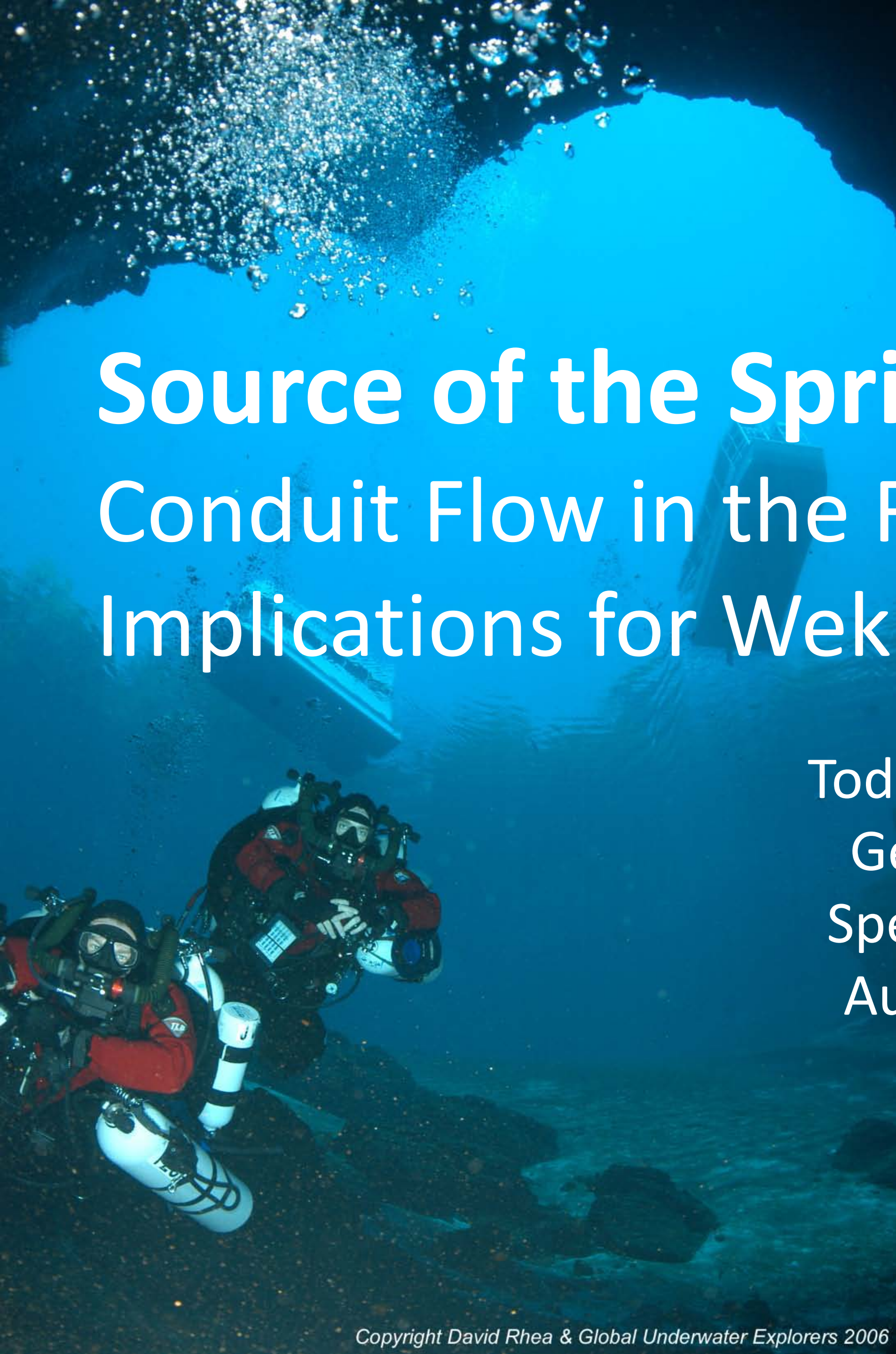
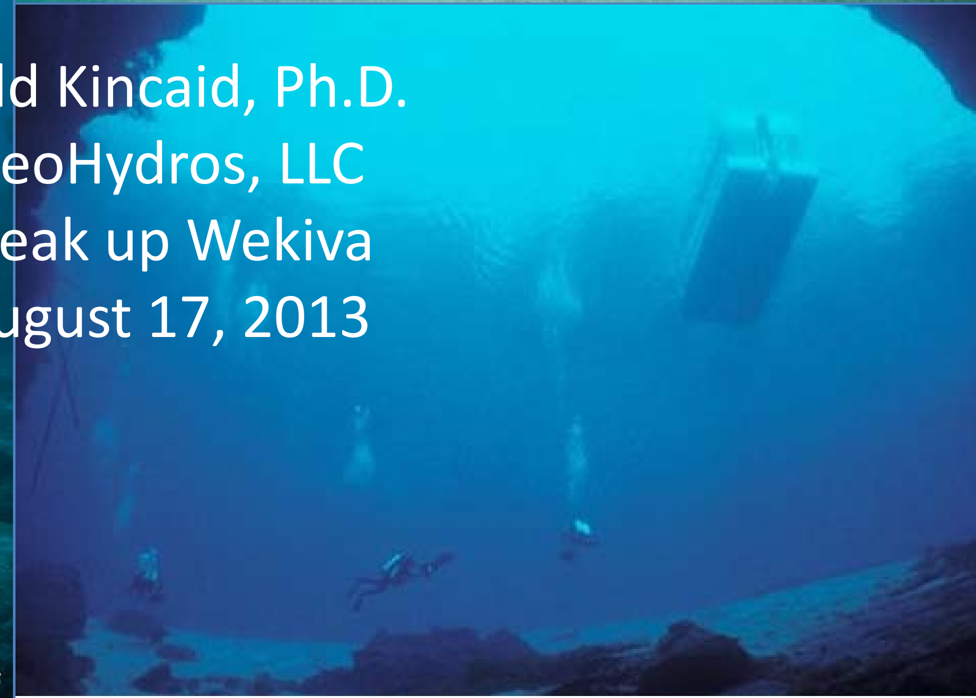




Source of the Spring Flows

Conduit Flow in the Floridan Aquifer

Implications for Wekiwa Springs

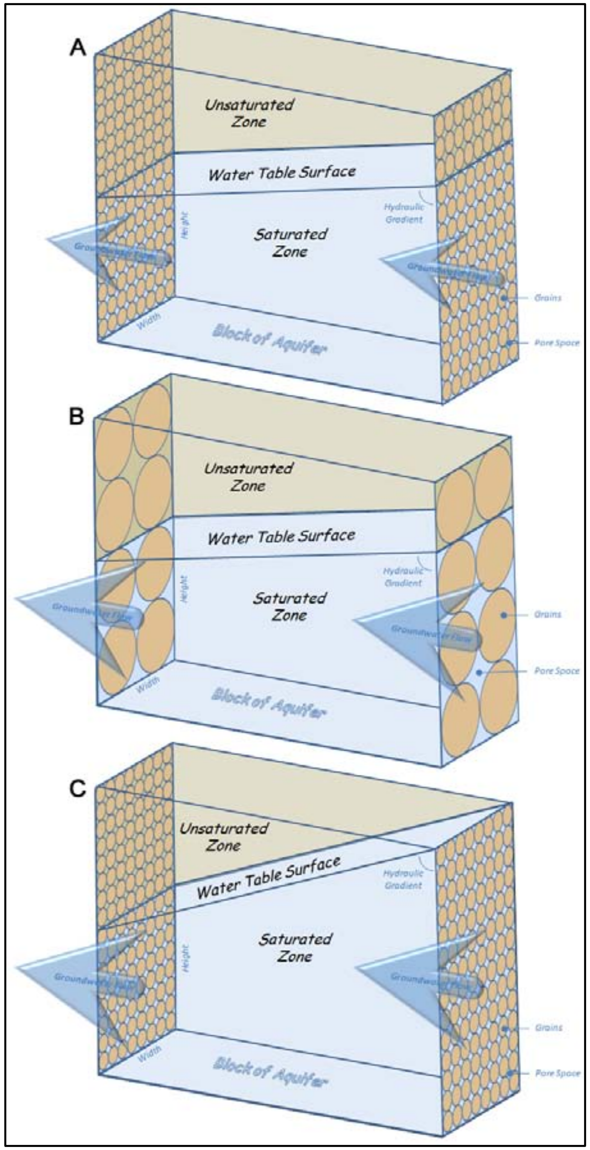
Todd Kincaid, Ph.D.
GeoHydros, LLC

Speak up Wekiva
August 17, 2013

The first things I learned…

"There are no such things as underground rivers"

- Groundwater flows through the spaces between rock grains.
- Groundwater flow is a diffuse slow process.
- Velocities tend to be on the order of feet per year or less.
- Mathematical concepts that evolved for America's great sandstone aquifer underlying the mid-west (the Ogallala Aquifer) render groundwater movement, aquifer storage, and contaminant movement very predictable.
- Amateurs study springs, whereas professionals study wells



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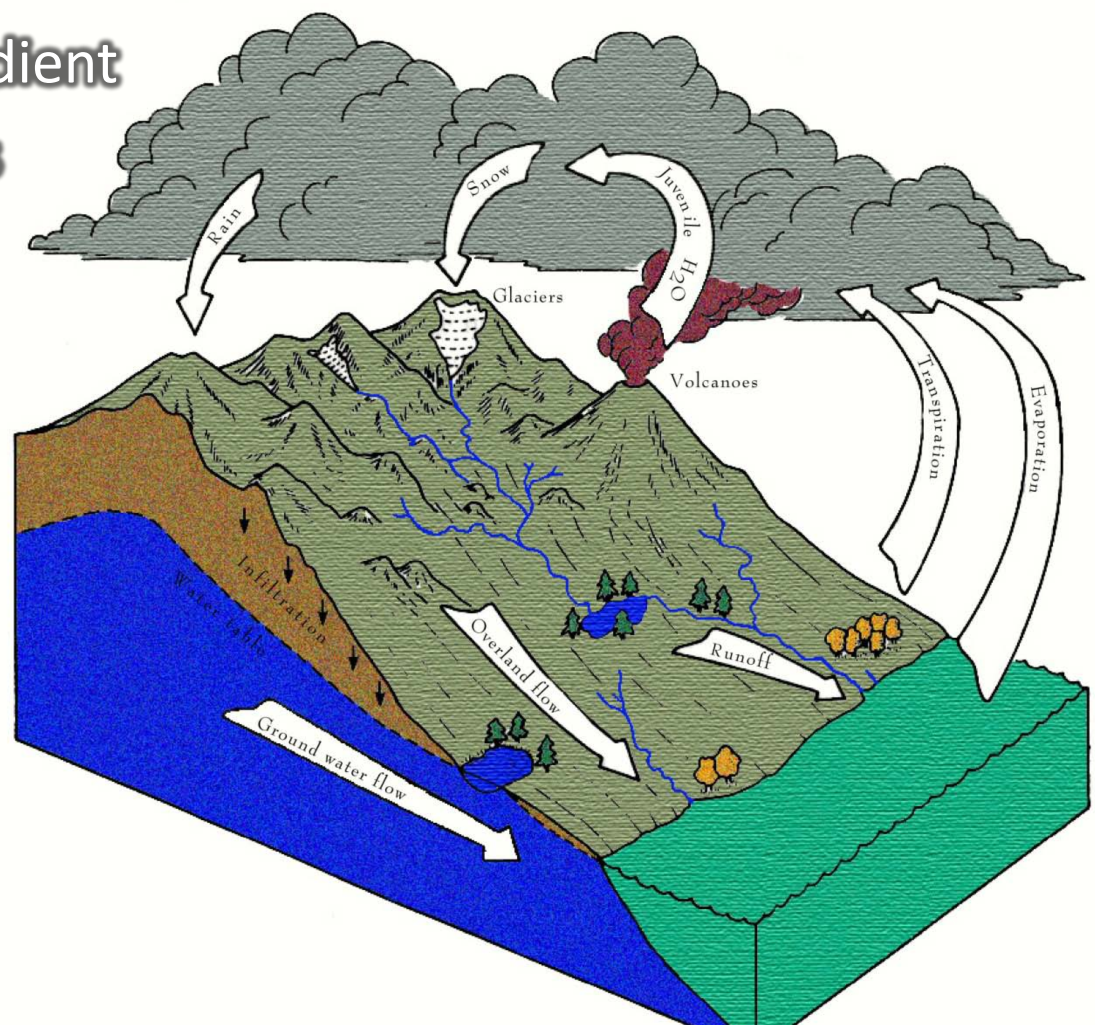
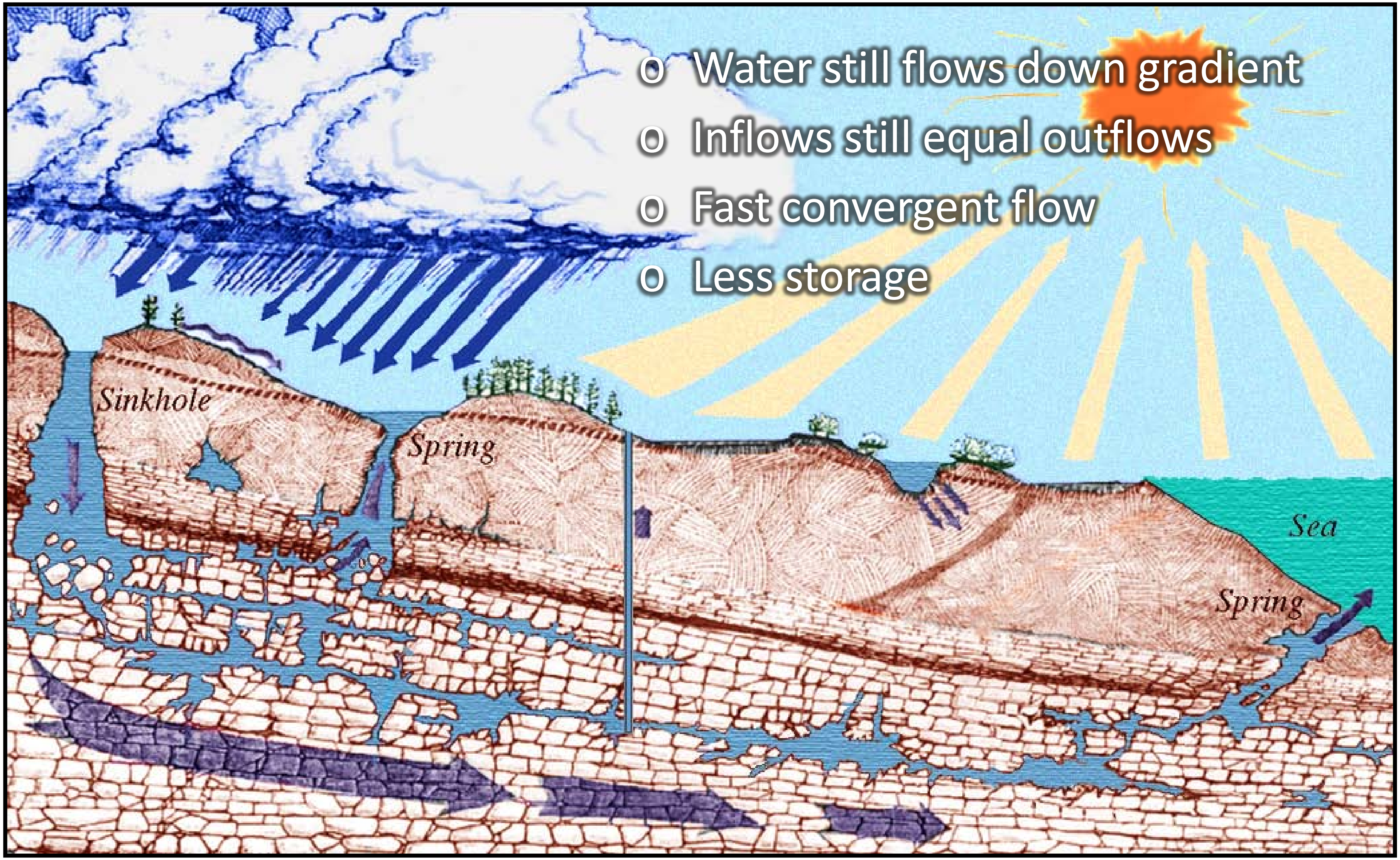
Hydrologic Cycle

- Water flows down gradient
- Inflows equal outflows
- Slow diffuse flow
- High storage



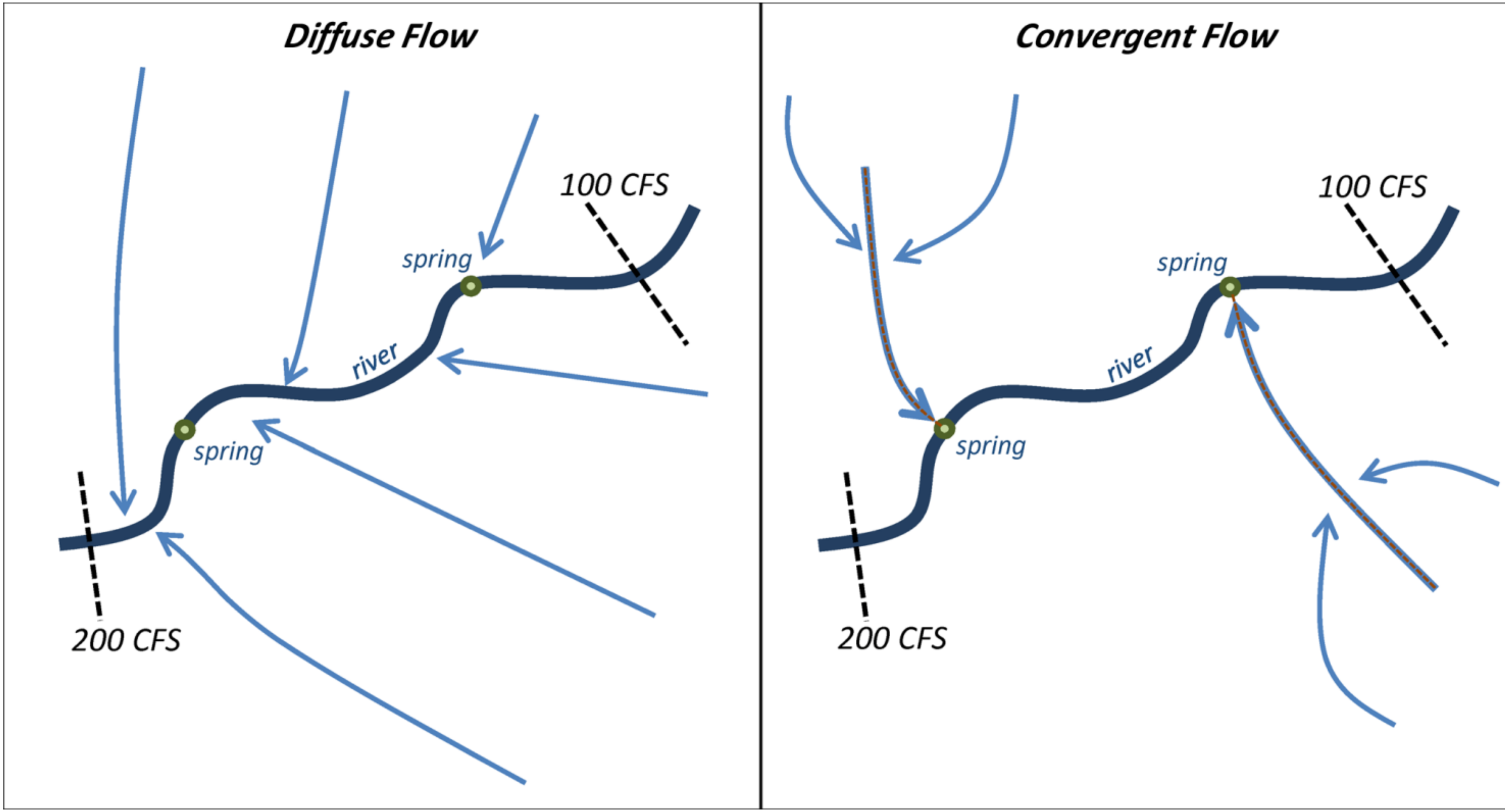
Adapted from Fetter, 1988 *Applied Hydrogeology*

Karst Hydrologic Cycle



- Water still flows down gradient
- Inflows still equal outflows
- Fast convergent flow
- Less storage

What's the Difference?



- Flow dispersed evenly along river
- No conduits required

- Flow focused at two points
- Requires conduits

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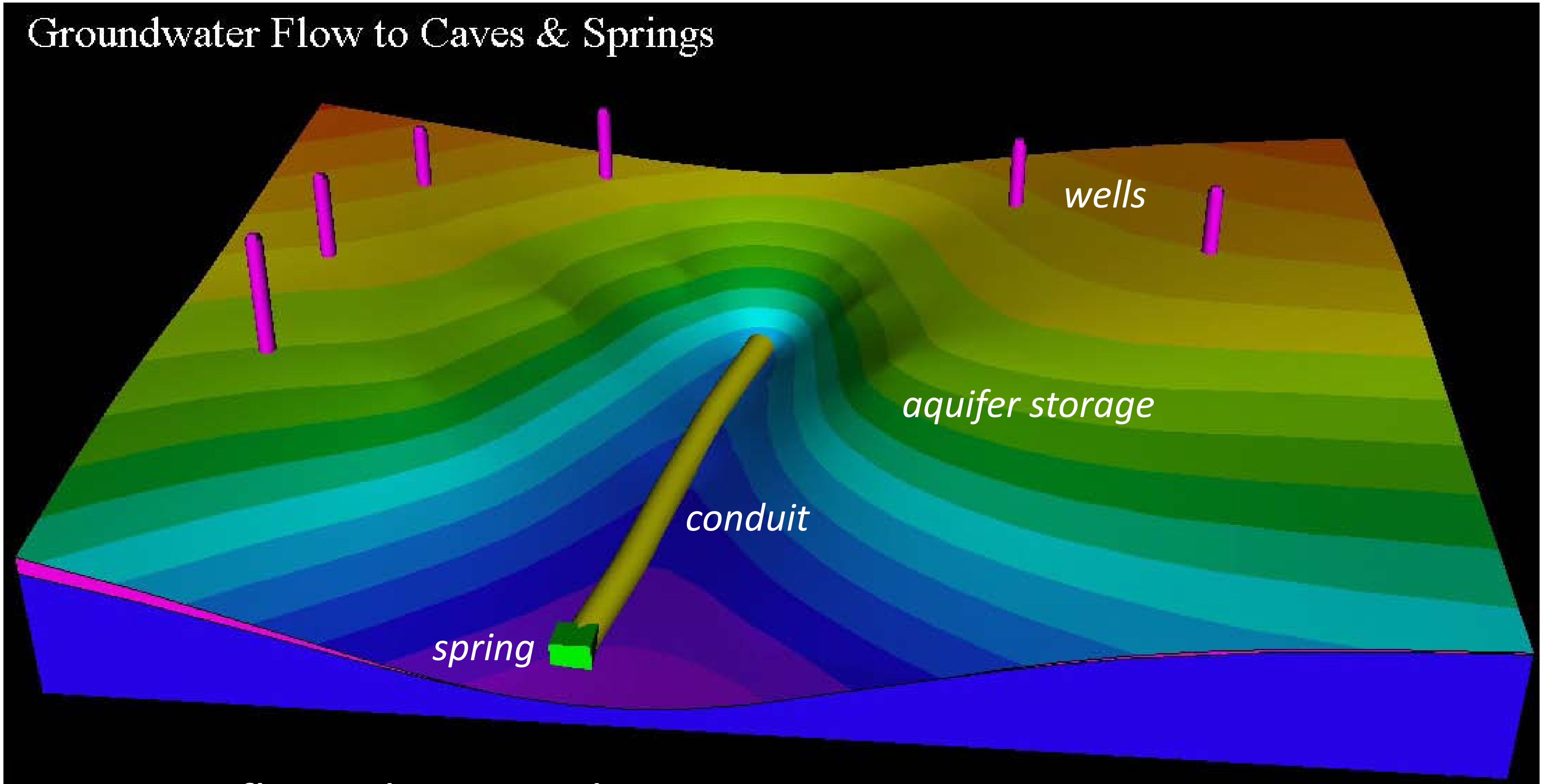
A Convergent System



- Water flows down gradient
- From storage to conduits

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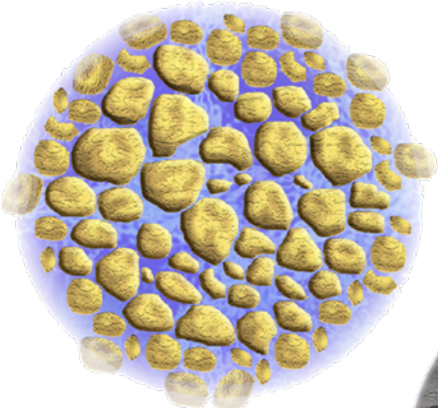
Different Approaches

Standard Approach

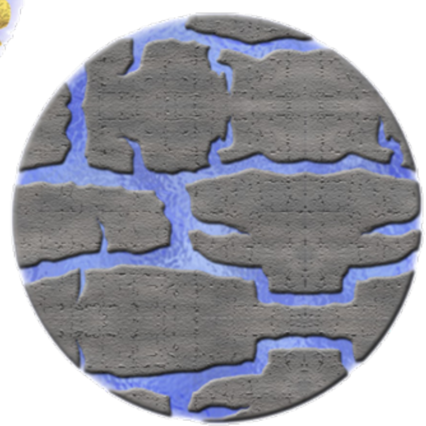
New Approach

Porous Media



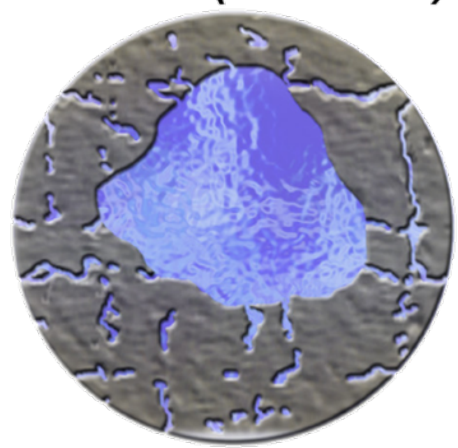
sand / sandstone
easy to characterize
simplest math

Fractered Rock



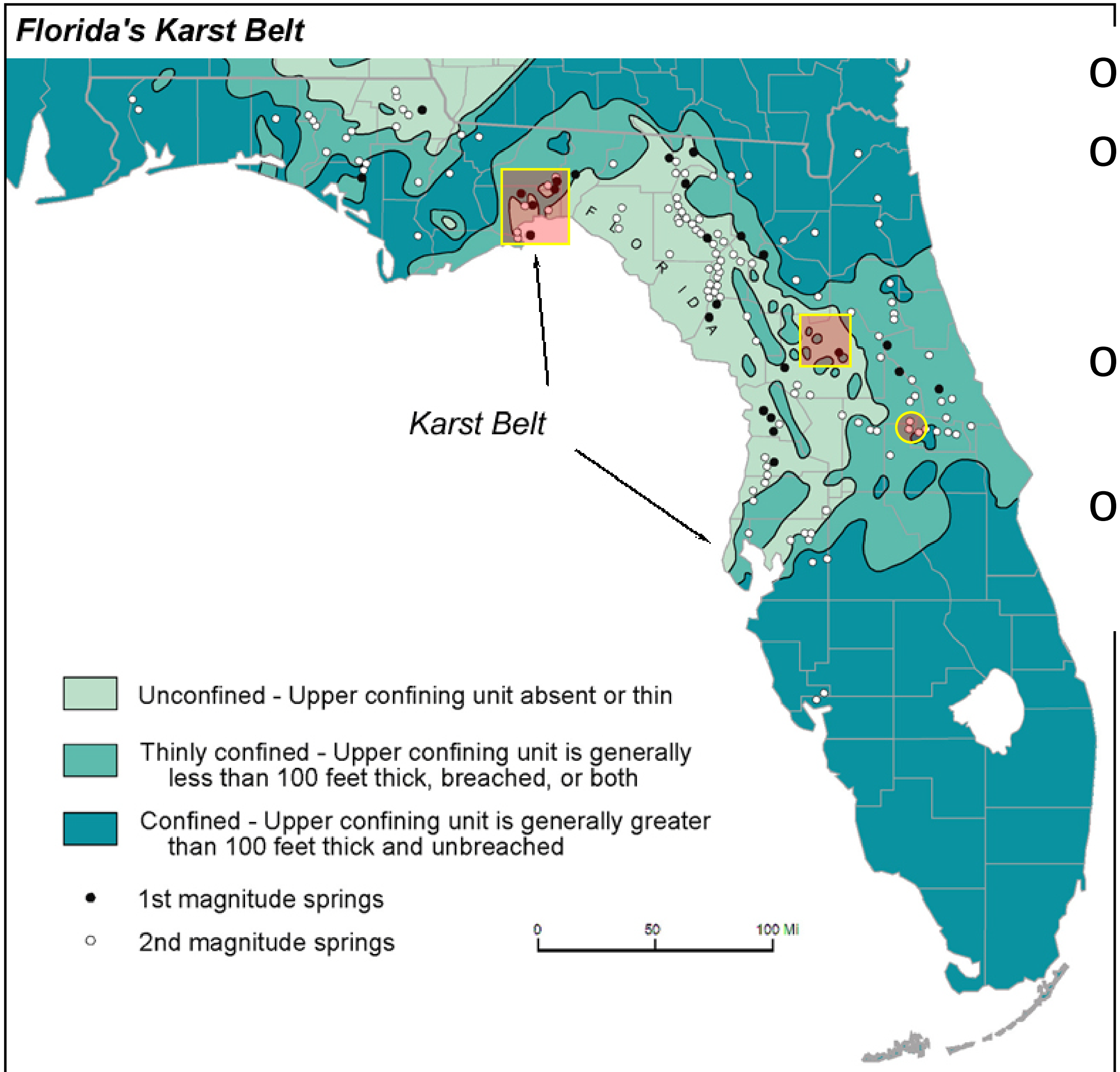
hard rocks (shale, granite, etc)
can map from surface
harder to characterize
more difficult math

Karst (Conduits)



Limestone (Floridan Aquifer)
cannot typically be mapped
hardest to characterize
most difficult math

Karst in Florida

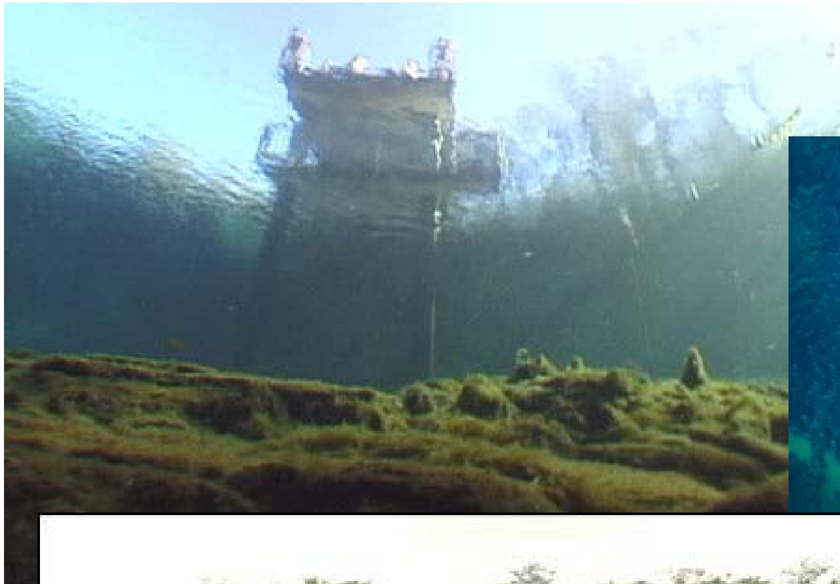


- part of "Karst Belt"
- highest concentration of very large springs in the world
- all discharge from major cave systems
- all but a few are similarly impacted

Wakulla Spring, Florida *(120-1500 cfs)*

Inside the Caves …

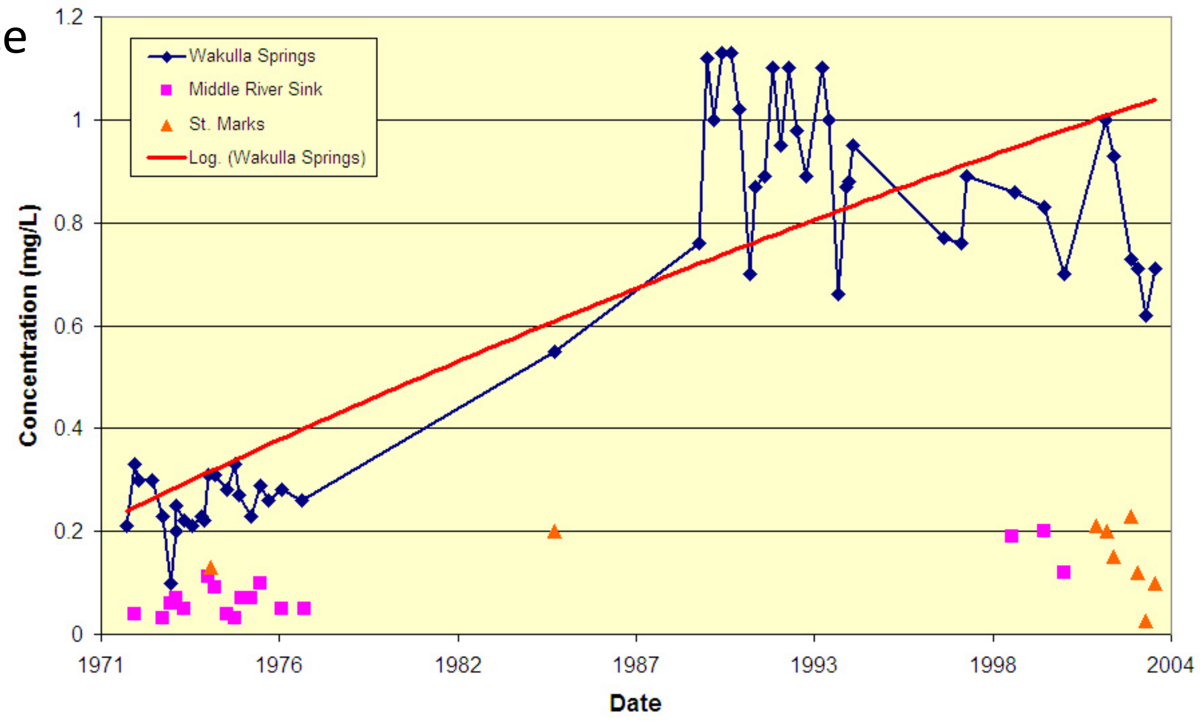
Wakulla Spring in Decline



Nitrate Loading to Groundwater & Springs

Problem

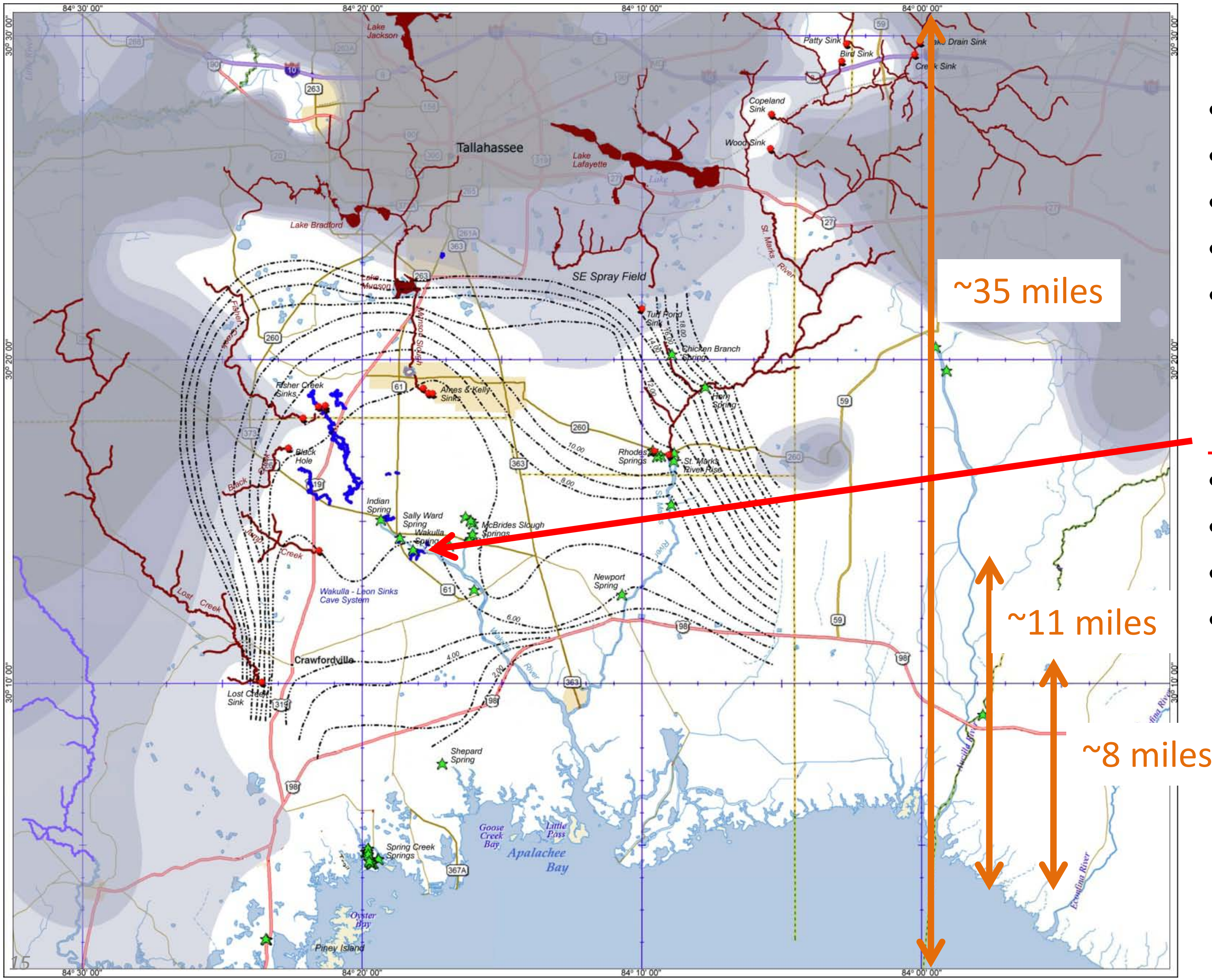
- Nitrate in Florida springs: 10 – 1000 X natural levels
- Very low ecological tolerance
- Very high human tolerance
- Promotes algae and bacterial growth



Sources

- Sewage (septic systems & wastewater treatment)
- Fertilizers (lawns & agriculture)
- Industry (*CAFOs*)

Hydrogeologic Setting



- confining unit
- springs
- swallets
- caves
- potentiometric surface

Wakulla Spring

- ~250 MGD
- ~400 cfs
- Age ~40 years
- Velocities
  - 0.1 ft/day
  - 25 ft/day

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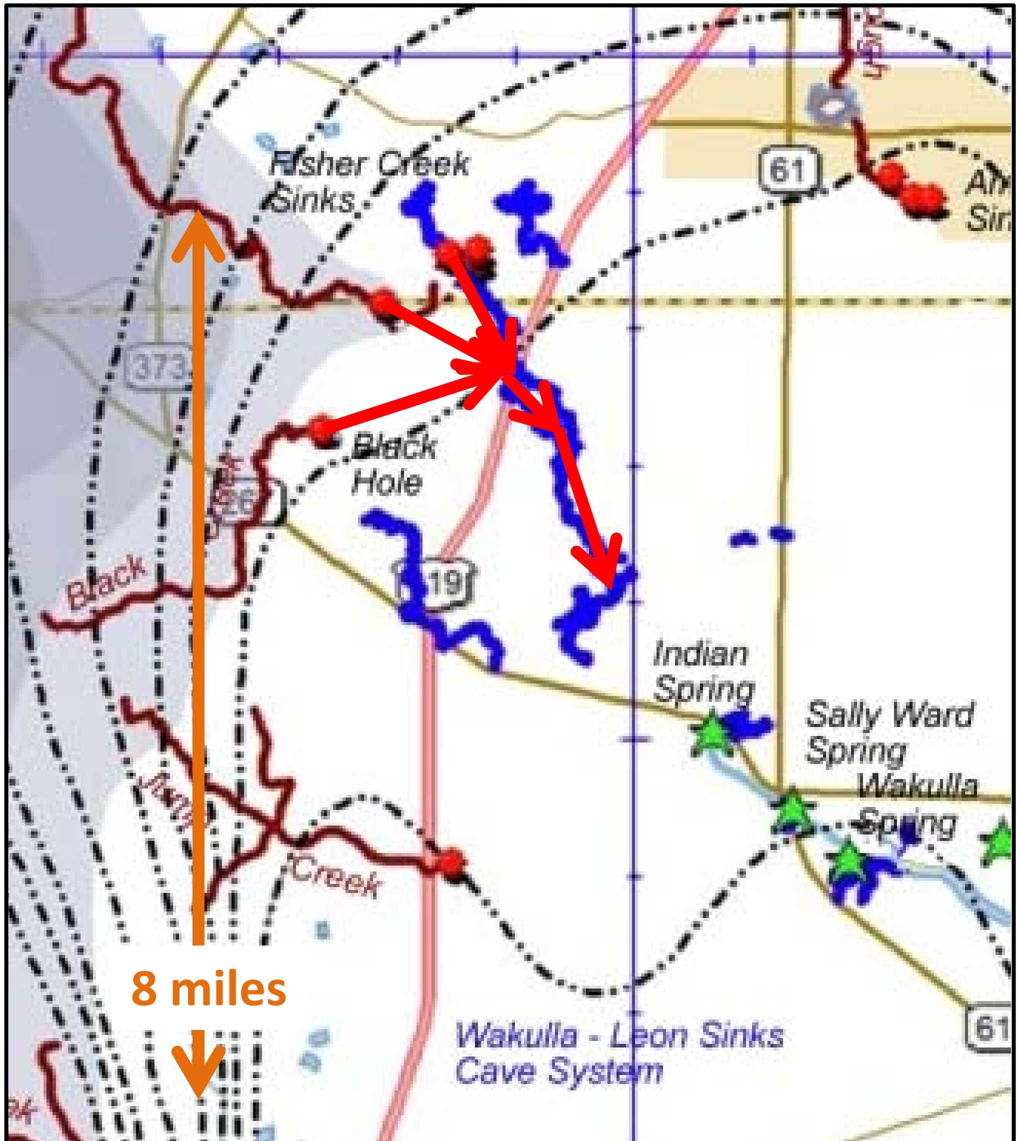
Initial Tracing



Tracing won't work: flows are too big

2001: Sullivan Sink – Cheryl Sink
1.6 miles / 0.96 days (8,800 ft/day)

2002: Fisher Creek – Emerald Sink
1.7 miles / 1.7 days (3,770 ft/day)

2003: Black Creek – Emerald Sink
1.6 miles / 1.6 days (2,670 ft/day)

Tracing seems to work
Cheryl Sink Age: ~35 years
Distance Traveled: ~21,000 miles – hmmm?

More Tracing

2004: Emerald Sink – Wakulla Spring

10.3 miles / 7.1 days (7,650 ft/day)

2005: Kelly Sink – Indian Spring

5.2 miles / 13.5 days (2,040 ft/day)

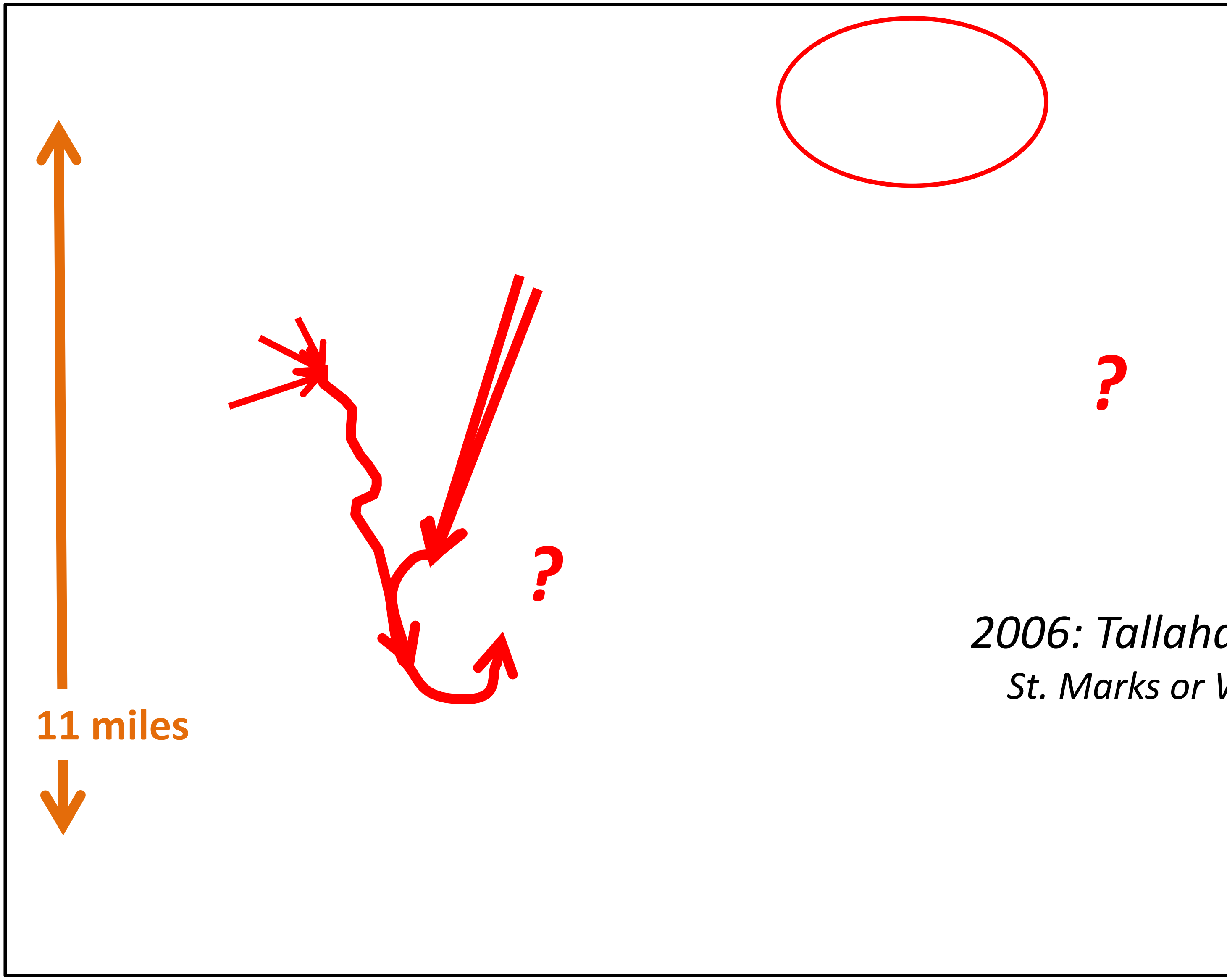
2005: Ames Sink – Indian Spring

5.2 miles / 17.2 days (1,600 ft/day)

2005: Indian Spring – Wakulla Spring

5.5 miles / 5.9 days (4,890 ft/day)

More Tracing



2006: Tallahassee Spray Field

St. Marks or Wakulla?

Tallahassee Spray Field

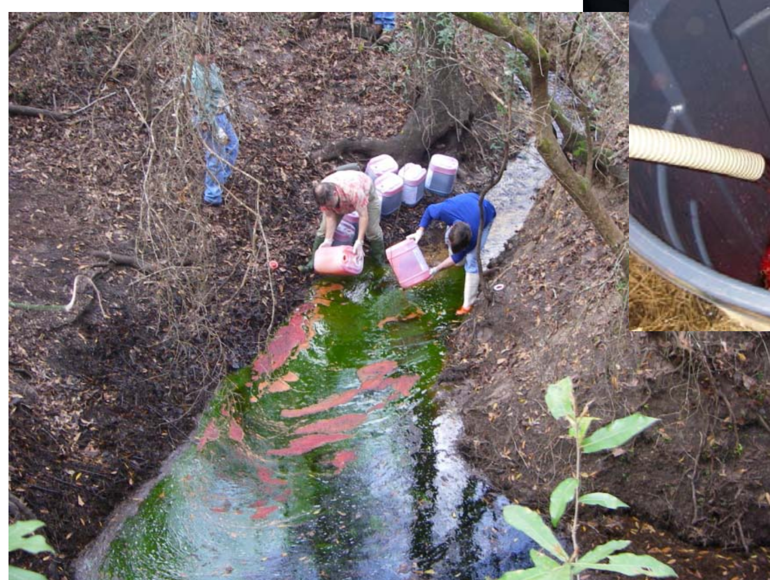
Tracer Injections

Near-field:

- 20kg phloxine-b, 3 wells

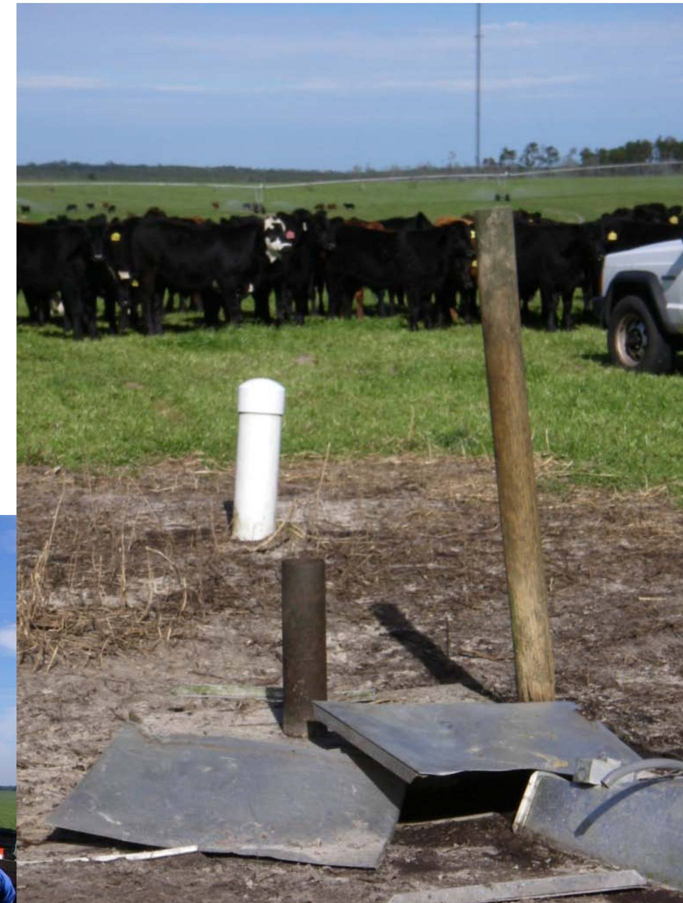
Far-field:

- 60kg uranine, 3 wells
- 60 kg eosine, 1 swallet



Unexpected Problems…

Cows are curious & mischievous!



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Sampling

- Collected water samples at all locations
- Varied sampling interval throughout duration of test (4 hrs – 12 hrs)
- Initial duration: 4 months – extended to 14 months
- Developed recovery curves for each station

fun stuff!

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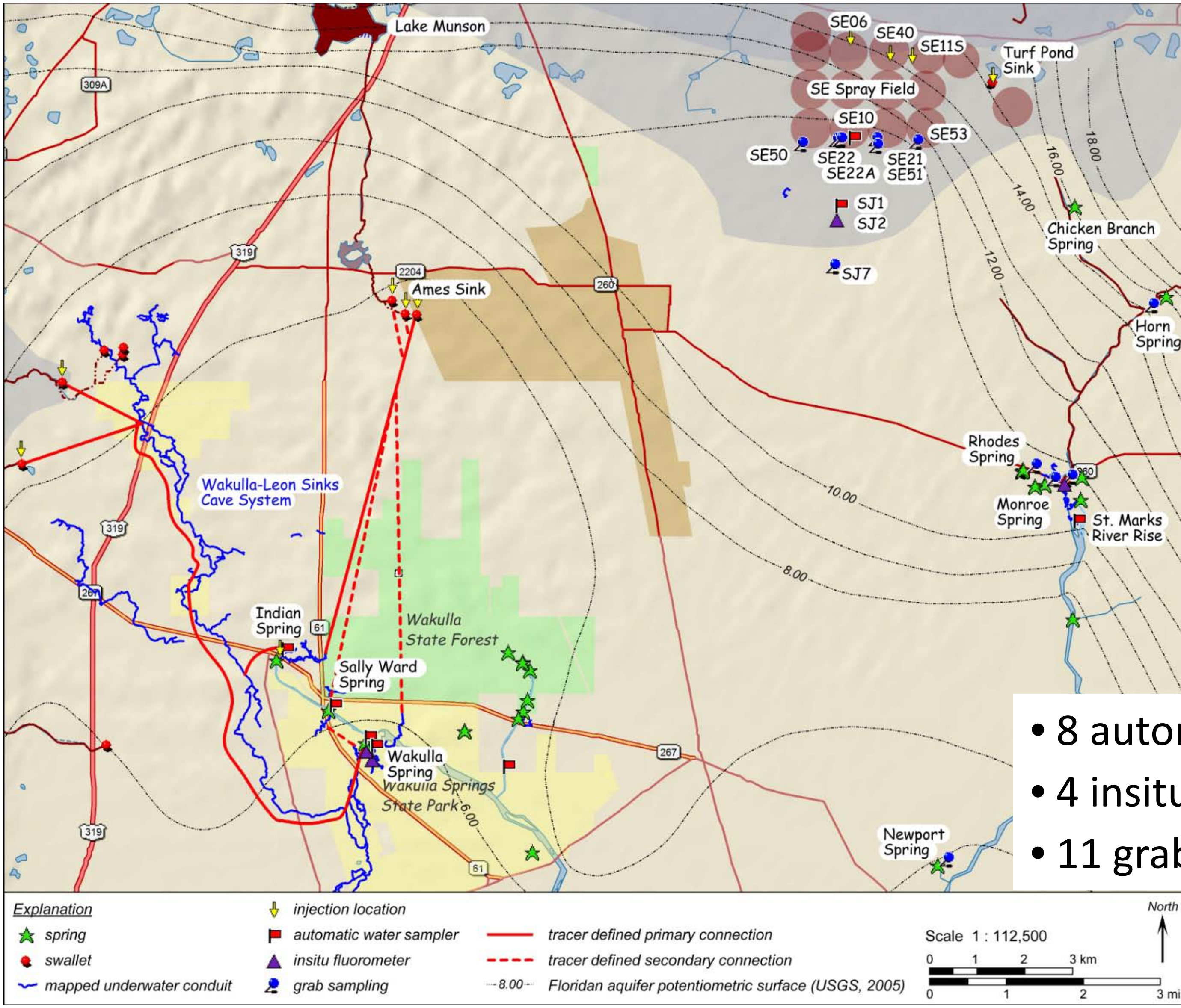
Sampling Strategy



- 8 automatic water samplers
- 4 insitu fluorometers
- 11 grab sample locations

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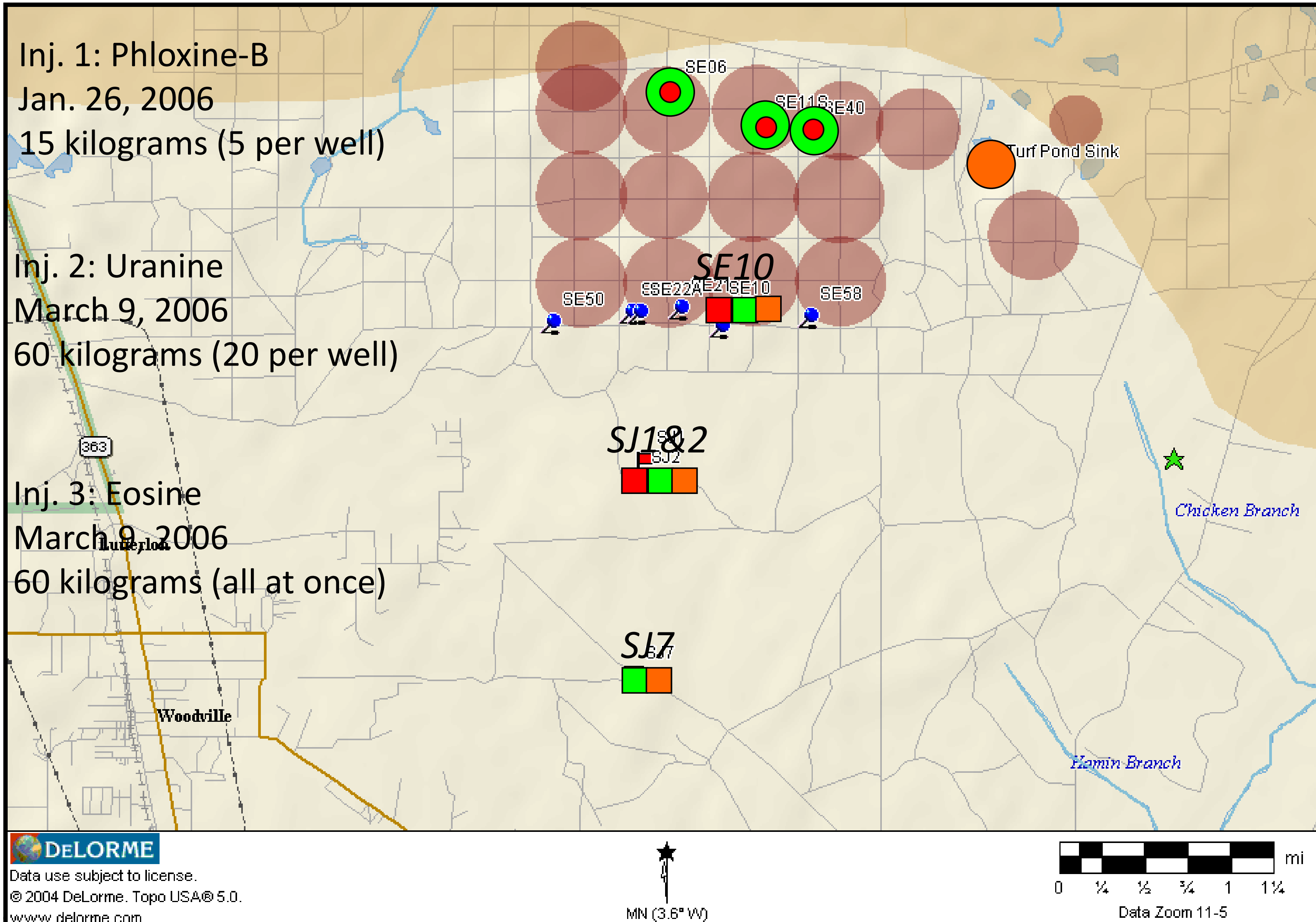
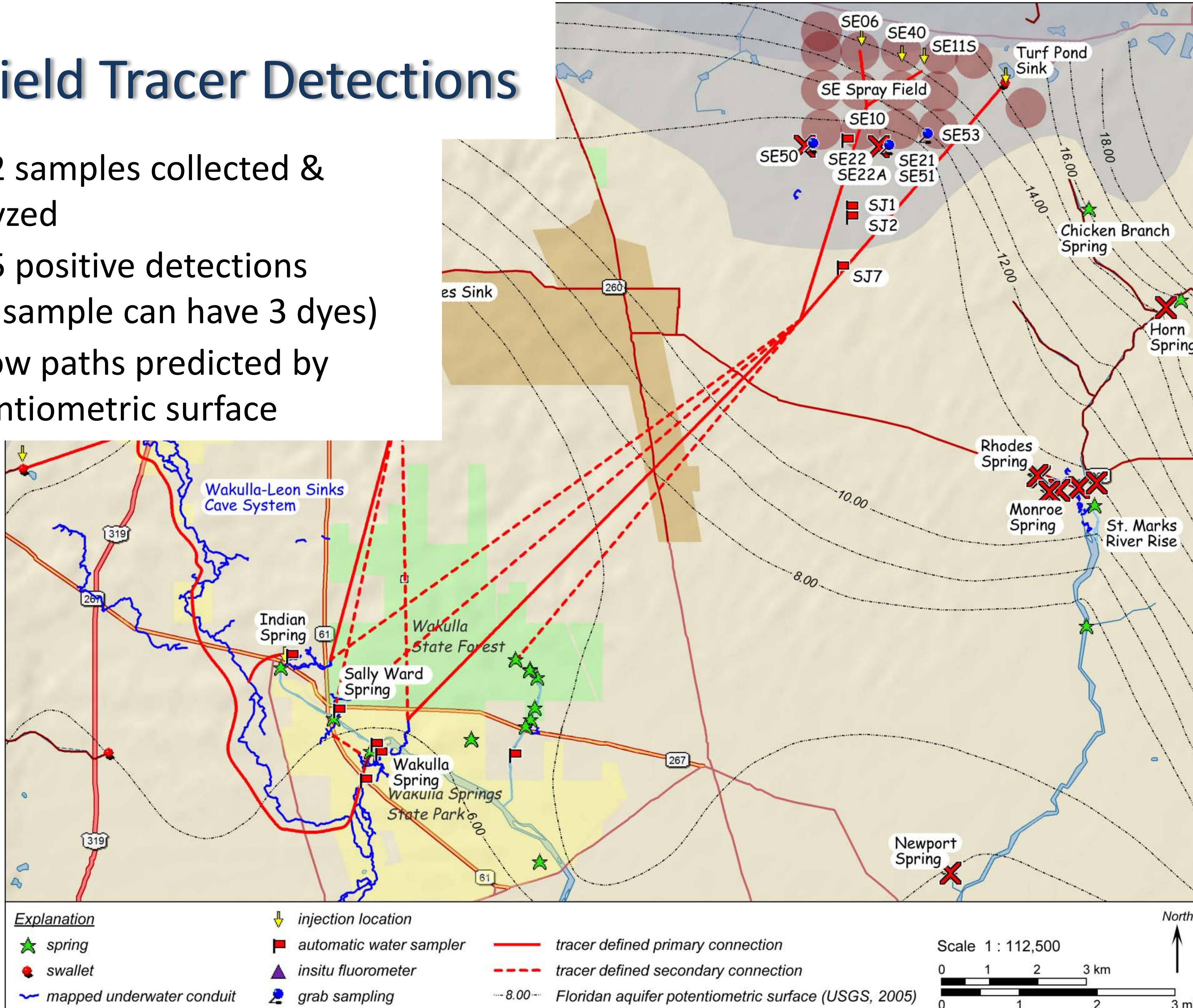
Injection & Near-Field Detections



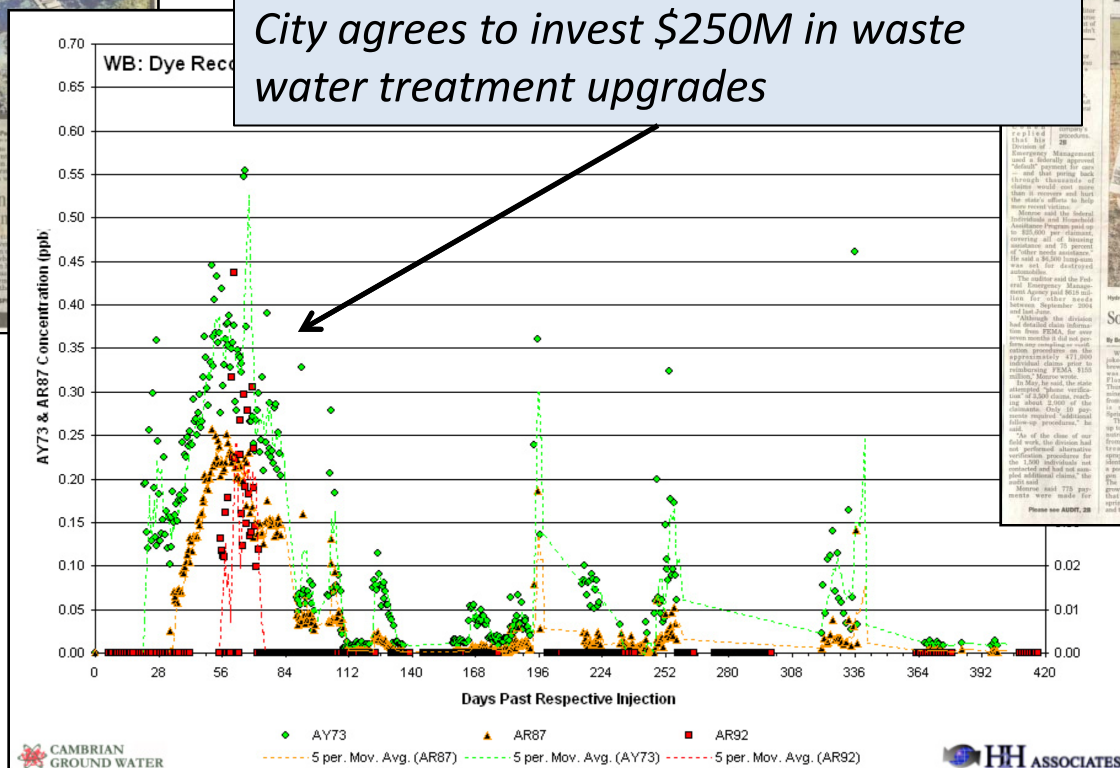
Far-Field Tracer Detections

- 5,262 samples collected & analyzed
- 6,485 positive detections (one sample can have 3 dyes)
- all flow paths predicted by potentiometric surface



And the Bottom Line?

- $250 Million Dollar Breakthrough Curve



Tracer arrives at Wakulla: ~60 days
City agrees to invest $250M in waste water treatment upgrades

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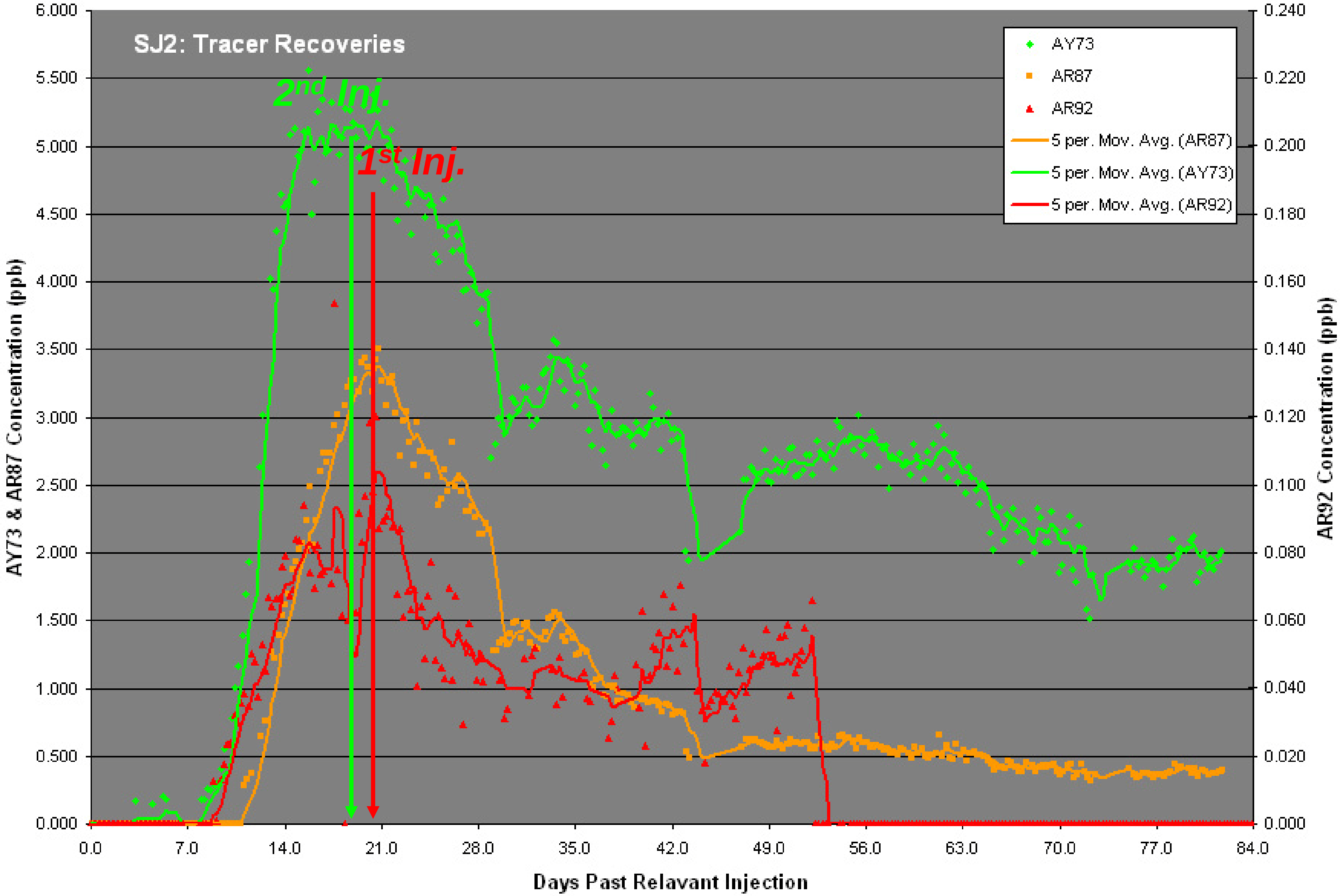
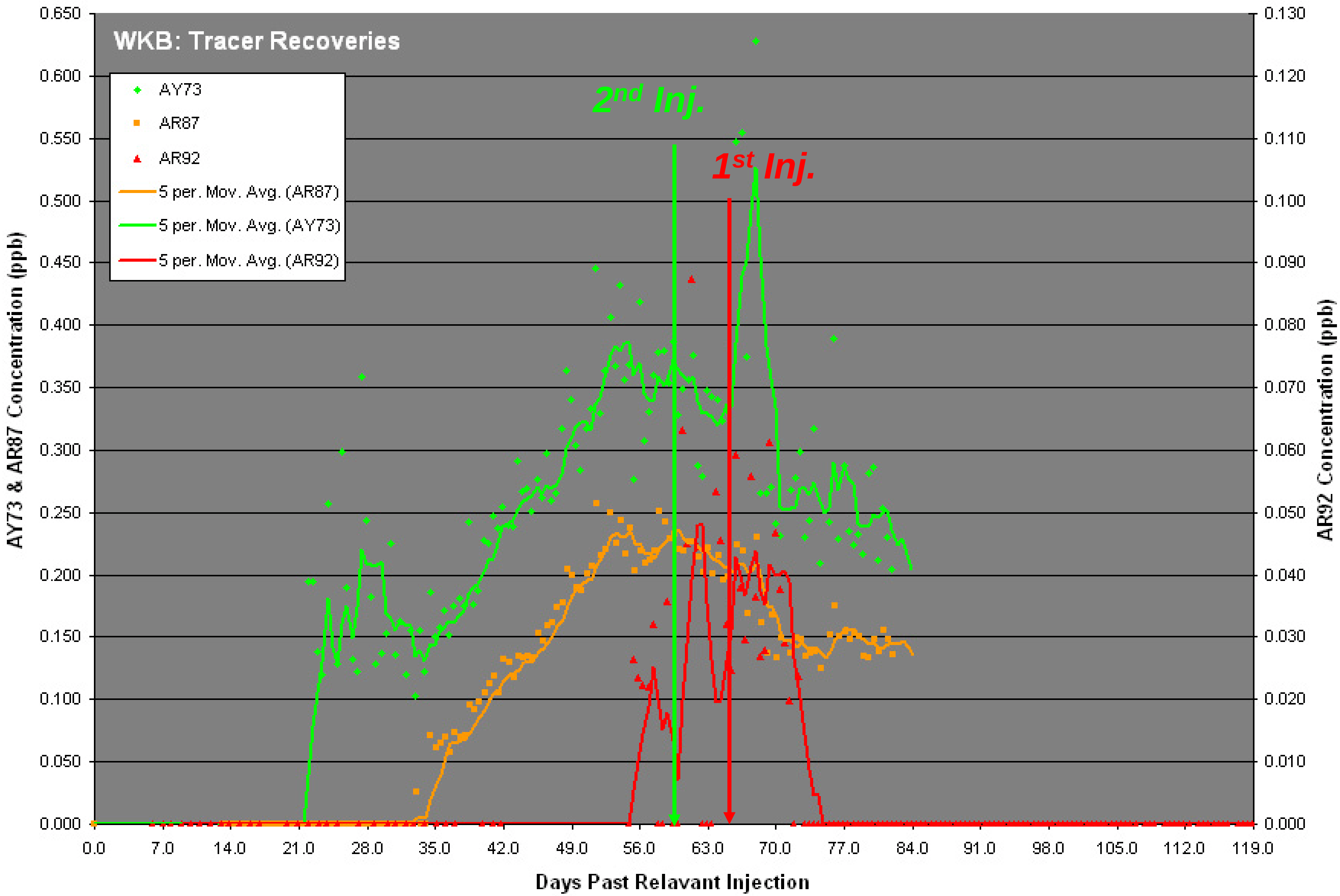
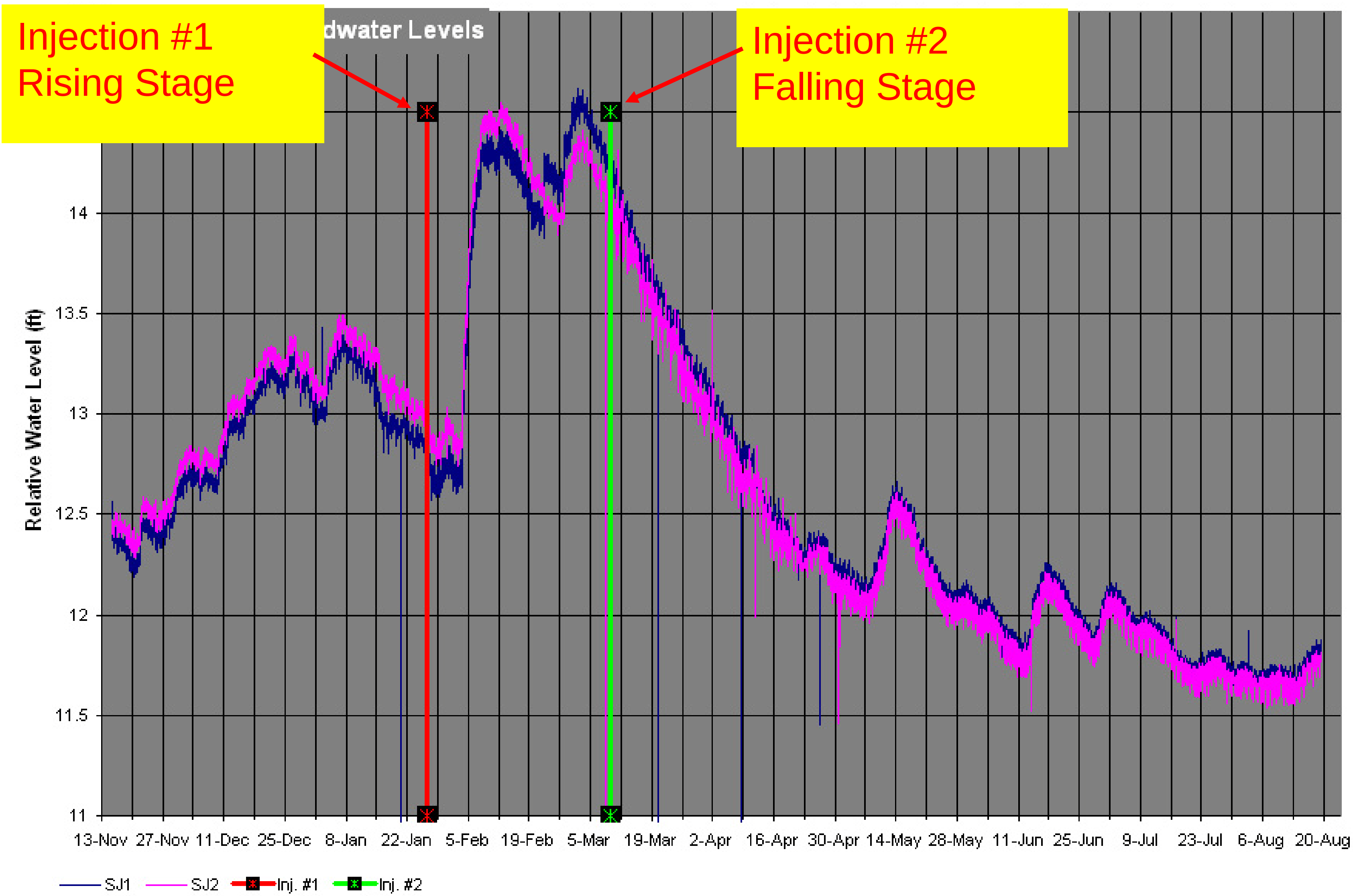
Recovery Curve Analysis – Aquifer Hydraulics



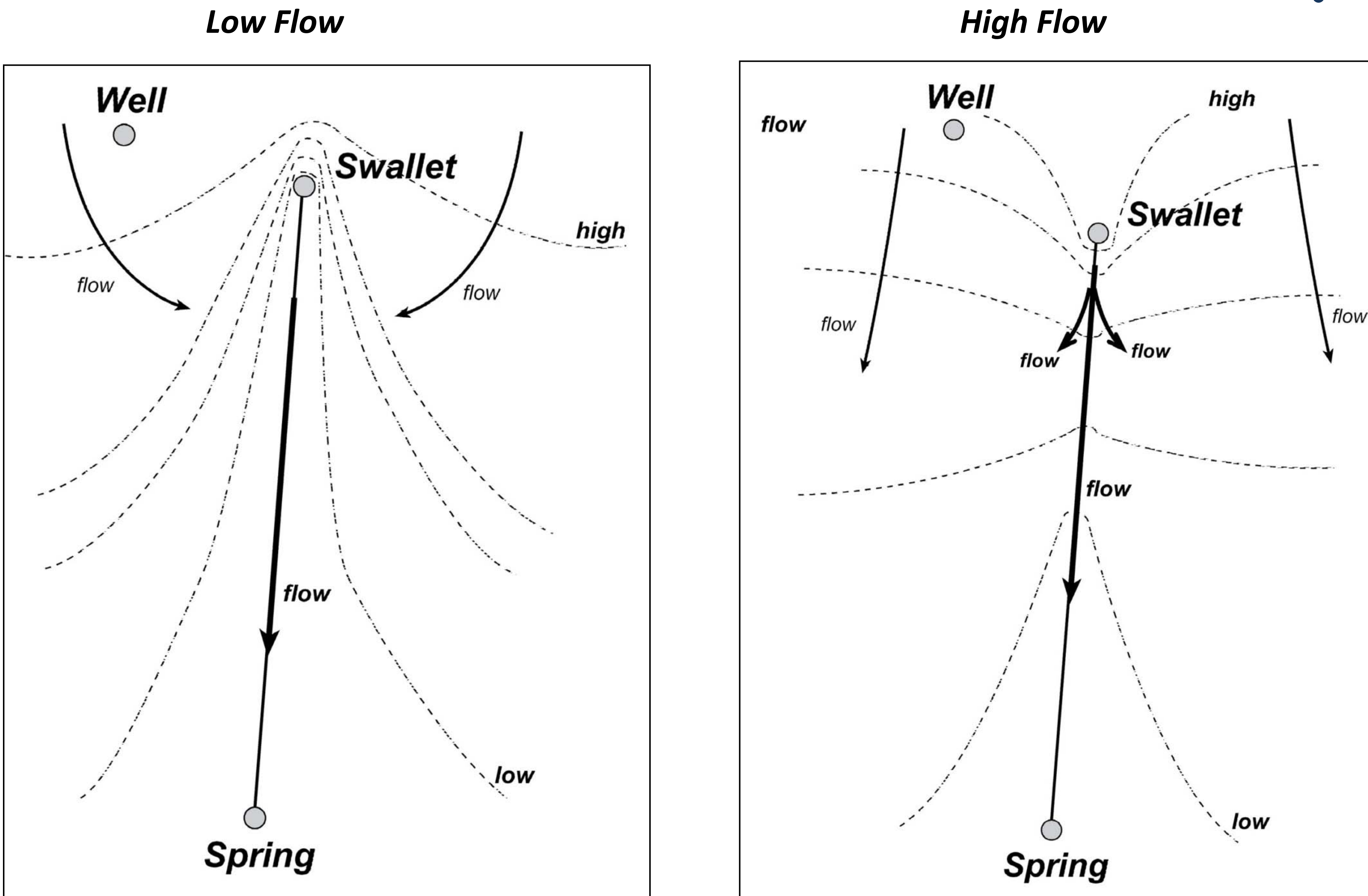
Recovery Curve Analysis – Aquifer Hydraulics



Aquifer Hydraulics – Aquifer / Matrix Interactions



Aquifer Hydraulics



Comparison of Calculated Groundwater Velocities

Method	Velocity (m/day)	Assumptions	Source
Tracing	252-2,337 m/day	none	…
Pumping Test Transmissivities	0.03-0.23 m/day	Calculated Gradient Aquifer b = 100m	Bush & Johnston, 1988
Model Derived Transmissivities	0.03 – 1.17 m/day	Calculated Gradient Aquifer b = 100m	Davis, 1996
Geochemical age dates	7.5 – 15 m/day	Age ~20-40 years 100% of Recharge derived from top of basin (~110 km to north)	Chanton, 2002 Katz et al, 2004

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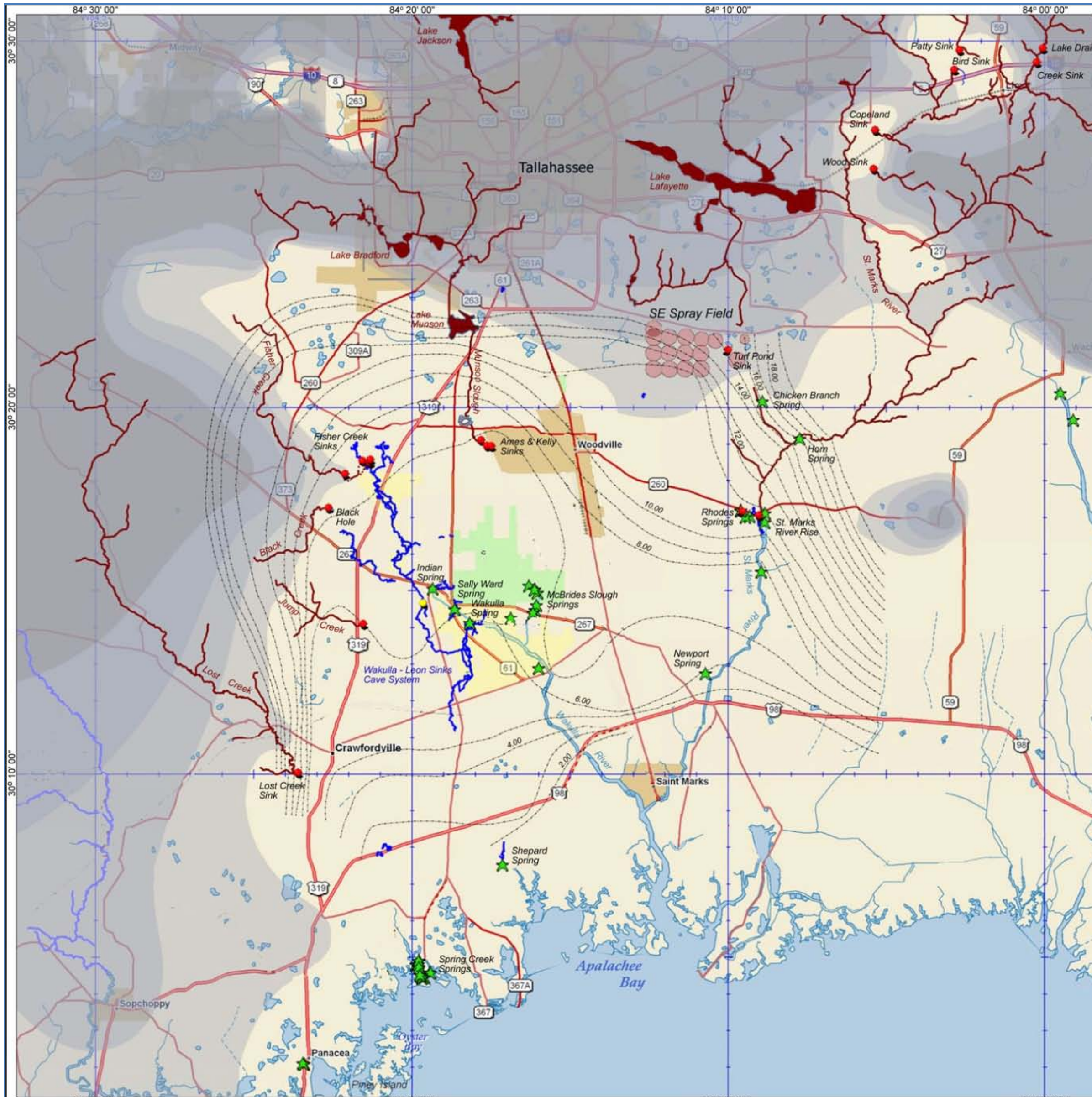
Caves in the WKP



	feet	*meters*
Wakulla Springs	168,900	51,484
Chip's Hole	22,292	6,795
Natural Bridge	12,108	3,691
Indian Springs	11,897	3,626
Sally Ward	6,857	2,090
Shepard's	5,689	1,734
Bird Sink	4,839	1,475
Little Dismal	2,968	905
McBride's	2,166	660
Church's	2,108	642
Rat Sink	1,463	446
Hideaway	1,228	374
Hatchet	1,120	341
Spring Creek 2	810	247
Meetinghouse	769	234
Farrell Shallow	566	173
Ventana Azul	363	111
TOTAL	**246,143**	**75,025**

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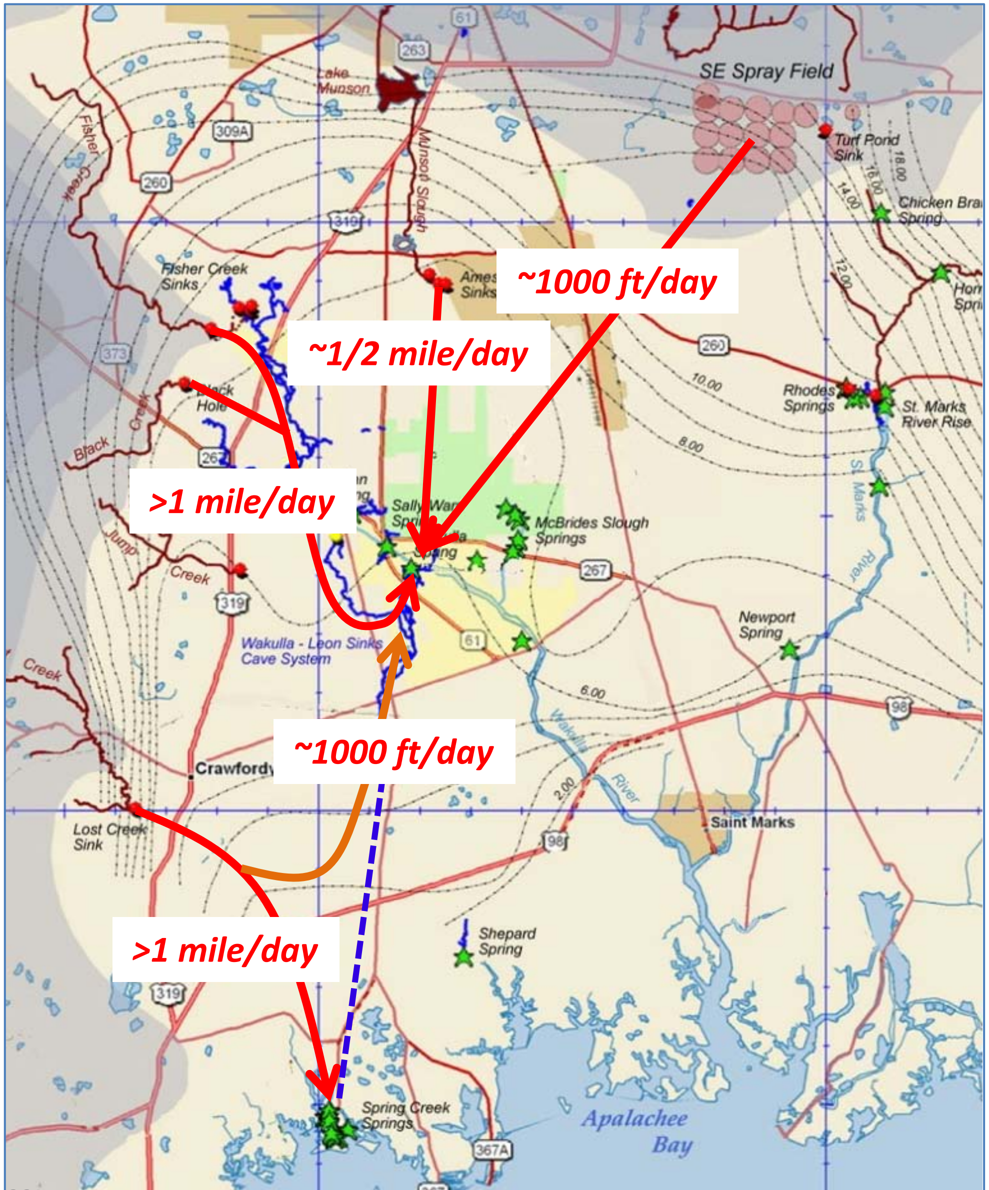
Flow to Wakulla Spring



- Wakulla & Spring Creek are connected
- Spring Creek began reversing for appreciable durations in 2006
- Spring Creek reverses now every summer for weeks - months
- We're loosing the largest spring in Florida & the associated fresh water that flows to the Gulf of Mexico estuaries

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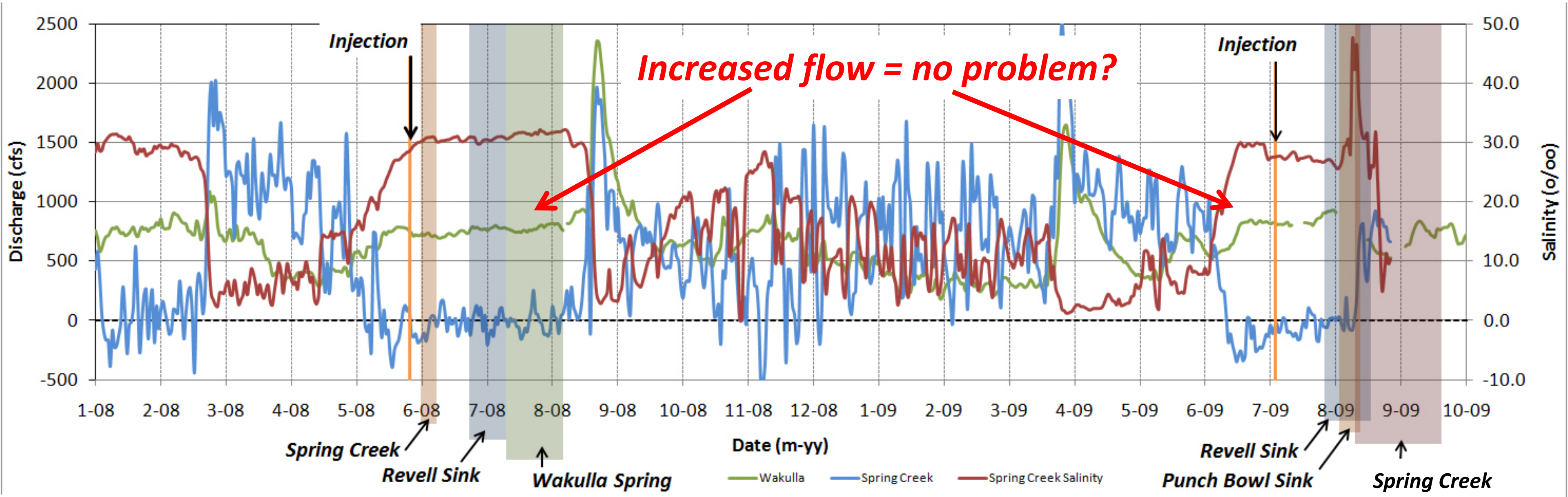
Wakulla / Spring Creek Flows

- Composite Spring Creek flow & salinity (USGS).
- Summers 2007 –: Spring Creek stops flowing / salinities rise to sea water levels.
- When Spring Creek stops flowing, Wakulla Spring flow increases
- When Spring Creek is flowing, Lost Creek water flows rapidly to Spring Creek.
- When spring Creek stops flowing, Lost Creek water flows slowly to Wakulla Spring.



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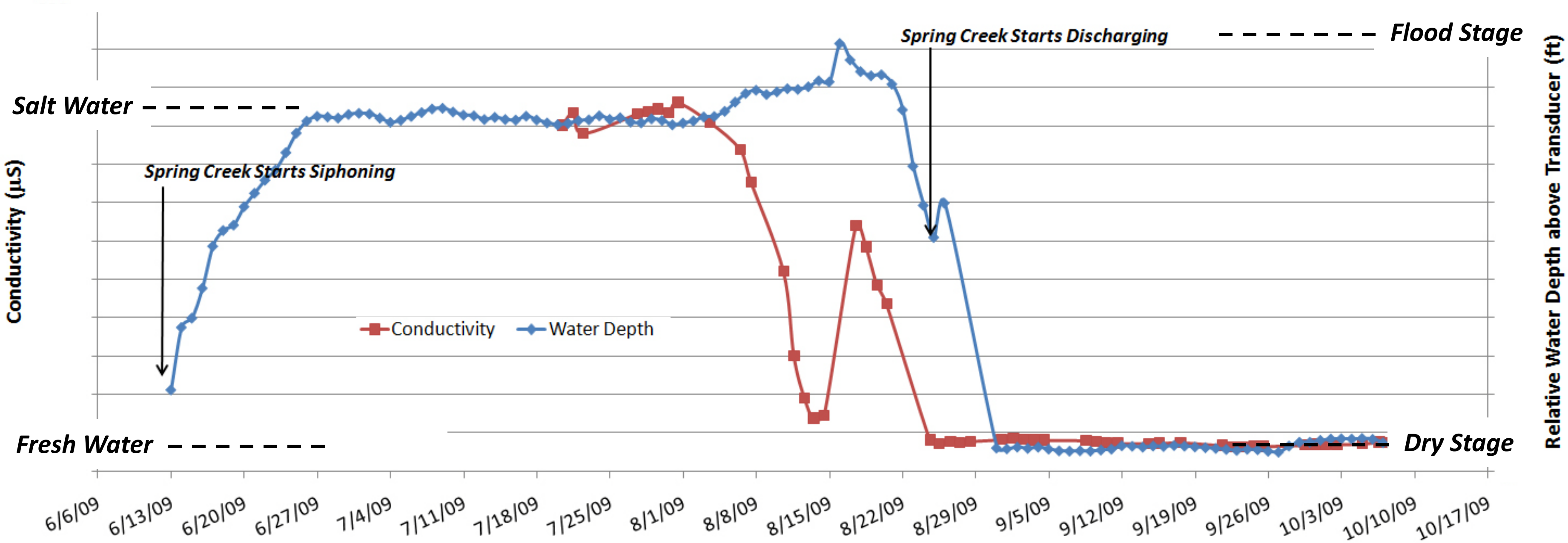
Consequences of Reversals…

- When Spring Creek stops flowing, water backs up into the aquifer matrix in the southern part of the WKP.
- Salt water travels rapidly for long distances (>= 2 miles to Punch Bowl Sink) in days.
- Sinkhole water levels rise to flood stage.
- When Spring Creek starts flowing, water levels drop precipitously and water in conduits returns to fresh water conductivities.



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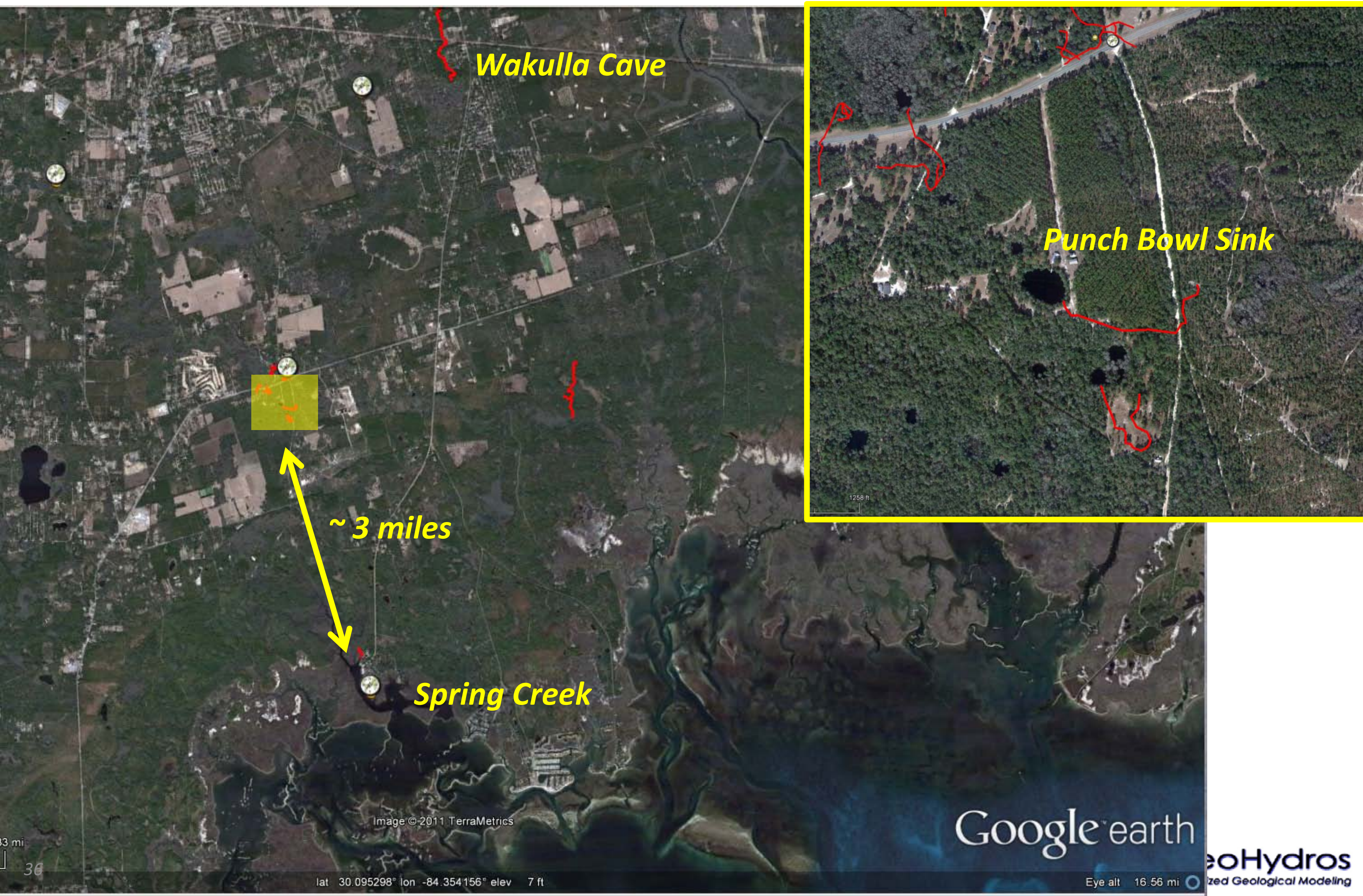
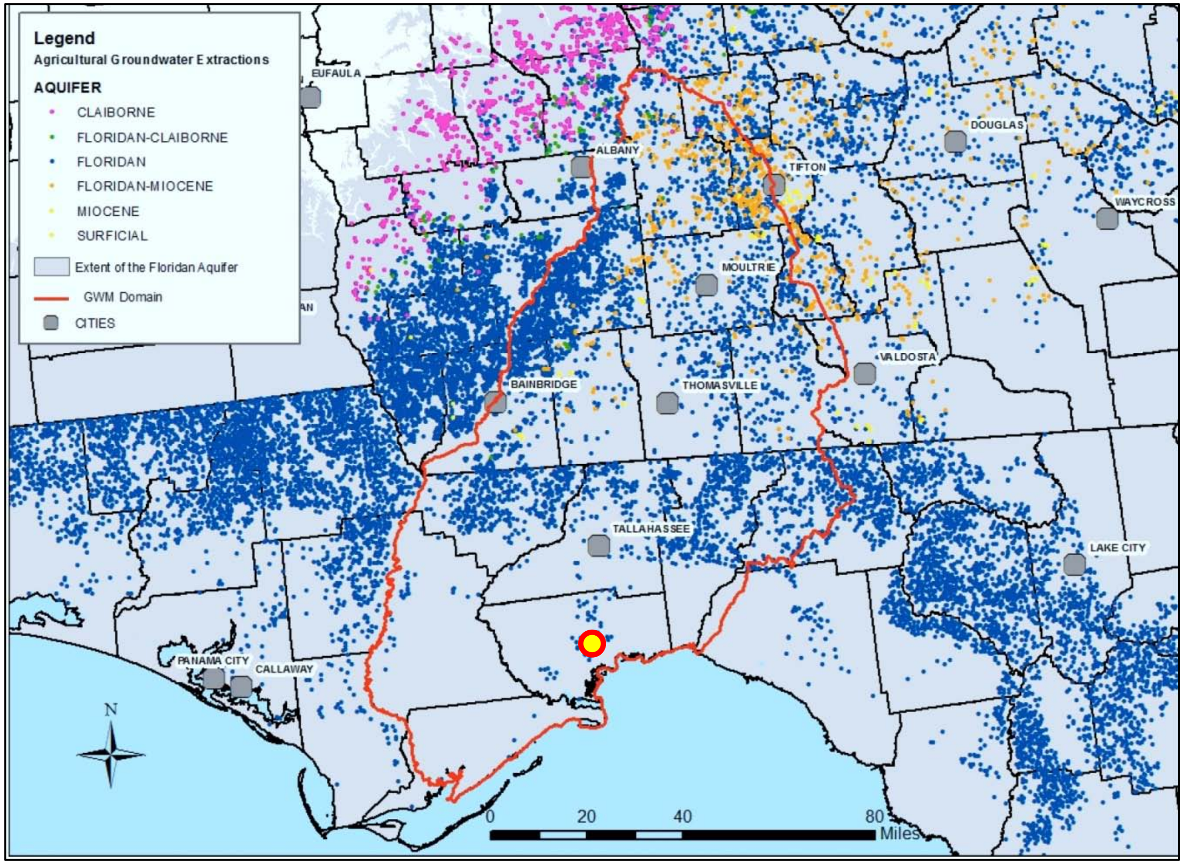
Consequences of Reversals Cont…



Agricultural Pumping



- GA
  183 MGD – Con. Counties
  93 MGD – Model Domain
- FL
  29 MGD – Con. Counties
  21 MGD – Model Domain

National Environmentally Sound Production Agriculture Laboratory (NESPAL)
University of Georgia's College of Agricultural and Environmental Sciences
Georgia EPD
NWFWMD
SRWMD

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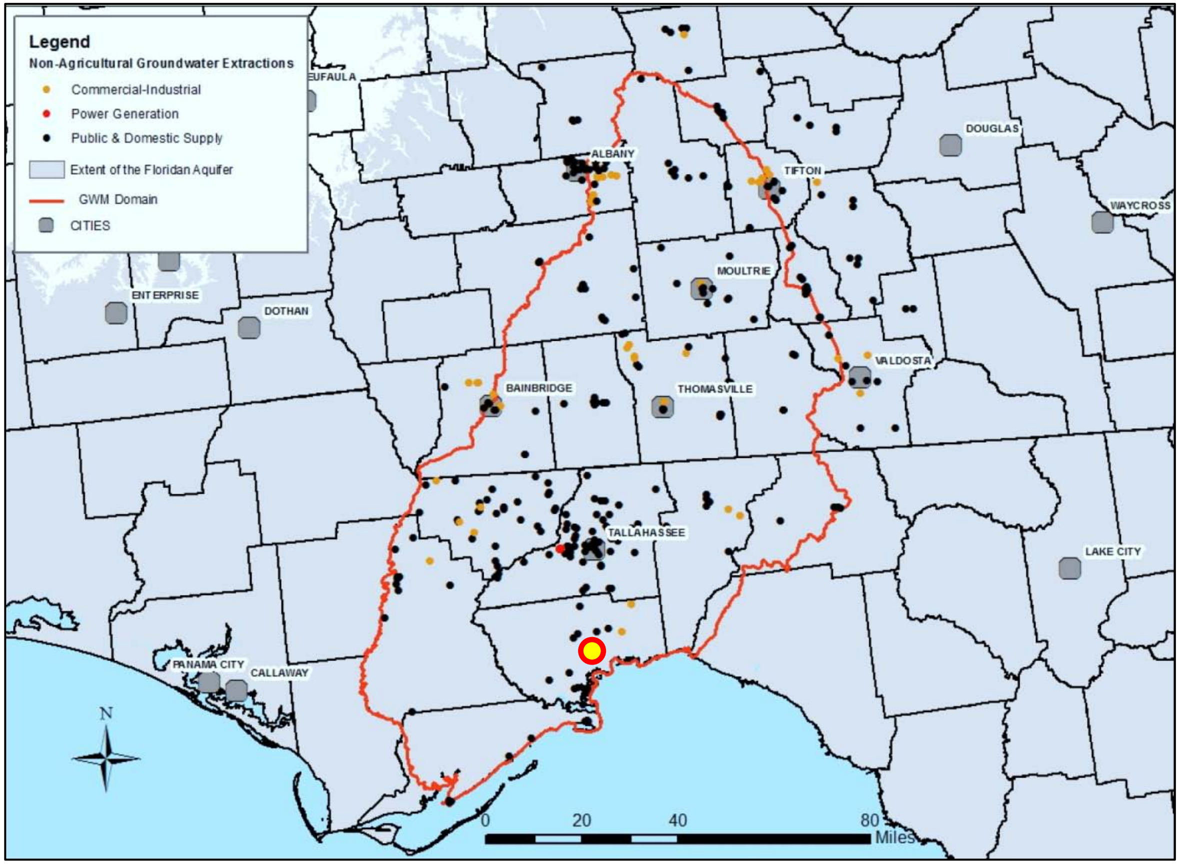
Municipal Pumping

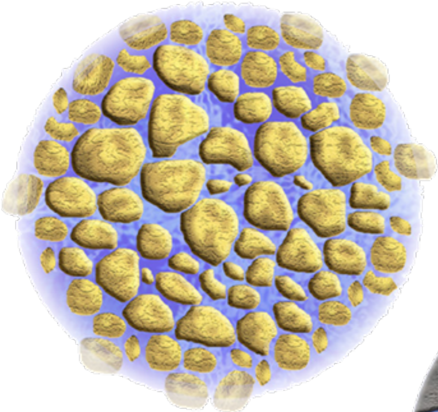


- GA
  54 MGD – Con. Counties
- FL
  24 MGD – Con. Counties

GA: Fanning & Trent 2009
FL: Marella 2009
FL: NWFWMD

Different Approaches

Porous Media

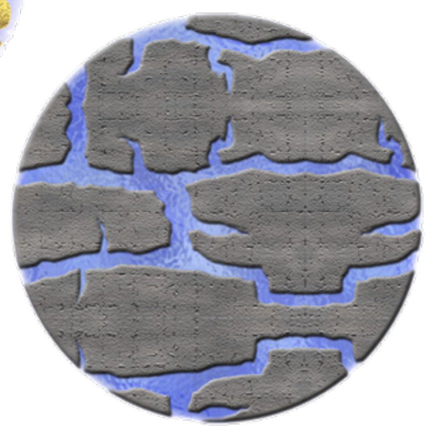


Standard Approach

sand / sandstone
easy to characterize
simplest math

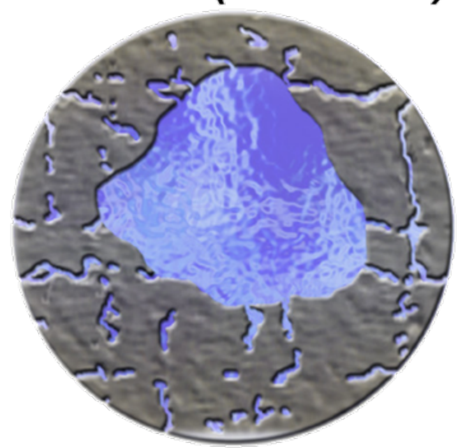
Fractered Rock

New Approach



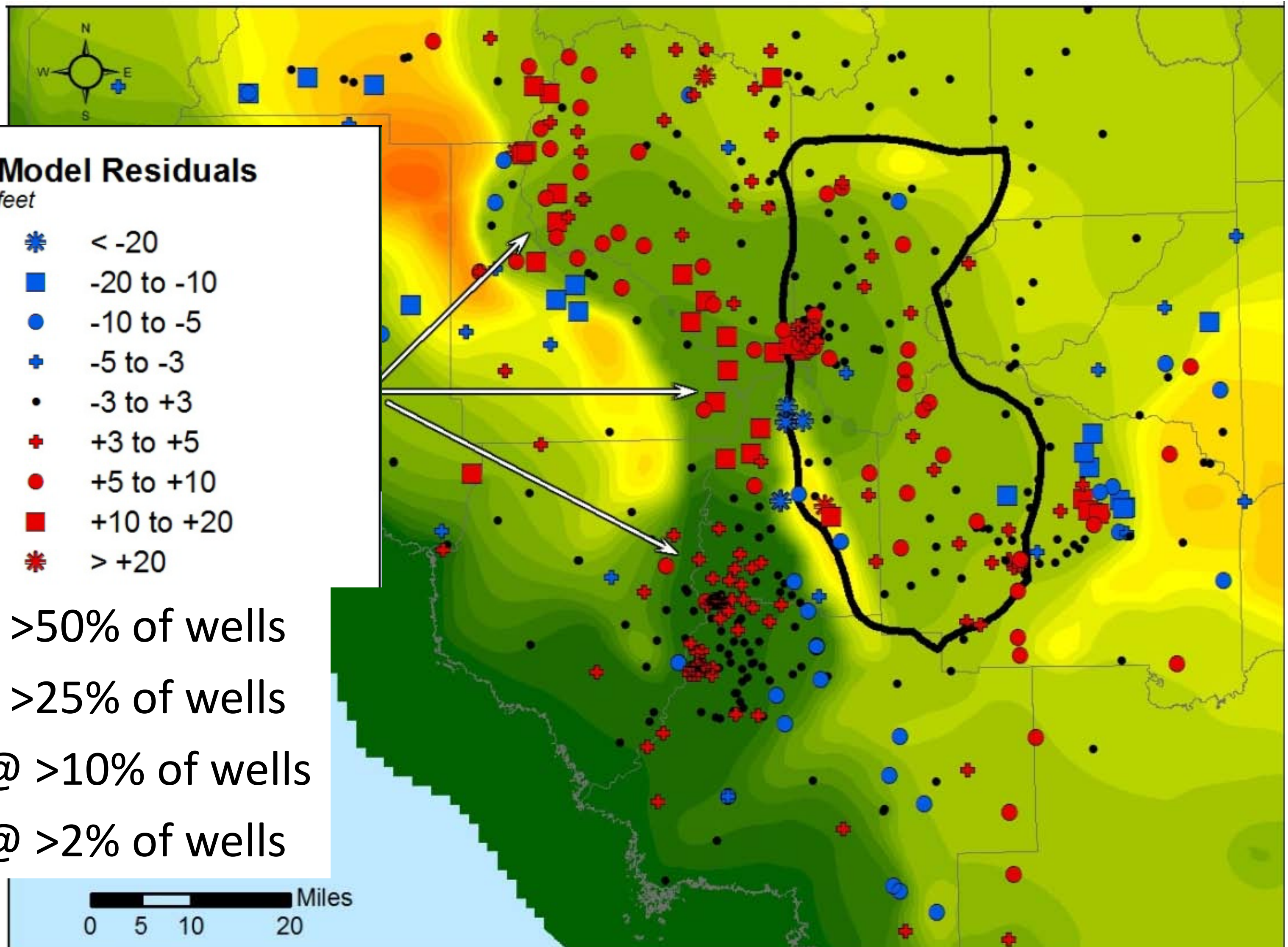
hard rocks (shale, granite, etc)
can map from surface
harder to characterize
more difficult math

Karst (Conduits)



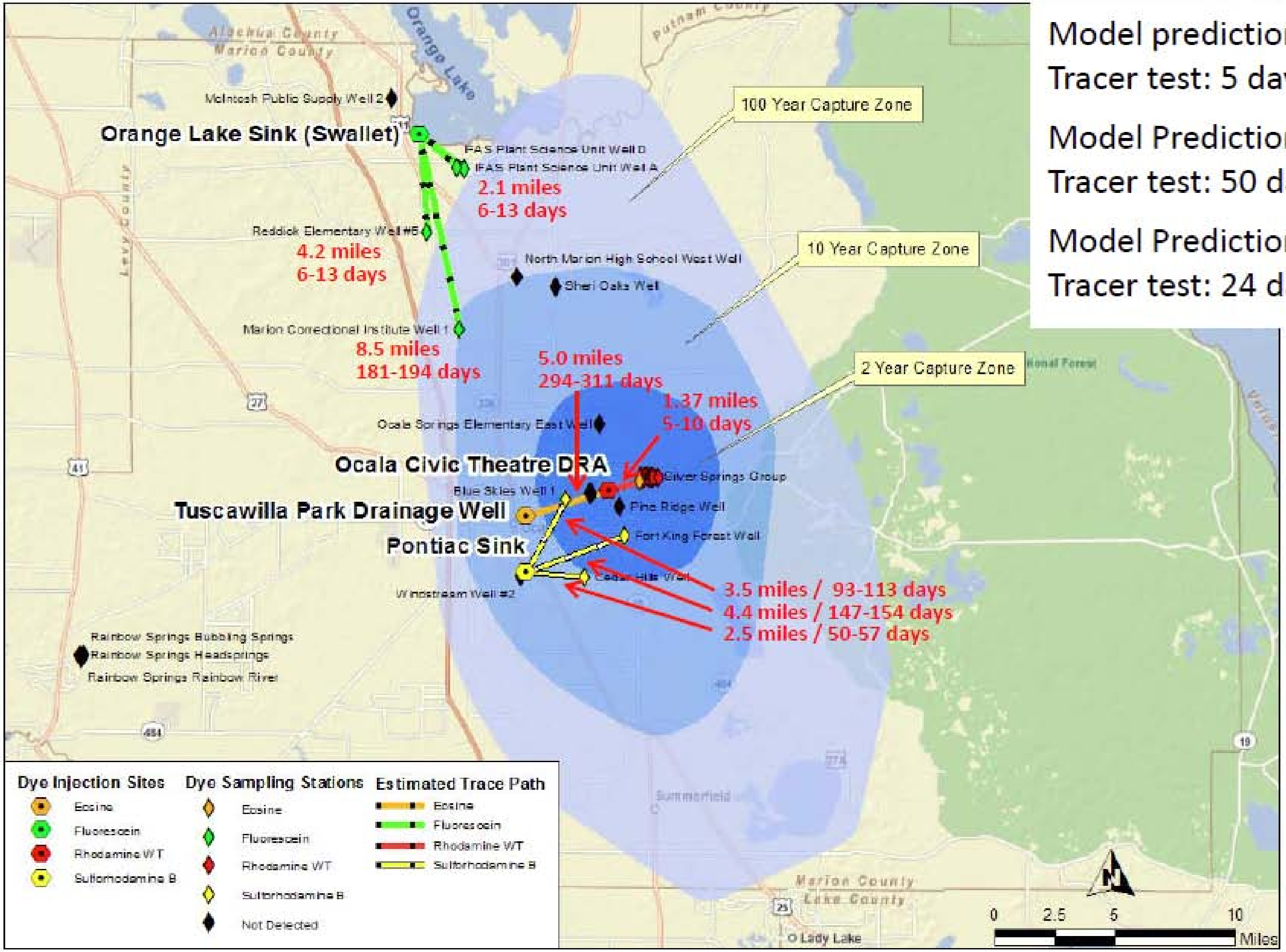
Limestone (Floridan Aquifer)
cannot typically be mapped
hardest to characterize
most difficult math

Typical Modeling Errors – Porous Media Approach



- >3 feet @ >50% of wells
- >5 feet @ >25% of wells
- >10 feet @ >10% of wells
- >20 feet @ >2% of wells

Typical Modeling Errors – Porous Media Approach



Model prediction: 2 years

Tracer test: 5 days – 10.5 months

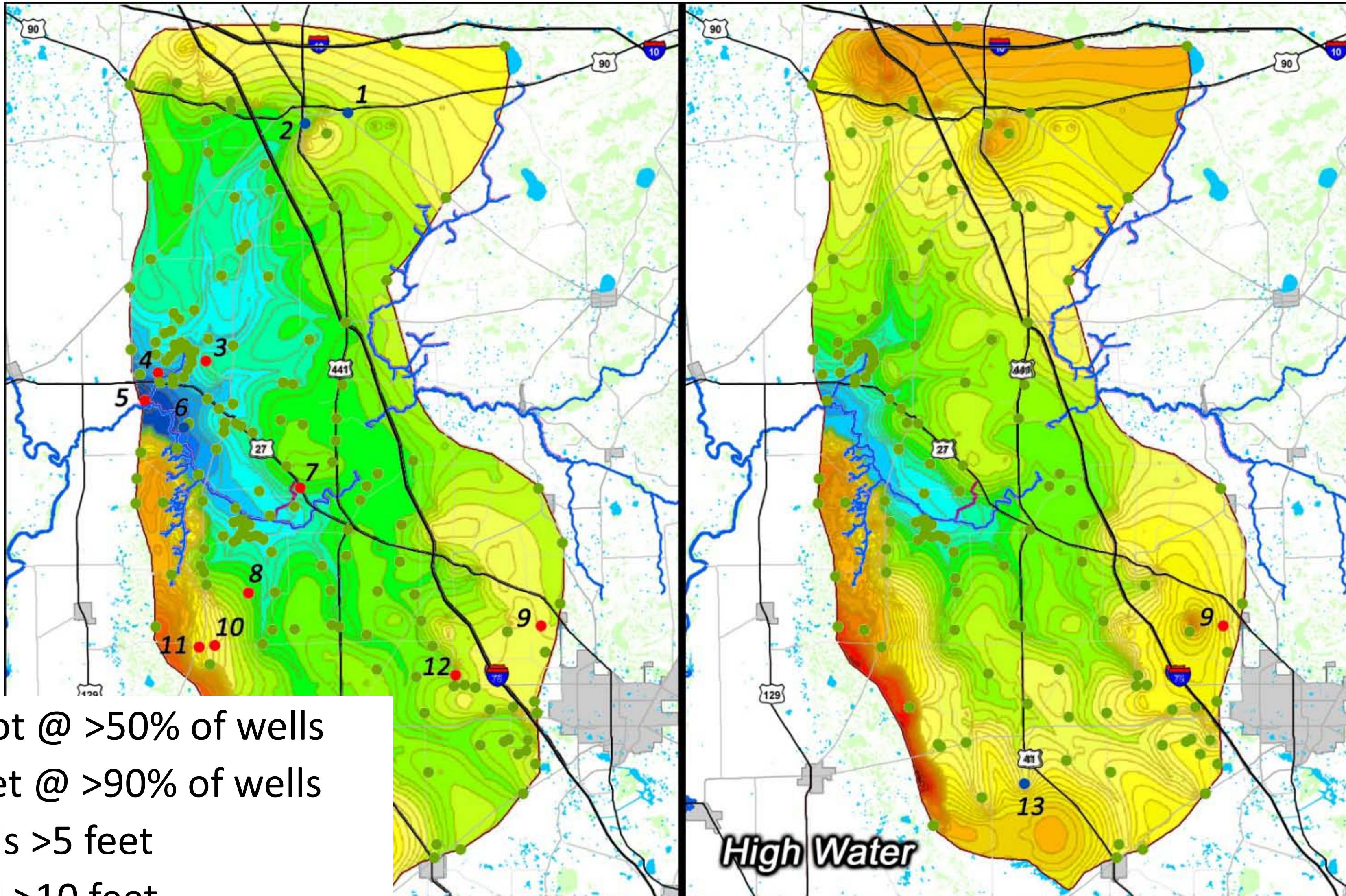
Model Prediction: 10 years

Tracer test: 50 days – 10.5 months

Model Prediction: 100 years

Tracer test: 24 days – 12.5 months

Modeling Errors – Conduit Flow Approach



- <1 foot @ >50% of wells
- <3 feet @ >90% of wells
- 3 wells >5 feet
- 1 well >10 feet

Modeled Travel Times – Conduit Flow Approach

Flow is to closest conduits

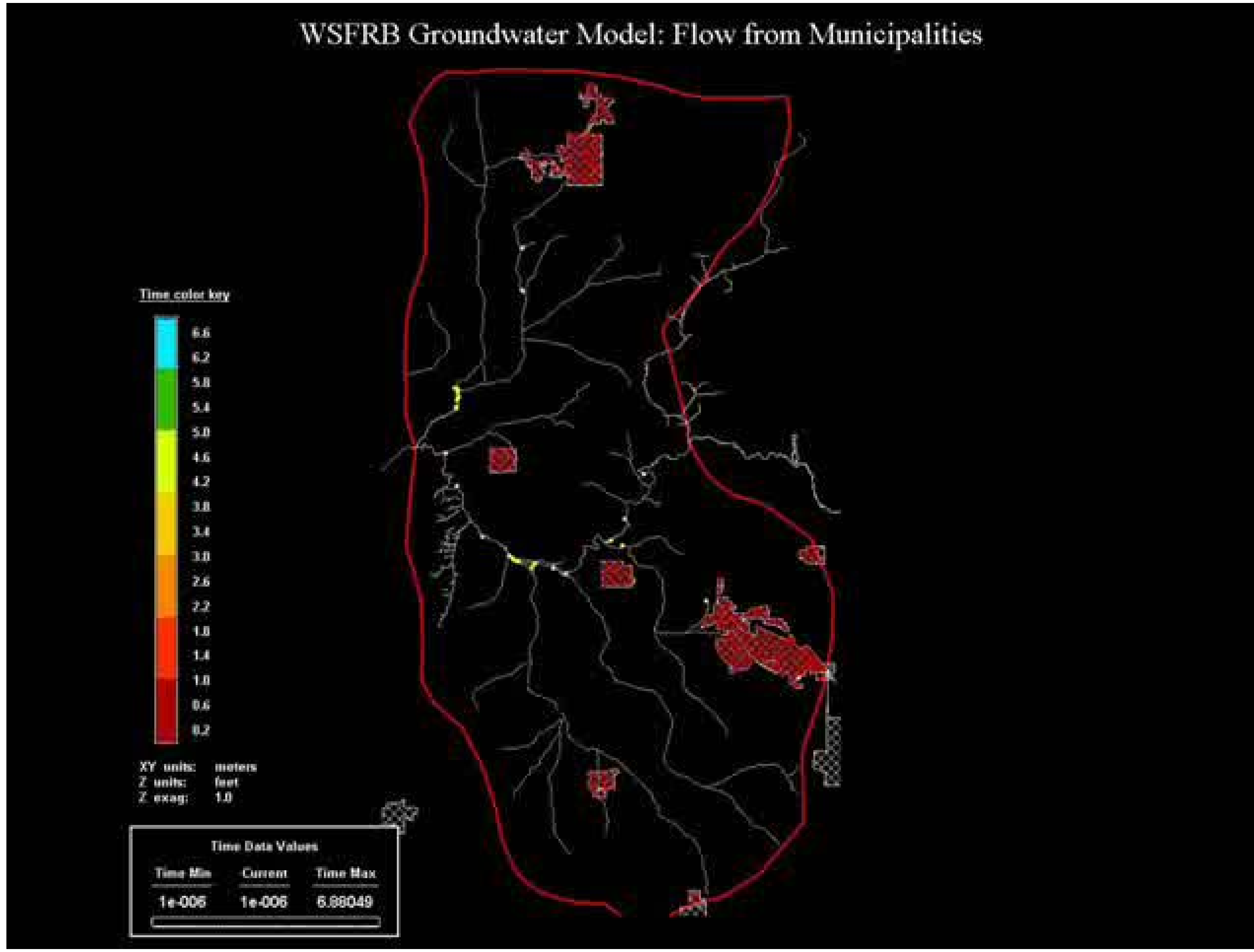
Closest towns not always of most concern

Newberry – Ginnie Spring
- *~12 miles*
- *~1000 days*
- *conduit flow*

Alachua – Hornsby Spring
- *~7 Miles*
- *~500 days*
- *conduit flow*

High Springs – River
- *~2 miles*
- *~10,000 days*
- *no conduit*

Municipalities: Santa Fe River Basin, Florida



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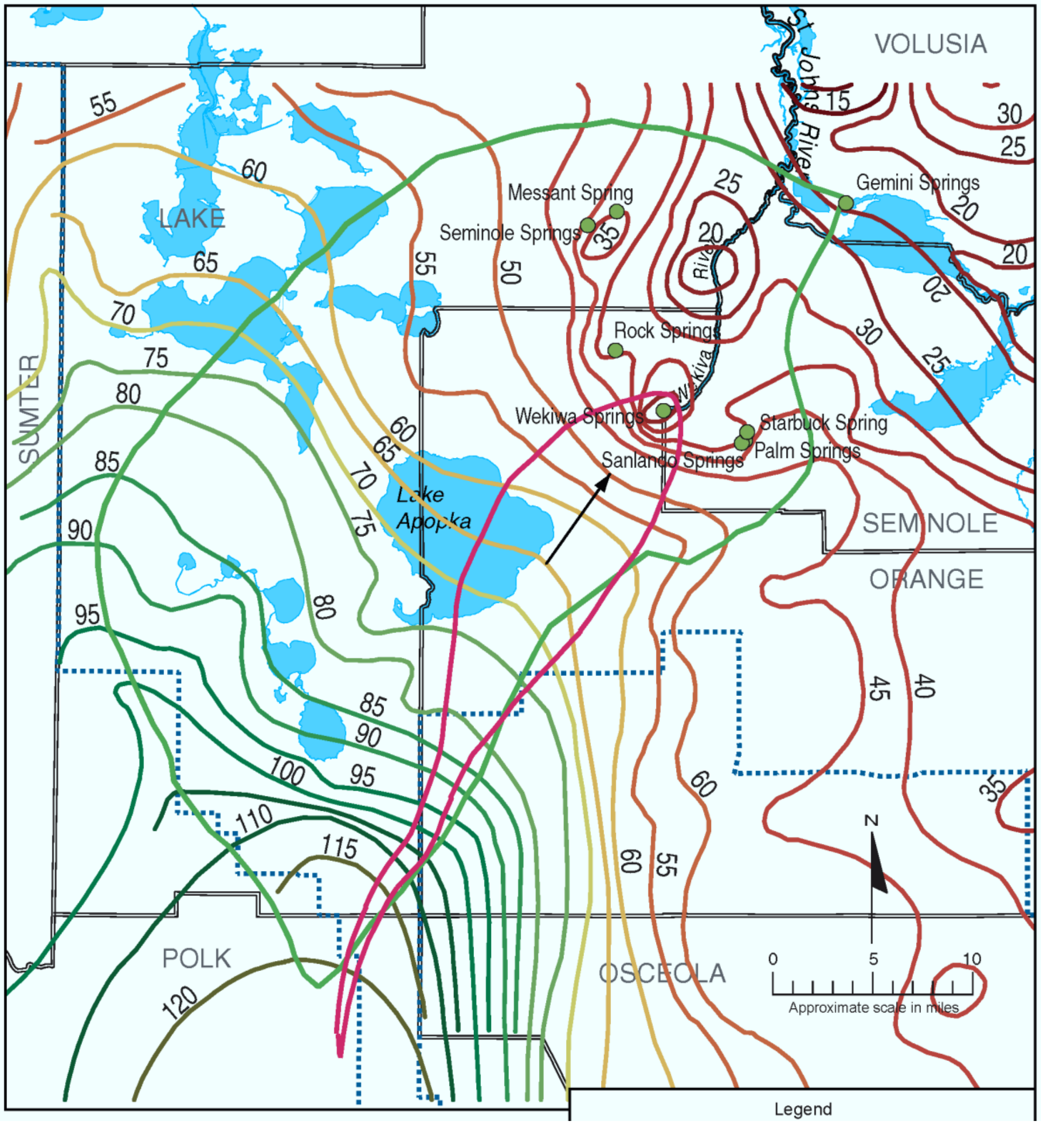
Implications for Wekiva



From Toth, 2002

- Same processes as other springs
- Combination of conduit and matrix flow
- Travel times very likely much faster than predicted by porous media models and age dating
- Will likely have to mitigate all significant sources of nitrate contamination
  - Agriculture
  - Independent residential
  - Municipal

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Summary

- Karst is prevalent in Florida
- Springs are fed by conduits
- Conduits drain water from the surrounding matrix and convey it rapidly to springs
  (There really are such things as underground rivers)
- Vulnerability is not necessarily directly related to proximity
- Distance to conduits more important than distance to spring
  - Applies to contaminant transport
  - Applies to saltwater intrusion
- Springs and Groundwater are more vulnerable to contamination than have been predicted
- There is probably less water in the Floridan than has been predicted
- Protecting Wekiva will require more stringent regulation on nitrogen discharges and very likely reduced consumption
- Protecting Wekiva will sustain the Floridan as a viable longterm fresh water resource

Core Problem: *Public Perception & Concern*

Topic	*Internet Hits*
• global water resources:	24,800,000
• aquifer protection:	1,350,000
• water shortage:	8,130,000
• water crisis:	27,900,000
• water pollution:	34,400,000
• bottled water:	10,100,000
• Florida springs:	40,900,000
• Florida springs decline:	651,000
• Britney Spears:	49,800,000
• free porn:	188,000,000
• free sex:	366,000,000

Clean Water / Free Sex = < 10%

Clean Water / Britney Spears = 68%

Questions?

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