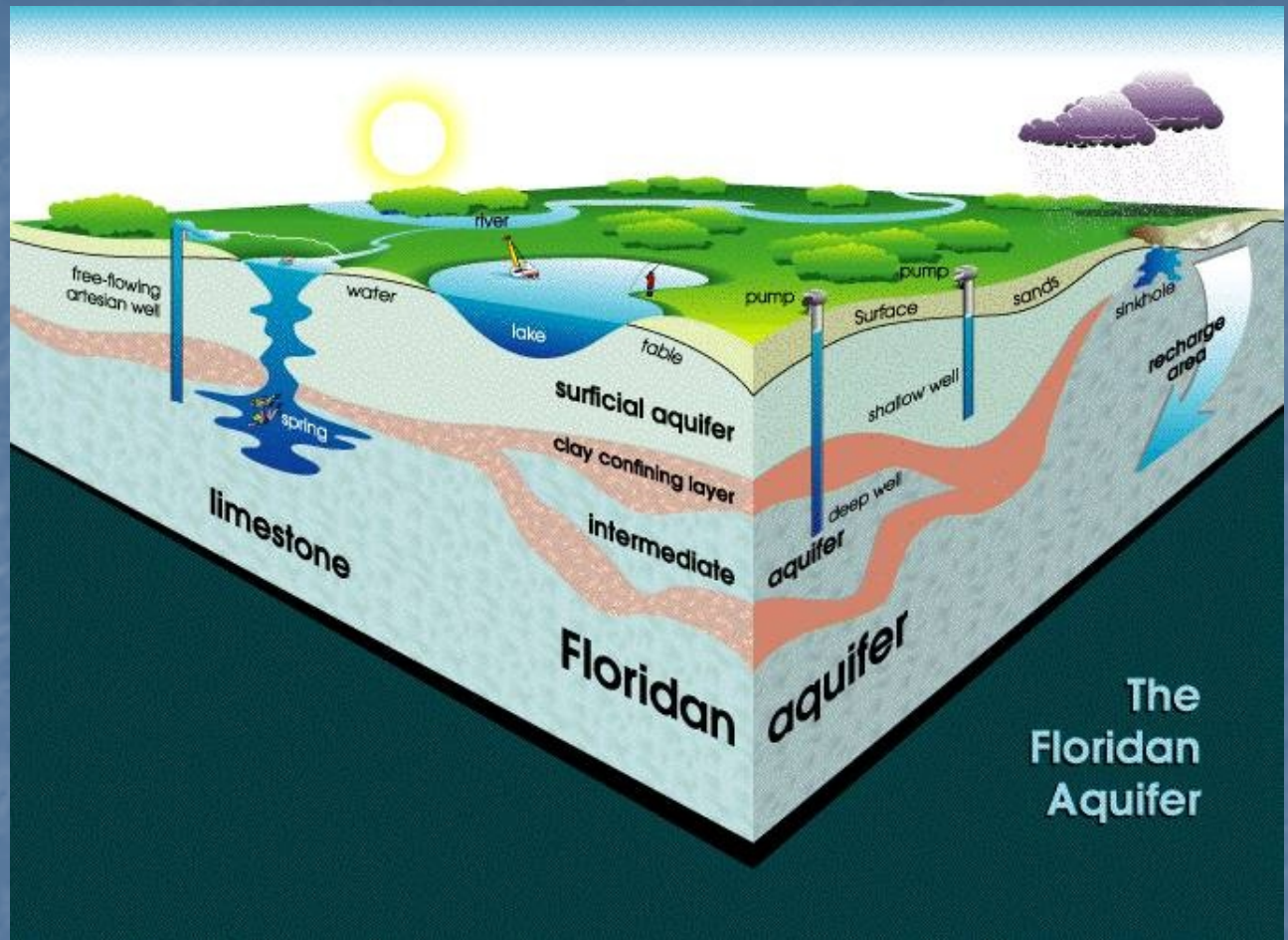


# Step Trend Analysis of Status Monitoring, Confined and Unconfined Aquifers

Rick Copeland  
Watershed Monitoring Section  
“ROC Fest”  
May 2017

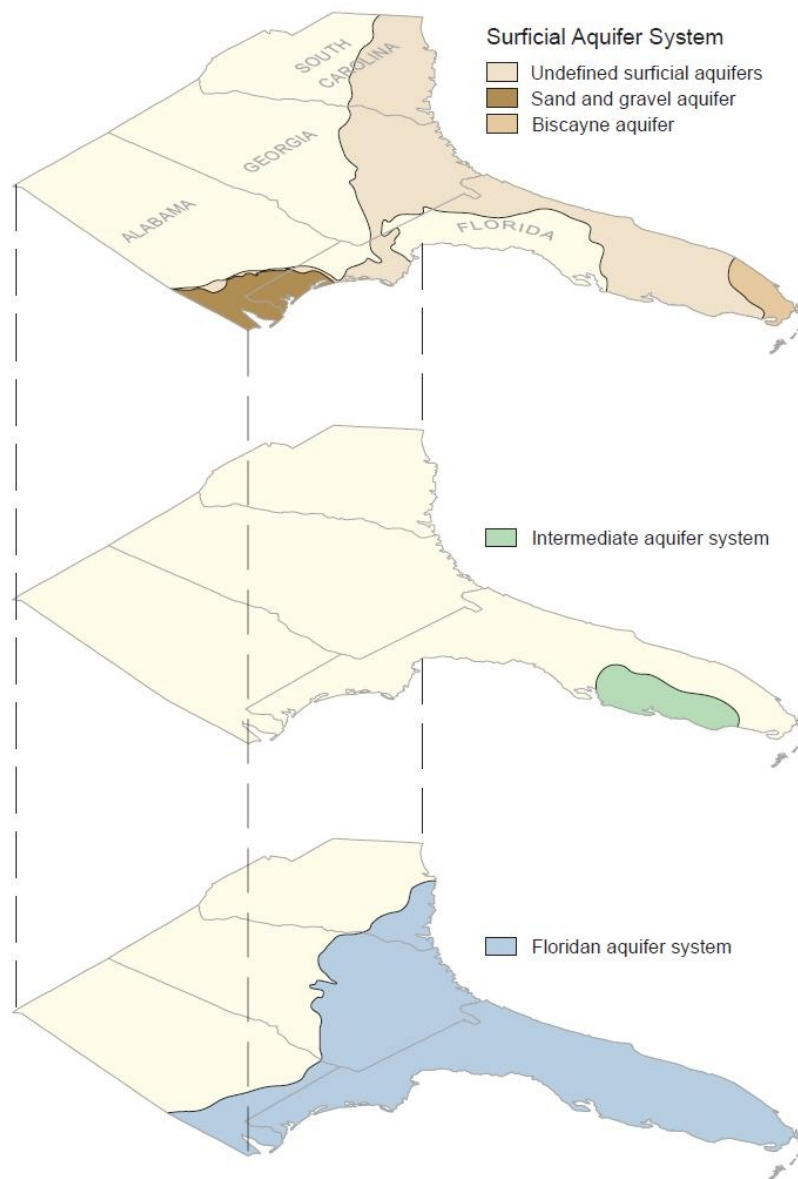
# Ground Water



## Aquifer Resources:

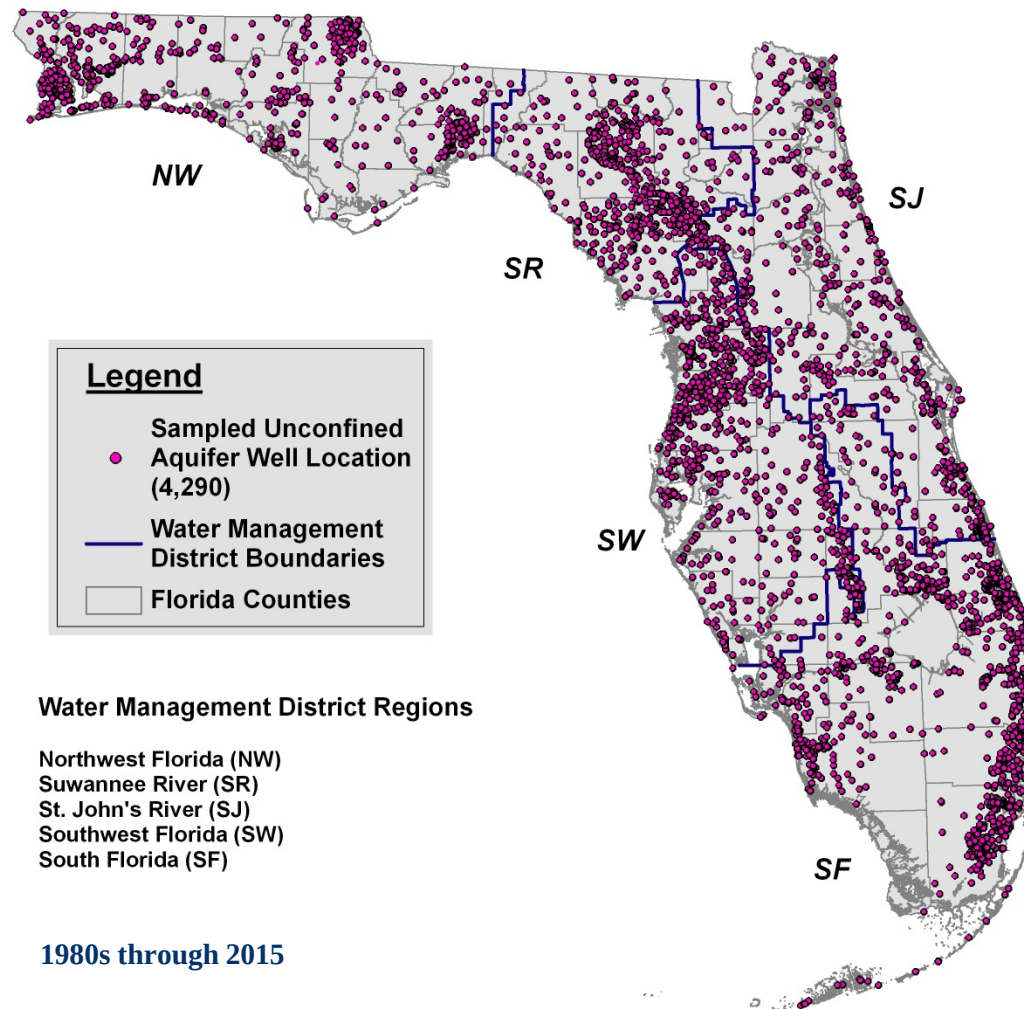
- Confined wells
- Unconfined wells

## Sequence of Aquifers

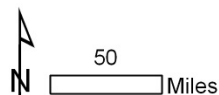




## Distribution of Sampled Unconfined Wells (Each Well Sampled for at Least One Sampling Event)

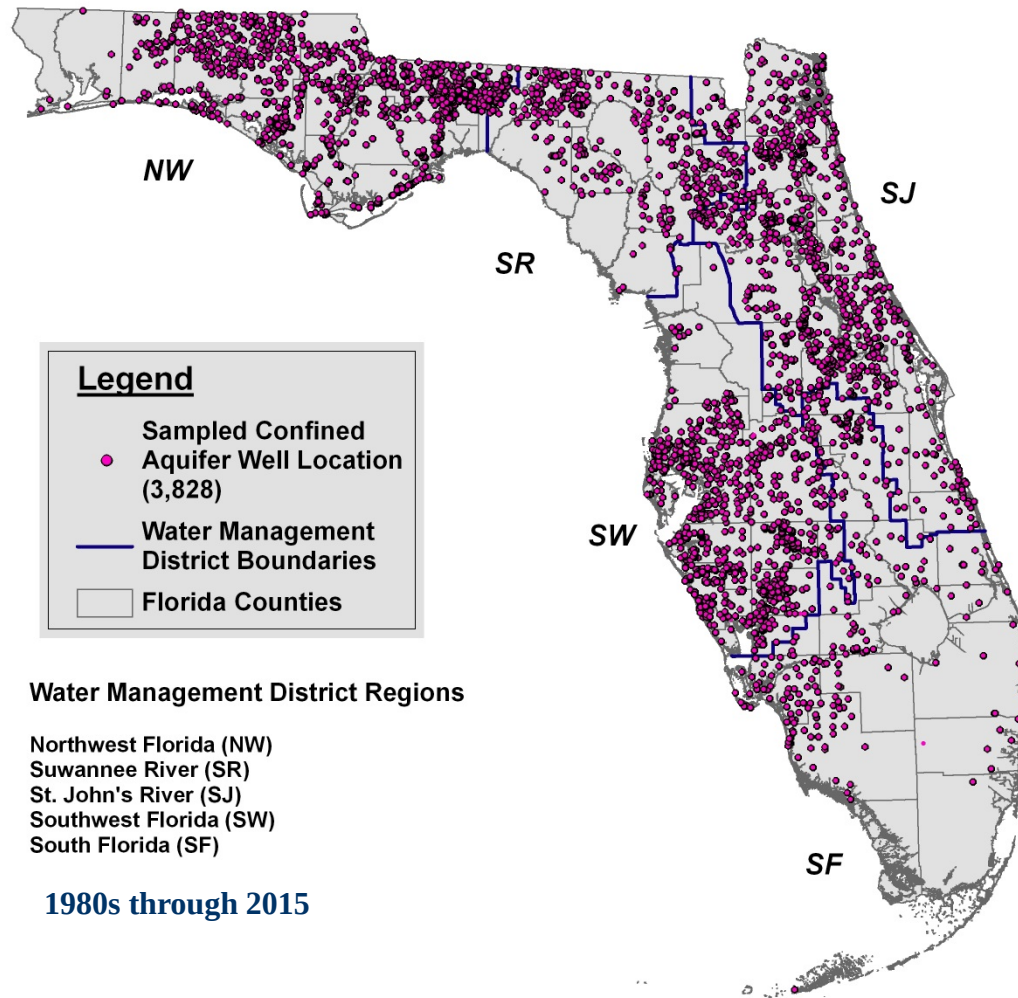


1980s through 2015



Created February 19, 2015. Map credited to Andy Woeber of the Watershed Monitoring Section, DEAR, FDEP.  
The map content is a cartographic representation and is not intended for further analysis.

# Distribution of Sampled Confined Wells (Each Well Sampled for at Least One Sampling Event)



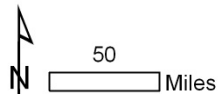
## Legend

- Sampled Confined  
Aquifer Well Location  
(3,828)
- Water Management  
District Boundaries
- Florida Counties

## Water Management District Regions

Northwest Florida (NW)  
Suwannee River (SR)  
St. John's River (SJ)  
Southwest Florida (SW)  
South Florida (SF)

1980s through 2015



Created February 19, 2015. Map credited to Andy Woeber of the Watershed Monitoring Section, DEAR, FDEP.  
The map content is a cartographic representation and is not intended for further analysis.

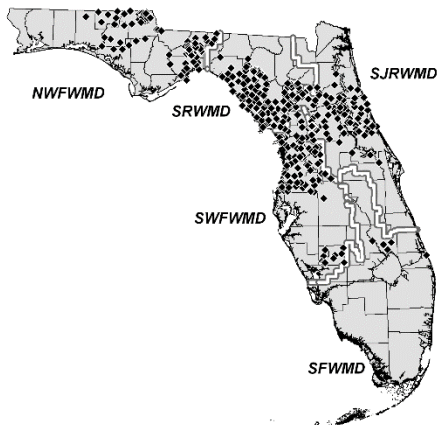
# Brief History

- 1984-1999 Status Monitoring Network was the Ambient GW Quality Monitoring Network
- 1991-1999 AGWQMN
  - Sampled all of FL in three-year cycles  
“Rotating Basins”
- “96-99” Developed Status Network (GW & SW)

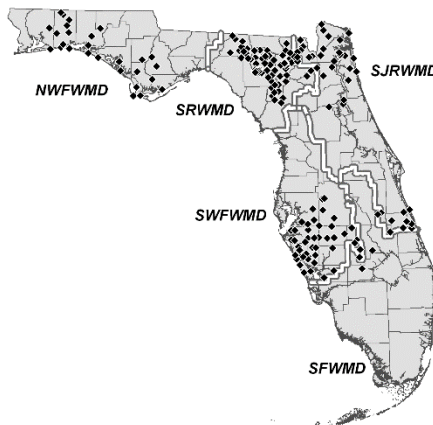


# 

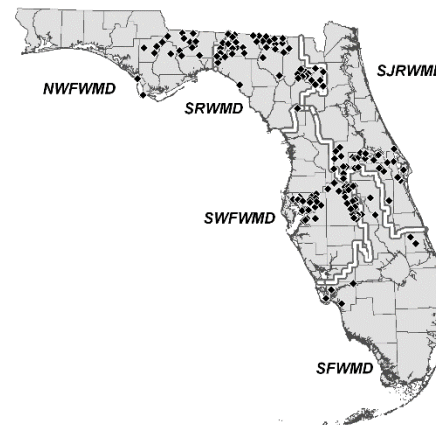
Monitoring Year: 1997  
Number of Wells = 466



Monitoring Year: 1998  
Number of Wells = 273



Monitoring Year: 1999  
Number of Wells = 189



### 

- ◆ Well Location
- Water Management Boundaries
- Florida Counties

### 

- Northwest Florida (NFWMD)
- Suwannee River (SRWMD)
- St. John's River (SJRWMD)
- Southwest Florida (SWFWMD)
- South Florida (SFWMD)



100

Miles

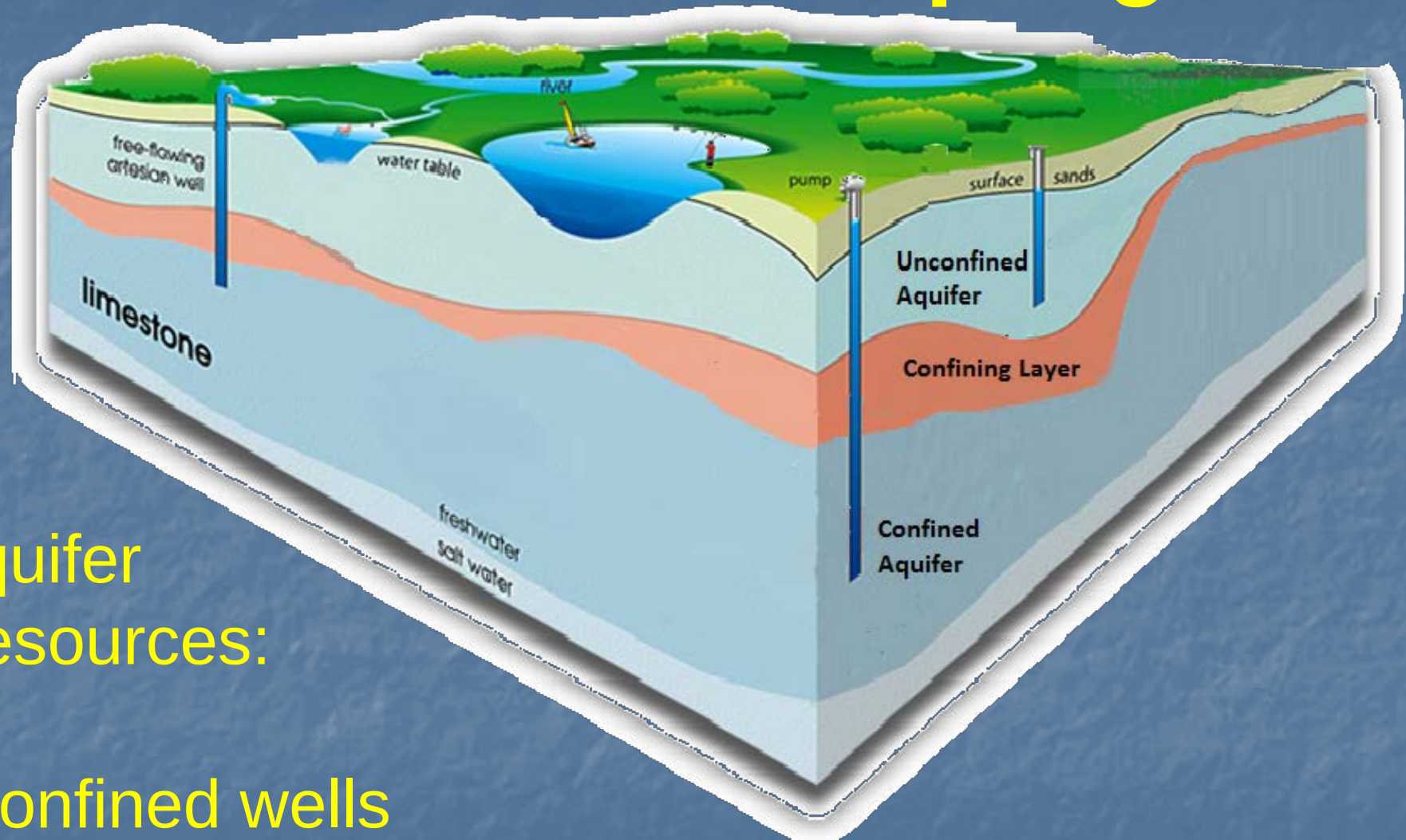
Map created by Andy Woelber, WMS, FDEP  
and dated April 5, 2016. This map is a  
cartographic representation and is  
not suitable for analysis.

# Brief History

- Beginning in 2000, Status Network sampled GW & SW as “Rotating Basins”
- Wells selected randomly (“Probabilistic”)
- 1<sup>st</sup> Cycle 2000-2003
- Instead of sampling by aquifers, GW sampled as **Confined** (CN) and **Unconfined** (UN) aquifers



# Ground Water Sampling



Aquifer  
Resources:

- Confined wells
- Unconfined wells

# Brief History

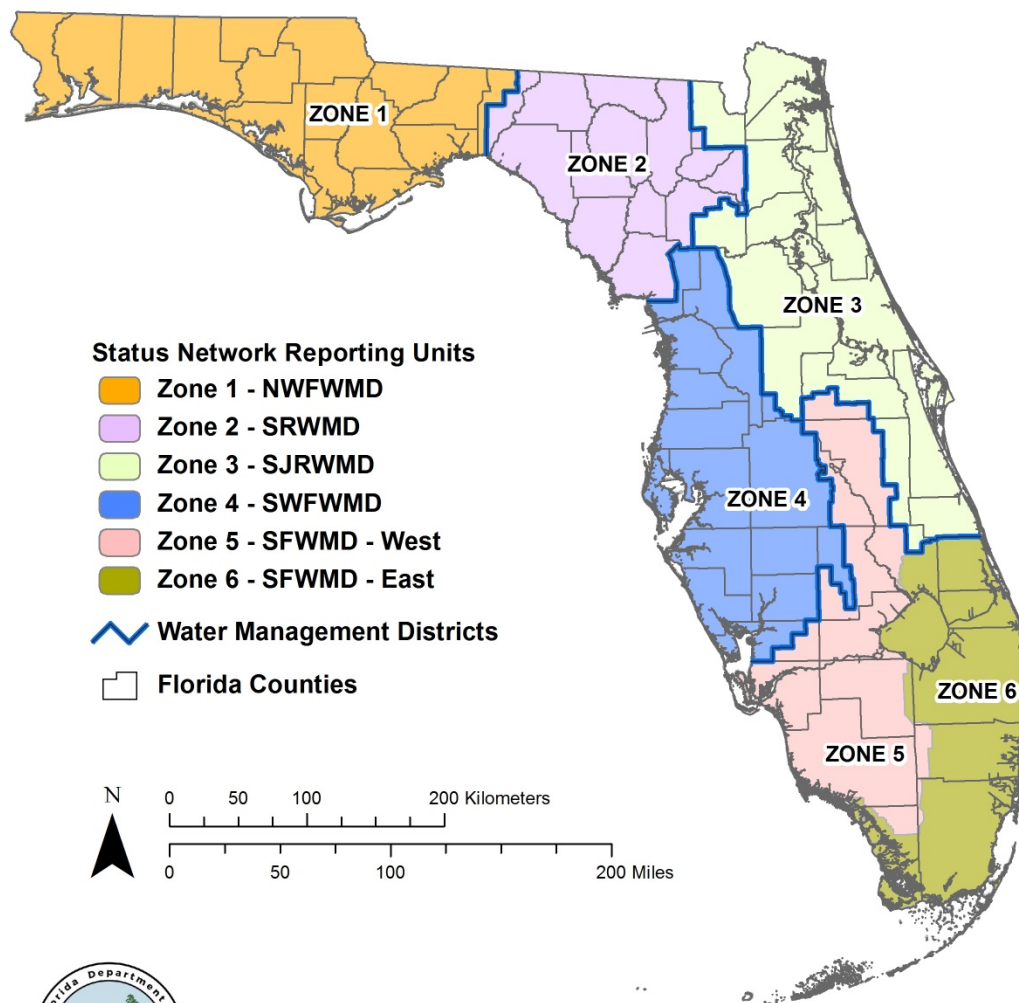
- Design Modifications in 2004 & 2009
- Beginning in 2009, FL sampled annually
- Maintained this design since 2009

# Brief History

- By 2016, SN has been in operation since 2000
  - Has GW quality changed?
  - If so, what parameters and at what scale?
- It was decided to compare:
  - 1<sup>st</sup> SN cycle (2000-2003) to last three (2013-2015)
  - Begin with statewide scale
- Use the STEP TREND for statistical evaluations
  - Can be used at a variety of time and areal scales
  - Can be used for SW as well as GW



# Watershed Monitoring Reporting Units



Created August 24, 2015 by Florida Department of Environmental Protection staff in the Division of Environmental Assessment and Restoration, Watershed Monitoring Section. This map is a representation of ground conditions and is not intended for further analysis. For more information contact (850)-245-8433.

# Step Trend: Helsel and Hirsch (2002)

- Useful for evaluating “long-term” changes in hydrologic variables
- Compares two non-overlapping sets of “early” (E) and “late” (L) data
- Step Trend: Because values step up or down 
- Compare median of E to L data groups
  - 1. When a known event has occurred which may change water quality
  - 2. When record is broken into to time periods with “long” gap between them

# Step Trend

- 1. Divide time interval into 3 periods
- 2. Determine coverage in each period (number of data points within each: E, M, L)
- 3. If any third has  $< 20\%$  of total coverage, do not use corresponding period
  - Note we are concerned with the E and L periods only



# Step Trend

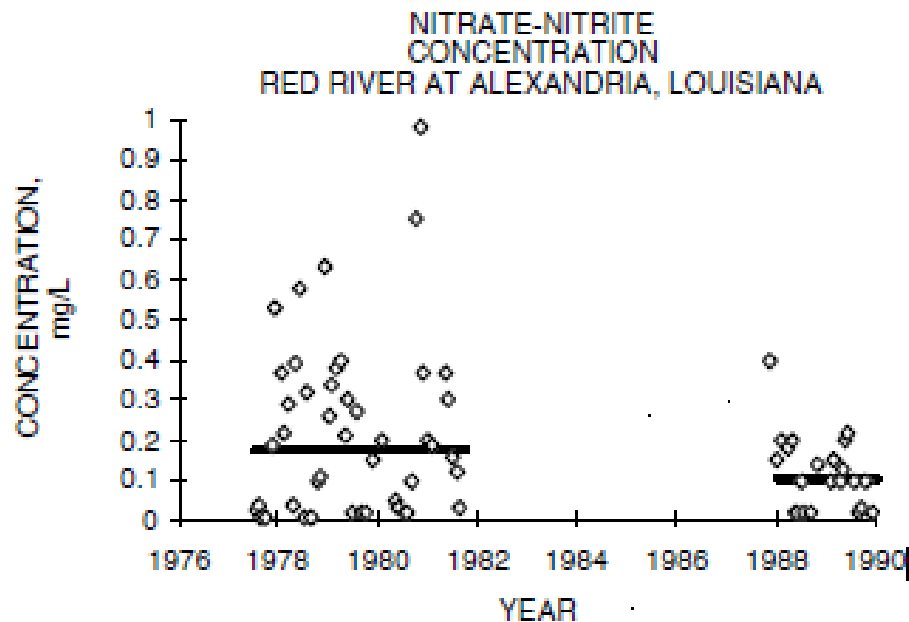
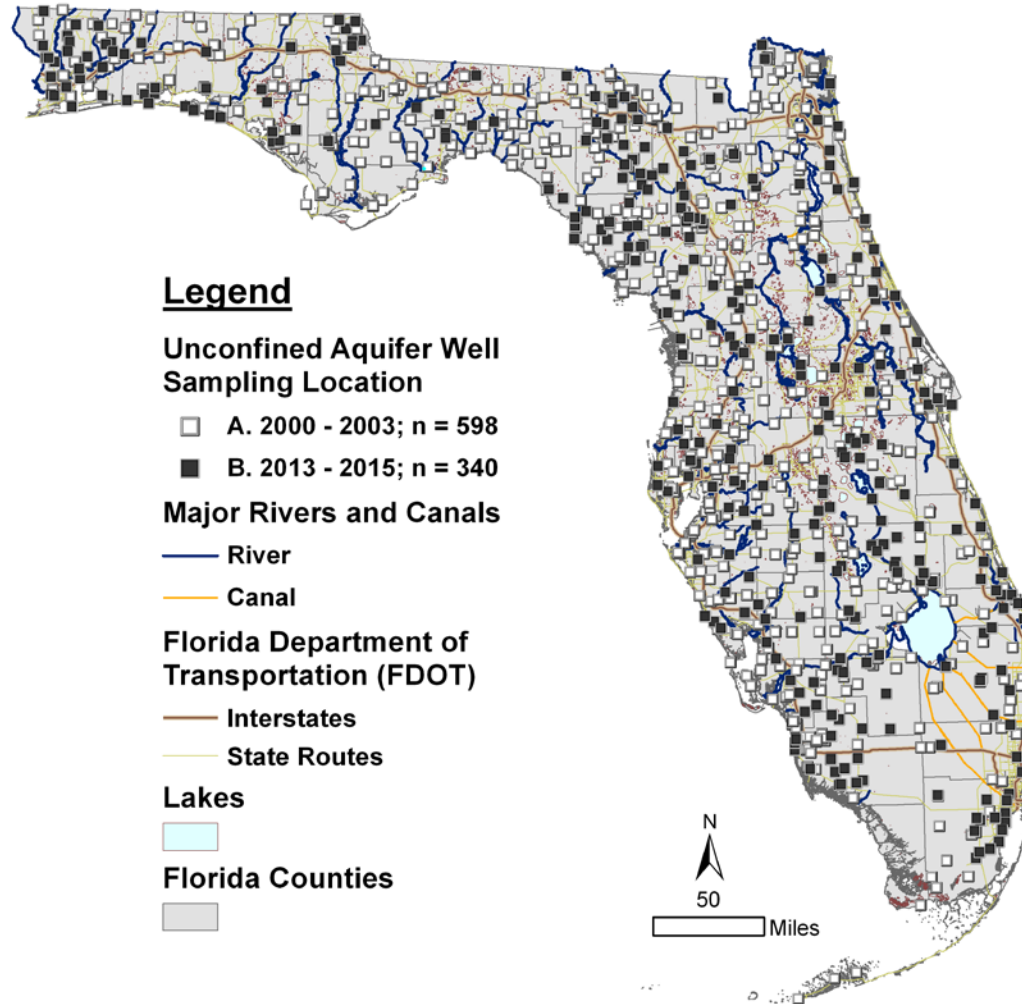


Figure 12.15 Significant ( $p=0.085$ ) step trend as measured by rank-sum test. Solid lines are group medians. Monotonic trend test is not significant ( $p=0.167$ ). Modified from Hirsch et al., 1991.

Helsel and Hirsch (2002)

# Unconfined Aquifer Wells Sampled in: A. 2000-2003 and in B. 2013-2015



Map created by Andy Woeber, Watershed Monitoring Section, DEP on April 26, 2017. The map is a cartographic product and not suitable for analysis.

# Step Trend

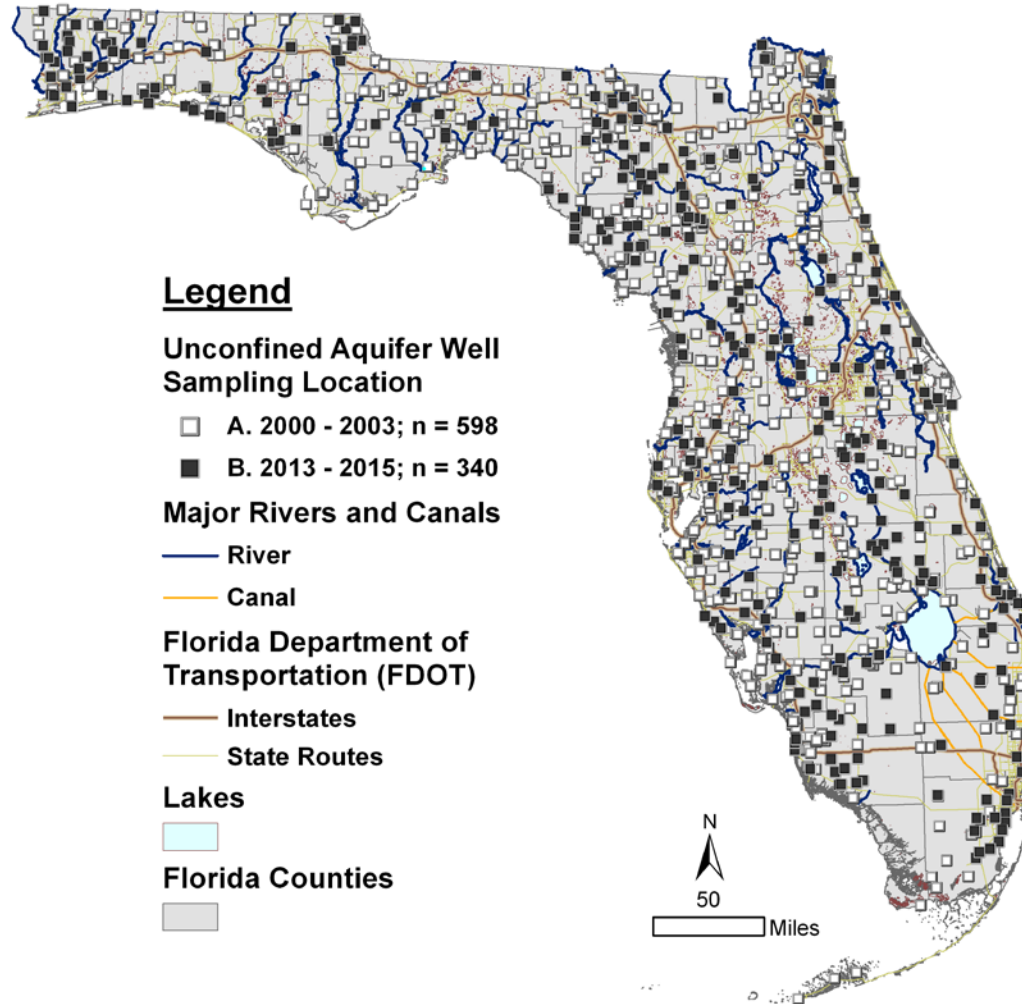
- Number of samples for E:  $598 - 41 = 557$
- Number of samples for L:  $340 - 41 = 299$
- Both E and L have  $> 20\%$  of total: **can use**



# Two Types of Step Trends Used

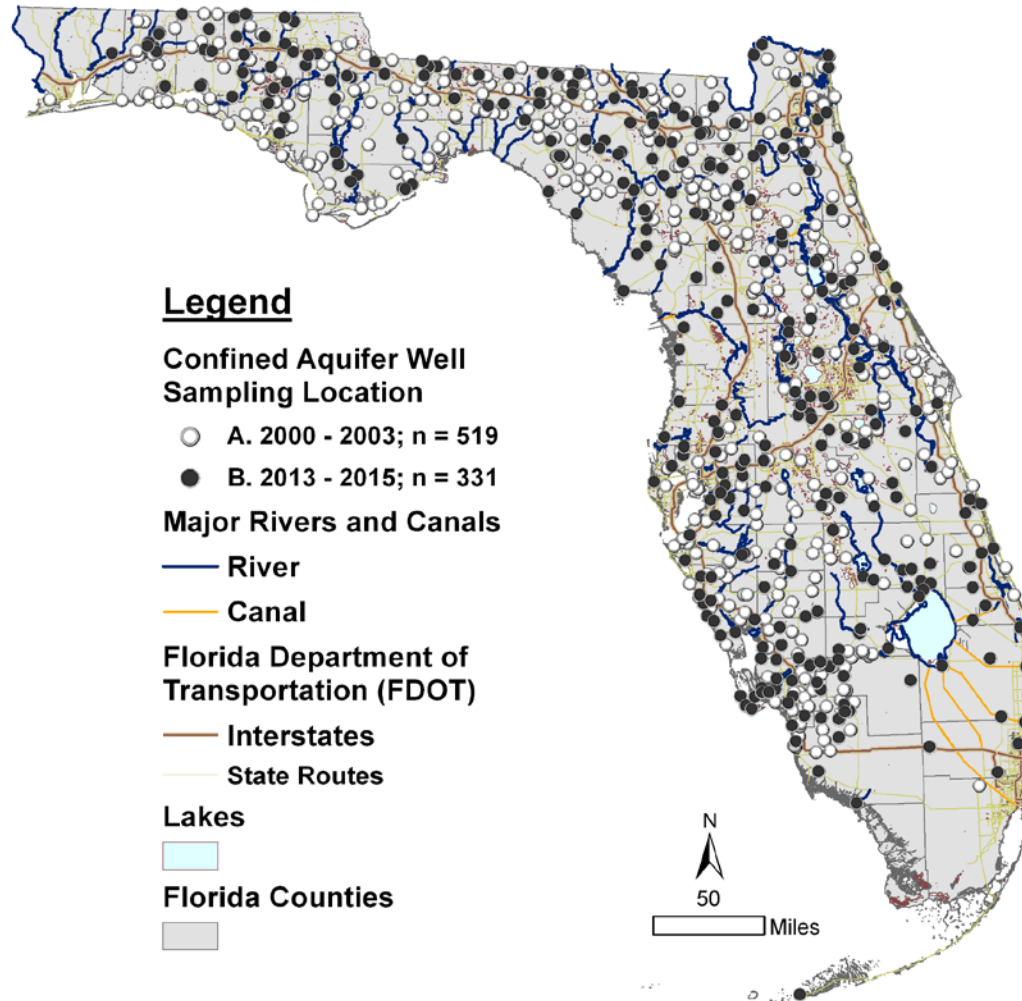
- 1. If wells are sampled either in E or L period, but not in both: Mann-Whitney (MW) test
- 2. If some of wells are sampled in both periods: Wilcoxon Sign-Rank (WSR) test (E.G. 41 wells)
- Null Hypothesis:  $\text{Med}(E) = \text{Med}(L)$ 
  - Confidence Level pre-set = 0.90 or 90%
  - If 10% to 100% sure of equal medians, do not reject
  - If < 10% sure they are equal, reject
  - If 5 to < 10% sure they are equal, “early warning”
  - Fraction (or %) is called the **p-val** of the test

# Unconfined Aquifer Wells Sampled in: A. 2000-2003 and in B. 2013-2015



Map created by Andy Woeber, Watershed Monitoring Section, DEP on April 26, 2017. The map is a cartographic product and not suitable for analysis.

## Confined Aquifer Wells Sampled in: A. 2000-2003 and in B. 2013-2015



Map created by Andy Woeber, Watershed Monitoring Section, DEP on April 26, 2017. The map is a cartographic product and not suitable for analysis.



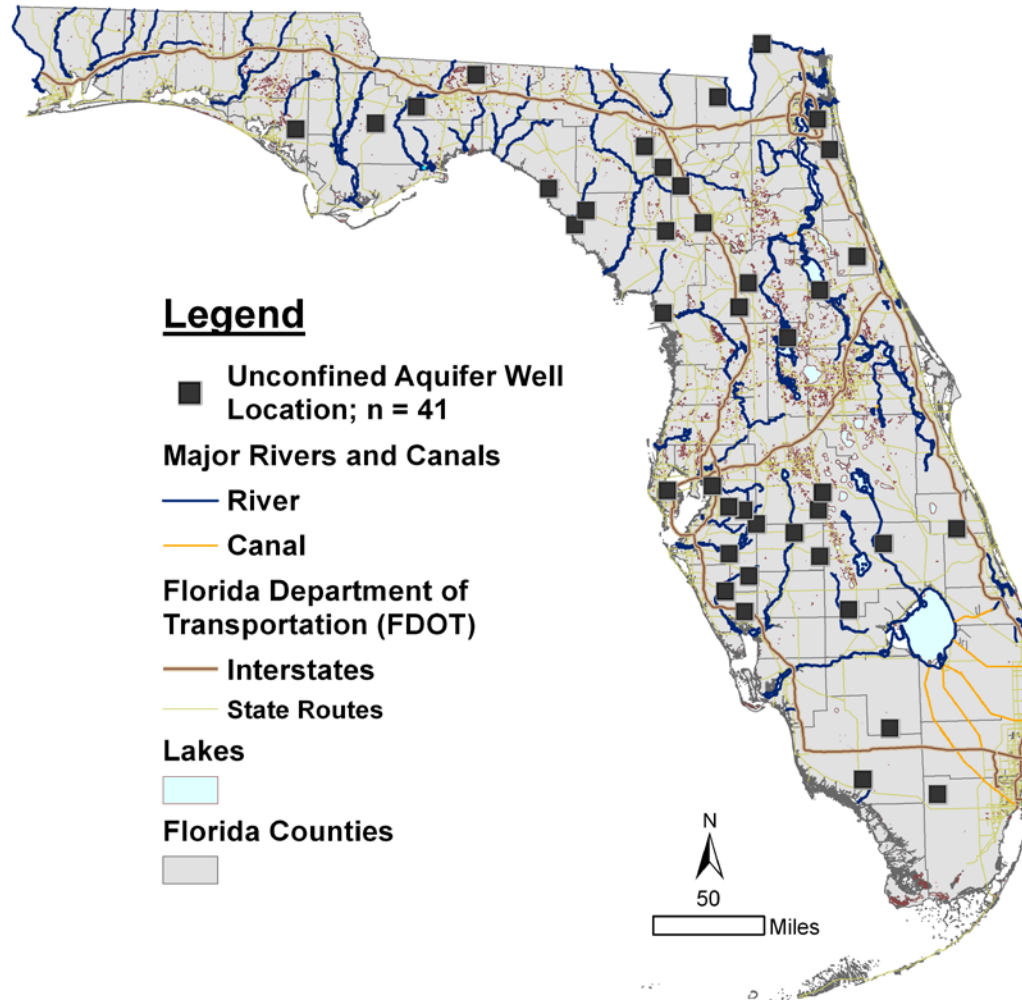
# MW Results (Selected Params)

(UN: n(E) = 557, n(L) = 299]

(CN: n(E) = 519, n(L) = 282]

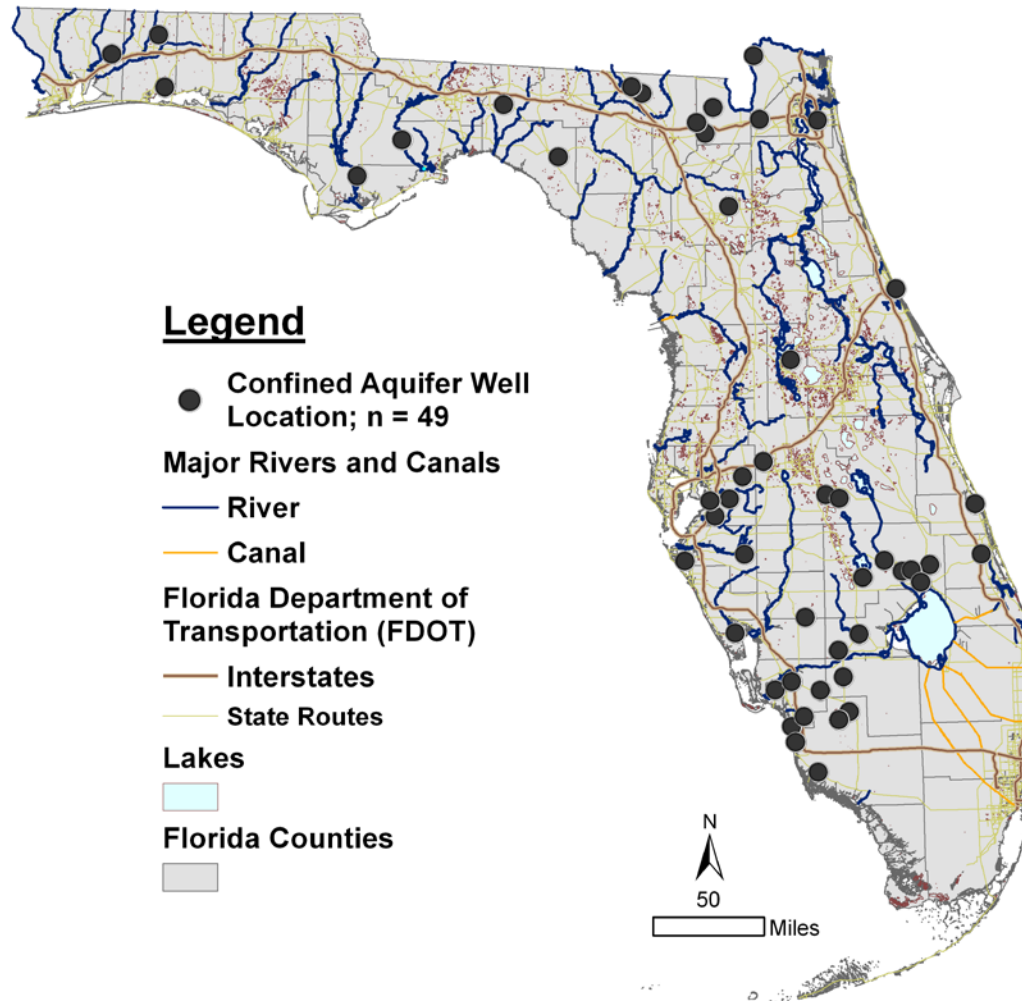
| Parameter | Unconfined<br>P-val | Unconfined<br>Direction | Confined<br>P-val | Confined<br>Direction |
|-----------|---------------------|-------------------------|-------------------|-----------------------|
| Ca        | 0.046               | Up                      | <0.001            | Up                    |
| Mg        |                     |                         | <0.001            | Up                    |
| Na        | 0.044               | Up                      | <0.001            | Up                    |
| K         | 0.001               | Up                      | <0.001            | Up                    |
| Alk       |                     |                         | 0.003             | Up                    |
| Cl        | 0.063 (EW)          | Up                      | <0.001            | Up                    |
| SO4       |                     |                         | <0.001            | Up                    |
| GW Level  | 0.004               | Up                      | 0.002             | Up                    |

# Unconfined Aquifer Wells Sampled Both Periods of 2000-2003 and 2013-2015



Map created by Andy Woeber, Watershed Monitoring Section, DEP on April 26, 2017. The map is a cartographic product and not suitable for analysis.

## Confined Aquifer Wells Sampled Both Periods of 2000-2003 and 2013-2015





# WSR Results (Selected Params)

(results in table, only if significant change)

[n(Un)= 41; n(CN) = 49]

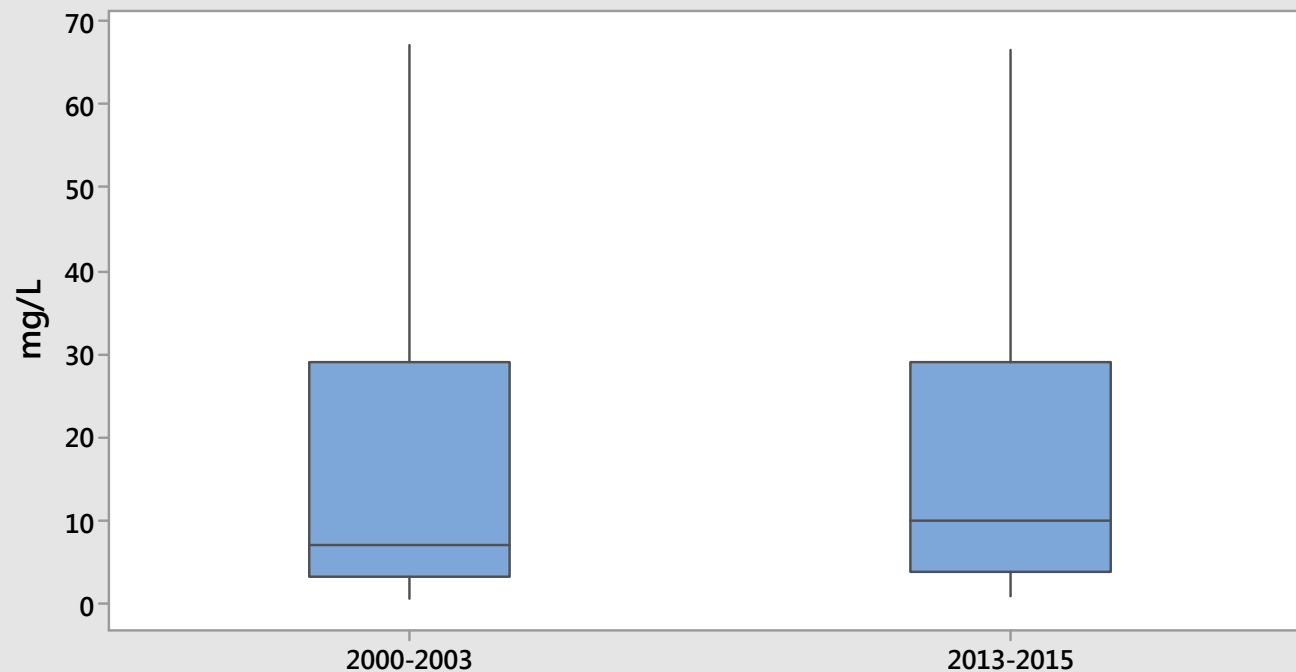
| Parameter | Unconfined<br>P-val | Unconfined<br>Direction | Confined<br>P-val | Confined<br>Direction |
|-----------|---------------------|-------------------------|-------------------|-----------------------|
| Ca        |                     |                         |                   |                       |
| Mg        |                     |                         | 0.009             | Up                    |
| Na        | 0.040               | Up                      | 0.001             | Up                    |
| K         | 0.051 (EW)          | Up                      | 0.017             | Up                    |
| Alk       |                     |                         |                   |                       |
| Cl        | 0.009               | Up                      | 0.011             | Up                    |
| SO4       |                     |                         |                   |                       |
| GW Level  | 0.005               | Up                      | 0.009             | Up                    |

# Step Trend Concern

- Have reasonable idea of data behavior during E and L periods
- Do not have knowledge of behavior of data during M period
- Examples: Na and Cl
  - MW Tests

# Sodium Concentrations Unconfined Aquifers

Unconfined Aquifers Sodium Concentrations in Florida  
(Outliers Removed)



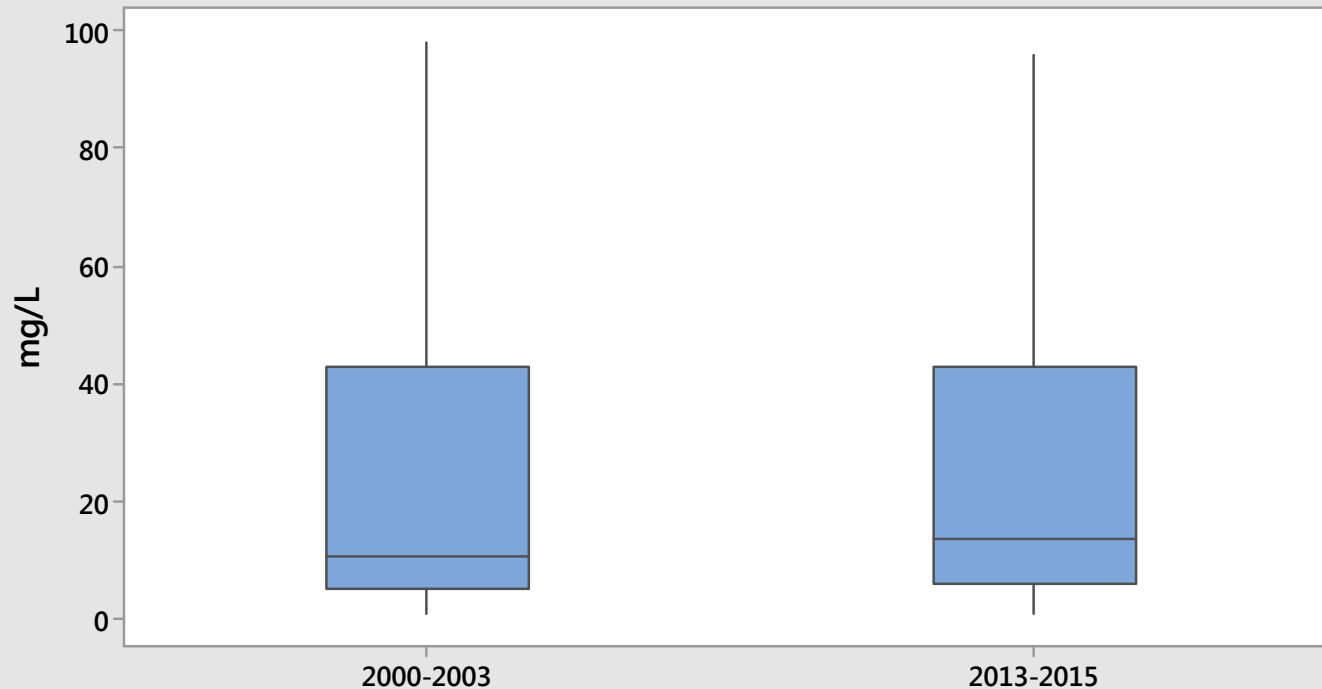
*Median (2000-2003) = 7.1*

*Median (2013-2015) = 9.9*



# Chloride Concentrations Unconfined Aquifers

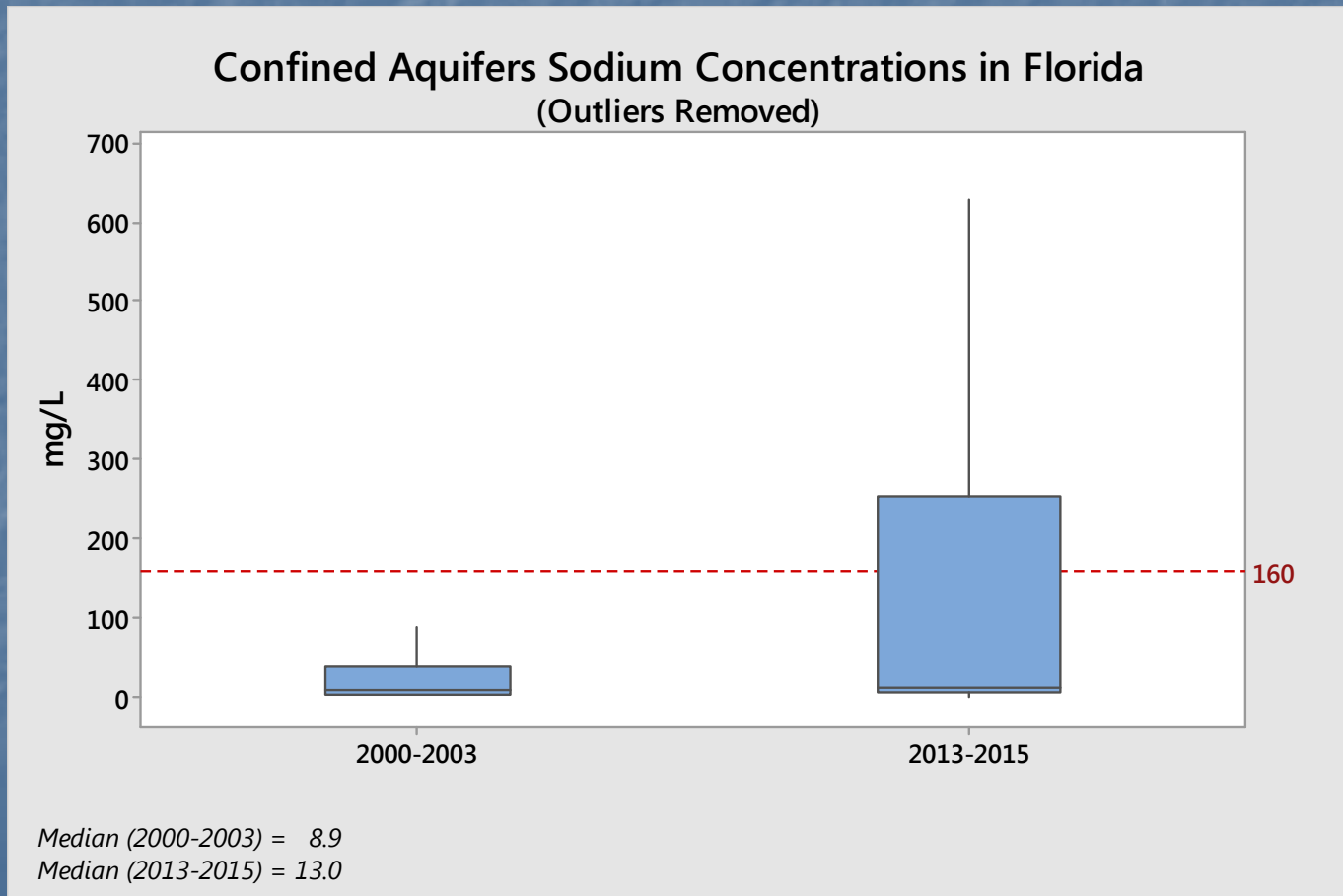
Unconfined Aquifers Chloride Concentrations in Florida  
(Outliers Removed)



*Median (2000-2003) = 11.0*

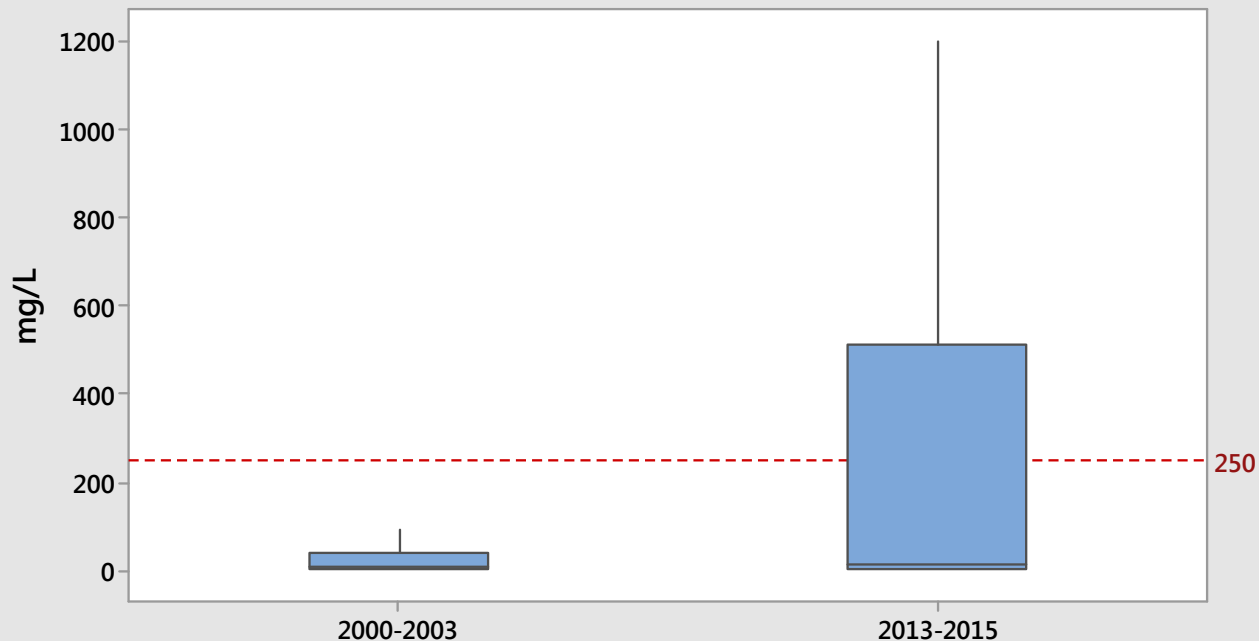
*Median (2013-2015) = 14.0*

# Sodium Concentrations Confined Aquifers



# Chloride Concentrations Confined Aquifers

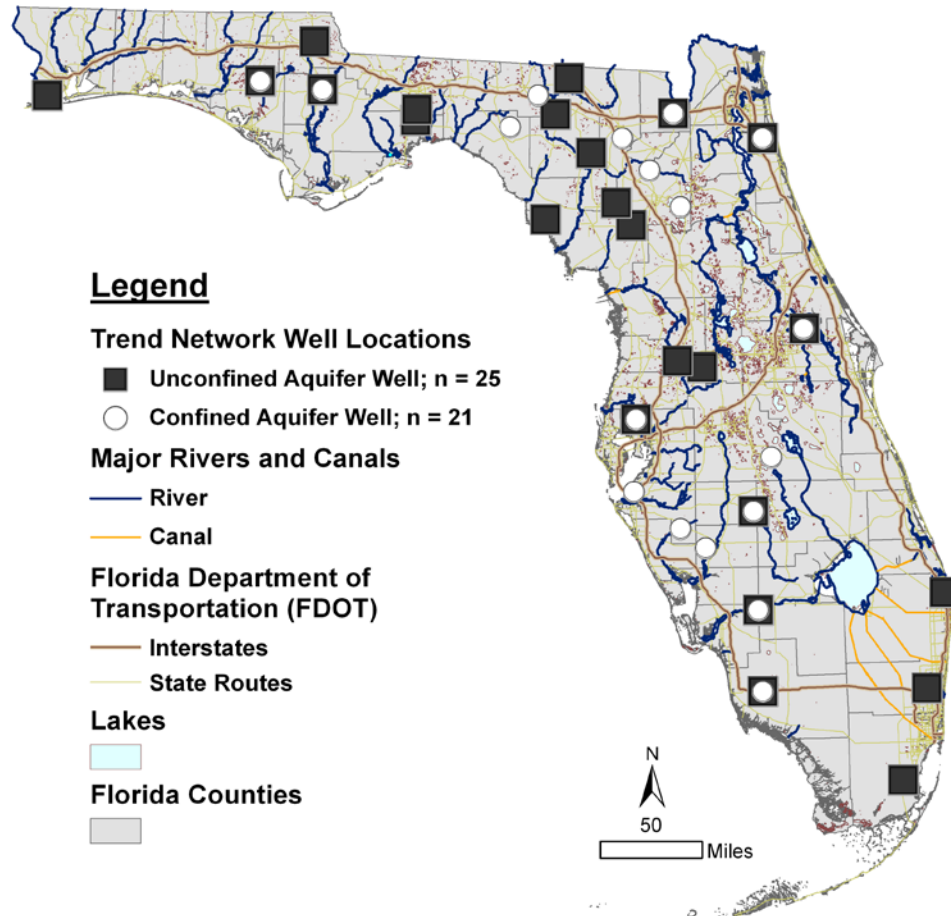
Confined Aquifers Chloride Concentrations in Florida  
(Outliers Removed)



Median (2000-2003) = 11.0  
Median (2013-2015) = 18.0



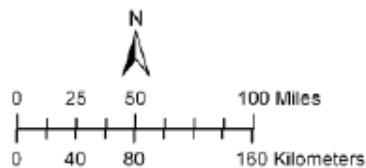
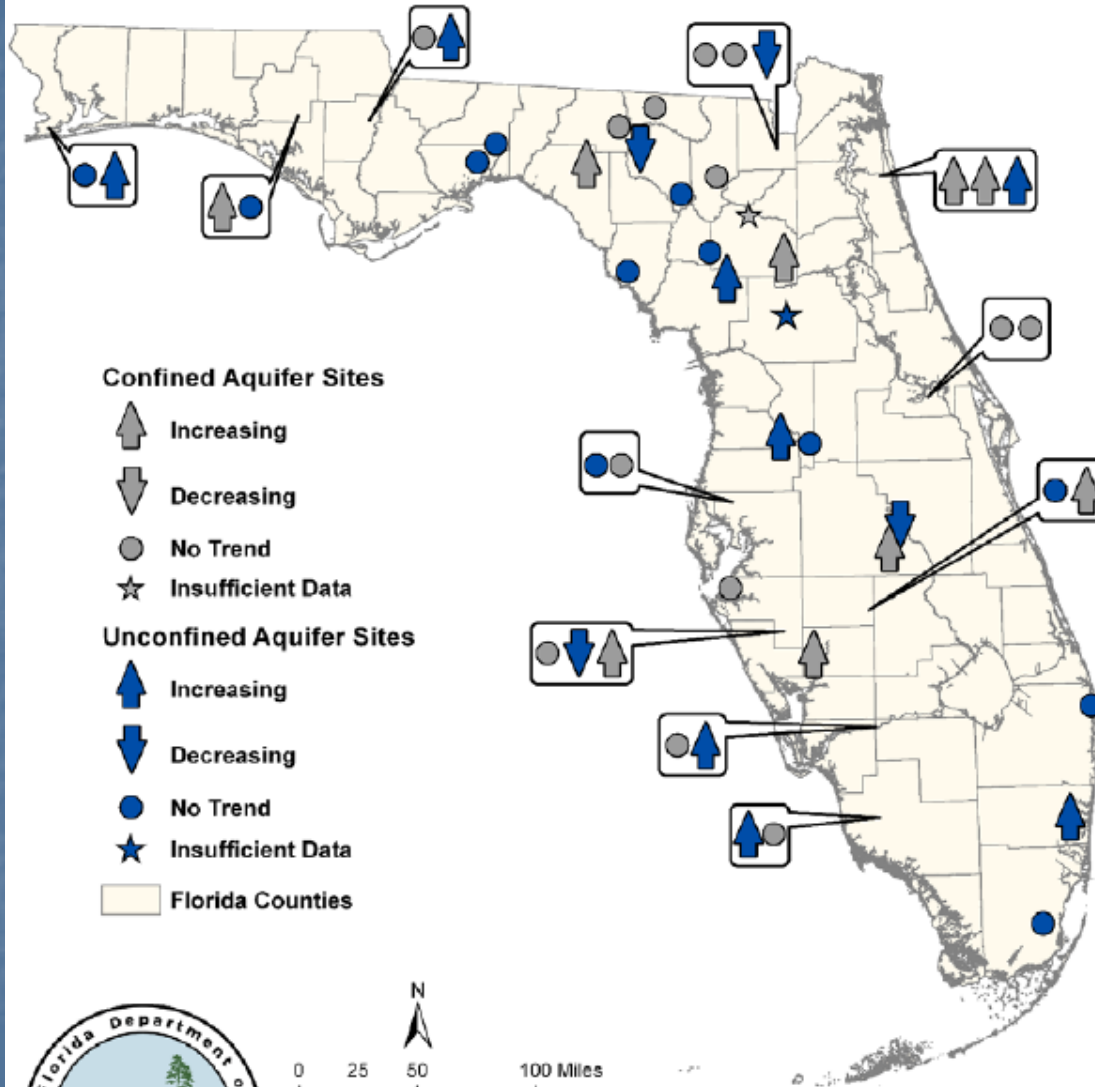
## Unconfined and Confined Trend Network Wells Sampled 2000 - 2015



# GW Trend Network

- From 2016 Integrated Water Quality Assessment Report [“305(b)”] for EPA
- GW Trends for Chloride (2000-2014) at 46 Trend sites

# Ground Water Trend Chloride

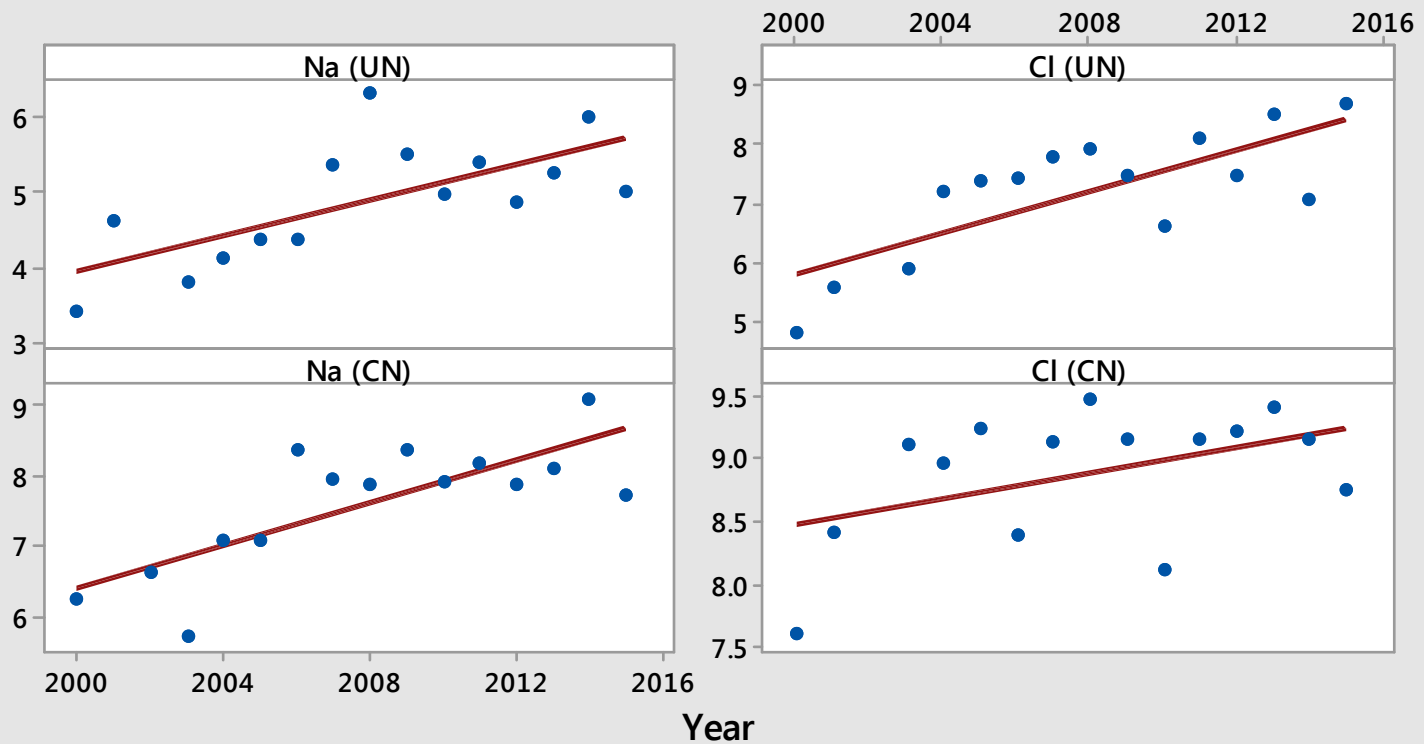


Created November 17, 2015 by Andy Woerber  
of the Watershed Monitoring Section, DEAR, FDEP.

The map content is a cartographic representation  
and is not intended for further analysis.

## Trend Network

### Median Concentration of Na and Cl for all Trend Network Wells (Annual Medians: 2000-2015) (Concentrations in mg/L)





# Kendall Tests for Trends

- Mann-Kendall (MK) test
  - Basic test for trend
- Seasonal-Kendall (SK) test
  - Adjusts for seasonality effects
- Regional-Kendall (RK) test
  - Relatively new
  - Agglomerates all sites in a region in order to evaluate a regional trend

# RK Results (Selected Params)

(results in table, only if significant change)

- Data from 25 UN and 21 CN Trend Wells
- Currently, analyses only partially completed

| Parameter | Unconfined P-val | Unconfined Direction | Confined P-Val | Confined Direction |
|-----------|------------------|----------------------|----------------|--------------------|
| Na        | 0.005            | Up                   | 0.001          | Up                 |
| Cl        | <0.003           | Up                   | <0.001         | Up                 |
| GW Level  | 0.265            |                      | Incomplete     |                    |

# Rates\* of Change (Na and Cl)

| Trend Type | UN Na | CN Na | UN Cl | CN Cl |
|------------|-------|-------|-------|-------|
| MW (SN)    | 2.47  | 5.65  | 2.61  | 3.96  |
| WSR (SN)   | 2.25  | 4.00  | 3.00  | 3.50  |
| RKT (TrN)  | 0.34  | 0.63  | 0.50  | 0.30  |

\*Rates (mg/L / decade)

“Typical” changes are in “several” mg/L / decade

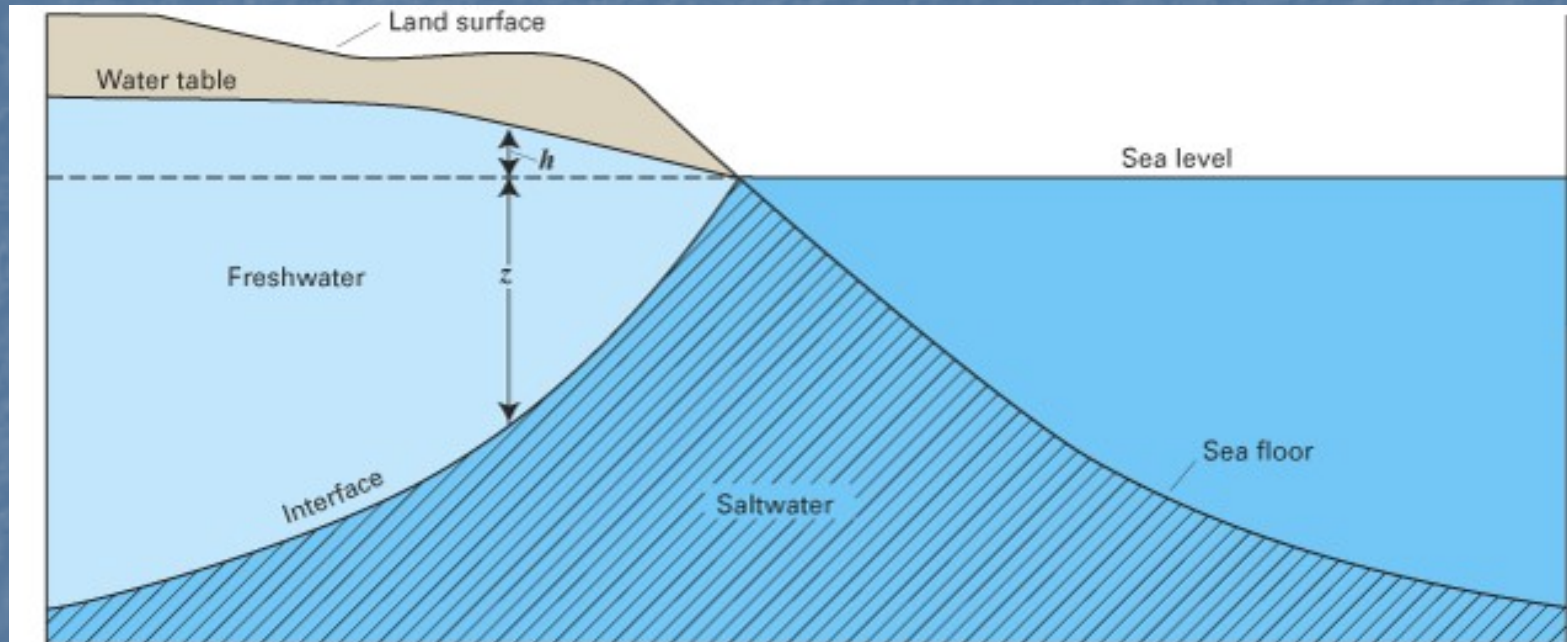
## Med Depth by Well Type

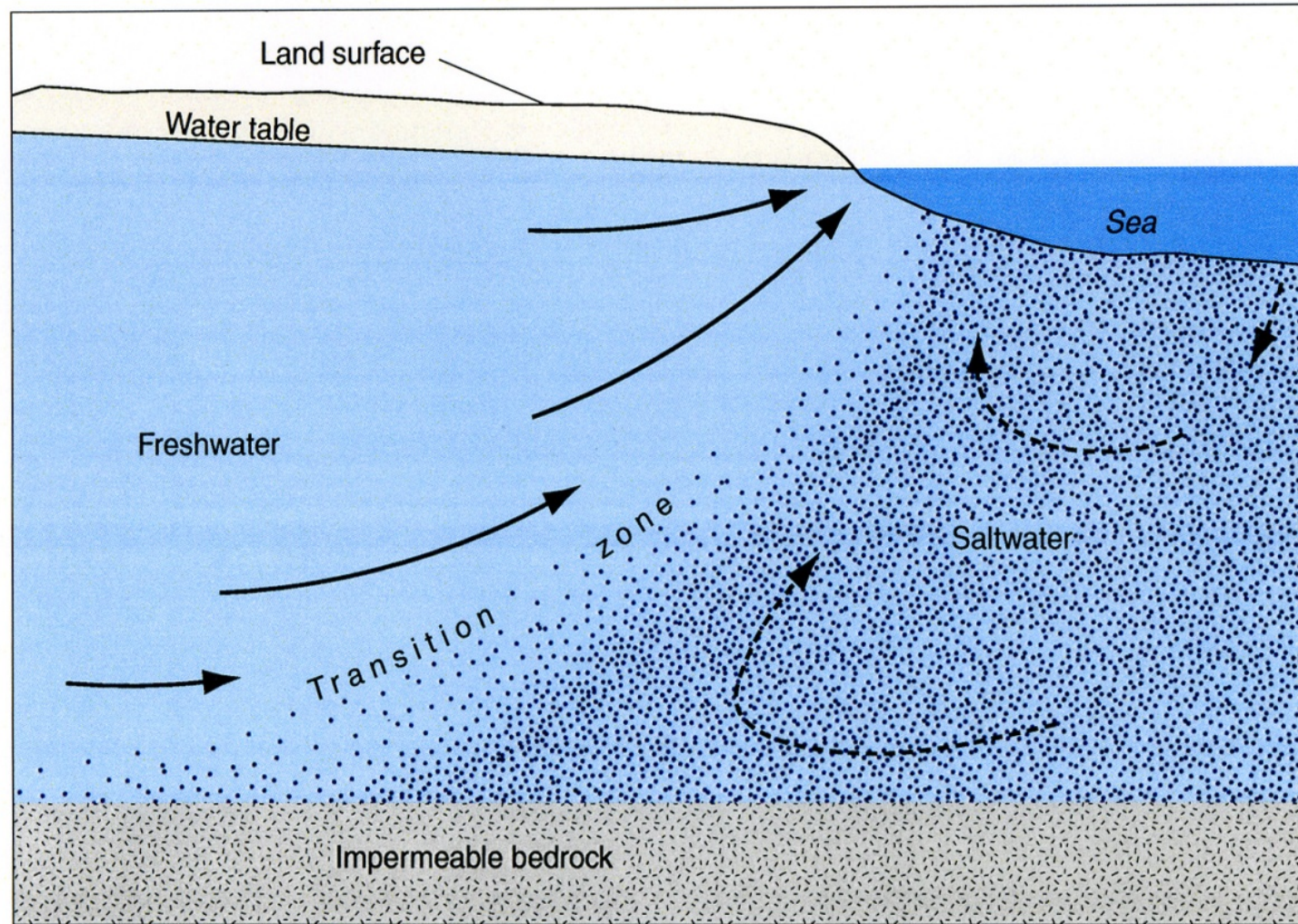
| Med Depth | TRN Wells UN | TRN Wells CN | UN Wells | CN Wells |
|-----------|--------------|--------------|----------|----------|
| ft        | 48           | 162          | 55       | 270      |

# Plausible Reasons



# Gyben-Herzberg Principle

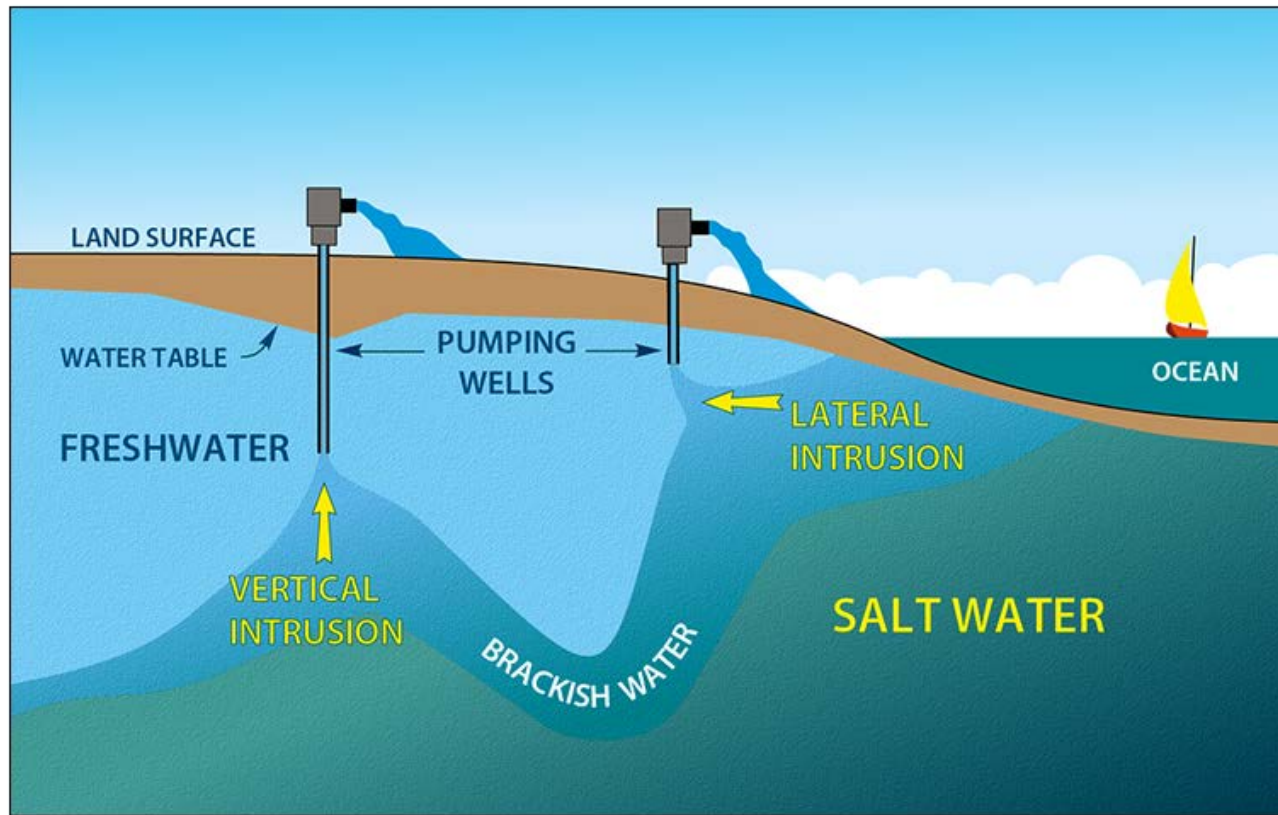




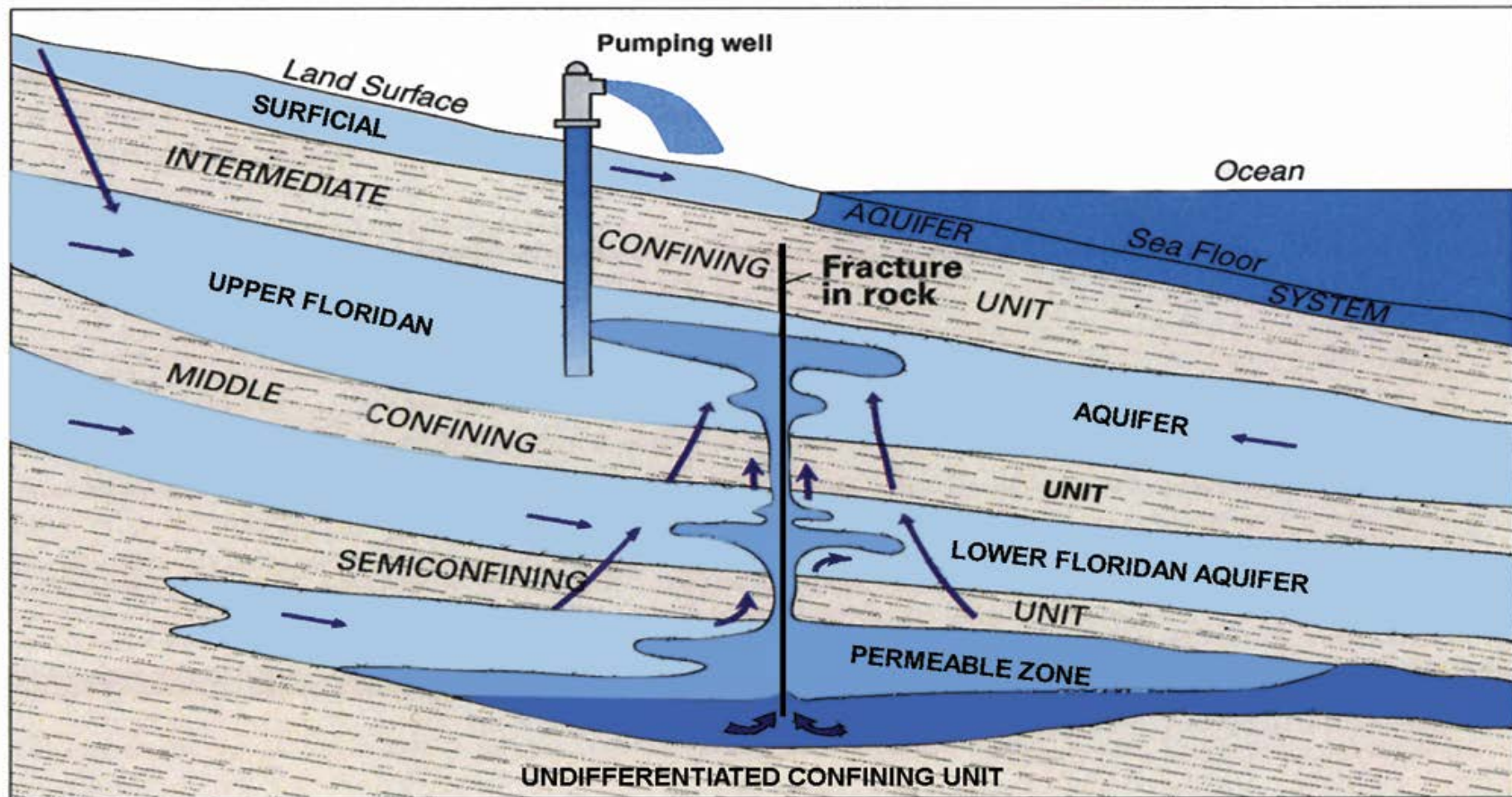
Not to scale

Modified from Cooper (1964)





Saint Johns River Water Management District (Date Unknown)



Modified from Krause and Randolph (1989) and Spechler (1994)

#### EXPLANATION

- Brackish water
- Saltwater
- Freshwater

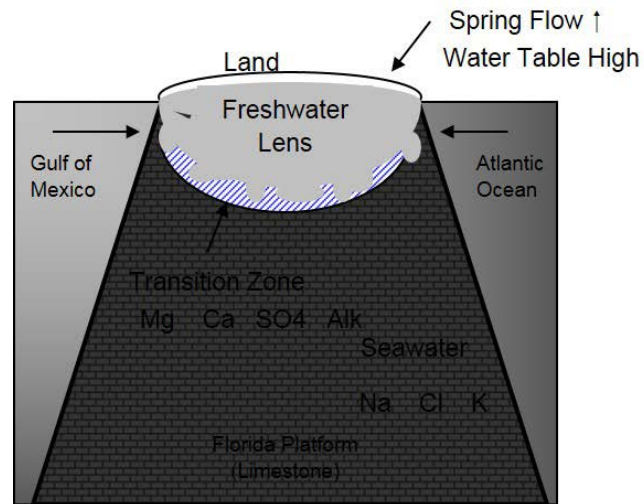
Direction of ground-water flow



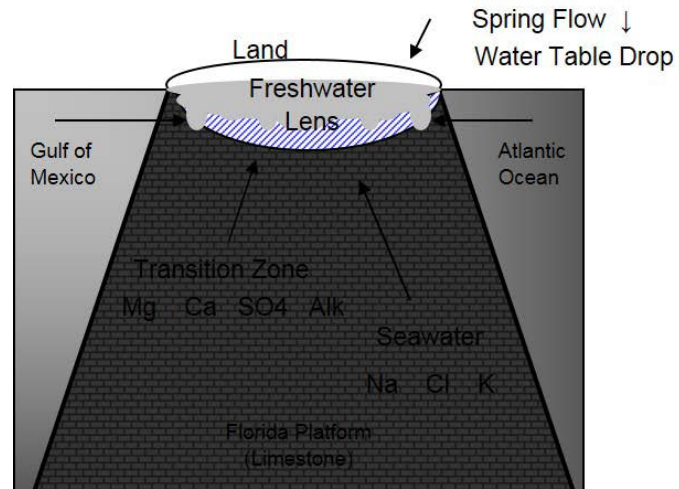
# Conceptual Model

- Think of Florida's hydrostratigraphic units containing freshwater as a "lens" with the Floridan aquifer system as its base

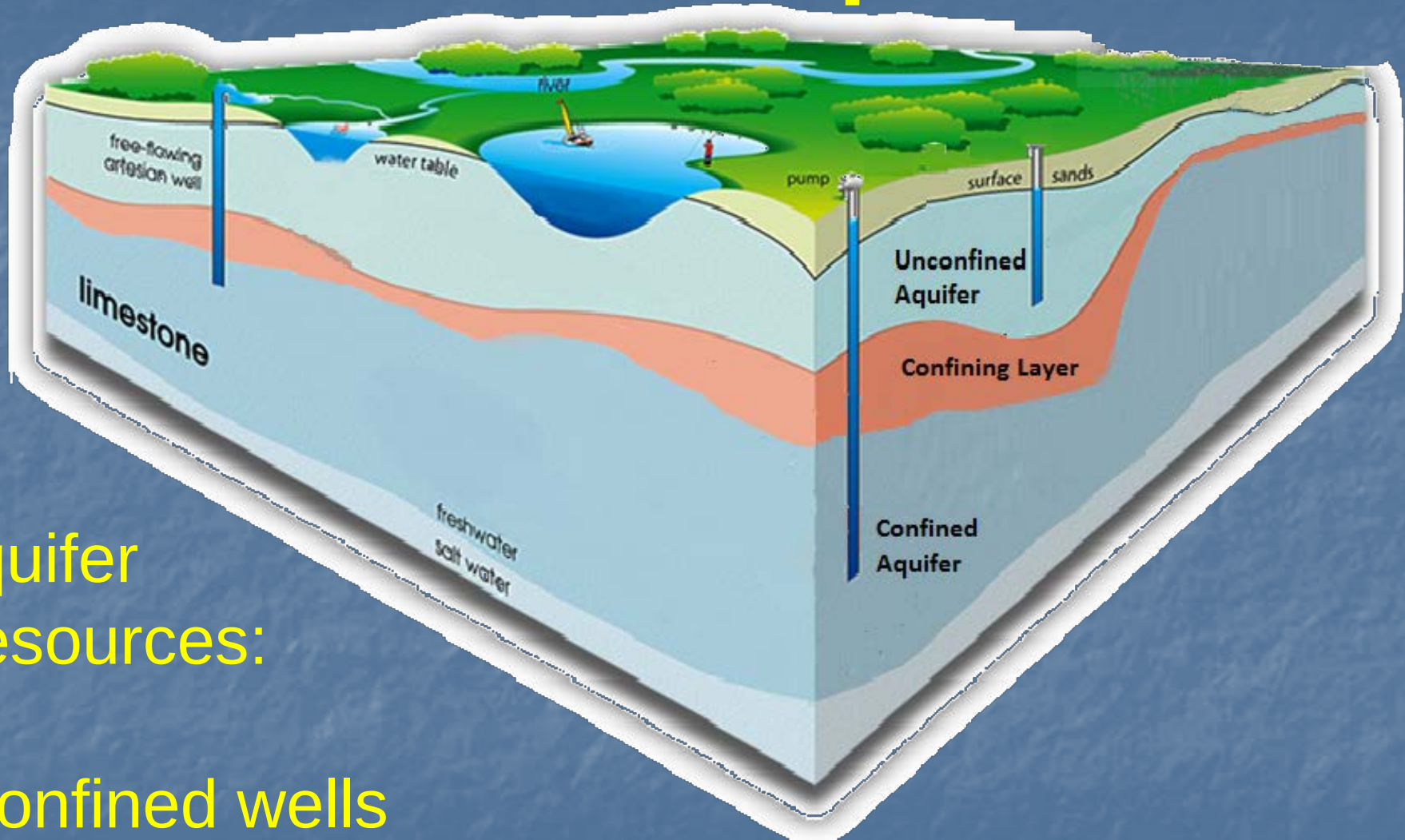
### 1. Normal Freshwater Lens



### 2. Reduced Freshwater Lens (Due to Drought)



# Ground Water Aquifers



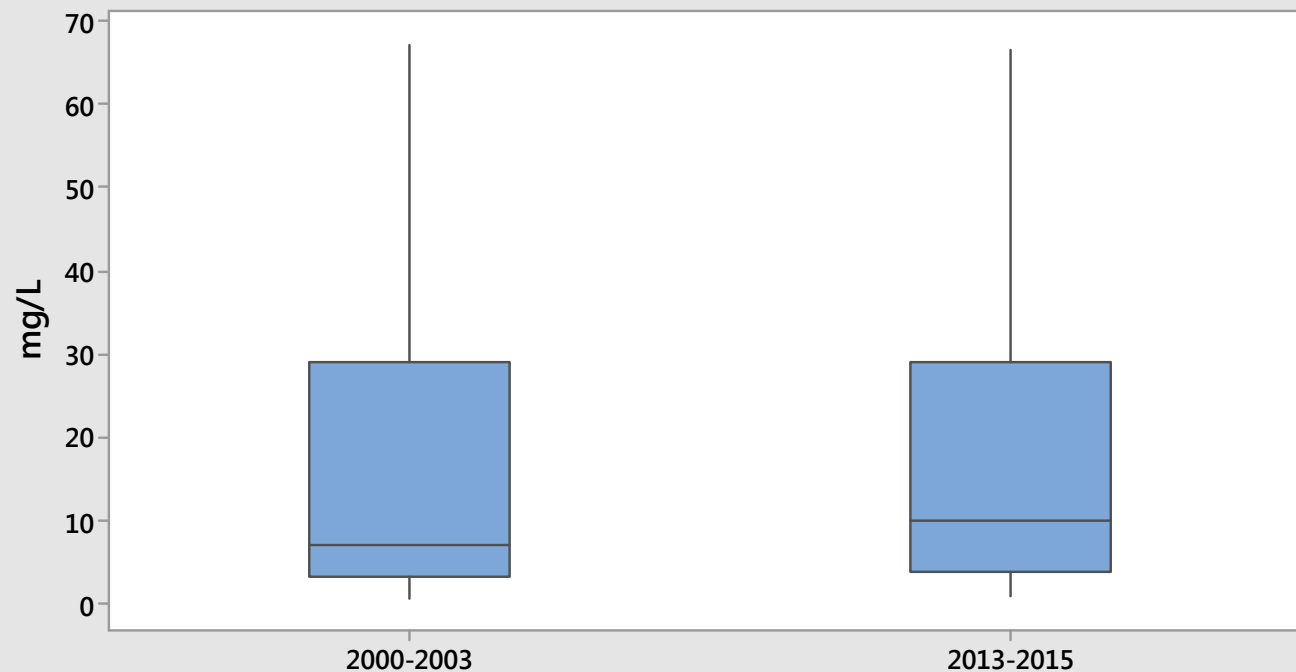
Aquifer  
Resources:

- Confined wells
- Unconfined wells



# Sodium Concentrations Unconfined Aquifers

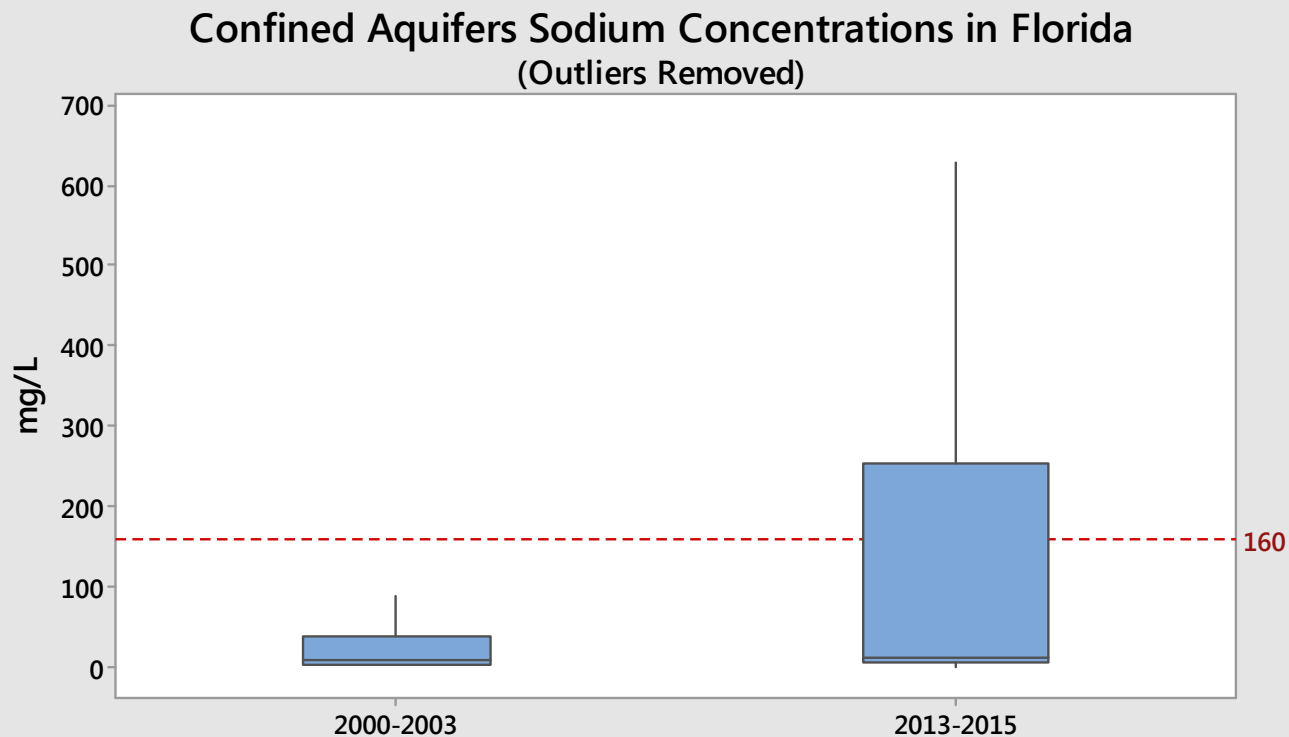
Unconfined Aquifers Sodium Concentrations in Florida  
(Outliers Removed)



*Median (2000-2003) = 7.1*

*Median (2013-2015) = 9.9*

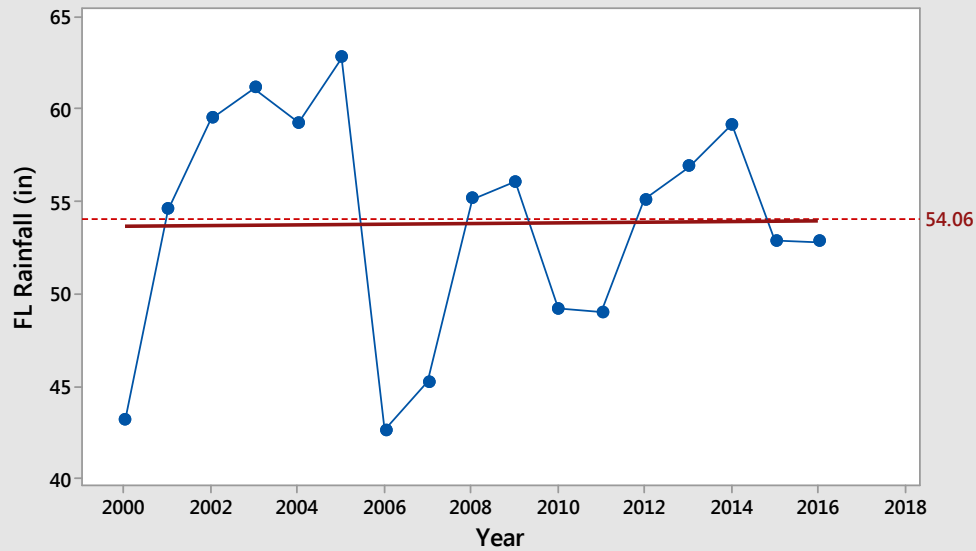
# Sodium Concentrations Confined Aquifers



*Median (2000-2003) = 8.9*

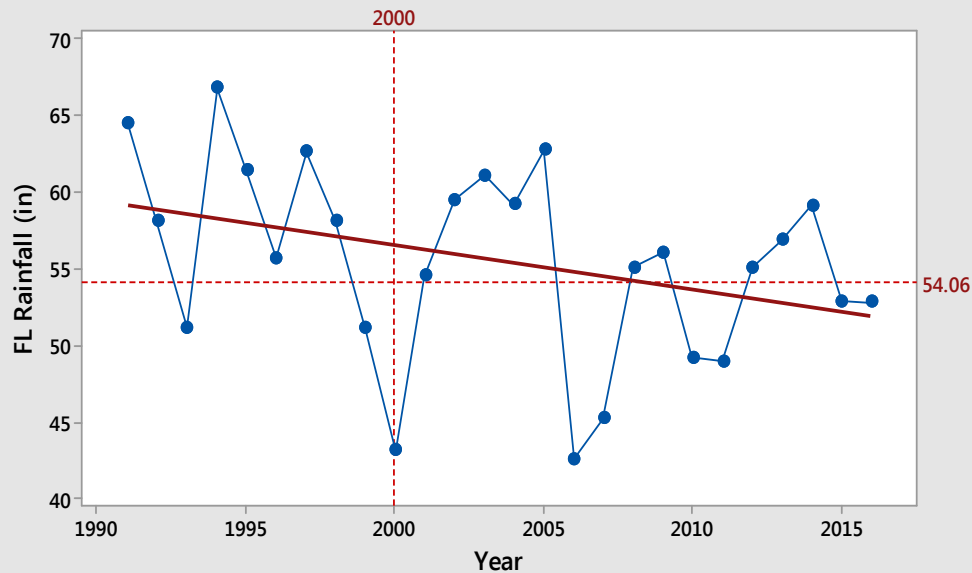
*Median (2013-2015) = 13.0*

### Mean Florida Rainfall (2000-2015)



*Slope = 0.02 in/yr*

### Scatterplot of FL Rainfall (in) vs Year



*p-val = 0.949; Slope = 0.02 in/yr*

SOURCE

SERCC,  
2016



# Florida's Water Quality

- GW Quality is significantly changing, but very slowly over large portions of Florida
- E.G. Saline and Rock-Matrix (E.G. Ca, Mg, Alk, SO<sub>4</sub>) parameters
- Later, Jay Silvanima will discuss evidence of that Emerging Contaminants are finding their way into both SW and GW over significant portions of Florida

# Questions?

- (850) 245-8503
- [rick.copeland@dep.state.fl.us](mailto:rick.copeland@dep.state.fl.us)