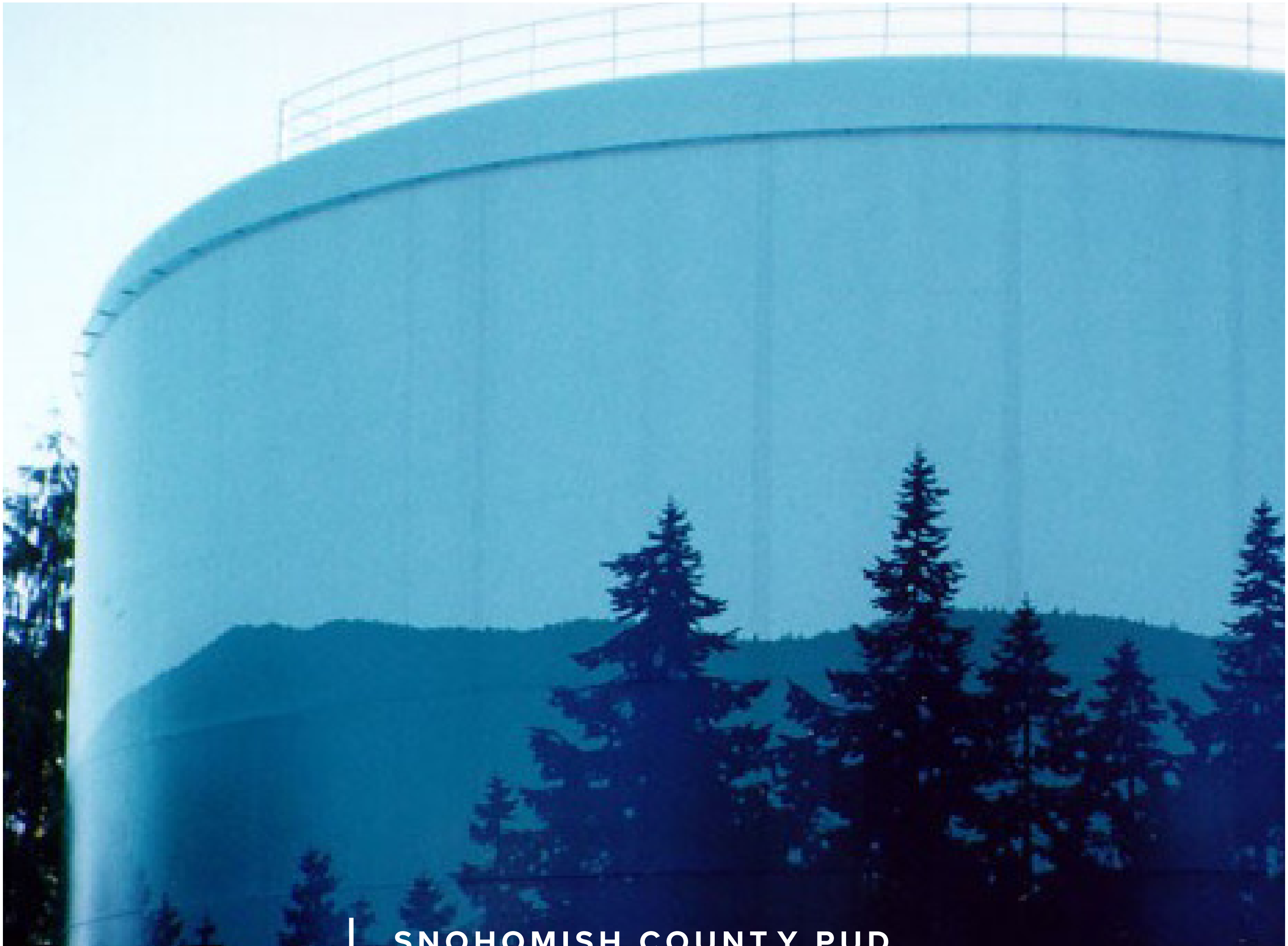


SNOHOMISH COUNTY PUD

2021 Water System Plan

Volume 12 of 16 - Chapter 7 Appendices

December 2022

THIS PAGE INTENTIONALLY LEFT BLANK

Appendices

Appendix 0-1	Submittal and Consistency Checklists
Appendix 0-2	SEPA Documentation
Appendix 0-3	Comments and Response
Appendix 0-4	Consumer WSP Meeting Minutes
Appendix 1-1	Policy Manual
Appendix 1-2	DOH Water Facility Inventory Forms
Appendix 1-3	DOH Operating Permits
Appendix 1-4	Warm Beach ALOP DOH Approval
Appendix 2-1	North Snohomish Coordinated Water System Plan
Appendix 2-2	Pertinent District Resolutions
Appendix 2-3	Current Satellite Management Program
Appendix 3-1	Reclaimed Water Reuse References
Appendix 3-2	Agreements
Appendix 3-3A	Snohomish County Land Use Map
Appendix 3-3B	Lake Stevens Land Use
Appendix 3-3C	Granite Falls Land Use
Appendix 3-3D	Gold Bar Land Use
Appendix 3-3E	Marysville Land Use
Appendix 3-3F	Snohomish City Land Use
Appendix 5-1	Water Multi-Family Unit Count
Appendix 5-2	Snohomish County FAZ Map
Appendix 6-1	Conservation Rates Meeting Agenda
Appendix 7-1	Hydraulic Model Calibration Tech Memo
Appendix 7-2	Storage Analyses
Appendix 8-1	2001 Drought Response Plan
Appendix 8-2	Water Rights
Appendix 8-3A	Wellhead Protection Program Lake Stevens
Appendix 8-3B	Kayak Wellhead Protection Plan

Appendix 7-1

Hydraulic Model Calibration Tech Memo

THIS PAGE INTENTIONALLY LEFT BLANK

TO:	Brant Wood, Snohomish PUD Kevin Presler, Snohomish PUD Max Selin, Snohomish PUD
FROM:	Matt Sellers, P.E., Sedaru Behnaz Khakbaz, Ph.D., P.E., Sedaru Jennifer Wood, P.E., Sedaru
CC:	Paul Hauffen, Sedaru
DATE:	July 30, 2019

1 Introduction

This technical memorandum (TM) has been developed by Sedaru, Inc. for the Snohomish Public Utility District No. 1 (SNOPUD/District) to report on the hydraulic model updates and the results of the Steady-State (SS) model calibration. The project goals are listed below:

- Update existing hydraulic model from the most current GIS geodatabase.
- Allocate existing Average Day Demands (ADD).
- Hydrant Testing Plan consisting of up to 10 hydrant test locations.
- Steady-State model calibration against 10 hydrant flow tests.
- Develop master planning scenarios.

This TM includes the following sections:

Section 1 – Introduction

Section 2 – Model Updates

Section 3 – Existing System

Section 4 – Demand Allocation

Section 5 – Steady State Calibration

Section 6 – Master Planning Scenario Development

Section 7 – Recommendations

2 Model Updates

The existing SNOPUD hydraulic model was updated from the most current GIS geodatabase. The focus of the update was only Lake Stevens area per SNOPUD. The existing pipe ID field and facility status field were used to identify updates with the District's feedback. Hydrant laterals were not imported. Existing facilities were assumed to be accurately represented in the existing model. Only new or updated facilities were reviewed for inclusion in the updated model.

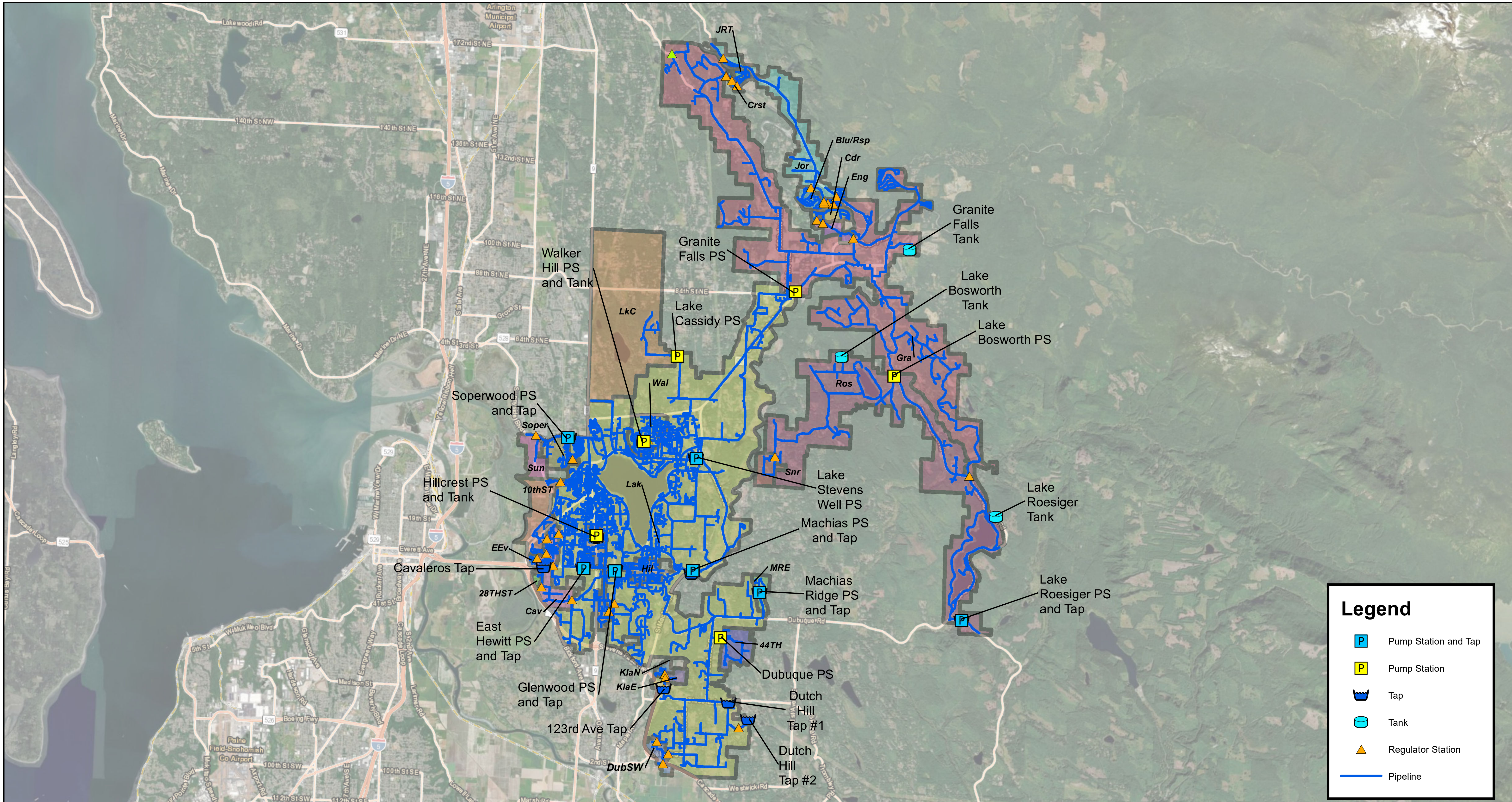
3 Existing System

The SNOPUD hydraulic system includes 26 pressure zones. Figure 1 on the following page shows a GIS map of the existing system and pressure zones. Table 1 lists pressure zones and their abbreviated names per the naming convention identified in the existing model. This section summarizes the basic elements included in the hydraulic model.

Table 1. SNOPUD System Pressure Zones

Pressure Zone	Abbreviated Name
Sunnyside	Sun
10th Street SE	10thST
28TH ST SE	28THST
44th Street	44TH
Blue Spruce & Rainbow Springs	Blu/Rsp
Cavaleros	Cav
Cedar Ln / Indian Summer	Cdr
Crest Lane	Crst
Dubuque	Dub
Dubuque Southwest	DubSW
E. Everett	EEv
Engebretson	Eng
Granite Falls	Gra
Hillcrest	Hil
Jordan	Jor
Jordan River Trails	JRT
Kla-Ha-Ya (East)	KlaE
Kla-Ha-Ya (North)	KlaN
Lake Stevens	Lak
Lake Cassidy	LkC

Pressure Zone	Abbreviated Name
Meeker Retreat	Meeker
Machias Ridge East (157th Ave SE)	MRE
Lake Roesiger	Ros
Sunset Ridge	Snr
Soper Hill	Soper
Walker Hill	Wal



N
W E
S

0 5,500 11,000 22,000 Feet

Figure 1
Water System Facilities and Pressure Zones

Snohomish County
Public Utility District No. 1

3.1 Sources of Supply

The system receives its water supply from the following primary sources summarized in Table 2.

Table 2. Sources of Supply Summary

Name	Model ID	HGL (ft) (in model)
123rd Avenue SE Tap (Kla-Ha-Ya)	123RD_AVE_TAP	430
Machias Ridge East (157th Avenue SE Tap)	157TH_AVE_TAP	478
Cavaleros Pump Station Tap	CAVALEROS_TAP	461
Dutch Hill Tap #1 (Dubuque)	DUTCHH_TAP1	545
Dutch Hill Tap #2 (Dubuque)	DUTCHH_TAP2	545
East Hewitt Pump Station Tap	EHEWITT_TAP	460
Glenwood Pump Station Tap	GLENWOOD_TAP	462
Lake Steven Well	LK_STVNS_WELL	166
Lake Roesiger Tap	LROESIGER_TAP	550
Machias Pump Station Tap	MACHIAS_TAP	464
Soperwood Pump Station Tap (Marysville JOA)	SOPERWOOD_TAP	432
*Williams Road Tap	WILLIAMSRD_TAP	466

*Abandoned per SNOPUD

3.2 Pump Stations

There are 13 pump stations and 40 pumps in the model. All but four (4) pumps have pump curves defined as single design point. The remaining four pumps have multi-point curves defined in the hydraulic model. Typically, multi-design points based on manufacturer curves, recent pump tests, or SCADA are preferred. Single design points can result in inaccurate simulated flow if the pump is operating far away from the design point. Table 3 summarizes the pump stations in the system.

Table 3. Pump Stations Summary

Name	Model ID	Design Points		From Zone[B]	To Zone[B]
		Head (ft)	Flow (gpm)		
East Hewitt	EHEWITT_P1	40	800	EHEWITT_TAP	Lak
	EHEWITT_P2	99	1,280		
Soperwood	SOPERWOOD_P1	128	90	SOPERWOOD_TAP	Lak
	SOPERWOOD_P2	106	1,510		
Lake Roesiger	LROESIGER_P1	280	450	LROESIGER_TAP	Ros
	LROESIGER_P2	280	450		
Lake Bosworth	LBOSWORTH_P1	132	202	Gra	Bos
	LBOSWORTH_P2	132	202		
Machias Ridge East	MACHIAS_RE_P1	190	75	157TH_AVE_TAP	MRE
Lake Stevens Well PS	LK_STVNS_WELLPUMP	395	1,000	LK_STVNS_WELL	Lak
Dubuque	DUBUQUE_P1	90	120	Dub	44TH
Glenwood	GLENWOOD_P1	35	1,375	GLENWOOD_TAP	Lak
	GLENWOOD_P2	40	2,000		
	GLENWOOD_P3	80	500		Hil
	GLENWOOD_P4	80	1,000		
	GLENWOOD_P5	80	1,000		
Lake Cassidy	LCASSIDY_P1	LK_CASSIDY1[A]		Lak	LkC
	LCASSIDY_P2	LK_CASSIDY2_3[A]			
	LCASSIDY_P3	LK_CASSIDY2_3[A]			
	LCASSIDY_P4	LK_CASSIDY4_5[A]			
Granite Falls	GRANITEFALLS_P1	273	1,146	Lak	Gra
	GRANITEFALLS_P2	370	815		
	GRANITEFALLS_P3	374	1,218		
	GRANITEFALLS_P4	374	2,218		
Machias	MACHIAS_P1	32	1,177	MACHIAS_TAP	Lak
	MACHIAS_P2	130	400		
	MACHIAS_P3	130	1,150		
	MACHIAS_P4	130	1,150		
	MACHIAS_P5	130	1,150		
Walker Hill	WALKERHILL_P1	80	95	Lak	Wal
	WALKERHILL_P2	80	200		
	WALKERHILL_P3	80	200		
	WALKERHILL_P4	80	500		
	WALKERHILL_P5	80	500		
	WALKERHILL_P6	80	500		
Hillcrest	HILLCREST_P1	80	100	Lak	Hil
	HILLCREST_P2	80	300		
	HILLCREST_P3	80	300		
	HILLCREST_P4	80	400		
	HILLCREST_P5	80	400		

[A] Pump curves in model.
[B] "From" and "To" Zones use abbreviations in the model.

3.3 Reservoirs

There are seven (7) cylindrical tanks in the model with a total capacity of 14.17 MG. Note this capacity is based on tank dimensions available in the model. None of the tank dimensions were modified or changed in this study. Table 4 summarizes the reservoirs within the system.

Table 4. Reservoirs Summary

Name	Model ID	Diameter (ft)	Ground Elevation (ft)	Height (ft)	Max Elevation (ft)*	Capacity (MG)
Granite Falls Tank	GRANITE_FALLS_TANK1	120	695	32	727	2.71
Hillcrest Tank #1	HILLCREST_TANK1	100	453	52	505	3.05
Hillcrest Tank #2	HILLCREST_TANK2	100	450	52	502	3.05
Lake Bosworth Tank	LBOSWORTH_TANK1	46	732	83	815	1.03
Lake Roesiger Tank	LROESIGER_TANK1	42	774	39	813	0.41
Walker Hill Tank #1	WALKERHILL_TANK1	70	428	68	496	1.96
Walker Hill Tank #2	WALKERHILL_TANK2	70	422	68	490	1.96
Total Capacity (MG)						14.17

*High Water Level

3.4 Pressure Regulating Stations

There are 38 regulating stations in the hydraulic model defining pressure zones. In most cases, each station is comprised of a small and large PRV. There are 35 large and 25 small PRVs in the model. Table 5 provides the PRV settings within the model. These settings were updated for this project based on spreadsheets provided by SNOPUD. A summary of the pressure regulating stations is shown below in Table 5.

Table 5. Pressure Regulating Stations Summary

Regulating Station Name	Size	Model IDs	From Zone	To Zone	Setting (psi)
PRV-1	8-inch	V100001	Gra	Jor	63
	2.5-inch	V100002			68
PRV-2	8-inch	V100004	Jor	Blu/Rsp	50
	2-inch	V100005			57
PRV-3	8-inch	V100007	Gra	Jor	105
	3-inch	V100008			115
PRV-4	8-inch	V100011	Jor	Blu/Rsp	40
	2-inch	V100012			48
PRV-5	2-inch	V100014	Jor	Blu/Rsp	55
	1-inch	V100118			62
PRV-6	2-inch	V100015	Jor	Blu/Rsp	61

Regulating Station Name	Size	Model IDs	From Zone	To Zone	Setting (psi)
PRV-7	1-inch	V100016	Jor	Blu/Rsp	65
PRV-8	8-inch	V100065	Eng	Cdr	45
	2-inch	V100067			55
PRV-9	8-inch	V100020	Gra	Eng	45
	2-inch	V100018			52
PRV-10	8-inch	V100021	Lak	Gra	85
PRV-11	6-inch	V100023	Bos	Gra	123
PRV-15	8-inch	V100030	Soper	Sun	92
	2-inch	V100031			97
PRV-17	2-inch	V100035	Bos	Snr	65
	1-inch	V100036			70
PRV-18	8-inch	V100037	Cav	10THSt	35
	2-inch	V100038			40
PRV-20	2-inch	V100040	Cav	28THSt	75
PRV-21	8-inch	V100041	Lak	Cav	90
PRV-23	8-inch	V100046	Lak	Wil	60
PRV-24	6-inch	V100048	Hil	Lak	35
	3-inch	V100049			35
PRV-25	6-inch	V100050	Dub	Dub	75
	3-inch	V100051			78
PRV-26	6-inch	V100052	Dub	DubSW	85
	2-inch	V100053			95
PRV-27	2-inch	V100055	Jor	Meeker	99
PRV-28	2-inch	V100132	Jor	JRT	0
	1.25-inch	V100058			28
PRV-29	6-inch	V100059	Dub	Dub	50
PRV-30	2-inch	V100060	Dub	KlaE	95
	1-inch	V100061			100
PRV-31	6-inch	V100062	Dub	KlaN	45
	2-inch	V100063			50
PRV-33	2-inch	V100074	Dub	DubSW	55
	1-inch	V100073			60
PRV-37	2-inch	V100070	Lak	Hil	99
PRV-42	2-inch	V100017	Cdr	Eng	50
PRV-43	2-inch	V100081	Jor	Crst	58
PRV-45	6-inch	V100126	Lak	Cav	67
	2-inch	V100127			70
PRV-46	8-inch	V100085	Cav	10THSt	43
	2.5-inch	V100086			48
PRV-47	8-inch	V100087	Lak	Soper	52
	4-inch	V100088			55
PRV-52	8-inch	V100096	Lak	10THSt	50
	2.5-inch	V100097			60
PRV-53	8-inch	V100098	Cav	Eev	40

Regulating Station Name	Size	Model IDs	From Zone	To Zone	Setting (psi)
	2.5-inch	V100099			45
PRV-54	12-inch	V100100	Lak	Cav	67
PRV-60	2-inch	V100101	DubSW	DubSW	70
PRV-61	8-inch	V100124	Ros	Gra	78
	2.5-inch	V100125			
PRV-65	8-inch	V100131	Wal	Lak	25

3.5 Pipelines

The District's water distribution system is comprised of 342 miles of pipelines. Pipeline diameters, materials, and age are summarized in Table 6, Table 7 and Table 8, respectively. C-factors have not been adjusted in this project and typically range between 100 to 140.

Table 6. Pipeline Diameter Summary

Diameter (in)	Length (ft)	%
1 - <6	218,911	12
6 - <8	158,402	9
8 - <12	991,747	55
12 - <16	351,518	19
16 - <24	64,347	4
24 - <36	20,763	1
>= 36	0	<1
Total	**1,805,687**	**100%**

Table 7. Pipeline Material Summary

Material	Length (ft)	%
AC	92,948	5
CI	24,661	1
C	637	<1
PVC	81,493	5
DI	1,583,500	88
PE	17,285	1
G	336	<1
STL	156	<1
Unknown	4,670	<1
Total	**1,805,687**	**100%**

Table 8. Pipeline Age Summary

Age	Length (ft)	%
<1940	0	<1
1940 - 1959	18,564	1
1960 - 1979	153,365	8
1980 - 1999	898,757	50
>2000	715,788	40
Unknown	19,213	1
Total	**1,805,687**	**100%**

4 Demand Allocation

Demand data was stored as three (3) usage types in the model: base consumption demand, wholesale demand, and non-revenue water (NRW) demand which sums up to the Average Day Demand (ADD). Base consumption demand data was provided by SNOPUD as average annual demand per model node. This was directly imported into the existing model. Wholesale user demands within Lake Stevens area were also provided by the District and allocated to the nearest nodes in the model.

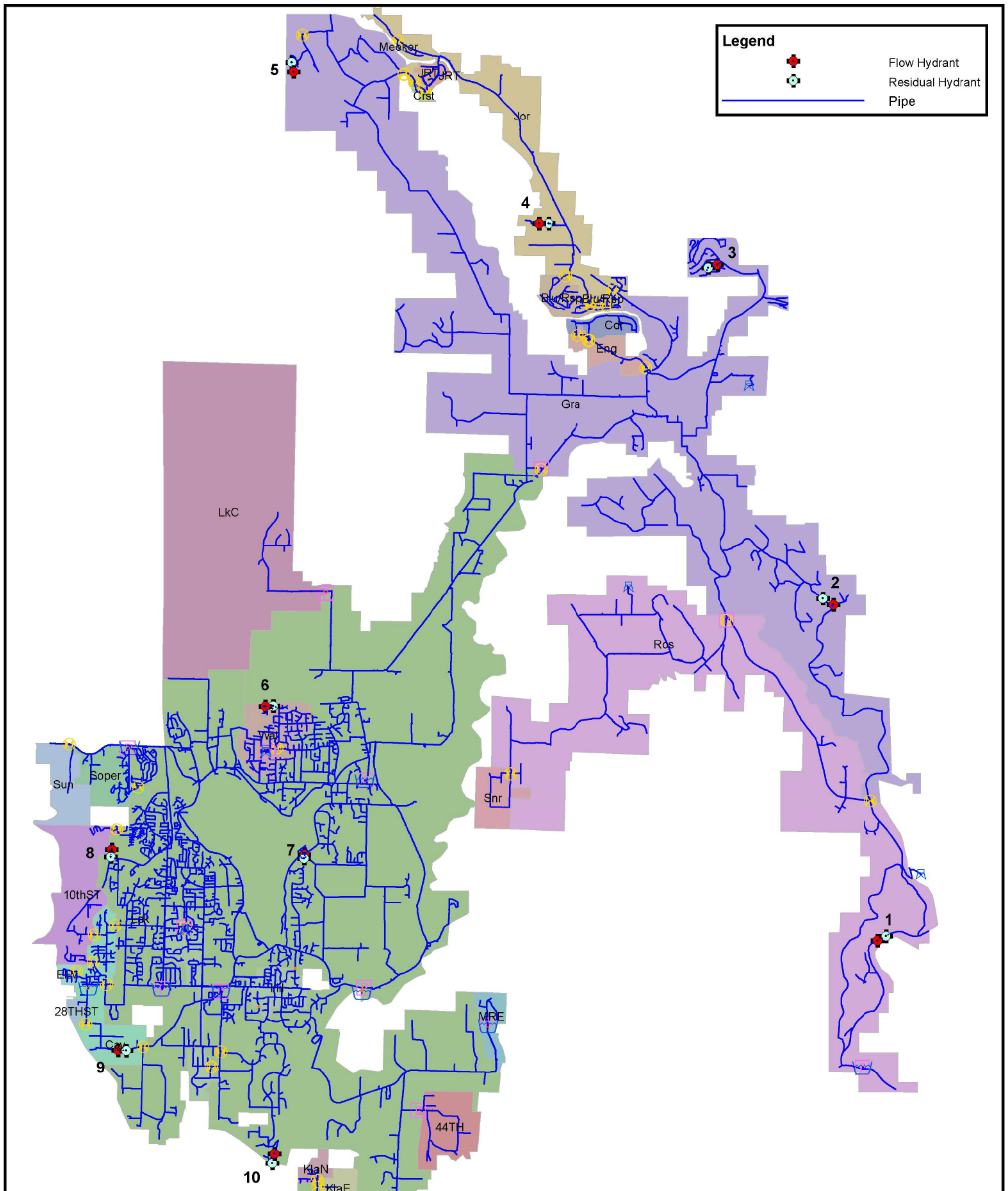
NRW is calculated as the difference between production and consumption, where the District provided the production and consumption data, and Sedaru calculated the NRW. NRW was allocated to the model based on pipe length, where the nodes connected to a pipe receives NRW demand based on the pipe's length proportionally when compared with the total system pipe length. Since it is impossible to know where all NRW exists, this method assumes that most NRW in the system is background leakage, which is typically true for most water systems. Therefore, areas with more pipe length are associated with connections that are more prone to background leakage such as tees, joints, and service connections. Table 9 summarizes the system demands.

Table 9. System Demands

Type	Demand (gpm)
Base Consumption	2,701
Wholesale	314
NRW	310
Total (ADD)	**3,325 (4.79 MGD)**

5 Hydraulic Model Calibration

The SNOPUD hydraulic model was calibrated for steady-state conditions, and the model results were compared against 10 hydrant flow tests conducted throughout the distribution system. Each test consists of opening a hydrant (i.e., flow hydrant) and flowing the open hydrant until the residual pressure at an adjacent hydrant (i.e., residual hydrant) stabilizes at least 10 psi lower than the static pressure recorded at the residual hydrant. The flow measured at the hydrant is then input to the hydraulic model as a fire flow demand and the pressure at the node that represents the residual hydrant with and without this fire flow demand will then be compared with the field residual and static pressures. The location of 10 fire hydrant tests are shown in Figure 2.



Test_No	F.H. Number	Function Type	Nearby Address	Pressure Zone
1	862	Flow Hydrant	23425 S Lake Roesiger Rd	Lake Roesiger
1	863	Residual Hydrant	23613 S Lake Roesiger Rd	Lake Roesiger
2	1649	Flow Hydrant	22515 Pilchuck Pl	Granite Falls
2	1647	Residual Hydrant	22216 Pilchuck Pl	Granite Falls
3	1321	Flow Hydrant	12618 Monte Cristo Way	Granite Falls
3	1322	Residual Hydrant	12522 Monte Cristo Way	Granite Falls
4	897	Flow Hydrant	16331 134th St NE	Jordan
4	896	Residual Hydrant	16612 134th St NE	Jordan
5	2701	Flow Hydrant	11400 169th St NE	Granite Falls
5	2700	Residual Hydrant	11351 169th Ave NE	Granite Falls
6	1738	Flow Hydrant	10985 36th St NE	Walker Hill
6	1740	Residual Hydrant	11215 36th St NE	Walker Hill
7	1802	Flow Hydrant	103 S Lake Stevens Rd	Lake Stevens
7	919	Residual Hydrant	103 S Lake Stevens Rd	Lake Stevens
8	1906	Flow Hydrant	703 79th Dr. NE	Lake Stevens
8	1905	Residual Hydrant	527 79th Dr. NE	Lake Stevens
9	1262	Flow Hydrant	8130 S Lake Stevens Rd	Cavaleros
9	1263	Residual Hydrant	8317 S Lake Stevens Rd	Cavaleros
10	1281	Flow Hydrant	5290 Old Machias Rd	Lake Stevens
10	1282	Residual Hydrant	5598 Old Machias Rd	Lake Stevens

Figure 2. Fire Hydrant Test Locations

5.1 Calibration Criteria

The calibration effort included only steady-state (SS) model scenario. The goal of the SS calibration was for the pressure drop between static and residual at the modeled residual hydrants to match field pressures drop within 5 psi at 90 percent of the hydrant test locations. The primary calibration targets for SS calibration were pressure values (static pressures and residual pressures) and the pressure drop between static and flowing hydrants. Calibration criteria for the steady-state calibration is summarized in Table 10.

Table 10. Calibration Criteria

Pressure Drop Range (psi)	Match
0 – 3	Excellent
3 – 5	Good
5 – 10	Fair
>10	Poor

5.2 Calibration Procedure and Results

For the SS model calibration, the model was setup to represent the boundary conditions of each hydrant test. SCADA provided by SNOPUD was used to determine boundary conditions, if available. The SS demands were estimated based on the ADD demands. Because demands were not known for the calibration day except for few wholesale customers (provided by SNOPUD as SCADA), the SS demands were adjusted during the calibration process to closely match the observed data by no more than +/- 5%.

The calibration procedure was an iterative process that required a trial-and-error approach to resolve differences between hydrant test data and the model. Model simulations were run, and the results were compared to the hydrant test data. Where obvious differences existed between the model and observed data, these differences were investigated. The District's staff provided additional information when available to help reconcile the differences.

As shown in Table 11, the pressure drop between static and residual at the modeled residual hydrants match the field pressure drop within 5 psi at 80% of the hydrant test locations. FH tests 1 and 3 were outside the acceptable limits.

Table 11. Summary of Calibration Results

Test	Zone	Date/Time	Hydrant No. (Flow/Observation)	Flow During Test (gpm)		Field Pressure (psi)			Model Pressure (psi)			Drop Difference	Match
				Range	Calibration	Static	Residual	Drop	Static	Residual	Drop		
1	Ros	3/1/19 9:56 AM	862/863	800-1,900	1,713	87	29	58	81	17	64	6	Fair
2	Gra	3/1/19 11:04 AM	1649/1647	800-1,800	1,701	80	15	65	81	16	65	0	Excellent
3	Gra	3/1/19 12:29 PM	1321/1322	700-1,300	1,140	96	24	72	99	8	91	19	Poor
4	Jor	3/4/19 9:18 AM	897/896	900-1,600	1,500	104	23	81	104	23	81	0	Excellent
5	Gra	3/4/19 10:40 AM	2701/2700	900-1,300	1,176	72	23	49	77	28	49	0	Excellent
6	Wal	3/8/19 1:29 PM	1738/1740	800-1,800	1,550	74	33	41	75	29	46	5	Good
7	Lak	3/4/19 12:42 PM	1802/919	800-3,400	3,066	112	87	25	106	81	25	0	Excellent
8	Lak	2/27/19 12:36 PM	1906/1905	700-2,700	2,250	112	72	40	113	76	37	-3	Excellent
9	Cav	2/27/19 11:11 AM	1262/1263	1,300-2,600	2,520	106	72	34	107	73	34	0	Excellent
10	Lak	2/27/19 9:30 AM	1281/1282	1,300-2,000	1,850	164	29	135	165	30	135	0	Excellent

5.2.1 Revisited Fire Hydrant Test Data

Based on the initial test results, Sedaru requested SNOPUD to revisit tests 1, 3, and 6 to confirm static gauge pressures and elevations for both the flow and residual hydrants at those locations. In addition, fire hydrant test 6 was re-done by SNOPUD and test data were provided for additional calibration efforts. The new information validated the original gauge pressures and elevations and did not significantly improve the results of the calibration for the above-mentioned test locations.

5.2.2 Calibration Discussion

As with any hydraulic model, there is always room for improvement of accuracy. Model accuracy improves when there is more and better data available; however, some data can require significant effort to gather. The engineer/modeler must be able to weigh the required level of investment versus the gain in model accuracy and determine if it is worth pursuing based on what the intended use of the model.

Overall, the model results matched field results well for the fire hydrant tests (i.e., 80% met calibration target). Possible causes for the discrepancies between the model and field data for tests 1 and 3 are listed below:

Test 1:

Test 1 was within 6 psi of matching the observed pressure drop, giving this test a "fair" calibration match. There are a number of possible reasons the test did not see a better match:

- **Test Duration:** The fire flow test data varies by several hundred gallons per minute every few seconds and is therefore difficult to determine how accurate the test data is. One possible cause was the duration was not long enough to produce an accurate average flow and pressure measurement. It is expected the hydrant test to have some variability in flow and pressure, however this error is corrected by running the flow test long enough to reach a stable flow and to produce enough data for an accurate average reading. Typically, a minimum flow duration of five (5) minutes is recommended to achieve this. If the flow never seems to stabilize, then an alternative site within that pressure zone may provide better results.

- **Unknown System Issues:** While boundary conditions are thought to be well known for this test, the static pressure is 6 psi lower than observed. A second hydrant test in this pressure zone at a different location may reveal what is causing the observed differences in pressure. In addition, an extended period calibration against SCADA with continuous HPR records at this location would provide excellent data to help uncover unknown issues for this zone.

- **Equipment Error:** While thought to be less likely, the difference in residual pressure could be explained by uncalibrated equipment. The flow from the test data would correlate with a high pressure drop in the system, however, that was not observed. Connectivity and headlosses were thoroughly checked within this zone to eliminate the model as the source of the simulated headloss.

- **SCADA or Measured Data Error**: The reported static pressure at the residual hydrant might be incorrect as the calculated HGL at the hydrant test location is higher than the HGL of the zone (i.e., HGLs of Lake Roesiger and Lake Bosworth tanks) from SCADA. A closed valve between the test site and Lake Roesiger Tank could result in a boosted pressure coming from Lake Roesiger

Pump Station, however when this was tested in the model, the pressure drop was too great. While a hydraulic bottleneck may still be a possible cause, it should be investigated by comparing new extended period SCADA data against an EPS model in order to have the best data needed to discover the issue.

Test 3

Test 3 was within 19 psi of matching the observed pressure drop, giving this test a "poor" calibration match. There are a number of possible reasons the test did not see a better match:

- **Test Duration:** Similar to test 1, the fire flow test data varies by several hundred gallons per minute every few seconds and is therefore difficult to determine how accurate the test data is. One possible cause was the duration was not long enough to produce an accurate average flow and pressure measurement. It is expected the hydrant test to have some variability in flow and pressure, however this error is corrected by running the flow test long enough to reach a stable flow and to produce enough data for an accurate average reading. Typically, a minimum flow duration of five (5) minutes is recommended to achieve this. If the flow never seems to stabilize, then an alternative site within that pressure zone may provide better results.
- **Unknown System Issues:** While boundary conditions are thought to be well known for this test, the static pressure is 3 psi higher than observed. A second hydrant test in this pressure zone at a different location may reveal what is causing the observed differences in pressure. In addition, an extended period calibration against SCADA with continuous HPR records at this location would provide excellent data to help uncover unknown issues for this zone.
- **Equipment Error:** While thought to be less likely, the difference in residual pressure could be explained by uncalibrated equipment. The flow from the test data would correlate with a high pressure drop in the system, however, that was not observed. Connectivity and headlosses were thoroughly checked within this zone to eliminate the model as the source of the simulated headloss.

5.3 Calibration Recommendations

The steady-state calibration results indicate the model provides accurate static pressure for most of the pressure zones. The District can confidently use the hydraulic model for planning purposes such as hydrant testing and potential pipe improvements. It is recommended that if the District needs to evaluate the system nearby Test 1 and Test 3 that additional hydrant tests be completed for the area of interest. In addition, it is recommended the District consider calibrating the model against extended period data. The benefits of an EPS calibration are discussed in more detail in Section 7.

If the District wishes to perform additional hydrant testing, following recommendations have been developed based on the model update and calibration effort along with Sedaru's experience with standard industry best-practices for hydraulic modeling:

- Determine the ground elevations (+/- 1-foot accuracy) for both flow and residual hydrants.
- Confirm pressure loggers used are properly calibrated and accurate. This can be achieved by comparing loggers against a calibrated digital or analog pressure gauge.

- Confirm a minimum of 5-minutes of stable flow is achieved. The total test would take approximately 10-15 minutes where the first and last parts are opening and closing of fire hydrants. If a stable flow is never achieved, then the test should be relocated to nearby hydrants in the same pressure zone to get a more stable flow rate.
- Gather detailed SCADA data for tank levels, pump flow, pump status, and pump station discharge pressures for relevant facilities for each zone where fire hydrant tests are conducted. Because the hydrant test is only for 5-minutes, it is important to gather SCADA at the smallest time interval possible. In addition, record if any pumps turn on briefly to meet the hydrant flow as this is critical information the model needs to achieve an accurate simulation.

6 Master Planning Scenario Development

This section summarizes the assumptions and results of evaluating the system under current normal operating conditions. Modeled scenarios included Average Day Demand (ADD), Maximum Day Demand (MDD), and Peak Hour Demand (PHD) conditions. These scenarios can be used for master planning and analysis. Table 12 summarized the ADD, MDD, and PHD demands and peaking factors.

Table 12. Demands and Peaking Factors

Scenario	Demand (gpm)	Peaking Factor
ADD	3,325	1
MDD	7,082	2.1*
PHD	11,421	1.6**

*MDD/ADD
**PHD/MDD

For each scenario, specific pumps had to be turned on to meet the demand. Our approach was to initially start with pumps that were commonly on during the steady-state calibration, and then added as-needed so that the system demand was met, and system pressures looked reasonable (i.e. at least above 40 psi and did not change too much from the ADD scenario).

6.1 ADD Scenario

This scenario has the following conditions:

- **Demands**: 3,325 gpm (4.79 mgd)
- **Simulation:** Steady-state

Figure 3 and Figure 4 show junction pressure and pipeline velocity under ADD condition, respectively.

Observations are listed below:

- Distribution system pressures were mostly above 40 psi.

- Pressures less than 30 psi were reported at nodes near tanks or at suction side of the pump stations. These locations are not demand nodes and are common for junctions nearby facilities.
- Pressures between 30 to 40 psi were reported at high elevation areas within Lake Stevens zone on the south west side of intersection of 8th Street and 91st Avenue, along 4th Street west of 95th Avenue, and near intersection of 117th Avenue and 28th Street.
- Pipeline velocities were mostly less than 2 ft/s except for a pipeline segment along 28th Street.

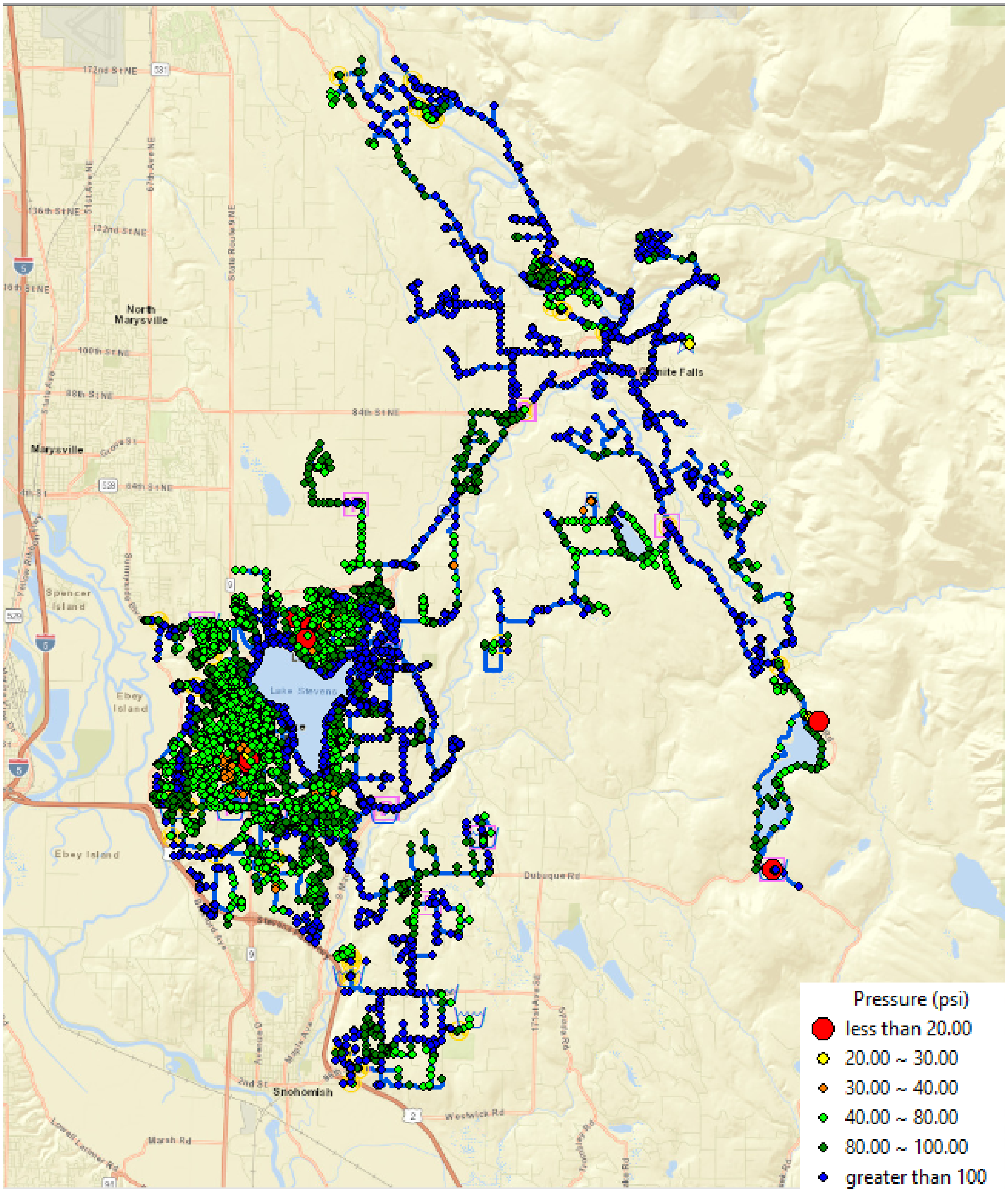


Figure 3. Junction Pressure under ADD Condition

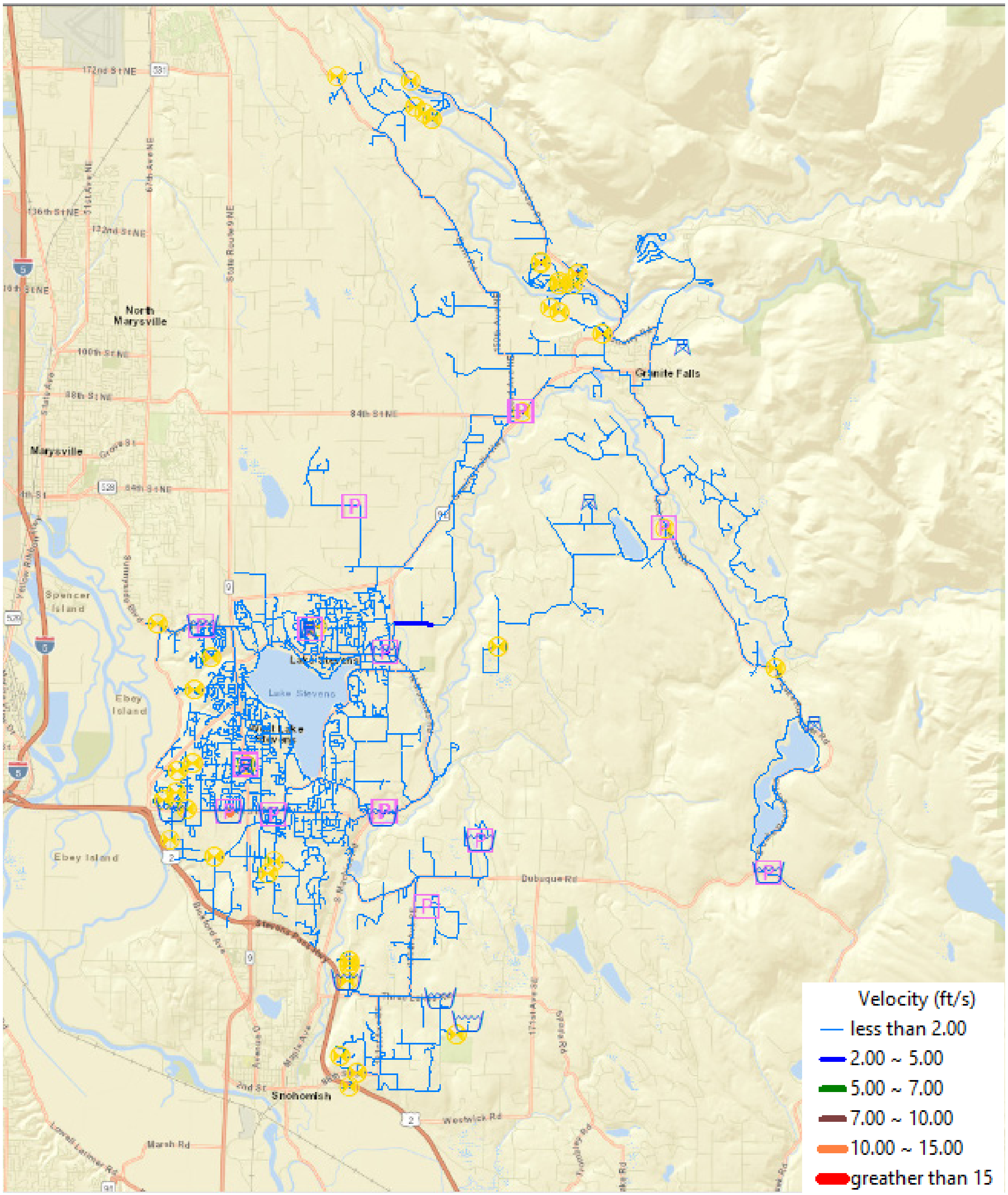


Figure 4. Pipeline Velocity under ADD Condition

6.2 MDD Scenario

This scenario has the following conditions:

- **Demands**: 7,082 gpm (10.2 mgd)
- **Peaking Factor**: MDD/ADD = 2.13
- **Simulation:** Steady-state

Figure 5 and Figure 6 show junction pressure and pipeline velocity under MDD condition, respectively.

Observations are listed below:

- Distribution system pressures were mostly above 40 psi.
- Pressures less than 30 psi were reported at nodes near tanks or at suction side of the pump stations. These locations are not demand nodes and are common for junctions nearby facilities.
- Pressures between 30 to 40 psi were reported at high elevation areas within Lake Stevens zone on the south west side of intersection of 8th Street and 91st Avenue, along 4th Street west of 95th Avenue, and near intersection of 117th Avenue and 28th Street.
- Pipeline velocities were all below 5 ft/s.

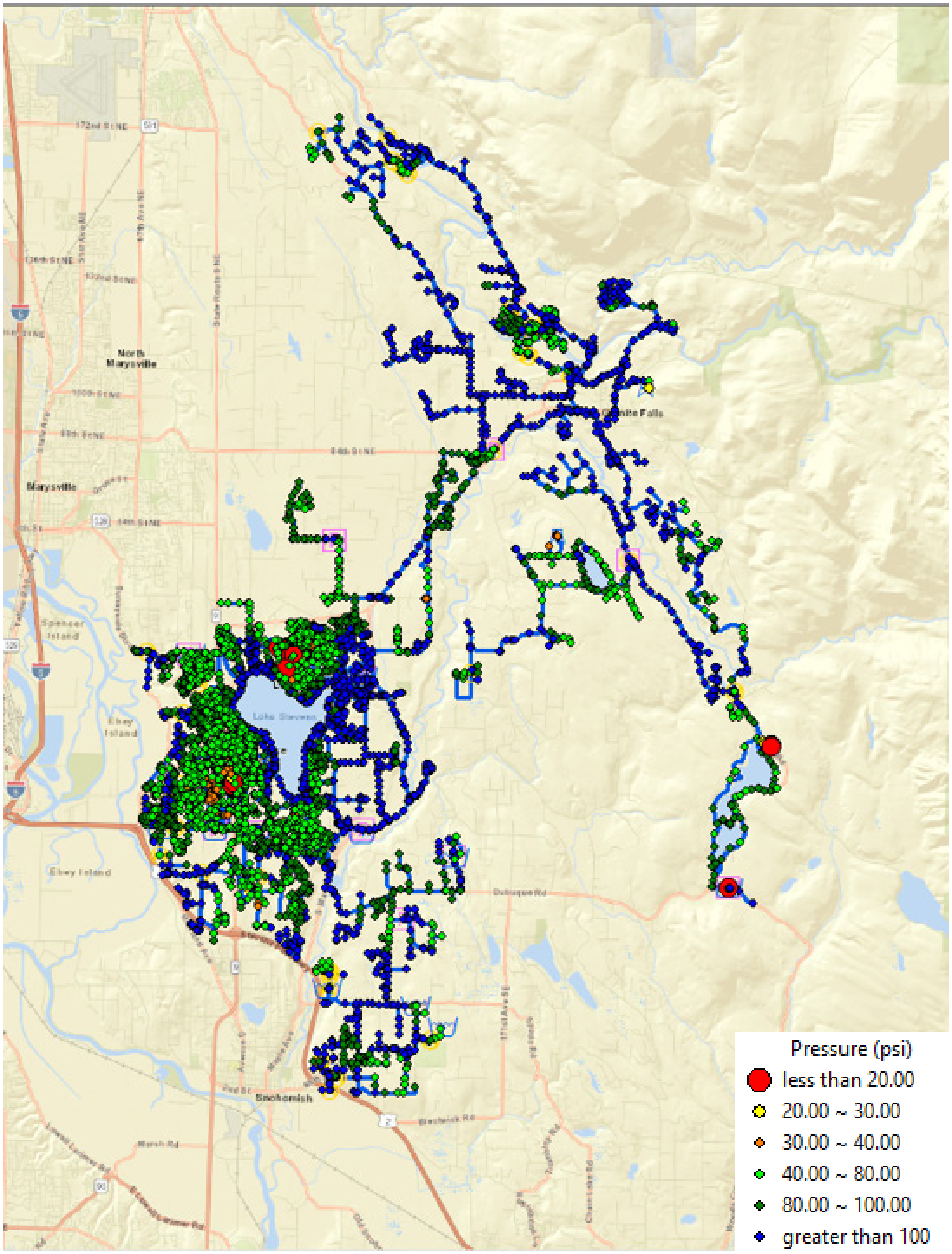


Figure 5. Junction Pressure under MDD Condition

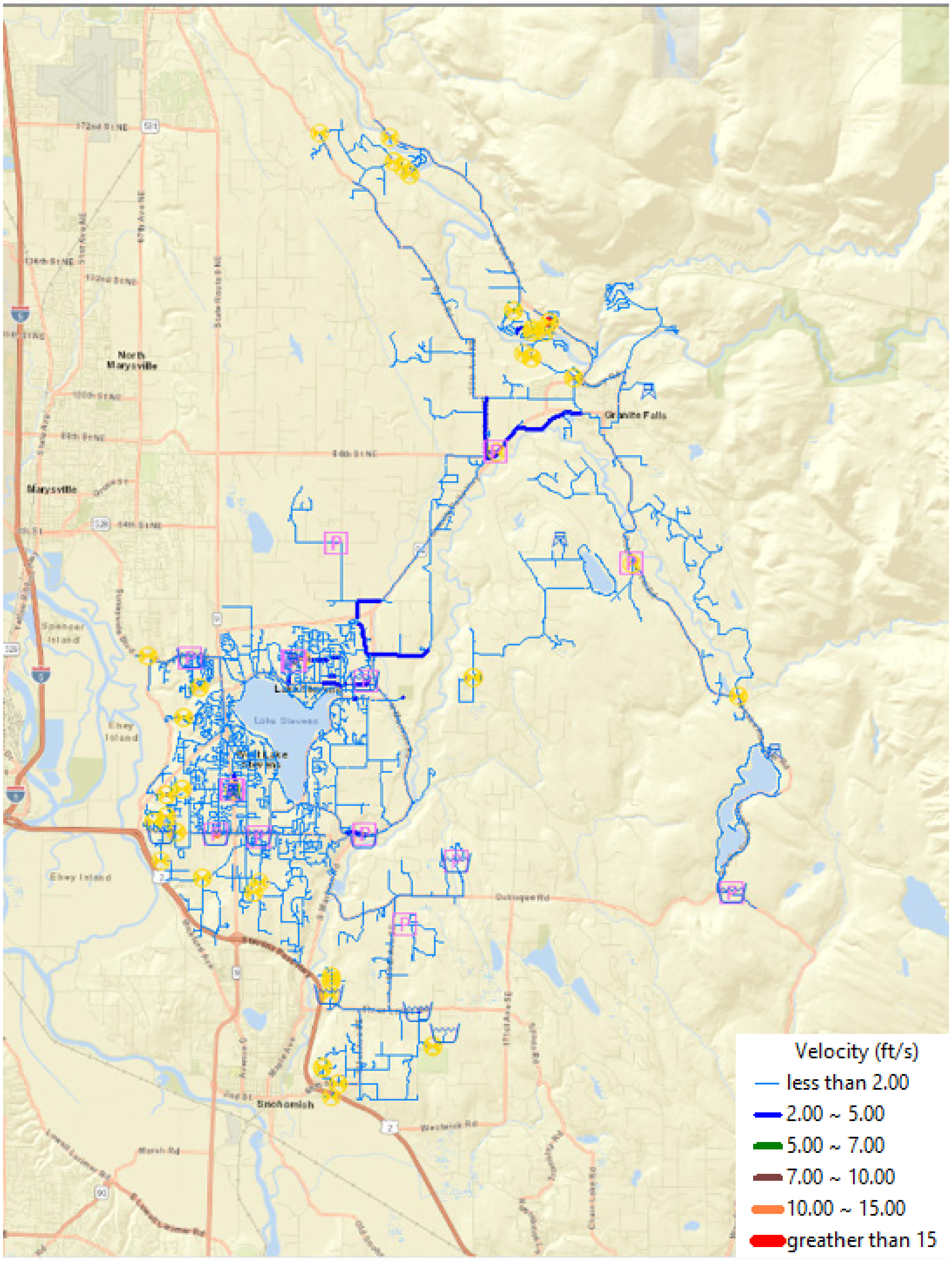


Figure 6. Pipeline Velocity under MDD Condition

6.3 PHD Scenario

This scenario has the following conditions:

- **Demands**: 11,421 gpm (16.45 mgd)
- **Peaking Factor**: PHD/MDD = 1.61
- **Simulation:** Steady-state

Figure 7 and Figure 8 show junction pressure and pipeline velocity under PHD condition, respectively.

Observations are listed below:

- Distribution system pressures were mostly above 40 psi.
- Pressures less than 30 psi were reported at nodes near tanks or at suction side of the pump stations. These locations are not demand nodes and are common for junctions nearby facilities.
- Pressures between 30 to 40 psi were reported at high elevation areas within Lake Stevens zone along 147th Avenue, on the south west side of intersection of 8th Street and 91st Avenue, along 4th Street west of 95th Avenue, and near intersection of 117th Avenue and 28th Street.
- Pipeline velocities were all below 5 ft/s.

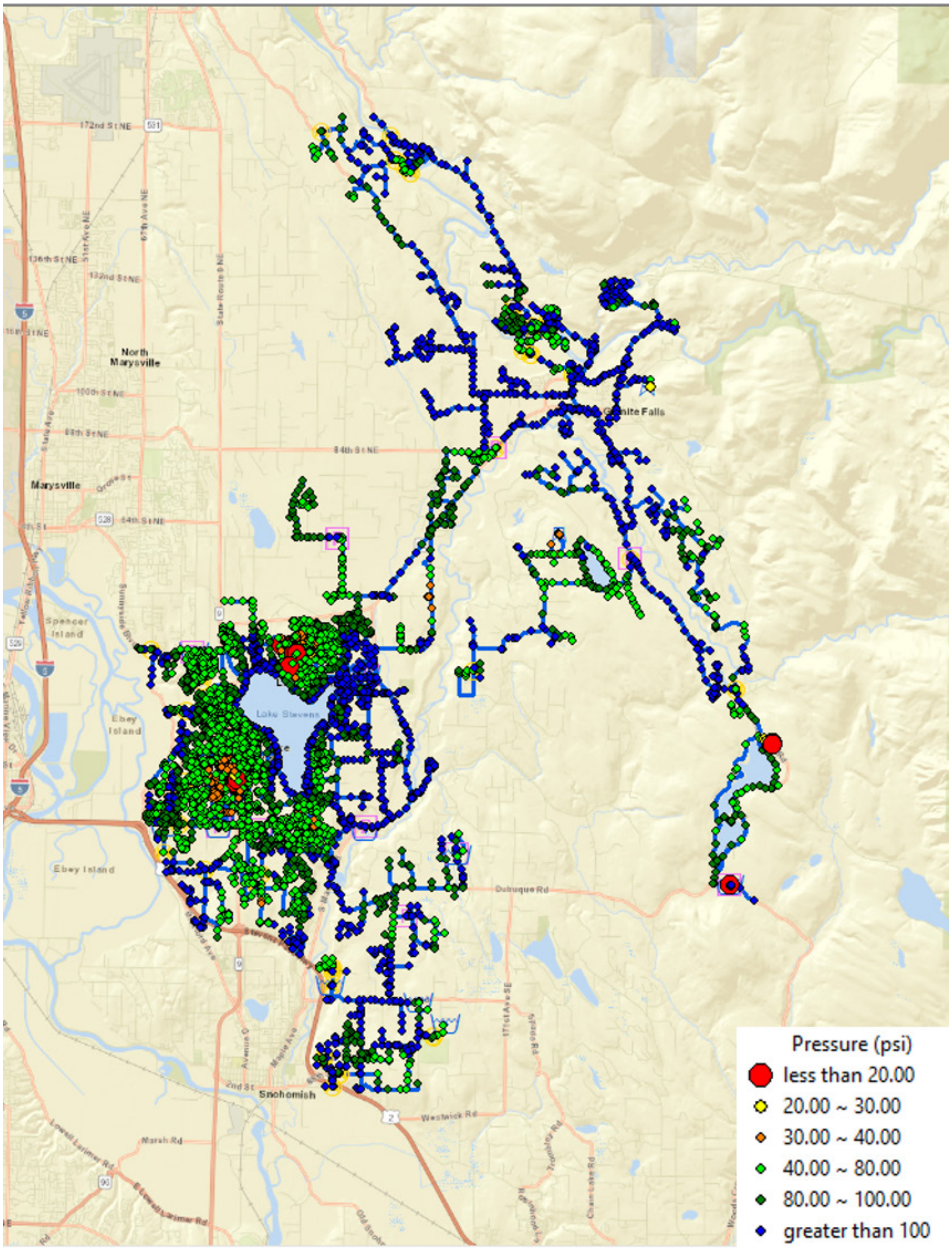


Figure 7. Junction Pressure under PHD Condition

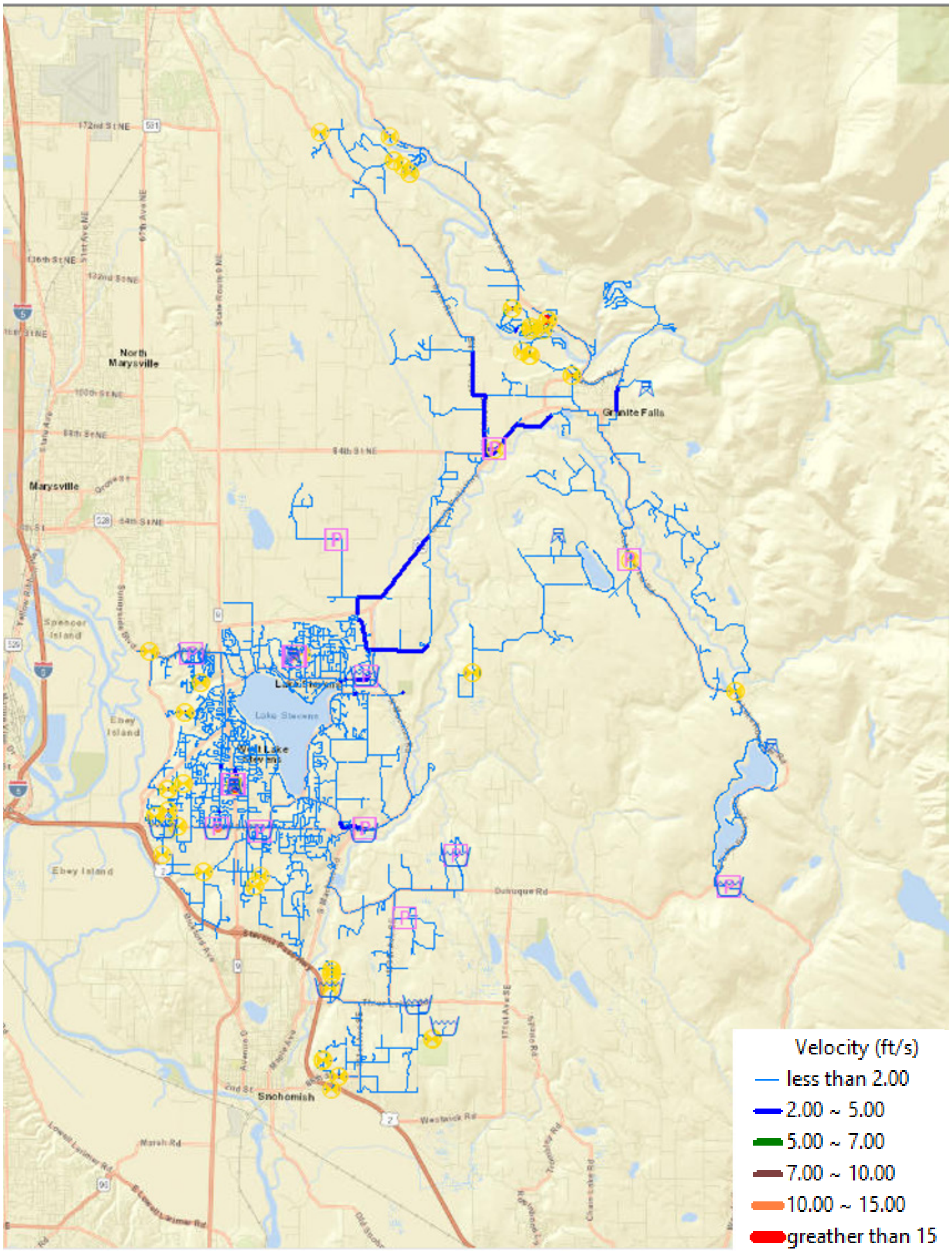


Figure 8. Pipeline Velocity under PHD Condition

7 Recommendations

This section includes a list of recommended areas of improvement for the model which assume the District wishes to use the model as a planning level model for capital improvements, operational decisions, and potentially real-time operations. The following recommendations have been developed based on the model update and calibration effort along with engineering experience with standard industry best-practices for hydraulic modeling.

- Perform a system-wide EPS calibration with additional pressure monitoring for specific trouble spots observed from the steady-state calibration (near Test 1, 3, and possibly 6). An EPS calibration is essentially hundreds of steady-state calibrations completed for each time-step of the EPS period. Additional hydrant testing can also be simultaneously completed if the District wishes to "stress-test" specific areas. Some benefits from completing a system-wide EPS are listed below:
    - Explore and potentially resolve the issues observed in the steady-state calibration. An EPS calibration allows for a modeler to compare hydraulic trends over time, whereas the steady-state is just a snapshot. An EPS can reveal a temporary or regular but unknown contributing factors that are undetectable in a steady-state.
    - An EPS can help calibrate a model's operations. The District has a large number of pumps (13 pump stations and 40 pumps), where model results can vary greatly if the wrong pumps are on for a specific demand condition. The steady-state model currently assumes specific pumps are on to meet either ADD, MDD, or PHD; however, there are not established controls that help define what pumps turn on and off based on specific demand or operating conditions (i.e. tank levels). Any controls that exist in the model are from the legacy model and may be outdated.
    - An EPS model can help find system issues that a steady-state might not reveal. For example, a pipe may show high velocity due to a pump turning on or tank filling that might not show up for a steady-state ADD, MDD, or PHD scenario.
    - The District also has a large number of PRV station (38 total). An EPS model will help the District optimize PRV settings and operations by not only showing if a PRV is active during PHD, but if the PRVs balance flow between station and how long each station is active.
    - An EPS model is also a prerequisite for evaluating any of the following: evaluating water quality through water age or modeling disinfectant, provide a tool for operations to test "what-if" scenarios, finding energy cost savings through pumping improvements, and support staff with a real-time model that updates with live SCADA.
- Continue to improve the District's GIS. The objective should be to achieve a geometric network, where all links have an upstream and downstream node. There were still a large number of edits completed in order to achieve a working model. Each element should have a unique ID as well. In

addition, the District should continue to actively track valves status such as open, closed, or partially closed.

- Update the model's pump curve definitions that only have design points. The following data is preferred to develop pump curves in this order 1) recent pump test data (test should have at least 3 performance points, near shut off head, throttled flow, and full flow) 2) curve calculated from SCADA (SCADA must have flow, discharge pressure, and upstream pressure/tank levels) 3) manufacturer's curve. It is recommended that all pumps at least be defined by the manufacturer's curve, where the District can determine if a pump has deteriorated based on current performance.
- Obtain <1ft accurate elevation data for all pressure transmitters, pressure reducing or sustaining valves, flow control valves, pump centerlines, and tank elevation data. The current elevation data is based on a 5-ft elevation contour map provided by the District. All pressure data in the SCADA system should have a corresponding elevation that is within 1-foot accuracy for X, Y, and Z coordinates. This will provide the best correlation of flows and pressures between the model and actual operations.
- The District should investigate hydrant tests that did not match the model results. Erroneous data, diameter discrepancies, C-factor differences, connectivity issues, and operational changes should all be considered when evaluating this data.
- 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.
- Using SCADA available for wholesale connections during an EPS calibration would improve model performance (when used for calibration or a real-time model) and allow for operators to optimize operations when wholesale connections are active.

Appendix 7-2

Storage Analyses

THIS PAGE INTENTIONALLY LEFT BLANK

LAKE STEVENS INTERGRATED
STORAGE ANALYSIS

Storage Tanks	Hillcrest 1	Hillcrest 2	Walker Hills 1	Walker Hills 2	Granite Falls	Bosworth	Lake Roesiger 1	Lake Roesiger 2
Reservoir Shape	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical	Cylindrical
Zone Served	**Lk Steven**	**Lk Steven**	**Lk Steven**	**Lk Steven**	**Granite**	**Lk Roesiger**	**Lk Roesiger**	**Lk Roesiger**
Diameter (Ft)	100	100	70.7	70.7	120	46	30	30
Overflow Elevation (Ft)	502	502	490	490	726	811	811	811
Base Elevation (Ft)	450	450	429	429	695	732	774	774
Storage Height (ft)	52	52	61	61	31	79	37	37
Reservoir Volume Per Foot Height (gal/ft)	58,748	58,748	29,365	29,365	84,597	12,431	5,287	5,287
Capacity (MG)	3.05	3.05	1.79	1.79	2.62	0.98	0.20	0.20
Usable Capacity (MG)	3.03	3.03	1.29	1.29	2.58	0.43	0.18	0.18

Tank Name	Hillcrest Tank 1	Hillcrest Tank 2	Walker Hill Tank 1	Walker Hill Tank 2	Granite Falls Tank 1	Bosworth Tank	Lk Roesiger Tank 1	Lk Roesiger Tank 2
Operational Storage (OS)								
Pump Off Water Height (ft)	45	45	61	61	29	80	37	37
Pump On Water Height (ft)	40	40	56	56	22	70	27	27
Operational Storage (gal)	293,739	293,739	146,825	146,825	592,178	124,310	52,873	52,873
Operational Storage Height (ft)	5	5	5	5	7	10	10	10

Fire Suppression Storage (FSS)								
Largest Fire Flow Requirement (gpm)	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Largest Fire Flow Duration (min)	120	120	120	120	120	120	120	120
Fire Suppression Storage (gal)	360,000	360,000	360,000	360,000	360,000	360,000	360,000	360,000
Fire Suppression Height (ft)	12.3	12.3	-	-	4.3	46.9	46.9	46.9

Dead Storage (DS)								
Max Service Elevation	400	400	400	400	600	730	730	730
Min Tank Elev for 20 psi	446	446	446	446	646	776	776	776
Min Tank Elev for 30 psi	469	469	469	469	669	799	799	799
Dead Storage (gal)	29,374	29,374	502,729	502,729	42,298	548,457	11,209	11,209
Dead Storage Height (ft)*	0.5	0.5	17.12	17.12	0.5	44.12	2.12	2.12

**Assumes 0.5' of dead storage for silt stop for Hillcrest & Granite Falls*

Arlington Demand (ADD & MDD)	214	1,000	1,000	
	Plan Yr. 2020	**10-Yr 2030**	**20-Yr 2040**	
SS = (System MDD) x (2 days) (MG)	18.39	23.02	27.13	<< System Wide Demand/ERU value without Arlington Wholesale
SS = (System MDD) x (1 day) (MG)	9.19	11.51	13.56	
SS = (System ADD) x (2 day) (MG)	8.67	11.11	13.07	
Min. SS = 200 gallons/ERU * NERU (MG)	4.61	5.90	6.97	

STORAGE ANALYSIS SUMMARY TABLE — WHOLE SYSTEM

Description	Plan Yr. 2020	10-Yr 2030	20-Yr 2040	
Usable Storage (MG)				
Maximum Storage Capacity	13.69	13.69	13.69	*All calcs adjusted to not include future tanks*
Dead (Non-usable) Storage	1.68	1.68	1.68	
Total Usable Storage	12.01	12.01	12.01	
Required Storage (MG)				
Operational Storage	1.70	1.70	1.70	
Equalizing Storage	0.00	0.00	0.00	*Use all sources except Cavaleros since it is not connected to all zones*
Standby Storage (Emergency)	8.67	11.11	13.07	
Fire Flow Storage (Emergency)	0.36	0.36	0.36	*Use largest fire flow requirement*
Total Required Storage	10.37	12.81	14.78	
Surplus Storage	**1.64**	**-0.80**	**-2.77**	

STORAGE ANALYSIS - PLAN YEAR (2020)

Description	Lk Stevens Service Area	Granite Service Area	Lk Roesiger Service Area	Total System
Usable Storage (MG)				
Maximum Storage Capacity	9.69	2.62	1.37	13.69
Dead (Non-usable) Storage	1.06	0.04	0.57	1.68
Total Usable Storage	8.63	2.58	0.80	12.01
Required Storage (MG)				
Operational Storage	0.88	0.59	0.23	1.70
Equalizing Storage	0.00	0.00	0.00	0.00
Standby Storage (Emergency)	7.54	0.83	0.30	8.67
Fire Flow Storage (Emergency)	0.36	0.36	0.36	1.08
Total Required Storage	8.42	1.42	0.59	10.43
Surplus Storage	**0.21**	**1.16**	**0.21**	**1.58**

STORAGE ANALYSIS - TEN-YEAR (2030)

Description	Lk Stevens Service Area	Granite Service Area	Lk Roesiger Service Area	Total System	Total System w/ CIPs
Usable Storage (MG)					
Maximum Storage Capacity	9.69	2.62	1.37	13.69	
Dead (Non-usable) Storage	1.06	0.04	0.57	1.68	
Total Usable Storage	8.63	2.58	0.80	12.01	
Required Storage (MG)					
Operational Storage	0.88	0.59	0.23	1.70	
Equalizing Storage	0.00	0.16	0.00	0.16	
Standby Storage (Emergency)	10.21	0.31	0.58	11.11	
Fire Flow Storage (Emergency)	0.36	0.36	0.36	1.08	
Total Required Storage	11.09	1.11	0.81	13.02	
Surplus Storage	**-2.46**	**1.47**	-0.01	**-1.01**	

STORAGE ANALYSIS - TWENTY-YEAR (2040)

Description	Lk Stevens Service Area	Granite Service Area	Lk Roesiger Service Area	Total System	Total System w/ CIPs
Usable Storage (MG)					
Maximum Storage Capacity	9.69	2.62	1.37	13.69	21.23
Dead (Non-usable) Storage	1.06	0.04	0.57	1.68	3.05
Total Usable Storage	8.63	2.58	0.80	12.01	18.17
Required Storage (MG)					
Operational Storage	0.88	0.59	0.23	1.70	2.20
Equalizing Storage	0.00	0.42	0.00	0.42	
Standby Storage (Emergency)	10.30	1.98	0.79	13.07	
Fire Flow Storage (Emergency)	0.36	0.36	0.36	1.08	
Total Required Storage	11.18	3.00	1.02	15.20	
Surplus Storage	**-2.55**	**-0.42**	**-0.22**	**-3.19**	

LAKE STEVENS INTERGRATED
STORAGE ANALYSIS

Storage	
Reservoir Name	Tank 1
Reservoir Shape	Cylindrical
Diameter (Ft)	30
Overflow Elevation (Ft)	762
Base Elevation (Ft)	718
Storage Height (ft)	44
Reservoir Volume Per Foot Height (gal/ft)	5,287
Capacity (MG)	0.23

Tank Name	**Storm Lake Tank 1**
Zone	**Storm Lake Ridge**
Operational Storage (OS)	
Pump Off Water Height (ft)	43
Pump On Water Height (ft)	32
Operational Storage (gal)	58,160
Operational Storage Height (ft)	11
Fire Suppression Storage (FSS)	
Largest Fire Flow Requirement (gpm)	1,000
Largest Fire Flow Duration (min)	120
Fire Suppression Storage (gal)	120,000
Fire Suppression Height (ft)	22.7
Dead Storage (DS)	
Max Service Elevation	670
Min Tank Elev for 20 psi	716
Min Tank Elev for 30 psi	739
Dead Storage (gal)	5,287
Dead Storage Height (ft)*	1

**Assumes a min of 1.0'ft dead storage for pump protection*

	Plan Yr. 2020	**10-Yr 2030**	**20-Yr 2040**
SS = (System ADD) x (2 day) (MG)	0.11	0.12	0.14
Min. SS = 200 gallons/ERU * NERU (MG)	0.05	0.06	0.07

STORAGE ANALYSIS SUMMARY TABLE

Description	**Plan Yr. 2020**	**10-Yr 2030**	**20-Yr 2040**
Usable Storage (MG)			
Maximum Storage Capacity	0.23	0.23	0.23
Dead (Non-usable) Storage	0.005	0.005	0.005
Total Usable Storage	0.23	0.23	0.23
Required Storage (MG)			
Operational Storage	0.06	0.06	0.06
Equalizing Storage	0.00	0.00	0.00

Standby Storage (Emergency)	0.11	0.12	0.14
Fire Flow Storage (Emergency)	0.12	0.12	0.12
Total Required Storage	0.18	0.18	0.20
Surplus Storage	**0.05**	**0.05**	**0.03**

LAKE STEVENS INTERGRATED
STORAGE ANALYSIS

Storage		
Reservoir Name	**Tank 1**	**Tank 2**
Reservoir Shape	**Cylindrical**	**Cylindrical**
Diamter (Ft)	26	26
Overflow Elavation (Ft)	392	392
Base Elevation (Ft)	347	347
Storage Height (ft)	45	45
Reservoir Volume Per Foot Height (gal/ft)	3,971	3,971
Capacity (MG)	0.18	0.18

Tank Name	**Tank 1**	**Tank 2**
Zone	**392 PZ**	**392 PZ**
Operational Storage (OS)		
Pump Off Water Height (ft)	44	44
Pump On Water Height (ft)	39	39
Operational Storage (gal)	19,857	19,857
Operational Storage Height (ft)	5	5
Fire Suppression Storage (FSS)		
Largest Fire Flow Requirement (gpm)	500	500
Largest Fire Flow Duration (min)	60	60
Fire Suppression Storage (gal)	30,000	30,000
Fire Suppression Height (ft)	7.6	7.6
Dead Storage (DS)		
Max Service Elevation	300	300
Min Tank Elev for 20 psi	346	346
Min Tank Elev for 30 psi	369	369
Dead Storage (gal)	1,986	1,986
Dead Storage Height (ft)*	0.5	0.5

**Assume min of 0.5 ft of dead storage to protect pumps.*

	Plan Yr 2020	**10-Yr 2030**	**20-Yr 2040**
SS = (System ADD) x (2 day) (MG)	0.18	0.21	0.26

STORAGE ANALYSIS SUMMARY TABLE

Description	**Plan Yr 2020**	**10-Yr 2030**	**20-Yr 2040**
Usable Storage (MG)			
Maximum Storage Capacity	0.36	0.36	0.36
Dead (Non-usable) Storage	0.004	0.004	0.004
Total Usable Storage	0.35	0.35	0.35
Required Storage (MG)			
Operational Storage	0.04	0.04	0.04
Equalizing Storage	0.00	0.00	0.00
Standby Storage (Emergency)	0.18	0.21	0.26

Fire Flow Storage (Emergency)	0.03	0.03	0.03
Total Required Storage	0.22	0.25	0.30
Surplus Storage	**0.14**	**0.10**	**0.05**

LAKE STEVENS INTERGRATED
STORAGE ANALYSIS

Storage	
Reservoir Name	**Tank 1**
Reservoir Shape	Cylindrical
Diameter (Ft)	30
Overflow Elevation (Ft)	170
Base Elevation (Ft)	150
Storage Height (ft)	20
Reservoir Volume Per Foot Height (gal/ft)	5,287
Capacity (MG)	0.11

Tank Name	**Tank 1**
Zone	**280 PZ**
Operational Storage (OS)	
Pump Off Water Height (ft)	17
Pump On Water Height (ft)	14
Operational Storage (gal)	15,862
Operational Storage Height (ft)	3
Fire Suppression Storage (FSS)	
Largest Fire Flow Requirement (gpm)	500
Largest Fire Flow Duration (min)	60
Fire Suppression Storage (gal)	30,000
Fire Suppression Height (ft)	5.7
Dead Storage (DS)	
Max Service Elevation	160
Min Tank Elev for 20 psi	206
Min Tank Elev for 30 psi	229
Dead Storage (gal)	2,644
Dead Storage Height (ft)*	0.5

**Assume min of 0.5 ft of dead storage to protect pumps.*

	Plan Yr. 2020	10-Yr 2030	20-Yr 2040
SS = (System ADD) x (2 day) (MG)	0.05	0.05	0.05
Min. SS = 200 gallons/ERU * NERU (MG)	0.03	0.03	0.03

STORAGE ANALYSIS SUMMARY TABLE

Description	Plan Yr. 2020	10-Yr 2030	20-Yr 2040
Usable Storage (MG)			
Maximum Storage Capacity	0.106	0.106	0.106
Dead (Non-usable) Storage	0.003	0.003	0.003
Total Usable Storage	0.103	0.103	0.103
Required Storage (MG)			
Operational Storage	0.016	0.016	0.016
Equalizing Storage	0.000	0.000	0.000

Standby Storage (Emergency)	0.051	0.052	0.053
Fire Flow Storage (Emergency)	0.030	0.030	0.030
Total Required Storage	0.067	0.068	0.069
Surplus Storage	**0.036**	**0.035**	**0.035**

LAKE STEVENS INTERGRATED
STORAGE ANALYSIS

Storage	
Reservoir Name	Tank 1
Reservoir Shape	Cylindrical
Diameter (Ft)	26
Overflow Elevation (Ft)	430
Base Elevation (Ft)	380
Storage Height (ft)	50
Reservoir Volume Per Foot Height (gal/ft)	3,971
Capacity (MG)	0.20

Tank Name	**Storm Lake Tank 1**
Zone	**430 PZ**
Operational Storage (OS)	
Pump Off Water Height (ft)	429
Pump On Water Height (ft)	427
Operational Storage (gal)	7,943
Operational Storage Height (ft)	2
Fire Suppression Storage (FSS)	
Largest Fire Flow Requirement (gpm)	500
Largest Fire Flow Duration (min)	60
Fire Suppression Storage (gal)	30,000
Fire Suppression Height (ft)	7.6
Dead Storage (DS)	
Max Service Elevation	340
Min Tank Elev for 20 psi	386
Min Tank Elev for 30 psi	409
Dead Storage (gal)	24,305
Dead Storage Height (ft)	6.12

	Plan Yr. 2020	**10-Yr 2030**	**20-Yr 2040**
SS = (System ADD) x (2 day) (MG)	0.07	0.09	0.11
Min. SS = 200 gallons/ERU * NERU (MG)	0.04	0.05	0.06

STORAGE ANALYSIS SUMMARY TABLE

Description	**Plan Yr. 2020**	**10-Yr 2030**	**20-Yr 2040**
Usable Storage (MG)			
Maximum Storage Capacity	0.20	0.20	0.20
Dead (Non-usable) Storage	0.02	0.02	0.02
Total Usable Storage	0.17	0.17	0.17
Required Storage (MG)			
Operational Storage	0.01	0.01	0.01
Equalizing Storage	0.01	0.01	0.02

Standby Storage (Emergency)	0.07	0.09	0.11
Fire Flow Storage (Emergency)	0.03	0.03	0.03
Total Required Storage	0.09	0.11	0.14
Surplus Storage	**0.08**	**0.06**	**0.04**

LAKE STEVENS INTERGRATED
STORAGE ANALYSIS

2020 Appr. Percent of System Demand per	*100.00%*	*29.82%*	*18.41%*	*0.57%*	*34.24%*	*2.83%*	*14.14%*	
Plan Year (2020)	**TOTAL**	**535 PZ**	**450 PZ**	**370 PZ**	**350 PZ**	**450 PZ**	**232 PZ**	**Blue outline:**
System ADD (gpm)	132.3	39	24	1	45	4	19	Warm Beach Zones
System MDD (gpm)	345.1	103	64	2	118	10	49	(access to
System PHD (gpm)	1,020.9	304	188	6	350	29	144	Warm Beach
# of ERUs (including Non-Rev & DSL	1,037.2	309	191	6	355	29	147	tank storage)
Ten-Year (2030)								
System ADD (gpm)	150.7	45	28	1	52	4	21	
System MDD (gpm)	393.6	117	72	2	135	11	56	
System PHD (gpm)	1,158.3	345	213	7	397	33	164	
# of ERUs (including Non-Rev & DSL	1,189.3	355	219	7	407	34	168	
Twenty-Year (2040)								
System ADD (gpm)	171.8	51	32	1	59	5	24	
System MDD (gpm)	449.2	134	83	3	154	13	64	
System PHD (gpm)	1,315.3	392	242	7	450	37	186	
# of ERUs (including Non-Rev & DSL	1,364.8	407	251	8	467	39	193	

Sources	**Kayak Well 1**	**Kayak Well 2**	**Kayak Well 3**	**WB Well 2**	**WB Well 3R**	**WB Well 4**	**WB Martha Lake**	**WB Well 1**	**WB Well 3**	**WB Well 5**
Source Type	**well**	**well**	**well**	**well**						
Zone Served	**535 PZ**	**535 PZ**	**535 PZ**	**350 PZ**	**350 PZ**	**450 PZ**	**350 PZ**	**350 PZ**	**350 PZ**	**350 PZ**
Largest Pump (QL) (GPM)										
Total Pumping Capacity (Qs) (gpm)	300	250	0	50	0	170	0	0	0	0
Water Right Qi (gpm)	70	300		50	200					
Water Right Qa (ac-ft)	72	156		135						

emergency only

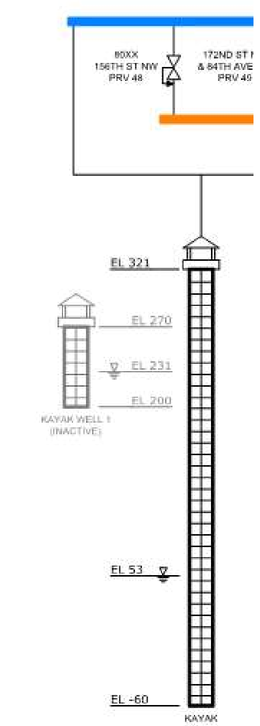
Pump Stations	**WB Well 4 BPS**
Zone Served	**450 PZ**
Number of Pumps	2
Largest Pump (QL) (GPM)	65
Total Pumping Capacity (Qs) (gpm)	130

Storage			
Reservoir Name	WB Tank 1	Kayak Tank 1	Future Tank
Reservoir Shape	Cylindrical	Cylindrical	Cylindrical
Diameter (Ft)	32.7	26	34
Overflow Elevation (Ft)	350	548.5	548.5
Base Elevation (Ft)	318	474	474
Storage Height (ft)	32	74.5	74.5
Reservoir Volume Per Foot Height (	6,282	3,971	6,791
Capacity (MG)	0.201	0.296	0.51
Usable Capacity (MG)	0.198	0.208	0.356
Tank Name	**WB Tank 1**	**Kayak Tank 1**	**Future Tank**
Zone	**450 PZ**	**535 PZ**	**535 PZ**
Operational Storage (OS)			
Pump Off Water Height (ft)	29.2	72	72
Pump On Water Height (ft)	25	65	65
Operational Storage (gal)	26,384	27,799	47,539
Operational Storage Height (ft)	4.2	7	7
Fire Suppression Storage (FSS)			
Largest Fire Flow Requirement (gpn	500	500	500
Largest Fire Flow Duration (min)	120	120	120
Fire Suppression Storage (gal)	60,000	60,000	60,000
Fire Suppression Height (ft)	9.6	15.1	8.8
Dead Storage (DS)			
Max Service Elevation	80	450	450
Min Tank Elev for 20 psi	126	496	496
Min Tank Elev for 30 psi	149	519	519
Dead Storage (gal)	3,141	87,846	150,222
Dead Storage Height (ft)	0.5	22.12	22.12

Equalizing 0.11 MG

	Plan Yr. 2020	10-Yr 2030	20-Yr 2040
SS = (System ADD) x (2 day) (MG)	0.20	0.22	0.25
:S = 200 gallons/ERU * NERU (MG)	0.11	0.12	0.14

	Plan Yr. 2020	10-Yr 2030	20-Yr 2040
S = (System ADD) x (2 day) (MG)	0.19	0.21	0.24
= 200 gallons/ERU * NERU (MG)	0.10	0.12	0.13



STORAGE ANALYSIS SUMMARY TABLE: EXISTING WARM BEACH TANK

Description	Plan Yr. 2020	10-Yr 2030	20-Yr 2040
Usable Storage (MG)			
Maximum Storage Capacity	0.201	0.201	0.201
Dead (Non-usable) Storage	0.003	0.003	0.003
Total Usable Storage	0.198	0.198	0.198
Required Storage (MG)			

STORAGE ANALYSIS SUMMARY TABLE: EXISTING KAYAK TANK

Description	Plan Yr. 2020	10-Yr 2030	20-Yr 2040
Usable Storage (MG)			
Maximum Storage Capacity	0.30	0.30	0.30
Dead (Non-usable) Storage	0.09	0.09	0.09
Total Usable Storage	0.21	0.21	0.21
Required Storage (MG)			

LAKE STEVENS INTERGRATED
STORAGE ANALYSIS

Operational Storage	0.03	0.03	0.03	Operational Storage	0.03	0.03	0.03
Equalizing Storage	0.05	0.06	0.07	Equalizing Storage	0.02	0.03	0.04
Standby Storage (Emergency)*	0.20	0.22	0.25	Standby Storage (Emergency)	0.19	0.21	0.24
Fire Flow Storage (Emergency)	0.06	0.06	0.06	Fire Flow Storage (Emergency)	0.06	0.06	0.06
Total Required Storage	0.27	0.30	0.35	Total Required Storage	0.23	0.27	0.31
Surplus Storage	**-0.07**	**-0.11**	**-0.15**	**Surplus Storage**	**-0.02**	**-0.06**	**-0.10**

THIS PAGE INTENTIONALLY LEFT BLANK

1102 BROADWAY PLAZA, SUITE #401
TACOMA, WA 98402
www.murraysmith.us