Florida Department of Environmental Protection

Florida Geological Survey

The Favorability of Florida's Geology to Sinkhole Formation

Clint Kromhout
Alan Baker

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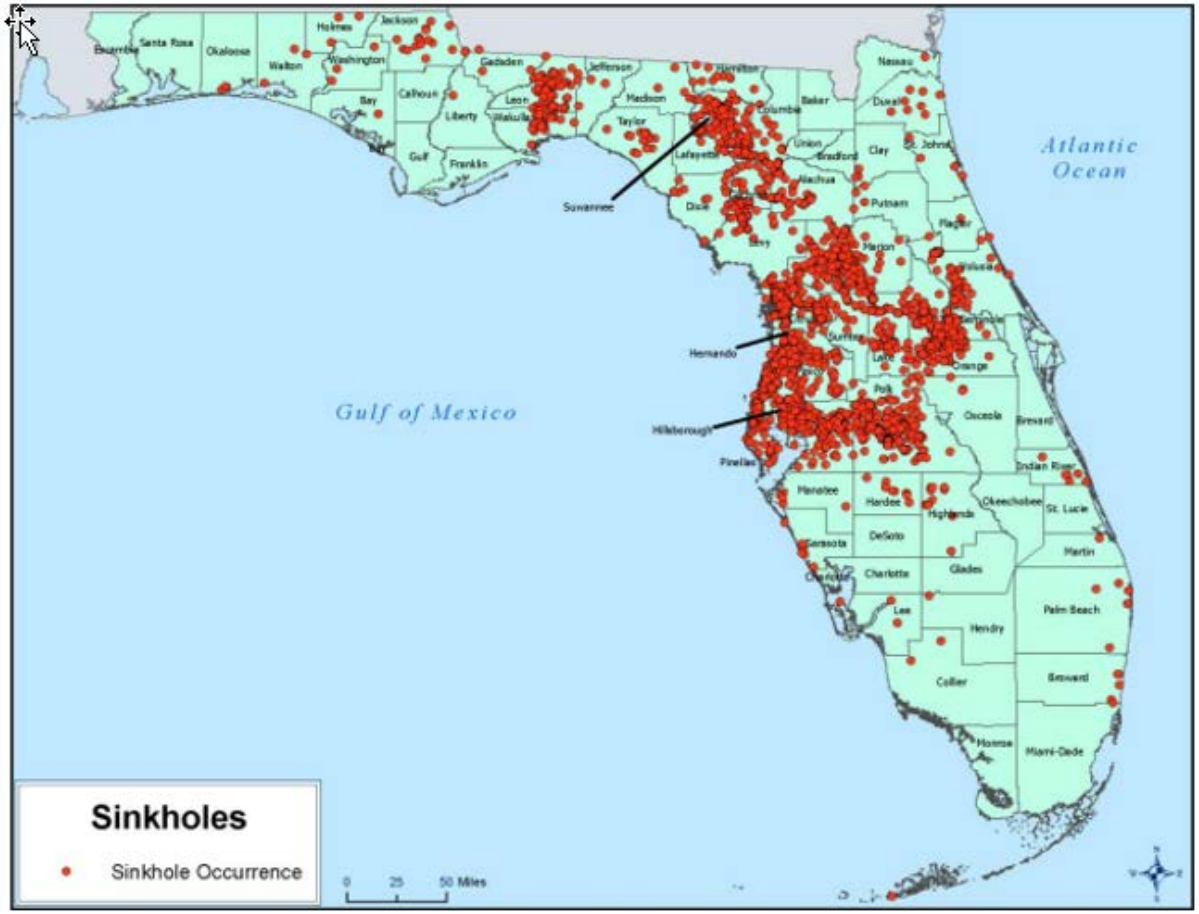
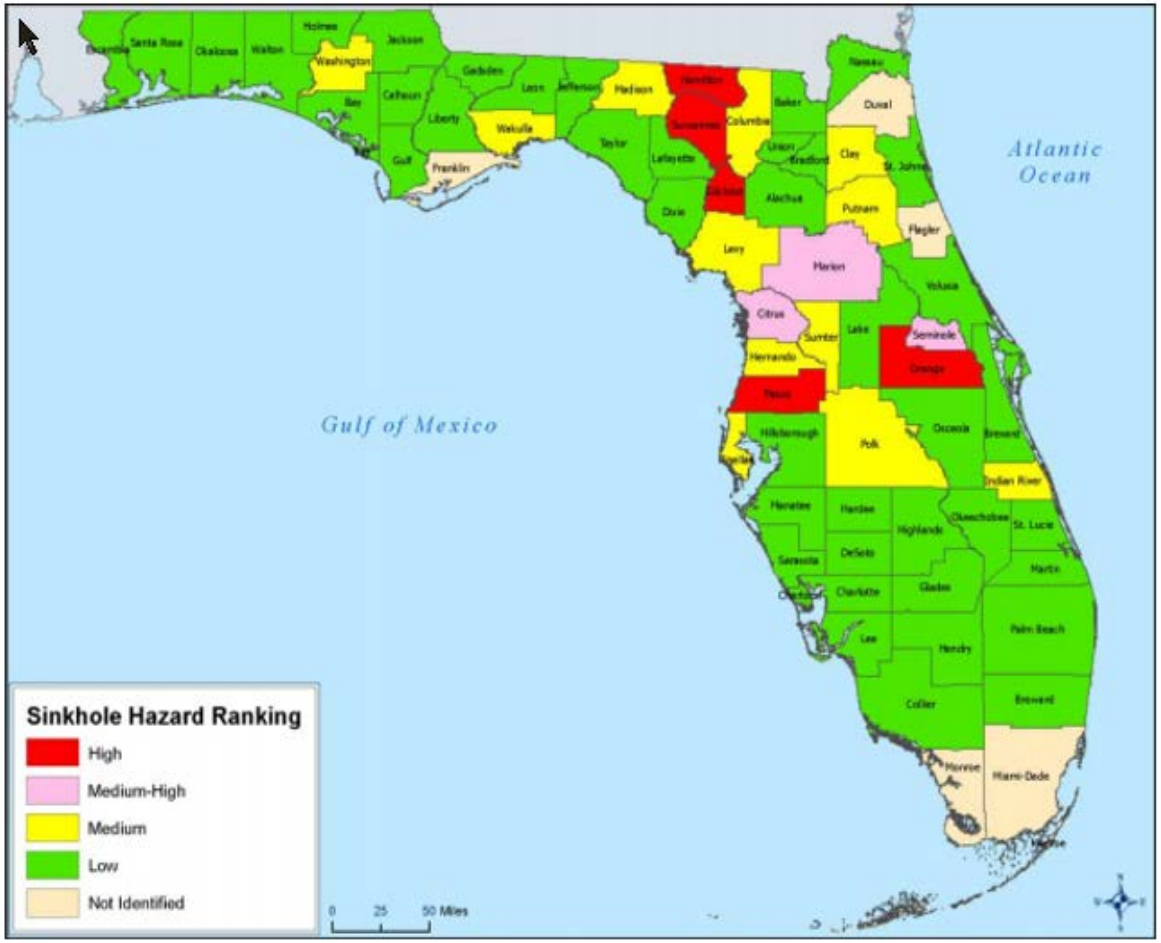
Subsidence Report Database

- Map of Subsidence Incident Reports taken from FL DEM 2013 State Hazard Mitigation Plan (SHMP 2013)



County Sinkhole Rankings

- Map of sinkhole hazard rankings by county taken from FL DEM 2013 State Hazard Mitigation Plan (SHMP 2013)



Purpose and Scope

- FGS contracted by DEM to produce a map depicting the State's favorability to sinkhole formation
- FGS used a spatial statistical modeling technique, called Weights-of-Evidence (WofE) (Bonham and Carter, 1994)
- The three-year project:
  - Year One: Pilot study in three northern Florida counties: Columbia, Hamilton, and that were selected due to their geomorphic diversity as well as impacts from the 2012 Tropical Storm Debby sinkhole event (Kromhout and Baker, 2015)
    - Selecting a pilot area with diversity was important to subsequently modeling the State's geology at the statewide scale
  - Years two and three: statewide study conducted building off what was learned from the pilot study.

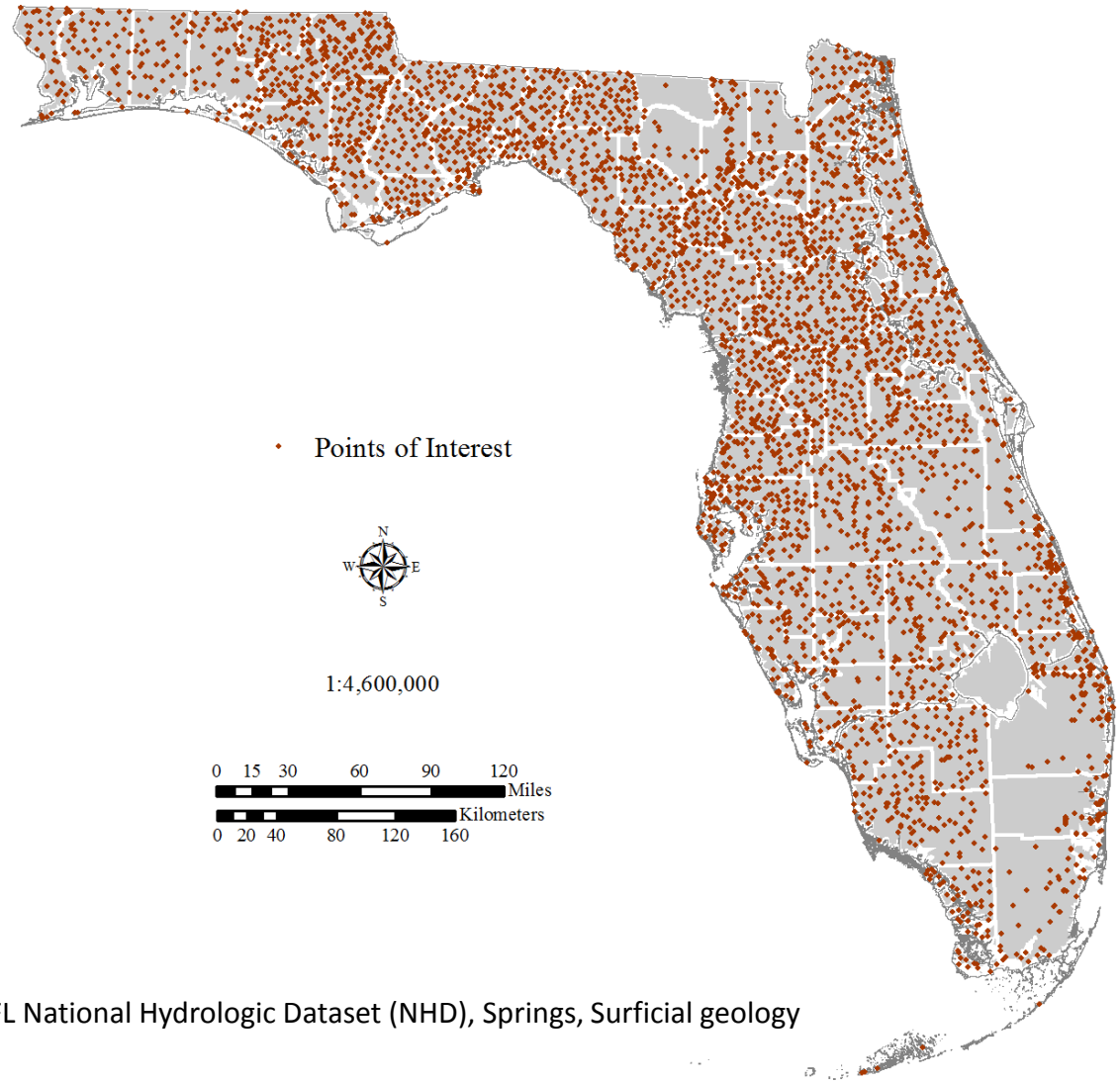
Sinkhole Types

Formation Speed	Sinkhole Type	Simplified Name
Rapid	Cover-collapse	Collapse Sinkhole
	Rock-collapse	
Slow	Cover-subsidence	Solution Sinkhole
	Solution	

- Focus of project was on collapse sinkholes

Field Investigation

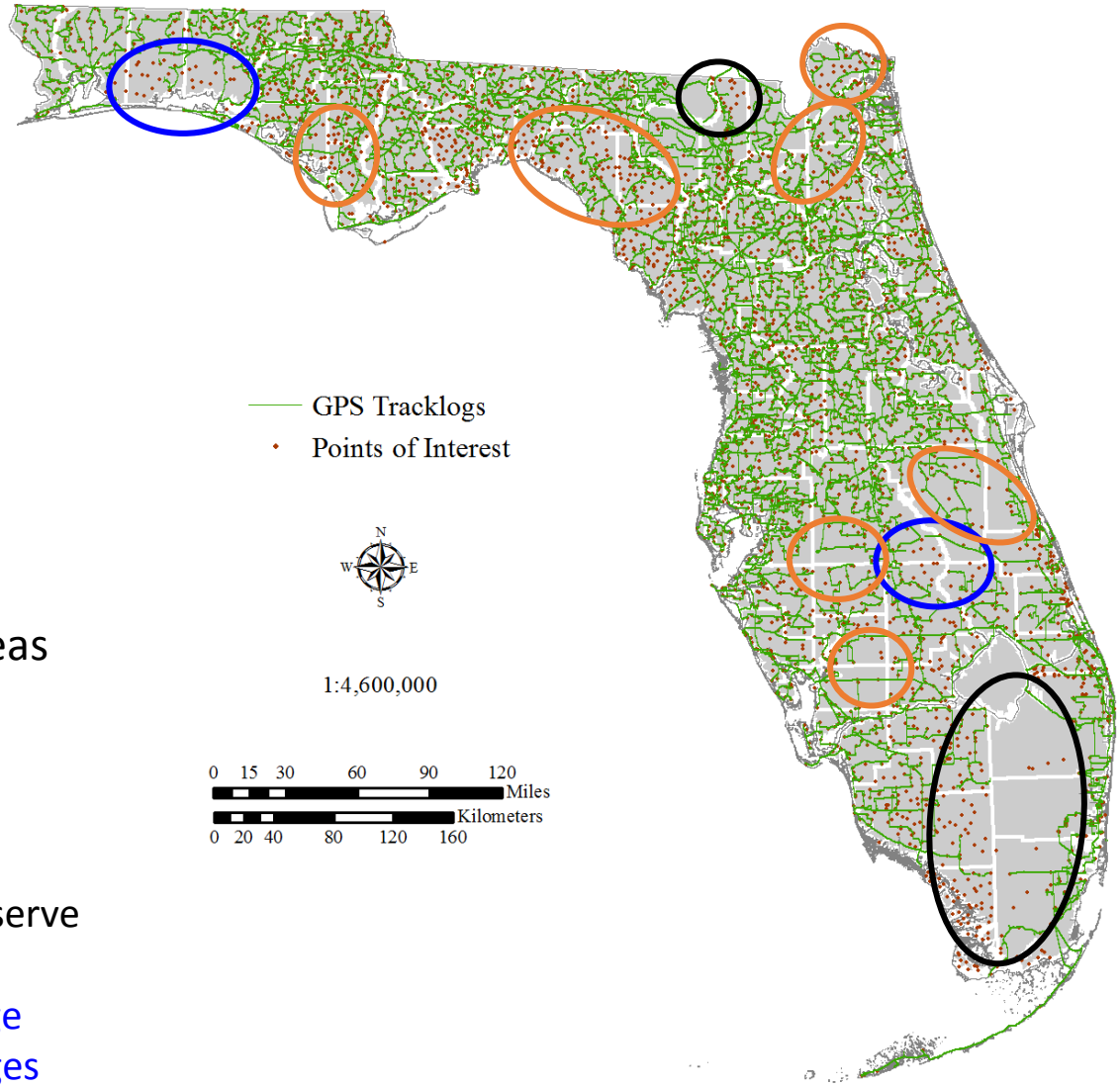
- >3,600 “Points of Interest” (POIs) identified as targets for field investigation
  - What are POIs?
    - Closed topographic depression features
- Planning tool - ensure adequate spatial coverage of field data collection
- Data collection not limited to POIs locations



POIs were identified using GIS layers:
Digital elevation models (DEM), Aerial photography, FL National Hydrologic Dataset (NHD), Springs, Surficial geology

Field Investigation

- 22,000 miles covered during field work
- Effort was made to get as close as possible to identified POIs
- Land access permission granted
  - Private
  - Government
- Some large inaccessible land areas
  - Private holdings
    - Timber/Mines/Cattle
  - Government holdings
    - Everglades National Park
    - Big Cypress National Preserve
    - Osceola National Forest
    - Avon Park Bombing Range
    - Eglin Air Force Base Ranges



Field Investigation

Sinkholes documented - 729
- Model training points

Generic Karst - 985
- Natural closed topographic depressions
- Not necessarily related to sinkholes or sinkhole activity

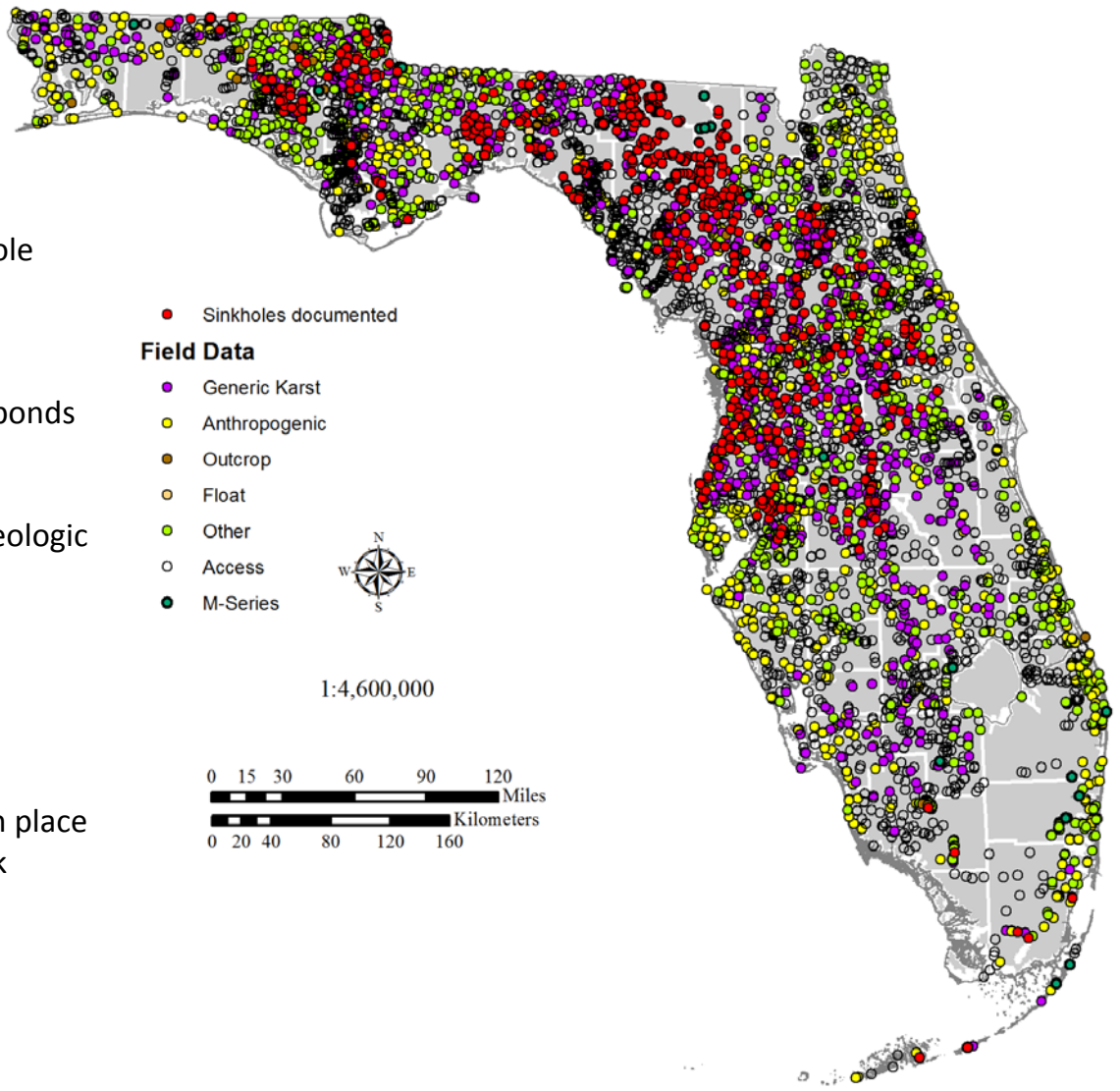
Anthropogenic – 676
- Dug ponds, borrow pits, mines, stormwater ponds

M-Series – 68
- Surficial geologic sample taken to improve geologic knowledge of area

Outcrop – 75
- Sites where geology is exposed at land surface

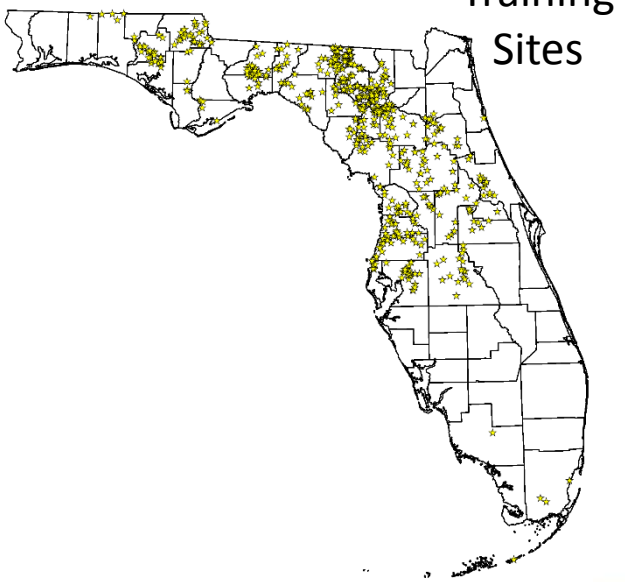
Float - 9
- Limestone or dolostone at surface, but not in place
- Used as proxy indicator for depth to bed rock

Other – field notes – 1,041
Access - POI or land access notes – 3,077



WofE - GIS - Modeling

- GIS layers (evidential themes) were evaluated relative to the study area's training sites (sinkholes)
- WofE model was generated using the evidential themes with the strongest association to the training sites and considered the strongest for identifying areas with geology favorable for sinkhole formation
- The strongest layers (themes) were:
  - Overburden
  - closed topographic depressions
  - Epiphreatic zone



Data Exploration

Explored Data:

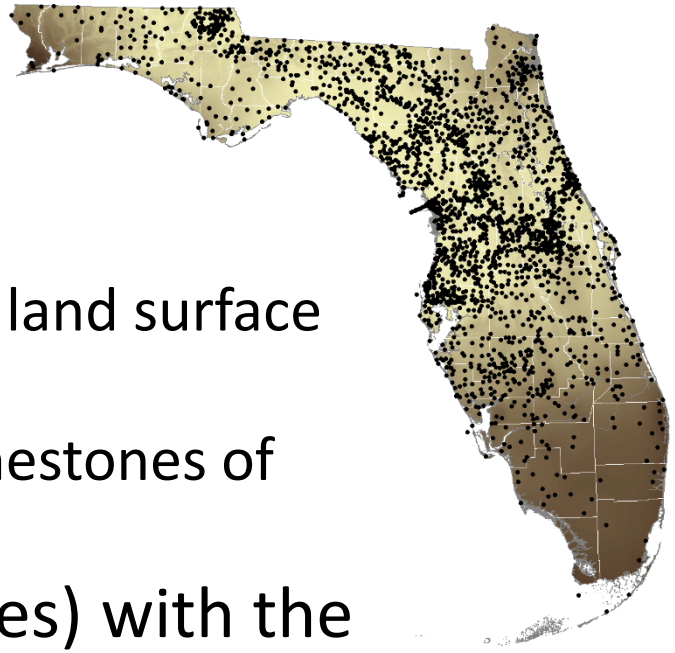
- Top of Carbonate Rock
- **Overburden thickness**
- Soils (hydraulic conductivity)
- Depth to water table
- Potentiometric surface of aquifer systems
- Lineaments
- **Closed topographic depressions (Circular Index)**
- Streams & surface water features
- Consumptive use wells
- **Epiphriatic zone**
- Head difference between aquifers
- *Groundwater hydraulic conductivity*

Evidence

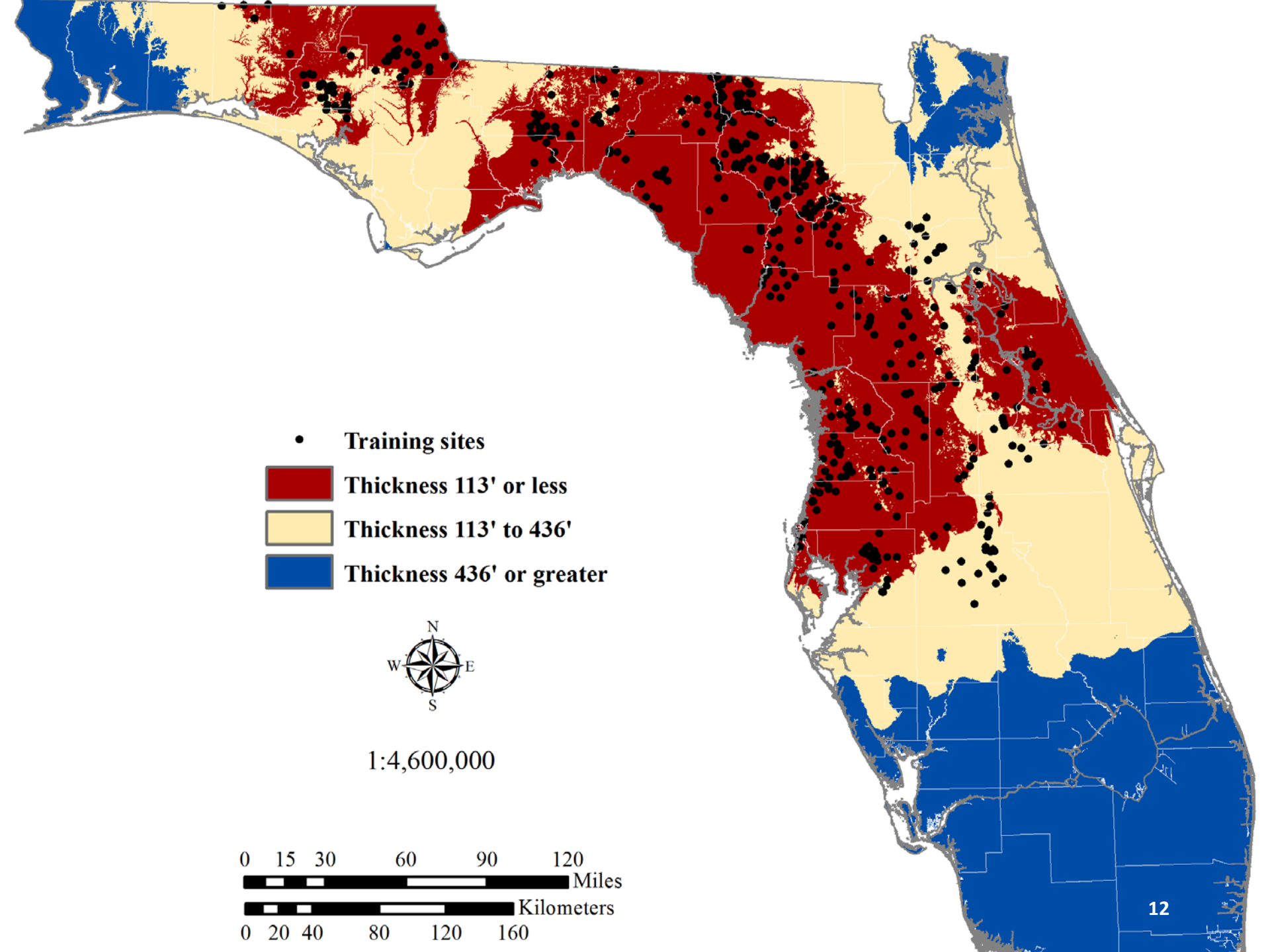
- **Sinkholes** (as model training points)

Problem

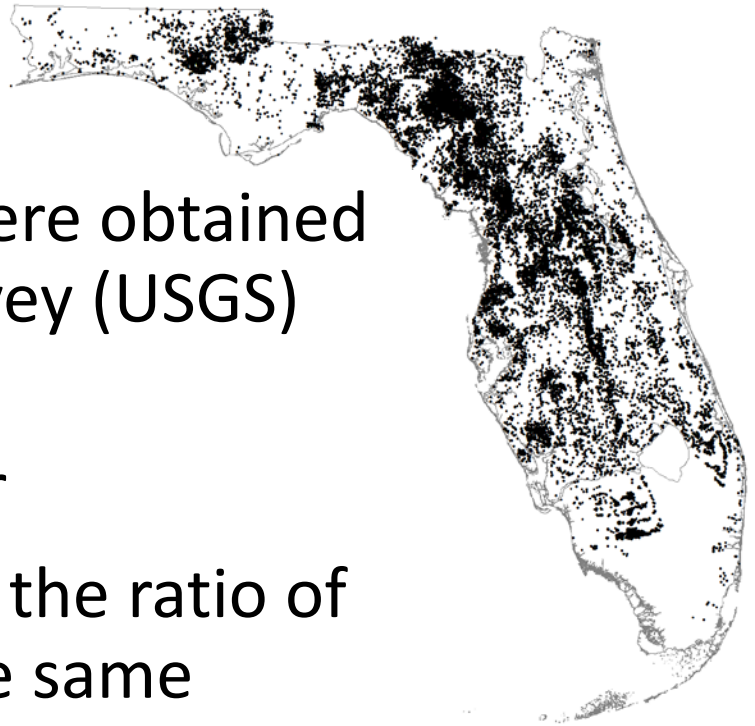
Evidential Theme (overburden)



- Overburden thickness
  - calculated by: top of limestone surface - land surface
  - Developed from >4000 boreholes
  - Targeted middle Eocene & Oligocene limestones of Floridan aquifer system
- Intersecting the training sites (sinkholes) with the overburden layer revealed the following associations:
    - STRONG: 34 meters (113 ft.) or less
    - WEAKLY: 34 meters (113 ft) to 133 meters (436 ft)
    - NO Association: >133 meters (436 ft)


Training sites
Thickness 113' or less
Thickness 113' to 436'
Thickness 436' or greater
N
W
E
S
1:4,600,000
0 15 30 60 90 120
Miles
Kilometers
0 20 40 80 120 160

Evidential Theme (closed topographic depressions)

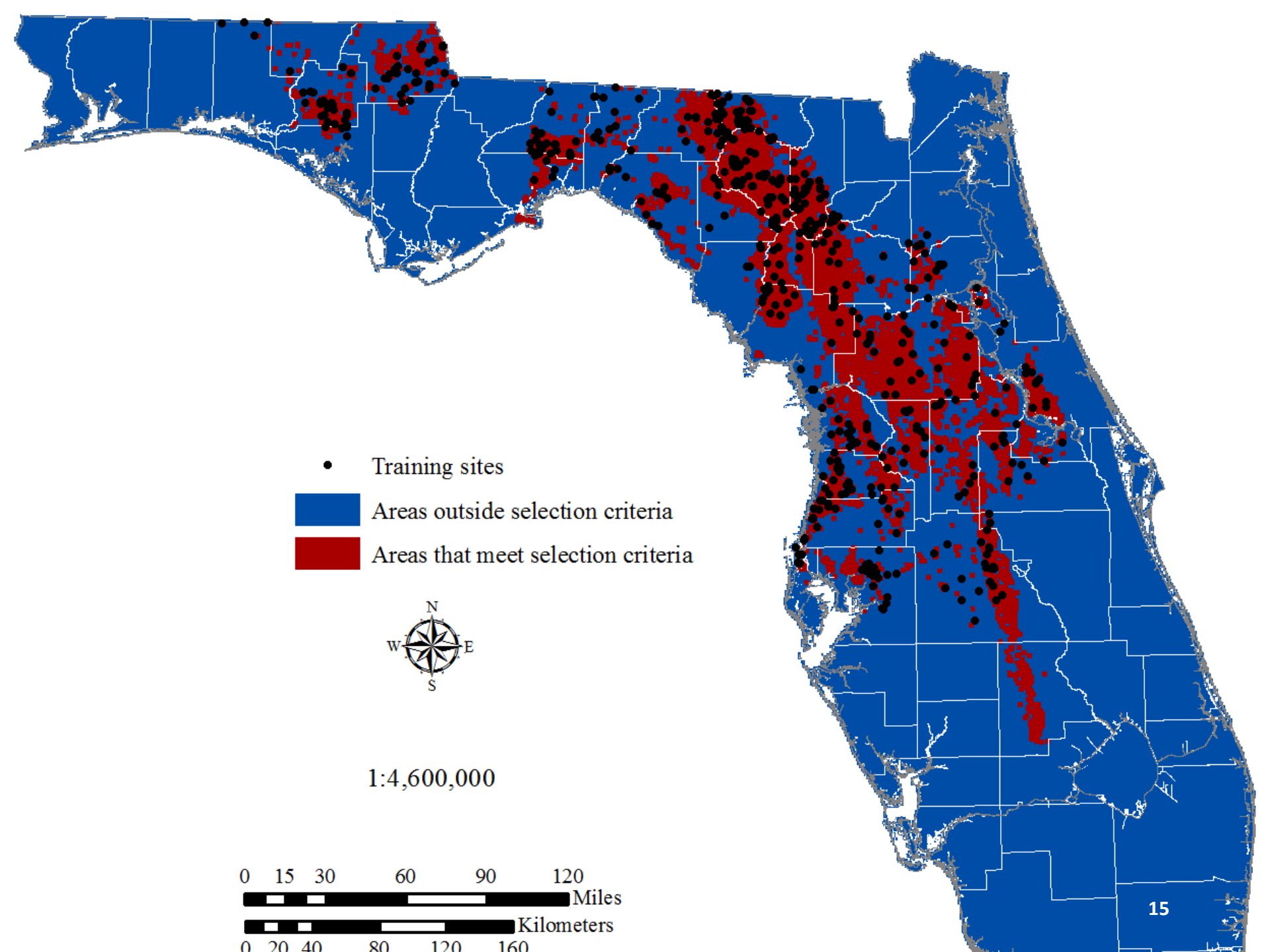


- Closed topographic depressions were obtained from United States Geological Survey (USGS) 1:24,000 topographic maps
- Sinkholes tend to be highly circular
- The circularity index of a feature is the ratio of the area of a perfect circle with the same perimeter as the closed depression
    - Used to filter out non-sinkhole depressions

Evidential Theme (closed topographic depressions)

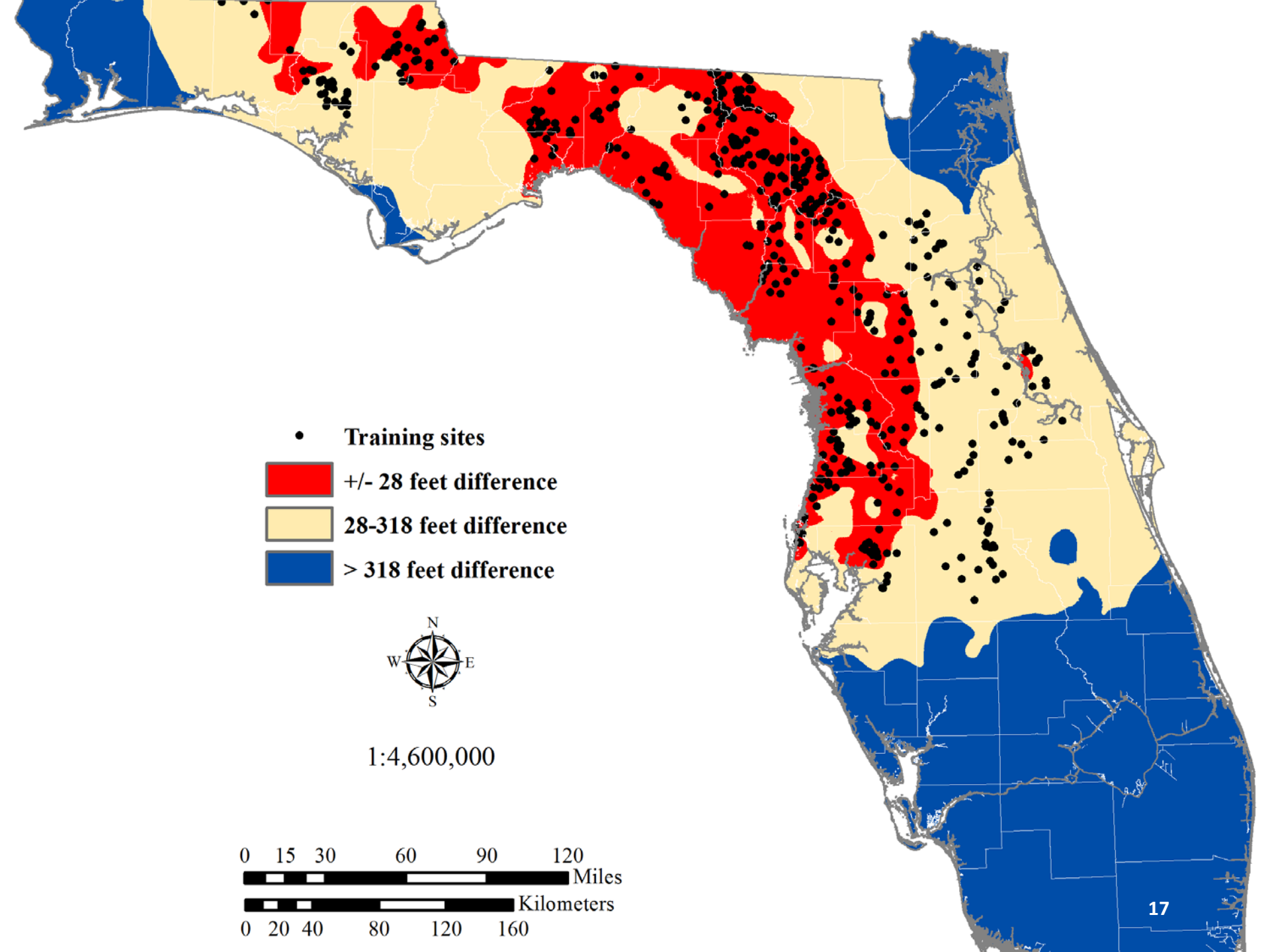
Filtering of CTDs

- A one kilometer grid of CTDs was queried to find the best fit with the training sites
- The query found the following characteristics:
  - CTD features with a circularity index of 0.75 or greater
  - Depth greater than five feet
- Training sites have the strongest association where multiple CTDs are present


Training sites
Areas outside selection criteria
Areas that meet selection criteria
N
W
E
S
1:4,600,000
0 15 30 60 90 120
Miles
Kilometers
0 20 40 80 120 160
15

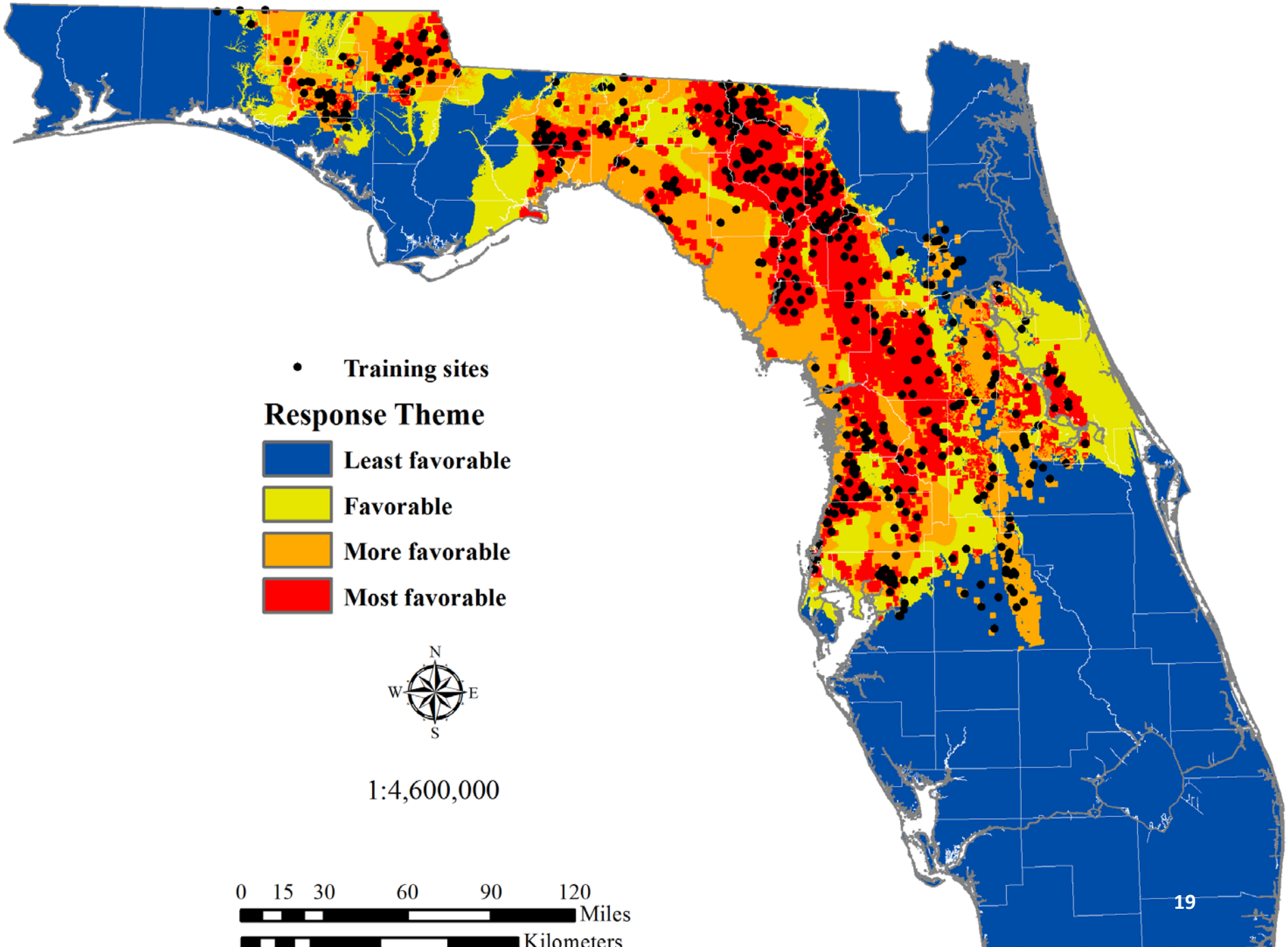
Evidential Theme (epiphriatic zone)

- Composite layer
  - Top of limestone surface - groundwater level surface = epiphreatic zone (theme)
- Reveals areas in the state where top of soluble rock is near the potentiometric surface.
  - Focuses on sediment / rock flushing zone
- Intersecting the training sites (sinkholes) with the epiphreatic zone evidential layer revealed the following associations:
  - STRONG: 0 - 8.5 meters (0-28 ft) from the top the limestone
  - WEAKLY: >8.5 meters (28 ft) to <97 meters (318 ft)
  - NO Association: >97 meters (318 ft) are not associated with training sites


Training sites
+/- 28 feet difference
28-318 feet difference
> 318 feet difference
N
W
E
S
1:4,600,000
0 15 30 60 90 120
Miles
Kilometers
0 20 40 80 120 160

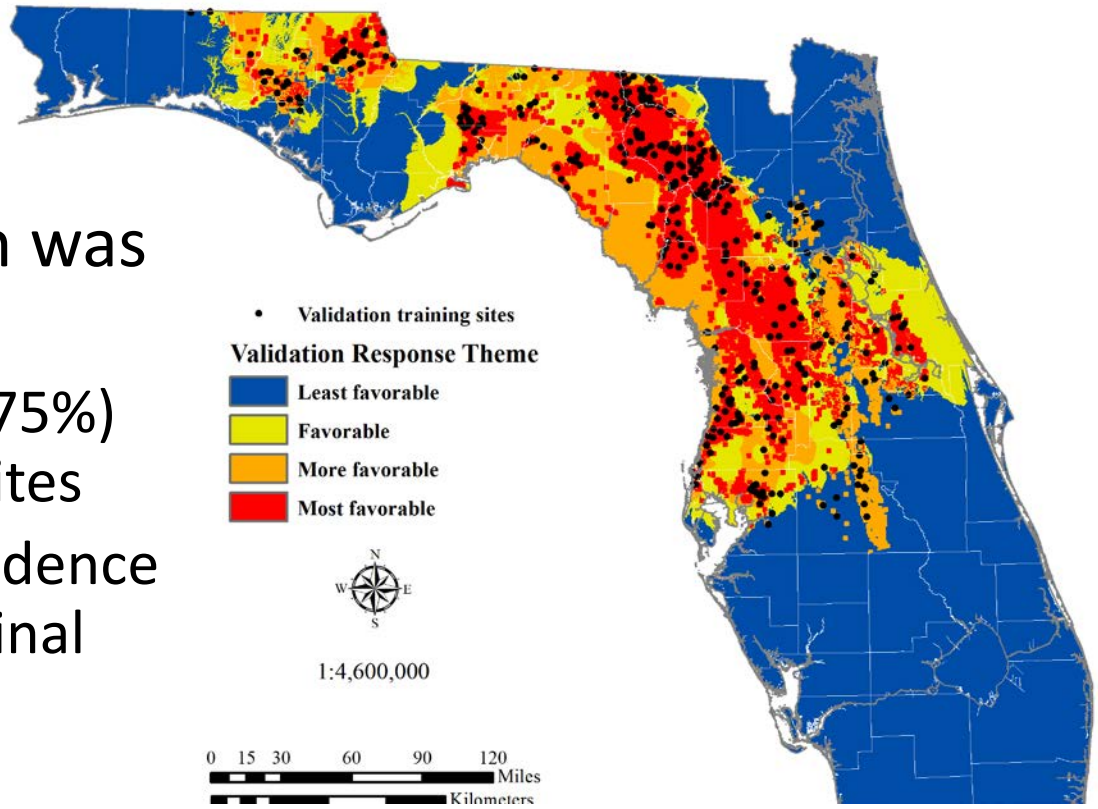
Combination of evidential themes – Response model (Result)

- Three evidential themes were combined in the WofE model to build the response theme
- Model reveals strong contrast, depicting areas with geology favorable sinkhole formation
- Areas calculated with a strong association to sinkhole formation include:
  - thin to absent overburden
  - high degree of closed topographic depressions
  - epiphreatic thickness of 28 feet or less


Training sites
Response Theme
Least favorable
Favorable
More favorable
Most favorable
N
W
E
S
1:4,600,000
0 15 30 60 90 120
Miles
Kilometers

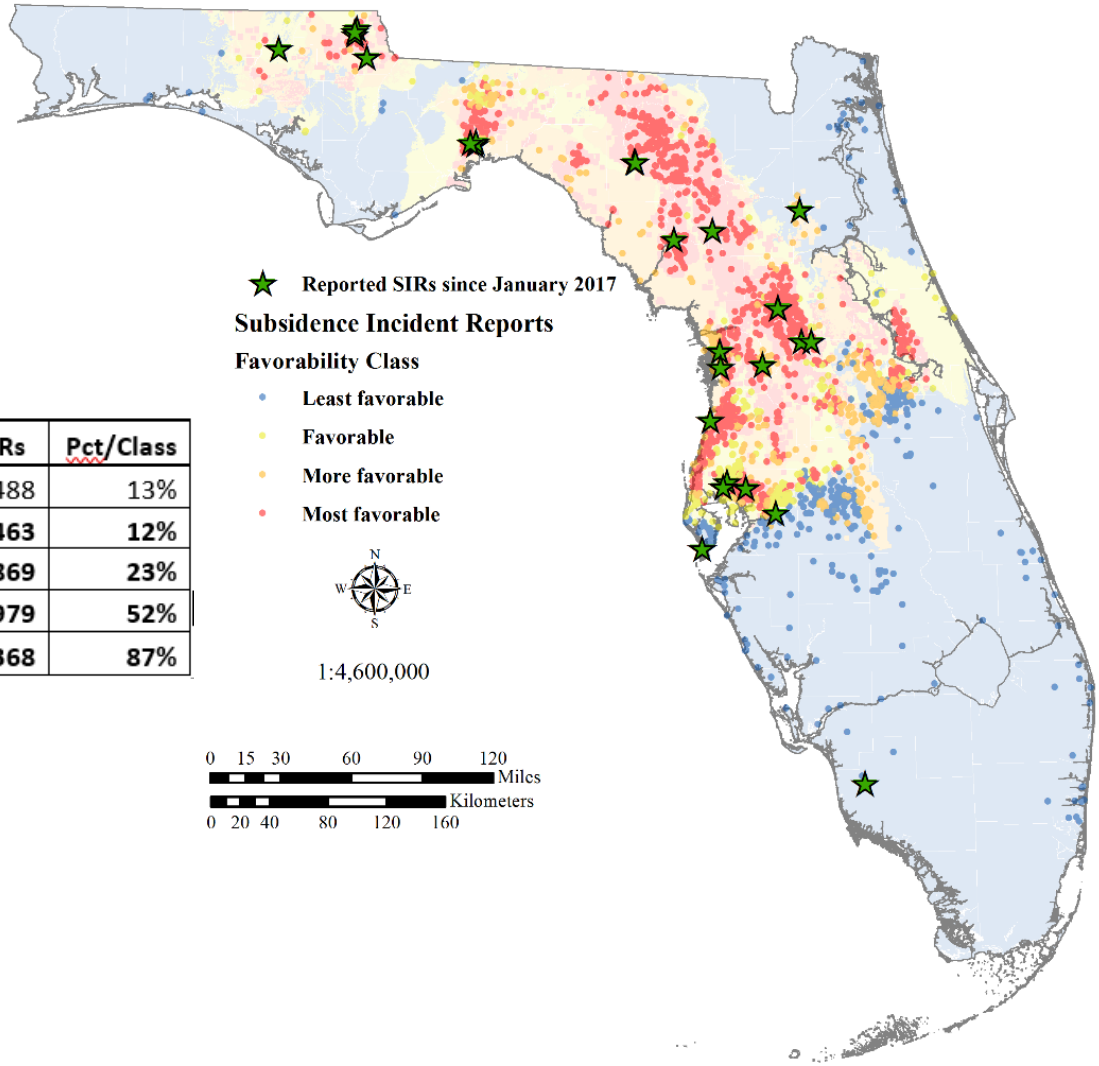
Validation – 75% hold back

- Model output validation was accomplished by:
  - Used a random subset (75%) of the original training sites
  - Compared existing subsidence incident reports to the final output map

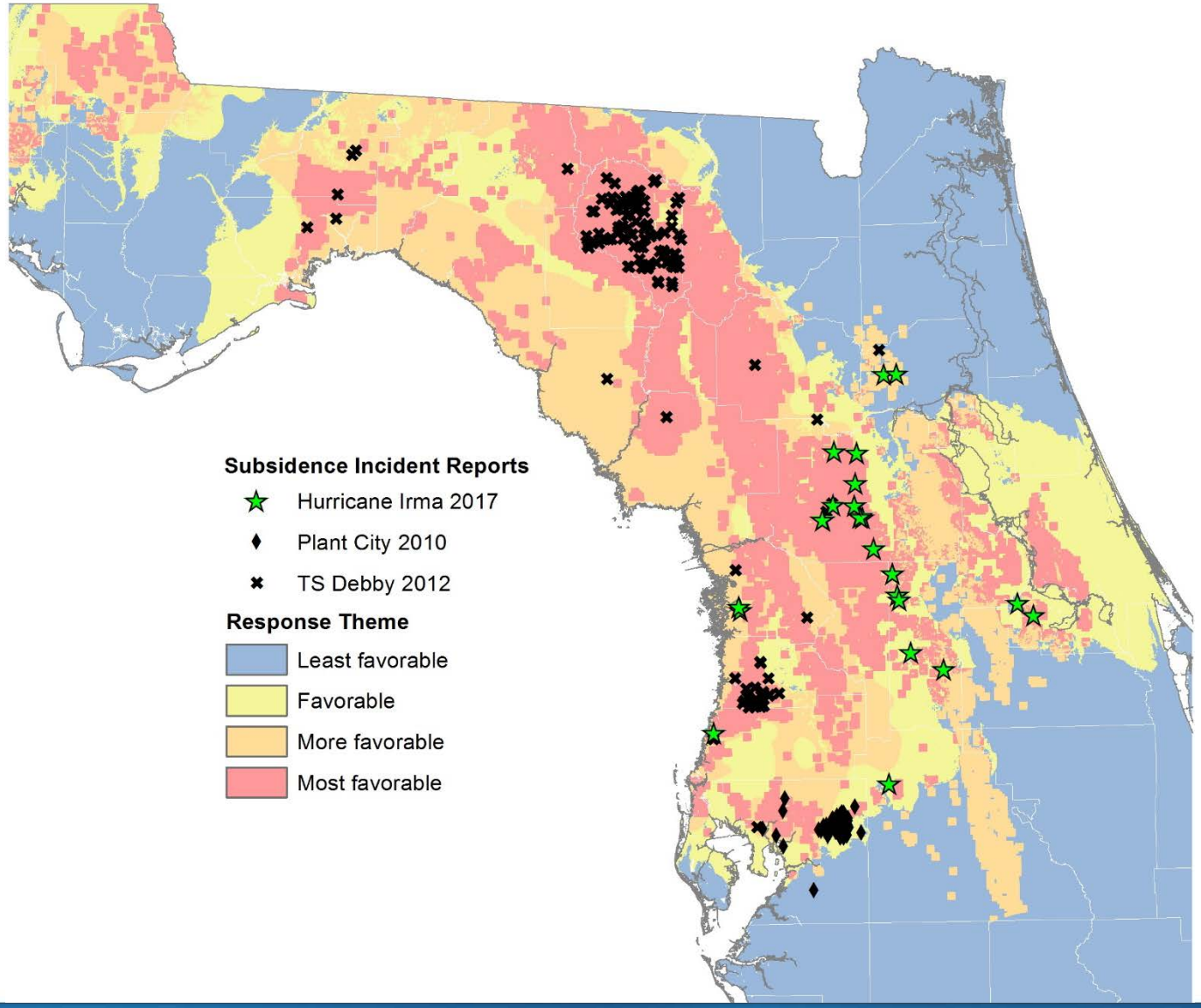


SIRs numbers & model results

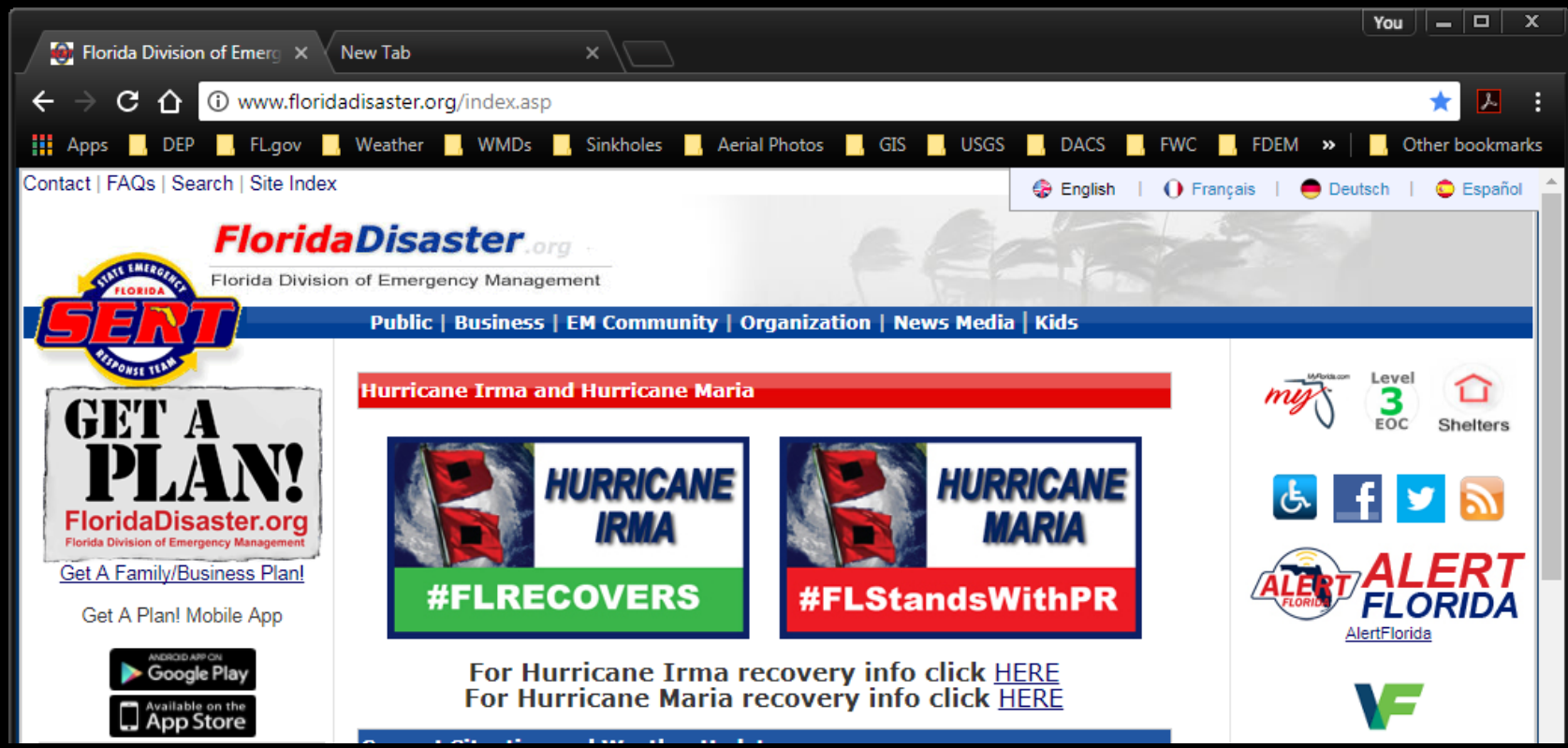
Class	SIRs	Pct/Class
Least Favorable	488	13%
Favorable	463	12%
More Favorable	869	23%
Most Favorable	1979	52%
Total	3368	87%



Model results vs. “swarm events”



FDEM Report


Florida Division of Emerg
New Tab
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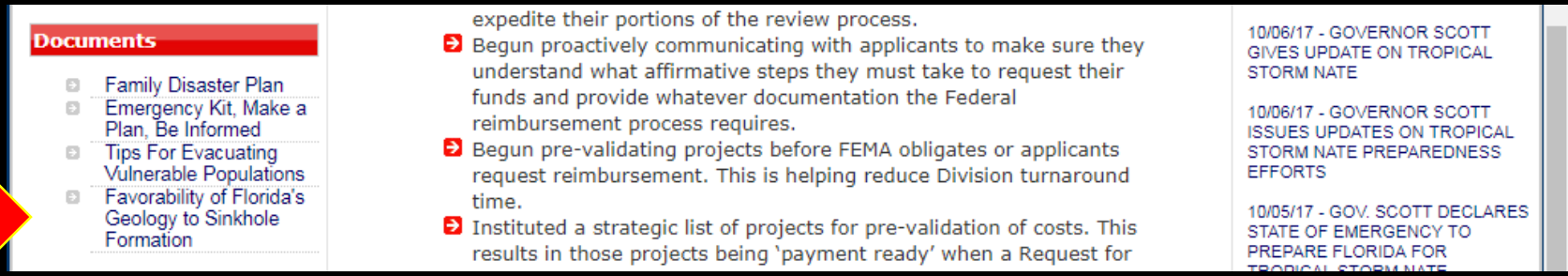
FloridaDisaster.org
Florida Division of Emergency Management
Get A Family/Business Plan!
Get A Plan! Mobile App
Google Play
App Store
Hurricane Irma and Hurricane Maria
HURRICANE IRMA
#FLRECOVERS
HURRICANE MARIA
#FLStandsWithPR
For Hurricane Irma recovery info click HERE
For Hurricane Maria recovery info click HERE
Level 3 EOC
Shelters
ALERT FLORIDA
AlertFlorida


Documents
Family Disaster Plan
Emergency Kit, Make a Plan, Be Informed
Tips For Evacuating Vulnerable Populations
Favorability of Florida's Geology to Sinkhole Formation
expedite their portions of the review process.
Begun proactively communicating with applicants to make sure they understand what affirmative steps they must take to request their funds and provide whatever documentation the Federal reimbursement process requires.
Begun pre-validating projects before FEMA obligates or applicants request reimbursement. This is helping reduce Division turnaround time.
Instituted a strategic list of projects for pre-validation of costs. This results in those projects being 'payment ready' when a Request for
10/06/17 - GOVERNOR SCOTT GIVES UPDATE ON TROPICAL STORM NATE
10/06/17 - GOVERNOR SCOTT ISSUES UPDATES ON TROPICAL STORM NATE PREPAREDNESS EFFORTS
10/05/17 - GOV. SCOTT DECLARES STATE OF EMERGENCY TO PREPARE FLORIDA FOR


Questions
Clint.Kromhout@dep.state.fl.us