Technical Memorandum

Elizabeth George, Loma Rica, & Cascade Shores Systems Hydraulic Model Update and Calibration

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1 Introduction

Sedaru (formerly IDModeling) has developed this technical memorandum to describe the model update and calibration for Nevada Irrigation District's (NID or District) water model (Project). The goal of this Project was to update and calibrate the hydraulic model of the District's water system and deliver within the Sedaru Modeling platform for the District's use for performing fire flow analyses, development planning, operational "what-if" scenarios, and numerous other applications. This document describes the model update and calibration process, summarizes the results of the steady-state (SS) and extended period simulation (EPS) model calibration, and includes recommendations for future updates and calibration efforts.

2 Model Update from GIS and As-builts

The existing water model was updated using the District's most current ArcGIS geodatabase and as-built drawings. The pipes and associated junctions in the model were checked against the existing feature layers in GIS. New features were imported into the model, and updates were made to the existing features as needed. During the model update process some additional improvements including BEP improvements, have been made that are not included in this report. Figure 1 shows the overall system with the new facilities highlighted in red. The model updates are described in the following sections.

2.1 Pipes

Using the existing pipe layer provided by the District, the current model was updated to include new pipes added to the geodatabase since the last model update, removing abandoned pipes, and splitting pipes where partial segments were improved. **Table 1** summarizes the pipe information by length and material for Cascade Shores (CS), EGeorge (EG), and Loma Rica (LR) systems.

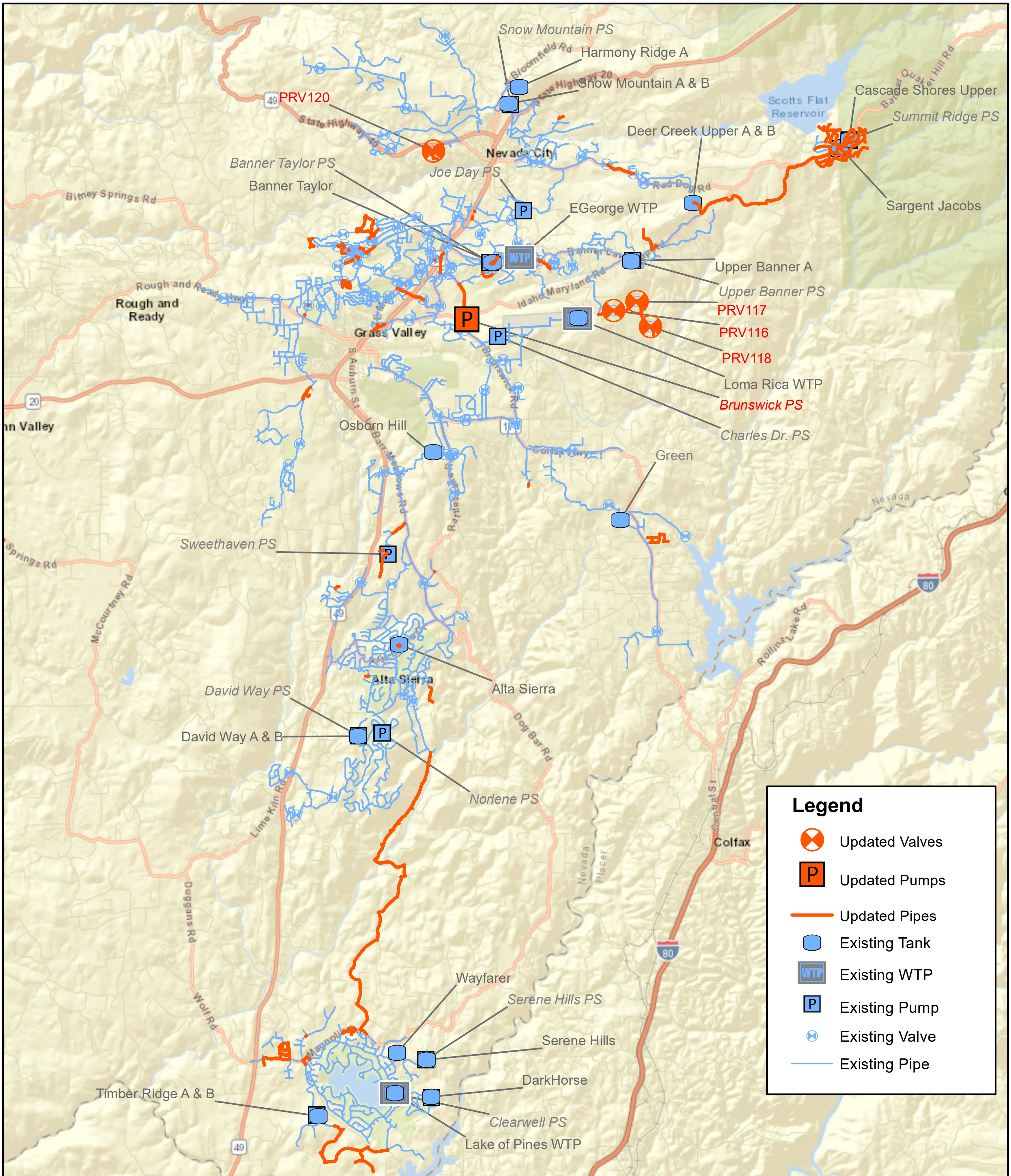

Figure 1
2018 Facility Updates

Model Update and Calibration
for EG/LR/CS
Nevada Irrigation District

Table 1 - Pipeline Summary by Diameter and Material for CS/EG/LR Systems Combined

Diameter (inches)	Length of Pipe (ft)														
	Material													Total	
	ABS	AC	BBP	CCP	CI	CML	DI	HDPE	Plastic	POLY	PVC	STL	UNKN[1]	Length (ft)	% of Total
1.5										1,940	562			2,502	0.2%
2							3	1,510	108	735	21,283	767	3,388	27,794	2%
3					73						2,778			2,850	0%
4	287	20,372	135		1,245		8,421	847			44,540	6,545	6,981	89,373	6%
6		150,931	68		89,522	2,809	14,086	3,921	185		15,976	17,987	19,308	314,793	22%
8		81,430			19,359	395	185,440	1,441			200,698	26,325	22,947	538,035	38%
10		18,982			2,512		95,890				26,975	5,814	3,768	153,941	11%
12		15,803			1,633		90,555				51,544	2,861		162,396	11%
14								75				4,637	2,284	6,996	0.5%
16							38,763	272			3,002	12,217	1,462	55,717	4%
18						249	23,252				33	5,880		29,415	2%
20							3,318					6,056	187	9,561	1%
24		174					13,408					1,819	24	15,425	1%
30		155					5,190					1,322		6,666	0.5%
36							4,565							4,565	0.3%
42				927								22		949	0.1%
Total Length	287	287,846	203	927	114,345	3,454	482,892	8,065	293	2,675	367,392	92,252	60,349	1,420,979	
% of Total	0.02%	20%	0.01%	0.1%	8%	0.2%	34%	1%	0.02%	0.2%	26%	6%	4%		

(1) UNKN indicates material information was not available

2.2 Tanks

The Red Dog tank in the EGeorge system was abandoned and replaced by a pressure reducing Valve Station (PRV). **Table 2** summarizes the key model information for the CS/EG/LR distribution system tanks.

Table 2 – Summary of Tank Information for Cascade Shores/EGeorge/Loma Rica Systems

Tank ID	Description	Volume (mg)	Bottom Elevation (ft)	Height (ft)	Diameter (ft)	System
T28B	Cascade Shores Sargent Jacobs A & B (Equivalent Diameter)	0.17	3,411.60	18.4	40	Cascade Shores
T29	Cascade Shores Upper	0.11	3,665.50	24.25	28	Cascade Shores
T10A	Banner Taylor (Equivalent Diameter)	10.50	3,049	18	315.11	EGeorge
T11B	Deer Creek Upper B and A (Equivalent Diameter)	1.42	3,655.70	35	83.19	EGeorge
T12A	Harmony Ridge A	1.00	3,250	22	89	EGeorge
T14B	Snow Mountain B and A (Equivalent Diameter)	1.60	2,914	28.5	98.41	EGeorge
T15	Taylor Tank	0.49	3,049	17	70	EGeorge
T16A	Upper Banner A	0.30	3,398	29.0	42	EGeorge
T16B	Upper Banner B	0.60	3,398	30.5	58	EGeorge
T22	Alta Sierra Reservoir	2.87	2,342	15.2	Variable Area-	Loma Rica
T23A	David Way A	1.50	2,380	31	101.12	Loma Rica
T23B	David Way B	0.42	2,380	31	48	Loma Rica
T24	Green Tank	0.25	2,633	29	39	Loma Rica
T25A	Loma Rica Clearwell A	0.85	3,149.50	30	70	Loma Rica
T25B	Loma Rica Clearwell B	0.85	3,149.50	30	70	Loma Rica
OSBORN _HILL _TANKS _ABC	Osborn Hill (Equivalent Diameter)	4.25	2,980	32	152	Loma Rica

2.3 Pressure Reducing Stations

Four (4) new PRV stations were added to the model-PRV114 replaced the Red Dog tank and three (3) PRV's (PRV116, PRV117, and PRV118) were added on the 8-inch main between Lee Lane and Tensy Lane. **Table 3** summarizes the modeled data for the PRV's.

Table 3 - Summary of the PRV Station Information

Model Valve (ID)	Location	Elevation (ft)	From Zone	To Zone	Valve 1 Size/Setting inch/psi)	Valve 2 Size/Setting inch/psi)	Valve 3 Size/Setting inch/psi)	System
PRV1	Oak Drive	1786	1	52	2"/37	2"/32		Loma Rica
PRV2	Alexandra	2073	50	1	3"/40	3"/35		Loma Rica
PRV3	Smith-Moulton	2349	28	76	2"/70	2"/65		Loma Rica
PRV4	Ruess Reservoir	2768	12	68	2"/40	2"/35		Loma Rica
PRV5	Mountain Air	2282	72	48	3"/40	3"/35		Loma Rica
PRV6	Sky Pines	2358	36	72	3"/60	3"/55		Loma Rica
PRV7	Dog Bar	2301	36	72	2"/90	2"/85		Loma Rica
PRV40	Whispering Pines	2716	42	94	3"/106	3"/101	6"/111	Loma Rica
PRV41	Greenhorn Rd & Tim Burr	2860	42	30	2"/75	2"/70		Loma Rica
PRV64	Highland Drive (Lower)	2726	62	33	2"/93	2"/		Loma Rica
PRV65	Rattlesnake Rd Bradford	2804	42	62	2"/93	2"/88		Loma Rica
PRV67	Meadow View Drive	2706	12	45	2"/55	2"/50		Loma Rica
PRV69	Smith Road	2388	36	77	1-/60	1-/55		Loma Rica
PRV71	LaBarr Meadows #2	2441	55	36	3"/98	3"/98	8"/155	Loma Rica
PRV74	Hidden Glen	2842	42	63	2"/45	2"/		Loma Rica
PRV75	Cedar Ridge	2909	42	90	3"/75	3"/70		Loma Rica
PRV76	Brunswick & Hwy 174	2856	42	12	2"/72	2"/67		Loma Rica
PRV77	The Cedars	2856	42	90	2"/105	2"/100		Loma Rica
PRV78	Rattlesnake	2715	42	63	2"/100	2"/95		Loma Rica
PRV79	Silver Way	2614	63	71	2"/90	2"/90		Loma Rica
PRV80	Highland Drive (Upper)	2791	42	33	2"/70	2"/65		Loma Rica
PRV81	Willaura Acres	1741	1	95	2"/45	2"/45	6"/70	Loma Rica
PRV83	Brewer Road #2	1827	11	9	2"/36	2"/31		Loma Rica
PRV84	Brewer Road #1	2000	2	11	2"/55	2"/50		Loma Rica
PRV85	Nancy Way	2035	2	11	2"/42	2"/37		Loma Rica
PRV100	Greenhorn Access Rd	2238	28	29	1 /60	1 /55		Loma Rica
PRV104	Towle Lane	2785	42	91	2"/103	2"/98		Loma Rica
PRV86	Alta Sierra Auto	2350	36	2				Loma Rica

Table 3 Cont'd - Summary of the PRV Station Information

Model Valve (ID)	Location	Elevation (ft)	From Zone	To Zone	Valve 1 Size/Setting inch/psi)	Valve 2 Size/Setting inch/psi)	Valve 3 Size/Setting inch/psi)	System
PRV92	Green Tank Altitude	2624	68	68				Loma Rica
PRV101	Osborne HIll Altitude	2985	42	42				Loma Rica
PRV113	LomaRica-EGeorge Intertie	2614	42	3				EGeorge
PRV10	Pittsburg Road	2714	3	59	2"/78	2"/73		EGeorge
PRV13	Deer Park Drive	2424	23	20	2"/120	2"/115		EGeorge
PRV14	Echo Ridge	2809	3	23	2"/60	2"/55		EGeorge
PRV15	Marjon Drive	2805	3	23	2"/54	2"/		EGeorge
PRV16	McPherson's	2814	3	27	2"/40	2"/35		EGeorge
PRV17	Mountaineer Forest Serv	2709	3	59	2"/80	2"/75		EGeorge
PRV18	Red Dog Road	3046	19	64	2"/40	4"/45		EGeorge
PRV19	Murchie Mine Road	2821	64	49	2"/65	2"/63		EGeorge
PRV21	Berggren Lane	2620	35	6	1-/65	1-/60		EGeorge
PRV22	Park Avenue	2610	35	57	2"/55	2"/		EGeorge
PRV23	Boulder St.	2580	35	8	2"/65	2"/60		EGeorge
PRV24	Quaker Hill Reg.	3413	92	61	2"/60	2"/55		EGeorge
PRV25	Red Hill	2664	79	65	2"/50	2"/45		EGeorge
PRV26	Lake Vera	2628	79	38	2"/55	2"/50		EGeorge
PRV27	Star Motel	2471	83	80	1-/40	1-/35		EGeorge
PRV28	Sunset	2538	74	83	2"/85	2"/80		EGeorge
PRV29	Adams Avenue	2592	74	83	3"/56	3"/-51		EGeorge
PRV30	Rough & Ready Highway	2614	74	83	4"/50	4"/45		EGeorge
PRV31	Carey Drive	2652	74	83	8"/33	8"/39 Relief Valve Setting		EGeorge
PRV32	Presley Way	2585	3	26	2"/102	2"/97		EGeorge
PRV33	Hills Flat	2583	3	34	2"/30	2"/25		EGeorge
PRV34	East Ridge Apartments	2608	3	74	2"/92	2"/87		EGeorge
PRV35	Idaho-Maryland	2495	84	34	2"/80	2"/75		EGeorge
PRV36	Slate Creek	2639	3	74	3"/80	3"/75		EGeorge
PRV37	Cypress Hill	2666	3	74	2-/66	2-/61		EGeorge
PRV38	Sutton Way Ext.	2583	3	84	3"/100	3"/95		EGeorge
PRV39	Dorsey Drive	2696	3	21	2-/60	2-/55		EGeorge
PRV42	Forest Knolls #1	3063	5	4	2 /53	2 /48		EGeorge
PRV43	Northview Drive	3044	24	4	2"/60	2"/		EGeorge
PRV44	Forest Knolls #2 (Upper)	3103	5	24	2-/80	2-/75		EGeorge

Table 3 Cont'd - Summary of the PRV Station Information

Model Valve (ID)	Location	Elevation (ft)	From Zone	To Zone	Valve 1 Size/Setting inch/psi)	Valve 2 Size/Setting inch/psi)	Valve 3 Size/Setting inch/psi)	System
PRV45	Old Tunnel Road	2815	3	54	2"/72	2"/67		EGeorge
PRV46	Glenwood Road	2664	3	27	2"/98	2"/93		EGeorge
PRV47	Morgan Ranch (Upper)	2746	3	46	2"/65	2"/60		EGeorge
PRV48	Success Mine Loop	2583	47	20	2"/50	2"/45		EGeorge
PRV49	Northridge Drive	2716	46	47	2"/47	2"/		EGeorge
PRV50	Via Vista Drive	2781	3	23	2"/63	2"/		EGeorge
PRV51	Sutton Way	2624	3	84	2-/80	2-/75		EGeorge
PRV52	Glenbrook Drive	2654	3	26	2"/72	2"/72		EGeorge
PRV53	Lyons	2641	3	26	2"/80	2"/75		EGeorge
PRV54	Old Tunnel Road Ext.	2687	54	84	2"/47	2"/		EGeorge
PRV55	Forest Knolls Court	2974	24	25	1-/35	1-/35		EGeorge
PRV56	Sierra College Way Upper	2717	3	47	2"/46	2"/		EGeorge
PRV57	Morgan Ranch (Lower)	2636	3	47	3"/80	3"/75		EGeorge
PRV58	Madrona Way	3167	5	24	2"/60	2"/		EGeorge
PRV59	Valley View Drive	3194	5	24	2"/45	2"/40		EGeorge
PRV60	Woodcrest Way	2710	46	47	2"/51	2"/		EGeorge
PRV61	Sierra College Way Lower	2690	3	26	2"/55	2"/		EGeorge
PRV62	Banner-Taylor	3045	5	4	2"/58	2"/53		EGeorge
PRV72	Old Auburn Road	2393	83	53	2-/72	2-/67		EGeorge
PRV73	Hidden Valley	2358	53	32	1-/25	1-/20		EGeorge
PRV99	Forest Knolls #2 (Lower)	3055	5	24	2"/100	2"/		EGeorge
PRV102	Indian Trail	2581	79	65	2"/74	2"/69		EGeorge
PRV103	Slate Creek Rd (Lower)	2507	74	73	2"/71	2"/66		EGeorge
PRV105	Chapa~De	2679	3	26	1"/64	1"/59		EGeorge
PRV106	Cement Hill Upper	2869	31	16	2"/85	2"/80		EGeorge
PRV107	Cement Hill Lower	2642	16	15	2"/50	2"/45		EGeorge
PRV114	Snowline Rd	3279	61	19	2"/15	2"/10	6"/25	EGeorge
PRV116	Lava Cap Mine Rd (Upper)	3098	5	41	2" /35	2 /30		EGeorge
PRV117	Lava Cap Mine Rd (Middle)	2893	41	40	2" /35	2 /30		EGeorge
PRV118	Lava Cap Mine Rd Tensy Ln	2651	40	39	2" /50	2 /45		EGeorge
PRV120	American Hill Project	2622	79	96	2" /60	6"/55		EGeorge

2.4 Pump Stations

A new pump station was added to the model at Brunswick Road south of Idaho Maryland Road to move water from the EGeorge system to the Loma Rica system in case Loma Rica water treatment plant (WTP) is offline. This pump station also has a bypass that allows water to transfer from the Loma Rica system to the EGeorge system in case of an emergency. **Table 4** summarizes key model information for all the pumps in the distribution system.

Table 4 – Summary of Pump Station Information

Pump ID	Source Zone	Service Zone	Design Flow (gpm)	Design Head (ft)	System
SARGENTJACOBS_PUMP1	13	69	100	402	Cascade Shores
SUMMITRIDGE_PUMP1	69	82	60	121	Cascade Shores
SUMMITRIDGE_PUMP2	69	82	60	121	Cascade Shores
BANNERTAYLOR_PUMP1	3	5	250	386	EGeorge
BANNERTAYLOR_PUMP2	3	5	250	386	EGeorge
BANNERTAYLOR_PUMP3	3	5	600	528	EGeorge
BANNERTAYLOR_PUMP4	3	5	600	528	EGeorge
JOEDAY_PUMP1	59	35	600	300	EGeorge
JOEDAY_PUMP2	59	35	600	300	EGeorge
SNOWMNT_PUMP1	35	78	260	307	EGeorge
SNOWMNT_PUMP2	35	78	260	307	EGeorge
UPPRBANNER_PUMP1	5	92	560	320	EGeorge
UPPRBANNER_PUMP2	5	92	560	320	EGeorge
CHARLESDR_PUMPSTATION	42	42	860	136	Loma Rica
DAVIDWAY_PUMPSTATION	50	18	320	185	Loma Rica
LOMARICA_EG_PUMP1	3	42	900	145	Loma Rica
LOMARICA_EG_PUMP2	3	42	900	145	Loma Rica
LOMARICA_EG_PUMP3	3	42	900	145	Loma Rica
NORLENE_PUMP1	2	50	600	300	Loma Rica
NORLENE_PUMP2	2	50	600	300	Loma Rica
SWEETHAVEN_PUMPSTATION	36	85	60	103	Loma Rica

3 Elevation Assignment

The District provided three sources of elevation data including contour lines, Digital Elevation Model (DEM), and Digital Terrain Model (DTM). Below is a brief description of each source:

- Contour lines are based on United State Geological Survey (USGS) with 40-foot contour intervals
- DEM is a representation of the elevation of the Earth's surface above a certain datum (e.g. mean sea level) in digital form. This is achieved by taking measurements at regular intervals (e.g. 50 meters) or irregular spaced points (e.g. every 3 arc seconds) over the Earth's surface. The DEM data provided by the District was based on the 1/3 arc second resolution of 10 meters (~30 feet).
- DTM is effectively a DEM that represents the elevation of the "bare earth" without taking into account any overground features (e.g. trees, buildings) and augmented by elements such as breaklines and observations other than the original data to correct for artifacts produced by using only the original data.

The three elevation data sources were evaluated and compared. As a result, the DTM data was used for updating the model node elevation because it is the most accurate.

4 Demand Allocation

Accurate demand allocation is one of the most important factors impacting model calibration. Model demands were developed and allocated based upon historical billing data and geocoded customer meter points provided by the District. Each customer point in GIS was given an "average" consumption in gallons per minute (gpm) based on 2016 historical billing data. This consumption data was spatially allocated to the hydraulic model junctions using GIS meter point data and the hydraulic model software functionality. This process provides high demand allocation accuracy which generally translates to better model calibration.

4.1 Existing Demands

Demand data was processed for each customer account to determine the individual and system (EG/LR/CS) average day demand (ADD) using 12 consecutive months of usage data provided by the District. The usage data contained the customer account and bi-monthly meter readings. The bi-monthly meter readings were averaged for the 2016 time period to create an ADD for each metered account. The individual demands were allocated to model junctions by first matching the individual customer ADD to the service meter feature class points in GIS. A total of 99.58 percent of the billing accounts was used in the demand allocation. There are 57 accounts in the consumption data with a total demand of 6.6 gpm that did not exist in GIS meter layer. Those accounts were located using the parcel number and allocated to the nearest node in the model. **Table 5** summarizes the consumption data and ADD by system.

Table 5 – Summary of Water ADD Consumption by System

System	Consumption Demand (gpm)	Plant Production		Water Loss Factor (%)
		(MG/Year)	(gpm)	
Cascade Shores[(1)]	41	28	53	23
E. George[(2)]	1406	334	2289	16
Loma Rica[(2)]	1057	1203	635	
Total	**2504**	**1565**	**2977**	

(1) For this evaluation Cascade Shores was a separate system with its own WTP, it became part of the EGeorge system in 2017
(2) EGeorge and Loma Rica systems are interconnected

GIS meter layer showed more customer accounts than consumption. Visual inspection using aerial photography shows lines are extended to serve some of those customers and some are adjacent to existing customers.

Figure 2 shows the monthly water treatment plants production by system. It is worth noting that since 2017 Cascade Shores WTP is no longer in service, and Cascade Shores system is served from EGeorge.

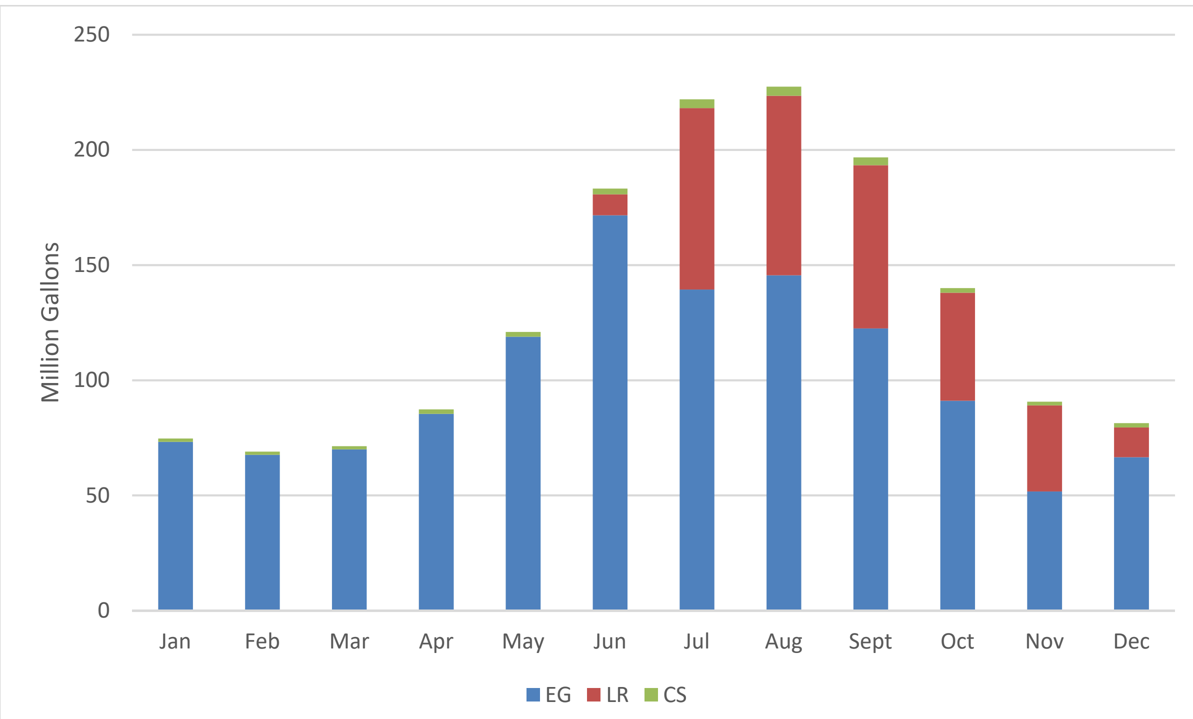

Figure 2 – 2016 Monthly Water Treatment Plants Production

Table 6 summarizes the customer accounts and their demands by system.

Table 6 – Total Demands by System

System	Demand (gpm)	Average Demand per Customer (gpm)	Number of Customers			Demands		
			Billing	GIS	In GIS Not in Billing	In GIS Not in Billing (gpm)	Total Consumption Demand (gpm)	Total Demand with Water Loss (gpm)
Cascade Shores	41	0.10	374	392	19	1.9	43	54
E. George	1,406	0.10	5,245	5,710	344	34.4	1,440	1,712
Loma Rica	1,057	0.10	4,937	4,968	186	18.6	1,076	1,286

The demand for the customers listed in GIS but not in billing data was estimated based on the annual average customer demand in each system which was 0.10 gpm.

4.1.1 Existing Demand Allocation

The customer meter consumption shapefile was spatially allocated to model junctions by system using the closest pipe methodology in InfoWater™'s demand allocator add-on tool. This tool calculates the pipe lengths on either side of where the meter would perpendicularly intersect the nearest pipe. These two lengths are used to proportionally split the demand between the pipe nodes. In addition, allocating demand by system reduces mistakes especially in areas near the boundaries. This process provides high accuracy of demand allocation which generally translates to better model calibration.

Consumption customer classes were preserved in the model by keeping each customer class in a separate demand field as shown below.

Model Demand Field	Customer Class
Demand1	Residential
Demand2	Commercial
Demand3	Unknown

Table 7 shows the 2016 demands by system that were allocated to the model nodes.

Table 7 – Existing Modeled Demands by System

System	Average Day Demands Including Unaccounted-for Water			
	Demand1[(1)] (gpm)	Demand2 (gpm)	Demand3 (gpm)	Total Demand (gpm)
Cascade Shores[(1)]	54	0.2	0	54
E. George[(2)]	1,269	427	16	1,712
Loma Rica[(2)]	1,108	172	6	1,286
Total	**2,430**	**599**	**22**	**3,052**

(1) Unaccounted-for water for Cascade Shores is 23%
(2) Unaccounted-for water for EGeorge and Loma Rica is 16%

5 Model Calibration

The hydraulic model calibration is performed to enhance the accuracy of the model, provide a planning tool that can be used to identify system deficiencies, and recommend pipelines and facilities improvement to address system deficiencies. Model calibration is the process of comparing model results with field results and making model modifications where appropriate and reasonable to simulate the field results as closely as possible. Typical adjustments include system connectivity, operational controls, facility configurations, diurnal patterns, elevations, etc. Several indicators are utilized to determine if the model accurately simulates field conditions: water levels in storage tanks, the run times for pumps, static and residual pressures from the fire flow tests, and roughness coefficients for pipelines. This also acts as the "debugging" phase for the hydraulic model where any modeling discrepancies or data input errors are discovered and corrected. The hydraulic model is calibrated for two scenarios:

- Steady-State Calibration: Simulating fire hydrant flow tests to match field results (November 14 and November 21, 2017)
- 24-hour EPS Calibration: Modifying the model until the trends closely match the field operations on the day of calibration (November 15, 2017)

5.1 Steady-State Model Calibration

The purpose of the steady-state model calibration was to adjust pipe roughness values to more closely match the head losses and pressures observed during hydrant tests. Based on the hydrant flow test data, the observed pressure drop at the residual hydrant over the duration of the test is related to the diameter and roughness of the pipe near the tested hydrants. This relationship is the basis for the adjustments in roughness values made during model calibration.

The model was calibrated based on nine (9) hydrant tests performed at locations throughout the EG/LR/CS systems. Based on the difference in hydrant pressure drop between the model and field data, pipeline roughness coefficients (Hazen-Williams C-values) were adjusted in the model which is described in more detail in subsequent sections.

5.1.1 Hydrant Flow Tests

The District staff conducted hydrants flow tests and collected data on November 14 and 21, 2017 at nine (9) locations across the EG/LR/CS systems. One location was tested in the Cascade Shores system, 4 locations in the EGeorge system, and 4 locations in the Loma Rica system. **Figure 3** shows the locations of the hydrant tests used for model calibration.

The specific locations were identified based on the following characteristics: 1) not too close to a reservoir or a pump station; 2) on a 6-, 8-, or 10-inch pipe – for larger diameter pipes, it is difficult to generate sufficient head loss during a hydrant test to detect changes due to pipe roughness; and 3) accessibility and safety considerations for staff conducting the tests.

At each of the test locations, one hydrant was selected as the flow hydrant and one adjacent hydrant was selected as the observation hydrant to measure the residual pressure. A static pressure reading was first taken at the observation hydrants. Then, the flow hydrant was opened. While the flow hydrant was opened and flowing, the pressure at the observation hydrant and the flow at the flow hydrant were recorded.

5.1.2 Model Input for Calibration

The District provided the hydrant test data and distribution system SCADA data for the hydrant testing period. This data included storage tank levels, pump on/off status, and water treatment plants production rates. This data was used in the model to set the boundary conditions to simulate actual system conditions during each hydrant test.

One calibration scenario was set up with 18 timesteps to simulate the 9 hydrant tests (one location was tested with two different system conditions). Each hydrant test comprised two timesteps of the model run. The first timestep of each hydrant test represented static conditions before the hydrant was turned on. The second time step represented residual conditions when the hydrant was flowing.

For each hydrant test (or every two timesteps), system demands, relevant pump operations and relevant tank levels were set to represent conditions at the time of the hydrant test. The appropriate multiplier from the diurnal curve was used to simulate the demands at the time of each hydrant test. Because the diurnal curve used in the model is general for the entire system, model demands are expected to approximate actual demands at the time of the test, which were not known.

The 2016 weekly total water production of the Cascade Shores, EGeorge, and Loma Rica water treatment plants was used as the basis for the SS calibration days (November 14 and 21, 2017) demand which was calculated to be 2,269 gpm assuming system demands for 2016 and 2017 are similar. This is equal to 0.90 times the ADD (2,507 gpm).

TEST_ID	HYD_ID	LOCATION
CS	H2555	Gold Bug Rd
CS-1	H1702	Yuba Clos
EG-1	H1482	Willow Valley Rd/Hill Creek Dr
EG-1_1	H1480	Coyote Ct & Willow Valley Rd
EG-2	H2356	Indian Trl & Woods Ravine Ct
EG-2_1	H2355	Indian Trl & Woods Ravine Ct
EG-3	H1381	Woodpecker Way
EG-3_1	H1382	Woodpecker Way
EG-5	H1454	Shangrila Ln
EG-5_1	H1455	Polaris Dr
LR-1	H791	Meadow Dr/High Sierra Way
LR-1_1	H2500	Meadow Dr/Octagon Ln
LR-3	H2377	Alta Sierra Dr.
LR-3_1	H323	Henson Way
LR-4	H2362	Fay Rd
LR-4_1	H35	Fay Rd/Janet Way
LR-5	H376	Geneva Ct
LR-5_1	H369	Willis Dr/Patricia Way

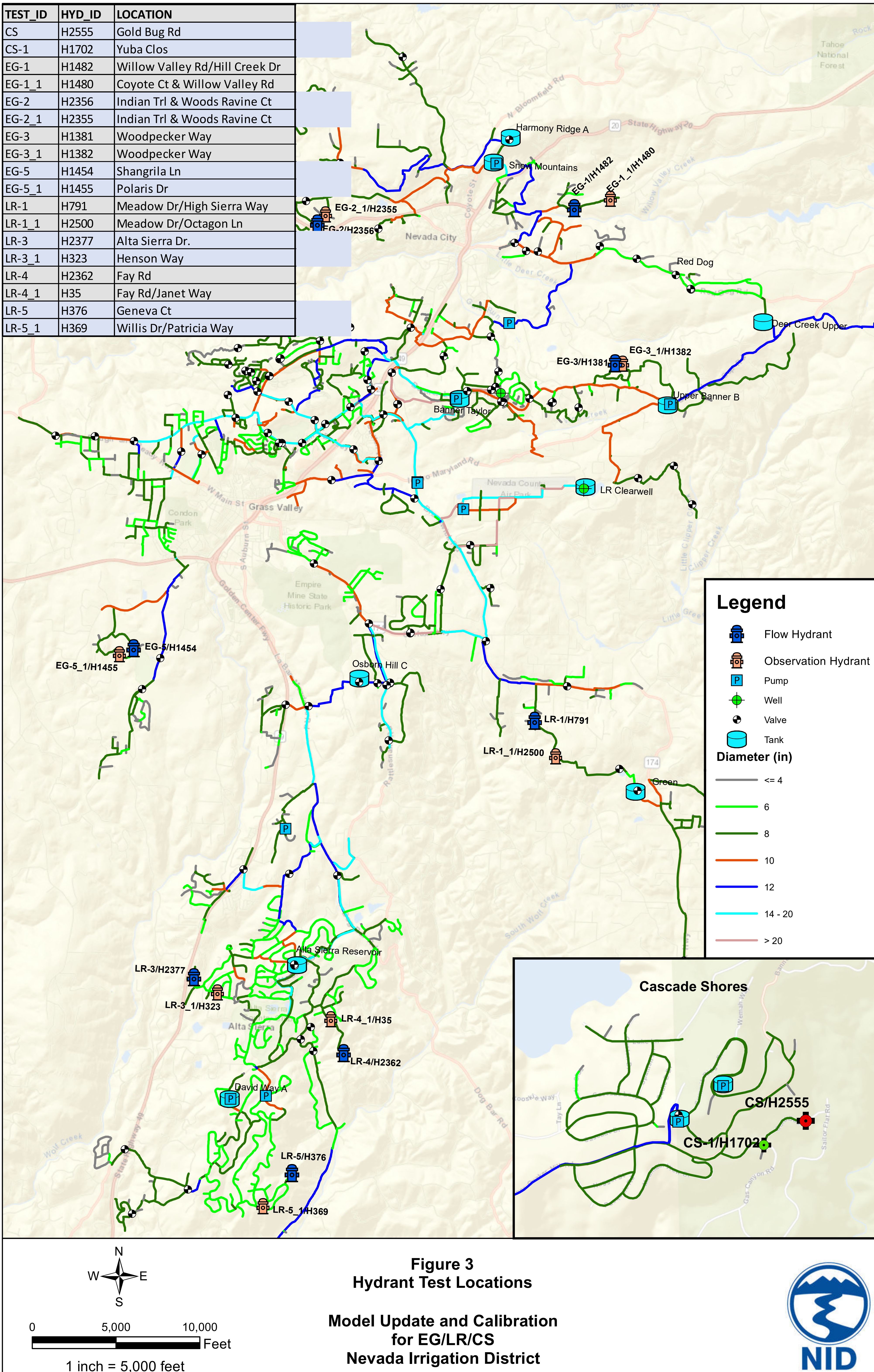

Figure 3
Hydrant Test Locations

Model Update and Calibration for EG/LR/CS Nevada Irrigation District

5.1.3 Calibration Method

Pipe roughness values in the model are represented by the Hazen-Williams roughness coefficient, or C-value, which is inversely proportional to head loss. High C-values correspond to relatively smooth pipes with small head losses. Most pipelines in good condition or with interior linings have C-values ranging from 120 to 140. Pipelines with extensive corrosion, such as unlined cast-iron mains, could have C-values as low as 70 or 80 which corresponds to relatively rough pipes with higher head losses. During the calibration process, in areas where modeled pressure drops were larger than observed pressure drops, the C-values are increased, and vice versa.

The roughness factors in the current model were used as a starting point for the calibration process. Those factors (C-values) were adjusted as needed during model calibration process described in the subsequent sections. The current (starting) and recommended (final) roughness factors based on the calibration findings are presented later in this memorandum.

Once the calibration model scenario was set up using system data provided by the District, each test location was analyzed for the following two conditions (two timesteps):

- With no flow at the hydrant location to simulate closed hydrant or “static” conditions
- With a demand equal to the hydrant flow applied at the hydrant location to simulate flowing hydrant conditions.

Modeled static pressures were also compared with actual (observed) static pressures. However, these comparisons were not used for calibration purposes because, under low flow conditions, modifying roughness values does not produce a large change in static pressure. An error in static pressure is most likely due to another source, such as errors in ground elevation or inaccurate field measurement.

Locations where large differences in static pressure were observed are noted as areas requiring potential future refinement (in the summary table of calibration results discussed later in this section).

Once model results were checked, the difference in pressure between the two runs (non-flowing hydrant and flowing hydrant) was compared with the pressure drop observed during hydrant testing. By comparing the pressure drop rather than modeled and measured pressures, potential errors due to incorrect model elevations were eliminated.

In some instances, model results could not be adjusted to obtain results within ± 5 psi of observed values, without selecting unrealistic Hazen-Williams C-values. Some possible sources of error that may cause poor agreement between modeled and observed pressures include: errors or anomalies in physical model data, node elevation errors, uncertainties in estimated pipe roughness factors, not having complete information on system conditions during the field tests, and poorly calibrated measuring equipment. For locations with significant differences between modeled and observed pressures, the following steps were taken to investigate the source of differences:

- Elevation verification – checked node and reservoir elevations in the model
- Geometric verification – checked for missing pipes or incorrect diameters in the model

- Distribution of supply from tanks and pumps was then investigated, to see whether the results may have been affected by the way these sources are modeled

For tests where the pressure difference was still significant after conducting the above three steps, Sedaru recommends further field investigations or possibly repeat the hydrant test with calibrated equipment.

5.1.4 Calibration Criteria

The calibration process consisted of changing pipe roughness values until the difference between observed and modeled pressure drops reached a minimum or acceptably low value. The model was considered to be calibrated when the modeled pressure drop was within ± 5 psi of observed pressure drops at two or more observation locations. This is the AWWA Engineering Computer Applications Committee recommended criterion for model calibration for models to be used for planning applications[1]. Generally, roughness factor adjustments were made to groups of pipes based on pipe material and diameter. **Table 8** summarizes the steady state calibration criteria.

Table 8 – Steady-State Calibration Criteria

Pressure Drop (psi)	Match
0 - 3	Excellent
3 - 5	Good
5 - 10	Fair

5.1.5 Calibration Results

During the calibration process, revisions were made to the model as needed to adjust the pipe roughness factors to reasonable values. **Table 9** summarizes the results from the calibration analysis after reasonable adjustments were made to the model. **Figure 4** shows the pressure comparison at the observation hydrants.

Field information provided by the District listed in the table includes: test location, test date and time, hydrant outlet size, measured static pressure and measured residual pressure. The nearest model node was selected or a model node was added, if needed, to represent the hydrant location.

[1] AWWA Engineering Computer Applications Committee, 1999. “Calibration Guidelines for Water” Distribution System Modeling ”1999 AWWA Information Management Technology Conference Proceedings”.

Table 9 - Summary of Hydrant Flow Test Data and Calibration Results

			DTM Data	Field Data						Model Data					ΔP Comparison			
Test	**Zone**	**Hydrant Location (Hydrant #)**	**Elevation**	**Test Date**	**Test Time**	**Hydrant Type**	**Static Pressure**	**Residual Pressure**	**ΔP = Static - Residual**	**Model ID**	**Model Fire Hyd Flow**	**Static Pressure (psi)**	**Residual Pressure (psi)**	**ΔP = Static - Residual (psi)**	**Static (Model-Field) (psi)**	**ΔP (Model - Field) (psi)**	**Matching Level**	**Static Pressure Comments**
1	13	Gold Bug Rd (H2555)	3188	11/14/2017	8:53 AM	Flow	110			F1011	401	104	98		-6			
		Yuba Clos (H1702)	3214			Observation	100	88	12	F1009		92	89	4	-8	-9	Fair	A static pressure of 100 psi corresponds to an HGL of 3445 ft which is higher than the tank HGL at 3427 ft.
2	35	Willow Valley Rd/Hill Creek Dr (H1482)	2596	11/21/2017	10:45 AM	Flow	144			F3139	405	147	142	6	3			
		Coyote Ct & Willow Valley Rd (H1480)	2722			Observation	94	87	7	J312		92	87	6	-2	-1	Excellent	Changed C-value for DI from 125 to 100
3	79	Indian Trl & Woods Ravine Ct (H2356)	2603	11/14/2017	11:33 AM	Flow	150			J314	401	144	124	20	-6			
		Indian Trl & Woods Ravine Ct (H2355)	2635			Observation	144	122	22	F1564		130	111	19	-14	-3	Excellent	Changed C-value for DI from 125 to 100
4	5	Woodpecker Way (H1381)	3275	11/14/2017	12:35 PM	Flow	68			J316	300	63	60	3	-5			
		Woodpecker Way (H1382)	3279			Observation	62	54	8	F1744		61	58.17	3	-1	-5	Good	Adjusting C-values imporved the results slightly by less than 0.5 psi. The difference could be attributed to inaccurate field flow measurements or partiallly closed valves
5	83	Shangrila Ln (H1454)	2364	11/14/2017	2:00 PM	Flow	160			F3078	503	152	113	39	-8			
		Polaris Dr (H1455)	2361			Observation	152	112	40	J318		153	116	38	1	-2	Excellent	
6	12	Meadow Dr/High Sierra Way (H791)	2782	11/21/2017	8:35 AM	Flow	99			F3422	500	93	86	7	-6			
		Meadow Dr/Octagon Ln (H2500)	2860			Observation	66	60	6	J320		59	52	7	-7	1	Excellent	
7	2	Alta Sierra Dr. (H2377)	2000	11/21/2017	9:50 AM	Flow	182			F3867	502	153	133	20	-29			-A static pressure of 182 psi corresponds to an HGL of 2420 ft which is higher than the Alta Sierra tank HGL at 2353 ft -The difference in static pressure between Flow Hyd and Obs hyd is 82 psi (189 ft) actual elevation difference is 120 ft
		Henson Way (H323)	2120			Observation	100	94	6	J322		101	96	5	1	-1	Excellent	
8	2	Fay Rd (H2362)	2034	11/21/2017	12:20 PM	Flow	120			F3767	501	138	124	15	18			The difference in static pressure between Flow Hyd and Obs hyd is 50 psi (116 ft) actual elevation difference is 175 ft
		Fay Rd/Janet Way (H35)	2209			Observation	70	64	6	F3769		63	55	8	-7	2	Excellent	
9	50	Geneva Ct (H376)	2049	11/21/2017	1:10 PM	Flow	120			F4051	501	167	133	34	47			The difference in static pressure between Flow Hyd and Obs hyd is 14 psi (32 ft) actual elevation difference is 140 ft
		Willis Dr/Patricia Way (H369)	2189			Observation	106	86	20	F4049		106	85	21	0	1	Excellent	

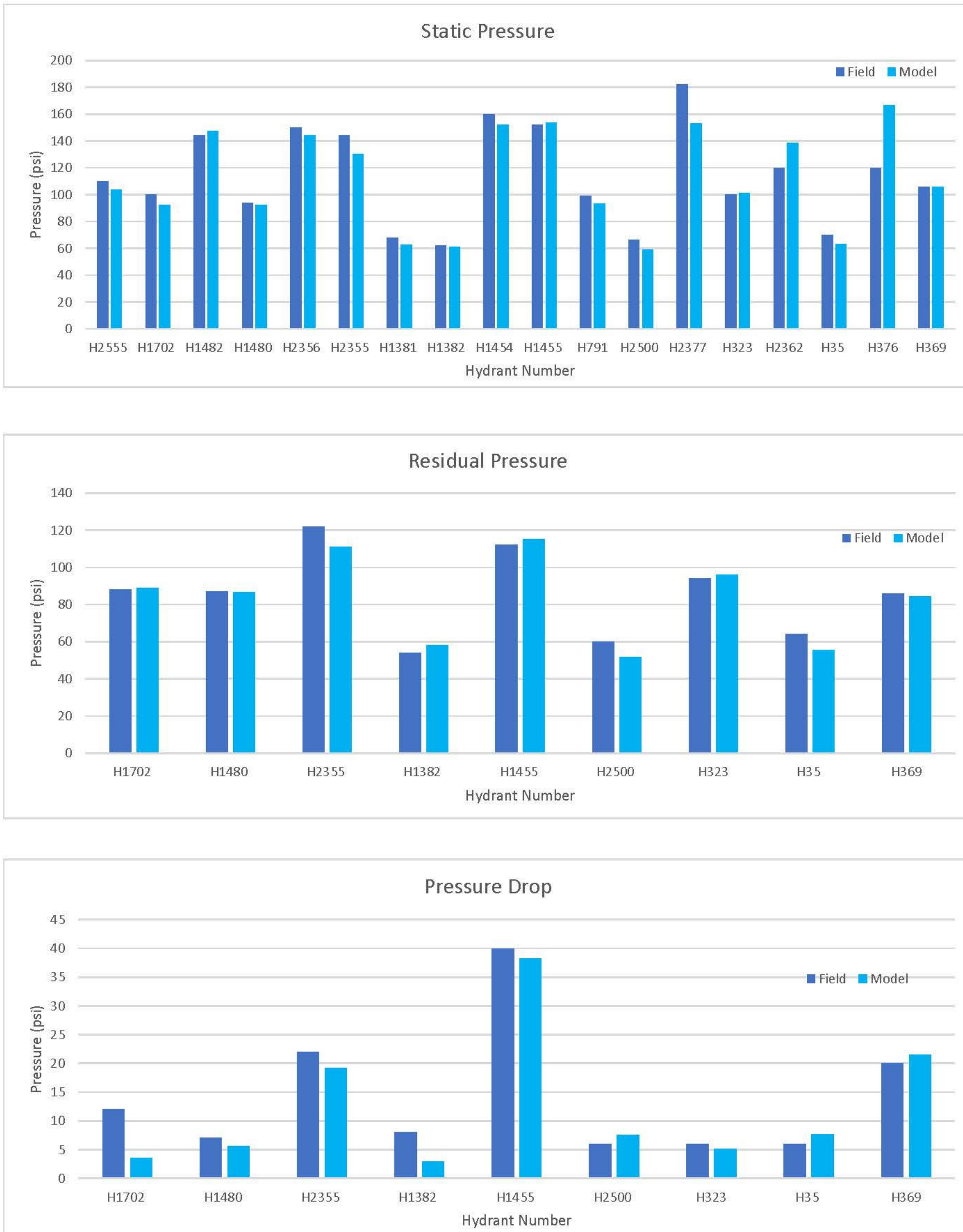

Figure 4 – Pressure Comparison at Observation Hydrants

Table 9 also shows key model results for flows and pressures. The last two columns of the table present the comparison of the measured and modeled static pressure and the comparison of the measured and modeled residual pressure drops as well as the matching levels.

Model results were considered to match field data well if the field measured pressure drop and the modeled pressure drop were within 5 psi. The overall calibration results based on the available data indicate that the model is a reasonable representation of the system. Eight (8) out of nine (9) test locations were within 5 psi of the measured pressure drop. The two locations with discrepancies are discussed below in detail. The discrepancies may be due to inaccuracy of field measurements or lack of detailed information on system operations on the test day.

The additional information below addresses the issues identified in the initial calibration model runs:

Cascade Shores System

<u>Hydrant H2555</u>

Model results showed a smaller pressure drop than the field results at observation hydrant H1702 along Yuba Close at Gas Canyon Road. The measured pressure at this observation hydrant of 100 psi corresponds to a hydraulic grade line (HGL) of 3,445 ft which is higher than the HGL at Sargent Jacobs Tank of 3,427 ft. The observed pressure drop was 12 psi compared to 3 psi predicted by the model. The difference in pressure drop is 9 psi which is too high to be accounted for by adjusting C-values. The higher pressure drop in the field could be attributed to partially closed valves, inaccurate flow measurement, or uncalibrated equipment.

EGeorge System

<u>Hydrant H1381</u>

Adjusting the C-value of 4,680 feet of DI material from 125 to 100 along Banner Lava Cap Road improved the pressure only by 0.5 psi. At a hydrant flow of 300 gpm, the model is predicting a pressure drop of 3 psi compared to 8 psi field measured drop. The C-value has to be very low and beyond reasonable limits to achieve a closer match. As a result, the difference is not due to C-value, but most likely due to field conditions such as partially closed valves.

5.1.6 Roughness Coefficient (C-Values)

Based on the calibration analysis, C values in the model were adjusted to improve the agreement between the observed field data and predicted model results. For each calibration location, adjustments to pipe roughness were compiled taking into account the diameter and material. Adjustments to C-values were then applied to pipes with the same attributes in that pressure zone.

Table 10 summarizes the initial C-Values that were used as a starting point for the model calibration. **Table 11** summarizes the recommended overall roughness values, which are based on the calibration analysis, and are also consistent with the reasonable values typically specified in standard references.

The ranges shown in **Table 11** are due to the fact that the C-value varies between zones based on the results of the calibration adjustments. For example, the C-value for an 8-inch asbestos cement pipe in one zone may be different than that for an 8-inch asbestos cement pipe in another zone.

Table -10 Initial Roughness Coefficient (C-value)

Material	Current Model Initial Roughness Coefficient (C-value)															
	Diameter (in)															
	1.5	2	3	4	6	8	10	12	14	16	18	20	24	30	36	42
ABS	-	-	-	120	-	-	-	-	-	-	-	-	-	-	-	-
AC	-	-	-	125	120-130	120-125	125	120-125	-	-	-	-	125	125	-	-
BBP	-	-	-	120	120	-	-	-	-	-	-	-	-	-	-	-
CCP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	120
CI	-	-	120	85	85	70-85	85	85	-	-	-	-	-	-	-	-
CML	-	-	-	-	122	122	-	-	-	-	122	-	-	-	-	-
DI	-	130	-	125-130	120-130	120-130	50-130	85-130	-	125	125	125	125	125	125	-
HDPE	-	120	-	120	120	120	-	-	120	125	-	-	-	-	-	-
Plastic	-	120	-	-	120	-	-	-	-	-	-	-	-	-	-	-
POLY	120	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PVC	120	120	120-125	70-125	70-125	70-125	120-125	85-125	-	120-125	120	-	-	-	-	-
STL	-	70	-	70	70	70-120	70	70	70	70	70	70	70	70-120	-	70
UNKN	-	120	-	120	120	120	120	-	120	120	-	120	120	-	-	71

Table 11 - Adjusted Roughness Coefficient (C-value) Based on Calibration Analysis

Material	Adjusted Roughness Coefficient (C-value)															
	Diameter (in)															
	1.5	2	3	4	6	8	10	12	14	16	18	20	24	30	36	42
ABS	-	-	-	120	-	-	-	-	-	-	-	-	-	-	-	-
AC	-	-	-	125	120-130	100-125	125	100-125	-	-	-	-	125	125	-	-
BBP	-	-	-	120	120	-	-	-	-	-	-	-	-	-	-	-
CCP	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	120
CI	-	-	120	70-85	85-120	85-120	85	85	-	-	-	-	-	-	-	-
CML	-	-	-	-	122	122	-	-	-	-	122	-	-	-	-	-
DI	-	130	-	125-130	100-130	100-130	100-130	85-130	-	100-125	125	125	125	125	125	-
HDPE	-	120	-	120	120	120	-	-	120	125	-	-	-	-	-	-
Plastic	-	120	-	-	120	-	-	-	-	-	-	-	-	-	-	-
POLY	120	120	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PVC	120	120	120-125	70-125	70-125	85-125	120-125	85-125	-	120-125	120	-	-	-	-	-
STL	-	70	-	70	70	70-120	70	70	70	70-90	70	70-100	70	70-120	-	70
UNKN	-	120	-	120	120	120	120	-	120	120	-	120	120	-	-	71

Note: Red indicates adjusted Roughness Coefficient (C-value)

5.2 Extended Period Simulation Model Calibration

The purpose of EPS calibration is to compare the model results with the actual field measurements over a specified time period, usually 24 – 48 hours. If the model is reasonably accurate, modeled pump station flows and suction and discharge pressures should match field measured flows and pressures, and modeled reservoir levels should track measured levels.

Depending on the data available, different levels of verification can be performed. Where detailed information is available (zone inflows, outflow and reservoir levels), it allows calculation of pressure zone demands, and hourly zone demands can be calculated. The model is then set up to reproduce both observed demands and operating conditions (pump starts/stops), and model results are reviewed to determine how well the model predicts zone operations (pump station flows, suction and discharge pressures, reservoir levels). Similarly, if pump station flow, suction and discharge pressure information is available, the pump total dynamic head and flow, based on measurements, can be compared with pump performance in the model, and model results adjusted to get the best fit of actual pump performance conditions.

Where system information is incomplete and a specific diurnal curve for the zone cannot be constructed, the model is run for a 24-hour period with the daily system demand set to match actual daily demand, and model trends are reviewed for consistency with operating data, recognizing that hourly trends may differ from observed. Although this comparison is more qualitative, the model's ability to represent observed conditions can still be assessed by evaluating parameters such as reservoir level operating ranges, and degree of cycling, to determine consistency with observed conditions.

Because flows are not recorded at all pump stations or regulating stations in the District's system, the model calibration used the second approach discussed above. The calibrated static hydraulic model was run for EPS and compared with historical operating data. After data review, November 15, 2017 was selected as the calibration day due to the most complete data and more active facilities. The total demand for EG/LR/CS is 1,910 gpm based on the weekly plant productions. Historic operating conditions were simulated on that day using system data provided the District.

5.2.1 EPS Model Input for Calibration

The District provided system data for the selected day for use in the calibration. This field data included the following:

- The weekly total water production of the Cascade Shores, EGeorge, and Loma Rica water treatment plants was used as the basis for the EPS calibration day (November 15, 2017) demand which was calculated to be 1,910 gpm. This is equal to 0.76 times the ADD (2,507 gpm). Since no daily plant production data was available, the demand for the EPS calibration day was established during the calibration process to match SCADA data and was estimated to be 2,092 gpm (0.83 times ADD).
- For tanks where SCADA data was available, electronic files were provided showing water elevation data. Electronic data was recorded at 15-minute intervals.
- For pump stations where SCADA data was available, electronic files were provided showing:
  - Flow data – electronic data was recorded at 15-minute intervals

- Current pressure settings at the PRV stations
- Normal booster pump station operational controls

5.2.2 Diurnal Pattern

A diurnal pattern is required for extended period simulations. A diurnal pattern shows the hourly variations in customer demand (hourly peaking factors) over a 24-hour period. Diurnal patterns are typically developed from historic hourly flow data that is analyzed to determine variations in customer demands that have been adjusted to account for flows going into storage or passed through to other zones, i.e. during parts of the day, some flows in the system may be going to re-fill storage rather than to meet customer demands.

Since there was no detailed system specific information available to develop a diurnal pattern by system, the SCADA tank level data and the estimated flow rates for Norlene Pump Station and David Way Pump Station provided by the District were reviewed to develop a diurnal curve.

A water balance was completed for the David Way Zone to estimate the hourly demand multipliers by balancing flow in and out of the zone. By viewing the July 2016 water balance data with each day plotted on the same chart, a demand pattern was identified from the data. **Figure 5** shows the demand curve estimated from viewing multiple days on the same graph. There is noise in the data, but a clear trend can be identified where multiple days experienced demands in similar magnitude at the same times. **Figure 6** shows the demand curve normalized into demand multipliers which were applied to the model. The peak hour multiplier is 2.0 on the 24-hour diurnal curve which is consistent with existing criteria established with the District.

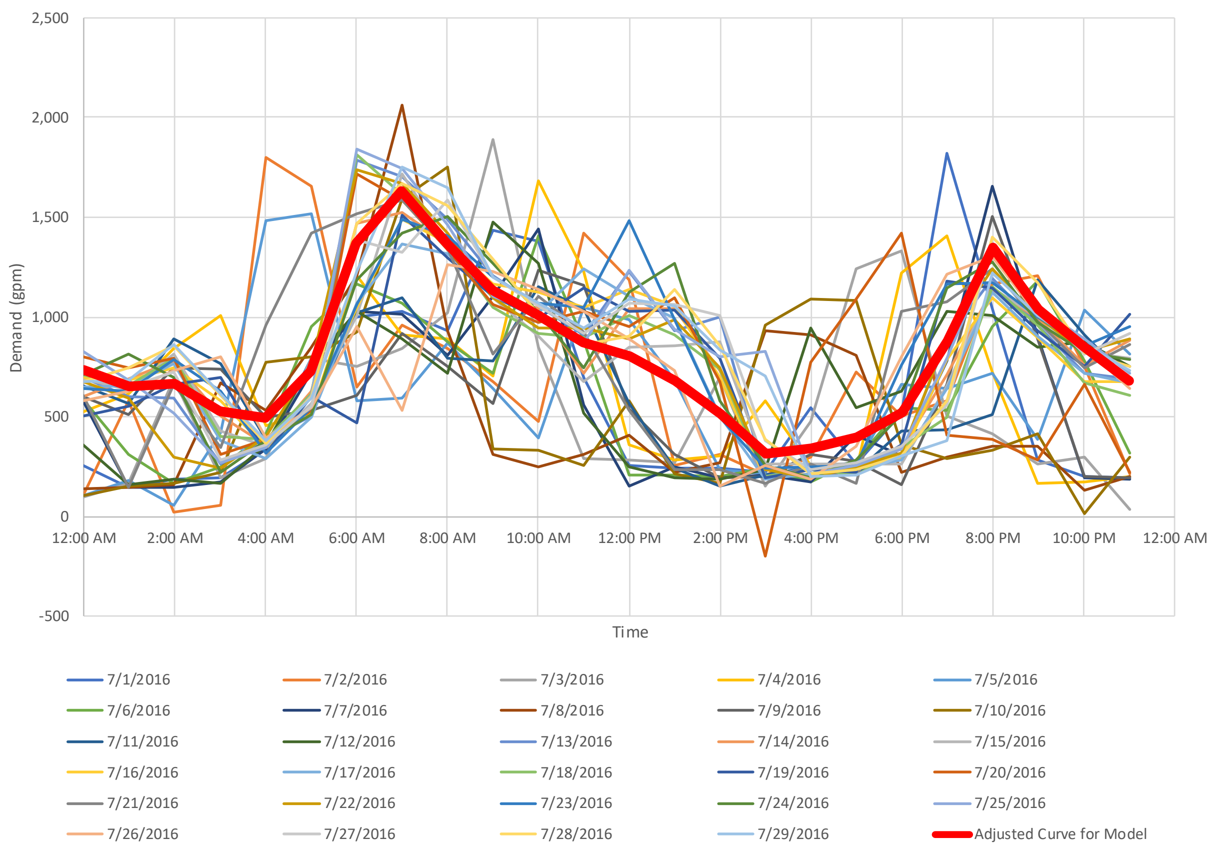

Figure 5 – David Way Water Balance and Estimated "Typical Demand"

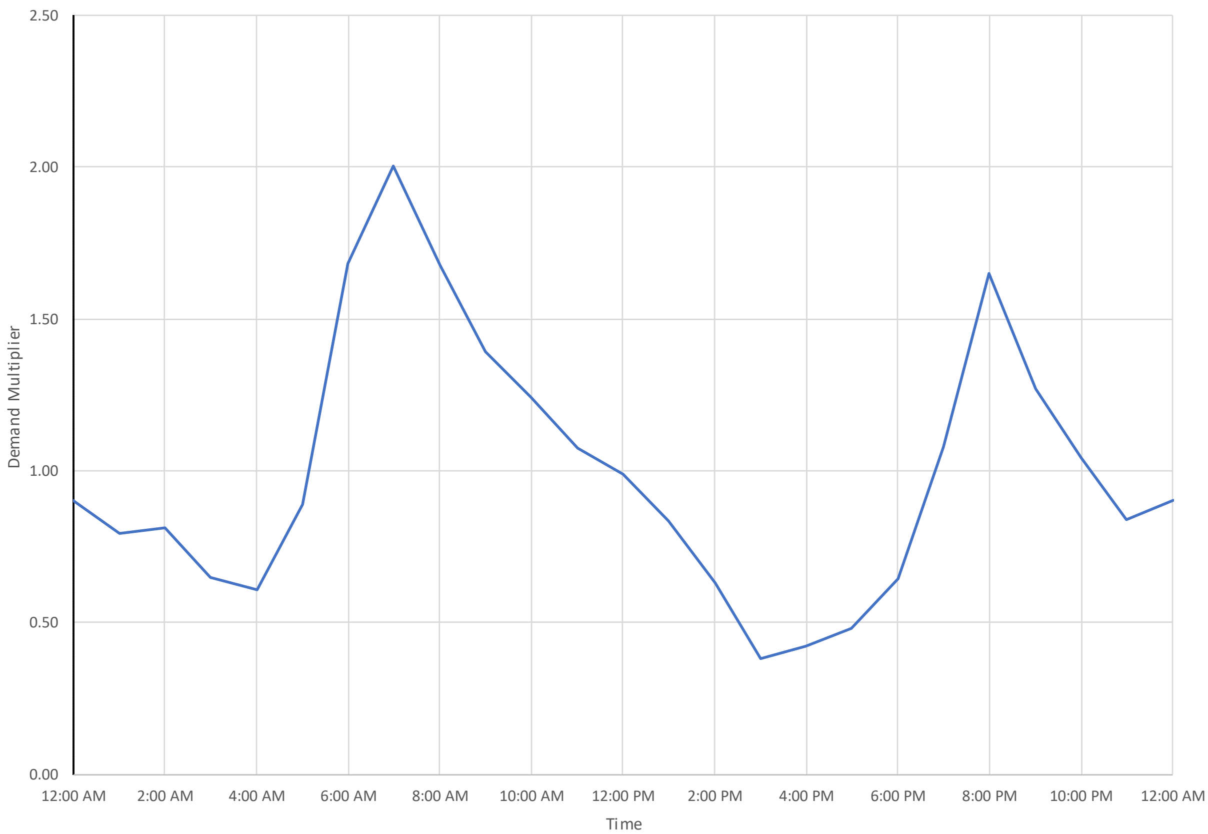

Figure 6 – David Way Normalized Diurnal Pattern "Typical Demand"

5.2.3 EPS Calibration Method

To consider the model to be an accurate representation of the physical system, modeled pump station flow, suction and discharge pressures should reasonably match the observed field measurements, and modeled reservoirs should operate within similar levels and cycling frequencies as observed conditions in the field data. The calibrated model from the hydrant test calibration was used for the EPS calibration runs.

The 24-hour simulation was set up to represent the selected day conditions using the system data provided by the District. Available SCADA data for pump flows and reservoir level trends were used as the basis of comparison. The calibration analysis evaluated whether the modeled results generally tracked the observed system performance trends in the field data.

Comparisons consisted of evaluating reservoir levels and cycling trends for consistency with operating data and comparing modeled pump station flows with observed. Where differences were observed, adjustments were made to model pump flow-head curves and station elevations to better match field data.

5.2.4 EPS Calibration Criteria

In general, definitive standards to assess the accuracy of model calibration for water distribution system have yet to be agreed upon or established. However, based on experience and common practice general criteria was established to assess the accuracy of the model calibration. Model calibration can be considered achieved when the difference between model output and field data were within the tolerances listed in **Table 12**. In the event that these tolerances could not be met, an explanation was provided justifying why calibration could not be achieved. **Table 12** summarizes the extended period simulation criteria.

Table 12 – EPS Calibration Criteria

Matching Level*
1 – Both trend and magnitude don't match/differ significantly
2 – Trend or magnitude somewhat match
3 – Trend and magnitude both somewhat match
4 – Trend or magnitude matches very well
5 – Trend and magnitude both match very well
*Matching level is an indicator of how well model results match field data in terms of trends, high and low range, slope of curves, etc. Match Levels are ranked from 1 to 5. One (1) is the lowest ranking and five (5) is the highest.

5.2.5 EPS Calibration Results

The model results were compared with the field data to determine if the model reflects the actual system operating conditions over a 24-hour period. Overall, the model results matched field results reasonably well over the calibration period. The water level fluctuations predicted by the model were all within 1 foot of those recorded in SCADA. For the available two pump stations, the pump flows predicted by the model are within less than 5% of those recorded in SCADA.

Figure 7 shows as an example of an EPS calibration tank level comparison at Upper Banner. All other calibration plots are presented in Appendix A**.**

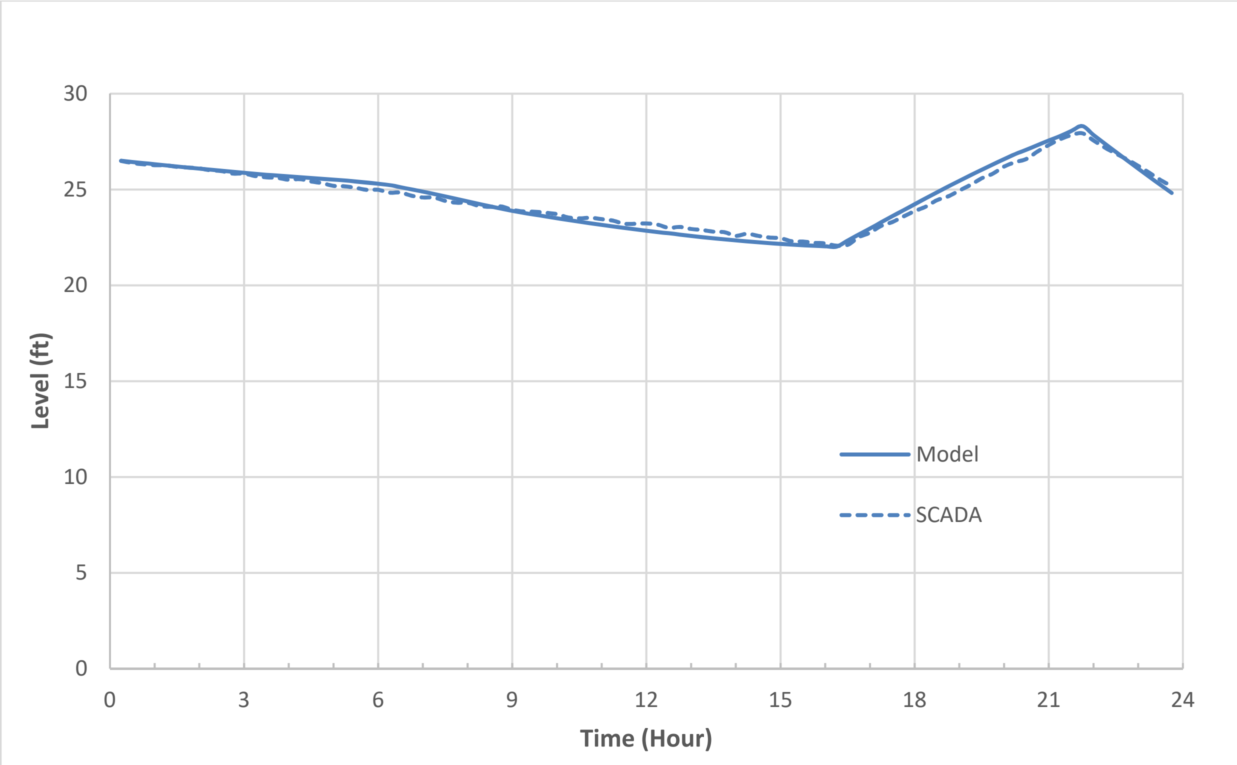

Figure 7 – Upper Banner Tank Level

Table 13 presents the matching level results from the calibration runs for reservoirs and pump stations where SCADA data was available.

Table 13 – Summary of EPS Calibration Results

Facility Description	System	Matching Level	Available SCADA Data
Tanks			
Banner Taylor Equivalent Tank	EGeorge	N/A	No
Deer Creek Upper B and A (Equivalent Diameter)	EGeorge	N/A	No
Harmony Ridge A	EGeorge	N/A	No
Snow Mountain B and A (Equivalent Diameter)	EGeorge	5	Yes
Upper Banner B	EGeorge	5	Yes
Cascade Shores Sargent Jacobs A & B Equivalent	Cascade Shores	5	Yes
Alta Sierra Reservoir	Loma Rica	5	Yes

Facility Description	System	Matching Level	Available SCADA Data
Cascade Shores Upper Tank	EGeorge	N/A	No
volume of A B and C, 4.2 MG	Loma Rica	N/A	No
David Way A	Loma Rica	5	Yes
Green Tank	Loma Rica	N/A	No
Loma Rica Clearwell A & B Equivalent	Loma Rica	5	Yes
Pump Stations			
Sargent Jacobs Pump Station	Cascade Shores	N/A	No
Joe Day Booster Station	EGeorge	5	Yes
Upper Banner Pump Station	EGeorge	5	Yes
Banner Taylor Pump Station	EGeorge	N/A	No
Snow Mountain Pump Station	EGeorge	N/A	No
Summit Ridge Pump Station	EGeorge	N/A	No
Charles Drive Pump Station	Loma Rica	N/A	No (OFF)
David Way Pump Station	Loma Rica	N/A	No
Brunswick Booster Station	Loma Rica	N/A	No (OFF)
Norlene Booster Station	Loma Rica	N/A	No
Sweet Haven Pump Station	Loma Rica	N/A	No (OFF)

6 Evaluation of Operational Scenarios

The steady-state and EPS calibrated model was used to evaluate operational scenarios to move water between EGeorge system and Loma Rica system. The EGeorge WTP has a maximum capacity of 18 mgd, and Loma Rica WTP has a maximum capacity of 8 mgd. However, based on recent plant operations and physical configuration constraints the EGeorge WTP is limited to 12 mgd and Loma Rica is limited to 6.5 mgd. Table 14 summarizes the MDD and ADD by system. Lake of Pines (LoP) system demands were included for water transfer from the Loma Rica system under low demand conditions.

Table 14 – Summary of System Demand

System	MDD(1)		ADD(2)	
	(gpm)	(mgd)	(gpm)	(mgd)
EGeorge	5,498	7.9	2,199	3.2
Loma Rica	3,929	5.7	1,572	2.3
Lake of Pines	2,073	3.0	829	1.2
Total	**11,500**	**16.6**	**4,600**	**6.6**

(1): MDD is computed based on the maximum month production of 2011

(2): ADD is computed as MDD divided by 2.5

For this evaluation the following EPS scenarios were considered:

- Baseline scenario using MDD to establish system performance and balance system storage
- Transfer water during MDD from EGeorge system to Loma Rica through Brunswick Pump Station
- Transfer water during MDD from Loma Rica system to EGeorge system through the bypass at Brunswick Pump Station
- Supply the entire system during ADD from EGeorge WTP only, transferring water from EGeorge system to Loma Rica and Lake of Pines (LoP) systems

6.1 Evaluation Criteria

Table 15 summarizes the criteria used for this evaluation.

Table 15 - Evaluation Criteria

Criteria	Value
Maximum daily demand (MDD)	ADD x 2.5
Peak hour demand (PH)	MDD x 2.0
Minimum pressure during normal operating conditions	30 psi
Minimum pressure during future operating conditions	40 psi
Maximum allowable pressure	150 psi
Target pipeline velocity during normal operating conditions	1-3 fps
Maximum pipeline velocity during PHD	5 fps

6.2 Baseline MDD

This baseline scenario was established as basis for comparing results with other scenarios. For this simulation, the pump stations were set to operate on level control of their corresponding tank(s). The system demand was supplied from both EGeorge WTP and Loma Rica WTP with no transfer of water between the two systems.

To make sure the system is balanced, a 7-day period simulation was performed to determine if the reservoirs were cycling within their normal range of operation between 70 and 100% full. The results of the first 24 hours can be ignored because they are influenced by initial boundary conditions. The hydraulic analysis shows the system is balanced, and reservoirs are cycling within normal levels. **Appendix B** shows the reservoir percent full charts in both EGeorge and Loma Rica systems during the entire 7-day MDD simulation for the operational scenarios compared to the Baseline scenario. **Figure 8** shows minimum pressures and maximum velocities that occurred during peak hour demand conditions. As shown on Figure 8, there are areas of low pressures, as expected, at high elevation near tanks and at specific locations with relatively high elevation in the system. **Figure 8** also shows pipelines exceeding the maximum velocity criteria of 10 fps.

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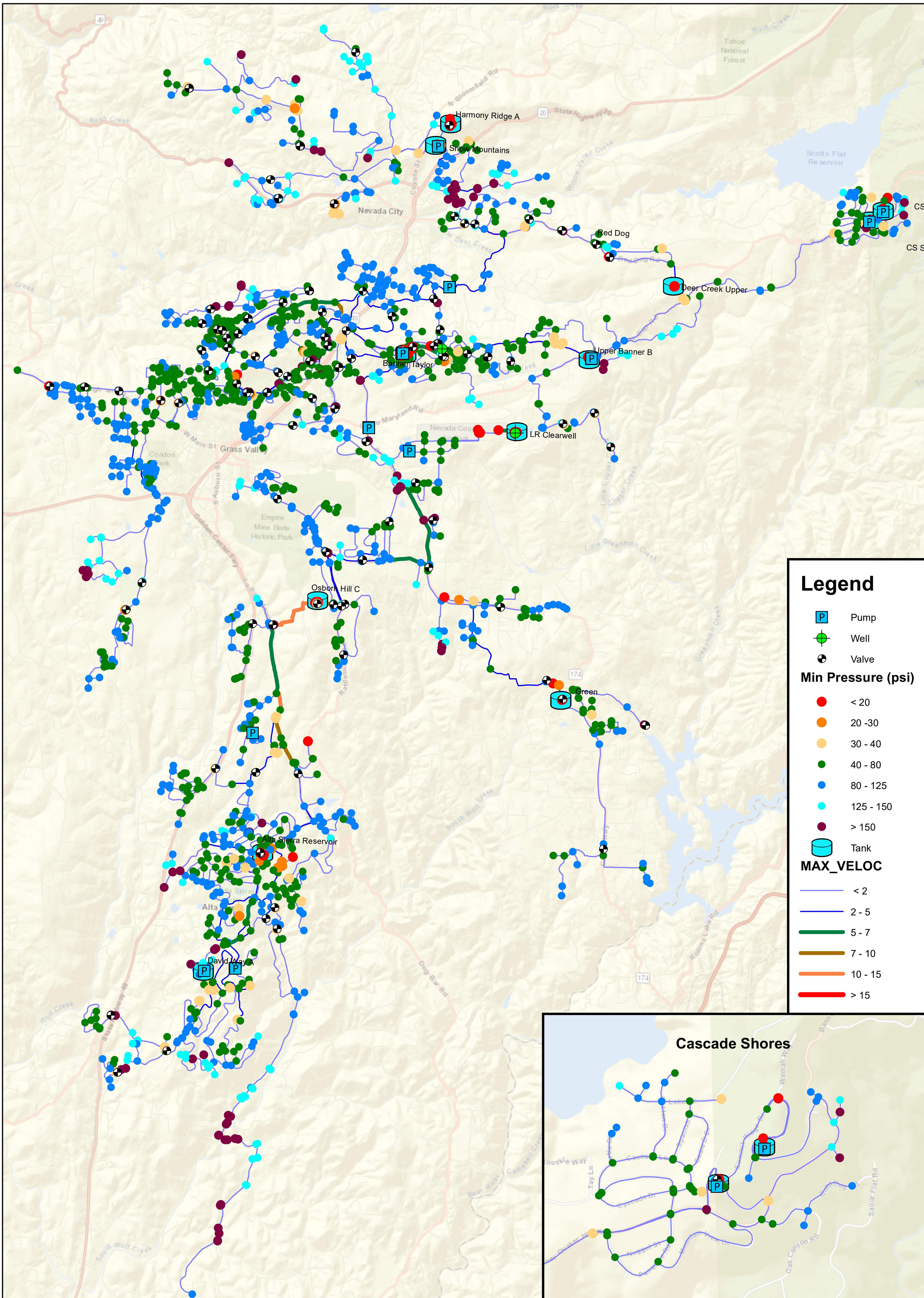

N
W E
S

0 6,000 12,000
Feet
1 inch = 6,000 feet

Figure 8
MDD Operation Scenario
Baseline EPS

Model Update and Calibration
for EG/LR/CS
Nevada Irrigation District

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6.3 Water Transfer from EGeorge to Loma Rica System

There are times when Loma Rica WTP is out of service or operating at lower capacity and the District would like to supply or supplement the Loma Rica system from the EGeorge system through the Brunswick pump station. This pump station has three pumps, each with a 900 gpm capacity at a TDH of 145 feet.

The Loma Rica System has a MDD of 5.7 mgd. This demand is met from Loma Rica WTP (4.2 mgd) and from Brunswick pump station (1.5 mgd). The hydraulic analysis shows the reservoirs in both EGeorge and Loma Rica system are balanced during the 7-day period simulation and are operating within their operational range between 70 to 100% full. To evaluate the results of this operational scenario, **Figure 9** was produced to show range of pressures and pipe velocities across the system under peak hour demand conditions. These results were similar to the Baseline scenario results which shows low pressures at high elevation near tanks and at specific locations with high elevation in the system. The EPS simulation results are also shown in Appendix B for comparison with the Baseline scenario. **Figure 9** also shows pipelines exceeding the maximum velocity criteria of 5.0 fps similar to the Baseline scenario.

6.4 Water Transfer from Loma Rica to EGeorge System

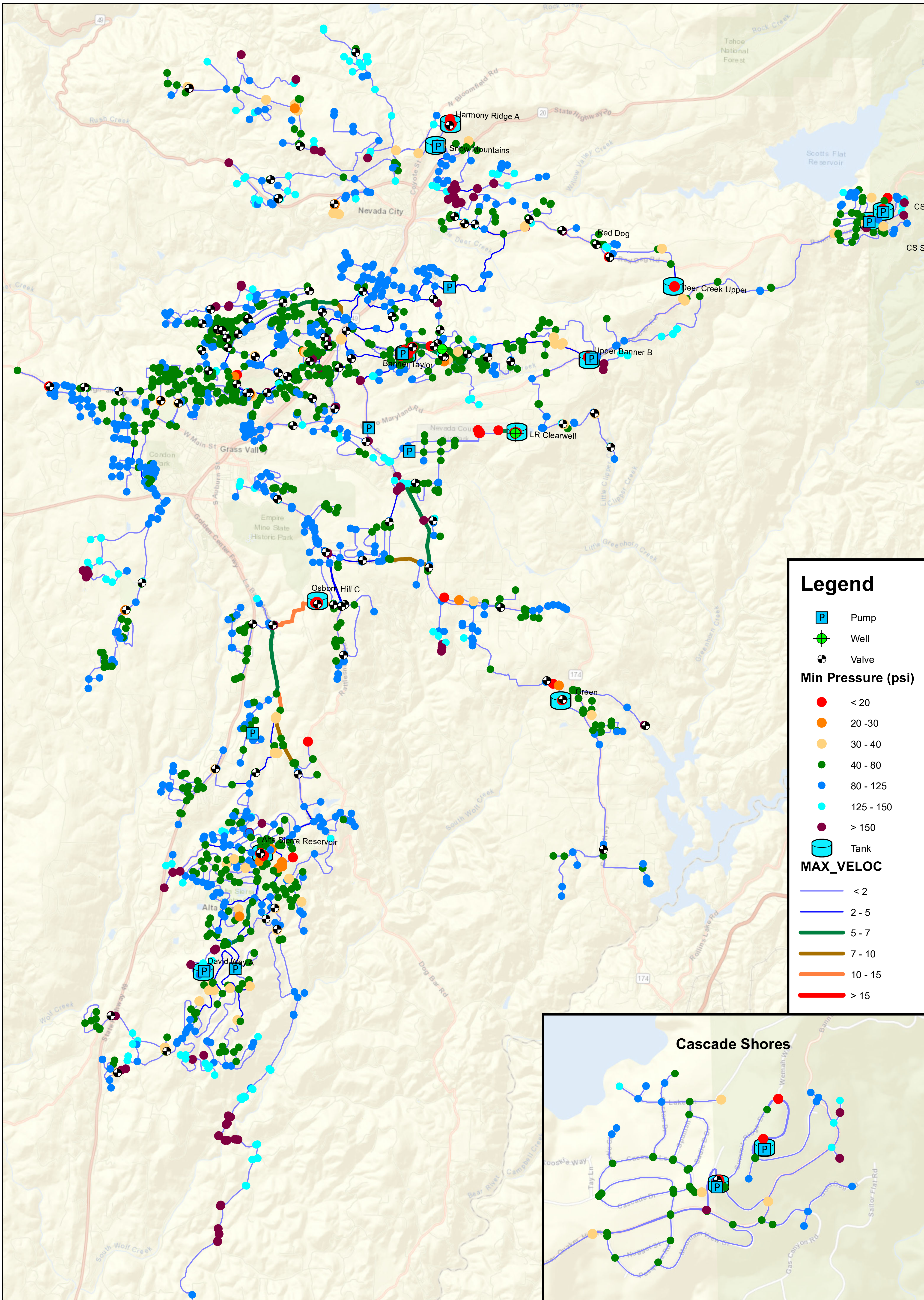
This operational scenario evaluated the possibility of transferring water from the Loma Rica System to the EGeorge system during an emergency through the bypass at Brunswick pump station. The EGeorge system has a MDD of 7.9 mgd. This demand is met from EGeorge WTP (7.1 mgd) and from the bypass at Brunswick pump station (0.8 mgd).

The hydraulic analysis shows the reservoirs in both EGeorge and Loma Rica system are balanced during the 7-day period simulation and are operating within their operational range between 70 to 100% full. **Figure 10** shows the range of pressures and pipe velocities across the system under peak hour demand conditions. These results were similar to the Baseline scenario results which shows low pressures at high elevation near tanks and at specific locations with high elevation in the system. **Figure 10** also shows pipelines exceeding the maximum velocity criteria of 5.0 fps similar to the Baseline scenario.

6.5 ADD EGeorge WTP Only

This operational scenario evaluated the system operation with supply provided only from the EGeorge WTP to meet the entire system ADD (6.6 mgd) including EGeorge, Loma Rica, and LoP systems. Loma Rica WTP is offline, and Brunswick pump station is supplying the Loma Rica system and the LoP system. The LoP system ADD (1.2 mgd) is assumed to be supplied through the Hacienda PRV station that is currently under construction.

The hydraulic analysis showed the reservoirs in both EGeorge and Loma Rica system are balanced during the 7-day period simulation and are operating within their operational range between 70 to 100% full. **Figure 11** shows the range of pressures and pipe velocities across the system under peak hour demand conditions. The results show the 12-inch line in Brewer Road connecting to the LoP system is experiencing low pressures. This finding is consistent with previous evaluation where the maximum flow that can be transferred to the LoP system is limited to 250 gpm (0.36 mgd) without exacerbating the low pressure at Dennis Way. It's worth noting this model has only existing facilities and does not have any facilities that are currently under construction such as Fay Road pipeline, Hacienda PRV Station or others.



N
W E
S

0 6,000 12,000 Feet

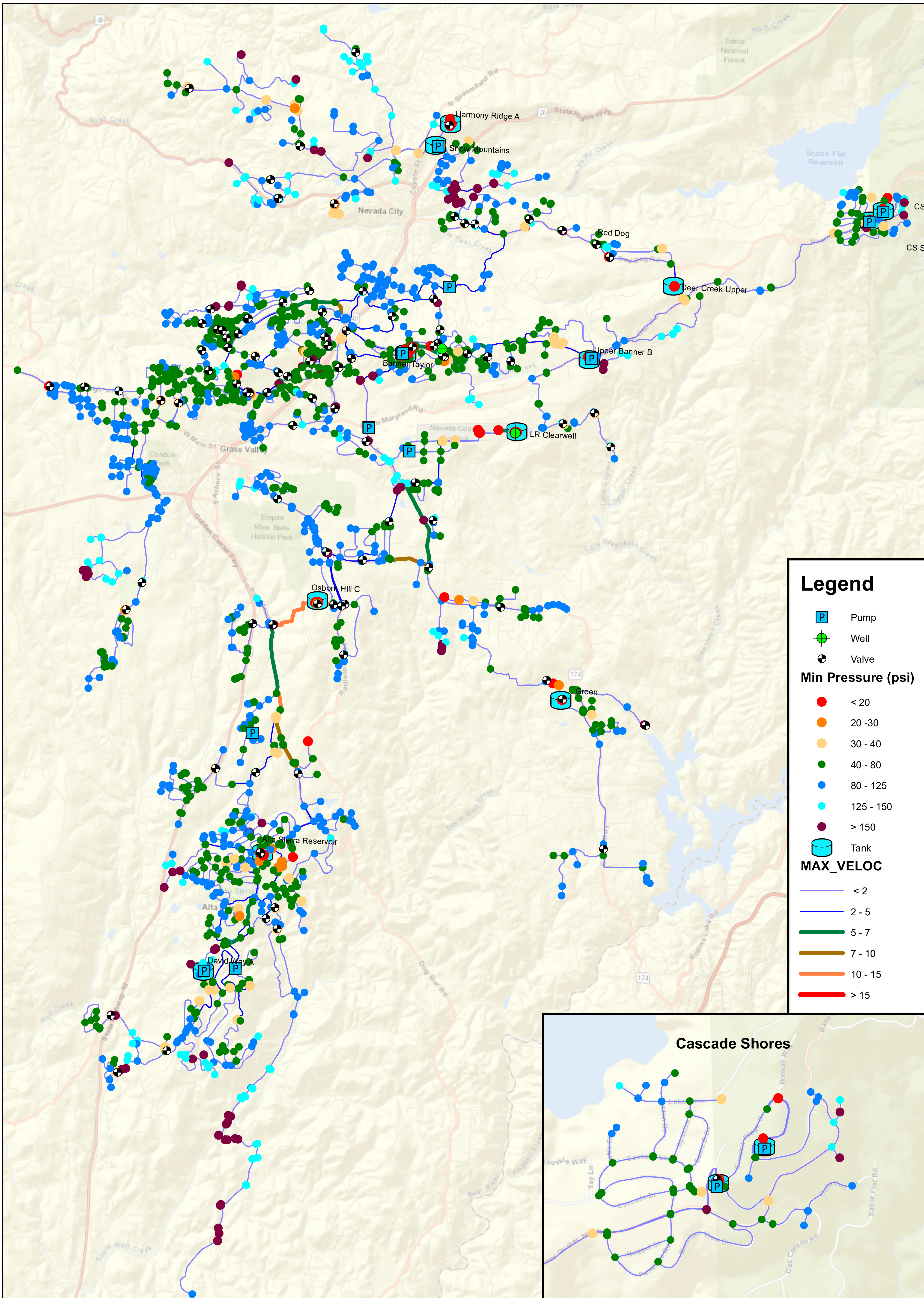
1 inch = 6,000 feet

Figure 9
MDD Operation Scenario
EGeorge to Loma Rica

Model Update and Calibration
for EG/LR/CS
Nevada Irrigation District

SEDARU®

NID



N
W E
S
0 6,000 12,000
Feet
1 inch = 6,000 feet

Figure 10
MDD Operational Scenario
Loma Rica to EGeorge

Model Update and Calibration
for EG/LR/CS
Nevada Irrigation District

SEDARU®

NID

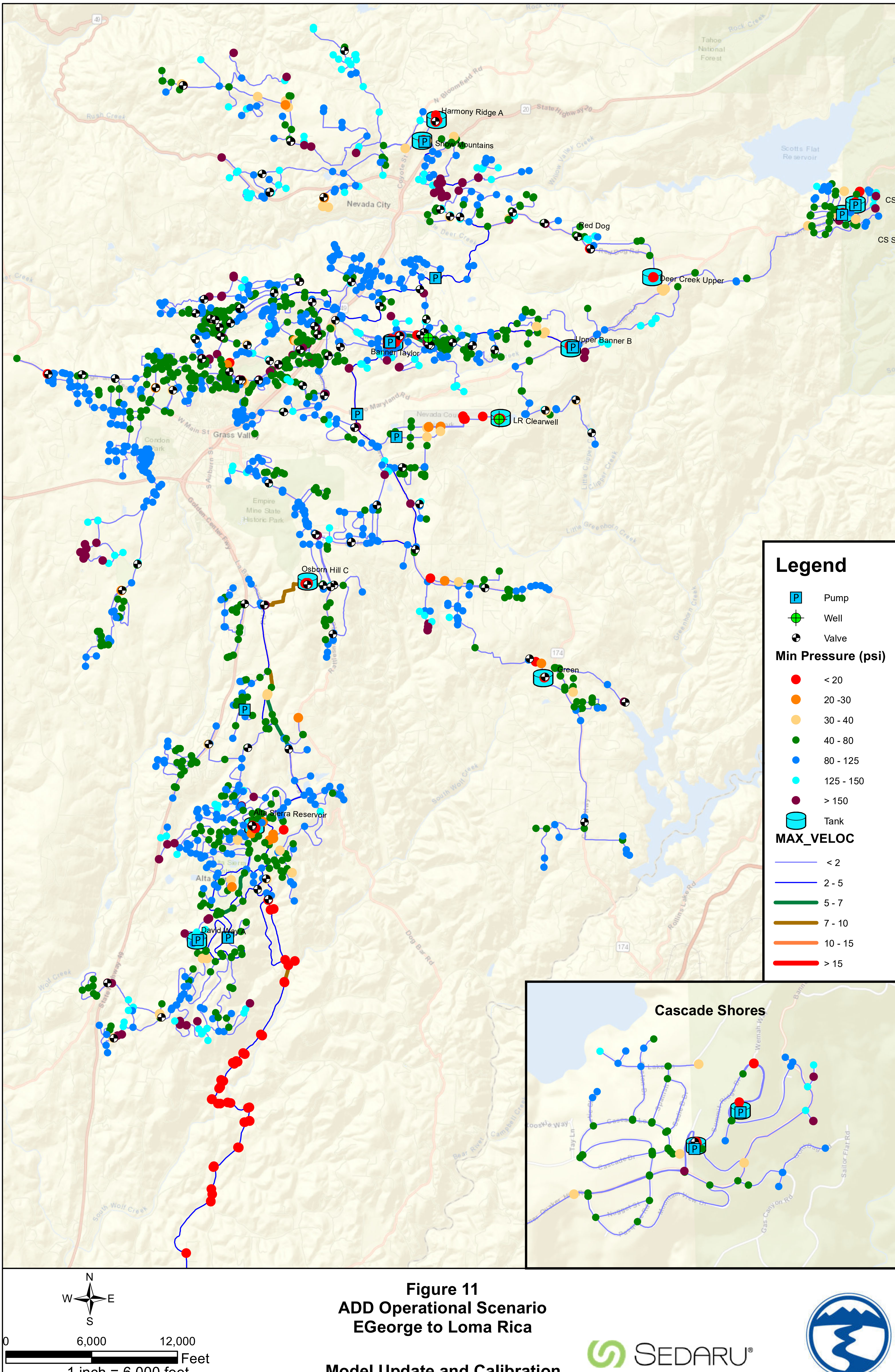


Figure 11
ADD Operational Scenario
EGeorge to Loma Rica

Model Update and Calibration
for EG/LR/CS
Nevada Irrigation District

SEDARU®

NID

7 Conclusions and Recommendations

7.1 Conclusions

Calibration

Overall, the model results matched field results reasonably well over the calibration period. As shown in **Table 9**, eight observation hydrants out of nine (89%) are within 5 psi and one (11%) is within 10 psi. Achieving the 5-psi tolerance for most comparison points involved making adjustments to pipe C-factors in the model. The water level fluctuations predicted by the model were all within 1 foot of those recorded in SCADA. For the available two pump stations, the pump flows predicted by the model are within less than 5% of those recorded in SCADA.

Based on the results of steady-state and EPS calibration where model results and field measurements are matching very well, it can be concluded that the hydraulic model is calibrated and can be used with confidence as a planning tool to predict system performance under various demand conditions.

Evaluation

- The results of the operational scenarios under PHD conditions shows pipes with velocities exceeding the 5.0 fps maximum criterion.
- The water delivery to the LoP system is limited due to hydraulic constraints to maintain minimum pressure required in the vicinity of Dennis Way.

7.2 Recommendations

Based on findings from the steady-state and EPS calibration and evaluations, the following items are recommended to improve and refine the predictive capability of the model in the future:

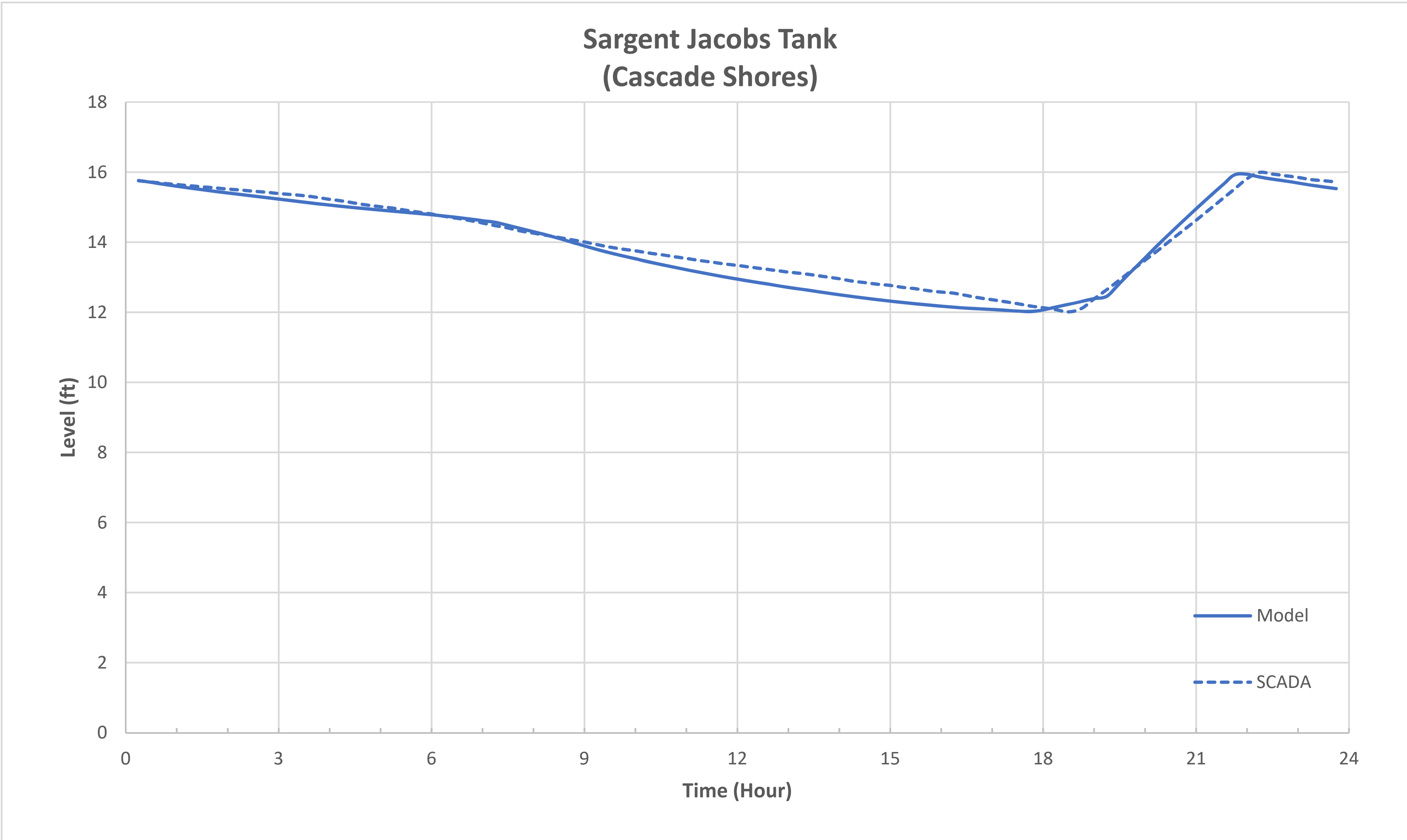
- Install SCADA devices at all tanks in the system to collect water levels.
- Install flow meters at the water treatment plants that are capable of collecting data at small time intervals (i.e. 5 minutes or 15 minutes). Also install flow meters at the pump stations that do not already have meters. Data should be relayed to SCADA. Having this data available, can be used to establish flow balance and develop a specific diurnal curve for each pressure zone for better representation system hydraulic and improving model accuracy to predict results.
- Install pressure loggers to capture at key points in the system such as suction and discharge pressure at the pump stations and pressure across the distribution system. Pressure at the logger should be relayed to District's SCADA system.
- For the hydrant test in Cascade Shores where the modeled pressure did not reasonably match that of field measurements, redo the test by installing HPRs along the main path to monitor pressure drops which could be indicative of closed or partially closed valves.
- Update or verify the hydraulic model including, but not limited to, facility modifications, PRV settings, zone boundary valves, piping improvements, demands, etc. on a bi-yearly basis, at a minimum.

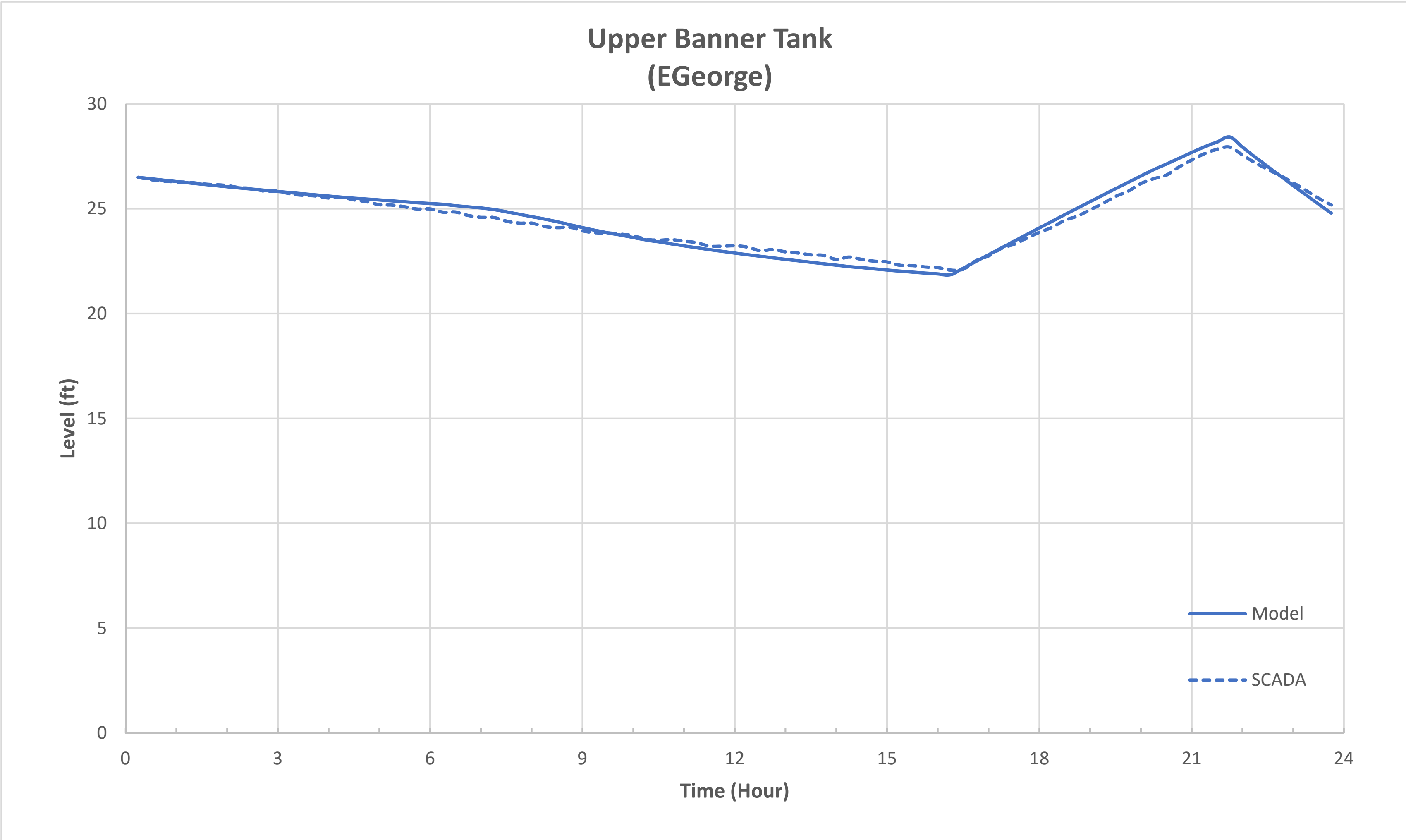
- Perform system capacity evaluation to identify deficient facilities across the system including pipes, pump stations and storage tanks.
- Establish a planning horizon demand scenario for sizing system improvements.
- Update the hydraulic model regularly to reflect physical and operational system changes.
- Perform a system-wide calibration preferably every 5 years in response to demand or operational changes.

In addition, for any future updates to the District's GIS, it is recommended that facility ID's are not reused for pipes and other features. Creating unique ID's for all newly installed pipes, appurtenances, and other facilities ensures the model can be updated without duplicating features and/or representing them in the incorrect location

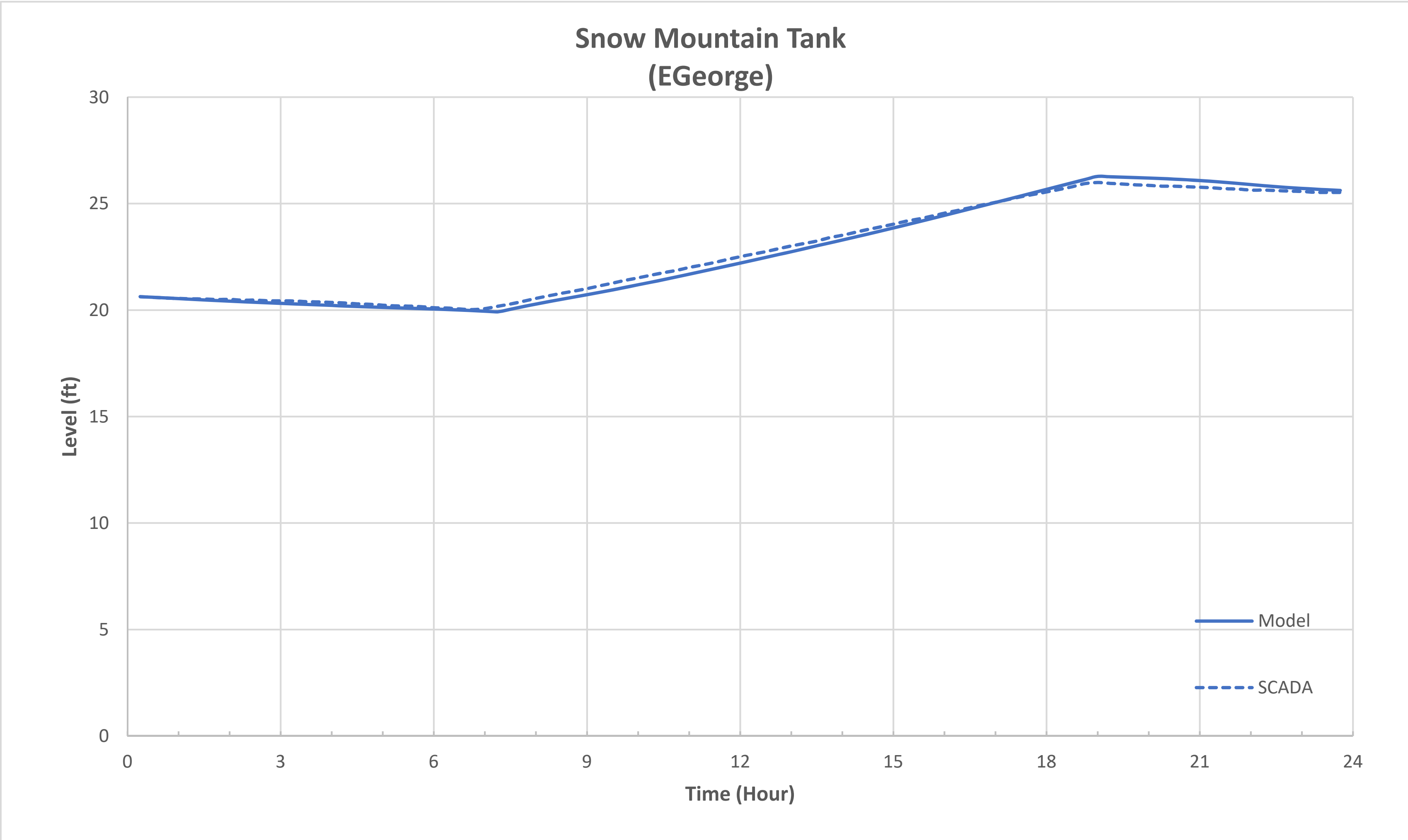
Appendix A

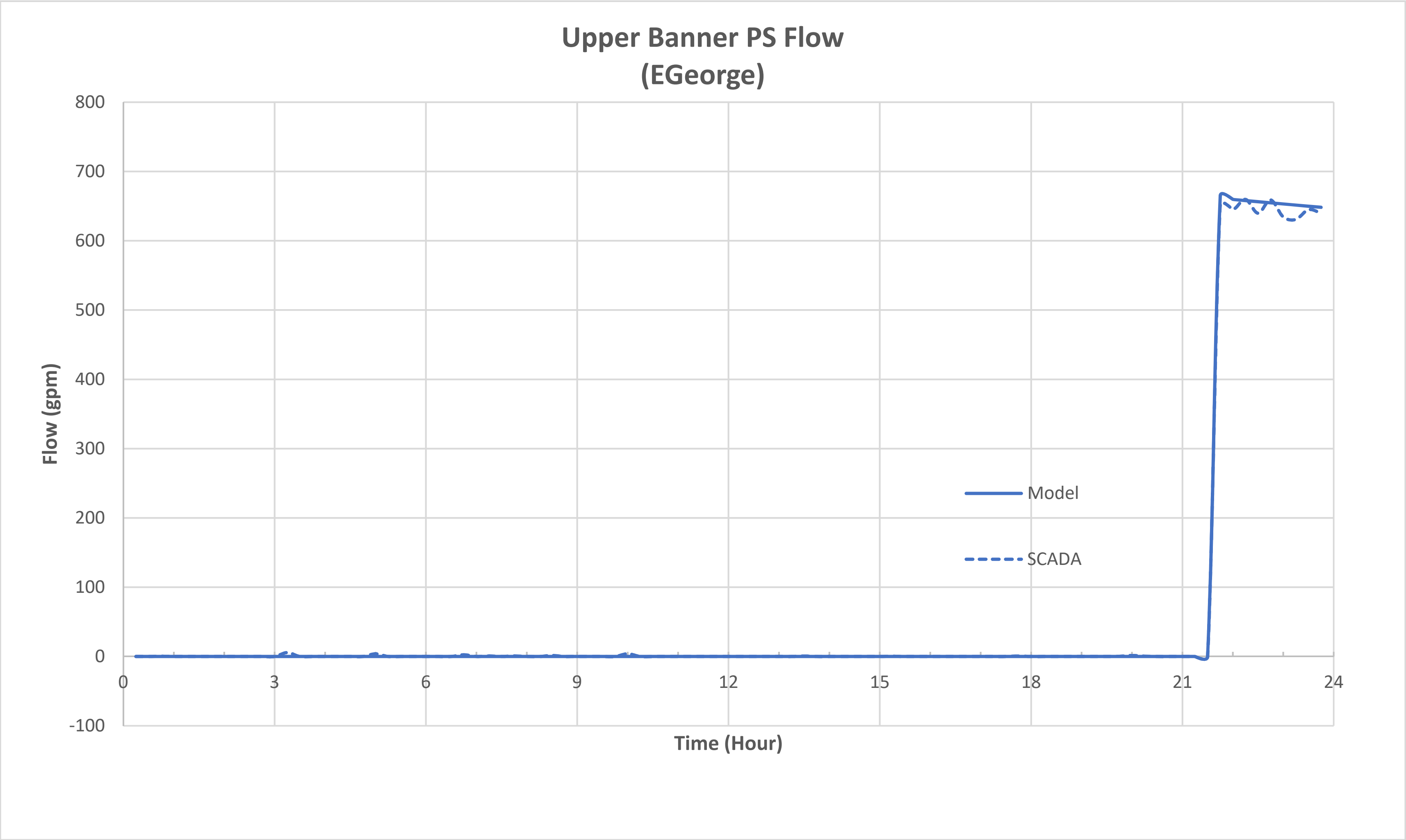
EPS Model Calibration Charts

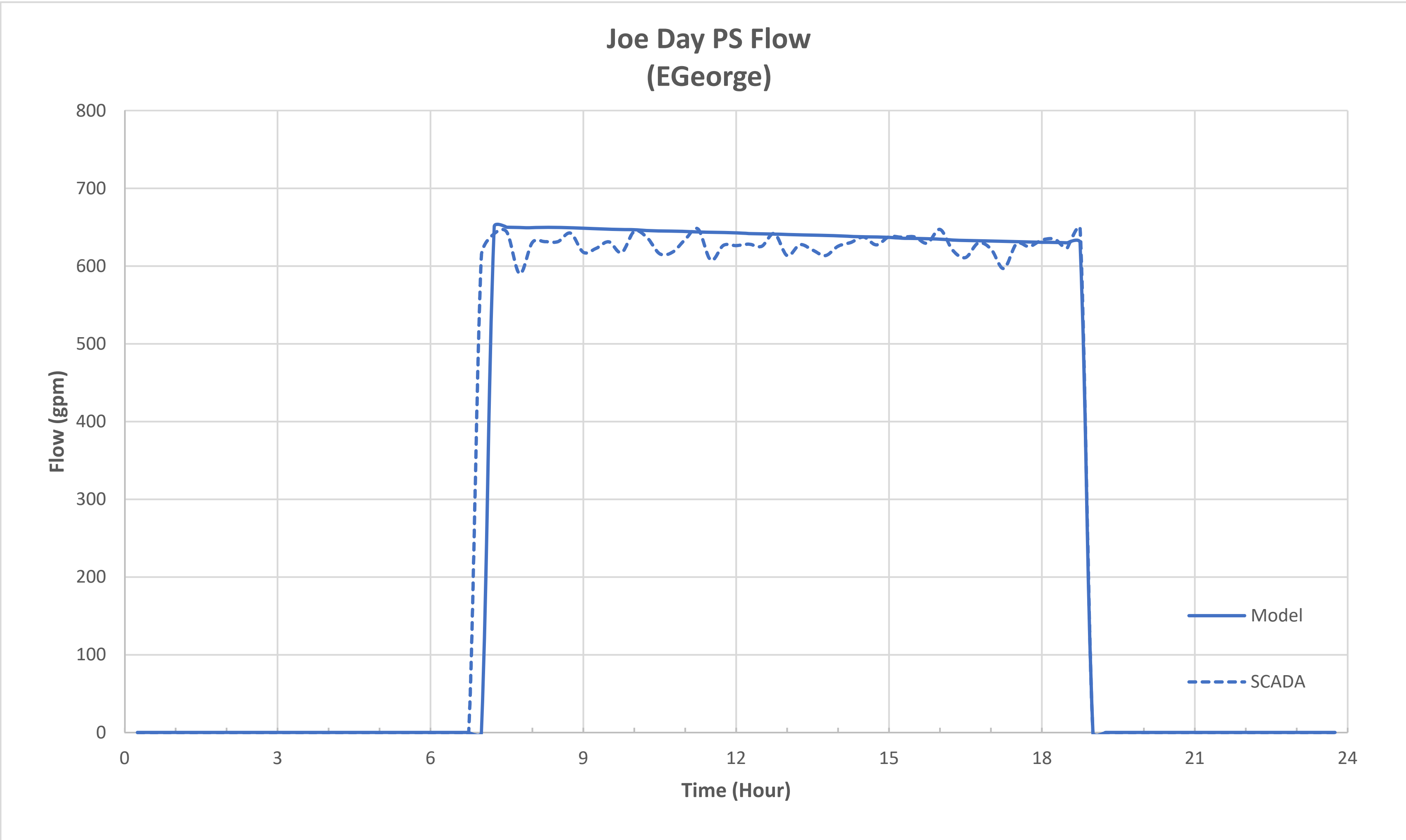

Sargent Jacobs Tank
(Cascade Shores)
Level (ft)
18
16
14
12
10
8
6
4
2
0
0
3
6
9
12
15
18
21
24
Time (Hour)
Model
SCADA

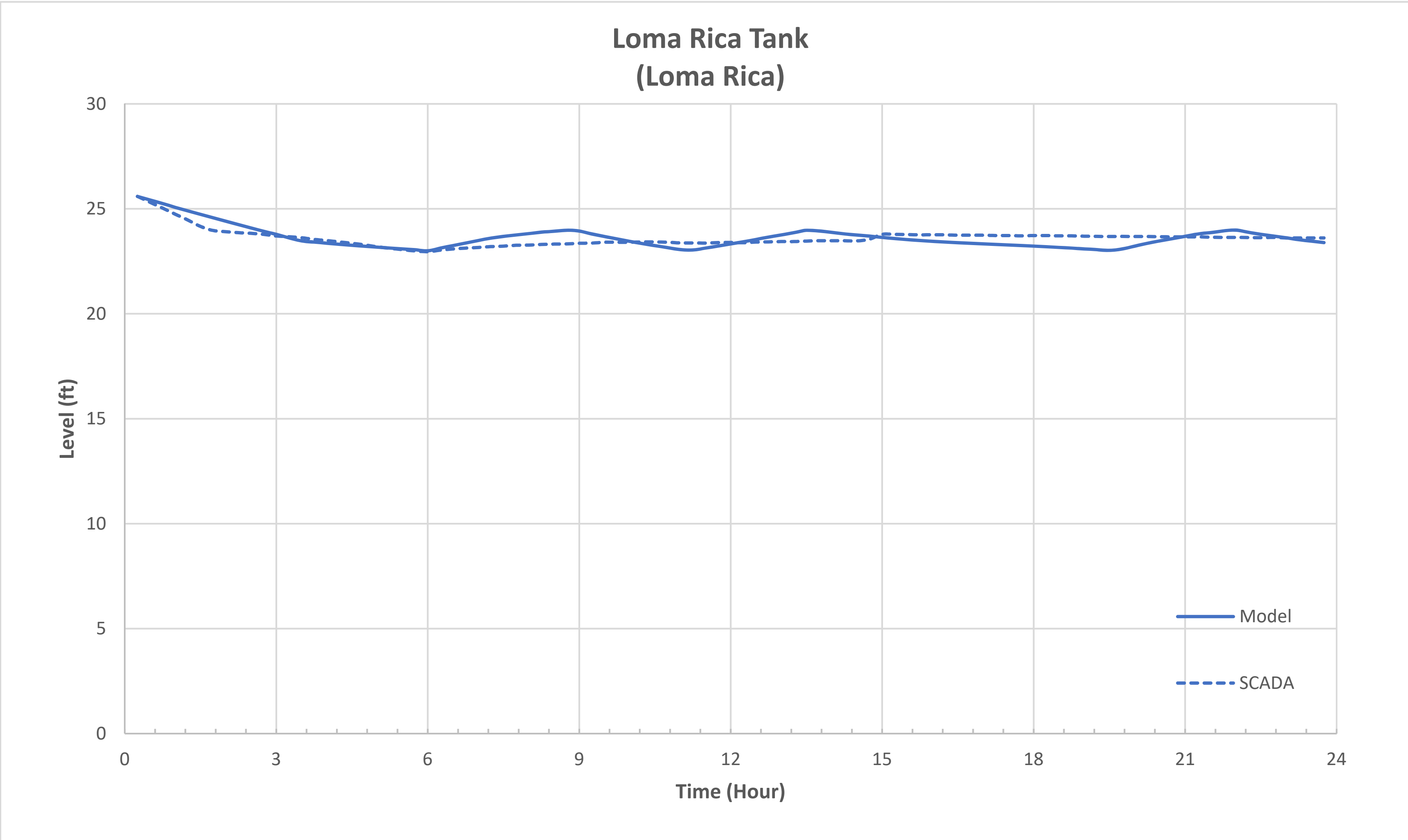


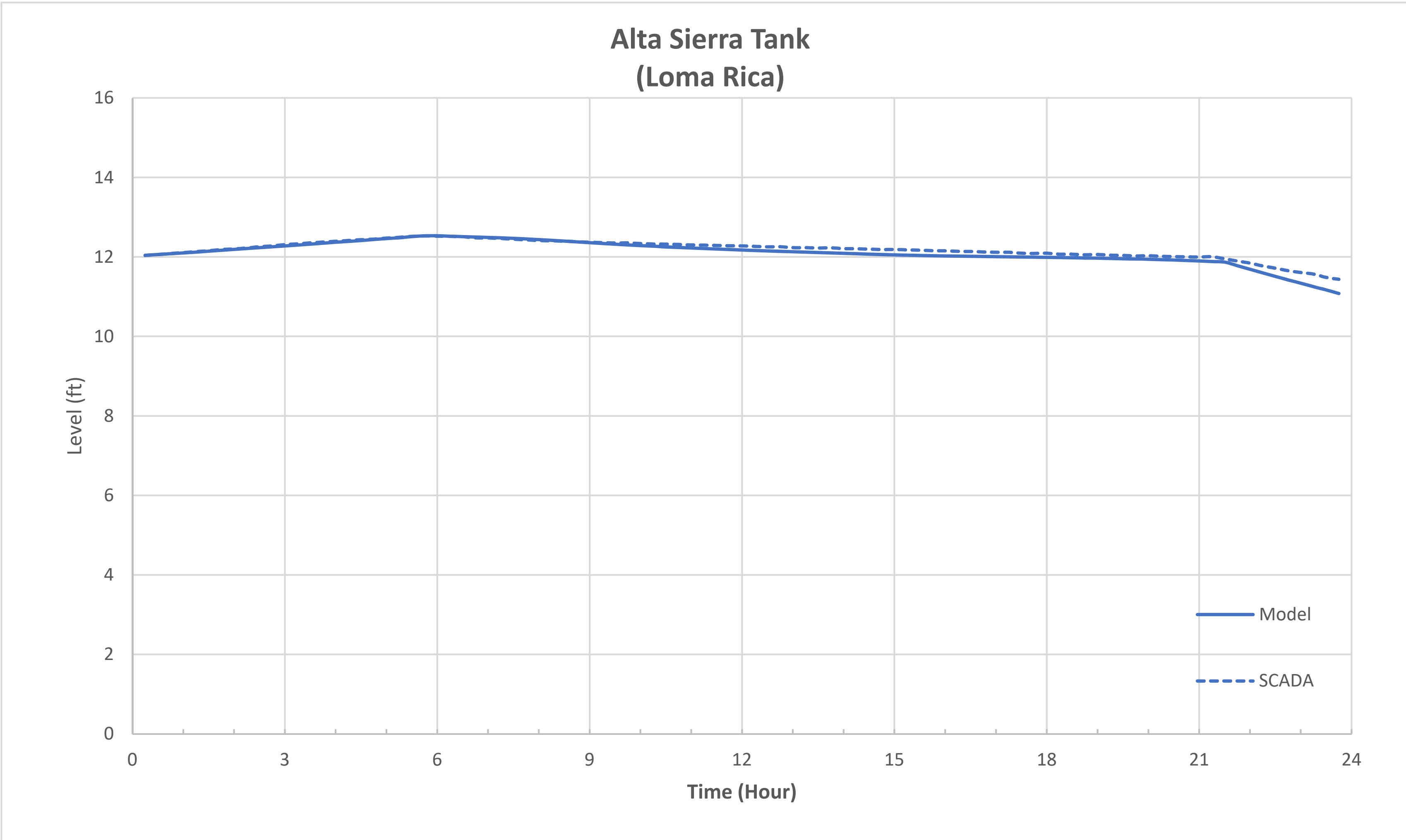
Upper Banner Tank
(EGeorge)
Level (ft)
30
25
20
15
10
5
0
0
3
6
9
12
15
18
21
24
Time (Hour)
Model
SCADA


Snow Mountain Tank
(EGeorge)
30
25
20
15
10
5
0
Level (ft)
0
3
6
9
12
15
18
21
24
Time (Hour)
Model
SCADA

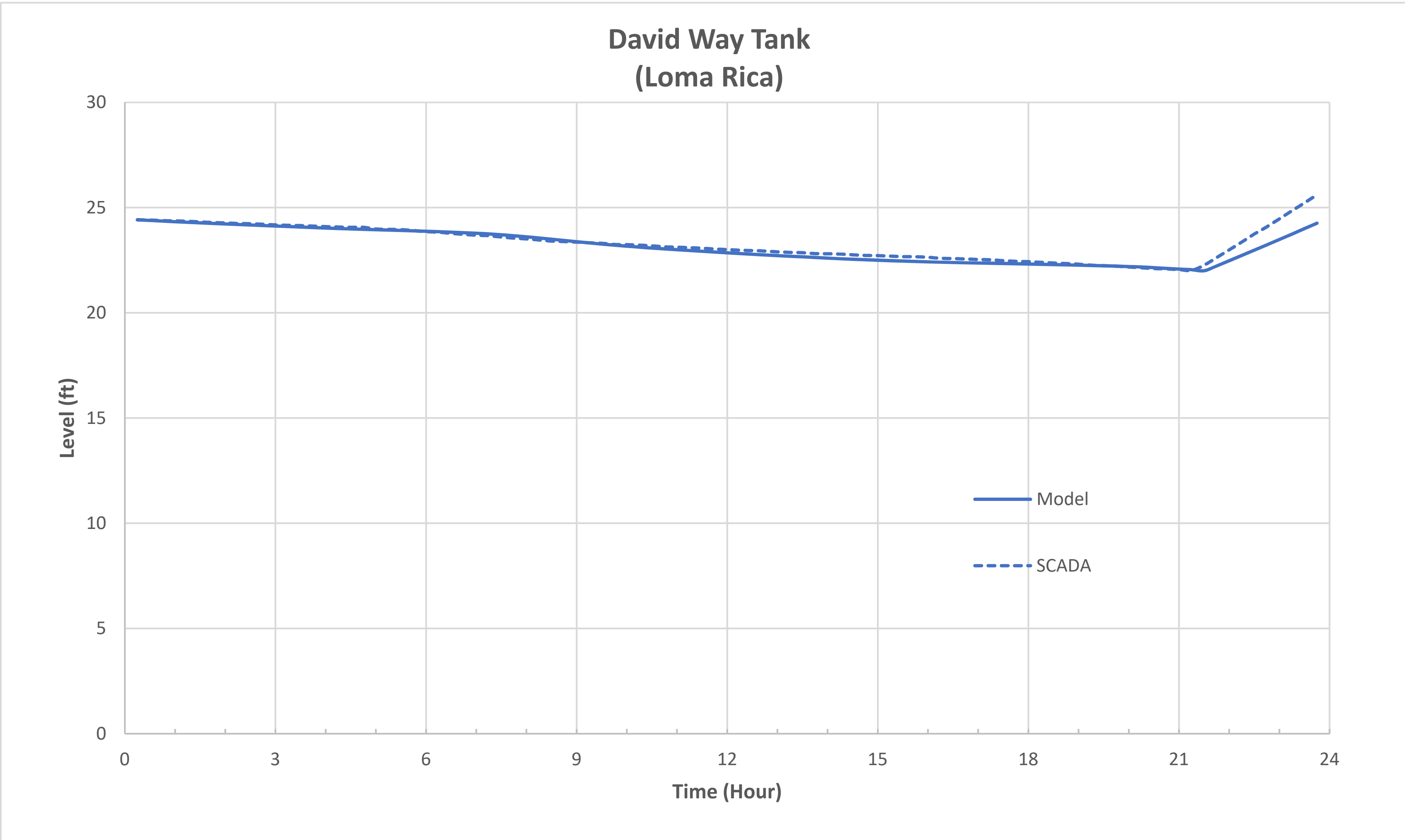

Upper Banner PS Flow
(EGeorge)
Flow (gpm)
800
700
600
500
400
300
200
100
0
-100
0
3
6
9
12
15
18
21
24
Time (Hour)
Model
SCADA


Joe Day PS Flow
(EGeorge)
800
700
600
500
400
300
200
100
0
Flow (gpm)
0
3
6
9
12
15
18
21
24
Time (Hour)
Model
SCADA


Loma Rica Tank
(Loma Rica)
Level (ft)
30
25
20
15
10
5
0
0
3
6
9
12
15
18
21
24
Time (Hour)
Model
SCADA



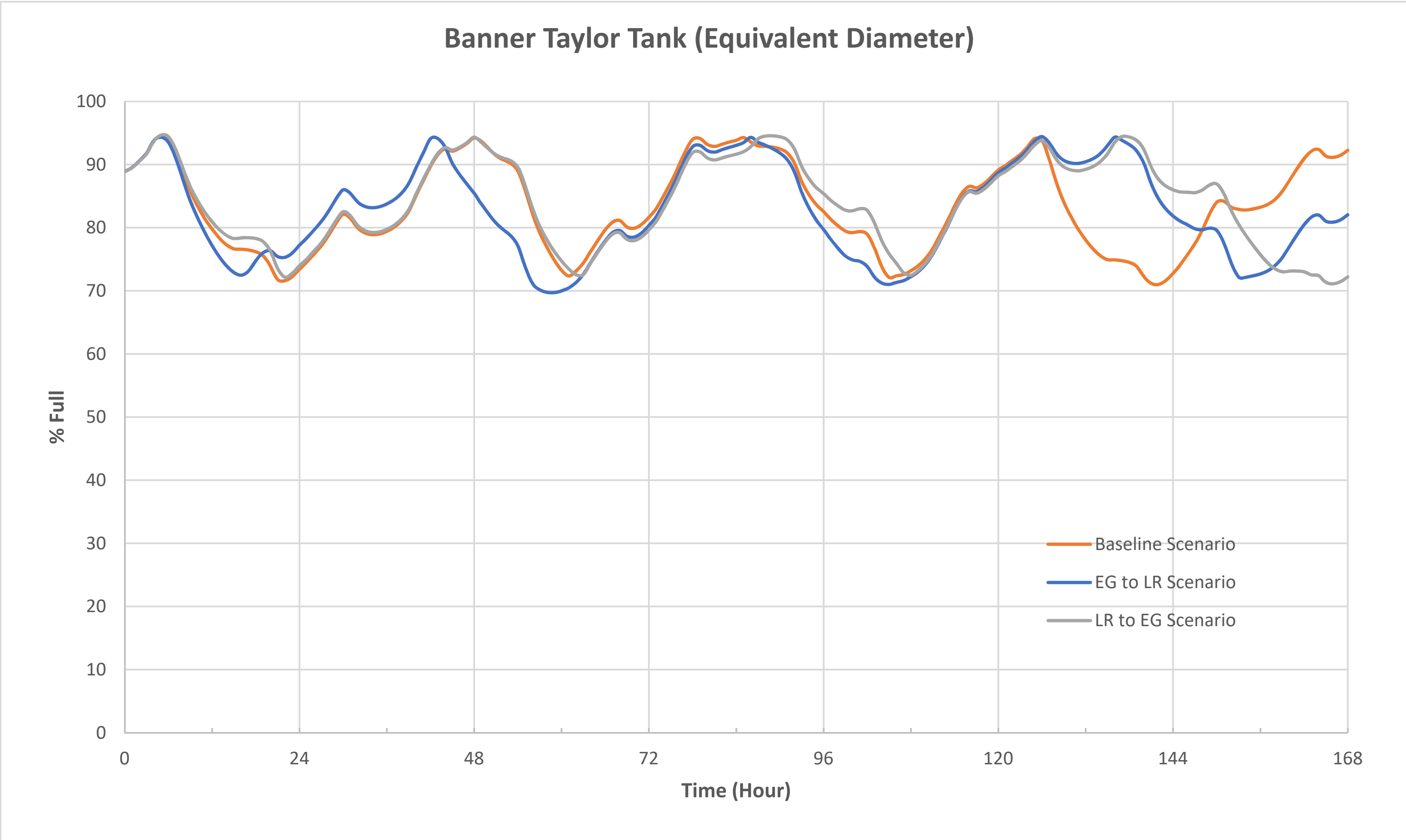
Alta Sierra Tank
(Loma Rica)
Level (ft)
16
14
12
10
8
6
4
2
0
0
3
6
9
12
15
18
21
24
Time (Hour)
Model
SCADA

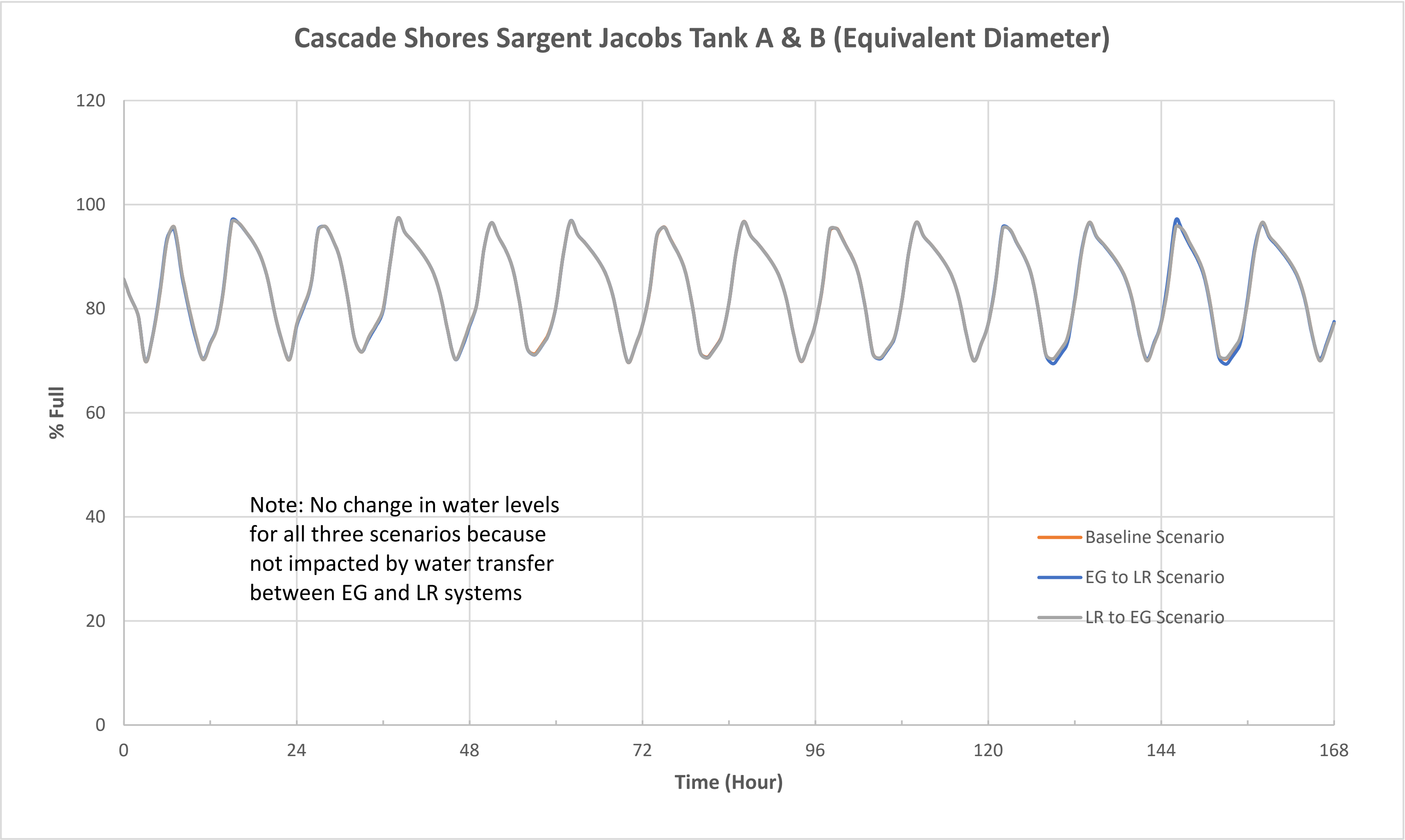


David Way Tank
(Loma Rica)
Level (ft)
30
25
20
15
10
5
0
0
3
6
9
12
15
18
21
24
Time (Hour)
Model
SCADA

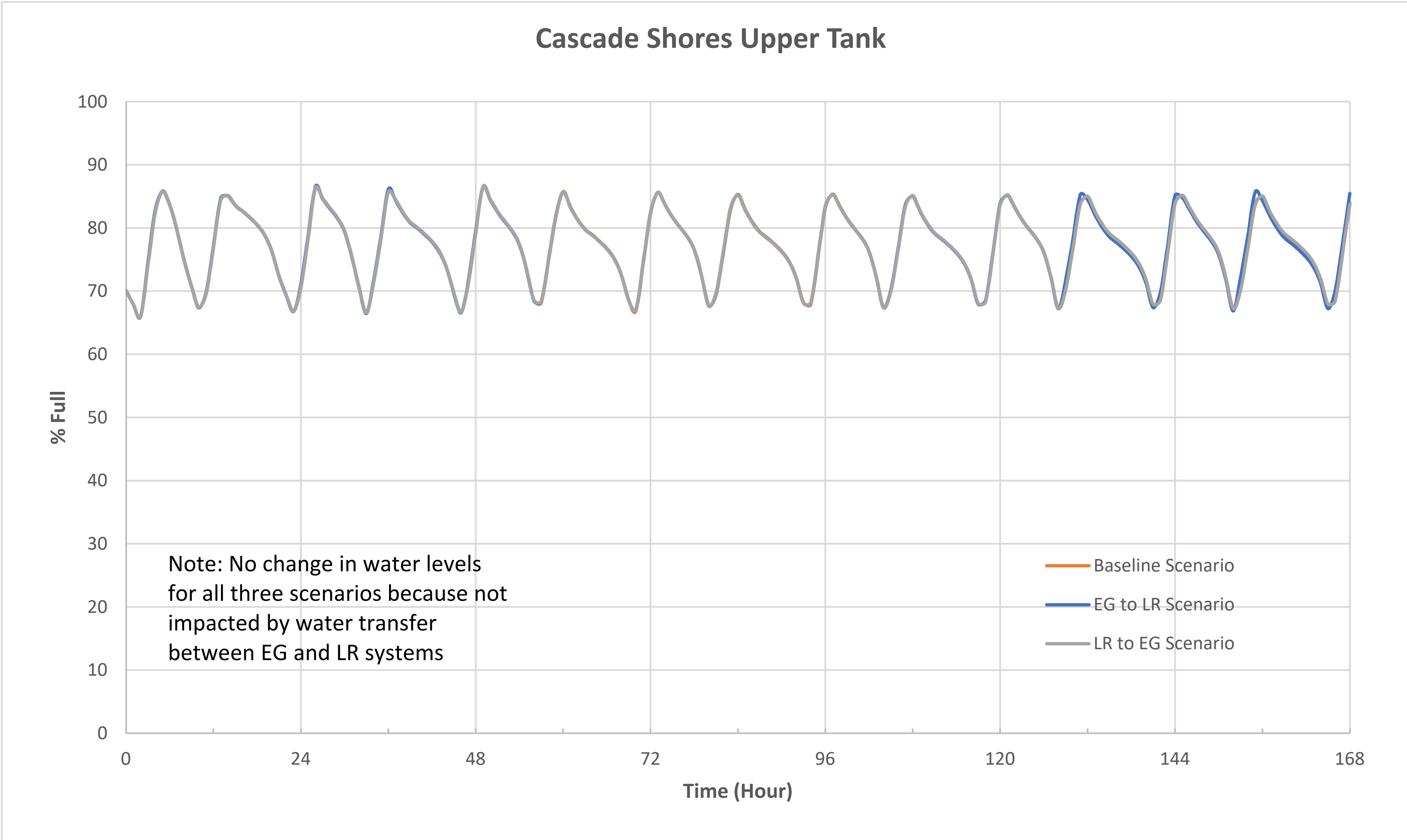
Appendix B

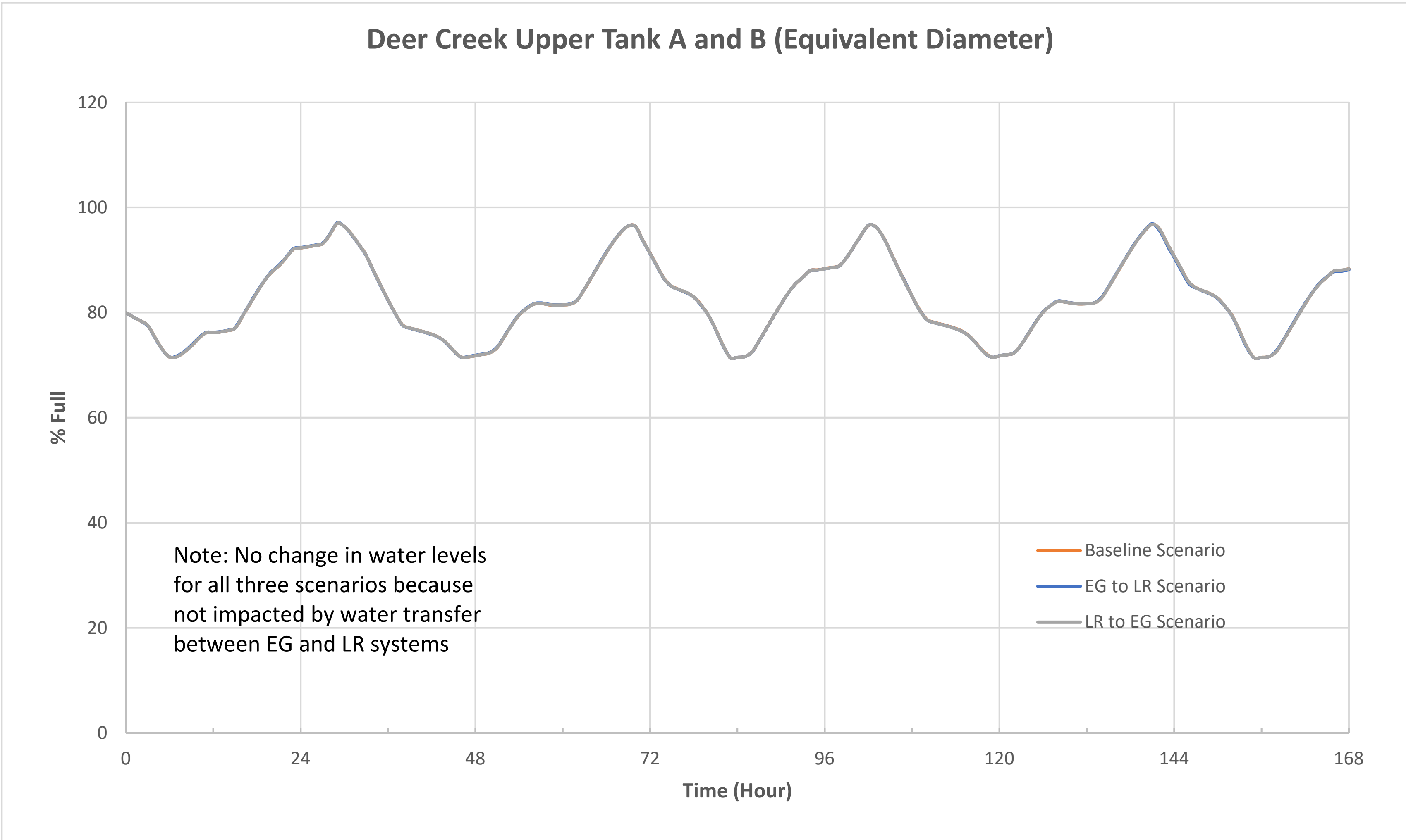
Reservoirs EPS Percent Full Charts of Operational Scenarios Compared to the Baseline Scenario

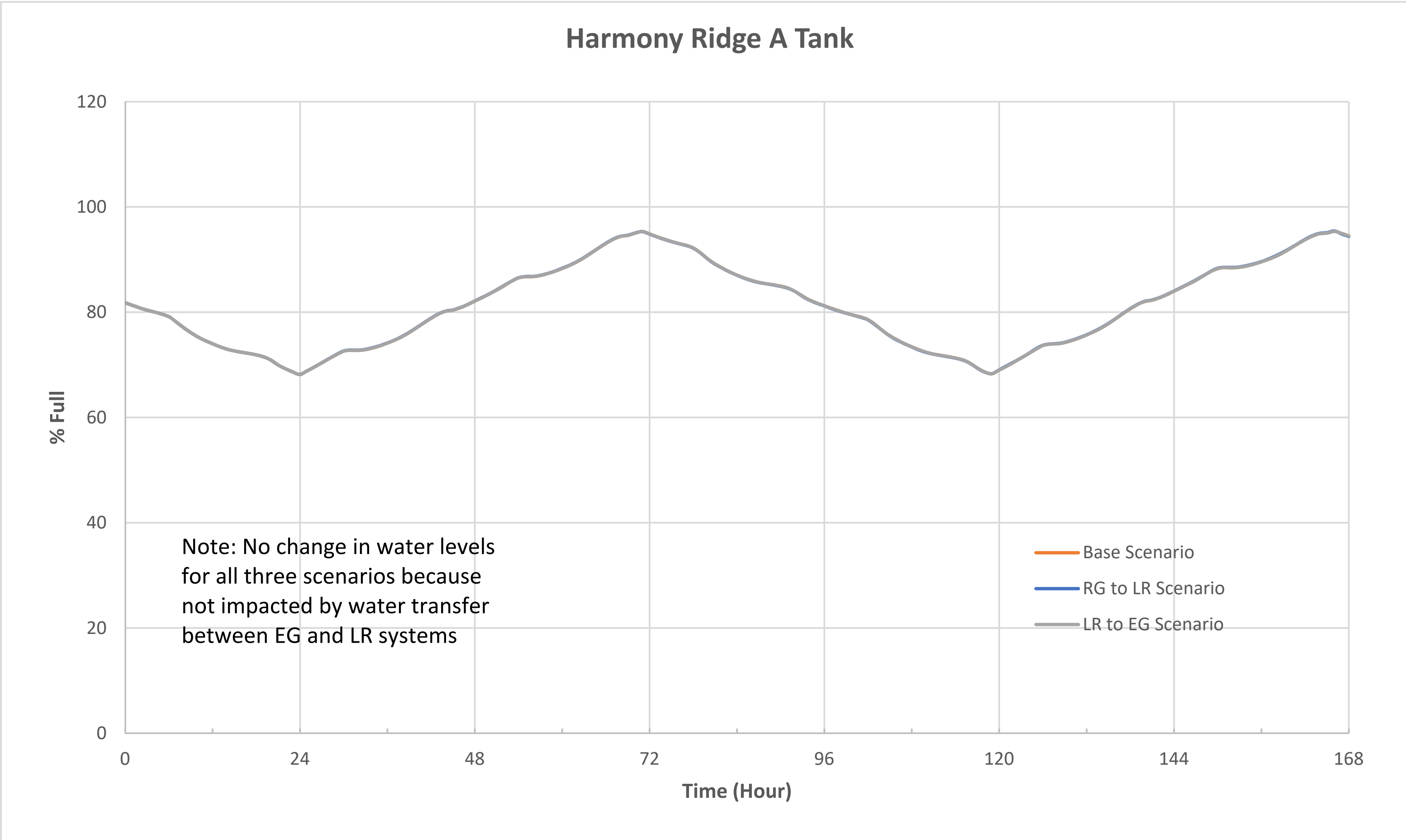

Banner Taylor Tank (Equivalent Diameter)
100
90
80
70
60
50
40
30
20
10
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Baseline Scenario
EG to LR Scenario
LR to EG Scenario

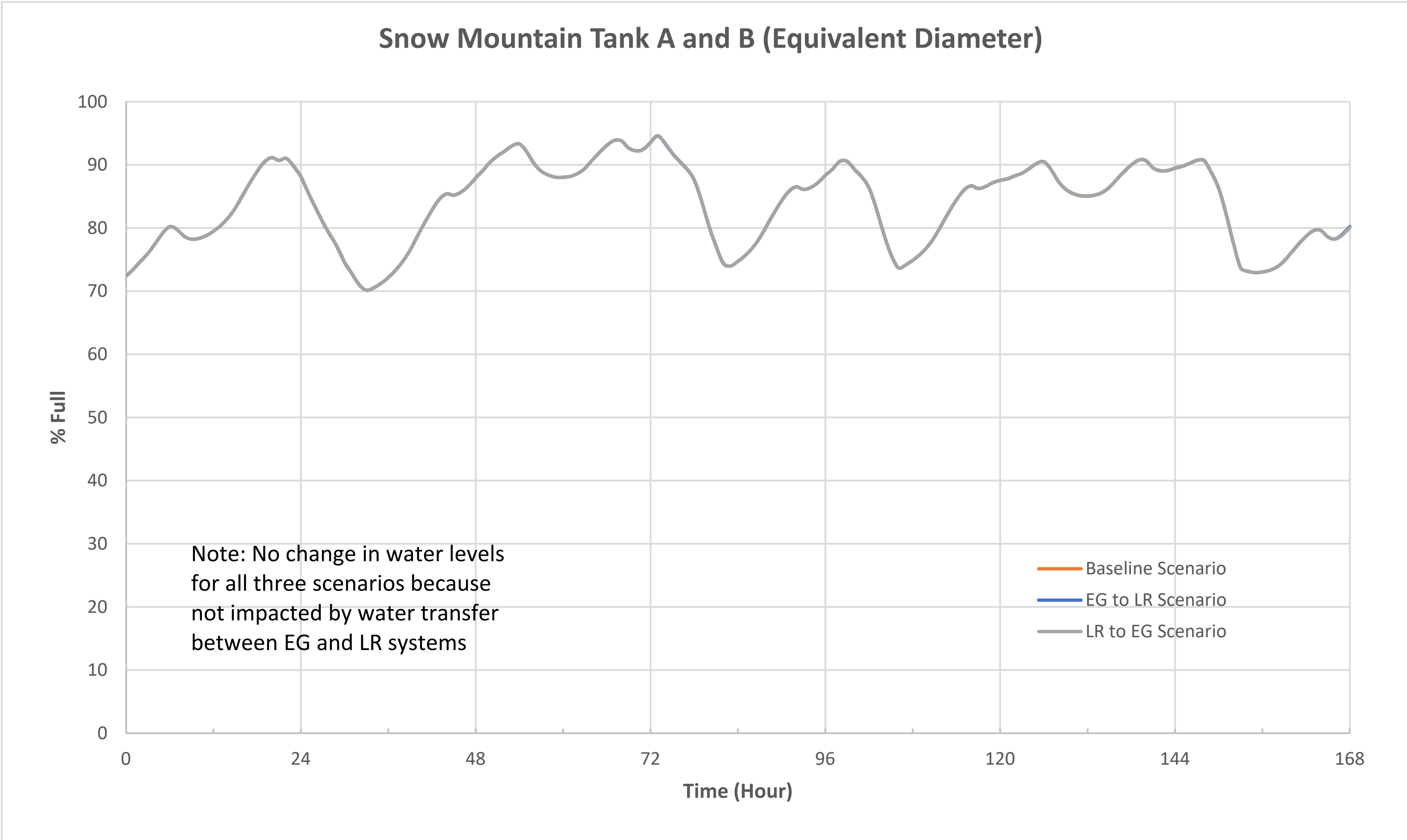


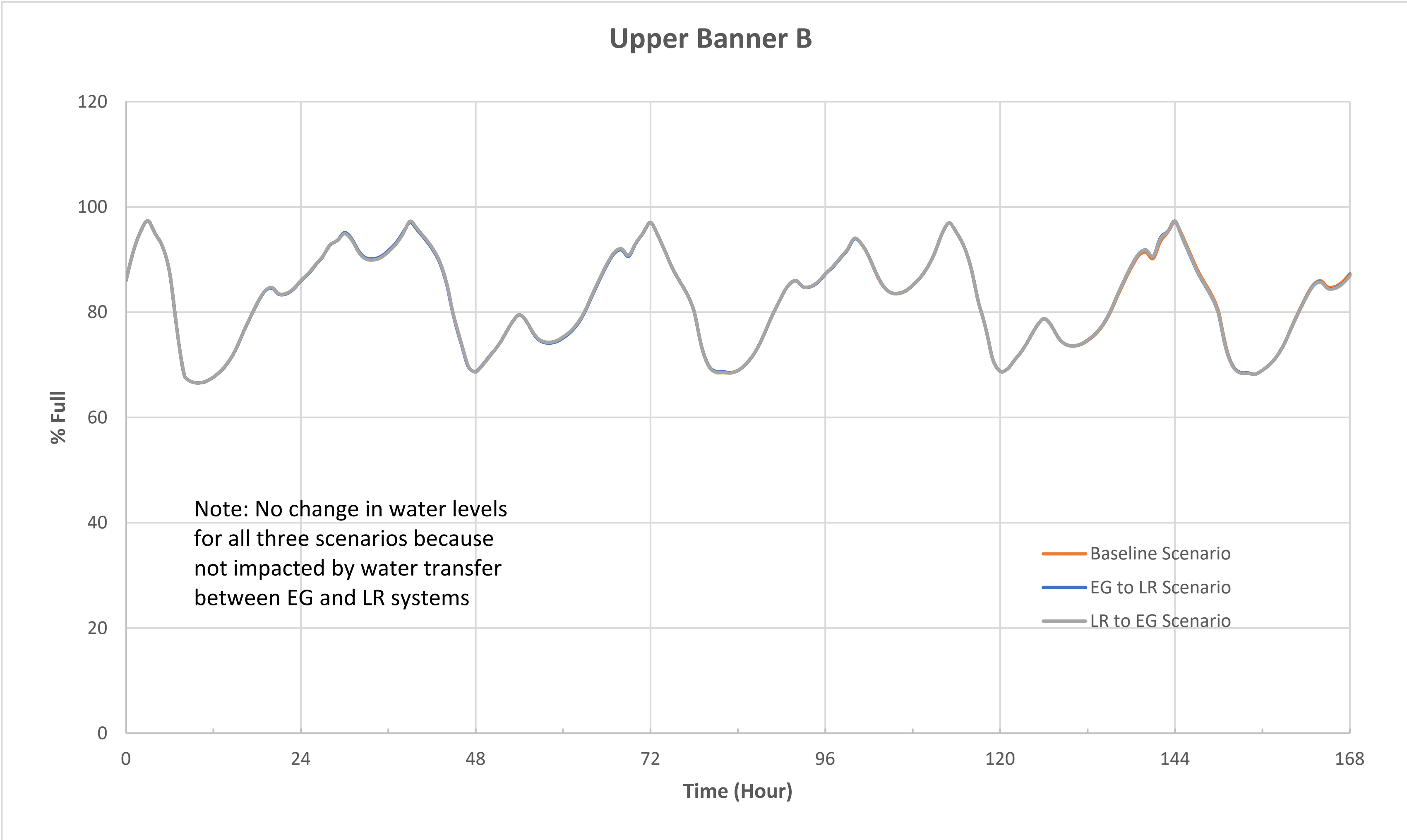
Cascade Shores Sargent Jacobs Tank A & B (Equivalent Diameter)
120
100
80
60
40
20
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Note: No change in water levels for all three scenarios because not impacted by water transfer between EG and LR systems
Baseline Scenario
EG to LR Scenario
LR to EG Scenario


Cascade Shores Upper Tank
100
90
80
70
60
50
40
30
20
10
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Note: No change in water levels for all three scenarios because not impacted by water transfer between EG and LR systems
Baseline Scenario
EG to LR Scenario
LR to EG Scenario

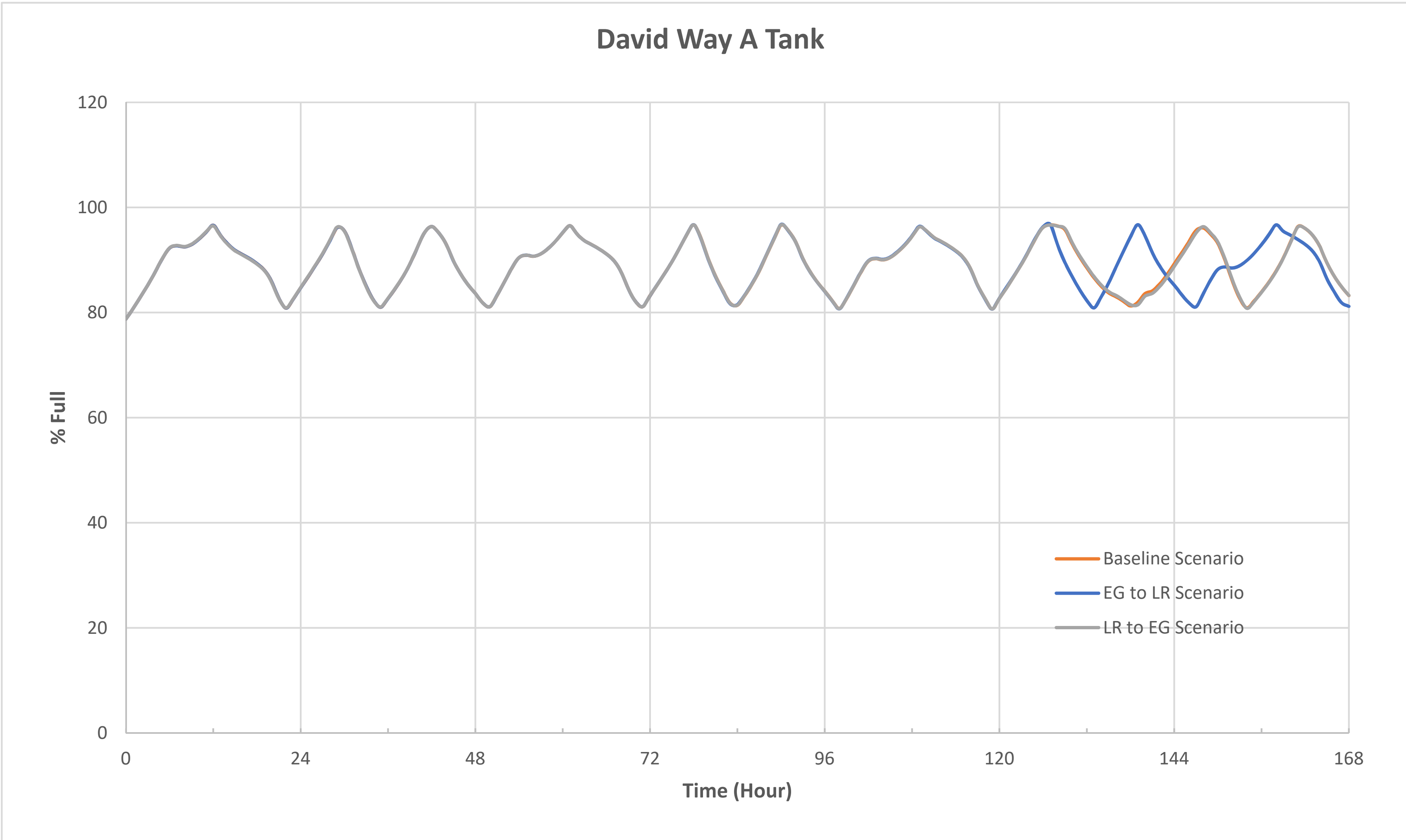

Deer Creek Upper Tank A and B (Equivalent Diameter)
120
100
80
60
40
20
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Note: No change in water levels for all three scenarios because not impacted by water transfer between EG and LR systems
Baseline Scenario
EG to LR Scenario
LR to EG Scenario

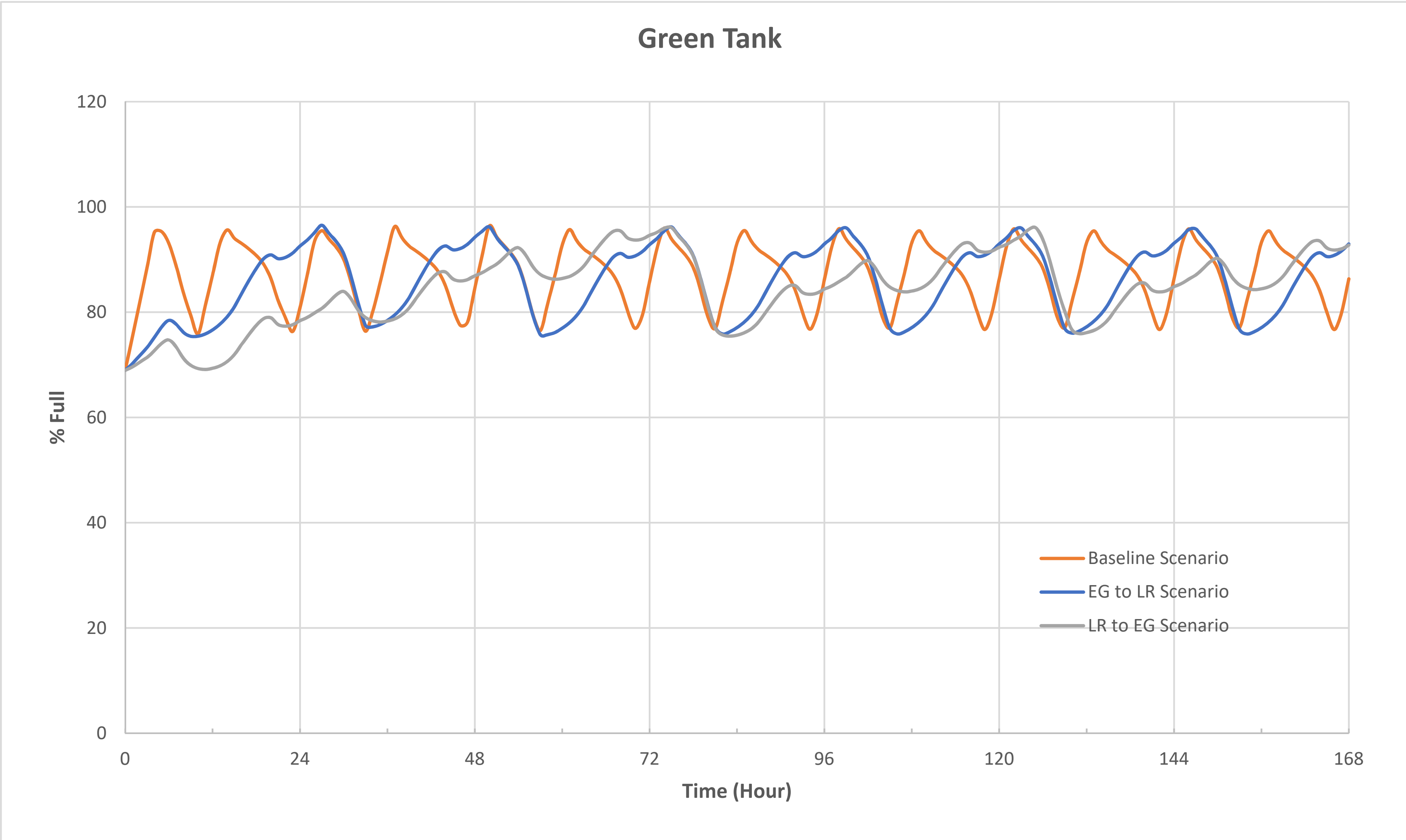

Harmony Ridge A Tank
120
100
80
60
40
20
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Note: No change in water levels for all three scenarios because not impacted by water transfer between EG and LR systems
Base Scenario
RG to LR Scenario
LR to EG Scenario


Snow Mountain Tank A and B (Equivalent Diameter)
% Full
Time (Hour)
0
10
20
30
40
50
60
70
80
90
100
0
24
48
72
96
120
144
168
Note: No change in water levels for all three scenarios because not impacted by water transfer between EG and LR systems
Baseline Scenario
EG to LR Scenario
LR to EG Scenario

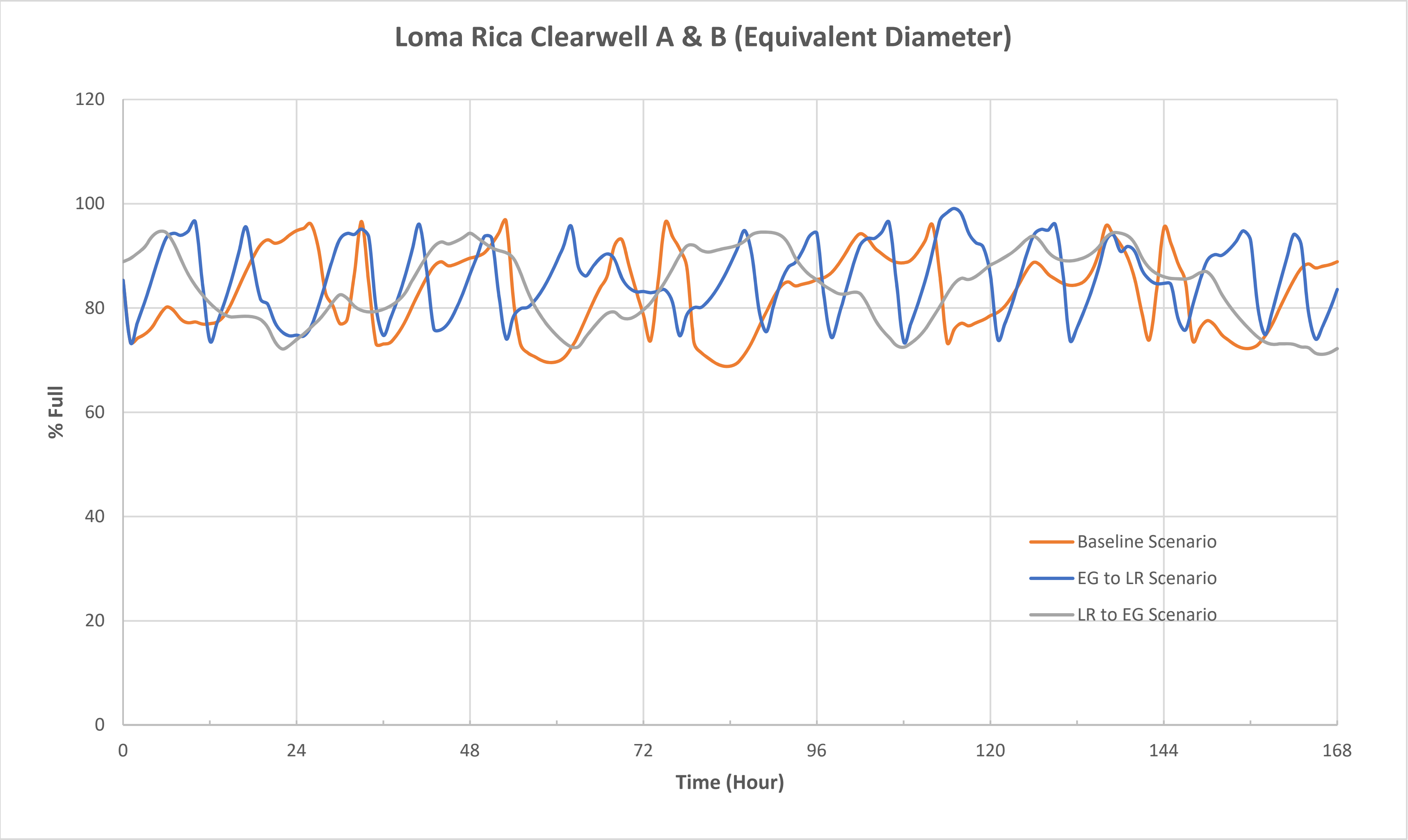

Upper Banner B
% Full
120
100
80
60
40
20
0
0
24
48
72
96
120
144
168
Time (Hour)
Note: No change in water levels
for all three scenarios because
not impacted by water transfer
between EG and LR systems
Baseline Scenario
EG to LR Scenario
LR to EG Scenario

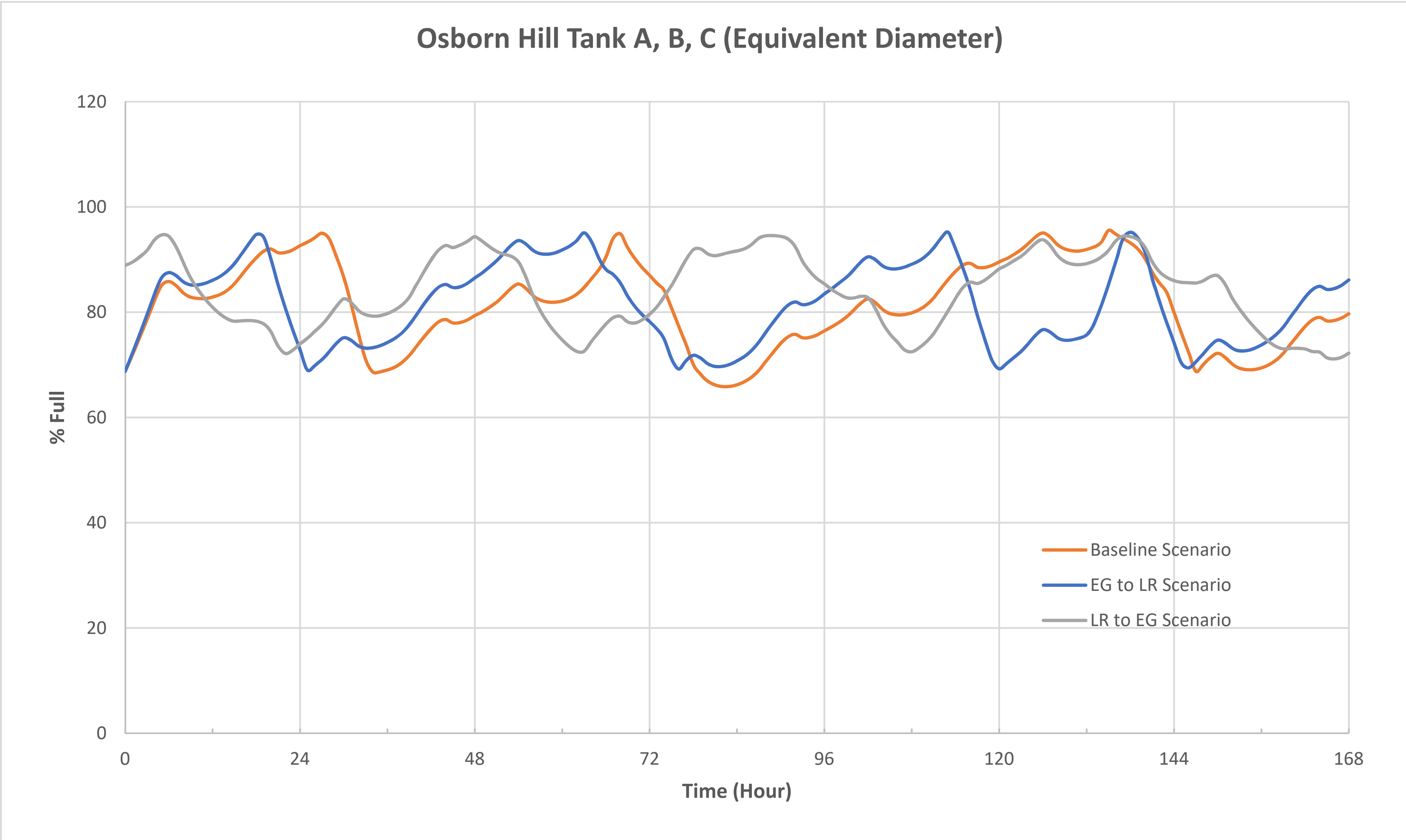

Alta Sierra Reservoir
100
90
80
70
60
50
40
30
20
10
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Baseline Scenario
EG to LR Scenario
LR to EG Scenario


David Way A Tank
120
100
80
60
40
20
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Baseline Scenario
EG to LR Scenario
LR to EG Scenario



Green Tank
120
100
80
60
40
20
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Baseline Scenario
EG to LR Scenario
LR to EG Scenario


Loma Rica Clearwell A & B (Equivalent Diameter)
120
100
80
60
40
20
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Baseline Scenario
EG to LR Scenario
LR to EG Scenario



Osborn Hill Tank A, B, C (Equivalent Diameter)
120
100
80
60
40
20
0
% Full
0
24
48
72
96
120
144
168
Time (Hour)
Baseline Scenario
EG to LR Scenario
LR to EG Scenario