The Northern Segment of the Edwards Balcones Fault Zone Aquifer: What we now know

Presented at the 16th Annual Bell County Water Symposium
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Today's presentation

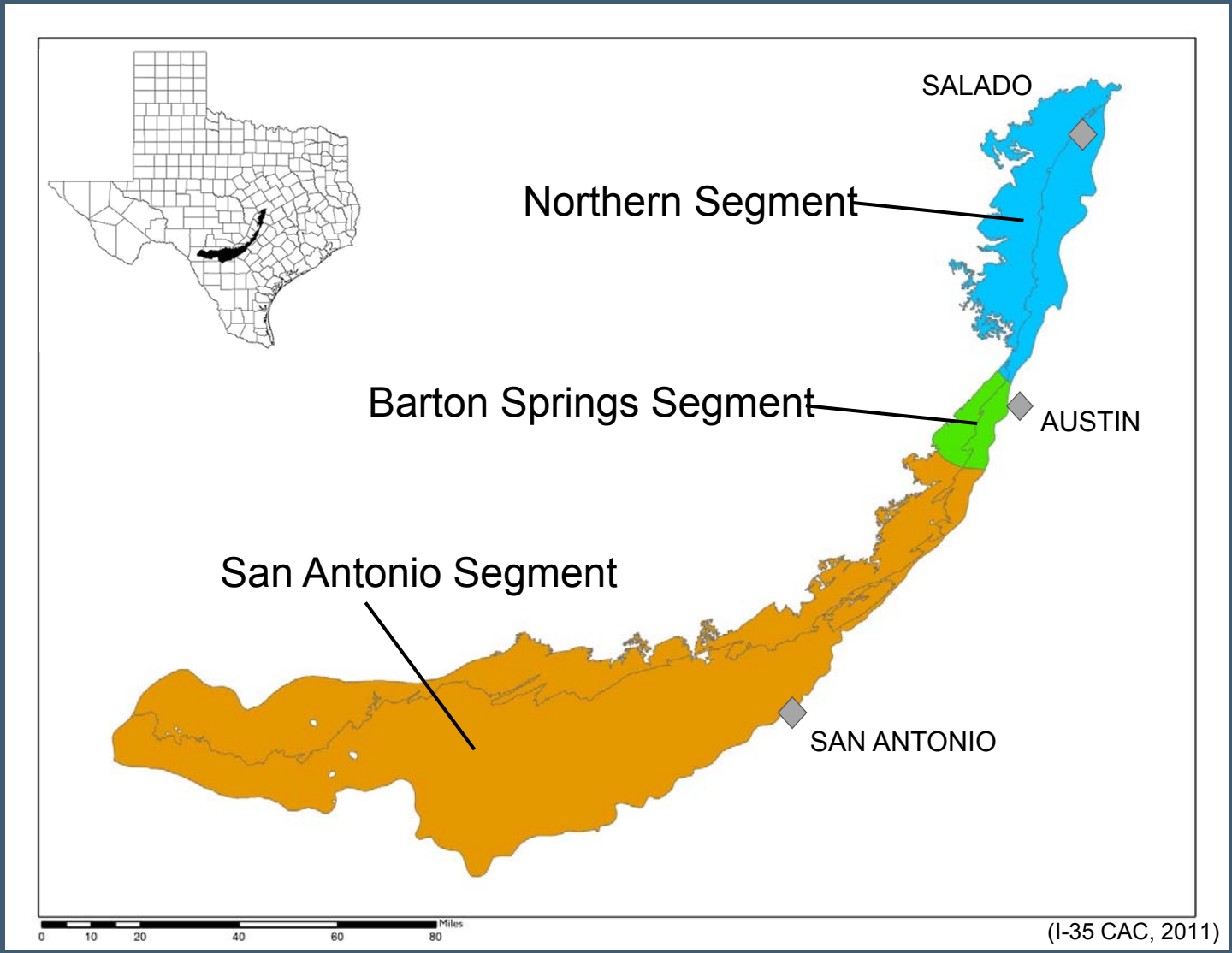
Our purpose today:

- ***Revisit milestones of Edwards aquifer study, & summarize our knowledge***

Outline:

1. **Summary of research activities**
2. **What we now know about the Northern Segment**

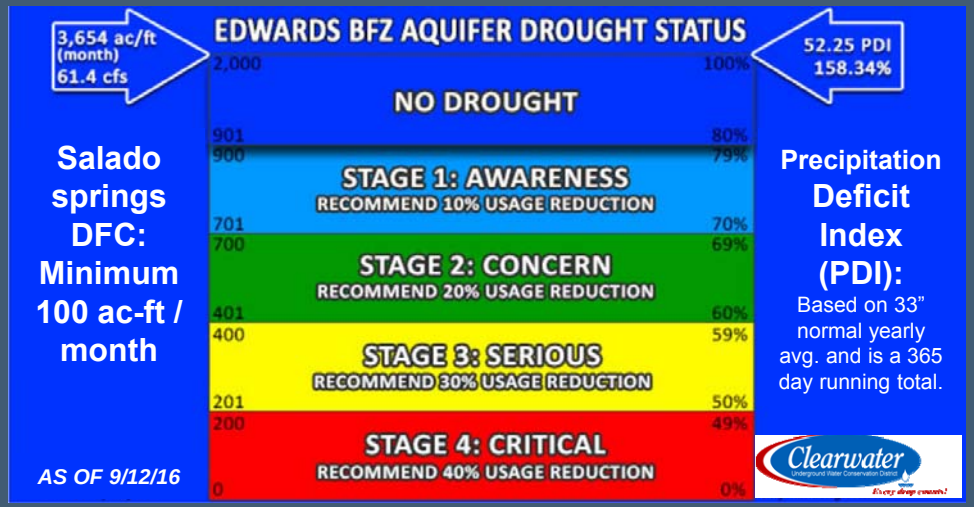
Setting: The Edwards BFZ Aquifer

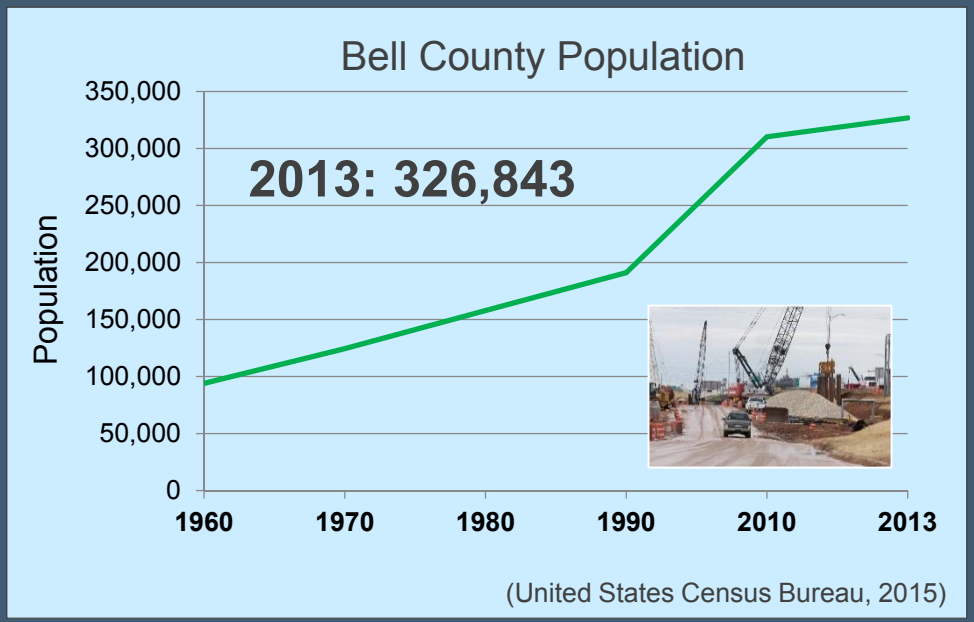


Study area: Salado Springs complex

Why should we study the Northern Segment of the Edwards aquifer?

- Not well-studied
- Important as water source and habitat
- Local groundwater management measure
- Continued growth in the area
  - What are impacts of development on aquifer?





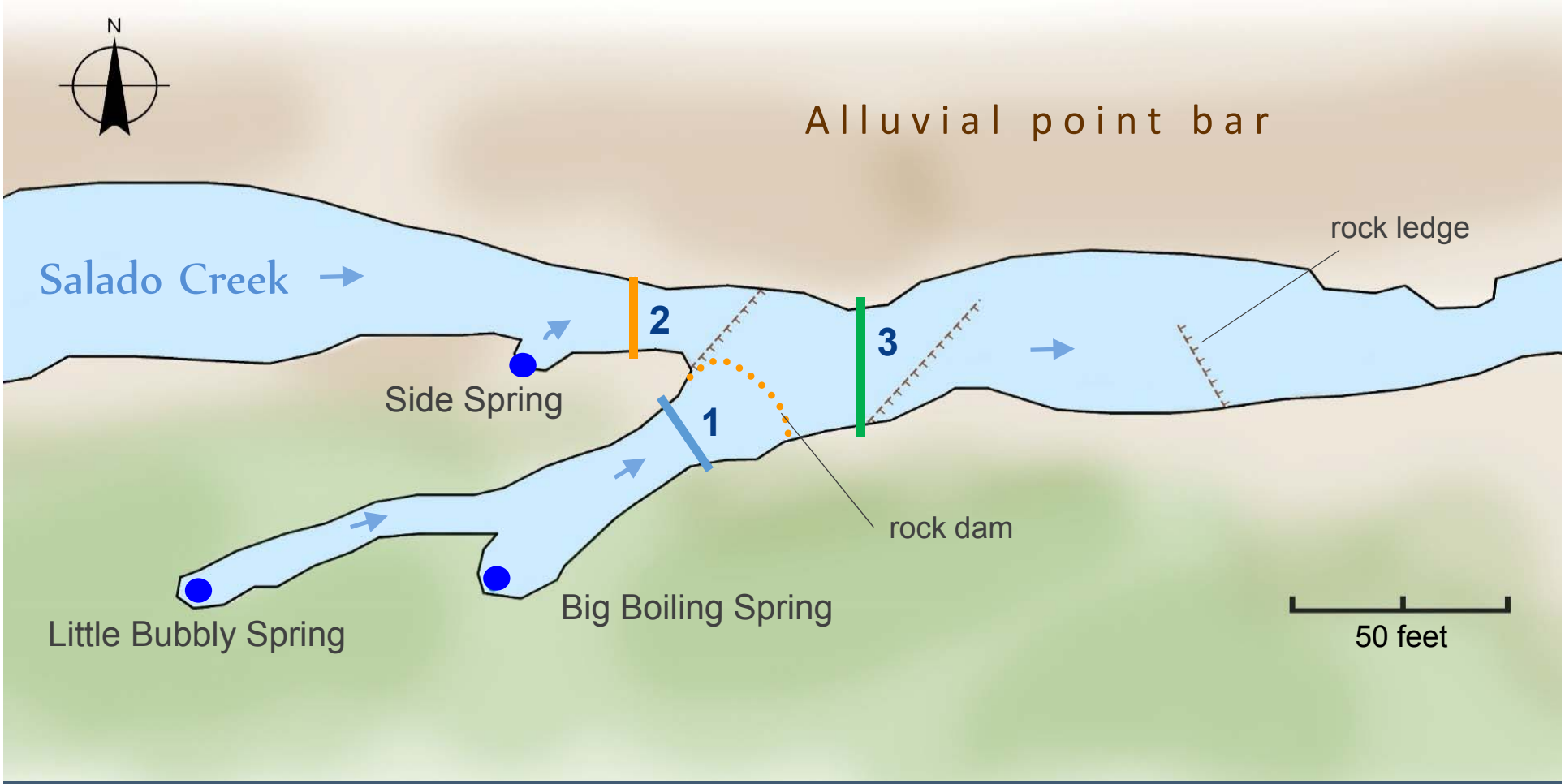
(United States Census Bureau, 2015)

Working together: Objectives

- To **improve** our understanding of the Northern Segment of the Edwards Aquifer,
  - Research
  - Monitoring
- to **communicate** research results and scientific knowledge with project partners and stakeholders,
  - Regular communication with CUWCD
  - Presentations
- so that **management** of the Northern Segment for water resource and critical habitat can be better informed

Research Activities

Quantifying GW/SW Interactions



Instruments

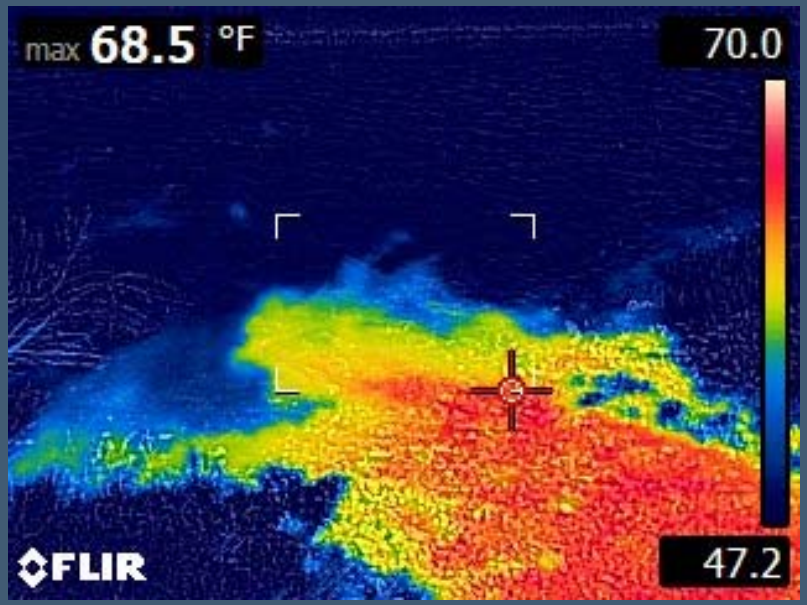
Solinst TLC
- Water level indicator
- Temperature (°C)
- Specific conductance (µS/cm)

SonTek FlowTracker ADV
- Flow velocity (**A**coustic **D**oppler **V**elocimeter)
- Water depth

FLIR-E63900
- Infrared camera

Thermal (infrared) imagery

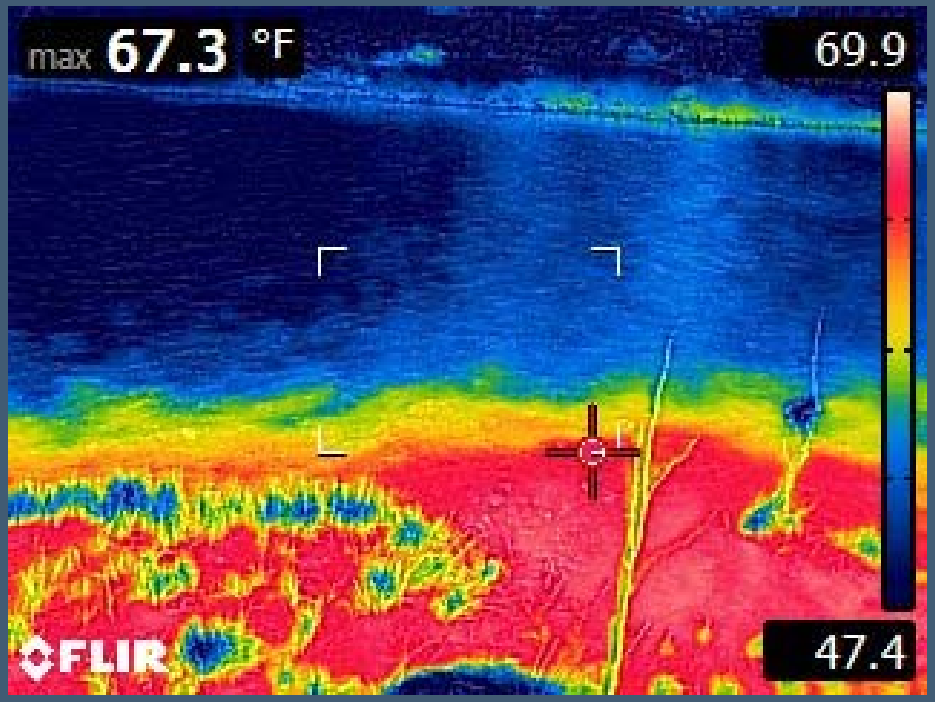
- FLIR - High-performance infrared imaging
- Spatial data calibrated to other water data (chemistry, flow etc.)
- Potential relevance:
  - Groundwater/surface water distinction and interaction
  - Habitat delineation
  - Recharge/discharge



Side Spring, Jan. 27, 2016

Infrared Basics: Settings

- Emissivity
  - Water = 0.95
- Distance: 3m, 9.1m, 16m (10 ft, 30 ft, 50 ft)
- Air temperature
- Spot check
  - Cool spot
  - Hot spot
- Auto mode vs Lock mode
  - By range



South bank, downstream from Big Boiling Spring
Jan. 27, 2016

Measuring synoptic water levels

Aquifer water chemistry

- ~30 sites visited; 20 sites sampled
- Sampled:
  - Water level
  - pH, temperature, specific conductance
  - Dissolved nitrates, phosphates, organic carbon
  - Nitrogen isotopes
  - Radon
- Lessons learned:
  - Site suitability

Monitoring recharge: Weather stations

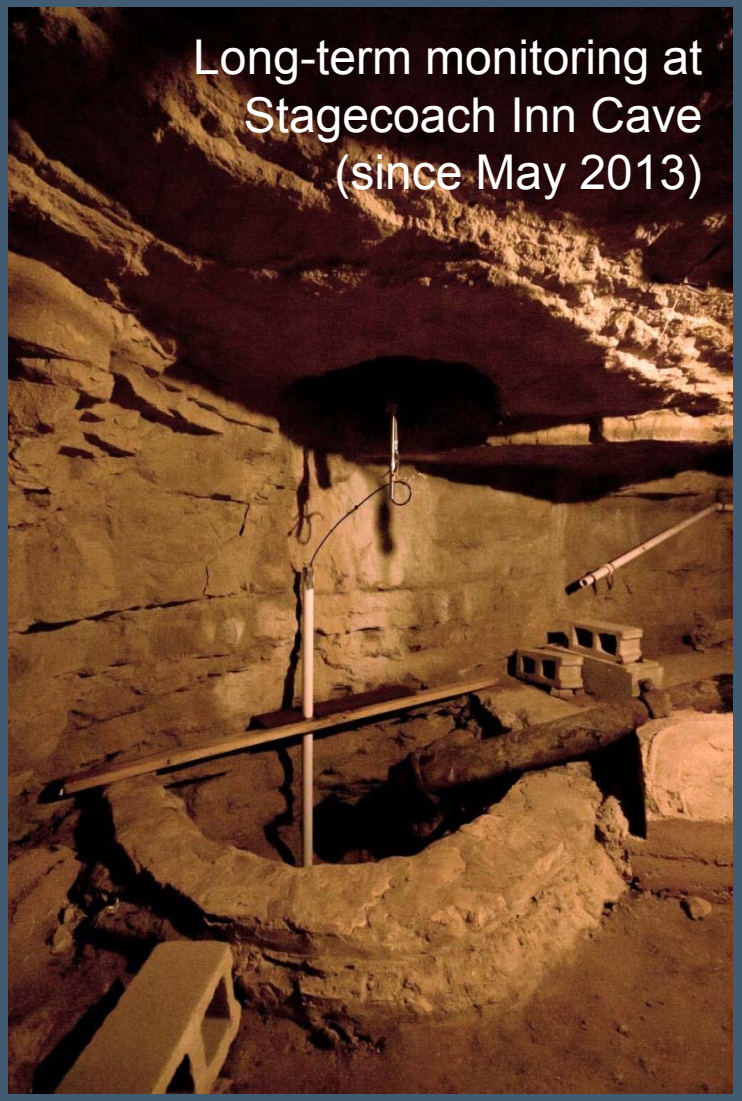
- Three strategic locations
- Important for correlating rainfall and recharge response

Station 3 (since fall 2014)

Station 2 (since fall 2014)

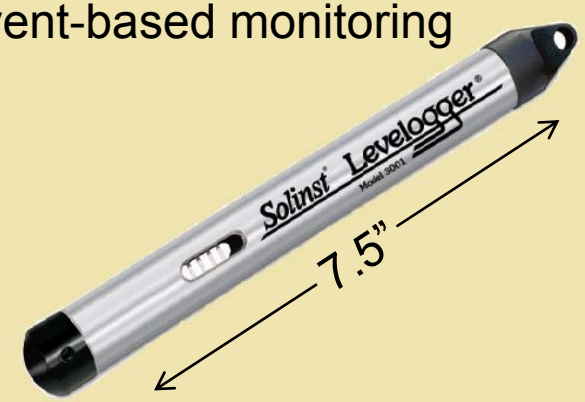
Station 1 (since spring 2014)

Multi-parameter monitoring

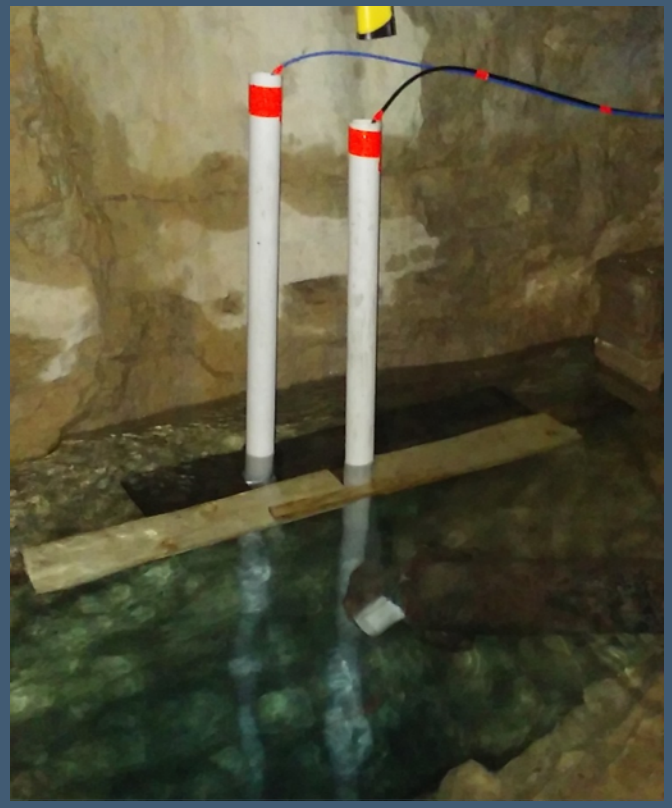


- **OTT CTD:** long-term monitoring
- **Solinst Levelogger:** event-based/short-term monitoring
- Three parameters:
  - Water level change
  - Temperature
  - Specific Conductance

Event-based monitoring



- **In-Situ Troll 9500**
- Added parameters:
  - Nitrate, dissolved oxygen, pH
- Added to Cave installation in February 2016
- Sensor issues in March
- Continued data collection in October 2016



March 30, 2016

Data correlation
(October – November 2015)

Nitrate sampling

- Sampled during a non-holiday weekend as control
- Sampled during several holiday weekends (eg. Labor Day)
- Sampled at all springs, in Salado Creek, and at Stagecoach Inn Cave

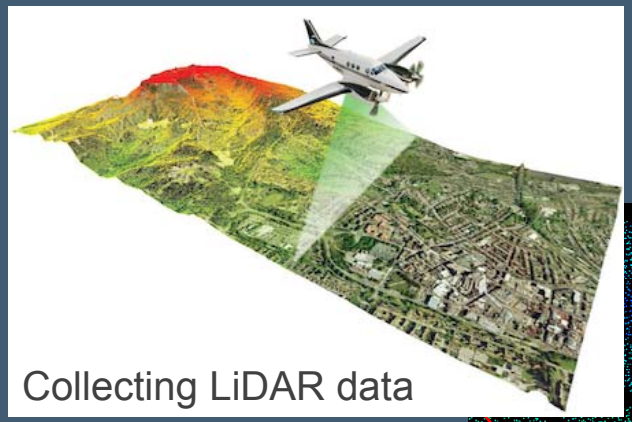
Radon: A natural tracer

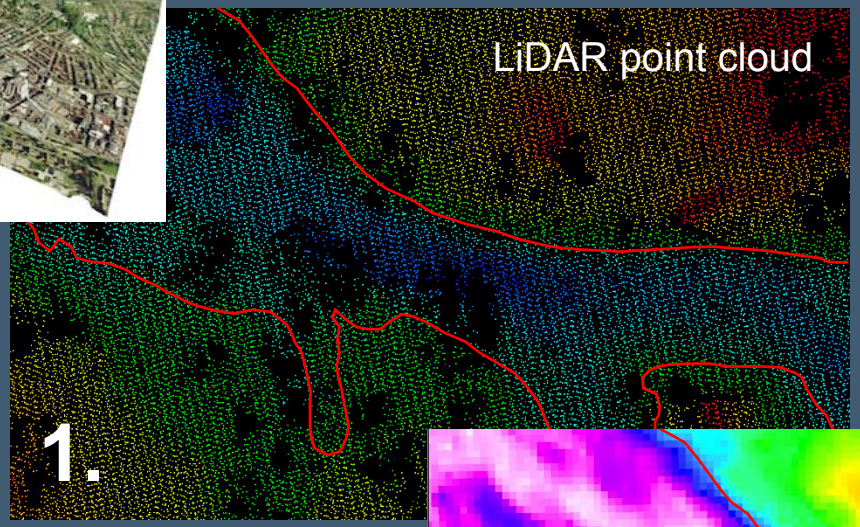
- Naturally-occurring
- Radioactive decay product of uranium and radium
- Source: trace amounts in soils and geology
- Half-life = 3.8 days
- Rapid dispersal from groundwater to atmosphere
- Focused sampling:
  - Salado Creek
  - Salado Springs complex
- Monitoring samples:
  - Big Boiling springs/Salado Creek

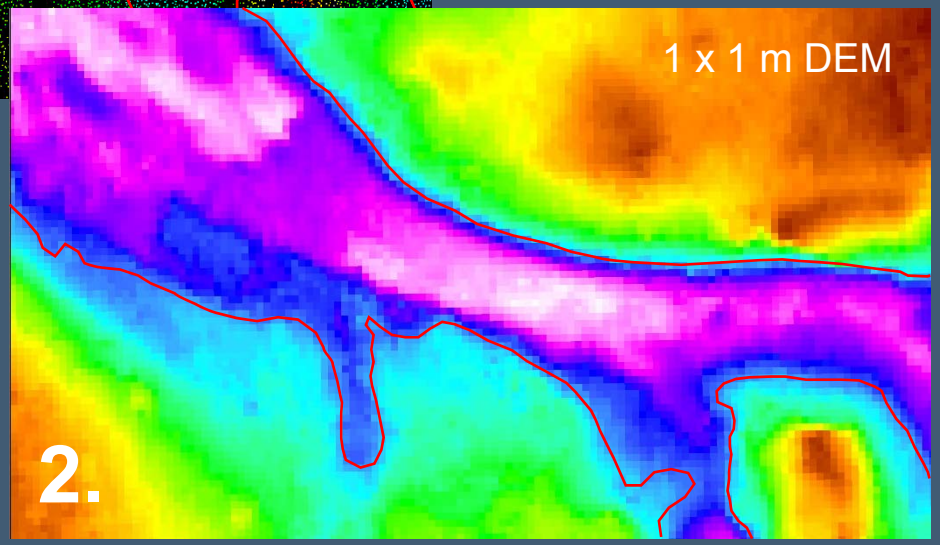
Field sampling

RAD7 with the RAD H2O accessory

Recharge features characterization: LIDAR


Collecting LiDAR data





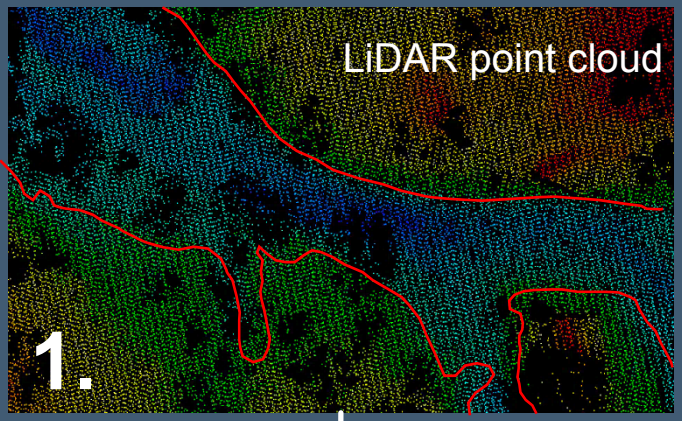
100 Feet

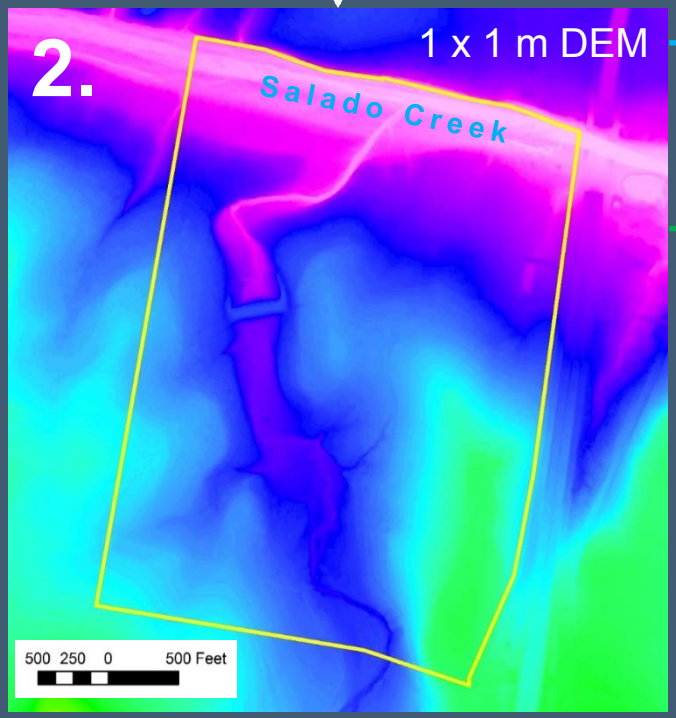
Elevation (masl)

198.425

193.937

Recharge features characterization: Approach





Fill sinks → Raster subtraction → Map of depressions

Aspect → Manual delineation → Map of lineations

Spring Assessment: SIP and SEAP (Springer & Stevens, 2007)

- SIP: Spring Inventory Protocol
- SEAP: Spring Ecological Assessment Protocol
- Aspects:

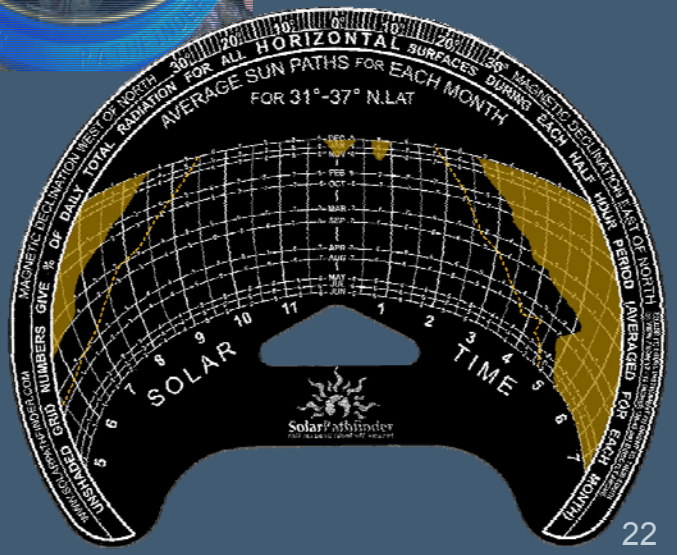
1. SIP
- Site description
- Solar budget
- Habitat
- Flora/fauna inventory
- Geomorphology
- Water quantity/quality

2. SEAP
- Aquifer/water quality
- Geomorphic integrity
- Habitat quality
- Biotic integrity
- Human influence
- Administrative context

- Option to upload data (global springs database)

SPRINGS ONLINE
SPRINGS STEWARDSHIP INSTITUTE *of the* MUSEUM *of* NORTHERN ARIZONA

Conducting solar budget evaluation at Side Spring
(Salado, Texas, Sept. 2016)



What we now know

Groundwater – surface water interactions:

- **Points of groundwater addition to Salado Creek can be identified**
- **The interaction of groundwater with surface water can be characterized**

Groundwater levels:

- **No big cone of depression is evident through the Epic Drought (2011)**
- **Net water level has been increasing**

Groundwater chemistry:

- **Measured parameters are generally steady, with seasonal and events-based fluctuations**
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Aquifer response to recharge events:

- ***Precipitation varies temporally and spatially***
- ***Precipitation affects the entire connected spring complex***

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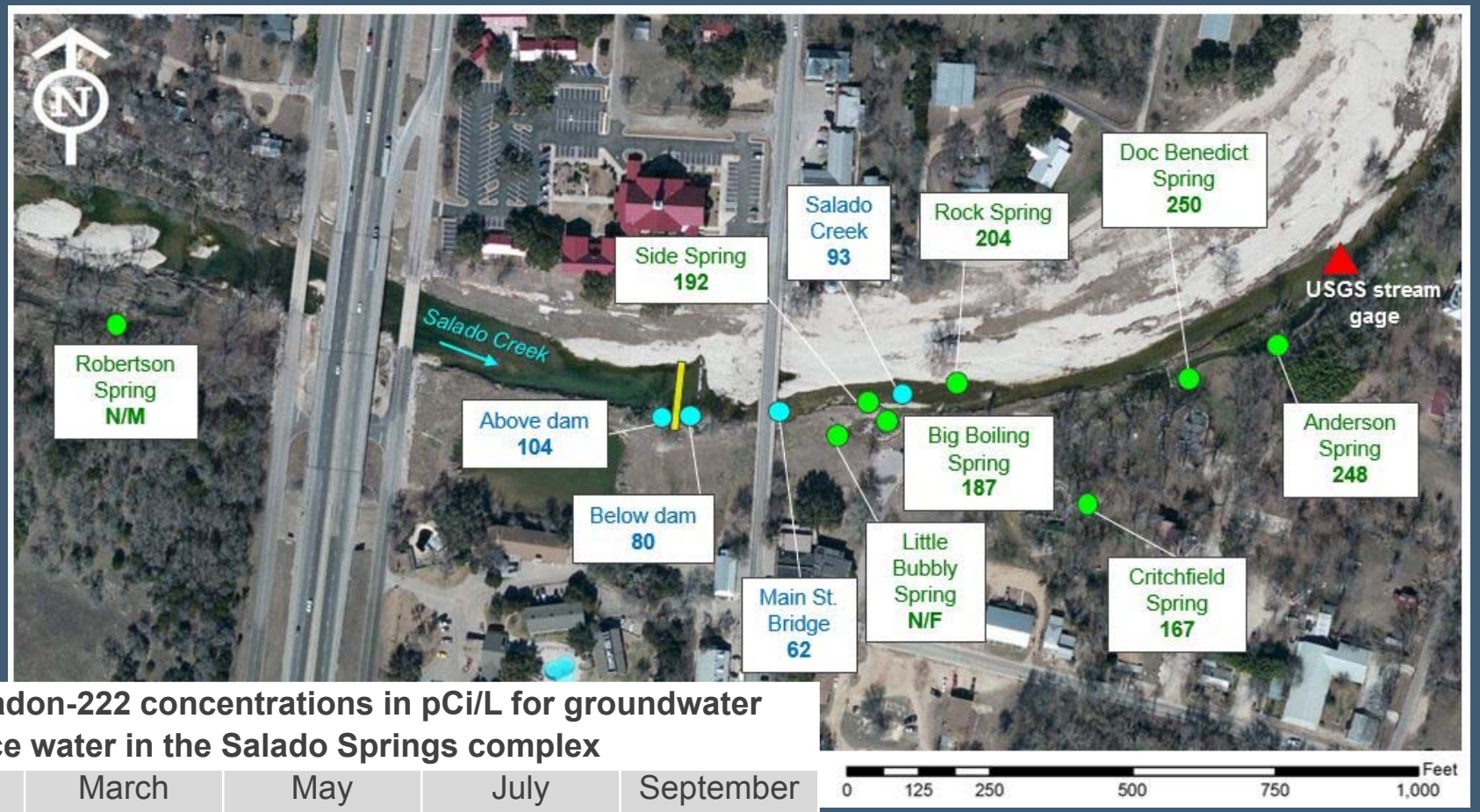
Groundwater – surface water interactions: Natural radon at Salado Springs

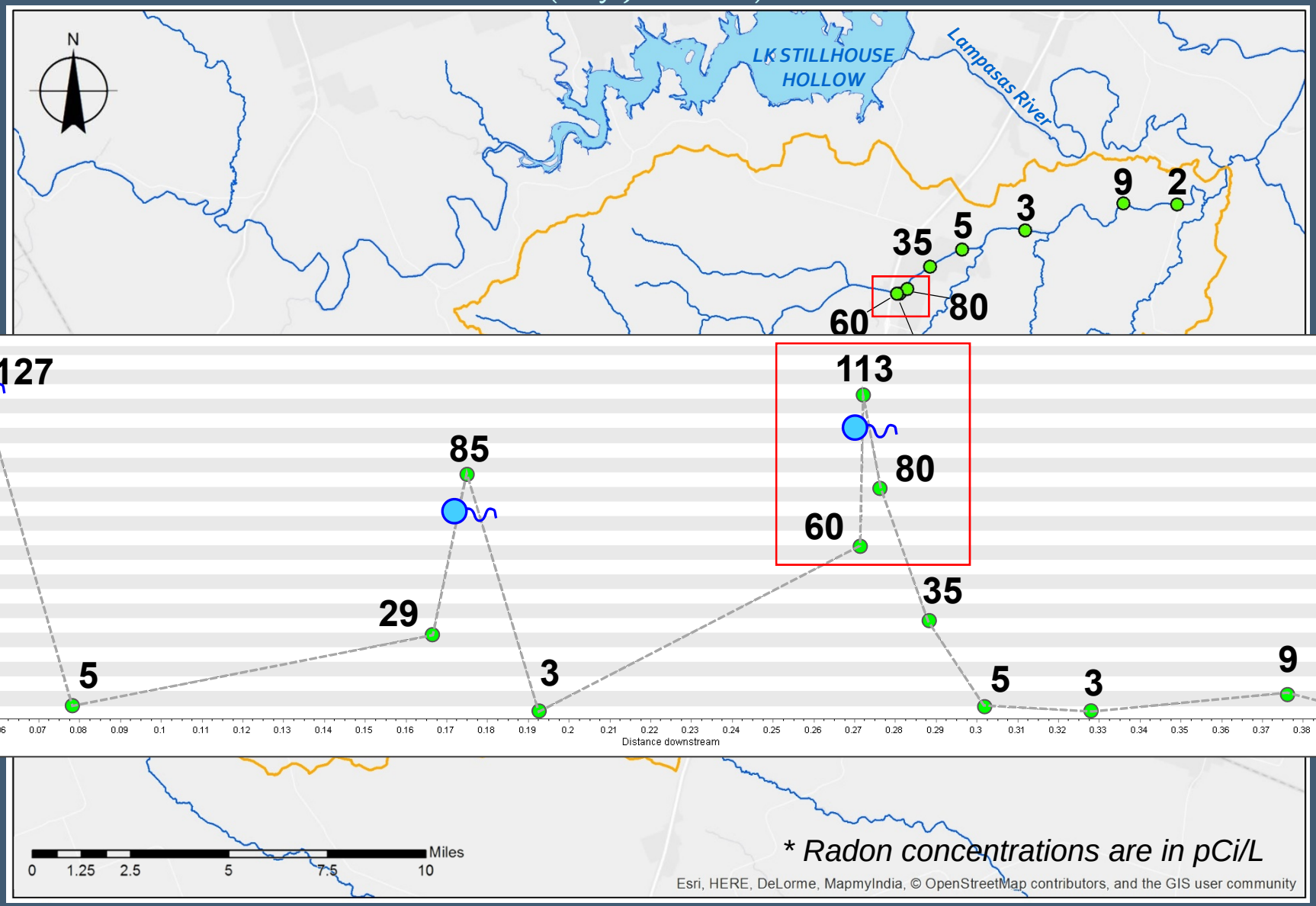


Average radon-222 concentrations in pCi/L for groundwater and surface water in the Salado Springs complex

	March 2014	May 2015	July 2015	September 2015
Groundwater	200.16	257.25	244.56	262.10
Surface water	84.75	N/M*	124.87	167.60

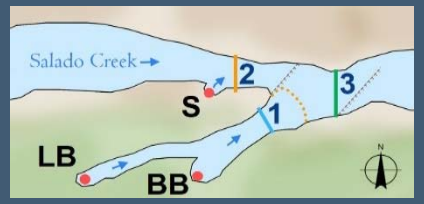
Groundwater – surface water interactions: Natural radon at Salado Creek basin

(May-June 2014)

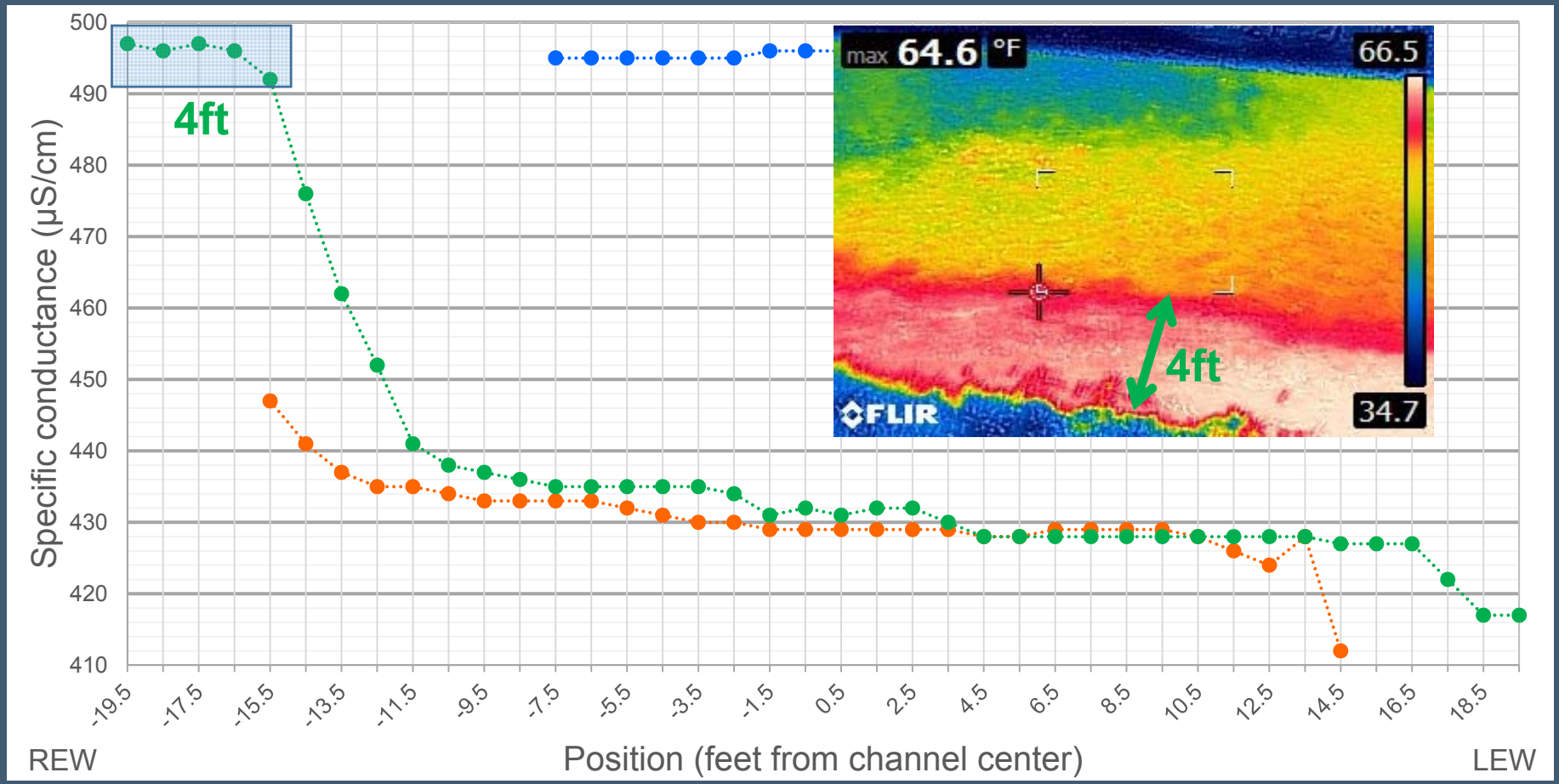


Groundwater – surface water interactions

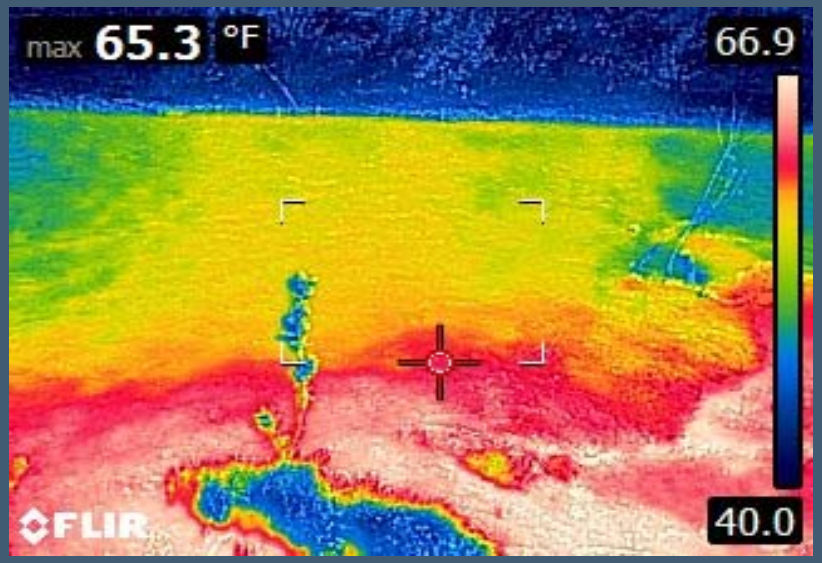
Conductivity profile
(April 6, 2016)

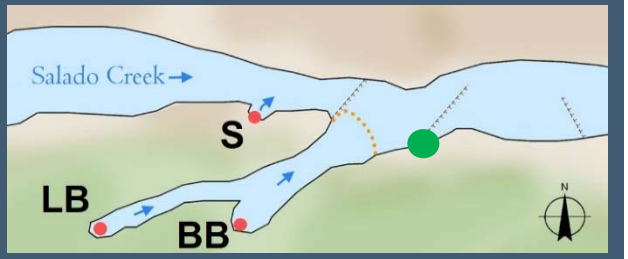


Section 1 Section 2 Section 3

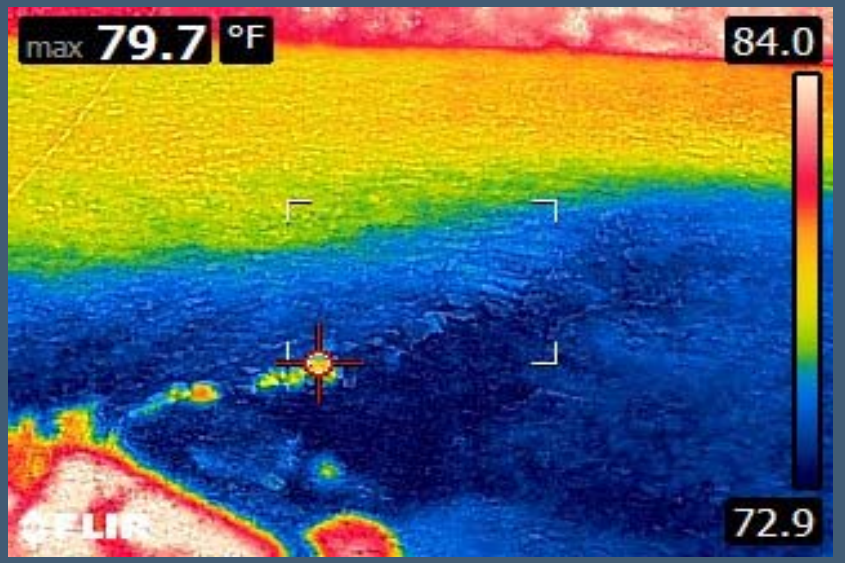


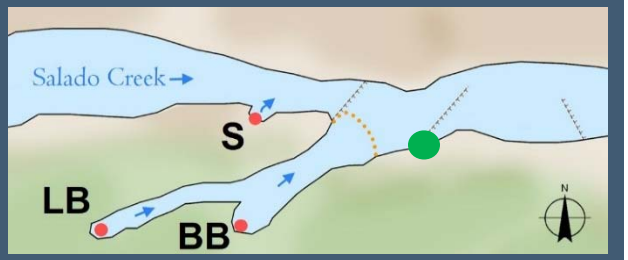
GW/SW Mixing April 6, 2016 natural obstruction deflection





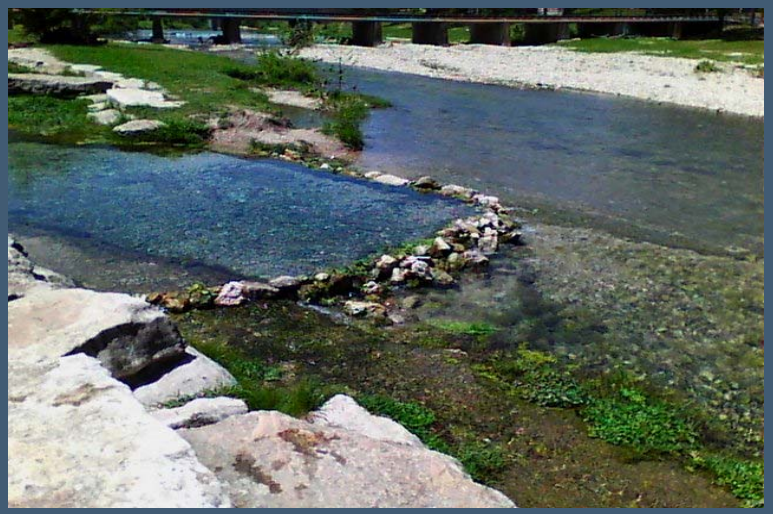
GW/SW Mixing July 26, 2016 natural obstruction deflection



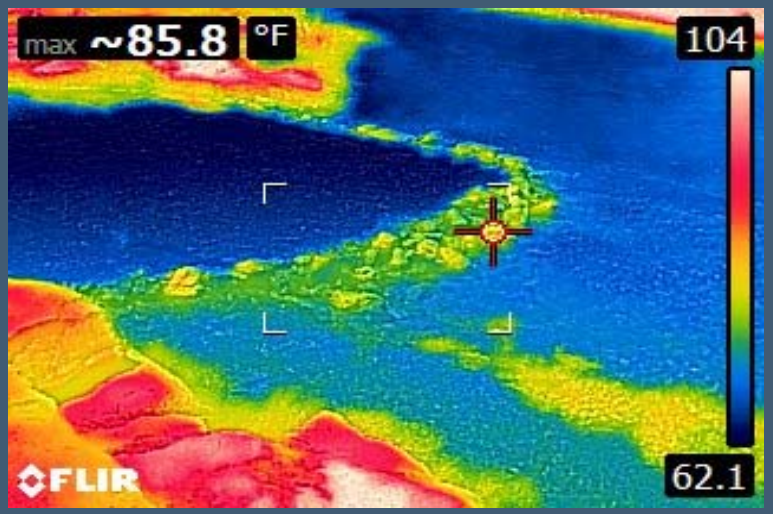


Construction Effects

Constructed Rock Dam

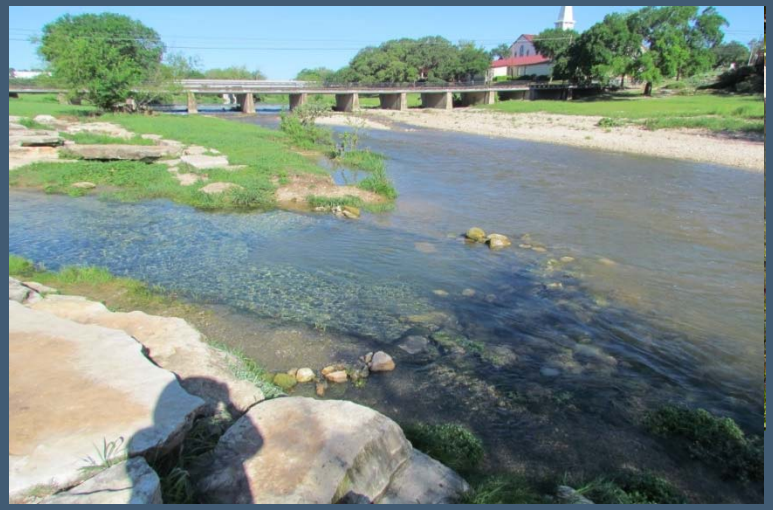


Temperature Effects



Construction Effects
High Flow and Sediment

Constructed Rock Dam

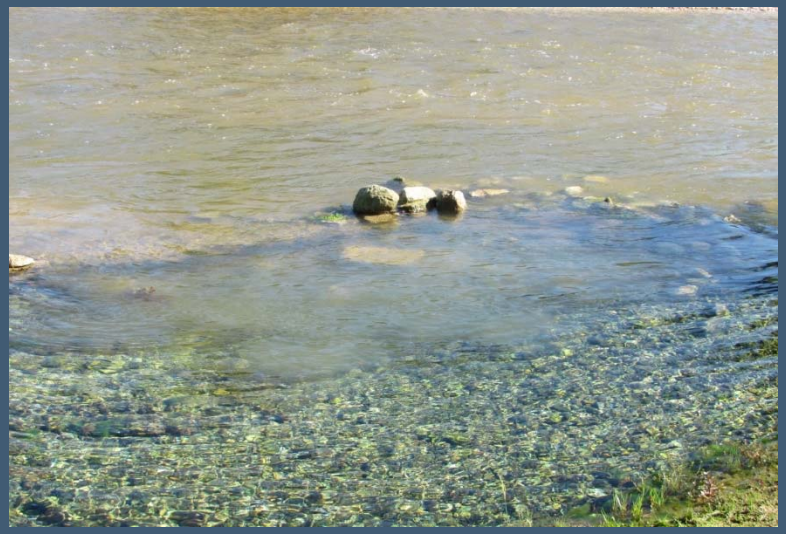


Sediment Effects

Construction Effects
High Flow and Sediment

Constructed Rock Dam

Sediment Effects

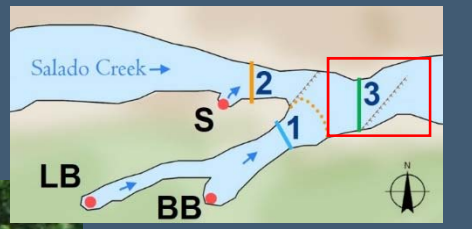


Construction Effects
High Flow and Sediment

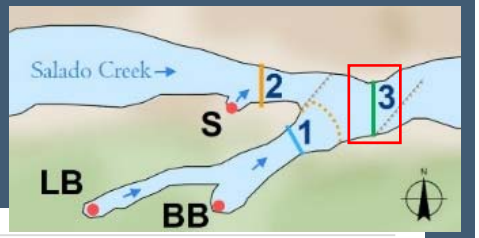
Surface Water/Groundwater

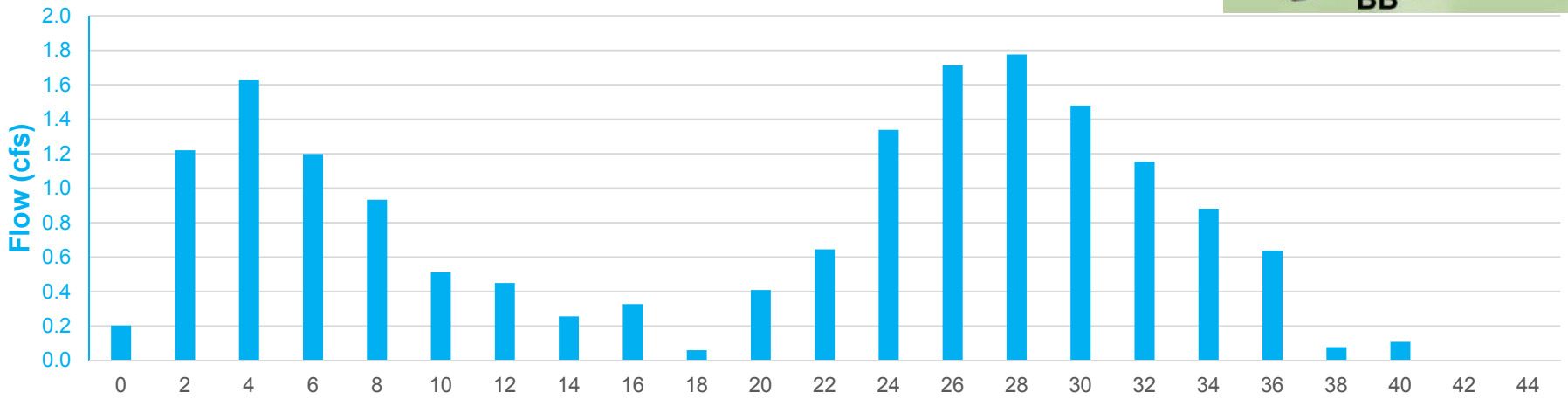
Surface Water/Groundwater

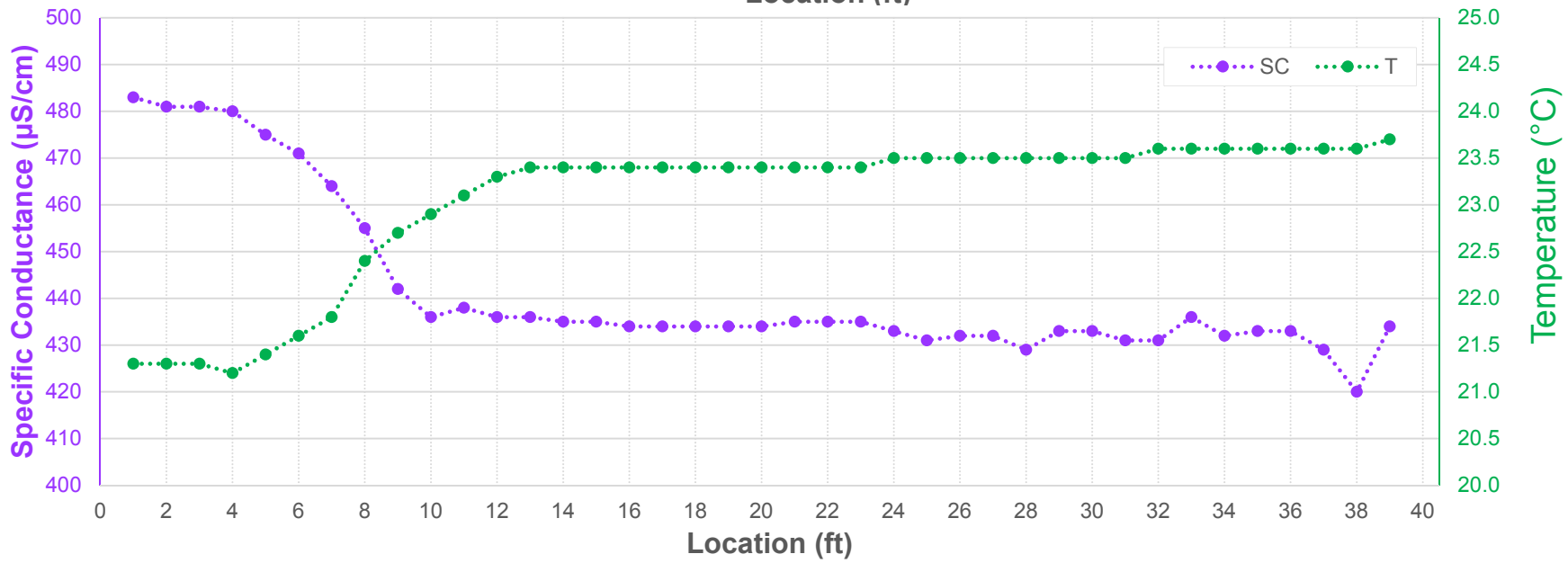
Groundwater – surface water interaction



Cross section 3, downstream of Big Boiling Spring







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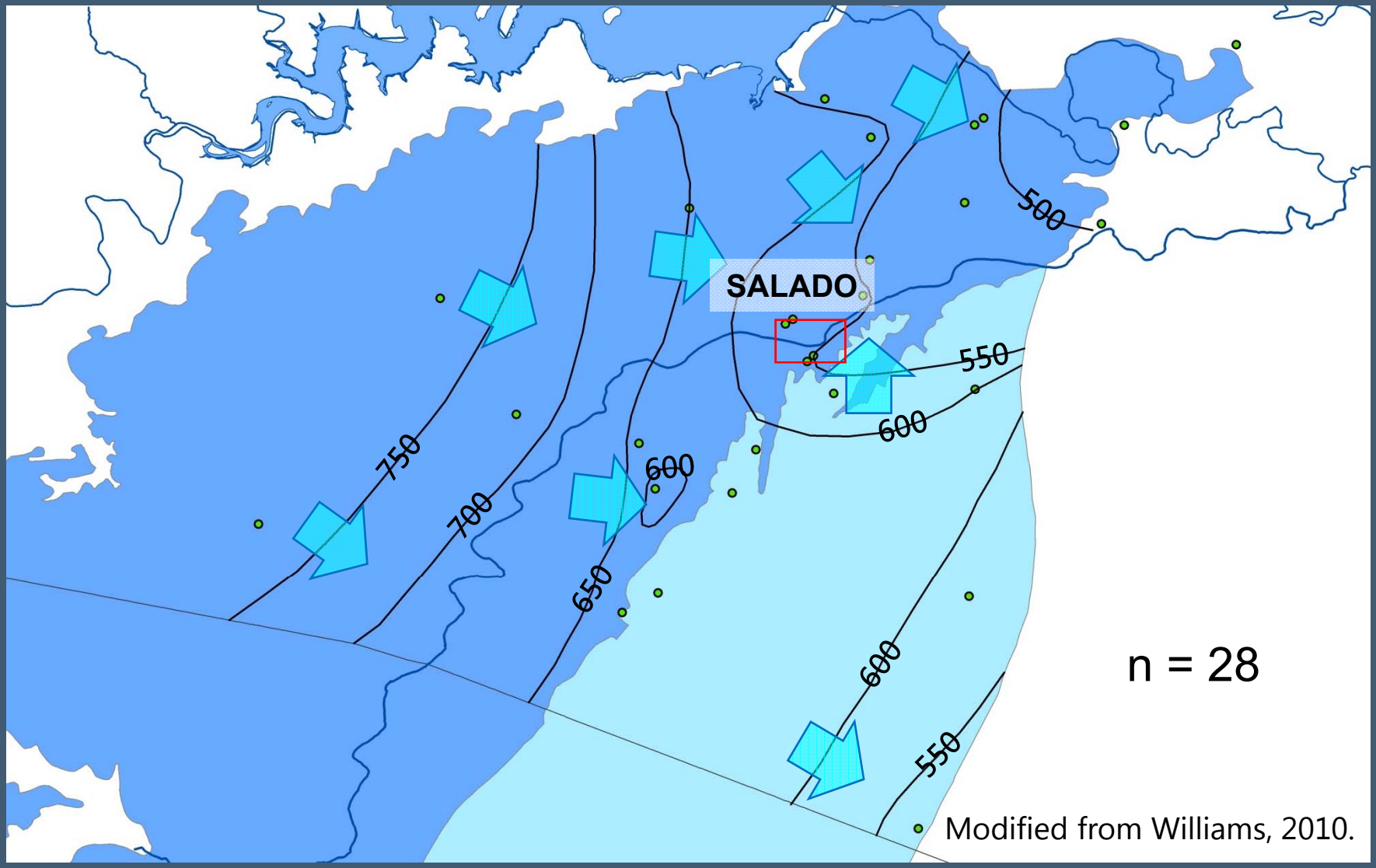
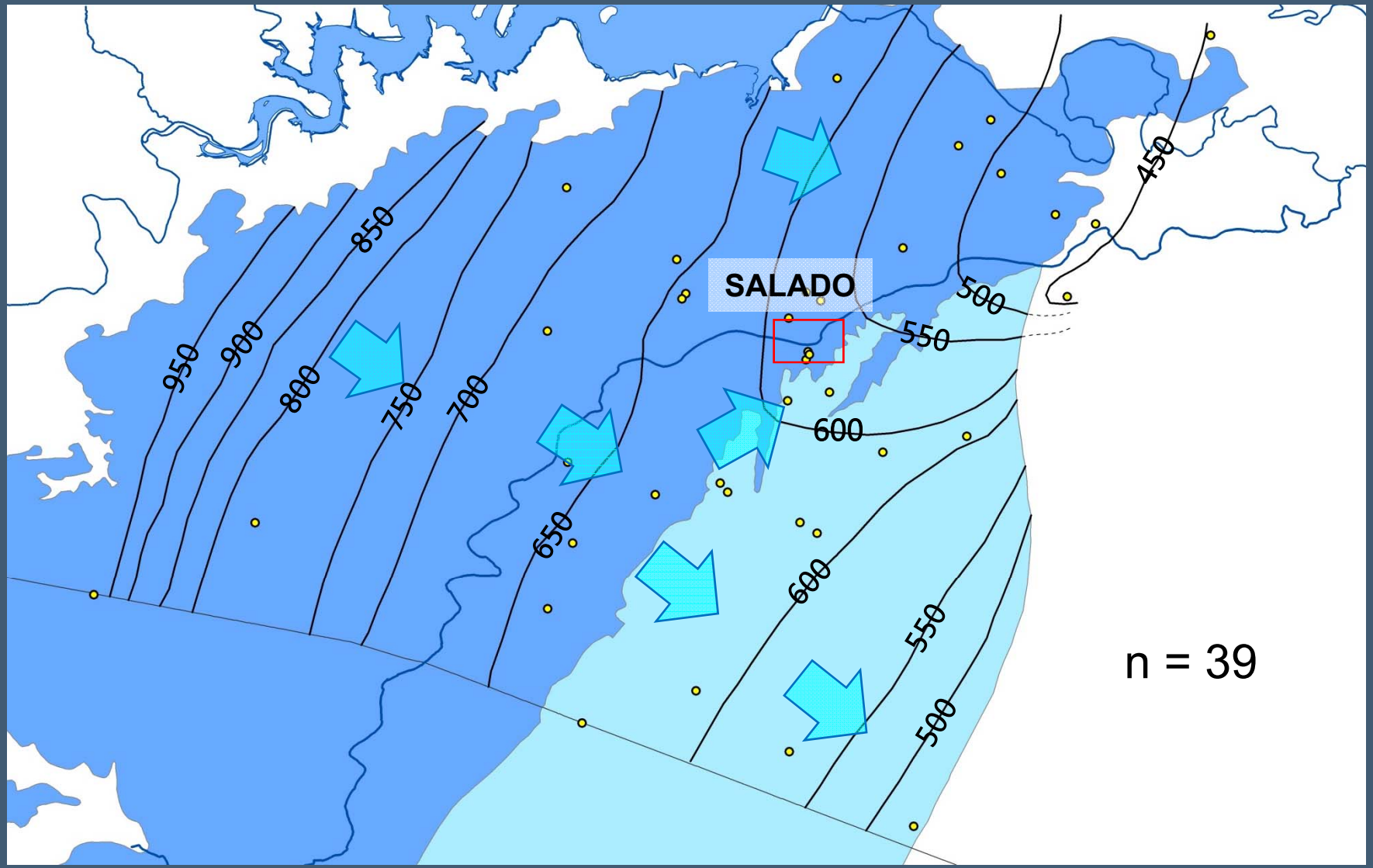
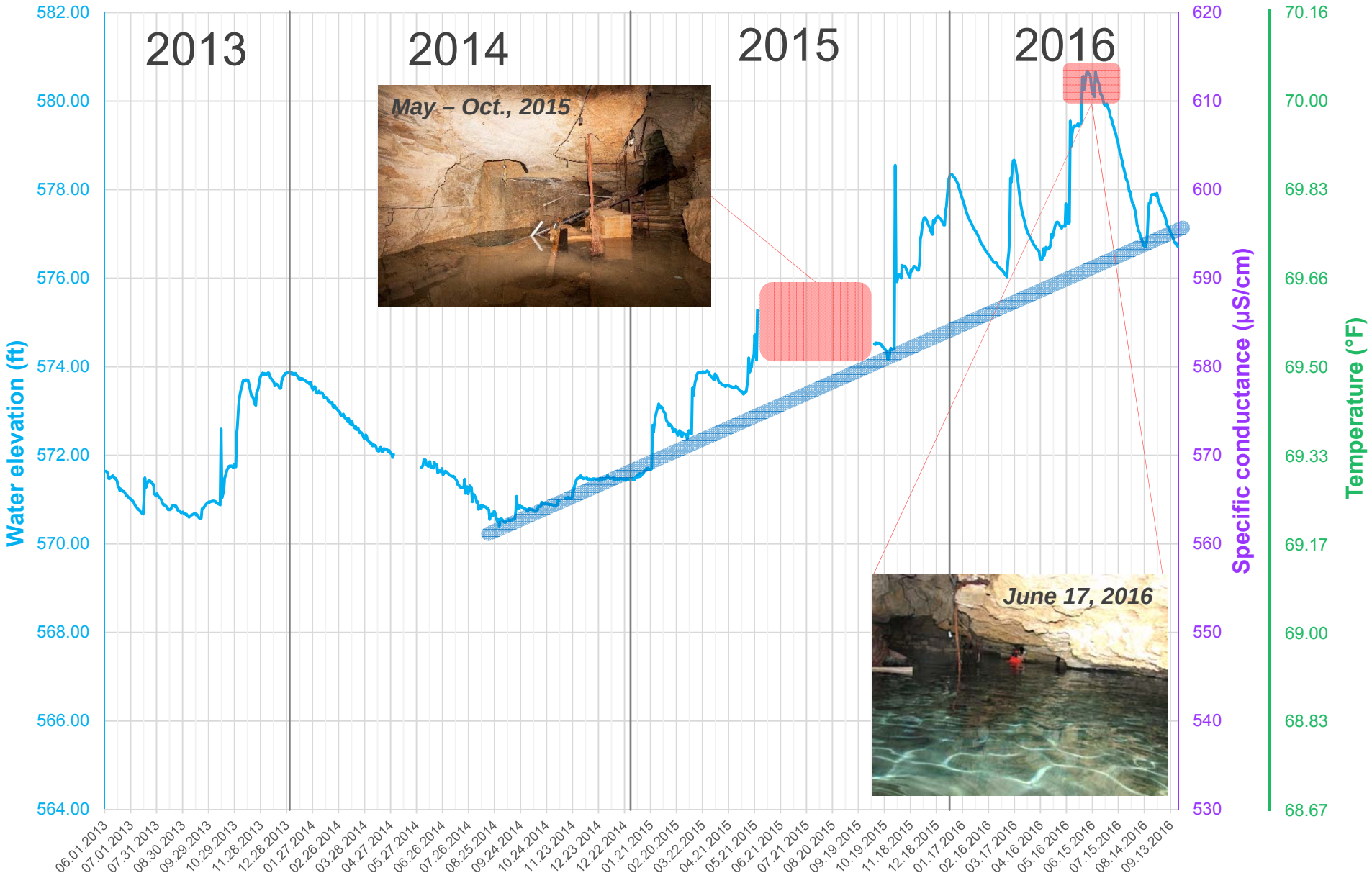
Groundwater elevations, 2010



Groundwater elevations, 2013




2013
2014
2015
2016
May – Oct., 2015
June 17, 2016
Water elevation (ft)
Specific conductance (µS/cm)
Temperature (°F)
582.00
580.00
578.00
576.00
574.00
572.00
570.00
568.00
566.00
564.00
620
610
600
590
580
570
560
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530
70.16
70.00
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69.66
69.50
69.33
69.17
69.00
68.83
68.67
06.01.2013
07.01.2013
07.31.2013
08.30.2013
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11.28.2013
12.28.2013
01.27.2014
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12.23.2014
12.22.2014
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03.22.2015
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08.20.2015
09.19.2015
10.19.2015
11.18.2015
12.18.2015
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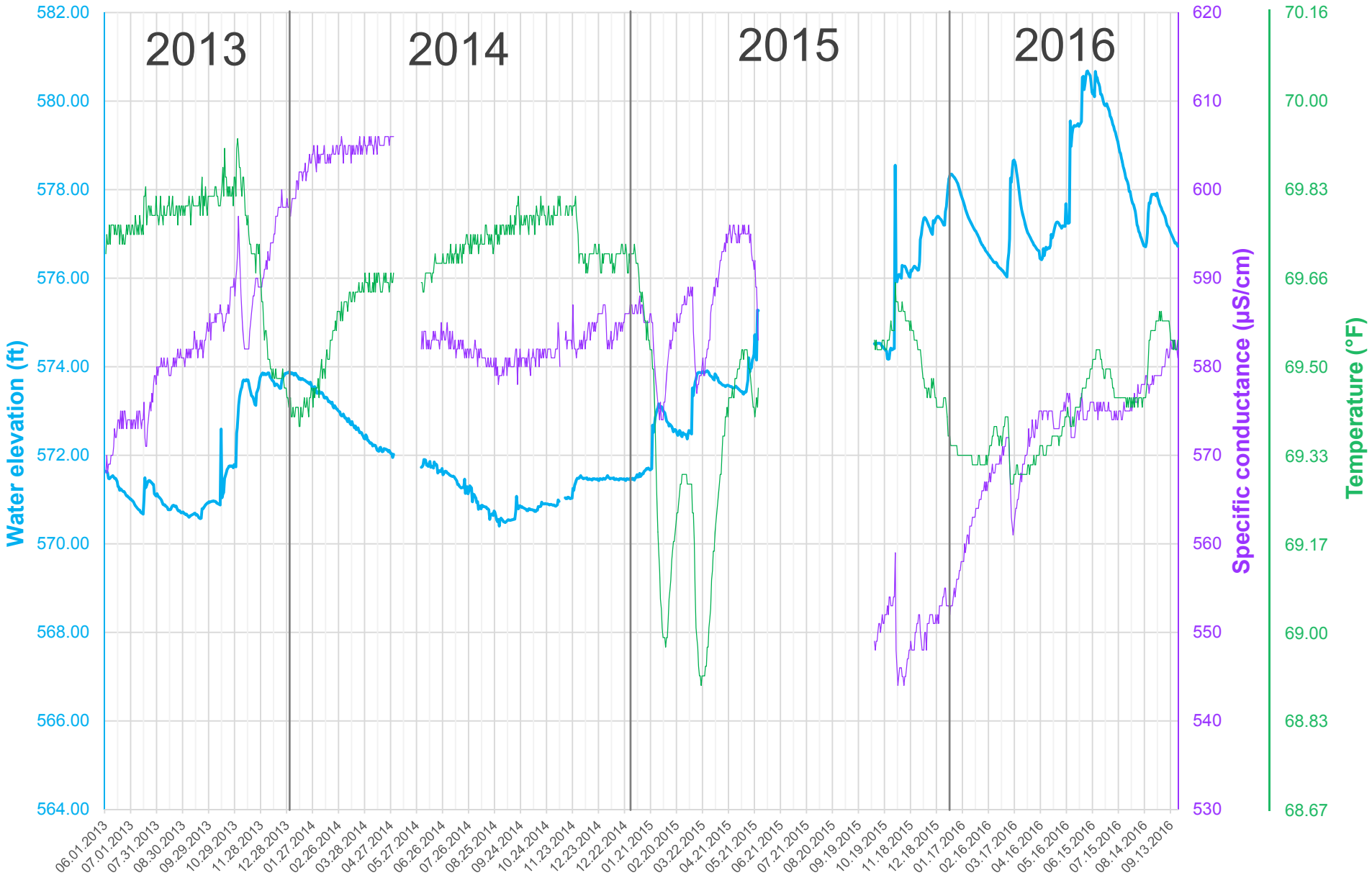
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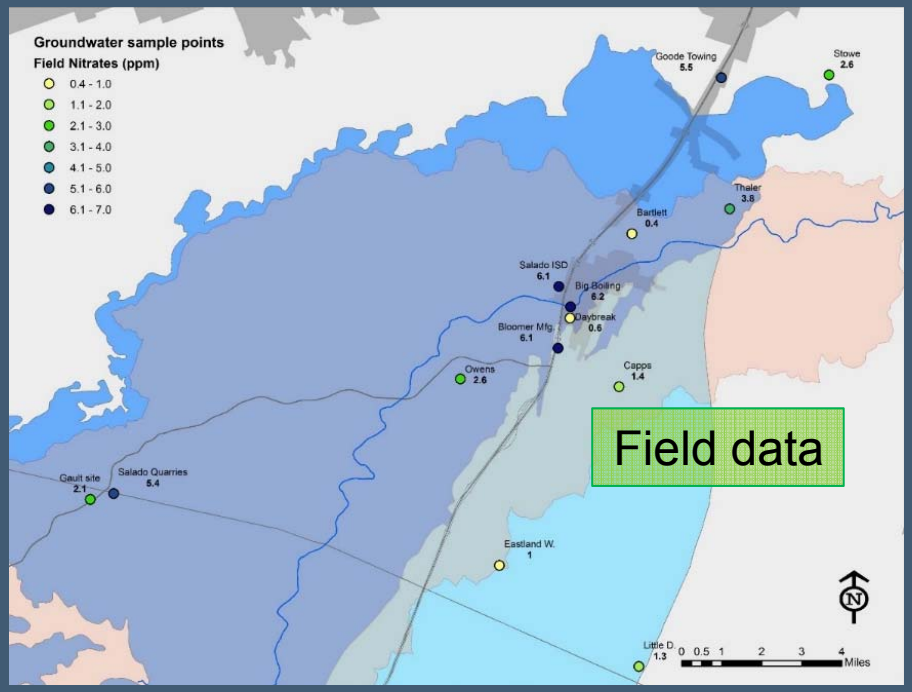
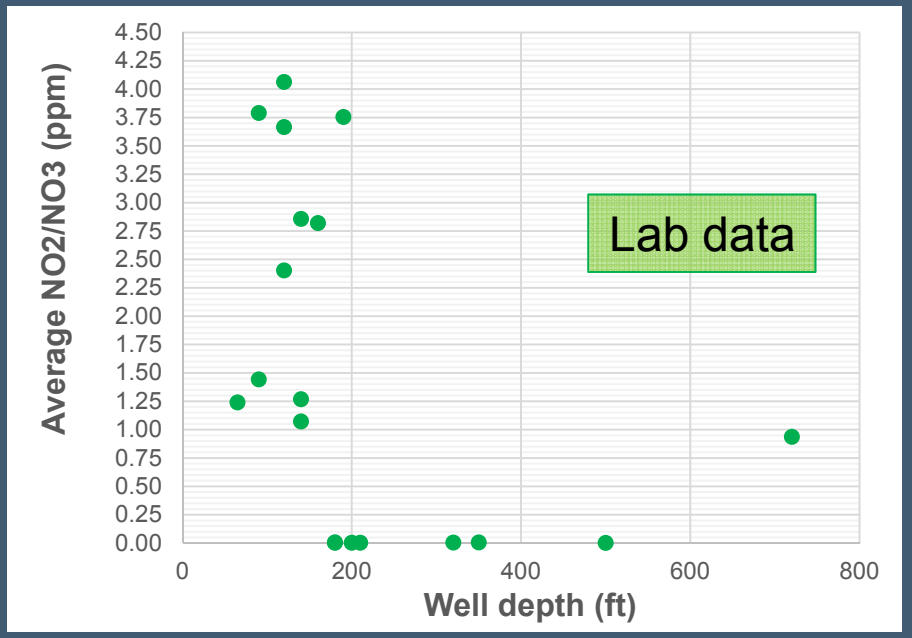
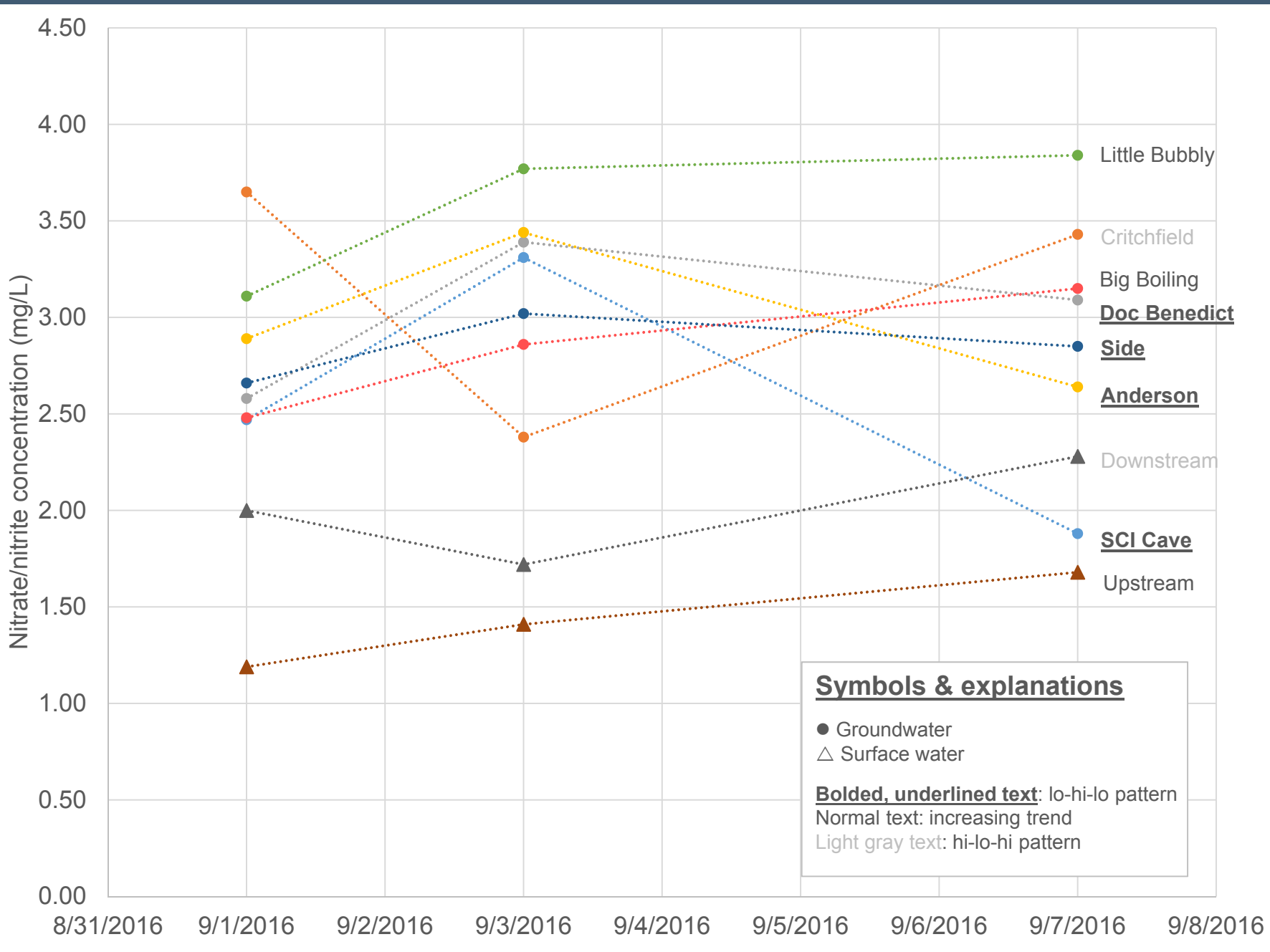
09.19.2015
10.19.2015
11.18.2015
12.18.2015
01.17.2016
02.16.2016
03.17.2016
04.16.2016
05.16.2016
06.15.2016
07.15.2016
08.14.2016
09.13.2016

Aquifer water chemistry

- Nitrogen data (field and lab) slightly above expected background levels
- **No nitrate values observed to be over the drinking water limit (10 ppm)**
- No strong trends, but some of the higher values were found in the more developed areas.






4.50
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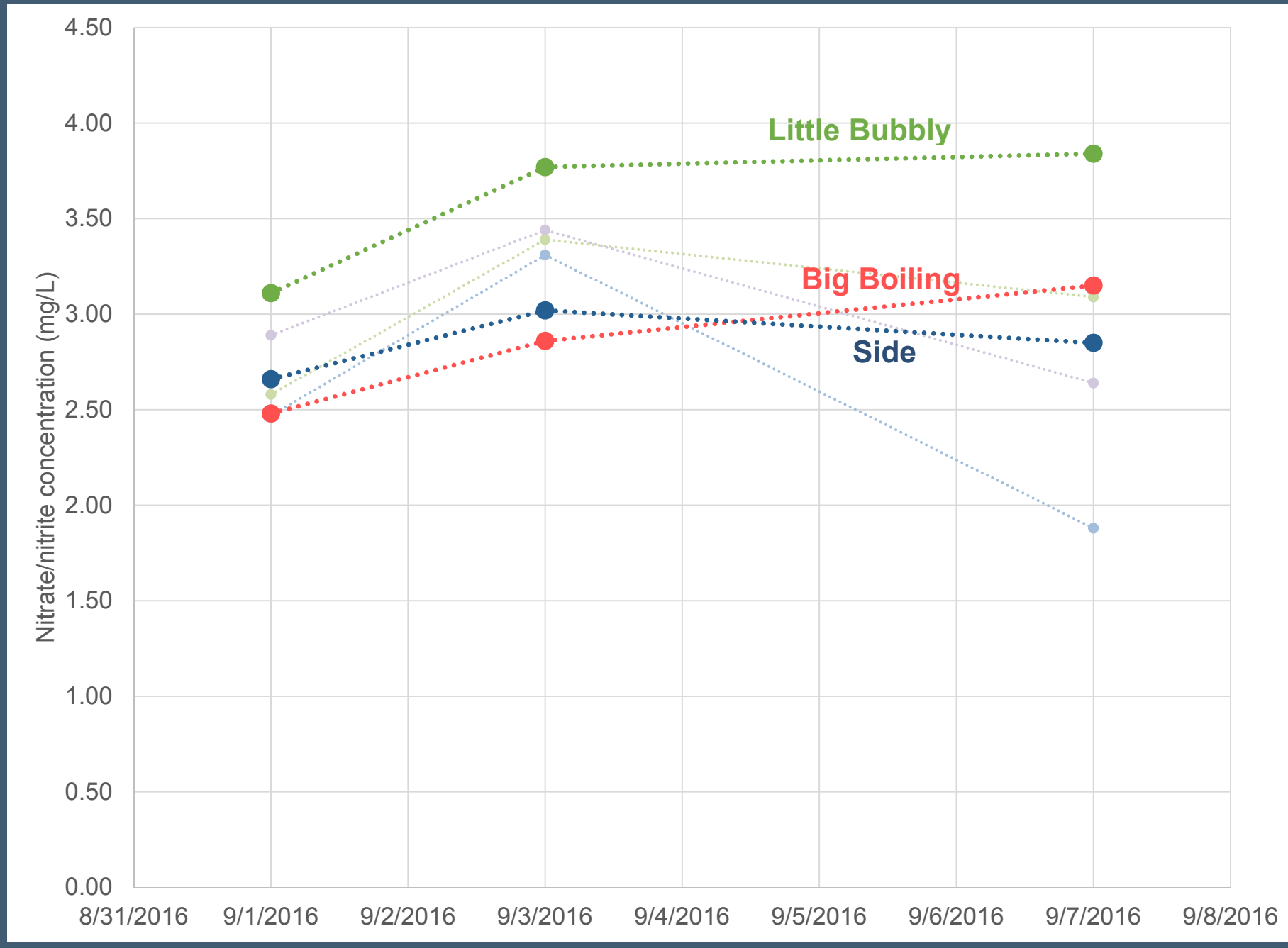
Nitrate/nitrite concentration (mg/L)
8/31/2016
9/1/2016
9/2/2016
9/3/2016
9/4/2016
9/5/2016
9/6/2016
9/7/2016
9/8/2016
Little Bubbly
Critchfield
Big Boiling
Doc Benedict
Side
Anderson
Downstream
SCI Cave
Upstream
Symbols & explanations
● Groundwater
△ Surface water
Bolded, underlined text: lo-hi-lo pattern
Normal text: increasing trend
Light gray text: hi-lo-hi pattern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9/1/2016
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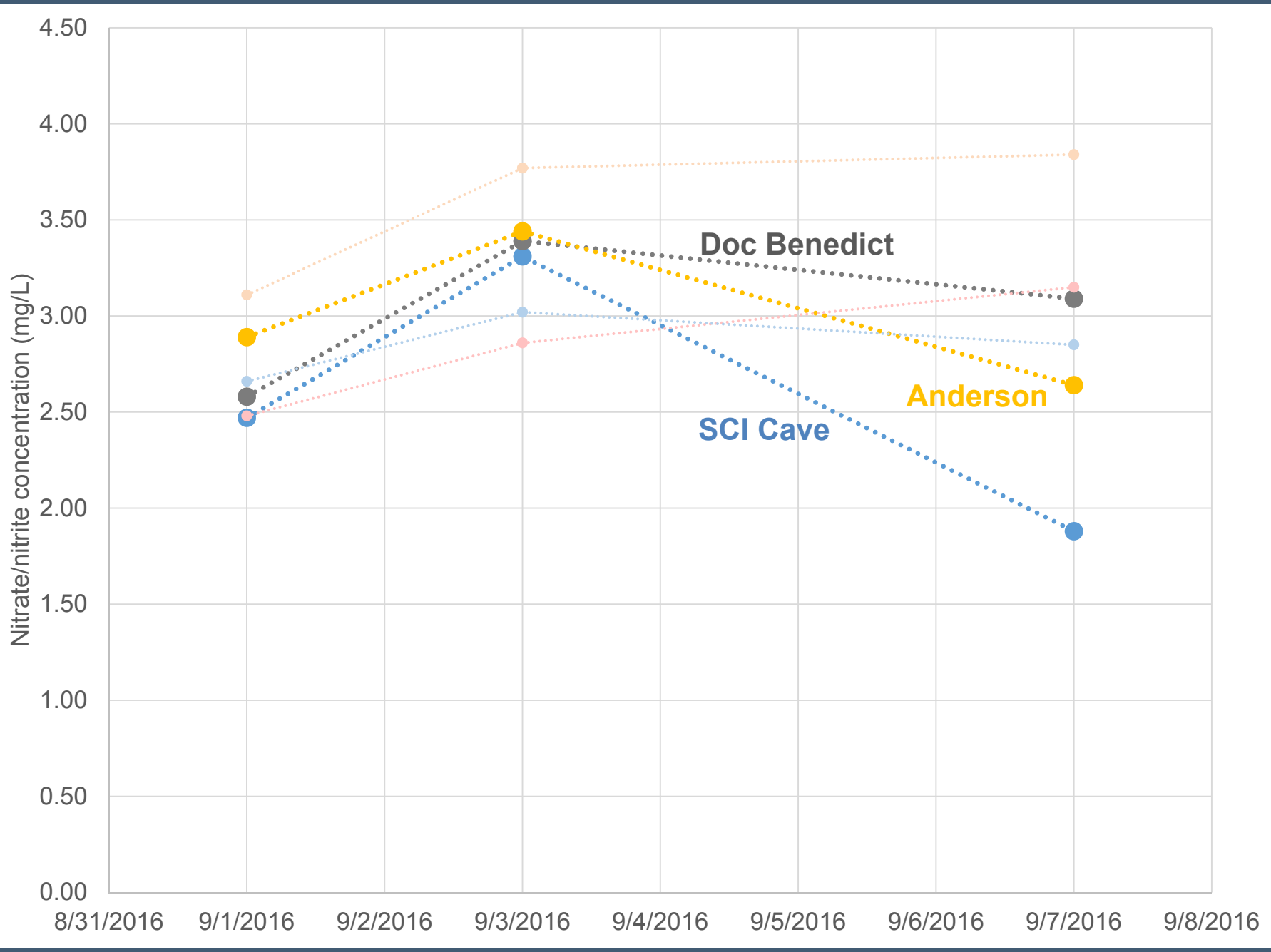
9/4/2016
9/5/2016
9/6/2016
9/7/2016
9/8/2016
Little Bubbly
Big Boiling
Side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9/4/2016
9/5/2016
9/6/2016
9/7/2016
9/8/2016
Doc Benedict
Anderson
SCI Cave

Groundwater – surface water interactions:

- **Points of groundwater addition to Salado Creek can be identified**
- **The interaction of groundwater with surface water can be characterized**

Groundwater levels:

- **No big cone of depression is evident through the Epic Drought (2011)**
- **Net water level has been increasing**

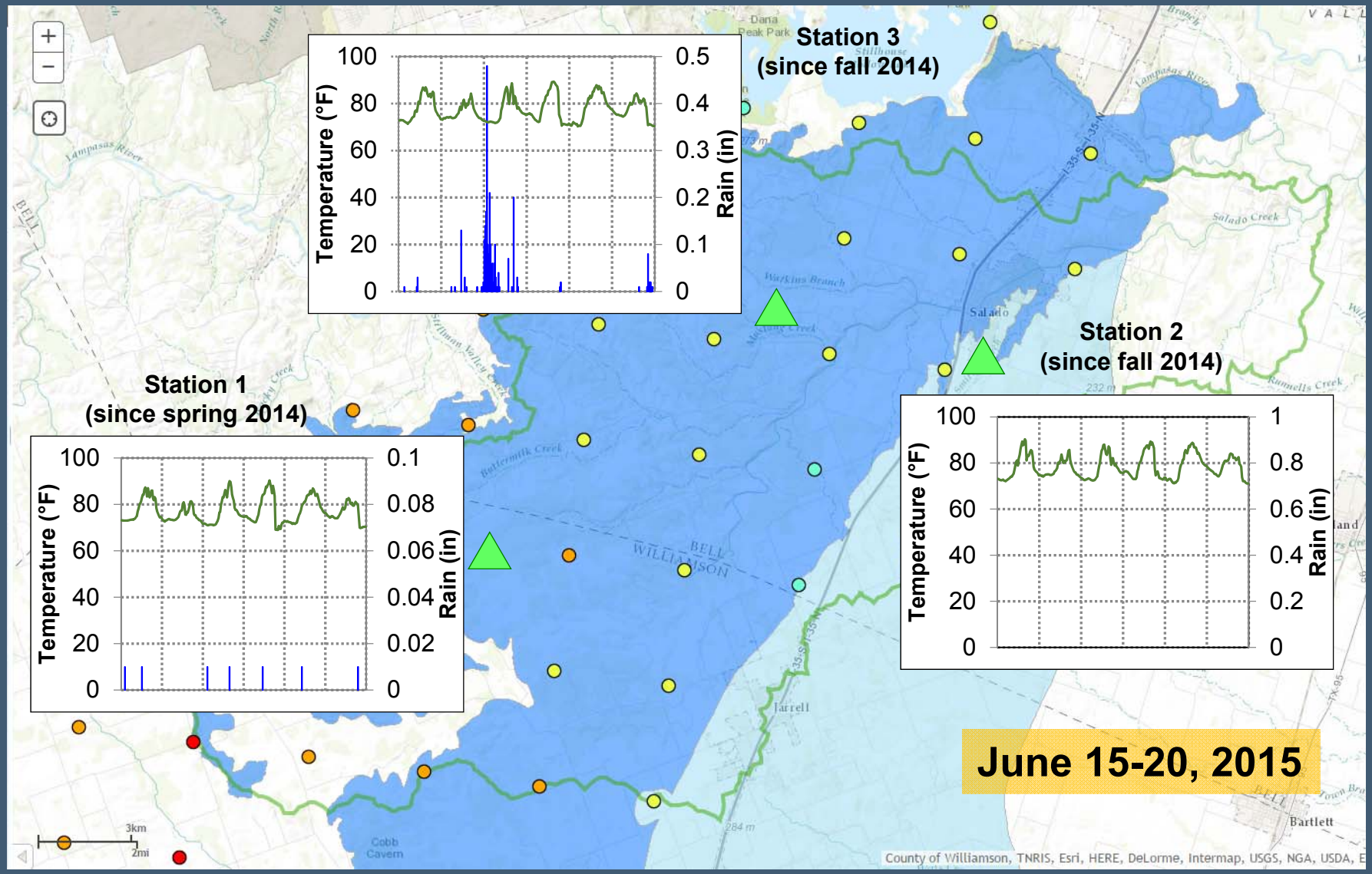
Groundwater chemistry:

- **Measured parameters are generally steady, with seasonal and events-based fluctuations**
- **Nitrate levels are slightly elevated but not of urgent concern**

Aquifer response to recharge events:

- ***Precipitation varies temporally and spatially***
- ***Precipitation affects the entire connected spring complex***

Monitoring recharge: Weather stations



Dye trace test: Spring connectivity

2013:

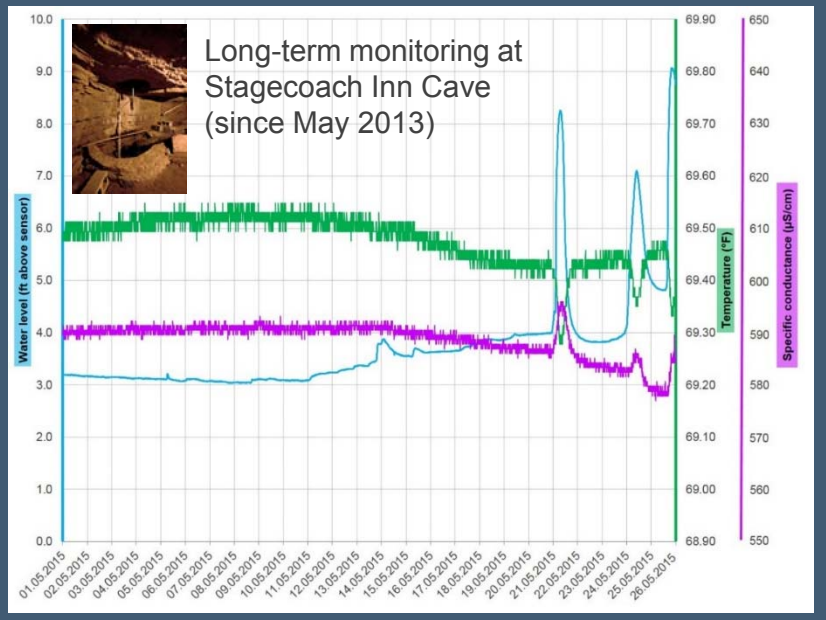
Detection	Time elapsed (hrs)	Avg. Velocity (mi/d)
Big Boiling		
First:	1.8	1.53
Peak:	2.7	

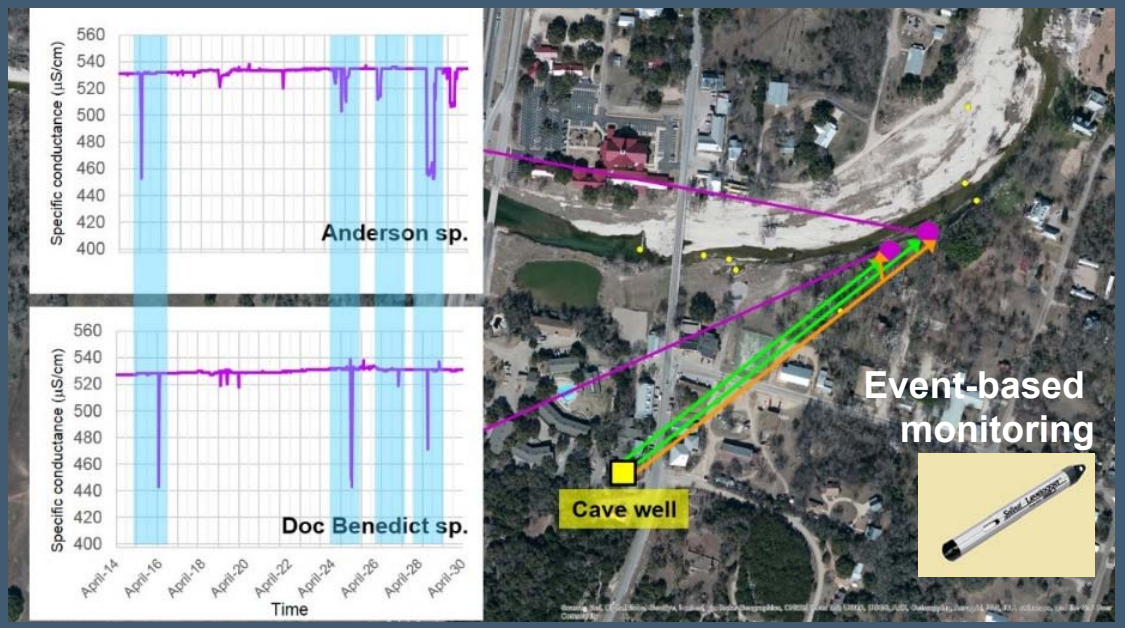
2015:

Detection	Time elapsed (hrs)	Avg. Velocity (mi/d)
Big Boiling		
First:	0.75	3.63
Peak:	1.25	

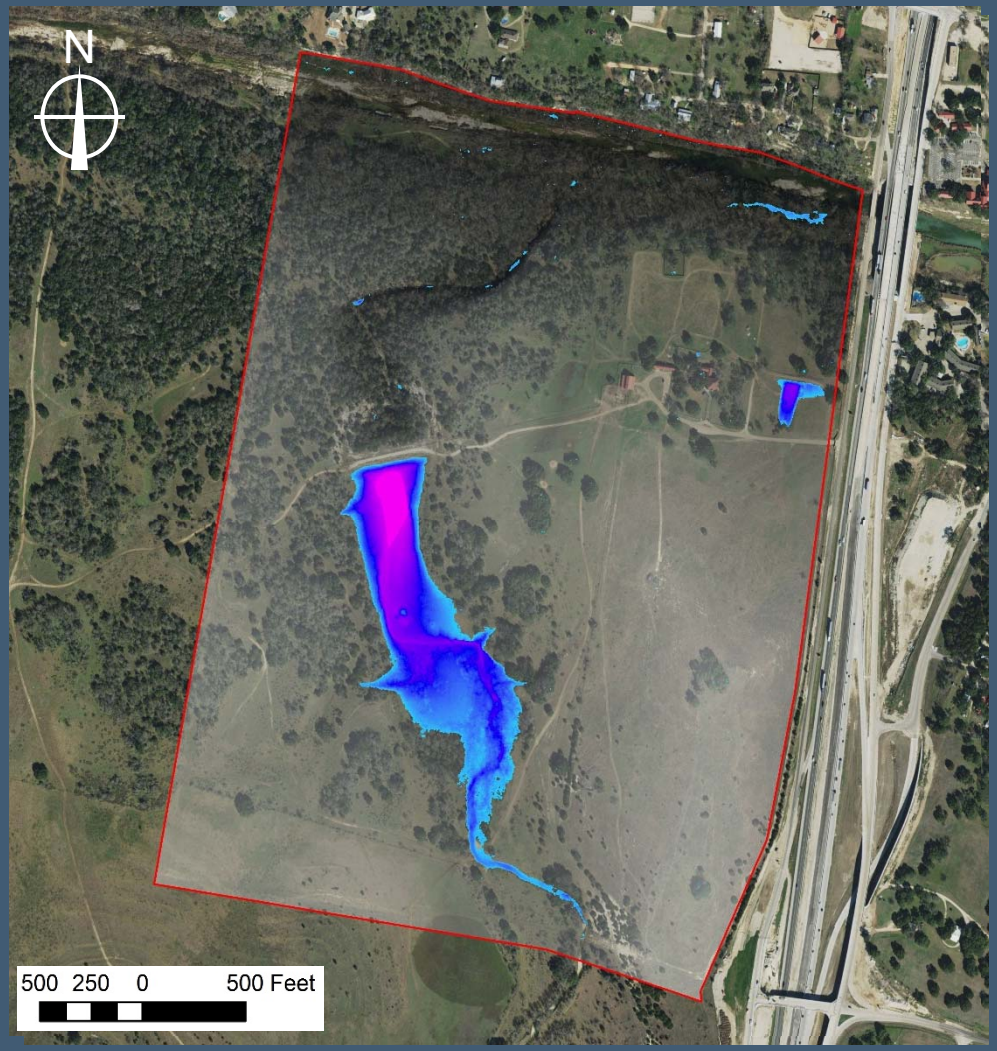
Monitoring response to recharge

- Data indicate **rapid groundwater responses to large rainfall events** and slight water quality changes
- The multi-parameter datalogger data **further refined the fracture system**
  - A slightly slower response at Doc Benedict Spring than Anderson Spring
- Recharge responses provide **important timing information to aid in the development of future monitoring**





Depressions

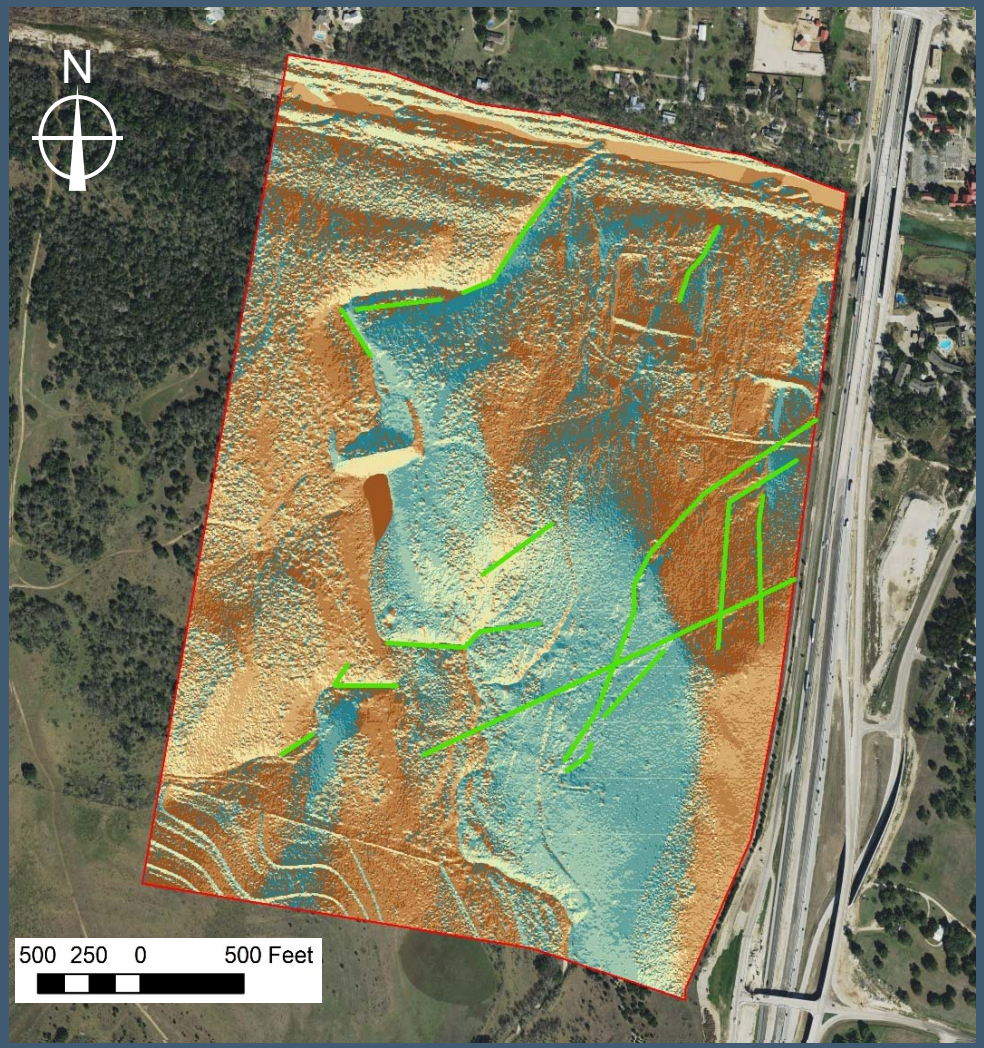


Depression depth

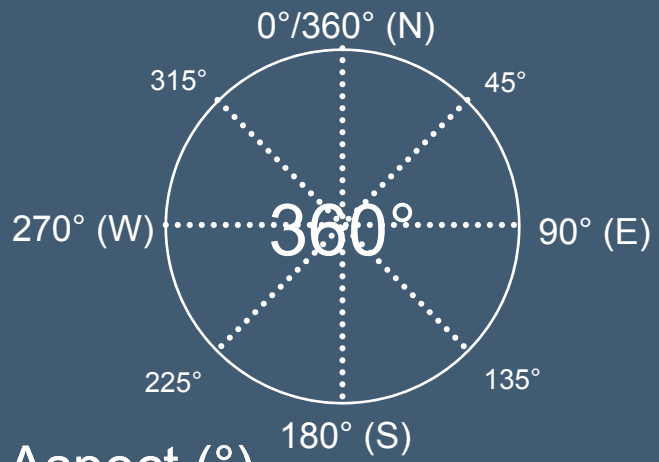
Deep: 12.24 ft (3.73 m)

Shallow: 1.02 ft (0.31 m)

Linear features



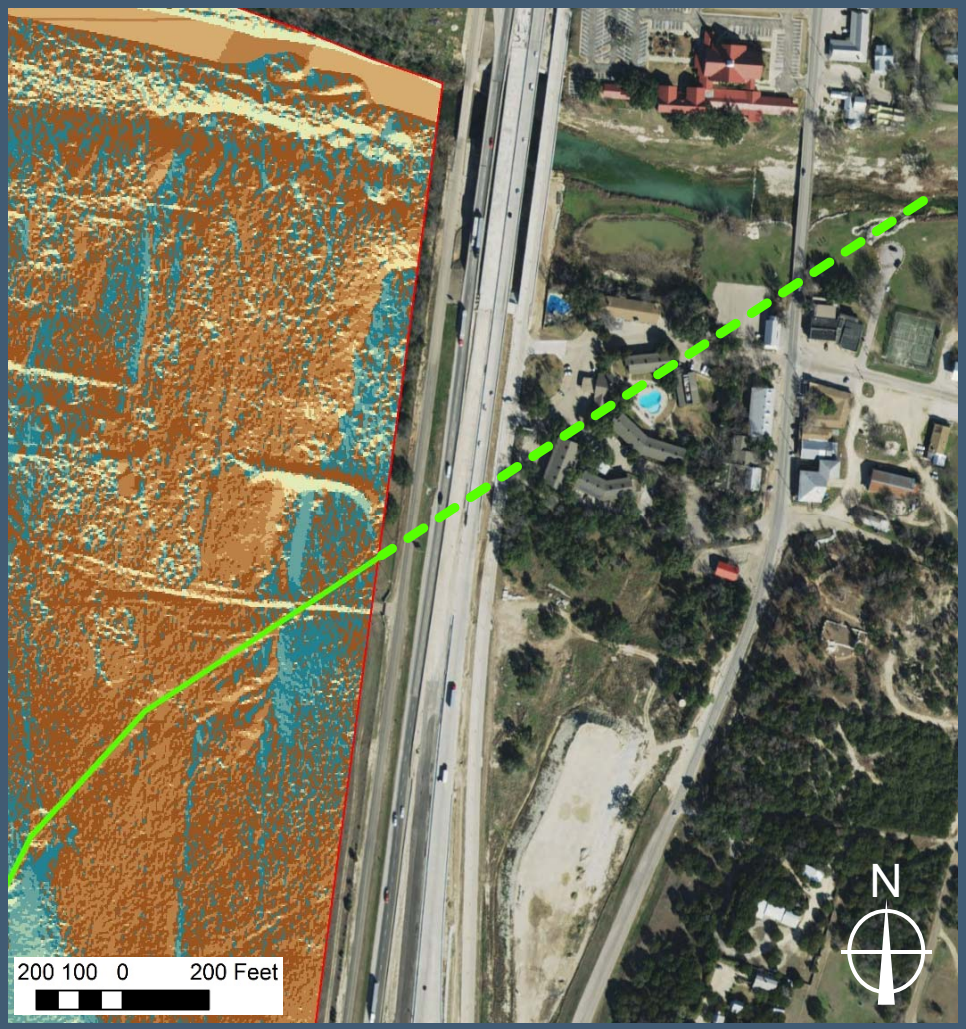
- Aspect: slope direction



Aspect (°)

- Manual selections
  - Anthropogenic lineations
  - Natural lineations

Linear features



- Lineation is directly in line with Big Boiling
- Desktop measurement: 213°
- Field measurement: 220°

Research & management

Spring Assessment: SIP and SEAP (Springer & Stevens, 2007)

- SIP: Spring Inventory Protocol
- SEAP: Spring Ecological Assessment Protocol
- Aspects:

1. SIP
- Site description
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Conducting solar budget evaluation at Side Spring
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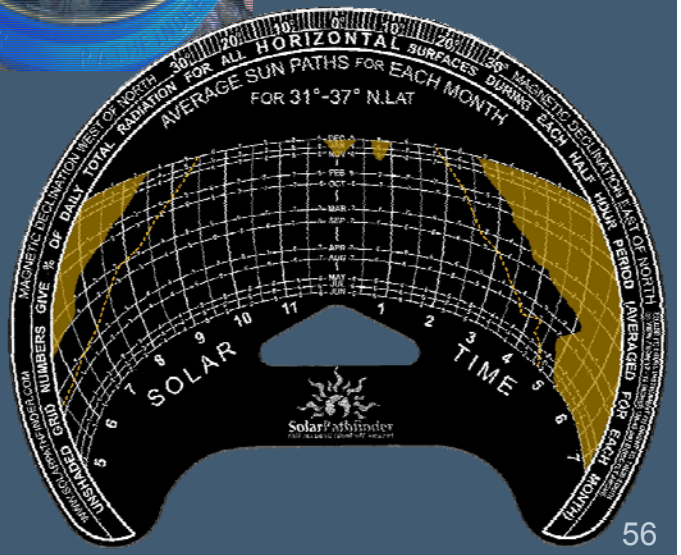
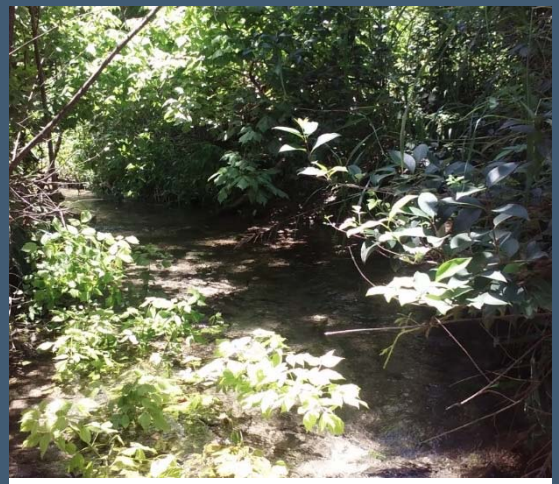
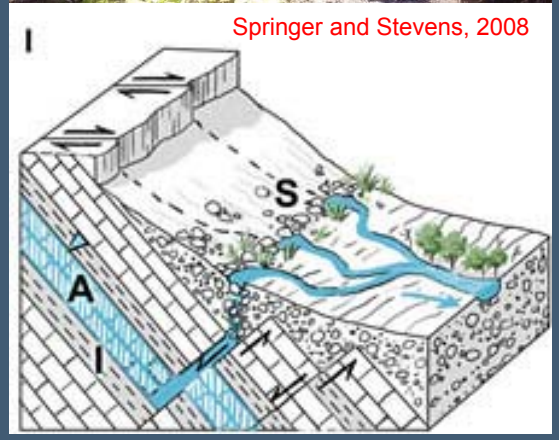


Spring Assessment: Robertson Spring

- **Rheocrene spring**
  - Discharge emerges as flowing streams and forms spring "runs"



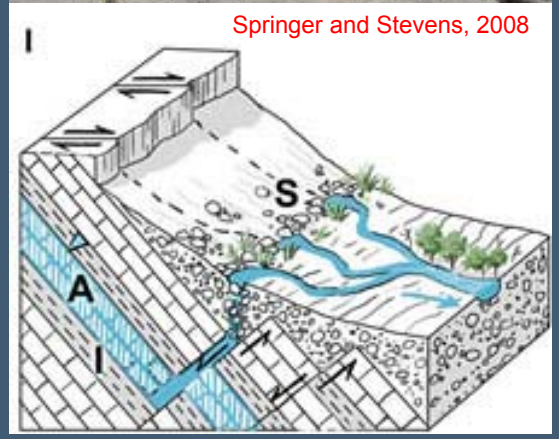


Springer and Stevens, 2008

Spring Assessment: Big Boiling Spring

A. Rheocrene spring

- **Discharge emerges as flowing streams and forms spring "runs"**



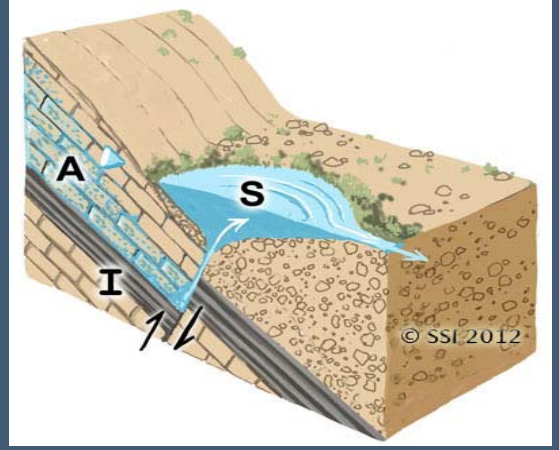
Springer and Stevens, 2008

Spring Assessment: Big Boiling Spring

A. Rheocrene spring

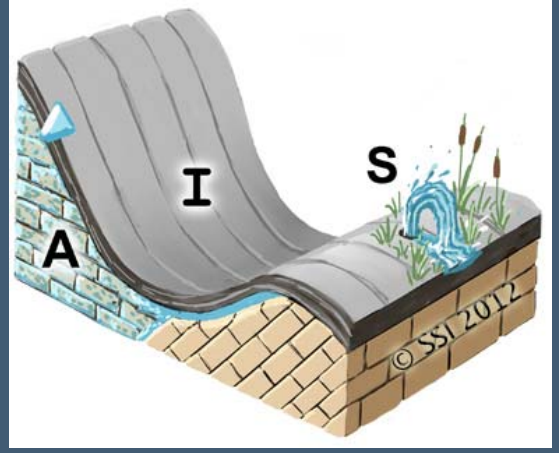
B. Limnocrene spring

- **Discharge emerges as 1 or more pools**



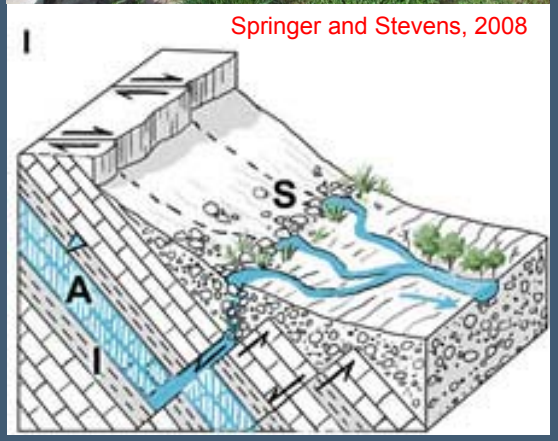
Spring Assessment: Big Boiling Spring

A. Rheocrene spring
B. Limnocrene spring
C. **Fountain spring**
   - **Cool-water Springs that are forced above the land surface by head**



Spring Assessment: Little Bubbly Spring

- **Rheocrene spring**
  - Discharge emerges as flowing streams and forms spring "runs"



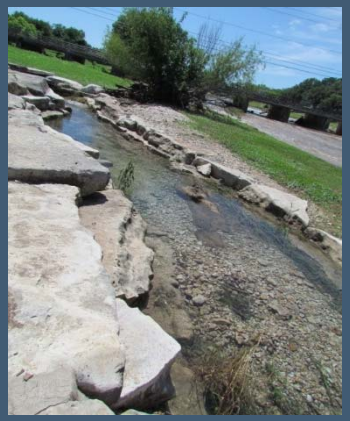
Springer and Stevens, 2008

Spring Assessment: Little Bubbly Spring

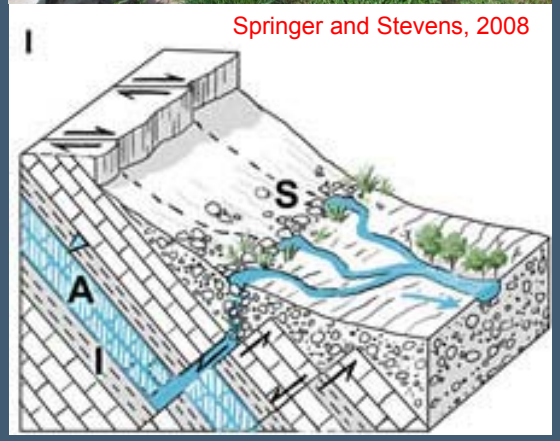
- **Rheocrene spring**
  - Discharge emerges as flowing streams and forms spring "runs"

April-6- 2016

May-29- 2015

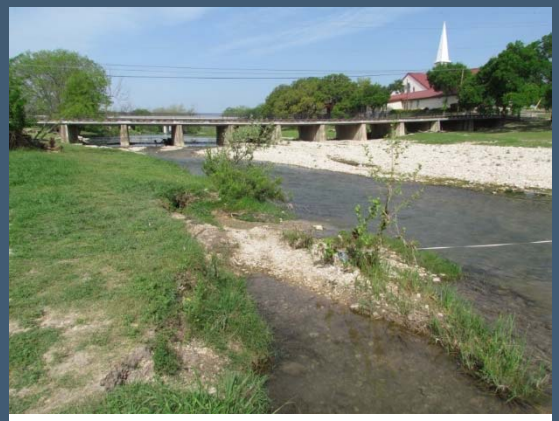


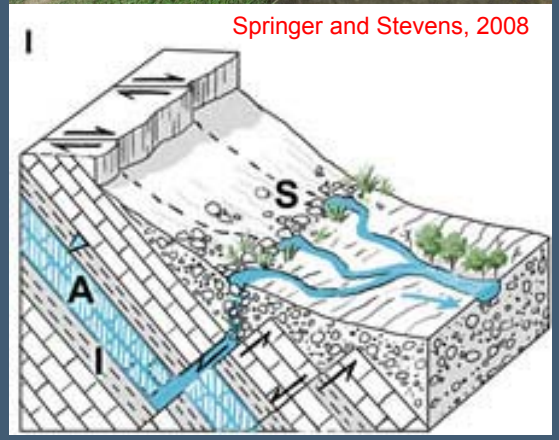
Springer and Stevens, 2008



Spring Assessment: Side Spring

- **Rheocrene spring**
  - Discharge emerges as flowing streams and forms spring “runs”

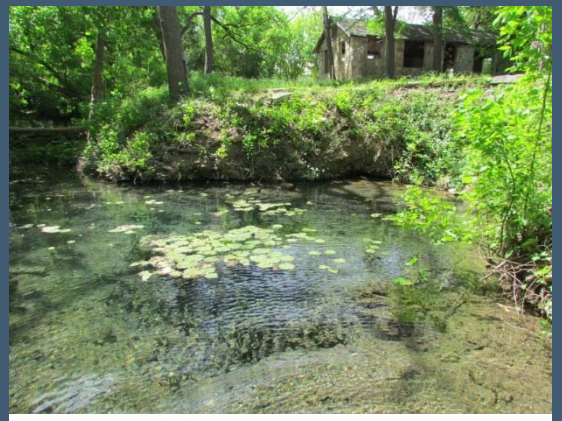


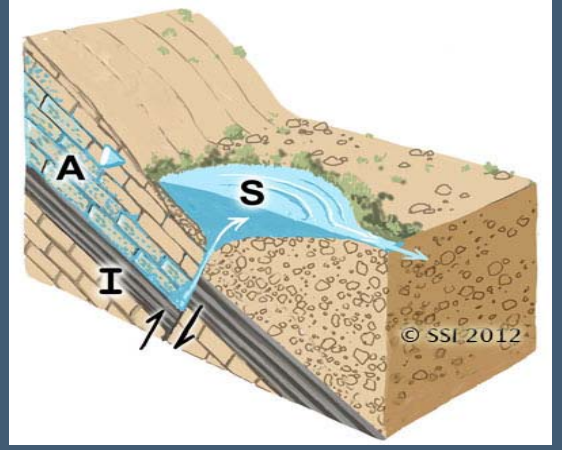


Springer and Stevens, 2008

Spring Assessment: Critchfield Spring

A. **Limnocrene spring**
   - **Discharge emerges as 1 or more pools**



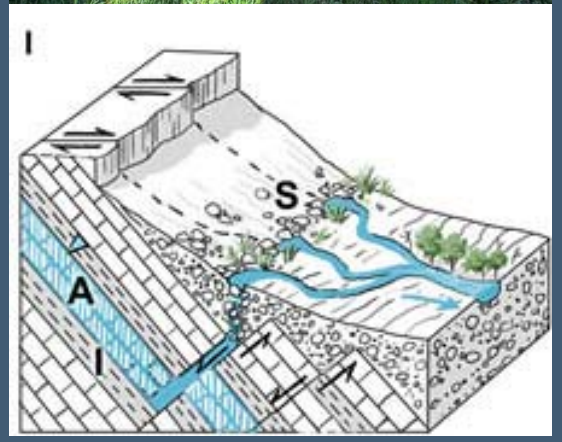


Spring Assessment: Critchfield Spring

A. Limnocrene spring

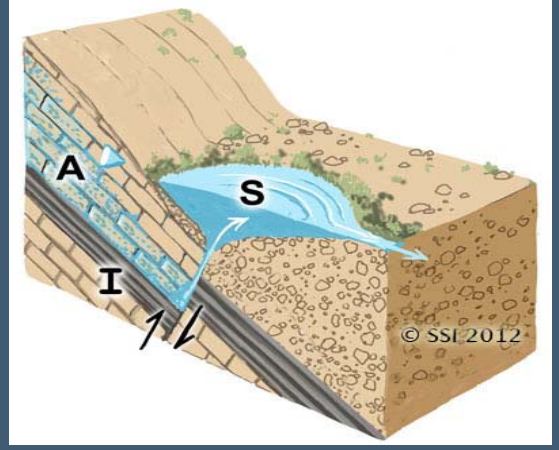
B. Rheocrene spring

- **Discharge emerges as flowing streams and forms spring "runs"**



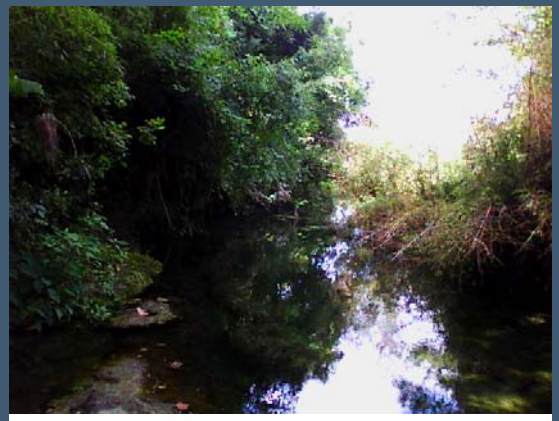
Spring Assessment: Doc Benedict Spring

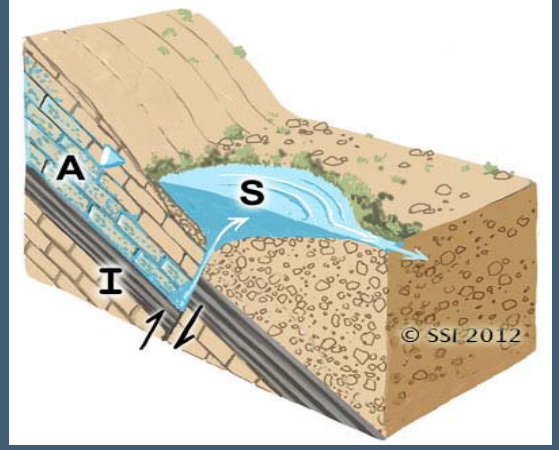
- **Limnocrene spring**
  - Discharge emerges as 1 or more pools



Spring Assessment: Anderson Spring

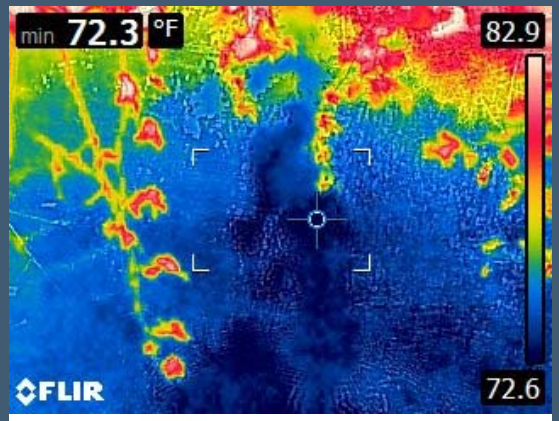
- **Limnocrene spring**
  - Discharge emerges as 1 or more pools

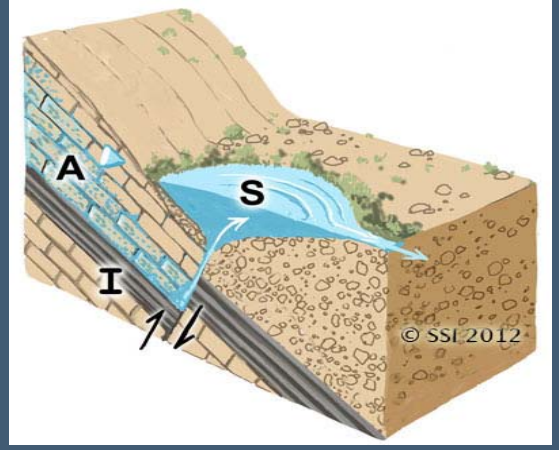




Spring Assessment: Anderson Spring

- **Limnocrene spring**
  - Discharge emerges as 1 or more pools





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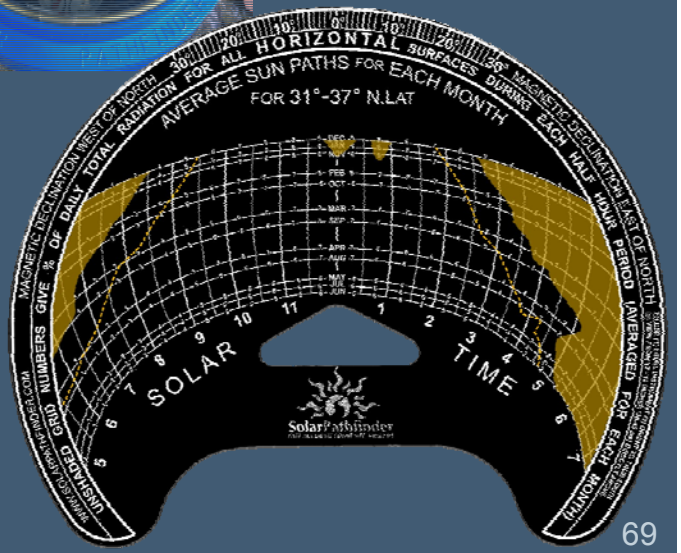

Spring assessment: Aquifer Quality

- AFWQ0 Springs Dewatered (Y/N)
- AFWQ1 Aquifer functionality
- 0 Aquifer depleted
- 1 Aquifer nearly depleted
- 2 Aquifer in significant decline
- 3 Aquifer declining slightly but detectably ?
- 4 Low to moderate aquifer withdrawal ?
- 5 Aquifer not or only very slightly pumped
- 6 Aquifer pristine; good potential reference site
- 9 Unable to assess aquifer functionality

Spring assessment: Aquifer Quality

- AFWQ2 Springs discharge
- 0 No flow
- 1 Less than 0.1 liters per second
- 2 Between 0.1 and 1 liters per second
- 3 Between 1 and 10 liters per second (16-160 gpm)
  Little Bubbly
- 4 Between 10 and 100 liters per second
- 5 Between 100 and 1000 liters per second (3.5-35 ft^3/s)
  Big Boiling
- 6 Over 1000 liters per second
- 9 Unable to assess flow

Spring assessment: Aquifer Quality

- AFWQ3 Flow naturalness
- 0 Springs dewatered
- 1 Springs mostly dewatered
- 2 Springs flow strongly reduced
- 3 Springs flow slightly, but distinctively, reduced
- 4 Springs flow only slightly reduced
- 5 Springs flow apparently natural
- 6 Springs pristine; good potential reference site
- 9 Unable to assess flow naturalness

Spring assessment: Aquifer Quality

- AFWQ4Flow persistence
- 0 No springs flow
- 1 Flow ephemeral, less than 50% of time
- 2 Flow rarely ephemeral
- 3 Flow recently persistent
- 4 Flow apparent during Holocene
- 5 Flow continuous since late Pleistocene
- 6 Flow since mid-Pleistocene or earlier
- 9 Unable to assess flow persistence

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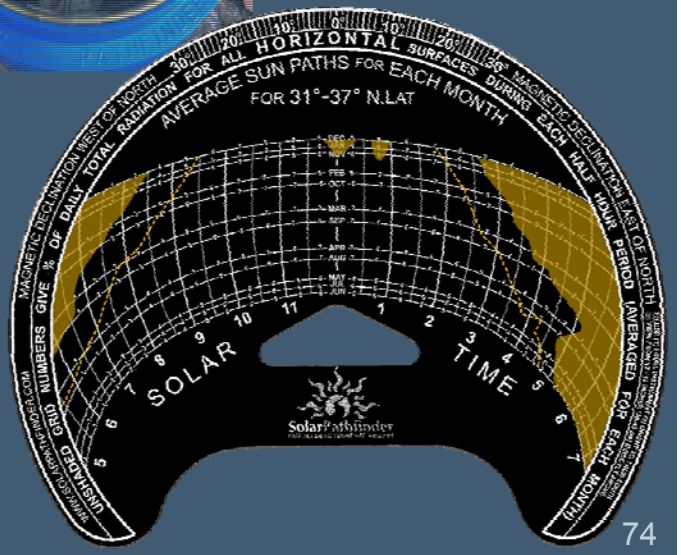
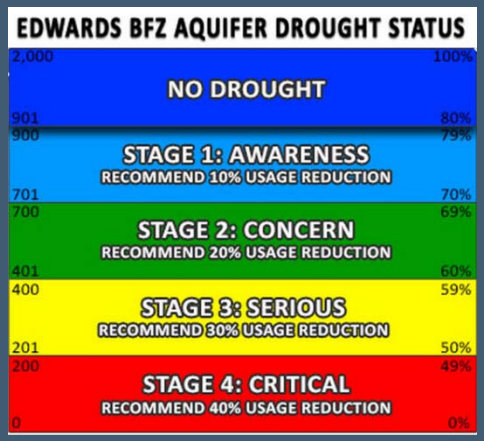


Spring assessment: Geomorphology

- GEO2 Runout channel geometry
- 0 Original runout channel unnaturally obliterated
- 1 Channel virtually obliterated, trenched, or otherwise manipulated
- 2 Channel strongly altered, with only scant evidence of original course
- 3 Channel highly altered but with some functionality
  Little Bubbly
- 4 Channel slightly altered, mostly functional
  Big Boiling
- 5 Channel functioning apparently naturally
  Robertson
- 6 Channel pristine
  Robertson?
- 9 Unable to assess channel geometry

Management contributions

- **Stream gauge** location is suitable for aquifer monitoring
- Aquifer study important to listing process of **Salado Salamander**
- As **development** in the area continues, a monitoring program builds baseline for aquifer conditions
  - Facilitates change detection
  - Prepares managers to assess, respond to, and manage aquifer impacts
  - Future monitoring directions



Groundwater / Surface-water Interaction & Spring management

November, 2012:

February, 2015:


Thank you for your support!
BAYLOR UNIVERSITY
1845
Clearwater
Underground Water Conservation District
THE STATE OF TEXAS
BELL COUNTY
Village of Salado
U.S. FISH & WILDLIFE SERVICE
USGS
science for a changing world

Northern segment research through time