AMERICAN WATER WORKS ASSOCIATION

Pacific Northwest Section

2010 Spring Conference

Tacoma, Washington

City of Bend, Oregon

Construction and Calibration of an All-pipes Dynamic Model for the City of Bend using GIS and SCADA

Friday, May 14, 2010

CITY OF BEND
WATER MODEL DEVELOPMENT

Presented by:

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Murray, Smith & Associates, Inc.

PRESENTATION OUTLINE

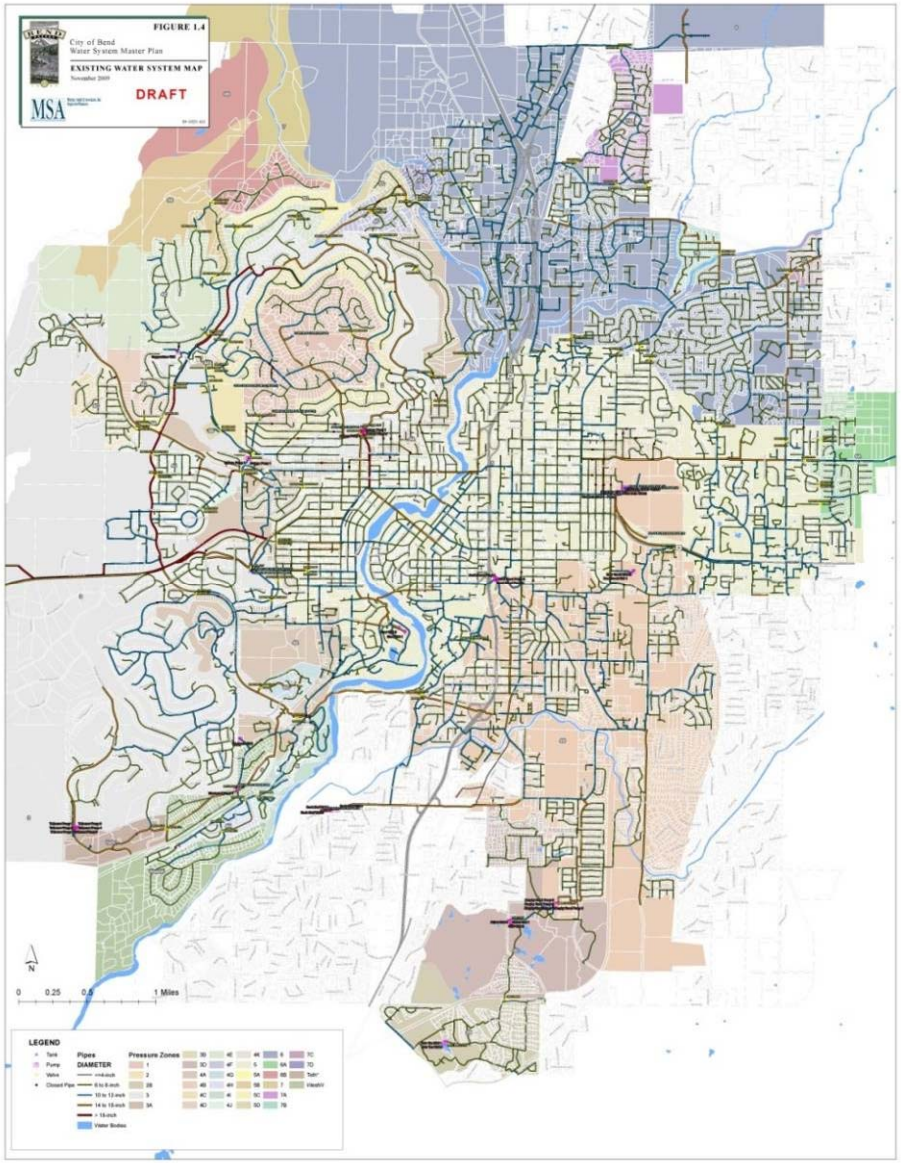
- Project Background
- System Overview
- Create Model Network from GIS
- Update Customer Demands
- Basic Validation of Model Operation
- Steady State Calibration
- Extended Period Calibration
  - Summer
  - Winter
- Model Documentation
- Conclusions

PROJECT BACKGROUND

- Why Was Model Being Updated
  - Recent Investments Had Been Made in the City's GIS
  - Create Model in Stateplane NAD83
  - City had Recently Performed a Comprehensive Valve Inventory & Status Check
  - Develop Accurate Model Reflecting Significant Growth that had Occurred Over Previous 10 years
  - Provide Tool for City to Perform Development Evaluations and Fire Flow Analysis
  - Critical that a Calibrated (Steady State & Dynamic) Model Exist for the Water System Optimization Project

SYSTEM OVERVIEW

- **Service Population:** 75,000
- **ADD:** 13 mgd
- **MDD:** 29 mgd
- **Pressure Zones:** 7 Main & 25 Sub-Zones
- **Wells:** 22
- **Pump Stations:** 6
- **Reservoirs:** 15
- **PRVS:** 80



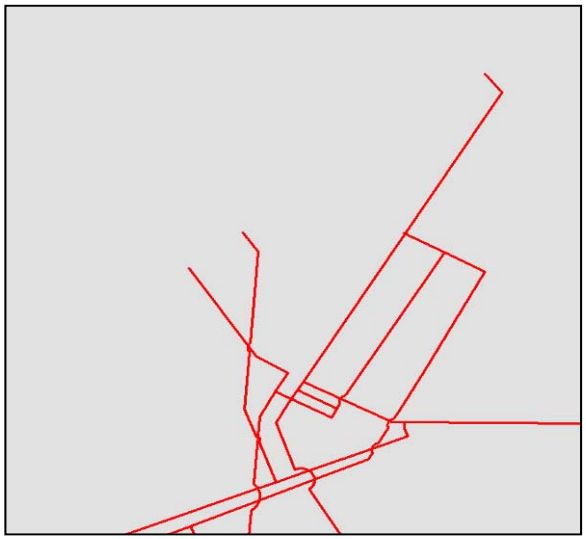
CREATING THE MODEL NETWORK

- The Decision was Made to Include All Pipes with the Exception of Hydrant and Service Laterals
  - Consistent with GIS Structure
- Unique Pipe Identifiers from GIS were Used in Model
- Pipes were not Split at Valves or Laterals
- A Protocol for Representing PRVs was Developed for Implementation in the GIS Prior to Creating Model

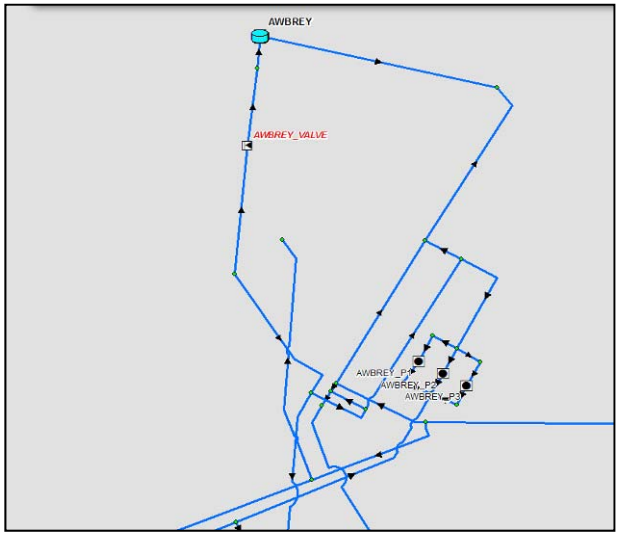
CREATING THE MODEL NETWORK CONT.

- **No Facility Detail was Included in the GIS**
  - **GIS Facilities to be Based on Model Requirements**

GIS



Model



- **Model "Network" QA/QC Tools were Utilized to Validate the Topology**
  - **Changes to Model were Transferred Back to GIS**
    - **Several Iterations**

UPDATE CUSTOMER DEMAND

- **Data Reduction of Customer Billing Records**
  - **ALWAYS CHALLENGING ☹**

Rate Class & Meter Type	Sum of Consumption (cubic feet)*	Sum of Consumption (Gallons)	Average Gallons/ day	Record Count*	Meter Count*	Average Gallons/ day meter
Commercial (CM)	**187,305,854**	**1,401,145,000**	**3,838,753**	**34,535**	**2,878**	**1,334**
0 (unknown)	5,985,578	44,775,230	122,672	77	6	19,118
1	41,929,431	313,653,905	859,326	13,649	1,137	756
1.5	36,035,825	269,566,674	738,539	5,447	454	1,627
2	64,039,015	479,045,068	1,312,452	4,591	383	3,431

- **Development of ADD by Customer**
- **Geocode Customers by Parcel Address**
- **Reduced Water Production Data into ADD, MDD, PHD**
- **Peaked Customer Billing Records to Match Production**
- **Identify Locations Where Demand Should Not be Assigned**
- **Allocated Demand from Meter Address to Nearest Demand Node**

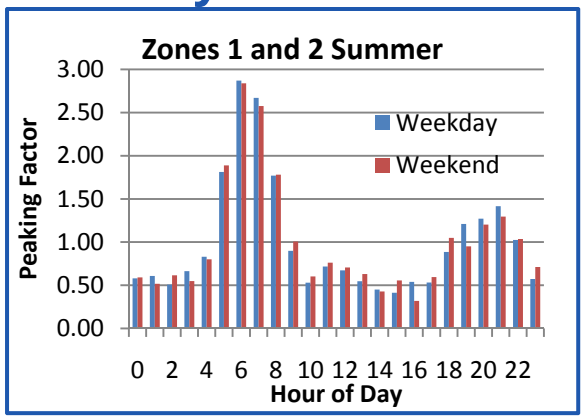
IDENTIFICATION OF WINTER AND SUMMER DEMAND

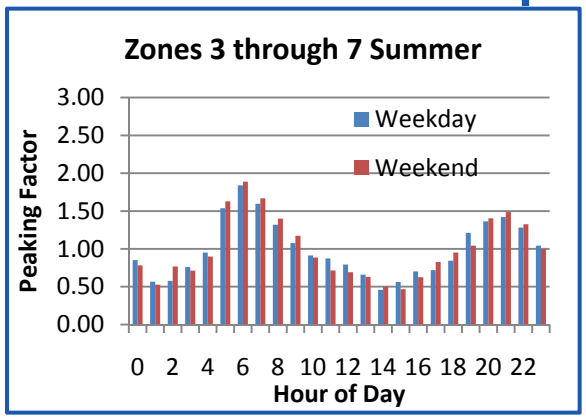
- Developed Using Customer Billing Records
- Highlights Variability of Demand by Area/Pressure Zone
- Highlights ADD as a Misnomer

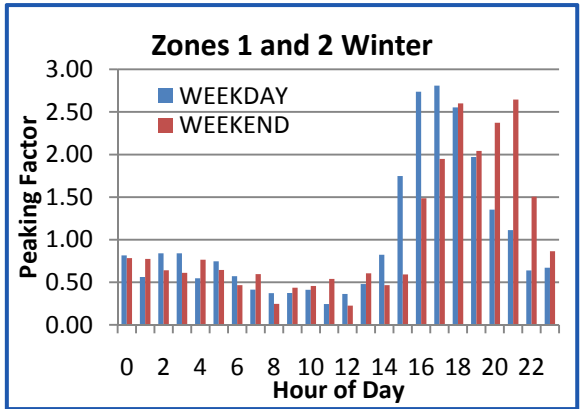
Pressure Zone	Demand Summer - July 2009 (gpm)	Demand Winter - January 2009 (gpm)	Winter to Summer Peaking Factor
1	603	51	12
2	524	53	10
2B	82	29	3
3	1,775	195	9
3A	16	4	4
3B	64	10	6
3D	66	33	2
4A	929	188	5
4B	2,345	652	4

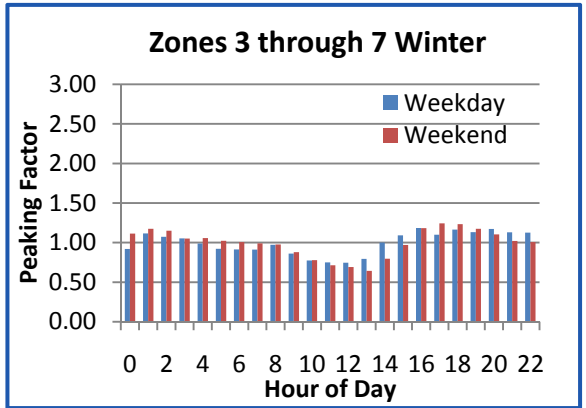
DEVELOPMENT OF DIURNAL CURVES

- Leverage SCADA
- Ideally Diurnal Curves Would be Developed for Every "Major" Pressure Zone
  - Challenging Due to the 80+/- "Unmetered" PRV Stations
- Ultimately 2 Distinct Diurnal Curves Were Developed









BASIC VALIDATION OF MODEL OPERATION

- A Number of Basic Validation Steps Were Performed Prior to Calibration
  - Elevation Verification
  - Pipe Friction Factor and Minor Loss Review
    - Important to “Reality Check” C-Factors
  - Others on Following Slides

- <u>Important for Any Model Building/Planning Effort!!</u>

PUMP, RESERVOIR AND PRV INFORMATION

- **Things Change Over Time, Do Not Assume the Last Planning Document or Model has Accurate Information**

Well Pump Description	Status	VFD	Pump Zone Fr-To*	Flow Rate (gpm)	Elevation (ft)	Well GW Surface Elevation (ft)
Bear Creek Well 1	Active	No	GW to 4	1,050	3,656	3,027
Bear Creek Well 2	Active	No	GW to 4	1,150	3,656	3,027
Copperstone Well	Active	No	GW to 3	1,050	3,779	3,269

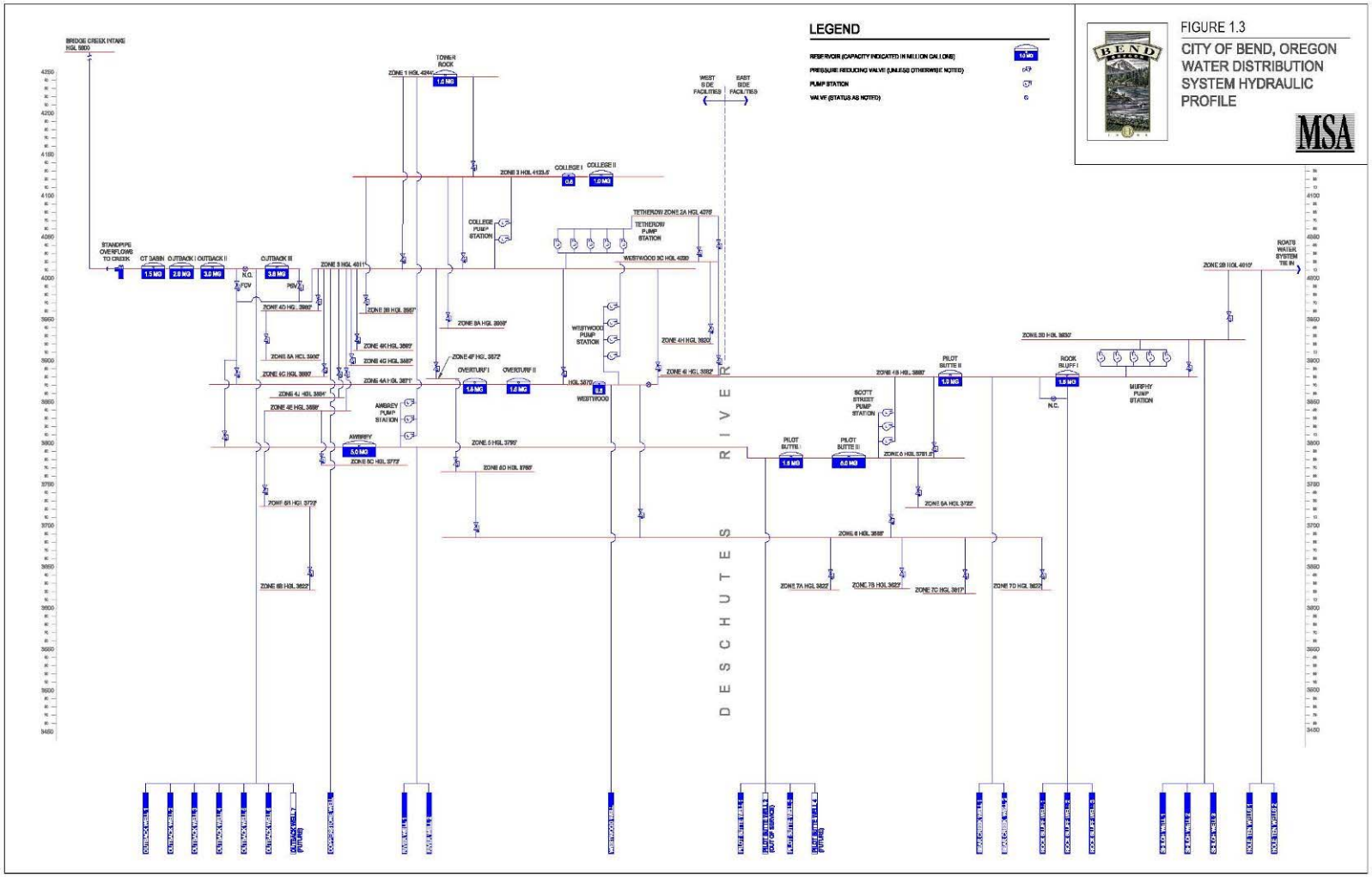
Pump Description	Status	VFD	Pump Zone Fr-To	Flow Rate** (gpm)	Elevation (ft)
Awbrey Pump 1	Active	No	3 to 1	950	3785
Awbrey Pump 2	Active	No	3 to 1	1,340	3785
Awbrey Pump 3	Active	No	3 to 1	1,200	3785

Reservoir Name	Elevation (ft)	Volume (million gallons)	Zone Served	Max Level (ft)	Diameter (ft)
Awbrey	3,775.00	5.00	5	20.5	206.3
College 1	4,095.80	0.50	2	23.27	60.8
College 2	4,087.93	1.00	2	31.5	74.1

Valve Identifier	Valve Type*	Elevation (ft)	Diameter (in)	From Zone	To Zone	Setting (gpm or psi)
AWBREY VALVE	FCV	3,775.00	12	3	5	6,000
HOLE10WELLPSV	PSV	3,866.00	4	2B	2B	62
MURPHY-PS_PR	PRV	3,746.00	10	3D	4B	57

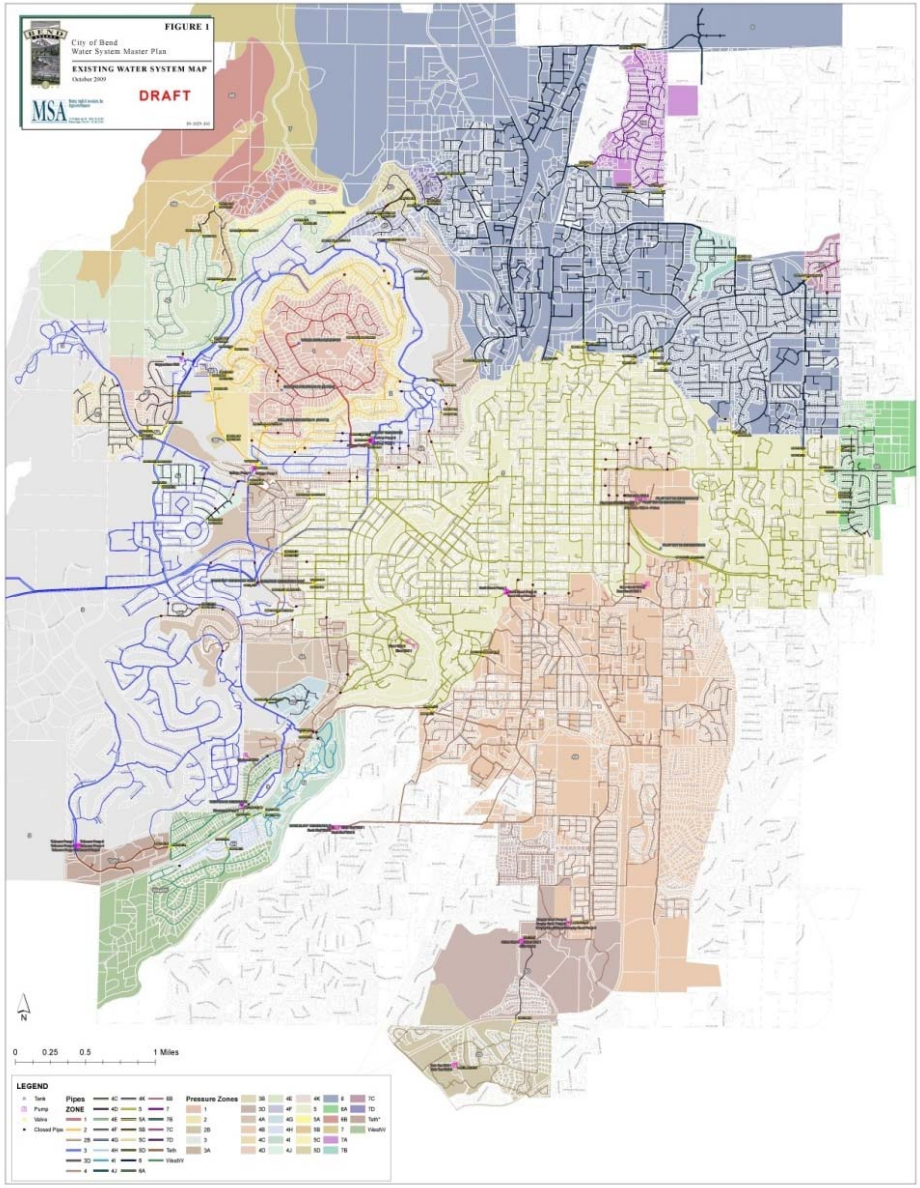
DEVELOP OR UPDATE THE HYDRAULIC PROFILE

- Critical for Understanding How Water Moves in the System

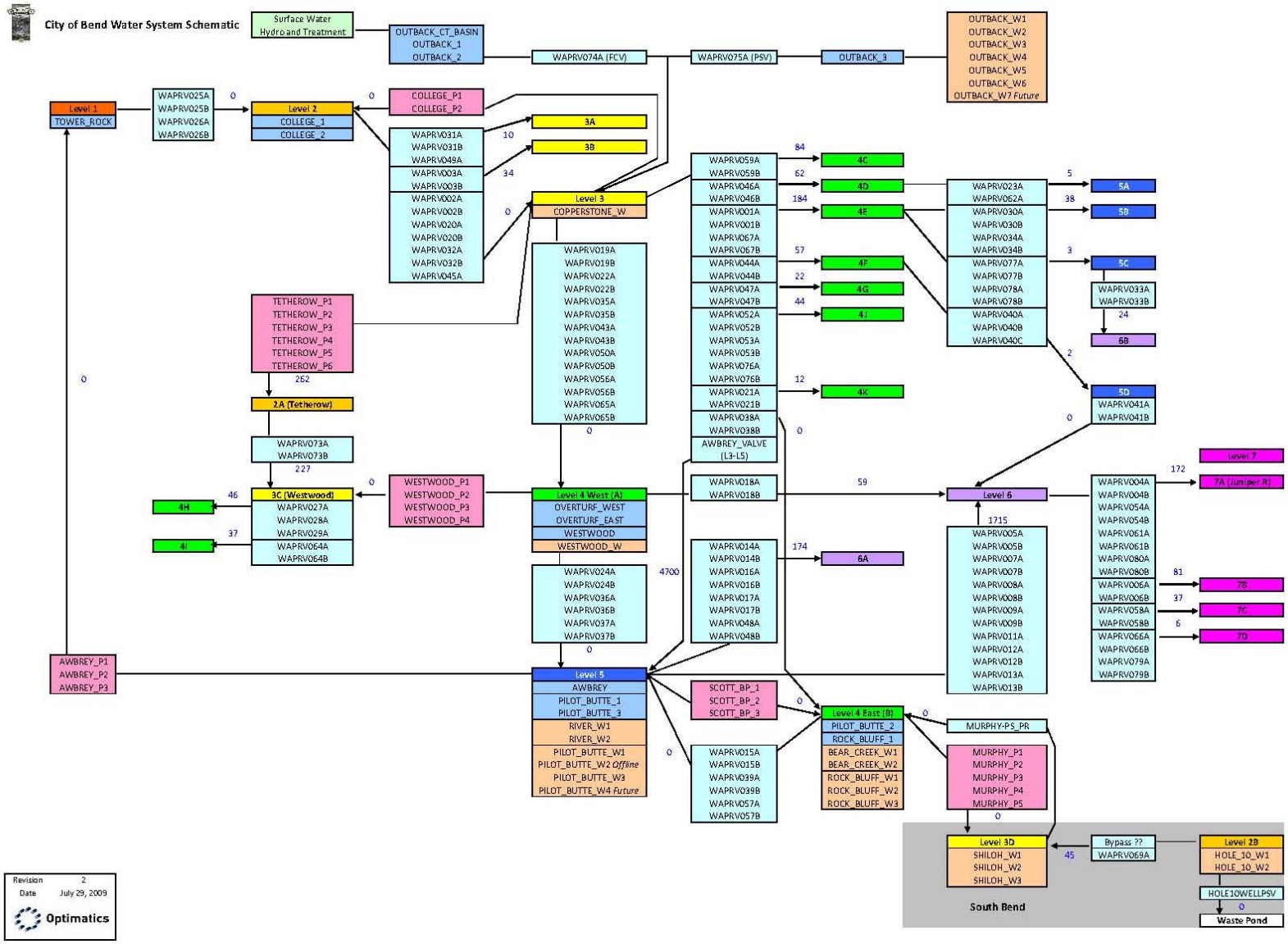


VALIDATE PRESSURE ZONES

- Develop or Refine Polygon Pressure Zone File Based on Parcel Boundaries
  - Where Pipes Cross Boundaries, There Should be:
    - A Pump
    - A PRV
    - A Closed Valve
    - Nothing, if Pipe is a Transmission Line
  - Development of a “Pipe Zone” Graphic can be Valuable to the QA/QC



DEMAND BY ZONE – MASS BALANCE



STEADY STATE CALIBRATION

- **A Calibration Plan was Developed Identifying:**
  - **Where, When and How Data was to be Collected**
- **Ultimately Included Approximately 150 Hydrant Based Pressures and Flows – 3 Iterations**
- **Included Monitoring Pump and Tank Status Using SCADA**

Level of Importance	Input Data
1	Pipe lengths and diameters and pipe connectivity
	Valve status
2	Reservoir water surface elevations
	Large source pump flows
	Large booster pump flows
3	Pipe roughness factors (lining type, installation date, etc)
4	Large PRV/BPV pressure settings (assuming valve elevations are known)
	Average day nodal demand distribution
5	Small source pumps
	Small booster pumps
	Small PRV/BPV flow information
6	Pressure information

STEADY STATE CALIBRATION CRITERIA

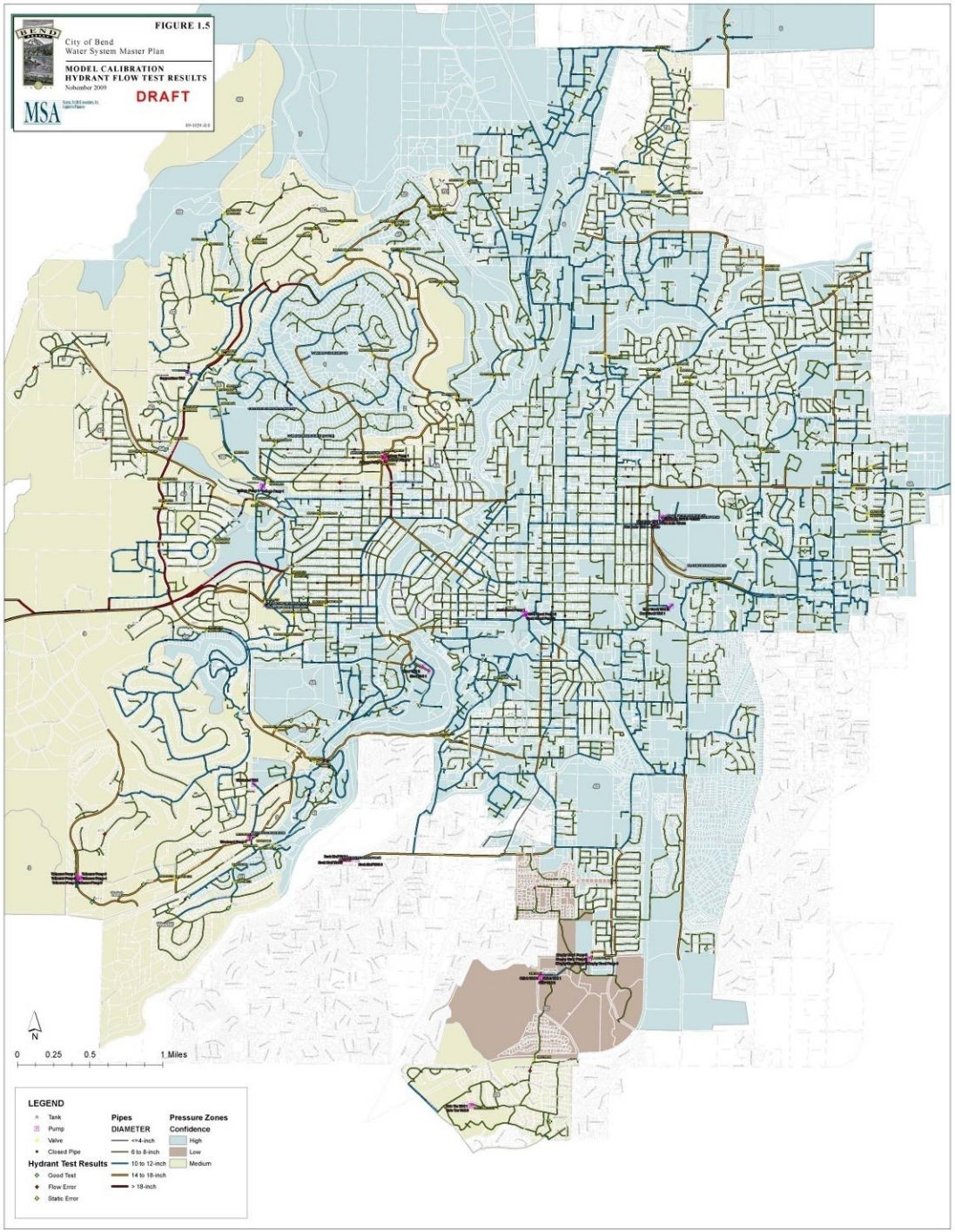
- **Utilized a Zone by Zone Rating System Approach for Calibration Confidence Level**
  - **Reduces Rating Oversimplification**
  - **Provides Clear Guidance to Identify Where Future Calibration is Needed**
- **Developed Criteria for Rating**

Confidence Level	Static Pressure Results	Residual Fire Flow Pressure Results
High	Nearly all results ±5 psi	{Field Pressure Drop – Model Pressure Drop} Nearly all results < =10 psi
Medium	Few results >5 psi error	{Field Pressure Drop – Model Pressure Drop} Few Results >10 psi
Low	Several results >5 psi	{Field Pressure Drop – Model Pressure Drop} Several Results >10 psi

- **<u>Know When to Say When!</u>**

STEADY STATE CALIBRATION CONT.

Pressure Zone	Confidence
1	High
2	High
2B	Medium
3	Medium
Tetherow (2)	Medium
3A	High
3B	Medium
3D	Low
4A	High
Westwood (3)	Medium
4B	High
4C	Medium
4D	Medium
4E	Medium
4F	High
4G	High
4H	High
4I	High
4J	High
4K	High
5	High
5A	High
5B	High
5C	Medium
5D	High
6	High
6A	High
6B	Medium
7	High
7A	Medium
7B	High
7C	High
7D	Medium



EXTENDED PERIOD CALIBRATION

- **Difference Between Steady State (SS) and Extended Period Simulation (EPS) Calibration:**
  - **SS is Very Quantitative – number to number comparisons**
  - **EPS is More Qualitative – comparisons of "trends"**
  - **SS is more focused on the overall validation of the physical network that stresses the system in specific locations**
  - **EPS evaluates the overall operation of the system focusing on the "control" of the supplies, valves and pumps**
  - **EPS allows for the validation of how water moves in the system over a period of time**

EXTENDED PERIOD CALIBRATION - BEND

- Important in Bend to Validate Both Winter and Summer Operations
  - During Winter, System is Supplied for the most part by Surface Water; < 10 mgd
  - During Summer, System Uses a Combination of Surface and Groundwater Supply; > 25 mgd
  - Two different “supply” models:
    - Centralized Source
    - Distributed Sources
  - Summer Challenge: Utilize All Surface Water While Meeting Peak Demands and Keeping Tanks Relatively Full
  - Winter Challenge: Utilize All Surface Water While Turning Over Tanks

EXTENDED PERIOD CALIBRATION APPROACH

- Load Pump Controls – Winter & Summer
- Assign Diurnal Curves to Model Nodes – Winter & Summer
- Collect 2 Weeks of SCADA During July and December
- SCADA Includes:
  - All Wells – Mostly Flow Rates, Some On/Off
  - Most Booster Pumps – Mostly Flow Rates, Some On/Off
  - Most Reservoirs – Level
  - Some Other Flows
  - Set to Record Every 10 Minutes
  - No PRV Flow Rates
- Resulted in a Spreadsheet Containing over 100 Columns and 2,500 Rows for each dataset

- <u>Easy to Experience “Death by Data”</u>

EXTENDED PERIOD CALIBRATION CONT.

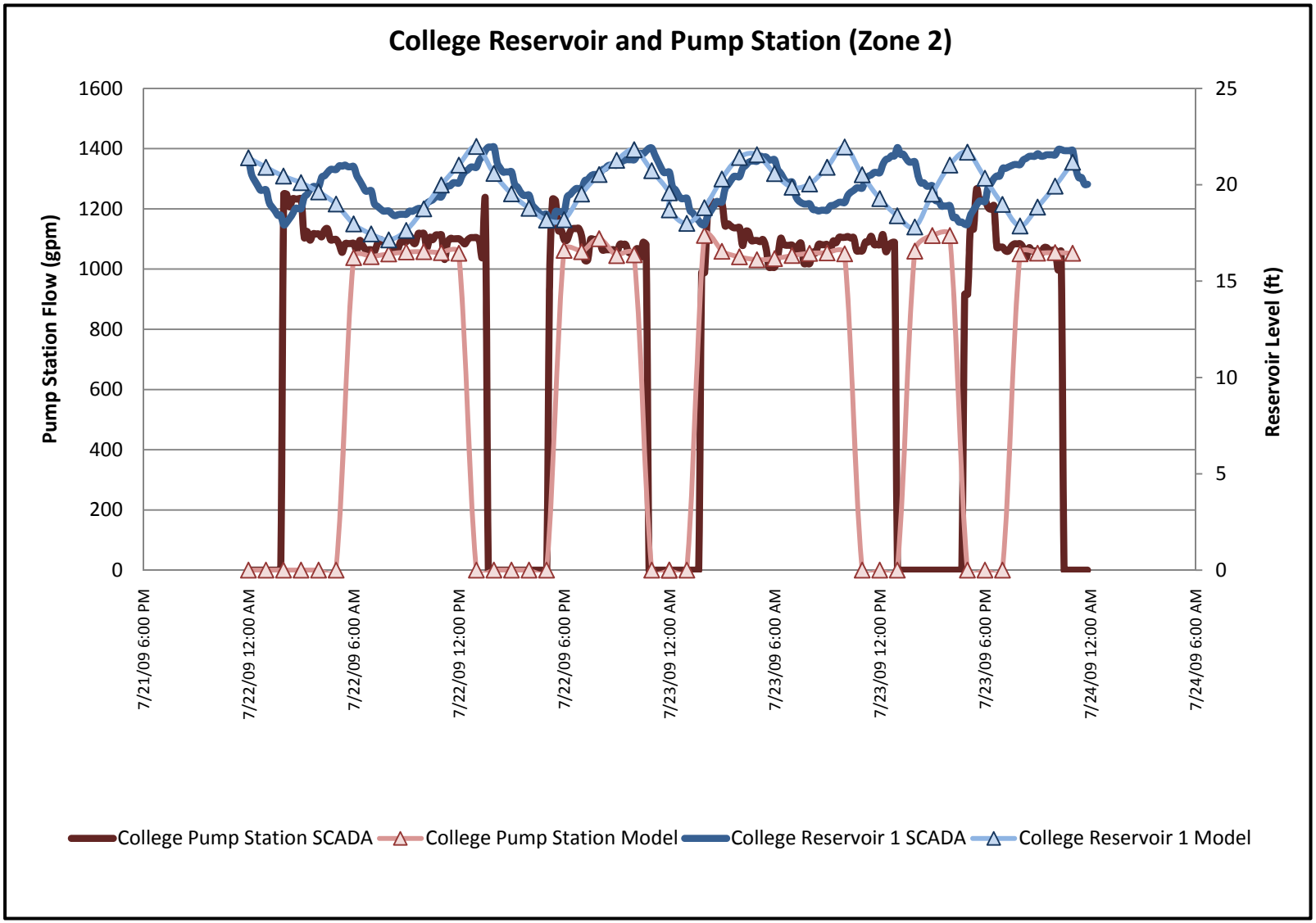
- **Primarily Compared 2 System Facilities:**
  - **Well and Booster Pump Flows**
  - **Reservoir Level**
- **Typically Evaluated Facilities in Same Zone Concurrently**
  - **Pump and Controlling Reservoir Shown Together**
- **PRV Settings Updated for Winter and Summer Conditions**
  - **Proved to be a Challenging Factor as City Staff were Actively Adjusting PRVs During Project**

PUMP CONTROL

- **Need to Understand the Set Points and the Level of Confidence in the Model Flows**

Pump Description	Control	On Setting	Off Setting	Manufacturer's Pump Curve Available
Awbrey Pump #1	Tower Rock Reservoir	<27.5 (ft)	>29.5 (ft)	Unverified Design point
Awbrey Pump #2	Tower Rock Reservoir	<26.0 (ft)	>27.5 (ft)	Awbrey Pump Curve
Awbrey Pump #3	Off	-	-	Awbrey Pump Curve
Bear Creek Well 1	Pilot Butte 2 Reservoir-Level	<35 (ft)	> 37 (ft)	Bear Creek Well 1 Curve
Bear Creek Well 2	Pilot Butte 2 Reservoir-Level	<34 (ft)	> 36 (ft)	Unverified Design point
College Pump #1	College Reservoir #1	<17.8 (ft)	>22.0 (ft)	Design Point (Different from that noted on pump)
College Pump #2	College Reservoir #1	<16 (ft)	>20 (ft)	Design Point (Different from that noted on pump)

EXAMPLE OF EPS CALIBRATION FIGURES - SUMMER



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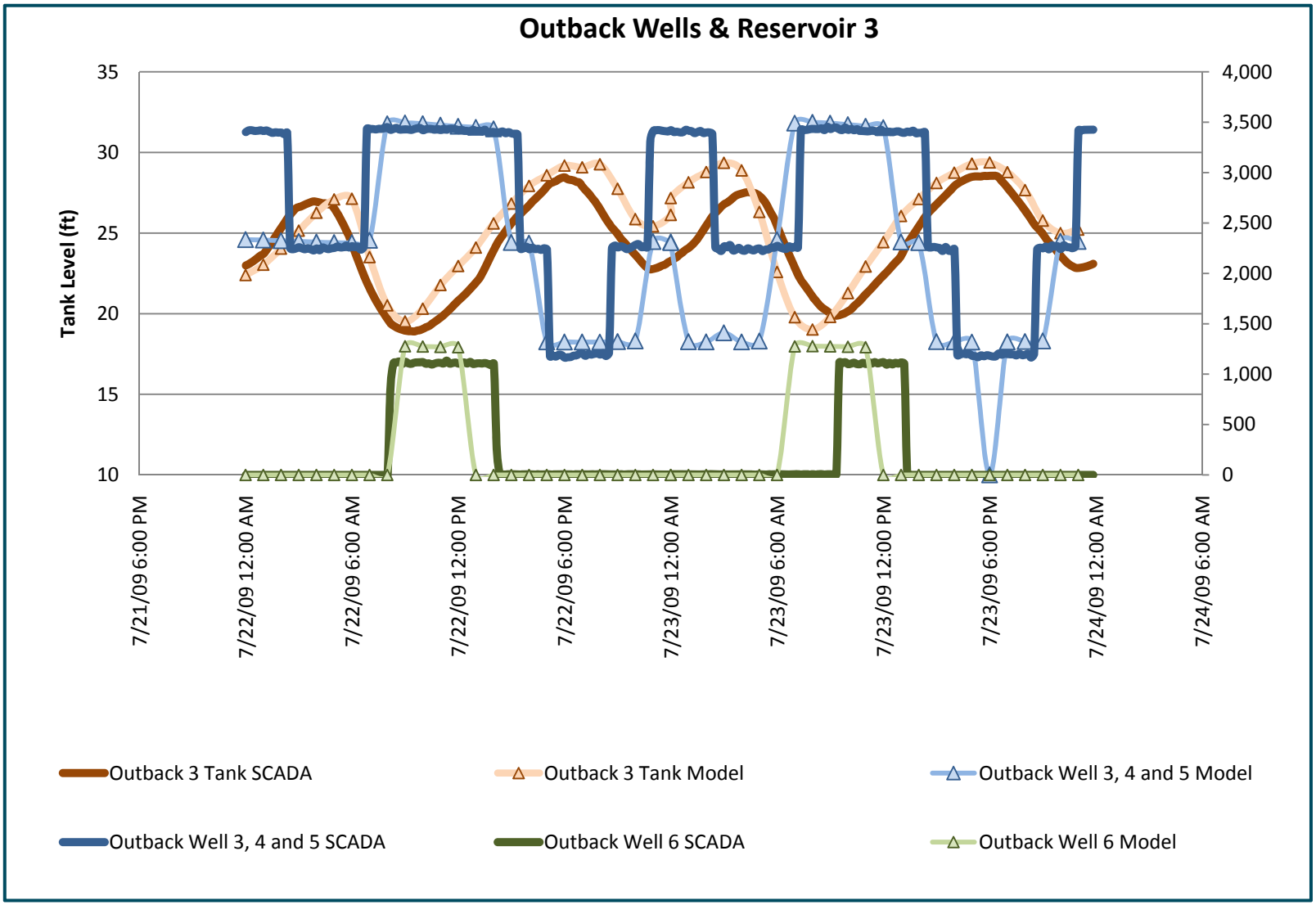

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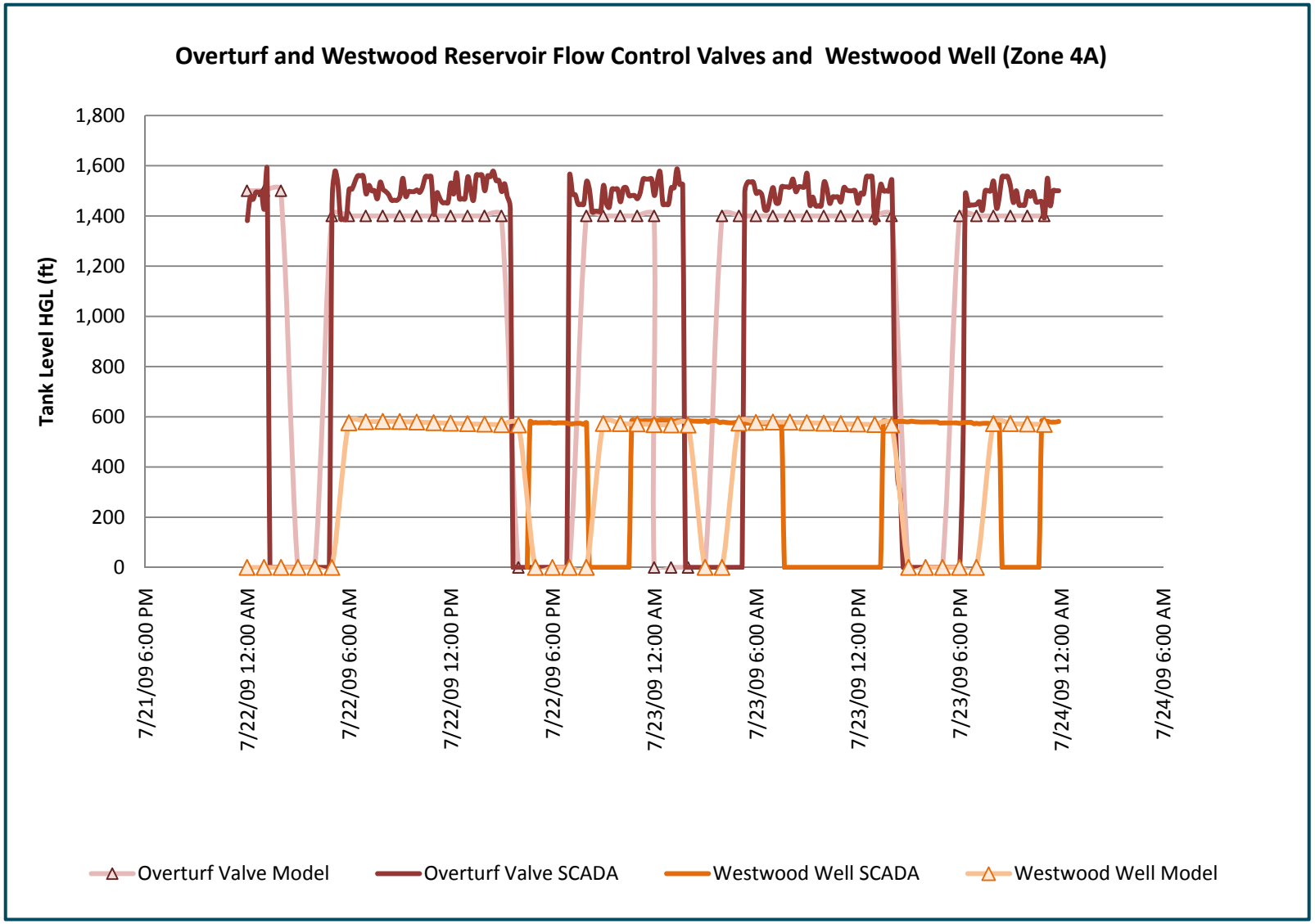
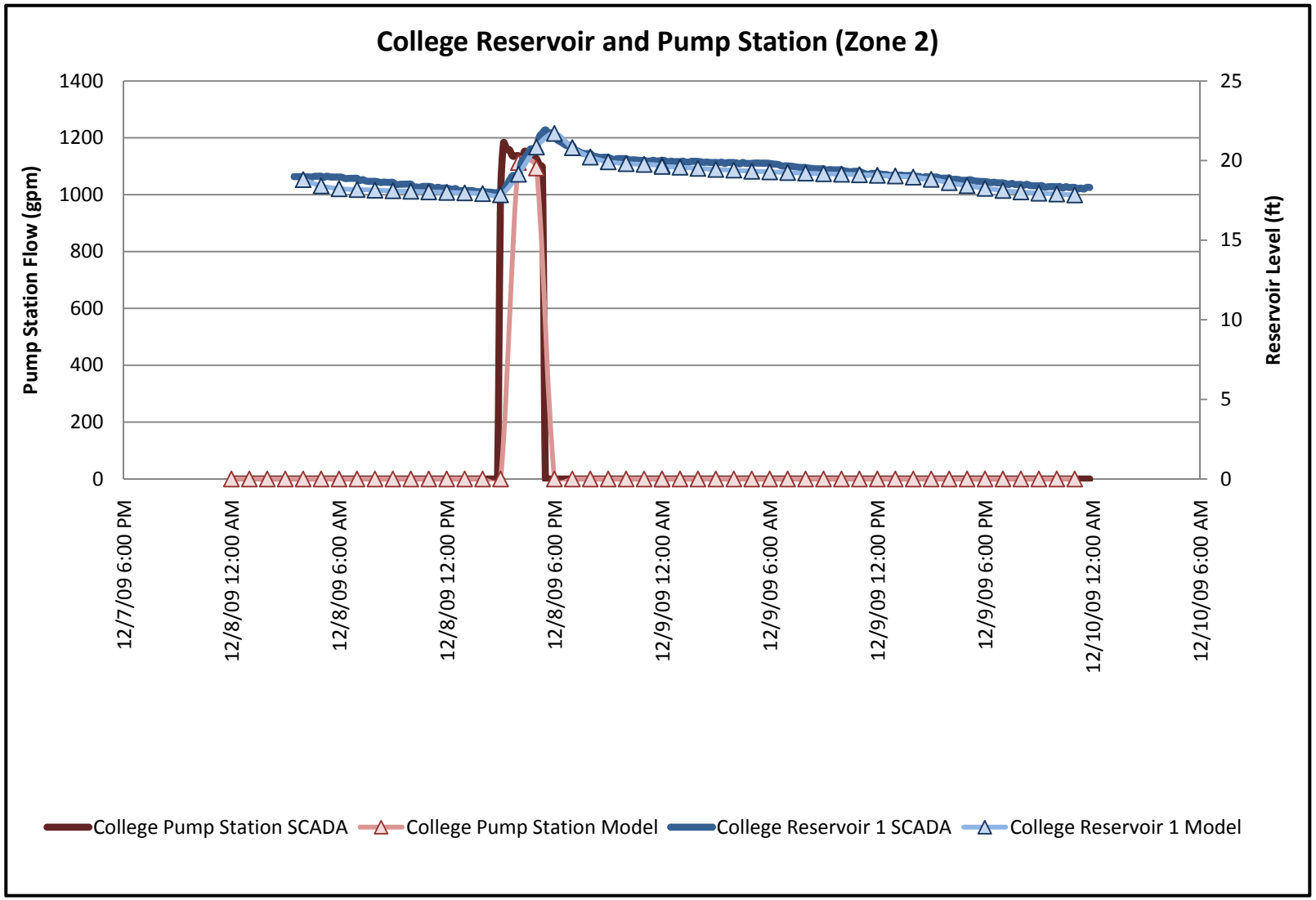


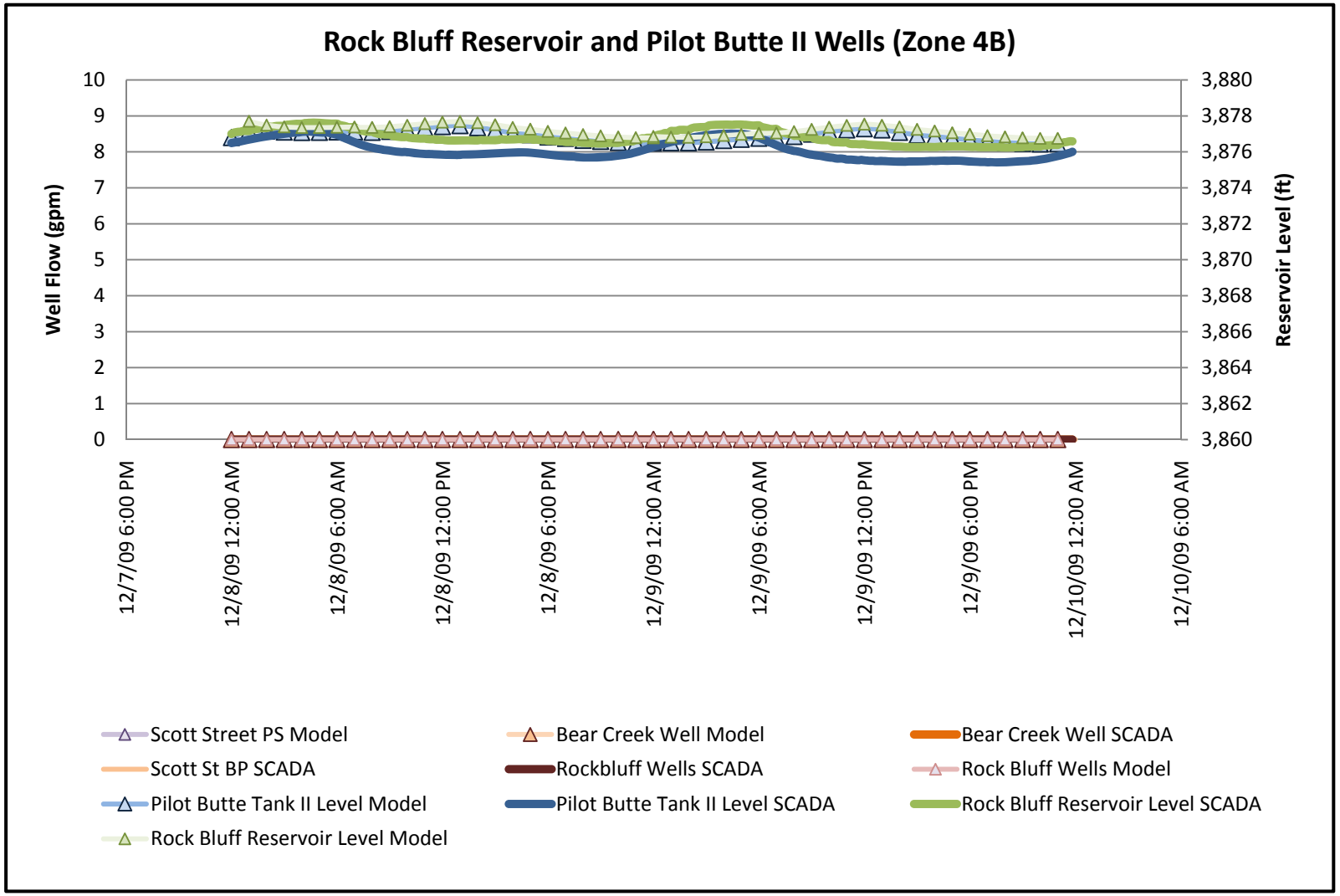
WINTER EXTENDED PERIOD CALIBRATION

- Initially Data From January 2009 was Utilized However Discrepancies in the PRV Settings and SCADA Could Not be Resolved
- Second Round of SCADA was Recorded in December 2009
- As Noted, During Winter, System is Essentially Surface Water Supplied
  - Few Wells Operating
- Enabled Focus on
  - Reservoir Levels
  - Flow Control Valves
  - Sensitivity to PRV Settings

EXAMPLE OF EPS CALIBRATION FIGURES - WINTER



EXAMPLE OF EPS CALIBRATION FIGURES - WINTER

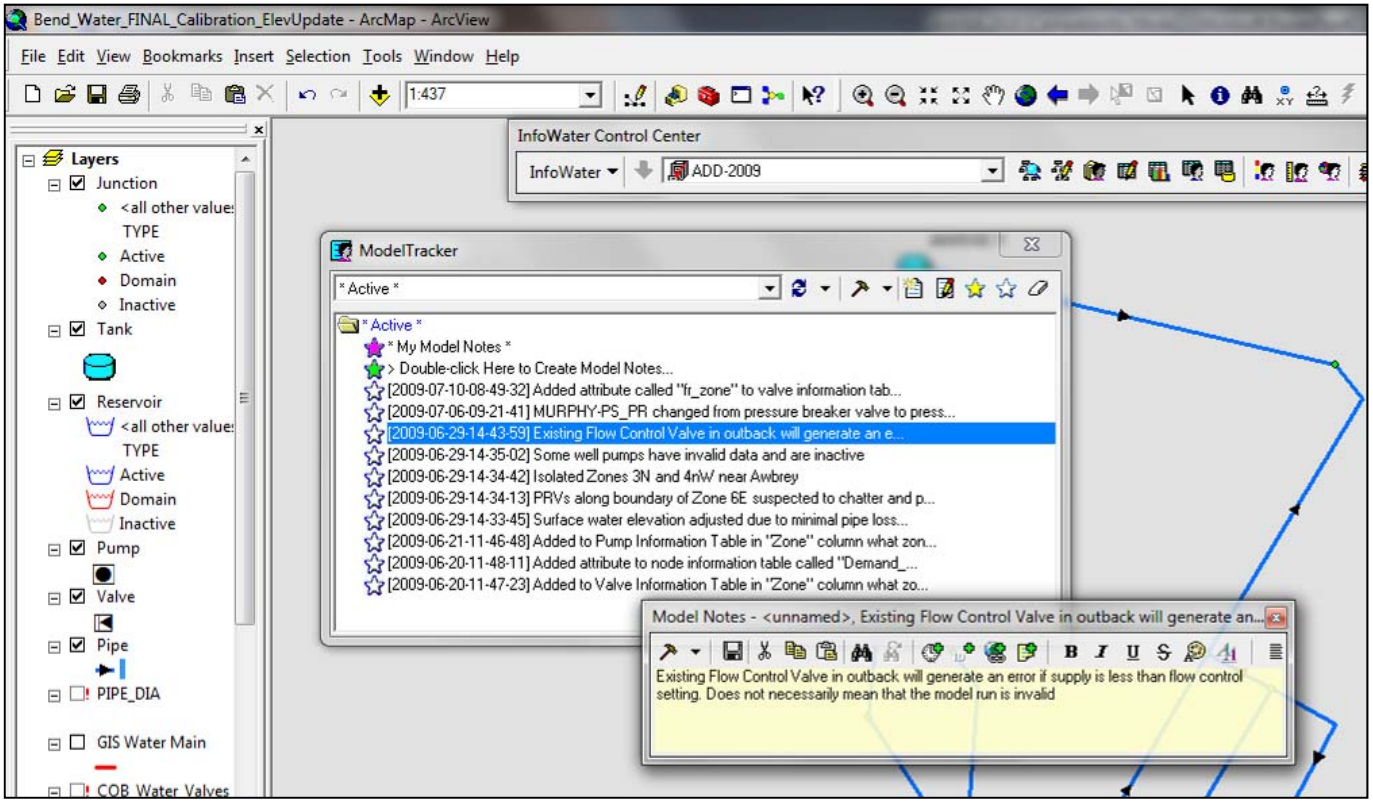


EXTENDED PERIOD CALIBRATION SUMMARY

- Flow Meters on Major PRVs are Extremely Valuable
  - City Planning to Implement PRV Meters in Future
- Peak Demands and High Flows Can Obscure Elevation and Setting Issues
  - Tank Levels Were Surveyed and Adjusted Based on Winter Results
  - Have Reservoir Level Sensors Been Calibrated and
    - What Base Elevation are they Referencing
  - PRVs Were Surveyed and Settings Adjusted Based on Winter Results
- Where Operational Set Points Change Throughout the Year, Winter (low demand) EPS Calibration is Important, Particularly if Model will be Used for Water Quality or Reservoir Turnover Analysis

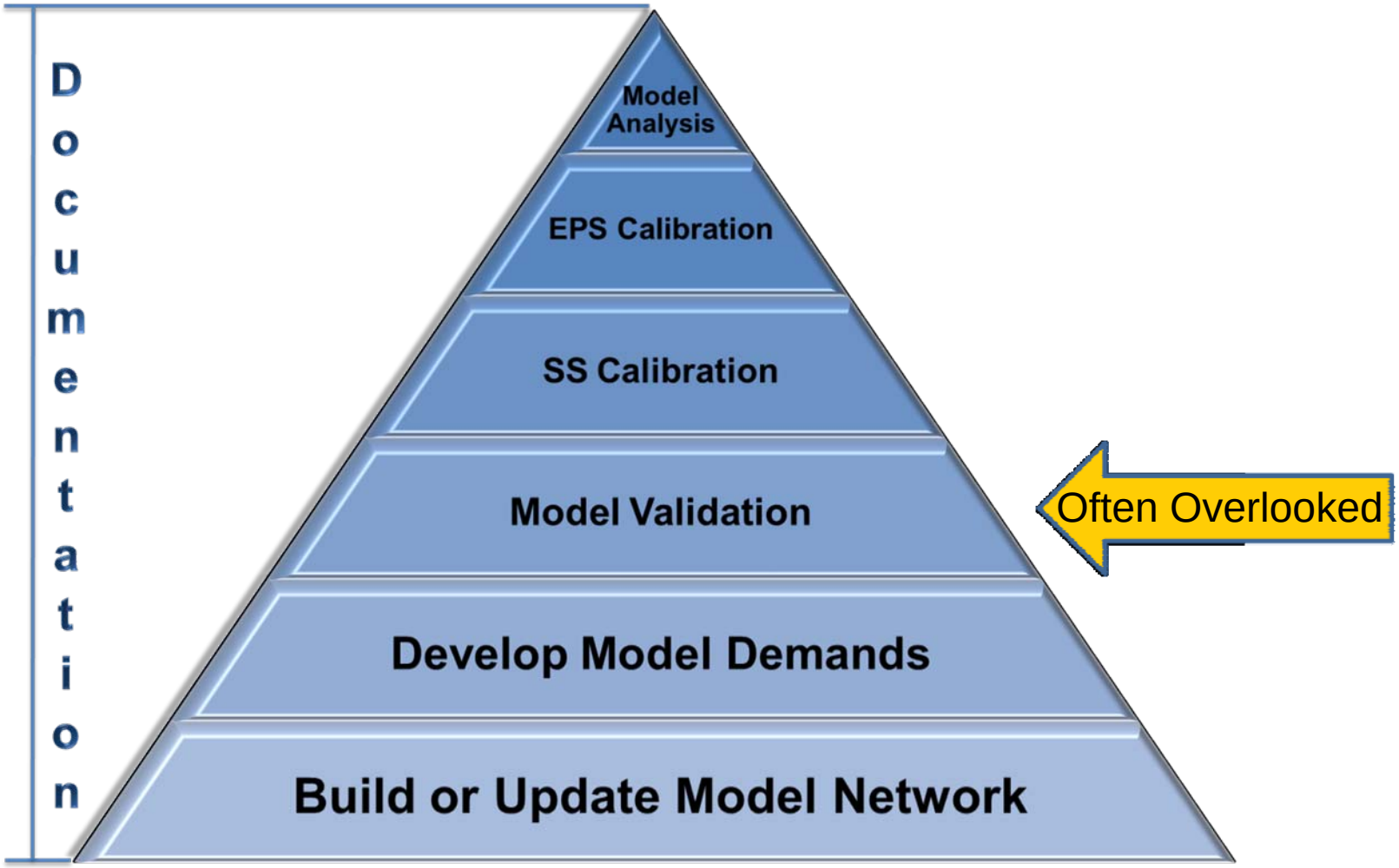
DOCUMENTATION

- **Model "Documentation" is Critical Recordkeeping**
  - **Provides a "Snapshot" of the Assumptions During Process**
  - **Modeler Uses the Document to Reality Check Model Results**
  - **Great Tools Are Now Available in Software to Track Changes**



CONCLUSIONS

- **Model Building and Calibration is a "progressive" process**
  - **Must Build a Solid Base Before Proceeding to Next Step**



CONCLUSIONS CONT.

- Willingness of GIS Staff to Consider Hydraulics is Critical to Model Construction and Ongoing Maintenance
- Billing Records are Typically the Most Challenging of the Base Data

  …though SCADA is a Close Second
- Documentation and Model Change Tracking is Critical
- One Size Does Not Necessarily Fit All
- Easy to Get Caught in the Details – Step Back from Time to Time -- Forest for theTrees --
- Model Calibration is Never Done!

QUESTIONS

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