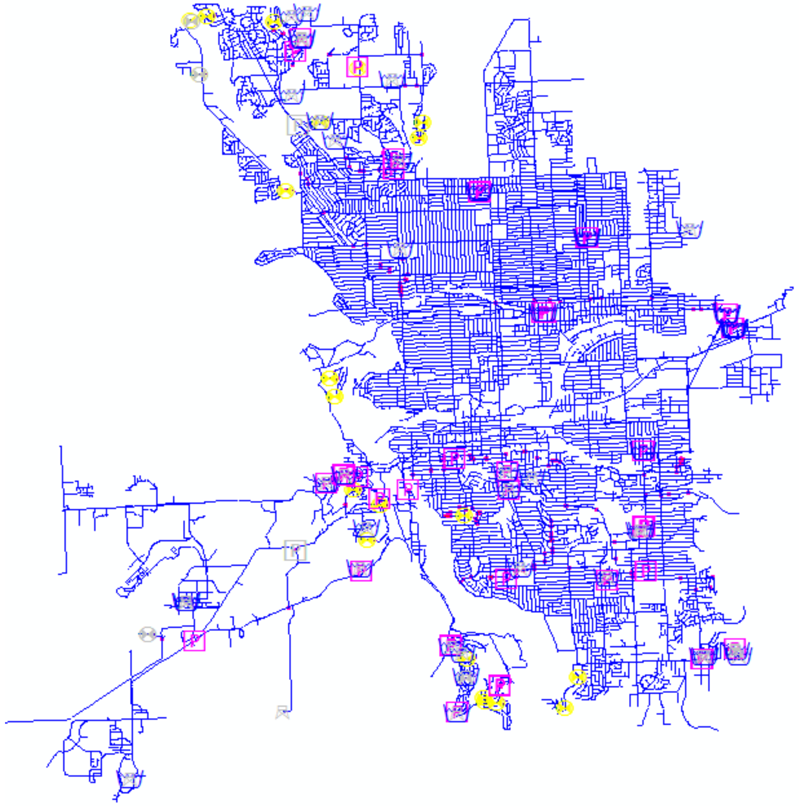
Taking Your Hydraulic Model to the Next Level



Presented by
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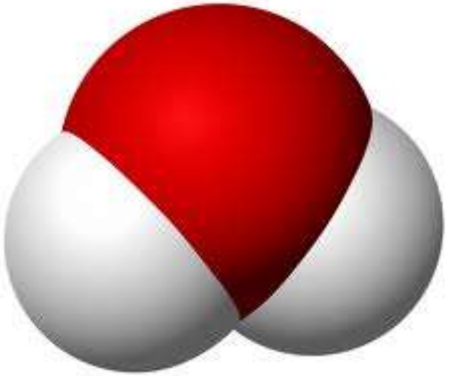
Chris Peterschmidt, PE (WA) | City of Spokane

Items to Discuss

- Background on Hydraulic Modeling
- Model Development and Calibration
- Summary and Path Forward



Water Models

- Water models mean different things to different people…
- It's a tool not artificial intelligence…

Model Limitations and Uncertainty

- Pressure pipe networks can be complex with variable boundary conditions.
- Models are always constrained by computational limitations, assumptions, and knowledge gaps.
- Models are best be viewed as tools to help inform decisions
- Technological advances will never allow the building of a perfect model that accounts for every aspect of reality.

Types of Model Simulations

- Steady-State Simulation
  - State of system that is a snapshot in time, under a specific set of demand and boundary conditions
- Extended-Period Simulation
  - Quasi-dynamic system, which computes the state of system over time, represented by a series of steady-state simulations

Engineering and Operation Staff Implications for Hydraulic Model Use

- Initially hydraulic models are used to solve design problems:
  - Interpreting past or current data,
  - diagnosing a problem or define capital improvements, and
  - provide an important line of evidence.
- The next level of hydraulic modeling focuses on variation in the systems over time and location:
  - Operational scenarios
  - Energy management
  - Water age
  - Risk management and mitigation

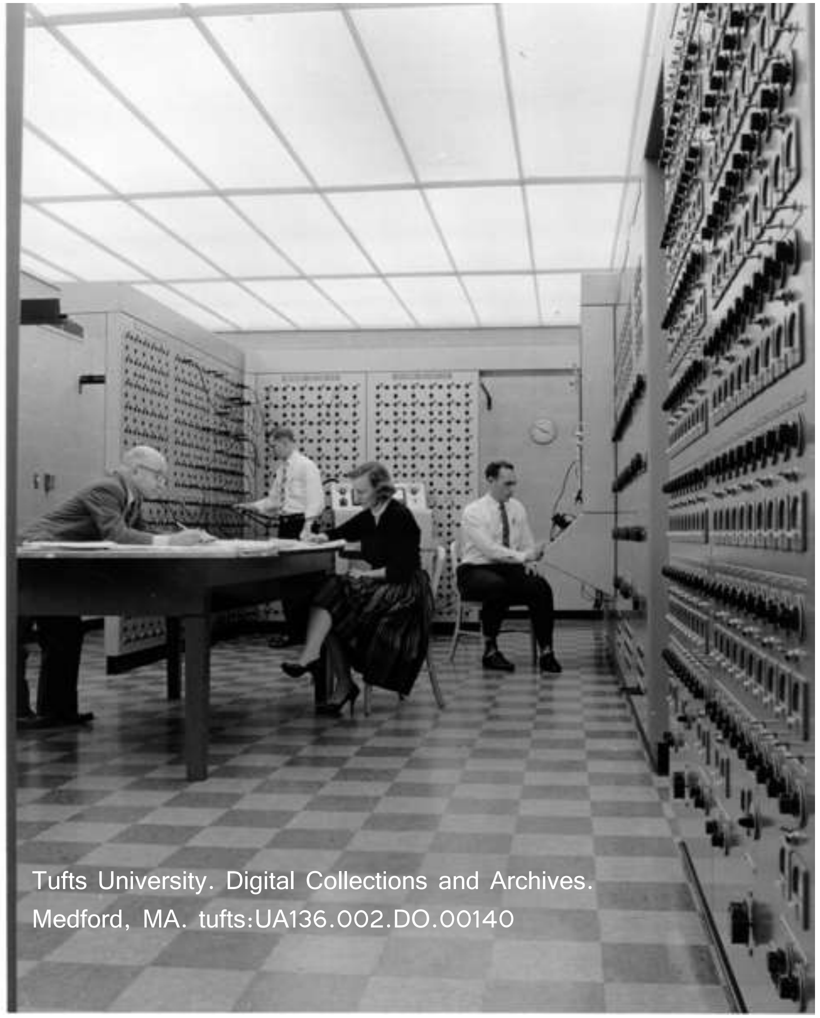
Extended-Period Simulation

- Start with calibrated steady-state model
- Develop demand diurnal pattern
- Determine control scenarios
- Hydraulic Time Step

History of City of Spokane water system hydraulic modeling

- 1950s and 1960s – McIlroy Fluid Network Analyzer analog computer developed
  - Used electricity to simulate water flow

HAL: I know that you and Frank were planning to disconnect me, and I'm afraid that's something I cannot allow to happen.



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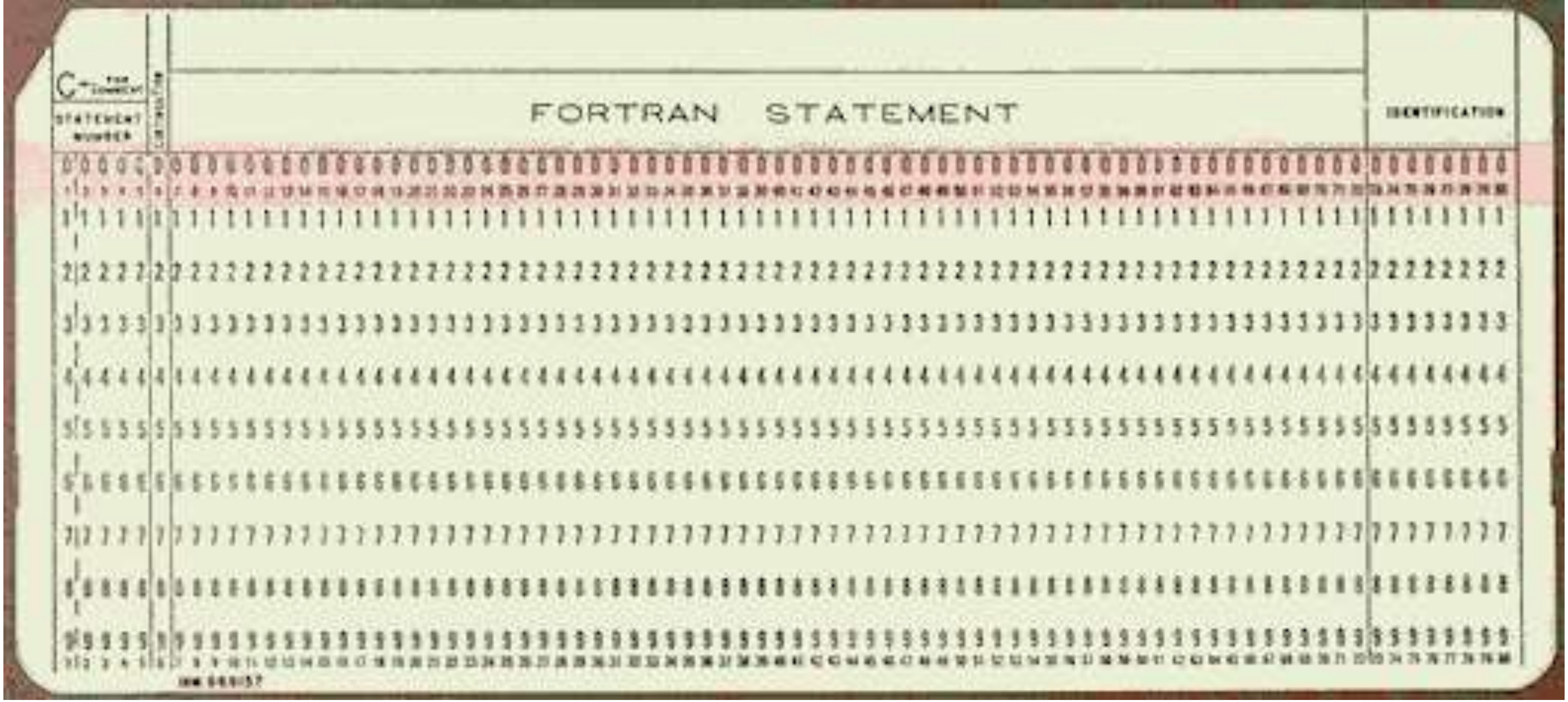


Part of the Punched Card Collection by Douglas W. Jones
THE UNIVERSITY OF IOWA Department of Computer Science

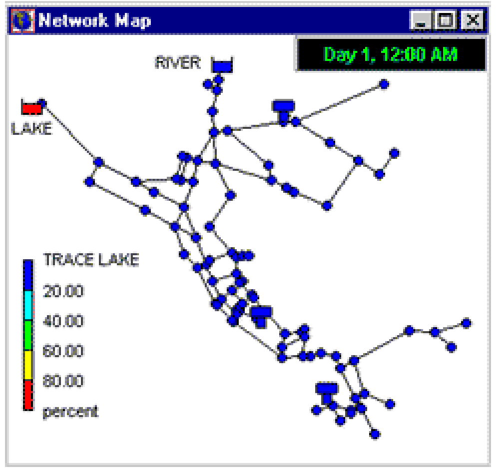
History (continued)

- 1970s – Digital network model (FORTRAN)
  - City initially used a main frame at Gonzaga University with punch cards
  - Personal computers (PC) expanded applicability

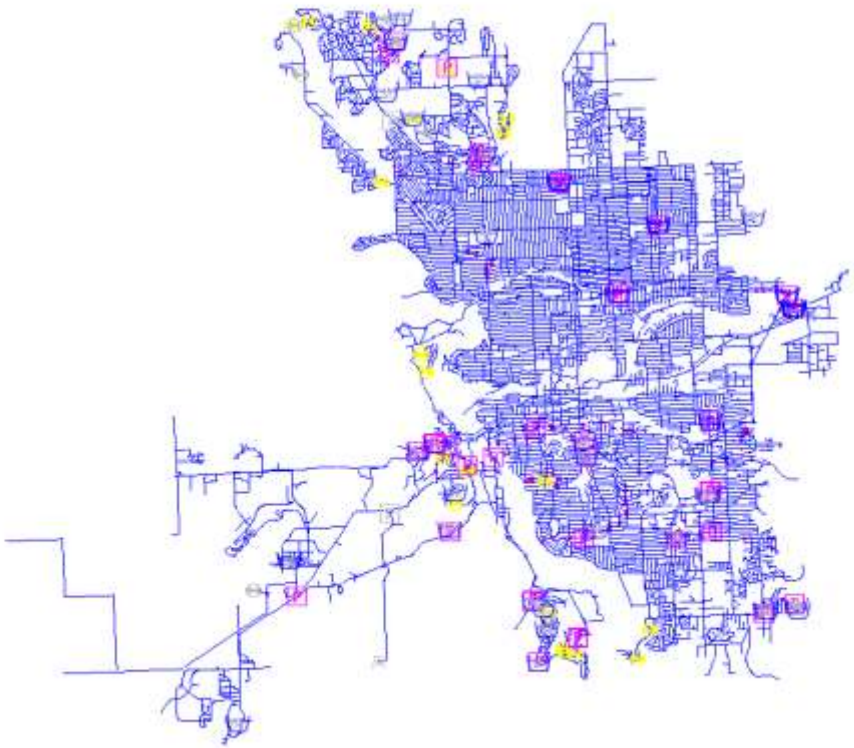
History (continued)

1990s – Commercial modeling software available

City develops first system-wide trunk model comprising of multiple areas

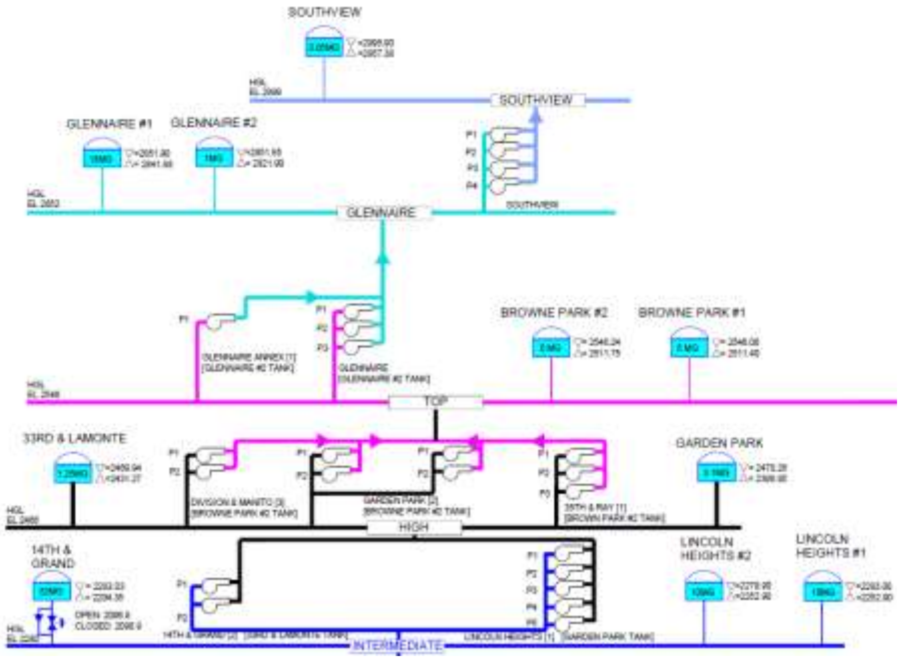


2000s – GIS based model using H2OMap



Current Model Development

- Source of Information : ESRI GEODATABASE
- Import pipes into INFOWATER (1 to 1 relationship)
- Generate nodes in INFOWATER
- Assign unique IDs
- Generate node elevations from City elevation information in ArcInfo, spot check with old model
- Test network connectivity
  - Abandoned Mains
  - Private Mains
- Validate Attributes
  - Closed Links (Valves)
  - Pressure Zone Attribute
  - Confirm Transmission Mains (no demand)



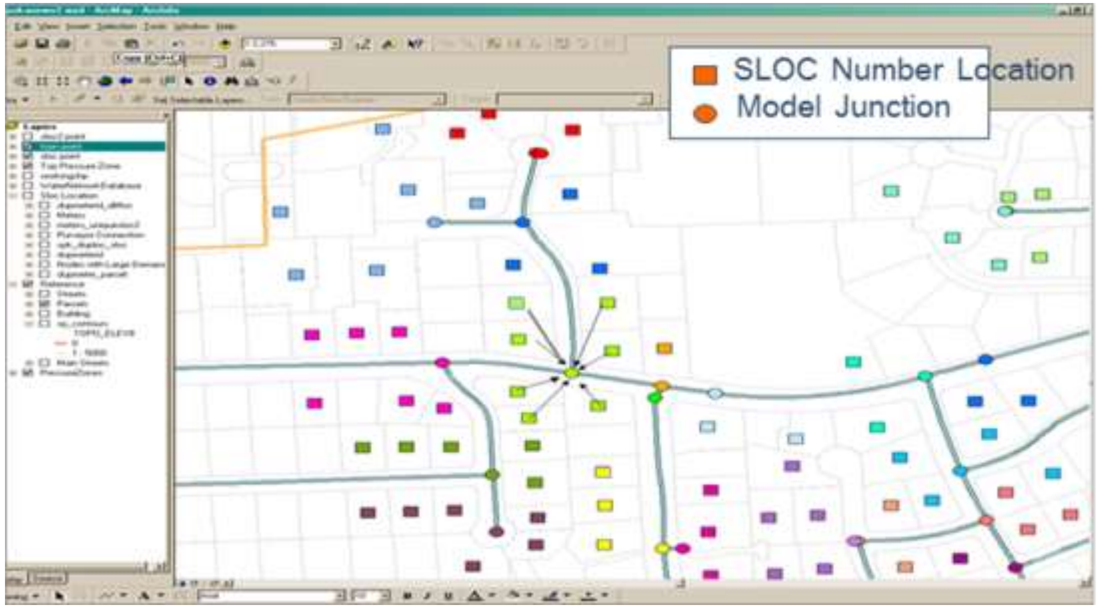
Model Development Summary

Element/Facility	Model	GIS
Pipe (miles)	1,047	1,206
Hydrants	7,310	8,983
System Valves	15,648	17,317
Fittings	13,382	20,379
Booster Pumps	80	77
Wells	14	14
Well Pumps	27	27
Tanks	35	35
PRVs	48	64

- Number of Links – 41,103
- Number of Nodes – 38,575
- Primary reason for differences:

  No “Abandoned,” “Out of Service,” “Plans Approved for Construction,” or “Private” elements in the model, GIS missing some facility information

Demand Allocation Process



- Existing Demand Allocation
  - Review of customer meter data
  - Production record comparison
  - Identification of demand nodes
  - Using spatial tools in GIS transfer customer demand to nearest model node
- Future Demand Allocation
  - Used demand projections developed in City's Water Master Plan
  - Spatially allocated future demand based on Spokane Regional Transportation Authority traffic analysis zone (TAZ) projections
  - Existing service boundary for 5-year
  - Coordinated Water System Plan boundary for 20-year

Demand Analysis

- Average Demand by Billing Record
  - 83,354 billing records (2011 to 2013)
  - 77,563 active billings record for 2013
- Demand
  - 3 year average demand developed for each meter record
  - 2013 demand - 44 mgd
  - 2013 production - 58 mgd
  - Difference of 25% between production and customer billing (eg non-revenue water)

Steady-State Calibration

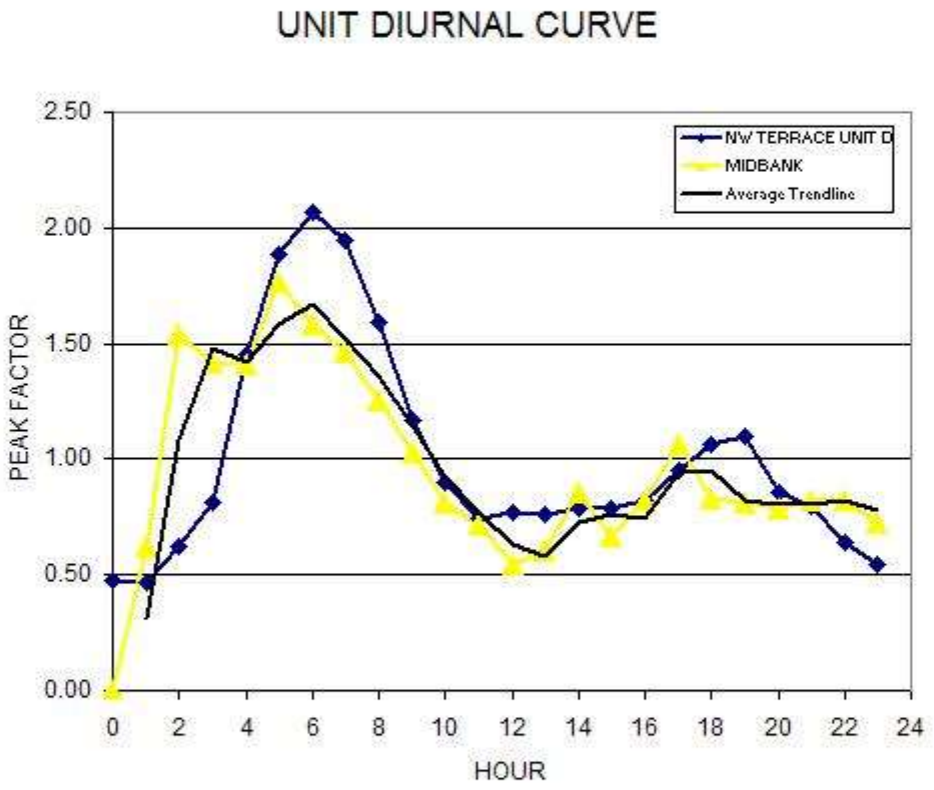
- 78 Flow Tests
  - 87 hydrants flowed (1 or 2 per test)
  - 78 residual pressures taken
- 25 Static Only Tests

Steady-State Calibration Results

- Confidence Levels—Difference in Model and Field Pressures
  - High: Within 10 psi
  - Medium: Between 10 and 20 psi
  - Low: Greater than 20 psi
- 103 Static pressure measurements
  - 98 High, 5 Medium, 0 Low
- 78 Residual pressure measurements
  - 42 high, 20 medium, 13 low

Extended-Period Model Development

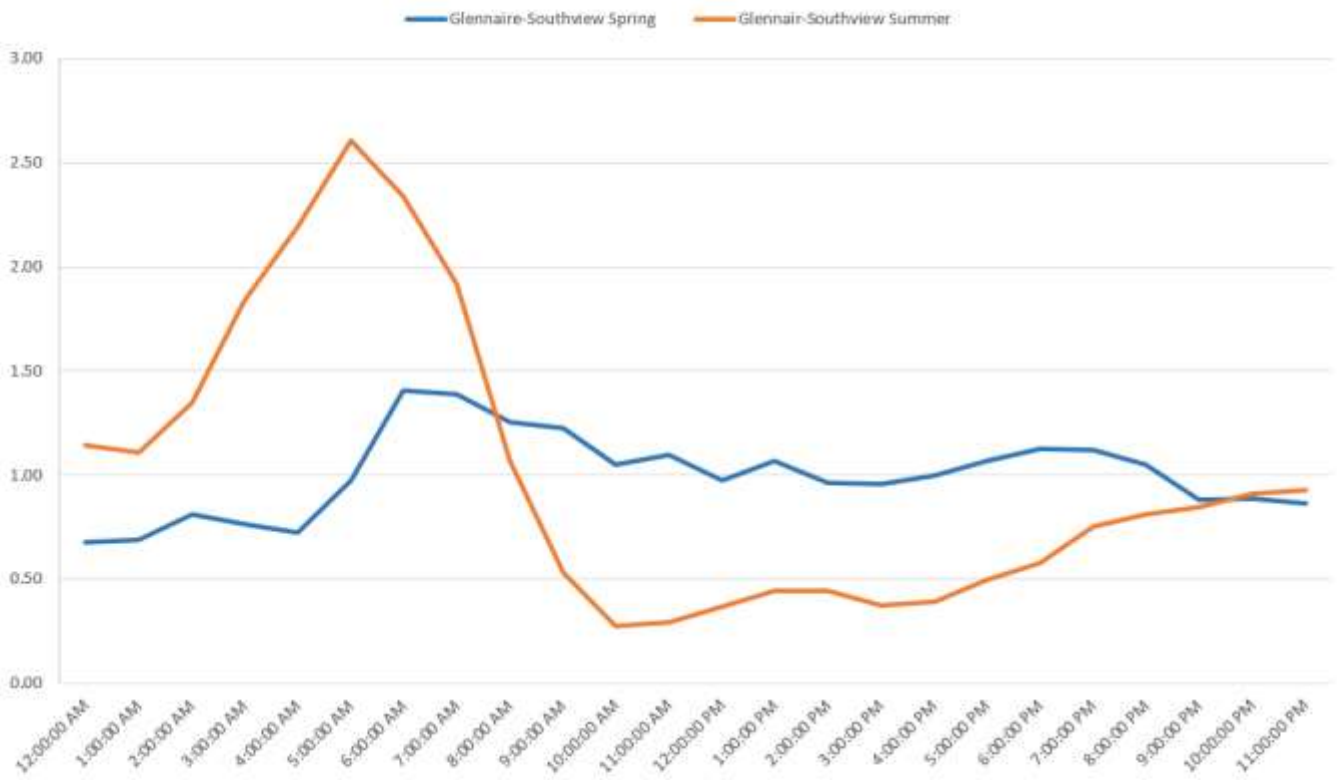
- Start with Calibrated Steady-State Model
- Develop Diurnal Demand Curve
- Summarize System Control
- Representative System SCADA Information
- Calibration – Compare Trends Between Model and SCADA Output

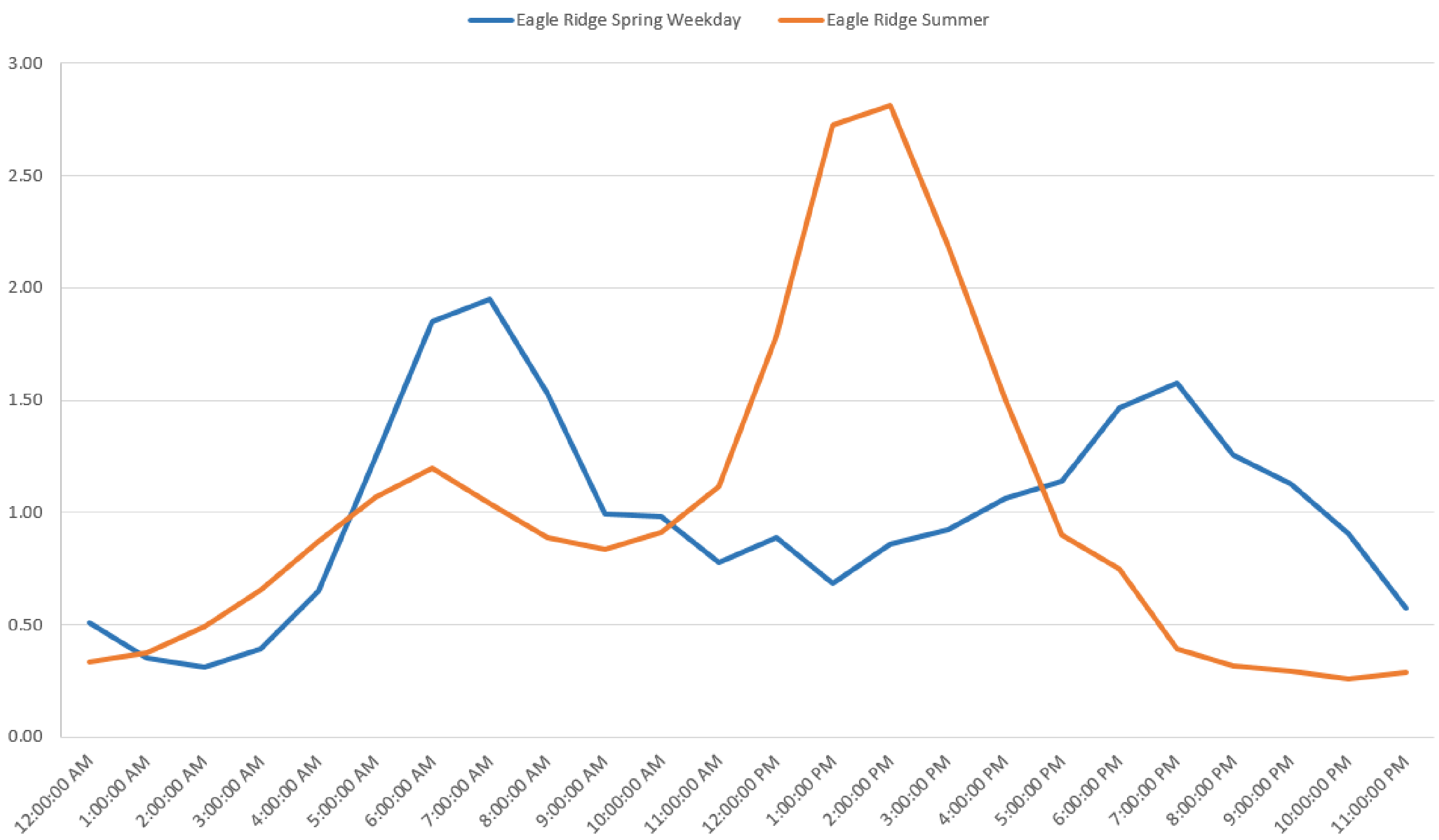


Diurnal Demand Curve

- Developed by System or Pressure Zone

- Evaluation of the SCADA Data
  - System/Pressure Zone Mass Balance
  - Pumps In/Out and Change in Reservoir Volume



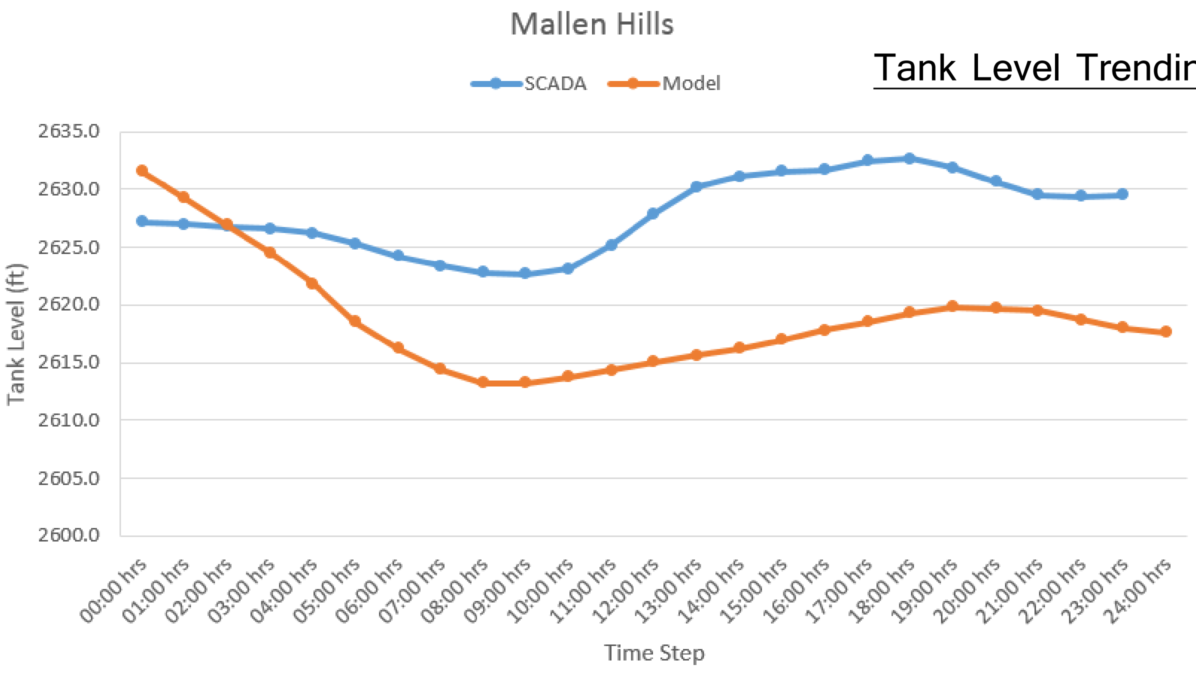


Diurnal Demand Curve Varies

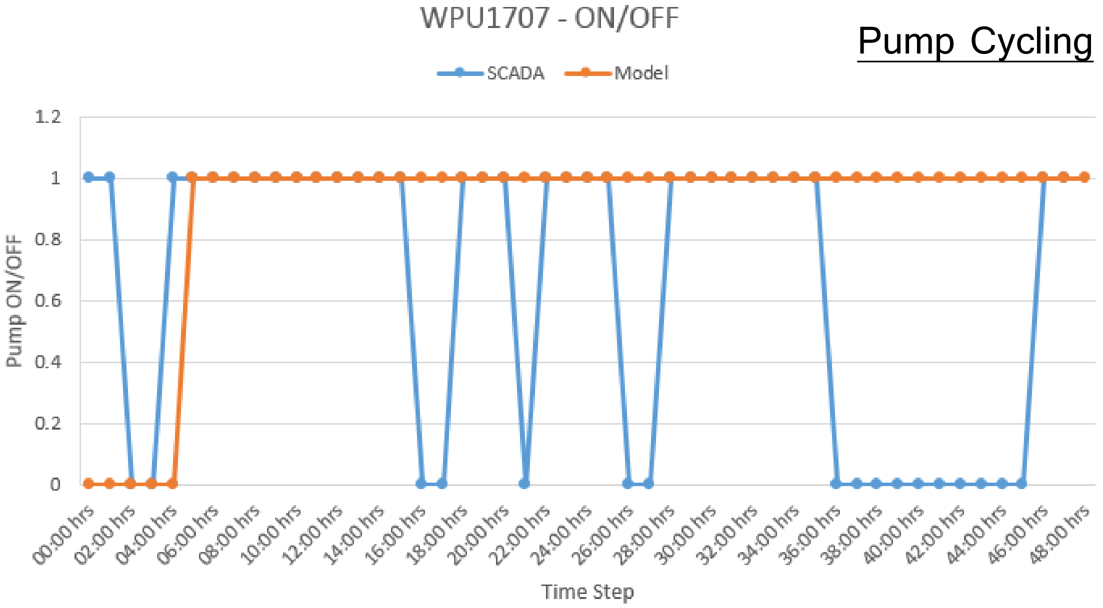
Control Set Points

- Met with City operators to develop control schemes
- Auto/manual operation
- Developed control schemes for manual operation
- All controls based on reservoir level
- Operational strategies for summer and winter
- Load controls in model (summer & winter)

Tank Level Trending



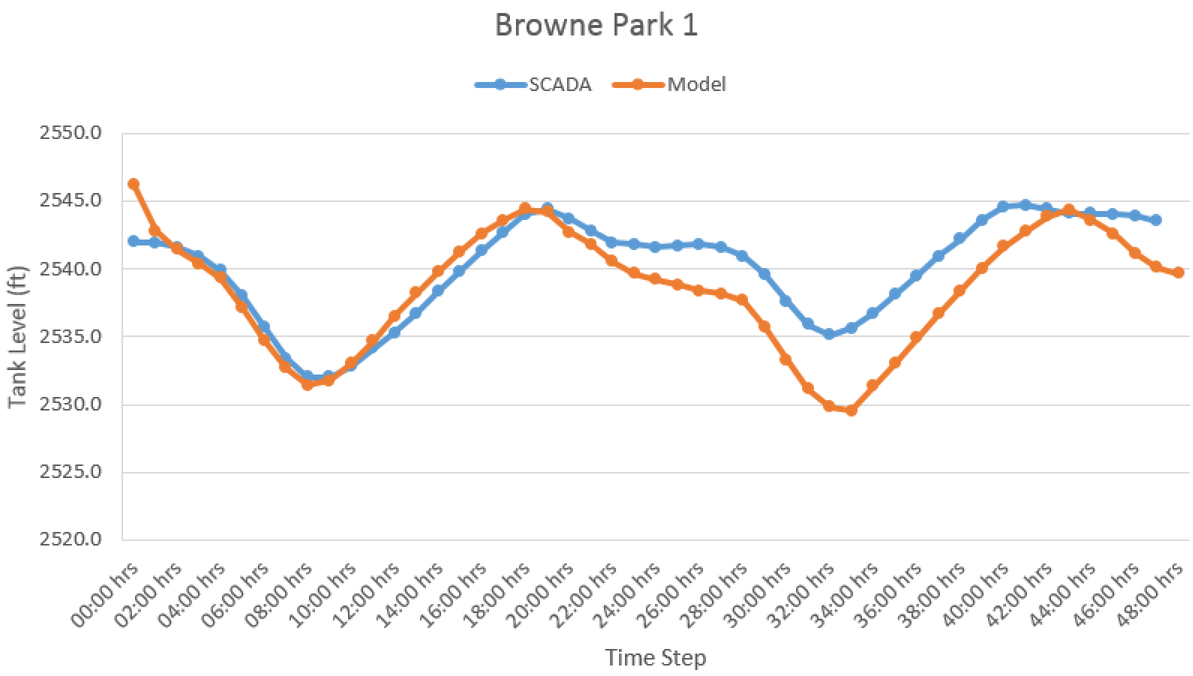
Pump Cycling

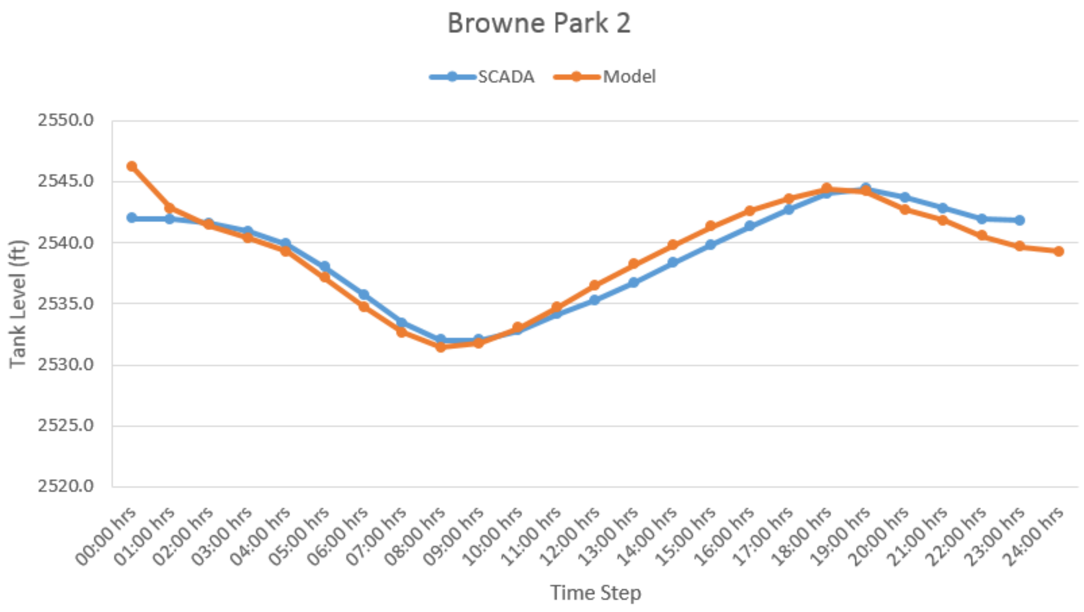


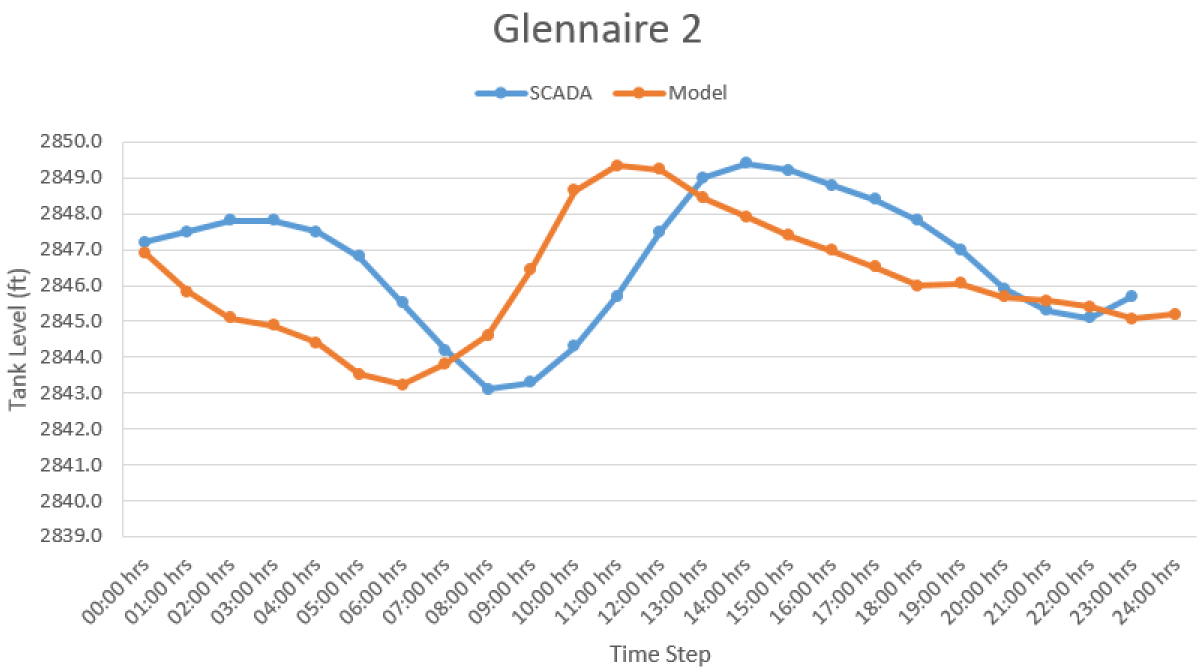
Extended-Period Calibration - Compare Trends

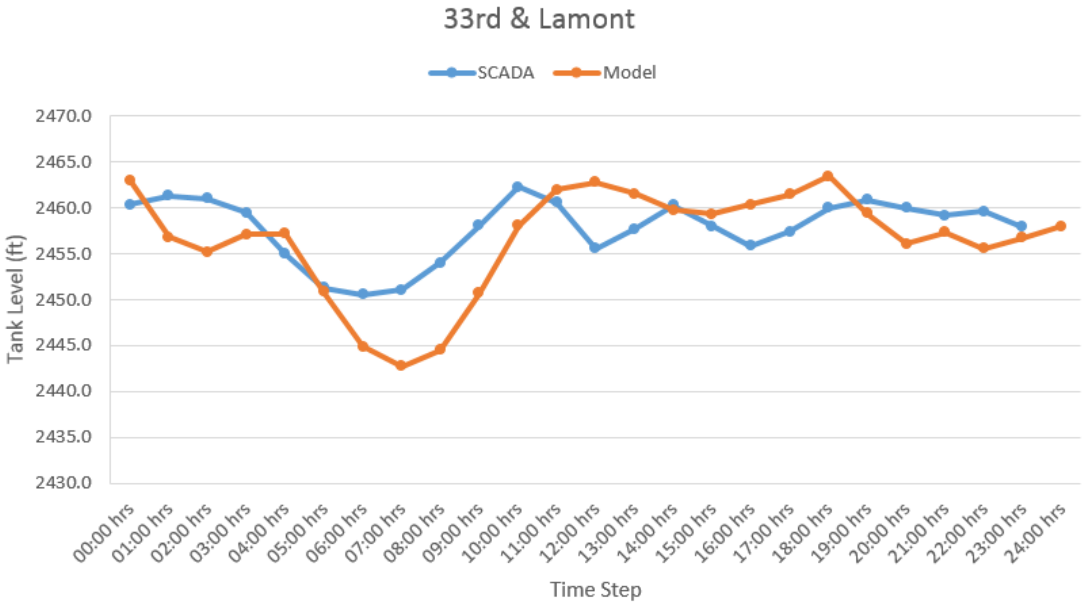
- Representative SCADA Data
- Typically Comparing:
  - Tank Level Trends
  - Pump Cycling

Top Zone – Tank Comparison









Tank Level Trends Not Aligning

Glennaire Pressure Zone

- Potential demand difference

High Pressure Zone

- Potential demand difference
- Pump control potentially different

Calibration Challenges

- Manually controlled system
  - Set points not consistent
  - Influenced by operator preferences
- Internal organizational priorities
- Demand diurnal curves and demand allocation by pressure zone, needs to be assessed further
  - Difference between production records and meter records
  - Majority of pumps stations do not have flow meters
  - No PRV flows meters serving entire pressure zones

Next Steps

- Complete development of winter and summer diurnal curves for all zones where possible
- Have City operate system using a consistent set points for a period of time
- Recalibrate under these conditions
- Setup model for specific analysis the City wants to run
  - Winter time control strategies
    - Optimization to minimize energy costs
  - West Plains area expansion analysis
    - Impacts on system from large whole water customers
- Recommend additional metering at unmetered locations (pump and PRV stations)

Q&A