GROUNDWATER/SURFACE-WATER EXCHANGE AND THE EFFECTS ON SURFACE WATER QUALITY AND QUANTITY IN THE MISSISSIPPI DELTA

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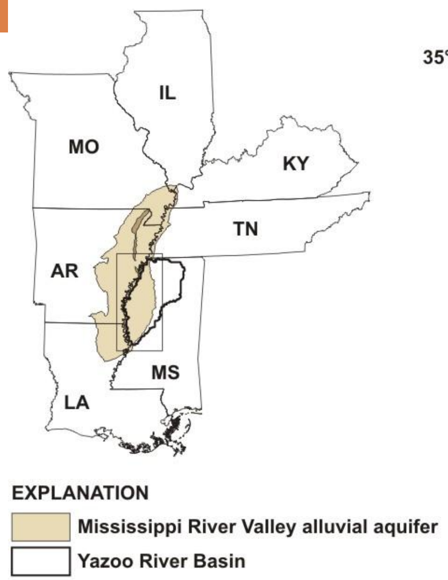
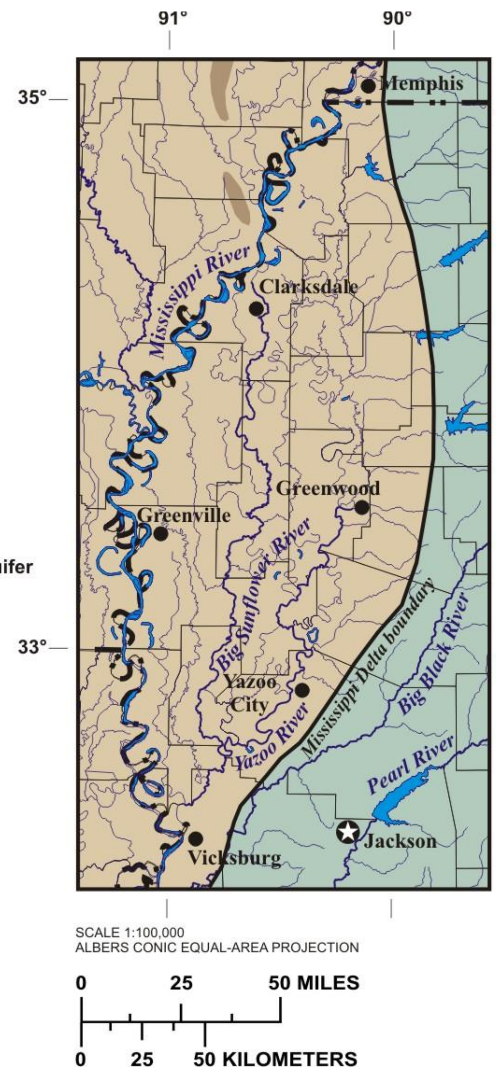
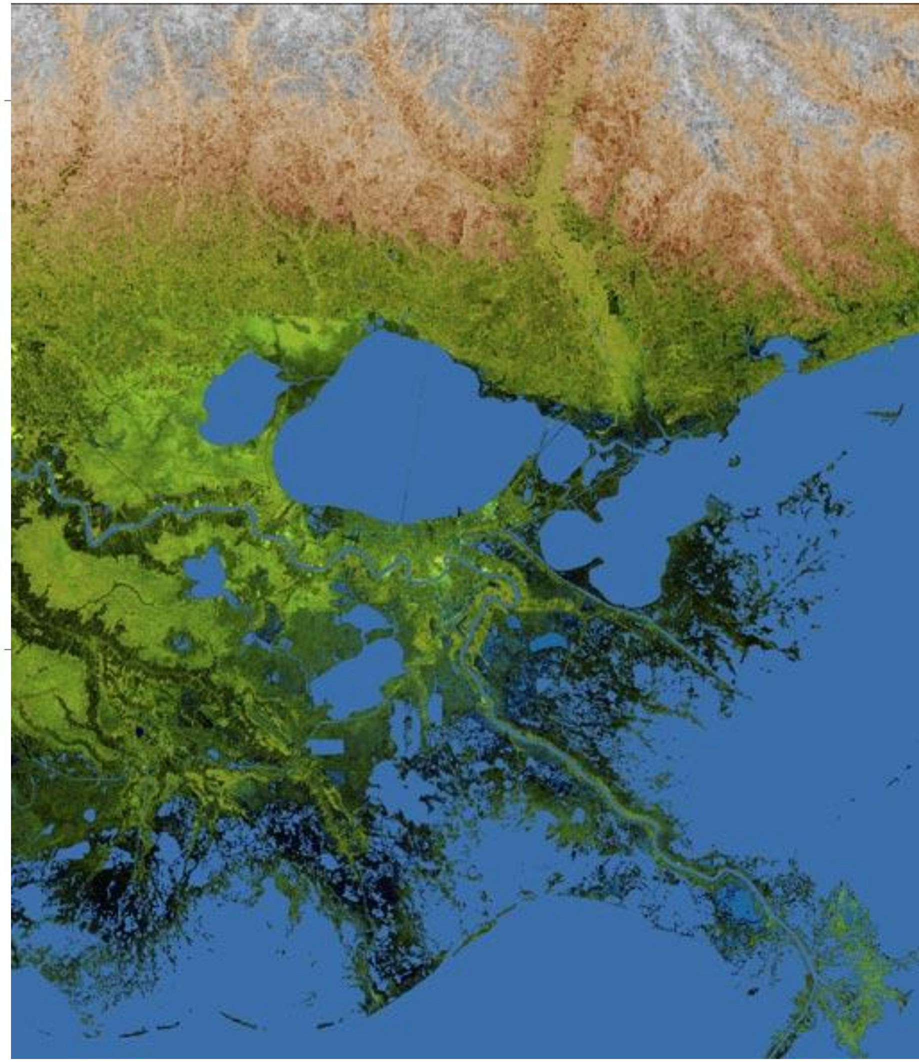
Jackson, MS

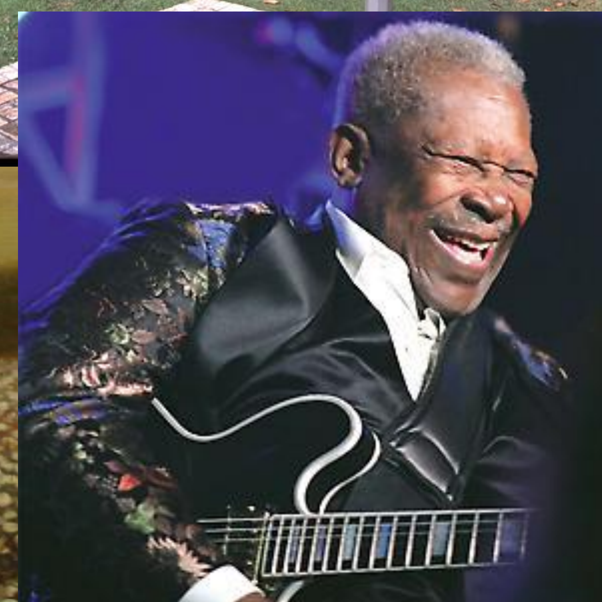
Mississippi Delta (not the MS River Delta)







Land of cotton, blues, and rock & roll



Lower Mississippi River Flood Plain Altered

Mississippi River Flood Plain

Land Characterization:

- Bottomland hardwood wetlands
- Annual flooding distributes nutrient-rich matter

Logged, drained, channelized
Levees built

Land Characterization:

> 80% Agriculture

- Row crops
- Rice
- Aquaculture

John James Audubon

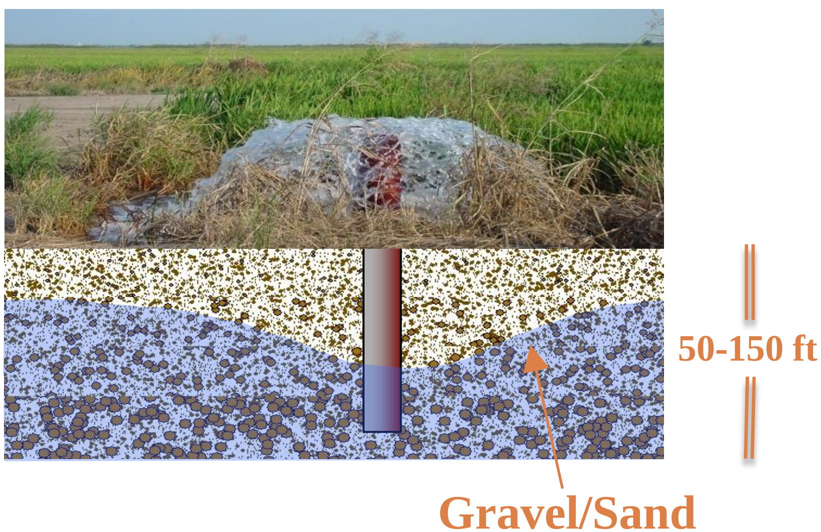
Referring to the Yazoo River Audubon described it thus: “a beautiful stream of transparent water, covered by thousands of geese and ducks and filled with fish

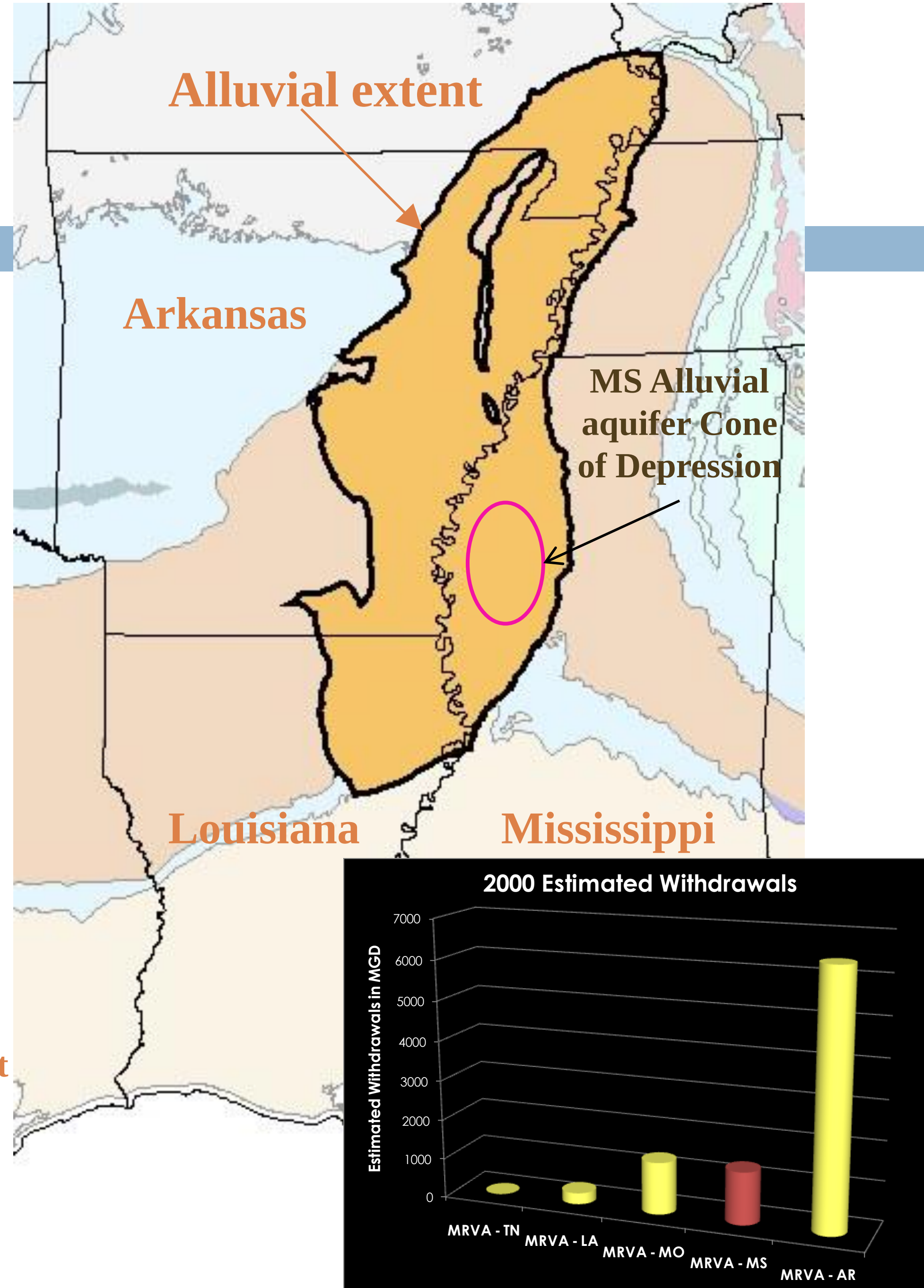
In the Louisiana Canebrakes (Roosevelt, 1908)

Roosevelt describes a virtual wilderness, with old growth forest and wetlands dominating the landscape with a few farms hacked out of the forest. He describes canebrakes 20 feet tall extending for miles and the bayous teaming with alligator, garfish, and “monstrous snapping turtles, fearsome brutes of the slime”

Water Availability: Alluvial Aquifer

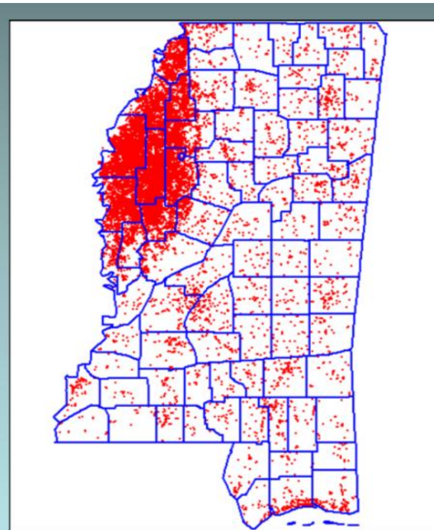
- Agriculture / Irrigation
- 3rd most intensively used aquifer in US in 2000
- MS 2nd largest user behind AR



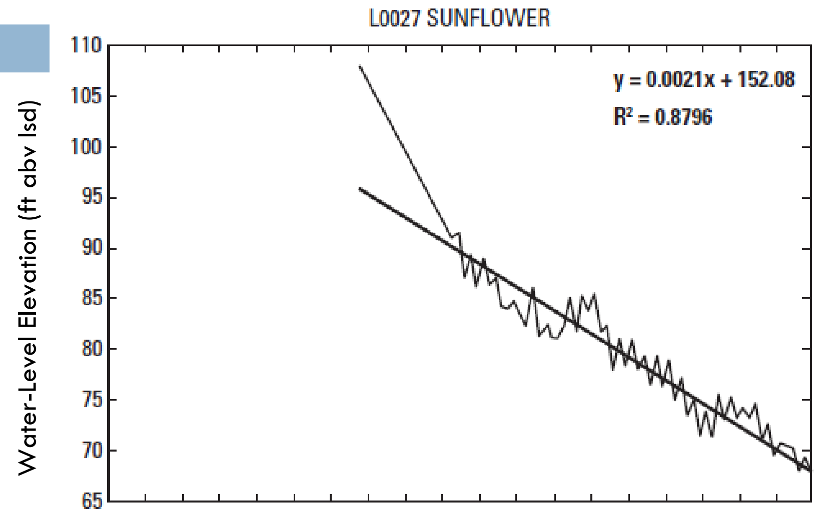


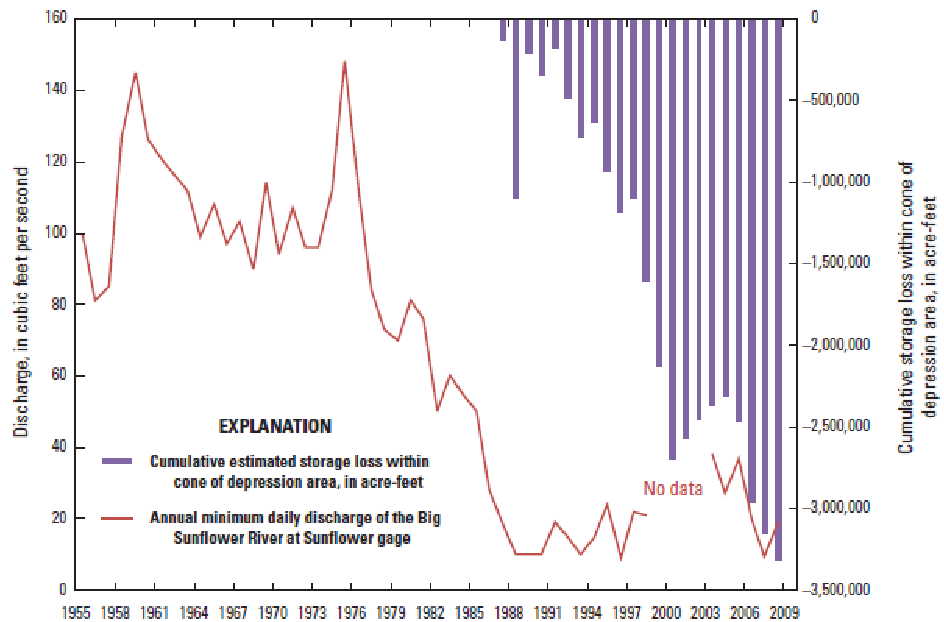
Water Availability: Alluvial Aquifer

Permitted Water use locations in Mississippi



+90% Groundwater



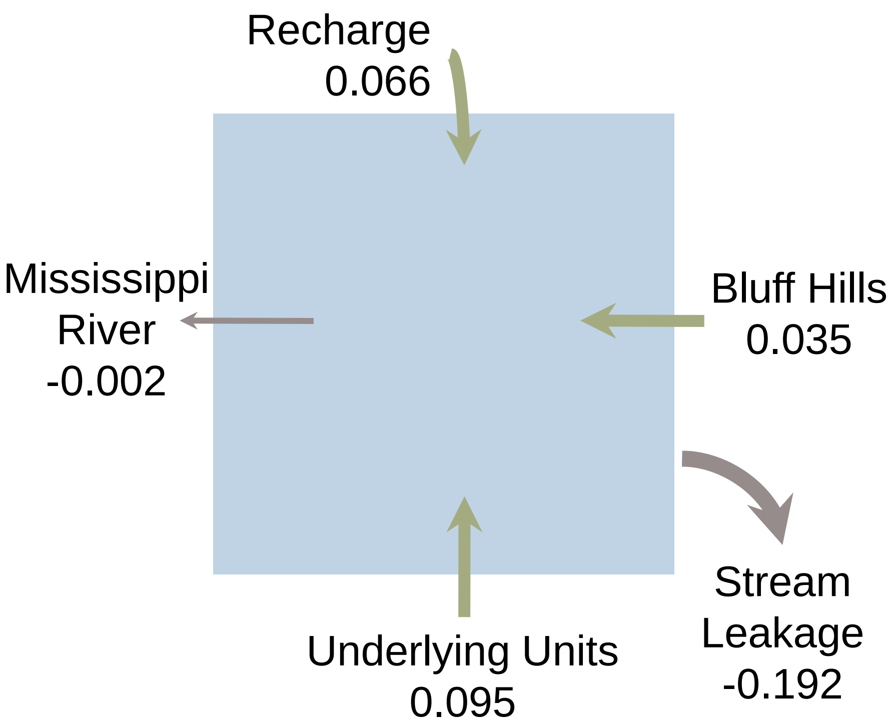


Storage data from Yazoo Mississippi Delta Joint Water Management District, 2010

Taken from Barlow and Clark, 2011

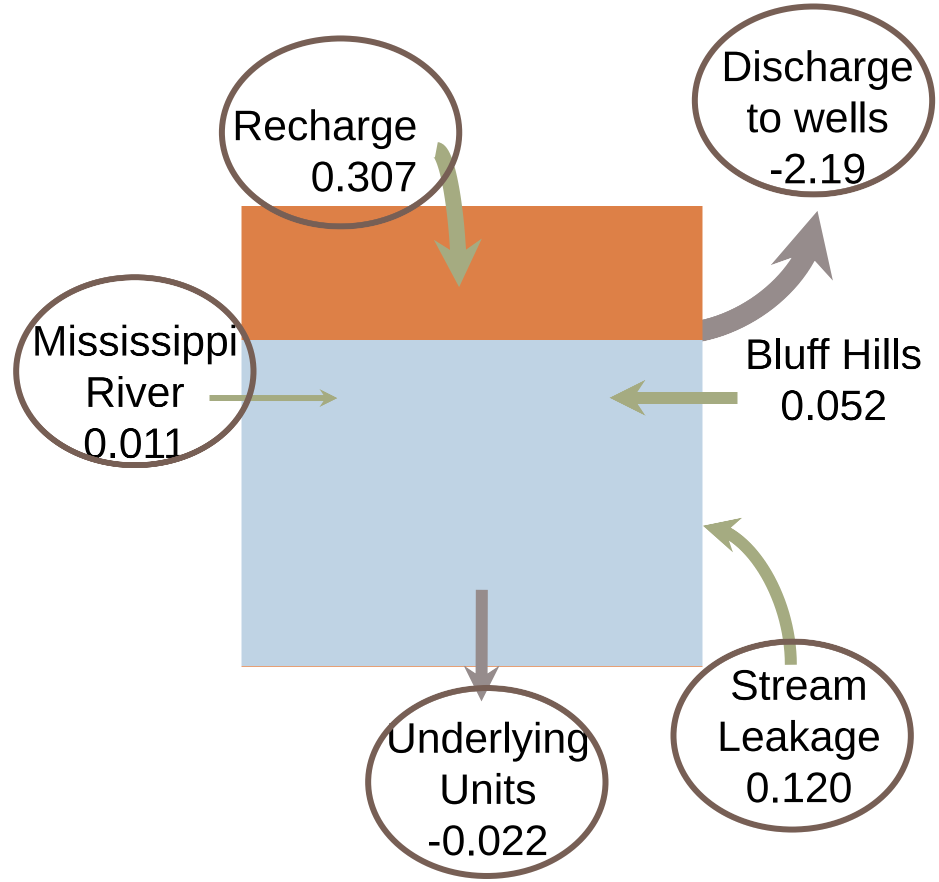
How has flow in the alluvial aquifer changed over time?

Conditions in 1870 (Predevelopment)



Total In = 0.196
Total Out = 0.194
Net Storage Gain = 0.002

Conditions in 2007



Total In = 0.49
Total Out = 2.20
Net Storage Loss = 1.71

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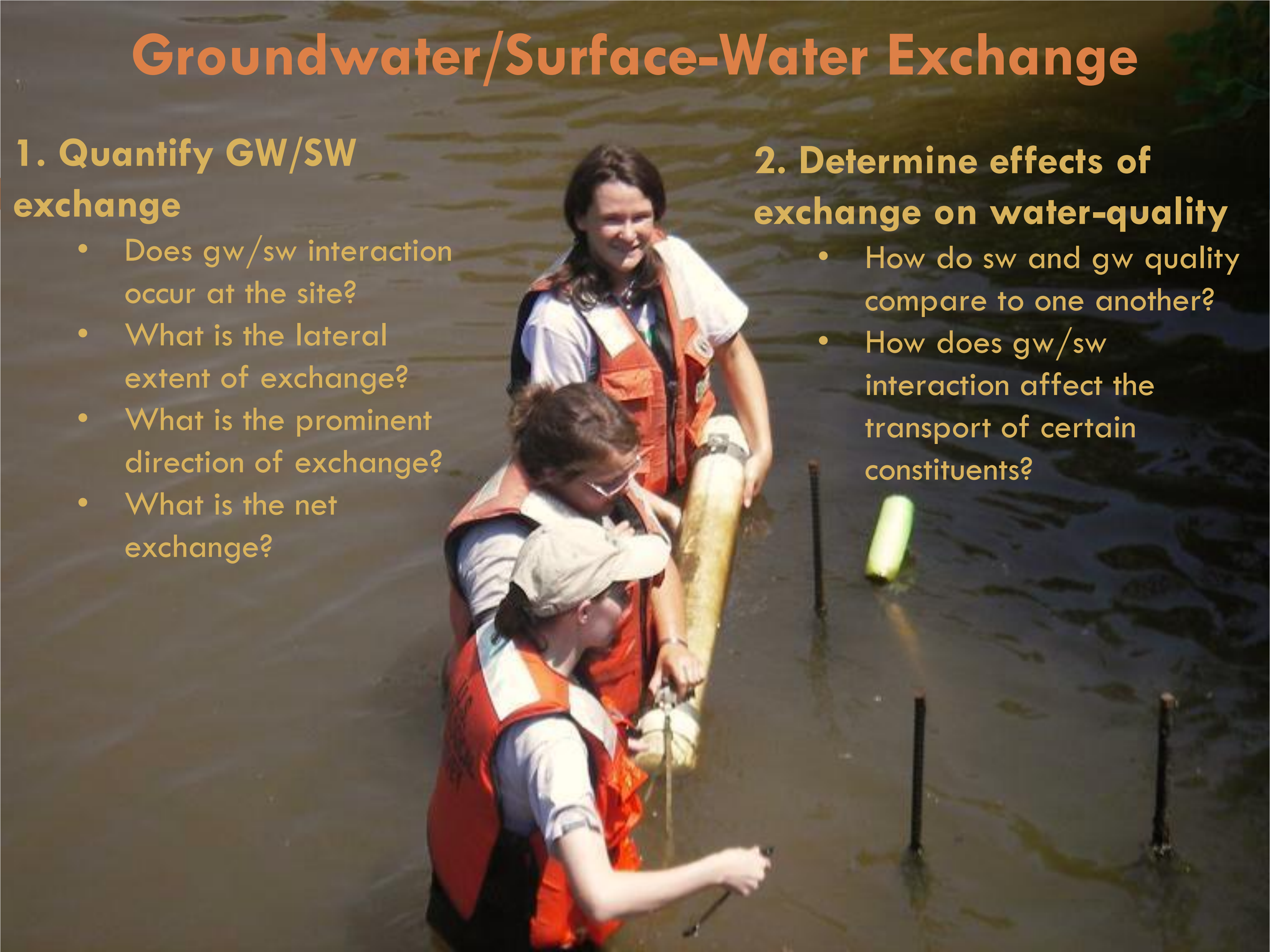
NAWQA –ACT Study

Groundwater/Surface-Water Exchange



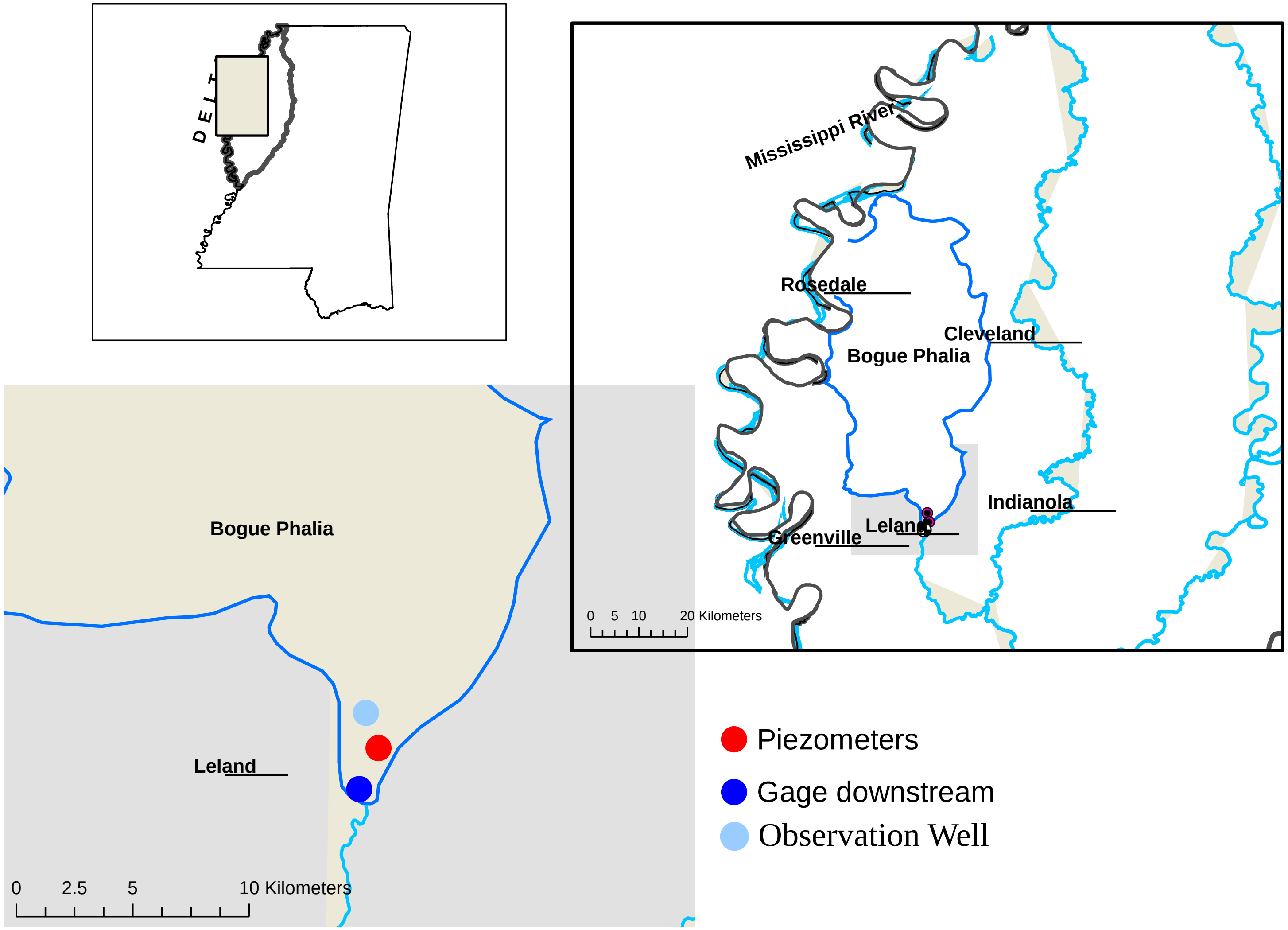
1. Quantify GW/SW exchange

- Does gw/sw interaction occur at the site?
- What is the lateral extent of exchange?
- What is the prominent direction of exchange?
- What is the net exchange?

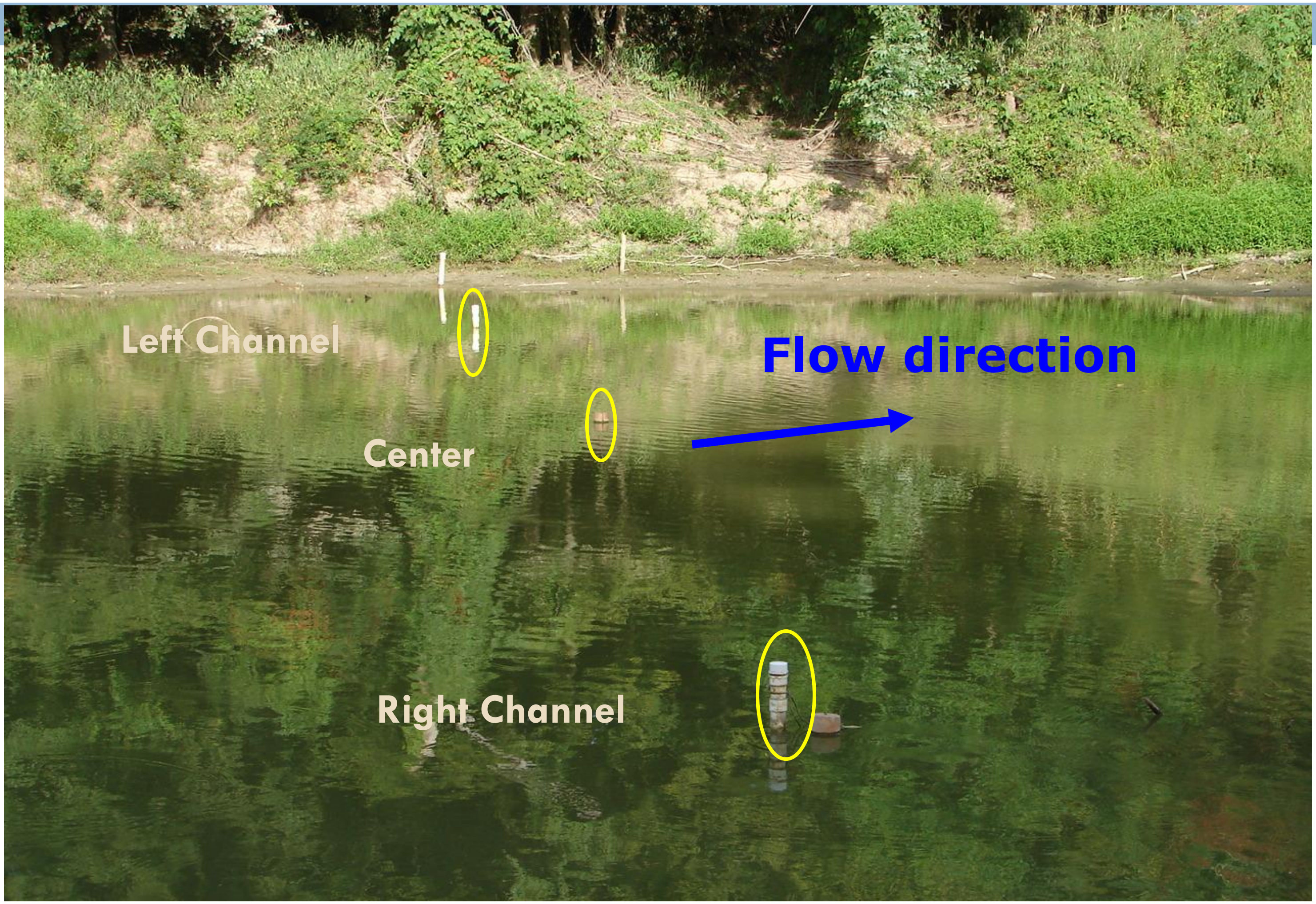
2. Determine effects of exchange on water-quality

- How do sw and gw quality compare to one another?
- How does gw/sw interaction affect the transport of certain constituents?

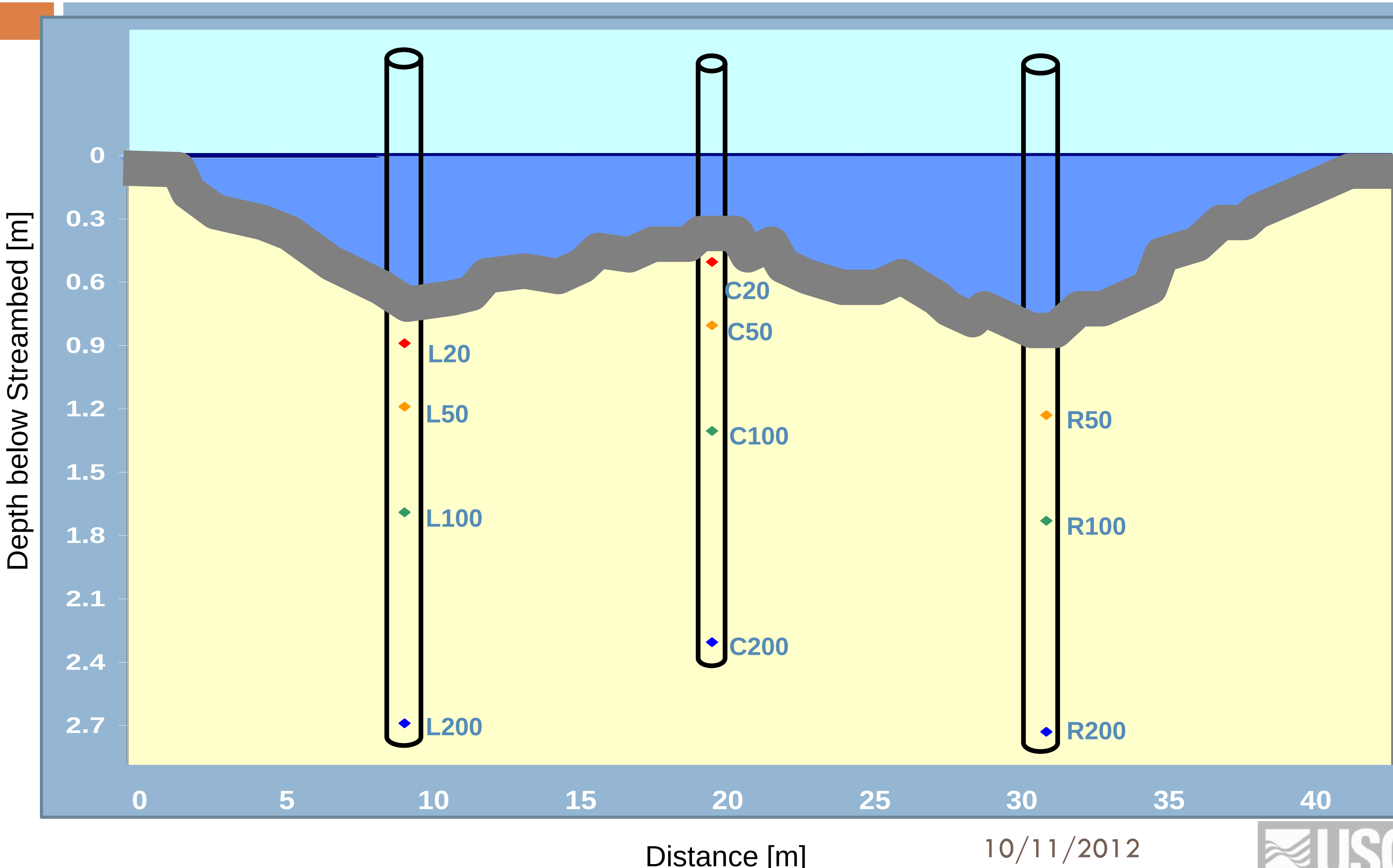
Bogue Phalia Basin and Heat Tracer Site



Bogue Phalia Heat Tracer Transect



Piezometer Installation and Instrumentation



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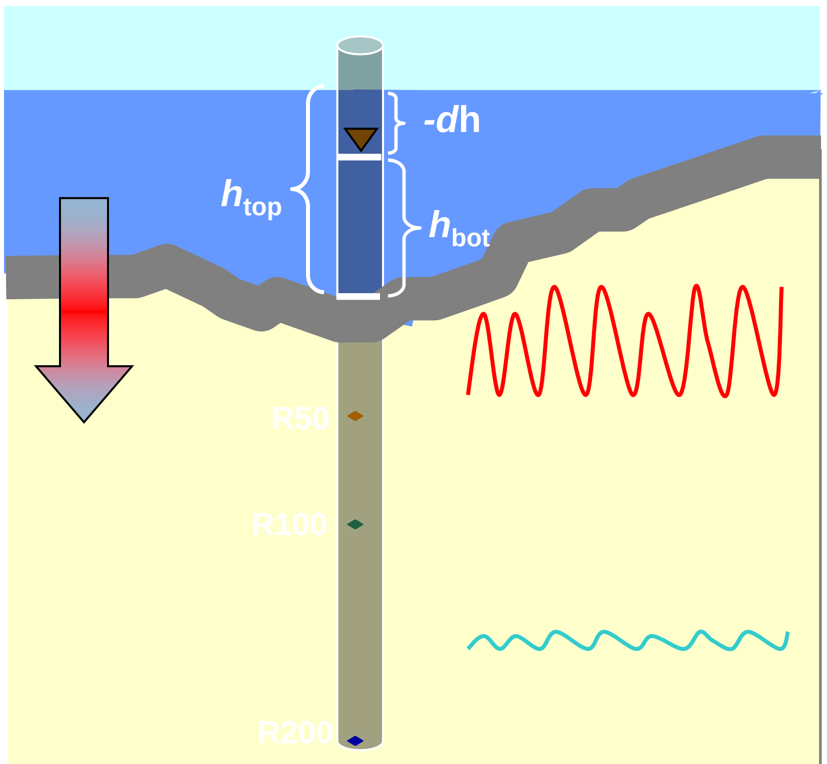
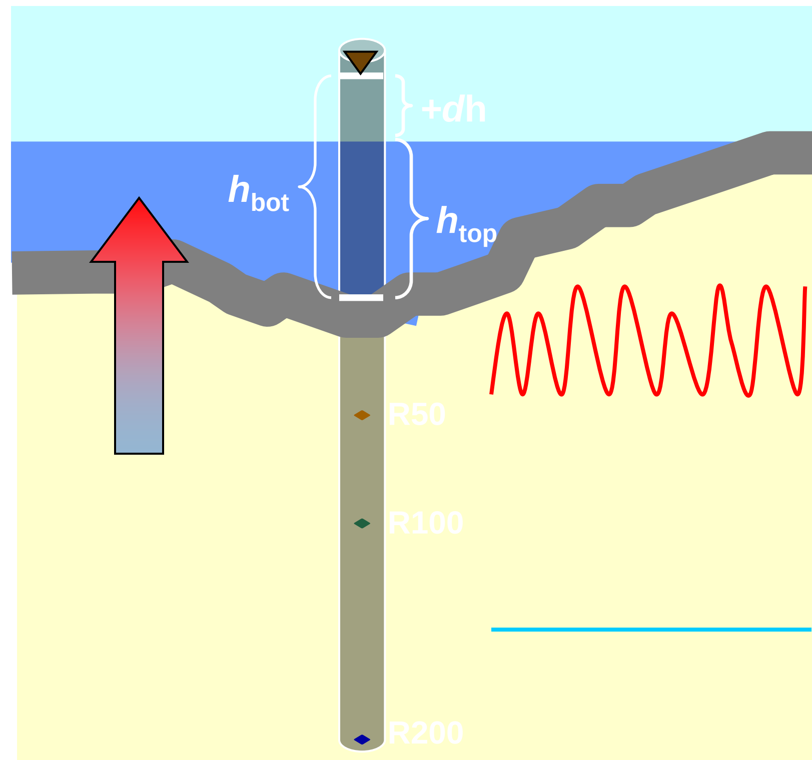
Methods: Heat Tracing

Losing Stream:
$h_{bot} - h_{top} = -dh$

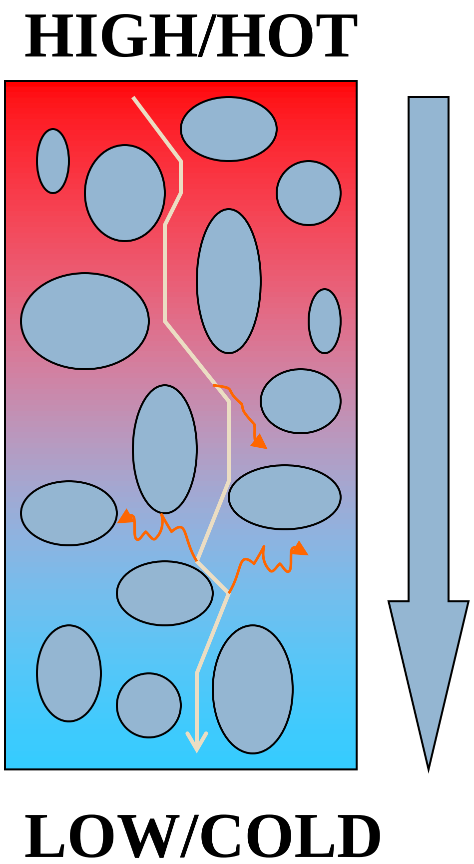


Gaining Stream:
$h_{bot} - h_{top} = +dh$



Methods: *Energy (Heat) Transport*

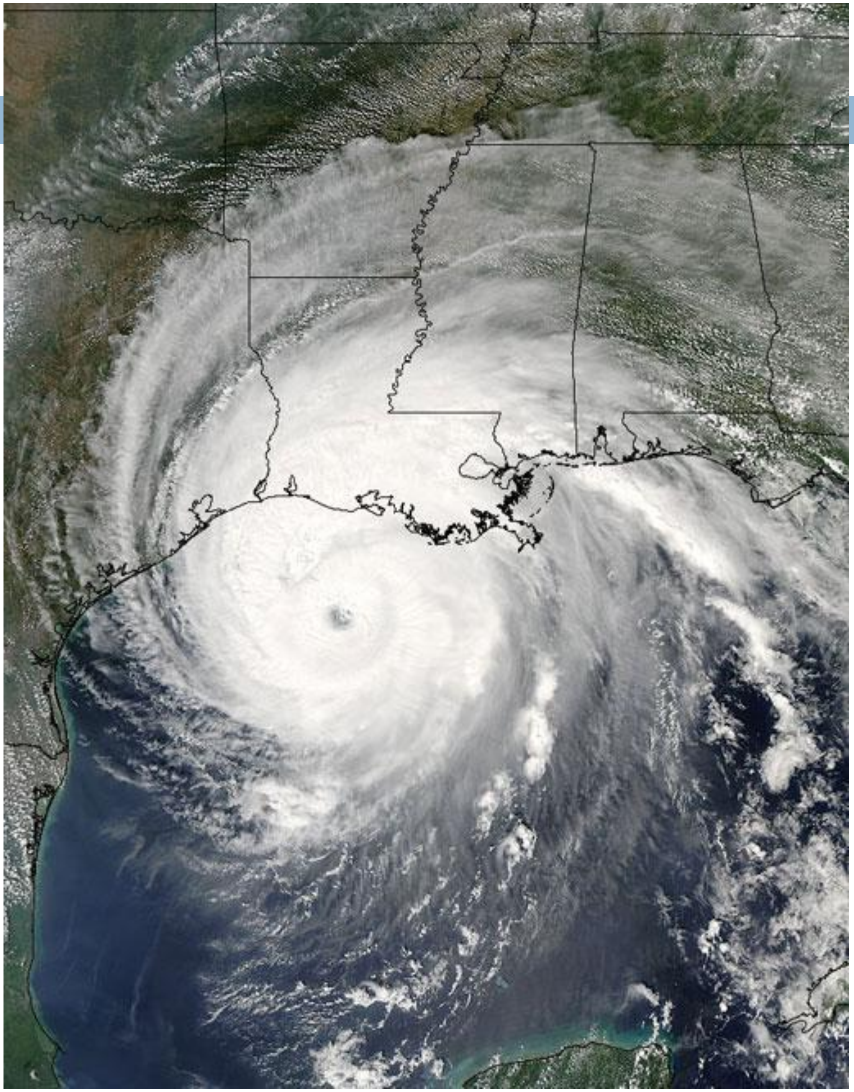
- Solute Transport
  - Advection
    - fluid movement
  - Dispersion
    - concentration gradients (high to low) and pore space



- Energy Transport
  - Advection
    - fluid movement
  - Conduction
    - temperature gradients (hot to cold)

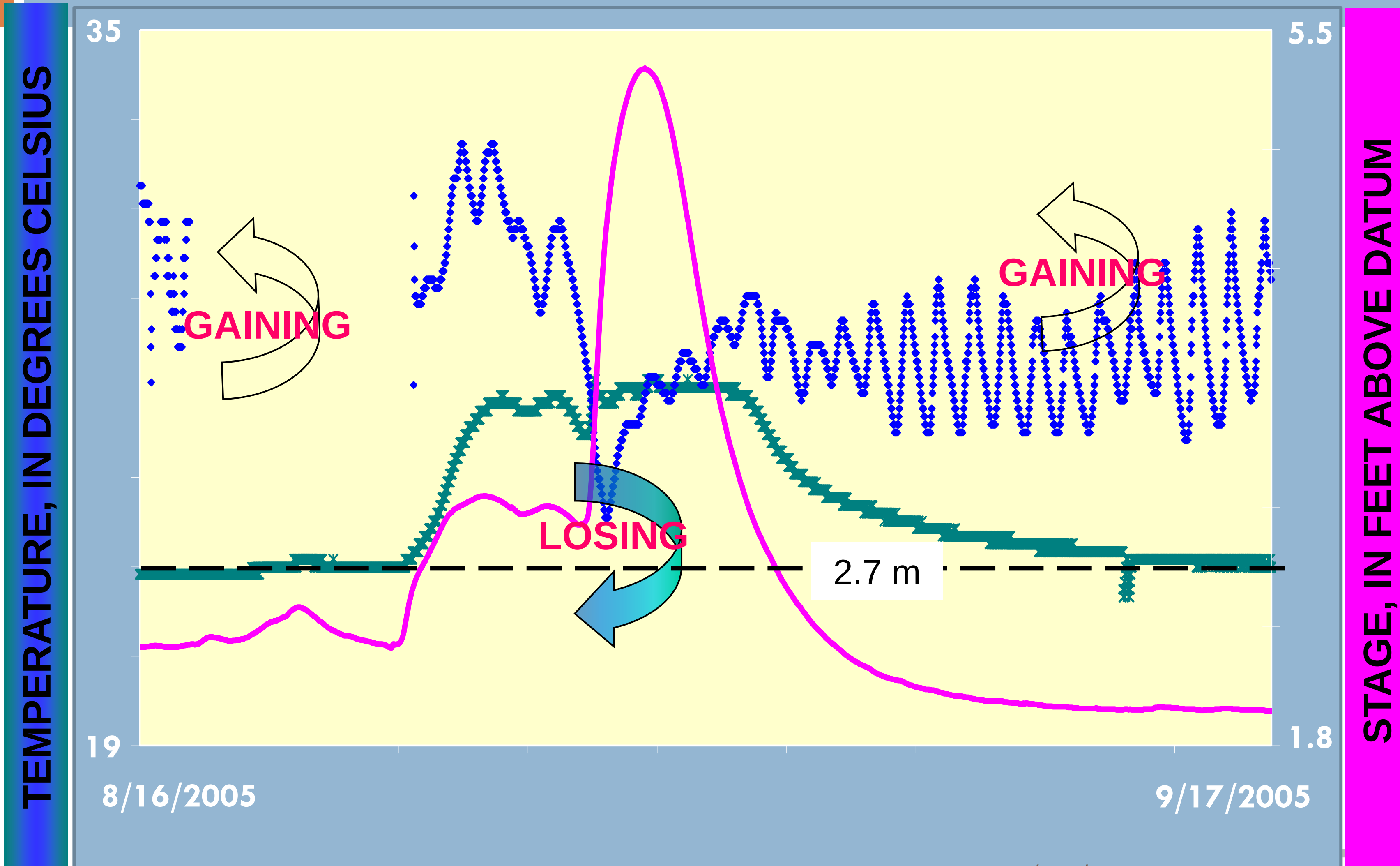
2005 Hurricane Season

Hurricane Katrina August 2005

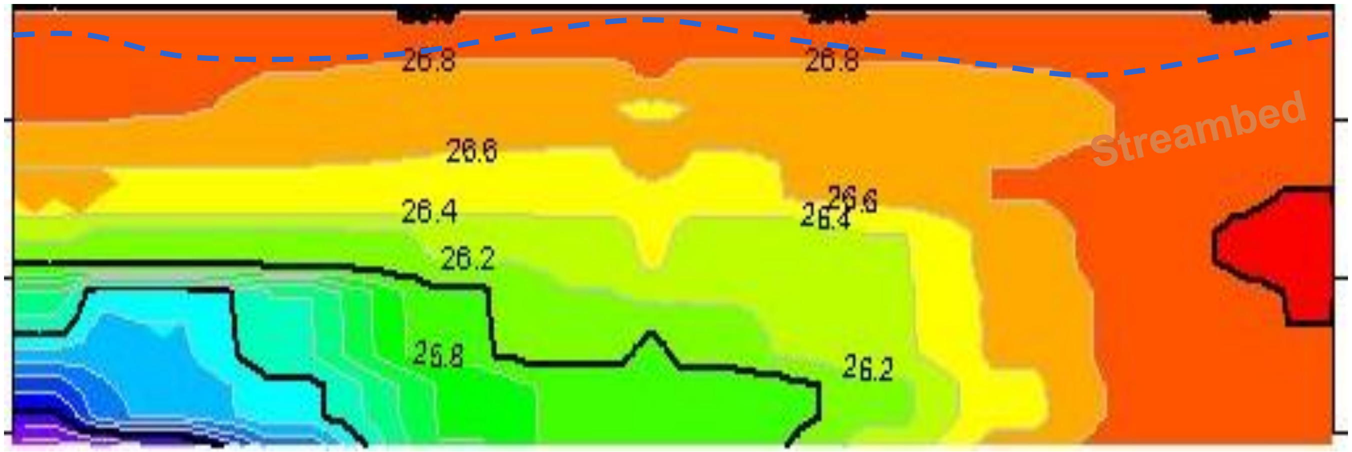


Hurricane Rita September 2005

Hurricane Katrina

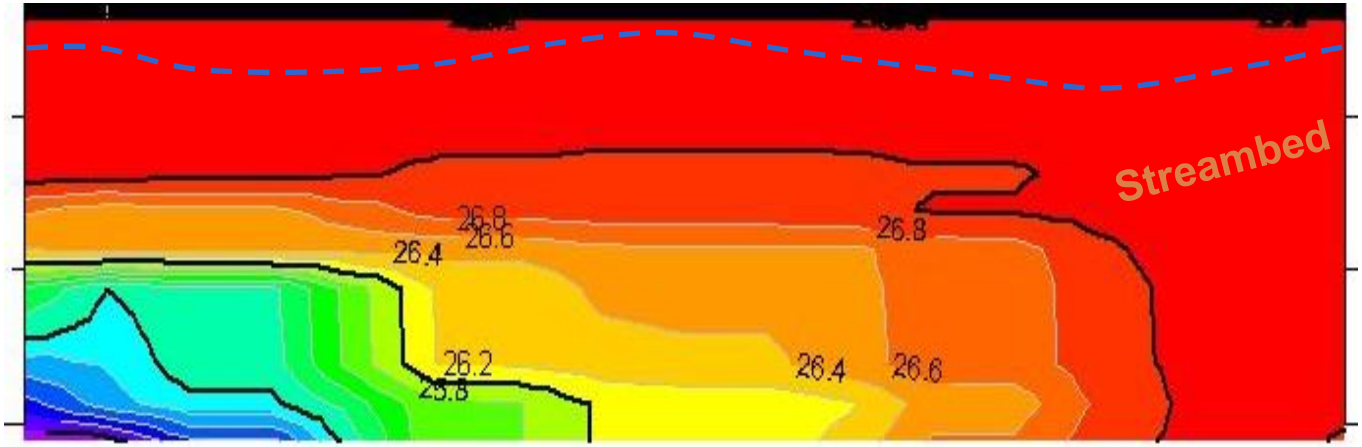


Katrina: Temperature Contours

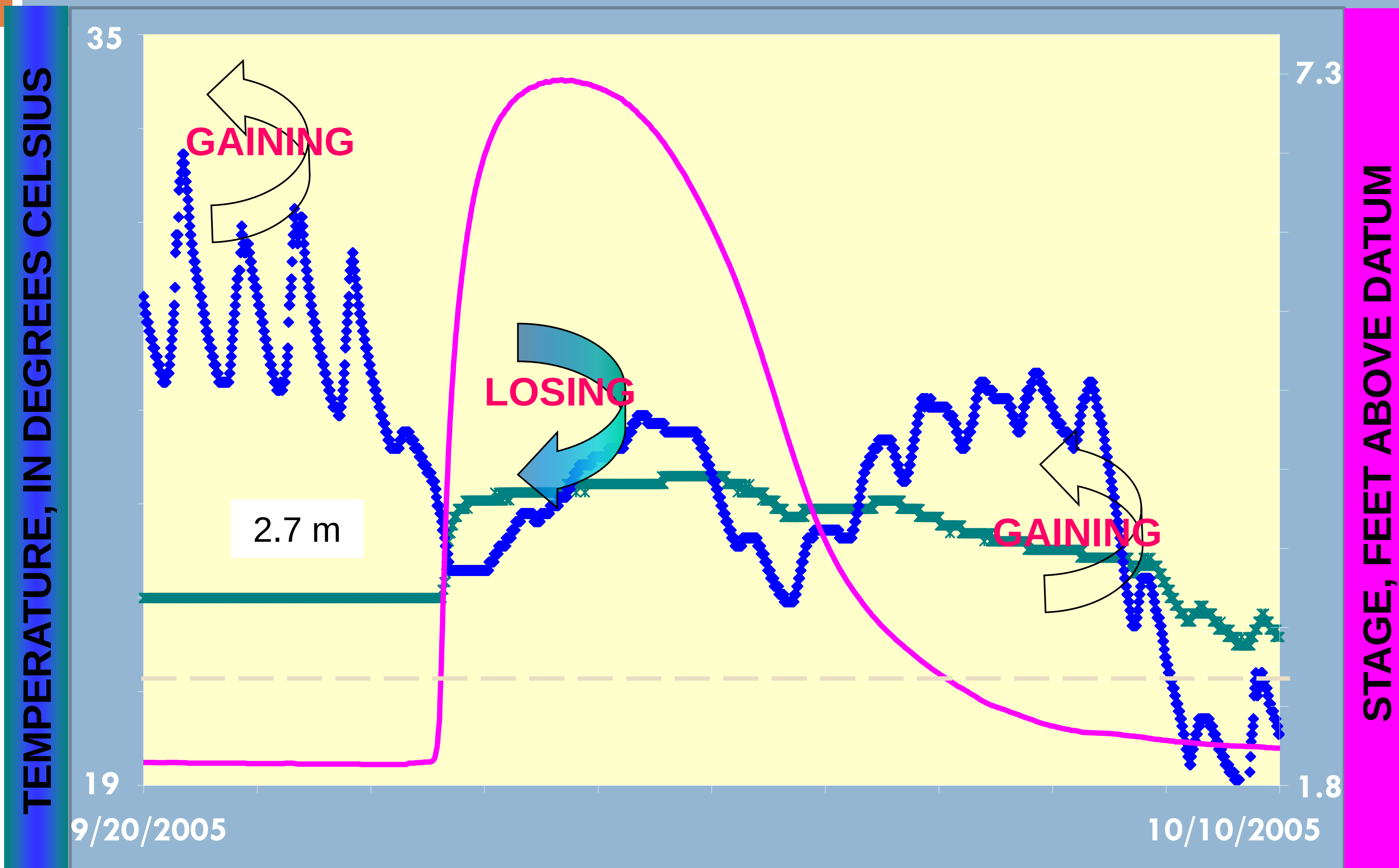


Stage = 2.7 m (9')

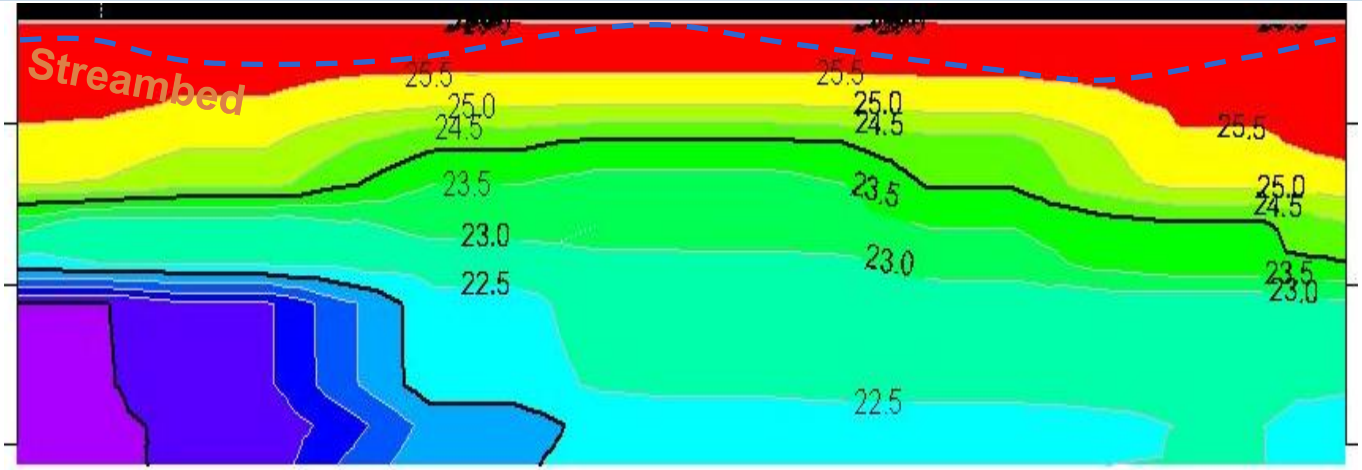
Stage = 5.3m (17.4')



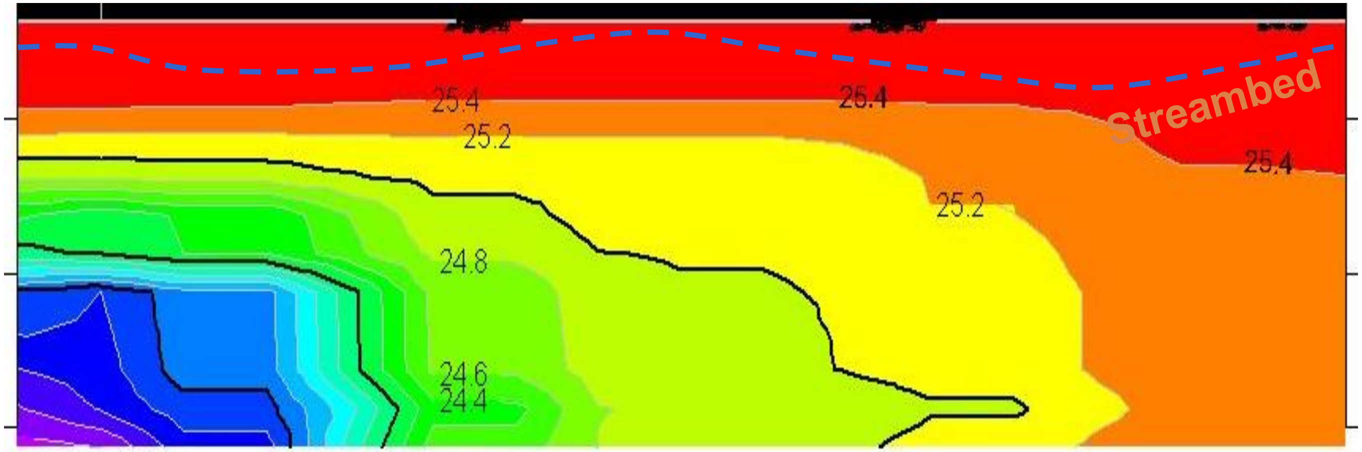
Hurricane Rita



Rita: Temperature Contours



Stage = 2m (6.6')



Stage = 7.3m (23.84')

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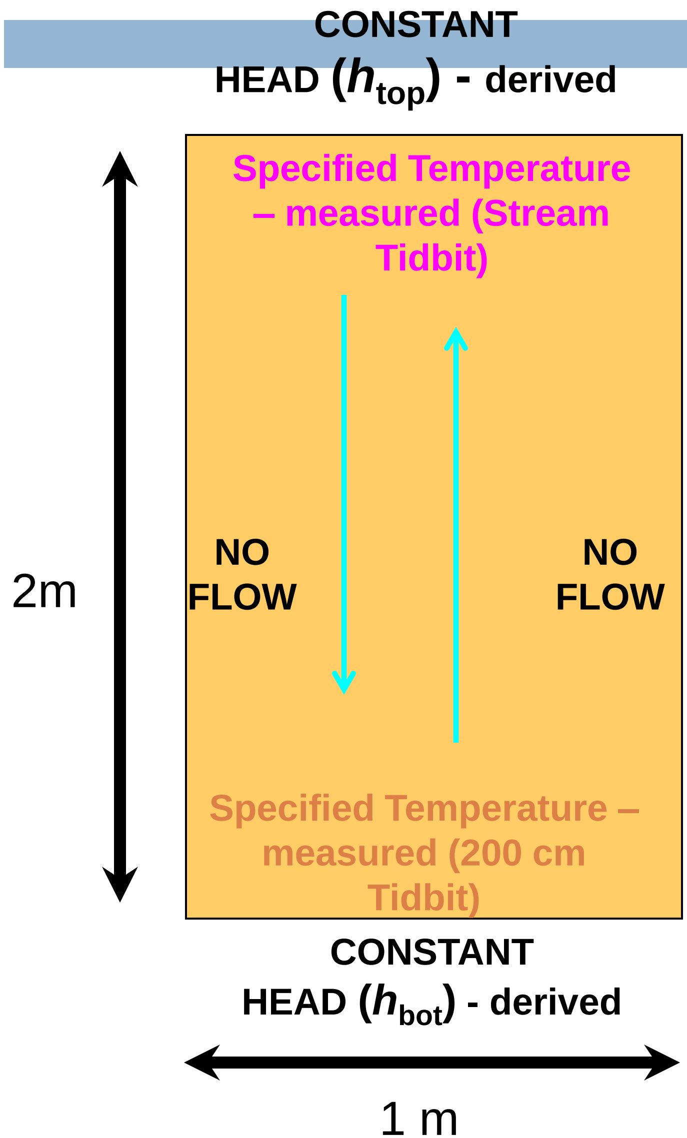
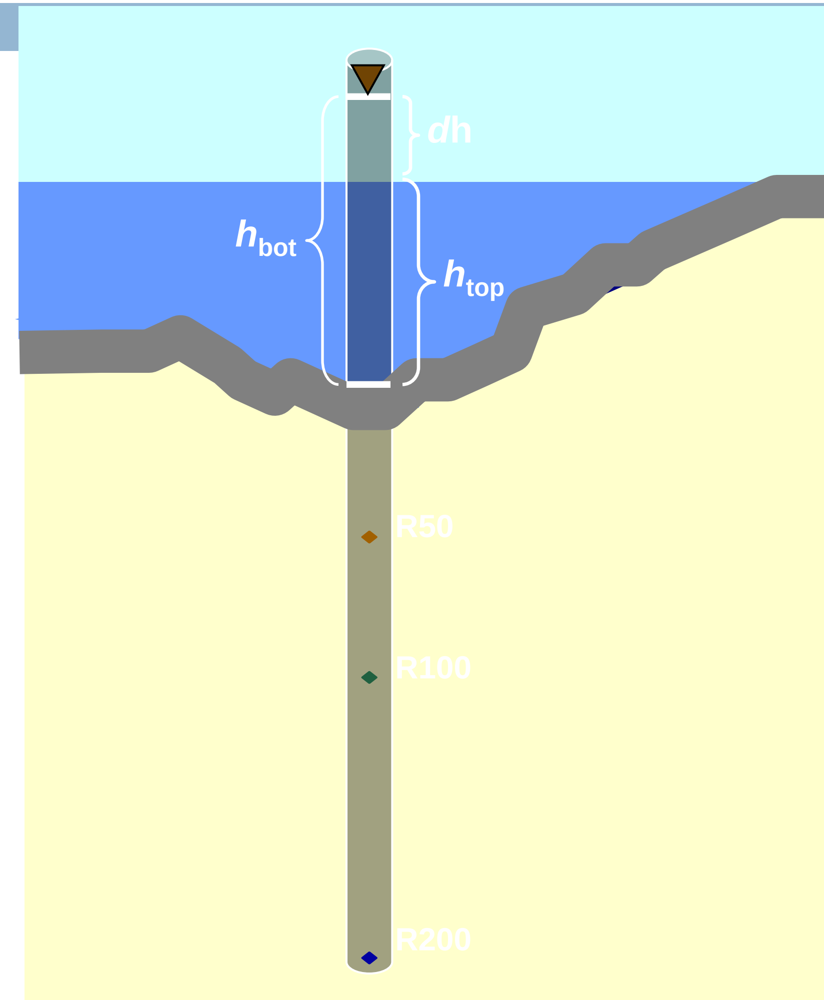
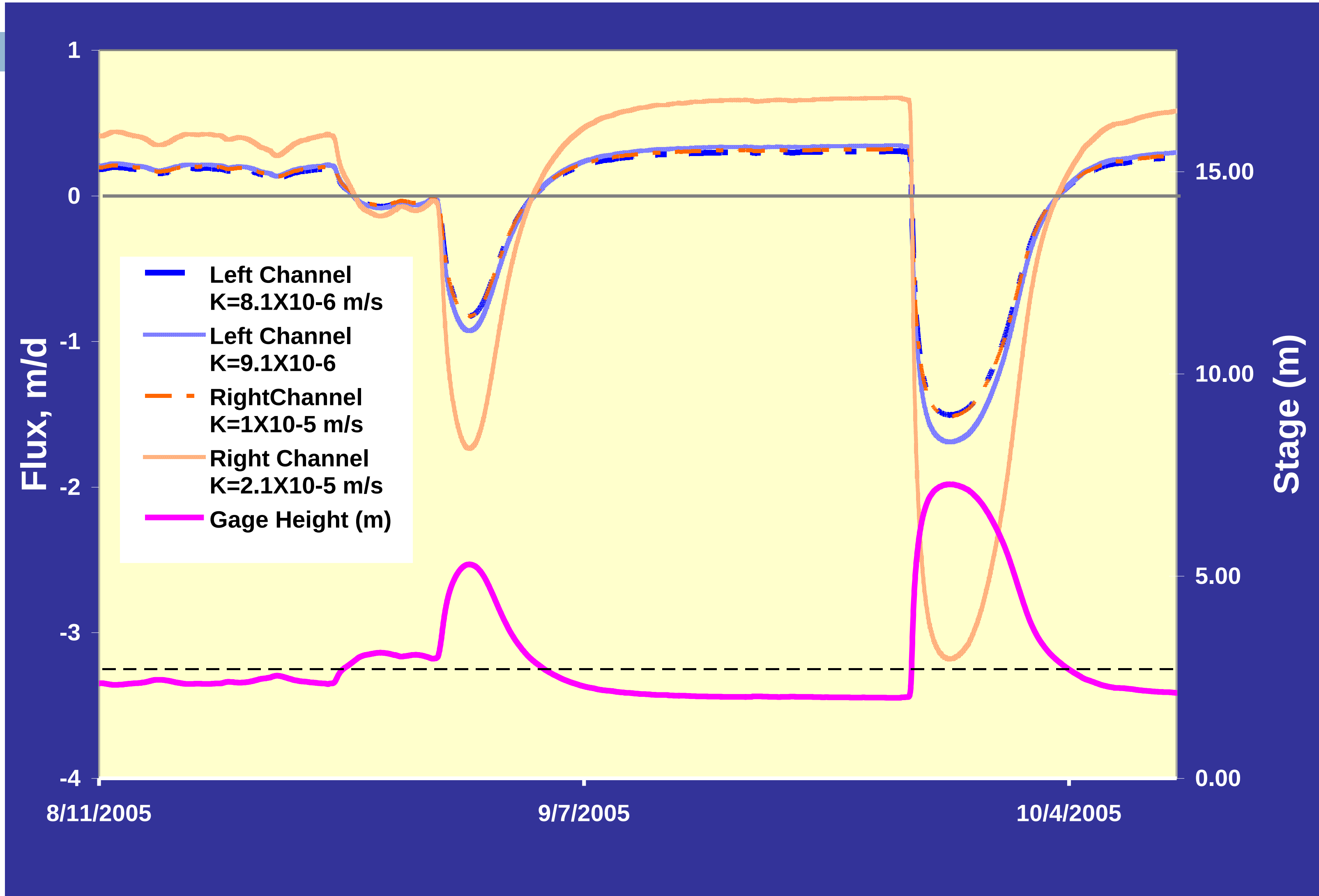
Boundary Conditions





GW/SW Exchange



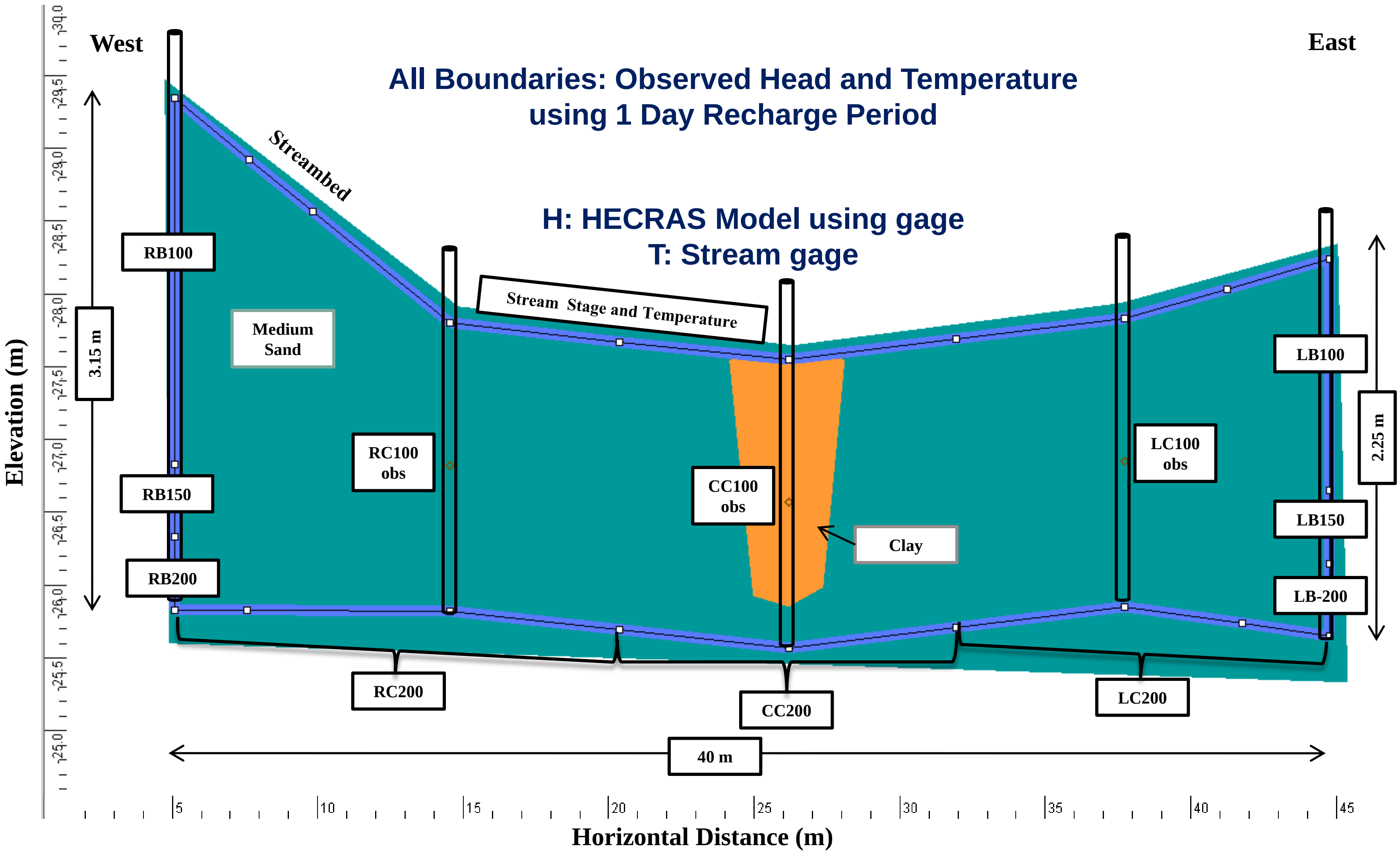
GW/SW Exchange

Station	Katrina: 8/29/2005 - 9/7/2005			Rita: 9/24/2005 - 10/10/2005		
	Max Discharge (m^3/d)	***Cumulative Volume (m^3)***	***Percent of total Flow***	***Max Discharge (m^3/d)***	***Cumulative Volume (m^3)***	***Percent of total Flow***
Bogue Phalia near Leland	66890188.8	207491259	100	180392832	859064901	100
Left Channel K=8.1E-6 m/s	-0.83	1938	0.0009	-1.51	9787	0.0011
Left Channel K=9.1E-6 m/s	-0.93	2177	0.0010	-1.69	10996	0.0013
Right Channel K=1.1E-5 m/s	-0.83	1881	0.0009	-1.52	9641	0.0011
Right Channel K=2.1E-5 m/s	-1.74	3949	0.0019	-3.18	20245	0.0024

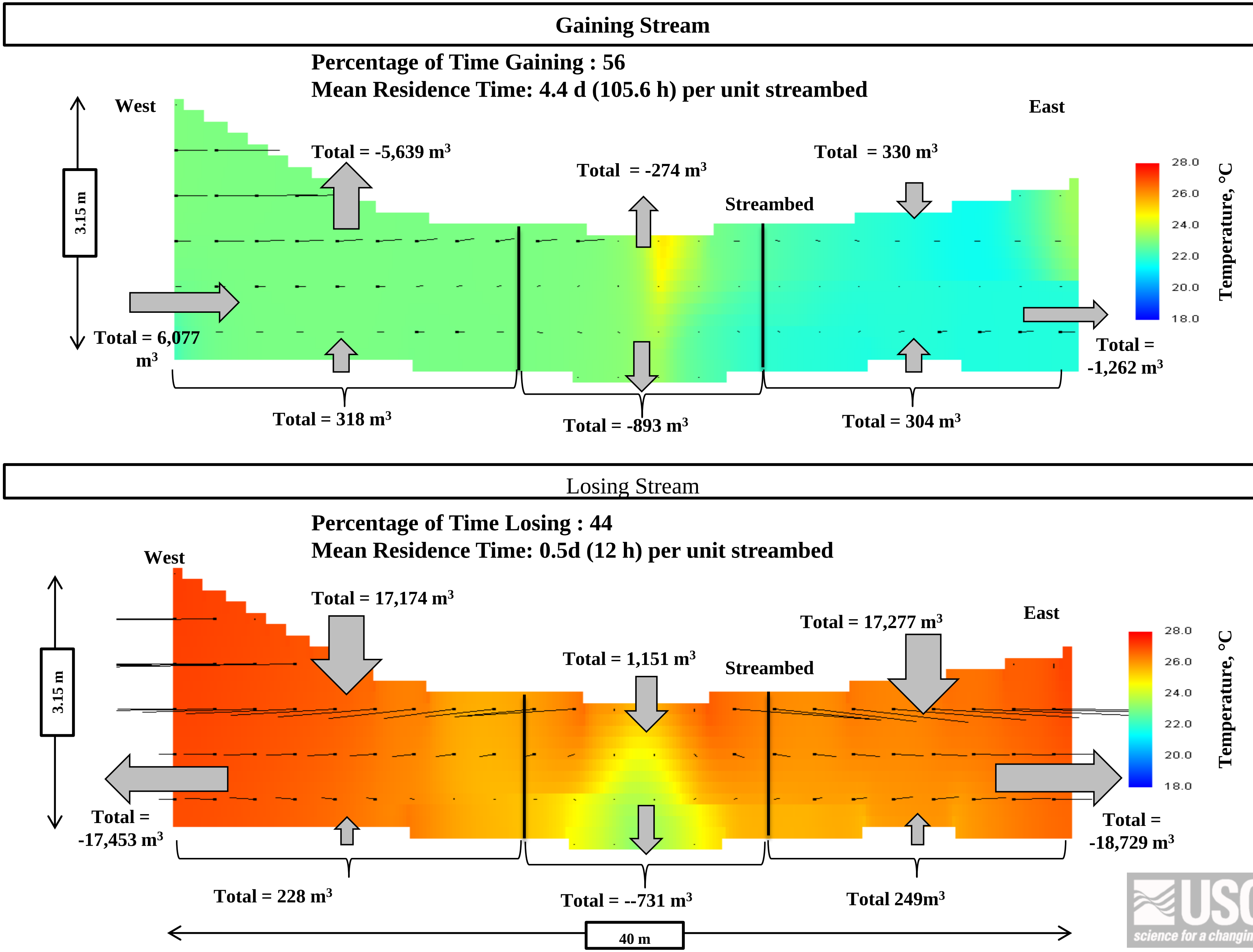
Station	Katrina: 8/29/2005 - 9/7/2005		Rita: 9/24/2005 - 10/10/2005	
	Cumulative Volume (m^3)	***Percent of total Flow***	***Cumulative Volume (m^3)***	***Percent of total Flow***
Bogue Phalia near Leland	207491259	100	859064901	100
BPTR1 25 m Reach	1881000	0.91	9641000	1.12


N
AR-1
Flow
Direction
FS-3
FS-2
FS-1
CC
RB
LB
RC
LC
0 12.5 25 50 Meters

VS2DH – Variable Saturated 2-D Heat/Flow Model



Heterogeneous Streambed Flux Patterns



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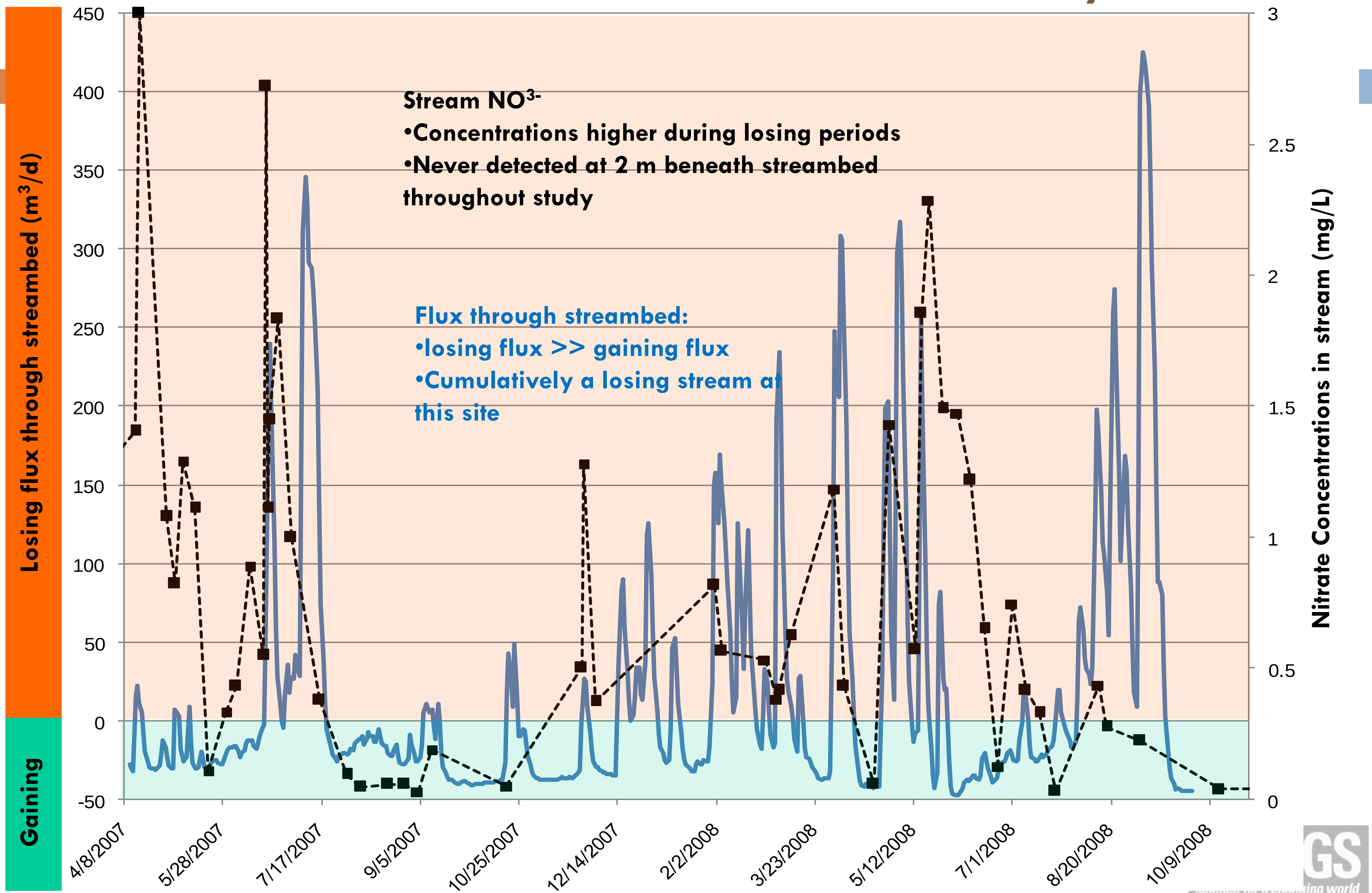
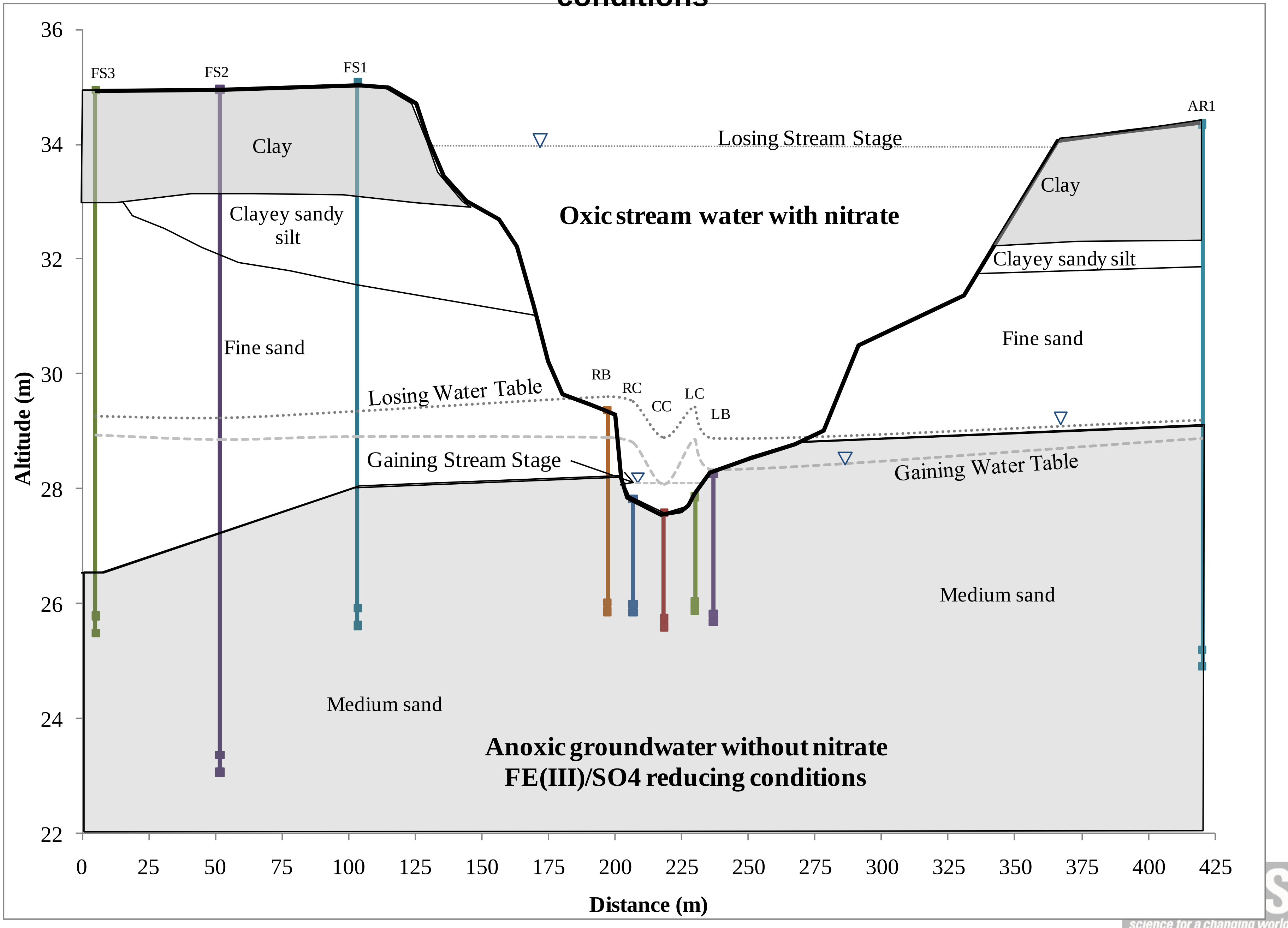
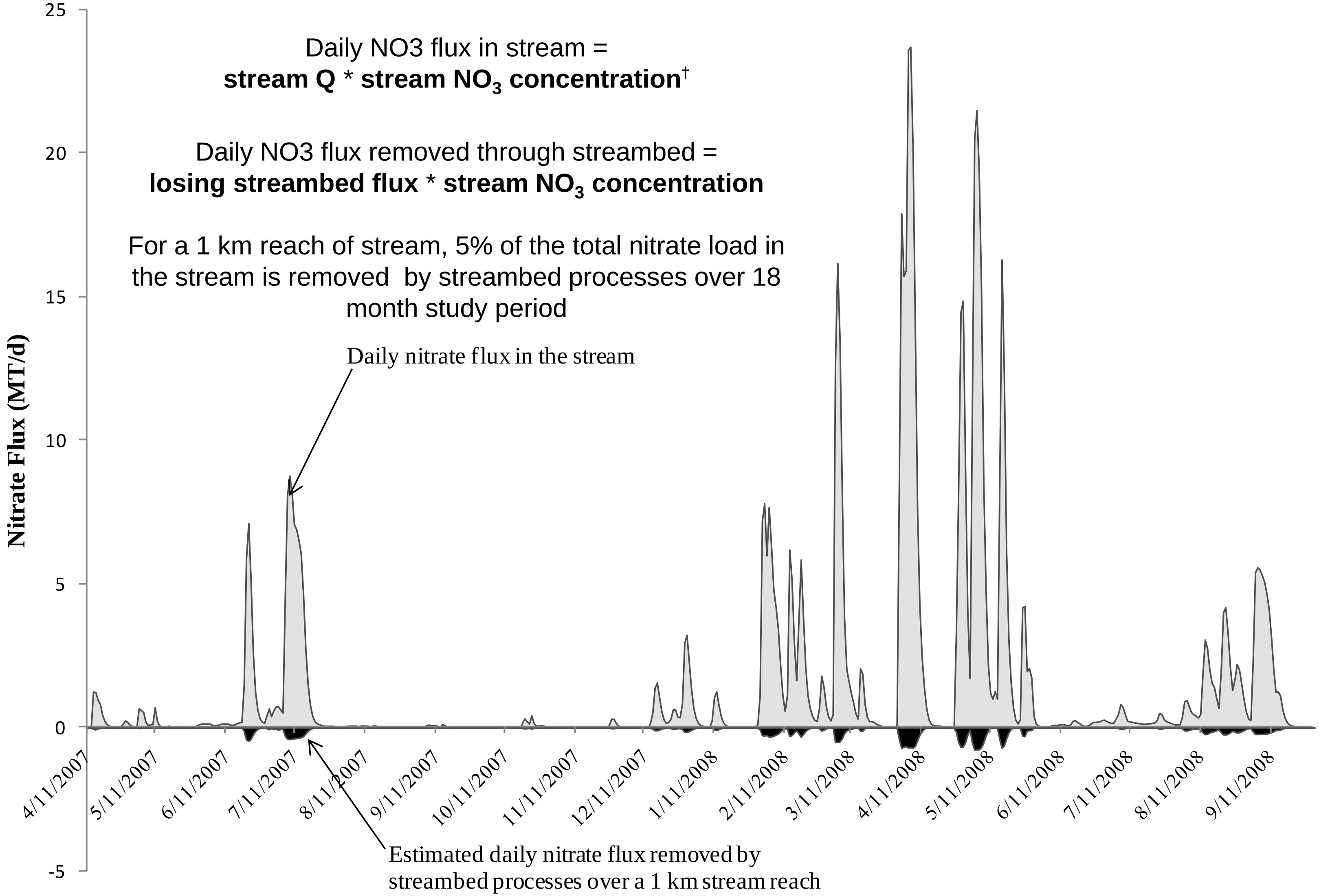
Streambed Flux and Water Quality



Nitrate removed from stream water moving through anoxic streambed during losing conditions

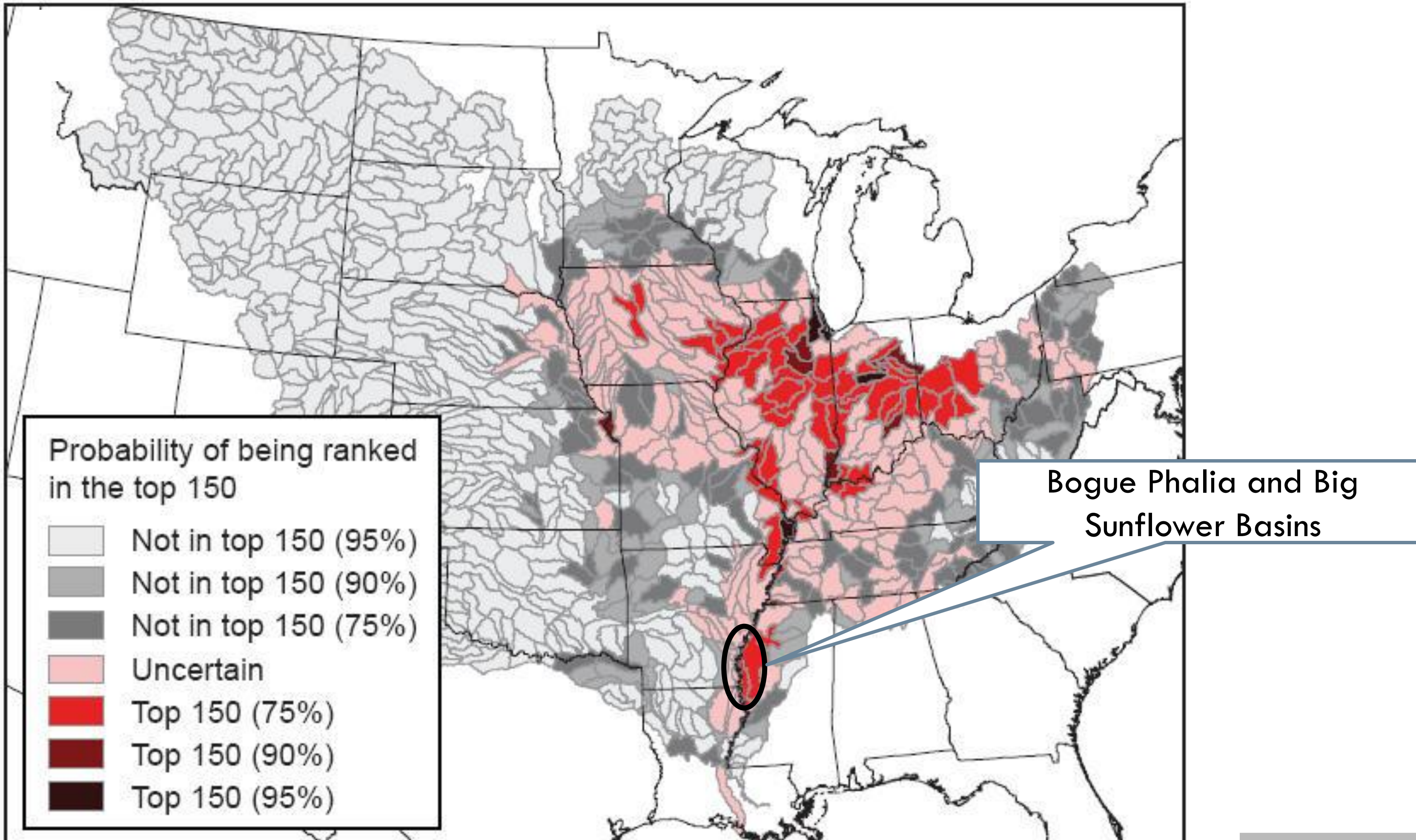


Streambed Flux coupled with stream NO_3 data to estimate amount removed during losing conditions



† Daily NO_3 concentrations estimated from discrete data using USGS regression program, LOADEST

Total Nitrogen Yields delivered to the Gulf of Mexico



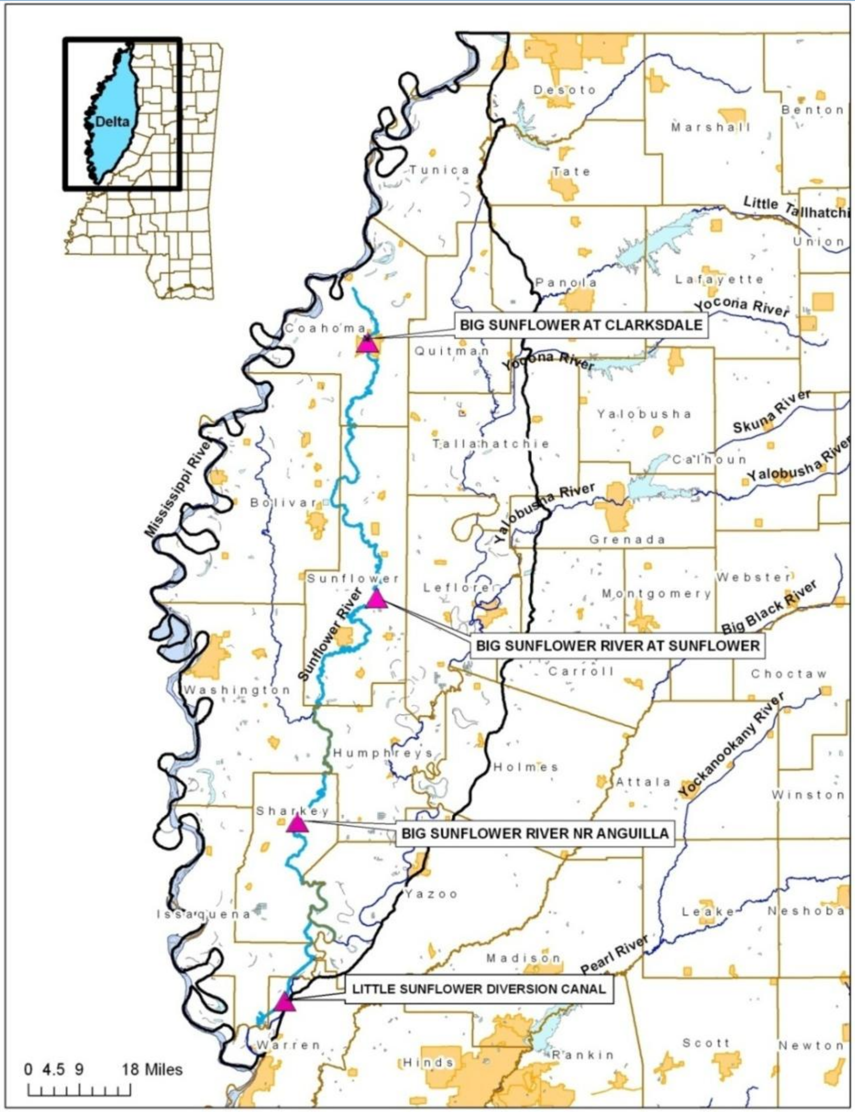
Taken from: http://water.usgs.gov/nawqa/sparrow/nutrient_yields/

Real-time coupled groundwater streamgaging stations (MT, WY, and MS Pilot Study)

Study Objective

- Assess the role of groundwater/surface-water exchange on the transport of nutrients in the northwestern MS
- Assess the feasibility of monitoring groundwater/surface-water exchange at existing streamgaging locations

- **4 piezometers installed July 2010 near existing stream gages**
  - Big Sunflower at Clarksdale
  - Big Sunflower at Sunflower
  - Big Sunflower at Anguilla
  - Little Sunflower Diversion Canal



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- Big Sunflower River at Clarksdale, MS
- Big Sunflower River at Sunflower, MS
- Big Sunflower River near Anguilla, MS
- Big Sunflower Diversion Canal near Redwood, MS

Coupled Real-time Streambank Piezometer and Streamflow Gaging Station

Project Objective:

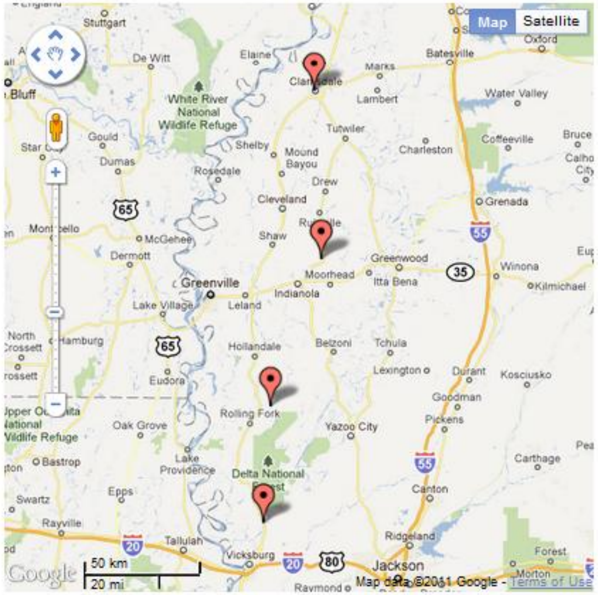
- Demonstrate the feasibility and utility of including groundwater level and temperature data from shallow streambank piezometers with existing suites of real-time data collected and transmitted at active streamflow gaging stations.

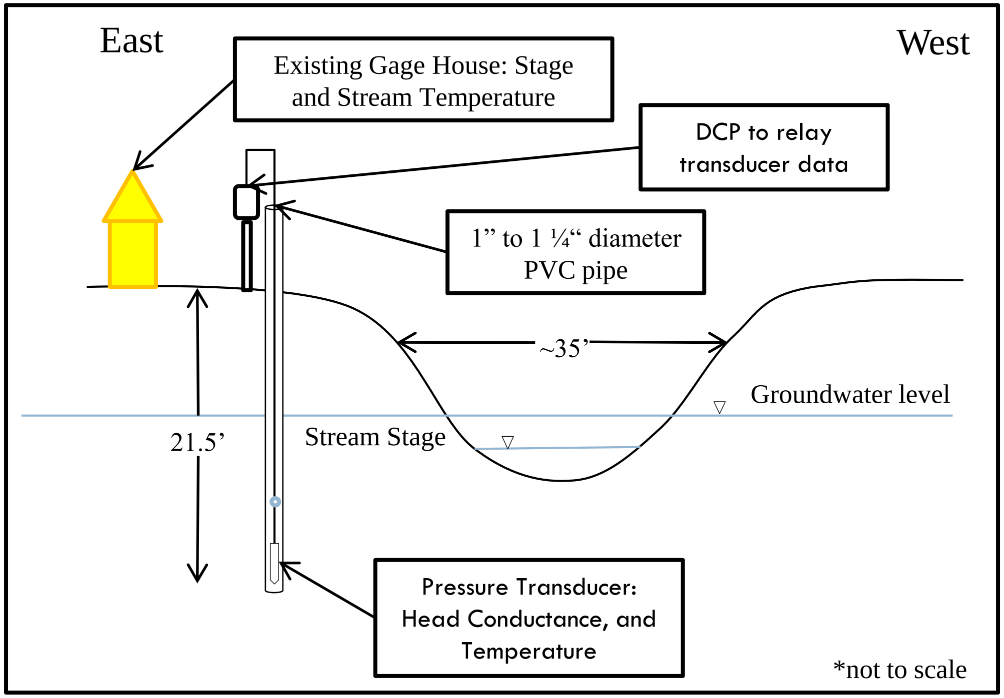
Project Benefits:

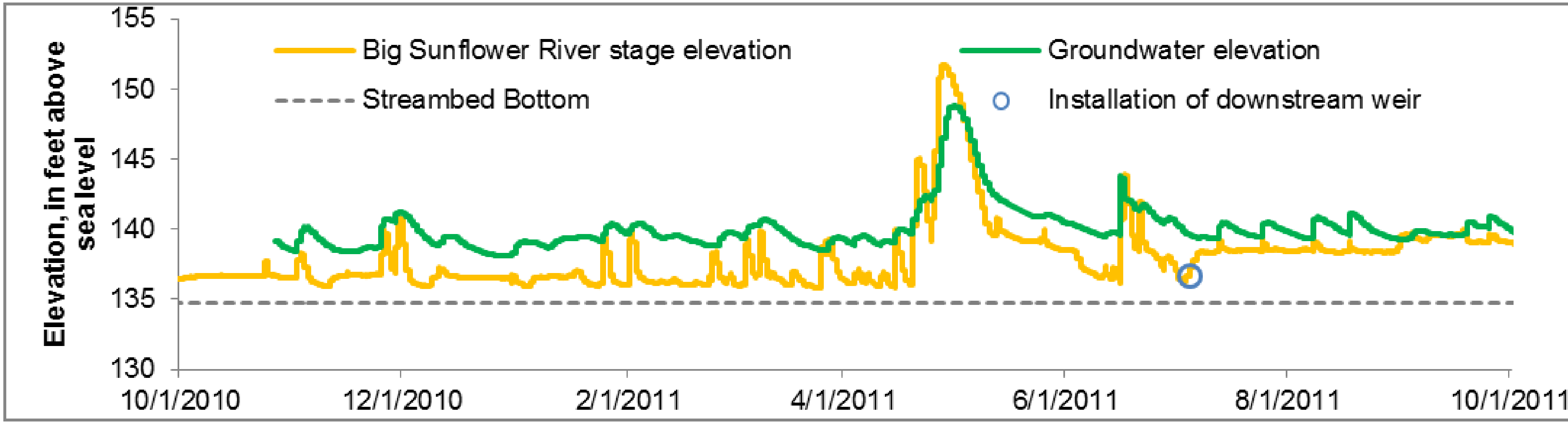
- Demonstrate the usefulness of real-time groundwater data in a dynamic environment. Data could be used to assist water managers making day-to-day decisions about water use (the impact of nearby groundwater and surface-water withdrawals on streamflow, water depth, and (or) water temperature for example) in a watershed.
- Provide personnel operating streamflow gaging stations with another tool for interpreting streamflow gaging station records when data must be interpolated, such as streamflow under ice cover.
- Provide a long-term groundwater/surface-water data set for future methods development and analysis of groundwater/surface-water interaction.

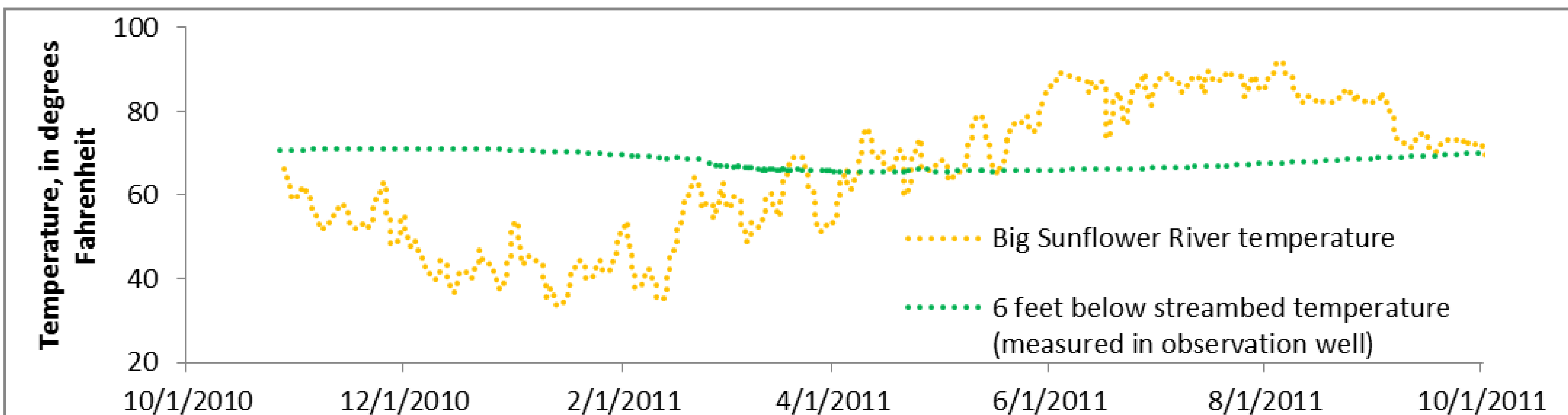
Real-time streambank piezometer and gaging station pairs are being studied in different hydrologic and geologic settings in Wyoming and Montana.

Click on one of the markers on the map below to view all available data for a site:




East
West
Existing Gage House: Stage and Stream Temperature
DCP to relay transducer data
1" to 1 ¼" diameter PVC pipe
~35'
Groundwater level
21.5'
Stream Stage
Pressure Transducer: Head Conductance, and Temperature
*not to scale





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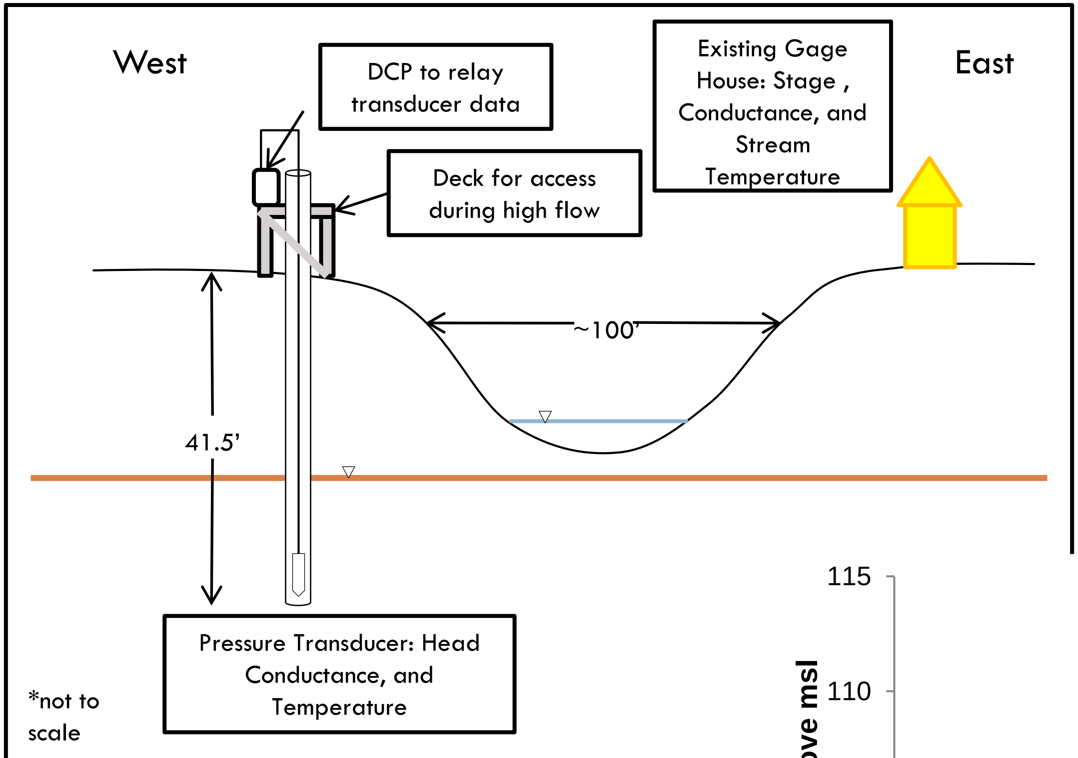
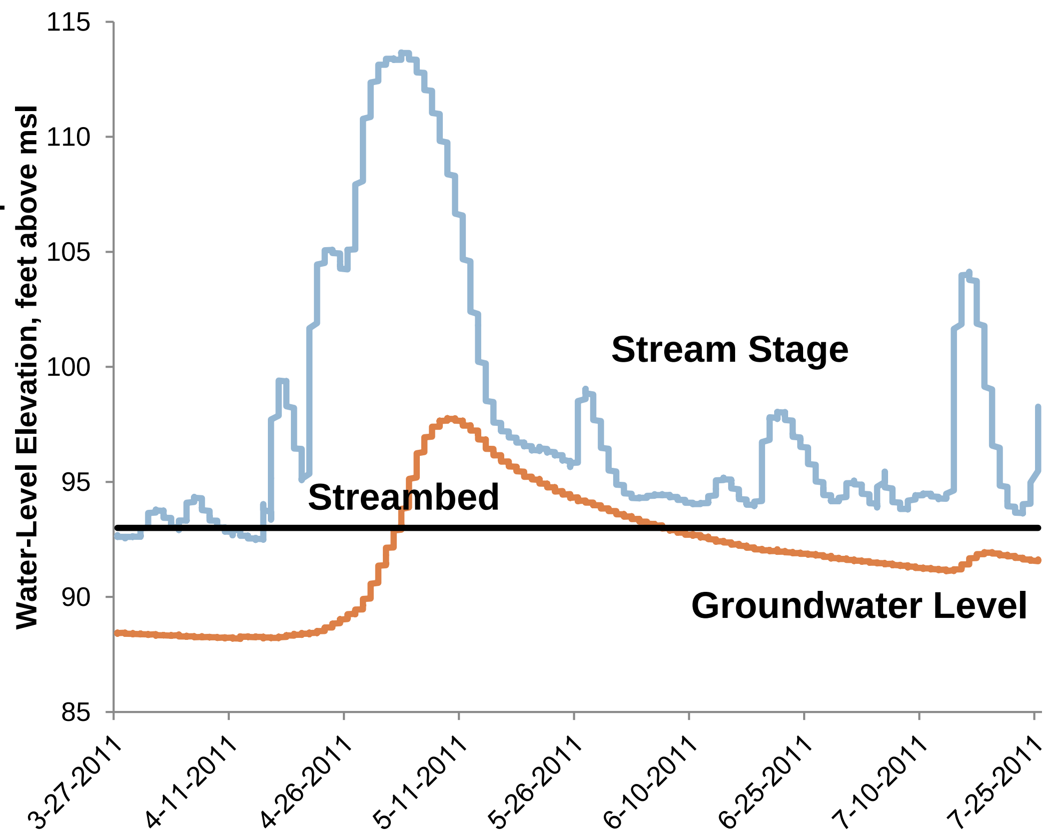


2011 Mississippi River Basin Flood: Groundwater/Surface-water response in the Mississippi Delta

- **GW/SW Exchange**
  - Site located in middle of alluvial aquifer cone of depression – groundwater levels typically more than 10 feet below streambed
  - Flood induced stages increased GW/SW exchange to the point that groundwater levels were above the streambed



Recent and potential uses for real-time groundwater monitoring at streamgages

- Recent Uses:
  - Illustrating the effects of irrigation practices on local groundwater levels
  - Early warning of flooding due to rapidly rising groundwater caused by infiltration from a stream
  - Determining an estimate of stream stage at sites where streamgages are damaged by floods
  - Understanding of the groundwater/surface-water interaction and how changes to any part of the system such as a weir installation, effect the dynamic

- Potential uses:
  - Understanding impacts of groundwater/surface-water exchange on fisheries and other aquatic populations
  - Managing of irrigation practices to minimize effects on instream flows to reduce potential impacts on endangered species
  - Estimating water fluxes across the streambed using water-level/temperature-based simulations
  - Real-time modeling of chemical fluxes moving between the groundwater into streams
  - Pairing with existing groundwater wells in a watershed to understand ecosystems dynamics and water exchange

Summary

- GW/SW exchange occurs regularly at study transect and the extent of exchange extends laterally into MRVA
- Redox conditions appear to prevent transport of agricultural chemicals
- Groundwater/surface-water exchange removes nitrate in surface-water
- GW recharge to stream aids in dilution of agricultural chemicals in stream
- Groundwater/surface-water exchange is heterogeneous in the Delta and many streams have lost connection with the aquifer
- Real-time groundwater/surface-water networks aid in monitoring the connection between streams and the aquifer

Thank-you!

Recent Publications

Barlow, J.R.B, Kingsbury, J.A., and Coupe, R.H., 2012, Changes in shallow groundwater quality beneath recently urbanized areas in the Memphis, Tennessee Area, accepted - Journal of the American Water Resources Association

Barlow, J.R.B., and Coupe, R.H., 2012, Groundwater and surface-water exchange and resulting nitrate dynamics in the Bogue Phalia Basin in northwestern Mississippi. J. Environ. Qual. 41:155-169.

Barlow, J.R.B., and Clark, B.R., 2011, Simulation of water-use conservation scenarios for the Mississippi Delta using an existing regional groundwater flow model: U.S. Geological Survey Scientific Investigations Report 2011–5019, 14 p.

Barlow, J.R.B., and Coupe, R.H., 2009, Use of heat to estimate streambed fluxes during extreme hydrologic events. Water Resources Research. Vol. 45, W01403, DOI: 10.1029/2007WR00612.

Bryson, J.R., Coupe, R.H., and Manning, M.A., 2007, Characterization of Water Quality in Unmonitored Streams in the Mississippi Alluvial Plain, Northwestern Mississippi, May-June 2006, U.S. Geological Survey, Scientific Investigations Report 2007-5116, # p.

Bryson, J.R, Blasch, K.W., Hoffmann, J.P., 2006, A Local Meteoric Water line and Isotope-Elevation Gradient Relations for the Upper and Middle Verde River Watersheds: Southwest Hydrology, January/February 2007.

Bryson J.R., 2005, Determination of Ground-water Flow Paths Using Stable Isotopes as Geochemical Tracers: Upper and Middle Verde Watersheds, Arizona, USA: Master's Thesis, University of Arizona, 2005.