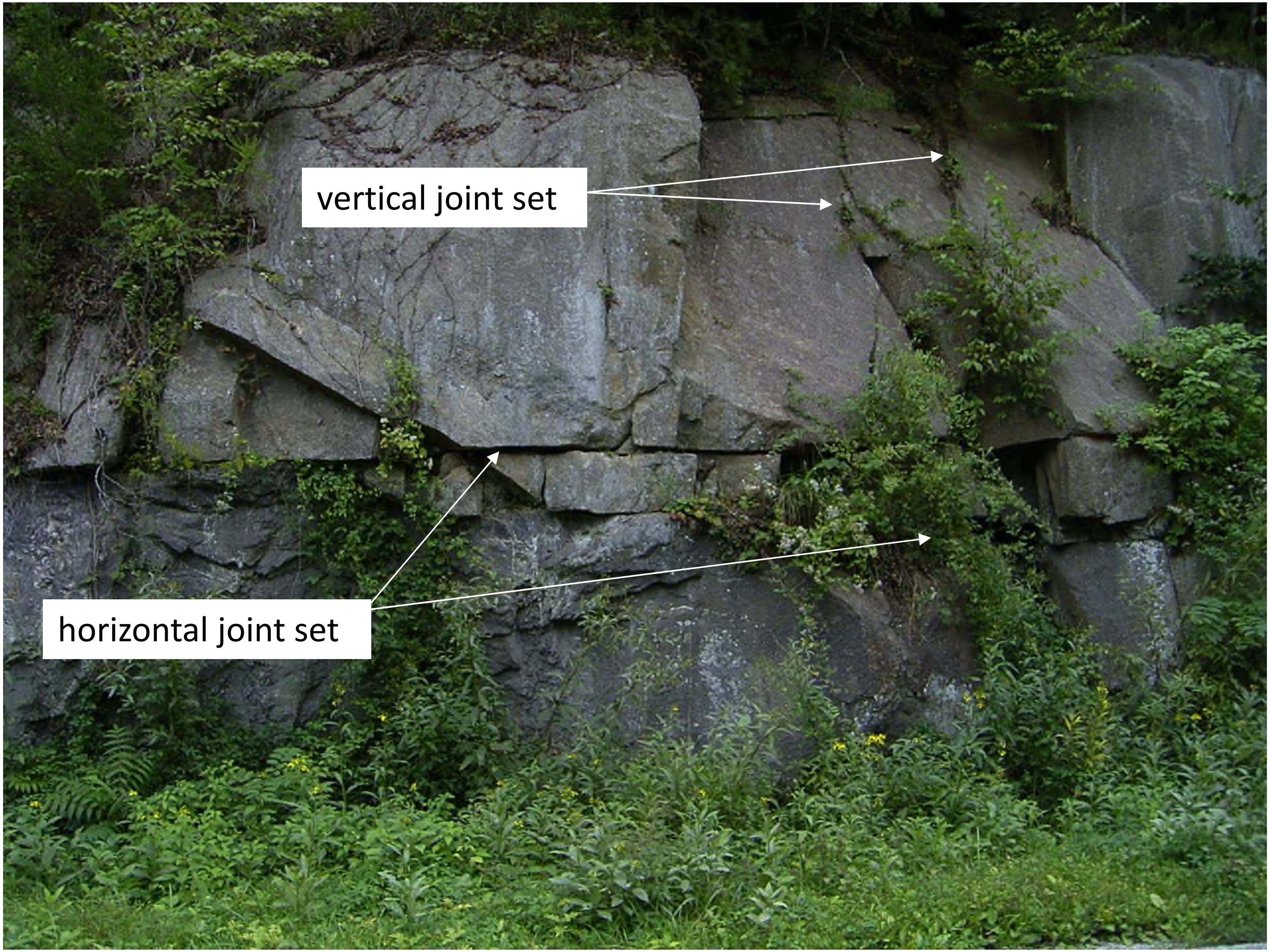


Drilled Wells



What is an Aquifer?




vertical joint set
horizontal joint set

local shear zone fault plane
-possible pathway for
ground water recharge

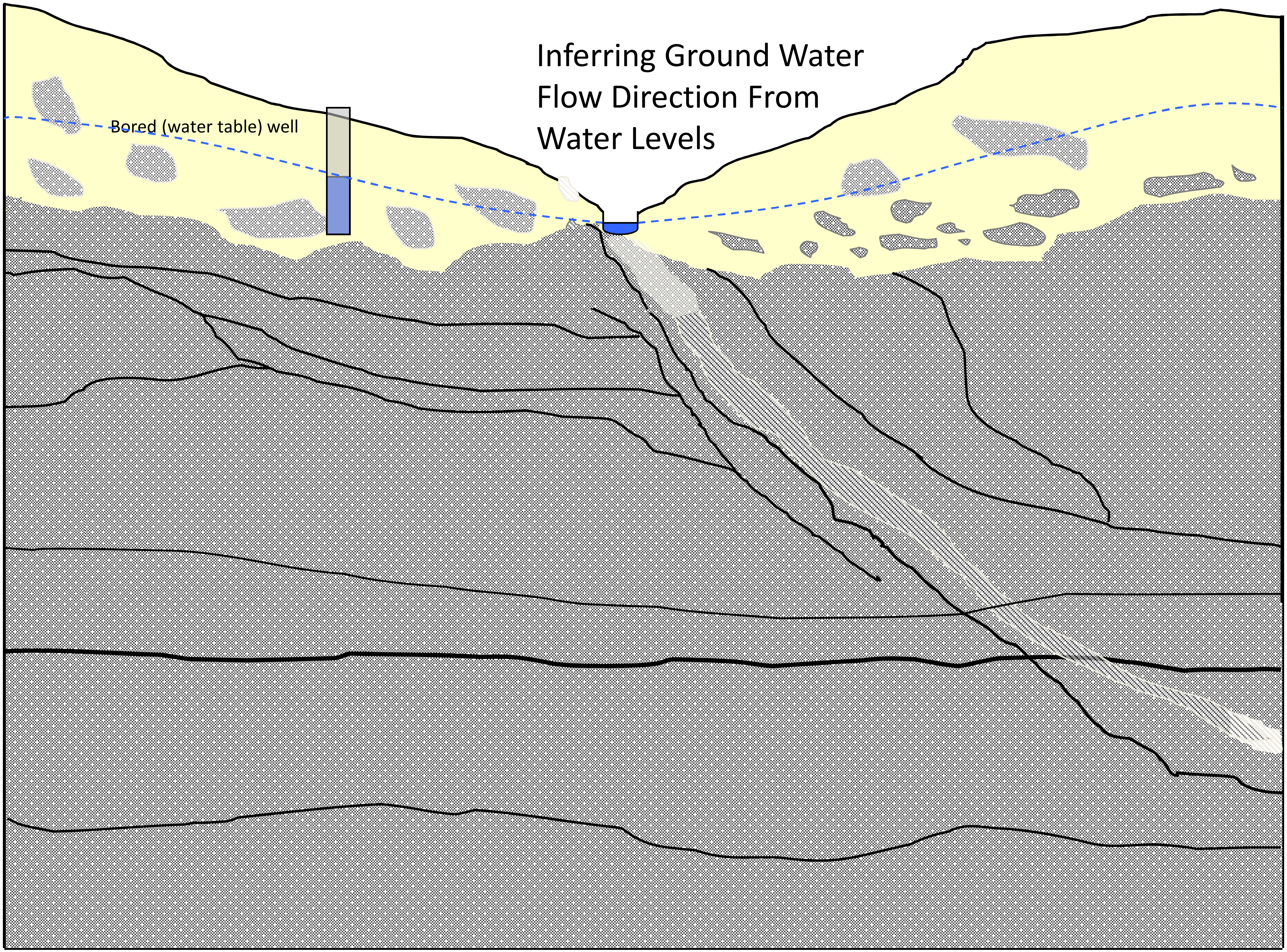
Conduit – can form along pre-existing fractures or bedding planes in carbonate rock (limestone).

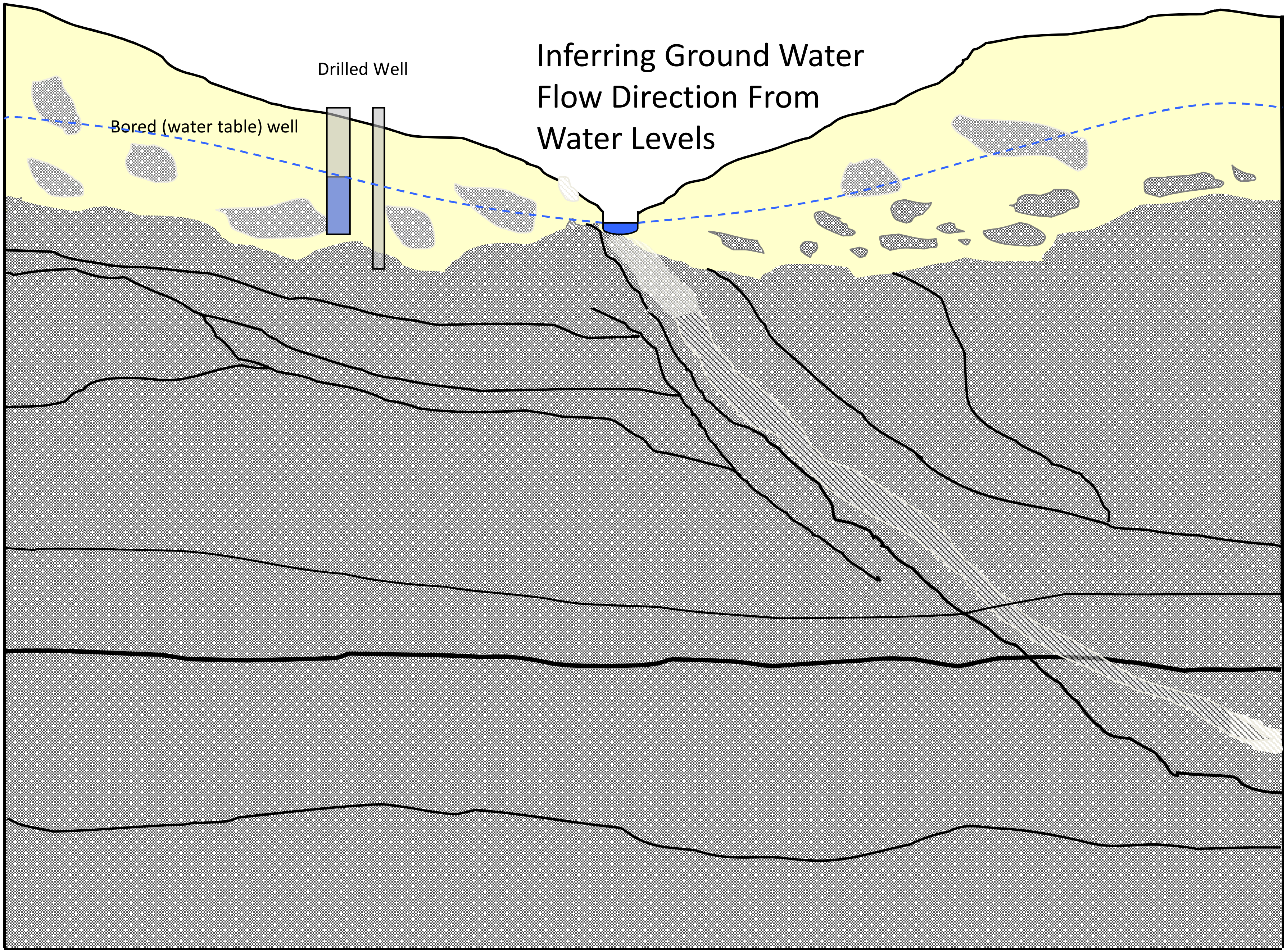
What is an Aquifer?

- Discrete network of fractures blanketed by porous media. Storage in fractures ultimately replenished by recharge from:
  - regolith (soil and weathered bedrock)…most common
  - surface water feature
  - direct input

Ground Water Flow Systems in Fractured Rock

- Porous Flow
  - restricted to the saturated portions of the regolith (soil and saprolite overlying bedrock)
  - flow is generally unconfined and gravity driven (differences in elevation)
- Fracture Flow
  - occurs in openings of the bedrock underlying the regolith
  - flow is generally confined and driven by pressure gradients and differences in elevation
- Conduit Flow
  - occurs in solutionally enlarged openings in bedrock
  - restricted to carbonate rock
  - can be confined or unconfined


Inferring Ground Water Flow Direction From Water Levels
Bored (water table) well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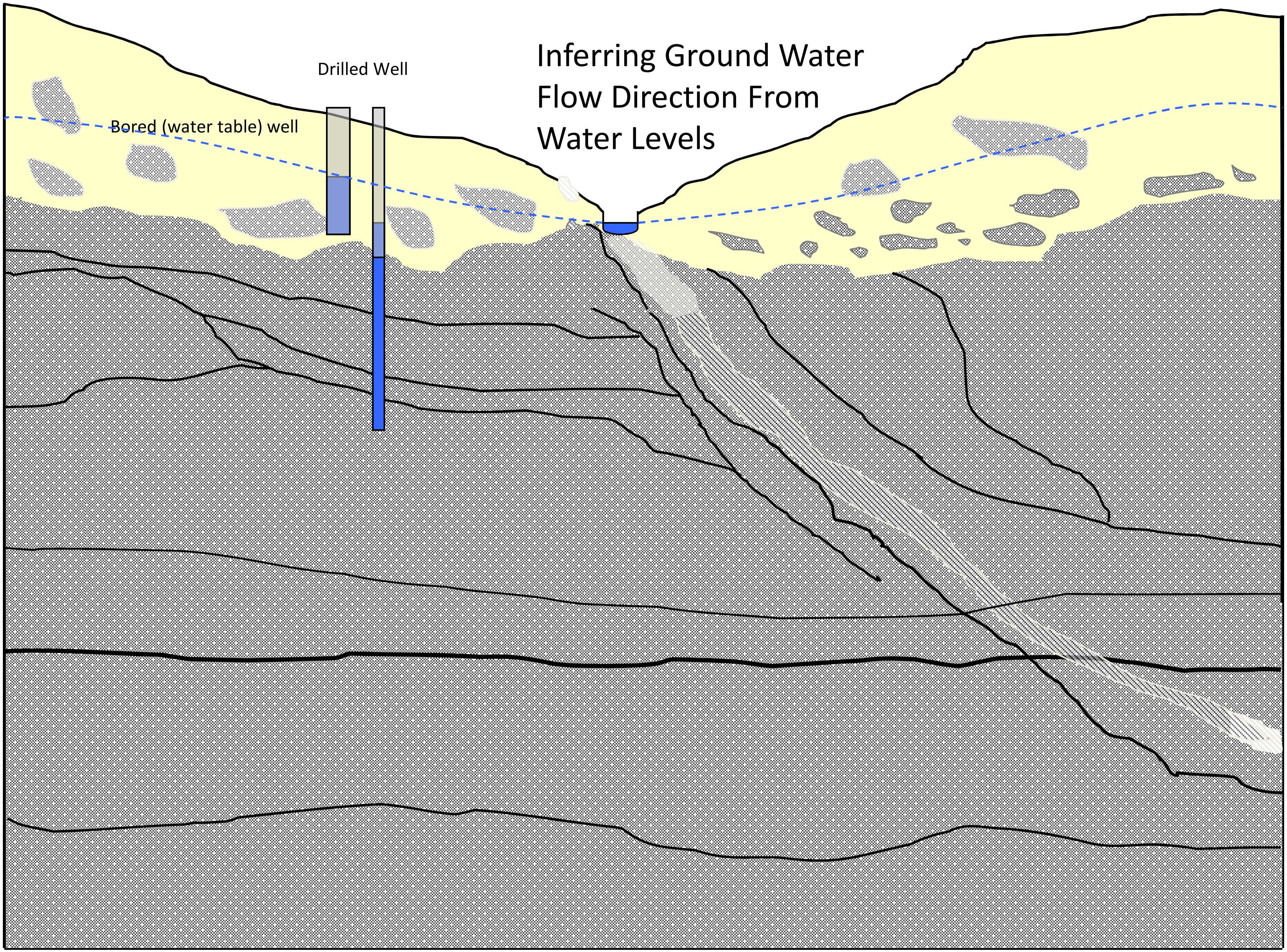
Inferring Ground Water Flow Direction From Water Levels
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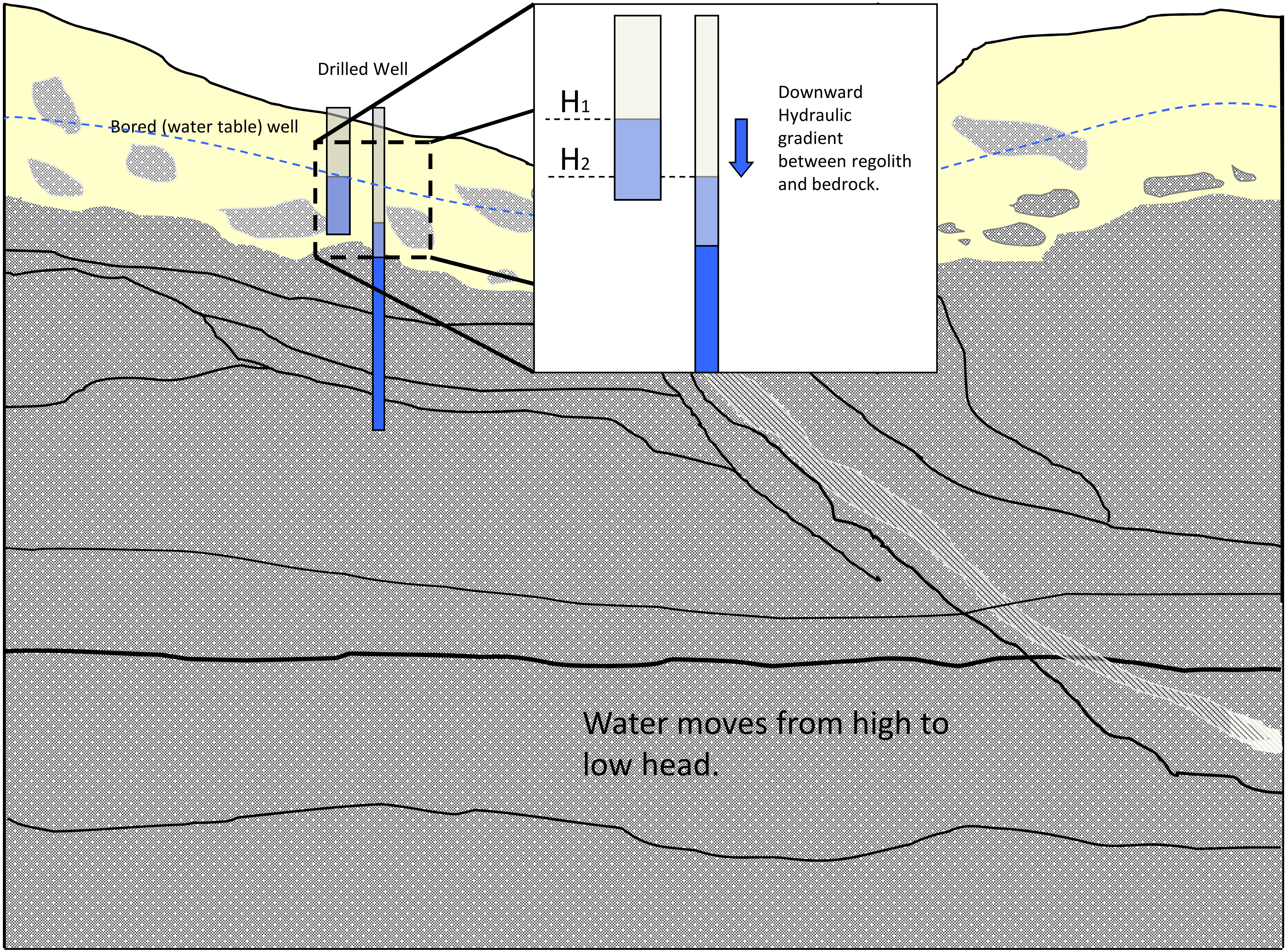
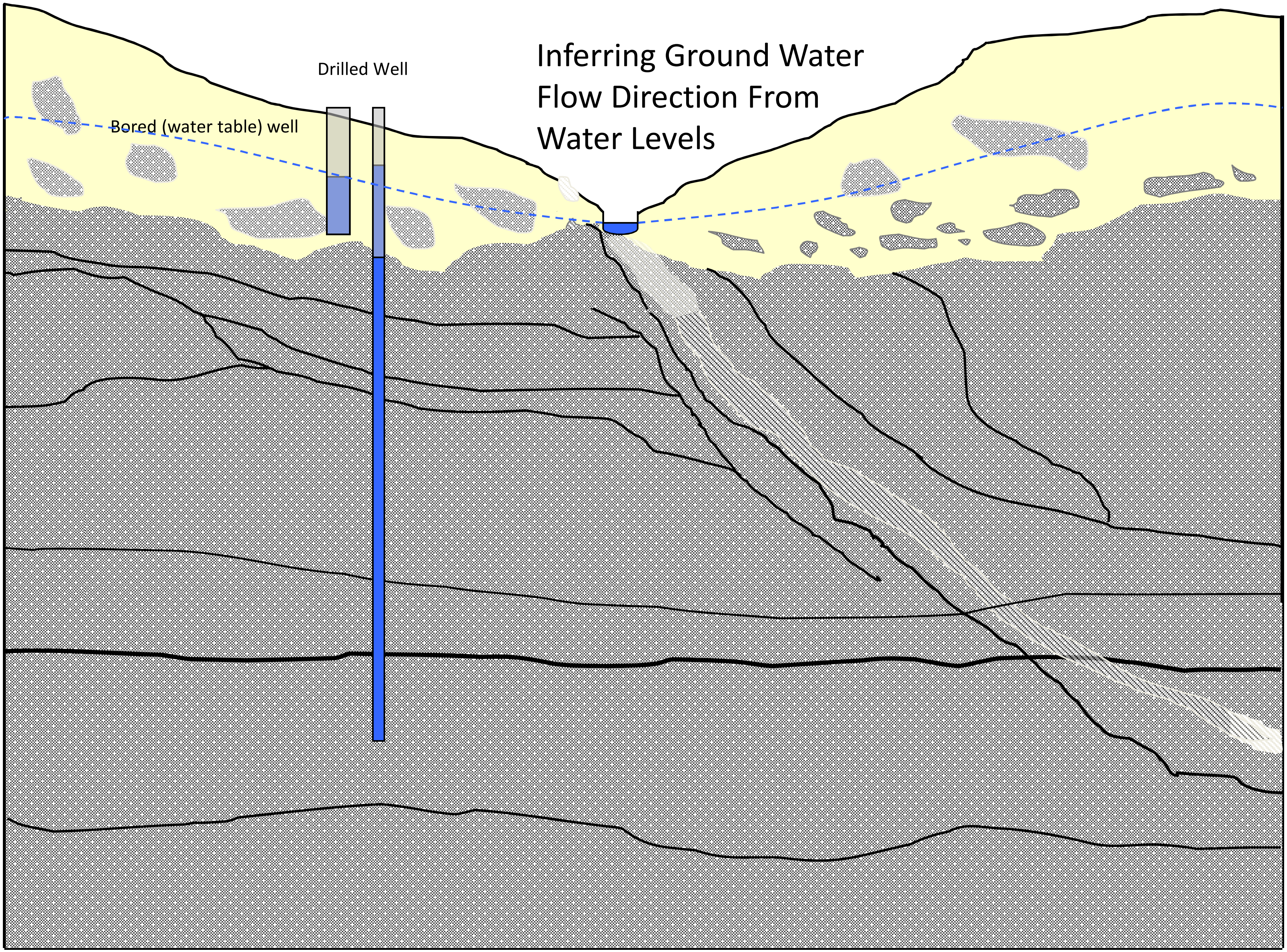
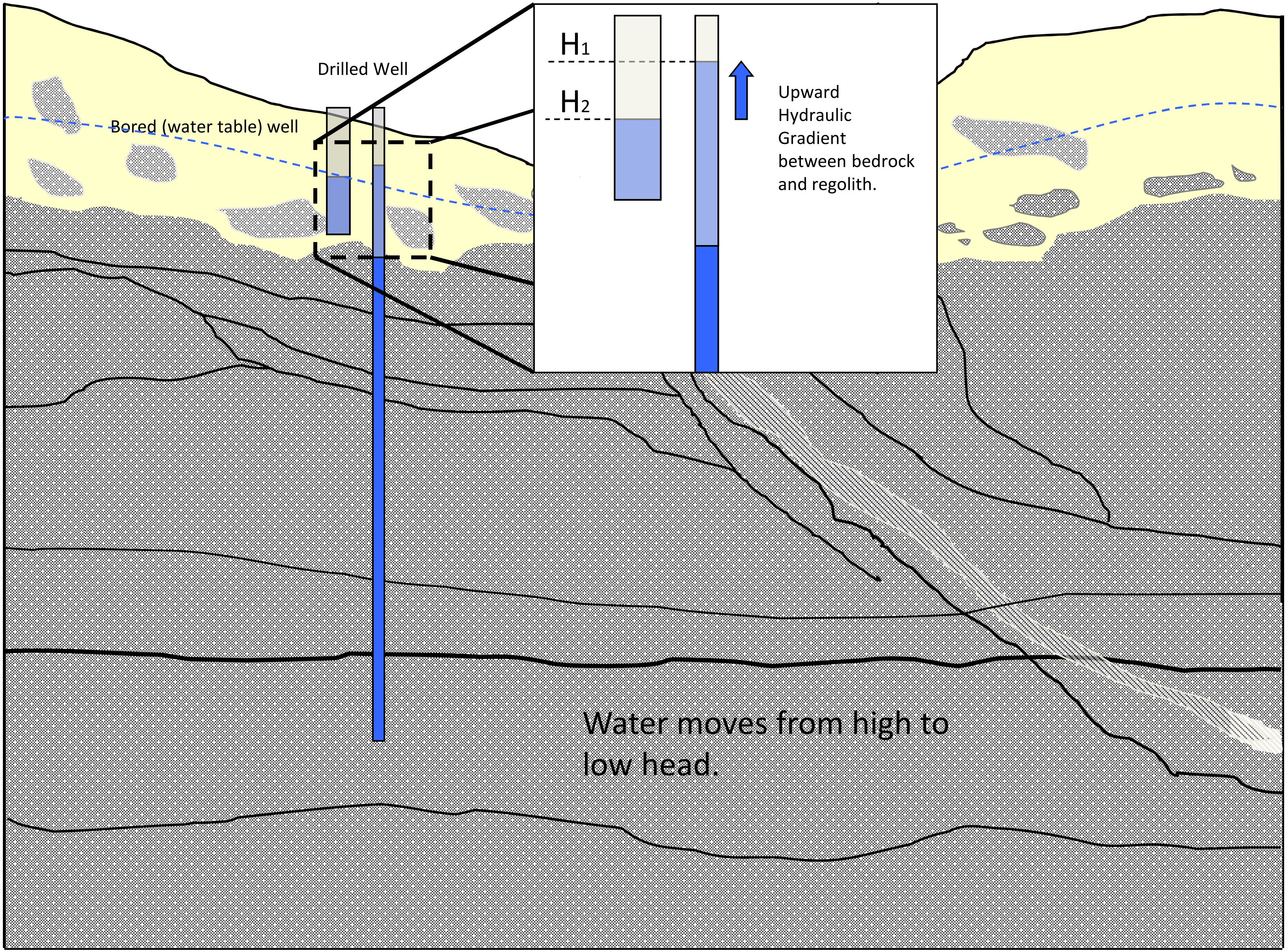

Drilled Well
Bored (water table) well
H1
H2
Downward Hydraulic gradient between regolith and bedrock.
Water moves from high to low head.

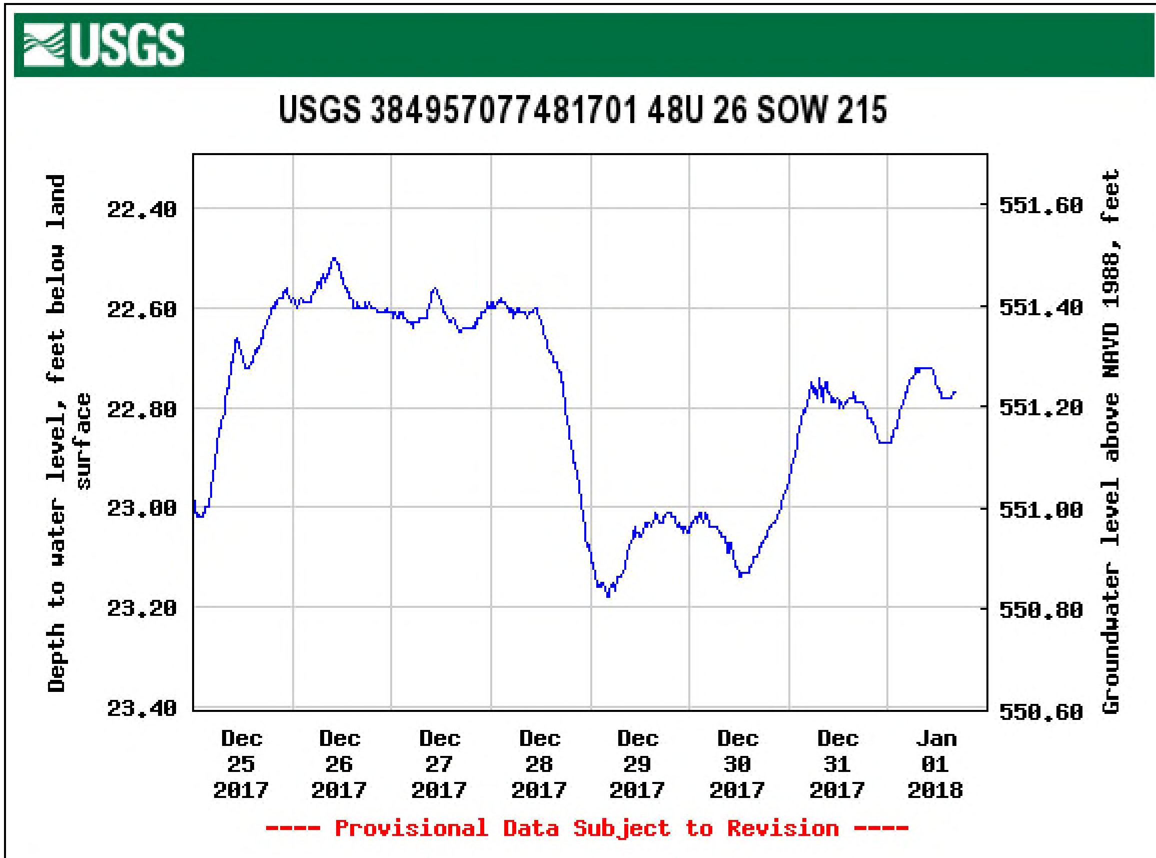
Inferring Ground Water Flow Direction From Water Levels

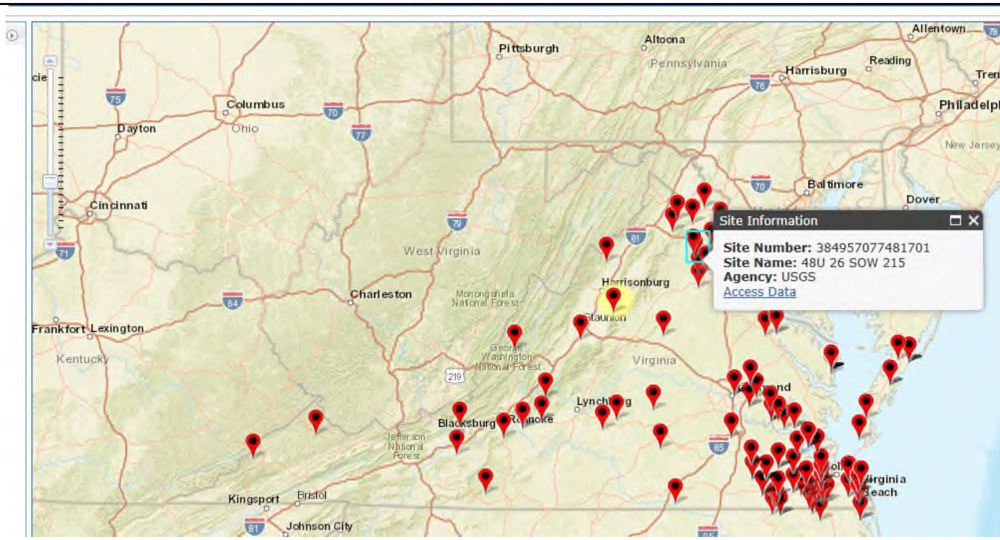


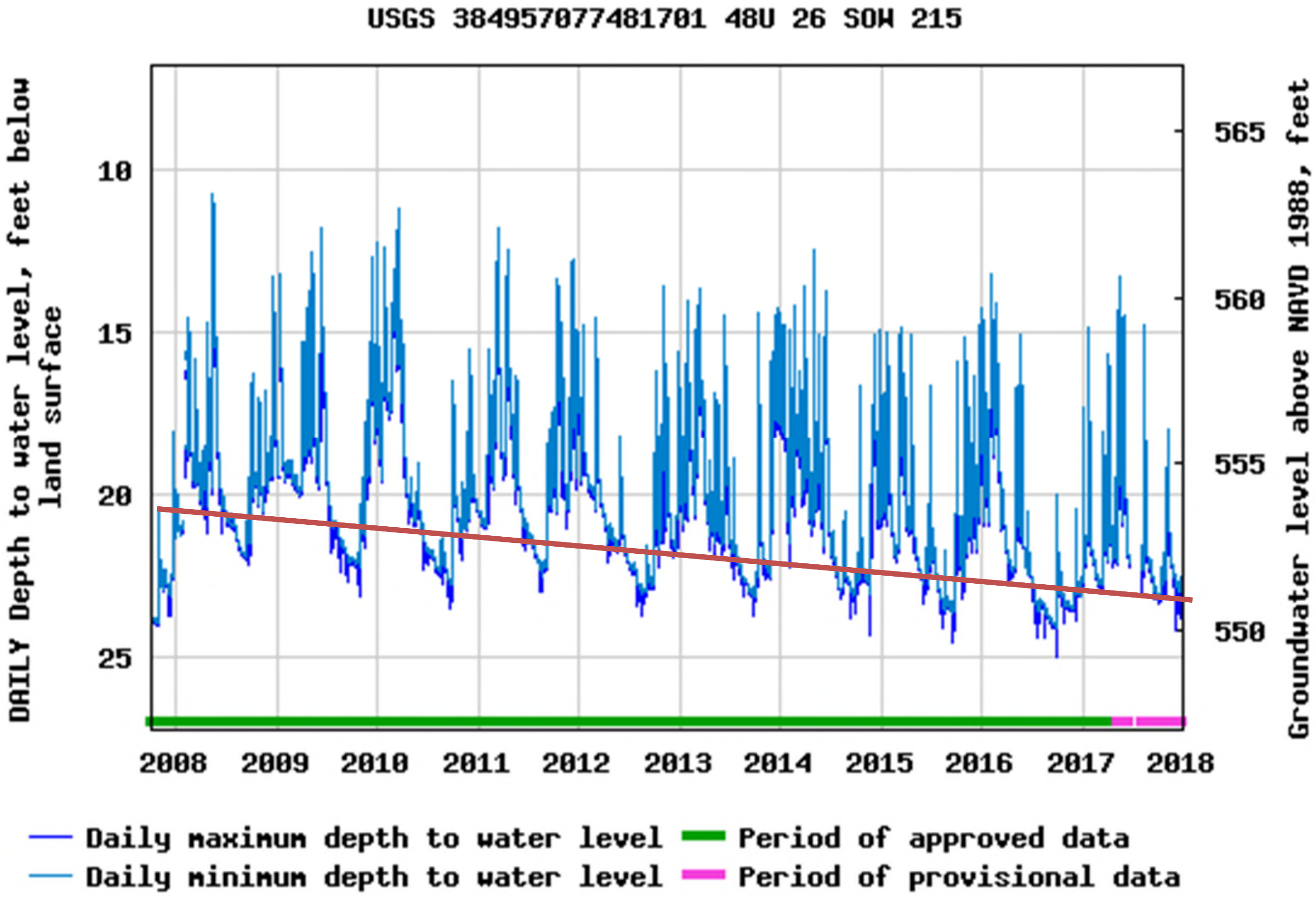

Drilled Well
Bored (water table) well
H1
H2
Upward Hydraulic Gradient between bedrock and regolith.
Water moves from high to low head.

State Observation Well Network

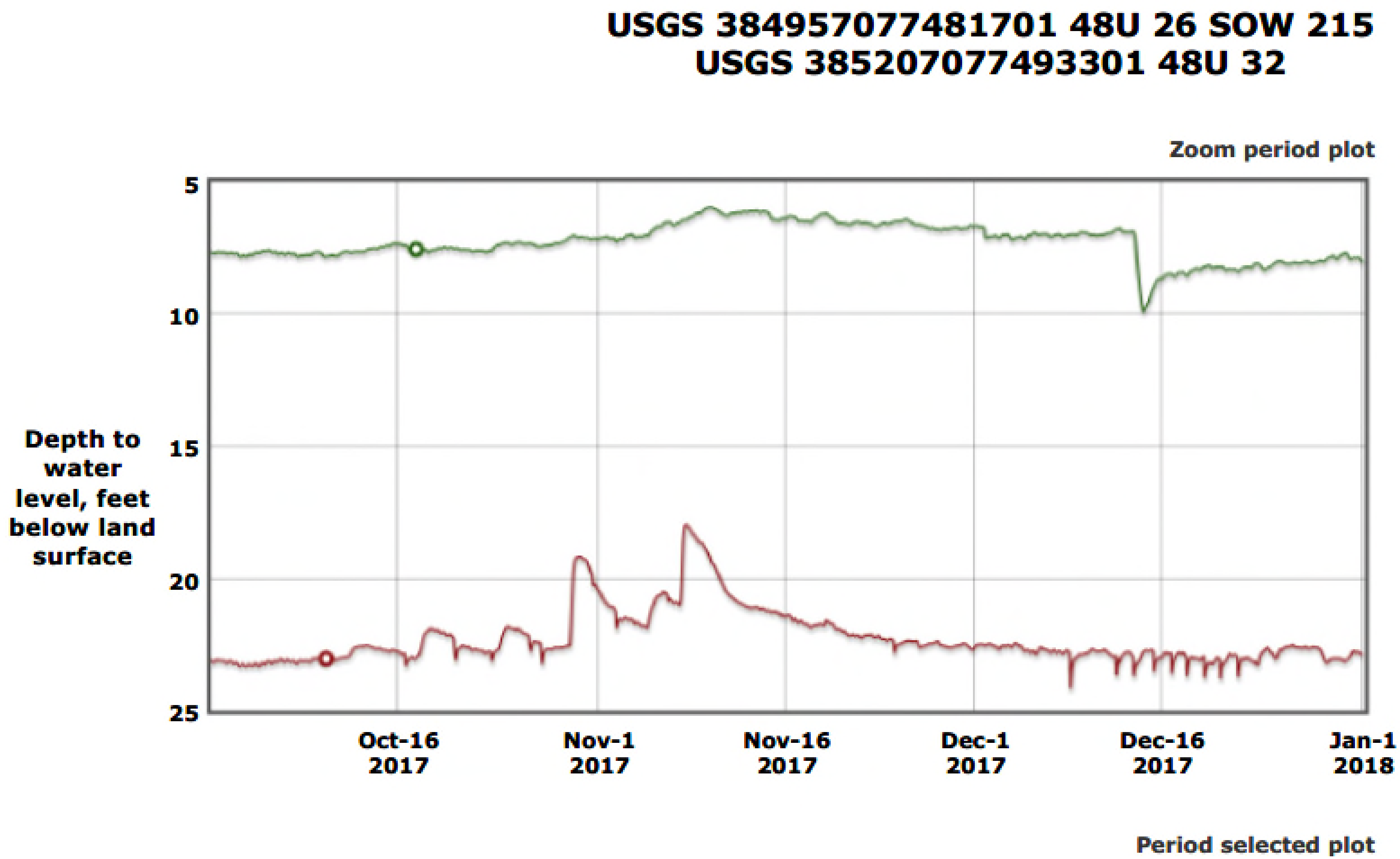
https://waterdata.usgs.gov/va/nwis



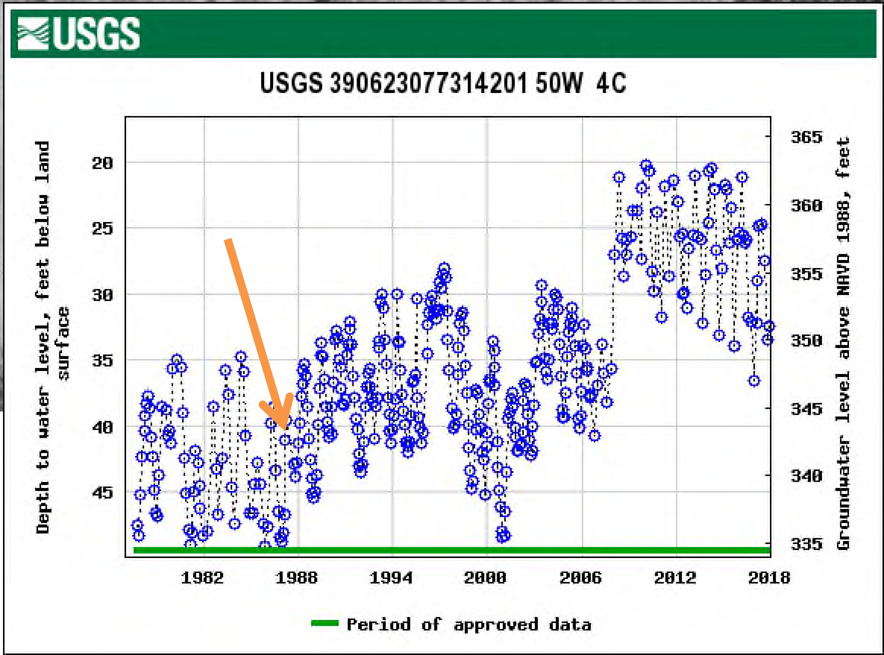




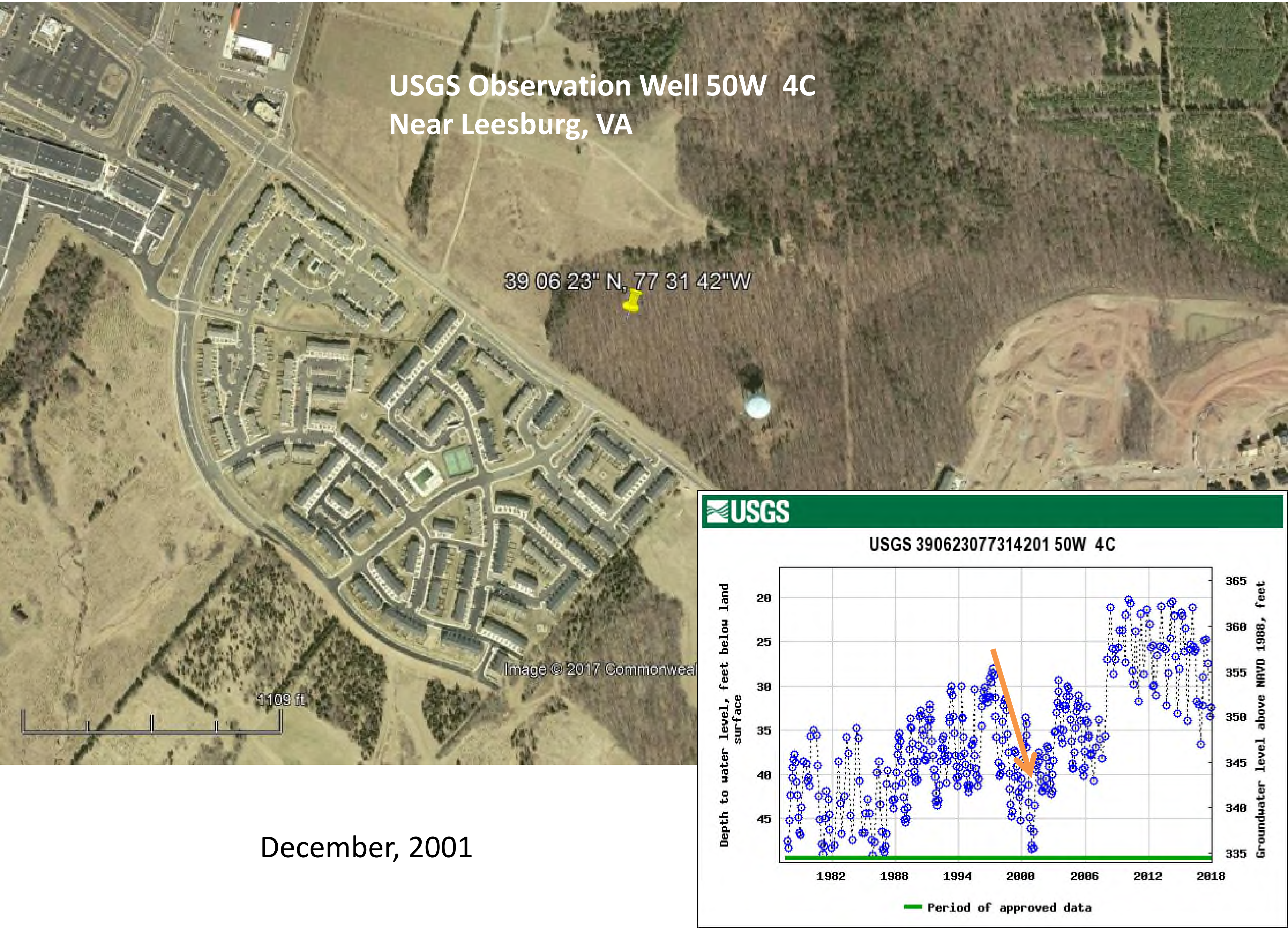
USGS 384957077481701 48U 26 SOW 215
DAILY Depth to water level, feet below land surface
10
15
20
25
Groundwater level above NAVD 1988, feet
565
560
555
550
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Daily maximum depth to water level
Daily minimum depth to water level
Period of approved data
Period of provisional data


USGS 384957077481701 48U 26 SOW 215
USGS 385207077493301 48U 32
Zoom period plot
Depth to water level, feet below land surface
5
10
15
20
25
Oct-16 2017
Nov-1 2017
Nov-16 2017
Dec-1 2017
Dec-16 2017
Jan-1 2018
Period selected plot

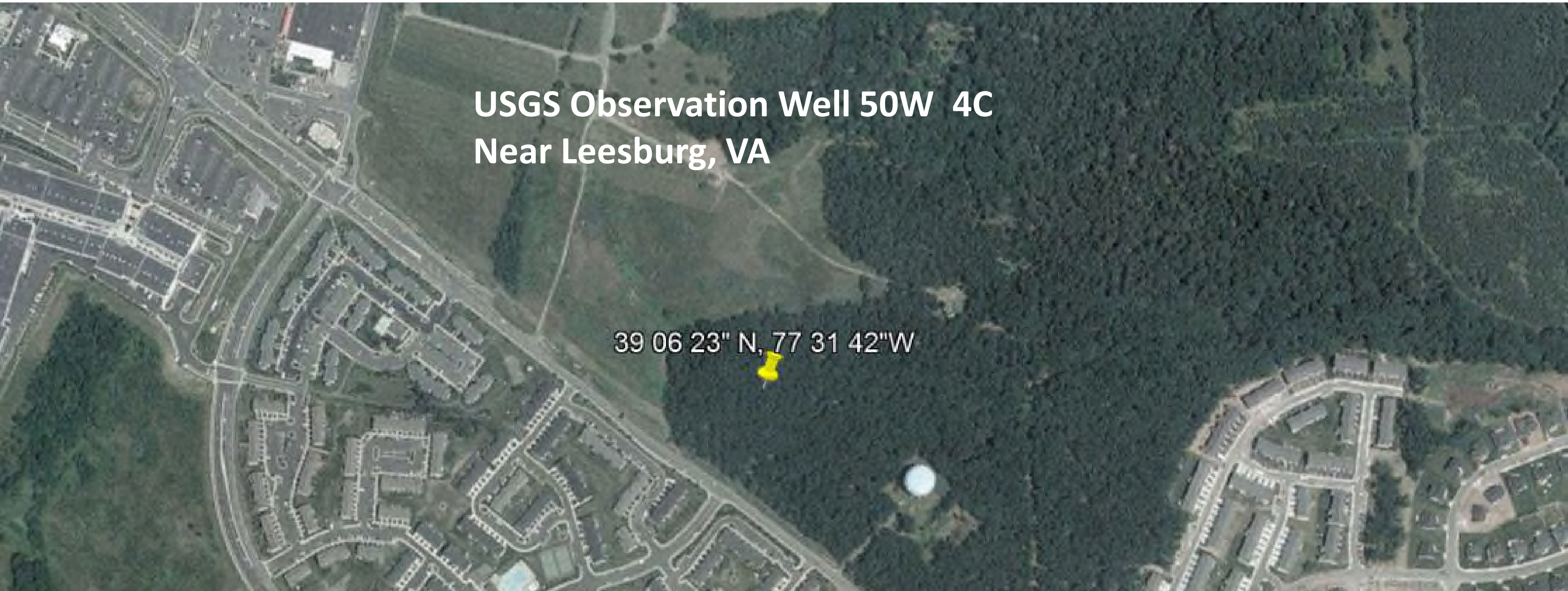

USGS Observation Well 50W 4C
Near Leesburg, VA
39 06 23" N, 77 31 42"W
Image U.S. Geological
1109 ft

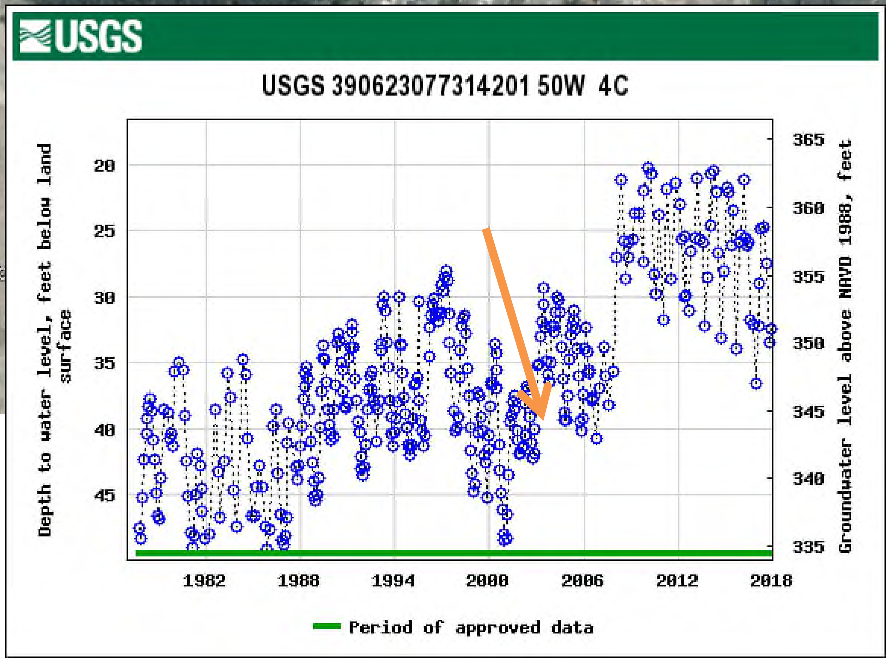

USGS
USGS 390623077314201 50W 4C
Depth to water level, feet below land surface
20
25
30
35
40
45
Groundwater level above NAVD 1988, feet
365
360
355
350
345
340
335
1982
1988
1994
2000
2006
2012
2018
Period of approved data

April, 1988

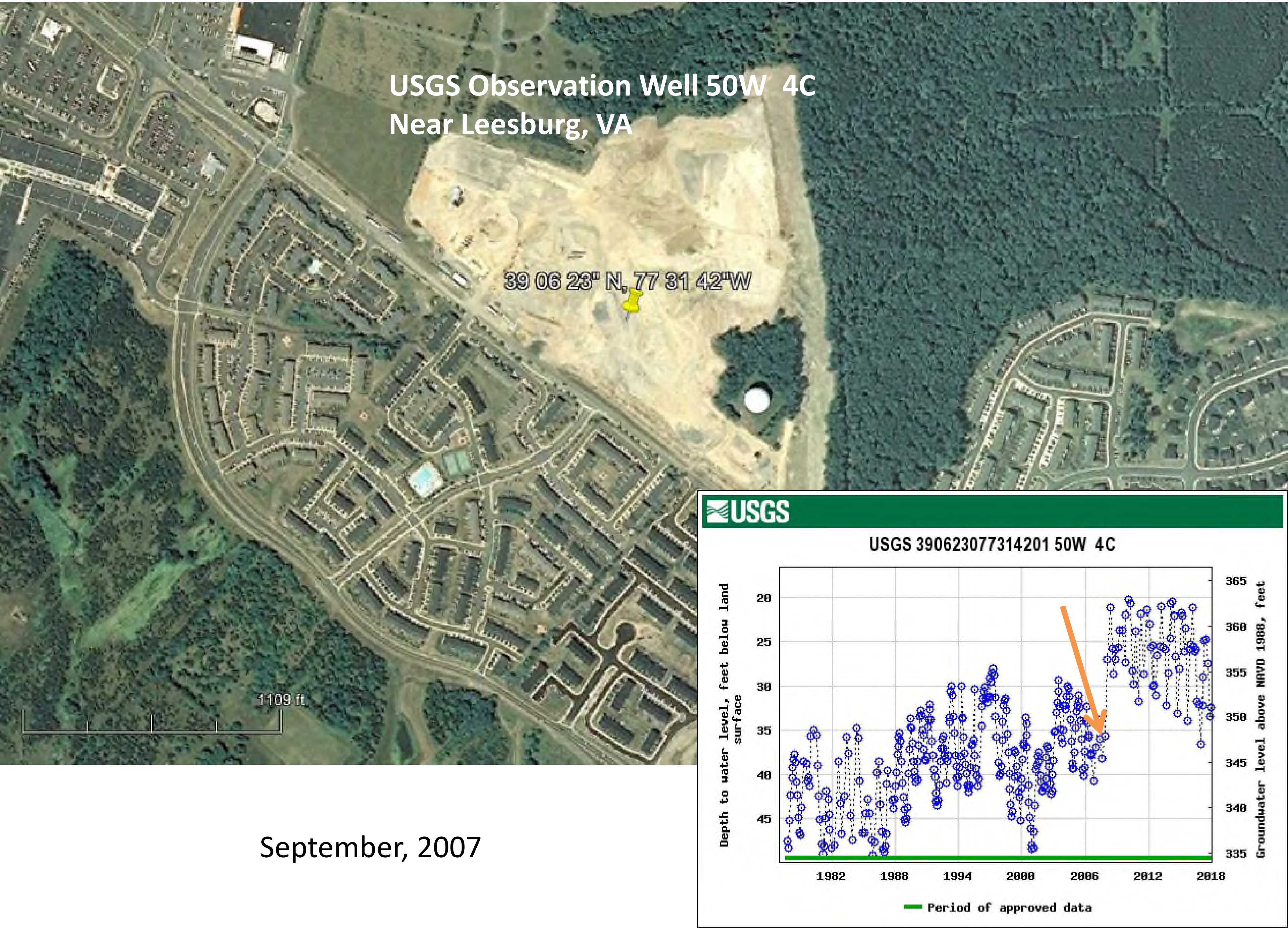


December, 2001

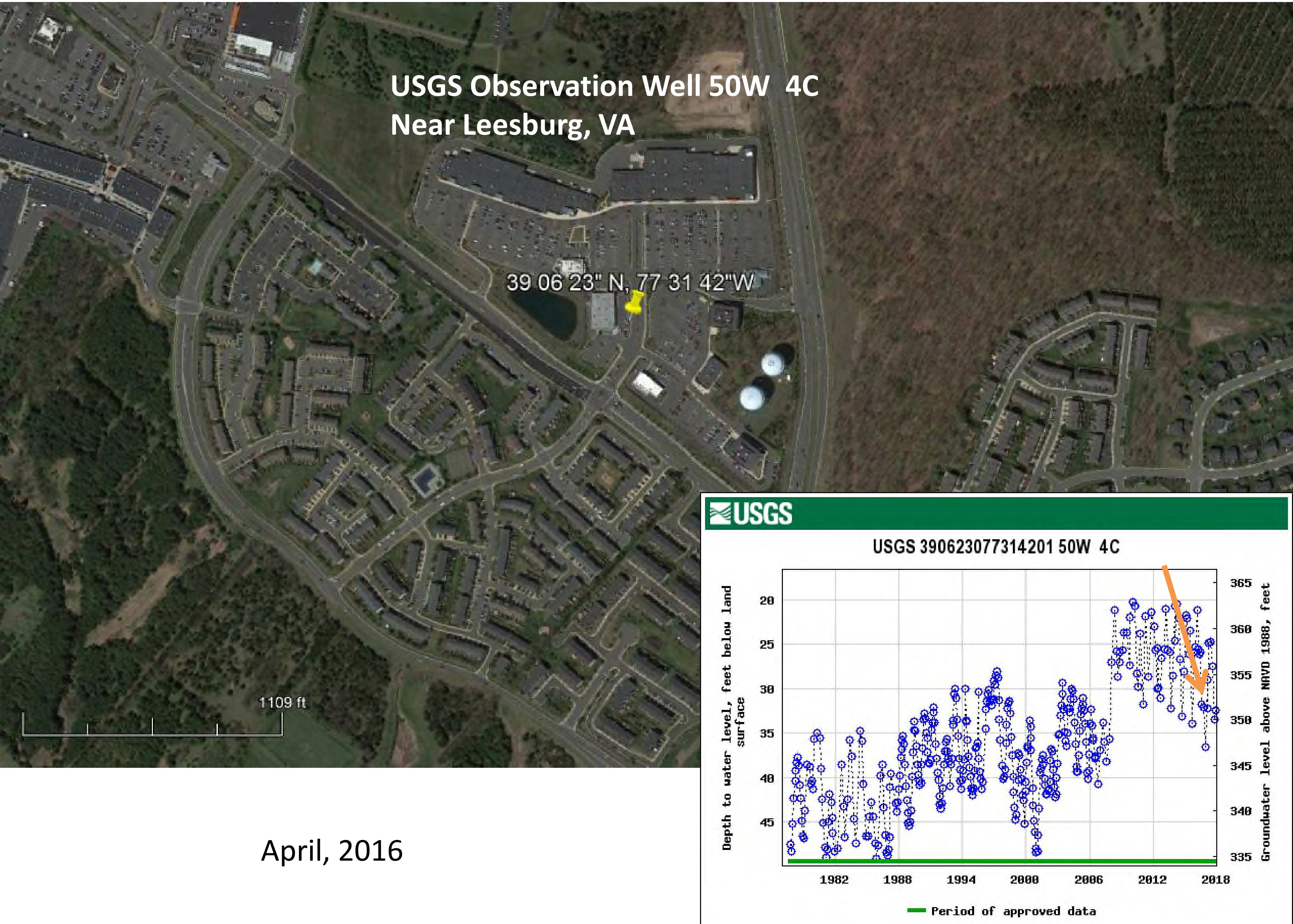




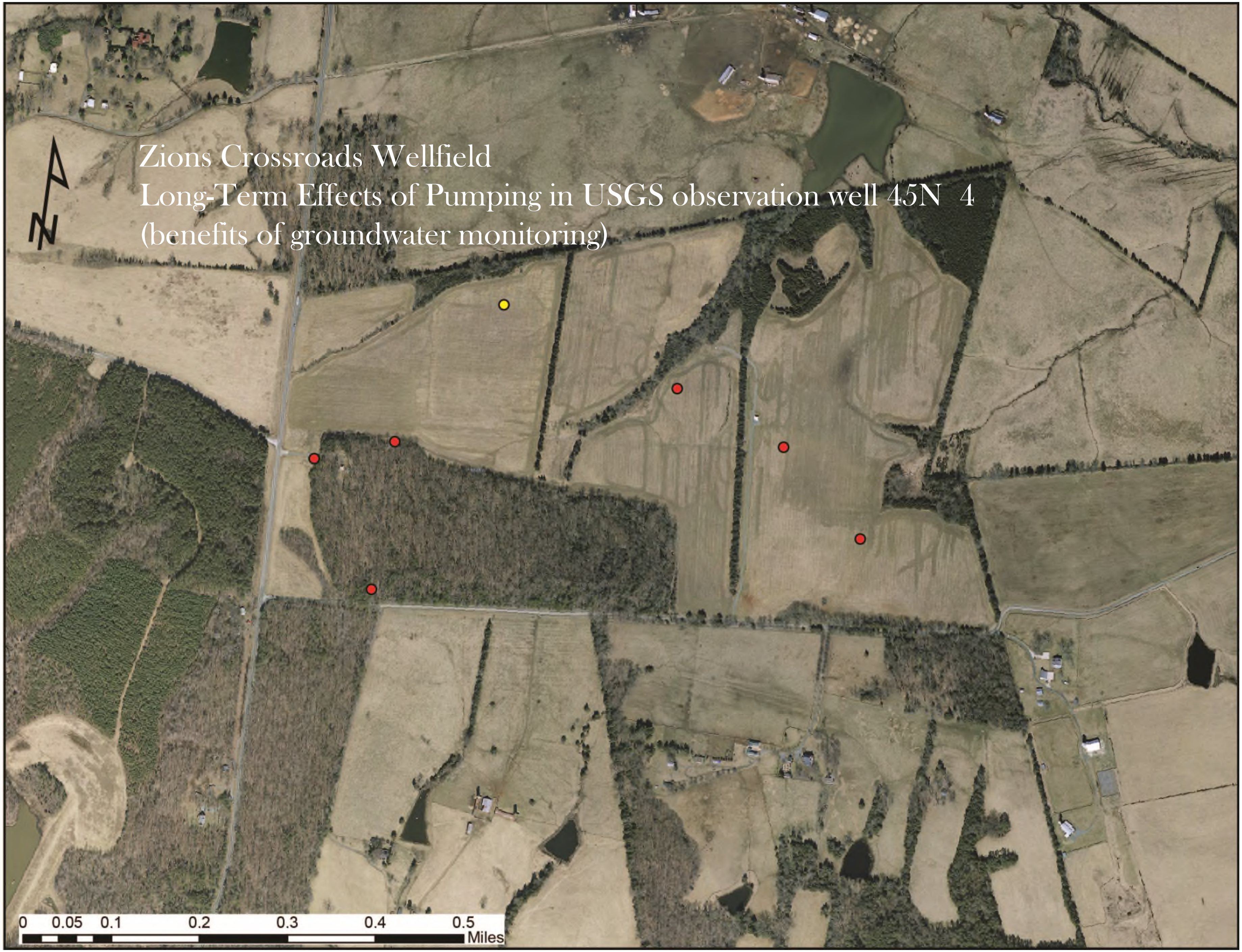
September, 2003

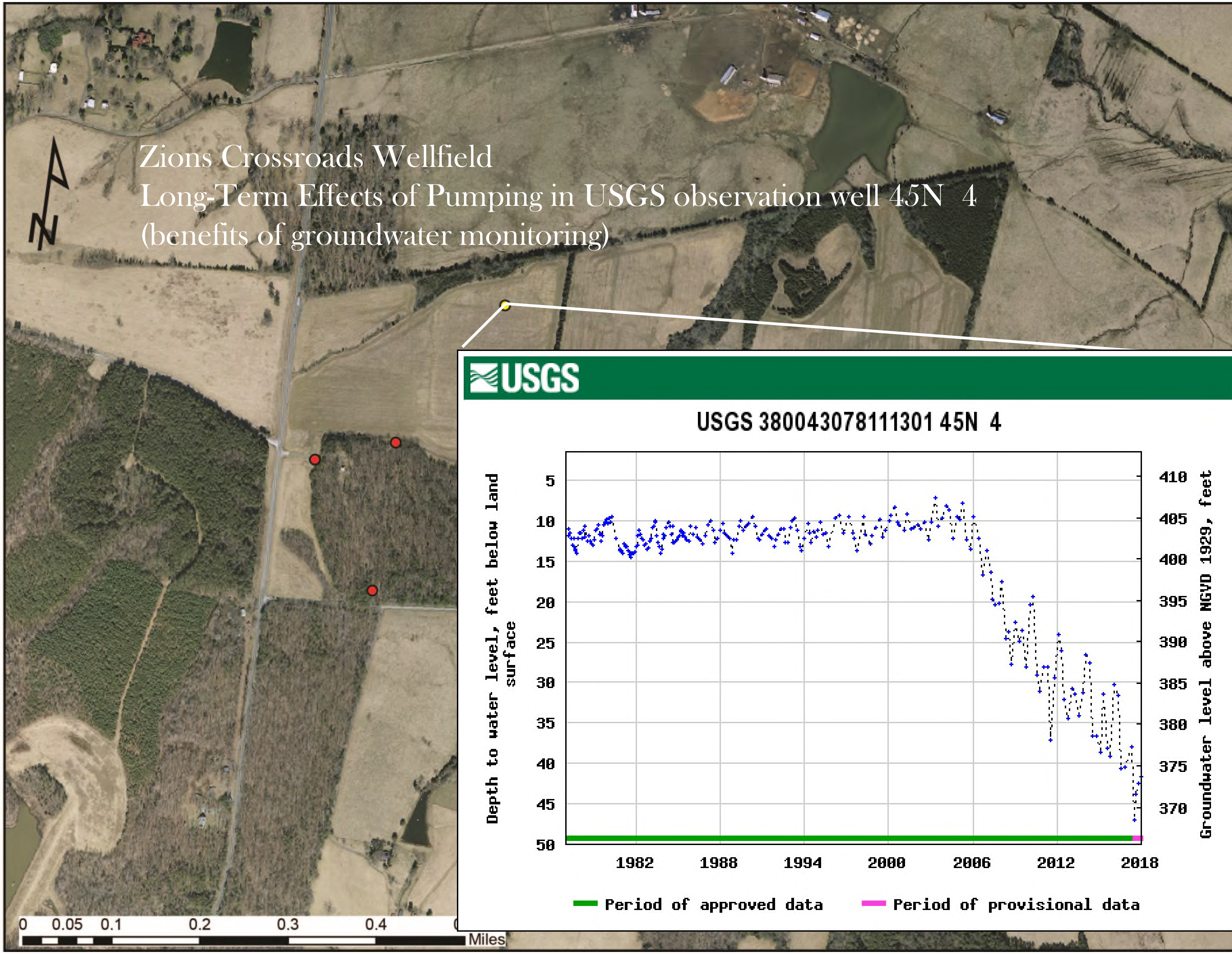


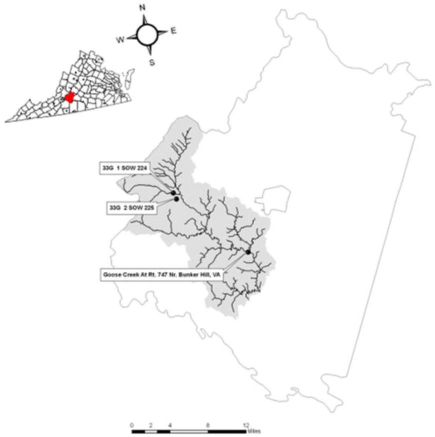
September, 2007


USGS Observation Well 50W 4C
Near Leesburg, VA
39 06 23" N, 77 31 42"W
1109 ft
USGS
USGS 390623077314201 50W 4C
Depth to water level, feet below land surface
20
25
30
35
40
45
Groundwater level above NAVD 1988, feet
365
360
355
350
345
340
335
1982
1988
1994
2000
2006
2012
2018
Period of approved data

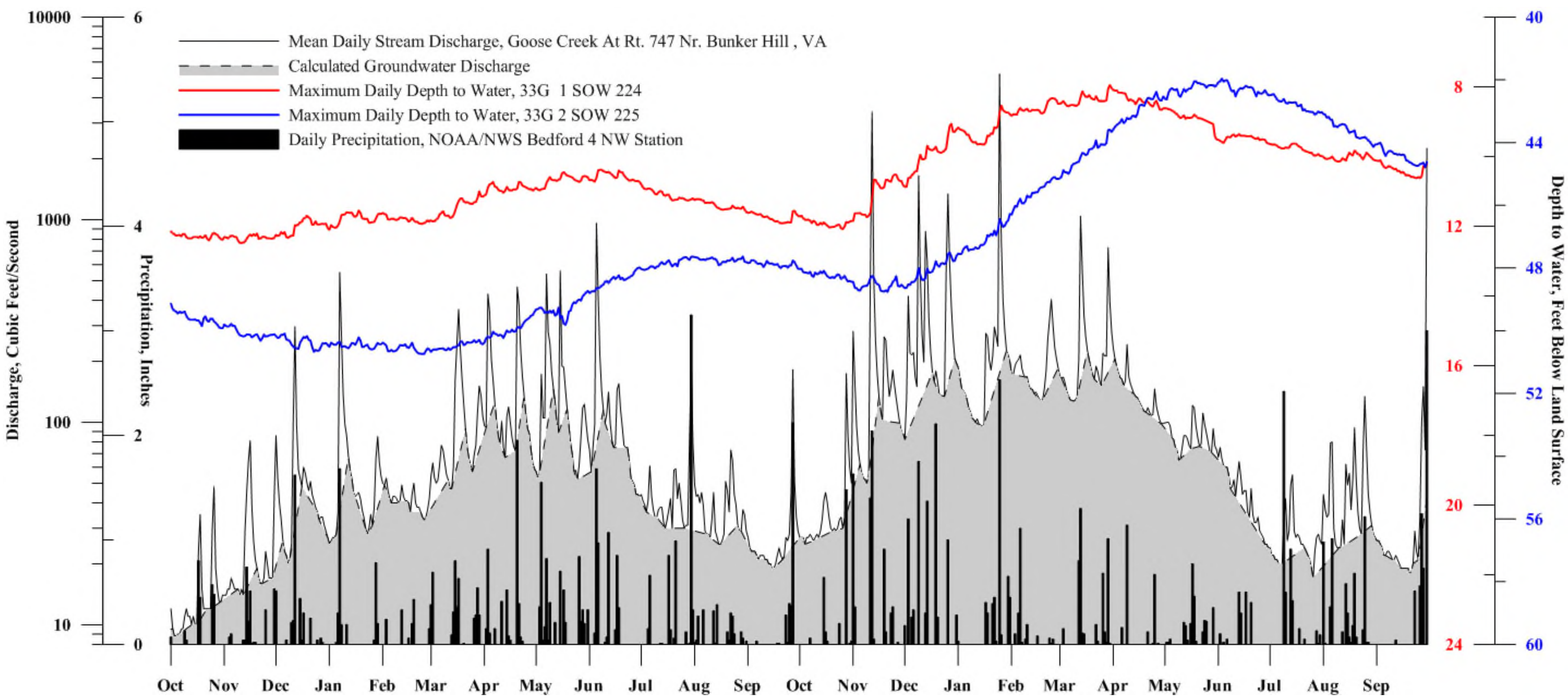
April, 2016


Zions Crossroads Wellfield
Long-Term Effects of Pumping in USGS observation well 45N 4
(benefits of groundwater monitoring)
0 0.05 0.1 0.2 0.3 0.4 0.5
Miles


Zions Crossroads Wellfield
Long-Term Effects of Pumping in USGS observation well 45N 4
(benefits of groundwater monitoring)
USGS
USGS 380043078111301 45N 4
Depth to water level, feet below land surface
Groundwater level above NGVD 1929, feet
5
10
15
20
25
30
35
40
45
50
410
405
400
395
390
385
380
375
370
1982
1988
1994
2000
2006
2012
2018
Period of approved data
Period of provisional data
0
0.05
0.1
0.2
0.3
0.4
Miles



Benefits of multiple monitoring points in one watershed

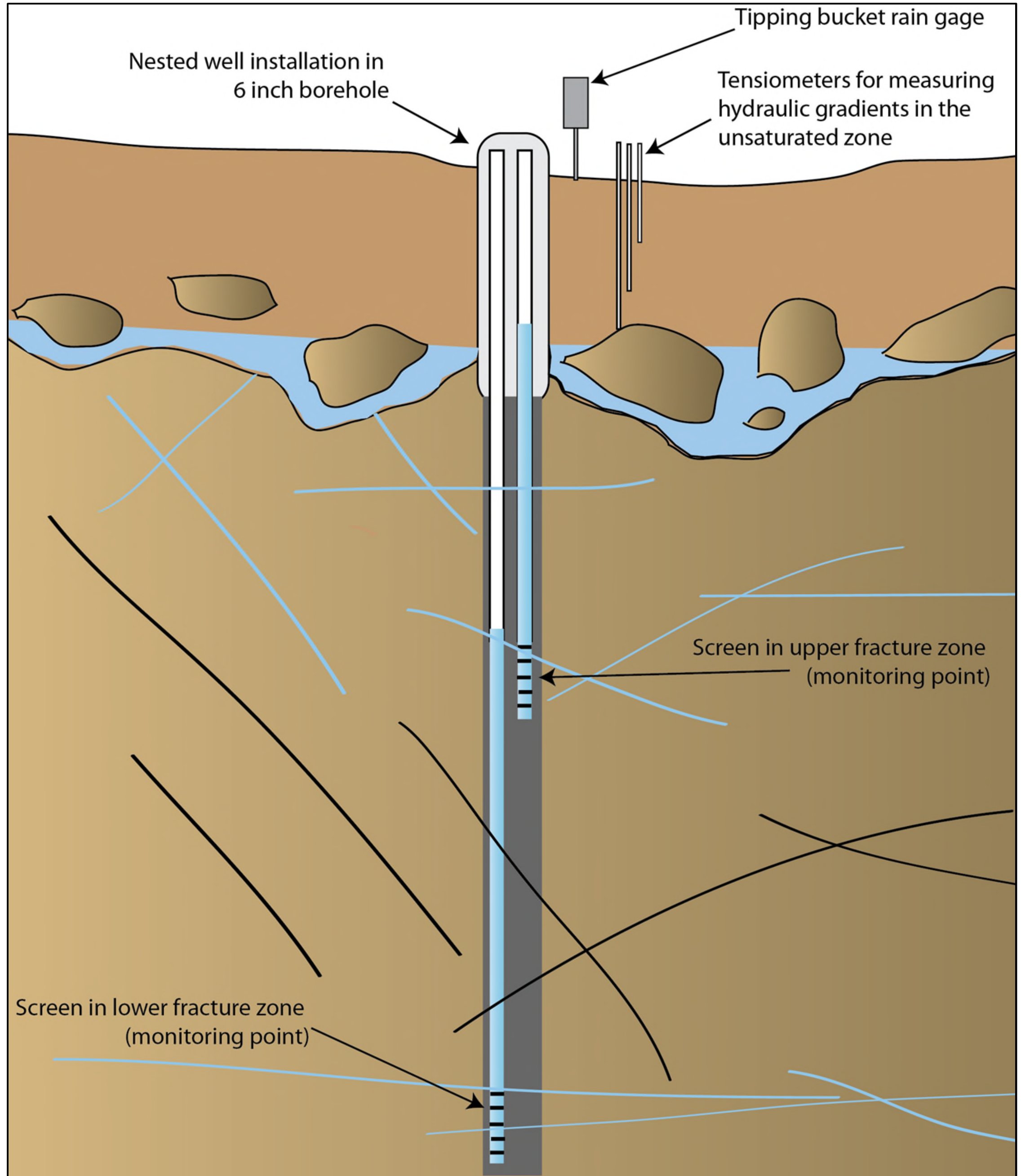


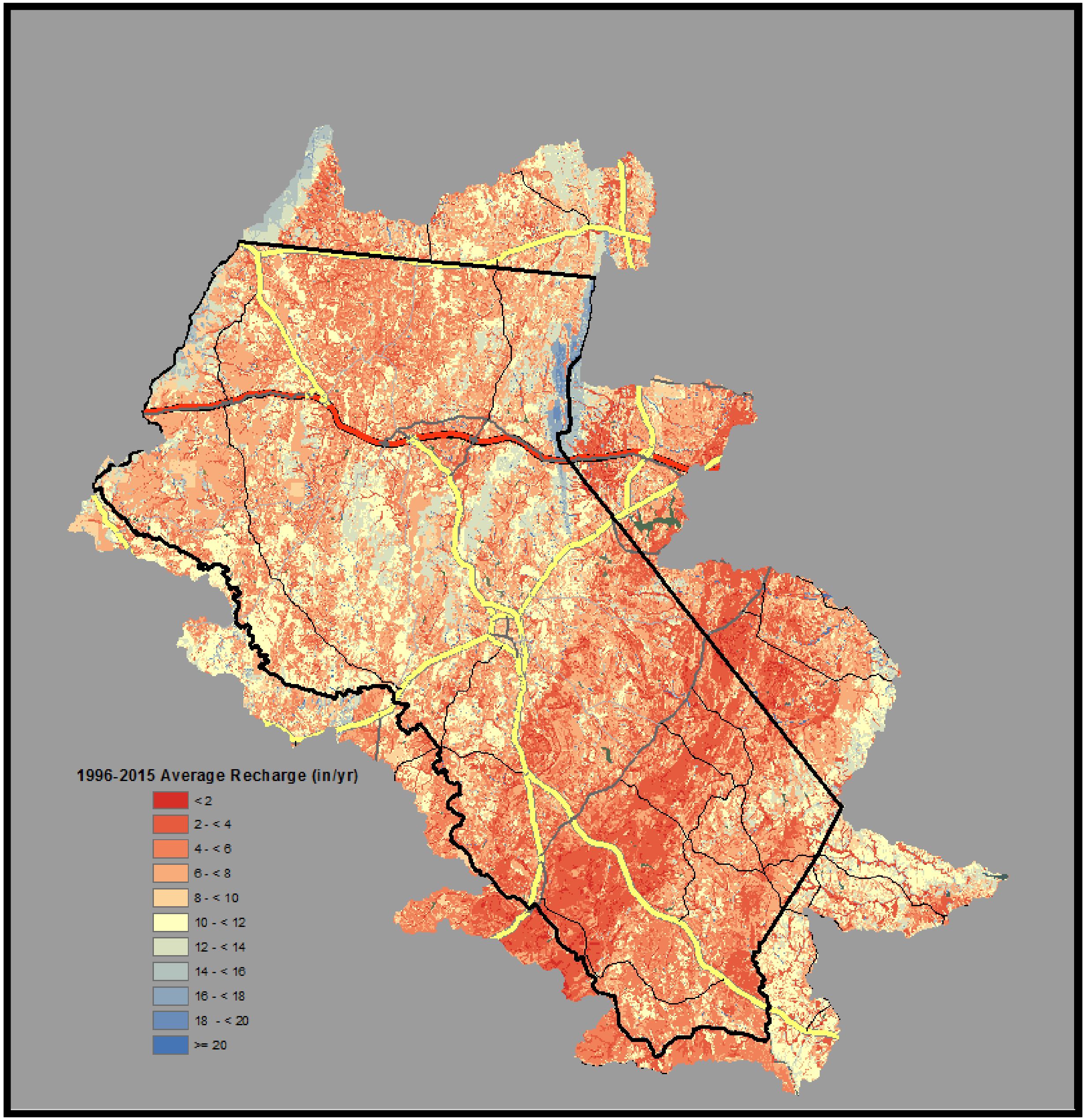
Groundwater Level Observation "Supergage"

Allow logging of vertical hydraulic gradients from near ground level, through the unsaturated zone, and into shallow and deeper groundwater flow systems.

Provide hydraulic levels information throughout the aquifer instead of hydraulic levels at a single point in the aquifer.

Data can be analyzed to learn more about the timing of groundwater recharge and its relation to stream discharge at a scale (if installed in a small, gaged watershed)where significant groundwater withdrawals or land use changes could have a correlative and measurable impact on groundwater availability.





Soil-Water Balance

Annual Precipitation

40-56 in/yr

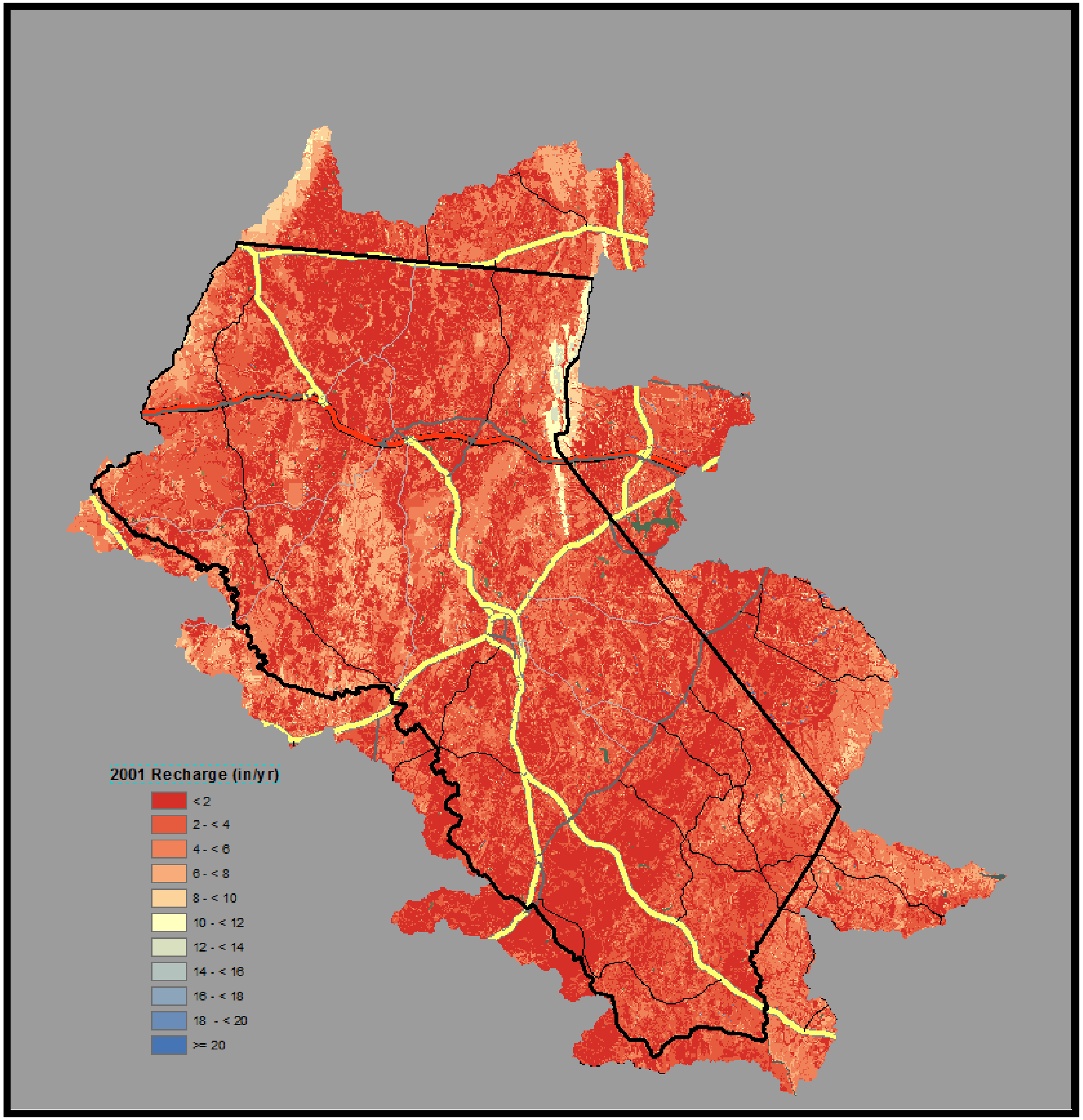
20-yr average recharge

2-10 in/yr

Drought recharge

<2-6 in/yr

Differences amongst aquifers



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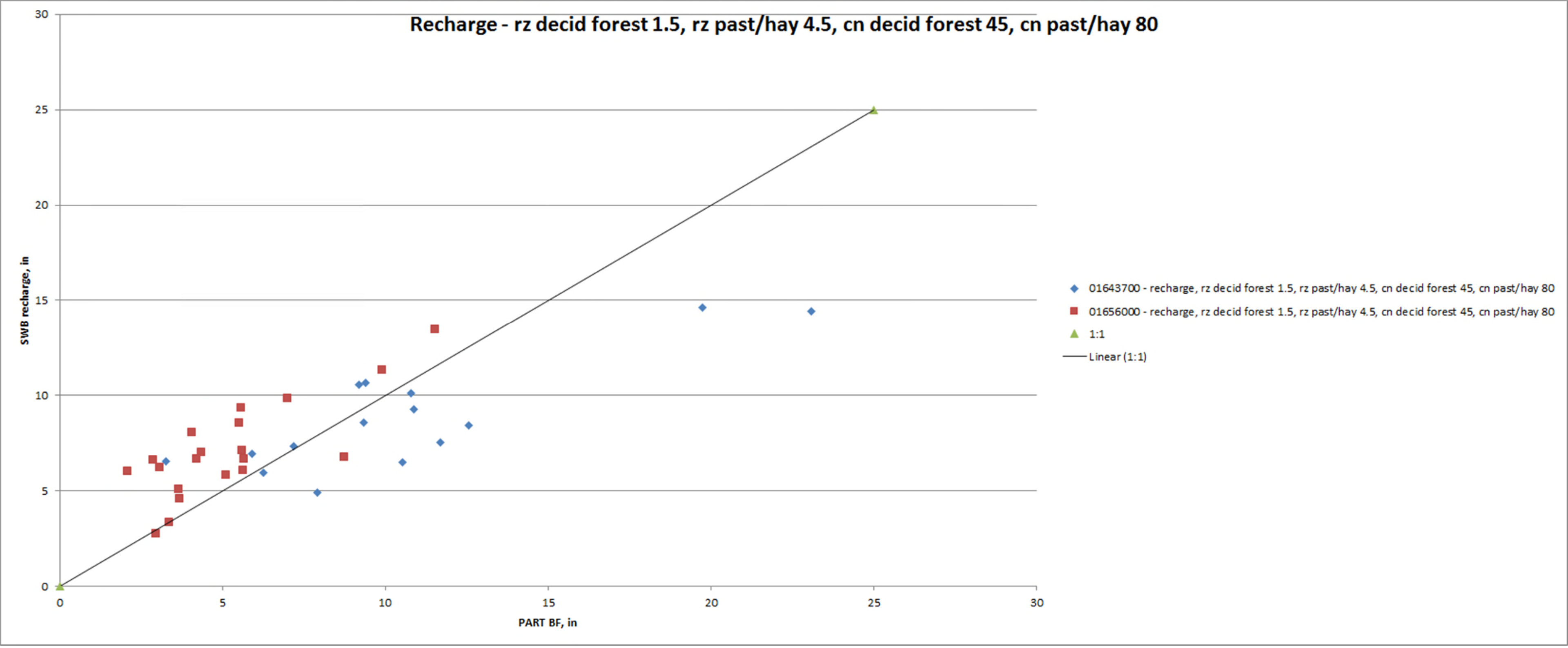
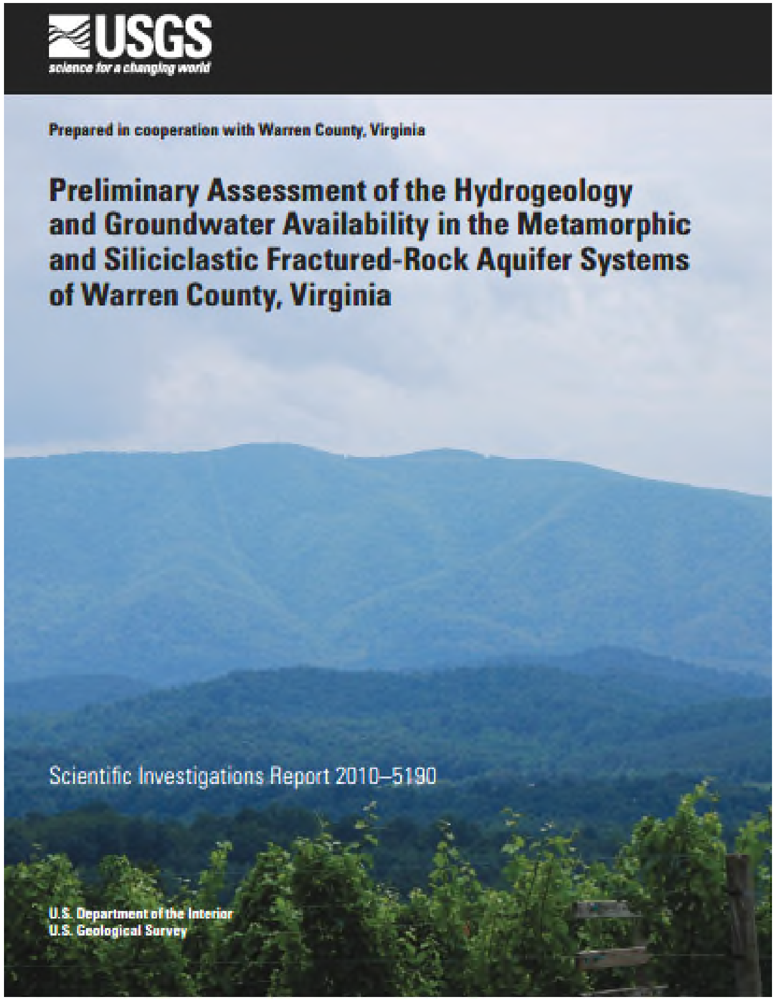


Recharge - rz decid forest 1.5, rz past/hay 4.5, cn decid forest 45, cn past/hay 80
SWB recharge, in
PART BF, in
0
5
10
15
20
25
30
01643700 - recharge, rz decid forest 1.5, rz past/hay 4.5, cn decid forest 45, cn past/hay 80
01656000 - recharge, rz decid forest 1.5, rz past/hay 4.5, cn decid forest 45, cn past/hay 80
1:1
Linear (1:1)



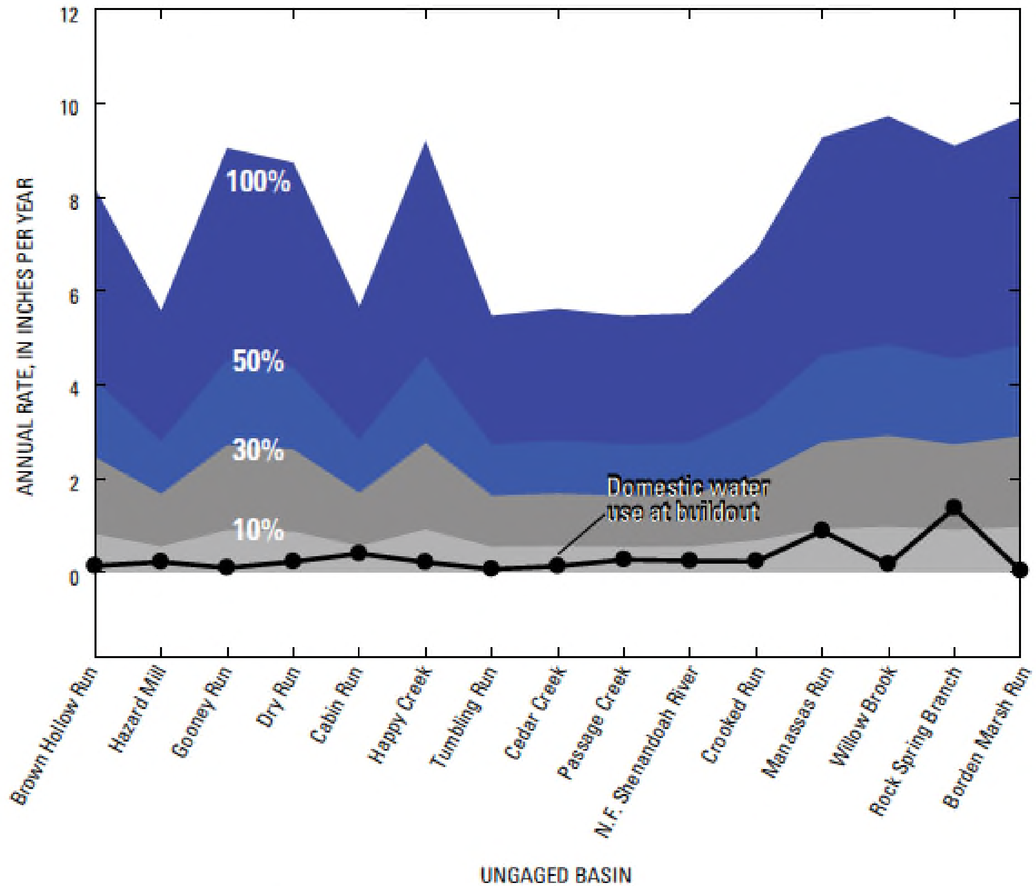
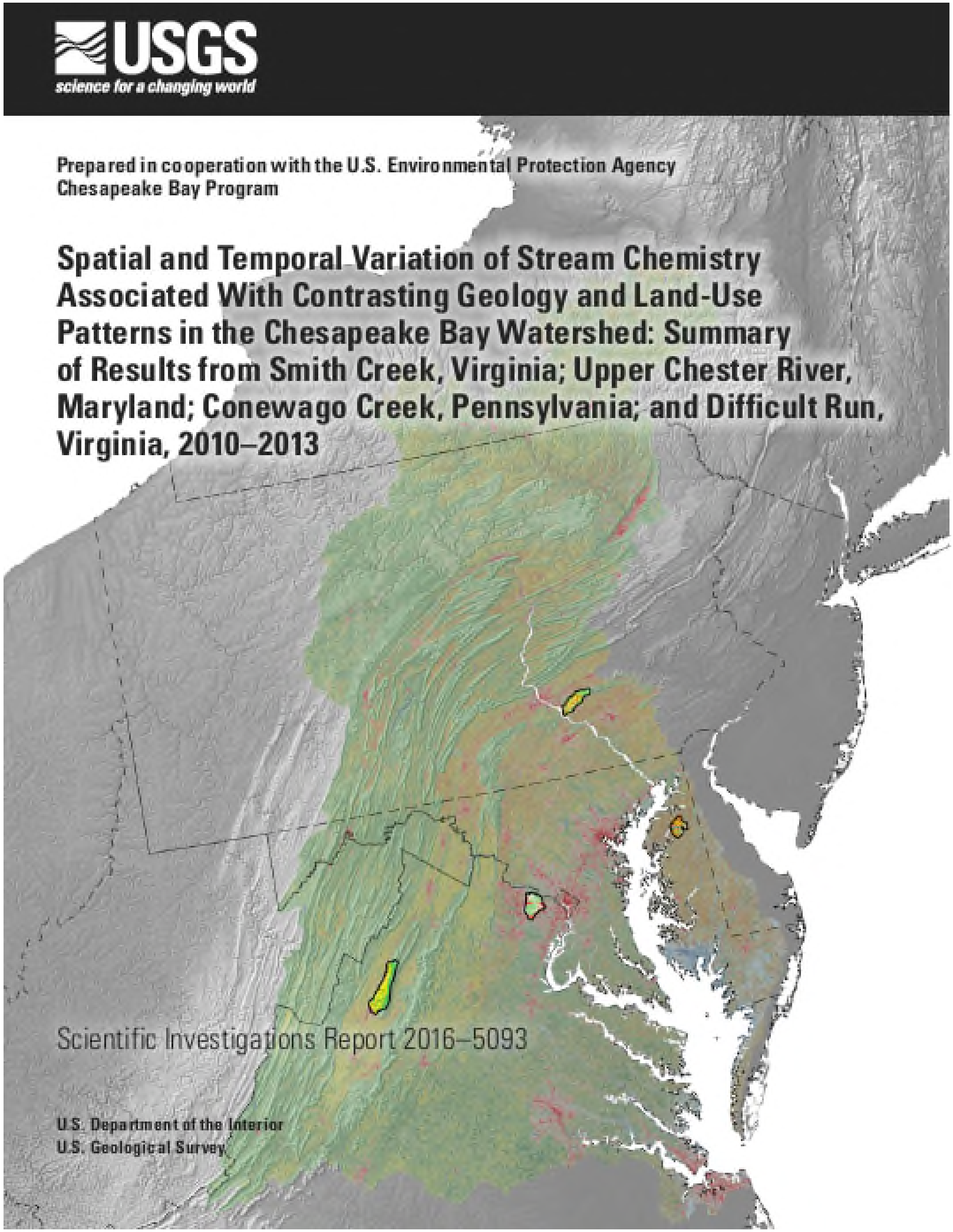


Figure 30. Relation between estimated domestic water usage at buildout and varying percentages of annual effective recharge estimated from the linear regression method of Yager and others (2008) for ungaged basins in Warren County, Virginia. Domestic usage is based on 2.48 individuals per parcel multiplied by 75 gallons per day per person normalized over the drainage basin area.

stresses on local groundwater storage within smallwatersheds (in fractured rock) can result in measurable changes to stream discharge and are more easily observed at the small watershed scale.

(Nelms et.al 2010)



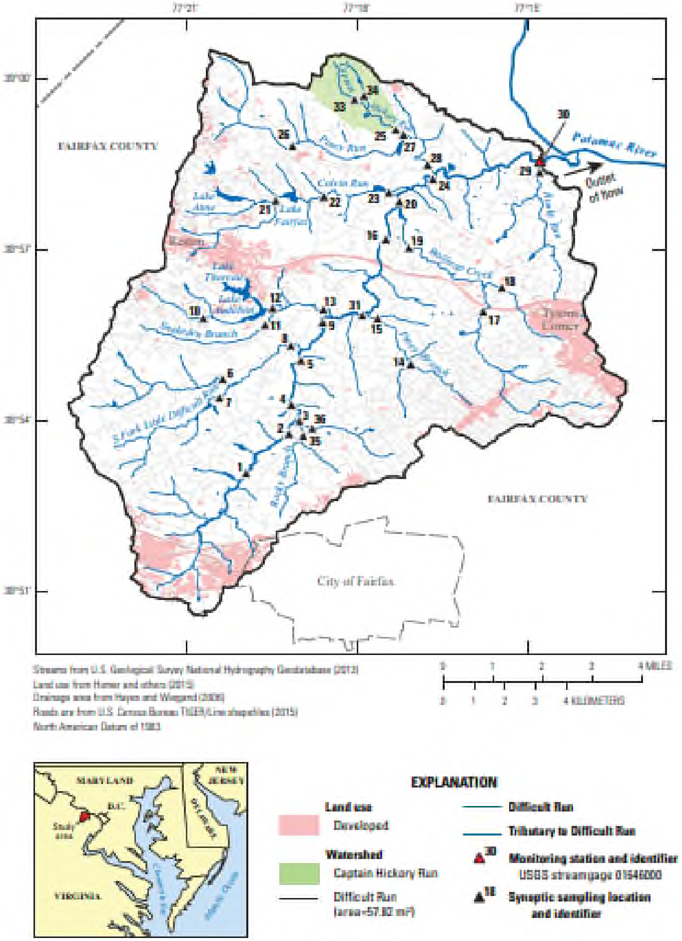


Figure 100. Monitoring stations and the stream network within the Difficult Run watershed, Virginia.

"The Difficult Run watershed is a 57.82 mi^2 watershed that drains to the Potomac River. The long-term Difficult Run base-flow index (from 1936 to 2010) was 57.9 indicating that approximately 58 percent of streamflow exited the watershed as base flow and 42 percent as stormflow; however, with continued development and urbanization of the watershed, the base-flow index has decreased to 50 percent during the last 20 years."

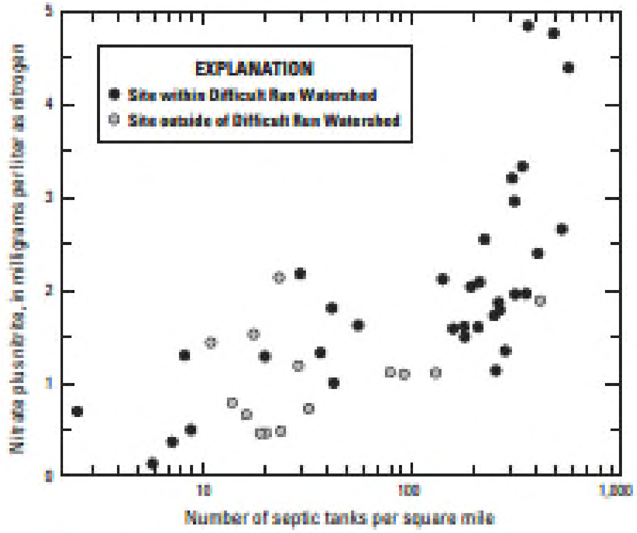
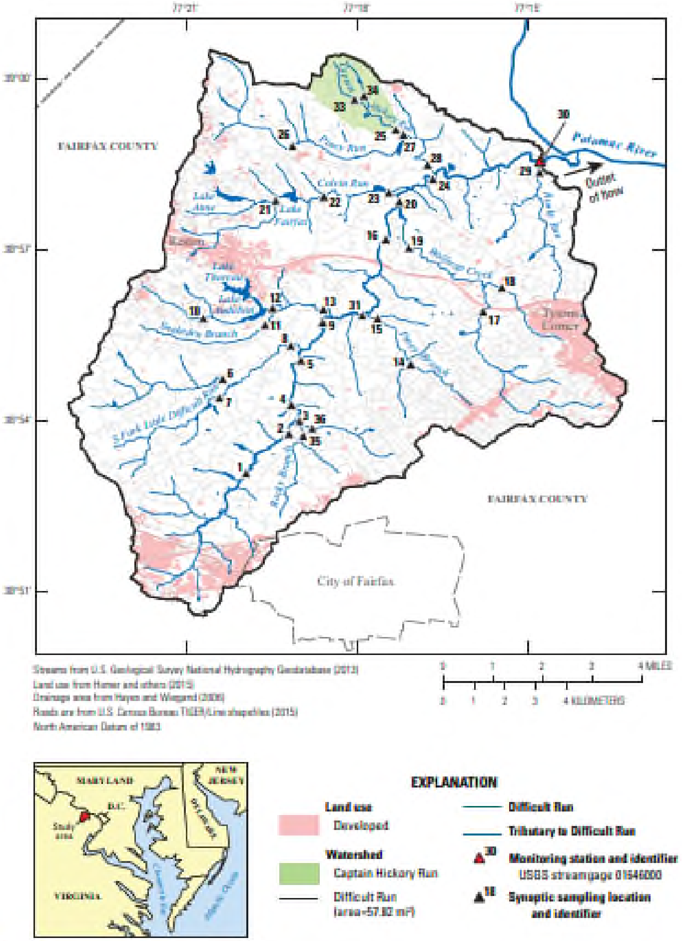


Figure 130. Median nitrate concentration results from synoptic sampling events within the Difficult Run watershed and from additional U.S. Geological Survey base-flow monitoring in Fairfax County compared to the septic tank density within the drainage area of each monitoring location.



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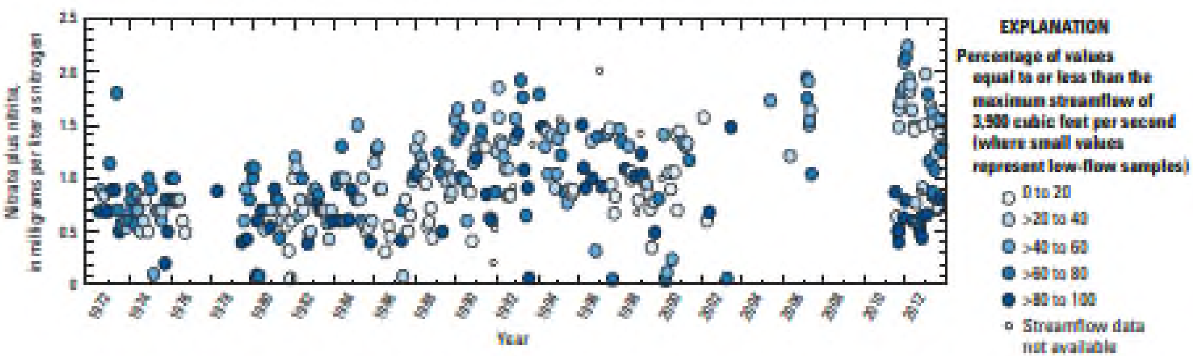
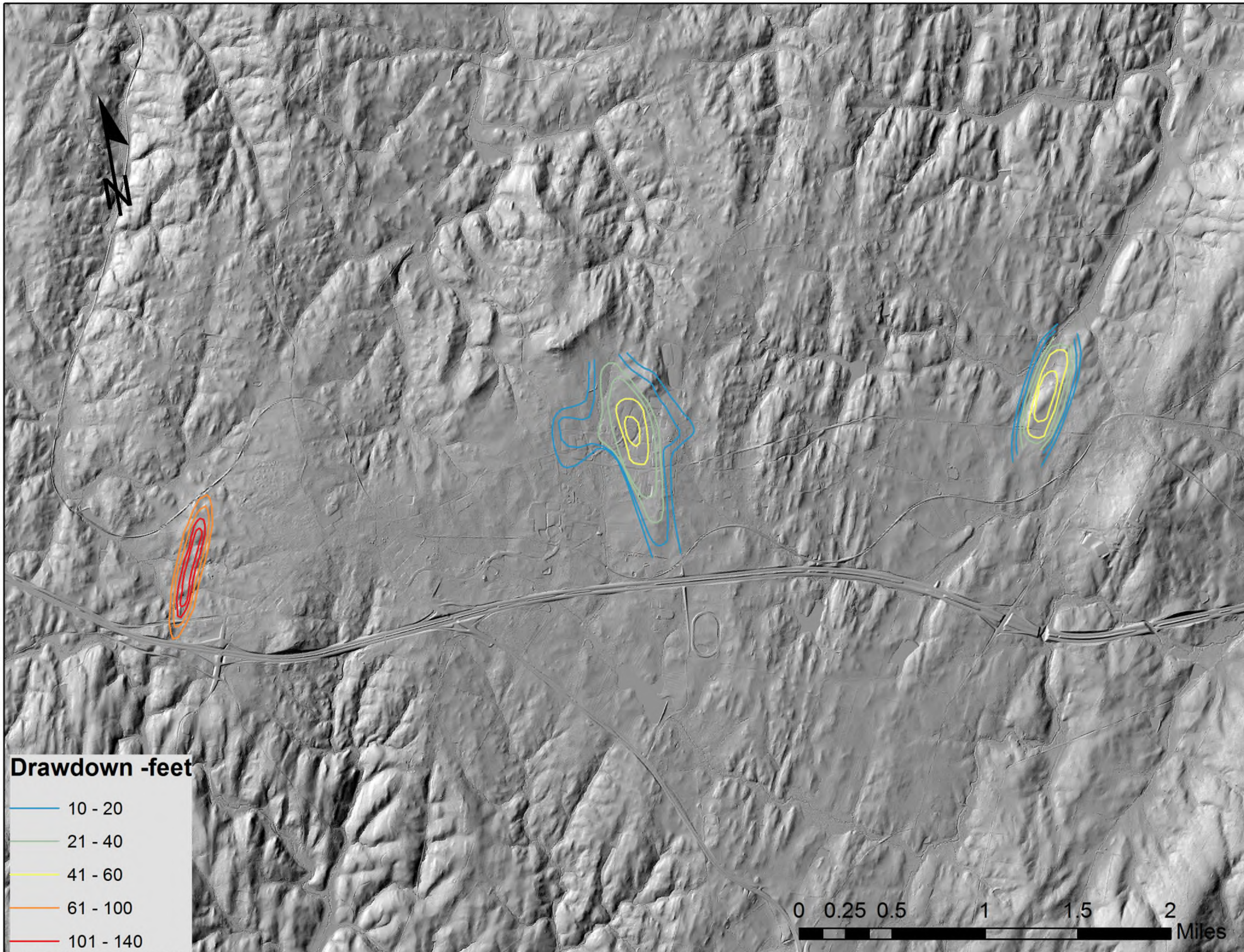
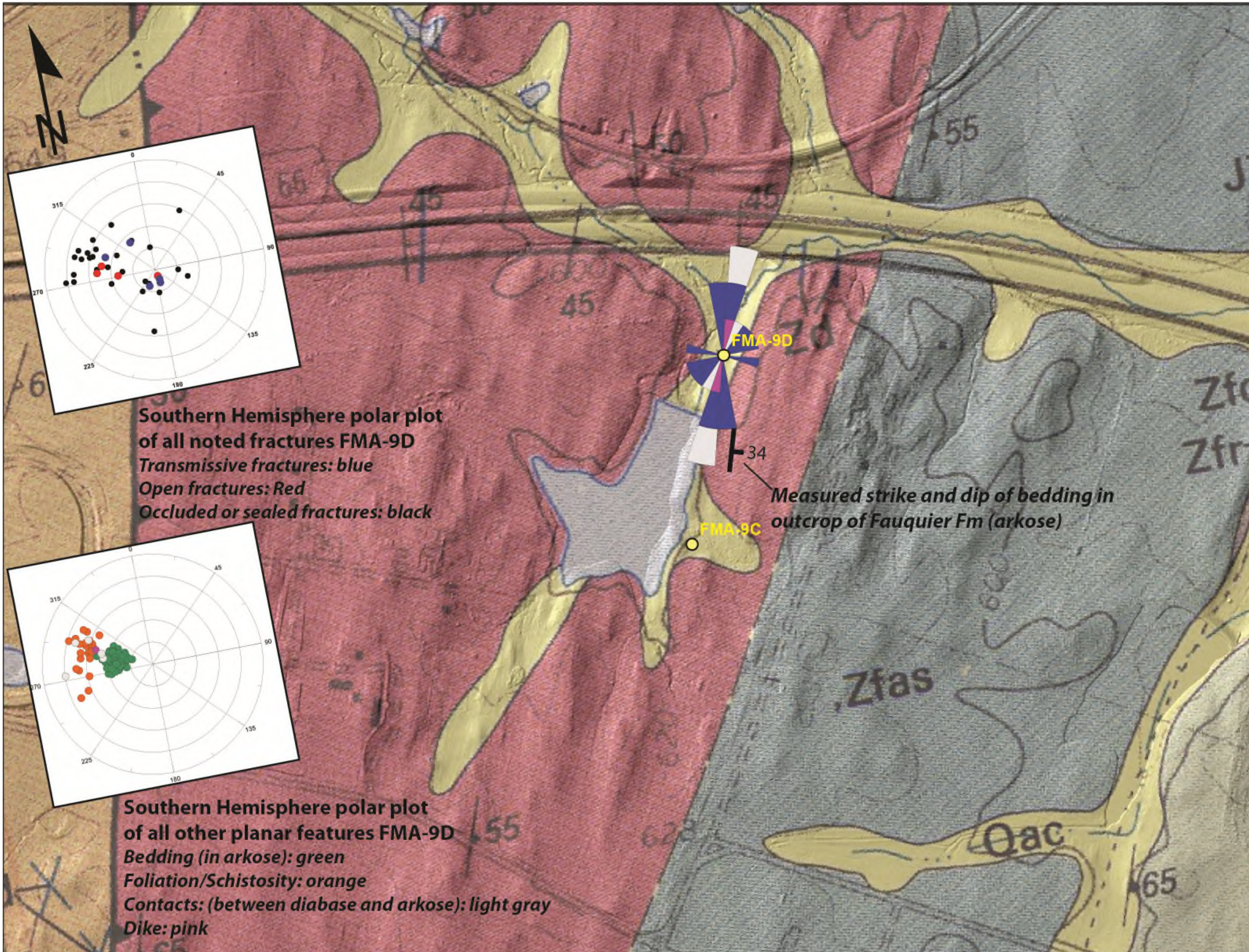
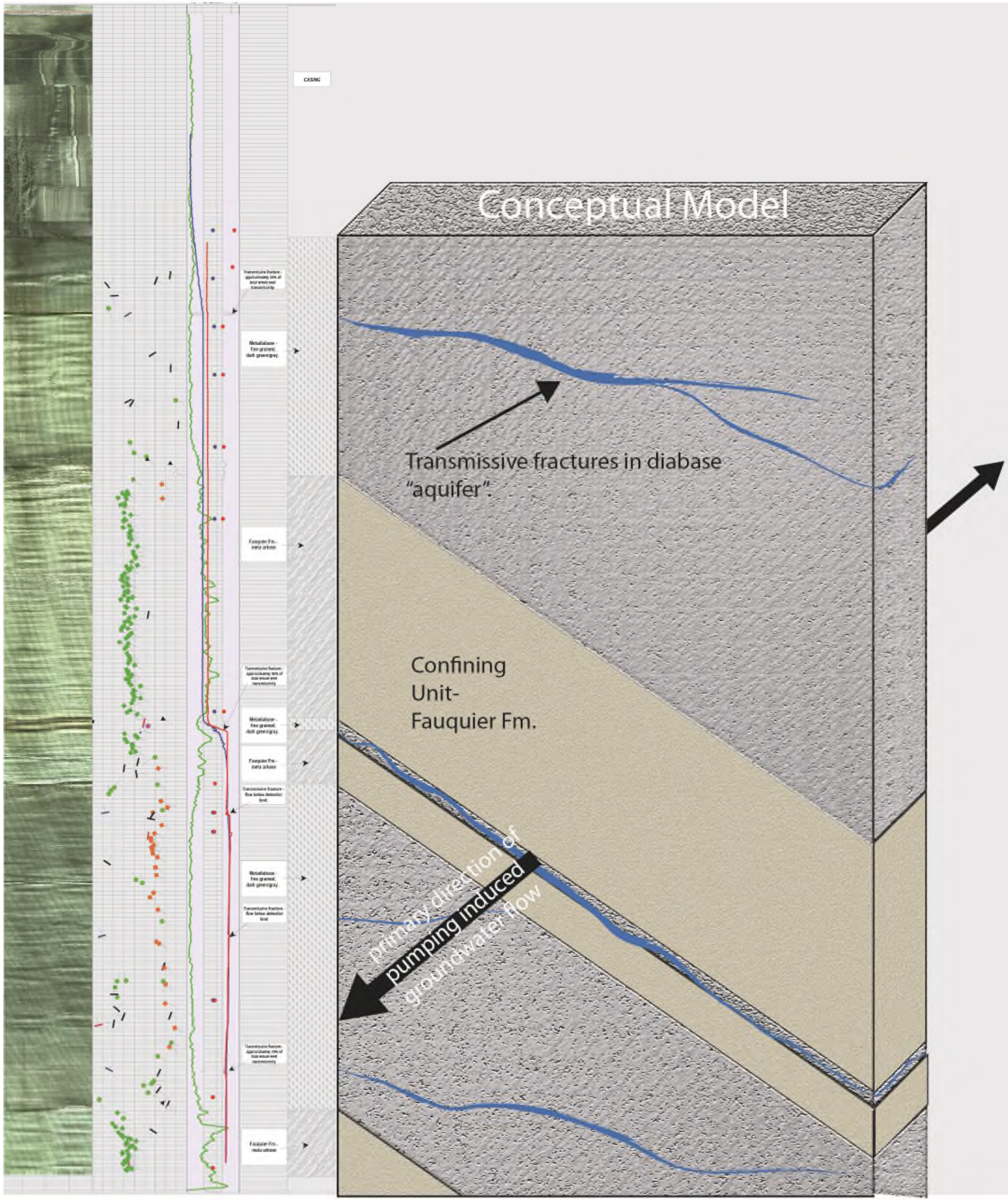


Figure 135. Nitrate concentrations for the Difficult Run watershed water years 1972 through 2013.


N
Drawdown -feet
10 - 20
21 - 40
41 - 60
61 - 100
101 - 140
0
0.25
0.5
1
1.5
2
Miles


N
FMA-9D
FMA-9C
34
Measured strike and dip of bedding in outcrop of Fauquier Fm (arkose)
Southern Hemisphere polar plot of all noted fractures FMA-9D
Transmissive fractures: blue
Open fractures: Red
Occluded or sealed fractures: black
Southern Hemisphere polar plot of all other planar features FMA-9D
Bedding (in arkose): green
Foliation/Schistosity: orange
Contacts: (between diabase and arkose): light gray
Dike: pink
Zd
Zfd
Zfr
Zfas
Qac
55
45
65



Formation of transmissive fractures primarily in diabase.

Hydrostatic pressures indicate confined conditions in the diabase.

Flow theorized to occur along strike of diabase dikes. Bounded by metasedimentary units of Fauquier Formation.

Is recharge restricted to outcrop of diabase units or is it more diffuse?

How pervasive are these conditions?

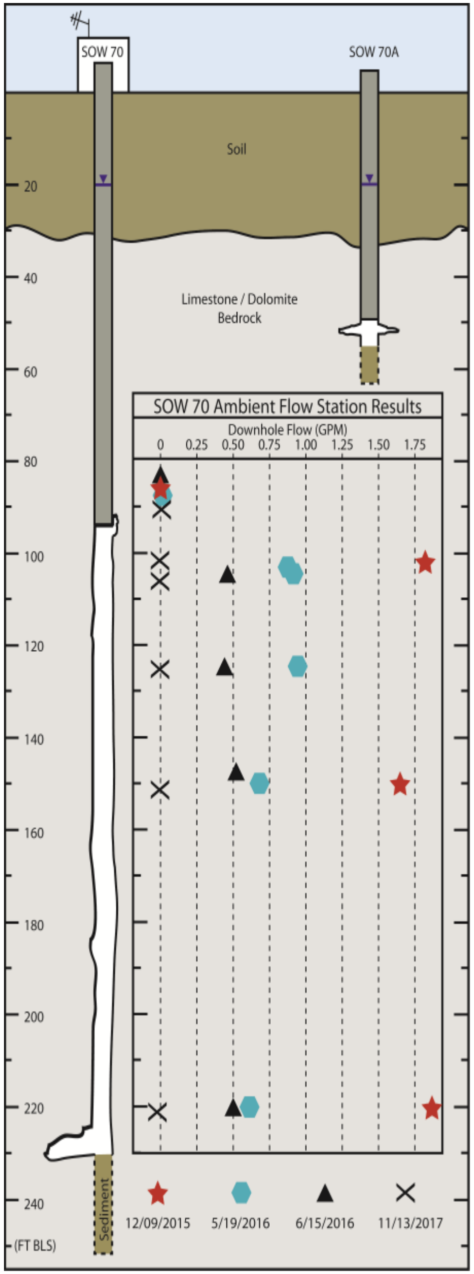


Figure 5.
Schematic summarizing construction and ambient open borehole flow conditions observed during geophysical logging.

Hydrogeolgic Characterization of carbonate aquifers:

Packer Testing and Borehole Geophysical Characterization of Observation Wells in a Vertically Integrated Karst Aquifer in Augusta County, Virginia.

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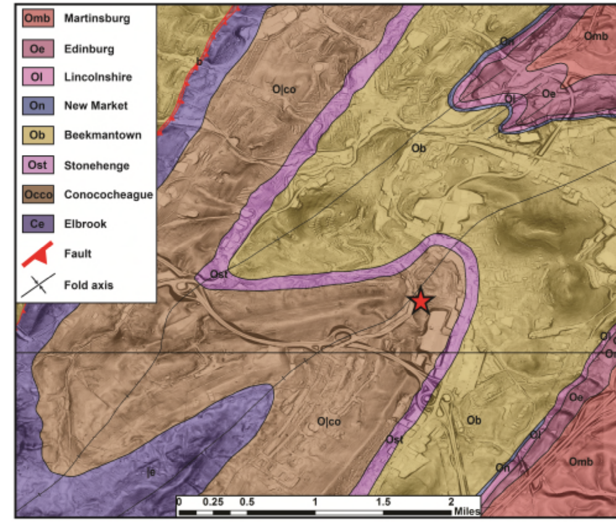

Figure 2.
Geologic setting of the Augusta County state observation well site. Geology from Campbell et al. 2006.

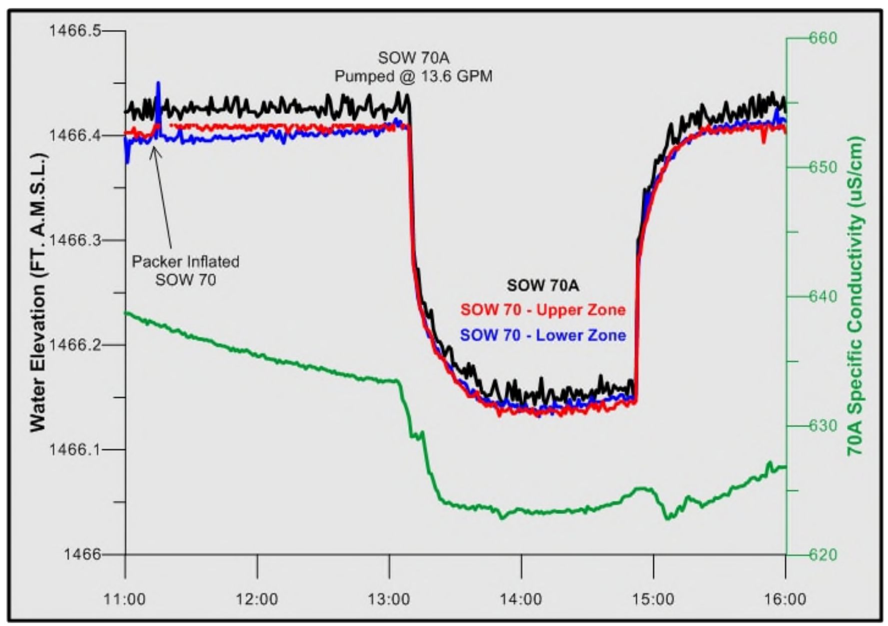

Figure 6. Groundwater level and specific conductivity responses to pumping of SOW 70A on April 14, 2016. Green line shows specific conductance of groundwater at the main water bearing conduit15 m (52 ft) bls in SOW 70A.

Concluding Remarks

- Watershed scale hydrogeologic studies mainly focus on some aspect of the water budget:

I-O= dS where:

> **I=P(precip)+Qin(other water coming into the watershed…typically negligible) ;**
>
> **O=Qs(streamflow)+ ET + Qw(withdrawals…surface and groundwater)**
>
> **Qs= Qsfc+Qgnd**
>
> **dS=Change in storage**

- Site-scale hydrogeologic studies usually focus on aquifer mechanics and delineation:
  - Aquifer testing, geophysics, geologic mapping, groundwater sampling

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>
> **Qs= Qsfc+Qgnd**
>
> **dS=~~Change in storage~~**
>
> ***Under non-stressed conditions, budget assumed to reduce to: P- (Qs+ET) =0***

- Site-scale hydrogeologic studies usually focus on aquifer mechanics and delineation:
  - Aquifer testing, geophysics, geologic mapping, groundwater sampling

Contact Information

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References and Links

- Groundwater Resources of the Blue Ridge Geologic Province, Virginia
- Water Use in the Shenandoah Valley, Virginia
- County – Wide Resource Publications
- USGS Virginia Water Science Center
  - Publications
  - Current Water Conditions