Improvement and Calibration of Flint's Hydraulic Model

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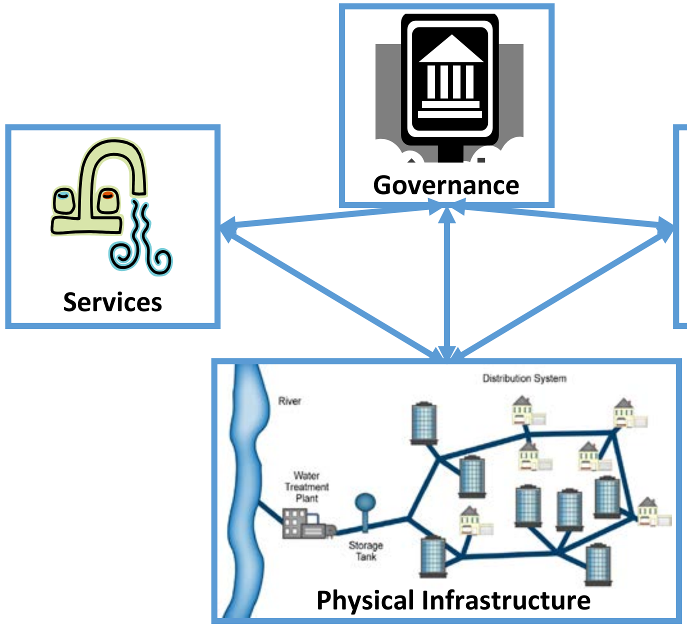
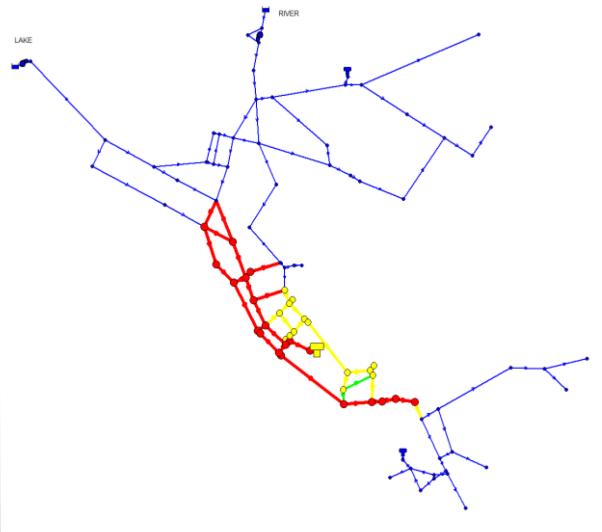
Hydraulic Modeling: Systems Approach



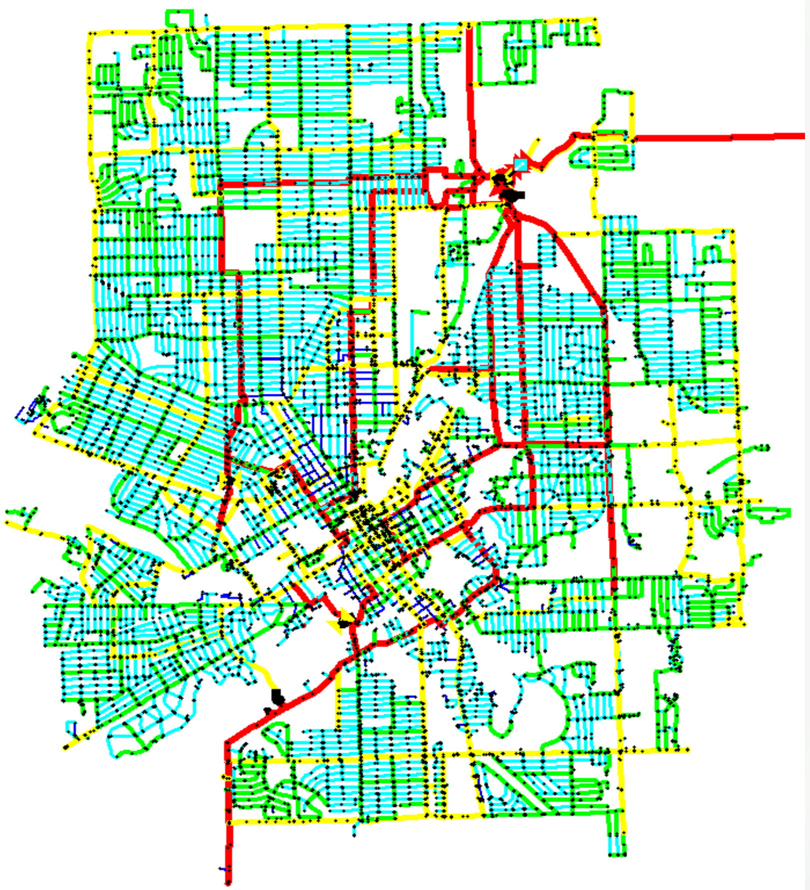
EPANET or other software: first principles physics-based equations for flow, pressure and water quality



Hydraulic modeling is a systems-based approach to solving problems

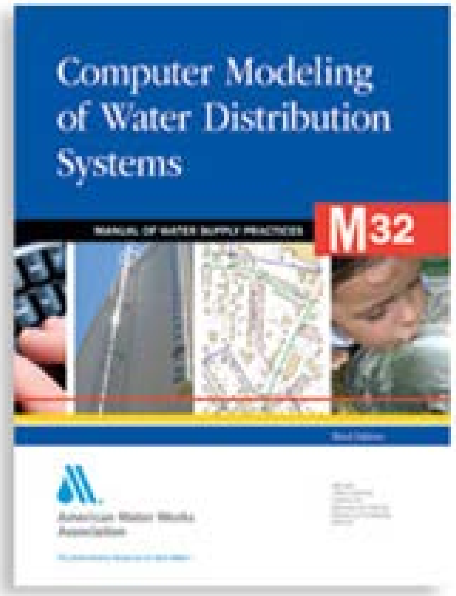
Motivation to Improve Flint's Model

- What are the flow patterns?
- What is the residence time?
- How has customer usage changed?
- Can sampling locations be improved?
- How will new water source & operating rules affect pressure and water quality?
- How can common summer water quality problems be mitigated?
- What are the effects of oversized infrastructure on water quality?



Life Cycle of a Hydraulic Model

- Construction
  - Planning, data collection, infrastructure model development, customer demands, operational data
- Calibration
  - Fire flow tests, hydraulic gradient tests, C factor tests, pressure monitoring, meter calibration, establishing correct elevation data, tracer studies
- Maintenance
  - Establish regular schedule for updating model components, ideally link model to databases, perform periodic calibration

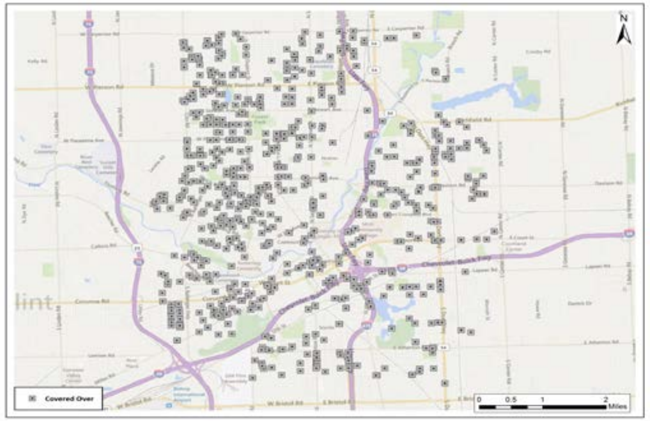


Approach to Model Improvement

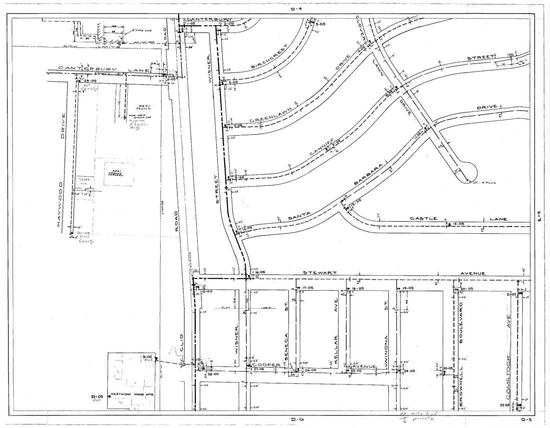
- Data collection
- Infrastructure & operations updates
- Integration of model, SCADA & GIS
- Customer demand updates
- Field data collection (flow & pressure monitoring)
- Model calibration
- Model accuracy assessment
- Versions of model for specified applications

Data Collection

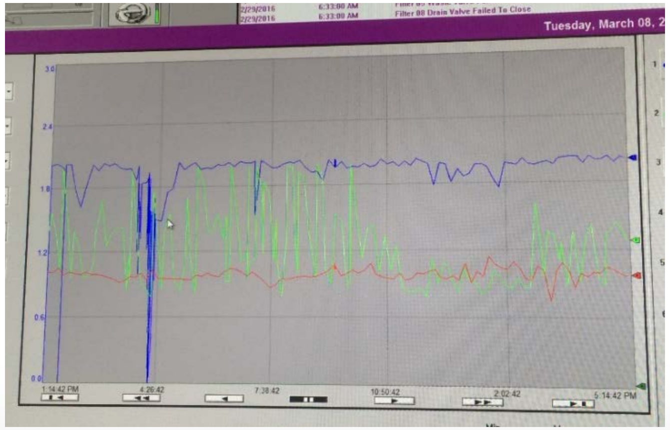
- Hydraulic model
- GIS layers & maps
- Info on operations
- Valve study data
- SCADA data
- Customer billing data
- Design diagrams
- Chlorine decay bottle tests



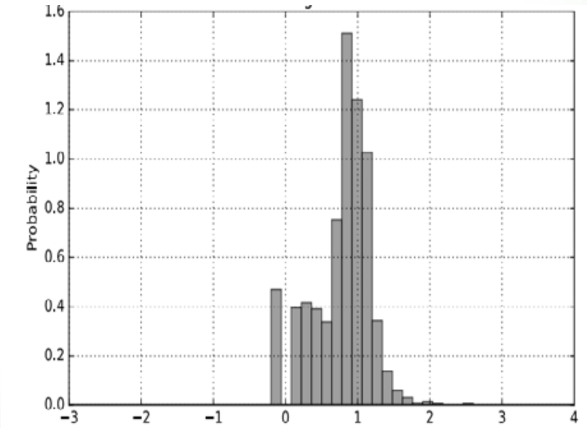
Covered Over Valves



Piping Diagrams



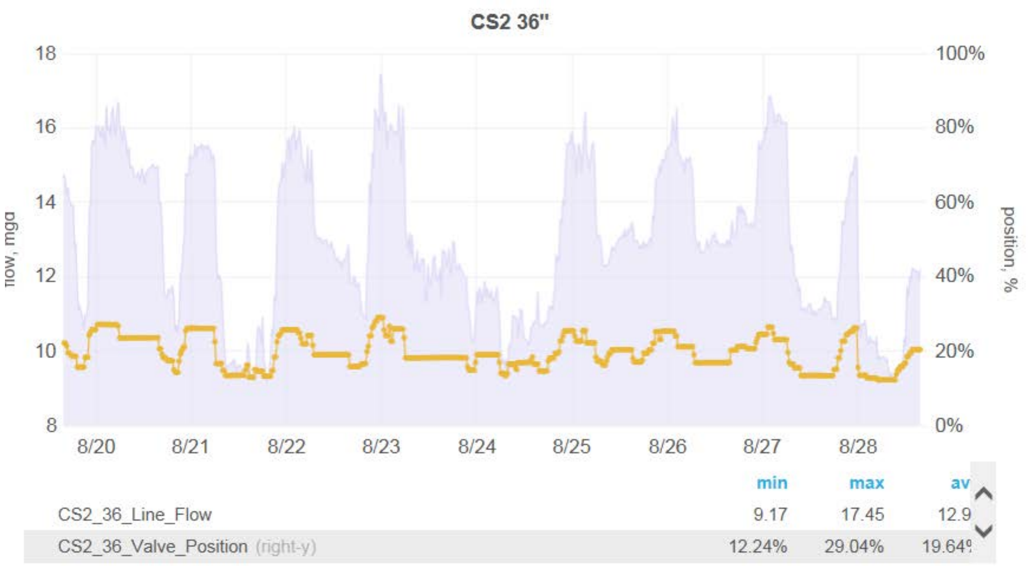
Chlorine SCADA Data



Usage Data

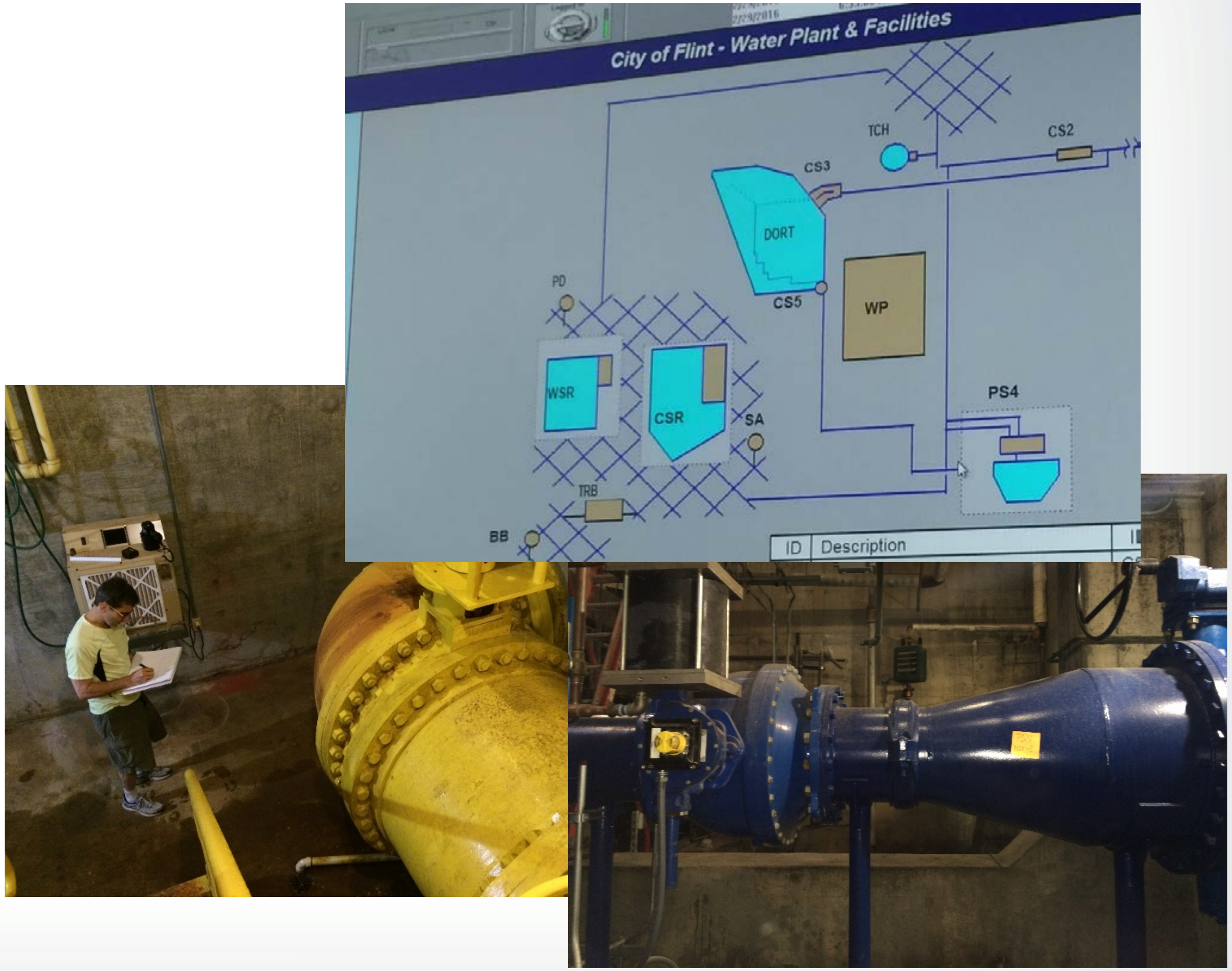
RTX:LINK for SCADA Data

- Weekly data dumps of Flint SCADA
  - Pump status, valve position, flow, tank level, pressure, chlorine residual, turbidity
- Posted on flint.rtx-link.io website weekly
  - Graphics
  - Analysis
  - Access via smartphone or computer
- Planned change to real-time updates



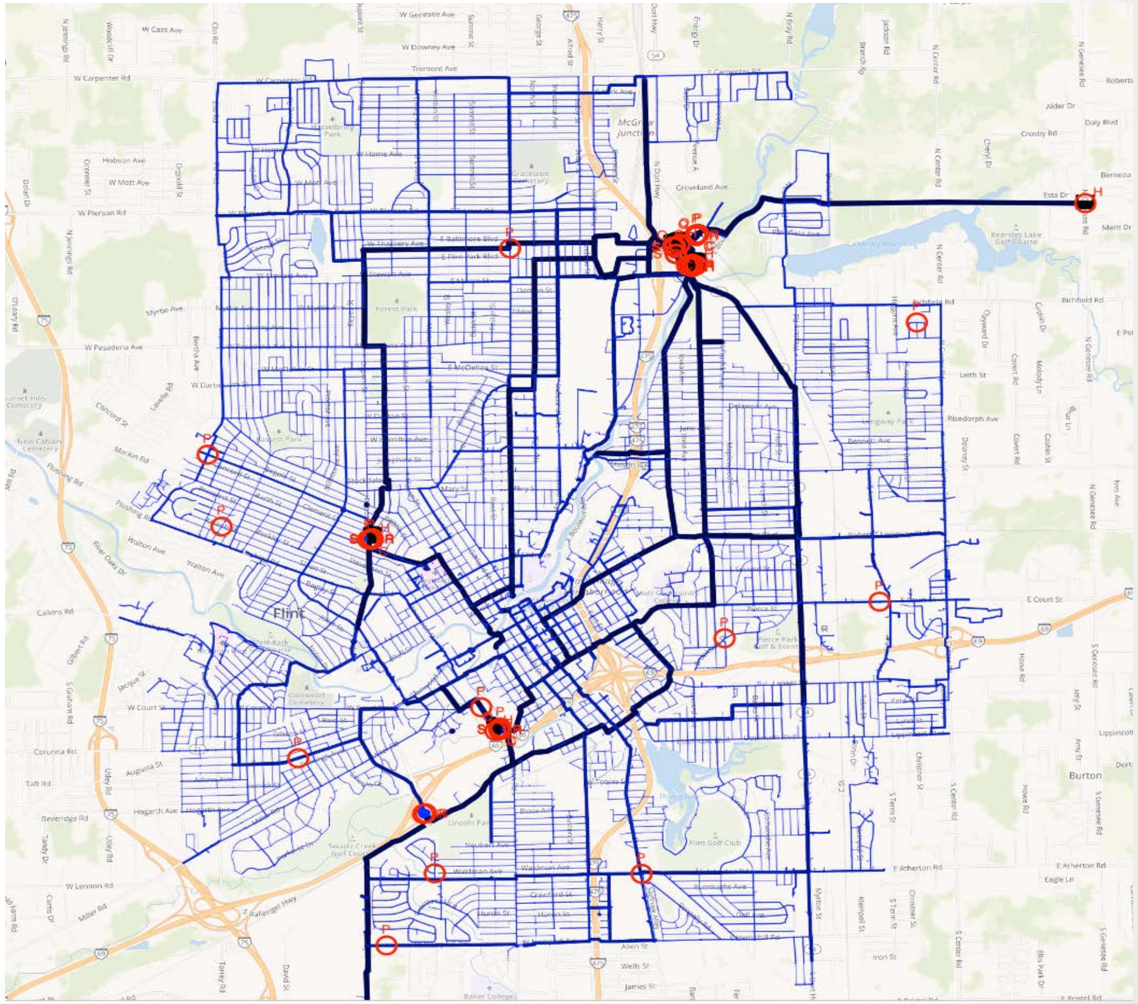
Infrastructure & Operations Updates

- Visited facilities, recorded diameter & lengths of pipes, type & characteristics of pumps
- Replaced flow control & other model valving with actual installed valve type, size, & characteristics
- Updated pump characteristic curves to match manufacturer (where available)
- Changed node elevations to match USGS/NED datasets



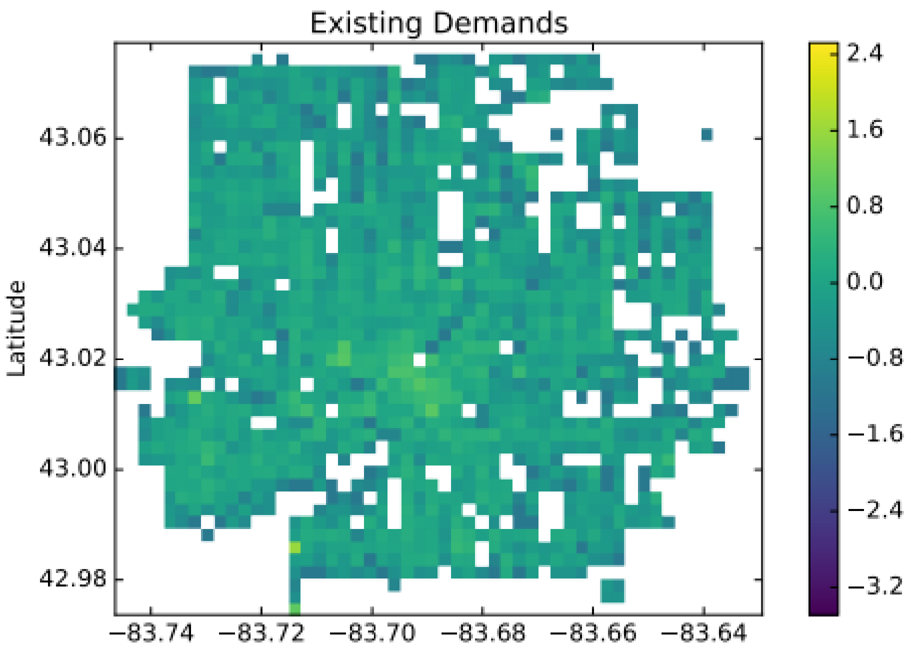
Integration of Model, SCADA & GIS

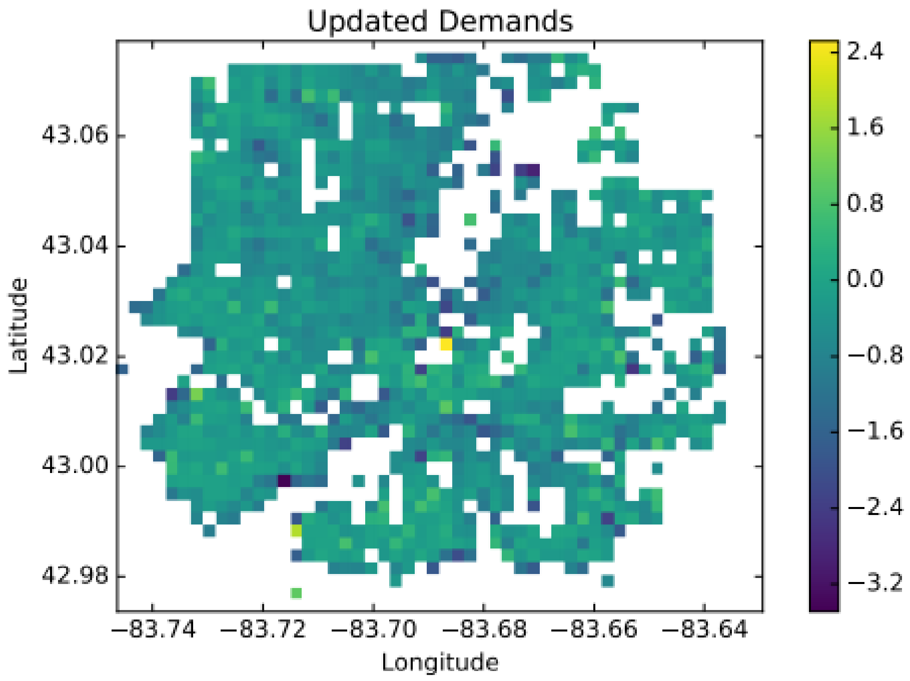
- Field data measured at entrance to system, treatment plant, tanks/reservoirs, pump stations
- Data in form of pump status, valve position, flow, tank level, pressure, chlorine residual, turbidity
- Pump status and valve position used to define operations in model
- Pressure head at entrance to system used to define model boundary condition



Customer Demand Updates

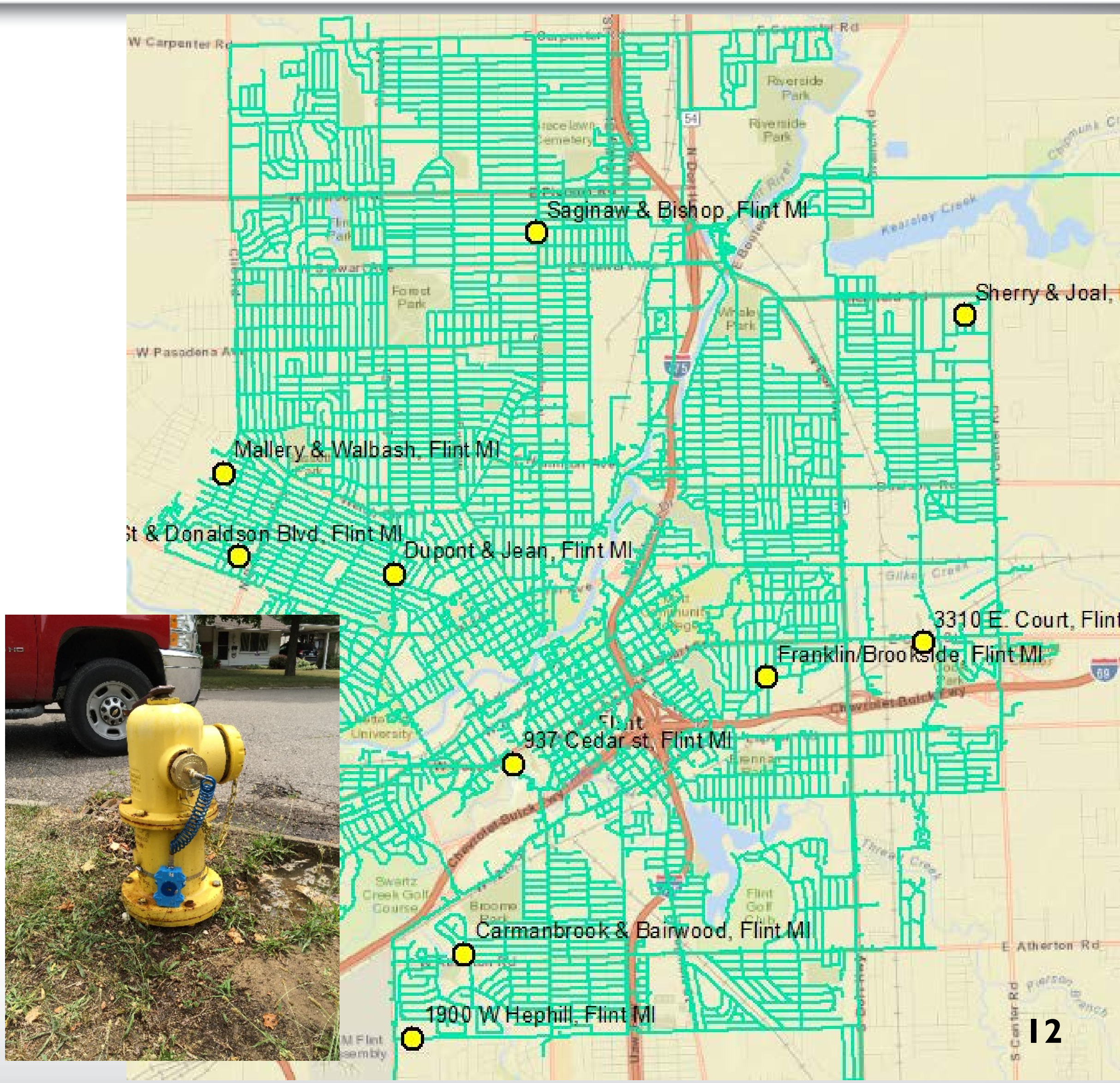
- Created database of 2013-16 billed water usage
- Using nearest neighbor GIS tool, updated base demands at each node
- Spatial changes from existing model to updated model shown below





Field Data Collection

- Pressure loggers
  - 14 loggers installed on hydrants
  - July - October
  - Data recorded every 5 minutes
- Flow meters
  - Plan to install this month (HydroMax)
  - Data recorded every 5 minutes
  - 2 week duration



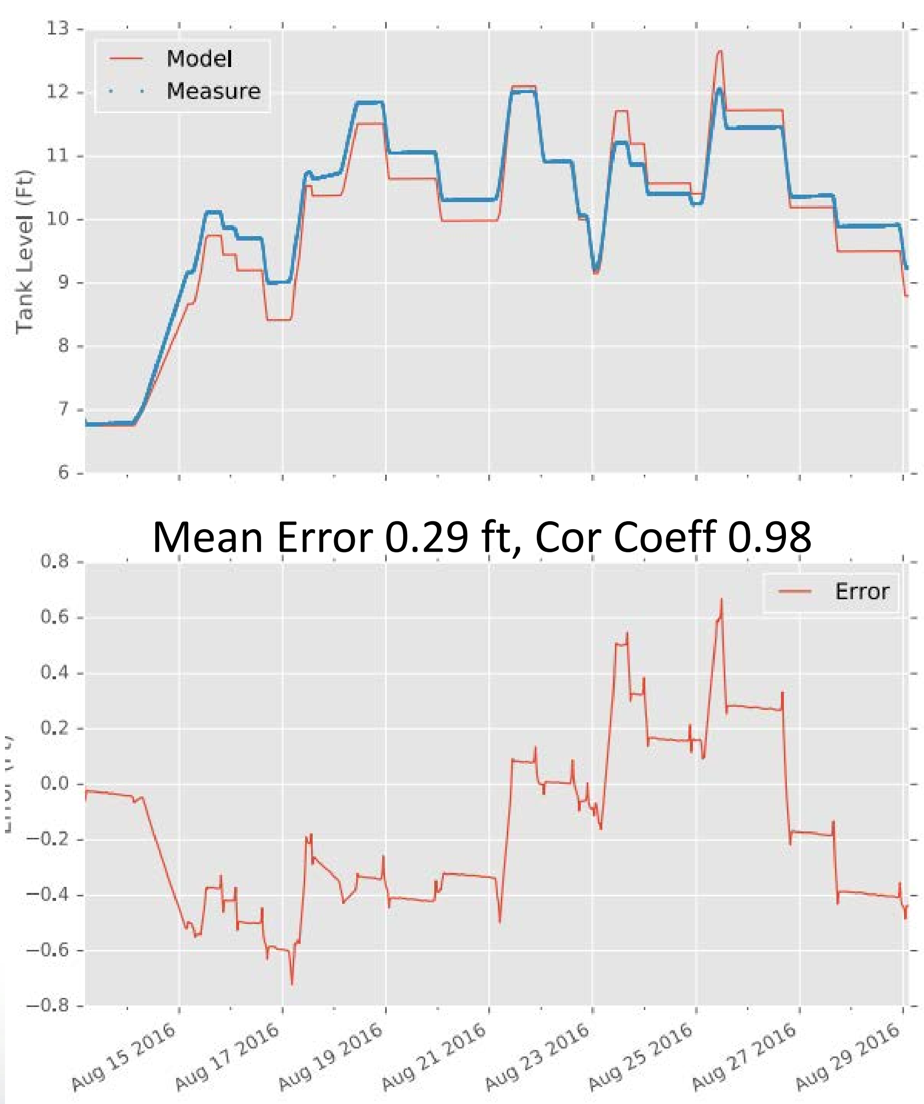
Model Calibration

- Challenges to calibration
  - Frequent changes in system operation (no set rules)
  - Uncertainty in valve status
  - Large volume of unbilled water usage
- Initial calibration adjusted following parameters
  - Valve loss curves (loss coefficient (K) vs. % open)
  - Pump head-discharge curves
- Potential additional calibration using flow data and chlorine residual samples
  - Closed isolation valves
  - Pipe roughness factors
  - Wall decay terms

Model Accuracy Assessment

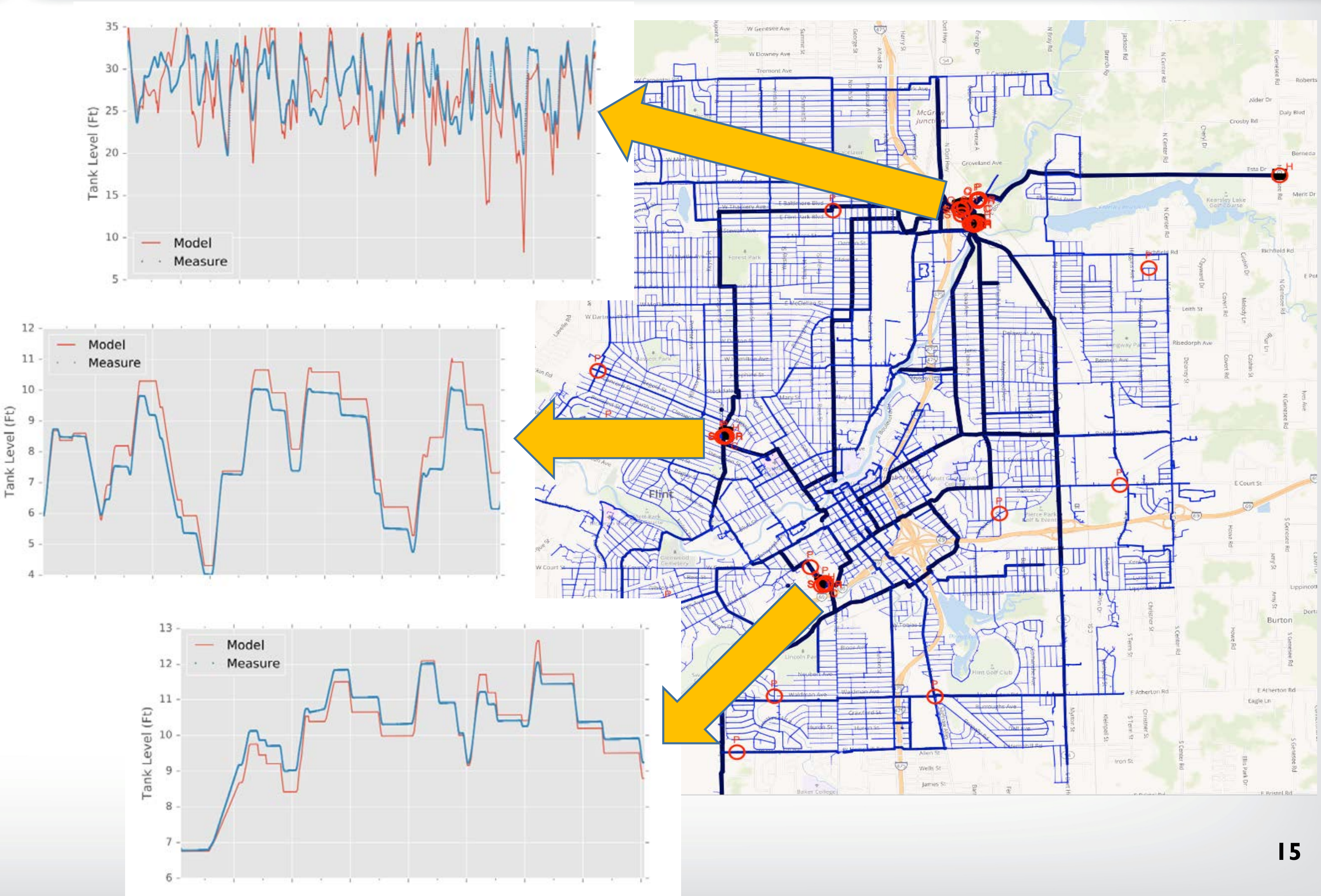
- Accuracy assessment used data from August 2016
  - SCADA & pressure logger data
  - Longer periods resulted in similar performance

- Model results compared to SCADA-measured
  - HGL / pressure (psi)
  - Flow (gpm)
  - Tank levels (ft)
  - System demand (gpm)



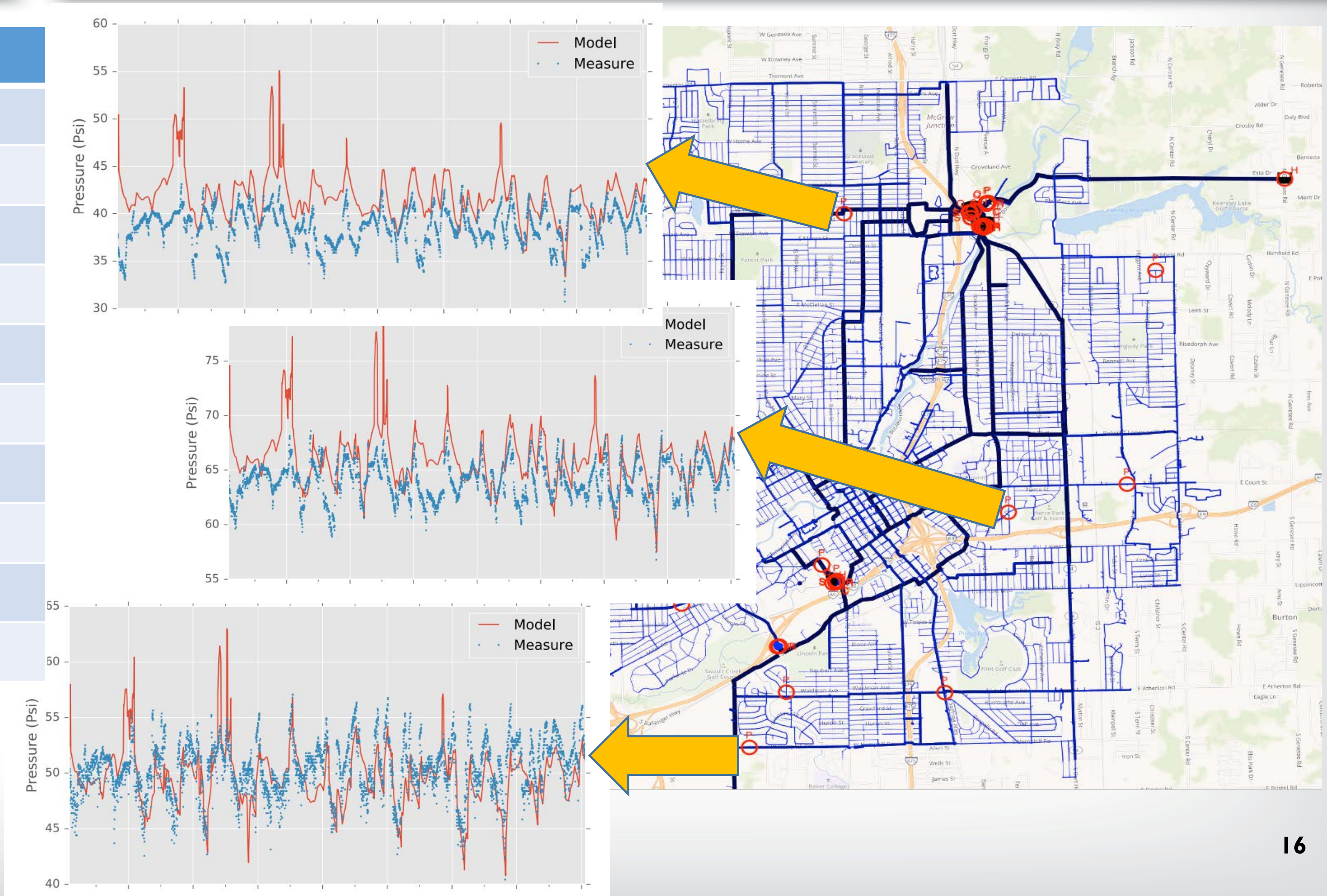
Accuracy of Modeled Tank Levels

Location	Mean Error	Correl Coeff
Tank 1	2.65 ft	0.7
Tank 2	0.55 ft	0.98
Tank 3	0.29 ft	0.98

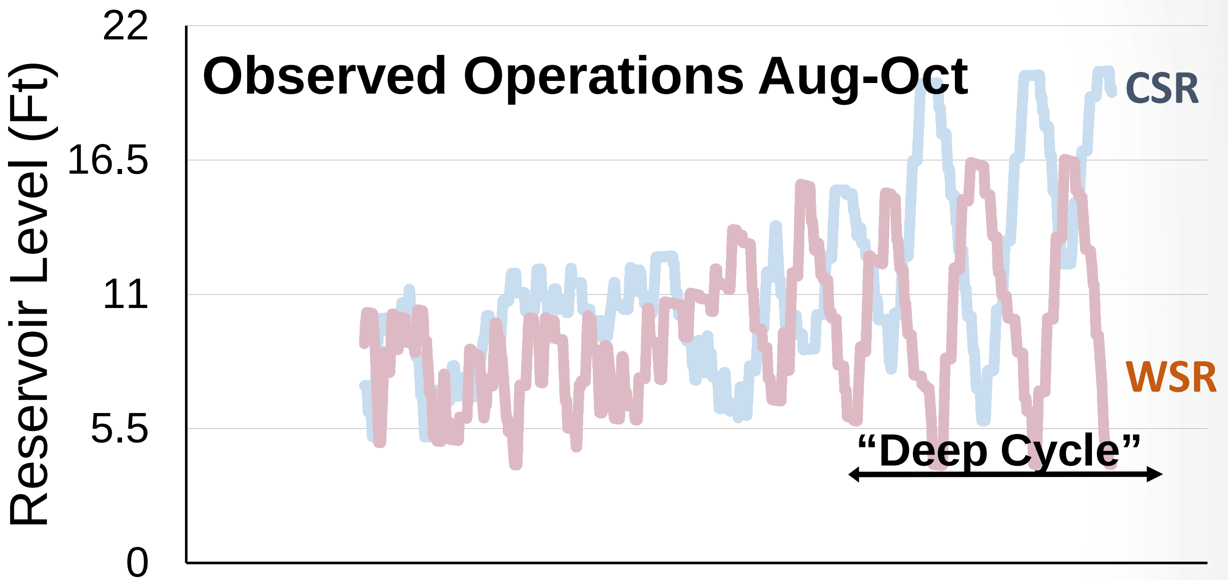


Accuracy of Modeled Pressures

Location	Mean Error	Cor Coeff
Log 4	4.55 psi	0.47
Log 5	1.75 psi	0.56
Log 6	2.23 psi	0.54
Log 7	2.25 psi	0.54
Log 8	3.42 psi	0.46
Log 9	3.88 psi	0.43
Log 10	1.55 psi	0.54
Log 11	2.23 psi	0.6
Log 12	2.07 psi	0.52
Log 13	3.31 psi	0.46



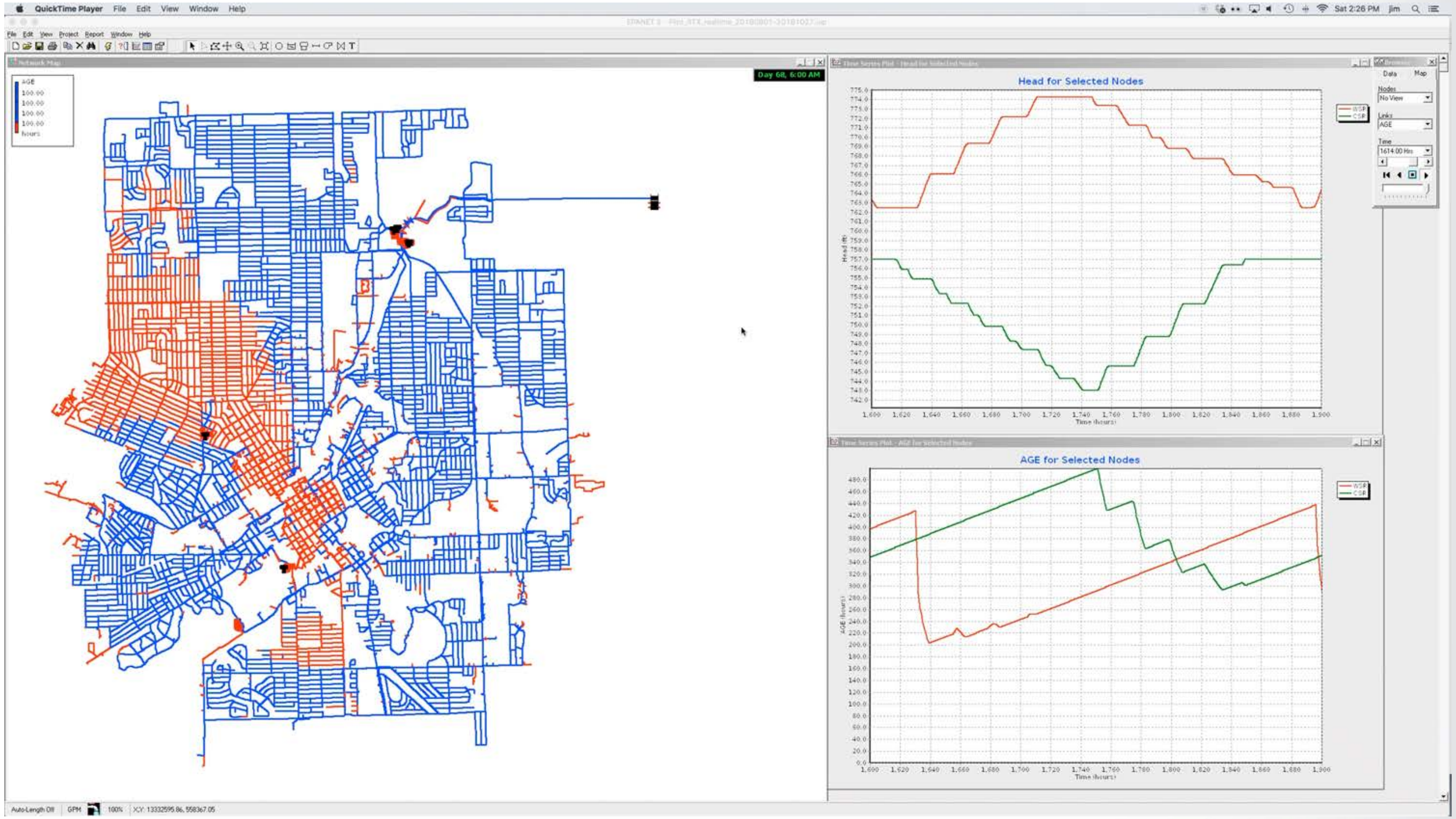
Example Application: Tank Operation



- Change to "deep cycling"
  - Single day cycle to intermittent to 8-10 day cycle
- Change in storage volume
  - Nearly full to half full to nearly full
- (+) supply reliability
  - min. stored volume from ~12.5MG to ~17.5MG
- (?) Water quality impacts

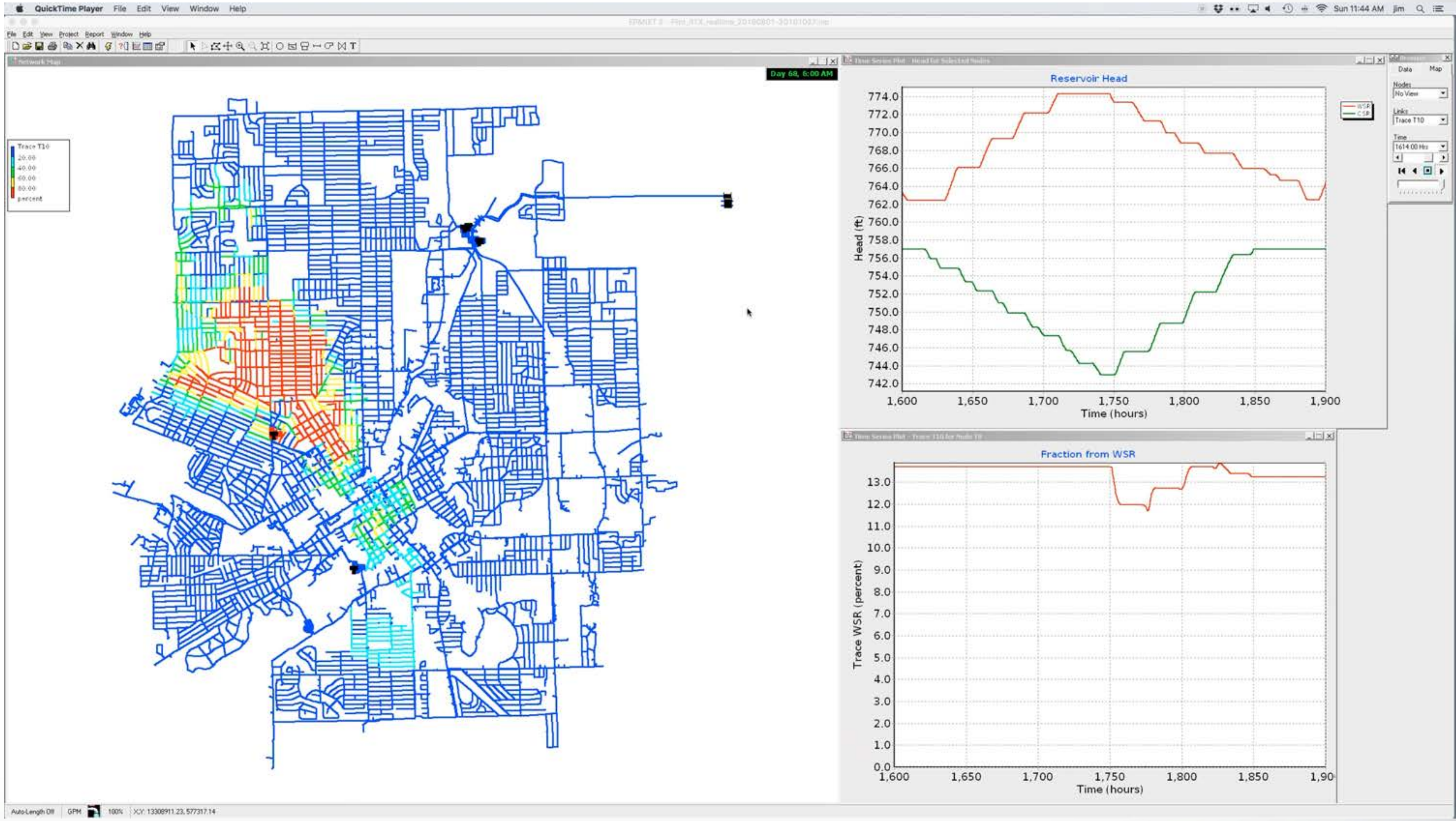
Water Age Analysis

- Simulation of one actual operations cycle, October 2016
- Water age varies from 8-20 days in reservoirs
- Red: Aged water from reservoirs (> 100 hours)
- Blue: Fresh water from supply (< 100 hours)



Example Application: Tank Transfer

- Same operations cycle, October 2016
- Tracing water from WSR
- Observe cyclic water transfer pumped from WSR to CSR
- Results indicate ~13% of CSR water was originally pumped from WSR
- Reservoir transfer may not be beneficial to water quality management

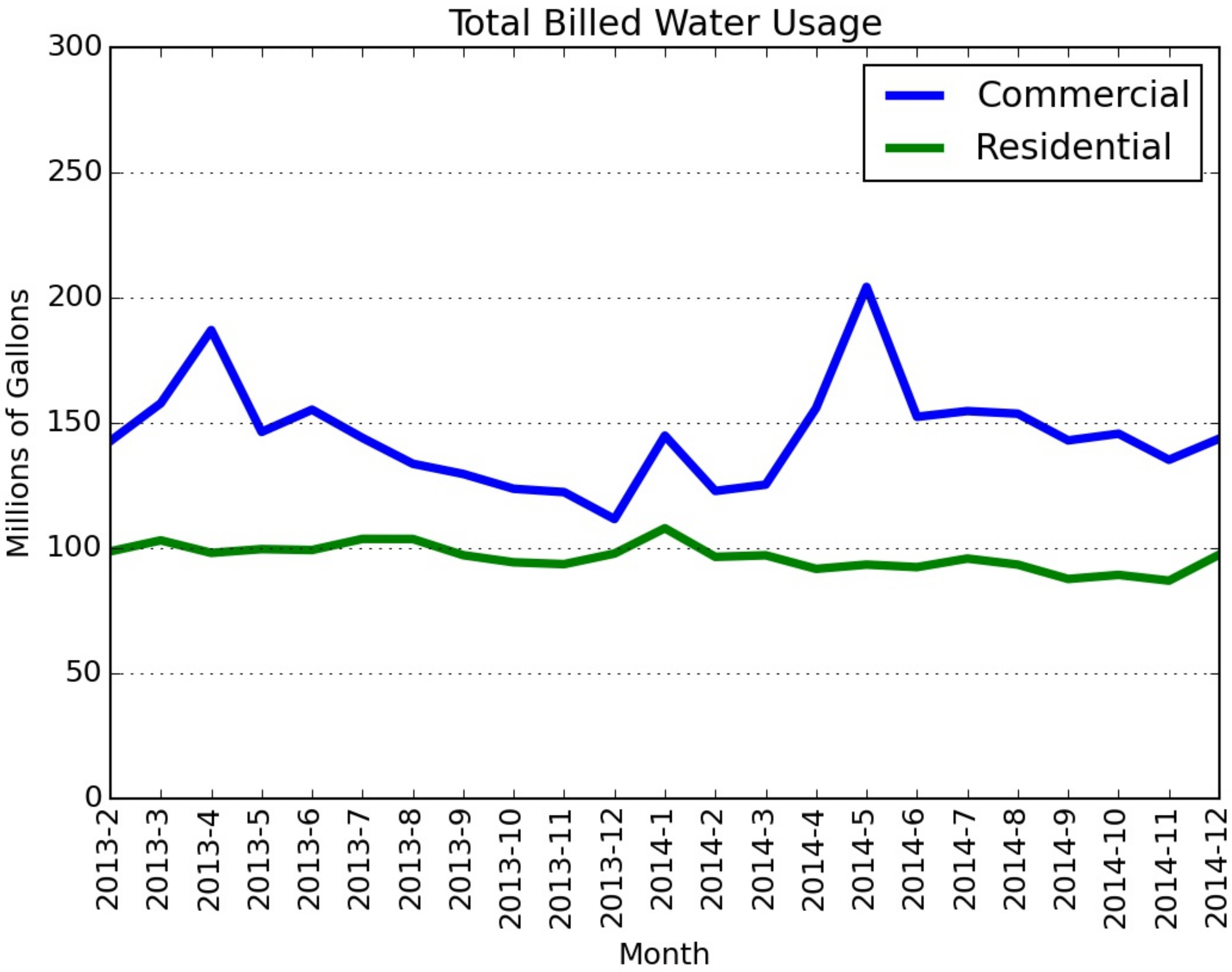


Next Steps

- Complete hydraulic calibration
  - Using flow data from field study
- Water quality calibration
  - Using chlorine residual sampling data & bulk decay study data
- Expert review
  - Provide additional confidence in use of model
- Applications
  - Chlorine residuals, sampling locations, optimizing operation of tanks

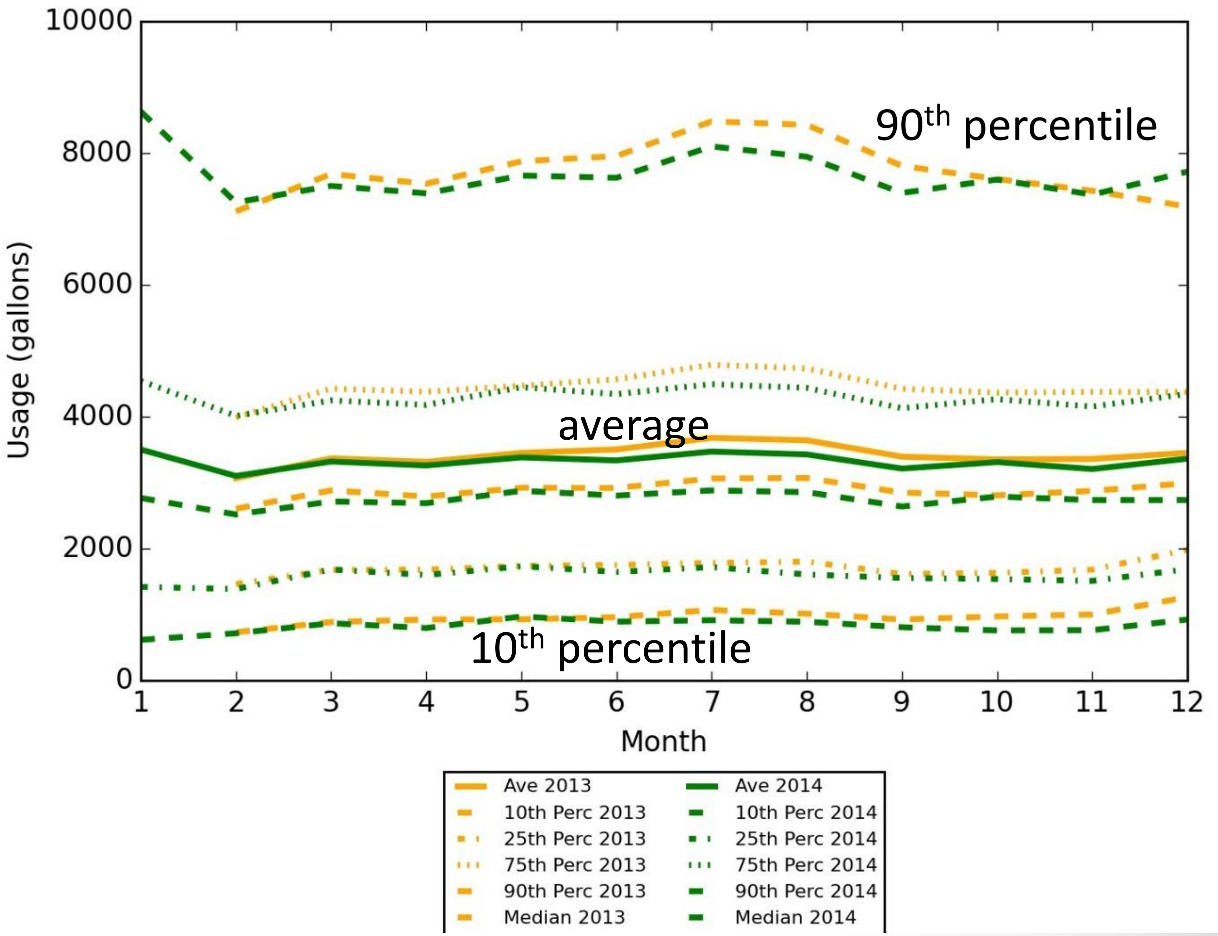
Billed Water Usage Data

- >100 Excel files from City Treasurer
- Monthly billing records
- > 49,000 accounts
- January 2013 – July 2016
- Data issues
  - Monthly aggregated data
  - Negative values
  - Estimated vs. Actual
  - Faulty meters
  - Interference with meters



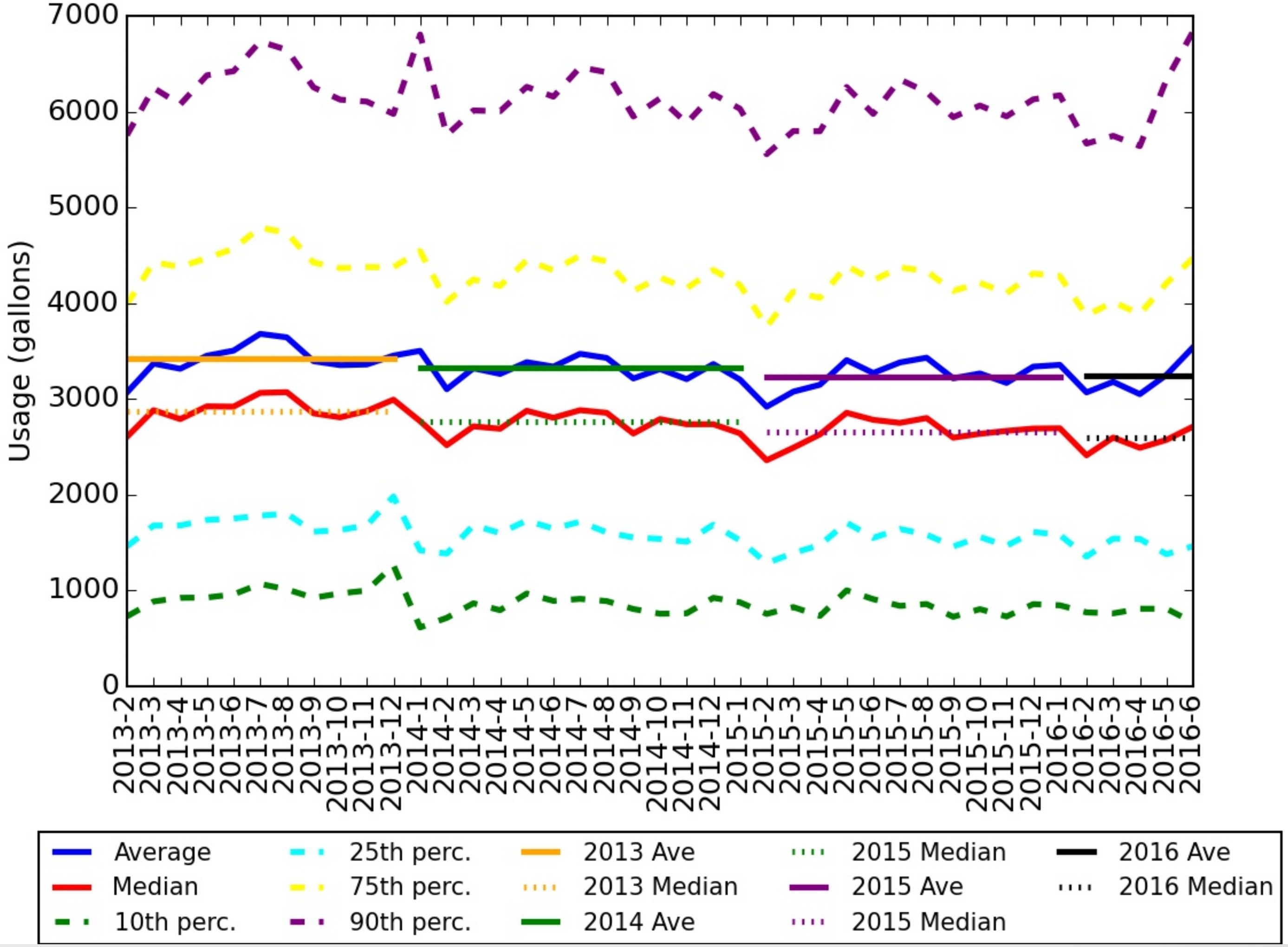
Water Usage Data 2013-2014

- 19,500 accounts active for entire period 2013-2016
- Average US household usage: 7,500 gal/month
- Average Flint usage (2013): 3,420 gal/month
- Slight seasonal effects



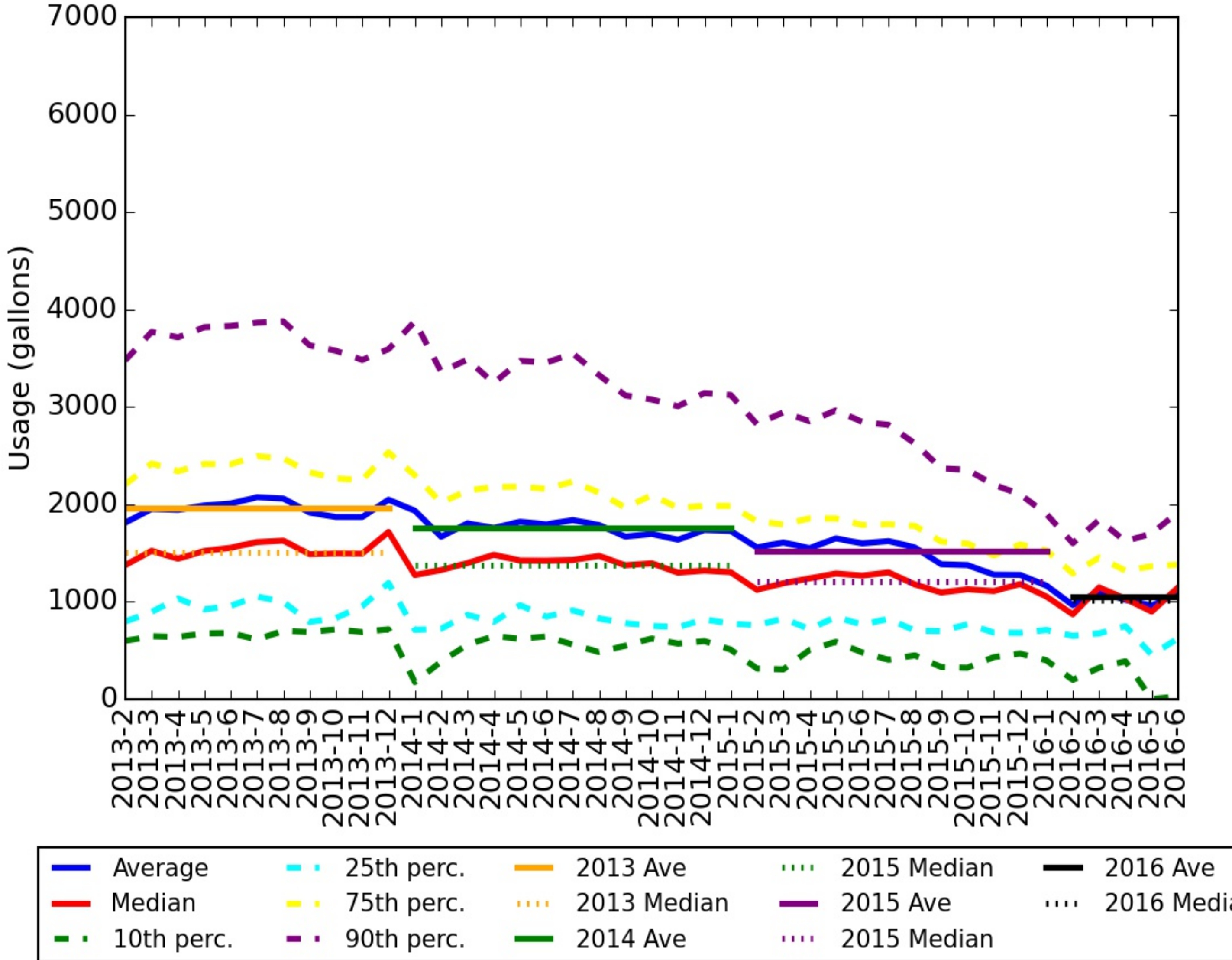
Water Usage Data 2013-2016

- Averages trend slightly downward over time:
  - 2013 Avg: 3,420
  - 2014 Avg: 3,330 (-3%)
  - 2015 Avg: 3,230 (-6%)
  - 2016 Avg (Jan-Jun): 3,240



Trends Among Lowest Water Users

- Consider only the lowest 25% of users in 2016
- Averages trend strongly downward over time:
  - 2013 Avg: 1,958
  - 2014 Avg: 1,762 (-10%)
  - 2015 Avg: 1,515 (-23%)
  - 2016 Avg (Jan-Jun): 1,050 (-46%)



Water Usage May-June 2016

- Flushing in May should have caused increase in water usage
  - Kitchen faucet – 5 min*(1.5-2.2) gal/min*15 = 112.5-165 gal
  - Bathroom – 5 min* (2-8) gal/min * 15 = 150-600 gal
  - Approximate increase of 250 - 800 gallons
- 65% of accounts increased usage from April to May more than 250 gallons
- 40% had higher usage in May 2016 than average May usage over three previous years

Water Usage and Lead Measurements

- Lead data from MDEQ
- Water usage data from City
- October 2015 – July 2016
- Spearman's correlation
- Water usage was found to be weakly anti-correlated with lead levels, accounting for 4% of the variance in the data