Static Calibration versus Dynamic EPS Calibration

Aurelie Nabonnand, Carollo Engineers

Alena Bennett, Carollo Engineers

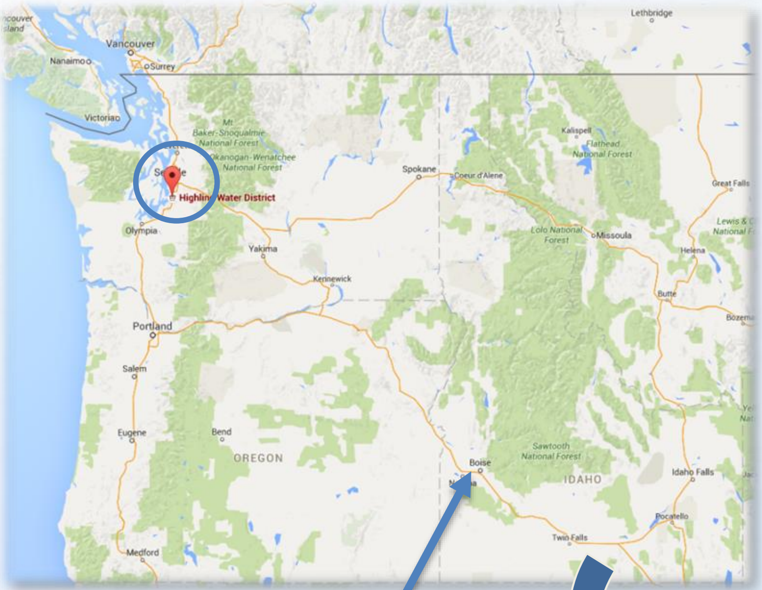
Jeremy Delmar, Highline Water District

PNWS – AWWA

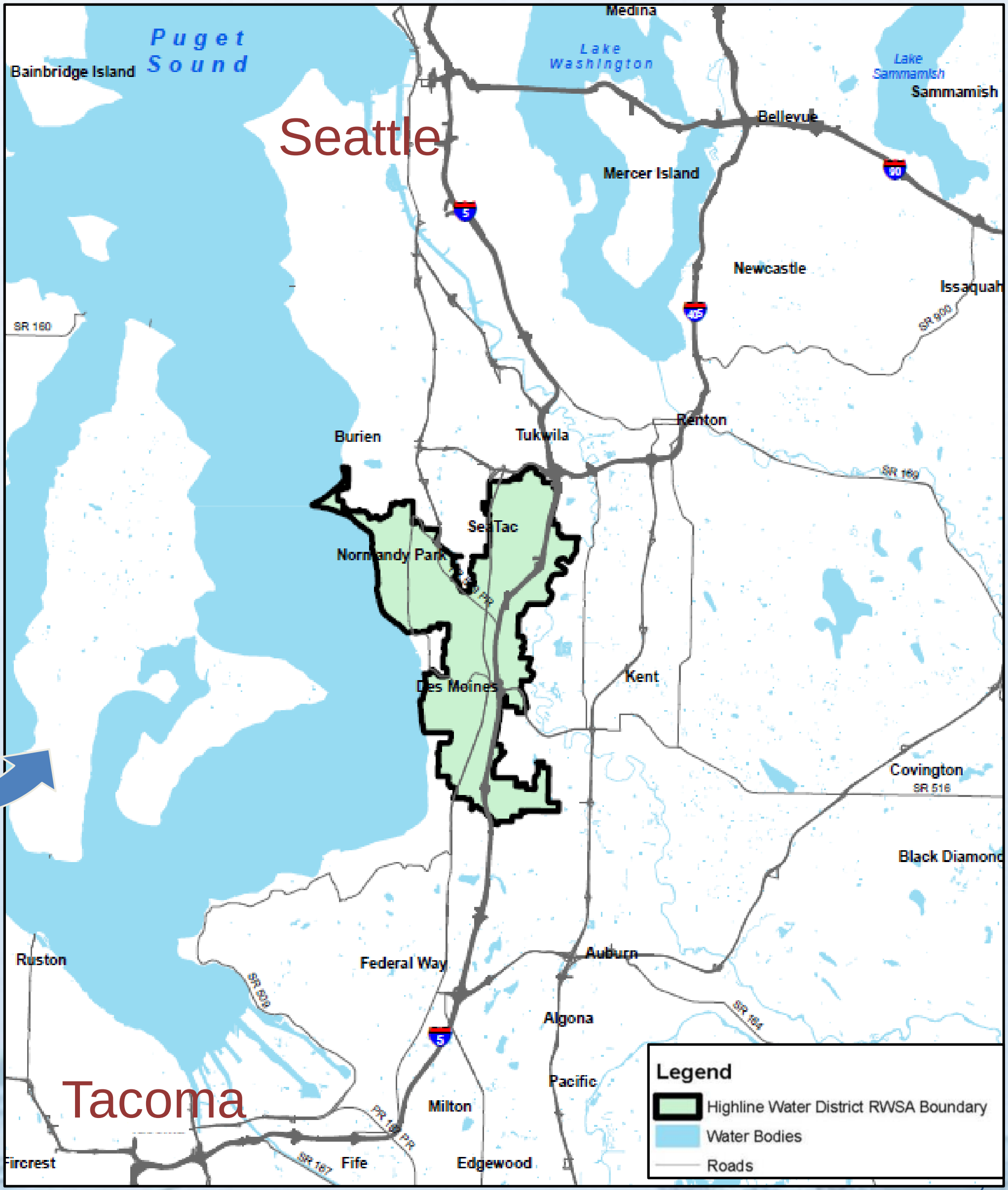
May 6, 2016

Engineers...Working Wonders With Water®

Where is Highline Water District?



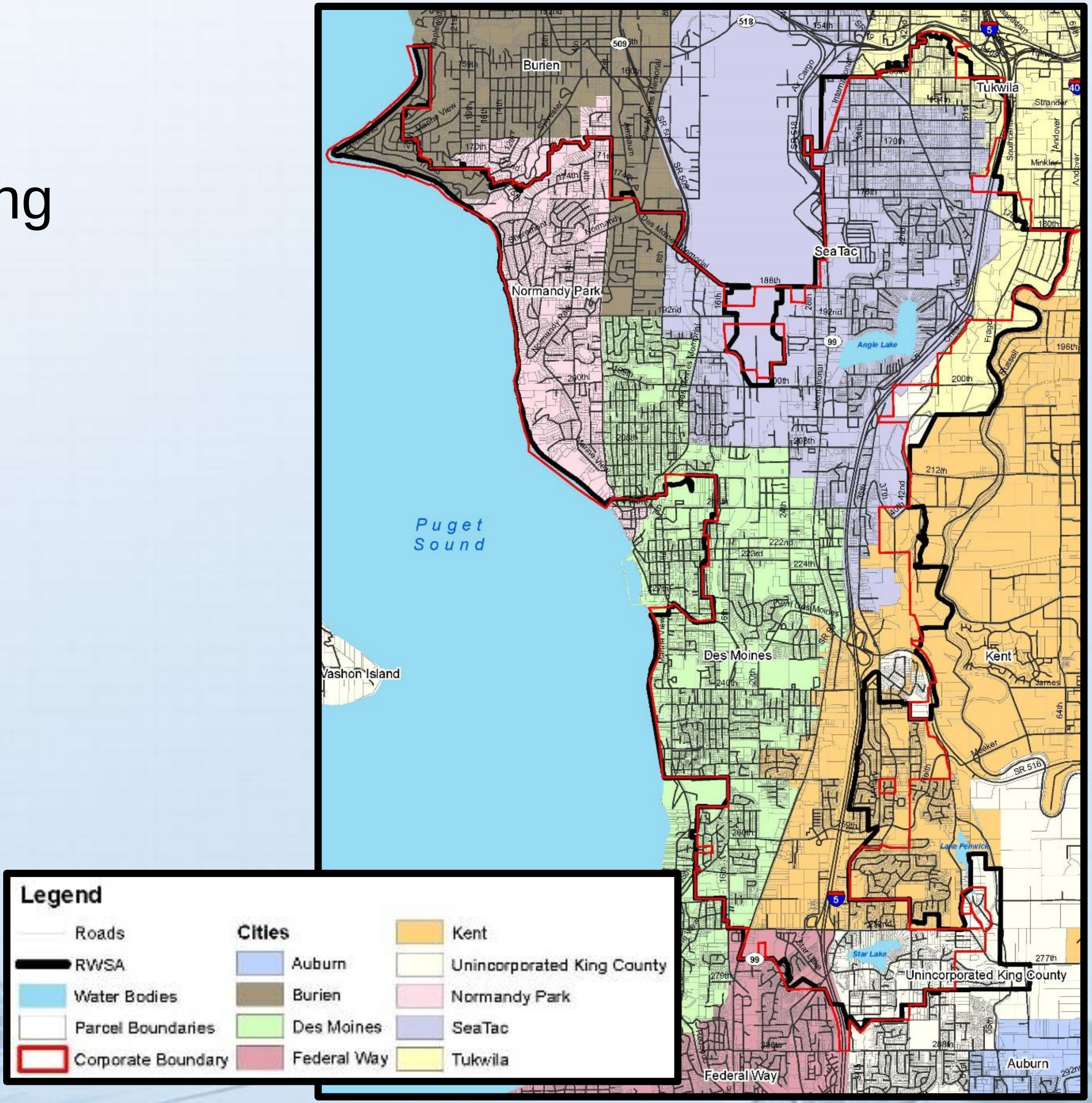
Boise



Legend
- 🟩 Highline Water District RWSA Boundary
- Water Bodies
- Roads

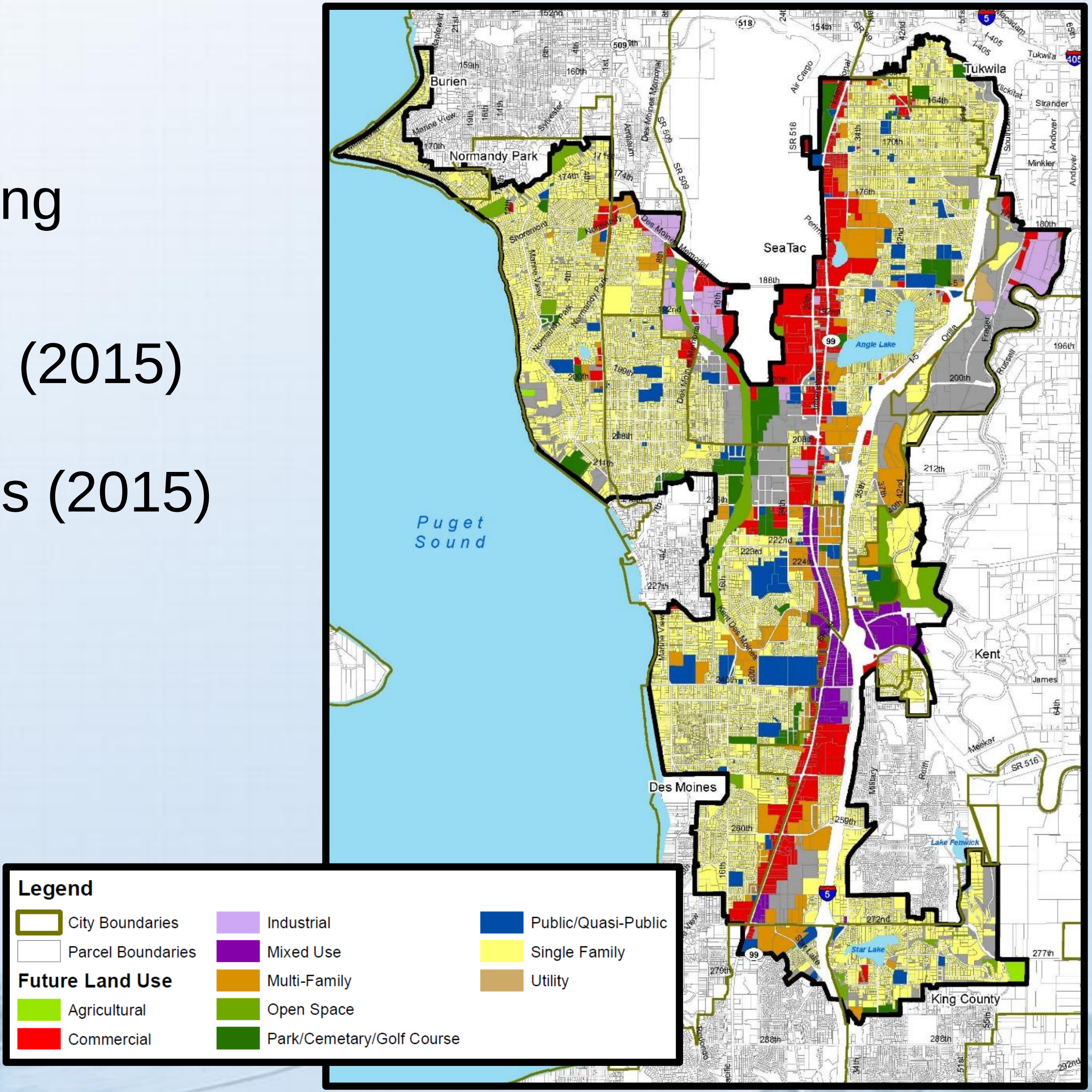
Who does Highline Serve?

- **7** Cities and Unincorporated King County



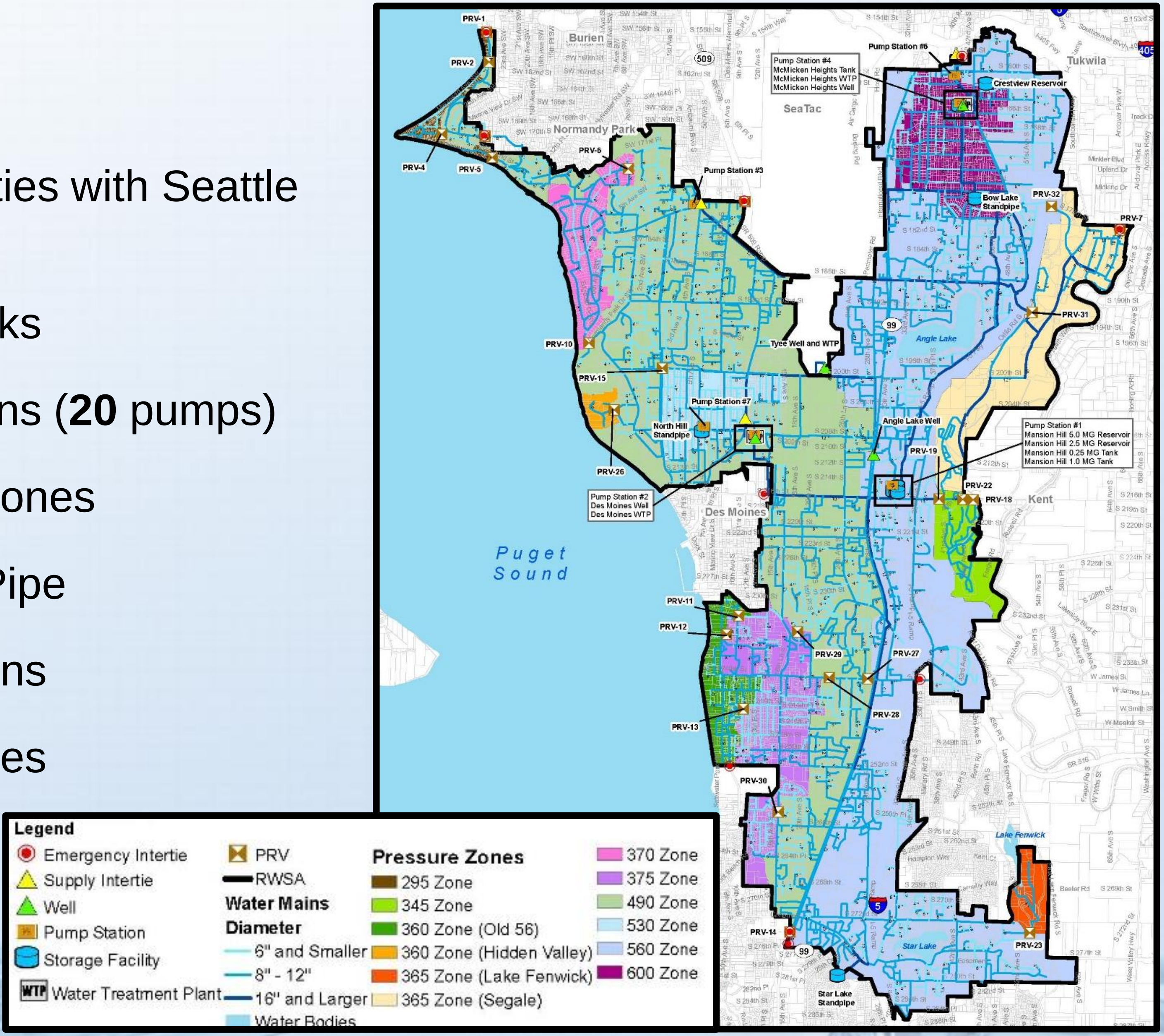
Who does Highline Serve?

- **7** Cities and Unincorporated King County
- **70,000** Residents (2015)
- **28,000** Employees (2015)



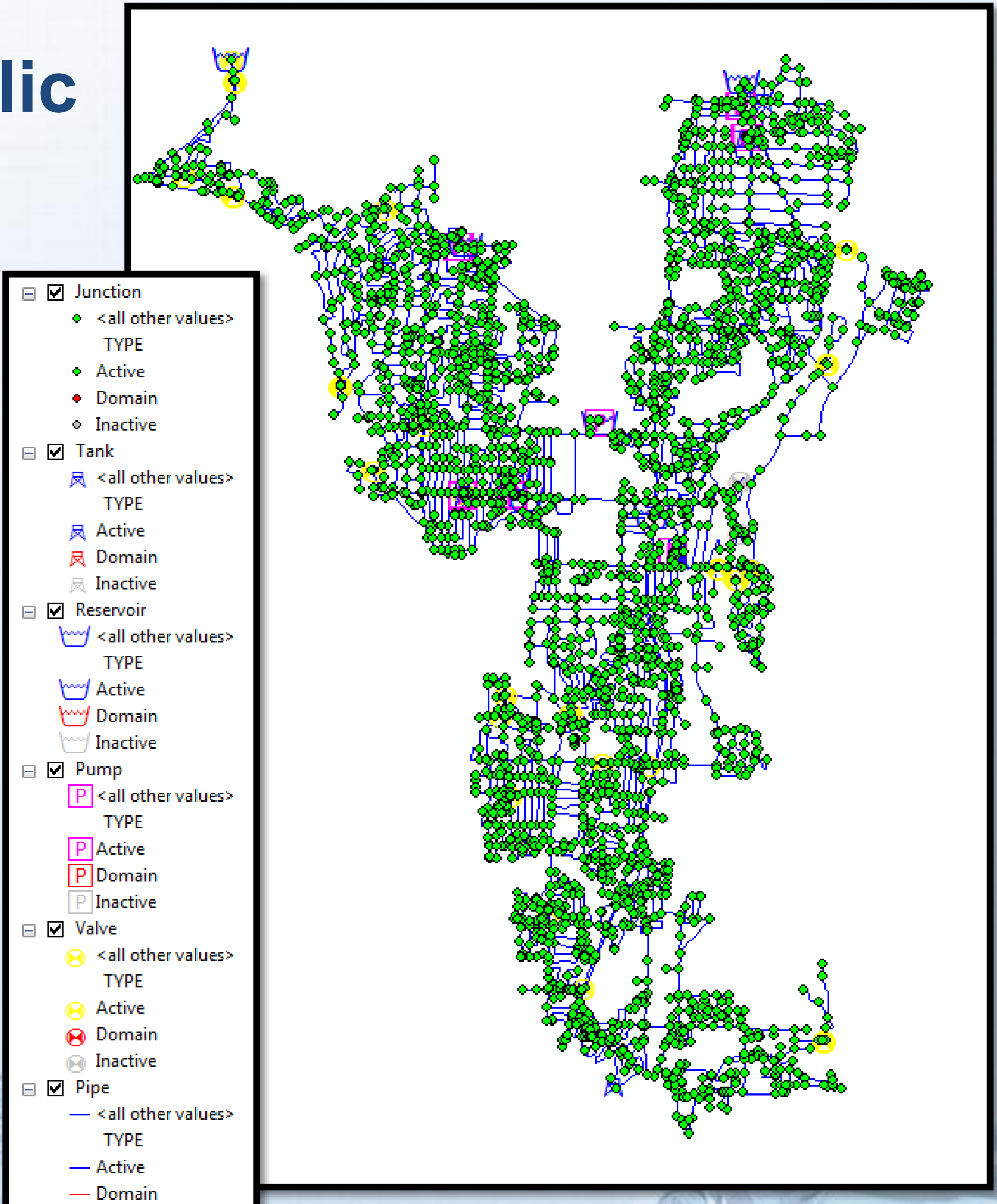
Water System Assets

- **4** Wells
- **3** Supply Interties with Seattle Public Utilities
- **9** Storage Tanks
- **6** Pump Stations (**20** pumps)
- **12** Pressure Zones
- **300** Miles of Pipe
- **25** PRV Stations
- **2** Altitude Valves



District's Hydraulic Model

- All Pipe Model
- $H_2ONET^{®}$ (Innovyze)
- **2,890** Junctions
- **3,760** Pipes
- **39** PRVs
- **2** Float Valves

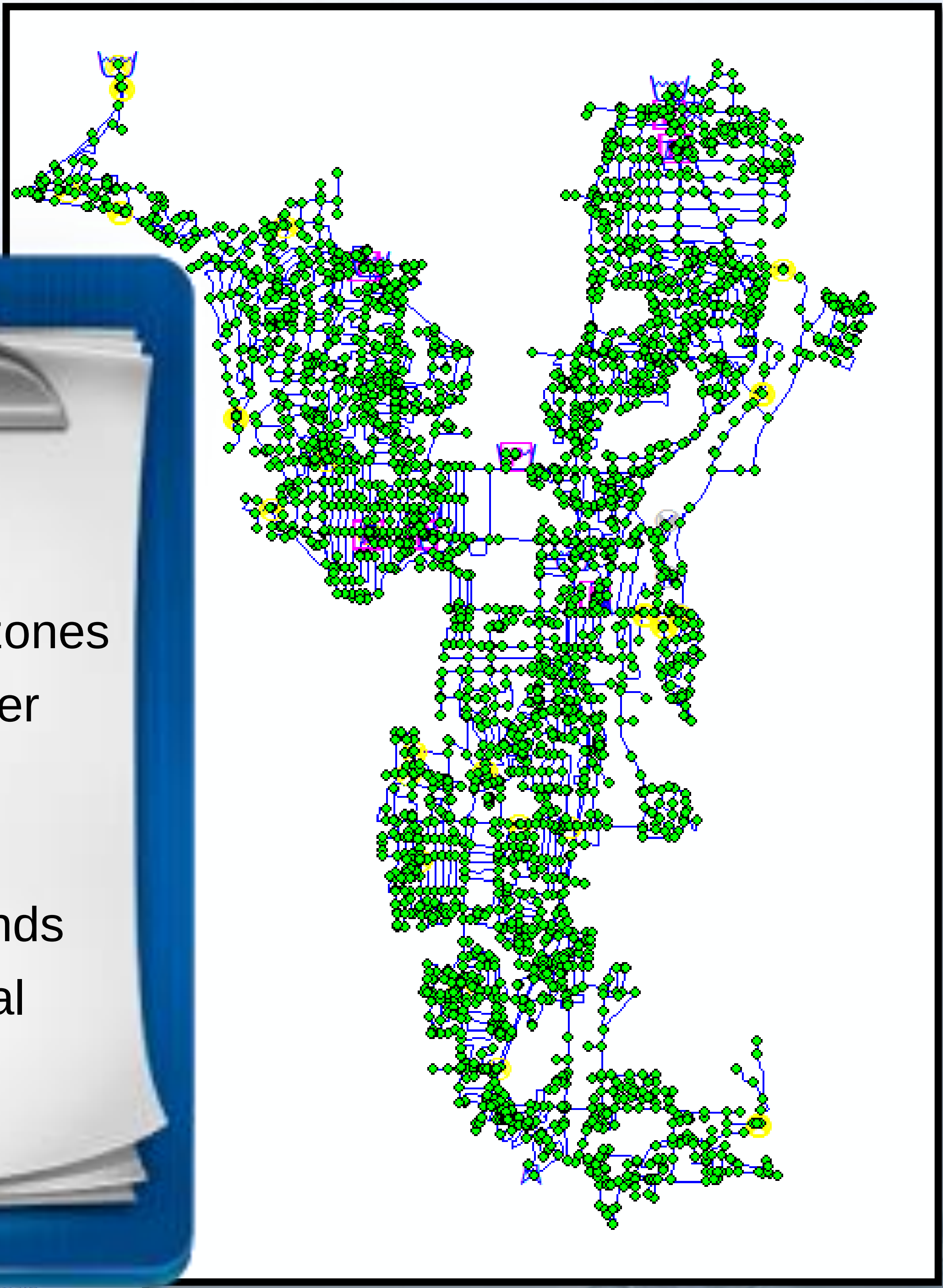


⊟ ☑ Junction
● <all other values>
TYPE
● Active
● Domain
○ Inactive
⊟ ☑ Tank
<all other values>
TYPE
Active
Domain
Inactive
⊟ ☑ Reservoir
<all other values>
TYPE
Active
Domain
Inactive
⊟ ☑ Pump
P <all other values>
TYPE
P Active
P Domain
P Inactive
⊟ ☑ Valve
<all other values>
TYPE
Active
Domain
Inactive
⊟ ☑ Pipe
— <all other values>
TYPE
— Active
— Domain

District's Hydraulic Model

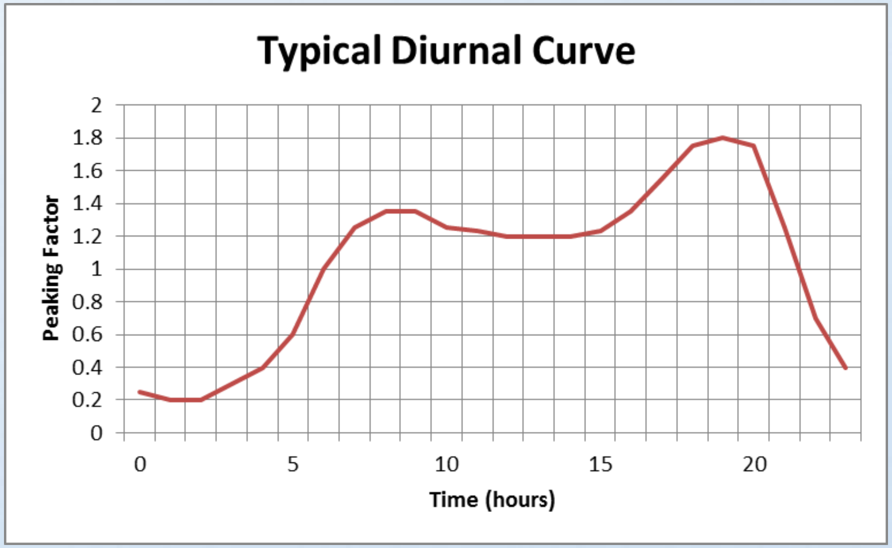
Model Update
Checklist

- ☐ Add new pressure zones
- ☐ Update pipe diameter
- ☐ Add 2nd PRV
- ☐ Update controls
- ☐ Allocate new demands
- ☐ Insert custom diurnal curves



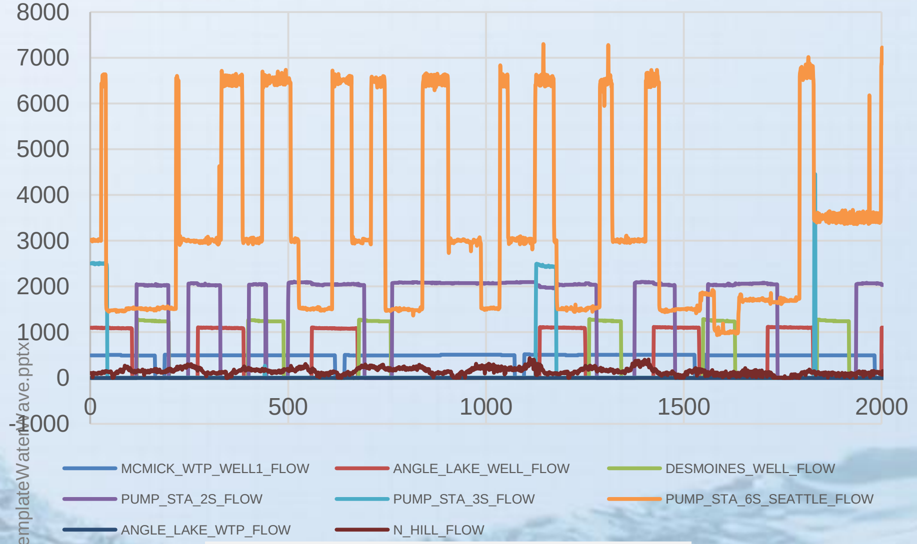
Why Create a Customized Diurnal Curve?

- Diurnal Curve: shows variation in demand over a 24 hour period.
- Different Customer types have different demand patterns.
- Seasonal differences in demand patterns.
- Required for an accurate Extended Period Simulation

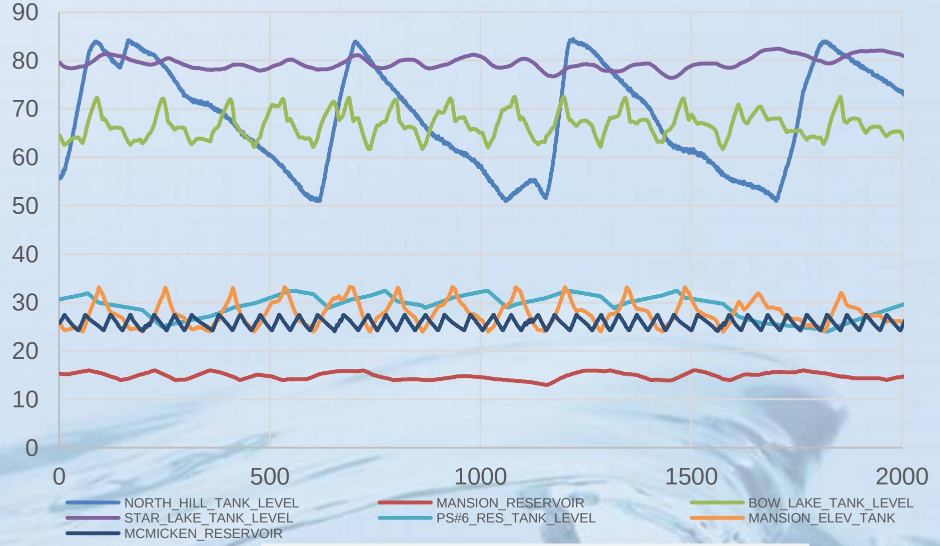


How to Create a Custom Diurnal Curve

- Use SCADA Data
- $Q_{demand} = Q_{inflow} – Q_{outflow} + \Delta V_{storage}/\Delta t$
  - Where
    - Q_{inflow} = average rate of production
    - Q_{demand} = average rate of demand
    - $Q_{outflow}$ = average outflow rate
    - $\Delta V_{storage}$ = change in storage within the system
    - Δt = time between volume measurements

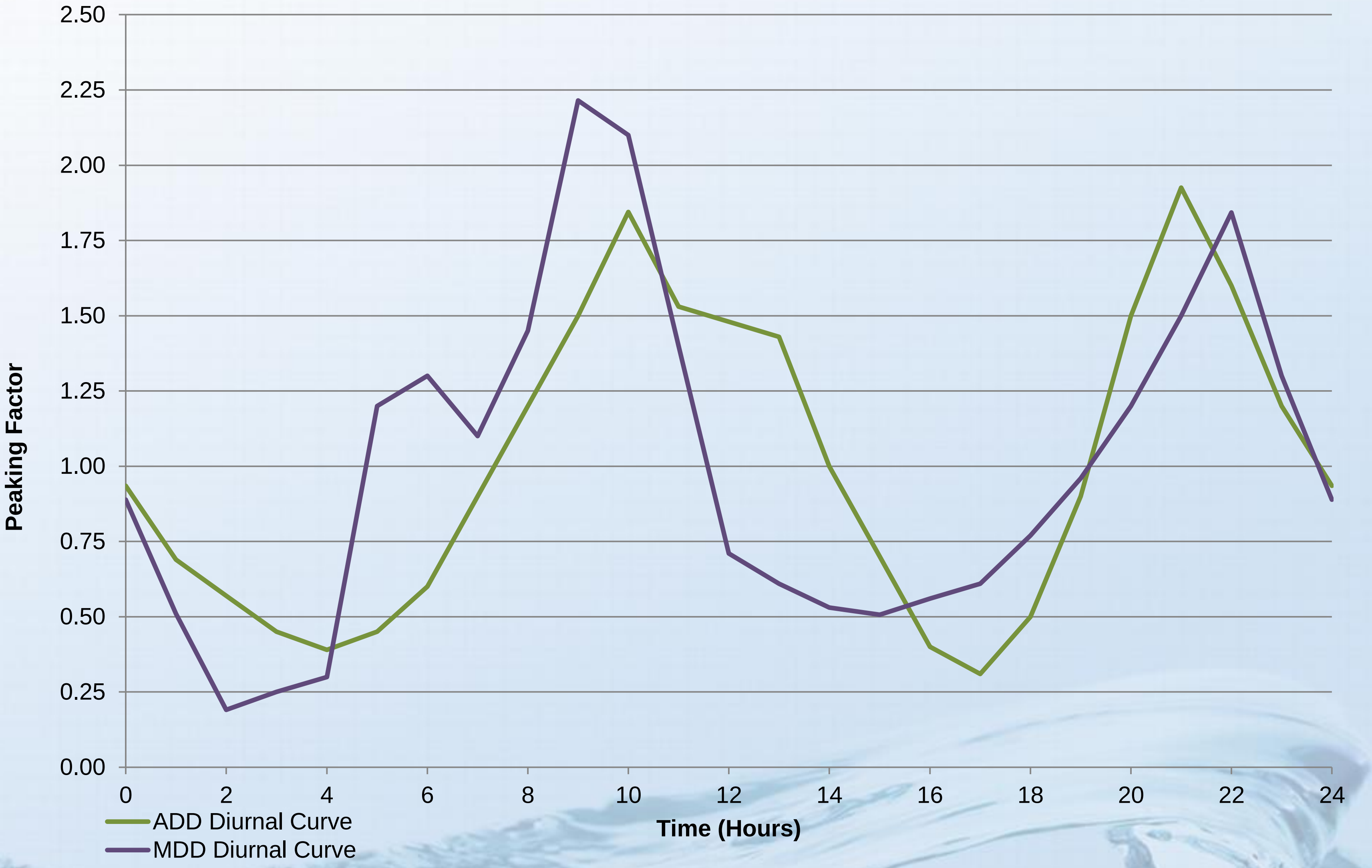


Pumps/Wells SCADA Data



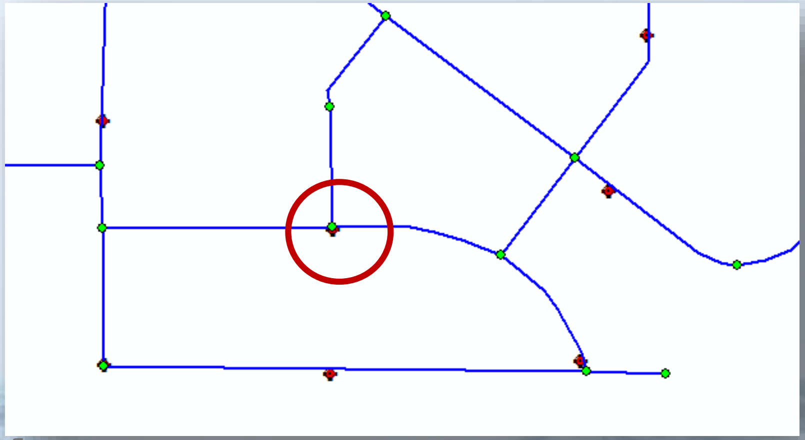
Reservoir Levels SCADA Data

District's Custom ADD and MDD Patterns



What is calibration?

- A comparison of model simulated results to observed data
- Adjustment of model parameters to achieve close agreement between computer-calculated values and field measurements
- What level of calibration?



Model

Field

Why do we have to calibrate models?

- Build most accurate tool possible that will help us make good decisions
  - Build confidence in model results

- Account for:
  - Unknowns and uncertainties
  - Change in conditions over time

- Help gain insight into the distribution system

Two Types of Calibration

- Static Calibration or Hydrant-Test Calibration:
  - Uses field hydrant tests
  - Compares static and residual pressures

- Extended Period Simulation (EPS) Calibration:
  - Compares tanks, sources, pump stations operations

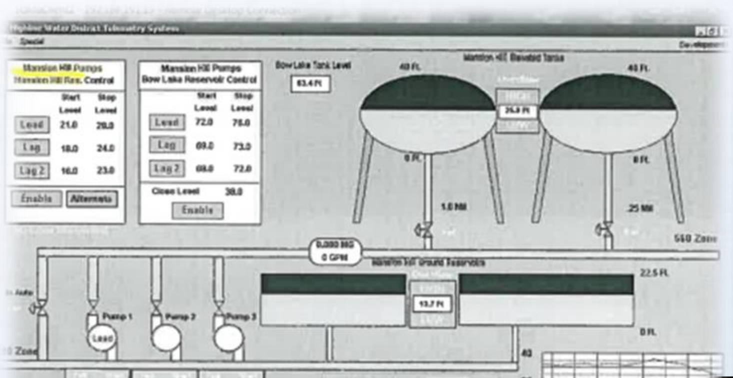
→ Iterative Processes

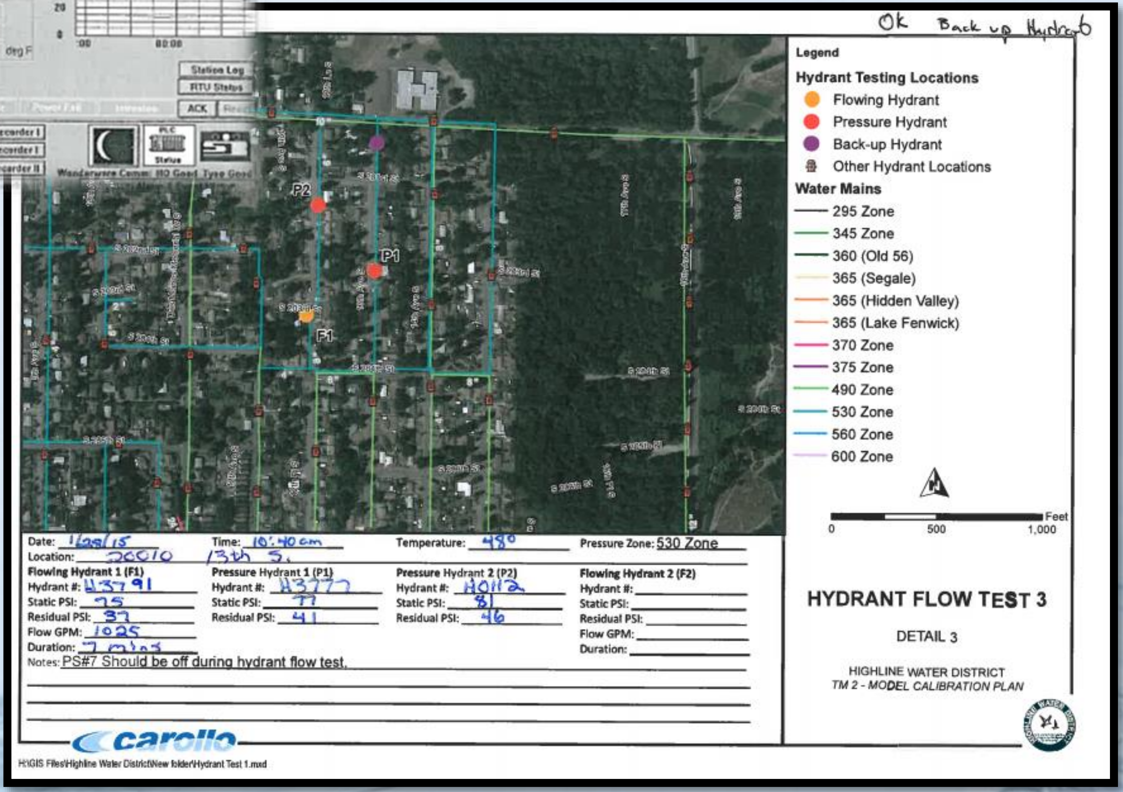
Two Types of Calibration

- Static Calibration or Hydrant-Test Calibration:
  - Uses field hydrant tests
  - Compares static and residual pressures
- Extended Period Simulation (EPS) Calibration:
  - Compares tanks, sources, pump stations operations

→ Iterative Processes

Example of Fire Hydrant Tests Data





Ok Back up Hydrant

Legend

Hydrant Testing Locations
- 🟠 Flowing Hydrant
- 🔴 Pressure Hydrant
- 🟣 Back-up Hydrant
- Other Hydrant Locations

Water Mains
- 295 Zone
- 345 Zone
- 360 (Old 56)
- 365 (Segale)
- 365 (Hidden Valley)
- 365 (Lake Fenwick)
- 370 Zone
- 375 Zone
- 490 Zone
- 530 Zone
- 560 Zone
- 600 Zone

0 500 1,000 Feet

Date: 1/28/15
Time: 10:40 am
Temperature: 48°
Pressure Zone: 530 Zone
Location: 20010 13th S.

Flowing Hydrant 1 (F1)
Hydrant #: H3791
Static PSI: 75
Residual PSI: 37
Flow GPM: 1025
Duration: 7 mins

Pressure Hydrant 1 (P1)
Hydrant #: H3777
Static PSI: 77
Residual PSI: 41

Pressure Hydrant 2 (P2)
Hydrant #: H0112
Static PSI: 81
Residual PSI: 46

Flowing Hydrant 2 (F2)
Hydrant #:
Static PSI:
Residual PSI:
Flow GPM:
Duration:

Notes: PS#7 Should be off during hydrant flow test.

HYDRANT FLOW TEST 3

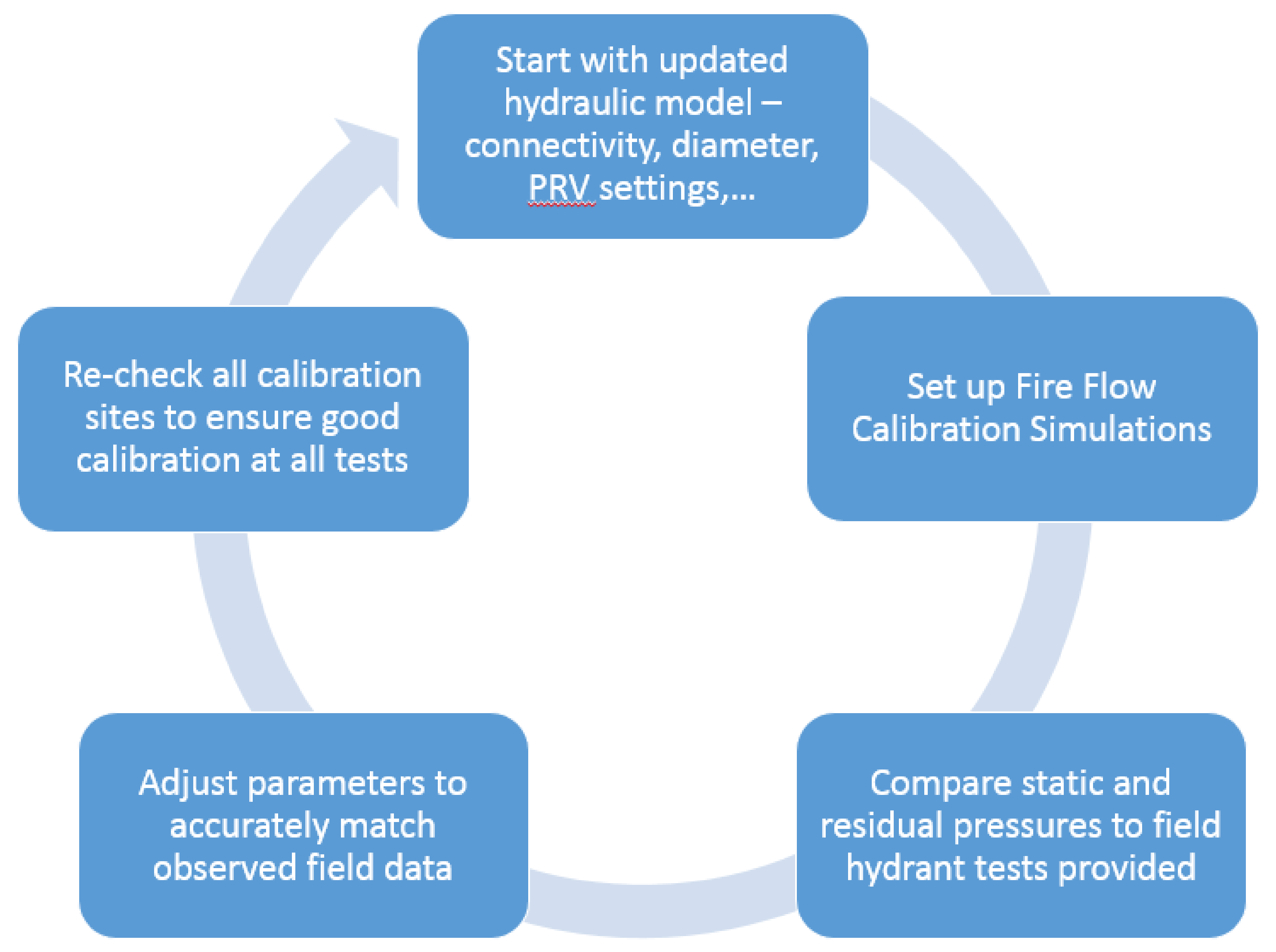
DETAIL 3

HIGHLINE WATER DISTRICT
TM 2 - MODEL CALIBRATION PLAN

carollo

H:\GIS Files\Highline Water District\New folder\Hydrant Test 1.mxd

Steps to calibrating a Static Model



Start with updated hydraulic model – connectivity, diameter, PRV settings,…

Set up Fire Flow Calibration Simulations

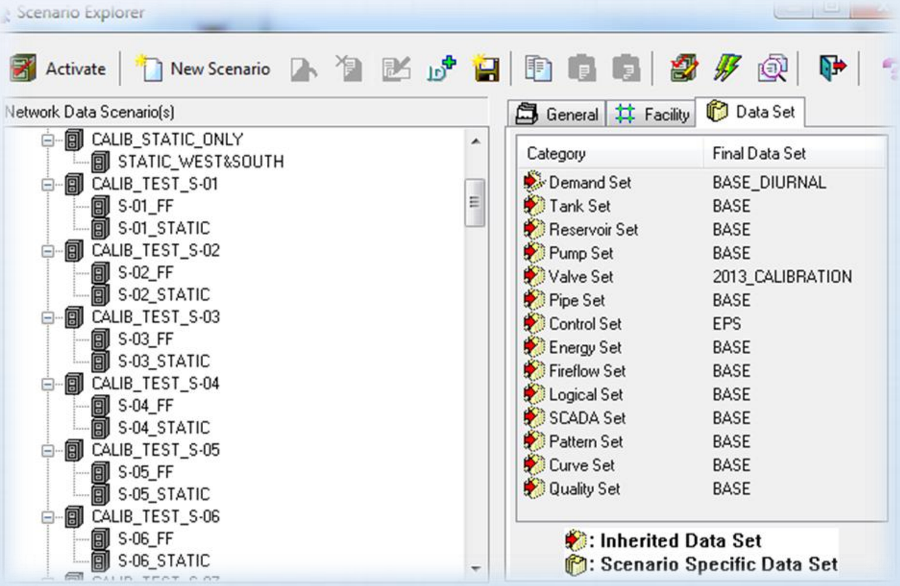
Compare static and residual pressures to field hydrant tests provided

Adjust parameters to accurately match observed field data

Re-check all calibration sites to ensure good calibration at all tests

Fire Flow Calibration Set-up

- Two scenarios set up for each fire hydrant test
  - Static pressure
  - Residual pressure



Network Data Scenario(s)

- CALIB_STATIC_ONLY
  - STATIC_WEST&SOUTH
- CALIB_TEST_S-01
  - S-01_FF
  - S-01_STATIC
- CALIB_TEST_S-02
  - S-02_FF
  - S-02_STATIC
- CALIB_TEST_S-03
  - S-03_FF
  - S-03_STATIC
- CALIB_TEST_S-04
  - S-04_FF
  - S-04_STATIC
- CALIB_TEST_S-05
  - S-05_FF
  - S-05_STATIC
- CALIB_TEST_S-06
  - S-06_FF
  - S-06_STATIC

Category	Final Data Set
Demand Set	BASE_DIURNAL
Tank Set	BASE
Reservoir Set	BASE
Pump Set	BASE
Valve Set	2013_CALIBRATION
Pipe Set	BASE
Control Set	EPS
Energy Set	BASE
Fireflow Set	BASE
Logical Set	BASE
SCADA Set	BASE
Pattern Set	BASE
Curve Set	BASE
Quality Set	BASE

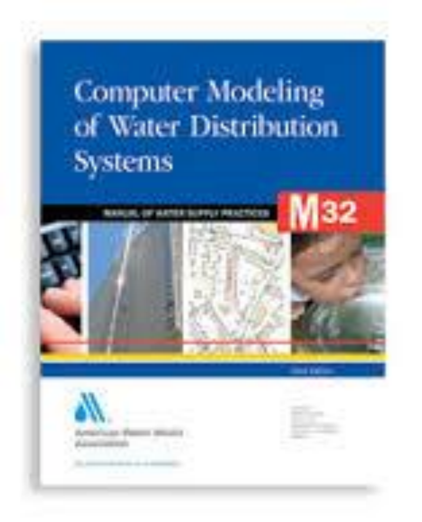
: Inherited Data Set
: Scenario Specific Data Set

- SCADA Data to set up system at the time of each test
  - Demands using the diurnal pattern
  - Tank levels
  - Pump status
  - Sources on and off

Static Calibration Criteria and Industry Practices

- Review of AWWA M32 : master planning static calibration goals from hydrant test data:
  - HGL within +/- 10 feet **(+/- 4.3 psi**) of field values.

- Some sites allowed to go up to +/- 10 psi
  - (United Kingdom WRc guidelines allow up to +/- 15 psi)



Computer Modeling of Water Distribution Systems

M32

11 Field Hydrant Tests are used for calibrating the model to static current condition

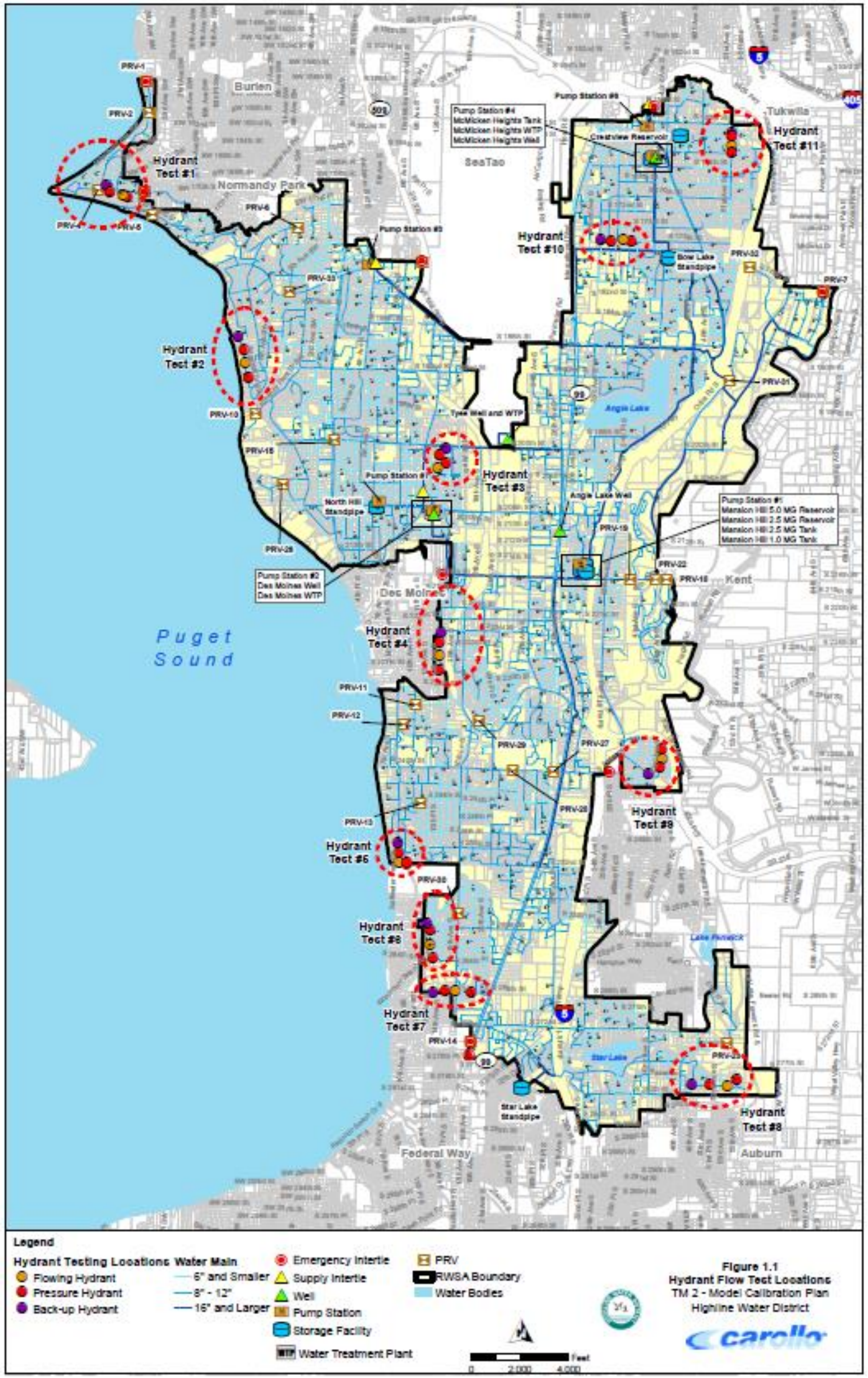
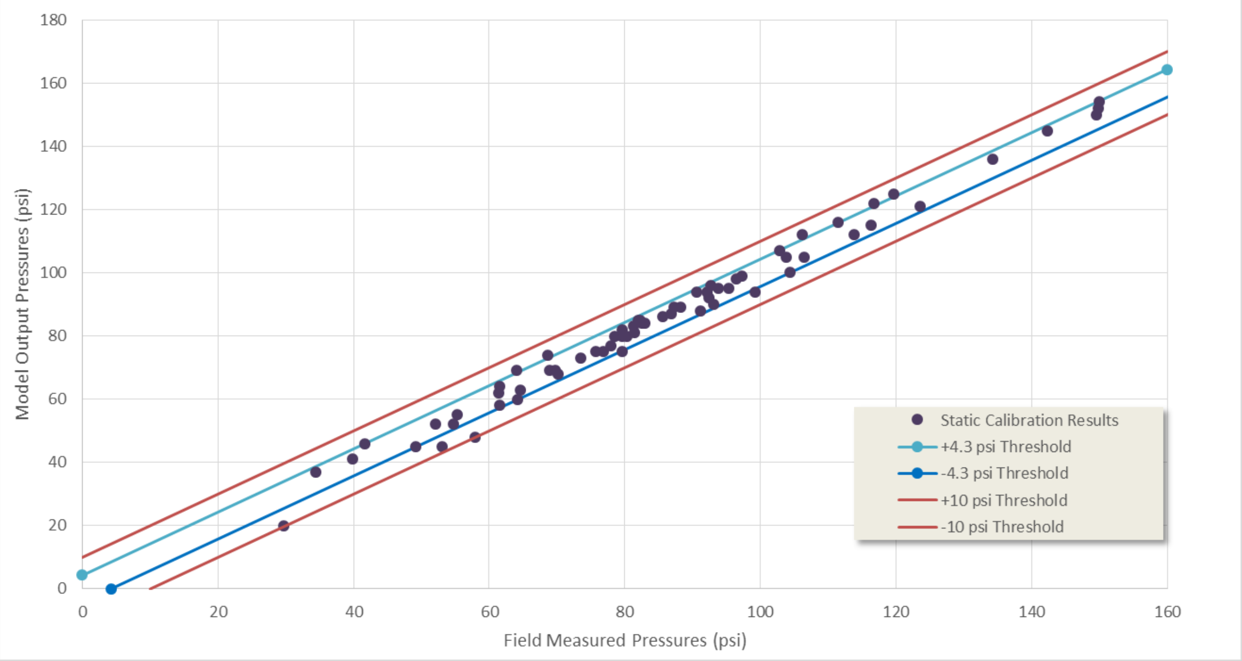


Figure 1.1
Hydrant Flow Test Locations
TM 2 - Model Calibration Plan
Highline Water District

Static Calibration Results

					Field Results		Model Results		Comparison			
Test No.	Hydrant Number	Model Junction ID	El. (ft)	Flow (gpm)	Static Pressure (psi)	Res. Pressure (psi)	Static Pressure (psi)	Residual Pressure (psi)	Static Pressure Diff (psi)	Res. Pressure Diff (psi)	Static Pressure Error (%)	Residual Pressure Error (%)
1	H0932	J368	183.15	1127	107	55	102	55	4.6	0.3	4.3%	0.6%
	H0931	100	165.71		112	68	113	70	-1.5			
	H0933	J370	147.15		121	80	123	78	-2.2			
2	H2911	J372	129.86	1359	94	80	92	80	1.9			
	H0884	J418	117.8		99	89	97	87	1.7			
	H2910	J374	154.89		83	73	81	73	1.8			
3	H3791	J376	362.9	1025	75	37	76	34	-0.7			
	H3777	J378	349.89		81	46	81	42	-0.4			
	H0112	J380	357.79		77	41	78	40	-0.9	1.1	-1.2%	2.8%
4	H0149	J382	137.37	1720	152	105	150	106	2.3	-1.5	1.5%	-1.4%
	H0147	J384	146.91		154	122	150	119	4.1	3.4	2.7%	2.8%
	H0150	J386	138.03		150	112	149	108	0.6	4.0	0.4%	3.6%
5	H0240	J390	160.19	1105	80	52	80	55	-0.5	-2.8	-0.6%	-5.3%
	H0241	9110	146.24		89	63	89	65	-0.1	-1.6	-0.1%	-2.5%
	H0242	J388	130.62		92	69	93	69	-1.3	0.1	-1.4%	0.2%
6	H0273	J392	179.66	630	75	2						
	H0274	J394	170.83		85	6						
	H0275	J396	159.59		87	6						
7	H0282	10200	260.2	961	95	4						
	H0283	J398	269.84		88	6						
	H3136	J420	288.56		84	7						
8	H1111	J400	277.73	1401	115	9						
	H1112	10340	259.57		136	11						
	H1094	J402	244.69		145	12						
9	H3092	J404	310.01	1316	100	7						
	H3096	2622	321.7		105	9						
	H3091	J406	312.26		94	8						
10	H3351	J408	449.47	1020	60	4						
	H3232	J410	453.61		58	4						
	H3811	J412	455.85		62	5						
11	H2436	J414	334	1225	95	8						
	H2233	J424	328		98	8						
	H2235	2017	336.35		96	8						

- 100% between +/- 10 psi
- 92% between +/- 4.3 psi



What to Adjust?

- PRV settings mainly to match static conditions
- Hazen-Williams Roughness Coefficients (C-factors) mainly to match residual conditions
- Elevations
- Closed valves,…

- All adjustments need to be reasonable and make sense!

Two Types of Calibration

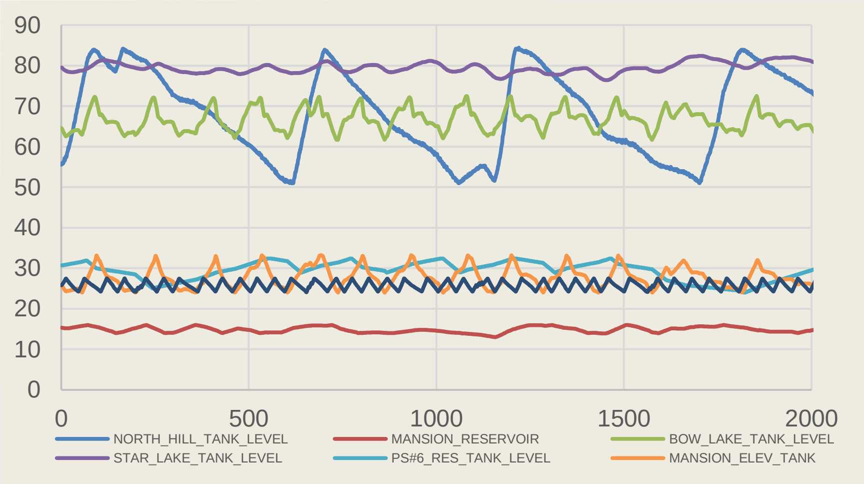
- Static Calibration or Hydrant-Test Calibration:
  - Uses field hydrant tests
  - Compares static and residual pressures

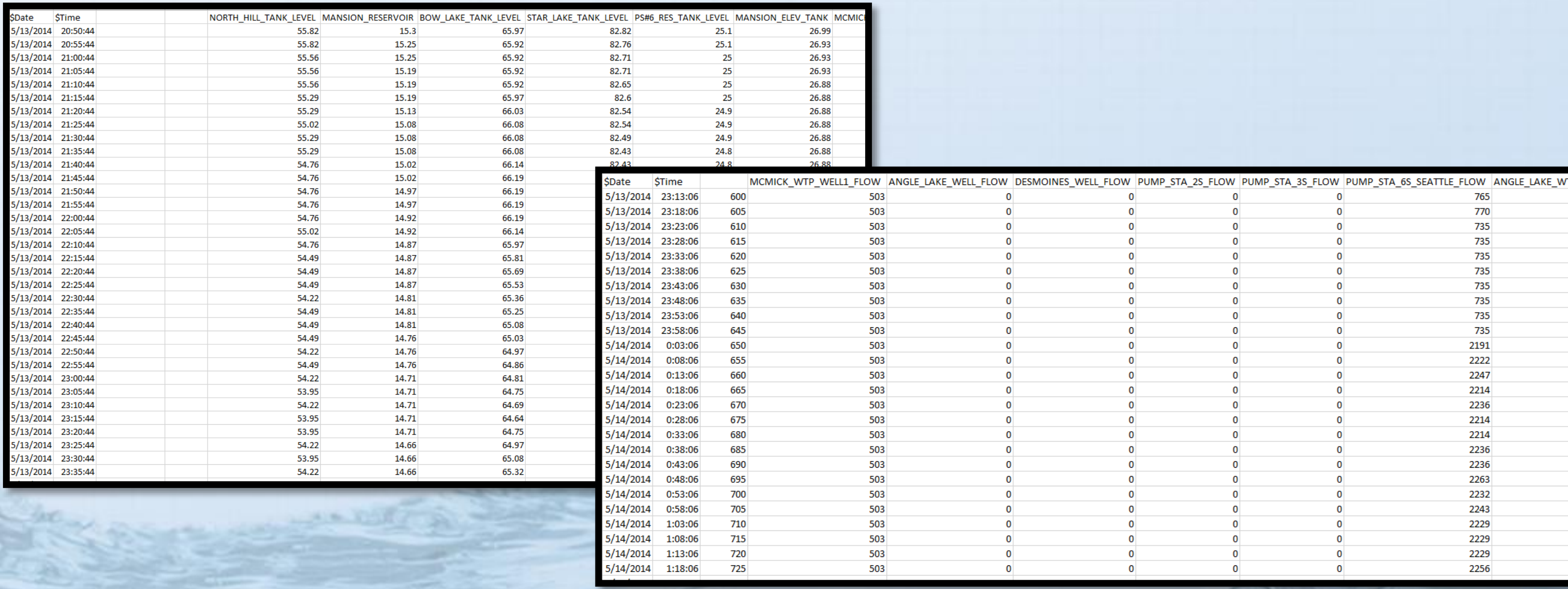
- Extended Period Simulation (EPS) Calibration:
  - Compares tanks, sources, pump stations operations

→ Iterative Processes

Example of SCADA Data

- SCADA data received for two weeks:
  - 5/13/2014 – 5/20/2014: ADD
  - 8/6/2014 – 8/13/2014: MDD

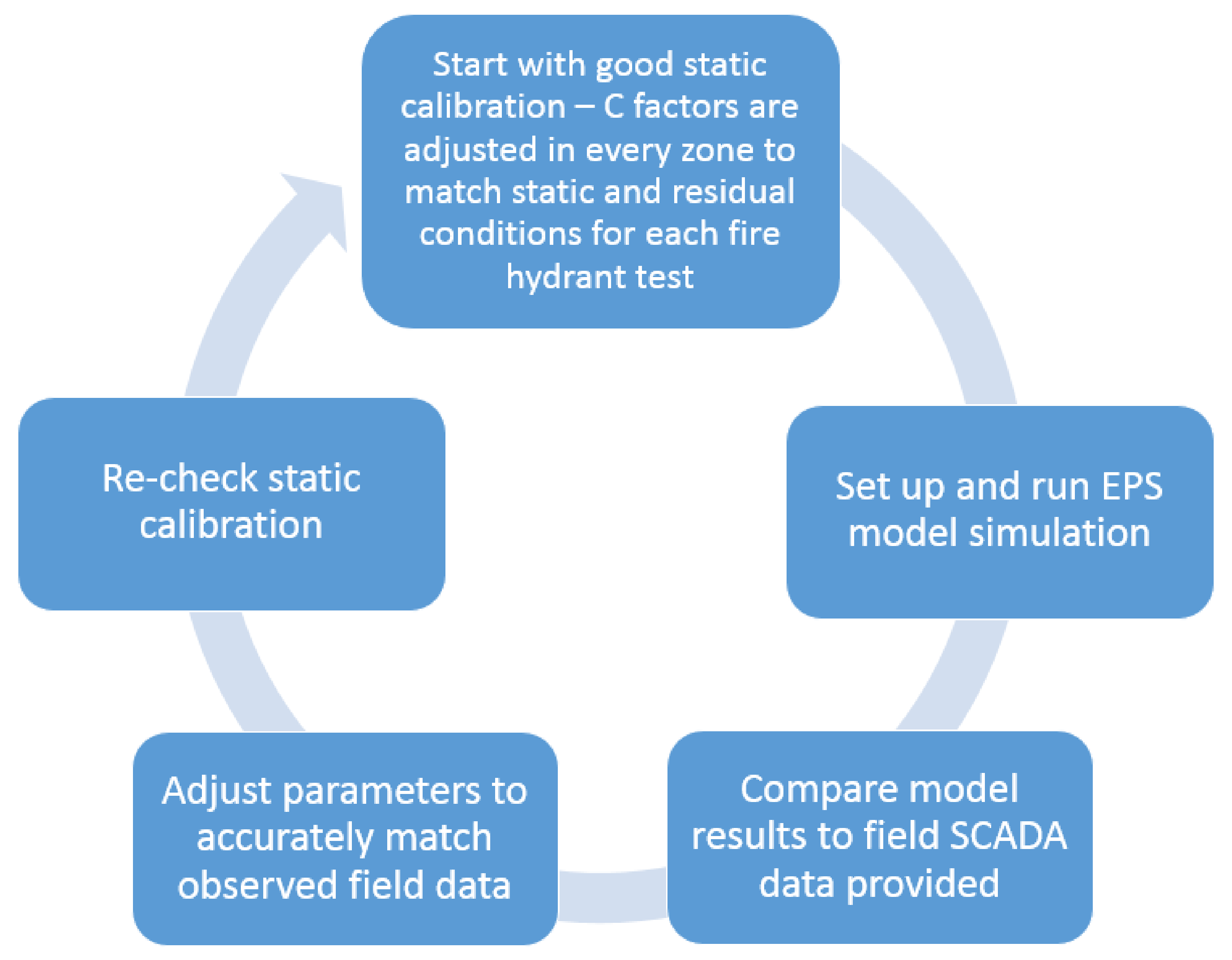




$Date	$Time			NORTH_HILL_TANK_LEVEL	MANSION_RESERVOIR	BOW_LAKE_TANK_LEVEL	STAR_LAKE_TANK_LEVEL	PS#6_RES_TANK_LEVEL	MANSION_ELEV_TANK	MCMIC
5/13/2014	20:50:44			55.82	15.3	65.97	82.82	25.1	26.99	
5/13/2014	20:55:44			55.82	15.25	65.92	82.76	25.1	26.93	
5/13/2014	21:00:44			55.56	15.25	65.92	82.71	25	26.93	
5/13/2014	21:05:44			55.56	15.19	65.92	82.71	25	26.93	
5/13/2014	21:10:44			55.56	15.19	65.92	82.65	25	26.88	
5/13/2014	21:15:44			55.29	15.19	65.97	82.6	25	26.88	
5/13/2014	21:20:44			55.29	15.13	66.03	82.54	24.9	26.88	
5/13/2014	21:25:44			55.02	15.08	66.08	82.54	24.9	26.88	
5/13/2014	21:30:44			55.29	15.08	66.08	82.49	24.9	26.88	
5/13/2014	21:35:44			55.29	15.08	66.08	82.43	24.8	26.88	
5/13/2014	21:40:44			54.76	15.02	66.14	82.43	24.8	26.88	
5/13/2014	21:45:44			54.76	15.02	66.19				
5/13/2014	21:50:44			54.76	14.97	66.19				
5/13/2014	21:55:44			54.76	14.97	66.19				
5/13/2014	22:00:44			54.76	14.92	66.19				
5/13/2014	22:05:44			55.02	14.92	66.14				
5/13/2014	22:10:44			54.76	14.87	65.97				
5/13/2014	22:15:44			54.49	14.87	65.81				
5/13/2014	22:20:44			54.49	14.87	65.69				
5/13/2014	22:25:44			54.49	14.87	65.53				
5/13/2014	22:30:44			54.22	14.81	65.36				
5/13/2014	22:35:44			54.49	14.81	65.25				
5/13/2014	22:40:44			54.49	14.81	65.08				
5/13/2014	22:45:44			54.49	14.76	65.03				
5/13/2014	22:50:44			54.22	14.76	64.97				
5/13/2014	22:55:44			54.49	14.76	64.86				
5/13/2014	23:00:44			54.22	14.71	64.81				
5/13/2014	23:05:44			53.95	14.71	64.75				
5/13/2014	23:10:44			54.22	14.71	64.69				
5/13/2014	23:15:44			53.95	14.71	64.64				
5/13/2014	23:20:44			53.95	14.71	64.75				
5/13/2014	23:25:44			54.22	14.66	64.97				
5/13/2014	23:30:44			53.95	14.66	65.08				
5/13/2014	23:35:44			54.22	14.66	65.32				

$Date	$Time		MCMICK_WTP_WELL1_FLOW	ANGLE_LAKE_WELL_FLOW	DESMOINES_WELL_FLOW	PUMP_STA_2S_FLOW	PUMP_STA_3S_FLOW	PUMP_STA_6S_SEATTLE_FLOW	ANGLE_LAKE_W
5/13/2014	23:13:06	600	503	0	0	0	0	765	
5/13/2014	23:18:06	605	503	0	0	0	0	770	
5/13/2014	23:23:06	610	503	0	0	0	0	735	
5/13/2014	23:28:06	615	503	0	0	0	0	735	
5/13/2014	23:33:06	620	503	0	0	0	0	735	
5/13/2014	23:38:06	625	503	0	0	0	0	735	
5/13/2014	23:43:06	630	503	0	0	0	0	735	
5/13/2014	23:48:06	635	503	0	0	0	0	735	
5/13/2014	23:53:06	640	503	0	0	0	0	735	
5/13/2014	23:58:06	645	503	0	0	0	0	735	
5/14/2014	0:03:06	650	503	0	0	0	0	2191	
5/14/2014	0:08:06	655	503	0	0	0	0	2222	
5/14/2014	0:13:06	660	503	0	0	0	0	2247	
5/14/2014	0:18:06	665	503	0	0	0	0	2214	
5/14/2014	0:23:06	670	503	0	0	0	0	2236	
5/14/2014	0:28:06	675	503	0	0	0	0	2214	
5/14/2014	0:33:06	680	503	0	0	0	0	2214	
5/14/2014	0:38:06	685	503	0	0	0	0	2236	
5/14/2014	0:43:06	690	503	0	0	0	0	2236	
5/14/2014	0:48:06	695	503	0	0	0	0	2263	
5/14/2014	0:53:06	700	503	0	0	0	0	2232	
5/14/2014	0:58:06	705	503	0	0	0	0	2243	
5/14/2014	1:03:06	710	503	0	0	0	0	2229	
5/14/2014	1:08:06	715	503	0	0	0	0	2229	
5/14/2014	1:13:06	720	503	0	0	0	0	2229	
5/14/2014	1:18:06	725	503	0	0	0	0	2256	

Steps to calibrating an EPS Model



Start with good static calibration – C factors are adjusted in every zone to match static and residual conditions for each fire hydrant test

Set up and run EPS model simulation

Compare model results to field SCADA data provided

Adjust parameters to accurately match observed field data

Re-check static calibration

What additional information is needed to set up an EPS model?

- Diurnal patterns for demands throughout the day
- Pumps ON/OFF controls
- Valves operations

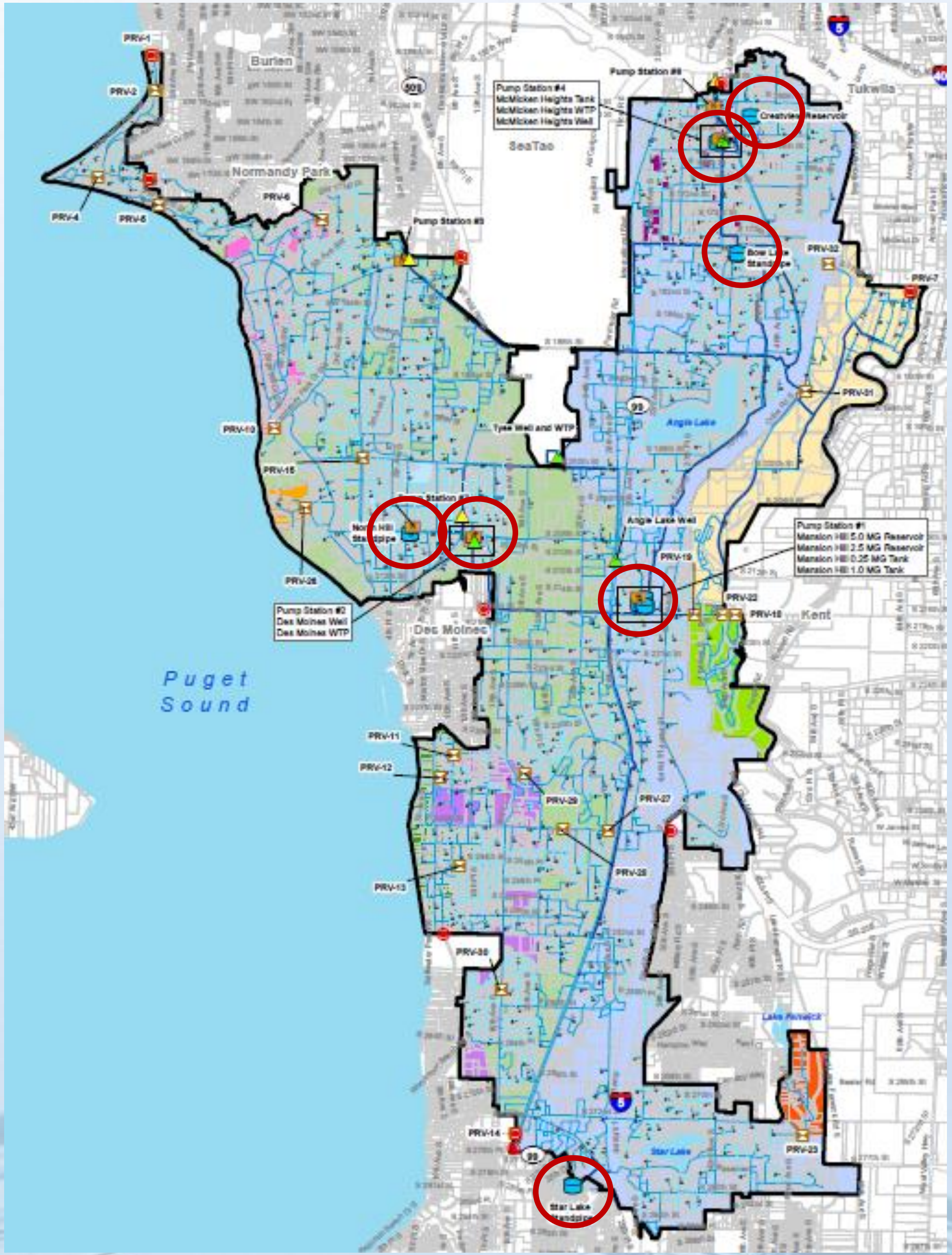
→ Model becomes dynamic with tank levels changing over time

Industry Standards for EPS Calibration

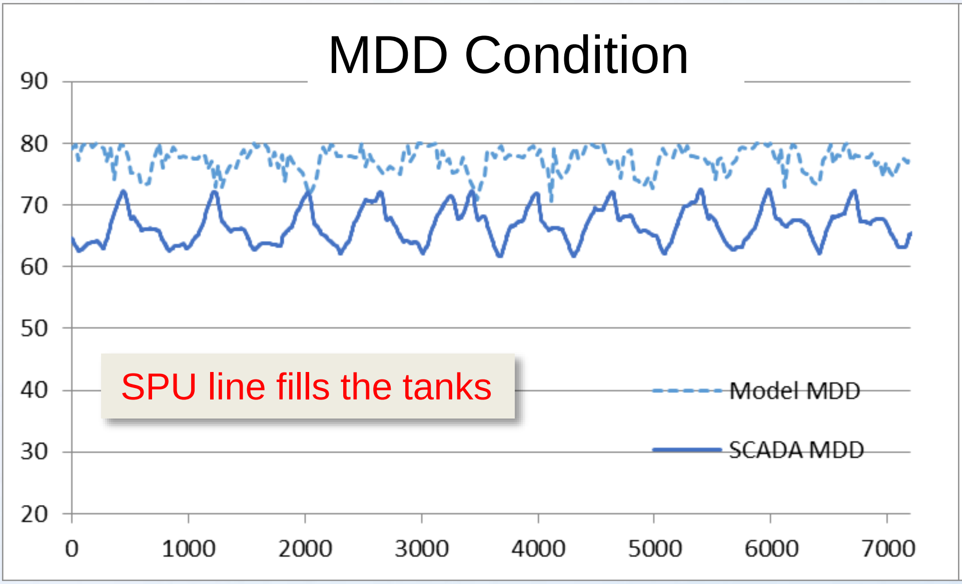
- No published Industry Practices
- Regional Benchmarks
- Intended model use drives calibration needs:
  - Master Planning
  - Design Purposes
  - Water Quality
  - Flushing

15 Sites are used for calibrating the model to EPS condition

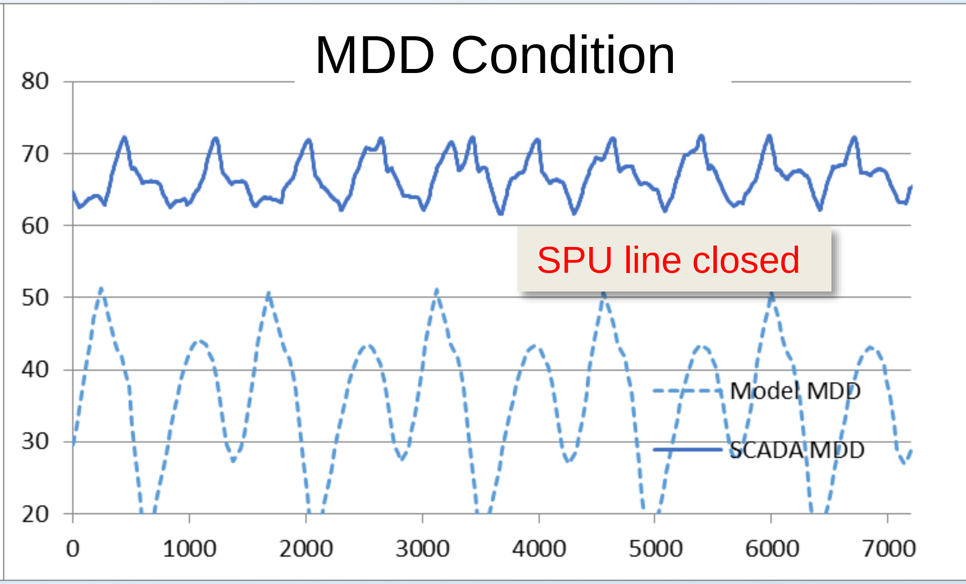
- 9 tanks
- 3 pump stations
- 3 wells



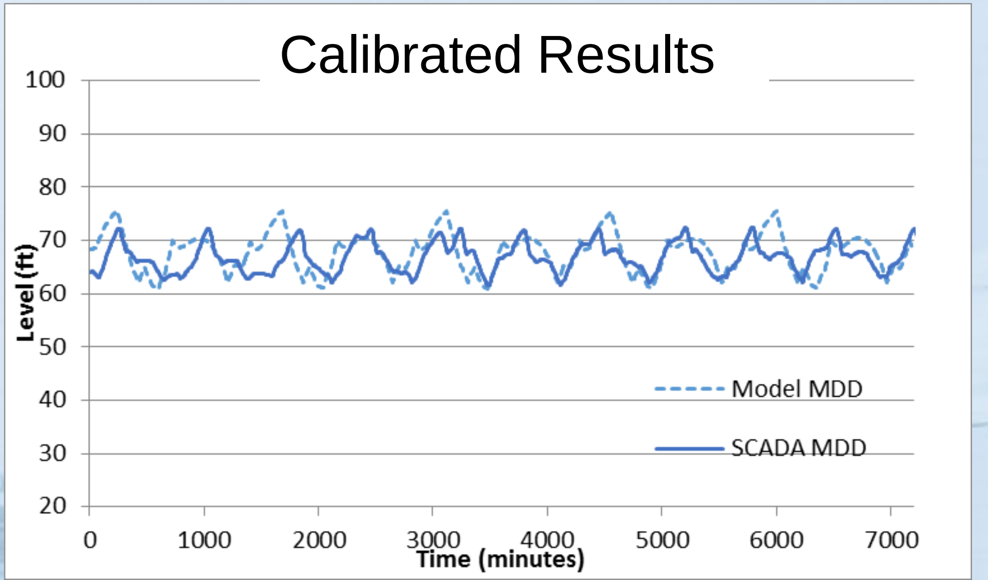
EPS Calibration – Tank A


MDD Condition

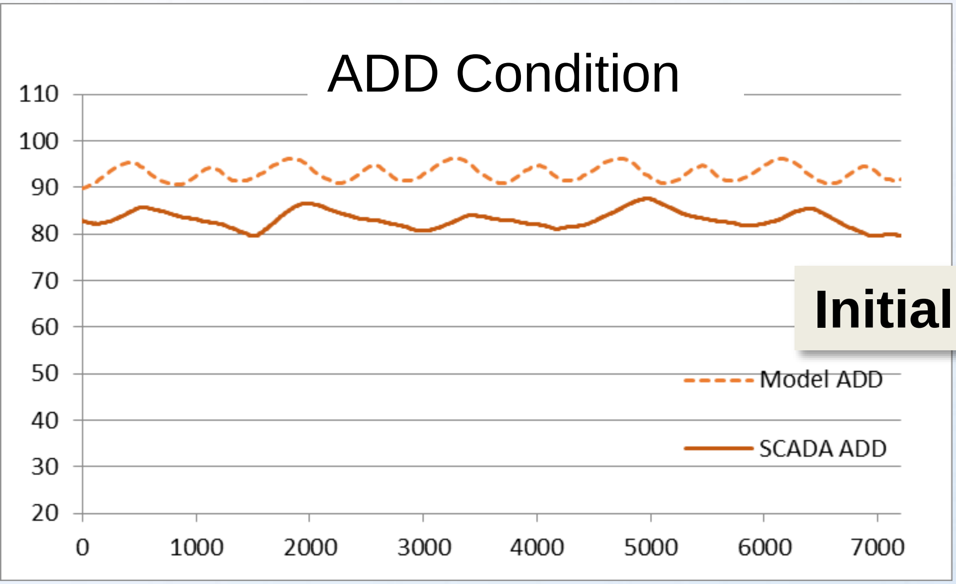
SPU line fills the tanks


MDD Condition

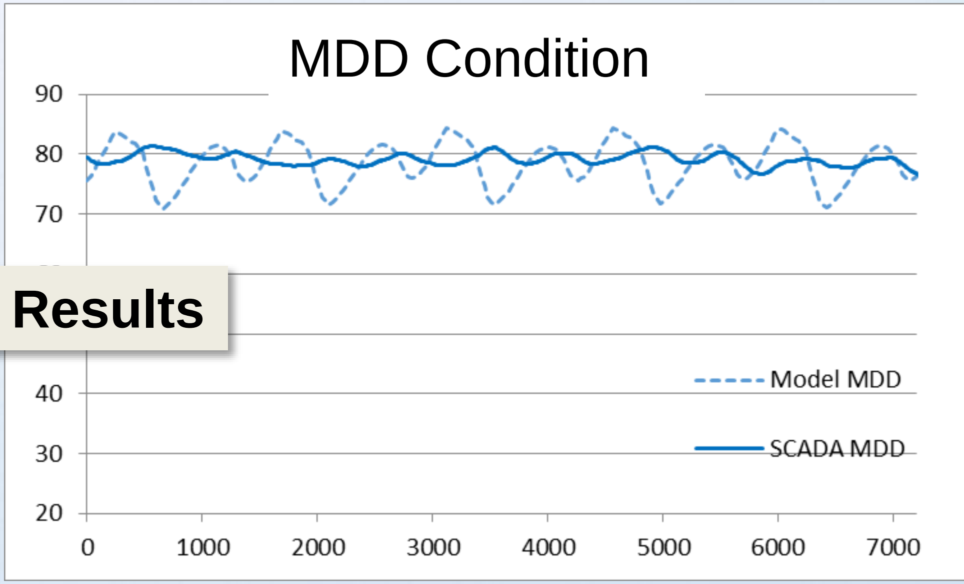
SPU line closed

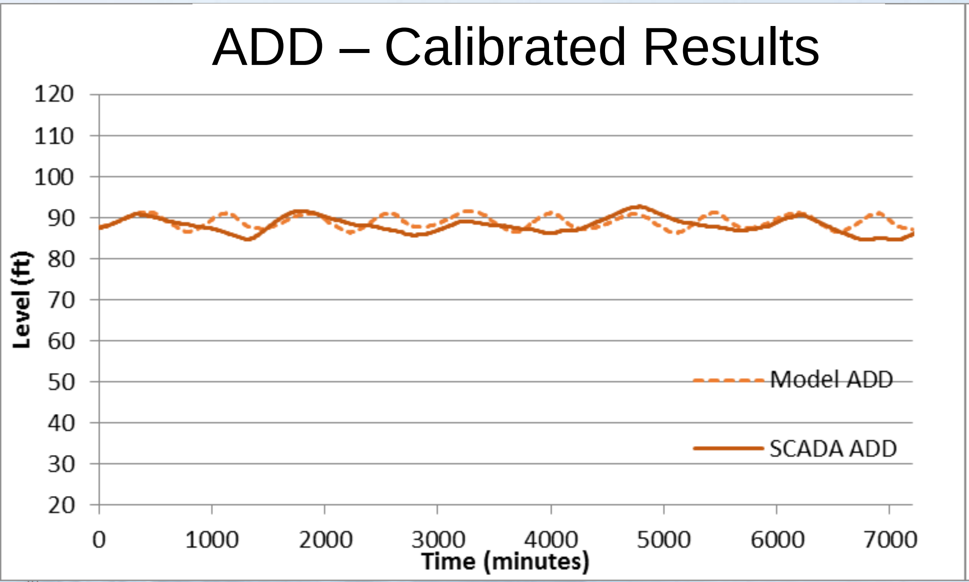

Calibrated Results

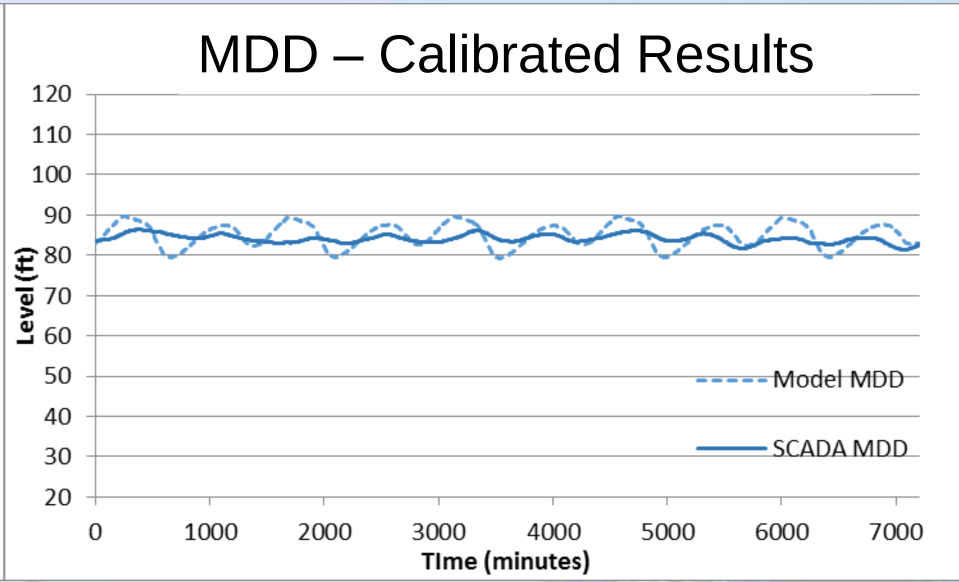
EPS Calibration – Tank B


ADD Condition

Initial Results

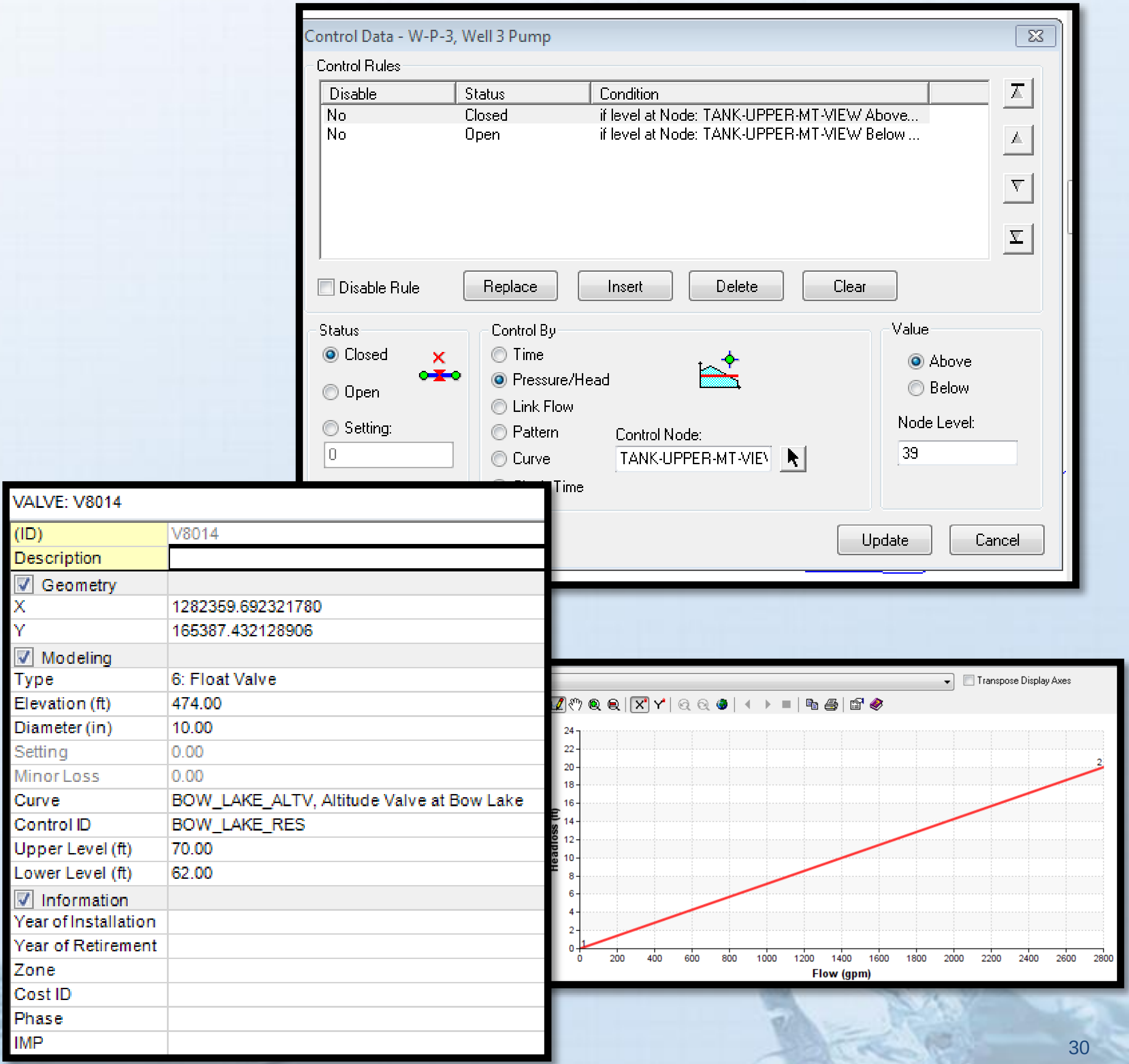

MDD Condition


ADD – Calibrated Results


MDD – Calibrated Results

What adjustments can be made and what to look for?

- Pump controls
- Valve controls
- Sources
- Tank elevations
- Flows
- Closed valves



Control Data - W-P-3, Well 3 Pump

Control Rules

Disable	Status	Condition
No	Closed	if level at Node: TANK-UPPER-MT-VIEW Above...
No	Open	if level at Node: TANK-UPPER-MT-VIEW Below ...

☐ Disable Rule

Status: ● Closed ○ Open ○ Setting: 0

Control By: ○ Time ● Pressure/Head ○ Link Flow ○ Pattern ○ Curve

Control Node: TANK-UPPER-MT-VIE\

Value: ● Above ○ Below

Node Level: 39

VALVE: V8014

(ID)	V8014
Description	
☑ Geometry	
X	1282359.692321780
Y	165387.432128906
☑ Modeling	
Type	6: Float Valve
Elevation (ft)	474.00
Diameter (in)	10.00
Setting	0.00
Minor Loss	0.00
Curve	BOW_LAKE_ALTV, Altitude Valve at Bow Lake
Control ID	BOW_LAKE_RES
Upper Level (ft)	70.00
Lower Level (ft)	62.00
☑ Information	
Year of Installation	
Year of Retirement	
Zone	
Cost ID	
Phase	
IMP	

☐ Transpose Display Axes

Why calibrating under EPS conditions?

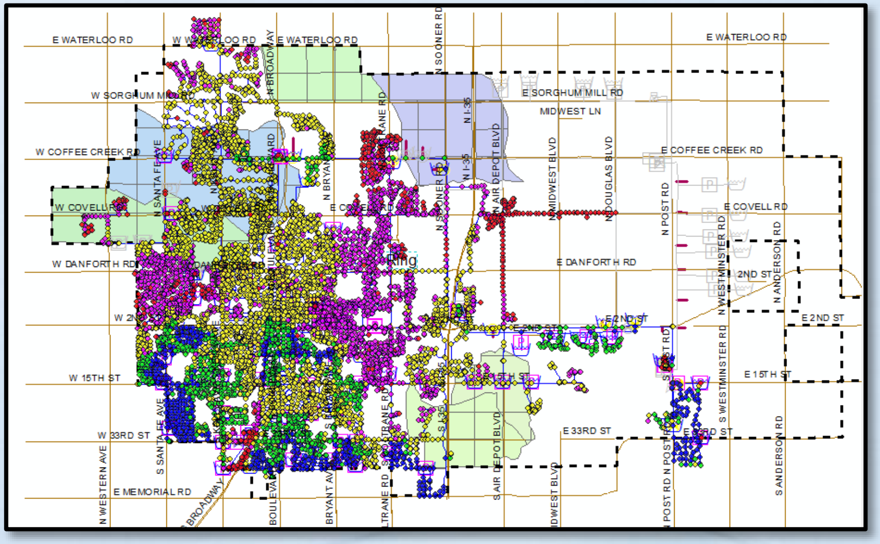
- EPS calibration ensures the model accurately simulates real world operations:
  - Tank cycling
  - Pump station operations
  - Pressure fluctuations throughout the day

- Allows for optimization of operational controls for current and future conditions

- Allows for advanced model simulations
  - Water quality/age
  - Energy usage
  - Time of use analysis

What’s next?

- Impacts of Operational changes on the system,
- Storage vs production analysis,
- Energy Optimization,
- Sizing Storage Tanks,
- Water Age and Water Quality analyses



Water Age Analysis Results

Questions on Static Calibration versus Dynamic EPS Calibration

Anabonnand@Carollo.com

Abennett@Carollo.com

PNWS – AWWA

May 6, 2016

HIGHLINE WATER DISTRICT

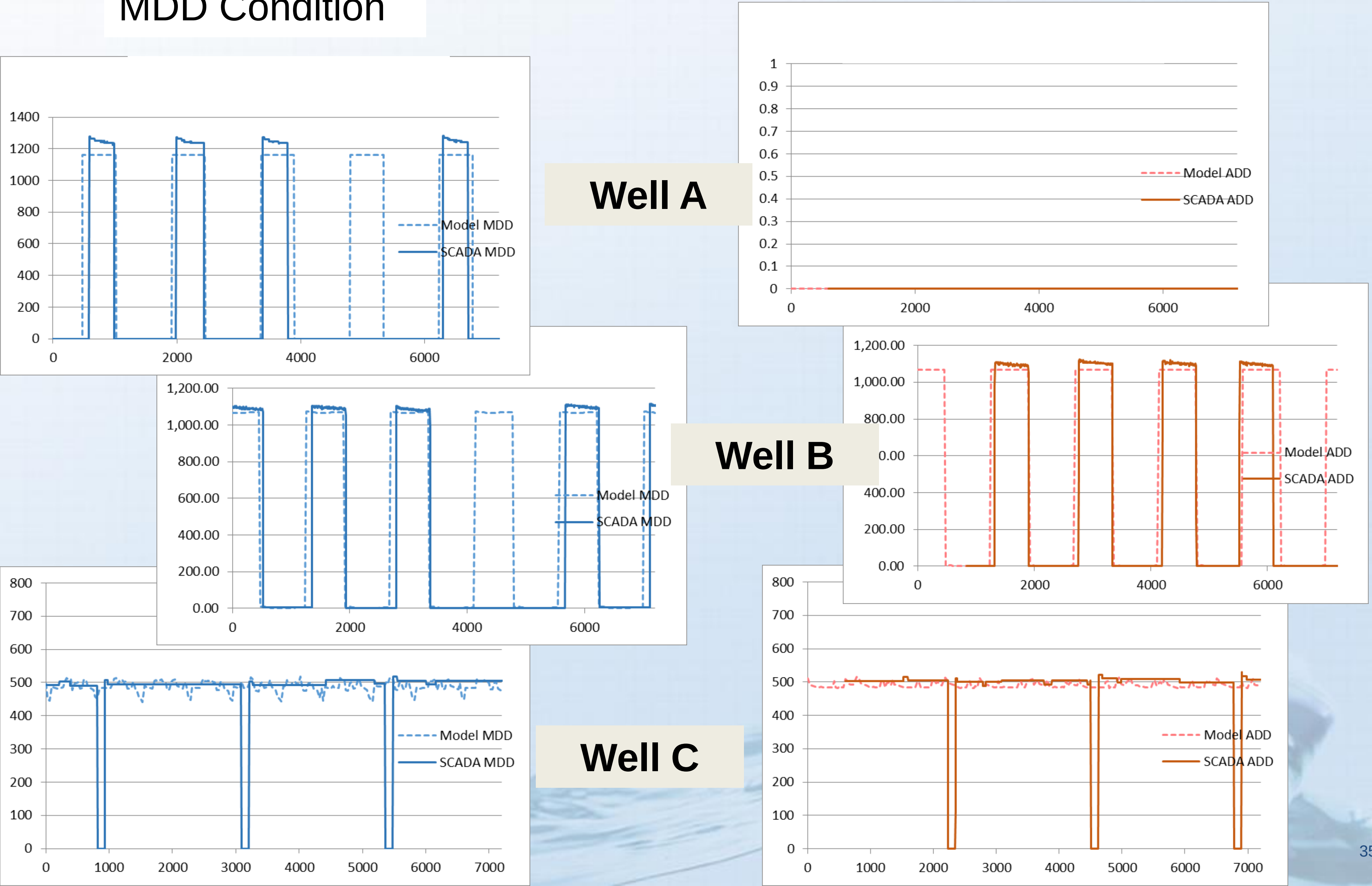
carollo
Engineers...Working Wonders With Water®

PARKING LOT SLIDES

EPS Calibration – City Wells

MDD Condition

ADD Condition

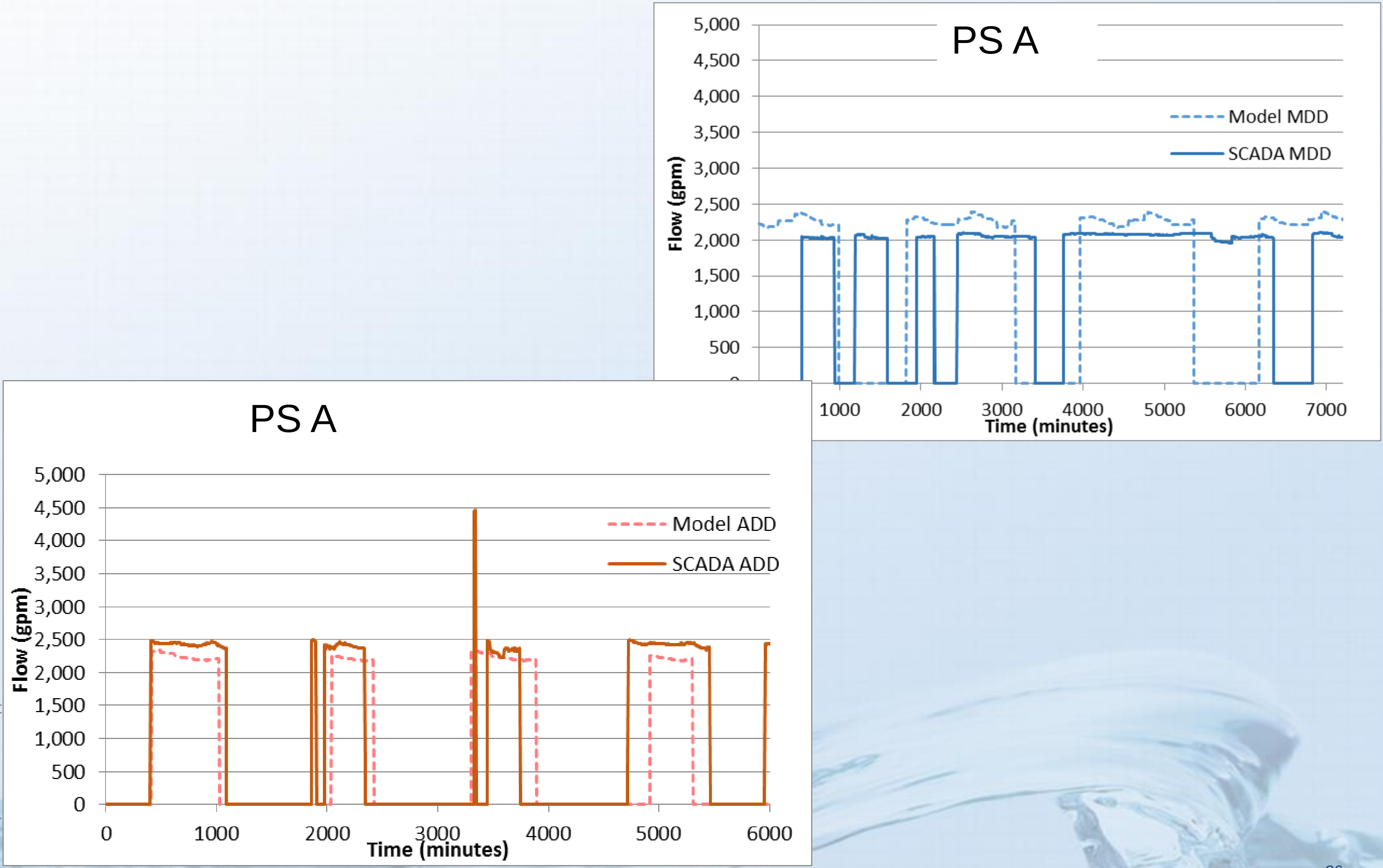


Well A

Well B

Well C

EPS Calibration – Pump Station A



Main Model Adjustments during EPS Calibration

- PS A – Pump 1: Closed at 14 feet in Tank C instead of 15 feet
- Altitude Valves added at Tank A
- PS C – Pump 2: Open set point changed to 25 feet in Tank D instead of 24 feet
- PS C – Design Flow Point adjusted to better match field data
- Adjustments to Wells Operating Pattern
  - Well A: 9pm – 7am
  - Well B: 8am - 4pm
- Updates to Tank E float valve headloss curve