



Development of an Emergency Warning System for Lakes

Quantifying Expected Lake Level Rise for Large Rainfall Events

By :
Nirjhar Shah¹, PhD, PE, Jie Gao², PE, CFM,
Leland Dicus², PE, and Aayushi Vagadia¹

¹: Wood Environment and Infrastructure Solutions

²: Hillsborough County, Florida

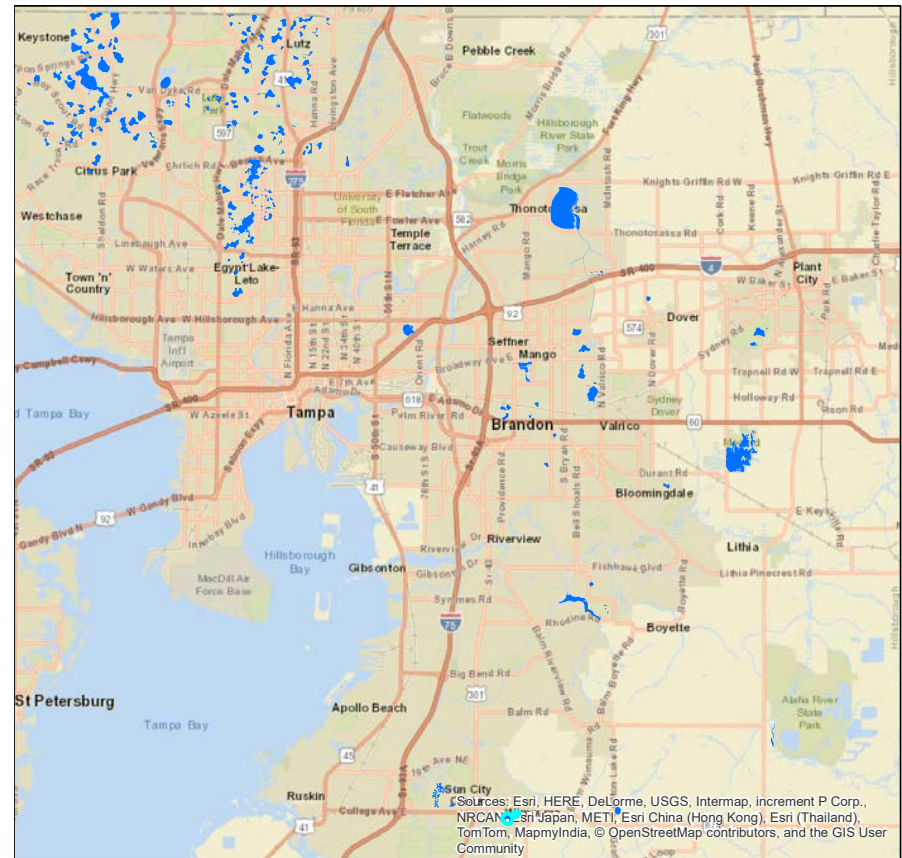
Problem Statement

- Hillsborough County has 186 named lakes
- Lake level management is a key aspect in controlling flooding during wet season
- Limited emergency resources coupled with large number of lakes makes management very difficult
- Lake management decisions are based on tabular dataset and/or institutional knowledge



Major Lakes in Hillsborough County

- Approximately 60% (114) of the lakes are in the northwest area
- Most of the lakes are in an urban environment
- High lake levels can potentially impact backyards/houses



Objectives

- Use available data to estimate rainfall and lake level relationship
- Develop an automated system to predict expected lake level rise based on forecasted rainfall
- Create a user-friendly spatial interface to access the warning system
- Allow creation of reports for review and actions

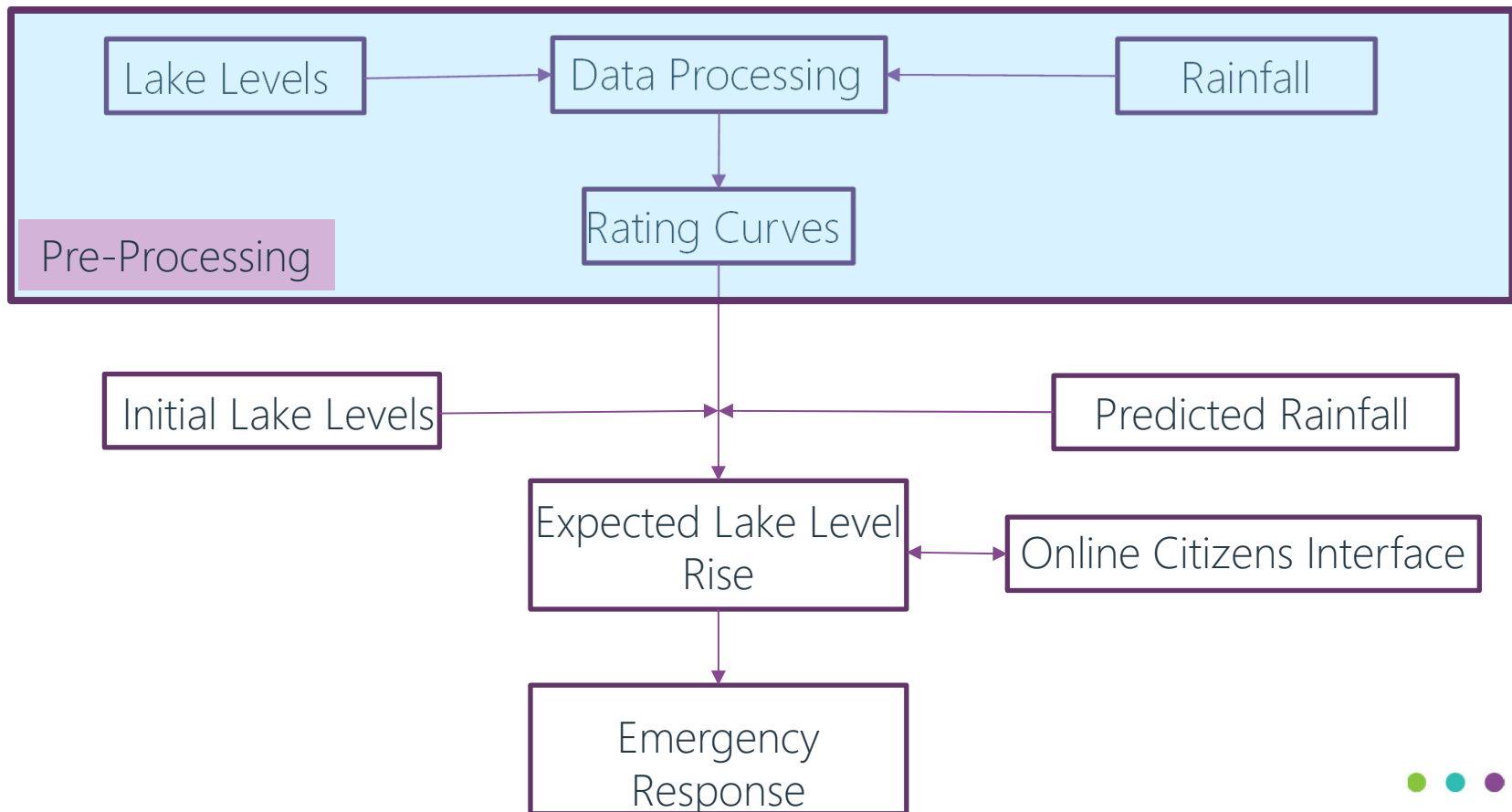


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Development of Lake Rating Curves

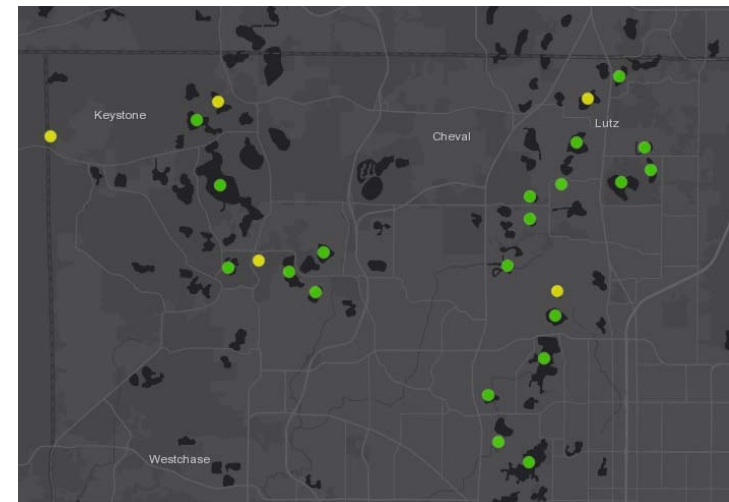
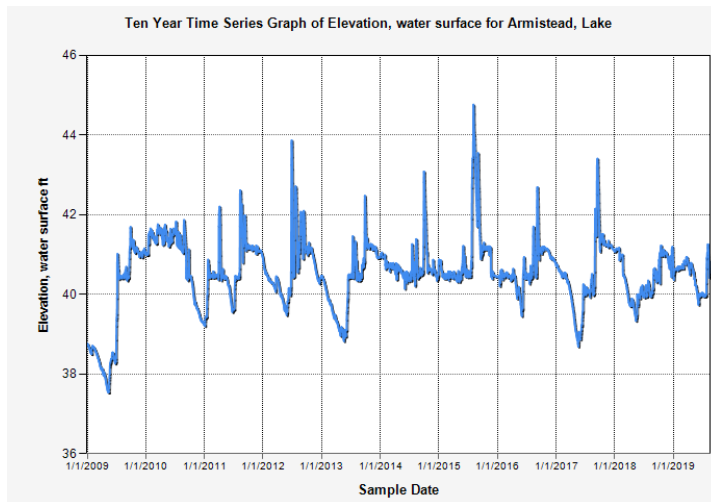
Data Processing and Results

Overall Workflow



Components of the Analysis

- Establishment of working definition of an “event”
- Determination of event-rainfall and increases in lake levels
- Reviewing influence of initial water level on lake level rise



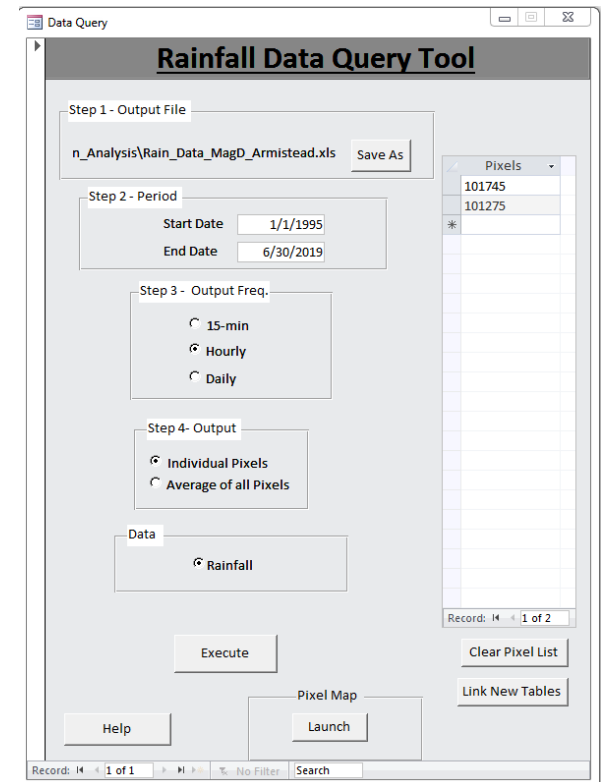
Type of Elevation Data Available

Lake	Type of Data	Record of Data
Cooper	Mostly Daily & Weekly	8/25/15 - 8/14/19
Wee Lake	Mostly Daily & Weekly	10/11/16 - 8/12/19
Martin Borrow Pit	Mostly Daily & Weekly	1/3/17 - 8/13/19
Lake Meade	Mostly Daily & Weekly	10/11/16 - 8/12/19
Timber Pond	Mostly Daily & Weekly	10/11/16 - 8/12/19
Shangri La	Mostly Daily & Weekly	2/26/19 - 8/14/19
Armistead	Daily	12/31/99 - 8/22/19
Magdalene	Daily	9/11/98 - 8/22/19



Rainfall

- Hourly rainfall data acquired from SWFWMD NEXRAD dataset
- Rainfall time-series and lake-level data used to evaluate definition of rainfall "event".



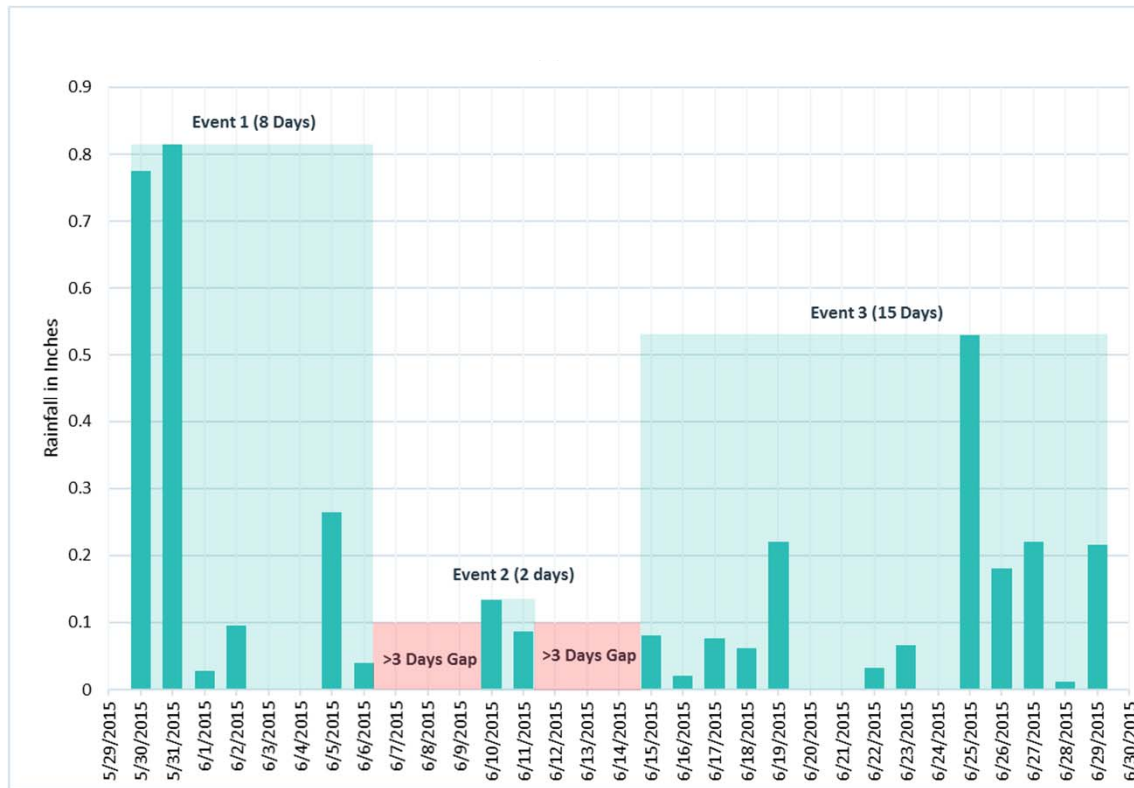
Establishment of Event (Corr. Coef)

- Rainfall events defined as continual period of rainfall
- Events separated by a minimum duration of zero rainfall
- Correlation between rainfall and change in lake level used to determine most appropriate gap between rainfall events


Min. Duration of No-Rain	Lake Meade	Wee Lake
12-Hr	0.64	0.55
1-Day	0.63	0.45
3-Day	0.89	0.71
7-Day	0.72	0.92



72 Hours Rainfall Gap



Event-Based Starting and End Elevations



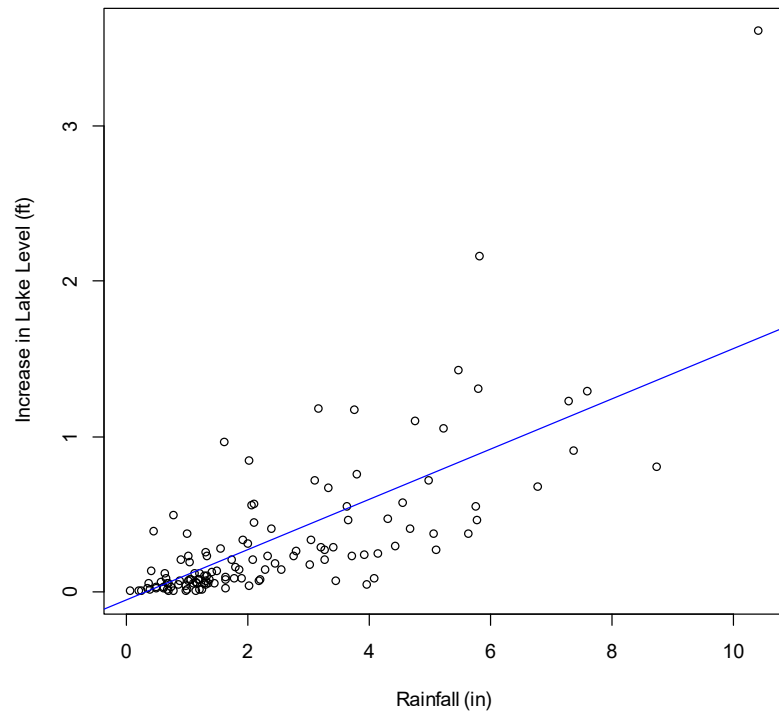
Event	Start Date & Time	End Date & Time	Rainfall (in)	Start Elevation ¹	End Elevation ¹
1	6/2/17 2:00 PM	6/2/17 8:00 PM	0.245	57.08	57.10
2	4/13/18 3:00 PM	4/13/18 7:00 PM	0.297	57.13	57.15
3	6/3/18 11:00 AM	6/8/18 10:00 AM	1.997	57.15	57.28

- Rainfall event depth and change in water level noted
- Changes in water level is plotted against rainfall-event depth
- Initial water level was considered when developing relationships

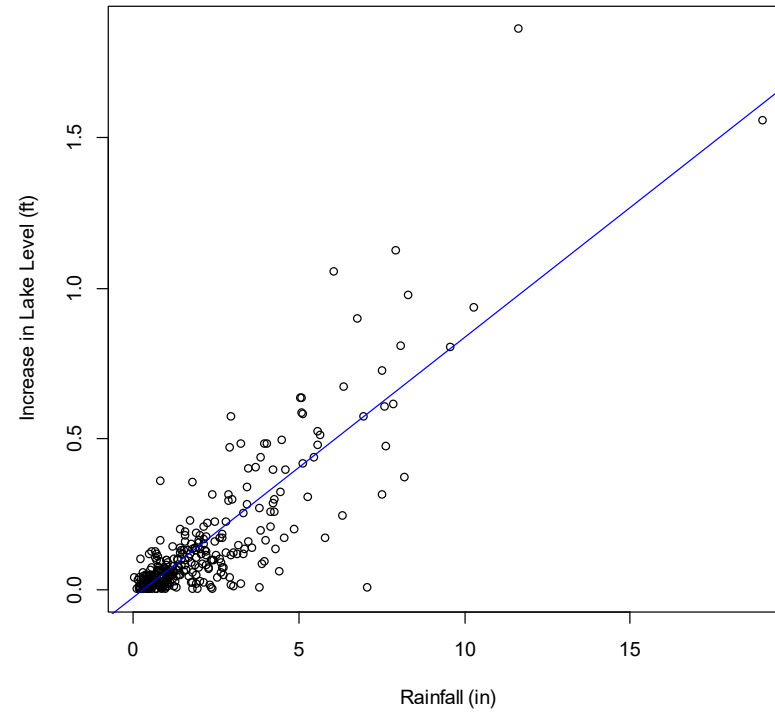


Rainfall vs. Increase in Lake Level

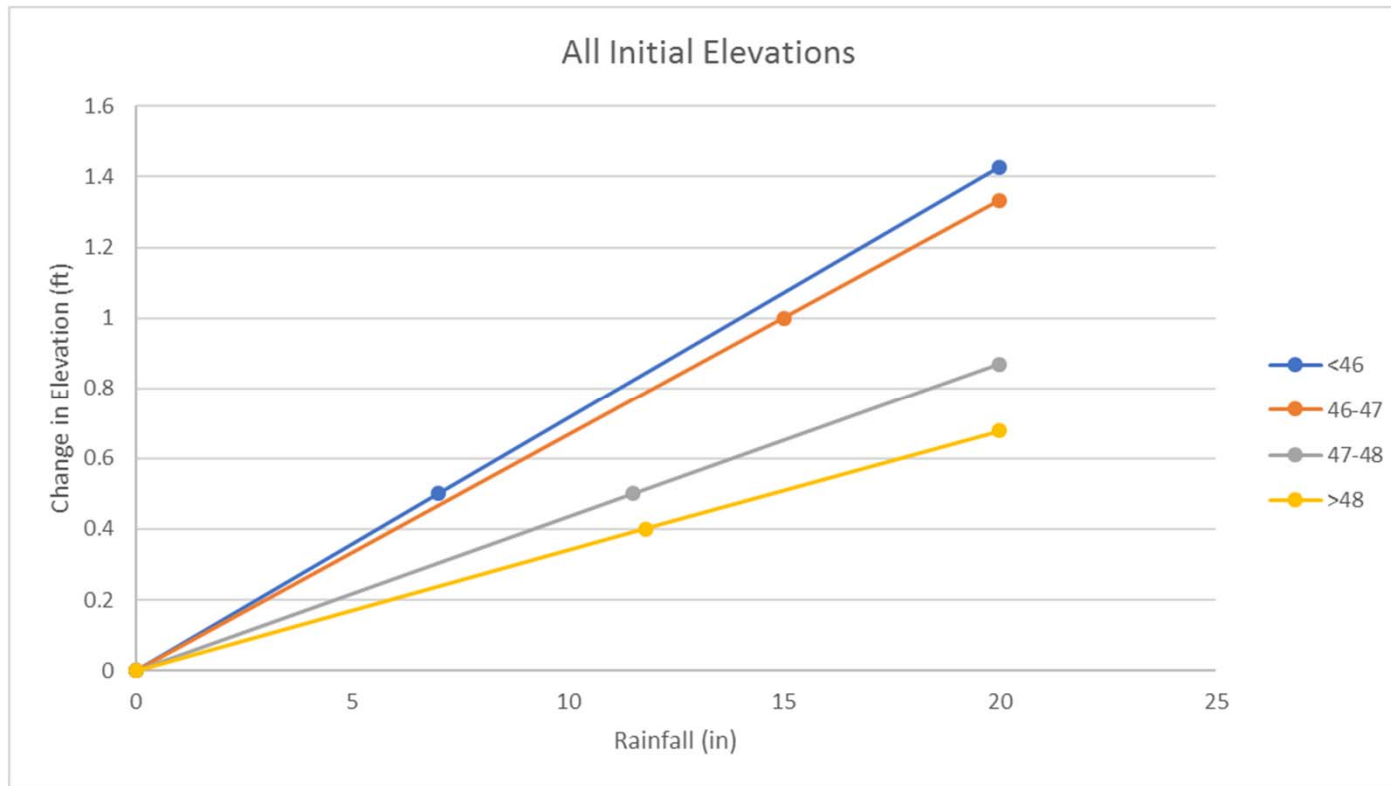
Lake Armistead



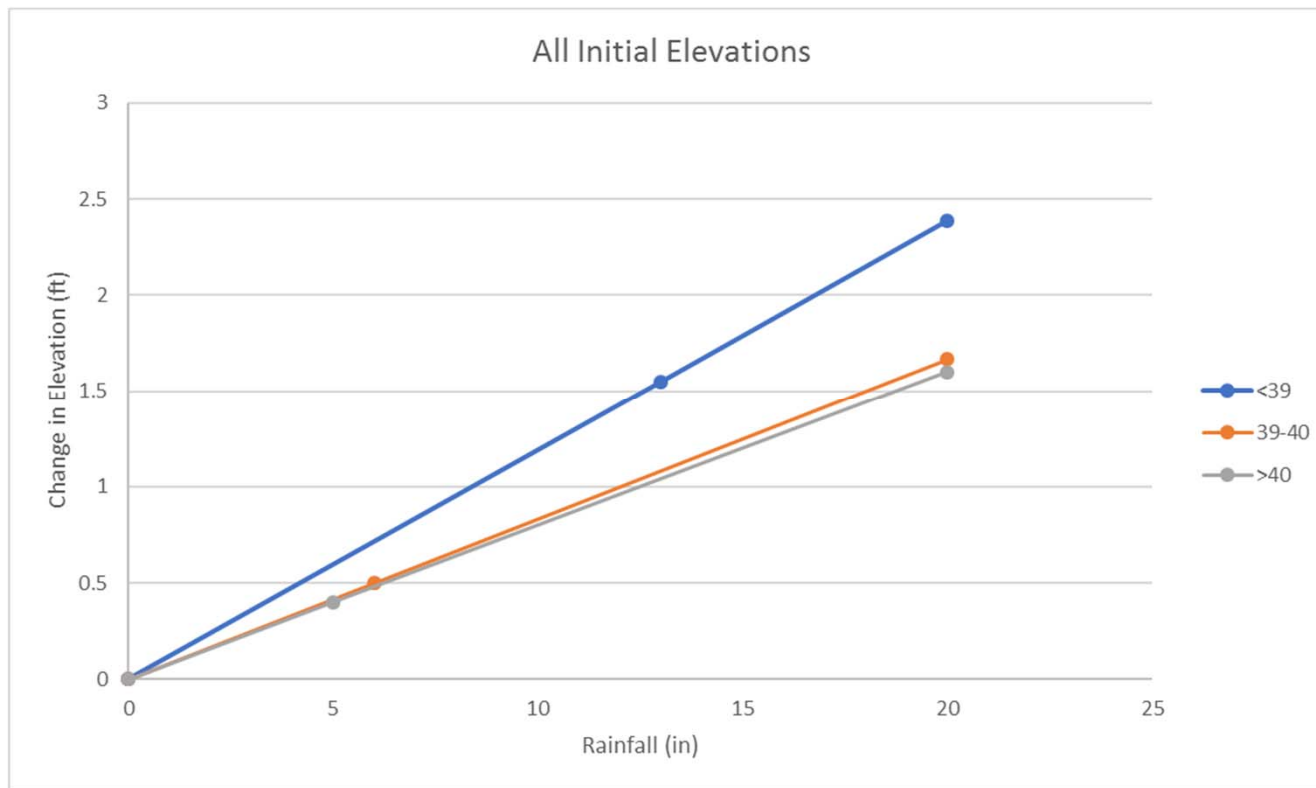
Lake Magdalene



Lake Magdalene Rating Curves

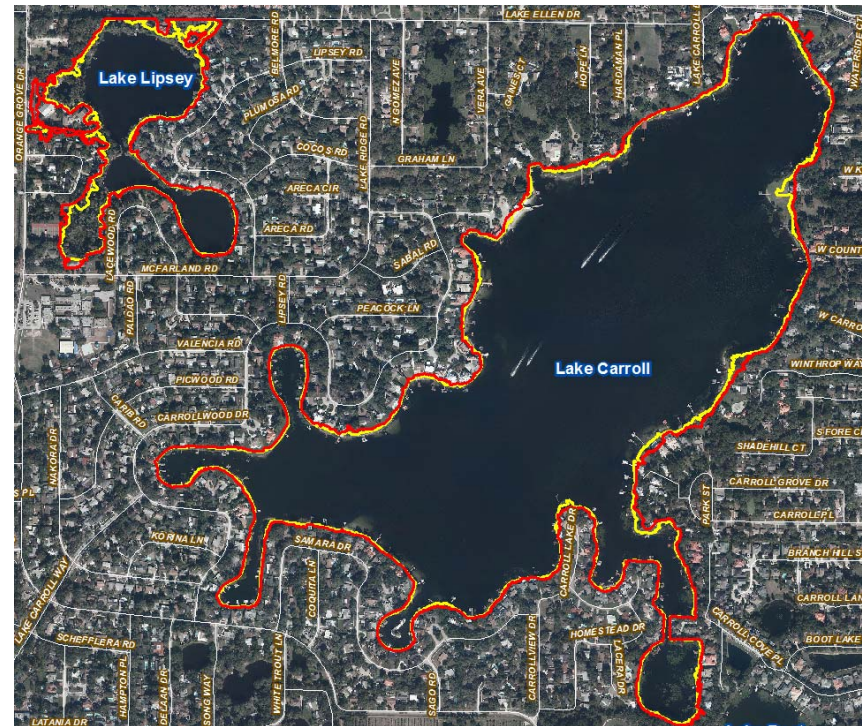


Lake Armistead Rating Curves



Lake Rating Curves

- Lake rating curves based on rainfall event and initial lake level can be used to predict expected lake level rise
- Expected increase in lake levels can be used to plan appropriate responses
- Available structure, road, and backyard elevation data can be used to estimate location of flooding

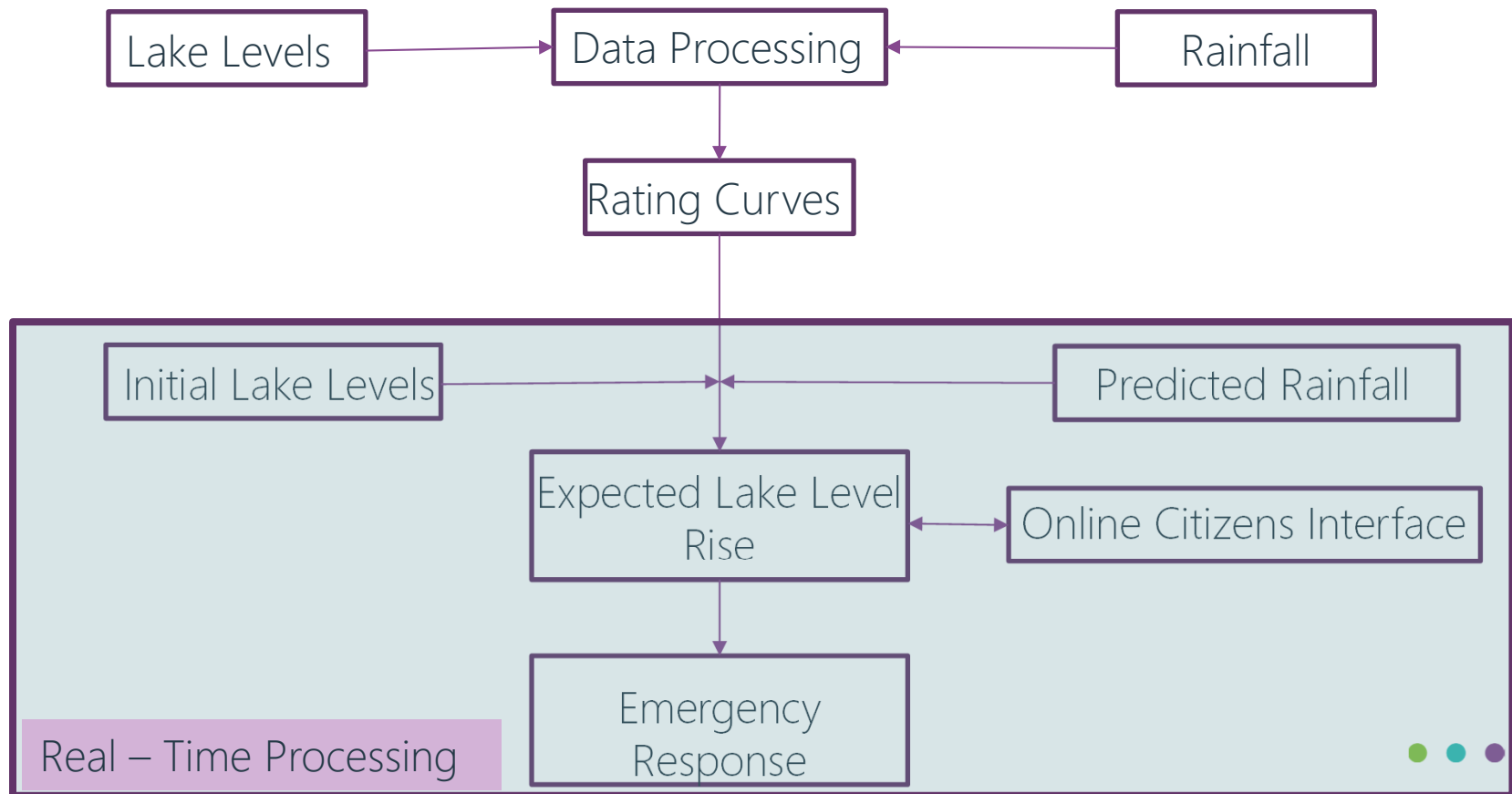


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Use of Lake Rating Curves

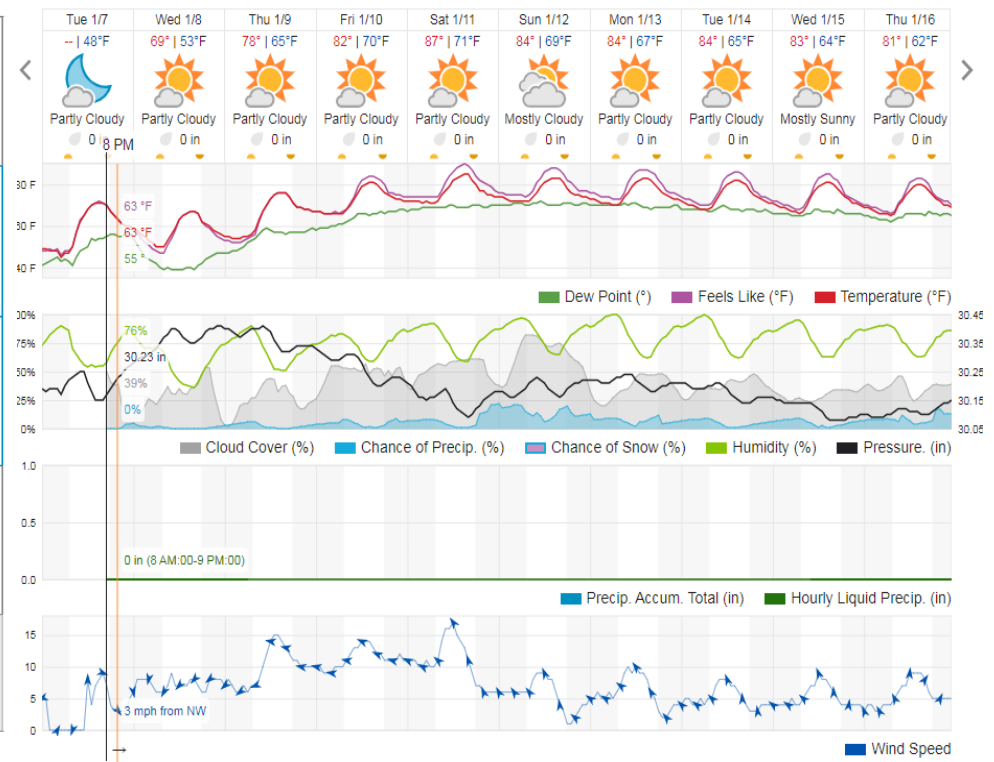
Development of a Lake Warning System

Overall Workflow



Predictive Rainfall Data

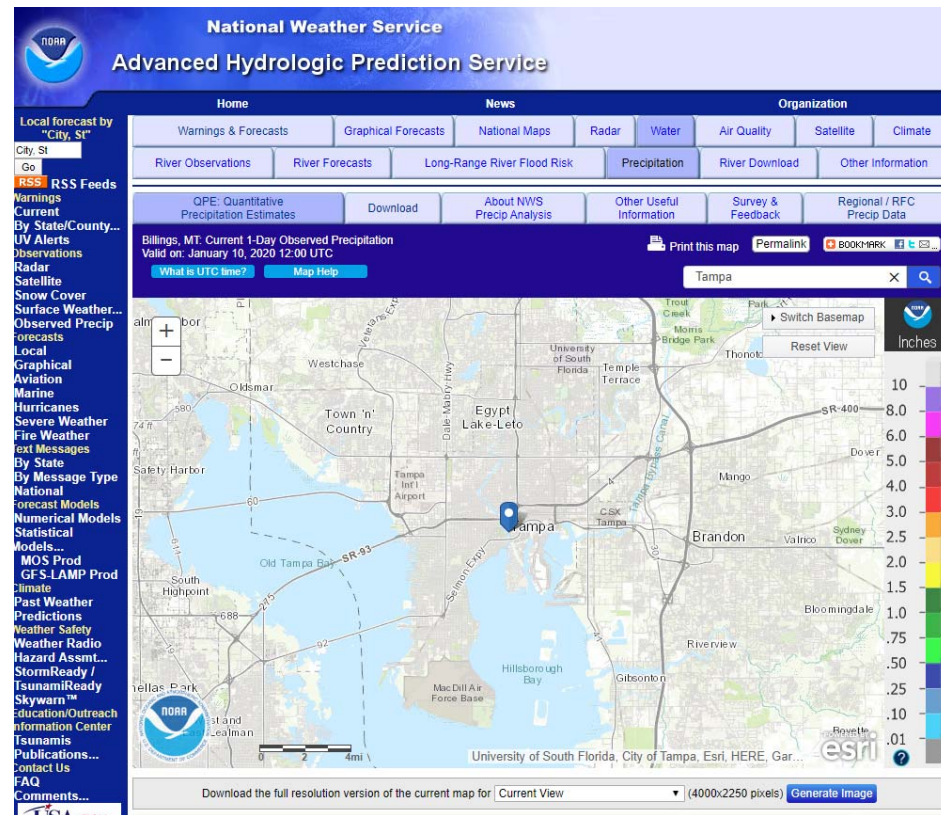
SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
29 Cloudy Actual: 81° 72° 0.39 in	30 Cloudy Actual: 77° 0° 0 in	31 Mostly Cloudy Actual: 71° 0° 0 in	1 Mostly Sunny Actual: 72° 57° 0 in	2 Mostly Cloudy Actual: 80° 0° 0 in	3 Cloudy Actual: 82° 0° 0 in	4 Cloudy Actual: 74° 0° 0 in
5 Mostly Sunny Actual: 67° 60° 0 in	6 Mostly Sunny Actual: 68° 49° 0 in	7 Mostly Sunny Forecast: 68° 47° 0 in	8 Partly Cloudy Forecast: 68° 51° 0 in	9 Partly Cloudy Forecast: 77° 64° 0 in	10 Partly Cloudy Forecast: 82° 70° 0 in	11 Mostly Sunny Forecast: 85° 70° 0 in
12 Mostly Cloudy Forecast: 84° 69° 0 in	13 Mostly Sunny Forecast: 84° 68° 0 in	14 Mostly Sunny Forecast: 83° 67° 0 in	15 Partly Cloudy Forecast: 81° 67° 0 in	16 Mostly Sunny Forecast: 80° 62° 0 in	17 Partly Cloudy Forecast: 77° 65° 0 in	18 Partly Cloudy Forecast: 77° 64° 0 in
19 Partly Cloudy Forecast: 77° 63° 0 in	20 Mostly Sunny Forecast: 76° 61° 0 in	21 Mostly Sunny Forecast: 74° 62° 0 in	22 Average: 70° 52° 0 in	23 Average: 70° 52° 0 in	24 Average: 70° 52° 0 in	25 Average: 70° 52° 0 in
26 Average: 70° 52° 0 in	27 Average: 70° 52° 0 in	28 Average: 71° 52° 0 in	29 Average: 71° 52° 0 in	30 Average: 71° 53° 0 in	31 Average: 71° 53° 0 in	1 Average: 71° 53° 0 in



<https://www.wunderground.com/forecast/us/fl/tampa>



NOAA Advanced Hydrologic Prediction Service



Gage Data From County

- County currently has 76 gage locations
- Gages monitored weekly or daily
- County is in the process of using SCADA system to allow for near real-time collection of gage data
- The water-level data collected from gages can be incorporated into lake rating curves along with rainfall to predicted expected lake level rise



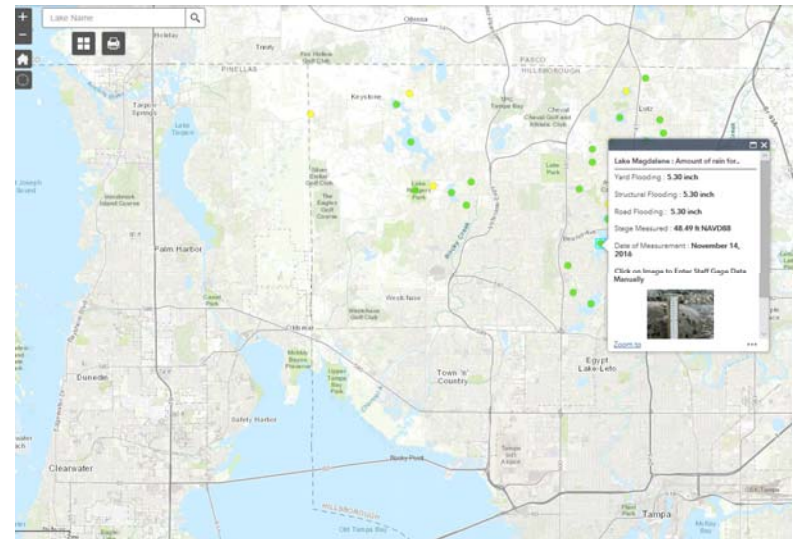
Developing Web-Based Application

- Development of web-based spatial interface to view county-wide lake water-levels and available lake capacities
- Display data in searchable format on a map for ease of access
- Provide online base storage calculator to allow user to enter custom stage data
- Develop backend application to update online map when new data becomes available



ArcGIS Online Portal (County/Citizen's Interface)

- Multi-platform based online GIS Application
- Allows access from variety of devices such as iPad, Cellphones, etc.
- Can be customized to generate PDF maps for reporting purposes
- Lake rating curves can be programmed in the portal
- User-provided data can be used for real-times estimates of flooding



Custom Lake Stage Data Entry for Lake Cooper

Enter Manually Observed Lake Stage from Staff Gauge
58 ft NAVD88

Optional : Property Specific Data

Enter any of the Following Values if Available (before you click "Enter")

Yard Elevation
58.5 ft NAVD88
Finished Floor Elevation
59 ft NAVD88
Road Elevation
59.5 ft NAVD88

Results

Amount of Rainfall for Yard Flooding 1.56 inches
Amount of Rainfall for Structural Flooding 3.12 inches
Amount of Rainfall for Road Flooding 4.68 inches



Tabular Product for Reporting and Actions

Lake Name	Node	Watershed	Latest Stage (ft, NAVD)	Warning Stage (ft, NAVD)	Available Depth (ft)	Additional Rainfall Can Handle (inches)	Yard (ft, NAVD)	Additional Rainfall Can Handle (inches)	Structure (ft, NAVD)	Additional Rainfall Can Handle (inches)	Road (ft, NAVD)	Additional Rainfall Can Handle (inches)	Road Name
Crescent Lake	490470	Brooker Creek	41.16	42.00	0.84	2.54	42	2.54	43.5	11.73	44.2	11.73	Crescent Dr
Island Ford Lake	490430	Brooker Creek	39.86	41.50	1.64	6.37	41.5	6.37	42.4	9.41	42.6	10.44	Crescent Rd
Martin Borrow Pit	491701	Brooker Creek	25.22	26.00	0.78	1.19	26	1.19	26.5	1.96	26.7	2.28	Tyler Run Ave
Keystone Lake	490580	Brooker Creek	40.77	42.50	1.73	5.67	42.5	5.67	42.8	6.47	42.8	6.47	Colony Dr
Horse Lake	491620	Brooker Creek	46.24	46.50	0.26	1.58	46.5	1.58	48	10.55	49.6	10.97	Cosme Rd
Rogers Lake	491580	Brooker Creek	41.38	45.60	4.22	12.00	52	12.00	52	12.00	45.6	12.00	Crawley Road
Rock Lake	433480	Rocky Brushy	43.58	45.20	1.62	8.44	46	8.44	47	10.04	45.2	5.88	Willow Glen Dr
Pretty Lake	465320	Rocky Brushy	43.52	45.50	1.98	7.50	45.5	7.50	46	9.30	45.8	8.53	Hutchison Rd
Armistead, Lake	433380	Rocky Brushy	41.40	44.00	2.60	5.08	44	5.08	45.5	8.52	44	5.08	Armistead Ln
Kell, Lake	510930	Cypress Creek	64.90	67.50	2.60	11.65	67.5	11.65	68.6	11.65	67.5	11.65	New Berger Rd
Hobbs Lake	453190	Rocky Brushy	64.64	65.50	0.86	2.54	65.5	2.54	66	3.89	66.6	5.63	Crooked Ln
Cooper Lake	453150	Rocky Brushy	59.42	61.00	1.58	5.96	61	5.96	61.5	7.19	61	5.96	5th PL SW
Keene, Lake	510770	Cypress Creek	61.62	63.00	1.38	8.79	63	8.79	63.6	9.66	63.2	9.66	Tracer Dr
Lake Hanna	510750	Cypress Creek	60.46	61.50	1.04	5.91	61.5	5.91	62.2	8.98	62.6	10.61	Hanna Rd
Stemper, Lake	510650	Cypress Creek	59.92	61.50	1.58	11.41	61.5	11.41	62	12.00	63.7	12.00	Cypres Cove Ln
Crystal Lake	453130	Rocky Brushy	59.26	61.00	1.74	6.23	61	6.23	62	7.27	61.5	7.27	Loretta Ln
Reinheimer, Lake	453040	Rocky Brushy	58.34	59.81	1.47	7.25	59.81	7.25	60	8.07	61	8.71	Van Dyke Rd
Merrywater, Lake	453030	Rocky Brushy	56.90	58.00	1.10	9.45	58	9.45	60	9.45	58.3	9.45	Crenshaw Lake Rd
Heather, Lake	452640	Rocky Brushy	49.97	52.50	2.53	8.11	53	8.11	54	8.11	52.5	7.52	Cullendale Dr and North Lakeview Dr
Byrd Lake	418616	Sweet Water	48.49	50.00	1.51	2.88	50	2.88	50.8	4.47	50	2.88	Lake Byrd Dr
Platt Lake	418532	Sweet Water	48.00	51.00	3.00	8.50	51	8.50	51.9	11.50	53	11.50	Lake Magdalene Blvd
Magdalene, Lake	418380	Sweet Water	48.49	50.00	1.51	5.30	50	5.30	51	5.30	51	5.30	Lake Magdalene Cir
Bay Lake	418155	Sweet Water	44.83	46.00	1.17	5.10	46	5.10	46.8	7.80	49	9.10	Levinson Rd / Bay Lake Ln / Moran Rd
Lipsey, Lake	415510	Sweet Water	39.76	42.00	2.24	4.20	42	4.20	42.8	5.47	42	4.20	McFarland Rd
Carroll, Lake	415125	Sweet Water	36.03	37.50	1.47	7.02	37.5	7.02	38.5	9.47	38.2	9.47	Carroll Lake Dr
Lake Meade East	614425	TBC	30.20	33.00	2.80	3.35	34	3.35	34.2	3.35	33	3.35	
Timber Pond	614450	TBC	30.41	32.20	1.79	2.50	32.2	2.50	33.2	2.50	34	2.50	





Evaluation of Current Lake Levels

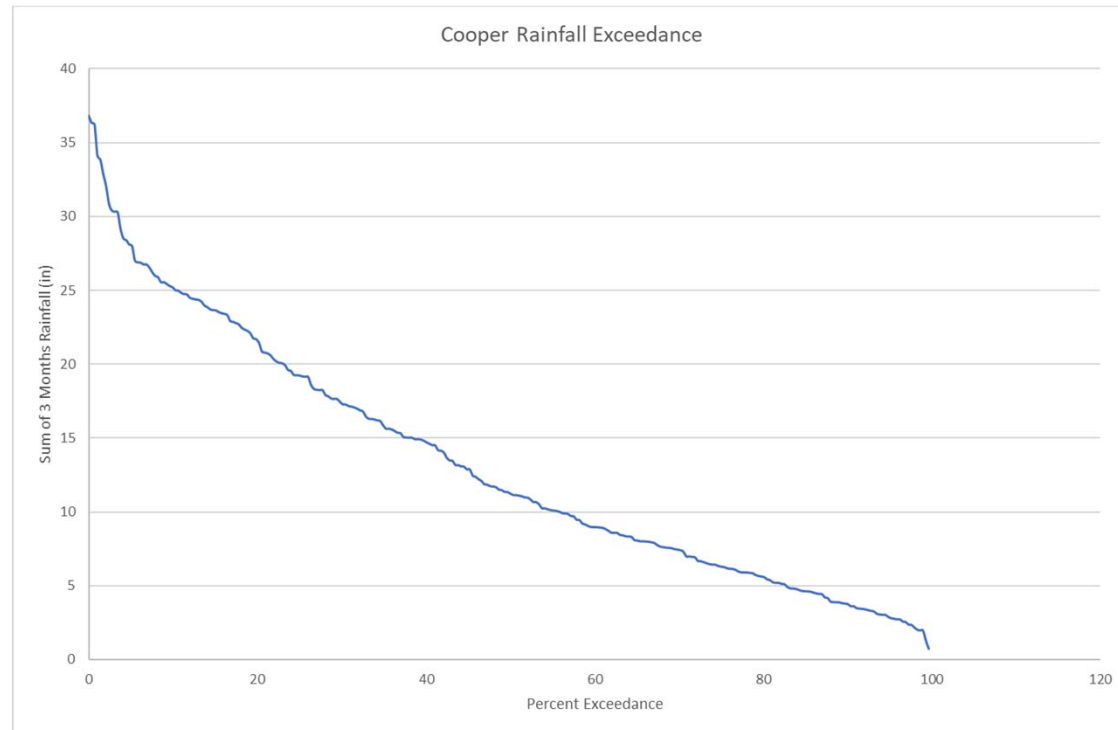
Are we in dry wet or really wet conditions ?

Current Lake Status

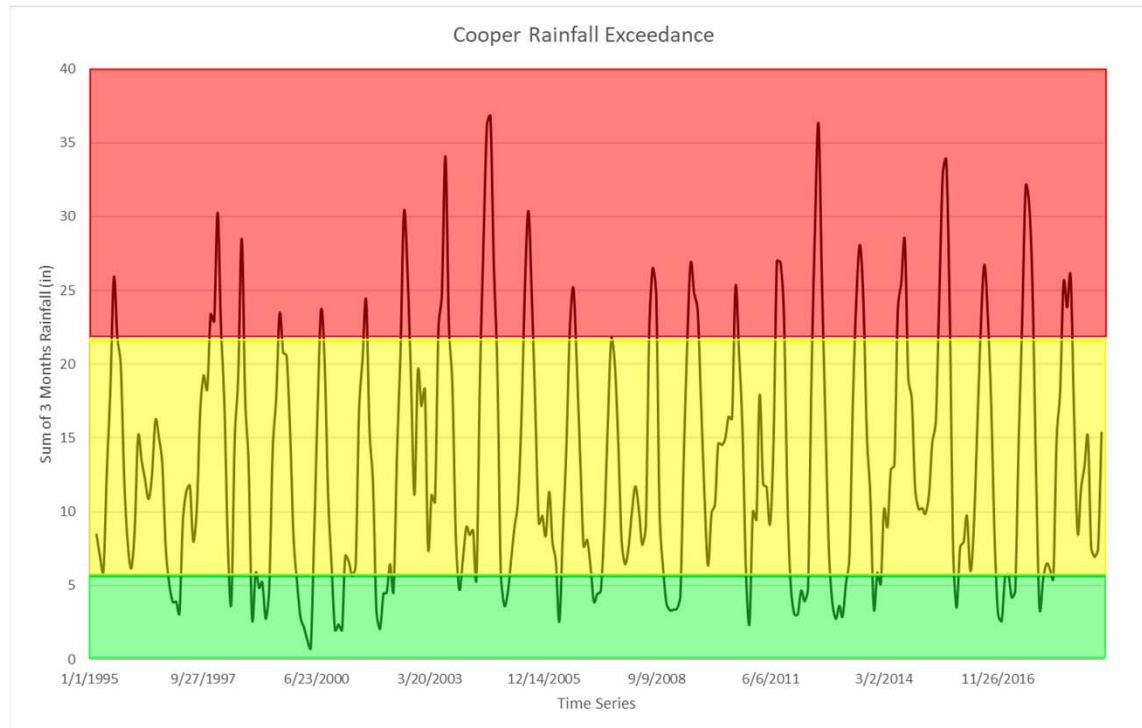
- The available lake level data lacks context in terms of lake condition (being wet/dry)
- Available historical lake level data can be used to develop parameters for establishing thresholds for wet/dry conditions
- Consistent with SWFWMD P10 (10th percentile) water level can be used to establish wet conditions
- P90 (90th percentile) can be used to establish dry conditions
- Comparison of existing water level with the percentiles can help in verifying lake status



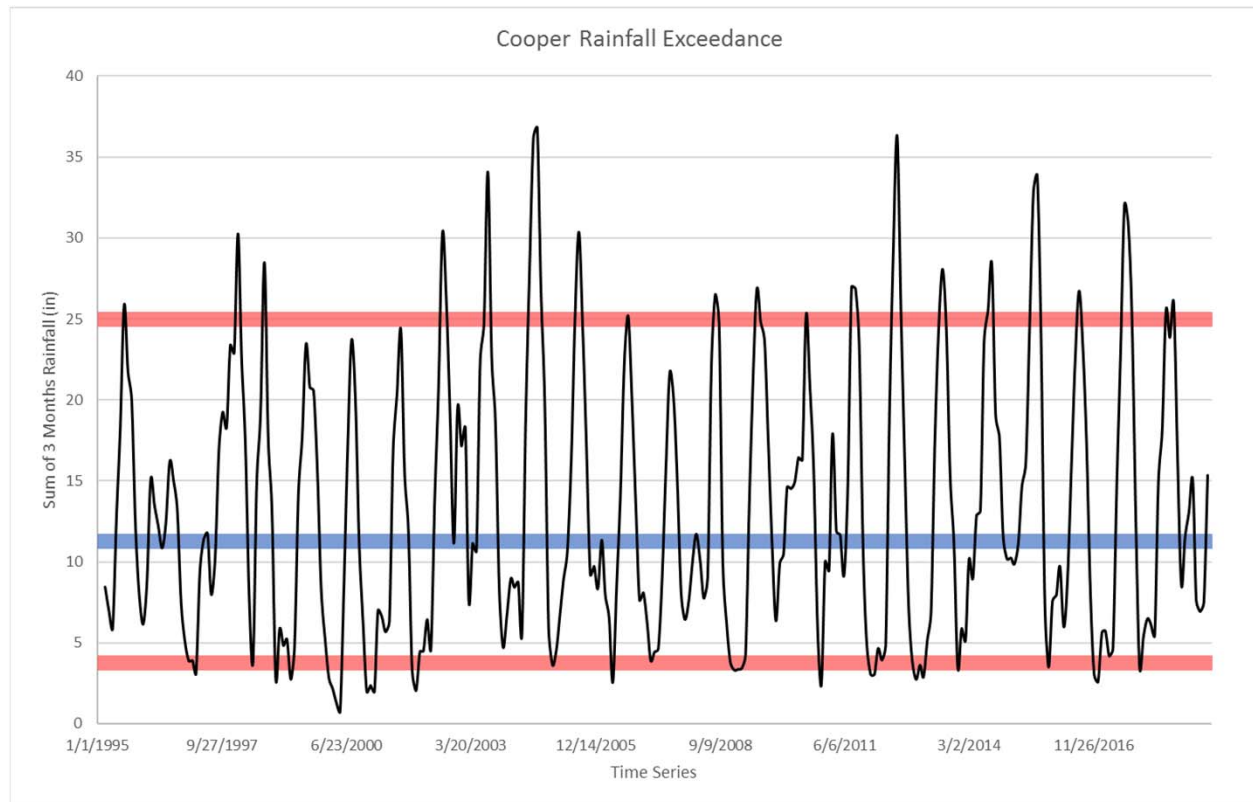
Lake Cooper Rainfall



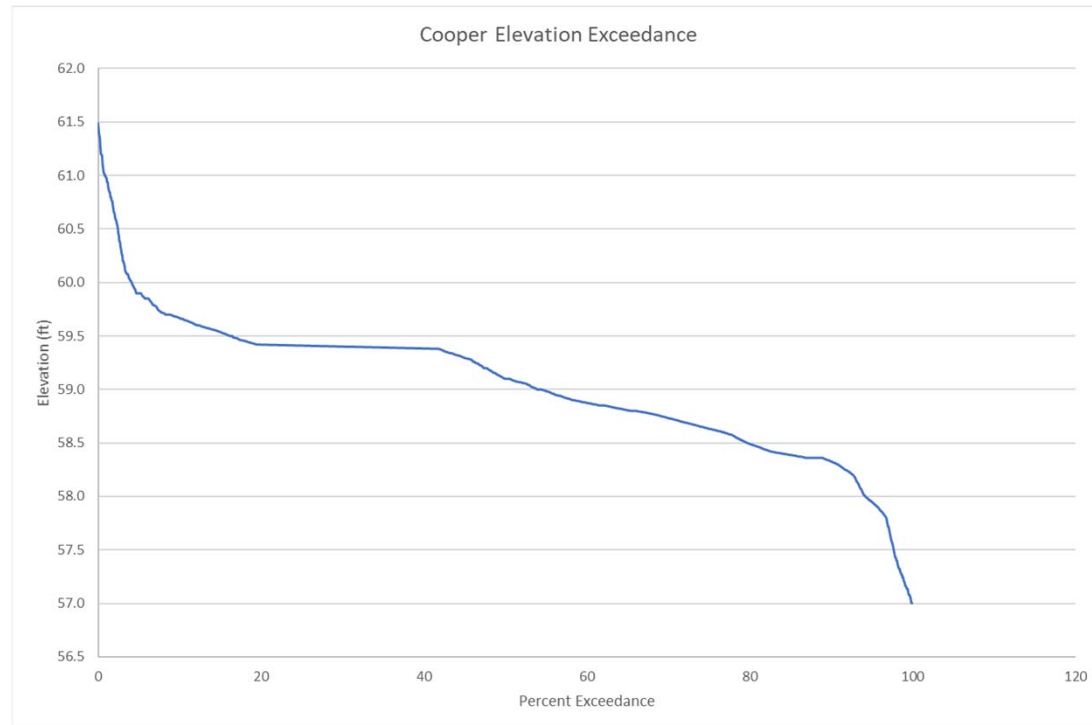
Lake Cooper Rainfall(Percentile Zones)



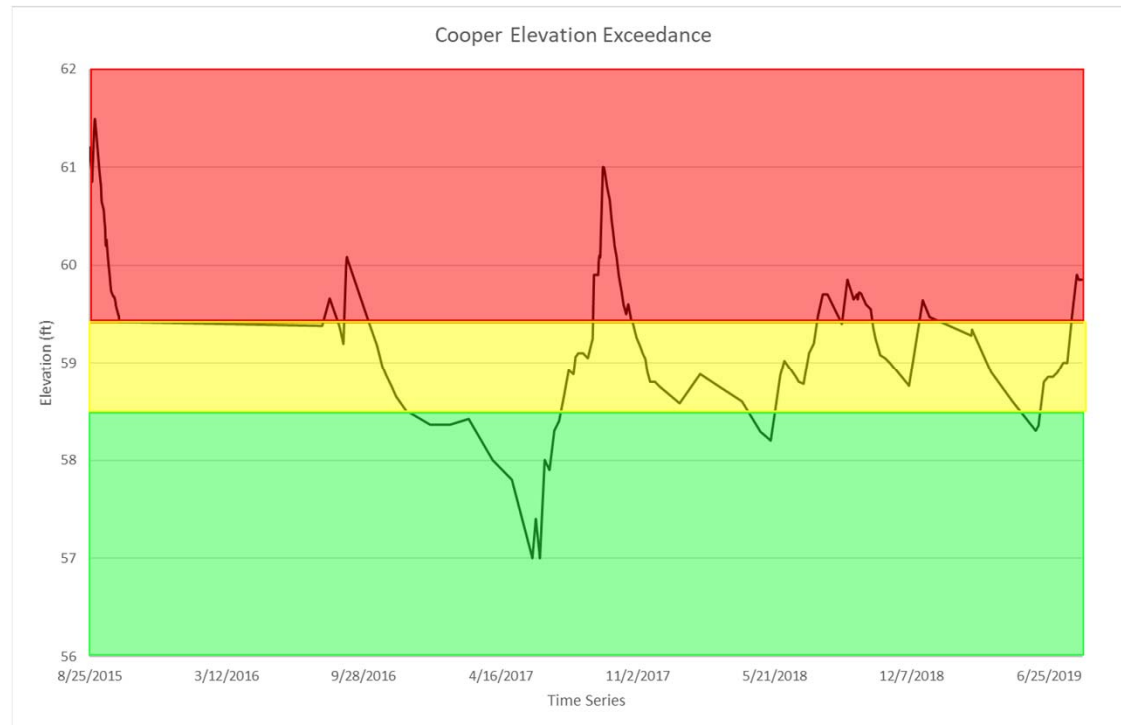
Lake Cooper Rainfall (P10, P50, and P90)



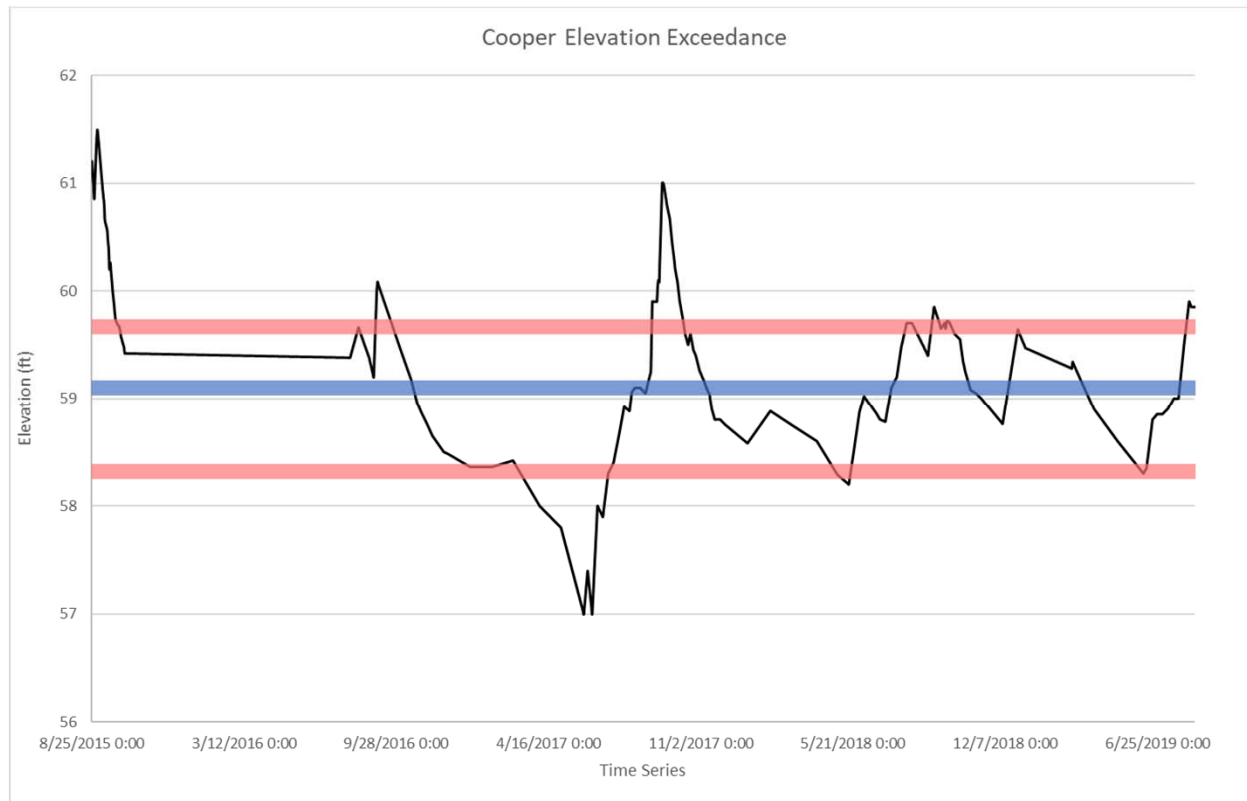
Lake Cooper Elevation



Lake Cooper Elevation



Copper

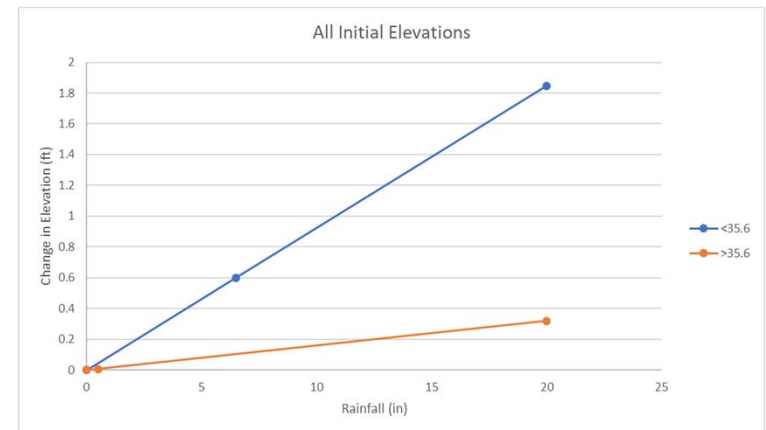
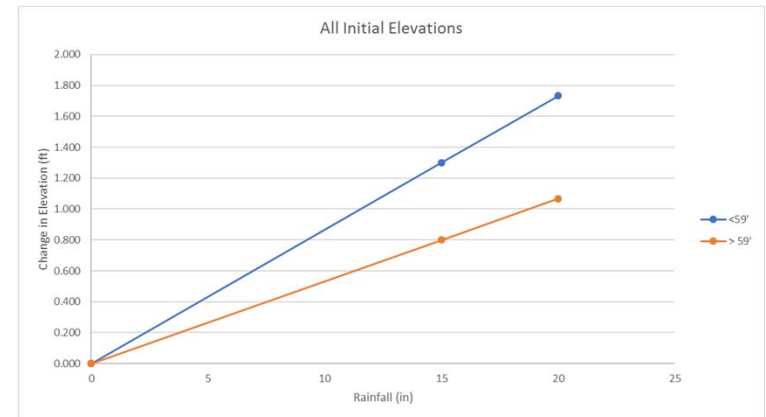


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Conclusions

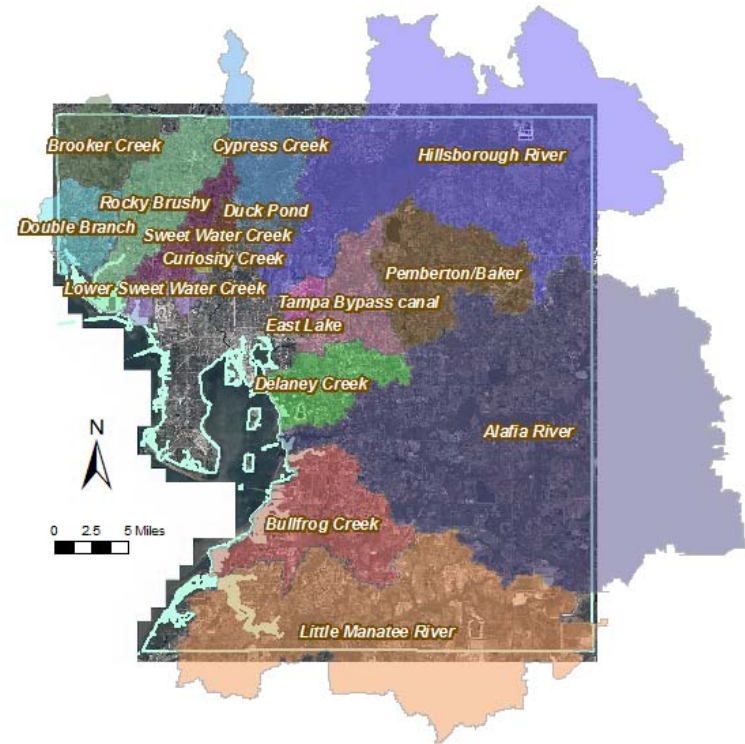
Conclusions

- Rainfall and observed lake level data was used to develop lake rating curves that can be used to allow for predicting lake level rises
- The lake rating curves can be programmed into a stand-alone/web-based application to allow for automated calculations and citizens interaction
- Historical lake level data can be used to determine current lake conditions and estimate dry/wet status of lake.



Future Work

- Automate existing data collection network to allow for near-real time water level data
- Refinement of lake rating curves based on newly collected rainfall and water-level data
- Integration of all data sources in to the lake warning system



Questions?

