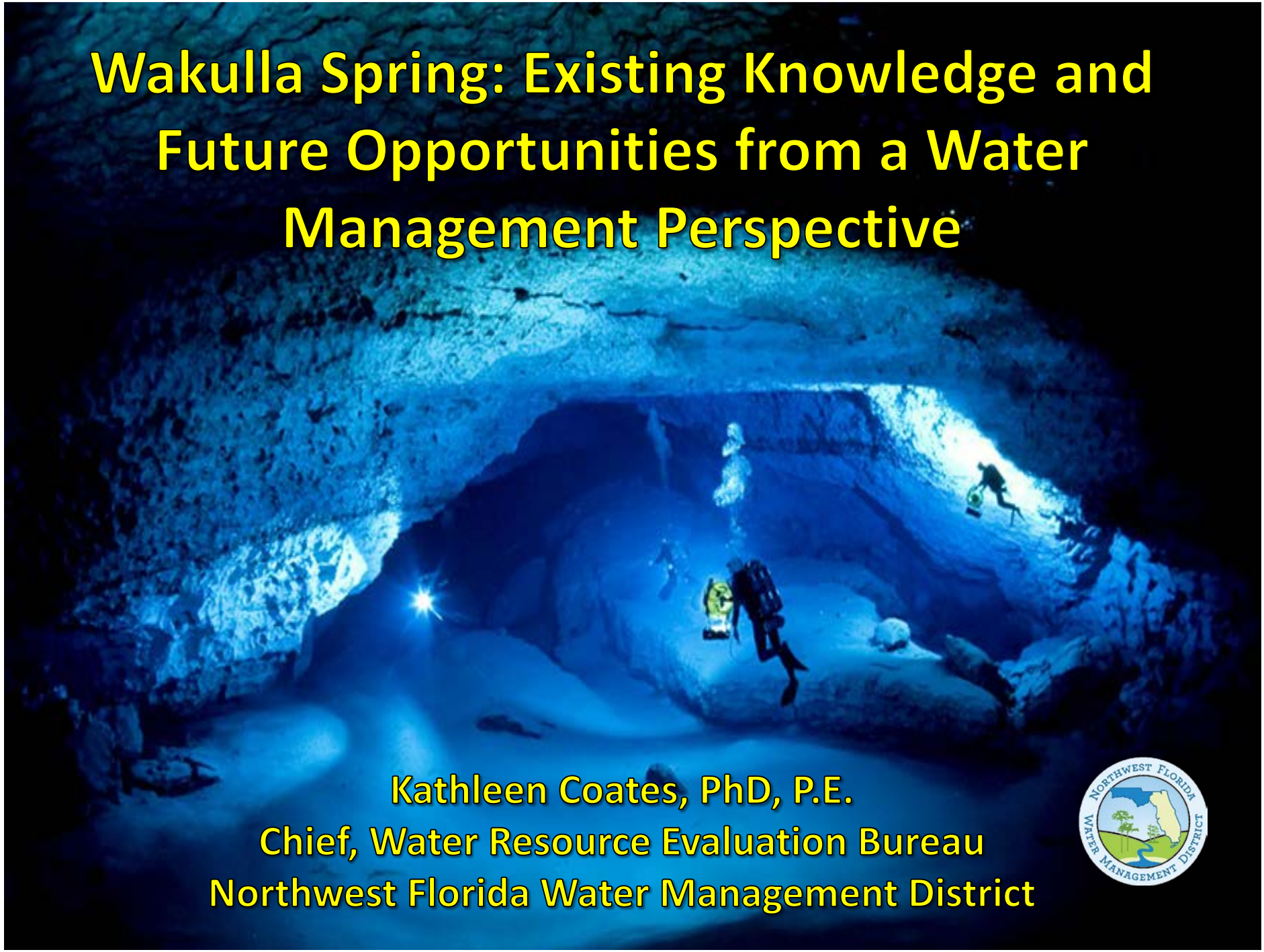
Wakulla Spring: Existing Knowledge and Future Opportunities from a Water Management Perspective



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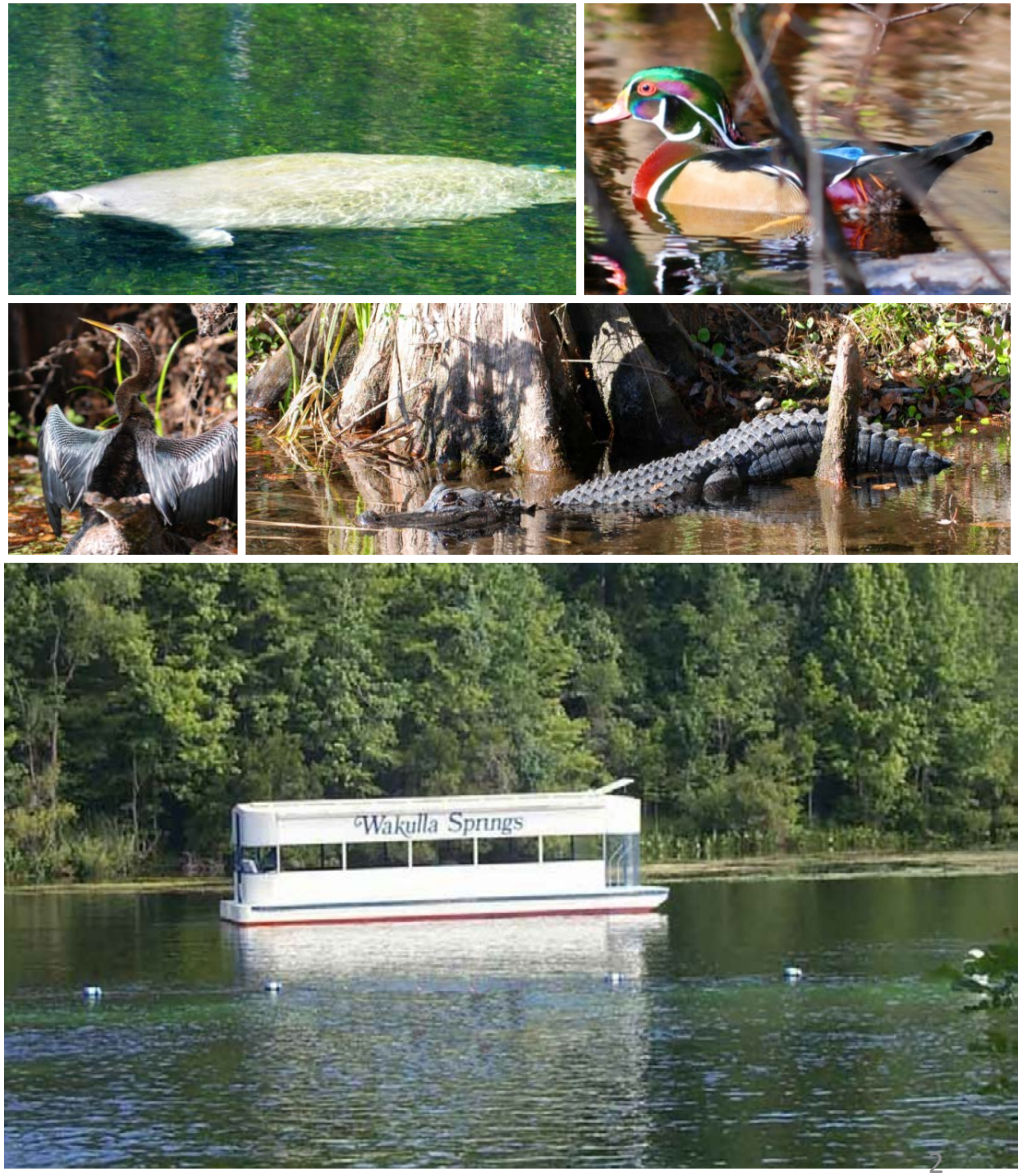
Wakulla Spring

- "Outstanding Florida Spring" and National Natural Landmark
- Edward Ball Wakulla Springs State Park
- Human habitation for nearly 15,000 years
- Spring flow more than 400 cfs
- More than 35 miles of mapped caves and conduits



Overview

(1) Summarize Wakulla Spring data and analysis performed to date to address:

- Increased spring flow
- Potential changes in water clarity
- Improved nitrate levels
- Changes in salinity indicators

(2) Identify opportunities for future analysis

Hydrology

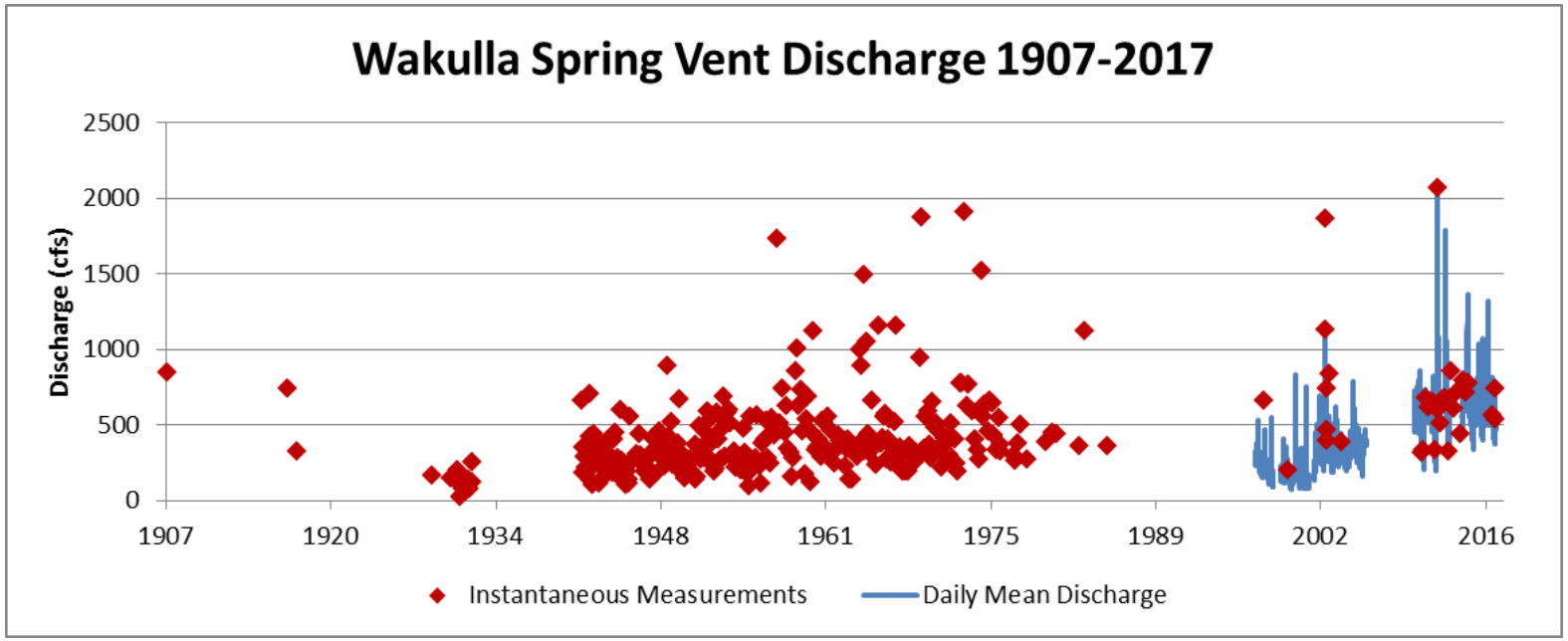
- 1st magnitude spring: Average discharge = 417 cfs

  Average discharge, 2000- 2017= 487 cfs

- Increasing trend in Wakulla Spring discharge

  1907 - 2017: Slope = 3.91 cfs/yr; p = 0.001

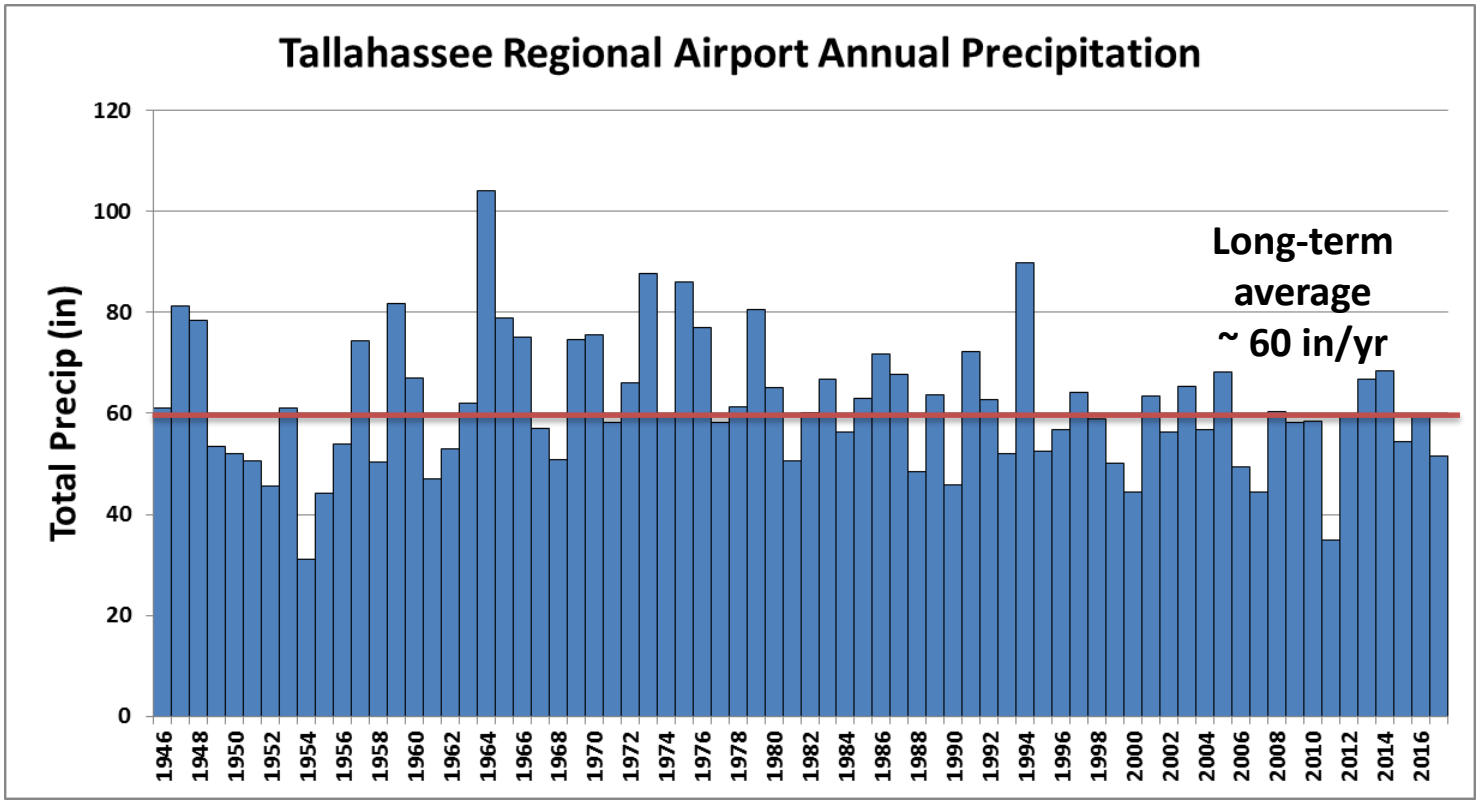
  1907 – 1999: Slope = 3.37 cfs/yr; p = 0.013



Increasing Spring Flows

Increasing rainfall /recharge?

- Tallahassee Airport NWS, daily rainfall 1946 to present
  - 1946 – 2017, no trend, slope = -0.075 in/yr p = 0.314
  - 1974 – 2017, significant declining trend, slope = -0.241 in/yr, p = 0.032



Increasing Spring Flows

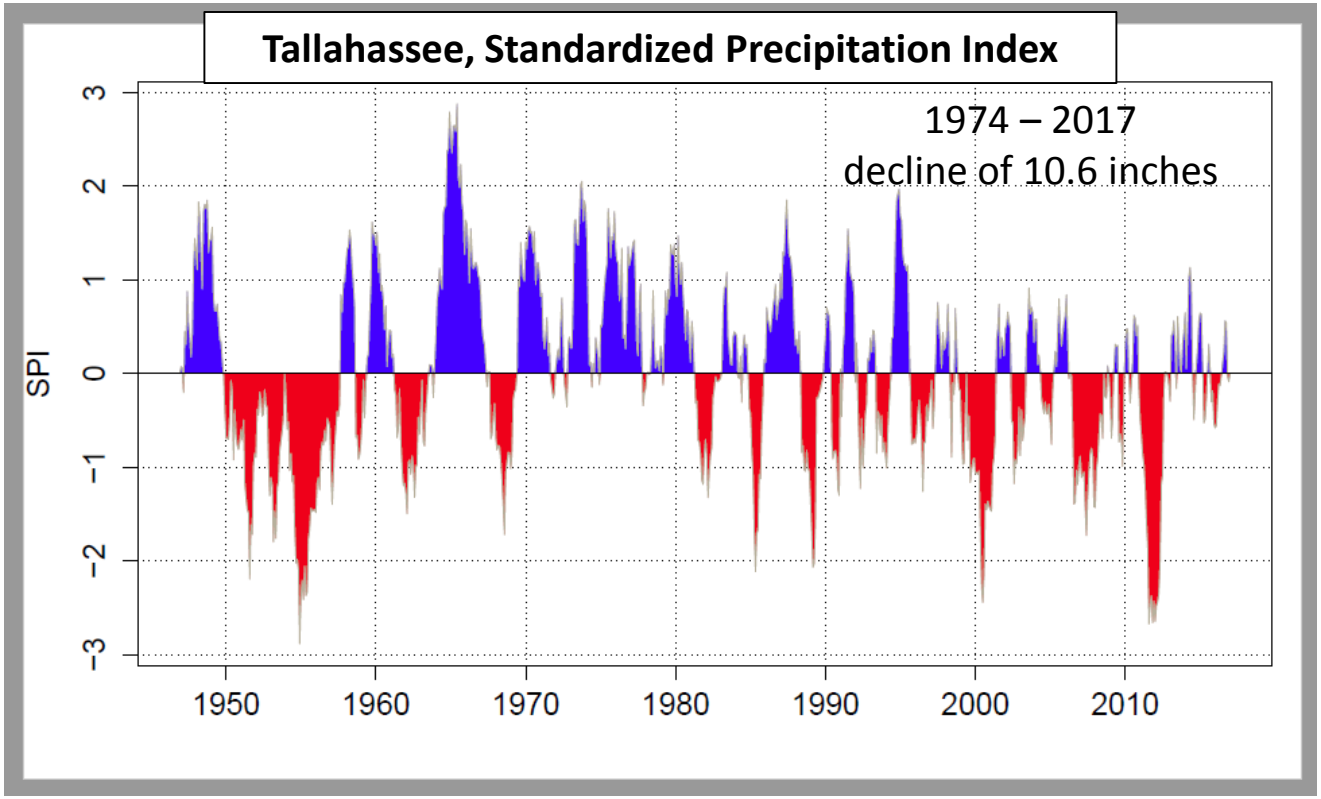
Possible explanations?

- Increased rainfall and recharge
- Changes in spring run hydraulics
- Increases in aquifer levels
- Capture of groundwater from Lost Creek basin
- Other?

Increasing Spring Flows

Rainfall and recharge

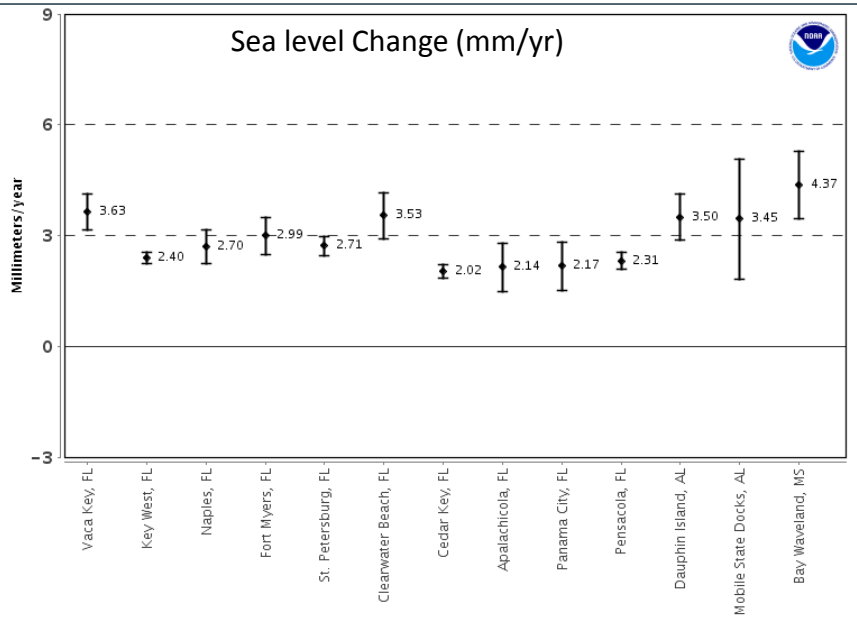
- Decadal patterns and extended wet and dry periods
- ….increased rainfall and recharge not responsible for increasing spring flows



Increasing Spring Flows

Spring run hydraulics?

- Downstream head at the coast
  - Sea-level rise
- Reductions in vegetation (e.g., channel friction)?
  - Unlikely. Long-term historical vegetation data are limited.
- Changes in river channel due to scour from hurricanes, tropical storms, or storm surge?
  - Historical data are limited. Channel surveys show no changes between 2009 and 2016.



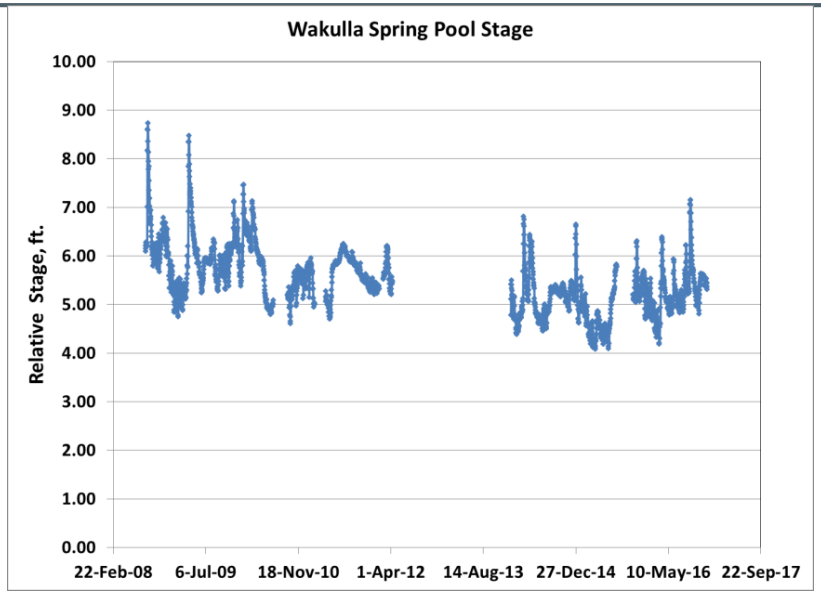
Source: Smithsonian Marine Station. Accessed 10/: http://www.sms.si.edu/irLspec/Hydrilla_verticillata

Hydrilla at Wakulla Spring, 1998

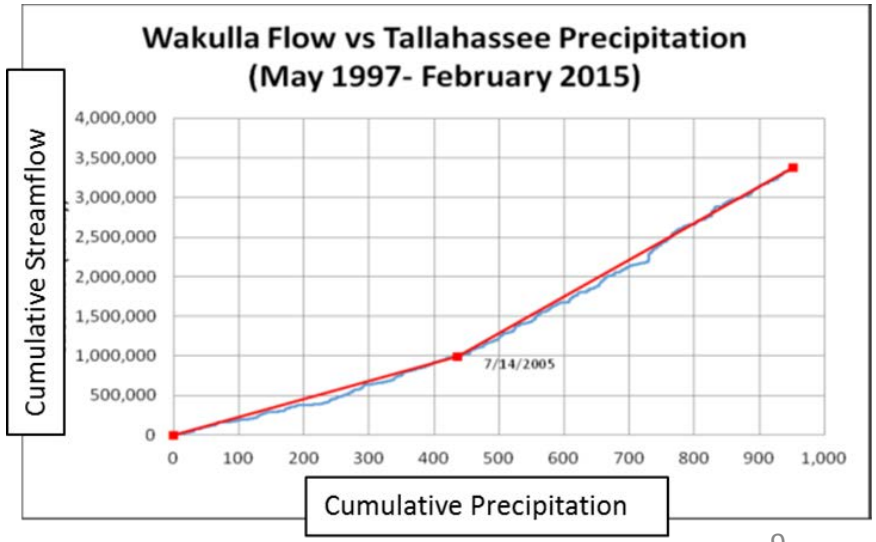
Increasing Spring Flows

Spring run hydraulics?

- Decline in spring pool stage?
  - Insufficient data
- Increases in aquifer levels?
  - No long-term aquifer level data at Wakulla Spring park
  - Analysis of wells in region
- Plot of spring flow and precipitation double mass curve suggest a possible inflection point on or near July 14, 2005?
- Changes in the conduit system?



***TS Fay in August 2008 and TS Claudette in August 2009**



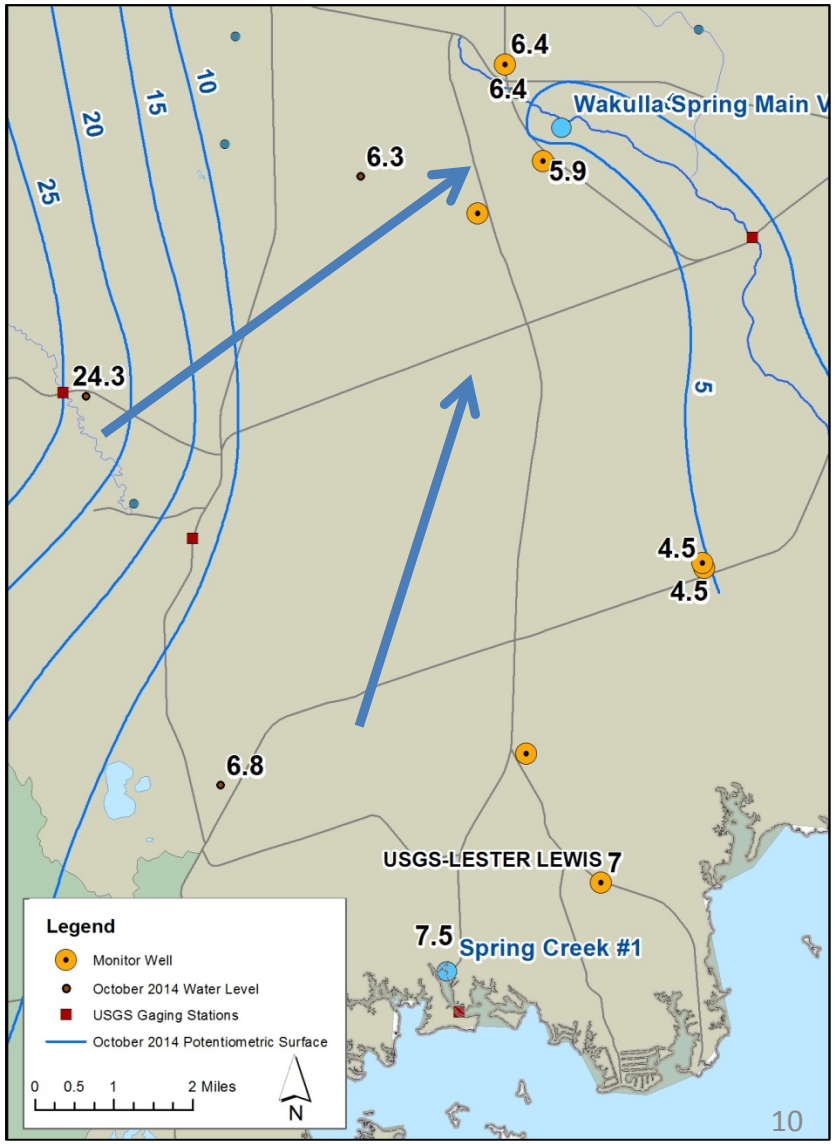
Source: Interflow Engineering

Increasing Spring Flows

Increased Capture of Groundwater Flow from Lost Creek Basin?

- Empirical data:
  - Lost Creek Tracer Test (Dyer 2016; and others)
  - Aquifer levels (FGS, NWFWMD)
- A possible causative mechanism… although thought to be associated with periods of low rainfall.
- Difficult to determine the degree to which this process may explain long-term changes at Wakulla Spring.
  - No long-term trend in aquifer levels at Lester Lewis well (1961 – 2017).
  - No long-term records at Spring Creek

October 2014 Aquifer Levels



Increasing Spring Flows

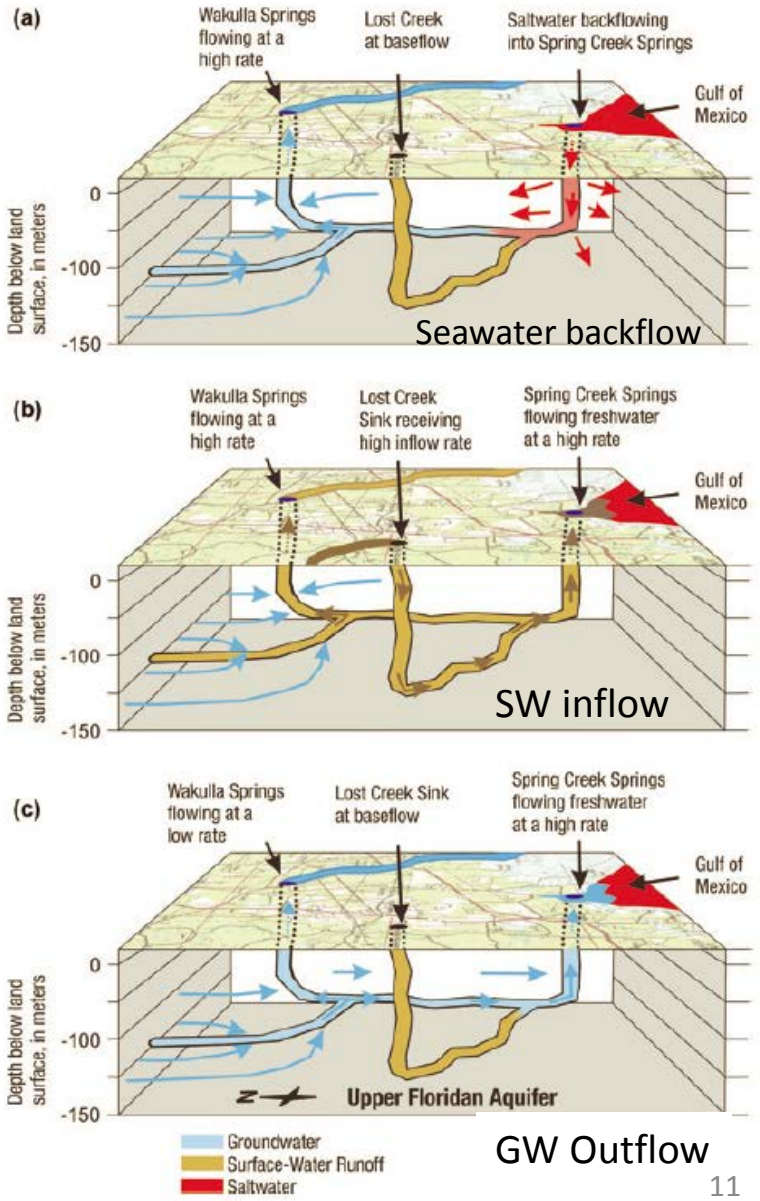
Capture of groundwater from Lost Creek basin during Spring Creek Spring Group reversals

(from Davis and Verdi 2014)

(a) Seawater backflow. Seawater fills coastal conduits. Gradients change and groundwater in Lost Creek basin flows north toward Wakulla Spring.

(b) High rainfall. Surface water flows into the system, Spring Creek and Wakulla Spring discharge at high rates.

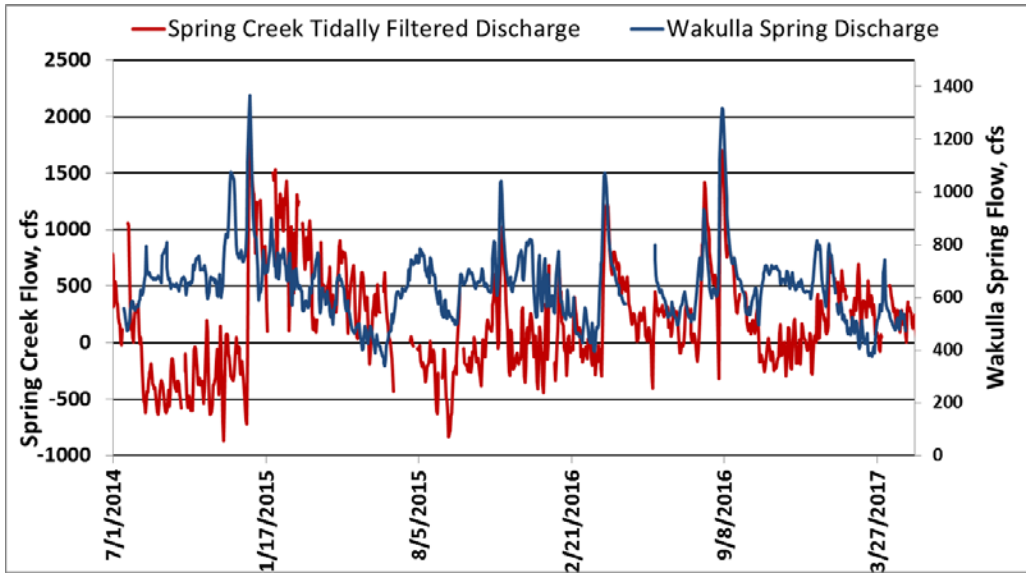
(c) Rainfall decreases and ceases. Discharge from Spring Creek Spring Group and Wakulla Spring reflects baseflow conditions.



Increasing Spring Flows

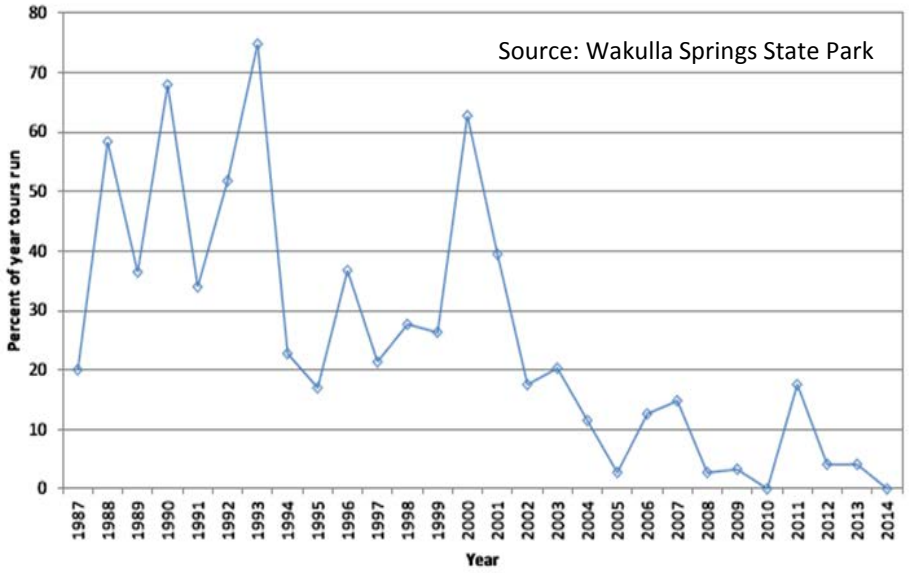
Increased capture of Groundwater Flow from Lost Creek Basin?

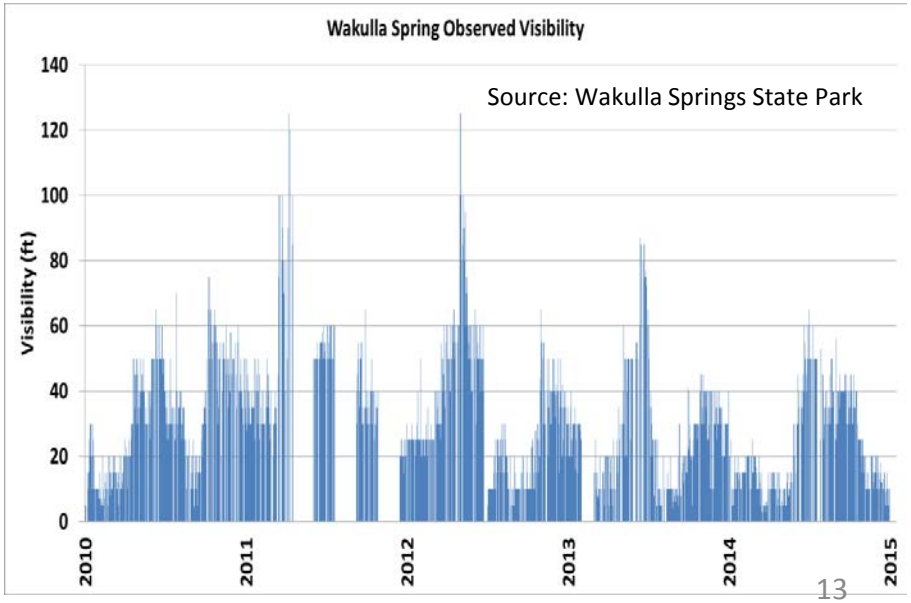
- Highest discharge at Wakulla Spring does not correspond to Spring Creek reversal events
- Slightly elevated flows following Spring Creek reversals
- Further analysis is needed



Water Clarity / Transparency / Color

- Anecdotal observations suggests that water clarity has decreased in recent decades (1980s to present?)
- Periods of tannic / dark water reported in the 1940s
- No quantitative long-term data (secchi disk, color, turbidity, etc.)





Water Clarity / Transparency / Color

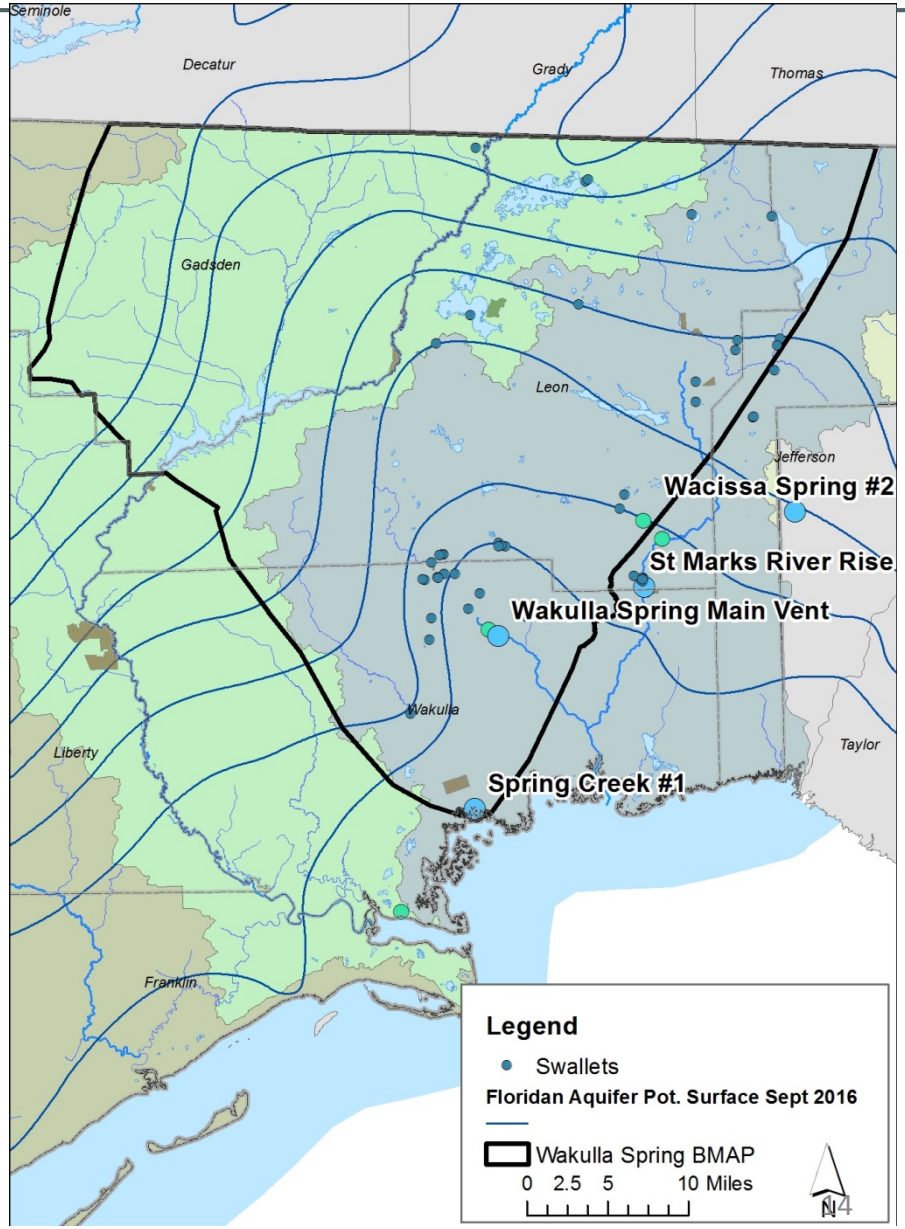
Spring flow is generally a mixture of groundwater originating from diffuse recharge, and point recharge via swallets and sinks.

Some hypotheses:

(1) Reduced “clear” water from areas north of Wakulla Spring

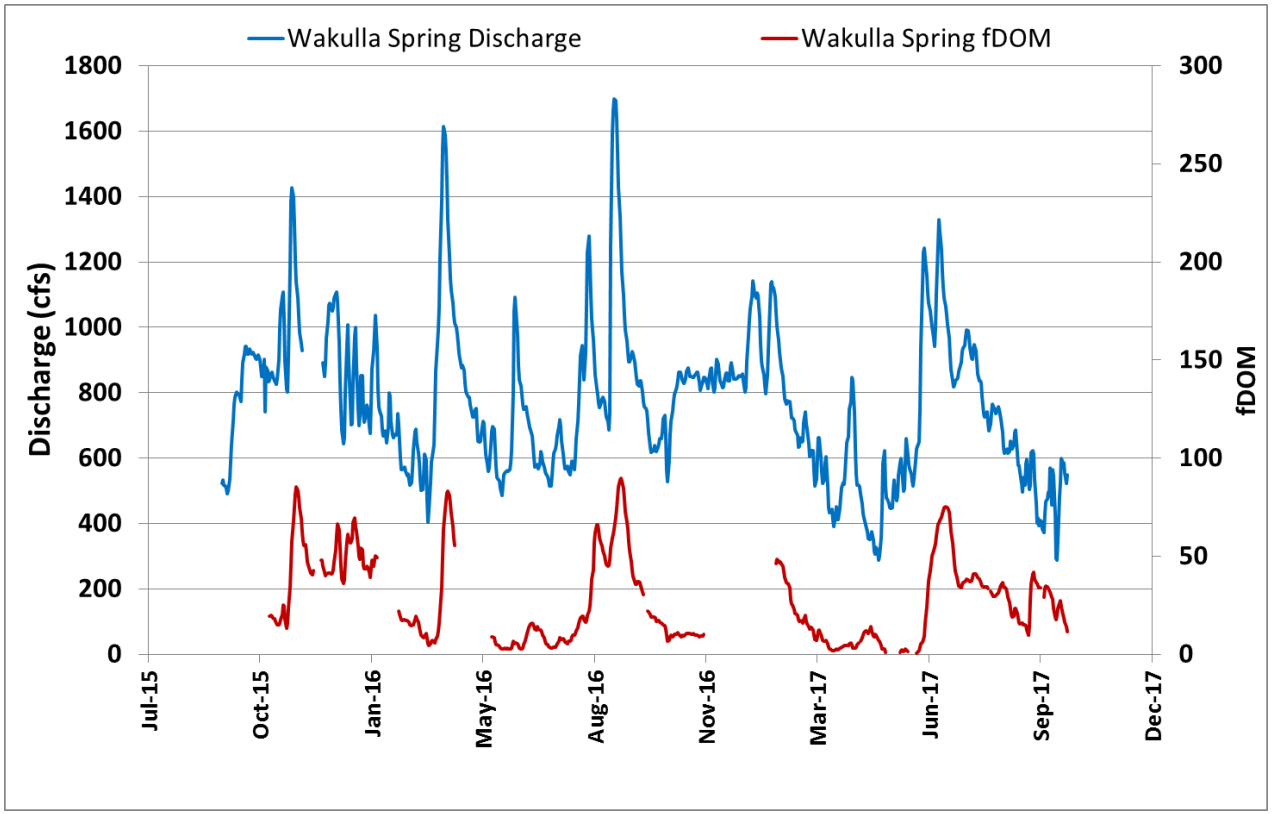
(2) Increased tannic (“dark”) water from areas west of Wakulla Spring in Apalachicola National Forest (via changes in swallet inputs?)

(3) Increased chlorophyll in “clear” water from areas north of Wakulla Spring, derived from lakes with karst features



Water Clarity / Transparency / Color

- Better water clarity associated with lower spring flows
- Mechanism? Increased swallet inflows, changes in conduit inflows, reduced diffuse groundwater inflow?

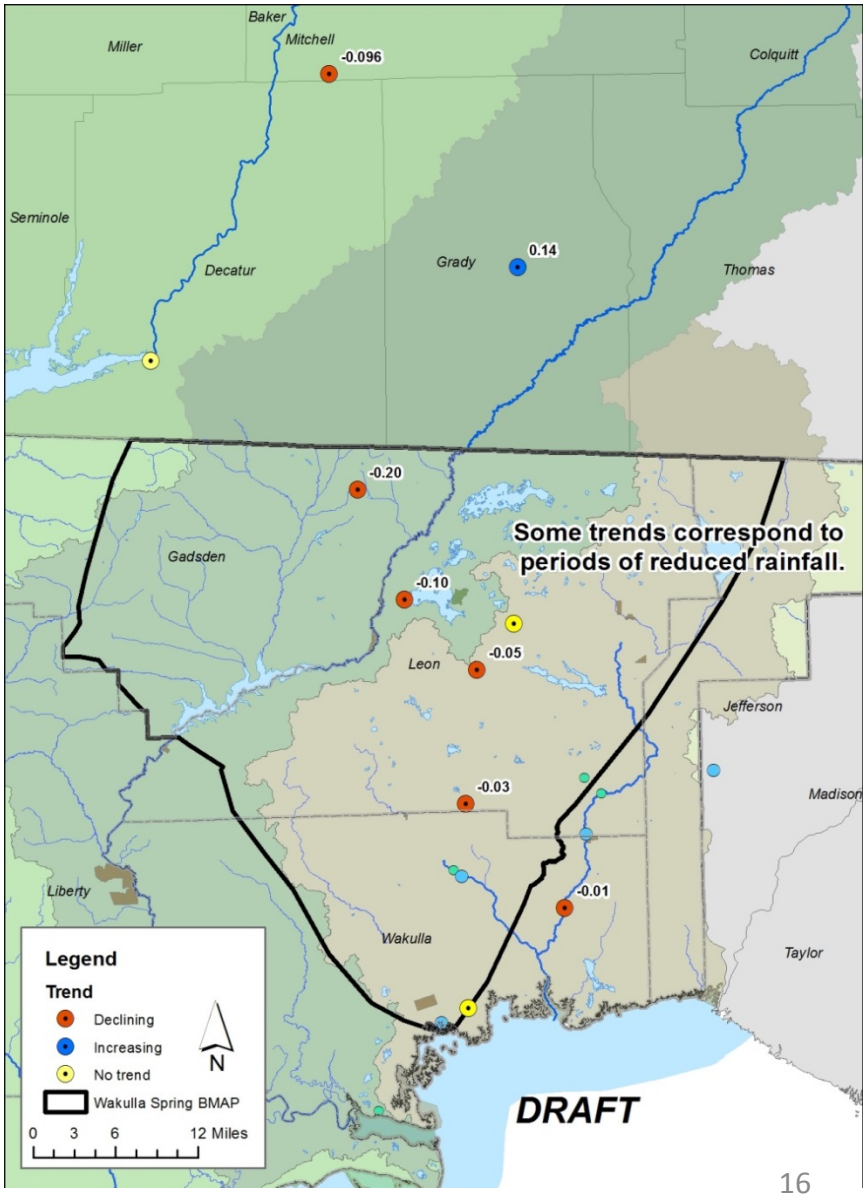


Trends in Aquifer Levels

Changes in groundwater inflows?

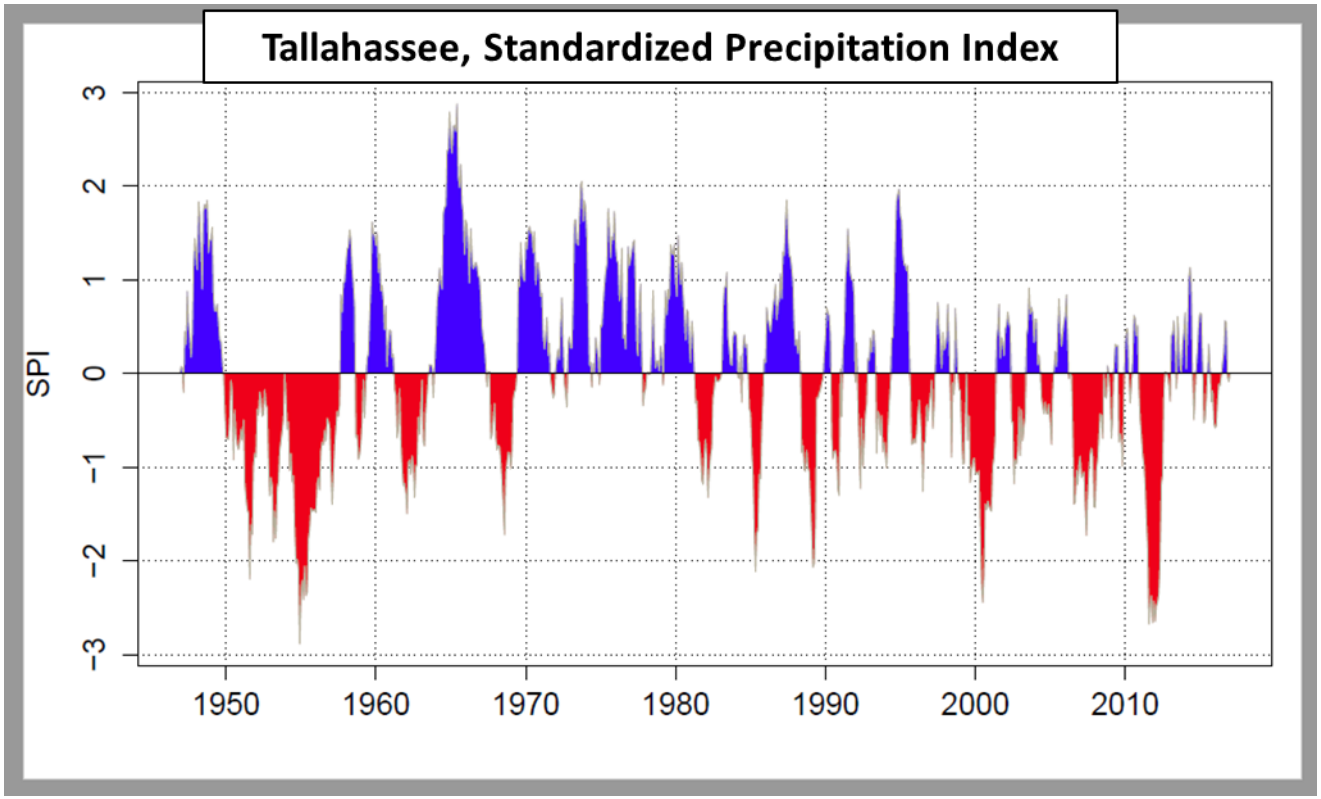
- Trend analysis results
  - One increasing trend
  - Six decreasing trends
  - Three no trend
- Declining trend at background well in Washington County:

  (-0.15 ft/yr; 1962 – 2017)
- Limited long-term aquifer level data in Georgia
- Magnitude of trends is very small, hundredths or tenths of feet/year



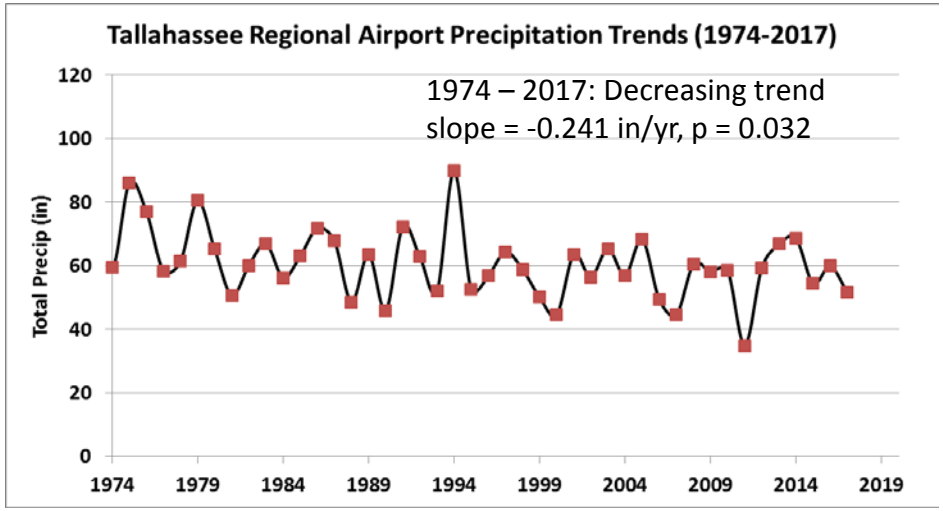
Trends in Aquifer Levels – Influence of Rainfall

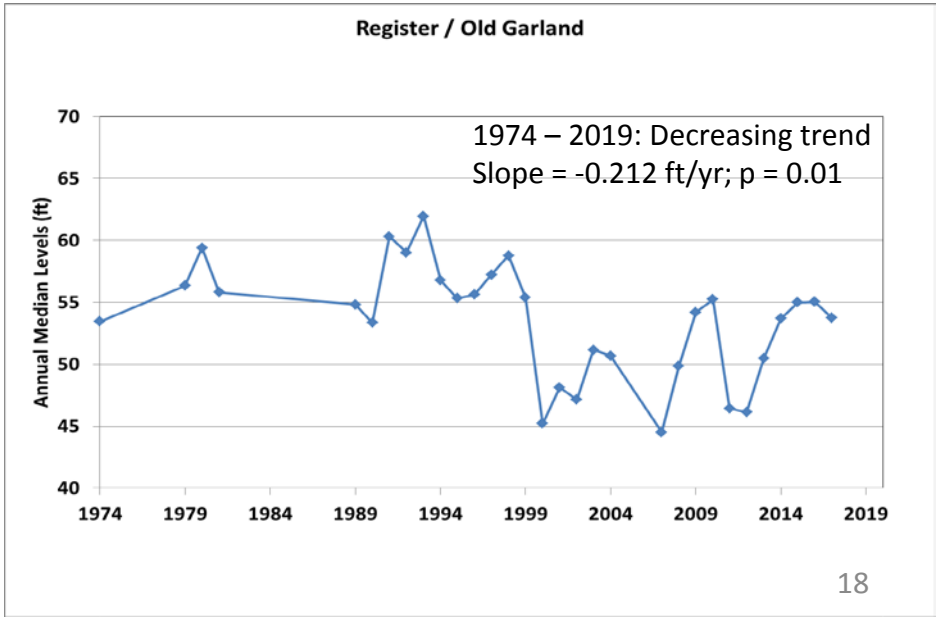
Name	Frequency	Test	N	Period of record	Sen slope	p value	Trend
USGS-Lester Lewis/S788 all	Annual medians	2 sided mann kendall	42	1961-2017	-0.001	0.922	no trend
Newport Recreation	Annual medians	2 sided mann kendall	57	1961-2017	-0.01	0.002	declining trend
C. Donahue Deep	Annual medians	2 sided mann kendall	28	1989-2017	-0.032	0.009	declining trend
Lafayette Park	Annual medians	2 sided mann kendall	68	1945-2017	-0.053	0.043	declining trend
USGS-Olson Rd./S677	Annual medians	2 sided mann kendall	40	1977-2017	-0.08	0.139	no trend
USGS-Lake Jackson	Annual medians	2 sided mann kendall	52	1966-2017	-0.1	0.01	declining trend
Register/Old Garland all	Annual medians	2 sided mann kendall	31	1974-2017	-0.202	0.01	declining trend



Trends in Aquifer Levels

- Example: Rainfall and aquifer levels exhibit decreasing trends during 1974 – 2020
- Rainfall and aquifer levels rebound in recent years, with 2014-2016 aquifer levels similar to historical levels
- Pumpage and rainfall effects can be inversely correlated (e.g. low rainfall, increased irrigation use)
- Can be difficult to quantify rainfall, period of record, and pumpage effects





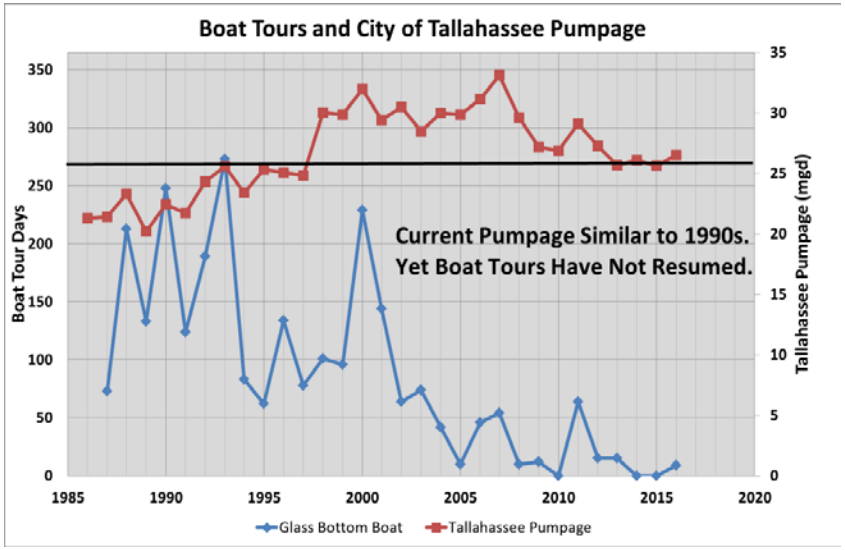
Trends in Aquifer Levels

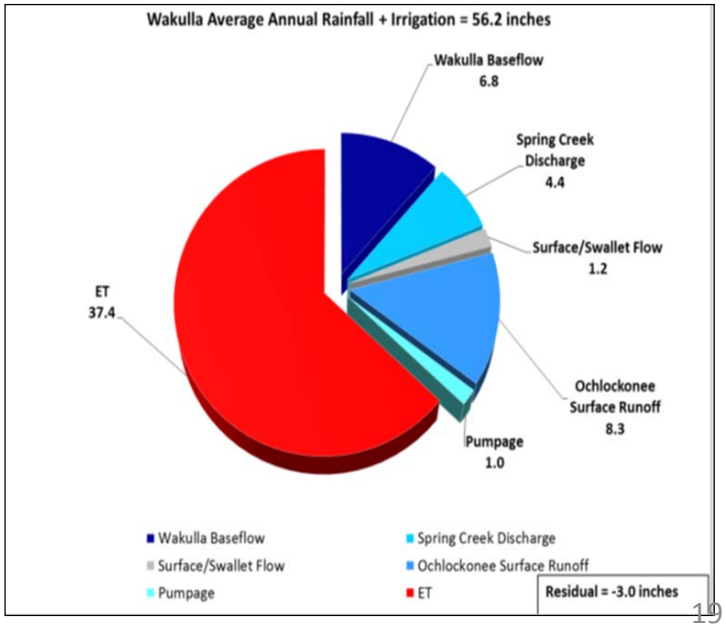
Recharge and pumpage

- City of Tallahassee
  - Current pumpage similar to 1990s
  - Pumpage: 26.5 mgd in 2016
  - Sprayfield returns: 19.7 mgd in 2015
  - Net consumptive use is a very small fraction of spring discharge (<5%)
- Georgia
  - 1980 groundwater withdrawals in Georgia counties totaled about 99 mgd.
  - 2005 withdrawals totaled 98 mgd.
  - Withdrawals higher in 2000 and 2010
  - Recent withdrawals?
- 2009 Water Budget for Springshed

  Pumpage: ~ 1 inch

  Recharge: ~ 12 inch

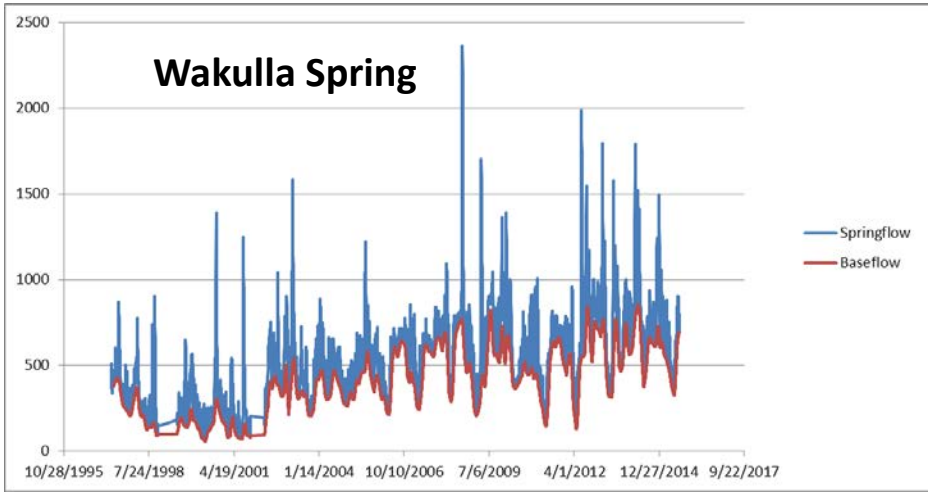


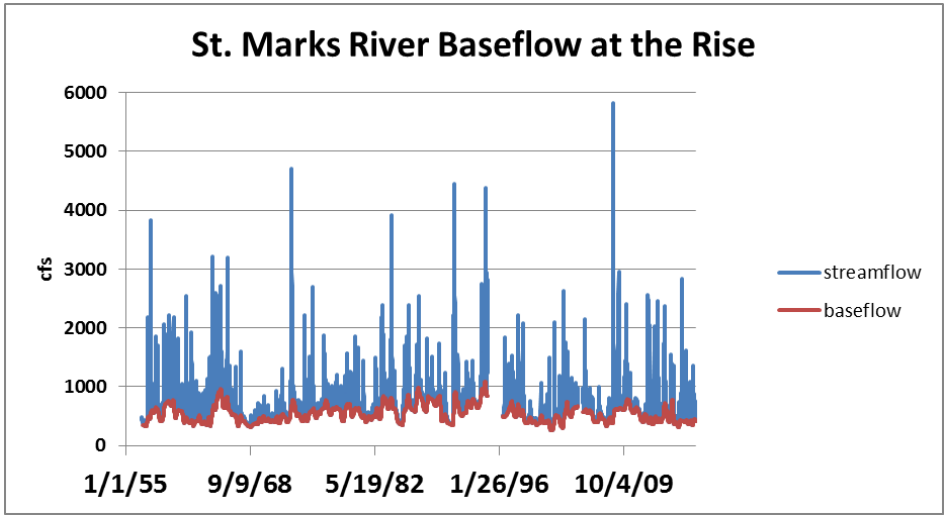


Water Clarity / Transparency / Color

Groundwater inflows

- Increase in spring discharge
- No long-term decreases in “baseflow” at streams in Leon or Wakulla counties
- Limited data regarding historical swallet flows
- Limited information on conduit flows

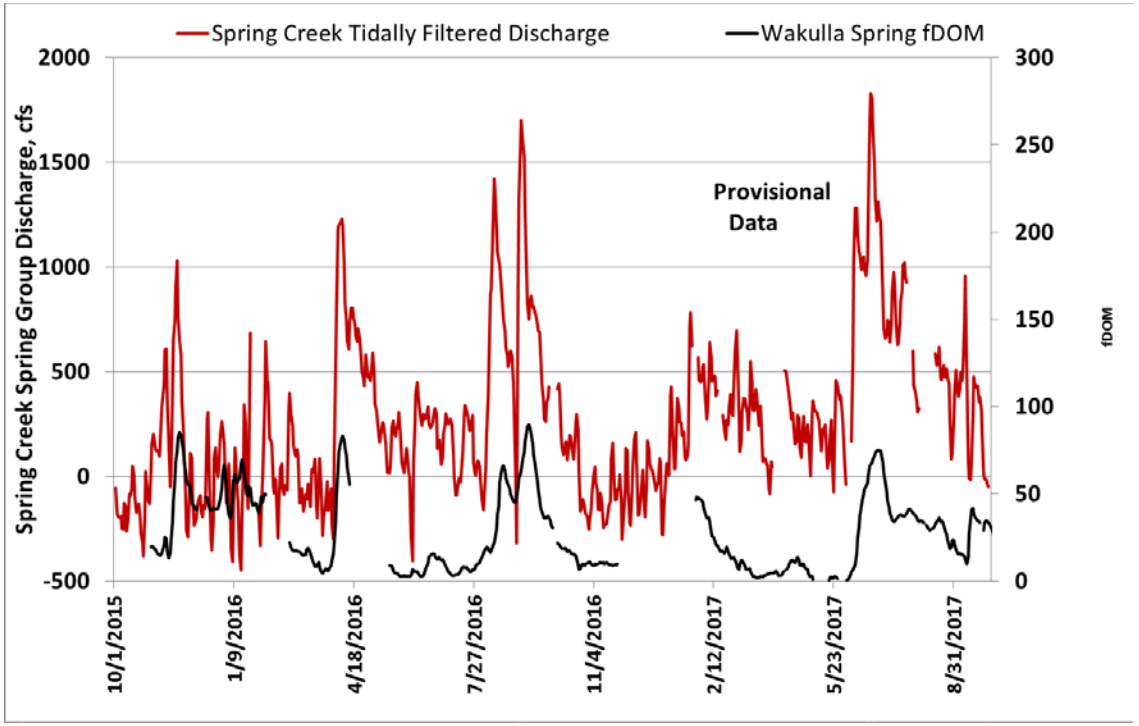




Water Clarity / Transparency / Color

Increased inflows from areas west of Wakulla Spring or chlorophyll from lakes to the north?

- FSU research indicates that “dark” tannic water originates in Apalachicola National Forest
- Limited data regarding trends in chlorophyll?



Water Quality - Nitrate

Upper Wakulla River TMDL and BMAP

WBID	PARAMETER	TMDL (MG/L)	TMDL% REDUCTION
1006	**Nitrate, as monthly average**	**0.35**	56.2%

- BMAP was adopted by the FDEP for Upper Wakulla River and Wakulla Spring (October 2015) to implement nitrate reductions to achieve the TMDL.
- Addresses nitrate loading from Wastewater Treatment Facilities (WWTFs), OSTDS, fertilizer, livestock, and stormwater.
- BMAP contains management strategies and projects for achieving nitrate reductions.

Wakulla Spring Water Quality Restoration

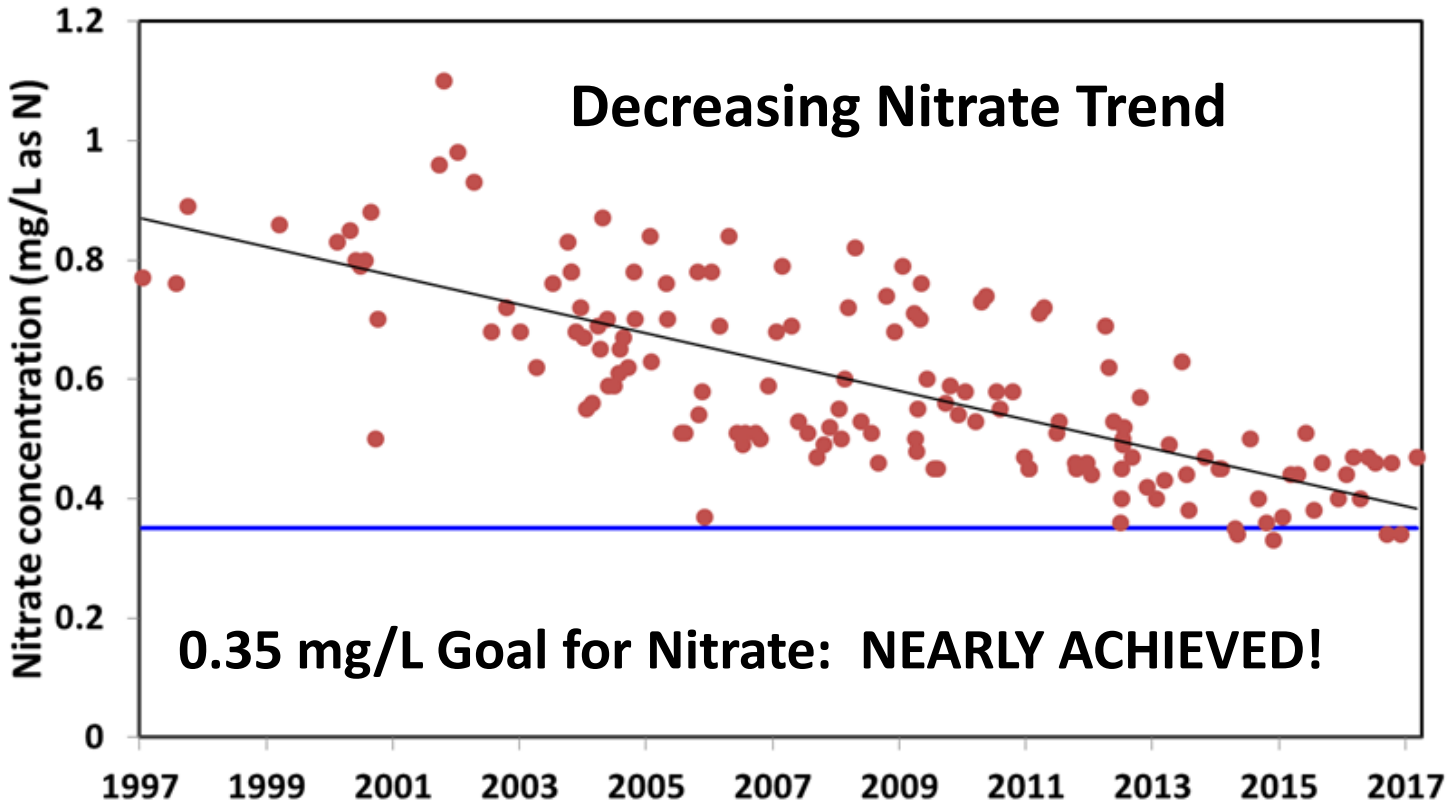
Project Metrics (FY 13/14 through FY 17/18)

- 5 Partners/Cooperators
- **$42.6 million** in grant funding, including local match
- **3,795** septic tank conversions to central sewer
- 32% of septic tanks in PFA1 and PFA2
- Reduce nitrogen loading by more than **43,000 lbs/year**

Water Quality – Nitrate Reductions

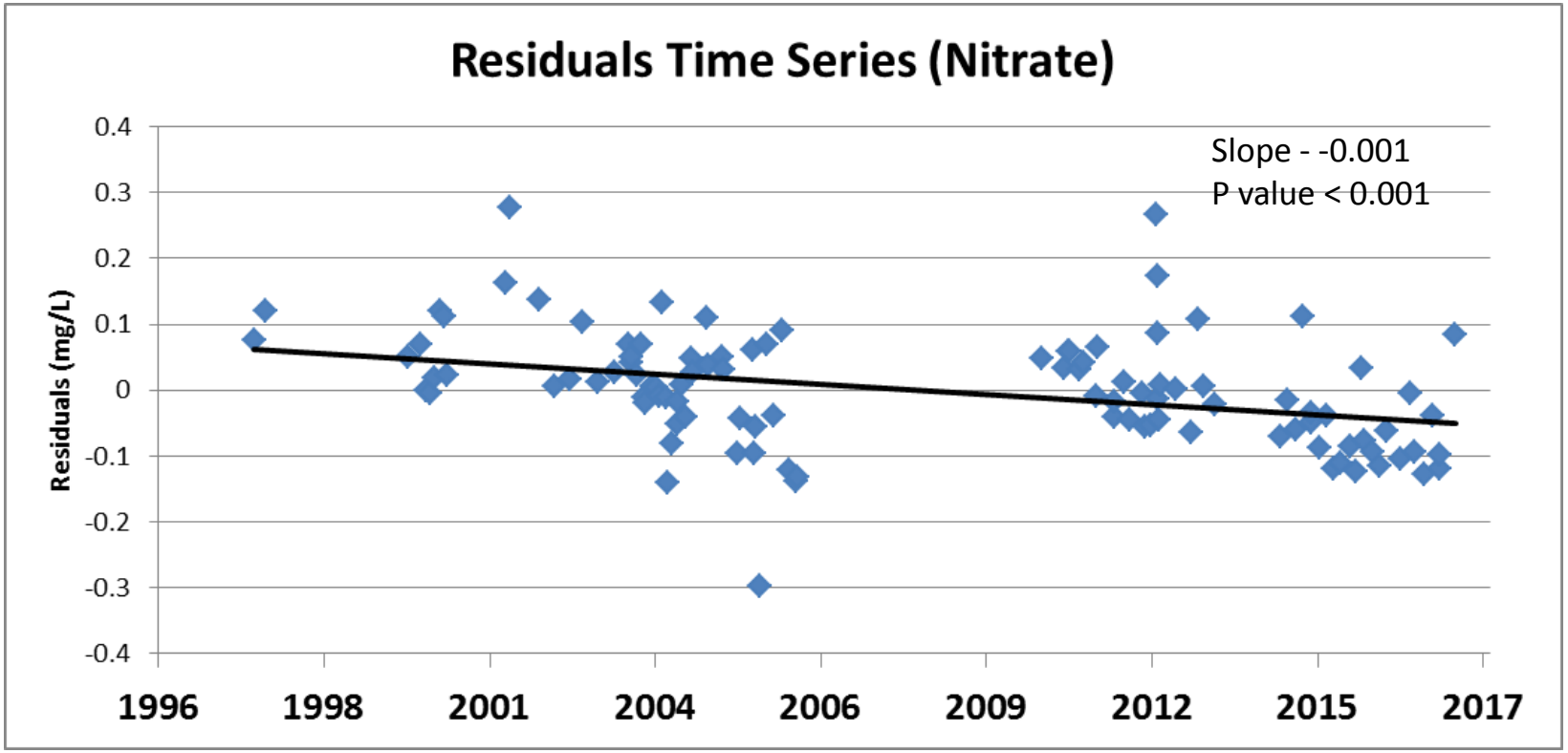
Wakulla Spring Restoration? Where are we now?

BMAP	Completed	Current/Ongoing	Total
Wakulla	$332,973,847	$64,137,780	**$397,111,627**



Water Quality – Nitrate Reductions

Nitrate levels, when adjusted for spring flow dilution, also exhibit a statistically significant declining trend.

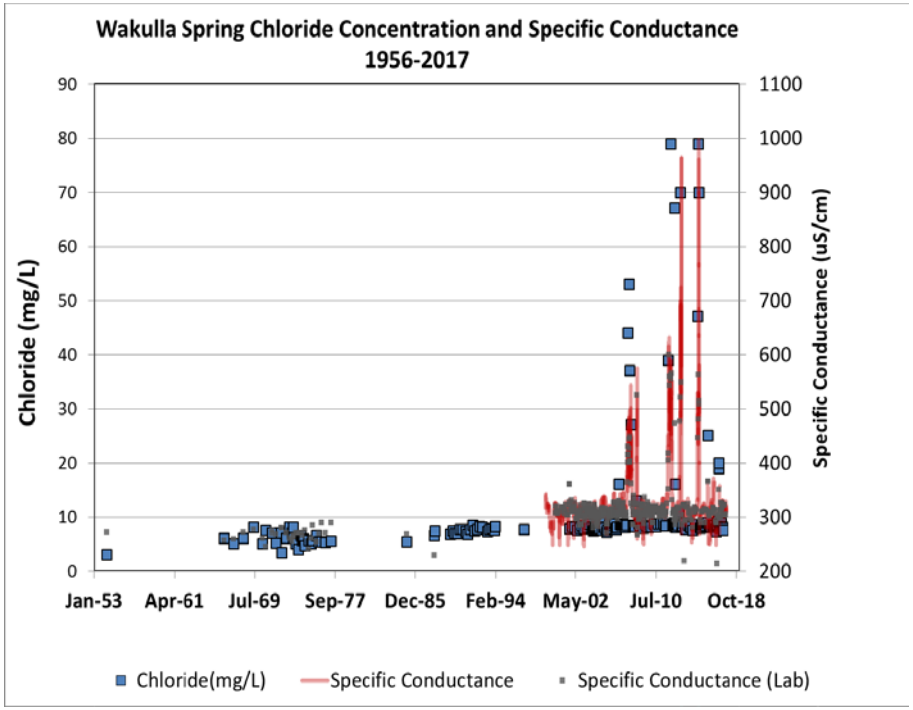


Specific Conductance and Chloride

Increasing Trend in Specific Conductance

1946 – 1987: mean = 267 uS/cm

1999-2017: mean = 323 uS/cm



Potential Causes:

- Seawater intrusion through the conduits (Xu, Bassett, Hu, and Dyer, 2016)
- Upward movement of the underlying mixing zone or saltwater interface
  - Interface estimated at 300 to 350 ft BLS based on St. Marks Refuge well
  - Divers report halocline at 240 to 270 ft BLS, and always below 300 ft at Punchbowl Sink.
- Other mechanisms ?

Opportunities for Future Analysis

- Better quantify cause and effect relationships related to discharge and water quality at Wakulla Spring
  - Rainfall / recharge
  - Conduit flow
  - Sea level rise
  - Groundwater pumpage
  - Other factors?
- Further evaluate existing and newer data
- Improve water budgets and mixing models
- Develop calibrate groundwater flow and/or statistical models
- Assess effects of changes in flow and water quality on ecology
- Continue monitoring and evaluation

Thank You

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