Chapter 5

Hydraulic Water Model

2020 City of Billings Water Master Plan (Draft)

City of Billings, MT

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Introduction

This chapter describes the development, update, and calibration of the City's water system hydraulic model. This hydraulic model was instrumental in the analysis of numerous system performance evaluations documented herein including: Chapter 6 to evaluate water system operation for a new two water treatment plant operating condition; Chapter 7 to evaluate waterline and pump station capacity and performance improvements; Chapter 8 to evaluate new potential reservoir siting locations; and Chapter 9 to support the evaluation of the projected distribution system expansion. A summary of the water distribution system and associated hydraulic model update and calibration process is provided in the following sections.

Existing Water System Review

Water Distribution System

As previously discussed in Chapter 2, the City's water distribution system consists of 12 pressure zones, approximately 493 miles of watermains, 18 water reservoirs, one water treatment plant (WTP) and 12 water system booster pump stations. Figure 5-1 summarizes the length of pipe located in each of the City's pressure zones as well as portions of the Heights Water District (HWD) included in the model. As shown, a large majority of the City's pipeline network is located in the main zones (Zones 1-4), with smaller subzones need to serve higher elevations in the City.

The pipeline network is mostly comprised of polyvinyl chloride (PVC) (37%), cast iron pipe (CIP) (26%), and ductile iron pipes (DIP) (25%). Figure 5-2 provides the breakdown of pipe by age and material, sorted by the total pipeline length. As shown, approximately 40 percent of the total length of water mains were installed less than 20 years ago, with only 5 percent of the system length installed prior to the 1950s and are over 70 years old. The majority of these older pipes were installed with cast iron pipe materials, a material known to generally have higher roughness and produce more system losses.

Figure 5-3 shows the breakdown of pipe size and material, by length of pipe. Excluding transmission mains (as defined in the City GIS data), 99 percent of the City's water mains are 12-inches or smaller. Of those pipelines, 69 percent are 6-inch and 8-inch pipes. The material of these 6-inch and 8-inch pipelines indicates that 31 percent are CIP, 16 percent are DIP, and 45 percent are PVC mains. The City's GIS data indicates that the City's transmission mains are mostly DIP (64%) and pre-stressed concrete cylinder (PCCP) (16%), with 94-percent of the larger system pipes (36-inch and above) being PCCP material.

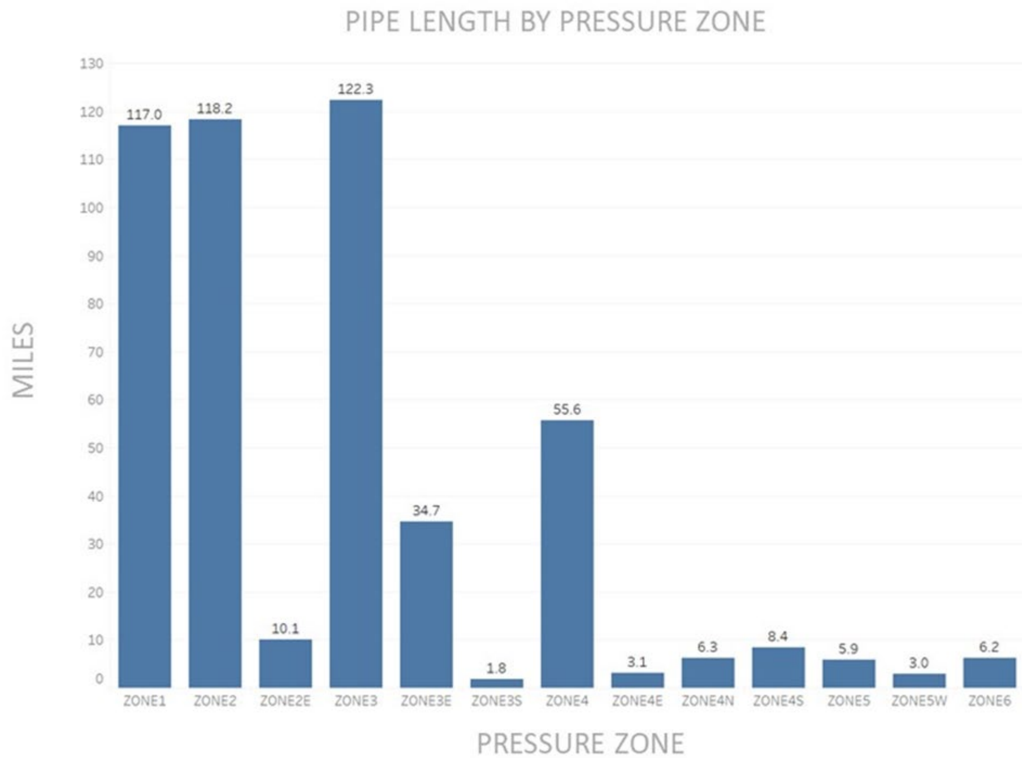

Figure 5-1. Pipeline Length by Pressure Zone

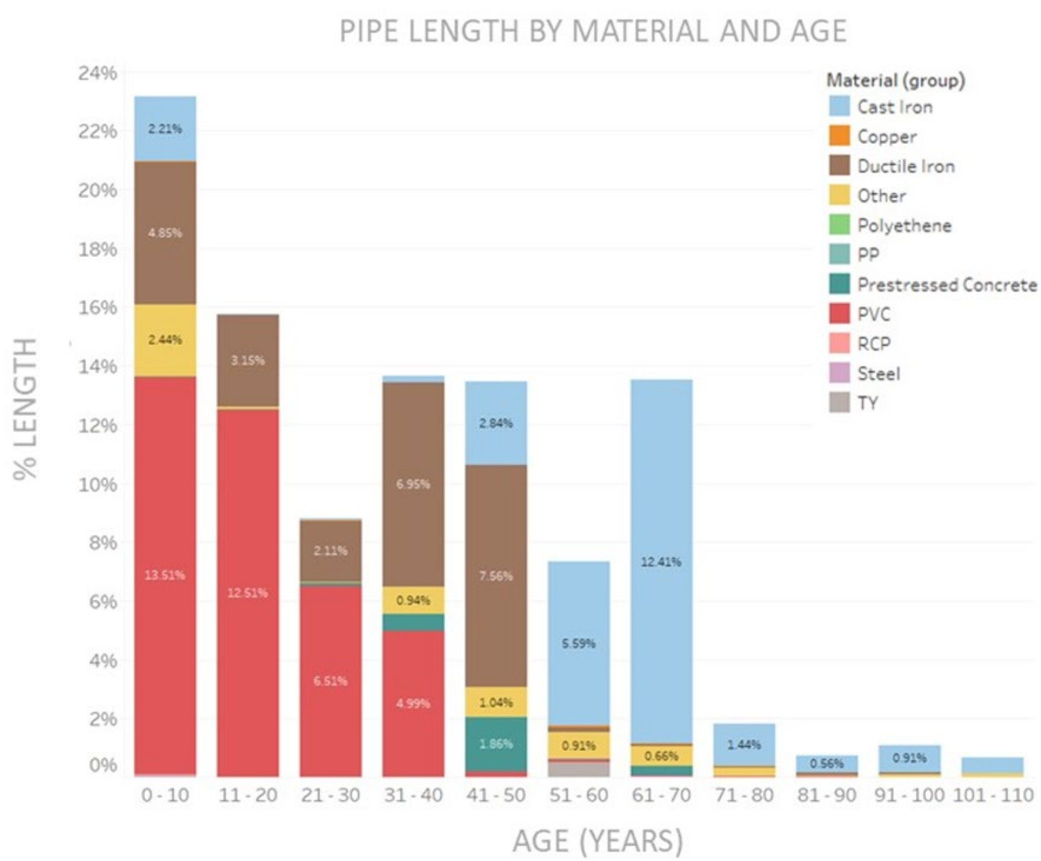

Figure 5-2. Pipeline Age and Material by Length

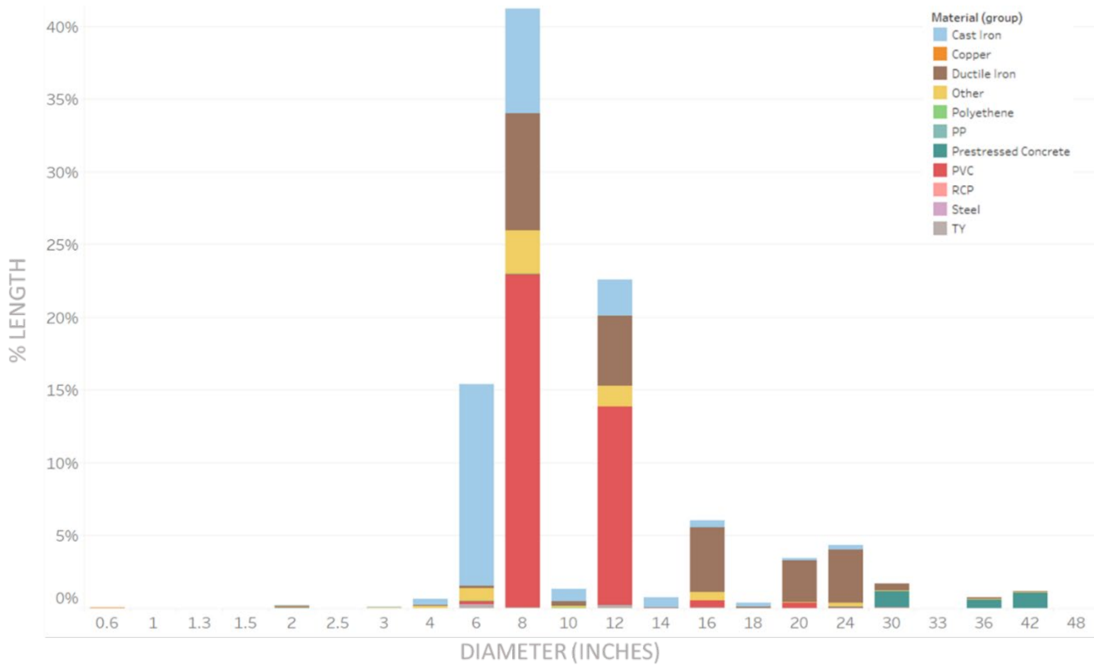

Figure 5-3. Pipeline Size and Material by Length

Model Development

Model Software

A water system hydraulic model was built utilizing the InfoWater Executive Suite 12.4, Update #5 by Innovyze, Inc. The model was based on the current GIS, metered water demands, SCADA information, operational procedures and control settings, projects completed since the last model update, projects currently underway, other available system performance and connectivity information, and discussions with City staff. The previously constructed model was also used in the model update process to assist with model construction and data resolution when pipe diameters and network connectivity was unclear from the City's GIS.

Model Network

A system schematic of the treatment plant, reservoirs, pumps, and pressure zones was previously shown in Figure 2-3 and provided an important basis for system facility operation and overall connectivity.

Documents Reviewed

Documents analyzed and used to build the existing hydraulic model include:

- Previous hydraulic model (updated in 2016)
- City GIS data (valves, hydrants, mains, laterals, reservoirs, pumps)
- Screenshots of SCADA panels of control settings at the water treatment plant

- Pump curves
- Pump station general operation procedures
- Reservoirs, pump, and pressure zone elevation schematic
- SCADA pump station flows and reservoir levels for May and June of 2019
- Account-level customer classification and monthly meter demand data for 2014 through 2018
- Parcel-level land use classification and acreage data
- Street spot elevations
- USGS 1/3 arcsecond Digital Elevation Model

Water Treatment Plant

In the previous water system hydraulic model, the water treatment plant clearwells were treated as two separate, adjacent reservoirs. These two reservoirs were combined into a single equivalent source. This change does not affect the model results, but it simplifies the model for future use and hydraulic simulations.

The flow pumped from the clearwells by the High Service Pump Station (HSPS) Zone 2 Pumps is split between Zones 2 and 2E (HWD). The City of Billings only supplies water to the HWD. In order to model this one-way flow of water, a throttle control valve is used to split flow between Zones 2 and 2E. Time based coefficients based on May 2018 were added to the valve to simulate flow split between the zones.

Water Storage - Reservoirs

The system schematic was used to assign elevation information for the 18 system reservoirs and the two HWD reservoirs that the City monitors to maintain appropriate water level. To assist with model stability, reservoirs that were hydraulically close (Staples, Chapple, Fox and Cedar Park) were modeled as a combined equivalent reservoir based on elevation and the combined volume of each individual reservoir. For example, the three identical rectangular Cedar Park reservoirs were converted into a single rectangular reservoir with three times the area of a single reservoir and with side water depth (SWD) equal to all three reservoirs SWD. This change will not affect the hydraulic results and it will significantly improve the model stability. If the City decides to extend the hydraulic model to support detailed water quality analysis in future simulations, special attention should be given to the reservoir mixing parameters for the combined reservoirs.

Watermains

As previously discussed, the City owns and maintains approximately 493 miles of water system pipelines. These pipelines are incorporated in the hydraulic model as 22,011 distinct pipeline segments. The location of these lines serving the City's pressure zones was shown in Figure 5-1. The piping configuration, including connectivity, pipe IDs, material, age, and size, were based on the City's current GIS data. The previous model and aerial images were also used as reference in locations where connectivity was uncertain. GIS Facility IDs are stored as attributes in the description user field of the watermains data. Using the previous model as a reference, roughness coefficients for different materials of different ages were used to assign preliminary C-factors for the system's mains (see Table 5-1).

Table 5-1. Hazen-Williams Coefficients

Material	Roughness
DI	140
CI	110
PVC	140
PP	135
Welded Steel	100
HDPE	140
PCCP	120
COP	135
RCP	120
Steel	100

In the current GIS, there are two pairs of duplicate pipes, which sit on top of one another in GIS:

- FacilityID AIRPORT037 and AIRPORT038
- FacilityID 329012T329012 and R329001329012

In addition to this data cleanup item, it was noted that there are over 6,000 pipes with a length shorter than 10 feet in the model. While this is not a concern for the hydraulic analysis performed in this planning effort, this item should be addressed should the City desire to use the model for future water quality analysis simulations. These short pipeline segments tend to overestimate water age because the minimum pipe travel time is equal to the water quality time step. This leads to an overestimate of water age when water travels through a short pipe quicker than the water quality time step. This can be avoided by shorter time steps which would lead to longer calculation times. Alternatively, these short pipelines can be merged with longer pipes to avoid this issue in future distribution system water quality assessments.

Additionally, there are a few small diameter pipes connecting pumps. These were checked with GIS and are currently included in the model (refer to Table 5-2). While these pipes will cause high headloss rate, their short length will limit the impact on the results.

Table 5-2. Small Diameter Pipes

Model Pipe ID	Diameter (inches)	Pump
P31859	1	Christensen 6-1
P31855	1.5	Christensen 6-2
P31847	2	Christensen 6-4
P31851	2	Christensen 6-3
P31853	2	Christensen 6-2
P31857	2	Christensen 6-1
P11767	2	Terrance Estates 3
P11769	2	Terrance Estates 3
P31845	2.5	Christensen 6-4
P31849	2.5	Christensen 6-3

Pumps

The City's pumping system is served by 56 pumps located in 12 booster pump stations and the HSPS at the WTP. Pumps with a variable frequency drive (VFD) that pump into closed loop pressure zones were modeled as fixed-speed pumps with a pressure reducing valve (PRV) downstream of the pump station. This approach leads to the same results in terms of flow and pressure and improved the stability of the City's model during hydraulic simulations. Other VFD pumps were modeled as regular pumps with appropriate pumping speeds. Similar to the previous discussion regarding modeling configurations that may be needed to support a distribution system water quality analysis, this VFD pumping configuration should also be revisited should the City desire to perform a future water system energy efficiency analysis.

Junctions

The newly constructed water system hydraulic model has 20,715 junctions. Model junctions are used to indicate valves and pipe fittings such as tees and crosses. Junction elevation data was acquired throughout the City using vehicle-mounted survey grade GPS equipment. The elevation data was then adjusted to account for the estimated height difference from the waterline and the road surface. In a few cases where the modeled junctions were more than 250 feet from a spot elevation measurement, the USGS Digital Elevation Model and Google Earth were used to approximate junction elevations at those locations.

The model development process also resulted in the identification of a few negative pressure nodes located around Leavens, Chapple, and Waldo reservoirs. This condition is a typical model development reconciliation item because all junctions are assumed to be located at a standard distance (6.5 feet) below ground level. In these cases, the junction elevation is greater than the hydraulic grade line (HGL), which is controlled by the reservoir water surface level elevation. Junctions that were very close to reservoirs and pump stations sometimes had elevations above the bottom of reservoirs and therefore, were reassigned to be just below the reservoirs.

Operational Controls

SCADA information was reviewed, and operators were interviewed to determine how pump stations were operated to maintain reservoir levels and thus system pressure. Table 5-3 provides a summary of each pump station and how they are normally operated.

Table 5-3. Pump Station Guidelines and Operations

Pump Station	Zone Served	VFD	Auto Y/N?	Operator Settings	Controlled By	Panel Guidelines	Operational Regime
HSPS Zone 1	1	2 of 3	N	Speed	Leavens	-	Keep Leavens above 15 ft by varying Zone 1 pump speeds (50%-90%).
Willet	2	Y	N	Speed	Staples Reservoir	-	Run Pumps in the summer so only one of pumps H2-1 or H2-2 needs to operate
HSPS Zone 2	2	3 of 4	N	Speed and modulating valve position (Zone 2E)	Staples, Lanier, Hilltop	-	Generally keep Staples 3 MG between 10 and 13 feet and Lanier and Hilltop at least ¾ full, vary speed of Zone 2 pumps, use modulating valve to control flow to Zone 2E.
Walter	2 East	2 of 3	N	Level	Lanier and Hilltop	-	Walter not normally used to supply Zone 2 East. When it is, pumps are operated to maintain level at ¾ full in reservoirs.
Staples Zone 3	3	1 of 3	N	Level and speed	Chapple and Standpipe	20-29 ft. Pump 1 at 86% speed	Typically Pump 2 with VFD in operation to maintain level in Standpipe and Chapple. .
Voelker	3	1 of 4	N	Level	Chapple	-	Keep reservoir between 19-21ft using combination of pumps.
Walter	3 East	2 of 3	N	Level and speed	Fox	9.7 ft. - 48ft.	Generally keep Fox between 25 and 34 feet (fill at 85% speed).
Walter	3 East	Y	N	Level and speed	Fox	9.7 ft. - 48ft.	In backup mode when pumping from Zone 1, Pump 1 is used to supply Zone 3E.
Thomas Cedar Park	3 South	N	Y	Levels and valve position	Cedar Park Reservoirs	2.8 ft. - 5ft.	Follows controls, all pumps.
Chapple	4	Y	N	Level and Speed	Ironwood	7 ft. - 10 ft.	Keep Ironwood 26-35ft (fills at 90% speed).
Staples Z4	4	Y	N	Level	Waldo	6.2 ft. - 10.5 ft.	Follows level guidelines (7-10ft), any one pump. Open valve to Waldo when pump is on.
Terrace Estates	4 East	2 of 3	Y	NA	Discharge pressure	NA	Full speed with PRV to set discharge pressure.
Fox	4 North	Y	Y	Discharge pressure and Flow setpoint stages	Discharge pressure	60 psi-75 psi 50 gpm – 700 gpm	Full speed with PRV to set discharge pressure.
Thomas Briarwood	4 South	N	Y	Level	Briarwood Reservoir	4 ft. – 10 ft.	Follows controls on screen (not summer/winter), any one pump needed.
Waldo	5	N	Y	Level	Logan	15 ft. – 24 ft.	Follows controls, all pumps.
Ironwood	5W	4 of 5	Y	Discharge pressure and Flow setpoint stages	Discharge Pressure	65 psi 90 gpm – 1750 gpm	Full speed with PRV to set discharge pressure.
Christensen	6	4 of 5	Y	Discharge pressure and Flow setpoint stages	Discharge Pressure	86 psi – 88 psi 100 gpm-1000 gpm	Full speed with PRV to set discharge pressure.

Demand Allocation

The existing water demands in the hydraulic model were allocated to modeled demand nodes using account-level water meter information obtained from the City's customer billing records for 2017. The demands for HWD were extracted from 2018 reported system usage (933,184,000 gallons for that year) and assigned to the last node in the HWD portion of the model. The future water demands are based on development projections and 2017 gallons-per-capita-per-day (GPCD) water usage rate. Non-revenue (or unaccountable) water is estimated at 14% of demand system-wide (other than HWD), and proportionally scaled to each demand node. Although water loss may decrease as the City continues their watermain rehabilitation and replacement projects, watermains and service lines continue to age. Therefore, for modeling purposes, water loss was assumed to remain at the 2017 water loss value.

The largest 30 customer demands were individually checked to verify that these large demands were assigned to the correct location. This procedure is used to verify the spatial accuracy of the demand allocation, since customers sometimes have different billing addresses than their physical locations (i.e., corporate offices different from physical operations).

Future demands were assigned to the model based on population growth and potential developments that are currently planned , as described in Chapter 3. These were assigned to model demand nodes based on pressure zones and spatial locations. The results of this assessment is that an additional 4.3 MGD and 8.2 MGD are added to the system in years 2030 and 2040, respectively. Table 5-4 shows the breakdown of changes in system demand over time:

Table 5-4. Future Additional Average Day Demand by Source.

Demands (MGD)	Zone	2018	2030	2040
Heights Water District Growth	2E	-	0.71	1.54
Potential Developments	2	-	0.87	1.62
West Development	3 and 4	-	2.07	3.86
North Development	3E and 4N	-	0.46	0.86
One Big Sky or Zone 1 Commercial and Industry	1	-	0.18	0.33
Growth in other Zones	3S, 4S, 5, 5W, 6	-	0.01	0.03
Total System Demands	**-**	**19.96**	**24.26**	**28.20**

Peaking Factors

System capacity is typically evaluated using a steady state model for peak demand conditions. Peaking factors are used to scale average demand to peak demands under both a maximum day and peak hour conditions. For the City's hydraulic model, a 2.44 system wide peaking factor is assigned for maximum day demand (MDD) conditions. This value is calculated as the ratio between the total pumped flow at the HSPS on the peak day and the three-year average system-wide demands excluding HWD. As discussed with City staff, a 3.4 factor is used to represent peak hour conditions. This value was based on the 2006 Water and Wastewater Facilities Master Plan and is assumed to remain the same for existing and future demand scenarios.

Diurnal Patterns

A diurnal curve or cycle is a pattern that represents water demand variations over a 24-hour period. The development of these patterns are essential elements in water system calibration process. For the City's water model, diurnal patterns were assigned to model demand nodes based on the analysis of water delivery and storage volume using data from SCADA for the month of May 2019 for each pressure zone, as shown in Figure 5-4 and 5-5. Weekdays and weekends were averaged together, and holidays were not considered separately.

For each pressure zone, the demand pattern is dependent on the average storage volume change and pump station volume delivery into and out of that zone in a 24-hour time period. At each time step, average demands are multiplied by the appropriate peaking factor throughout the day based on the diurnal curve and the time step being calculated. The diurnal pattern of Zone 5 was calculated using cumulative (rather than incremental) mass balance because of SCADA mass imbalances between the Waldo and Christensen pump stations and Logan Reservoir. The diurnal pattern of Zone 5 is shown to follow the typical water use at the airport, which increases in the early morning hours, remaining steady throughout the day, then drops off abruptly after the last flights of the day in the late evening.

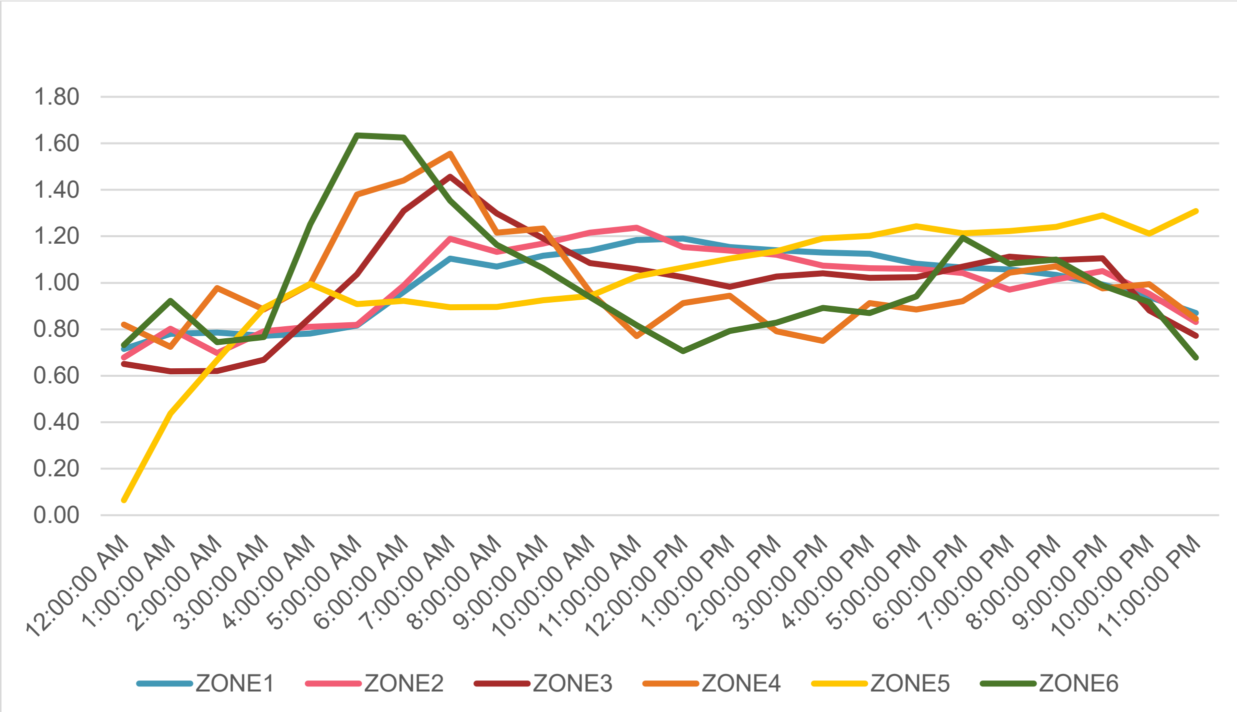

Figure 5-4. Diurnal Patterns: Zones 1, 2, 3, 4, 5, 6

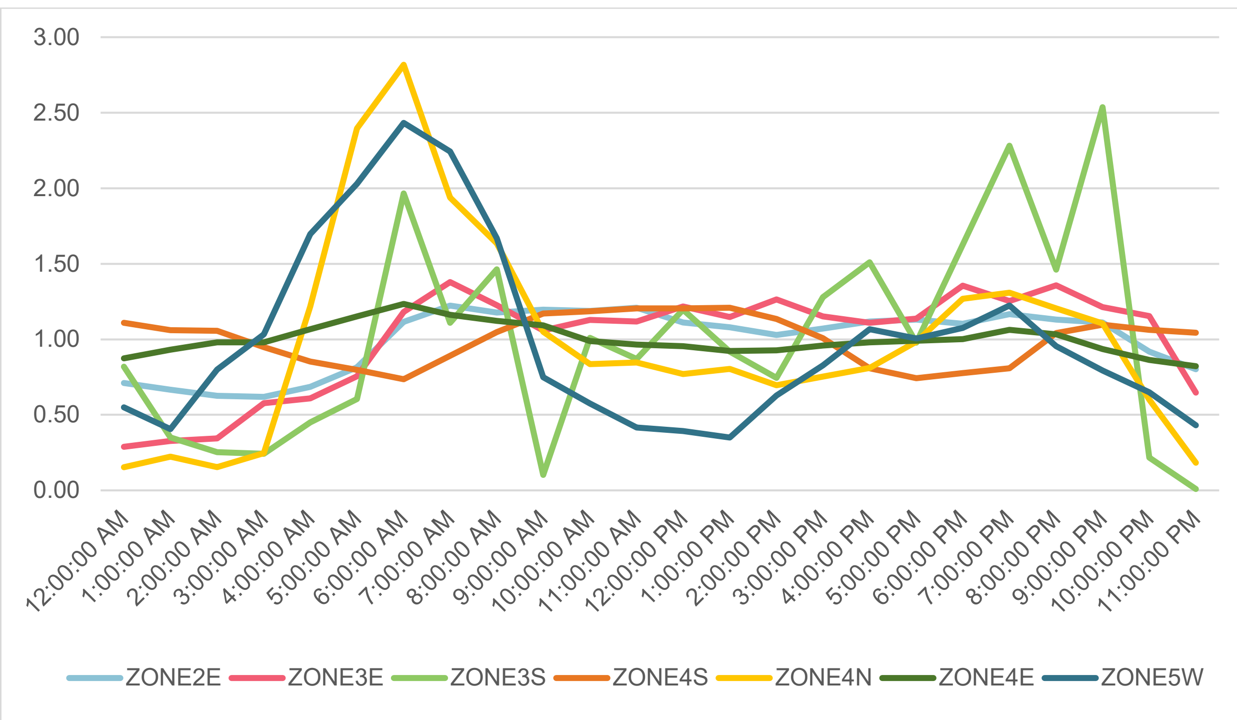

Figure 5-5. Diurnal Patterns: Zones 2E, 3E, 3S, 4S, 4N, 4E, 5W

Model Quality Control / Quality Assurance

HDR performed a quality assurance/quality control (QA/QC) check on the data to detect model demands that were missing, unexpected, and/or unusual. HDR's QA/QC protocol is used to further define boundary conditions (i.e. reservoir levels, pump station discharge pressures, PRV settings), determine network connectivity issues, and ensure proper pressure zone isolation. The QA/QC process uncovered errors that were resolved prior to and during model calibration. GIS inconsistencies that were noted during the calibration process are shown in the Appendix 5A – Calibration Insights.

Model Calibration

A comprehensive model calibration process is integral to increasing the model's ability to accurately represent actual field conditions. The hydraulic model calibration process is designed to support the development of accurate and reliable hydraulic analysis results and thus, is of utmost importance. Calibration of the City's model was completed in two steps: Steady-State (SS) and Extended Period Simulation (EPS) conditions.

Fire Hydrant Test (Steady State) Calibration

The City provided fire hydrant testing information for 27 fire hydrants across all pressure zones except 3 East, 3 South, 4 East, and 4 North. The hydrant test results show discrepancies between measured flow and witness hydrants' static HGLs, ranging from 0 feet to 18 feet. Overall, the HGL at witness hydrants matched model results much more closely than residual HGL at the flow hydrant. Calibration was performed for each pressure zone based on witness hydrant static and residual measurements.

A steady-state simulation was conducted to simulate each of the hydrant tests (using SCADA data at the time of the hydrant tests to set the model controls and boundary conditions). For each simulation, the observed and modeled static and residual pressure of the witness hydrants were compared and calibrated to match as closely as possible. The static conditions calibration process included adjusting pressure zone delineation, node elevation assignments, PRV settings, pump operations and settings, and valve configuration. C-factors are important when calibrating hydrant fire test pressure drops because of the high flows through the affected pipelines. For static conditions, 88% of the modeled results fell within 10 feet. For residual conditions, 83% of the modeled results fell within 5 feet or 2 psi and 71% fell within 3 feet of the observed data. Table 5-5 summarizes the results of the static calibration process.

Table 5-5. Model Static Calibration

Flow Hydrant	Flow	Pressure Zone	Witness Hydrant	Observed - Modeled Flow Static HGL (ft)	Observed - Modeled Witness Static HGL (ft)	Observed - Modeled HGL Drop (ft)
H 10-23	1280	Zone 1	H 84-4	4.9	6.0	-3.2
H 13-32	1240	Zone1	H 13-2	11.2	4.8	2.1
H 40-6	1140	Zone1	H 40-5	12.0	4.6	-4.5
H 52-3	1150	Zone 1	H 52-10	16.3	24.3	1.5
H 219-25	1445	Zone 2	H 219-24	12.4	-2.2	1.8
H 27-9	1300	Zone 2	H 27-6	12.8	6.2	-0.2
H 39-19	1140	Zone 2	H 39-18	7.8	4.0	7.5
H 47-15	1280	Zone 2	H 47-12	10.4	3.2	3.1
H 78-25	1465	Zone 2	H 78-24	3.0	4.4	4.7
H 140-23	1565	Zone 3	H 140-20	16.3	6.1	1.1
H 20-10	1425	Zone 3	H 20-9	12.4	3.0	-5.1
H 30-20	1240	Zone 3	H 30-19	17.3	4.5	-1.7
H 335-12	1140	Zone 3	H 335-16	2.7	2.7	2.6
H 96-21	1583	Zone 3	H 96-15	16.9	7.3	2.5
H 104-21	1150	Zone 3E	H 104-23	7.4	3.9	3.0
H 109-3	1435	Zone 3E	H 109-4	6.4	6.7	6.7
H 415-6	1555	Zone 4S	H 415-9	5.8	15.2	0.3
H 421-2	1373	Zone 4S	H 421-1	20.7	-7.4	-2.6
H 24-30	1405	Zone 4	H 24-40	10.8	-4.8	4.7
H 328-10	1455	Zone 4	H 327-6	10.9	9.5	-0.6
H 90-19	1548	Zone 4	H 90-21	24.3	2.4	-17.7
H 94-11	1280	Zone 4	H 94-12	25.2	6.0	7.3
H AIR	995	Zone 5	H AIR2	-6.7	-6.7	-4.1
H 305-27	1060	Zone 5W	H 300-8	28.7	6.3	CLOSED
H 294-6	860	Zone 6	H 294-7	25.9	19.9	CLOSED
H 71-14	710	Zone 6	H 71-16	20.2	22.1	CLOSED

Extended Period Simulation Calibration

The primary goal of an extended period simulation (EPS) calibration is to match the observed reservoir cycling values over the selected periods of time, in timing and magnitude with the modeling simulation results. Generally, reservoir level oscillations should be similar on a daily basis. This step in the calibration process is mainly governed by pump controls (level that a reservoir begins to drain and fill) and demands (how quickly a reservoir fills and drains).

The City's hydraulic model was calibrated and validated against the provided reservoir level SCADA data. Multiple days were compared to calibrate and validate the reservoir oscillations to avoid anomalies. Pump operations in the model were calibrated based on the information received from the City and incorporated in the model to approximate the SCADA reservoir cycling data provided. The resulting EPS model predicted reservoir cycling closely matched the facility performance information provided from the City's SCADA system. A sample EPS reservoir calibration (for Waldo Reservoir) is shown in Figure 5-6, with the observed versus modeled EPS calibration results for all reservoirs, by pressure zone provided in Appendix 5B.

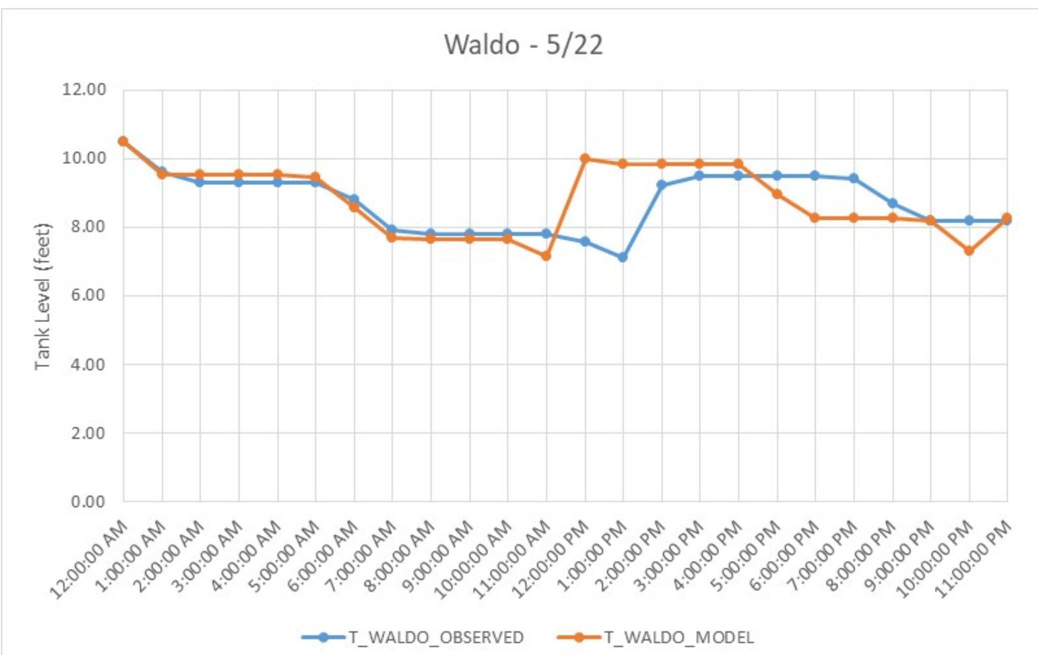

Figure 5-6. EPS Calibration – Zone 4 – Waldo Reservoir

The completion of the calibration process resulted in the City's hydraulic water model being up to date and is a tool that can be confidently utilized for the water system analysis prescribed in this Master Plan. The results of the system analysis are summarized and provided in the following chapters.

Appendix 5A – Calibration Insights

Calibration Insights

During the review, build and calibration process of the City's water system hydraulic model, there were a few important observations on GIS data, operation guidelines, and demand allocations. These were:

- Controls:
  - Most pump stations are manually controlled
  - For an extended period of time in May, the depth of Briarwood Reservoir level was observed to be less than 1 ft
  - Chapple Pump Station is likely controlled by Ironwood tank (not Waldo, as indicated in the City's pump operations general procedure document)
- Capacity Bottlenecks:
  - There is likely a partially closed valve or other obstruction between Rimrock Road (pipe 68094) and hydrants H90-19 and H90-21. It is recommended that the City investigate the reason for the large pressure drop in this localized area.
- Pipelines Added:
  - Bay Hills Road (P15511) - observed pressure drop was much lower than the modeled drop in pressure
  - Sycamore Ln between Gregory Dr. and Palm Dr. (P15527) - connection likely missing in GIS
- Some pipline diameters should be double-checked and potentially corrected:
  - Pipe 59529 should be 8-inch
  - Pipe R032029T032047 should be 24-inch
  - Pipe R032029T032047 and R133015C133004 to 24-inch
  - Pipe R032029T032047 and R133015C133004 to 24-inch
  - Pipe R032029T032047 and R032029T032047 to 24-inch
  - Pipe 032023R032016 and T032047032023 to 18-inch
  - Pipes 59800, 33235, and 44141 are likely 12-inch mains, since they connect 16-inch and 12-inch mains.
- Meter Demands Assignments:
  - Demands for meters 158004 and 158400 should be assigned to J-11367 (Zone 2) and J-6098 (Zone 4 South), respectively. Demands from these meters will be incorrectly assigned if automated based on spatial distance and pressure zone model development protocols.
  - Meters 223747 and 223762 are HWD meters that total 470 GPM and should be assigned to Zone 2 East.
- Other:

  - Waldo Reservoir likely has separate input/output pipelines, which is not reflected in the GIS.
  - Calibration of the cycling for the Waldo Reservoir was only achieved by inserting a check valve on the upstream side of the reservoir. This has a large impact on available fire flows and will be discussed in the Fire Flow Analysis section of the report.

Operational Insights: During project meetings with the City's water system operators, a few important operational findings were noted to better reflect the applicable operational settings during high demand. The following operations changes were incorporated in the high demand model scenarios:

- Thomas Pump Station to Cedar Park Reservoir
  - Isolation valve added because Zone 2 HGL is sometimes high enough to fill Cedar Park Reservoir
- Thomas Pump Station to Briarwood Reservoir
  - Use pumps 2 and 3
  - Reservoir operating levels: 10 ft to 18 ft
- Staples Pump Station Zone 3 pumps
  - Use Pump 3 in summer and Pump 4 in peak hour conditions
- Staples Pump Station Zone 4 pumps
  - Use 2 pumps
- Chapple Pump Station
  - Run all 3 pumps at least 84% speed
- Leavens Pump Station
  - Only operates during very high demand (did not run in June)
- Terrace Estates is a booster, 4E is a closed loop
- Willet Pump Station
  - Used only in the summer
- Voelker Pump Station
  - Summer – Pumps 1, 2 and 4
- High Service Station
  - Use H1-1 instead of H1-2 to meet high demand
- Fox Pump Station
  - Existing station struggles to meet system needs in the summer

Appendix 5B – EPS Calibration

The information in this Appendix is designed to provide a graphical depiction of the hydraulic model's final EPS calibration findings by comparing the modeled EPS simulation results of reservoir operations with the actual data obtained from SCADA for each facility. As shown, the calibrated model provides a reasonable representation of the observed performance for each of the City's reservoirs during the calibration-based EPS simulation.

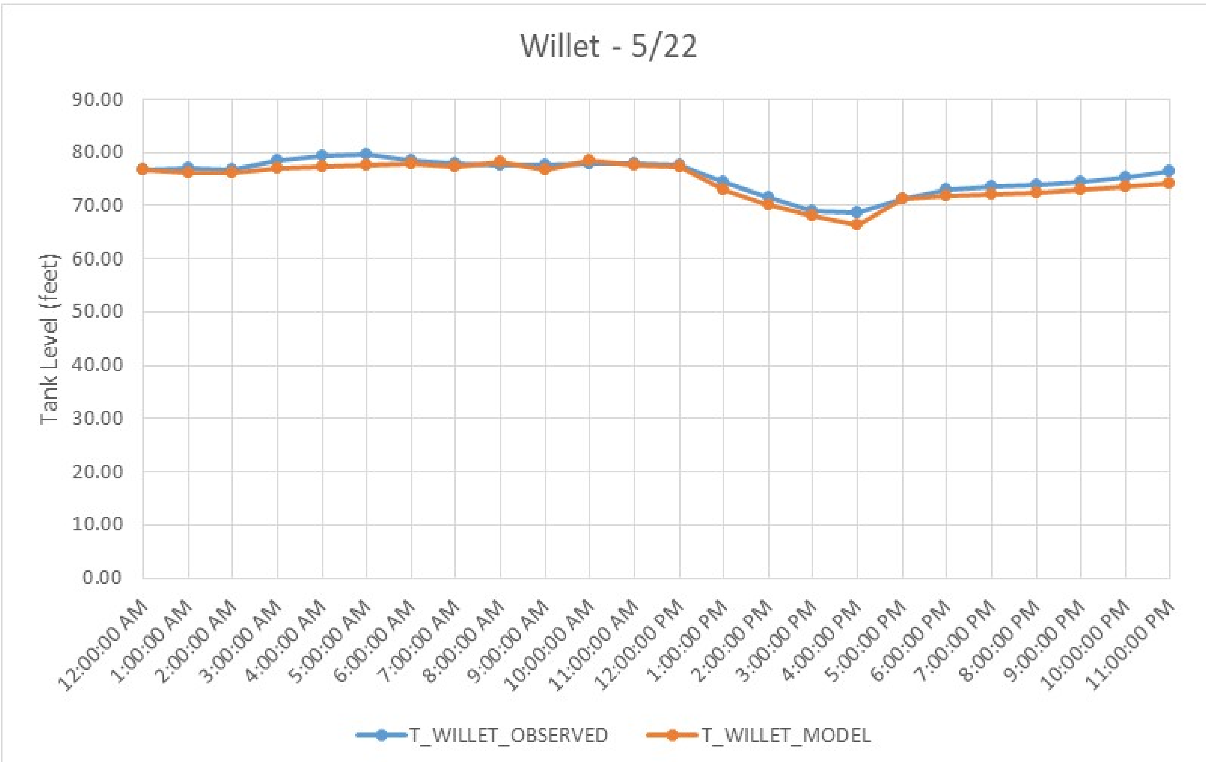

Figure 5B-1. EPS Calibration – Willet Reservoir

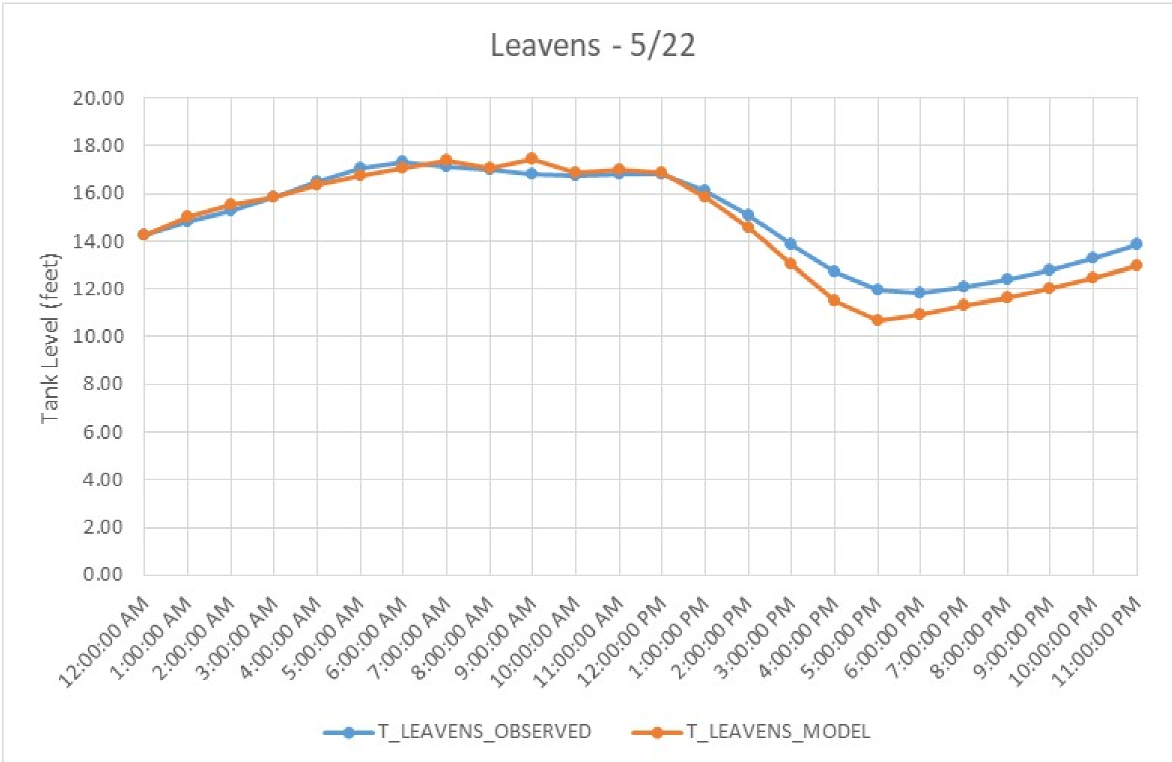

Figure 5B-2. EPS Calibration-Zone 1 – Leavens Reservoir

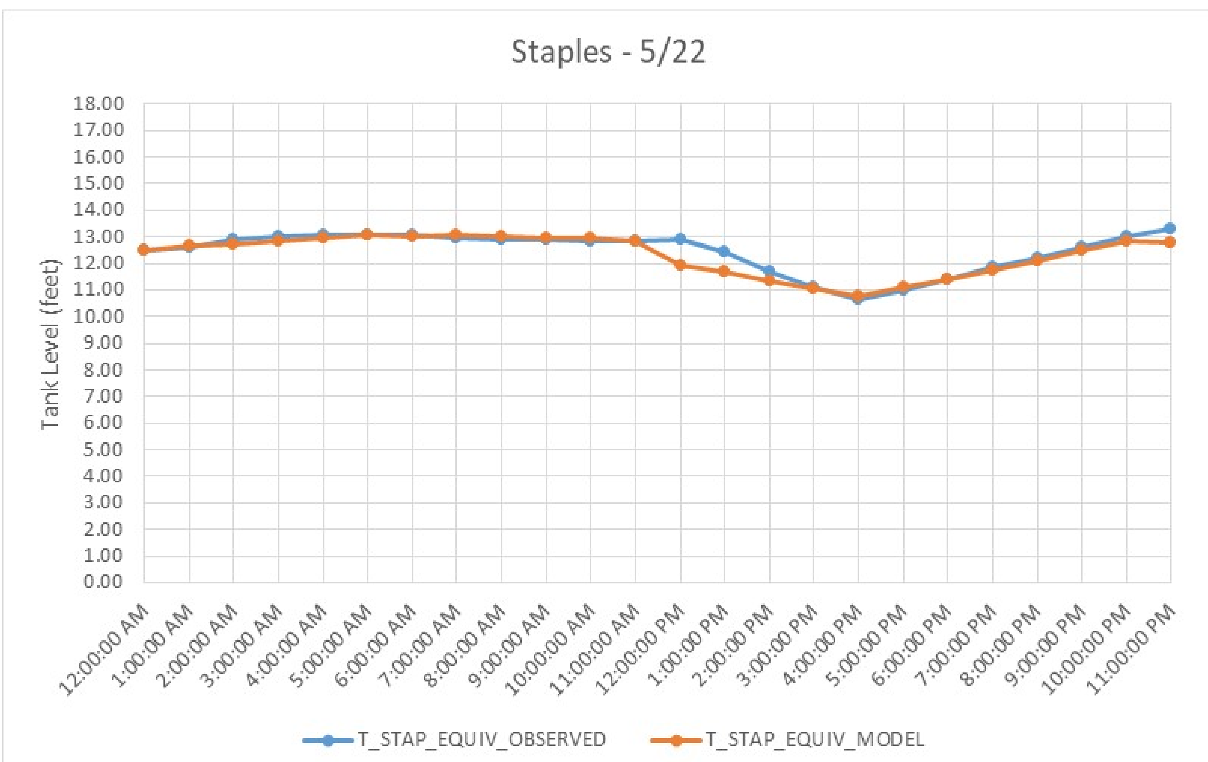

Figure 5B- 3. EPS Calibration - Zone 2 – Staples Reservoir

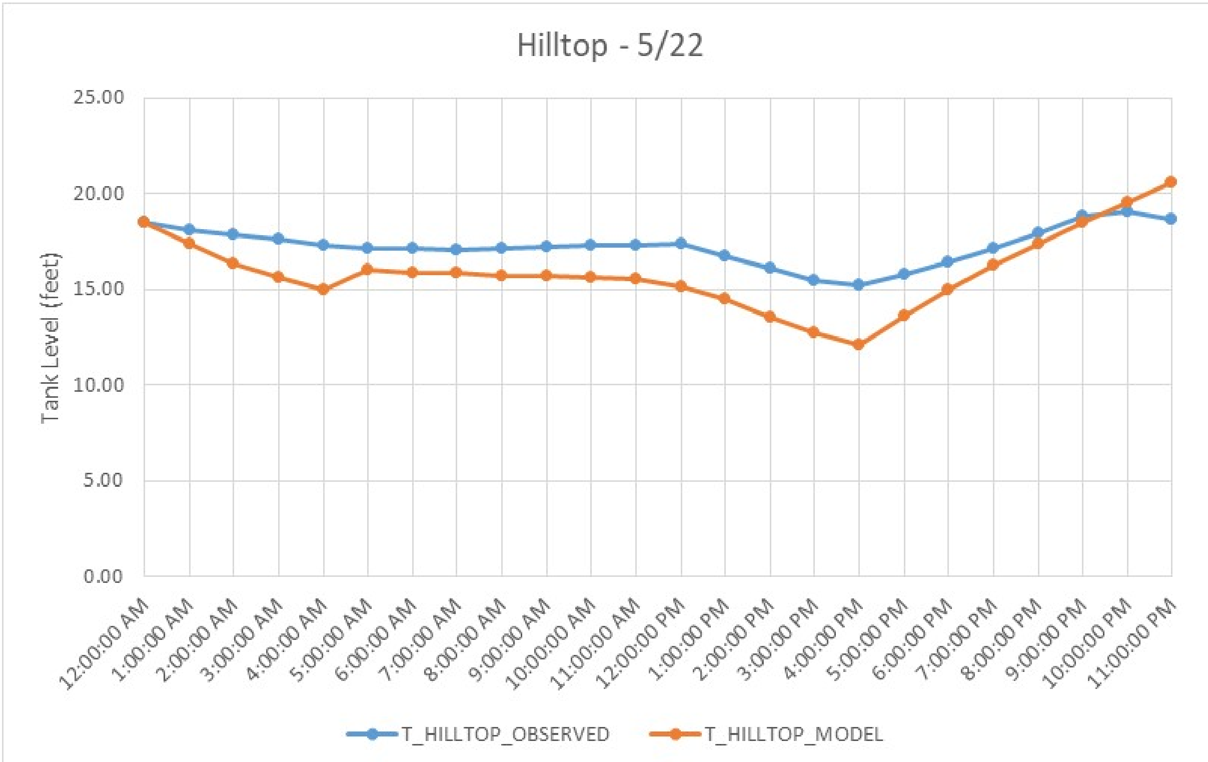

Figure 5B-4. EPS Calibration - Zone 2E – Hilltop Reservoir

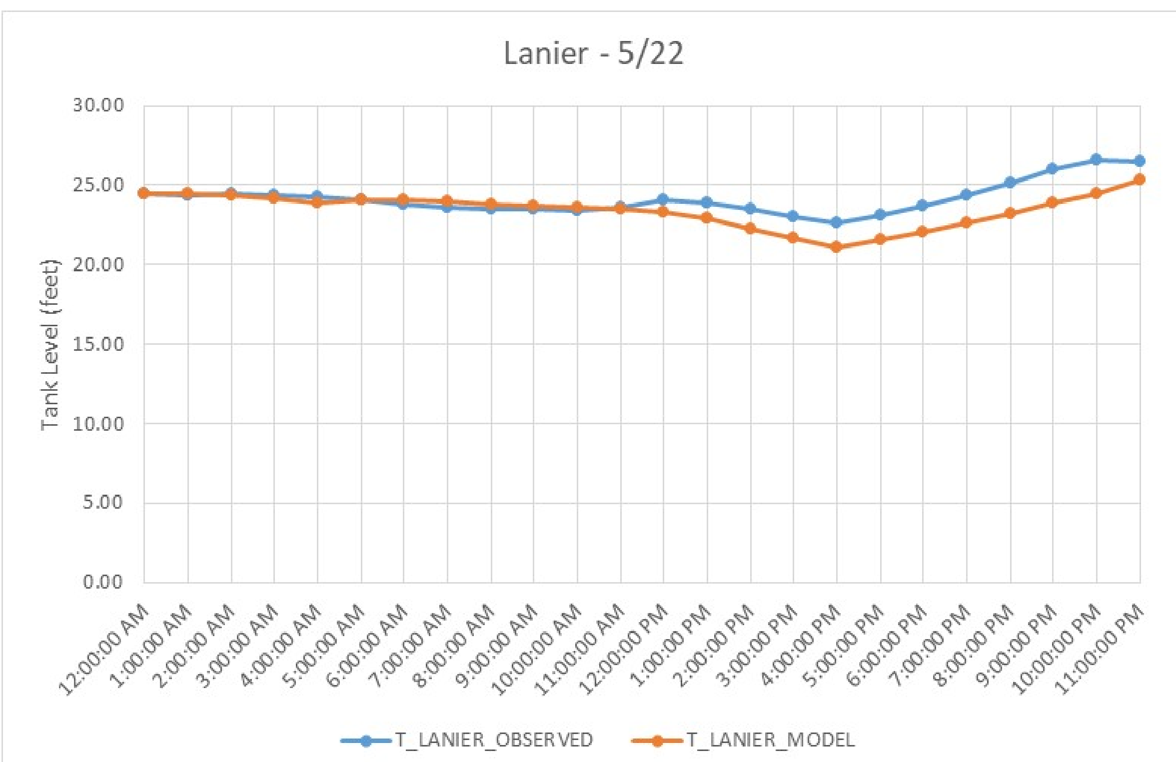

Figure 5B-5. EPS Calibration - Zone 2E – Lanier Reservoir

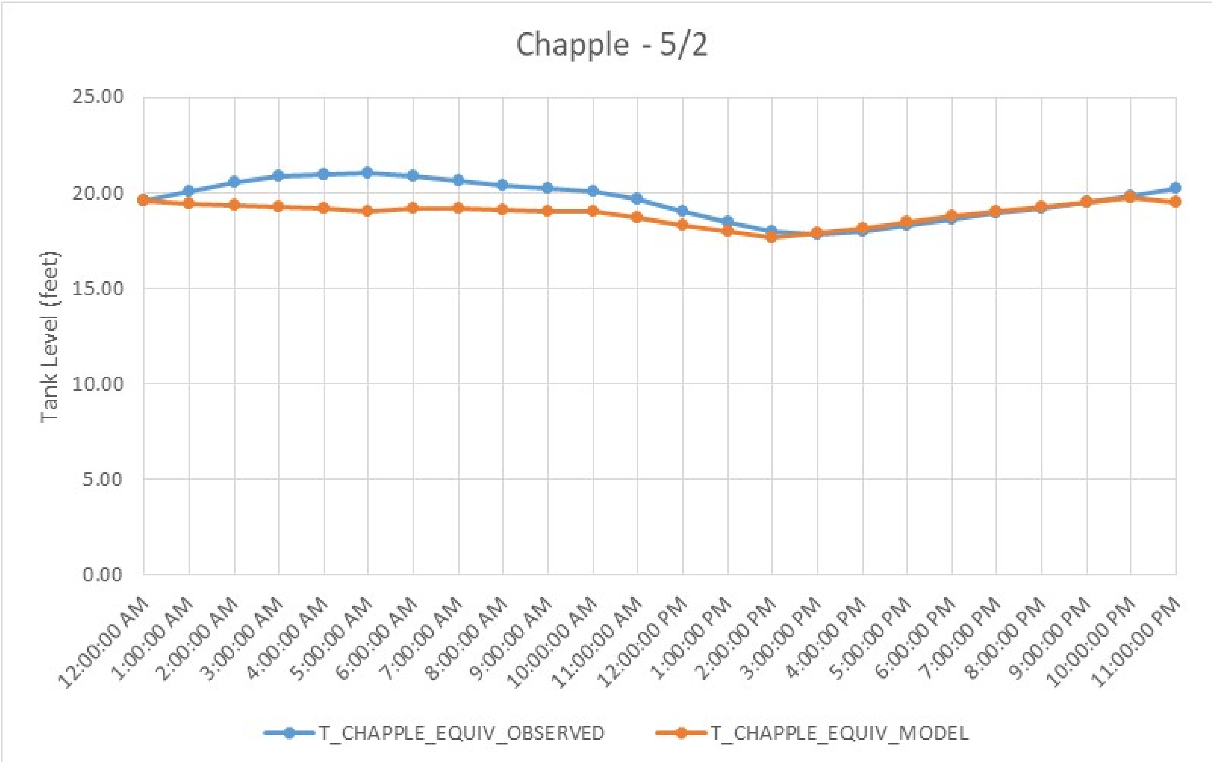

Figure 5B-6. EPS Calibration - Zone 3 – Chapple Reservoir

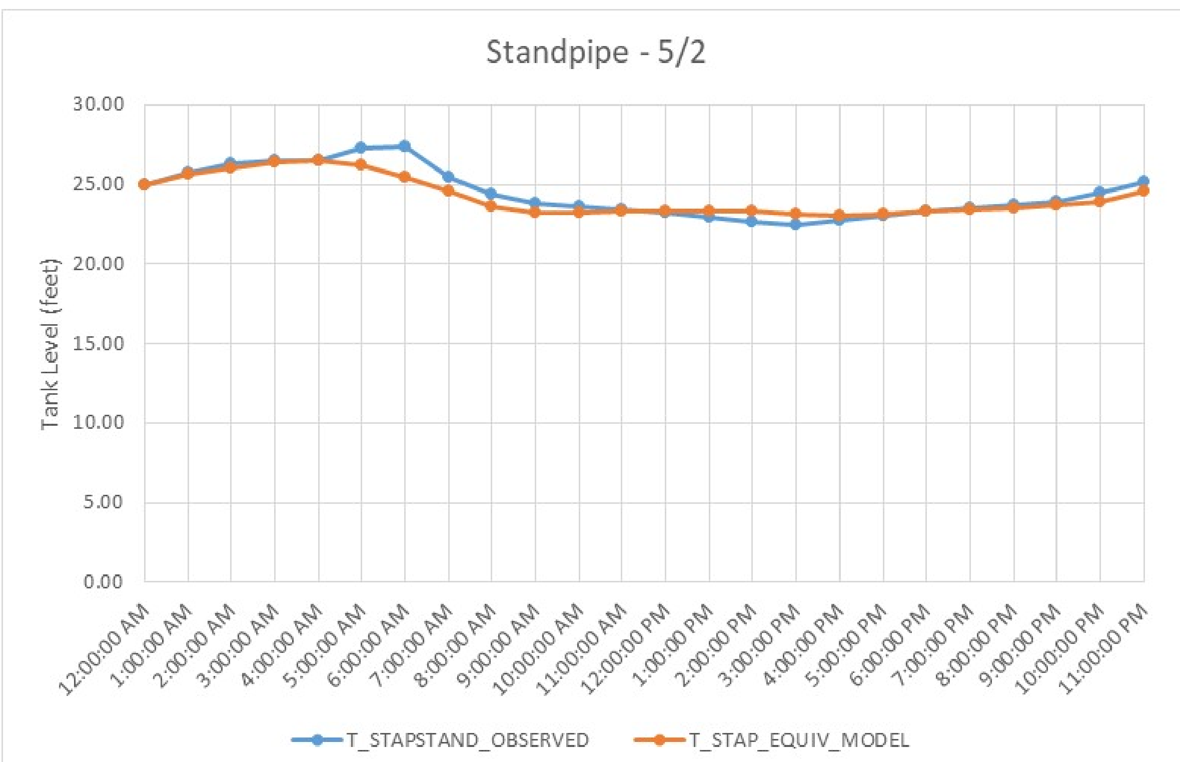

Figure 5B-7. EPS Calibration-Zone 3 – Staples Standpipe Reservoir

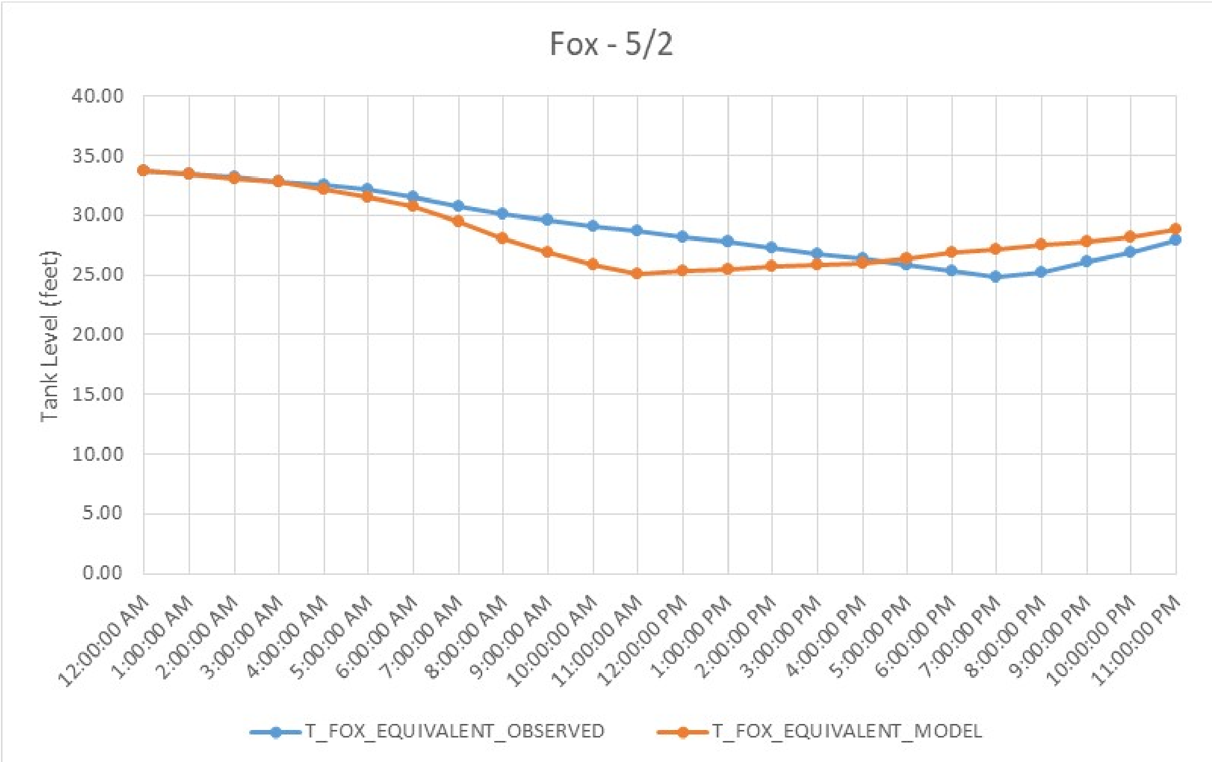

Figure 5B-8. EPS Calibration - Zone 3E – Fox Reservoir

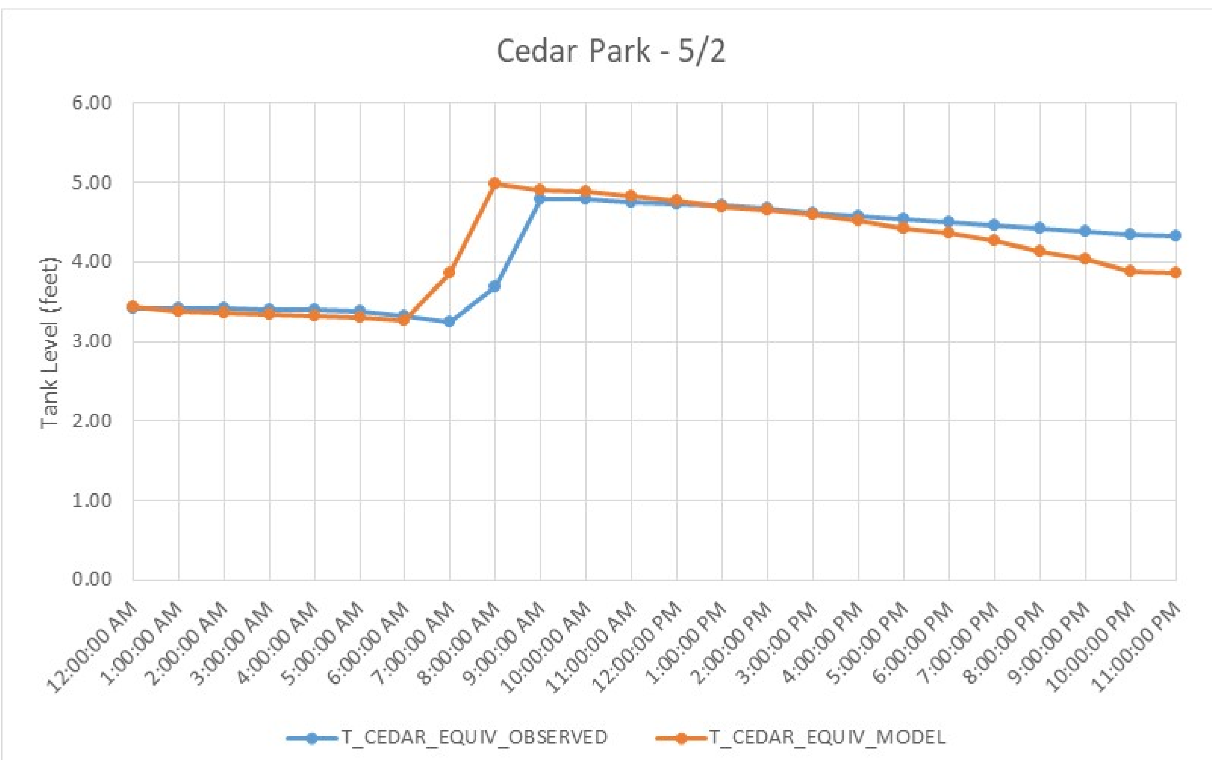

Figure 5B-9. EPS Calibration - Zone 3S – Cedar Park Reservoir

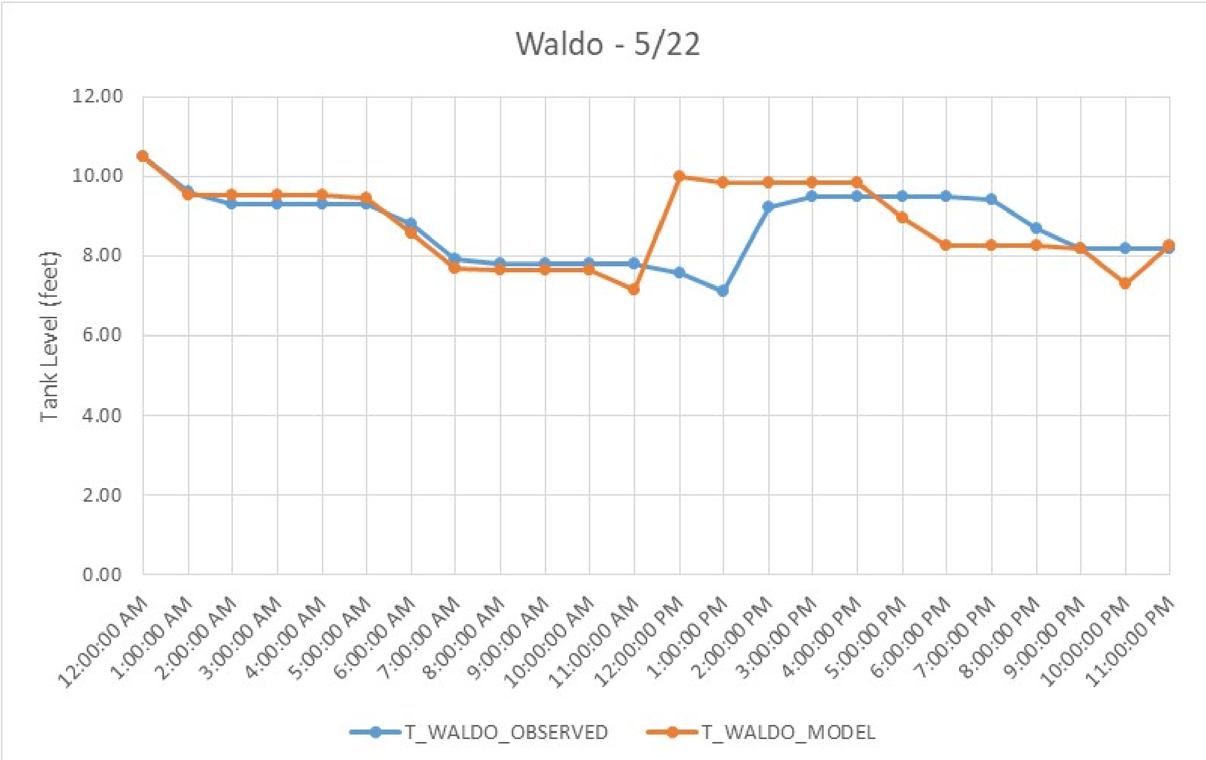

Figure 5B-10. EPS Calibration - Zone 4 – Waldo Reservoir

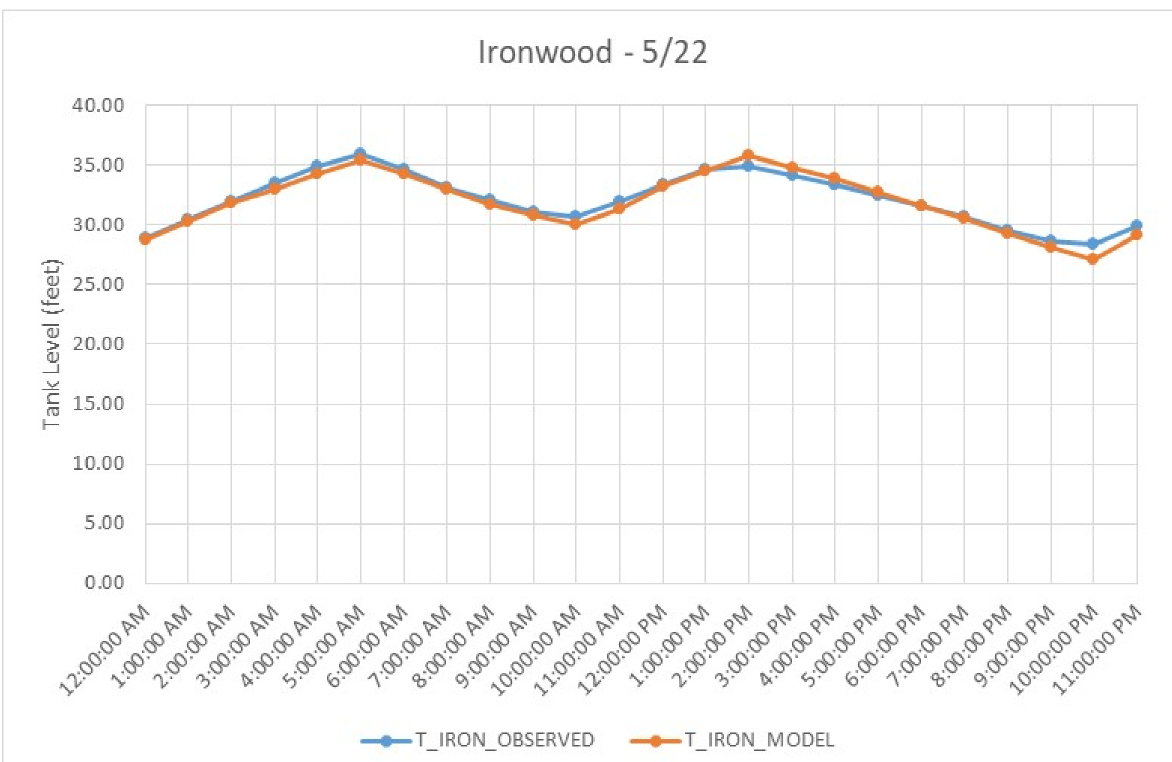

Figure 5B-11. EPS Calibration - Zone 4 – Ironwood Reservoir

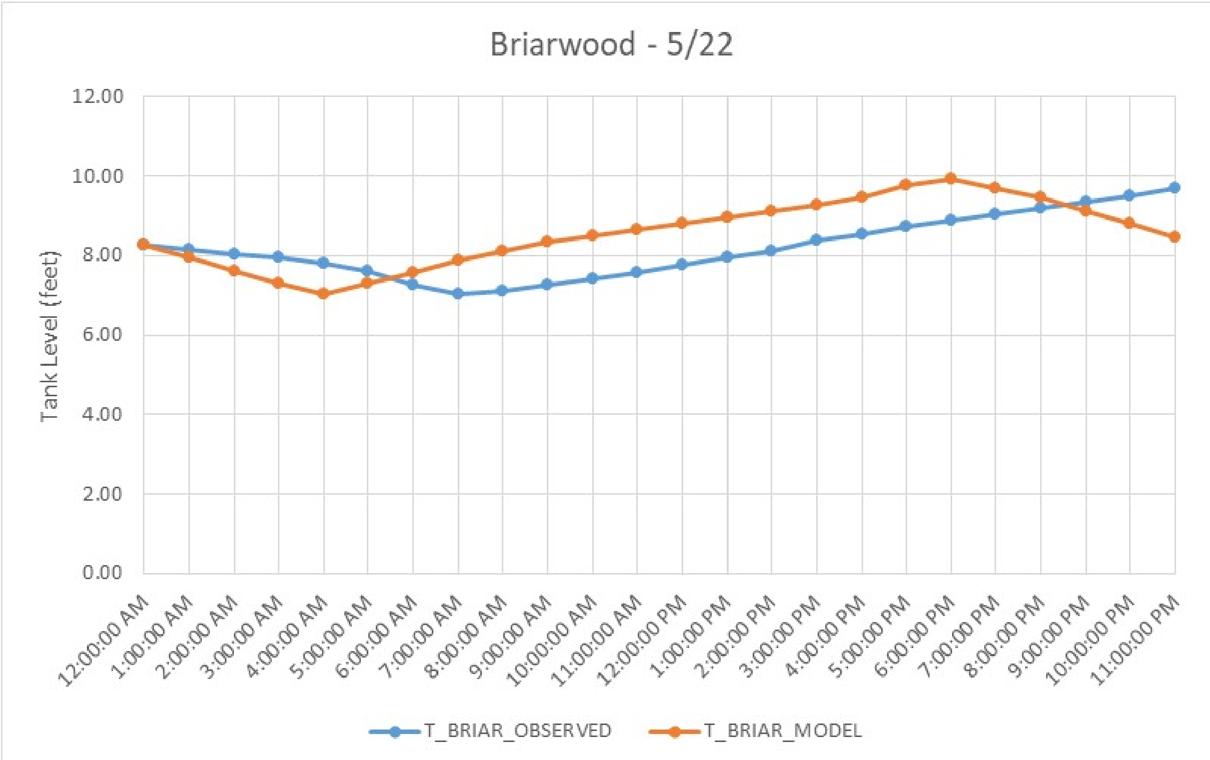

Figure 5B-12. EPS Calibration - Zone 4S - Briarwood Reservoir

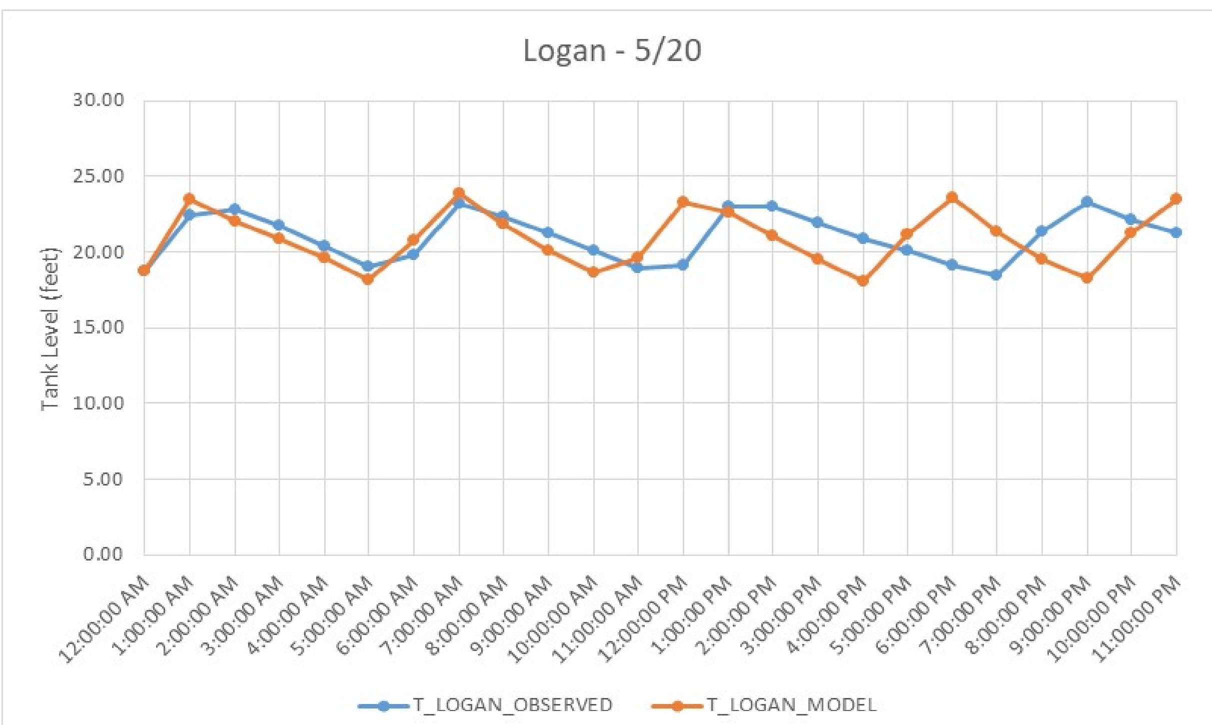

Figure 5B-13. EPS Calibration – Zone 5 – Logan Reservoir