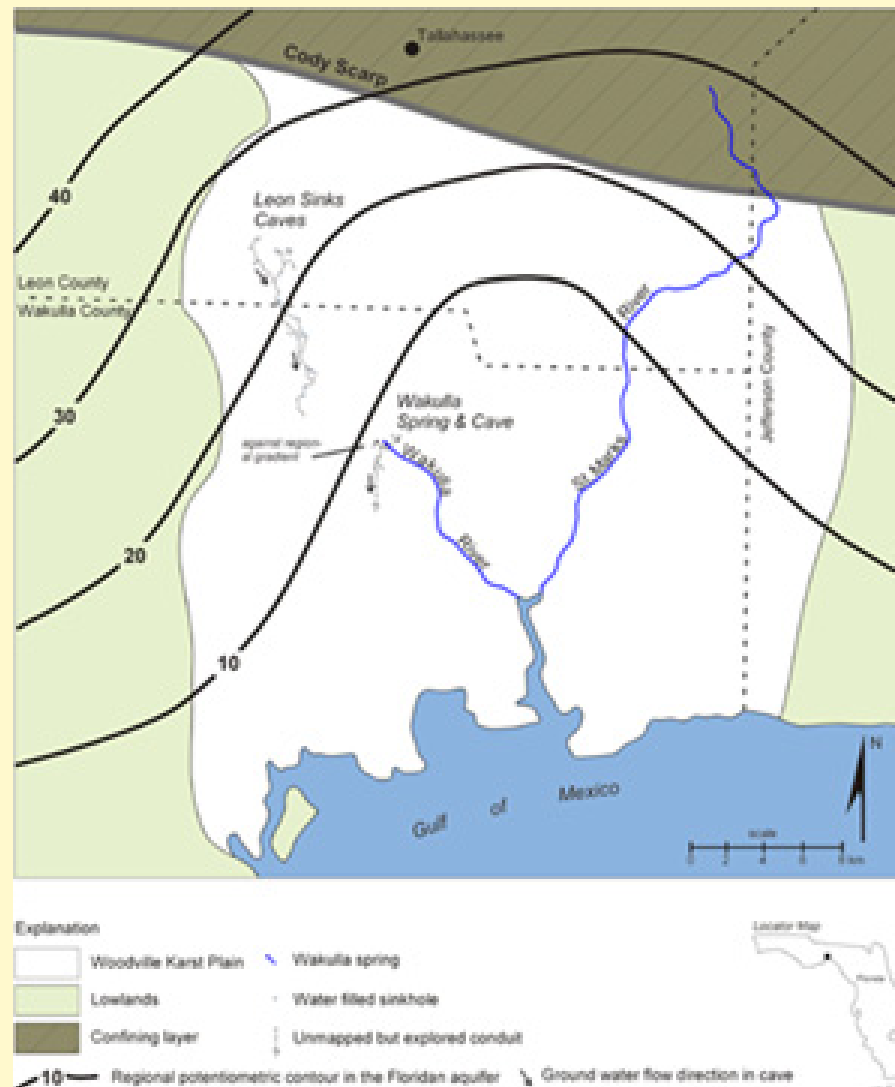


**Studying the Interaction
between Surface and Ground
Water
Understanding Wakulla Spring
System as a Component of a
Larger Watershed**

**David Loper-FSU
Rodney DeHan-FGS
Todd Kincaid-H-K Inc.
James McClean-FGS**

Overview of the Woodville Karst Plain



Surface water basins

Most of the drainage is below the surface



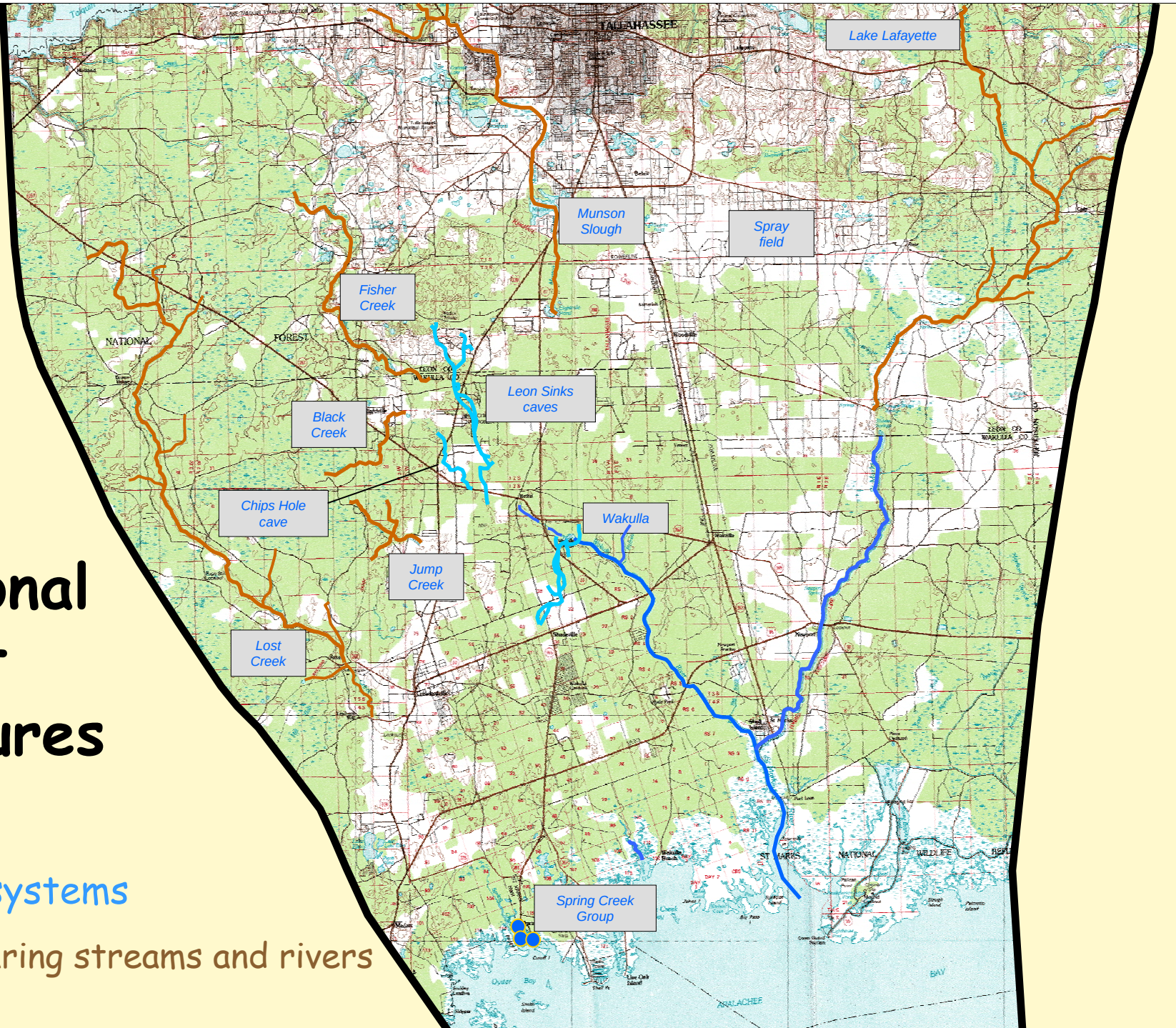
FIGURE 18

Regional karst features

rivers

tunnel systems

disappearing streams and rivers



Septic tanks!

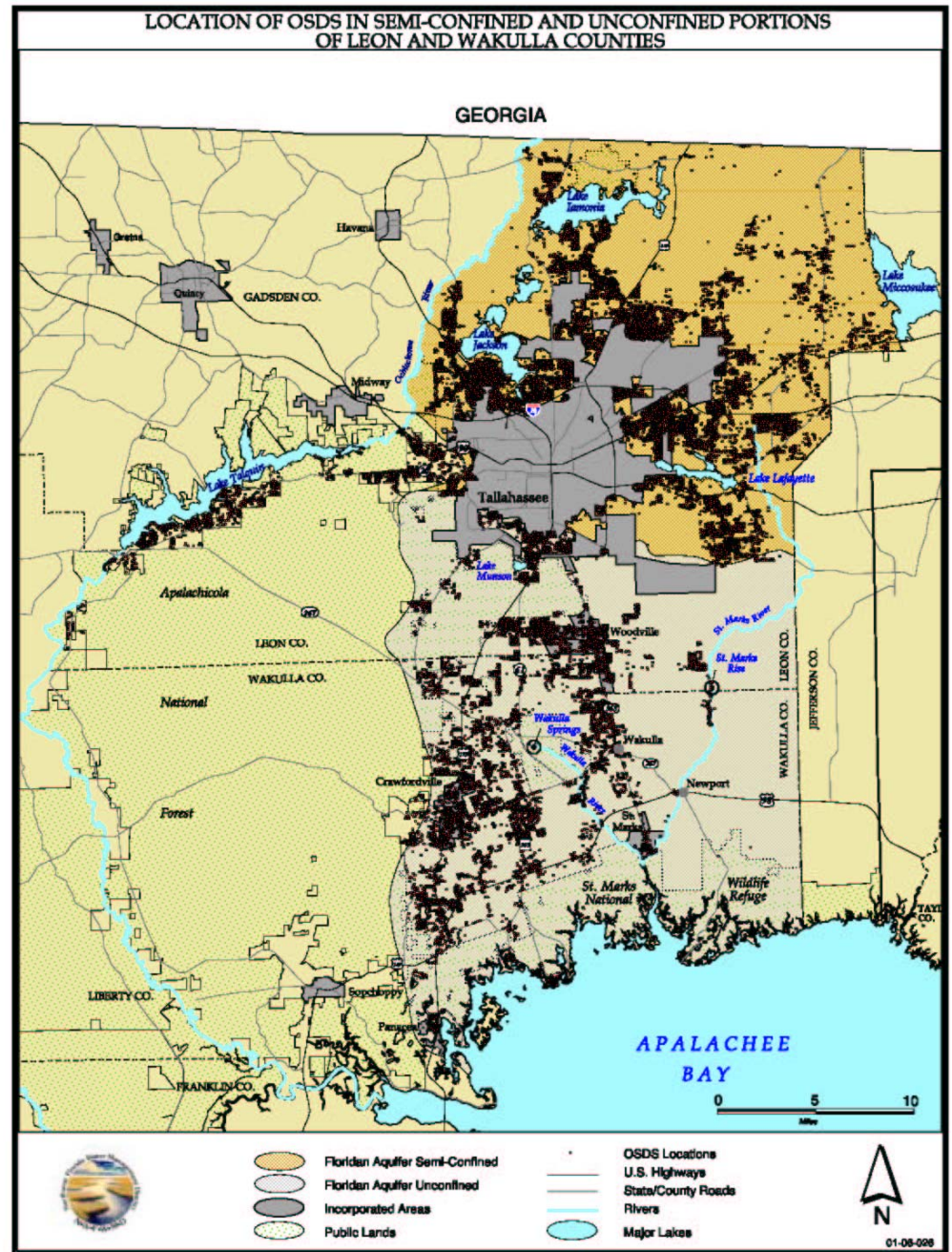


FIGURE 53

Wakulla spring from the surface

A navigable river comes out the main vent.

This is reputed to be the largest single spring vent in the world.

The conduits (or tunnels) feeding the spring are very deep, as much as 300 feet down.

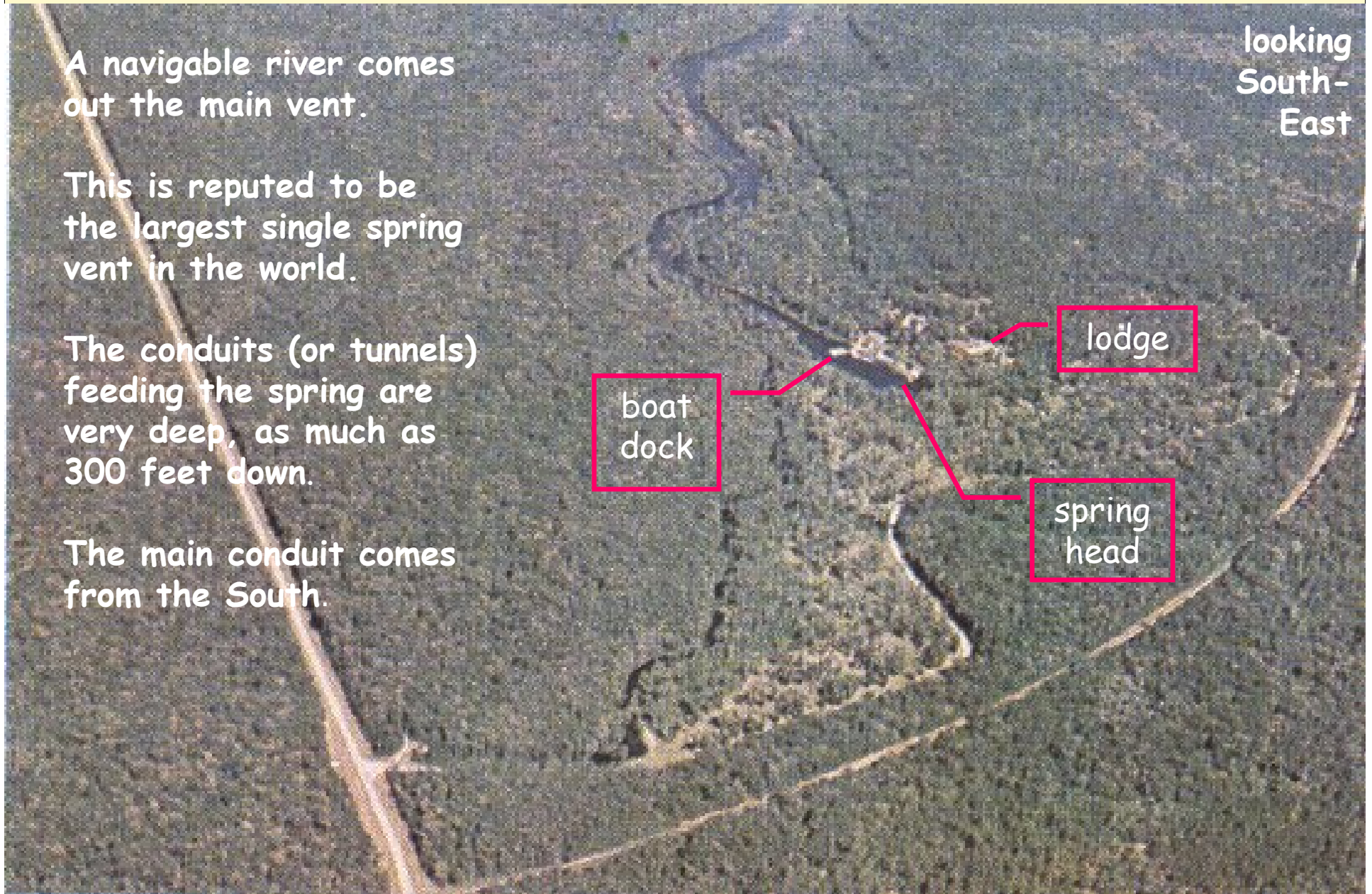
The main conduit comes from the South.

looking
South-
East

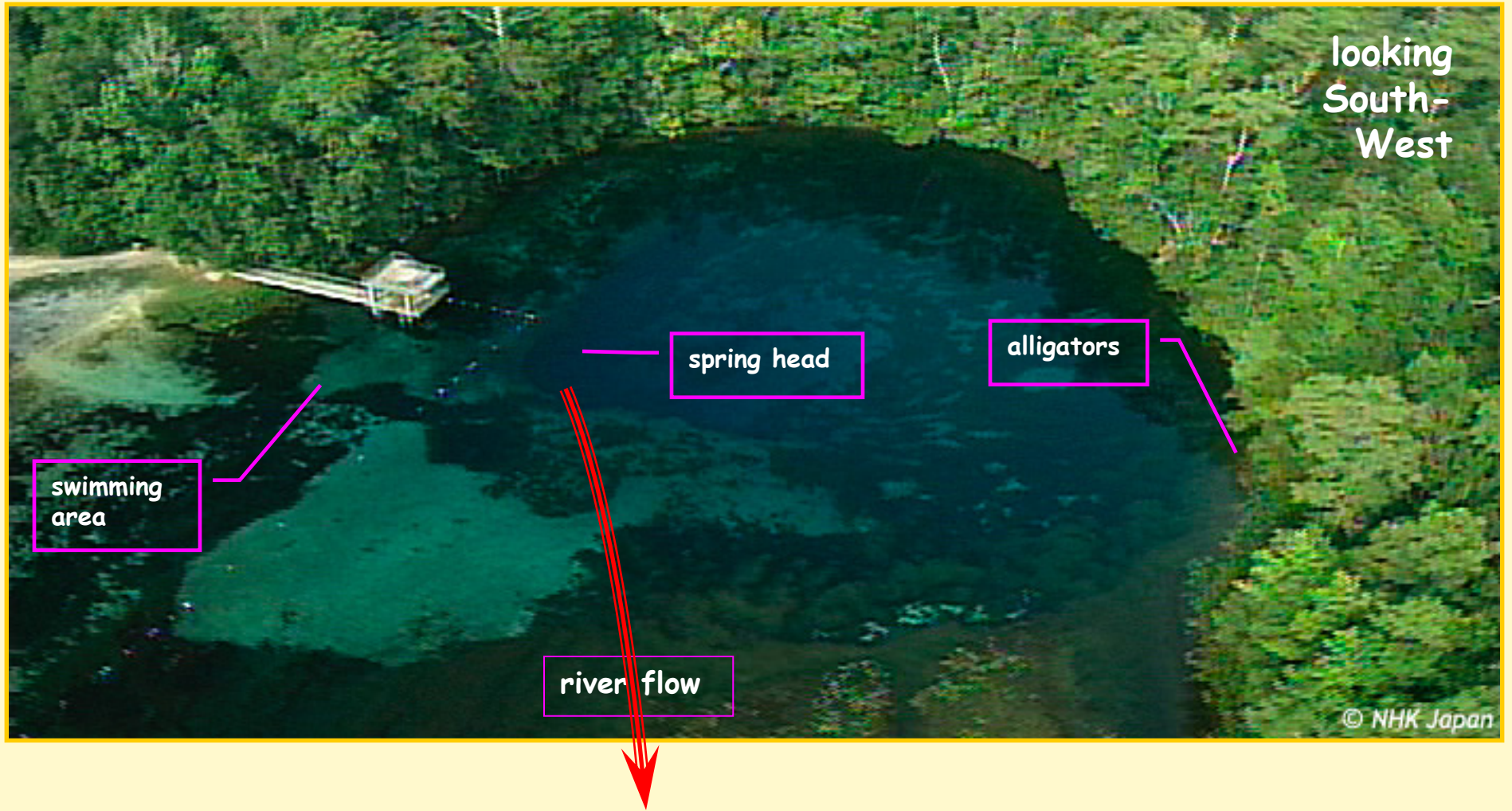
boat
dock

lodge

spring
head



Spring head

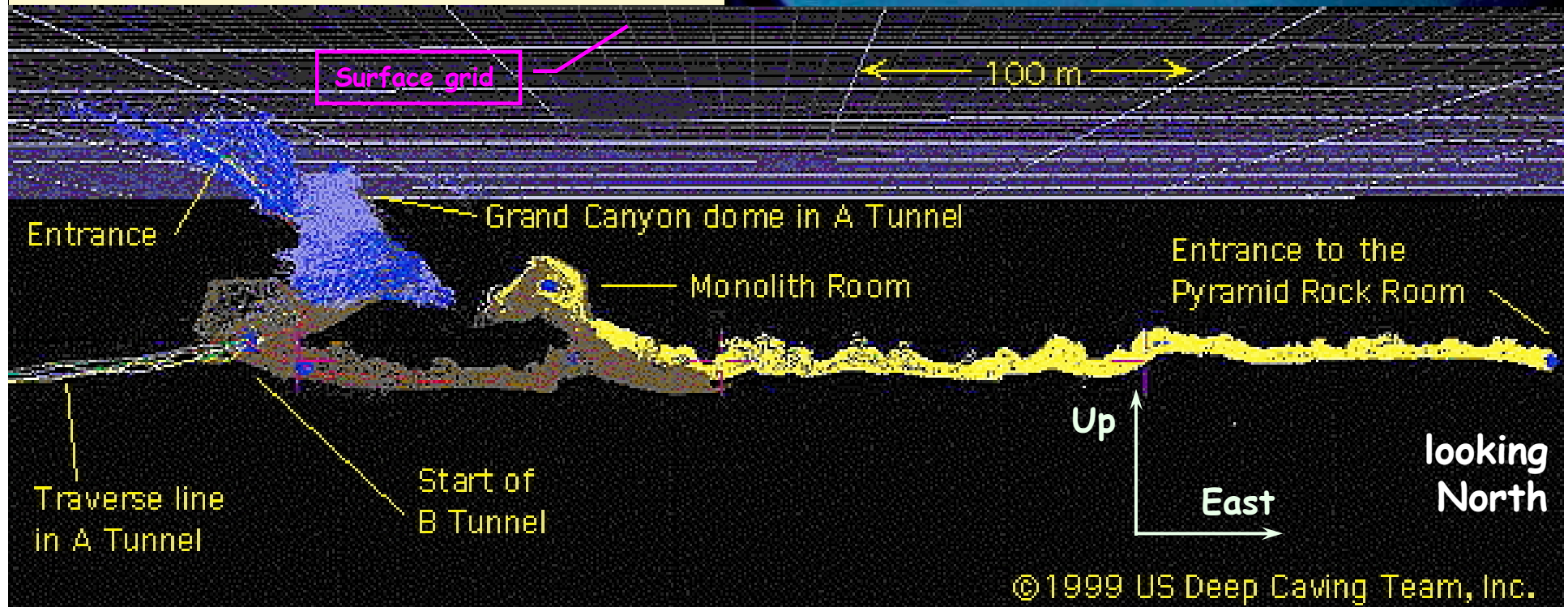


Divers' view of Wakulla spring

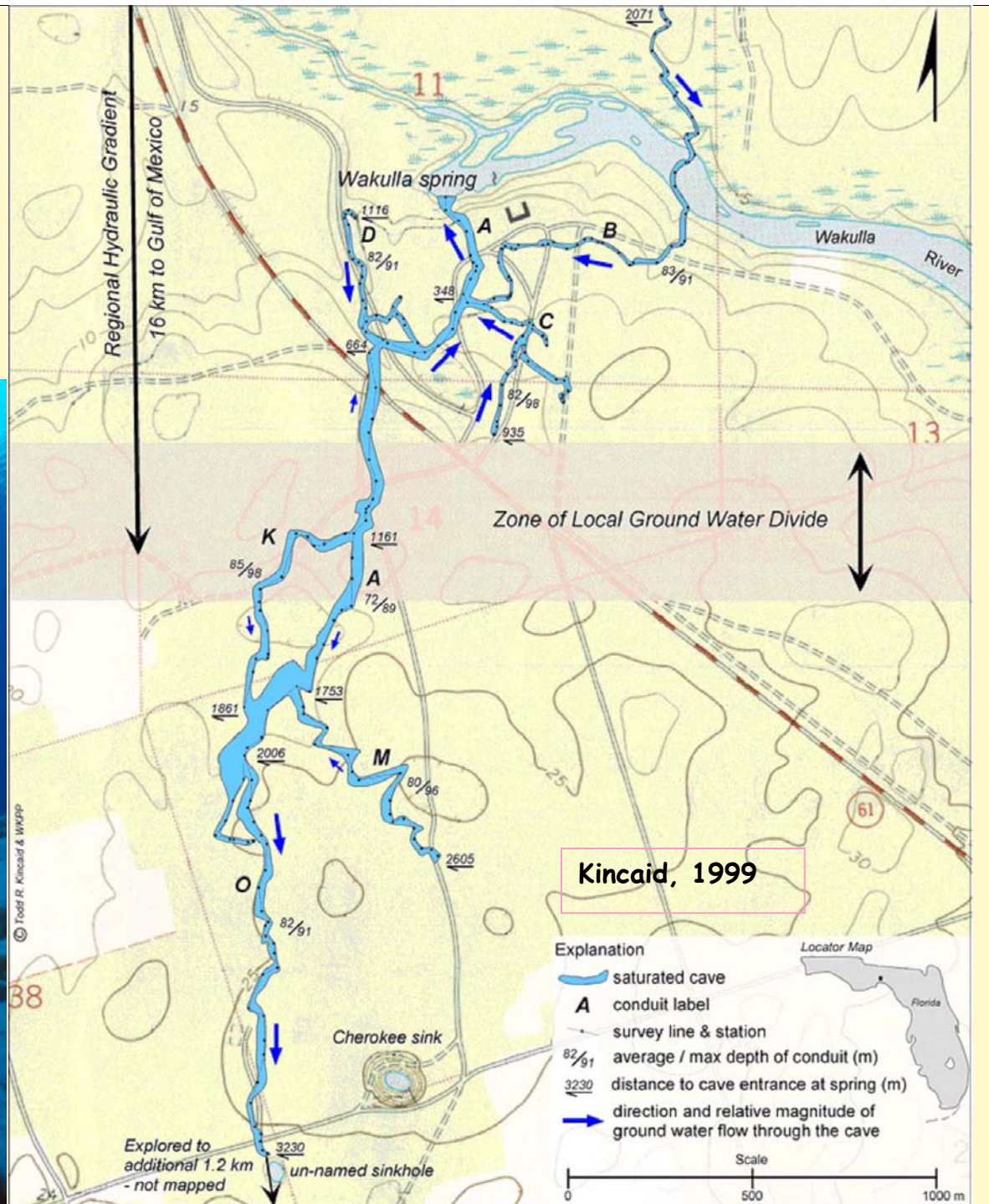
depths average about 80 m

maximum depth exceeds 100 m

By comparison, the highest point in Florida is 105 m

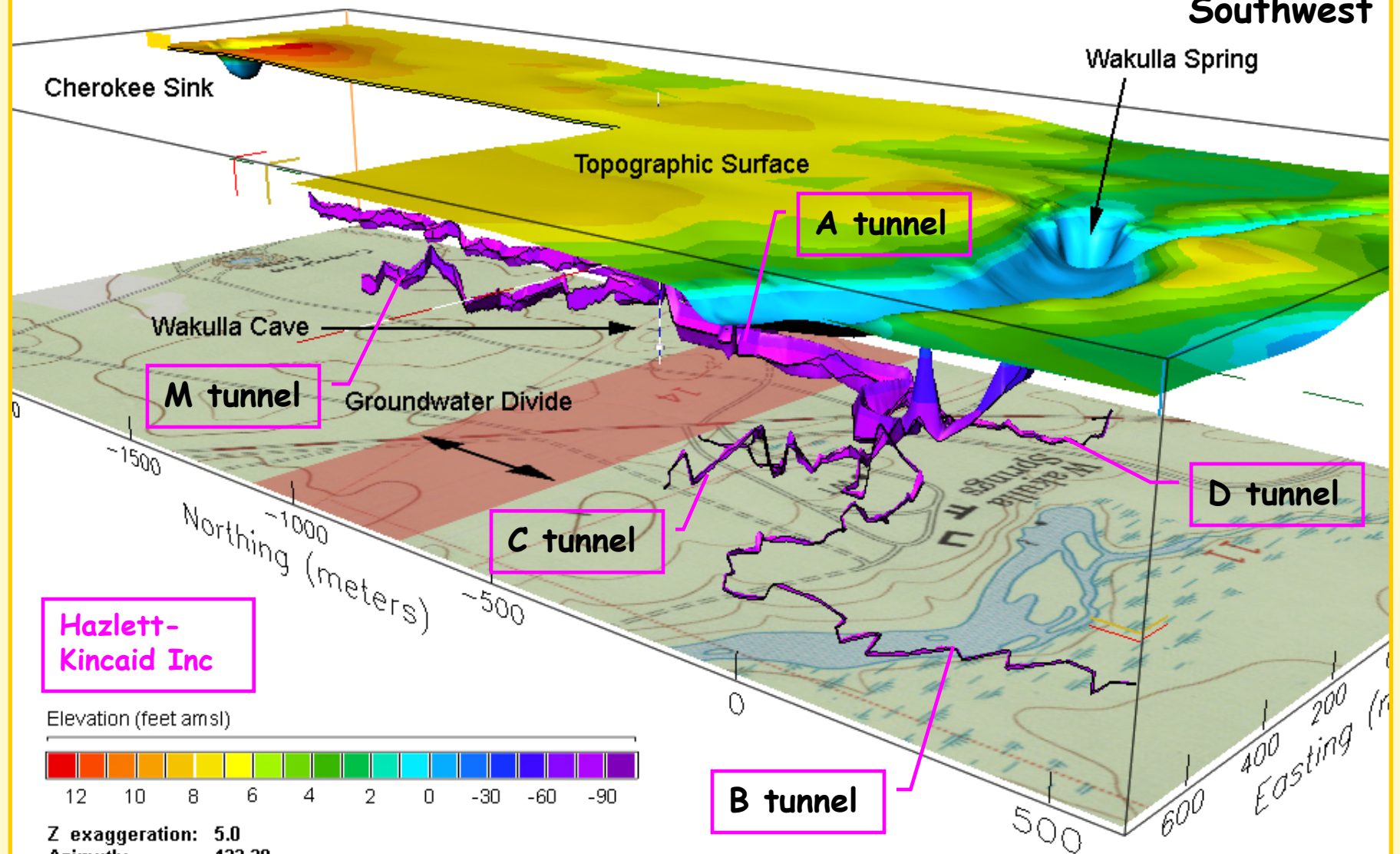


Merging surface and divers' views



Wakulla Cave: Woodville Karst Plain, North Florida

looking
Southwest



Strange features of Wakulla

Tunnels are very deep

Flow to Wakulla is **opposite** to the regional gradient

Water temperature is constant (indicating a deep source of ground water) but flow is variable

constant temperature implies disconnect from sources but variable flow and dark water days imply close connection to sources

No tunnels convey distant water toward Wakulla spring

Flow in southern tunnel A is away from Wakulla

Tunnels to the North (B and D) are small, narrow and short

Questions about Wakulla's plumbing

Why are the tunnels so deep?

Why do they trend southward?

What are the boundaries of the catchment basin for Wakulla?

Does the Leon Sinks tunnel system connect to Wakulla's?

What is the relation between Wakulla and Spring Creek springs?

Tallahassee spray field

Does water from Lake Munson/Ames Sink reach Wakulla?

Lake Lafayette sinks

Where did all that dirty water go when Lake Jackson drained in 1999?

What are the sources of dark water and nitrates seen at Wakulla?

Why is the water temperature so constant?

A search for answers

Collect and analyze data

meters - flow, temperature, conductivity, etc.

dye tracing

rainfall, tides, water levels, etc.

Identify sources of pollution at Wakulla

nitrates, dark water, etc

Answer questions about Wakulla plumbing,
Processes that created the tunnels, are
they expanding?

Boreholes, cables and tubes

The three **boreholes** allowed cables and sampling tubes to be run from the surface to each of the meters (we will not have to dive every time we want to read the record or collect water samples)

Each borehole services two meters and sampling tubes

The **cables** are to:

- provide continuous power to the meters
- permit real-time data acquisition

Make data
available
on the web

The **tubes** will permit water sampling whenever desired. Protective boxes have been installed at each well-head to house laptops, peristaltic pumps etc.

Flow meters- *Falmouth Scientific*

- Two dimensional (horizontal) acoustic vector-averaging current meters equipped with internal compass, X & Y tilt sensors, temperature sensitivity of 0.001 Celsius, flow detection 0-600 cm/sec, 1.0 MB internal memory, RS-232 data link, Windows-based interface software, alkaline batteries, 1.5 ton mooring frame and output/interface/power cable with polyurethane jacket. Cost about \$ 8,000 each.

Specific Objectives

- Measure variations in discharge, temperature and specific conductance directly and continuously through oceanographic meters installed in conduits conveying water to the spring.
- Correlate these measurements with rainfall, stream flow and conductivity at key points in the spring-shed.

Specific Objectives, continued

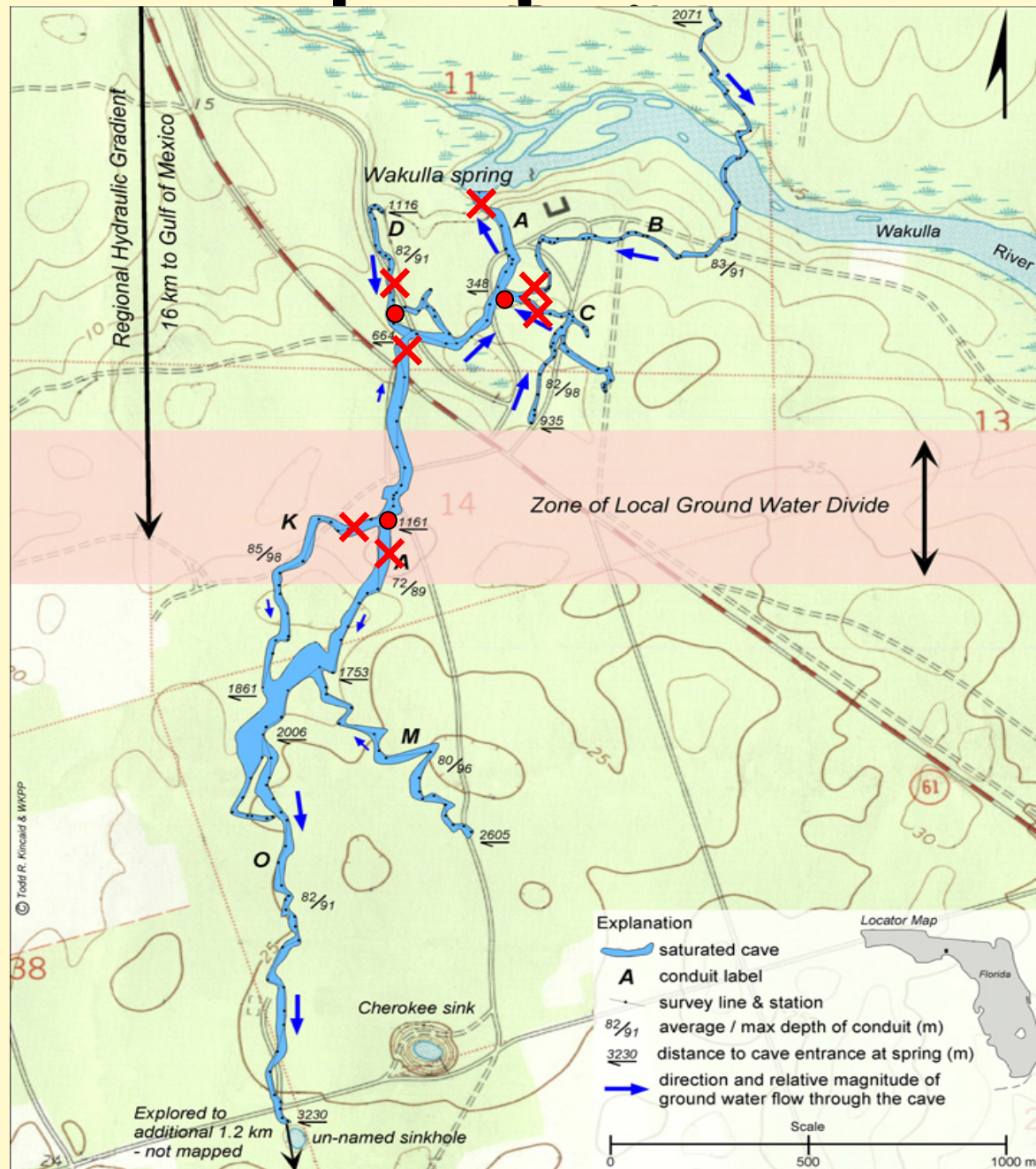
- Time-series measurements of discharge will be correlated using standard statistical tools (Fourier and wavelet analysis and empirical orthogonal function) with data on rain fall, hurricanes, variations in atmospheric pressure and other events in Leon and Wakulla Counties.
- In phase 1, Conduct statistical analysis of 5 years worth of discharge data generated by the S-4 meter (NWFWMD) and correlate with historical rain fall data (Dr. Henry Fuelberg, FSU meteorology).
- In phase 2, Conduct similar analysis of data from the seven Falmouth meters installed in conduits

Near future plans

- Seek funds to purchase three additional meters to be placed at strategic upstream locations in the spring shed (Fisher Sink, Black Creek Sink, and Ames Sink).
- Conduct the above described data correlation and analysis to better quantify input into the spring and interaction with surface water.

Meter Locations

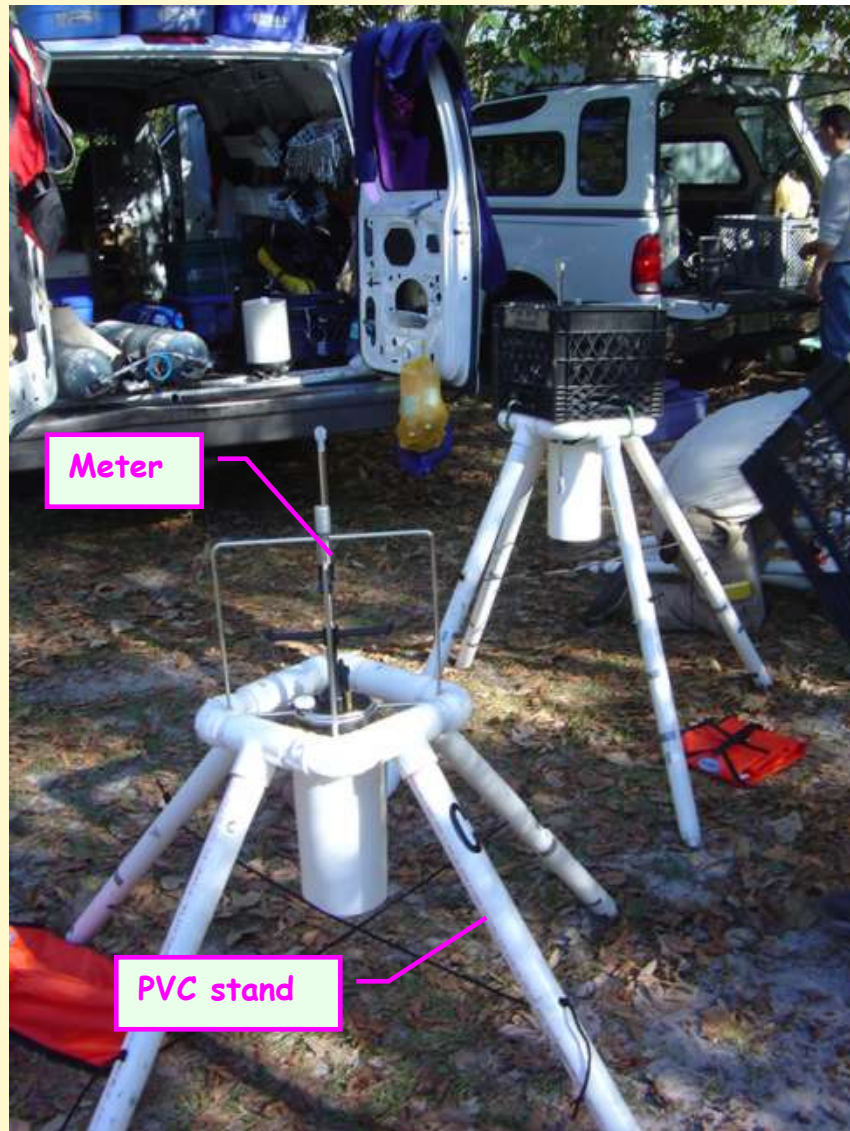
- Meters were installed by divers from the *Woodville Karst Plain Project* in A,B,C,D and K tunnels and in A-K junction carrying water into the main conduit (A) leading to the spring.
Water in effect will be used as a tracer to quantify the flow characteristics of the sub-basins



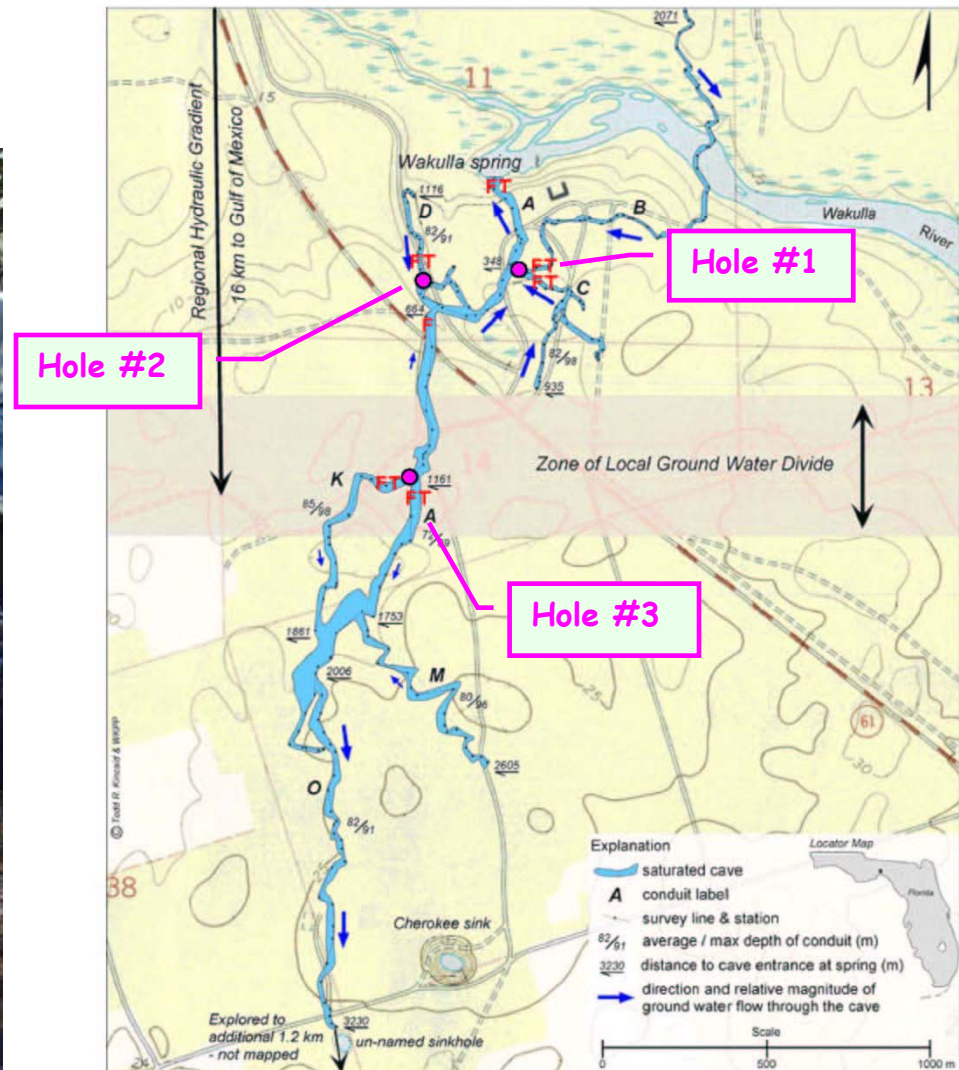
Long term objectives

- Data generated must be sufficiently accurate for identifying the principal timescales on which water flow varies, those will be used in the development of a **flow and transport model** which is both physically reasonable and quantitatively accurate.
- Correlating the data with rain fall, tidal cycles, atmospheric pressure and other events will enable us to measure changes in water flow and quality in the spring in response to such events, this in turn will help in understanding interaction between ground and surface waters and the impacts of land use.

Meter deployment



● bore hole FT flow and temperature F flow only



Start of drilling

October 7, 2003



Aiming for the
junction of
Tunnels B and C

Breakthrough at B-C junction

October 14, 2003





Inspection of first borehole

October 18, 2003



Testing the flow meter

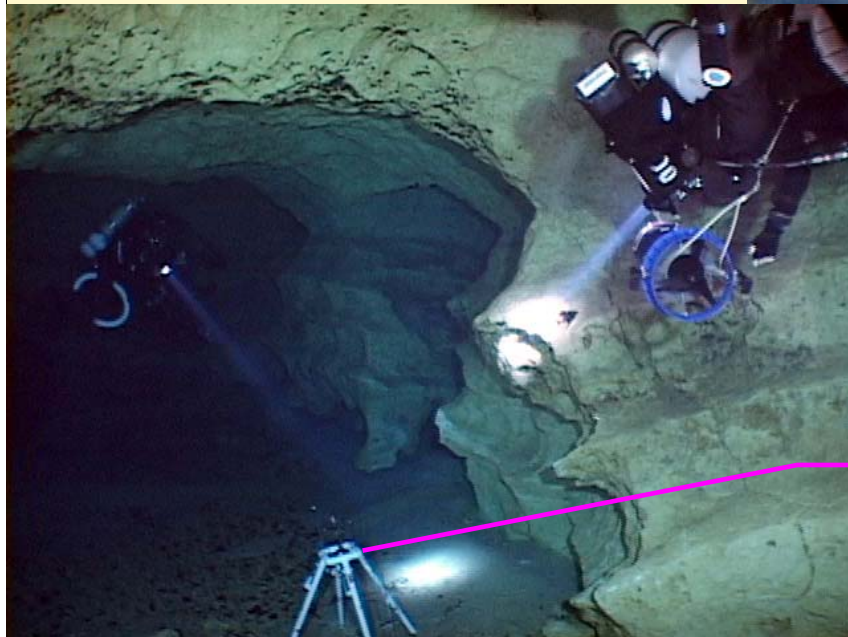
October 18, 2003



Meter installation

Bottom of hole #1
at B-C junction

Two power cables and
sampling tubes for
meters in B and C
tunnels



Meter in
B tunnel

The borehole at A-D junction nearly missed!

January 3, 2004

Drillers broke through
at 215 feet depth, then
re-entered rock and re-
emerged into the tunnel
at 225-230 feet.



Well casing penetration



Minimal debris



Cable coming through

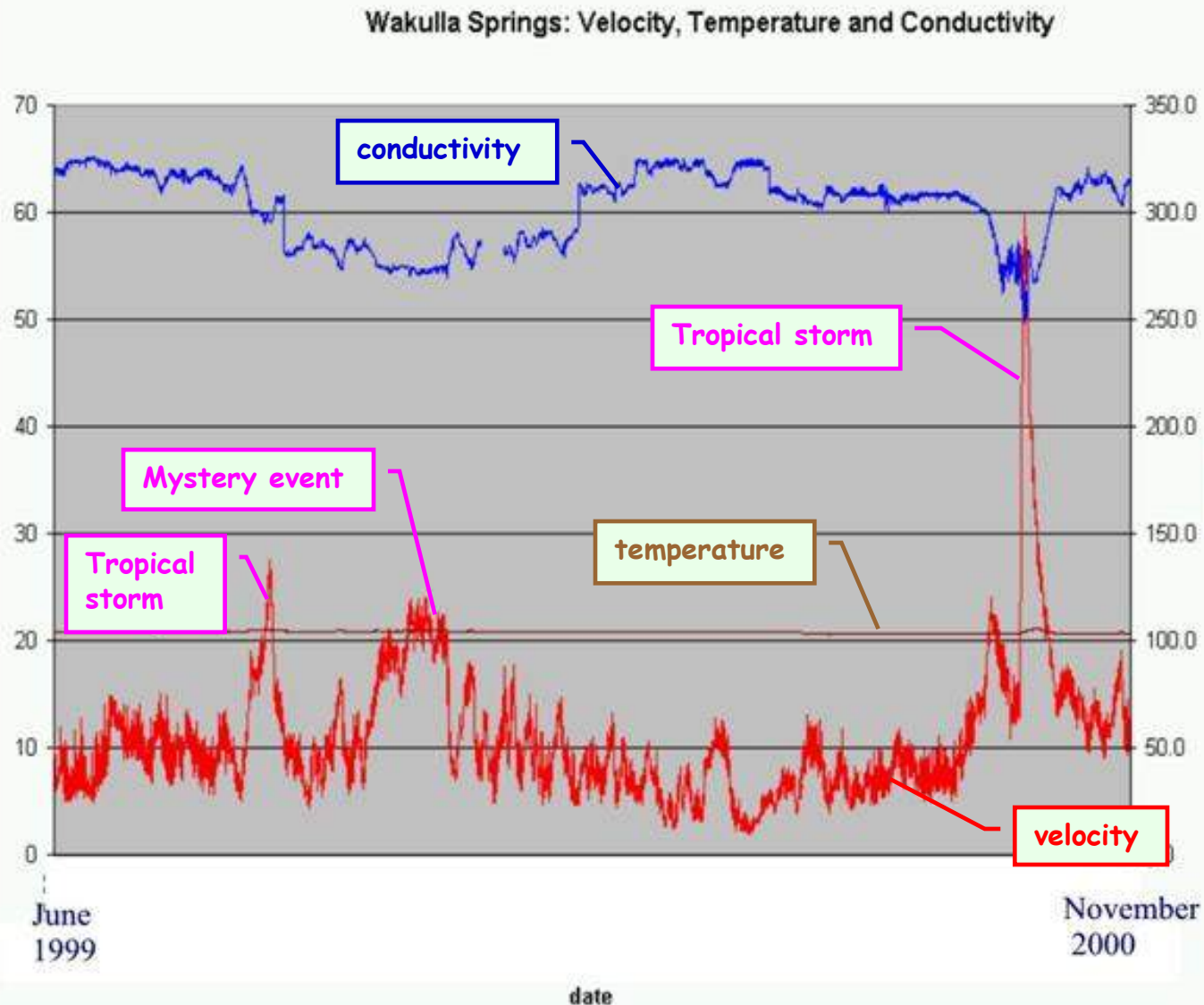


Final deployment

February 7, 2004



Past data acquisition



Data collected by
Northwest Florida
Water Management
District

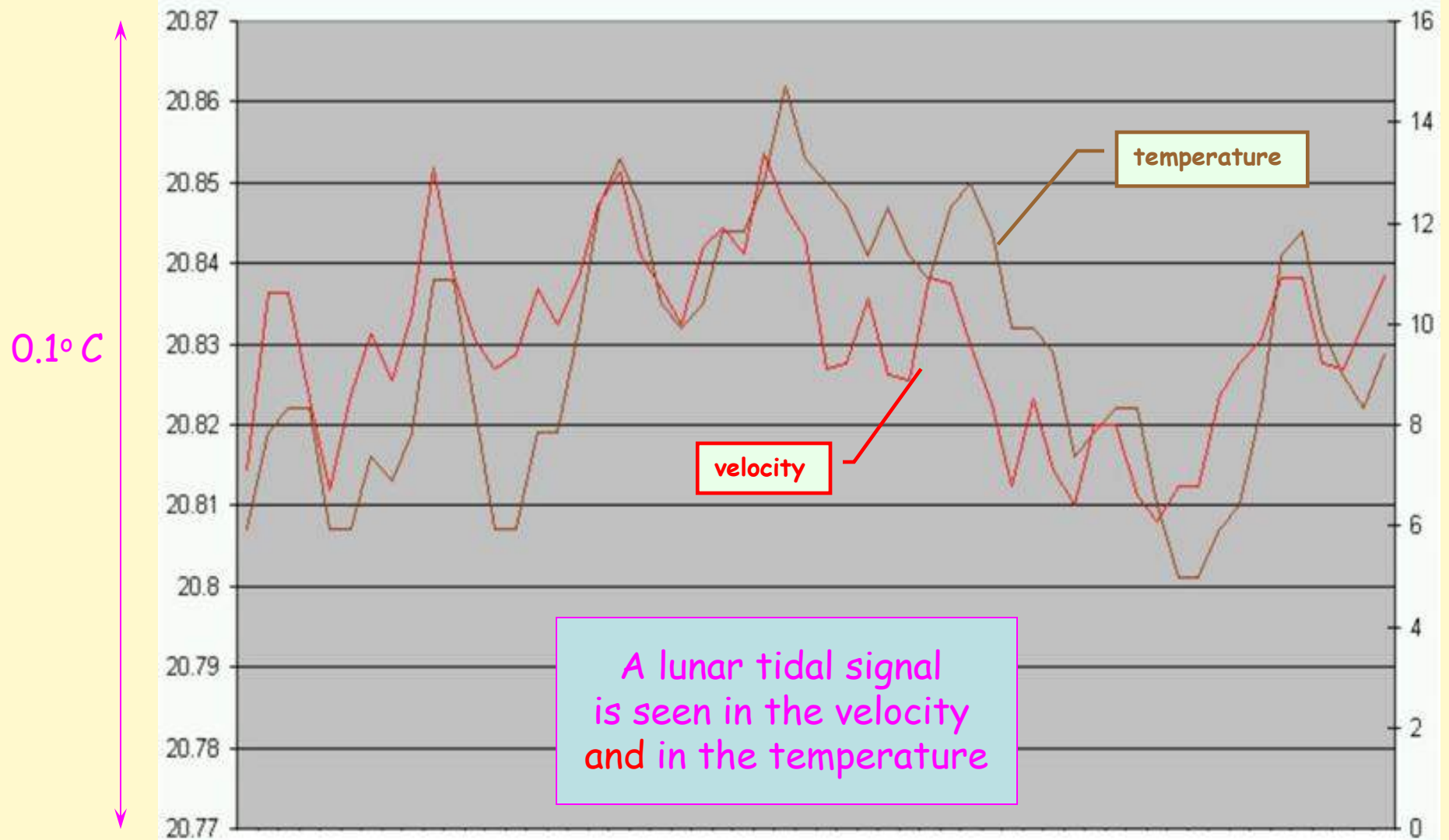
velocity =
discharge ?

Lots of variability
in velocity

Some variability
in conductivity

Local legend
(about constant
temperature) is
true!

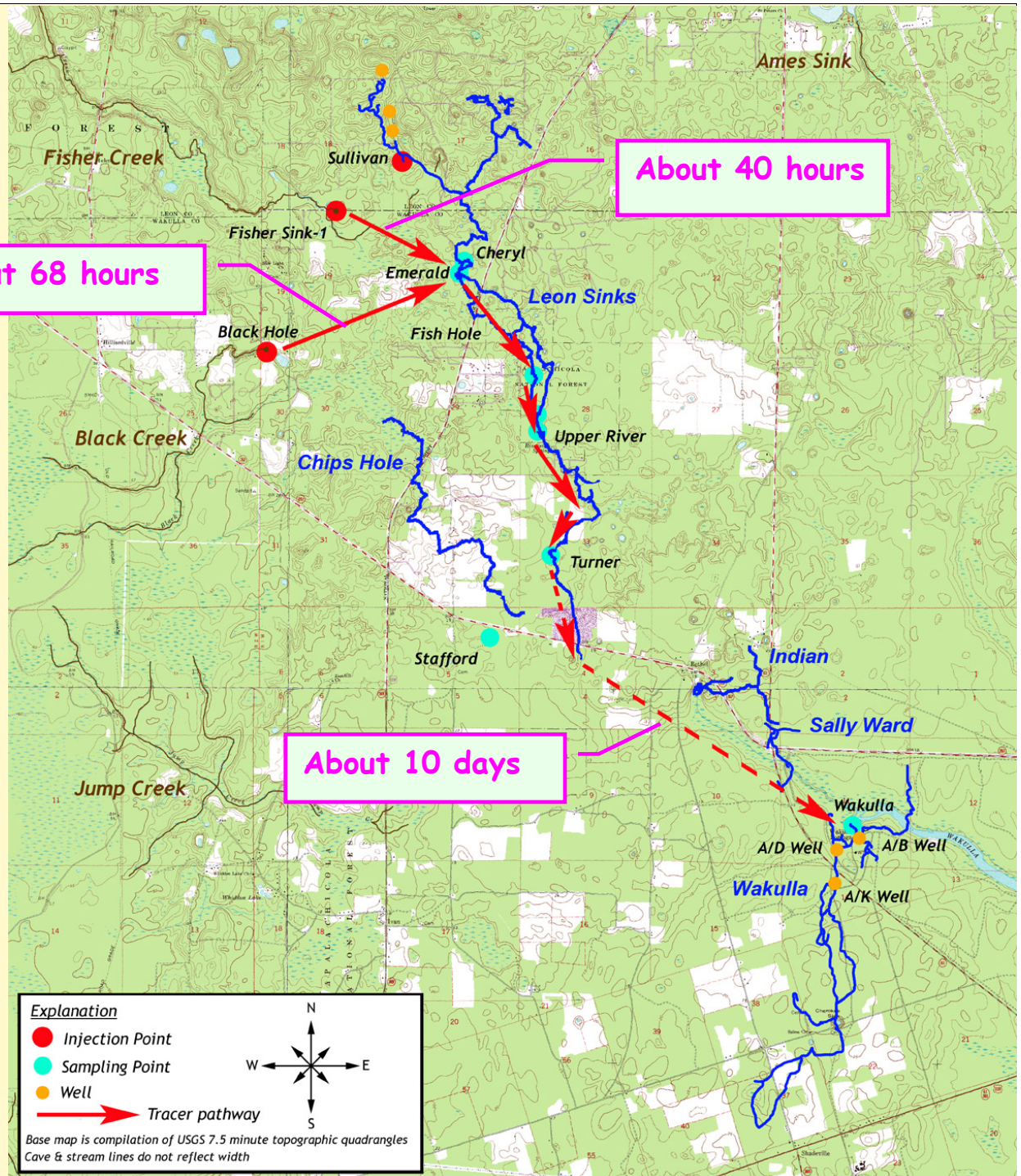
Second week, Nov 99



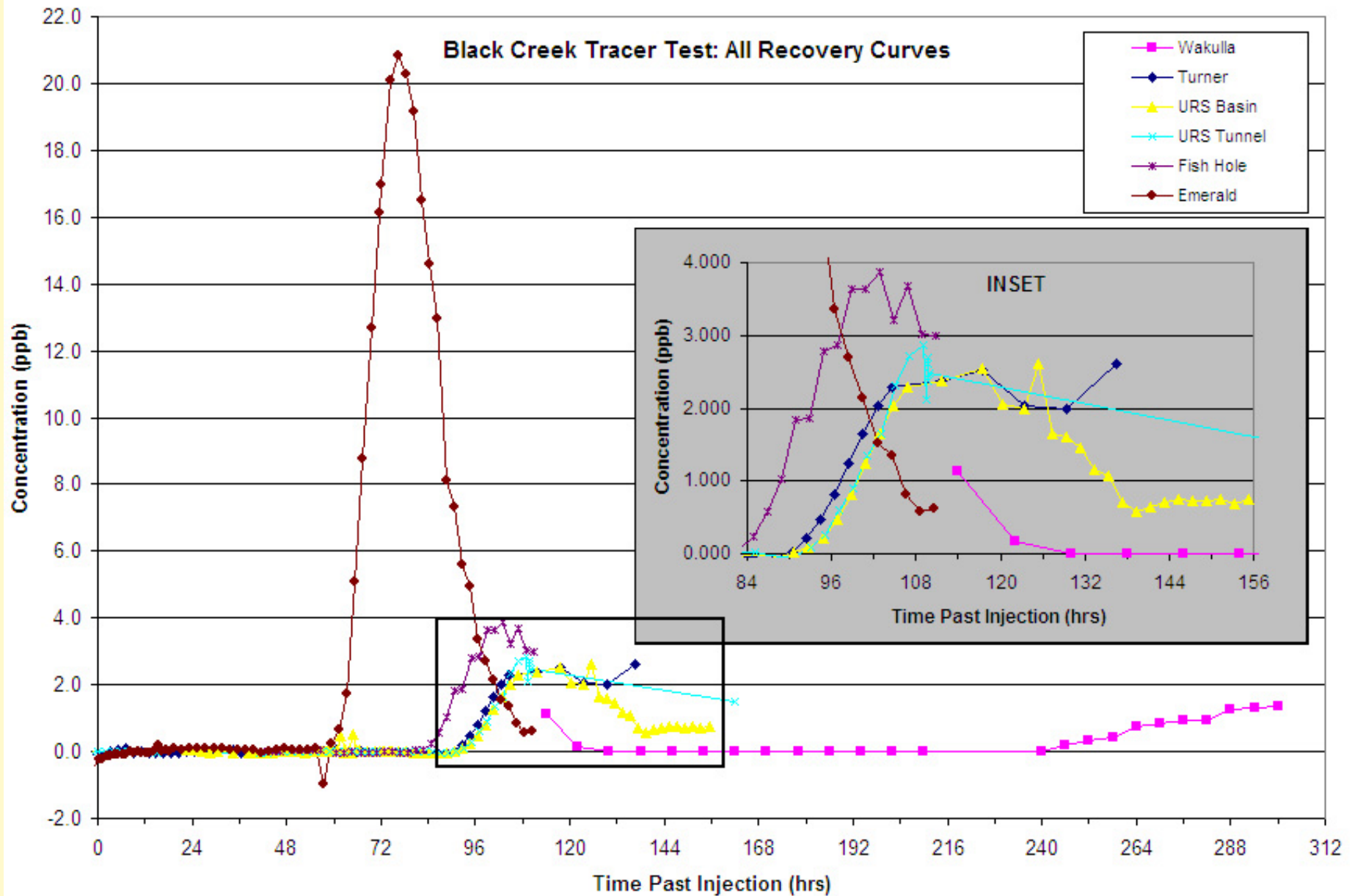
Dye tracing Nov 03

Hazlett-Kincaid.com/FGS/

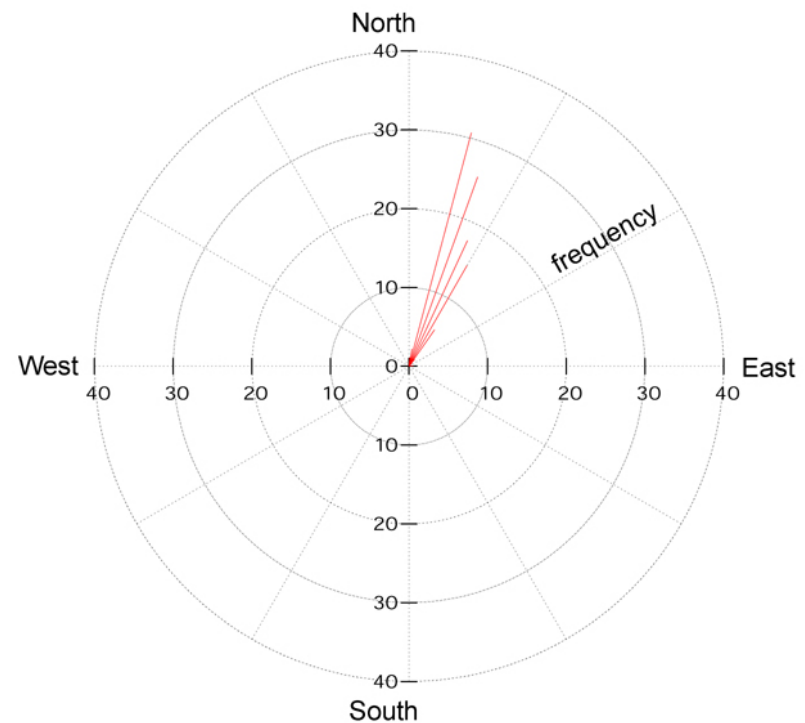
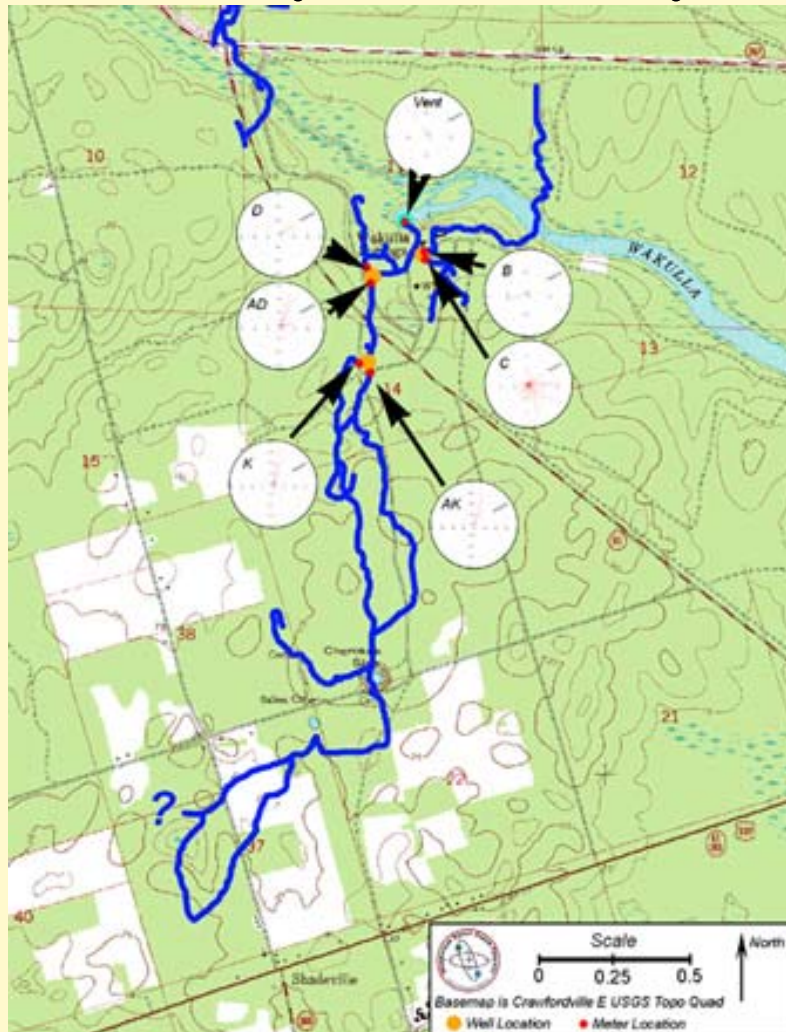
The measurement
at Wakulla was an
unexpected bonus



Break-through curves



Meter locations and example of the water flow velocity/direction measurements from each



Examples of data from one of the conduits



Flow

Temperature & Conductivity

Flow & Temperature

Potential applications of the reserach

- 1) Scientific: Modeling ground water flow and contaminant transport in multi-porosity aquifers, understanding interaction between surface and ground water.
- 2) Environmental: Quantifying impacts of land-use on water quality.
- 3) Educational: Training students, making the public aware of threats to the system.

Participating agencies and groups

Florida State University

Geophysical Fluid Dynamics Inst

Meteorology Dept

College of Education

Statistics Dept

Florida Geological Survey

Florida Springs Initiative

Hazlett-Kincaid, Inc

Hydrogeology Consortium

Northwest Florida Water Management District

US Geological Survey

Wakulla Springs State Park

Woodville Karst Plains Project