FINAL

WATER MODEL DEVELOPMENT DOCUMENTATION

FOR

WATER SYSTEM OPTIMIZATION

January 2011

MSA
Murray, Smith & Associates, Inc.
Engineers/Planners

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Introduction

The City has been actively using versions of their hydraulic model to support water master planning, water quality evaluations and developer reviews over the past few years. In early 2009, the City contracted with Optimatics and Murray, Smith & Associates (MSA) to provide a system-wide "optimization" of the water system capital improvement plan and operational settings. The optimization process requires a calibrated steady state and extended period model. MSA had responsibility to update the model and provide steady state and extended period calibrations. Due to recent investments made by the City in the water utility Geographic Information System (GIS), and because of inconsistencies between the existing model and the GIS, the decision was made to recreate the model from the updated GIS. The GIS provided a more accurate spatial representation of the piping as well as having included recently added piping and facilities.

The City of Bend water utilities GIS database was used to develop an updated water distribution system model using the InfoWater® software, which had been recently selected by the City. InfoWater® is a GIS integrated software that uses EPANet as the hydraulic engine. A major focus for recreating the model was to have consistent identifiers for elements in both databases. Facility IDs such as pipe and valve IDs were also carried over from the GIS to the hydraulic model so that a one to one relationship between the model and the GIS could be maintained.

This document provides background on the information used to create the updated model along with the process used in the calibration effort. As operational and system changes occur, the model will need to be updated to remain current and accurate. This documentation describes development and calibration of the model to reflect system conditions as of January 2010.

Geographic Information System

The City's water utility GIS data was used as the initial source of data to develop the distribution network in InfoWater®. This data was then supplemented with system operations data, obtained through discussion with City staff, to result in a complete update of the hydraulic model. The model was developed for both steady state and extended period simulation (EPS) analysis. Steady state analysis simulates the system for a particular snapshot in time under specified boundary conditions, while EPS analysis typically provides hourly water distribution system results, predicting system pressures, pump on/off status, tank elevations and valve status for the duration of the simulation.

Pipes

The City of Bend water utilities GIS database contained pipeline length, material and diameter information for existing pipelines, excluding raw water lines. This information is summarized in Table 1.1 and Table 1.2.

Table 1.1 – May 2009 GIS Pipeline Information

Diameter	Length (ft)	Length (mile)
2	30,742	6
4	24,067	5
6	358,226	68
8	990,187	188
10	168,825	32
12	417,591	79
14	9,860	2
16	180,062	34
18	13,222	3
24	15,723	3
30	12,297	2
36	14,131	3
Total	2,234,932	423

Table 1.2 – Summary of Pipeline Material

Material	Roughness	Length (ft)	Length (mile)
Cast Iron	120	262,659	50
Ductile Iron	130	1,888,499	358
Galvanized Iron	110	2,304	0
PVC	140	55,247	10
Steel	110	23,347	4
Total		2,232,055	423

Wells

The City currently has eighteen active drinking water wells. Specific inactive wells, ones that are either planned for rehabilitation or are about to be brought online, were also included in the model and may be updated with operating information and activated in the future as appropriate. Table 1.3 summarizes the City's groundwater wells.

Table 1.3 – Groundwater Wells (2009)

Pump Description	Status	VFD	Pump Zone Fr-To*	Flow Rate (gpm)	Elevation (ft)	Well GW Surface Elevation (ft)
Bear Creek Well 1	Active	No	GW to 4	1,050	3,656	3,027
Bear Creek Well 2	Active	No	GW to 4	1,150	3,656	3,027
Copperstone Well	Active	No	GW to 3	1,050	3,779	3,269
Hole Ten North (1)	Active	Yes	GW to 2	800	3,880	3,450
Hole Ten South (2)	Active	Yes	GW to 2	800	3,880	3,450
Outback Well 1	Active	No	GW to 3	650	3,981	3,476
Outback Well 2	Active	No	GW to 3	650	3,981	3,496
Outback Well 3	Active	No	GW to 3	1,200	3,981	3,500
Outback Well 4	Active	No	GW to 3	1,300	3,981	3,550
Outback Well 5	Active	No	GW to 3	1,000	3,981	3,495
Outback Well 6	Active	No	GW to 3	1,250	3,981	3,501
Outback Well 7	Future	No	GW to 3	-	3,981	3,500
Pilot Butte Well 1	Active	No	GW to 5	900	3,755	3,009
Pilot Butte Well 2	Inactive	No	GW to 5	-	-	-
Pilot Butte Well 3	Active	No	GW to 5	900	3,775	2,966
Pilot Butte Well 4	Future	No	GW to 5	-	-	-
River Well 1	Active	No	GW to 5	1,900	3,604	3,247
River Well 2	Active	No	GW to 5	2,200	3,607	3,362
Rock Bluff Well 1	Active	No	GW to 4	750	3,834	3,441
Rock Bluff Well 2	Inactive	No	GW to 4	700	3,835	3,440
Rock Bluff Well 3	Active	No	GW to 4	900	3,835	3,440
Shilo Well 1	Inactive	No	GW to 3	-	3,764	3,424
Shilo Well 2	Inactive	No	GW to 3	-	3,764	3,424
Shilo Well 3	Future	No	GW to 4	-	3,764	3,424
Westwood Well	Active	No	GW to 4	600	3,761	3,549

Flow rates indicate typical flow rates based on available SCADA data and model results if available to the nearest 50 gallons otherwise they are based on pump curves which may or may not be accurate.
**Denotes "groundwater"*

Pumps

Pump control and pump curve data was provided by the City of Bend in mid 2009. The City currently has 6 active pump stations. The pump stations are used to boost water from a lower pressure zone to a higher one. Table 1.4 identifies each pump station the specific pumps in each, the information on what they serve and design points.

Table 1.4 – Pump Stations (2009)

Pump Description	Status	VFD	Pump Zone Fr-To	Flow Rate** (gpm)	Elevation (ft)
Awbrey Pump 1	Active	No	3 to 1	950	3785
Awbrey Pump 2	Active	No	3 to 1	1,340	3785
Awbrey Pump 3	Active	No	3 to 1	1,200	3785
College Pump 1	Active	No	3 to 2	1,050	3725
College Pump 2	Active	No	3 to 2	900	3725
Murphy Road Pump 1	Active	Yes	4 to 3*	300	3743
Murphy Road Pump 2	Active	Yes	4 to 3*	300	3743
Murphy Road Pump 3	Active	Yes	4 to 3*	300	3743
Murphy Road Pump 4	Active	Yes	4 to 3*	300	3743
Murphy Road Pump 5	Active	Yes	4 to 3*	300	3743
Scott Street Booster Pump 1	Active	No	5 to 4	530	3643
Scott Street Booster Pump 2	Active	No	5 to 4	530	3643
Scott Street Booster Pump 3	Active	No	5 to 4	530	3643
Tetherow Pump 1	Active	Yes	3 to 2	150	3880
Tetherow Pump 2	Active	Yes	3 to 2	700	3880
Tetherow Pump 3	Active	Yes	3 to 2	700	3880
Tetherow Pump 4	Active	Yes	3 to 2	700	3880
Tetherow Pump 5	Active	Yes	3 to 2	700	3880
Tetherow Pump 6	Active	Yes	3 to 2	700	3880
Westwood Pump 1	Active	No	4 to 3	390	3841
Westwood Pump 2***	Active	No	4 to 3	550	3841
Westwood Pump 3	Active	No	4 to 3	900	3841
Westwood Pump 4	Active	No	4 to 3	550	3841

**Future pipe installation will enable Murphy Road Pump Station to pump from Zone 4 to Zone 2*
***Flow rates indicate typical flow rates based on available SCADA data and model results, if available, to the nearest 50 gallons; otherwise they are based on pump curves which may or may not be accurate*
****Flow includes some recirculation through the Westwood Reservoir and pump station.*

System pumps are controlled primarily by reservoir level, though some are controlled off of system pressure and others are manually set. The model controls facilities, such as valves and pumps, through two types of controls. The first type of control is the initial control setting. Initial controls are active in the first time step of simulation.

Simulations lasting more than one time step require more complex controls to identify how system components should respond under changing system conditions as tank levels and system pressures vary throughout a several hour simulation. These controls are referred to as extended period controls.

For steady state simulations, initial controls are the only controls needed because steady state analysis models only a single time step. Table 1.5 describes how the system operates under changing conditions. Copies of available pump curves are provided in Appendix A.

Table 1.5 – Pump Control and Operation (July 2009)

Pump Description	Controlled By	On Setting	Off Setting	MFR Pump Curve Available
Awbrey Pump 1	Tower Rock Reservoir Level	<27.5 (ft)	>29.5 (ft)	-
Awbrey Pump 2	Tower Rock Reservoir Level	<26 (ft)	>27.5 (ft)	Awbrey Pump Curve
Awbrey Pump 3	Manual	-	-	Awbrey Pump Curve
Bear Creek Well 1	Pilot Butte 2 Reservoir-Level	<35 (ft)	> 37 (ft)	Bear Creek Well 1 Curve
Bear Creek Well 2	Pilot Butte 2 Reservoir-Level	<34 (ft)	> 36 (ft)	-
Copperstone Well	Manual	-	-	Copperstone Well Curve
College Pump 1	College Reservoir 1	<17.8 (ft)	>22 (ft)	Design Point on Pump
College Pump 2	College Reservoir 1	<16 (ft)	>20 (ft)	Design Point on Pump
Hole Ten Well 1	Pressure at discharge	60-62 (psi)	-	-
Hole Ten Well 2	Pressure at discharge	53 (psi)	-	-
Murphy Road Pump 1	Pressure at discharge	53 (psi)*	-	Murphy Pump Station Curve
Murphy Road Pump 2	Pressure at discharge	43 (psi)*	-	Murphy Pump Station Curve
Murphy Road Pump 3	Pressure at discharge	33 (psi)*	-	Murphy Pump Station Curve
Murphy Road Pump 4	Pressure at discharge	23 (psi)*	-	Murphy Pump Station Curve
Murphy Road Pump 5	Pressure at discharge	Backup	-	-
Outback Well 1	Manual	-	-	-
Outback Well 2	Manual	-	-	-
Outback Well 3	Outback 3 Reservoir-Level	< 26 (ft)	>28 (ft)	-
Outback Well 4	Outback 3 Reservoir-Level	<24(ft)	>27(ft)	-
Outback Well 5	Outback 3 Reservoir-Level	<23 (ft)	>26 (ft)	-
Outback Well 6	Outback 3 Reservoir-Level	<20 (ft)	>24 (ft)	Curve Outback Well #6
Outback Well 7	Future – likely Outback 3 Res	-	-	-
Pilot Butte Well 1	Manual	-	-	PB#1 Curve
Pilot Butte Well 2	Offline	-	-	-
Pilot Butte Well 3	Manual	-	-	-
Pilot Butte Well 4	Future			

Pump Description	Controlled By	On Setting	Off Setting	MFR Pump Curve Available
River Well 1	Manual	-	-	-
River Well 2	Manual	-	-	-
Rock Bluff Well 1	Rock Bluff Reservoir-Level	< 34.9 (ft)	>38 (ft)	Rock Bluff Well 1 & 3 Curve
Rock Bluff Well 2	Manual	-	-	-
Rock Bluff Well 3	Rock Bluff Reservoir-Level	< 34.9 (ft)	>38 (ft)	Rock Bluff Well 1&3 Curve
Scott Street Booster Pump 1	Pilot Butte II Reservoir Level	< 29 (ft)	>33 (ft)	Scott Street Booster Curve
Scott Street Booster Pump 2	Pilot Butte II Reservoir Level	< 31 (ft)	>35 (ft)	Scott Street Booster Curve
Scott Street Booster Pump 3	Pilot Butte II Reservoir Level	< 27 (ft)	>32 (ft)	Scott Street Booster Curve
Shilo Well 1	Off Line	-	-	-
Shilo Well 2	Off Line	-	-	-
Shilo Well 3	Off Line – current redesign of well house in progress	-	-	Shilo Well 3 Curve
Tetherow Pump 1	Pressure at discharge	85 (psi)	-	Tetherow Pump 1 Curve
Tetherow Pump 2	Pressure at discharge	75 (psi)	-	Tetherow Pump 2-6 Curve
Tetherow Pump 3	Pressure at discharge	65 (psi)	-	Tetherow Pump 2-6 Curve
Tetherow Pump 4	Pressure at discharge	55 (psi)	-	Tetherow Pump 2-6 Curve
Tetherow Pump 5	Pressure at discharge	45 (psi)	-	Tetherow Pump 2-6 Curve
Tetherow Pump 6	Pressure at discharge	Backup	-	Tetherow Pump 2-6 Curve
Westwood Pump 1	Pressure at discharge	78 (psi)		
Westwood Pump 2	Pressure at discharge	73 (psi)		
Westwood Pump 3	Pressure at discharge	50 (psi)		
Westwood Pump 4	Timer based on irrigation demand			
Westwood Well	Westwood Reservoir-Level	< 19 (ft)	> 24 (ft)	-

**Future pipe installation will enable Murphy Road Pump Station to pump from Zone 4 to Zone 2, requiring changes in pressure settings*

Reservoirs

Table 1.6 includes a listing of the active water storage reservoirs in the system. As of July 2009, the Outback Contact Basin, Outback 1 and Outback 2 were supplied by surface water with Outback 3 being supplied by the wells at the site.

Table 1.6 – City of Bend Water Storage Reservoirs (2009)

Name	Elevation (ft)	Volume (million gallons)	Zone Served	Max Level (ft)	Diameter (ft)
Awbrey	3,775.00	5.00	5	20.50	206.3
College 1	4,095.80	0.50	2	23.27	60.8
College 2	4,087.93	1.00	2	31.50	74.1
Outback 1	3,976.00	2.00	3	40.10	98.6
Outback 2	3,976.00	3.00	3	35.38	120.8
Outback 3	3,982.00	3.63	3	29.38	146
Outback Contact Basin	3,980.00	1.5	3	31.00	91.5
Overturf East	3,844.00	1.45	4A	27.00	94
Overturf West	3,844.00	1.45	4A	27.00	94
Pilot Butte 1	3,750.00	1.50	5	31.50	89.3
Pilot Butte 2	3,839.90	1.00	4B	39.50	65.2
Pilot Butte 3	3,757.25	5.00	5	24.25	188
Rock Bluff 1	3,839.78	1.54	4B	39.00	82
Tower Rock	4,213.00	1.00	1	31.00	74
Westwood	3,842.00	0.50	4	28.00	53.3

Valves

Valve settings are presented in Table 1.7. Pressure reducing valves are controlled by a single pressure setting under both steady state and extended period simulations. The City standard is to provide a pressure reducing station that includes both a small (bypass) valve that supplies flow under typical flows and a larger (main) valve that provides flow under emergency conditions such as fire flows. In most cases each pressure zone will be served by at least two PRV stations, though in the case of some smaller zones, a single station may provide supply. Some system flow controls valves require additional extended period controls to define valve behavior under varying system conditions during extended period simulation. Valve information on the zone supplying the valve and the one it serves is also included in Table 1.7

Table 1.7 – City of Bend Water System Valve Summary (July 2009)

Valve Identifier	Valve Type*	Elevation (ft)	Diameter (in)	From Zone	To Zone	Setting (gpm or psi)
AWBREY VALVE	FCV	3,775.00	12	3	5	6,000
HOLE10WELLPSV	PSV	3,866.00	4	2B	2B	62
MURPHY-PS_PR	PRV	3,746.00	10	3D	4B	57
OVER_FCV	FCV	3,844.06	12	3	4A	1,500
SHILOPRV	PRV	3,764.00	12	3D	3D	50
WAPRV001A	PRV	3,738.55	2	3	4E	52
WAPRV001B	PRV	3,738.55	8	3	4E	48
WAPRV002A	PRV	3,749.91	2	2	3	95
WAPRV002B	PRV	3,749.91	8	2	3	90
WAPRV003A	PRV	3,864.00	2	2	3B	52
WAPRV003B	PRV	3,864.00	8	2	3B	47
WAPRV004A	PRV	3,486.09	3	6	7A	59
WAPRV004B	PRV	3,486.09	10	6	7A	54
WAPRV005A	PRV	3,542.87	4	5	6	61
WAPRV005B	PRV	3,542.87	8	5	6	56
WAPRV006A	PRV	3,480.77	2	6	7B	62
WAPRV006B	PRV	3,480.77	6	6	7B	57
WAPRV007A	PRV	3,552.95	4	5	6	57
WAPRV007B	PRV	3,552.95	12	5	6	51
WAPRV008A	PRV	3,541.54	2	5	6	62
WAPRV008B	PRV	3,541.54	6	5	6	57
WAPRV009A	PRV	3,570.03	4	5	6	51
WAPRV009B	PRV	3,570.03	14	5	6	46
WAPRV011A	PRV	3,572.10	12	5	6	47
WAPRV012A	PRV	3,529.89	2	5	6	69
WAPRV012B	PRV	3,529.89	8	5	6	65
WAPRV013A	PRV	3,573.92	2	5	6	48
WAPRV013B	PRV	3,573.92	12	5	6	44
WAPRV014A	PRV	3,592.18	2	5	6A	55
WAPRV014B	PRV	3,592.18	12	5	6A	50
WAPRV015A	PRV	3,665.87	2	4B	5	47
WAPRV015B	PRV	3,665.87	8	4B	5	43
WAPRV016A	PRV	3,567.98	2	5	6A	64
WAPRV016B	PRV	3,567.98	6	5	6A	59
WAPRV017A	PRV	3,590.16	2	5	6A	56
WAPRV017B	PRV	3,590.16	6	5	6A	51
WAPRV018A	PRV	3,609.21	3	4A	6	32
WAPRV018B	PRV	3,609.21	8	4A	6	27
WAPRV019A	PRV	3,727.88	2	3	4A	55
WAPRV019B	PRV	3,727.88	8	3	4A	50
WAPRV020A	PRV	3,781.07	3	1	3	80
WAPRV020B	PRV	3,781.07	10	1	3	75
WAPRV021A	PRV	3,760.07	2	3	4K	58

Valve Identifier	Valve Type*	Elevation (ft)	Diameter (in)	From Zone	To Zone	Setting (gpm or psi)
WAPRV021B	PRV	3,760.07	8	3	4K	53
WAPRV022A	PRV	3,808.49	2	3	4A	23
WAPRV022B	PRV	3,808.49	10	3	4A	18
WAPRV023A	PRV	3,756.34	2	4D	5A	62
WAPRV024A	PRV	3,639.17	2	4A	5	62
WAPRV024B	PRV	3,639.17	6	4A	5	57
WAPRV025A	PRV	4,068.69	2	1	2	16
WAPRV025B	PRV	4,068.69	8	1	2	13
WAPRV026A	PRV	4,049.82	2	1	2	24
WAPRV026B	PRV	4,049.82	6	1	2	22
WAPRV027A	PRV	3,798.23	2	3C	4H	53
WAPRV028A	PRV	3,769.14	4	3C	4H	60
WAPRV029A	PRV	3,774.18	6	3C	4H	61
WAPRV030A	PRV	3,642.53	2	4E	5B	35
WAPRV030B	PRV	3,642.53	6	4E	5B	30
WAPRV031A	PRV	3,830.52	2	2	3A	47
WAPRV031B	PRV	3,830.52	6	2	3A	42
WAPRV032A	PRV	3,884.75	2	2	3	36
WAPRV032B	PRV	3,884.75	6	2	3	30
WAPRV033A	PRV	3,470.48	2	5B	6B	66
WAPRV033B	PRV	3,470.48	6	5B	6B	61
WAPRV034A	PRV	3,612.22	2	4E	5B	48
WAPRV034B	PRV	3,612.22	8	4E	5B	43
WAPRV035A	PRV	3,760.22	2	3	4A	40
WAPRV035B	PRV	3,760.22	6	3	4A	35
WAPRV036A	PRV	3,643.14	6	4A	5	57
WAPRV036B	PRV	3,643.14	16	4A	5	51
WAPRV037A	PRV	3,683.40	2	4A	5	44
WAPRV037B	PRV	3,683.40	6	4A	5	39
WAPRV038A	PRV	3,711.00	4	3	4B	71
WAPRV038B	PRV	3,711.00	12	3	4B	63
WAPRV039A	PRV	3,653.68	6	4B	5	52
WAPRV039B	PRV	3,653.68	10	4B	5	48
WAPRV040A	PRV	3,622.55	4	4F	5D	57
WAPRV040B	PRV	3,622.55	12	4F	5D	52
WAPRV040C	PRV	3,622.55	2	4F	5D	62
WAPRV041A	PRV	3,579.60	6	5D	6	44
WAPRV041B	PRV	3,579.60	12	5D	6	40
WAPRV043A	PRV	3,757.87	2	3	4A	43
WAPRV043B	PRV	3,757.87	6	3	4A	38
WAPRV044A	PRV	3,764.15	3	3	4F	47
WAPRV044B	PRV	3,764.15	10	3	4F	43
WAPRV045A	PRV	3,834.64	10	2	3	57
WAPRV046A	PRV	3,820.35	3	3	4D	61
WAPRV046B	PRV	3,820.35	8	3	4D	56

Valve Identifier	Valve Type*	Elevation (ft)	Diameter (in)	From Zone	To Zone	Setting (gpm or psi)
WAPRV047A	PRV	3,726.20	3	3	4G	70
WAPRV047B	PRV	3,726.20	12	3	4G	65
WAPRV048A	PRV	3,595.77	2	5	6A	55
WAPRV048B	PRV	3,595.77	6	5	6A	50
WAPRV049A	PRV	3,817.01	10	2	3A	45
WAPRV050A	PRV	3,761.47	3	3	4A	43
WAPRV050B	PRV	3,761.47	8	3	4A	38
WAPRV052A	PRV	3,730.04	3	3	4J	58
WAPRV052B	PRV	3,730.04	8	3	4J	53
WAPRV053A	PRV	3,742.77	3	3	4J	52
WAPRV053B	PRV	3,742.77	8	3	4J	47
WAPRV054A	PRV	3,483.21	3	6	7A	56
WAPRV054B	PRV	3,483.21	8	6	7A	51
WAPRV056A	PRV	3,667.44	3	3	4A	80
WAPRV056B	PRV	3,667.44	8	3	4A	75
WAPRV057A	PRV	3,642.03	3	4B	5	58
WAPRV057B	PRV	3,642.03	10	4B	5	54
WAPRV058A	PRV	3,485.91	2	6	7C	57
WAPRV058B	PRV	3,485.91	6	6	7C	52
WAPRV059A	PRV	3,758.17	2	3	4C	53
WAPRV059B	PRV	3,758.17	6	3	4C	50
WAPRV061A	PRV	3,460.30	3	6	7A	68
WAPRV061B	PRV	3,460.30	8	6	7A	63
WAPRV062A	PRV	3,751.37	6	4D	5A	60
WAPRV064A	PRV	3,760.07	2	3C	4I	53
WAPRV064B	PRV	3,760.07	8	3C	4I	48
WAPRV065A	PRV	3,730.43	6	3	4A	54
WAPRV065B	PRV	3,730.43	10	3	4A	49
WAPRV066A	PRV	3,500.92	2	6	7D	47
WAPRV066B	PRV	3,500.92	6	6	7D	42
WAPRV067A	PRV	3,744.41	3	3	4E	49
WAPRV067B	PRV	3,744.41	8	3	4E	45
WAPRV069A	PRV	3,814.54	6	2B	3D	48
WAPRV073A	PRV	3,864.54	3	2A	3C	65
WAPRV073B	PRV	3,864.54	8	2A	3C	60
WAPRV074A	FCV	3,973.16	24	2	3	7,800
WAPRV075A	PRV	3,976.05	24	2	3	8
WAPRV076A	PRV	3,735.26	6	3	4J	56
WAPRV076B	PRV	3,735.26	10	3	4J	51
WAPRV077A	PRV	3,651.02	3	4E	5C	53
WAPRV077B	PRV	3,651.02	8	4E	5C	48
WAPRV078A	PRV	3,643.84	3	4E	5C	56
WAPRV078B	PRV	3,643.84	8	4E	5C	51
WAPRV079A	PRV	3,493.25	2	6	7D	47
WAPRV079B	PRV	3,493.25	6	6	7D	43

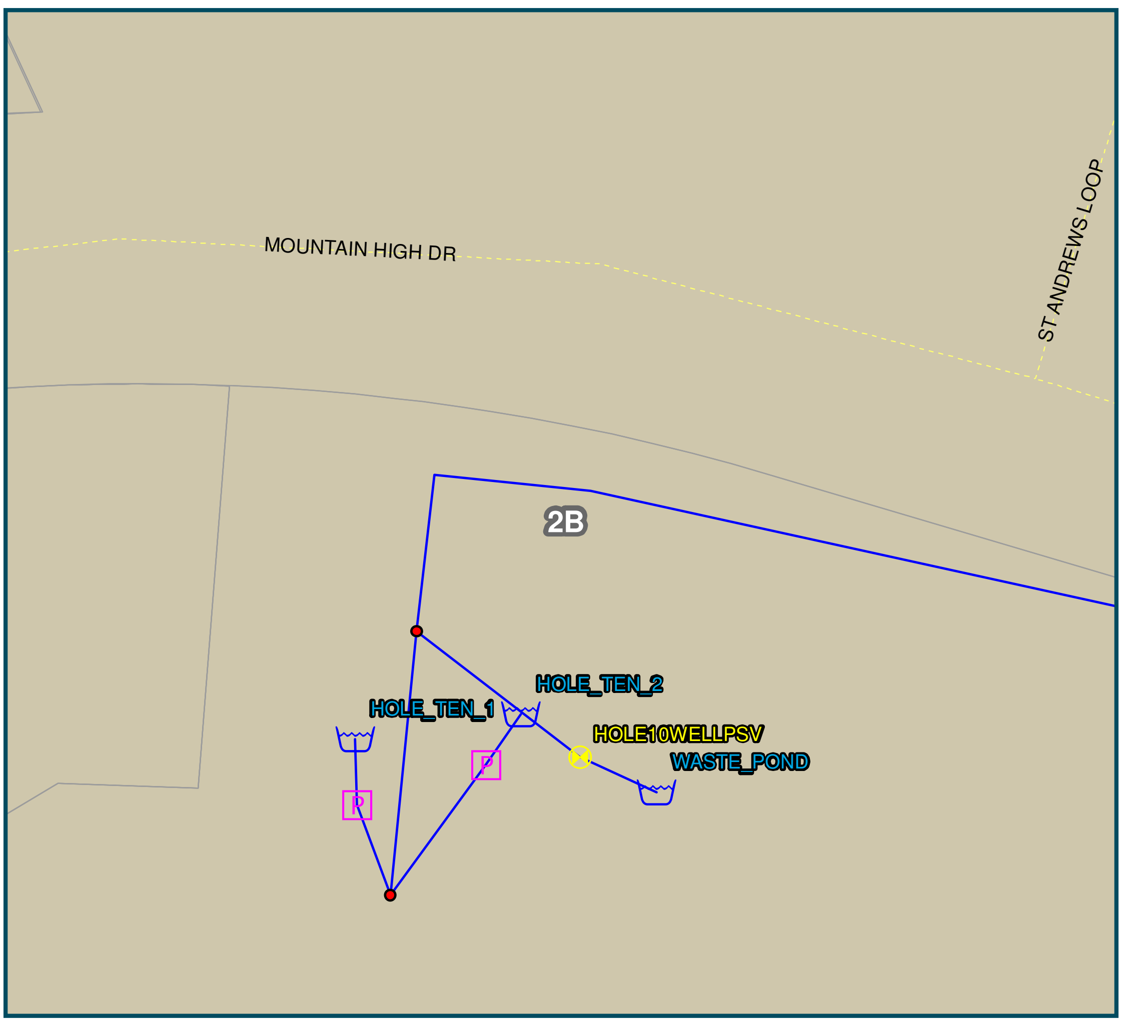
Valve Identifier	Valve Type*	Elevation (ft)	Diameter (in)	From Zone	To Zone	Setting (gpm or psi)
WAPRV080A	PRV	3,481.84	3	6	7A	59
WAPRV080B	PRV	3,481.84	8	6	7A	54
WESTWSUSTAIN	PSV	3,841.25	12	Westwood	4A	78

*FCV: Flow Control Valve, PSV: Pressure Sustaining Valve, PRV: Pressure Reducing Valve

Special Model Valves

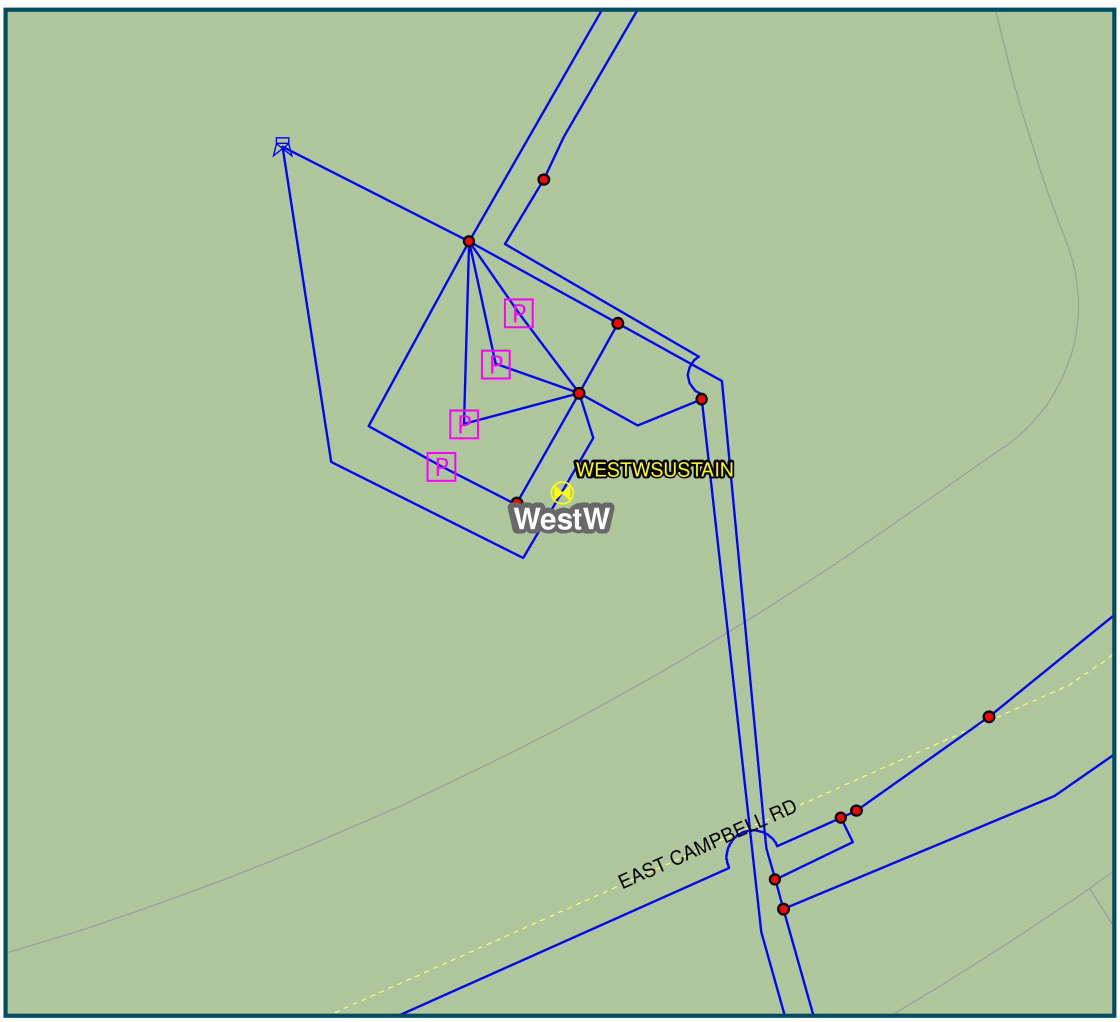
The water distribution system model includes two valves used in the model only to simulate existing facilities or operations. The first of these valves used to simulate operations is the Hole 10 pressure sustaining valve. The Hole 10 wells currently serve as the only supply for zone 2B. Excess water from the zone can be "wasted" to an irrigation pond if required. A pressure sustaining valve is used in the model to control the pressure in Zone 2B. If pressures exceed the PSV setting, water will flow through the valve into the waste pond modeled as a reservoir.

Figure 1.1
Hole 10 Well Model Configuration



The second valve used in the model used to simulate operations is the Westwood sustaining valve. The Westwood Pump #1 is always on and at times water will re-circulate through reservoir and the pump under low flow conditions. In the field the pump is set to maintain a discharge pressure of 78 psi with overflow back to the suction side of the pump. In the model the pump is set to be always on, and flow is re-circulated to the reservoir through a model sustaining valve. Westwood pump #2 will only turn on at discharge pressures below 73 psi in the field, and Westwood pump #3 will only turn on at pressures below 50 psi. Flow from these pumps does not re-circulate to the reservoir through the sustaining valve in the field because they only operate under low pressure conditions. In the model, pump #2 is typically on. If the field settings for pumps 2 and 3 are used in the model, the model cannot determine if the pumps should be on or off because the on/off settings for the pumps are too close to each other and to the sustaining valve pressure setting. The pump controls are set to keep the pumps conservatively on so that enough flow can be supplied to the system to maintain the control setting of 78 psi. Excess flow is returned to the reservoir through the model sustaining valve.

Figure 1.2
Westwood Facilities Model Configuration



The Westwood Pump Station was originally constructed as a temporary pump station, however now has been in operation for more than ten years. The City plans to improve or replace existing facilities.

Valve Controls

In addition to the PRVs that control much of the flow of water between zones in the system, there are four other valves that are important to overall system operation. These include; the Awbrey Flow Control/Altitude Valve, the Overturf Flow Control/Altitude Valve, the Outback Flow Control Valve and the Outback Pressure Sustaining Valve. Table 1.8 defines the settings for these valves. Flow control/altitude valves are used to control the maximum reservoir level of the Awbrey and Overturf Reservoirs. Flow control valve settings and open/closed set points have been adjusted on a seasonal basis. Example control settings provided by City staff (summer) or SCADA data (winter) are listed in Table 1.8. Typically during the summer, Awbrey settings are in the 17 to 18 foot range to force as much surface water into Zone 5 as possible, whereas during the winter, settings may be reduced to 10 to 11 feet or closed completely to facilitate adequate turnover of Pilot Butte Reservoirs 1 and 3.

The flow control valve at Outback (WAPRV074A) controls the supply of surface water into the system and is directly supplied by the Outback #2 Reservoir. During the summer of 2009, the valve was set to provide 7,800 gpm. This value is changed throughout the year depending on demand. The pressure sustaining valve (WAPRV075A) at Outback controls the flow of groundwater into the system and is fed directly by Outback Reservoir #3. The overall Outback Facility is configured to maximize the flow of surface water into the system as this can be supplied without pumping. The wells at Outback typically only operate when the flow control valve is supplying the current setting value and the Outback #3 Reservoir is still draining through the pressure sustaining valve.

Table 1.8 – Valve Control Settings (2009)

Valve ID	Valve Type	Control Based on Facility	Open Below (Summer)	Closed Above (Summer)	Open Below (Winter)	Closed Above (Winter)
AWBREY_ VALVE	Flow Control Valve	Awbrey Reservoir	17 ft	18 ft	17 ft	17.9 ft
OVER_FCV	Flow Control Valve	Overturf West	21.8 ft	23 ft	21 ft	25 ft
WAPRV074A	Flow Control Valve	Flow Setting	7,800 gpm	7,800 gpm	Variable	Variable
WAPRV075A	Pressure Sustaining Valve	Upstream Pressure	8 psi	8 psi	8 psi	8psi

Elevation Interpolation

Contour information was provided by the City for the majority of the existing service area in 2-foot contour interval. Elevations were assigned to the model by draping the nodes across a triangulated irregular network (TIN) that was generated from the contours. Lower accuracy United States Geologic Survey (USGS) digital elevation models (DEM) were utilized to assign elevation for nodes that fell outside of the City's contour coverage.

Demand Development

Model demands were developed using two primary pieces of information; customer billing records and overall system water production. Information from 2008 was used as it was the last complete year of data prior to the beginning of the project. Concern over the accuracy of the customer billing records was noted by City Staff, however it was determined that this information still constituted the most accurate spatial representation of demand in the system.

Customer Billing Data

Customer water billing data provided by the City of Bend for calendar year 2008 was used to determine the spatial distribution of demand within the service area. To spatially distribute water demand throughout the model, water meter address data was mapped and associated with the nearest model node serving the customers within each zone. Water meters are read and billed monthly, however any single month's billing data will include some number of billing corrections or meter misreads that may be corrected in a subsequent month. For this reason multiple months' billing data was averaged within a season to develop a more accurate picture of usage.

Water billing data does not represent all of the water distributed throughout the system. System leaks, unmetered uses and unmetered connections are some potential sources of non-revenue water. Because billing data does not include 100% of the water distributed in the system, water usage based on customer billing records was peaked to match water production and distributed among model nodes. This is done by calculating a relative percentage of total billed water usage at each model node, and distributing the total amount of water produced using the relative demand percentage calculated for each node.

A summary of the billing data provided by the City is presented in Table 1.9.

Table 1.9 – 2008 Water Billing Data Summary

Rate Class & Meter Size	Sum of Consumption (cubic feet)*	Sum of Consumption (Gallons)	Average Gallons/ day	Record Count*	Meter Count	Average Gallons/ day meter
Commercial (CM)	**187,305,854**	**1,401,145,000**	**3,838,753**	**34,535**	**2,878**	**1,334**
0 (unknown)	5,985,578	44,775,230	122,672	77	6	19,118
1	41,929,431	313,653,905	859,326	13,649	1,137	756
1.5	36,035,825	269,566,674	738,539	5,447	454	1,627
2	64,039,015	479,045,068	1,312,452	4,591	383	3,431
3	2,965,426	22,182,926	60,775	116	10	6,287
3/4	8,851,380	66,212,916	181,405	3,976	331	548
4	6,804,910	50,904,259	139,464	92	8	18,191
5/8	531,154	3,973,308	10,886	375	31	348
5/8 x 3/4**	9,013,835	67,428,164	184,735	6,152	513	360
6	11,149,300	83,402,550	228,500	60	5	45,700
Laundry/Dry Cleaners (LD)	**277,800**	**2,078,088**	**5,693**	**36**	**3**	**1,898**
1.5	49,000	366,545	1,004	12	1	1,004
2	228,800	1,711,543	4,689	24	2	2,345
Residential (RS)	**107,254,350**	**802,318,199**	**2,198,132**	**118,231**	**9,853**	**223**
1	40,489,098	302,879,463	829,807	42,894	3,575	232
1.5	819,136	6,127,562	16,788	297	25	678
2	158,663	1,186,882	3,252	62	5	629
3	15,400	115,200	316	1	0	3,787
3/4	60,969,225	456,081,446	1,249,538	70,033	5,836	214
5/8	322,809	2,414,779	6,616	283	24	281
5/8 x 3/4	4,264,340	31,899,476	87,396	4,578	382	229
6	215,679	1,613,391	4,420	83	7	639
School (SC)	**8,446,903**	**63,187,218**	**173,116**	**356**	**30**	**5,835**
1	38,000	284,260	779	12	1	779
1.5	112,600	842,306	2,308	24	2	1,154
2	2,155,405	16,123,548	44,174	148	12	3,582
3	2,876,998	21,521,438	58,963	76	6	9,310
¾	7,900	59,096	162	24	2	81
4	1,826,200	13,660,924	37,427	48	4	9,357
5/8 x 3/4	3,100	23,190	64	12	1	64
6	1,426,700	10,672,456	29,240	12	1	29,240

Rate Class & Meter Size	Sum of Consumption (cubic feet)*	Sum of Consumption (Gallons)	Average Gallons/ day	Record Count*	Meter Count	Average Gallons/ day meter
Single Family Residential (SF)	**234,130,510**	**1,751,417,729**	**4,798,405**	**105,444**	**8,787**	**546**
1	115,667,129	865,250,157	2,370,548	43,503	3,625	654
1.5	6,240	46,678	128	7	1	219
3/4	110,646,004	827,689,535	2,267,643	58,495	4,875	465
5/8	39,320	294,134	806	30	3	322
5/8 x 3/4	7,771,817	58,137,225	159,280	3,409	284	561
Grand Total	**537,415,417**	**4,020,146,235**	**11,014,099**	**258,602**	**21,550**	**511**

** Denotes information taken directly from the City's HTE database. The City has expressed concern over the accuracy of the information provided by the HTE database.*

*** Denotes a meter that has a 5/8" inlet and a 3/4" outlet.*

***General Note:** It is important to note that the data shown in Table 1.9 is currently being reevaluated as part of the 2010 Water Conservation and Management Plan Project. This has included the reclassification of some customers to different Rate Classes/Meter Sizes. The revised data also included some additional accounts that had been excluded from the data that was evaluated as part of this project, which changed the overall totals slightly.*

Winter and Summer Usage

The spatial distribution of water demand varies seasonally as most areas of the City consume more water during the summer for irrigation and other summer uses, while other areas maintain more consistent water consumption throughout the year. Three demand distributions were ultimately developed; winter, summer and average day. The winter and summer distributions are based on customer billing records from representative months, while the average day distribution is an overall yearly average. The effort to create winter and summer demand distributions was conducted after it was identified that peaking the average yearly distribution up or down did not necessarily provide a representative distribution for those scenarios.

Production Summary

The following table provides a summary of production data for 2008

Table 1.10 – 2008 Water Production

Source	Annual Average Daily Production (MGD)	Total production (MG)	Maximum Day (MGD)
Surface Water	5.75	2104.45	9.96
Bear 1	0.50	180.10	1.62
Bear 2	0.23	83.69	1.56
Pilot 1	0.54	198.19	1.62
Pilot 2	0.00	0.00	0.00
Pilot 3	0.34	123.50	2.42
Rock 1	0.20	71.70	1.28
Rock 2	0.07	25.52	1.17
Rock 3	0.48	176.22	1.35
River 1	0.85	312.62	2.94
River 2	0.31	111.93	2.98
Copperstone	0.56	203.16	2.91
Westwood	0.13	48.99	2.65
Outback 1	0.14	49.54	1.66
Outback 2	0.29	105.96	3.11
Outback 3	0.78	286.89	3.32
Outback 4	0.43	155.93	1.81
Out back 5	0.27	99.43	1.75
Outback 6	0.43	155.70	2.42
Outback 7	0.00	0.00	0.00
Outback 8	0.00	0.00	0.00
Shilo 1	0.00	0.13	0.02
Shilo 2	0.00	0.13	0.02
Shilo 3	0.18	64.32	2.08
Hole 10 N (1)	0.33	120.73	1.87
Hole 10 S (2)	0.25	90.83	0.82
Total Well*	7.09	2595.07	22.20
Known/Unaccounted	0.03	12.69	6.90
Total Well + Surface*	**12.84**	**4,699**	**29.25**

** Irrigation uses have been subtracted by the City to obtain Total Well and Total Well + Surface totals presented*

Demand by Zone (for Steady State Analysis)

The maximum day demand determined based on production data was distributed using the spatial demand distribution obtained using summer billing data. The number of customers served has been equated to the number of meters served per zone. Where a single large meter serves many customers, this number will provide an under-estimate of customers.

Table 1.11 – 2008 Water Demand and Customers by Zone

Zone	Demand ADD (gpm)	Demand MDD (gpm)	Estimate of Customers (Meters)
1	264	745	394
2	236	648	485
2B	50	102	338
3	820	2,193	2,083
3A	9	20	21
3B	34	80	6
3D	50	81	277
4A	481	1,148	1,105
4B	1,359	2,897	3,572
4C	83	222	270
4D	58	152	168
4E	144	375	292
4F	34	94	62
4G	17	39	14
4H	48	127	163
4I	36	79	138
4J	48	120	193
4K	12	29	53
5	2,972	6,085	6,403
5A	7	20	21
5B	15	42	26
5C	2	5	2
5D	19	49	30
6	1,485	3,336	3,476
6A	169	409	506
6B	24	67	39
7A	173	420	546
7B	76	187	214
7C	37	89	127
7D	6	12	37
Teth (2)	0	0	1
WestW (3)	148	403	367
Grand Total	**8,916**	**20,278**	**21,429**

Hydraulic Profile Development

The hydraulic profile was updated from previous planning efforts. It was modified to present a slightly different format where all horizontal lines represent the hydraulic grade line (HGL) of each zone. Where reservoirs serve zones by gravity the HGL represents the overflow elevation of the tank. Where zones are supplied by pump stations only, the discharge pressure of the lead pump converted to HGL is shown. Where zones are supplied by PRVs, the HGL of the first PRV to open is represented as the HGL of the zone (See Figure 1.3 Hydraulic Profile).

Pressure Zone Delineation

A significant effort was invested in developing a pressure zone map that identifies all the small subzones in the system. This enables detailed evaluations of how all areas of the system are served and if adequate redundancy in terms of supply and piping are available. The pressure zone nomenclature was developed as part of work to identify PRV settings by the City Staff. As an example, all Zone 4 pressure zones will have similar hydraulic grade lines but will serve distinct areas that are not connected to other Zone 4 areas (See Figure 1.4 Existing Water System Map).

Calibration

The first step in the development of an extended period simulation model is calibration of the steady state model. The required level of model accuracy can vary according to the intended use of the model, the type of system, the available boundary condition data as well as the size of the system and the way the system is controlled and operated. The minimum calibration exercise for any system is to match field-measured pressures and fire flows with model simulated system pressures and flows. This calibration exercise will test model pipeline friction factors, valve status, network configuration as well as facilities such as tank elevations and pump controls and curves.

Steady State

Fire hydrant flow test data was used to calibrate the steady state model (See Figure 1.5 Calibration Fire Tests and Confidence). Calibration consists of adjusting model parameters so that modeled results match measured (field) data. Pipeline friction-factors may be defined based on pipe material and age. Where this information does not exist, adjustments to friction factors may be made based on areas of similar age. Friction factors are never changed arbitrarily to match field measurements. Friction factors used in the model were identified by pipe material in Table 1.2. In general, the City experiences very little tuberculation in its piping and therefore even older piping exhibit relatively high C-factors.

The relative importance of all pertinent information is as follows:

Figure 1.3
Water Distribution Hydraulic Model

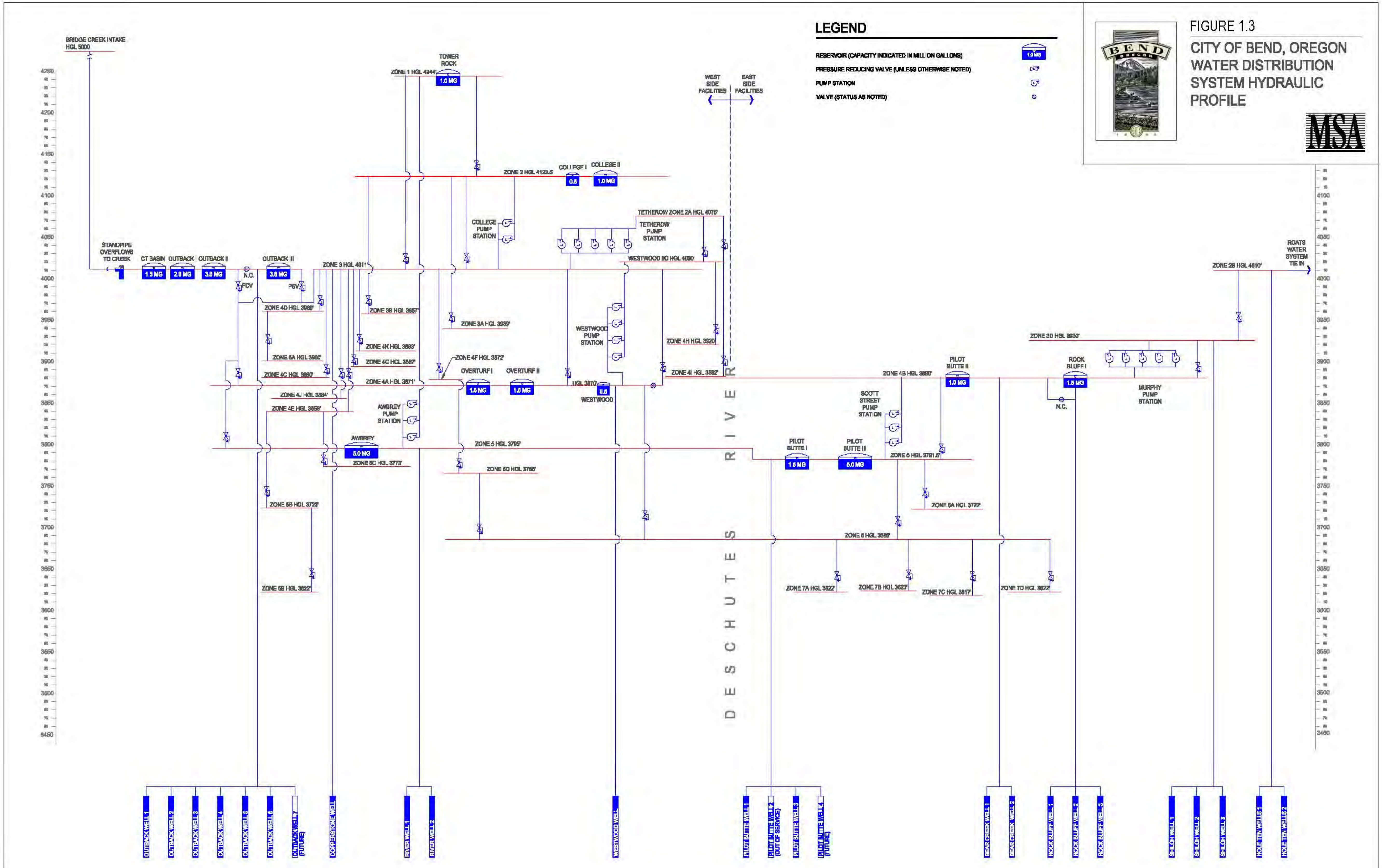


Table 1.12 – Relative Priority of System Data

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

Boundary Condition Data

Boundary condition data, such as reservoir levels and pump on/off status, must be known for the time of field pressure and flow data collection so that the same conditions can be represented in the model. A steady state model provides a "snap-shot" in time of the system. Boundary condition data used to evaluate and improve model calibration must be available at the time the hydrant flow test is completed.

The time of testing was recorded for each hydrant flow test. Boundary condition data during testing was collected from available system SCADA data. Field crew observed and noted the status of facilities that do not have recorded SCADA data.

Steady State Calibration Results

For any system, a portion of the data describing the distribution system will be missing, or inaccurate, and assumptions will be required. This does not necessarily mean that the accuracy of the hydraulic model will be compromised. Depending on the accuracy and completeness of the available information, some pressure zones may achieve a higher degree of calibration than others. Models that do not meet the highest degree of calibration are still useful for planning purposes. The descriptions in Table 1.13 were used to identify the level of calibration accuracy.

Table 1.13 – Calibration Confidence

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

See Figure 1.5 for a map of hydrant calibration test results and confidence levels. Results are also summarized in Table 1.14. Specific test results are listed in Table 1.15.

Calibration Results by Zone

Table 1.14 – 2009 Calibration Confidence Results

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

Table 1.15 – Individual Fire Flow Test Results (May-June 2009)

Pressure Zone	Flow Hydrant Number	Static Delta (absolute) psi	Flow Delta (absolute) psi
1	2422	2	5
1	1283	1	0
1	1319	2	3
2	568	1	3
2	1216	2	0
2	3358	2	0
3	4418	3	3
3	3072	1	5
3	3989	1	6
3	495	3	6
3	1372	1	6
3	3508	1	5
3	3835	0	12
3	4870	0	13
3	4027	1	1
3	4543	5	0
3	1922	4	6
3	1984	2	8
3	2982	0	0
5	3231	1	4
5	115	5	3
5	1708	1	2
5	18	2	3
5	2569	0	0
5	2807	2	3
5	2873	5	2
5	2899	1	4
5	3032	2	4
5	321	2	5
5	34	2	5
5	349	1	5
5	3920	1	2
5	4261	4	5
5	472	0	1
5	55	4	5
5	610	0	6
5	770	1	4
5	876	1	1
5	2522	0	1
6	4921	1	21

Pressure Zone	Flow Hydrant Number	Static Delta (absolute) psi	Flow Delta (absolute) psi
6	4930	4	9
6	3868	1	2
6	1313	2	1
6	1886	2	5
6	2042	2	0
6	2270	2	1
6	3770	1	2
6	4278	0	1
6	906	2	4
6	931	2	3
6	698	3	5
2B	4531	2	3
2B	JHY00027	0	2
2B	JHY00016	1	30
3A	2444	3	3
3A	NA	1	0
3B	1250	5	18
3B	1250	11	25
3D	JHY00046	3	12
3D	JHY00013	3	10
3D	JHY00012	0	10
4A	4469	5	10
4A	2056	3	5
4A	2335	1	2
4A	2431	5	1
4A	246	1	2
4A	792	0	3
4B	1711	4	2
4B	2087	1	4
4B	405	3	3
4B	832	1	3
4B	916	2	2
4B	2859	1	8
4B	4196	3	0
4B	4723	3	6
4B	1870	0	2
4B	3688	1	3
4B	4013	2	3
4B	4350	1	3
4B	581	3	8
4B	749	2	1
4C	3807	5	11

Pressure Zone	Flow Hydrant Number	Static Delta (absolute) psi	Flow Delta (absolute) psi
4C	4581	0	4
4D	945	0	14
4D	1737	4	8
4E	2017	2	5
4E	2577	0	2
4E	4291	4	15
4F	2254	5	0
4F	2256	3	5
4G	3044	4	2
4H	2022	0	0
4H	3547	6	2
4I	1026	3	1
4J	3966	0	3
4J	4443	0	0
4K	3863	5	4
4K	3865	1	1
5A	943	2	3
5B	1686	1	6
5C	4458	2	13
5C	4517	1	3
5D	1157	4	4
5D	1818	1	0
6A	3138	2	4
6A	972	4	2
6B	535	1	25
6B	538	0	2
6B	1473	0	2
7A	3877	23	21
7A	2334	2	6
7A	4899	9	1
7B	2369	1	5
7B	3927	1	6
7C	1598	0	3
7D	4913	0	6
7D	1773	5	9
Tetherow	4814	0	1
Tetherow	4819	1	2
Westwood	1270	1	2
Westwood	3302	0	3
Westwood	1522	2	9

Overall calibration confidence was considered high with a few areas of lower confidence. The highest priority areas to improve future operations and future calibration are zones 3D, 2B, and Westwood. These areas in general had the highest level of uncertainty in terms of the input data related to the piping extent and size along with questions on the current and historical operation of the facilities, all of which will impact the accuracy of the calibration.

Recommendations

The City plans to make substantial changes to Zones 3D, 2B (the former Juniper Utility) and to the Westwood facilities. It is recommended that as changes are made to existing facilities, the status, location, and characteristics of new pipelines, open/closed valves, PRVs and new well and pump station facilities should be carefully documented. The City should maintain records of any new pumping facilities, including manufacturer's operational curves. New facilities should be added to the drinking water distribution system model. Additional hydrant flow testing should be conducted and used to evaluate model calibration with updated facilities.

Extended Period

Demand by Zone

The summer distribution of demand used in the steady state analysis was used to distribute average production for the days used in summer extended period simulation calibration simulations. For the winter extended period calibration simulation, the average of water usage billed in December, January, February and March of 2008 was used to identify the spatial distribution of winter demand. Actual water production for the days used in the winter simulation was used in the model utilizing the winter demand distribution. The summer and winter demand distribution by zone used in extended period simulation calibration scenarios is presented in Table 1.16.

Table 1.16 – Extended Period Simulation Calibration Demand Distribution

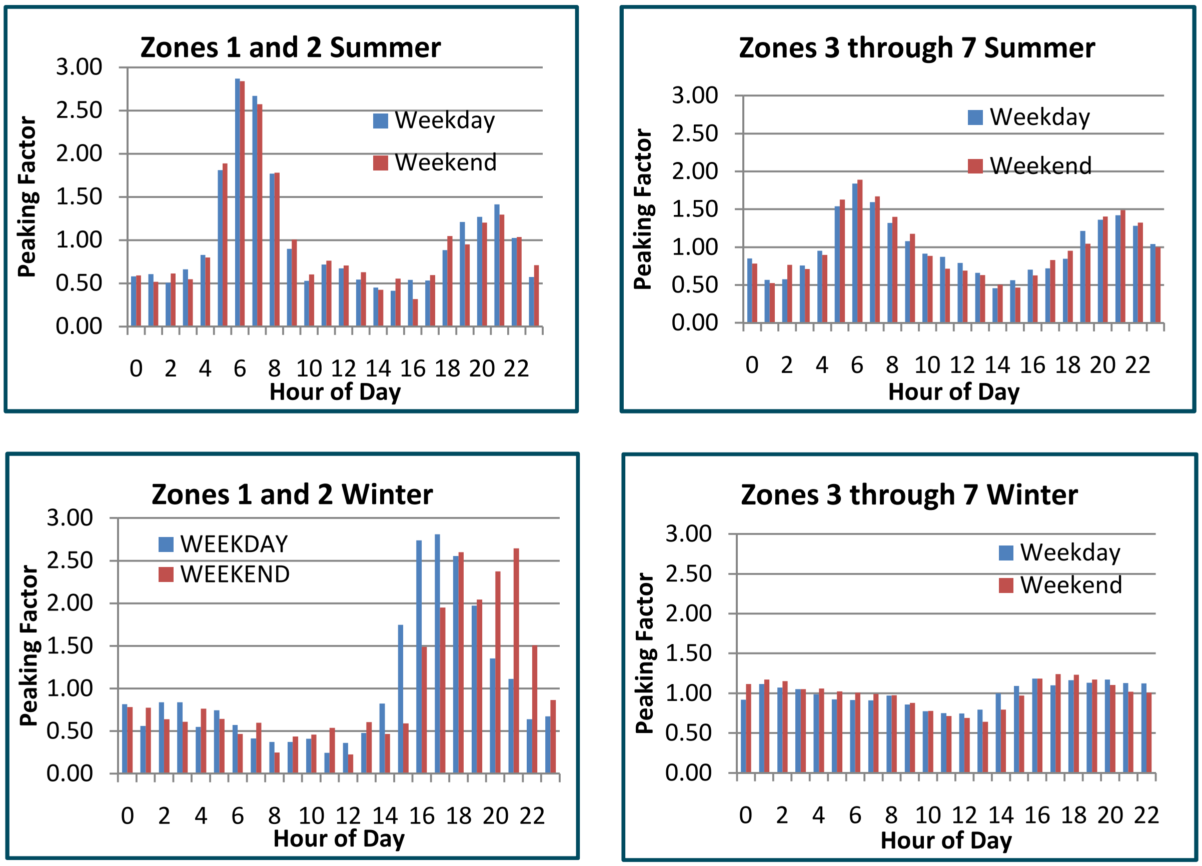
Zone	Demand Summer - July 2009 (gpm)	Demand Winter- January 2009 (gpm)
1	603	51
2	524	53
2B	82	29
3	1,775	195
3A	16	4
3B	64	10
3D	66	33
4A	929	188
4B	2,345	652
4C	180	24
4D	123	17
4E	303	35
4F	76	9
4G	31	6
4H	102	15
4I	64	14
4J	97	13
4K	24	3
5	4,926	1,520
5A	16	2
5B	34	3
5C	4	0
5D	40	4
6	2,700	626
6A	331	66
6B	54	5
7A	340	65
7B	152	24
7C	72	13
7D	10	3
Tetherow	0	0
Westwood	326	32
Total	**16,413**	**3,715**

Demands listed in Table 1.16 are for the specific days used in extended period calibration

Diurnal Pattern Development

The City's SCADA was used to develop seasonal diurnal patterns for hourly weekday and weekend water use. The change in reservoir level was used, along with reservoir dimensions, to determine the flow from reservoirs on a 10 minute interval. Pump SCADA was used to identify the flows from wells and boosters. Consumption was averaged on an hourly basis to result in the hourly diurnal patterns shown. Because the movement of water through pressure reducing valves is not monitored by the SCADA system, the City was separated into two distinguishable areas for diurnal curve development. Zones 1 and 2 are assumed not to allow significant flow through PRVs to the rest of the system and can be isolated through the flows supplied by the Awbrey and College Pump Stations. Zones 1 and 2 are almost entirely comprised of residential customers, so the diurnal curve from these zones is considered representative of a typical diurnal residential use pattern in the City of Bend. The residential use pattern will typically show higher daily peaks than a combined residential and non-residential use pattern. Supply and storage information from SCADA available for the rest of the system (zones 3 through 7 combined) were then used to develop a second set of diurnal curves representing a mixture of residential and non-residential land uses shown in Figure 1.6. The accuracy of the diurnal curves depends on the accuracy of the SCADA available in terms of pump flows and change in reservoir water surface elevations.

Figure 1.6
Diurnal Curves



Current zoning contained in the City's Buildable Lands Inventory (BLI) database was used to identify other pressure zones that are predominately residential. Pressure zones with less than 25% non-residential area were considered residential, and the pattern developed from Zones 1 and 2 was applied. Pressures zones with 25% or more area, zoned for uses other than residential, were assigned the mixed use diurnal curve developed from zones 3 through 7. Table 1.17 provides a summary of the distribution of residential and mixed diurnal curve patterns throughout the system.

Table 1.17 – 2009 Diurnal Curve Distribution

Pressure Zone	Non-Residential Percent	Type
1	0%	Residential
2	1%	Residential
2B	0%	Residential
3	10%	Residential
3A	0%	Residential
3B	0%	Residential
3D	0%	Residential
4A	23%	Residential
4B	21%	Residential
4C	0%	Residential
4D	8%	Residential
4E	0%	Residential
4F	0%	Residential
4G	98%	Mixed
4H	13%	Residential
4I	10%	Residential
4J	0%	Residential
4K	0%	Residential
5	33%	Mixed
5A	0%	Residential
5B	0%	Residential
5C	0%	Residential
5D	0%	Residential
6	35%	Mixed
6A	0%	Residential
6B	0%	Residential
7A	0%	Residential
7B	0%	Residential
7C	0%	Residential
7D	0%	Residential
Tetherow*	100%	Residential
Westwood	5%	Residential

**The Tetherow area was not included in the BLI database; however a residential demand pattern was applied to the small demand in this zone.*

Pump and Well Controls and Curves

During steady state calibration, any pump curves not available in the City's files were researched by the City. Many of the City's pump curves were obtained from the manufacturer or a design point could be identified on the pump from available system information. Some of the pump curve data obtained by the City was adjusted in the model to match measured SCADA information. Pumps with adjusted operational data include the Rock Bluff Well 1, the College Pump Station and the Scott Street Booster Station.

Some manufacturers pump curves could not be obtained as of the time of this report. For Outback Well 3, Outback Well 4, and Outback Well 5 a design point was estimated based on available SCADA. Other pumps were modeled using curves estimated or provided by the City that were not verified by manufacturers pump curves. Table 1.18 indicates the source of pump curve information and control settings used in the summer extended period simulation.

Table 1.18 – Pump Curve and Pump Control (Summer EPS, July 2009)

Pump Description	Control	On Setting	Off Setting	Manufacturer Pump Curve Available	Shutoff Head (ft)	Design Head (ft)	Design Flow (gpm)	High Head (ft)	High Flow (gpm)	Curve Name (Char)
Awbrey Pump #1	Tower Rock Reservoir	<27.5 (ft)	>29.5 (ft)	Unverified Design point	-	500	840	-	-	-
Awbrey Pump #2	Tower Rock Reservoir	<26.0 (ft)	>27.5 (ft)	Awbrey Pump Curve	670	500	1200	375	1600	-
Awbrey Pump #3	Off	-	-	Awbrey Pump Curve	670	500	1200	375	1600	-
Bear Creek Well 1	Pilot Butte 2 Reservoir-Level	<35 (ft)	> 37 (ft)	Bear Creek Well 1 Curve	-	-	-	-	-	-
Bear Creek Well 2	Pilot Butte 2 Reservoir-Level	<34 (ft)	> 36 (ft)	Unverified Design point	-	900	1,050	-	-	-
College Pump #1	College Reservoir #1	<17.8 (ft)	>22.0 (ft)	Design Point (Different from that noted on pump)	-	280	675	-	-	-
College Pump #2	College Reservoir #1	<16 (ft)	>20 (ft)	Design Point (Different from that noted on pump)	-	300	250	-	-	-
Copperstone Well	On	-	-	Copperstone Well Curve	-	-	-	-	-	CURVE3
Hole Ten Well 1	On	-	-	Unverified Curve	-	-	-	-	-	XNG7
Murphy Road Pumps 1 - 5	Off	-	-	Murphy Pump Station Curve	-	-	-	-	-	MURPHY
Outback Well 1	Off	-	-	Unverified Design Point	-	600	680	-	-	-

Pump Description	Control	On Setting	Off Setting	Manufacturer Pump Curve Available	Shutoff Head (ft)	Design Head (ft)	Design Flow (gpm)	High Head (ft)	High Flow (gpm)	Curve Name (Char)
Outback Well 2	Off	-	-	Unverified Design Point	-	570	680	-	-	-
Outback Well 3	Outback 3 Reservoir-Level	< 22 (ft)	>26 (ft)	Unverified Design Point Based on SCADA	-	500	1,200	-	-	-
Outback Well 4	Outback 3 Reservoir-Level	<29(ft)	>30(ft)	Unverified Design Point Based on SCADA	-	500	1,200	-	-	-
Outback Well 5	Outback 3 Reservoir-Level	<25.5 (ft)	>28 (ft)	Unverified Design Point Based on SCADA	-	500	1,050	-	-	-
Outback Well 6	Outback 3 Reservoir-Level	<20 (ft)	>24 (ft)	Curve Outback Well #6	-	-	-	-	-	OUTBACK _WELL_ PUMPS
Outback Well 7	Off	-	-	-	-	-	-	-	-	-
Pilot Butte Well 1	On	-	-	PB#1 Curve	-	-	-	-	-	PB#1
Pilot Butte Well 3	On	-	-	Unverified Design Point Based on SCADA	-	800	900	-	-	-
River Well 1	On	-	-	Unverified River Well 1 Curve	-	-	-	-	-	RIVER WELLNO1
River Well 2	Off	-	-	Unverified River Well 2 Curve	-	-	-	-	-	RIVER WELLNO2
Rock Bluff Well 1	Rock Bluff Reservoir-Level	< 34.9 (ft)	>37.2 (ft)	Calibrated Curve Rock Bluff Well 1	-	-	-	-	-	ROCK BLUFF WELL 1-SCADA
Rock Bluff Well 2	Off	-	-	Unverified Curve	-	-	-	-	-	ROCK BLUFF

Pump Description	Control	On Setting	Off Setting	Manufacturer Pump Curve Available	Shutoff Head (ft)	Design Head (ft)	Design Flow (gpm)	High Head (ft)	High Flow (gpm)	Curve Name (Char)
Rock Bluff Well 3	Rock Bluff Reservoir-Level	< 36 (ft)	>37.9 (ft)	Rock Bluff Well 1&3 Curve	-	-	-	-	-	ROCK BLUFF_ 1&3
Scott Street Booster Pump 1	Pilot Butte Reservoir II	<29 (ft)	>33 (ft)	Adjusted Curve (not according to MFR)	110	90	1,100	30	1,600	-
Scott Street Booster Pump 2	Pilot Butte Reservoir II	<31 (ft)	>35 (ft)	Adjusted Curve (not according to available MFR Curve)	110	90	1,100	30	1,600	-
Scott Street Booster Pump 3	Pilot Butte Reservoir II	<27 (ft)	>32 (ft)	Adjusted Curve (not according to available MFR Curve)	110	90	1,100	30	1,600	-
Shilo Well 1	Offline	-	-	-	-	-	-	-	-	-
Shilo Well 2	Offline	-	-	-	-	-	-	-	-	-
Shilo Well 3	Offline	-	-	Shilo Well 3 Curve	931	786	850	450	1,375	-
Tetherow Pump #1	Downstream pressure	85 psi	-	Tetherow Pump 1 Curve	220	194	150	110	250	-
Tetherow Pump #2	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-
Tetherow Pump #3	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-
Tetherow Pump #4	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-
Tetherow Pump #5	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-
Tetherow Pump #6	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-

Pump Description	Control	On Setting	Off Setting	Manufacturer Pump Curve Available	Shutoff Head (ft)	Design Head (ft)	Design Flow (gpm)	High Head (ft)	High Flow (gpm)	Curve Name (Char)
Westwood Pump #1	On	-	-	Westwood Pump #1 Curve	-	-	-	-	-	XNG, Westwood PS#1
Westwood Pump #2	Downstream pressure	<73	>83	Westwood Pump #2 Curve	-	-	-	-	-	XNG1, Westwood PS#2
Westwood Pump #3	Downstream pressure	<50	>60	Westwood Pump #3 Curve	-	-	-	-	-	XNG3, Westwood PS#3
Westwood Pump #4	Timer – turned on during irrigation season	4:00 AM 4:00PM	10:00AM 11:00PM	Westwood Pump #4 Curve	-	-	-	-	-	XNG5, Westwood PS#4
Westwood Well	Westwood Reservoir-Level	< 19 (ft)	> 24 (ft)	Unverified Design Point	-	386	460	-	-	-

Valve Controls

For extended period calibration simulations, flow control valves supplying Awbrey and Overturf reservoirs were set with a maximum flow rate in addition to on/off controls based on the water level in the reservoir. The flow controls used in calibration simulations were based on discussion with the City Staff and available SCADA for valve flow rates and on/off level. Valve controls are summarized in Table 1.19.

Table 1.19 – Valve Control (July 2009)

Valve ID	Valve Type	Control Based on Facility	Flow Control Setting (Summer)	Open Below (Summer)	Closed Above (Summer)	Flow Control Setting (Winter)	Open Below (Winter)	Closed Above (Winter)
AWBREY _VALVE	Flow Control Valve	Awbrey Reservoir	6,200 (gpm)	17 ft	18 ft	3,500 (gpm)	17 ft	17.9 ft
OVER_ FCV	Flow Control Valve	Overturf West	1,400 (gpm)	21.8 ft	23 ft	1,200 (gpm)	23 ft	24.6 ft

When both extended period controls and initial status controls are defined in the model, the extended period controls will become active after the initial time step of the simulation. If an initial control is provided with no additional extended period control, the initial control will remain active.

Extended Period Simulation Results

Pump and well controls are as shown in Tables 1.18 and 1.20 for summer and winter calibration, respectively. Summer and winter valve settings are as shown in Tables 1.7 and 1.21, respectively.

The results of extended period simulation were charted together with system SCADA data (Figures 1.7 through 1.16) and compared for both summer and winter period simulations. In general, the figures are organized by pressure zone, though in some cases it requires more than one figure to depict a zone.

Summer Extended Period Simulation Results

The EPS calibration runs that were completed and compared with July 2009 SCADA are shown in **Figures 1.7 – 1.16.**

Figure 1.7
Summer EPS Calibration Results for Zone 1

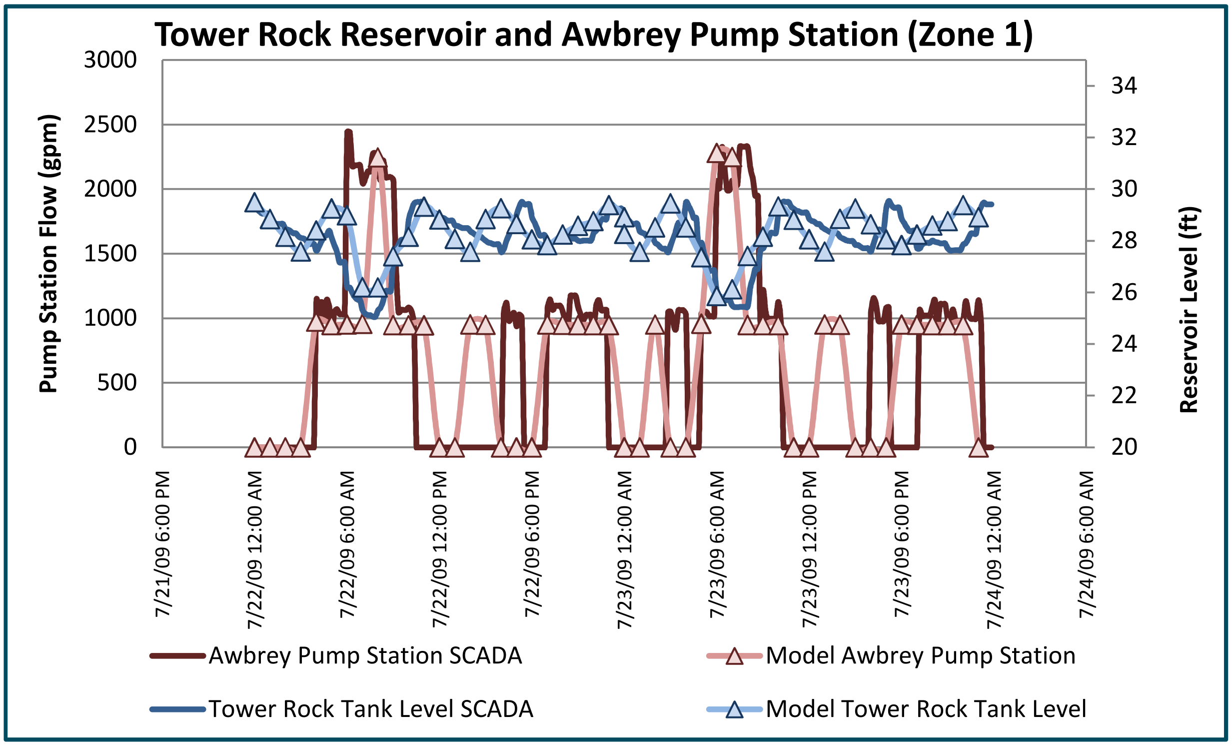


Figure 1.8
Summer EPS Calibration Results for Zone 2

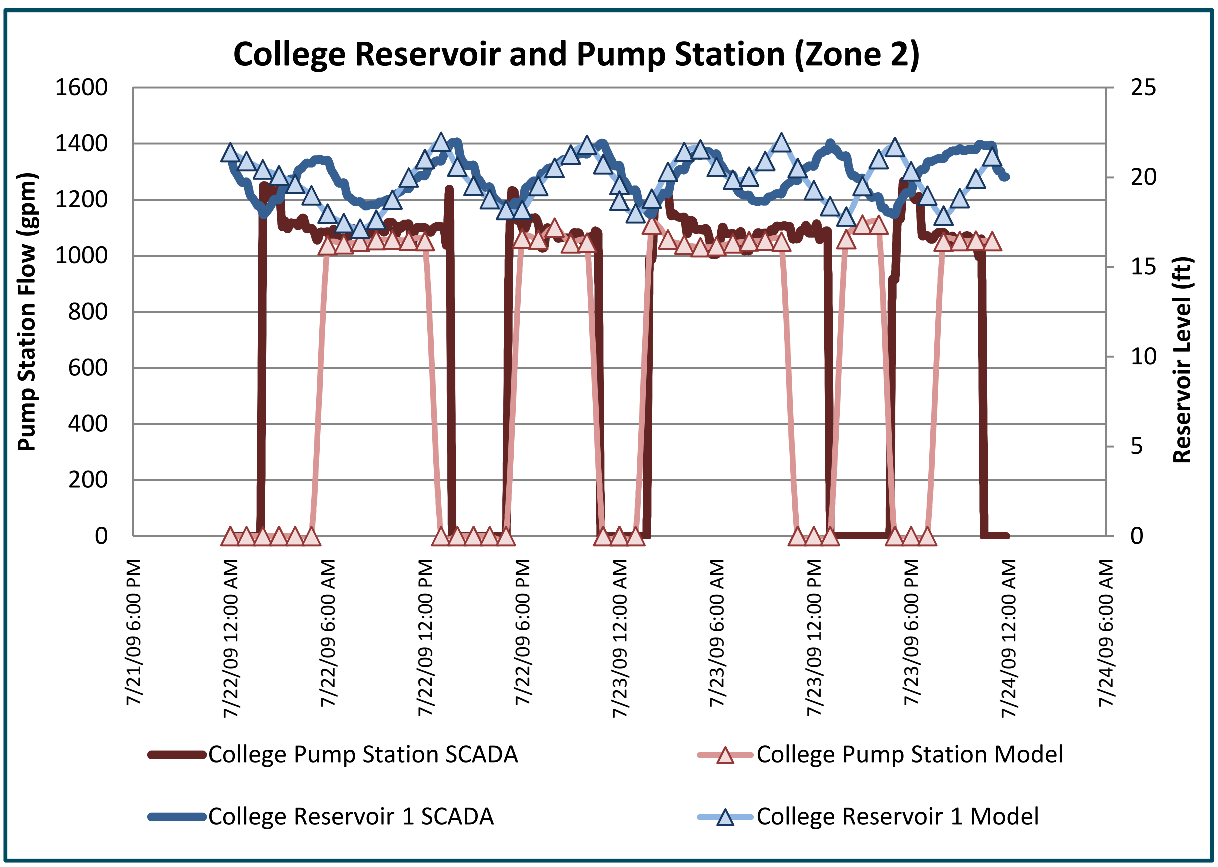


Figure 1.9
Summer EPS Calibration Results for Zone 5

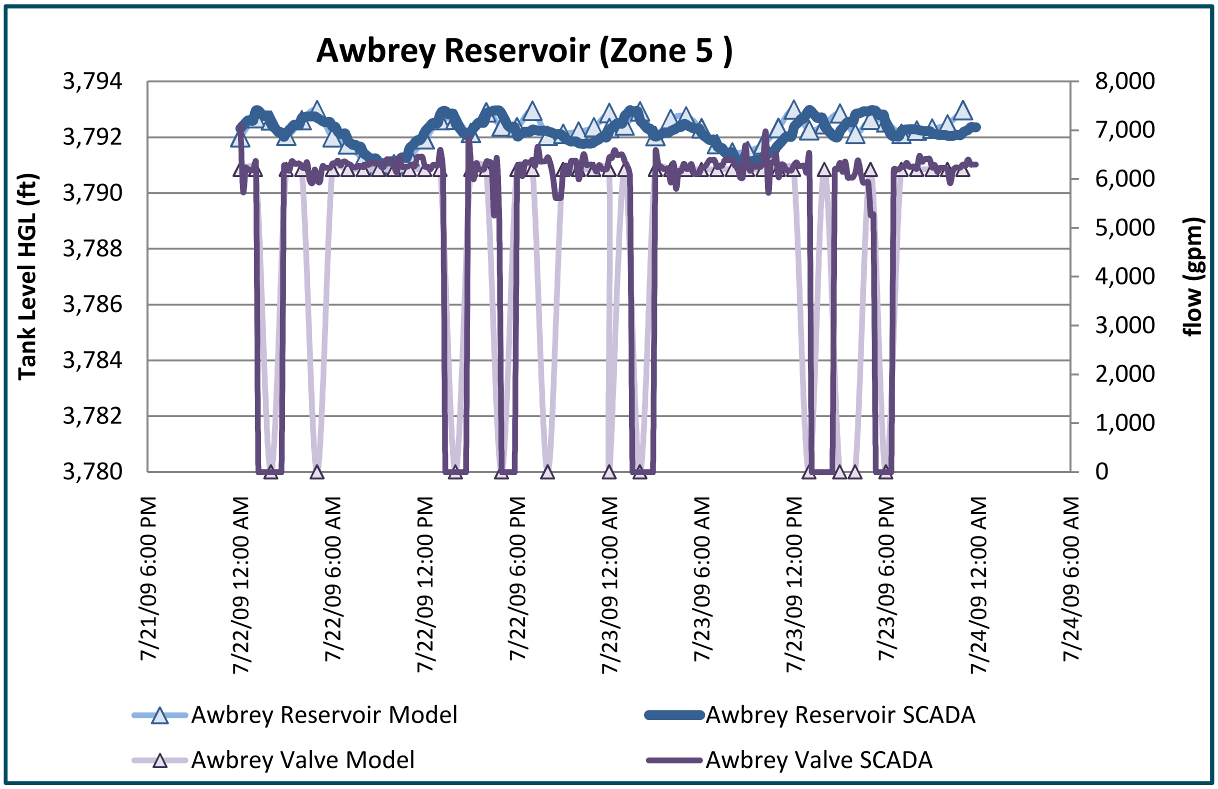


Figure 1.10
Summer EPS Calibration Results for Zone 5

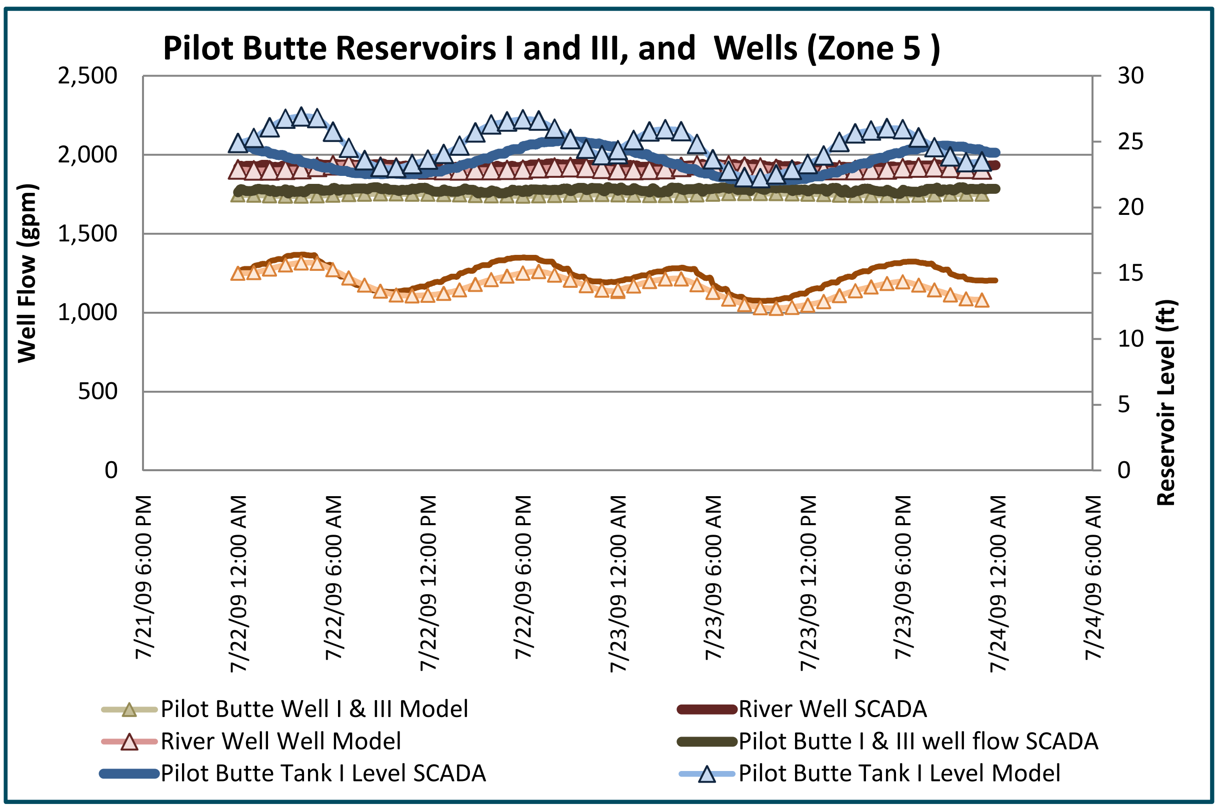


Figure 1.11
Summer EPS Calibration Results for Zone 4B

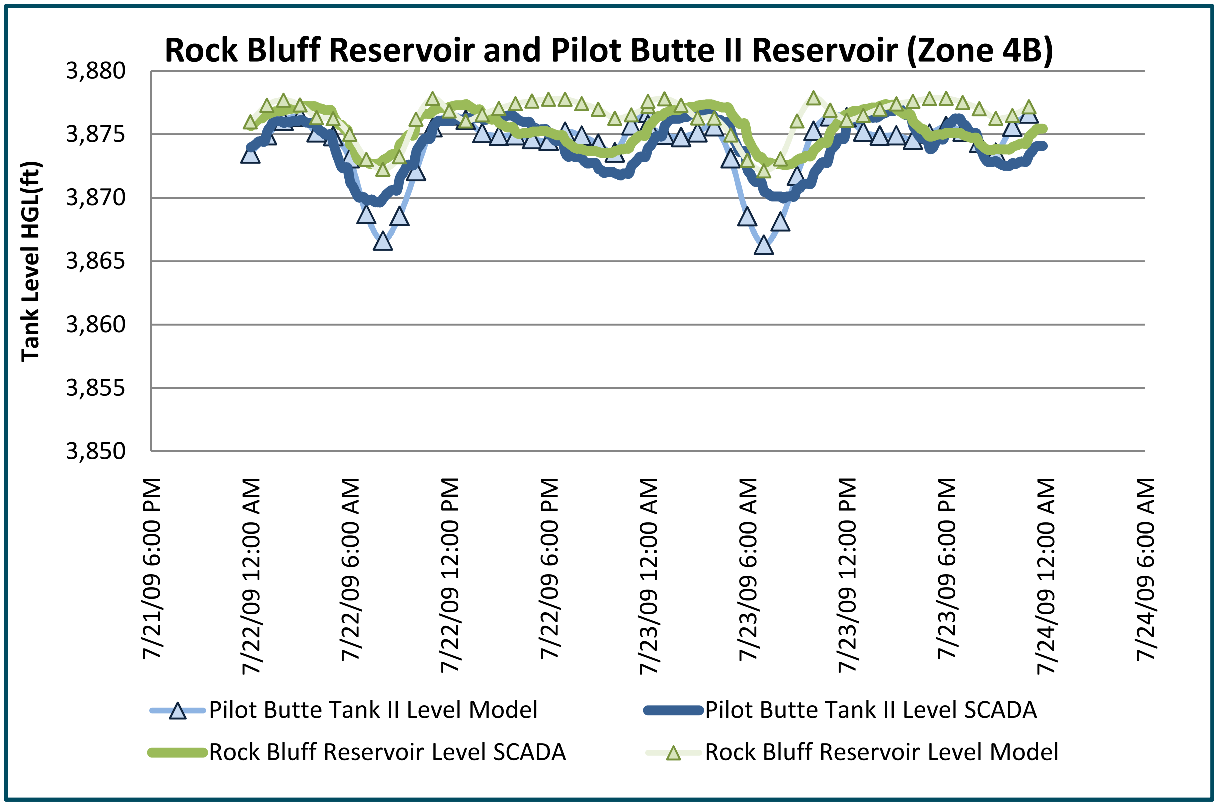


Figure 1.12
Summer EPS Calibration Results for Zone 4B

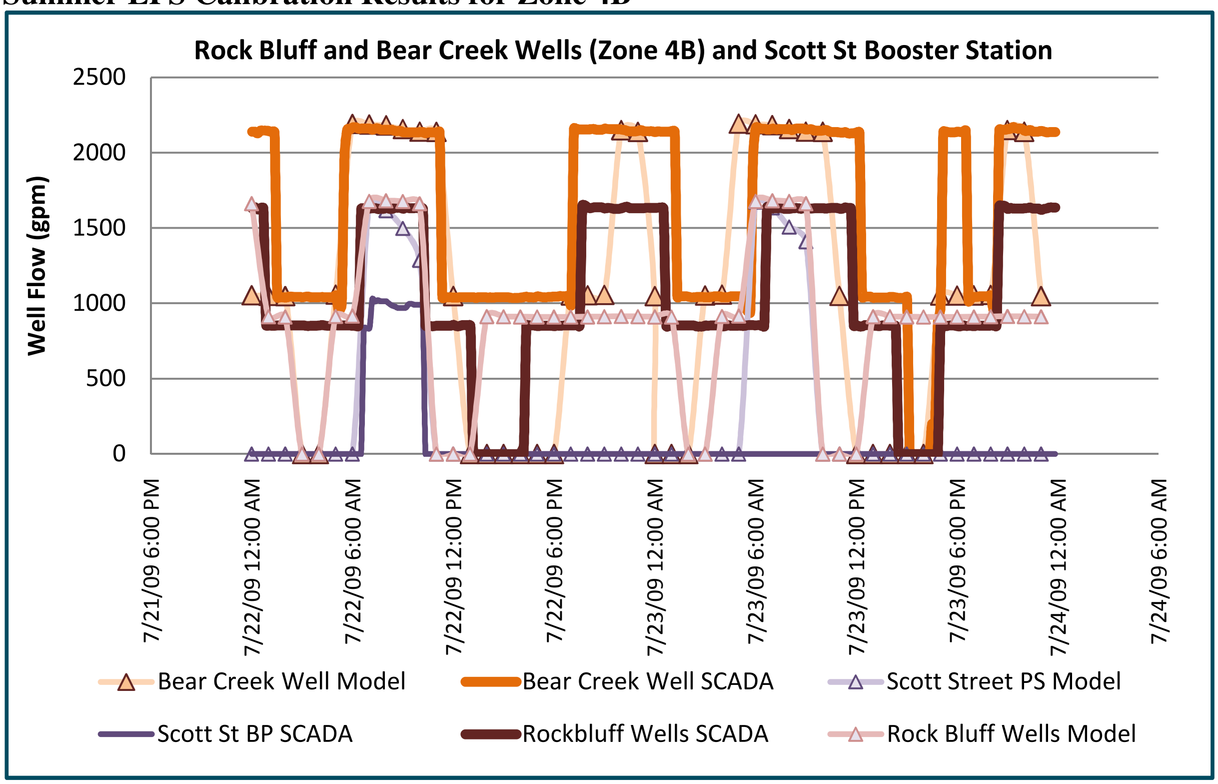


Figure 1.13
Summer EPS Calibration Results for Outback Reservoir 1 and 3

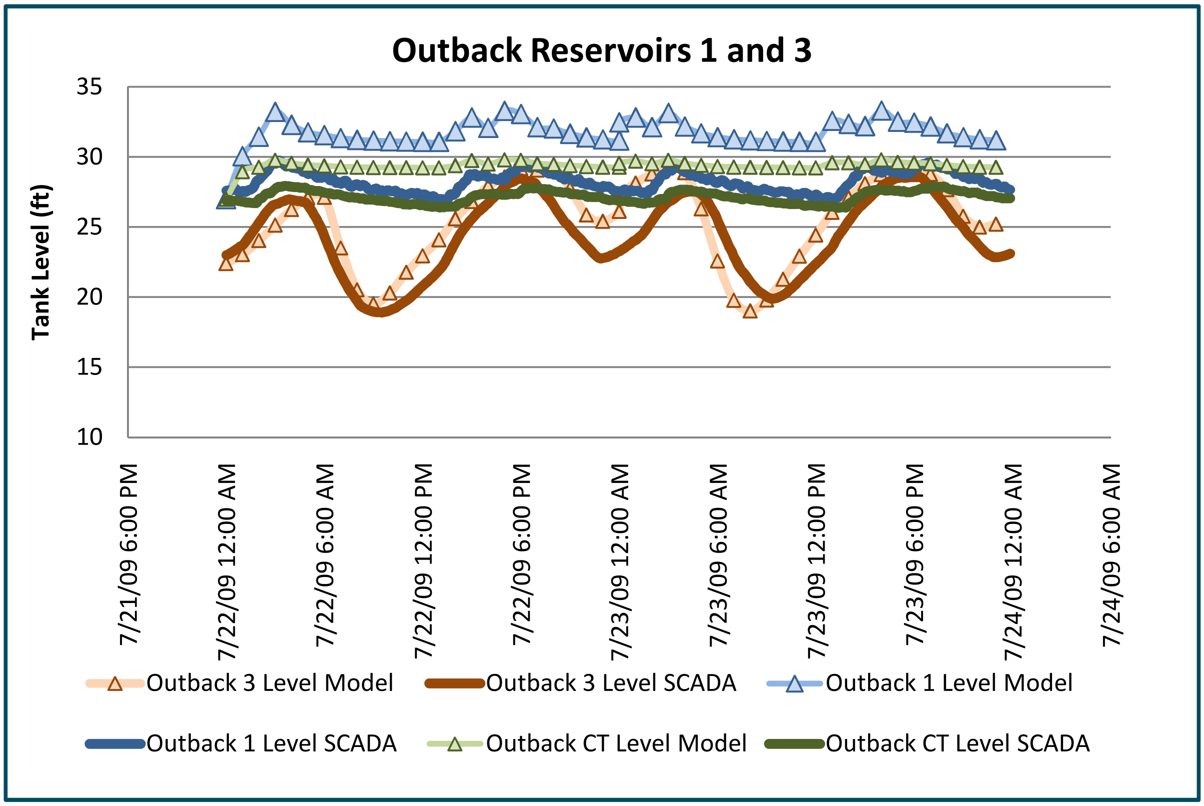


Figure 1.14
Summer EPS Calibration Results for the Outback Facility

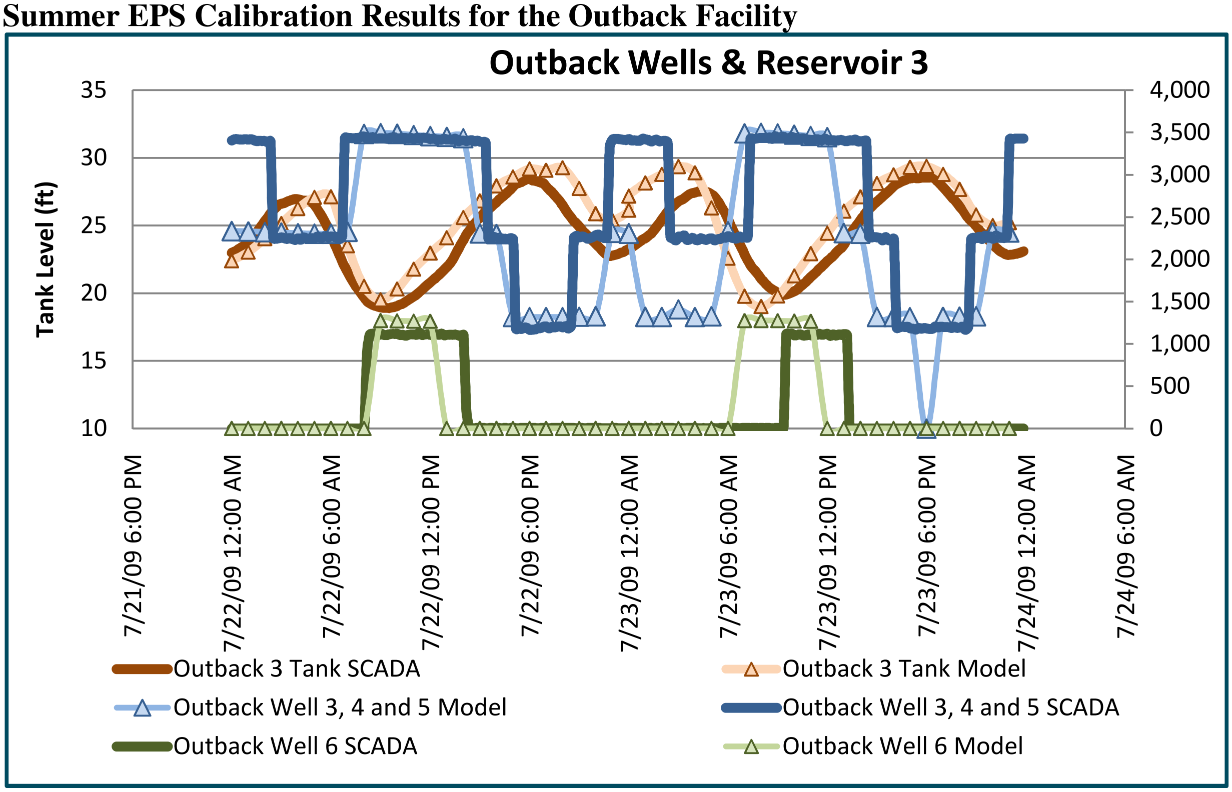


Figure 1.15
Summer EPS Calibration Results for Zone 4A

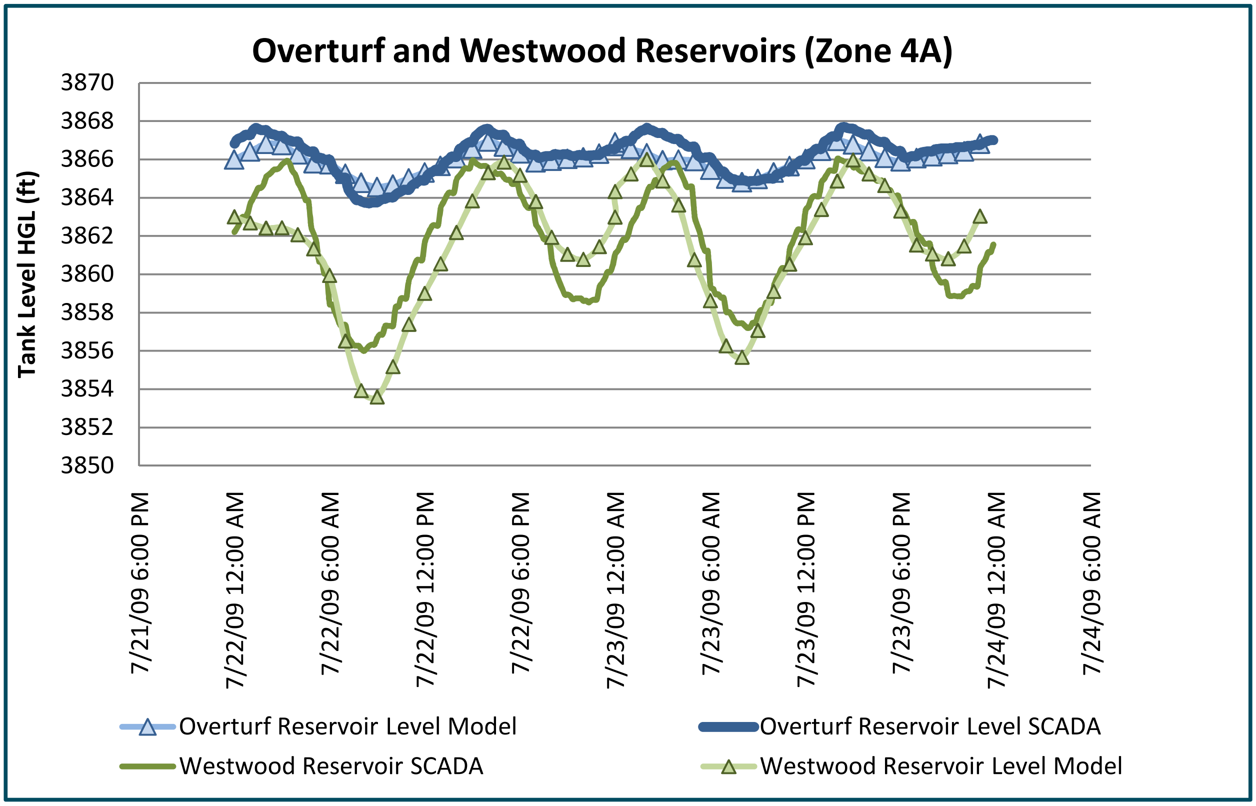
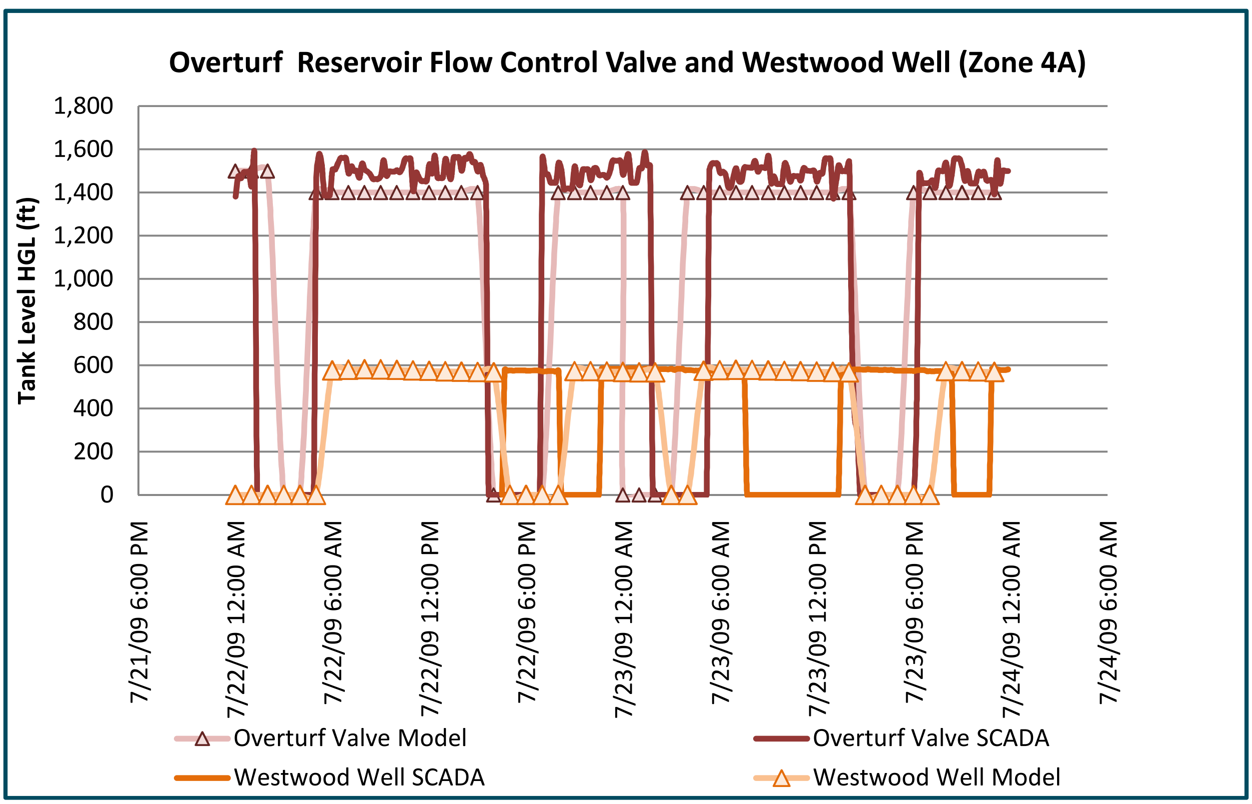


Figure 1.16
Summer EPS Calibration Results for Zone 4A Reservoir and Well Flows



Winter Extended Period Simulation Calibration Results

Pump Settings and Controls for winter simulation are summarized in Table 1.20 and are based on December 2009/January 2010 settings. SCADA information from December 2009 was used for the calibration analysis.

Table 1.20 – January 2010 Operational Settings

Pump Description	Control	On Setting	Off Setting	Manufacturer Pump Curve Available	Shutoff Head (ft)	Design Head (ft)	Design Flow (gpm)	High Head (ft)	High Flow (gpm)	Curve Name (Char)
Awbrey Pump #1	Tower Rock Reservoir	<28.9 (ft)	>29.5 (ft)	Unverified Design point	-	500	840	-	-	-
Awbrey Pump #2	Tower Rock Reservoir	<26.0 (ft)	>27.5 (ft)	Awbrey Pump Curve	670	500	1,200	375	1,600	-
Awbrey Pump #3	Off	-	-	Awbrey Pump Curve	670	500	1,200	375	1,600	-
Bear Creek Well 1	Pilot Butte 2 Reservoir-Level	<35 (ft)	> 37 (ft)	Bear Creek Well 1 Curve	-	-	-	-	-	-
Bear Creek Well 2	Pilot Butte 2 Reservoir-Level	<34 (ft)	> 36 (ft)	Unverified Design point	-	900	1,050	-	-	-
College Pump #1	College Reservoir #1	<18.3 (ft)	>22.0 (ft)	Design Point (Different from that noted on pump)	-	280	675	-	-	-
College Pump #2	College Reservoir #1	<16 (ft)	>20 (ft)	Design Point (Different from that noted on pump)	-	300	250	-	-	-
Copperstone Well	On	-	-	Copperstone Well Curve	-	-	-	-	-	CURVE3
Hole Ten Well 1	On	-	-	Unverified Curve	-	-	-	-	-	XNG7
Murphy Road Pump Station	Off	-	-	Murphy Pump Station Curve	-	-	-	-	-	MURPHY
Outback Well 1	Off	-	-	Unverified Design Point	-	600	680	-	-	-

Pump Description	Control	On Setting	Off Setting	Manufacturer Pump Curve Available	Shutoff Head (ft)	Design Head (ft)	Design Flow (gpm)	High Head (ft)	High Flow (gpm)	Curve Name (Char)
Outback Well 2	On	-	-	Unverified Design Point	-	570	680	-	-	-
Outback Well 3	Outback 3 Reservoir-Level	< 26 (ft)	>28 (ft)	Unverified Design Point Based on SCADA	-	500	1,200	-	-	-
Outback Well 4	Outback 3 Reservoir-Level	<24(ft)	>27(ft)	Unverified Design Point Based on SCADA	-	500	1,200	-	-	-
Outback Well 5	Outback 3 Reservoir-Level	<23 (ft)	>26 (ft)	Unverified Design Point Based on SCADA	-	500	1,050	-	-	-
Outback Well 6	Outback 3 Reservoir-Level	<20 (ft)	>24 (ft)	Curve Outback Well #6	-	-	-	-	-	OUTBACK_WELL_PUMPS
Outback Well 7	Off	-	-	-	-	-	-	-	-	-
Pilot Butte Well 1	Off	-	-	PB#1 Curve	-	-	-	-	-	PB#1
Pilot Butte Well 3	Off	-	-	Unverified design point based on SCADA	-	800	900	-	-	-
River Well 1	Off	-	-	Unverified River Well 1 Curve	-	-	-	-	-	RIVER WELLNO1
River Well 2	Off	-	-	Unverified River Well 2 Curve	-	-	-	-	-	RIVER WELLNO2

Pump Description	Control	On Setting	Off Setting	Manufacturer Pump Curve Available	Shutoff Head (ft)	Design Head (ft)	Design Flow (gpm)	High Head (ft)	High Flow (gpm)	Curve Name (Char)
Rock Bluff Well 1	Rock Bluff Reservoir-Level	< 34.9 (ft)	>37.2 (ft)	Calibrated Curve Rock Bluff Well 1	-	-	-	-	-	ROCK BLUFF WELL1-SCADA
Rock Bluff Well 2	Off	-	-	Unverified Curve	-	-	-	-	-	ROCK BLUFF
Rock Bluff Well 3	Rock Bluff Reservoir-Level	< 36 (ft)	>38 (ft)	Rock Bluff Well 1&3 Curve	-	-	-	-	-	ROCK BLUFF_ 1&3
Scott Street Booster Pump 1	Pilot Butte Reservoir II	<29 (ft)	>33 (ft)	Adjusted Curve (not according to MFR)	110	90	1,100	30	1,600	-
Scott Street Booster Pump 2	Pilot Butte Reservoir II	<31 (ft)	>35 (ft)	Adjusted Curve (not according to available MFR Curve)	110	90	1,100	30	1,600	-
Scott Street Booster Pump 3	Pilot Butte Reservoir II	<27 (ft)	>32 (ft)	Adjusted Curve (not according to available MFR Curve)	110	90	1,100	30	1,600	-
Shilo Well 1	Offline	-	-	-	-	-	-	-	-	-
Shilo Well 2	Offline	-	-	-	-	-	-	-	-	-
Shilo Well 3	Offline	-	-	Shilo Well 3 Curve	931	786	850	450	1,375	-
Tetherow Pump #1	Downstream pressure	85 psi	-	Tetherow Pump 1 Curve	220	194	150	110	250	-
Tetherow Pump #2	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-
Tetherow Pump #3	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-

Pump Description	Control	On Setting	Off Setting	Manufacturer Pump Curve Available	Shutoff Head (ft)	Design Head (ft)	Design Flow (gpm)	High Head (ft)	High Flow (gpm)	Curve Name (Char)
Tetherow Pump #4	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-
Tetherow Pump #5	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-
Tetherow Pump #6	Off	-	-	Tetherow Pumps 2 – 6 Curve	215	192	700	75	1,400	-
Westwood Pump #1	On	-	-	Westwood Pump #1 Curve	-	-	-	-	-	XNG, Westwood PS#1
Westwood Pump #2	Downstream pressure	<73	>83	Westwood Pump #2 Curve	-	-	-	-	-	XNG1, Westwood PS#2
Westwood Pump #3	Downstream pressure	<50	>60	Westwood Pump #3 Curve	-	-	-	-	-	XNG3, Westwood PS#3
Westwood Pump #4	Off	-	-	Westwood Pump #4 Curve	-	-	-	-	-	XNG5, Westwood PS#4
Westwood Well	Westwood Reservoir-Level	< 19 (ft)	> 26 (ft)	Unverified Design Point	-	386	460	-	-	-

Winter initial control settings for system valves are listed in Table 1.21.

Table 1.21 – January 2010 PRV Settings

Identifier	Valve Type	Elevation (ft)	Diameter (in)	Setting
AWBREY_VALVE	FCV	3,775.00	12	3,500.00
HOLE10WELLPSV	PSV	3,866.00	4	62
MURPHY-PS_PR	PRV	3,746.00	10	57
OVER_FCV	FCV	3,844.06	12	1,500.00
SHILOPRV	PRV	3,764.00	12	50
WAPRV001A	PRV	3,738.55	2	46
WAPRV001B	PRV	3,738.55	8	42
WAPRV002A	PRV	3,749.91	2	88
WAPRV002B	PRV	3,749.91	8	83
WAPRV003A	PRV	3,864.00	2	52
WAPRV003B	PRV	3,864.00	8	54
WAPRV004A	PRV	3,486.09	3	60
WAPRV004B	PRV	3,486.09	10	55
WAPRV005A	PRV	3,542.87	4	60
WAPRV005B	PRV	3,542.87	8	55
WAPRV006A	PRV	3,480.77	2	64
WAPRV006B	PRV	3,480.77	6	59
WAPRV007A	PRV	3,552.95	4	60
WAPRV007B	PRV	3,552.95	12	56
WAPRV008A	PRV	3,541.54	2	66
WAPRV008B	PRV	3,541.54	6	60
WAPRV009A	PRV	3,570.03	4	62
WAPRV009B	PRV	3,570.03	14	60
WAPRV011A	PRV	3,572.10	12	51
WAPRV012A	PRV	3,529.89	2	68
WAPRV012B	PRV	3,529.89	8	63
WAPRV013A	PRV	3,573.92	2	56
WAPRV013B	PRV	3,573.92	12	51
WAPRV014A	PRV	3,592.18	2	57
WAPRV014B	PRV	3,592.18	12	33
WAPRV015A	PRV	3,665.87	2	40
WAPRV015B	PRV	3,665.87	8	38
WAPRV016A	PRV	3,567.98	2	62
WAPRV016B	PRV	3,567.98	6	57
WAPRV017A	PRV	3,590.16	2	59
WAPRV017B	PRV	3,590.16	6	53
WAPRV018A	PRV	3,609.21	3	39
WAPRV018B	PRV	3,609.21	8	25

Identifier	Valve Type	Elevation (ft)	Diameter (in)	Setting
WAPRV019A	PRV	3,727.88	2	55
WAPRV019B	PRV	3,727.88	8	50
WAPRV020A	PRV	3,781.07	3	78.5
WAPRV020B	PRV	3,781.07	10	69.5
WAPRV021A	PRV	3,760.07	2	57
WAPRV021B	PRV	3,760.07	8	52
WAPRV022A	PRV	3,808.49	2	23
WAPRV022B	PRV	3,808.49	10	18
WAPRV023A	PRV	3,756.34	2	62
WAPRV024A	PRV	3,639.17	2	67
WAPRV024B	PRV	3,639.17	6	60
WAPRV025A	PRV	4,068.69	2	20
WAPRV025B	PRV	4,068.69	8	15
WAPRV026A	PRV	4,049.82	2	21
WAPRV026B	PRV	4,049.82	6	16
WAPRV027A	PRV	3,798.23	2	52
WAPRV028A	PRV	3,769.14	4	60
WAPRV029A	PRV	3,774.18	6	63
WAPRV030A	PRV	3,642.53	2	36
WAPRV030B	PRV	3,642.53	6	31
WAPRV031A	PRV	3,830.52	2	47
WAPRV031B	PRV	3,830.52	6	43.5
WAPRV032A	PRV	3,884.75	2	39
WAPRV032B	PRV	3,884.75	6	38
WAPRV033A	PRV	3,470.48	2	66
WAPRV033B	PRV	3,470.48	6	61
WAPRV034A	PRV	3,612.22	2	50
WAPRV034B	PRV	3,612.22	8	45
WAPRV035A	PRV	3,760.22	2	40
WAPRV035B	PRV	3,760.22	6	35
WAPRV036A	PRV	3,643.14	6	51
WAPRV036B	PRV	3,643.14	16	46
WAPRV037A	PRV	3,683.40	2	45
WAPRV037B	PRV	3,683.40	6	40
WAPRV038A	PRV	3,711.79	4	72
WAPRV038B	PRV	3,711.79	12	68
WAPRV039A	PRV	3,653.68	6	52
WAPRV039B	PRV	3,653.68	10	57
WAPRV040A	PRV	3,622.55	4	69
WAPRV040B	PRV	3,622.55	12	64
WAPRV040C	PRV	3,622.55	2	74
WAPRV041A	PRV	3,579.60	6	37

Identifier	Valve Type	Elevation (ft)	Diameter (in)	Setting
WAPRV041B	PRV	3,579.60	12	32
WAPRV043A	PRV	3,757.87	2	50
WAPRV043B	PRV	3,757.87	6	40
WAPRV044A	PRV	3,764.15	3	48
WAPRV044B	PRV	3,764.15	10	44
WAPRV045A	PRV	3,834.64	10	40
WAPRV046A	PRV	3,820.35	3	61
WAPRV046B	PRV	3,820.35	8	56
WAPRV047A	PRV	3,726.20	3	72
WAPRV047B	PRV	3,726.20	12	67
WAPRV048A	PRV	3,595.77	2	61
WAPRV048B	PRV	3,595.77	6	57
WAPRV049A	PRV	3,817.01	10	45
WAPRV050A	PRV	3,761.47	3	43
WAPRV050B	PRV	3,761.47	8	38
WAPRV052A	PRV	3,730.04	3	50
WAPRV052B	PRV	3,730.04	8	45
WAPRV053A	PRV	3,742.77	3	50
WAPRV053B	PRV	3,742.77	8	45
WAPRV054A	PRV	3,483.21	3	59
WAPRV054B	PRV	3,483.21	8	54
WAPRV056A	PRV	3,667.44	3	78
WAPRV056B	PRV	3,667.44	8	72
WAPRV057A	PRV	3,642.03	3	51
WAPRV057B	PRV	3,642.03	10	46
WAPRV058A	PRV	3,485.91	2	61
WAPRV058B	PRV	3,485.91	6	56
WAPRV059A	PRV	3,758.17	2	56
WAPRV059B	PRV	3,758.17	6	51
WAPRV061A	PRV	3,460.30	3	70
WAPRV061B	PRV	3,460.30	8	65
WAPRV062A	PRV	3,751.37	6	51
WAPRV064A	PRV	3,760.07	2	57
WAPRV064B	PRV	3,760.07	8	52
WAPRV065A	PRV	3,730.43	6	52
WAPRV065B	PRV	3,730.43	10	47
WAPRV066A	PRV	3,500.92	2	52
WAPRV066B	PRV	3,500.92	6	47
WAPRV067A	PRV	3,744.41	3	49
WAPRV067B	PRV	3,744.41	8	44
WAPRV069A	PRV	3,814.54	6	48
WAPRV073A	PRV	3,864.54	3	65

Identifier	Valve Type	Elevation (ft)	Diameter (in)	Setting
WAPRV073B	PRV	3,864.54	8	60
WAPRV074A	FCV	3,973.16	24	7,800.00
WAPRV075A	PRV	3,976.05	24	8
WAPRV076A	PRV	3,735.26	6	58
WAPRV076B	PRV	3,735.26	10	53
WAPRV077A	PRV	3,651.02	3	52
WAPRV077B	PRV	3,651.02	8	42
WAPRV078A	PRV	3,643.84	3	50
WAPRV078B	PRV	3,643.84	8	45
WAPRV079A	PRV	3,493.25	2	56
WAPRV079B	PRV	3,493.25	6	51
WAPRV080A	PRV	3,481.84	3	63
WAPRV080B	PRV	3,481.84	8	58
WESTWSUSTAIN	PSV	3,841.25	12	78

** FCV: Flow Control Valve, PSV: Pressure Sustaining Valve, PRV: Pressure Reducing Valve*

Winter Extended Period Simulation Results

Figure 1.17
Winter EPS Calibration Results for Zone 1

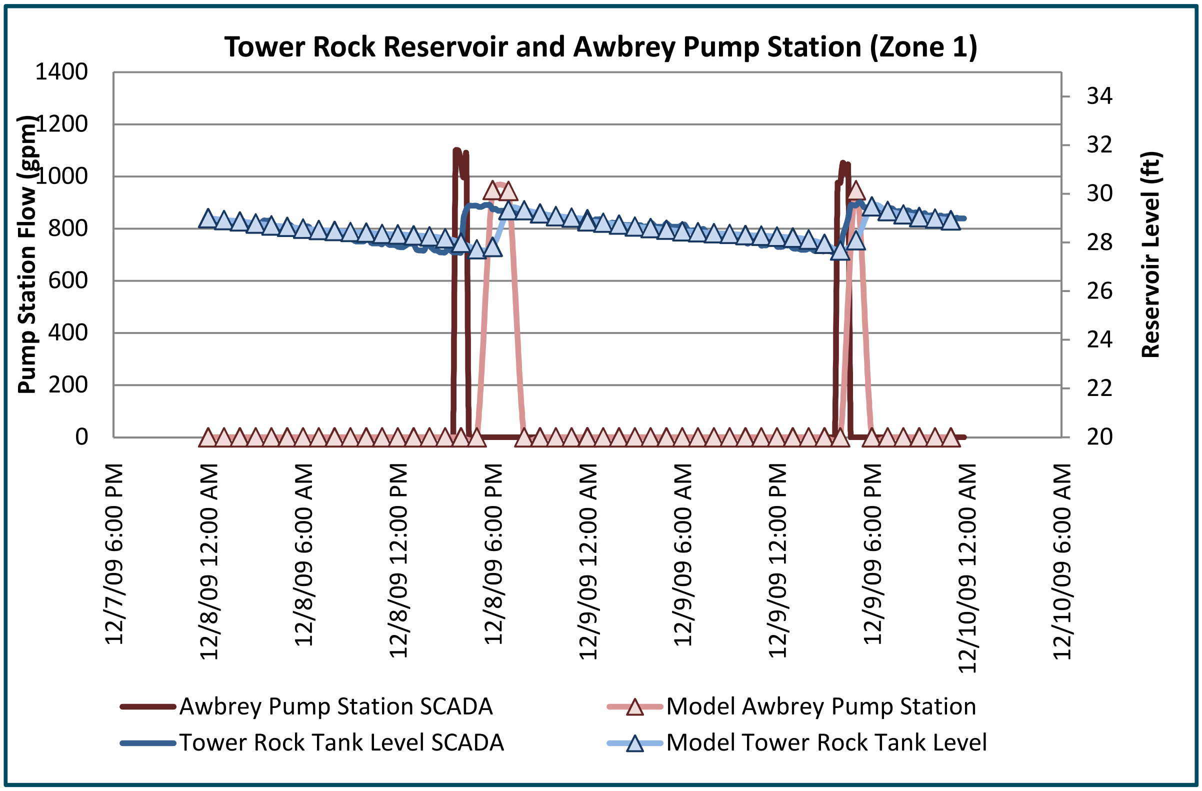


Figure 1.18
Winter EPS Calibration Results for Zone 2

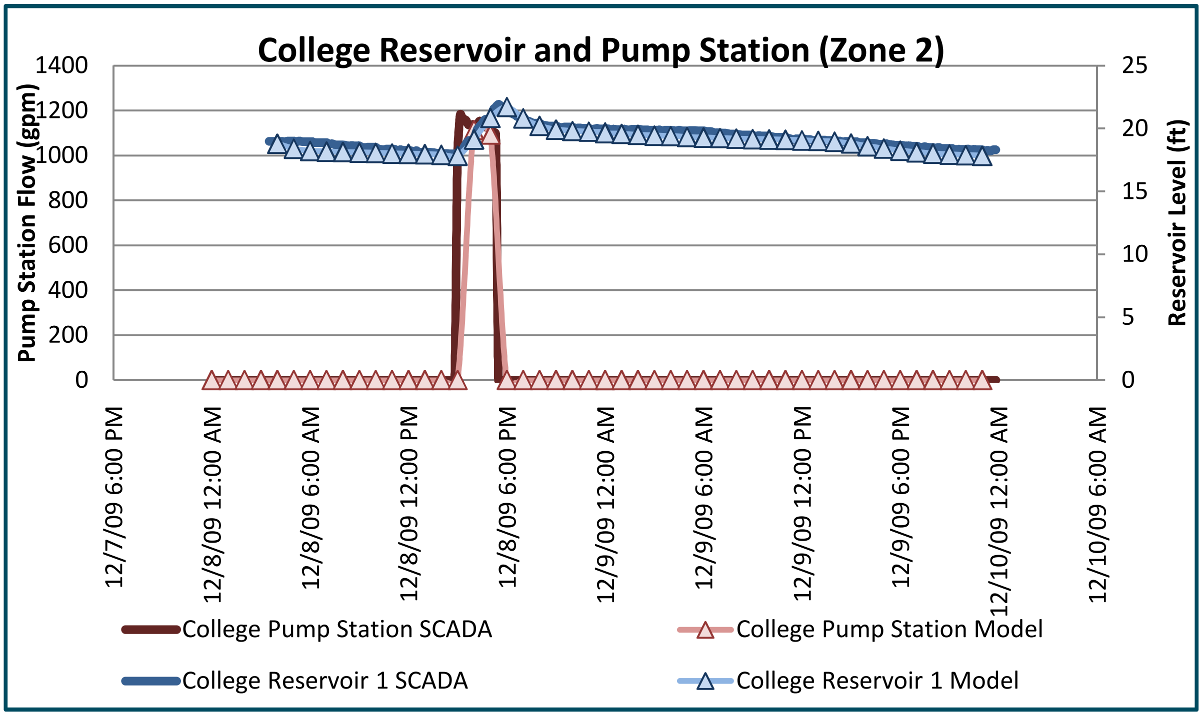


Figure 1.19
Winter EPS Calibration Results for Zone 5 and 4A

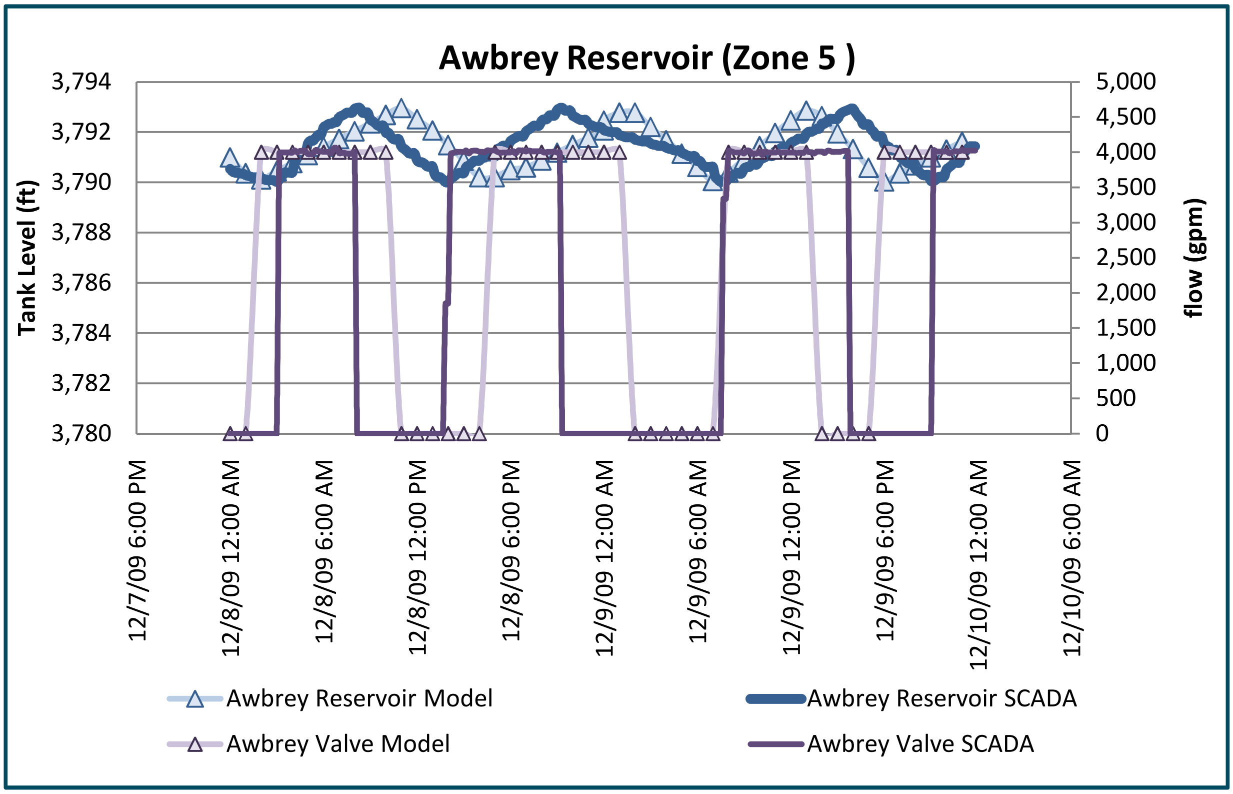


Figure 1.20
Winter EPS Calibration Results for Zone 5

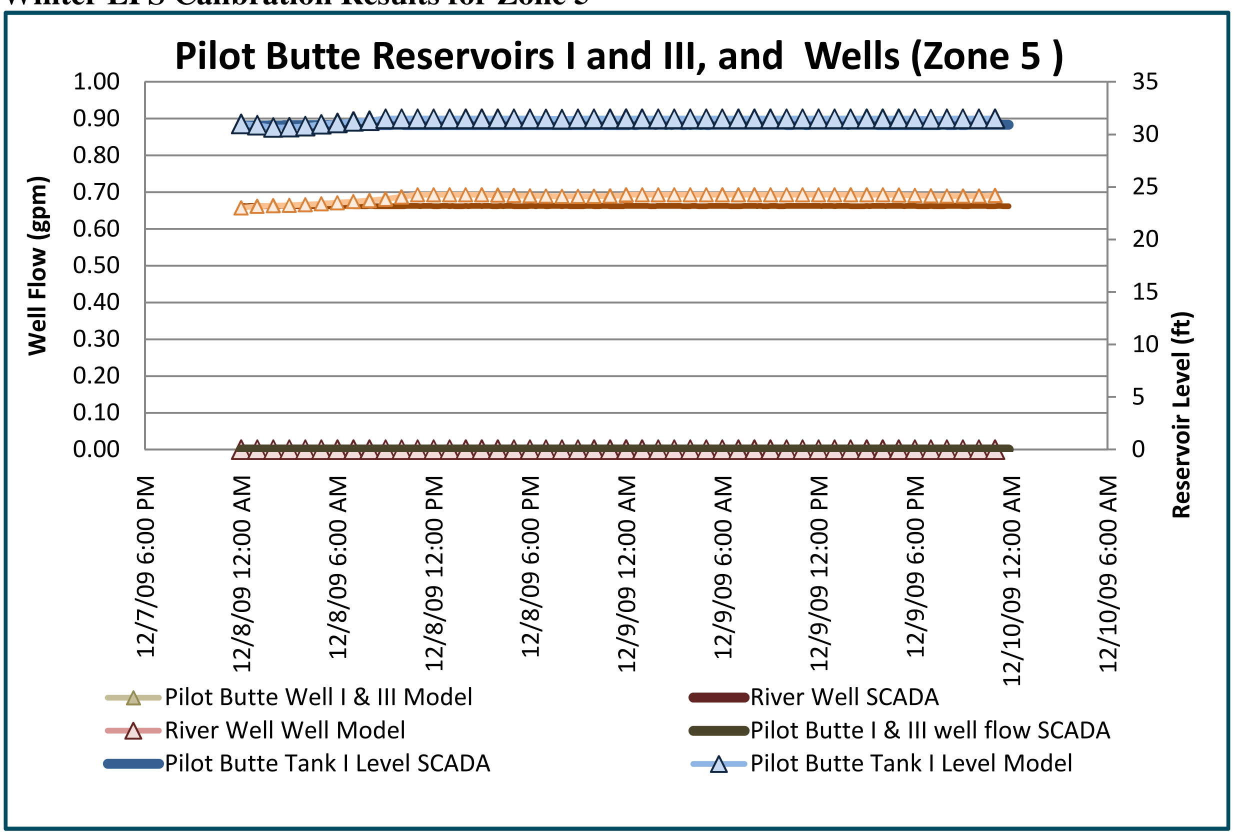


Figure 1.21
Winter EPS Calibration Results for Zone 4B

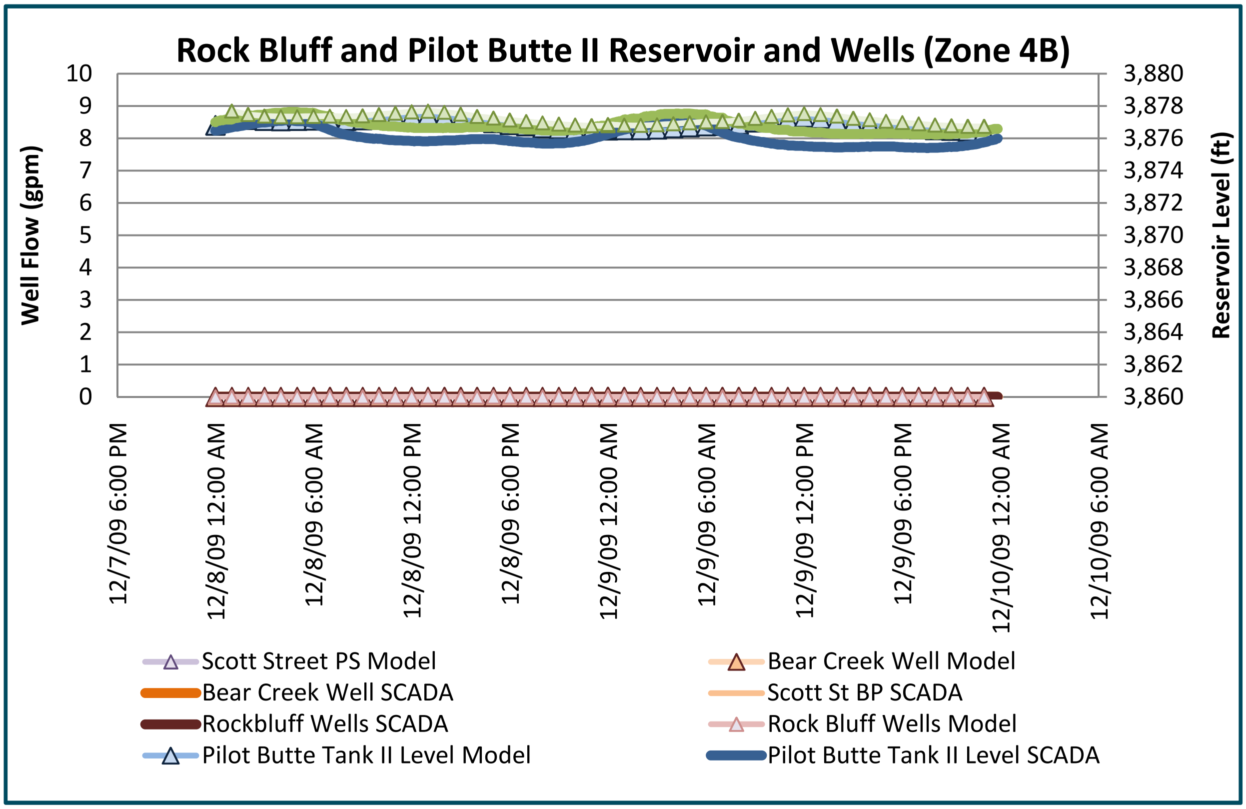


Figure 1.22
Winter EPS Calibration Results for Zone 4A

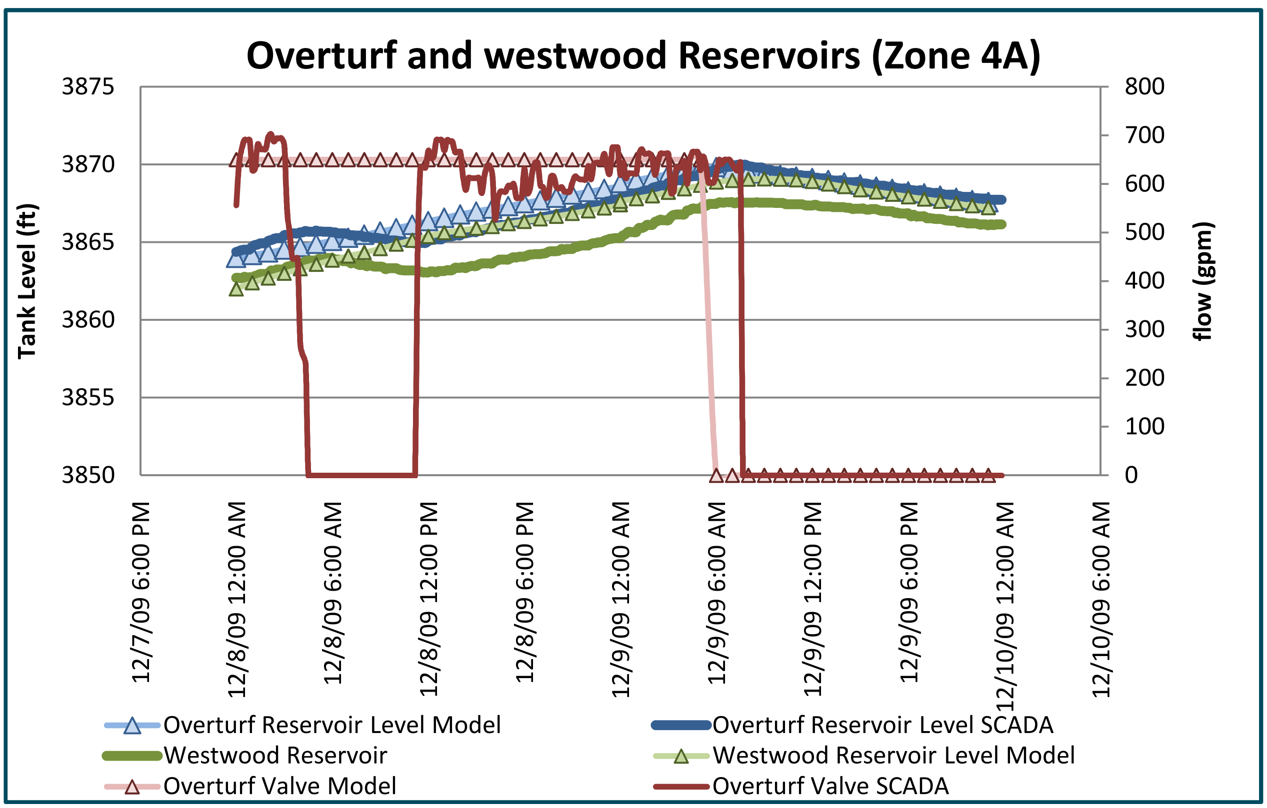


Figure 1.23
Winter EPS Calibration Results for the Outback Reservoirs

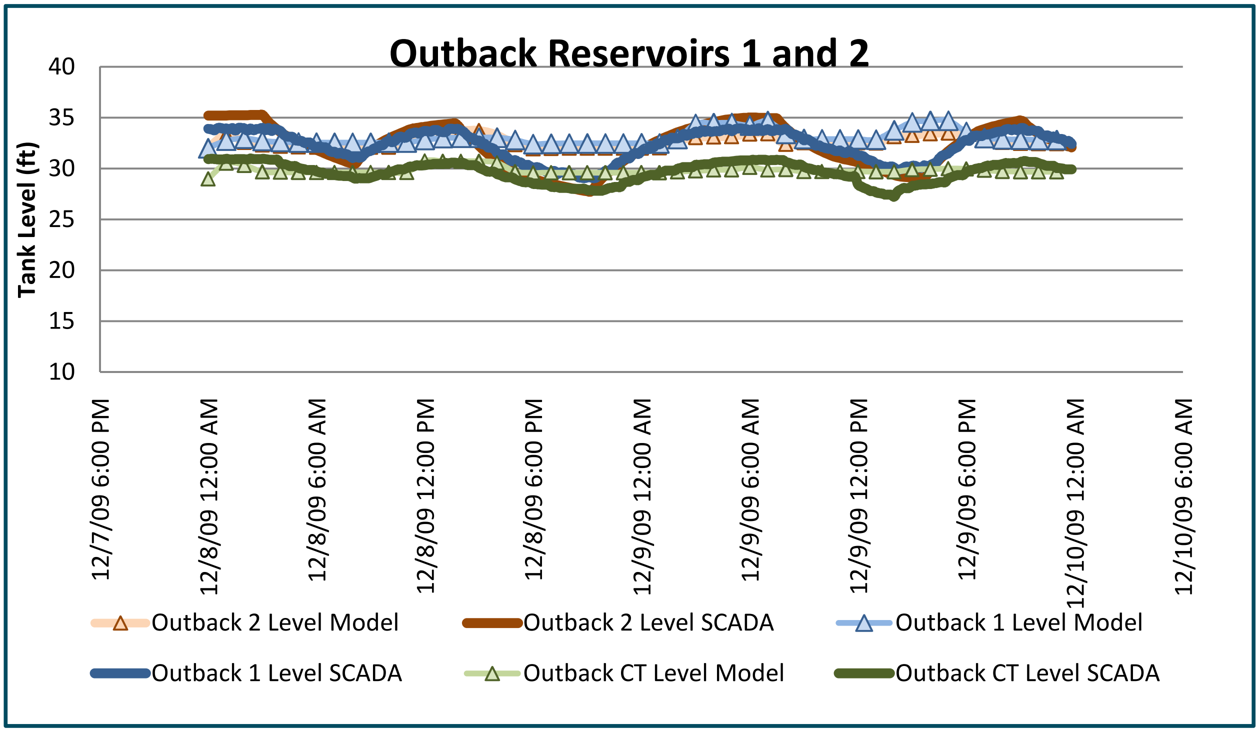
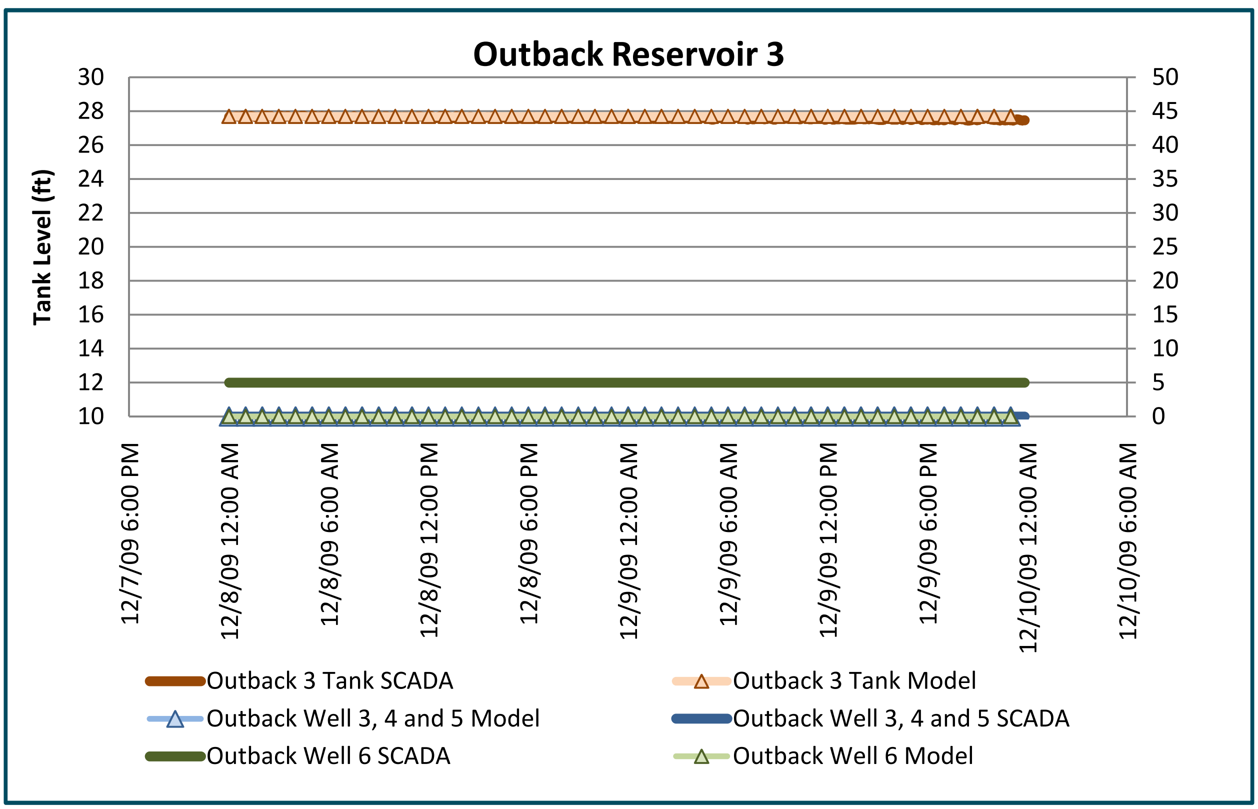


Figure 1.24
Winter EPS Calibration Results for Outback Reservoir 3



Extended Period Simulation Conclusions and Recommendations

The summer extended period simulation results show good agreement between the model and SCADA. This indicates that facilities and operational controls are accurately represented within the model, which can be used to predict system operation during the optimization scenarios involving peak demand periods.

Winter extended period calibration simulation results as shown in Figures 1.17 through 1.24, also show good comparison between model results and SCADA data. The model shows a similar pattern and magnitude of variation for Rock Bluff and Pilot Butte II, as well as other Reservoirs.

Design Demands

The deficiency analysis for the City of Bend is described in the report "Water System Master Plan Update Optimization Study – Final Report", Optimatics, 2011. The design Maximum Day Demand (MDD) and Peak Hour Demand (PHD) selected for use in this analysis will impact the number, size and extent of the recommended pipeline improvements and storage analysis for near term and build-out. The ratio of MDD:PHD is also used for predictive planning purposes for future analysis. The MDD:PHD peaking factor used in the 2007 Water Master Plan (MSA, 2007) was 1.5. Based on SCADA available from the City, the design demand and peaking factor was re-evaluated as part of this effort.

MDD is typically identified by evaluating water production records over multiple years. In 2008 and 2009 MDD based on production records was 29 and 27 MGD respectively.

The Peak Hour Demand can be calculated using the City's SCADA information, which describes pump and valve flow rates as well as reservoir levels. Use of the City's SCADA to identify hourly demands requires extraction and quality control of the SCADA for the period being evaluated, as well as the calculation of demand associated with each reporting time step. PHD does not necessarily occur on the day of MDD. Based on the summer SCADA data provided for the July 2009 EPS calibration (which included the 2009 MDD), a PHD of approximately 48 MGD was identified on July 29th, 2009. Due to the level of accuracy inherent in flow and level recorders this number is considered an estimate. It is recommended that Bend continue to monitor peak demands in the future and re-evaluate its peaking factors and design demands. Table 1.22 summarizes MDD and PHD as well the resulting peaking factors for 2008 and 2009.

Table 1.22 – Peak Hour Demand Peaking Factor

Overall System	MDD (MGD)	Peak Hour (July, 29, 2009) (MGD)	PHD:MDD Peaking Factor
2008 MDD	29	48	1.7
2009 MDD	27	48	1.8
Recommended	**29**	**48**	**1.8**

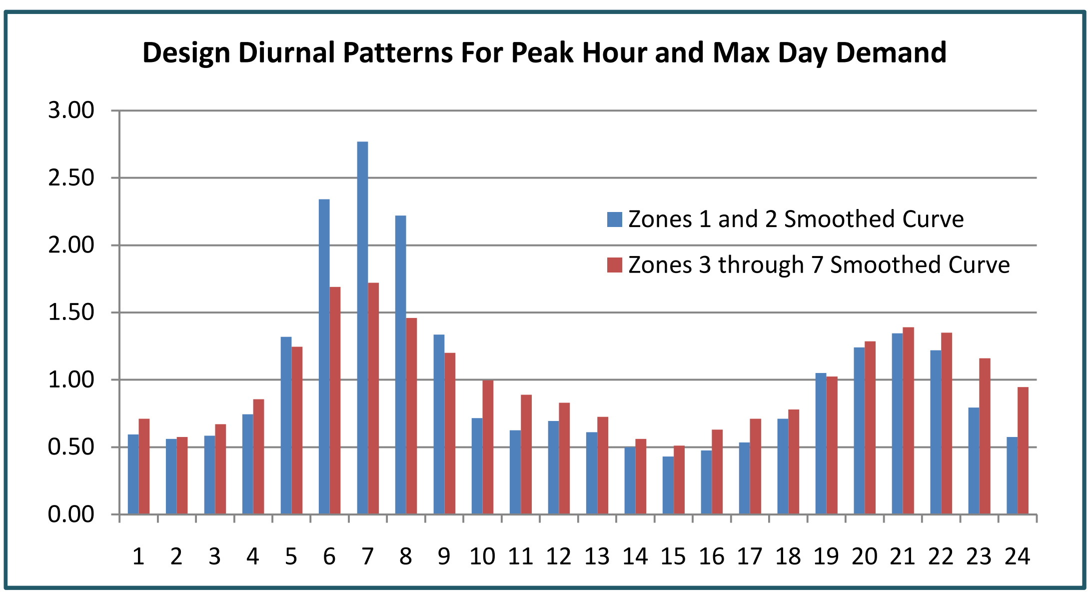
The design MDD was identified as 29 MGD, and the selected design PHD peaking factor was 1.8.

Design Diurnal Patterns for Identifying System Deficiencies and Improvements

The calibration demand curves were developed from a few weeks of SCADA collected during the winter (January 2010) and summer (July 2009) by averaging hourly demand for the same hour of each week day or weekend day within the period of available data for each season. The summer season represents the irrigation season from April 15 to October 15, 2010. Water system operations and water demand during this time are very different from those during winter when, no irrigation is occurring.

The demand curves developed for these periods do not necessarily provide a curve with a peaking factor equal to the selected design ratio of maximum day demand to peak hour demand. From an analysis perspective it is desirable to use a single 24-hour model simulation for which the daily average demand is equal to MDD and the peak demand for the day is equal to PHD. For the purposes of evaluating peak hour and maximum day demand using a single 24-hour model run, a set of adjusted curves was developed by smoothing the calibration diurnal curves using a two-hour running average. The design demand scenario also assumes that as growth in each zone continues, the diurnal pattern for most zones is expected to more closely resemble the overall system demand curve. Zones 1 and 2 however, are expected to remain primarily residential and vary more dramatically over a 24 hour period during the summer, due to particularly high irrigation demand. Figure 1.25 presents the design diurnal curves for peak hour and maximum day demand analysis. The Zones 1 and 2 curve is applied only to Zones 1 and 2, and the Zones 3 through 7 curve is applied to the rest of the system.

Figure 1.25
Design Diurnal Patterns for Peak Hour and Maximum Day Demand Analysis



The application of these curves in the existing model results in an overall system peaking factor of 1.8.

Future Demand

Study Area

The future water service study area was identified through discussion with the City, and leveraged existing GIS data that included the proposed Urban Growth Boundary (UGB), planned developments within that boundary, as well as the current extents of both the Roats and Avion water purveyors. The planning water boundary is shown in Figure 1.26.

Sources of Information for Future Demand Projections and Spatial Allocation

Future growth and water demand projections were made within the study area for both the year 2020 and build-out planning horizons. The spatial and water demand data sets used in the development of future water demand projections for the City of Bend include:

- The Buildable Lands Inventory (BLI) database
- Parcel Inventory & Alternative 4A UGB Proposal data for the area outside the existing UGB (Framework Plan)
- Parcel data for the Tetherow Development
- Water demand projections for the Juniper Ridge Development based on the Technical Memorandum "Water System Planning for the Juniper Ridge Development, Bend, Oregon" (Murray, Smith & Associates, Inc., September 2009)
- 2008 water billing records for the City of Bend
- Historical growth in yearly average water demand

The Bend Central Area Plan was also reviewed during the development of future growth projections. The Plan (Leland Consulting Group, 2007) provides growth projections for a part of the City's downtown area, based on aspirational goals, an assessment of the Central Area's potential for growth based on the economic indicators at the time of the study and the area's location within the region. The plan projects growth in terms of population and employment, however growth in the number of people employed has not been used in the overall growth approach applied to the rest of the planning area as part of this study. In addition, this study develops year 2020 and build-out demand projections, while the plan provides projections through the year 2030. The projected build-out demand identified in this study is not likely to coincide with the year 2030. Due to the relatively small spatial extent of the plan and the "modest" growth in population and employment projected, it was determined that the existing demand projections were more conservative. For these reasons the Bend Central Area Plan was not directly applied in the growth projections developed in this study.

The BLI and Framework Plan data sets were used throughout the planning area to identify future land use zoning for parcels within the City, as well as low (min), mean and high (max) dwelling unit per acre density estimates associated with each residential land use zoning category. The current development status of each residential parcel is identified in the data set so that fully developed areas can be distinguished from areas that are vacant, vacant and platted, or re-developable. The Framework Plan data provides similar information for larger master planned areas within the proposed UGB, outside the existing UGB.

Demand Projections

Residential water demand projections for the year 2020 were developed with consideration for both historical rates of water demand growth and the availability of developable and re-developable land within the existing UGB. Although the City's BLI database indicates the total potential for residential and non-residential growth as well as spatial distribution of potential growth in terms of residential units and non-residential land, it does not indicate the rate at which this growth and development will occur. For this reason, historical growth in water demand was also considered in the development of year 2020 demand. Growth in water demand was evaluated rather than growth in service area population because the current and historical service area populations and growth rates have not been quantified with certainty, due to portions of the City being served by Roats and Avion.

Table 1.23 – Historical ADD and Demand Growth

Year	Historical ADD (MGD)	Annual % Growth
1998	8.6	
1999	10.2	18.60%
2000	10.7	4.90%
2001	10.6	-0.93%
2002	11.5	8.49%
2003	11.4	-0.87%
2004	11.5	0.88%
2005	11.3	-1.74%
2006	11.55	2.21%
2007	12.72	10.13%
2008	12.84	1.10%
Average		**4.3%**

Table 1.23 illustrates that the City's growth in water demand has been highly variable over the past 10 years, at times experiencing rapid growth and at others, a decline in water demand. This is not unusual, as yearly water usage is highly dependent on yearly temperature and rainfall amounts. Overall a total growth rate between 1998 and 2008 of more than 4% has been measured.

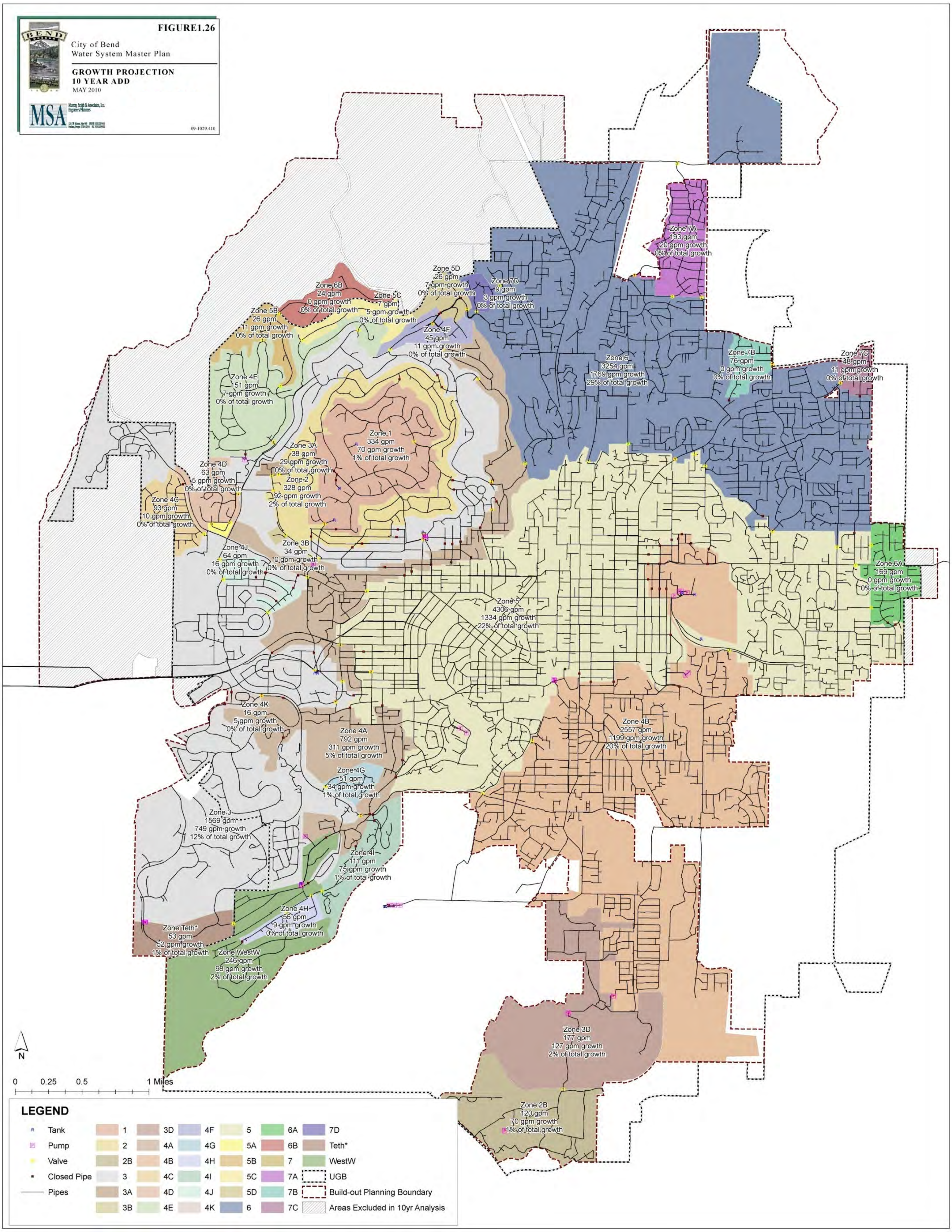
Table 1.24 – Projected ADD Based on Historical 4.3% per Year

Year	Projected (4.3% growth per year) ADD (MGD)
2009	13.4
2010	14.0
2011	14.6
2012	15.2
2013	15.8
2014	16.5
2015	17.2
2016	18.0
2017	18.8
2018	19.6
2019	20.4
2020	21.3

Several methods of projecting water demand growth based on historical water production were considered by the City. These included linear constant growth (0.36 MG/yr), exponential growth (approximately 3.3% per year), and the average historical rate of growth in water demand (4.3% per year). A projected ADD of approximately 20 MGD for 2020 was identified as a reasonable future demand. The spatial distribution of growth within the 10-year planning horizon was identified to be within the "existing" UGB as well as the Tetherow development and Phase 1 of Juniper Ridge Development by the City. This excluded other areas outside the existing UGB that are within the "proposed" UGB. It was also noted that higher growth rates were anticipated on the east side of the City than the west. This is due primarily to the construction of the Southeast Sewer Interceptor that will allow new home construction to occur in a large previously development restricted area. Using the BLI data to identify the mid-point in water demand between existing and mean density development within the existing UGB resulted in total ADD close to the projected target of 20 MGD (20.7 MGD) and the desired spatial distribution of growth within the "existing UGB", with higher growth rates on the east side of the City. Figure 1.27 shows projected demand and percentage of total growth by pressure zone.

For this reason, the approach used to calculate 10-year demand was to apply half of the growth in demand represented by "mean density" development within the existing UGB and Tetherow Development, with full development of Phase 1 of Juniper Ridge. Using the BLI data to estimate the demand associated with this development density, resulted in a 10-year ADD (21.7 MGD), which is similar to the demand projected using the average of historical demand growth (21.5 MGD). More detail on the development of spatial demand projections is provided in the following sections. These estimates of demand are likely to be conservatively high, particularly if the economy and housing market does not improve in the near term. For the purposes of planning water system storage and pipeline improvements, high estimates of water demand are conservative. This approach may not be "conservative" for other applications.

Figure 1.27
Growth Projection 10 Year ADD



Development of Spatial Demand Projections

To obtain the spatial distribution of year 2020 projected demand using the City's BLI data, the demand corresponding with mean residential development density (See Table 1.25) was first calculated within the existing UGB as well as build-out of the Tetherow Development. This calculation applied residential usage per dwelling unit based on the city's water billing data. Based on residential demand comprising 64% of the total water demand (excluding future Juniper Ridge demand), a non-residential demand of 4,000 gallons per non-residential acre per day was calculated. Half of the growth in water demand to reach build-out demand at mean density was then applied. Due to the unique character of the Juniper Ridge Development in terms of the type of projected water users, that area was calculated using higher per acre water use rates. Only Juniper Ridge Phase 1 was included in 10-year projections. The Tetherow Development was handled independently as it does not have associated BLI data and is outside both the existing and future UGB (see Figure 1.26). However, half of the growth associated with full development of Tetherow was applied for the 10-year planning horizon.

Build-out residential demand projections were made using the City's mean residential density estimates throughout the water planning area, which includes areas within the proposed UGB that are outside the existing UGB, particularly in the northwest. Special consideration was given to the Tetherow development, with a total of 889 anticipated residential units, and Phases 1 and 2 of Juniper Ridge. Build-out demand also includes the non-residential demand of 4,000 gallons per acre per day to non-residential areas except for Juniper Ridge, where a higher factor was applied, consistent with the memorandum "Water System Planning for the Juniper Ridge Development, Bend, Oregon" (Murray, Smith & Associates, Inc., September 2009). The City's mean residential density estimates by residential land use type are provided in Table 1.25.

Table 1.25 – Residential Dwelling Unit Densities

Land Use Zoning Code	Mean Density (Units/Acre)
RL	1.65
RS	4.80
RM	14.55
RH	32.40

Use Types

The BLI data was used to categorize parcels as non-developable, residential, or non-residential based on planned zoning and existing land use. Existing right of ways and water bodies were excluded from existing and future growth areas as non-developable. The remaining parcels were identified as either residential or non-residential based on proposed land use type.

Residential Demand

Residential per capita water usage from 2008 water billing records indicates a residential water demand of 156 gallons per capita per day (gpcd). This value was obtained by using the estimated number of single family meters from 2008 billing data, as well as the estimated number of "other residential" RS meters, of similar size to single family meters and the associated average annual usage. The per capita water usage was also calculated using a City provided factor of 2.4 people per household. Based on recommendations from the City, the total customer billing record usage was peaked by 10% to account for non-revenue water consumption in future projections. Non-revenue water may include things such as pipe leakage, hydrant flushing, or error in meter readings, as well as others. **The resulting demand is approximately 172 gallons per capita day.** This value can also be expressed in gallons per minute per dwelling unit (0.29 gpmdu).

Future water demand will reflect growth in the form of both the re-development of existing areas, and new development in vacant areas. Parcels categorized as developed, are considered to have the same development density in the future. The number of existing residential units within developed areas was identified in the BLI database and included in future demand projections. The number of proposed units for vacant parcels that have been platted is also provided in the database, this proposed number of units was applied in future demand projections for platted areas. The future number of residential units for both vacant (un-platted) and re-developable parcels, was calculated using the number of acres multiplied by a development density (dwelling units per acre), and finally by a developable area factor of 0.85, provided by the City. The developable area factor was applied to account for land that will be used as open space or road right-of-way as part of future development. Some residential parcels were identified as "constrained" for development, meaning that 50% or more of the area was not developable. For these parcels the resulting number of developable acres was also multiplied by a 0.5 factor.

Juniper Ridge Development

Water use projections for the Juniper Ridge Development were consistent with those used in the "Water System Planning for the Juniper Ridge Development, Bend, Oregon" (Murray Smith & Associates, Inc., September 2009) and equal to 4,500 gallons per acre per day, with a development factor of 0.7. The area used for 2020 analysis was limited to Phase 1, consisting of 294 total acres. Build-out analysis includes both Phase 1 and Phase 2 for a total of 515 acres. A higher water usage per area was utilized for this area compared to other parts of the City due to its unique character and intent to attract more water intensive users than generally exist in the City.

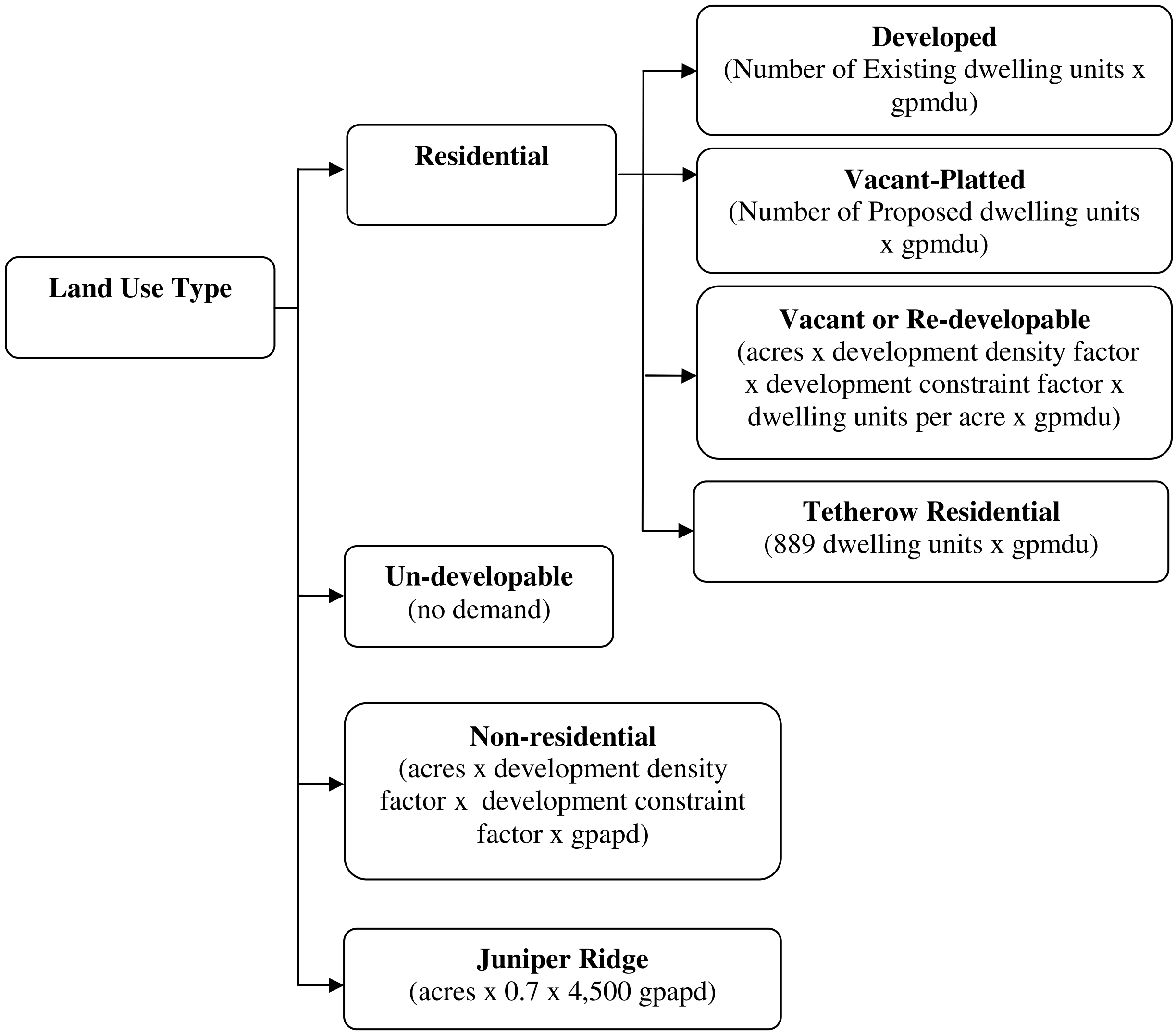
Tetherow Development

The Tetherow development includes areas in both Pressure Zone 3 and the Tetherow Pressure Zone. The development includes both residential and non-residential areas. The development is planned to include 889 residential units at build-out. Residential per-acre density was calculated to result in 889 residential units in the build-out scenario. Half of the growth in water demand to reach build-out demand was applied as the year 2020 demand.

Non-Residential Demand

The 2008 ratio of residential to total water demand in the City of Bend is 64% based on water billing data for 2008. Or in other words, 64% of the 2008 water billing record's volumetric use was associated with residential users. As the City grows, this proportion of residential to non residential demand was assumed to remain constant. To determine the number of developable acres to be used in future water demand projections, a factor of 0.7 was applied to all non-residential parcel acreages. This factor was applied to account for non-developable portions of the land and right-of-way. If the area was determined to be constrained for development, meaning 50% or more of the area was undevelopable, the acreage was also multiplied by a 0.5 factor. The number of gallons per acre per day for non-residential areas was then calculated using projected residential demand and the 2008 ratio of approximately 36% non-residential to total demand.

Figure 1.28
Water Demand Flow Chart



Definitions:

gpmdu: gallons per minute per dwelling unit = 2.4 people per dwelling unit times 172 gallons per capita per day

gpapd: gallons per acre per day

development density factor: 0.85 for residential and 0.7 for non-residential

development constraint factor: Constrained = 0.5, Unconstrained = 1.0

A summary of 2008, year 2020 and build-out water demand projections by zone is presented in Table 1.26.

Table 1.26 – Current and Future Demand by Zone

Pressure Zone	2008 ADD (gpm)	2020 (gpm)	Build-out (gpm)
1	264	334	403
2	236	328	421
2B	50	120	189
3	820	1,569	3,664
3A	9	38	67
3B	34	34	34
3D	50	177	304
4A	481	792	1,103
4B	1,359	2,557	3,757
4C	83	93	103
4D	58	63	101
4E	144	151	566
4F	34	45	55
4G	17	51	85
4H	48	56	66
4I	36	111	186
4J	48	64	79
4K	12	16	22
5	2,972	4,306	5,641
5A	7	7	7
5B	15	26	440
5C	2	7	13
5D	19	26	33
6	1,485	3,254	6,612
6A	169	169	268
6B	24	24	399
7	0	0	343
7A	173	193	212
7B	76	76	76
7C	37	48	58
7D	6	9	11
Tetherow	0	53	107
Westwood	148	246	343
Total	**8,916**	**15,043**	**25,768**

Table 1.27 provides a summary of demands, including ADD, MDD and PHD for 2008, 2020 and build-out.

Table 1.27 – ADD, MDD and PHD for 2008, 2020 and Build-out Conditions in mgd

Year	ADD	MDD	PHD
2008	12.8	29.2	52.5
2020	21.7	48.8	87.9
Build-out	37.1	83.5	150.3

2020 and Build-out ADD to MDD factor of 2.25
2020 and Build-out MDD to PHD factor of 1.8
Peaking factor based on 2007 and 2008 water production records and 2009 SCADA data.

Appendix A

FINAL TECHNICAL MEMORANDUM

DATE: September 11, 2009

PROJECT: 09-1034

TO: City of Bend

FROM: Murray, Smith & Associates, Inc.

RE: Water System Planning for the Juniper Ridge Development, Bend, Oregon

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Purpose

This technical memorandum presents findings and recommendations to help guide water system planning decisions associated with the Juniper Ridge Development. This memorandum includes revisions to costs based on updated information developed since the first version of the document.

Introduction

Juniper Ridge is a large proposed mixed-use development located in northeast Bend, Oregon. Approximately 500 acres of the proposed 1,500 acre development is located within the City's Urban Growth Boundary (UGB). Existing services within Juniper Ridge are limited to the Les Schwab corporate building near the intersection of Cooley Road and 18th Street. Water is currently provided through a main extension from existing piping along Cooley Road to the area. This technical memorandum presents the results of analyses of the water system infrastructure required to serve the initial 294 acres that are being developed, as well as the longer term 515 acres within the City's UGB. The Juniper Ridge Development lies downgradient from the existing water system infrastructure and can be supplied by gravity from Pressure Zone 6 through pressure reducing valves (PRV). Pressure reduction to the existing development, including the Les Schwab corporate building has not yet been implemented.

As part of the 2007 Bend Water System Master Plan Update (WSMP), calculations were performed to determine the supply, storage and transmission piping required to serve what was then planned to be an approximately 1500 acre development. Many of the basic planning criteria and demand information utilized in the WSMP have been used in this technical memorandum.

All calculations for demands, supply and storage in this TM have been made for both phases of the project (Phase 1: 294 acres, Phase 2: 221 acres, total development: 515 acres).

Hydraulic modeling has also been performed to ensure that peak demands and fire flows can be conveyed under both phases.

The Juniper Ridge Developer has provided information on the proposed land uses for both phases of the project. This information has been used to calculate demands, storage, supply and fire flow requirements. Some of the proposed land uses may still change and are dependent on the ultimate parcel developer, particularly for Phase 2. Due to some of the unknowns, conservative assumptions have been made where possible to ensure that adequate supply, storage and fire flows will be available to the development regardless of variations in land use.

Specific piping within the development has not been evaluated as part of this evaluation as much of the development has not been platted. The capacity of the piping currently installed serving Les Schwab and Suterra has been evaluated for capacity. The Juniper Ridge development engineer will be responsible for providing a pipeline grid capable of providing peak domestic as well as fire flows that meet the design criteria identified below.

Design Criteria

The City has developed design criteria for pipe sizing as well as service and fire flow pressures. The non-storage related criteria are listed below:

1. In general, minimum pipe size will be 8-inches
2. Service pressure during peak hour demands will be at least 40 psi at all customer meters
3. In general, 100 psi will serve as the maximum service pressure
4. Service pressure during fire flow events at all customer meters will be at least 20 psi
5. Minimum residential fire flows will be 1,500 gpm

The Juniper Ridge development will be designed to provide 3,500 gpm fire flows in all areas of the system. It should be noted that fire flows greater than 1,500 gpm may need to be acquired by flowing more than one hydrant, however the system in general will be designed to provide 3,500 gpm.

As part of the 2007 WSMP, criteria for sizing system storage were identified. This includes criteria for the operational, emergency and fire storage components. The storage criteria are as follows:

1. Operational Storage Volume: 25% of the maximum day demand (MDD)
2. Emergency Storage Volume: 2 times the average day demand (ADD)
3. Fire Storage Volume: Fire flow required times the duration of the fire

As described in the 2007 WMP the City has required larger fire storage volumes than would be provided to a single fire in the system. This has been done as a measure to help offset the potential risks for multiple simultaneous fires, heightened by the semi-arid environment in and around the City of Bend. This urban-wildland interface is particularly pertinent for an area like Juniper Ridge located on the edge of the City's development. For Juniper Ridge, a fire storage volume resulting from a 5,000 gpm fire flow for 5 hours is required even though the largest fire flow requirement at a single location is 3,500 gpm.

No specific criteria for pipeline velocity have been identified. However, when velocities greater than 5 feet per second under non-peak conditions and more than 8-10 feet per second under peak or fire flow conditions occur, excessive headlosses result, which may reduce system pressure below acceptable thresholds. Any transmission piping identified as part of this analysis will be sized to ensure typical operating velocities do not result in significant headlosses.

Demand Development

The goal with developing projected demands it to ensure that adequate water will be available for the full 515 acre development. General guidelines for the type of development have been provided, however water usage will be specific to the type of business that builds on each parcel, therefore being adequately conservative in the demand projections is important.

As part of the 2007 WSMP update, projected demands associated with the full 1,500 acres of the Juniper Ridge Development were identified. The WSMP referenced the 2004, City of Bend Water Management and Conservation Plan to arrive at a commercial land use water consumption value of 4,500 gallons per day per acre (gpdpa). This number also assumed that 70% of the area within the development was developable. By utilizing these numbers an ADD of 4.8 mgd for the full 1,500 acres was calculated. The vast majority of the revised 515 acres is still proposed as commercial or land uses such as institutional that have similar water use characteristics to commercial. By applying the 4,500 gpdpa at 70% developable factors to the 294 and 515 acres, yields 643 gpm and 1,127 gpm respectively, under ADD conditions.

As part of this analysis, additional calculations were performed using 2008 commercial and residential customer billing records to evaluate existing per acre water usage for these land uses. In general, these records produced lower per acre water usage than when the 4,500 gpapd factor is applied. It has been acknowledged by City staff however, that there are some inaccuracies with the billing records and existing commercial usage may not be as water intensive as those that may ultimately occupy the Juniper Ridge Development. It is therefore recommended to utilize the 4,500 gpapd factor identified in the 2007 WMP for overall water use planning purposes and to apply this factor for all land use types.

Figure 1 provides a conceptual illustration of the proposed land use types for the 515 acres of the Juniper Ridge Development. The "mixed employment" land use comprises the entire 294 acre first phase of the development, all other land uses are part of phase 2.

Table 1. Land Use by phase

Land Use Type	Phase	Acres
Business Park	2	83
Institutional	2	75
Mixed Employment	1	294
Residential	2	20
Open Space	2	43
Total		515

Figure 1. Juniper Ridge Area and Proposed Land Use

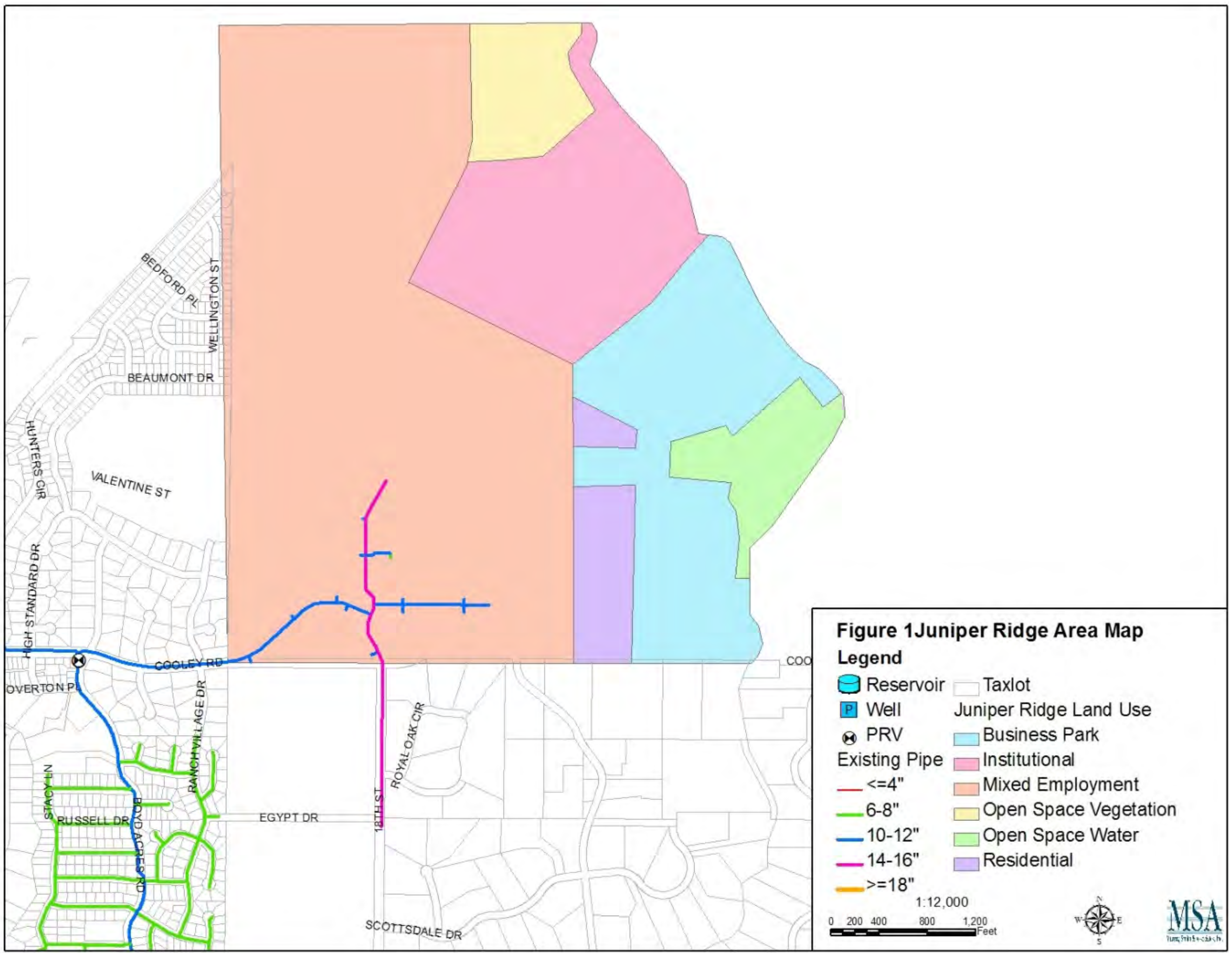


Table 2 includes a calculation of ADD, MDD and peak hour demand (PHD) for Phase 1 and Phase 2 of Juniper Ridge.

Table 2. Demands

Phase	Acres	ADD (gpm)	MDD* (gpm)	PHD** (gpm)
1	294	643	1,479	2,218
2	221	483	1,111	1,666
Total	515	1,126	2,590	3,884

* MDD is 2.3 times ADD
** PHD is 1.5 times MDD

Supply and Storage Requirements

Supply

Supply and storage quantities are directly dependent on calculated demand. Supply should equal or exceed MDD. This results in a Phase 1 supply requirement of 1,479 gpm and a total 515 acre requirement of 2,590 gpm. Wells with capacity of at least 1,479 gpm and 2,590 gpm for Phase 1 and the total 515 acres respectively, are needed.

Storage

As described in the Design Criteria Section, specific multipliers have been developed for identifying storage requirements in the City of Bend. Table 3 identifies the required fire components and total storage for both phases of the development.

Table 3. Required storage volumes

Phase	Acres	Fire (mg)*	Operational (mg)	Emergency (mg)	Total (mg)**
1	294	1.50	0.53	1.85	3.9
2	221	0	0.40	1.40	1.8
Total	515	1.50	0.93	3.25	5.7

See specific information on calculations in Design Criteria Section
* A single fire volume is assumed for Juniper Ridge since the entire area can be served by gravity
** Total volume rounded to nearest 0.1 mg

Based on the criteria provided in the 2007 WMP and the calculations in Table 3, Phase 1 of the Juniper Ridge Development requires 3.9 mg of storage and a total storage volume of 5.7 mg for the entire 515 acres.

Booster Pumps

If gravity storage is not provided to the development, a booster station will be required to pump water from the ground level storage into the development as described in the next section. The capacity of the booster station must equal PHD or MDD plus fire flow, whichever is largest. The booster station must also have redundancy, meaning that a spare for the largest pump should be installed in case of mechanical failure of any other unit.

Table 4. Required booster station capacity under a pumped storage scenario

Phase	MDD (gpm)	Fire Flow (gpm)	MDD + FF (gpm)	PHD (gpm)	Largest Requirement (gpm)
1	1,479	3,500	4,979	2,218	4,979
2	1,111	3,500	4,611	1,666	4,611
	2,590	3,500	6,090	3,884	6,090

Table 4 identifies the largest pumping requirement as MDD plus fire flow. Under Phase 1, a booster station with a capacity of nearly 5,000 gpm is required, which does not include a redundant pump (firm capacity). Under the full 515 acre development a booster station of nearly 6,100 gpm is required (firm capacity). For cost estimating purposes it has been assumed that the larger pumps capable of providing peak demands and fire flows will be in the 1,500 gpm range. Therefore one 1,500 gpm pump will be required in addition to the 5,000 gpm required for Phase 1, bringing the total to approximately 6,500 gpm (total capacity). The total pump station capacity for the full 515 acres would be approximately 7,600 gpm.

It should be reiterated that booster pumps will ***only*** be required if gravity storage options are not available and that different combinations of individual pump sizes could be selected during the design.

Supply and Storage Site Alternatives

A number of supply and storage location alternatives have been discussed with City staff to identify a short list of sites for further analysis. Storage locations that can serve the system by gravity and do not require additional booster pumping are viewed most favorably by the City of Bend. This reduces pumping energy costs, stabilizes system pressures, increases system reliability and eliminates costly operations and maintenance associated with a booster station. Due to site constraints from both a constructability and elevation perspective, siting a storage reservoir is more constrained than siting a new water supply well. Through previous discussions with City Staff a short list of sites was identified for storage in the following order of preference:

1. Middle School Track, near Pilot Butte, south of Neff Road– serve Zone 6 by gravity
2. On Pilot Butte – serve Zone 5 by gravity
3. On the Juniper Ridge Site – serve Juniper Ridge by pump station

As discussed, Juniper Ridge will also require approximately two new wells to supply water for the 515 acres. A corresponding list of potential sites has also been developed for wells. The City's general preference is to develop both wells at a single site in order to maximize; power, telemetry, backup power and general operations and maintenance efficiency along with site security factors. Ideally the wells would be located at the proposed tank site, however depending on the chosen tank solution that may not be a feasible option. The following well sites have been identified in general order of preference:

1. At Pine Nursery Site – serving Zone 6 directly
2. At Middle School Track site – in conjunction with tank
3. On Pilot Butte – in conjunction with tank
4. On the Juniper Ridge Site – in conjunction with tank

Each of the sites identified above are described below in terms of location, how connections to the existing system would be made, and some of the advantages and disadvantages of each.

The City is currently in the process under a separate contract, of constructing an updated hydraulic model for the water system based on GIS data. The model will ultimately be calibrated using hydrant pressures and flows collected in May of 2009. Part of this scope of work was to determine if any additional piping from potential supply and storage sites within the system was required. The preliminary hydraulic model has been used under conservative conditions (MDD) to simulate 3,500 gpm fire flows within the proposed Juniper Ridge Development. This evaluation determined that regardless of which identified supply or storage site that is selected, no additional piping supplying the Juniper Ridge Development will be required once the 16-inch pipe is constructed along 18th Street (5,500 feet) and assuming the existing 12-inch connection along Cooley Road remains in operation. It is important to note that no specific future piping configurations within Juniper Ridge have been evaluated and the City will need to continue coordinating with the development to ensure that adequate pipe diameters and looping of mains are constructed as specific parcels develop.

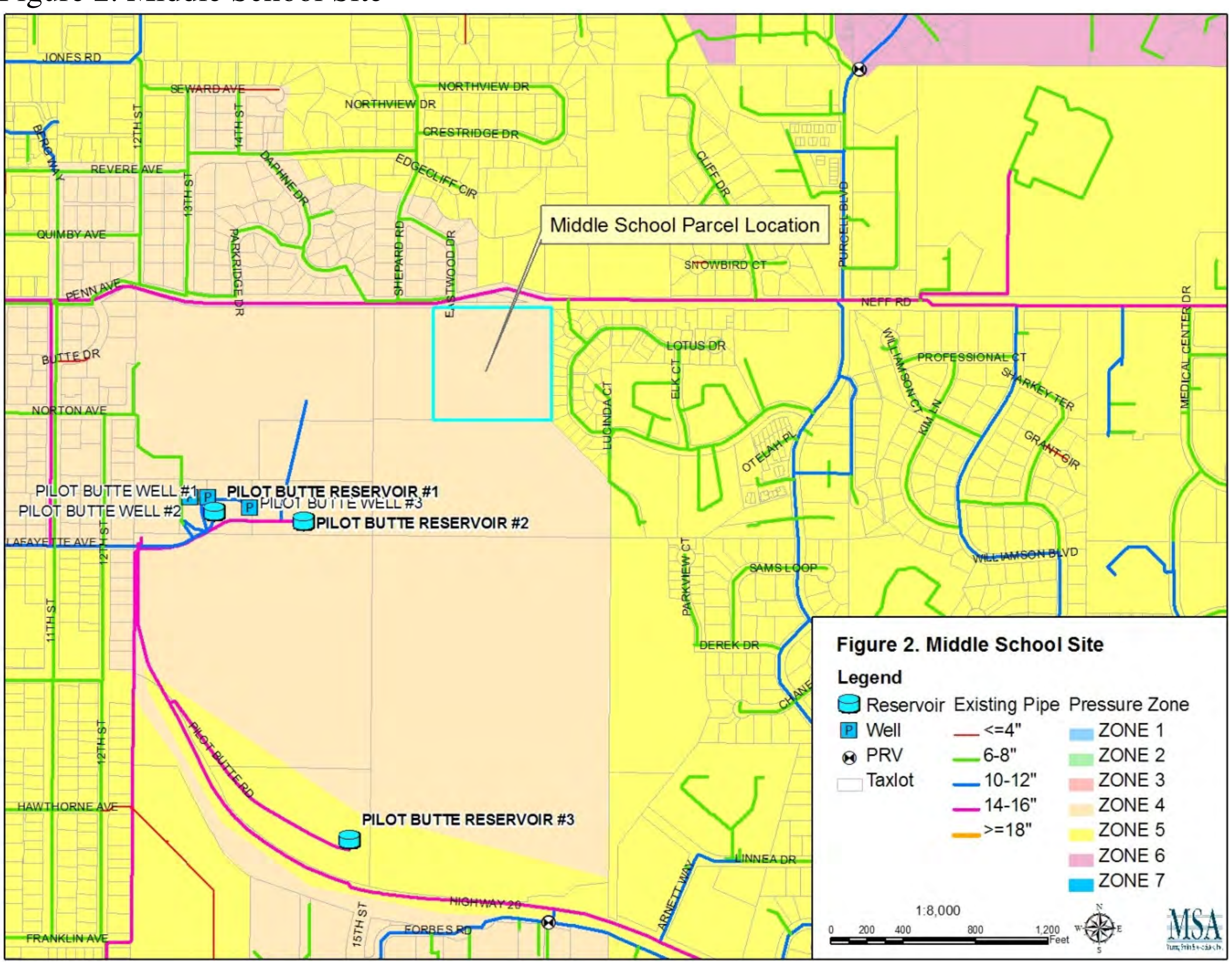
Pressure Reducing Valves

The Les Schwab and Suterra properties within Juniper Ridge are currently served directly from Zone 6 through the 12-inch pipeline along Cooley Road. Static pressure at Les Schwab is approximately 120 psi. The original plan, proposed two or more pressure zones within the full 1,500 acre Juniper Ridge Development. Based on an evaluation of elevations within the initial 294 acres, ranging between 3,368’ and 3,474’, the area can be served by a single pressure zone with a hydraulic grade line (HGL) of 3,600’. This would result in pressures between 55 and 100 psi. The City has proposed to combine the Phase 1 portion of Juniper Ridge with the Pressure Zone 7A which lies to the south of Cooley Road, which currently has an HGL slightly higher than 3,600’ and is served by four PRVs. This will require the reconfiguration of the existing PRV 61 located at the intersection of Cooley Road and Boyd Acres Road allowing it to supply both the existing Zone 7A as well as Juniper Ridge. Once the 16-inch pipeline is completed along 18th Street, an additional PRV will need to be installed to reduce pressure from Zone 6 to 7. No location has yet been specified for that PRV.

Middle School Track, near Pilot Butte, south of Neff Road

Currently, Pressure Zone 6 is served entirely by PRVs at a hydraulic grade of approximately 3,685’. The Pilot Butte Reservoirs serve Zones 4 and 5 with Zone 5 being the most direct feed for Zone 6. A 16-inch transmission line from Pilot Butte Reservoirs 1 and 3 (serving Zone 5) extends east and west along Neff Road. Along this alignment and on the north side of Pilot Butte a School District Property exists that has a middle school track on it. Based on City contour information the surface of the track is at 3,688’. Current ideas include burying the tank at the track site, allowing the school district to continue their use of the property. The 16-inch Zone 5 supply line on Neff Road would allow the tank to be filled by gravity through a pressure sustaining/reducing valve assembly. A dedicated Zone 6 pipeline (3,500 feet long) would then convey water east along Neff Road to the intersection of Purcell Boulevard where it would run north to the intersection of Full Moon Drive. At that point, the pipeline would connect downstream of the existing PRV, directly to existing 12-inch piping supplying Zone 6. Once implemented, this solution would allow Zone 6 to “float” off of the proposed reservoir. If well development is possible at this site, 2-3 wells would be drilled and piped directly into the reservoir. See Figure 2 that identifies the immediate area and proposed property location.

Figure 2. Middle School Site



Site Advantages:

1. Serves Zone 6 by gravity, no pumping required
2. With or without a well, good turnover would occur in the reservoir, minimizing water quality concerns
3. Allows current use of property to continue
4. No visual impact from facility
5. Stabilizes Zone 6 pressure
6. Direct pipeline connection through Zone 6 to the Juniper Ridge Development
7. Benefits Zones 6 and 7, which will need storage in the future
8. May allow for additional storage to be constructed in the future
9. Good transmission piping exists in the area

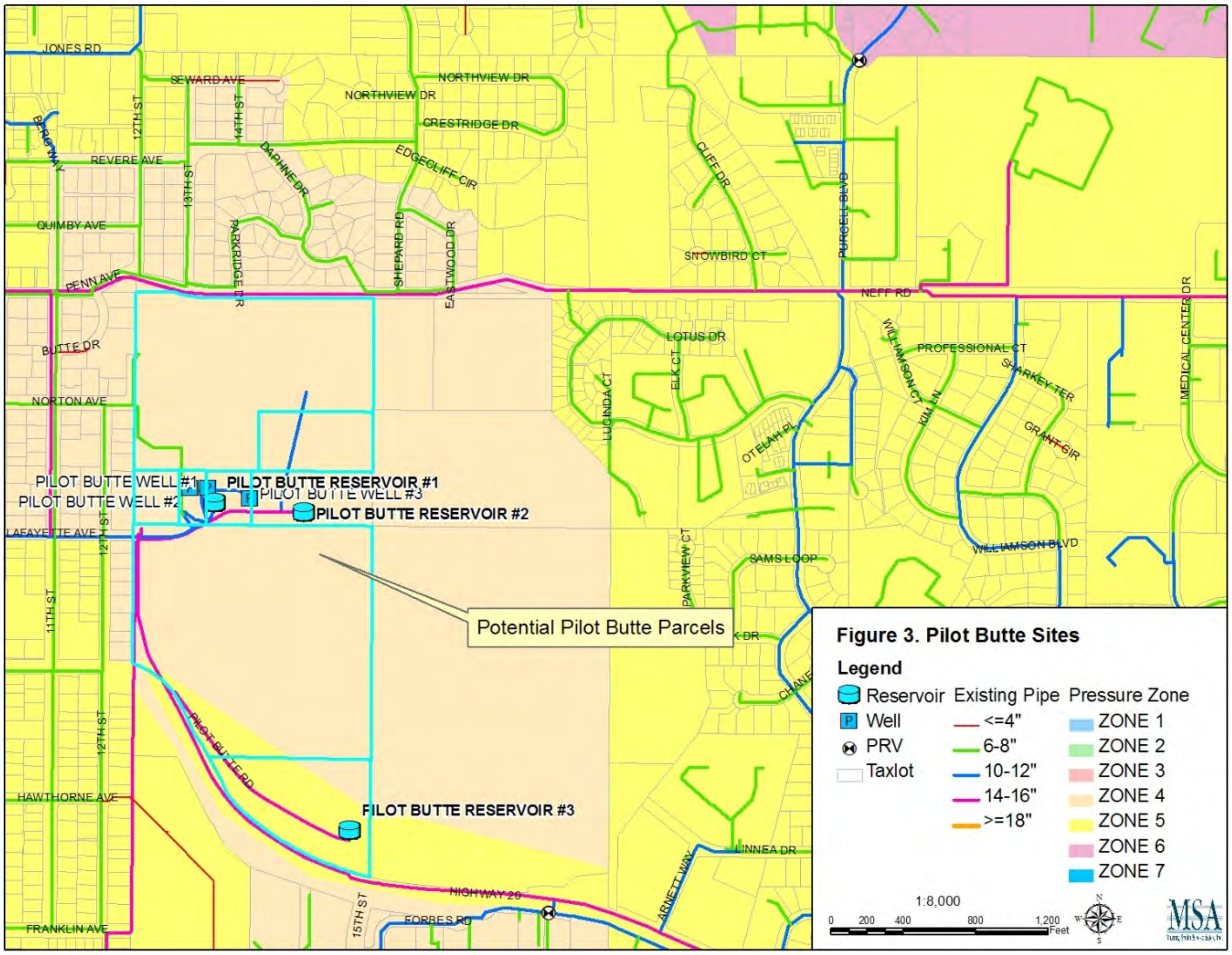
Site Disadvantages:

1. Approximately 3,500' of dedicated pipeline
2. Some disruption of school activities during construction
3. Coordination with school district

Pilot Butte Site

Three storage reservoirs currently exist on Pilot Butte; Pilot Butte 1 and 3 that serve Zone 5 by gravity, and Pilot Butte 2 serving Zone 4 by gravity. A number of wells also exist on the Butte that supply these reservoirs and subsequent pressure zones. In addition, there are no additional storage requirements projected in Zone 4, therefore any new storage on the Butte itself is proposed to serve Zone 5. No specific location has been proposed for a new reservoir on the Butte, however it is believed that somewhere between Pilot Butte 1 and 3 a new one could be sited. Additional water wells could also be drilled in this area and their operation could be coordinated with existing facilities. Zone 6 and subsequently Juniper Ridge would be served through PRVs, consistent with current operations. See Figure 3 that identifies the immediate area and potential parcels that could be considered for future Zone 5 storage. The highlighted properties north of Pilot Butte 1 and 2 reservoirs is owned by the School District while the properties to the south are owned by the Oregon State Parks Department including the site where Pilot Butte 3 is sited.

Figure 3. Potential Pilot Butte Parcels



Site Advantages:

1. Serves Zone 5 by gravity, no pumping required
2. Good turnover should occur in the reservoir if piped properly, minimizing water quality concerns
3. Benefits Zones 6 and 7, which will need storage in the future
4. May allow for additional storage to be constructed in the future
5. Proven aquifer at location
6. Good transmission piping exists in the area

Site Disadvantages:

1) Challenging and costly construction on the Butte
2) Probably some visual impact unless completely buried
3) Could pull local aquifer down with new wells

Juniper Ridge Site

The last tank option is to construct ground level storage on the Juniper Ridge Development itself. This reservoir would be located near the southern edge of the development to take best advantage of existing topography and would be filled by gravity from Zone 6. The assumption is that this tank would be at ground level, though it could be buried at significantly higher cost. A pump station would be required to boost water into the Juniper Ridge development itself as no land of adequate elevation exists in the area to facilitate supply by gravity. This booster station must be capable of providing the greater of PHD or MDD plus fire flow. Wells could be sited at the reservoir and pumped into the tank to force turnover. See Figure 1 showing the proposed 515 acres of Juniper Ridge. The reservoir would be sited near the intersection of Cooley Road and 18th Street on the newly installed 16-inch line in order to minimize parallel piping.

Site Advantages:

1. Serves Juniper Ridge directly,
2. Least costly tank construction unless buried
3. Good transmission piping will exist in the area once the 16-inch line is completed along 18th Street

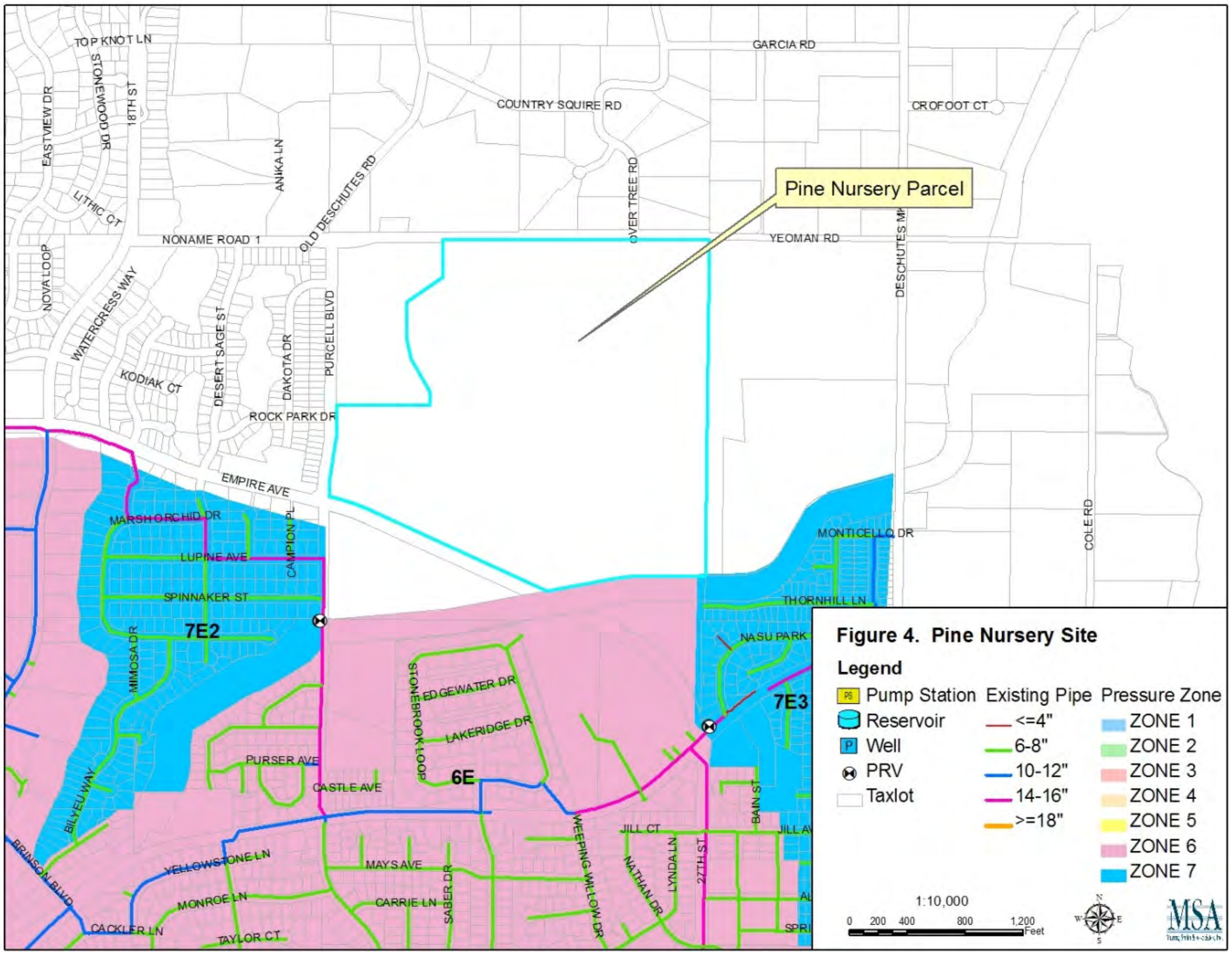
Site Disadvantages:

1) Costly booster pump and backup power required,
2) Water quality in tank could be a problem
3) Double pumping of water required
4) Little to no value to the rest of the Bend system
5) Inconsistent with City procedures to site tanks high in system and to eliminate double pumping
6) Potential visual impact of tank unless buried
7) No proven City wells in area

Pine Nursery Site

The Pine Nursery located north of the Pilot Butte Canal and east of Purcell Boulevard and the intersection of Empire Avenue was also evaluated for a potential tank site. This property is owned by the Bend Park and Recreation District. The highest elevation on the property is less than 3,500' requiring a very tall tank at the site in order to serve Juniper Ridge by gravity. Due to the potential for the obstruction of view for neighboring properties, this option was not acceptable to City Staff. A large irrigation well exists on this property that is used for the nursery. The City is interested in either converting the existing well to potable or drilling new ones. See Figure 4, showing the area.

Figure 4. Pine Nursery Parcel



Site Advantages:

1. Serves Zone 6 directly, which is projected to grow in future
2. Is in close proximity to Juniper Ridge and provides service through PRVs
3. Proven existing wells in area from a quantity perspective
4. Provides supply on the east side of system
5. Good transmission piping exists in the area

Site Disadvantages:

1. No reservoir site
2. Coordination with Bend Park and Recreation District

Order of Magnitude Capital Costs

This section provides order of magnitude costs for each of the sites. The costs are broken into three sections; reservoir, piping and well related costs. Where applicable, booster pump station costs have also been included. Order of magnitude level planning cost estimates are defined by accuracy of + 50 percent to – 30 percent. Costs for reservoirs, wells and pipelines were provided in the 2007 WMP. The City has recently undertaken an effort to "optimize" the capital improvement plan identified in the 2007 WMP and updated costs have been developed and are used in this estimate. Recently construction costs have declined due to the poor housing and development climate since 2007. Since some portions of the Juniper Ridge Development may not be completed for several years it was deemed unwise to "discount" any earlier cost estimates based on current conditions. In general costs are higher than those estimated for the 2007 WMP, which reflects the long term trend observed for municipal projects over the last 40 to 50 years.

Tank costs were developed using bid tabs for previous reservoir projects, some of which were provided by the City of Bend, and updated accordingly. These costs include construction, construction management, and 40 percent for engineering, administration and contingency. No property acquisition costs have been included for any of the sites. It should be noted that there are some economies of scale when constructing large reservoirs (greater than 3.0 mg) that reduce the cost per gallon. However, for this analysis it was assumed that one reservoir would be constructed for each phase of this project keeping the size more consistent with what was assumed in the WMP for future reservoirs. The following general costs for each tank type per gallon were developed:

1. Above ground welded steel tank: $1.09/gallon
2. Above ground welded steel tank on Pilot Butte requiring cut and fill: $1.25/gallon
3. Buried concrete tank: $1.92/gallon

No significant piping costs are associated with the development of the reservoir and well sites with the exception of the Middle School Track location. For planning purposes, a 16-inch pipe has been included at a cost of $240 per linear foot. This estimate includes costs for engineering, administration, contingency and rock excavation. It is important to note that all potential reservoir and supply sites assume that approximately 5,500 feet of 16-inch pipeline that is proposed to continue south along 18th Street from Egypt Drive to Empire Avenue is constructed. Costs for the pipeline are estimated at $1.4M, which includes the cost of a PRV station required along the 16-inch alignment. PRV stations are estimated at $75,000.

Costs for the development of water supply wells were also included in the 2007 WMP. Historically, production from new City wells has been approximately 1 mgd. For planning purposes it will be assumed that each new well can produce 1 mgd; thus, two wells will be required to meet the demands for Phase 1 of Juniper Ridge with an additional well required to serve the entire 515 acres. Costs for each well include engineering, administration, contingency and emergency backup power generation.

Middle School Track, near Pilot Butte, south of Neff Road

The only tank option that will work for the Middle School Track site is buried concrete. As described above, approximately 3,500 feet of 16-inch dedicated pipeline will also be required as part of this alternative. Miscellaneous site piping and valving is included in the tank cost. $500,000 has been added to the project cost to construct a new track surface and install field turf for a football field at the site. This would provide the middle school with an upgraded facility compared to what is currently installed and is included as part of the Phase 1 reservoir costs. See Table 5 for a cost summary.

Table 5. Capital Costs for the Middle School Track Site (in Million dollars)

Phase	Acres	Tank Size (mg)	Tank** Cost	Pipeline Cost*	Well Cost	Total Cost
1	294	3.9	$7.99	$2.24	$2.70	$12.93
2	221	1.8	$3.46	$0.00	$1.35	$4.81
Total	**515**	**5.7**	**$11.45**	**$2.24**	**$4.05**	**$17.74**

* includes the cost of one PRV station on the 16-inch pipeline on 18th Street
** includes $500,000 for a new track surface and the installation of a field turf football field in Phase 1

As shown in Table 5, a Phase 1 capital cost for the reservoir, pipeline and wells is estimated at $12.93 and a total project cost of $17.74 for the full 515 acres.

Pilot Butte Site

The potential for both an above ground steel tank as well as an additional buried concrete reservoir exist on Pilot Butte. Note that significant cut and fill is assumed with the above ground steel tank options. No significant additional piping is anticipated in order to connect the facility into existing Zone 5 piping. See Table 6 for capital costs associated with each of these options.

Table 6. Capital Costs for the Pilot Butte Site (in Million dollars)

Phase – Tank Type	Acres	Tank Size (mg)	Tank Cost	Pipeline Cost*	Well Cost	Total Cost
1 - Buried	294	3.9	$7.49	$1.40	$2.70	$11.59
2 - Buried	221	1.8	$3.46	$0.00	$1.35	$4.81
Total - Buried	**515**	**5.7**	**$10.95**	**$1.40**	**$4.05**	**$16.40**
1 – Above Ground	294	3.9	$4.88	$1.40	$2.70	$8.98
2 – Above Ground	221	1.8	$2.25	$0.00	$1.35	$3.60
Total – Above Ground	**515**	**5.7**	**$7.13**	**$1.40**	**$4.05**	**$12.58**

* includes the cost of one PRV station on the 16-inch pipeline on 18th Street

From Table 6 it is shown that Phase 1 total capital costs vary between $8.98M and $11.59M for above ground and buried tanks respectively. Capital costs for the full 515 acre development vary between $12.58M and $16.4M for above ground and buried construction respectively.

Juniper Ridge Site

A tank site near the south edge of the Juniper Ridge development could include an above ground or buried tank. This facility will also require a booster station for domestic and fire demands. Note that this is a less expensive above ground tank option that does not include significant cut or fill. Booster Station calculations also include costs for emergency backup power generation. Table 7 includes capital costs associated with each of these options.

Table 7. Capital Costs for the Juniper Ridge Site (in Million dollars)

Phase – Tank Type	Acres	Tank Size (mg)	Tank Cost	Booster Station Cost*	Pipeline Cost*	Well Cost	Total Cost
1 - Buried	294	3.9	$7.49	$3.00	$1.40	$2.70	$14.59
2 - Buried	221	1.8	$3.46	$0.50	$0.00	$1.35	$5.31
Total - Buried	**515**	**5.7**	**$10.95**	**$3.50**	**$1.40**	**$4.05**	**$19.90**
1 – Above Ground	294	3.9	$4.25	$3.00	$1.40	$2.70	$11.35
2 – Above Ground	221	1.8	$1.96	$0.50	$0.00	$1.35	$3.81
Total – Above Ground	**515**	**5.7**	**$6.21**	**$3.50**	**$1.40**	**$4.05**	**$15.16**

* includes the cost of one PRV station on the 16-inch pipeline on 18th Street

Pin Nursery Site

Well development costs are assumed to be consistent between locations, which hold true at the Pine Nursery Site. Wells at the Pine Nursery Site could be used with any of the tank locations listed above. It should be reiterated that if the Juniper Ridge Tank site is chosen and wells are not installed that pump directly into the tank, additional water quality issues are likely to develop. No significant additional piping is anticipated to connect wells at Pine Nursery into the existing transmission grid in Pressure Zone 6.

Capital Cost Comparison Summary

From a purely capital cost perspective the least expensive option is to construct an above ground steel reservoir on Pilot Butte to serve Pressure Zone 5.

Life Cycle Cost Comparison

Life cycle costs for facilities can be somewhat subjective and utility specific, however particularly in cases of mechanical systems can exceed the initial capital cost of the facility over a 50-100 year life and should be considered. The major difference in the supply and storage alternatives for Juniper Ridge is the addition of a booster station identified if storage is constructed at the development itself. All other storage options serve the system by gravity, eliminating the need for additional pumping. There are life cycle costs associated with the wells required for the development, however costs should be relatively consistent, regardless of location and therefore are not differentiators in terms of site selection. It is also acknowledged that there are differences in the life cycle costs between welded steel and concrete reservoirs as well. No recoating of concrete is required, however the costs associated with repainting steel are typically not shown to compensate for the higher initial capital cost of concrete. It should be noted however, that recoating costs for City reservoirs have approached $0.5M in some cases, and the coatings themselves have only lasted 15-20 years. The City's current preference is for concrete reservoirs when initial costs are relatively comparable due to the long term reduced maintenance. It is industry standard to anticipate a 100 year life from a concrete or well maintained welded steel tank.

Base assumptions in this calculation are a 100 year life for the facility, including the associated pumps, motors, electrical and piping. Most pump station components will be replaced at least once over 100 years, excluding the structure. Using a net present value calculation with a discount rate of 3 percent, no depreciation as well as including power costs at $0.05 kw-h, a life cycle cost of approximately the current construction value ($2.5 million) is made. This calculation is highly dependent on the discount rate which includes the inflation and investment interest rates over the next 100 years. See Table 8 for a Juniper Ridge Site cost comparison that includes booster station life cycle costs.

Table 8. Summary Costs for the Juniper Ridge Site (in Million dollars)

Phase – Tank Type	Tank Cost	Booster Station Cost	Booster Station Life Cycle Cost	Pipeline Cost*	Well Cost	Total Cost
1 - Buried	$7.49	$3.00	$2.13	$1.40	$2.70	$16.71
2 - Buried	$3.46	$0.50	$0.37	$0.00	$1.35	$5.68
Total - Buried	**$10.95**	**$3.50**	**$2.50**	**$1.40**	**$4.05**	**$22.39**
1 – Above Ground	$4.25	$3.00	$2.13	$1.40	$2.70	$13.48
2 – Above Ground	$1.96	$0.50	$0.37	$0.00	$1.35	$4.18
Total – Above Ground	**$6.21**	**$3.50**	**$2.50**	**$1.40**	**$4.05**	**$17.66**

* includes the cost of one PRV station on the 16-inch pipeline on 18th Street

When adding the life cycle costs for the booster station to the alternatives a final comparison can be made of the different storage locations. See Table 9 for a comparison.

Table 9. Total Capital and Partial Life Cycle Costs (in Million dollars)

Phase	Middle School Track Site (concrete)	Pilot Butte Site (buried-concrete)	Pilot Butte Site (above ground-steel)	Juniper Ridge Site (buried-concrete)	Juniper Ridge Site (above ground-steel)
1	$12.93	$11.59	$8.98	$16.71	$13.48
2	$4.81	$4.81	$3.60	$5.68	$4.18
Total	**$17.74**	**$16.40**	**$12.58**	**$22.39**	**$17.66**

Note: life cycle costs on all facilities with the exception of the Juniper Ridge Site Booster Station are assumed equal and not included.

Conclusions

The City's preferred site is the Middle School Track. This site is advantageous to both the Juniper Ridge Development and the City from a number of perspectives including:

- Providing storage by gravity to both Zone 6 and Juniper Ridge (no pumping required)
- Addresses storage needs in both Zone 6 and Juniper Ridge
- Minimizes the potential for water quality problems in the reservoir
- Allows the current use of the property to continue
- No visual impact from the project

As noted in Table 9, the Middle School Track site is not the least expensive, however the other options either are not believed to be viable or have significant disadvantages. The above ground or partially buried options on Pilot Butte are not viewed to be viable due to the community's opposition to constructing new above ground infrastructure on the butte, including additional tanks. The options that include tank(s) located on the Juniper Ridge Development are not viewed positively due to the large pump station that would be required and associated life cycle costs, as well as the limited value that a tank at that location would provide to the rest of the system under emergency conditions.

Shilo Well #3

Pump Data Sheet - Robbco

Company: UNITED PIPE AND SUPPLY
Name: MEL BAKER
Date: 9/3/2009

PUMP SER.# 22189 CITY OF BEND

Robbco Pumps

Pump:

Size: 11CHE (12 stage)
Type: TURBINE
Synch speed: 1800 rpm
Speed: 1770 rpm
Dia: 8 in
Curve:
Impeller:
Specific Speeds:
Ns: 2130
Nss: ---
Dimensions:
Suction: 8 in
Discharge: --- in
Vertical Turbine:
Bowl size: 11 in
Max lateral: 0.75 in
Thrust K factor: 7.9 lb/ft

Pump Limits:

Temperature: 120 °F
Pressure: 380 psi g
Sphere size: 0.68 in
Power: --- hp
Eye area: --- in²

Search Criteria:

Flow: 850 US gpm
Head: 786 ft

Fluid:

Water
SG: 1
Viscosity: 1.105 cP
NPSHa: --- ft
Temperature: 60 °F
Vapor pressure: 0.2563 psi a
Atm pressure: 14.7 psi a

Motor:

Standard: NEMA
Enclosure: WP1
Size: 250 hp
Speed: 1800
Frame: 447
Sizing criteria: Max Power on Design Curve

Pump Selection Warnings:

Pump shutoff dP exceeds limit for the pump.

---- Data Point ----

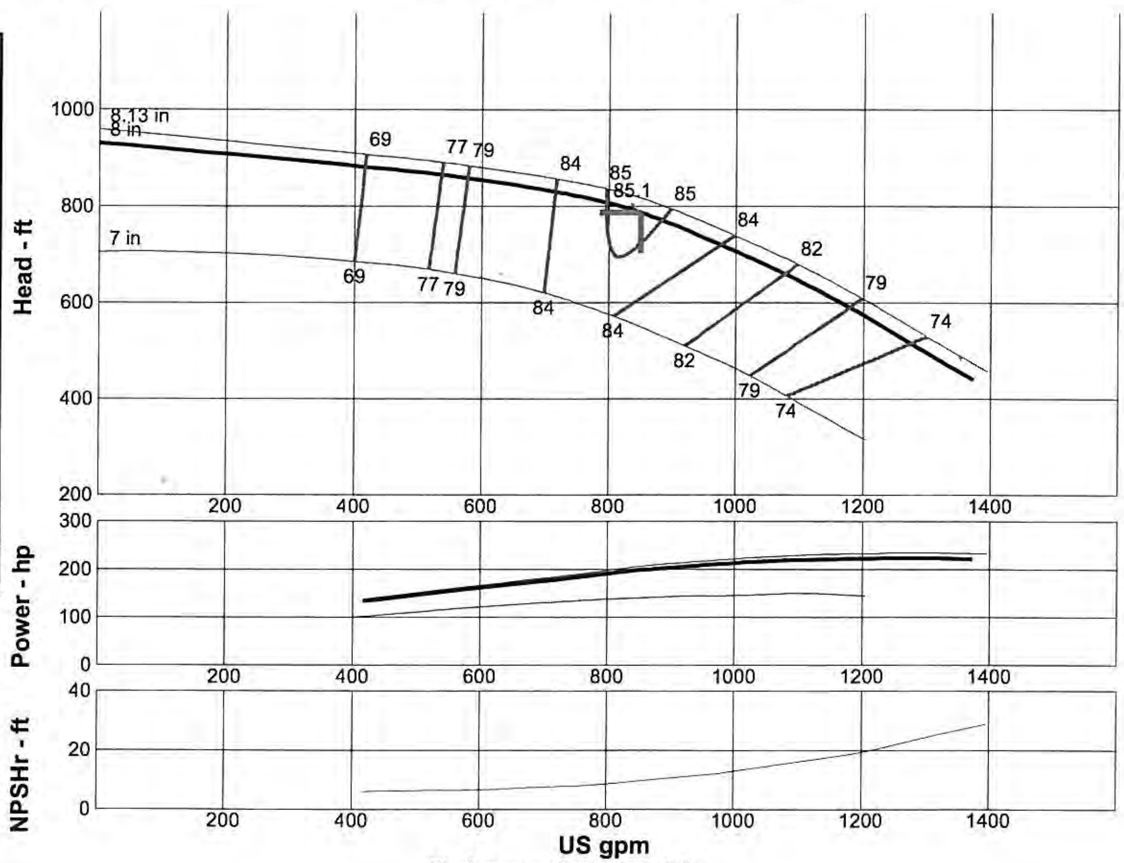
Flow:	850 US gpm
Head:	786 ft
Eff:	85%
Power:	198 hp
NPSHr:	9.69 ft

---- Design Curve ----

Shutoff head:	931 ft
Shutoff dP:	402 psi
Min flow:	--- US gpm
BEP:	85.1% @ 837 US gpm
NOL power:	224 hp @ 1275 US gpm

-- Max Curve --

Max power: 235 hp @ 1300 US gpm



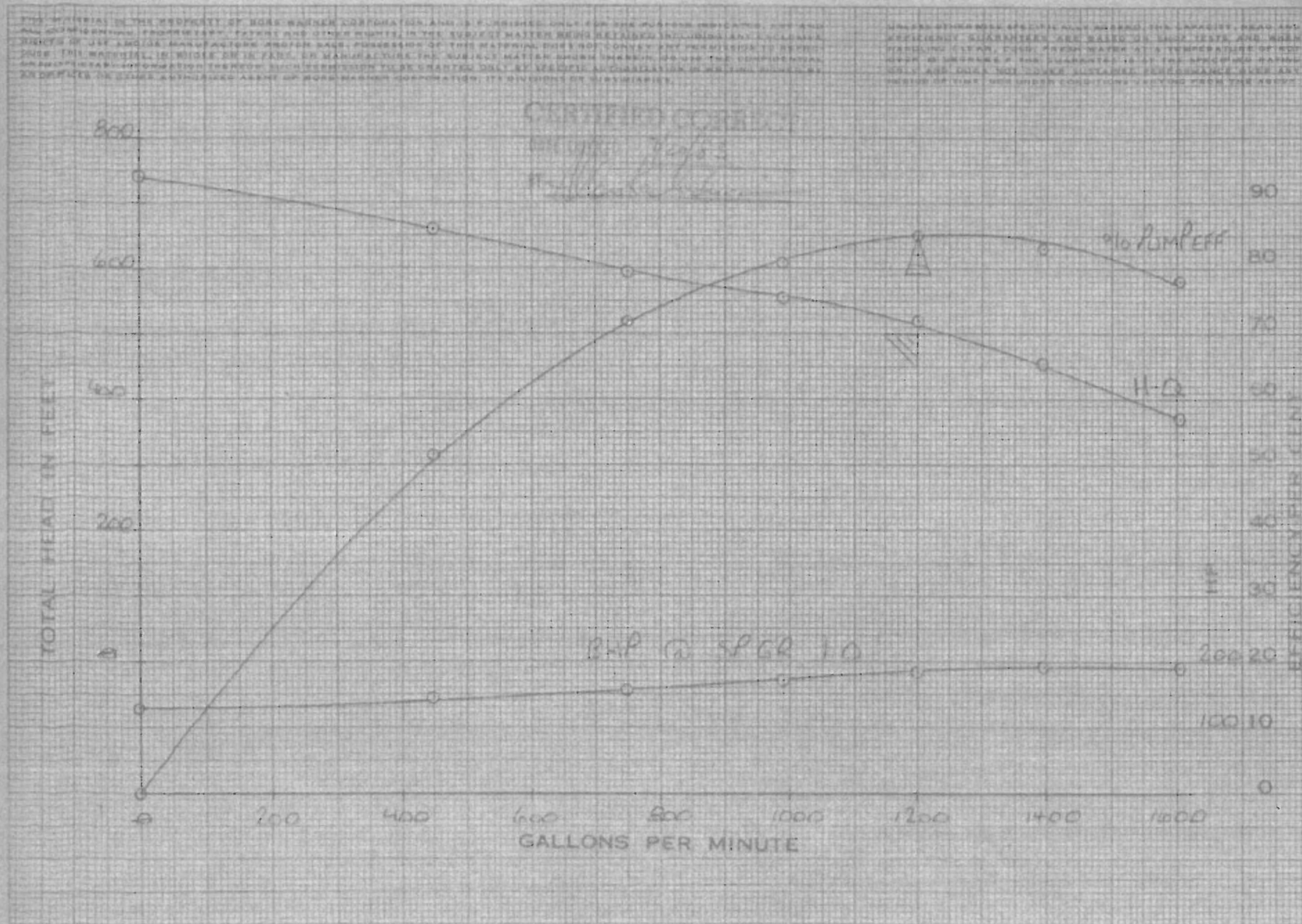
Discharge available 6, 8, 10"

Performance Evaluation:

Flow US gpm	Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft
1020	1770	694	83.1	215	13.6
850	1770	786	85	198	9.69
680	1770	838	82.7	173	7.51
510	1770	869	75.2	148	6.46
340	1770	891	64	123	6

Awbrey Booster

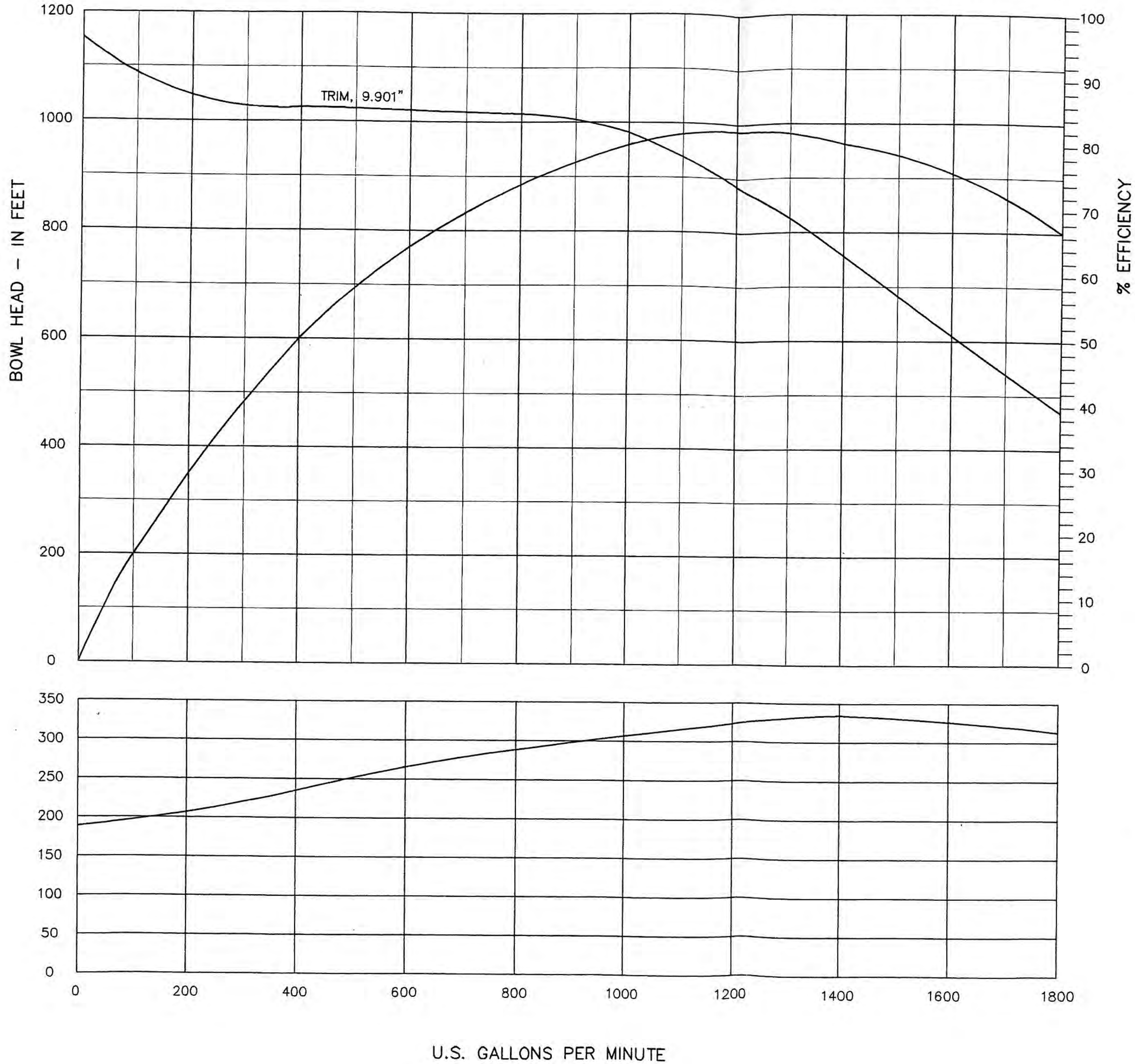
BYRON JACKSON



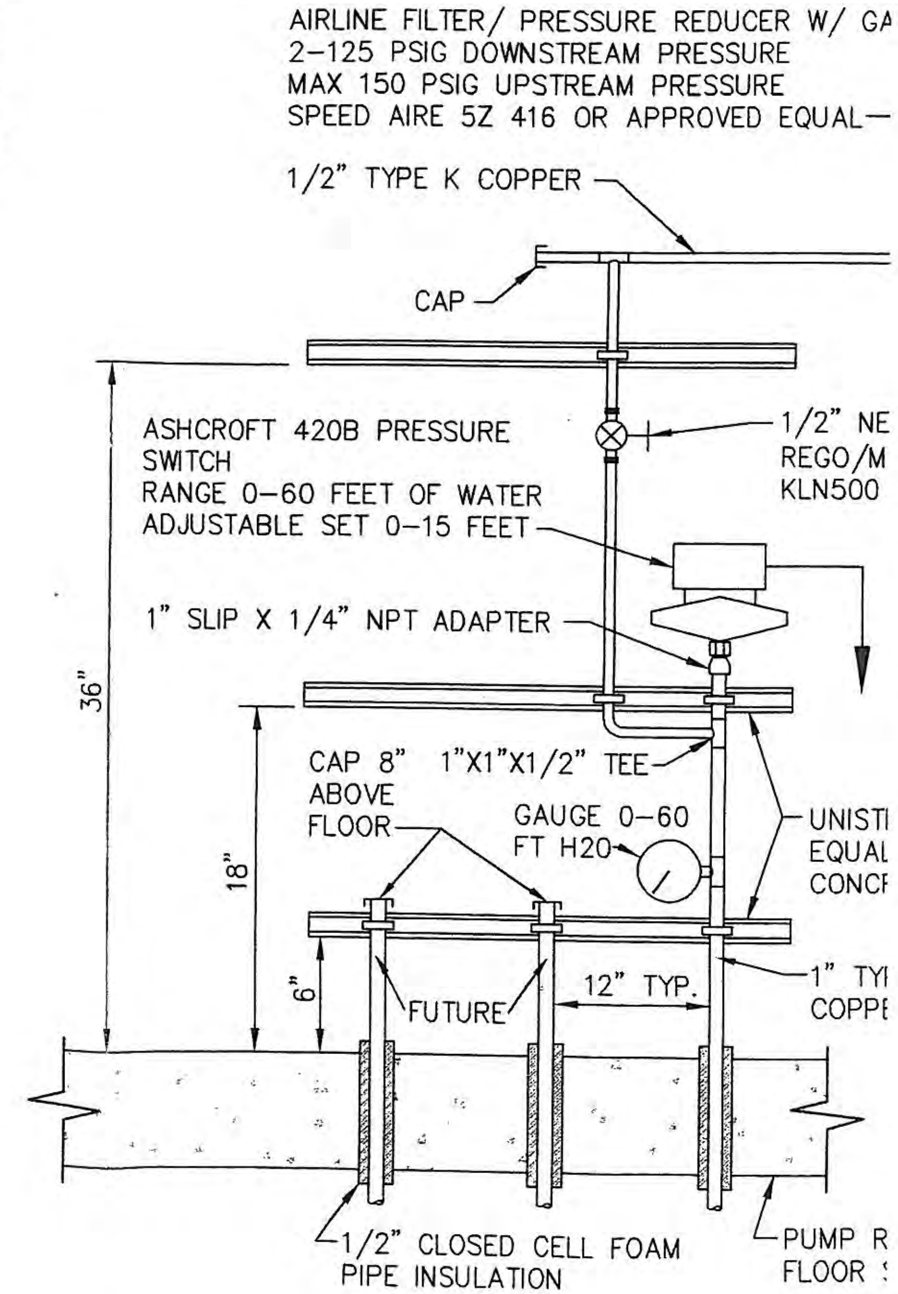
PUMP SIZE AND TYPE	RPM	ASSEMBLY NO. / FACTORY NO.	IMPELLER NO. / DATE			BYRON JACKSON TEST
12 MQH 7 STG	1800	836-61-1362	8 5/8		STD	T— F10311-1
			7/19/83	AK	AK	

Bear Creek Well #1

ESTIMATED BOWL ASSEMBLY PERFORMANCE



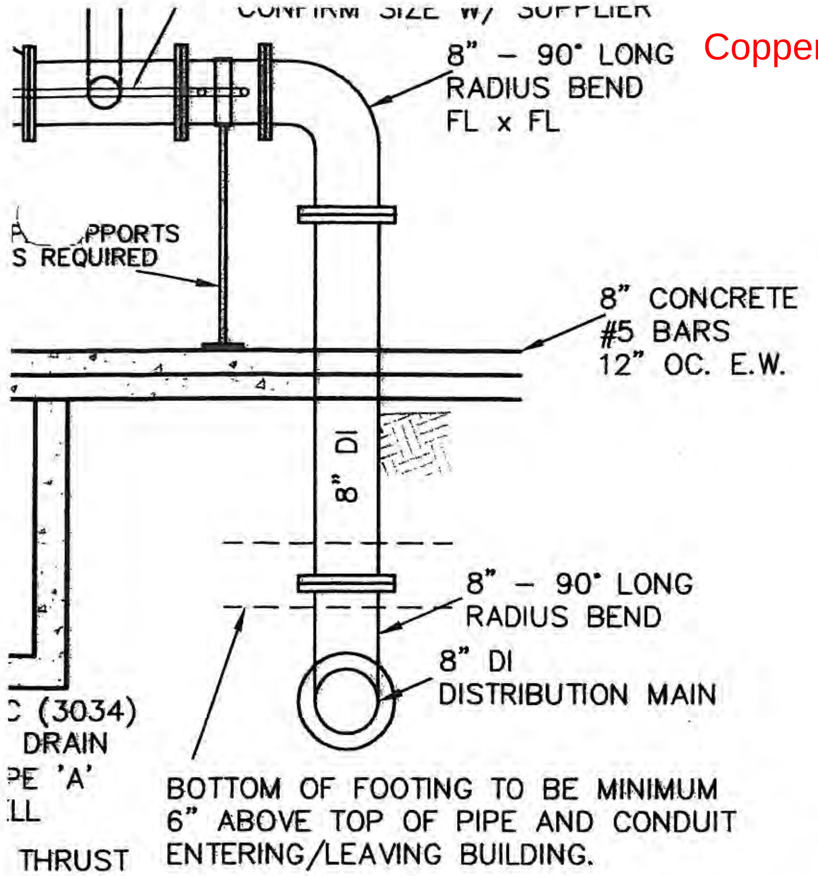
PUMP CURVES

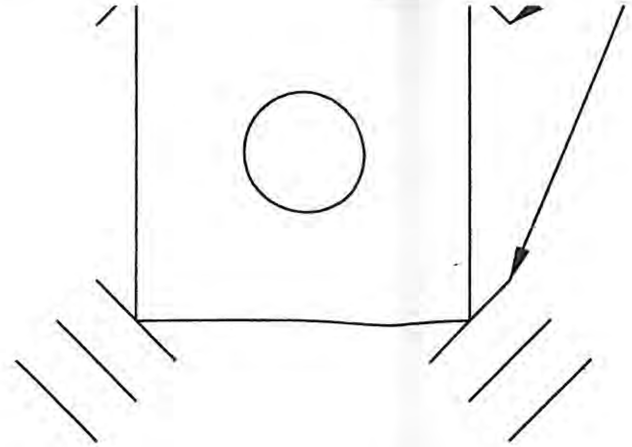


AIRLINE ASSEMBLY

NTS

Copperstone Well





SLAB AT PEDESTAL DETAIL ADDITIONAL BAR TO PREVENT LONGITUDINAL CRACKING

SCALE: NTS

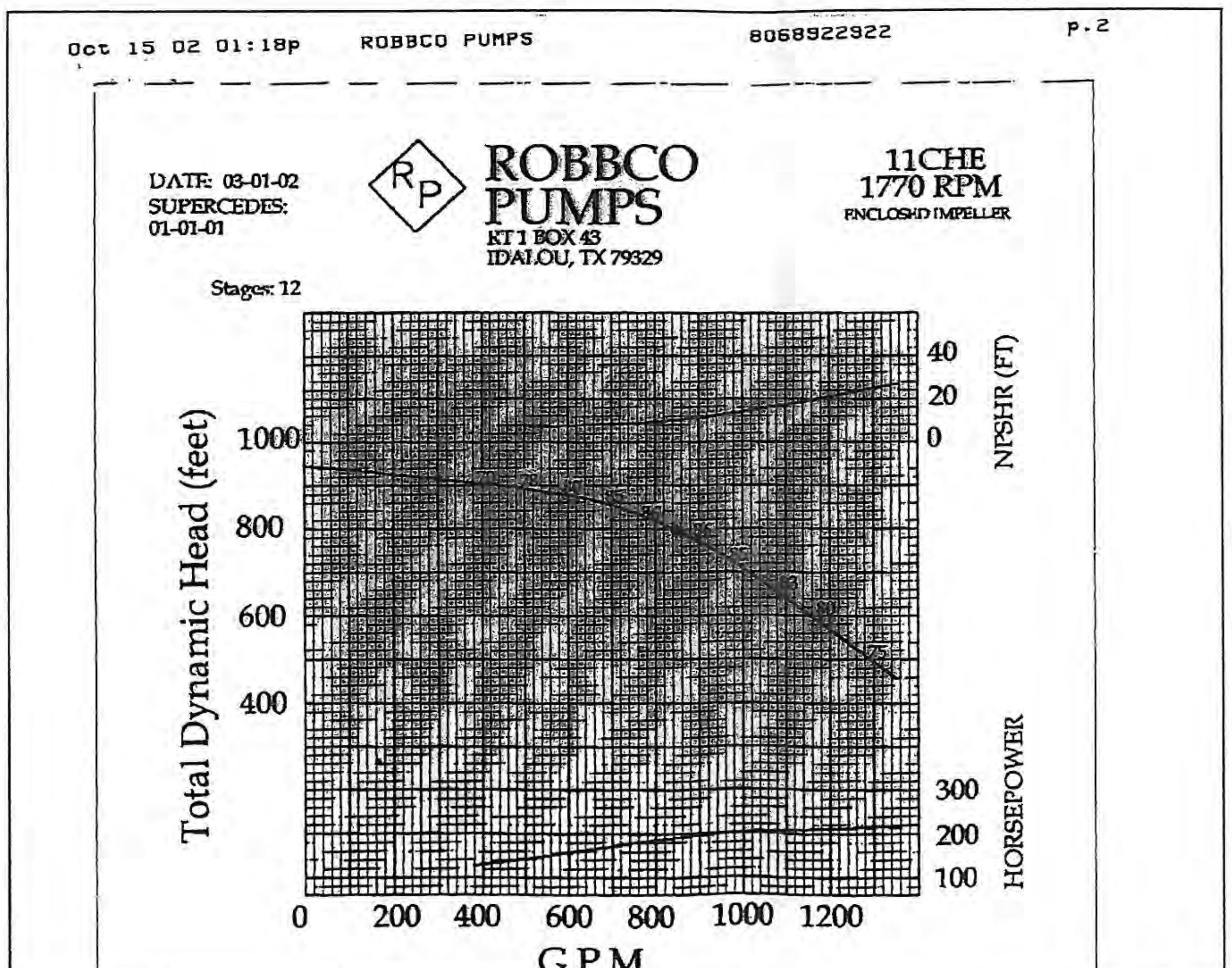
2
P4.0

STATIC WATER ELEV

DRAWDOWN

(3244

PERFORATIONS = –540



OFILE

ip proof motor

TOP OF PUMP STAGES, AND END OF AIR LINE
USE (2) EACH 1/4" TUBING STRAPPED T

ROBBCO 11 CHE, 12 STAGE, 1760 RPM, 850 GPM @
TRIM TO DES
INSTALL HYDROSURGE CONTR

) CATCH BASIN
DRYWELL.
ALL ANGLE VALVE ON.

BOTTOM OF HOLE

PUMP CURVE

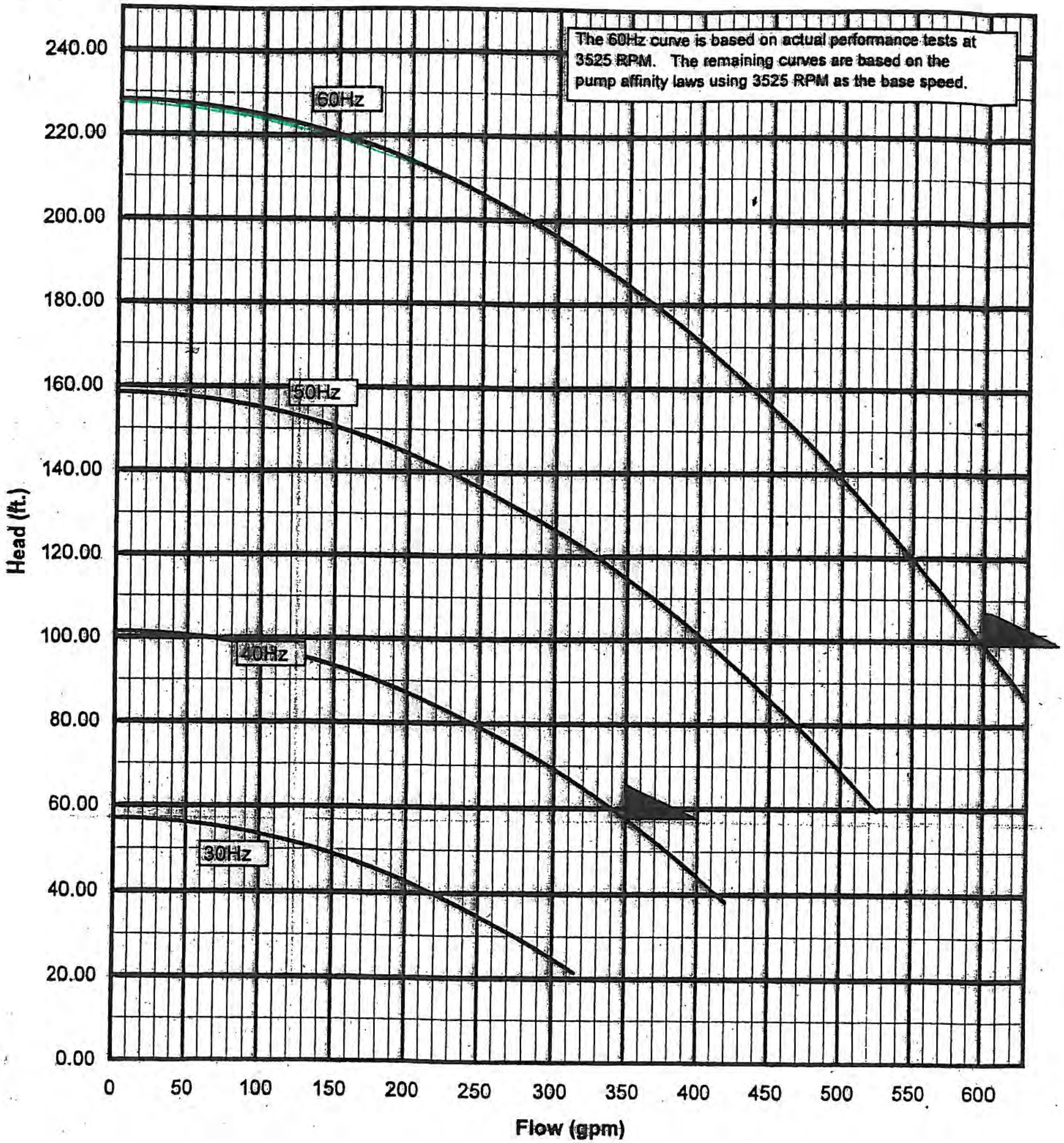
SCALE: N.T.S.

3
P4.0

Murphy Pump Road
Booster 1-5

Model CR(N)90-2-2, (25 HP)

3525 RPM @ 60Hz



GRUNDFOS

TEMPORARY LEVELING NUTS SHALL BE BACKED OFF. IF LEFT IN, THE WEDGES OR SHIMS SHALL NOT BE EXPOSED TO VIEW.

7. HEIGHT OF PADS SHALL BE MINIMUM REQUIRED FOR ANCHOR BOLT CLEARANCE TO KEEP ANCHOR BOLT OUT OF SLAB (SEE TABLE BELOW). WHERE EQUIPMENT OR PIPING ELEVATION REQUIRED A PAD HEIGHT LESS THAN THE MINIMUM SHOWN, USE TYPE B WITH BLOCKOUT.

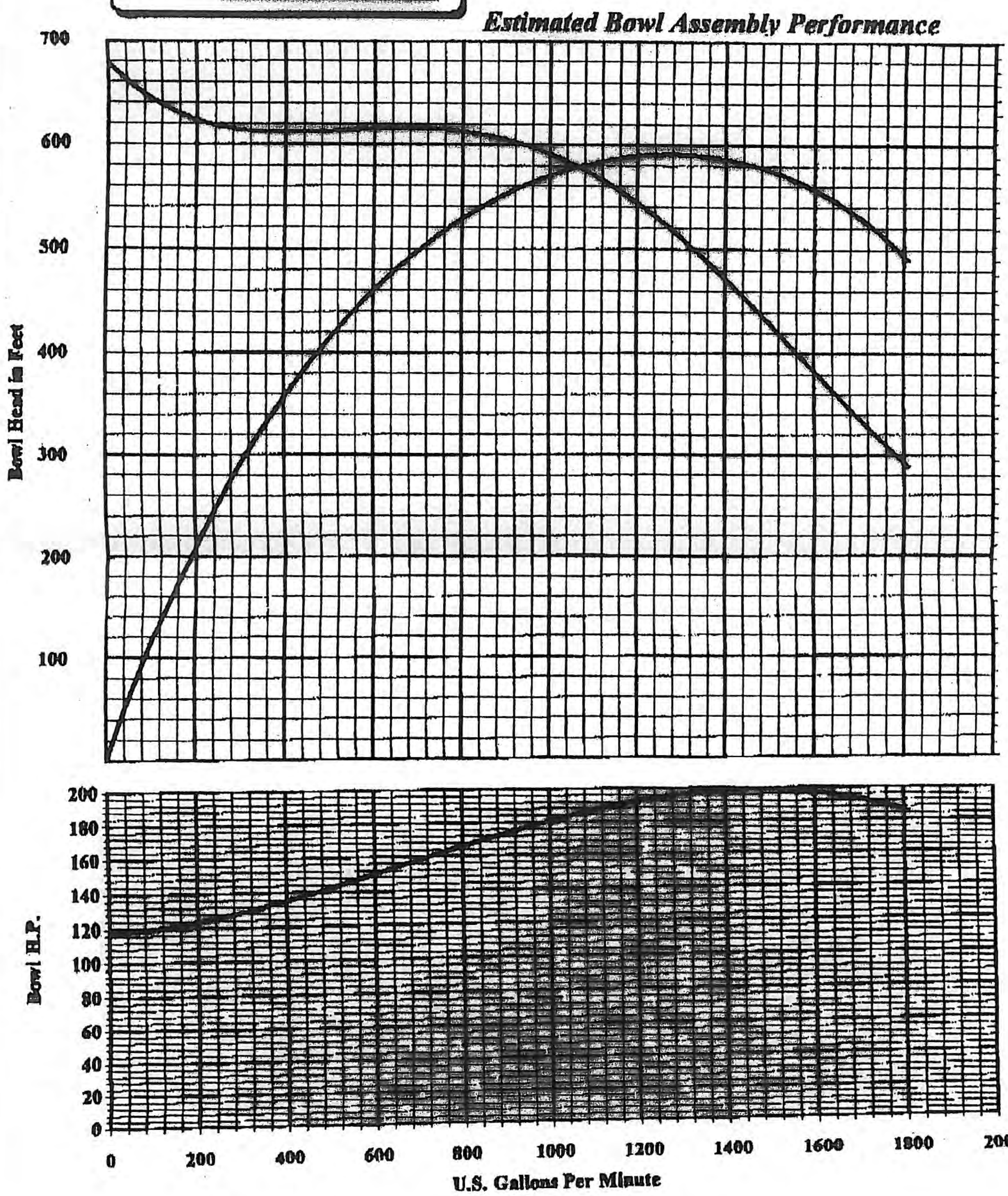
CONSTRUCTION JOINT, LEAVE ROUGH

NOTE
SEE EQUIPMENT BASE NOTES.

TYPE
EQUIPMENT
NTS

AB DIA (inch)	1/2	5/8	3/4	7/8	1	1 1/4	1 3/8	1 1/2	1 3/4
MIN. PAD HT (inch)	7	8 1/2	10	11	12 1/2	15	16 1/2	18	21

AMERICAN TURBINE



7 Stage 12-H-150 Bowl Assembly		21-Feb-00
1786 R.P.M.		sg = 1.00
Bowl Material 48-cl 30 cast iron/porcelain	1250 G.P.M. @ 525 T.D.H. Trim 7 Impellers 9.931 Diameter	Impeller Material C83800 bronze

Same as model "Outback 3-7"

Outback Well #6

Rock Bluff Wells 1 and 3

Pump Data Sheet - Robbco

Company: City of Bend, OR
Name: Ken Vaughn
Date: 8/31/2009

Fax 541-317-3046
Phone 541-330-4026

Serial # 24264 ; 25011
Attn: Ken Vaughn

Robbco Pumps

Pump:
Size: 9THE (15 stage)
Type: TURBINE
Synch speed: 1800 rpm
Speed: 1770 rpm
Dia: 6.44 in
Curve:
Impeller:
Specific Speeds:
Ns: 3500
Nss: —
Dimensions:
Suction: 6 in
Discharge: — in
Vertical Turbine:
Bowl size: 9.25 in
Max lateral: 0.75 in
Thrust K factor: 9 lb/ft

Search Criteria:
Flow: — US gpm
Head: — ft

Fluid:
Water
SG: 1
Viscosity: 1.105 cP
NPSHa: — ft
Temperature: 60 °F
Vapor pressure: 0.2563 psi a
Atm pressure: 14.7 psi a

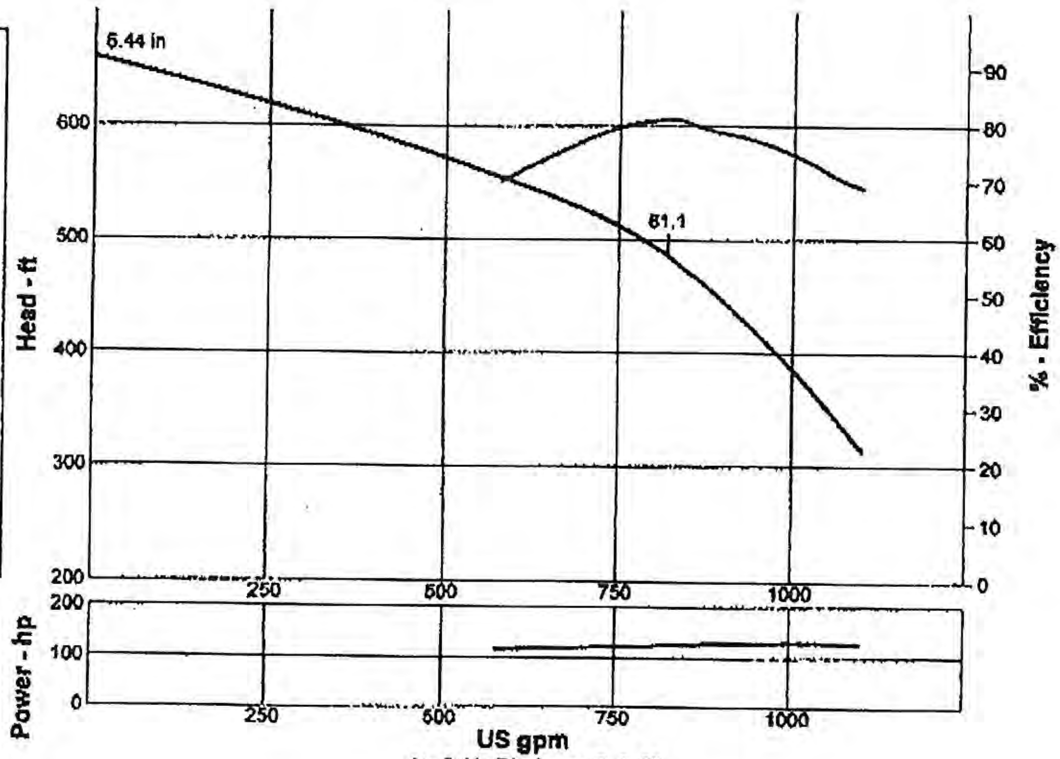
Motor:
Standard: NEMA
Enclosure: WP1
Size: 150 hp
Speed: 1800
Frame: 445
Sizing criteria: Max Power on Design Curve

Pump Limits:
Temperature: 120 °F
Pressure: 530 psi g
Sphere size: 1 in
Power: — hp
Eye area: — in²

— Data Point —
Flow: 820 US gpm
Head: 488 ft
Eff: 81.1%
Power: 124 hp
NPSHr: 2.95 ft

— Design Curve —
Shutoff head: 660 ft
Shutoff dP: 285 psi
Min flow: — US gpm
BEP: 81.1% @ 820 US gpm
NOL power:
130 hp @ 1000 US gpm

— Max Curve —
Max power:
130 hp @ 1000 US gpm



Available Discharge 5, 6, 8"

Performance Evaluation:

Flow US gpm	Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft
1058	1770	346	71.3	129	4.42
882	1770	454	79.4	127	3.25
706	1770	524	77.4	120	2.48
529	1770	564	67	114	1.92
353	1770	—	—	—	—

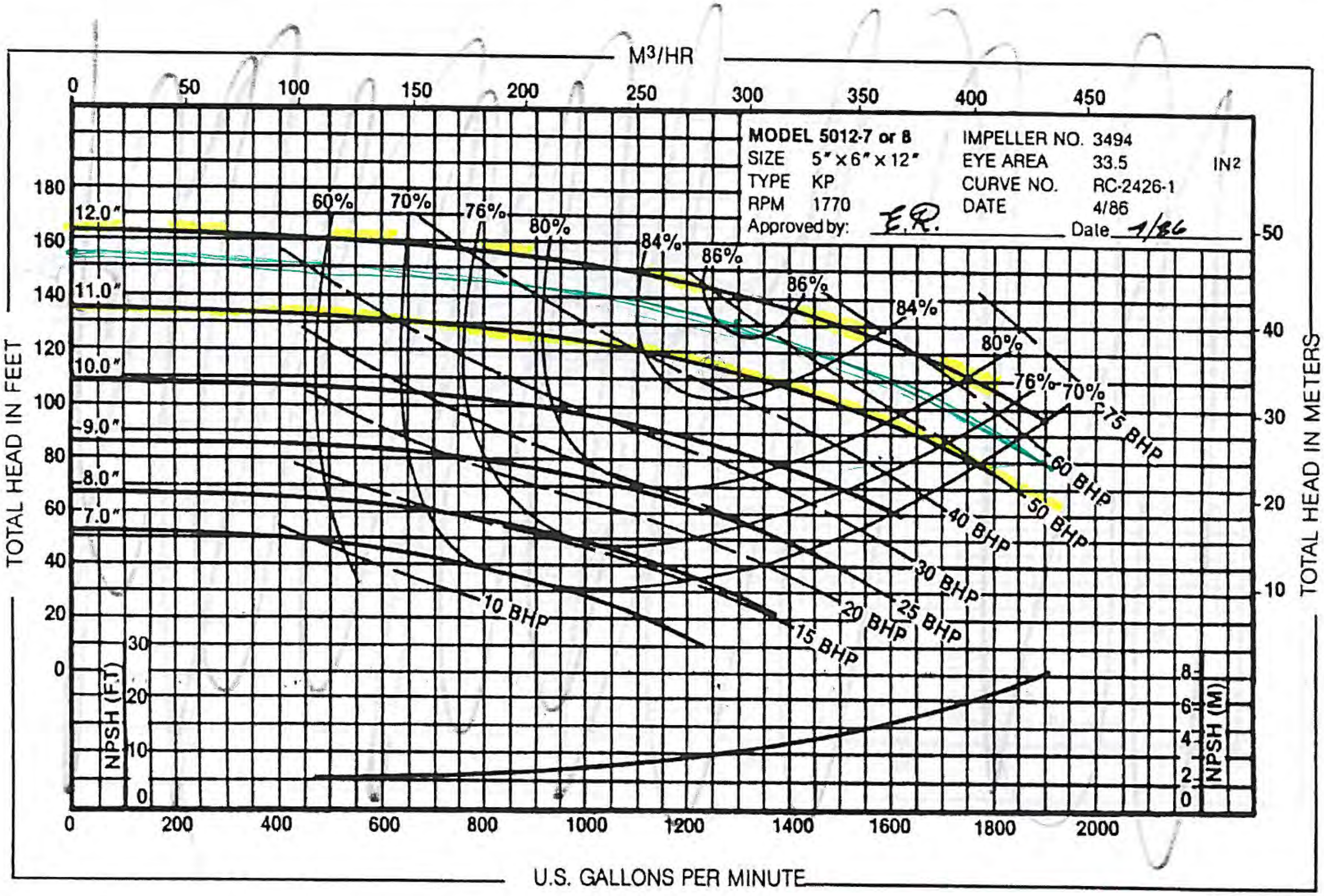
PACO PUMPS

Scott Street P.S. 1-3

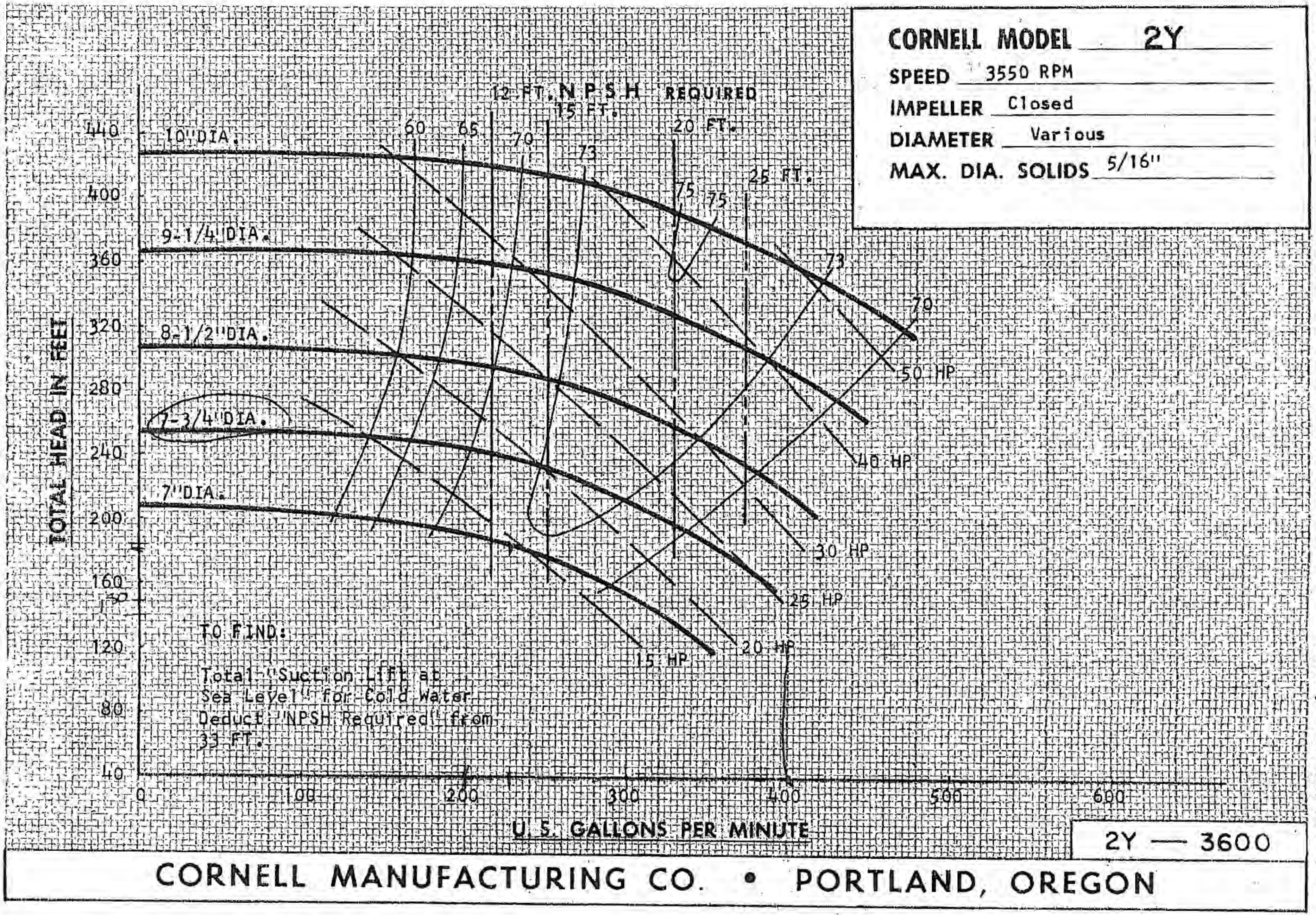
SPLIT CASE CENTRIFUGAL PUMPS

Type KP and KPV

PERFORMANCE CURVES 1750 RPM



Westwood Pump 1



134-14C

DECEMBER 1971

SUPERSEDES 134-14C
AUG., 1961 OR SC1398

Tetherow Pump Station

PUMP STATION NOTES:

1. CONTRACTOR TO PROVIDE FACTORY BUILT, BOOSTER PUMPING SYSTEM, FLOWTRONEX MODEL MVE-3500-6SL-105, OR EQUAL – SUBJECT TO APPROVAL BY THE CITY AND ENGINEER.

   THE PACKAGE PUMP STATION SHALL INCLUDE THE FOLLOWING SCHEDULE OF PRIMARY EQUIPMENT AND MATERIALS IN ACCORDANCE WITH THE SPECIFICATION NOTED, UNLESS OTHERWISE APPROVED IN WRITING BY THE ENGINEER, PRIOR TO MANUFACTURE OR DELIVERY.

   THE SCHEDULE MAY NOT INCLUDE ALL INCIDENTALS AND APPURTENANCES REQUIRED FOR A COMPLETE PACKAGE SYSTEM AS INTENDED. IT SHALL BE THE CONTRACTOR'S RESPONSIBILITY TO FURNISH AND INSTALL ALL INCIDENTALS, APPURTENANCES, AND PERFORM ALL WORK NECESSARY TO PROVIDE THE COMPLETE WORKING PUMP STATION AS SPECIFIED AND INTENDED IN THE PLANS AND SPECIFICATIONS.

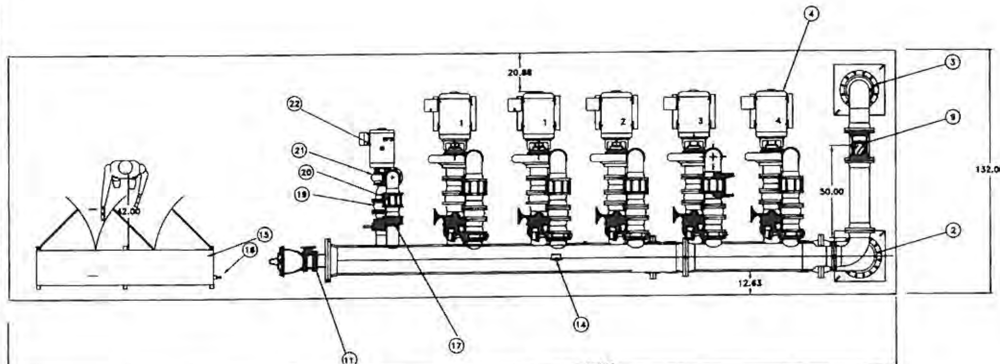
PIPE SIZE	ELEVATION TOLERANCE	OFFSET TOLERANCE FROM EDGE OF SKID	SETBACK TOLERANCE FROM EDGE OF SKID
8" OR LESS	±1/4"	±1/4"	±1/4"
10" THRU 16"	±3/8"	±3/8"	±3/8"
OVER 16"	±1/2"	±1/2"	±1/2"

SKID FRAME THICKNESS	LENGTH TOLERANCE	WIDTH TOLERANCE
6" OR LESS	±1/4"	±1/4"
8" OR MORE	±3/8"	±3/8"

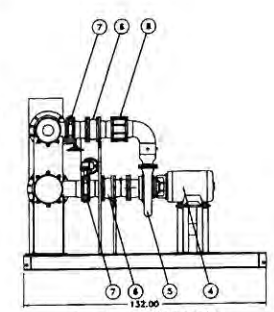
ITEM	QTY	SIZE	DESCRIPTION	LGTH	PART NO./NOTE
22	1	15HP	MOTOR – BALDOR, 3600RPM		
21	1		PUMP – GOULDS		
20	1	4"	VALVE – CHECK		
19	1	4"	COUPLING – PROCO		
18	1	1/2	CONNECTION-SURGE ANTICIPATOR		
17	2	4"	AWWA VALVE – BF ISO		
16	1		TRANSDUCER-PRESSURE		
15	1		PANEL-84X84X18		
14	1	4.5"	GAUGE-0-300 PSI PRESSURE		
13	1	4.5"	GAUGE-0-160 PSI PRESSURE		SUCT HEADER
12	1	14"	FLANGE-BLIND		
11	2	6"	AWWA VALVE-BF ISO		
10	1	6"	VALVE-52-03B SURGE ANTICIPATOR		
9	1	8"	FLOWMETER-KROHNE		
8	5	6"	VALVE-WAFER CHECK		
7	10	6"	AWWA VALVE-BF GEAR OPERATED ISO		
6	10	6"	COUPLING-PROCO FLEXIBLE		
5	5		PUMP-GOULDS CENTRIFUGAL		
4	5		MOTOR-60HP 3600 RPM ELECTRIC		
3	1	14"	DISCHARGE-UNIFLANGE		
2	1	14"	SUCTION-FLANGE		
1	1		SKID -UNIT		

TO PRODUCE: 3500 GPM @ 100 PSI
MAIN DISCONNECT: 600 AMPS
POWER REQUIREMENTS: 460/60/3

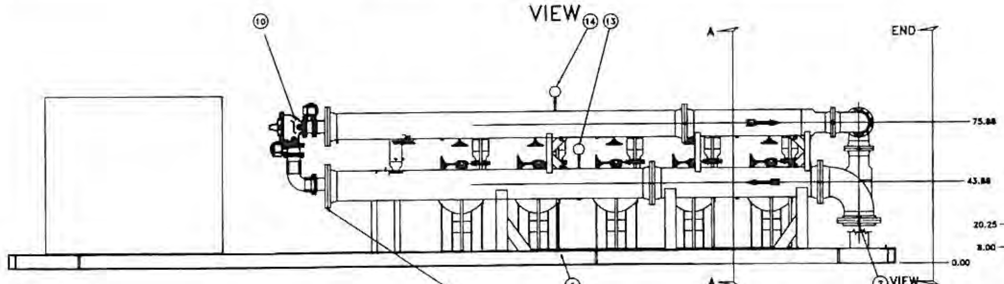
1. MINIMUM TO ANY OBSTRUCTION REQUIRED BY NATIONAL ELECTRIC CODE
2. SUCTION AND DISCHARGE PIPING CONNECTIONS MUST BE RESTRAINED AGAINST THRUST BY OTHERS.
3. ALL DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED
4. ALL SADDLES TO BE DETACHABLE.
5. PIPING TO HAVE FUSION BONDED COATING



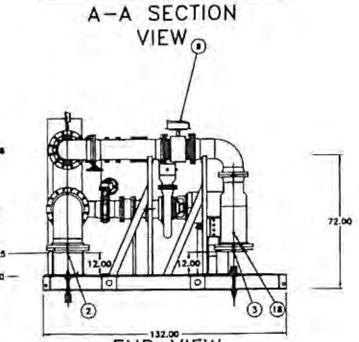
PLAN VIEW



A–A SECTION VIEW



ELEVATION VIEW



END VIEW

Flowtronex
ITT Industries
PACKAGE PUMP STATION SKID/ASSEMBLY DIAGRAM

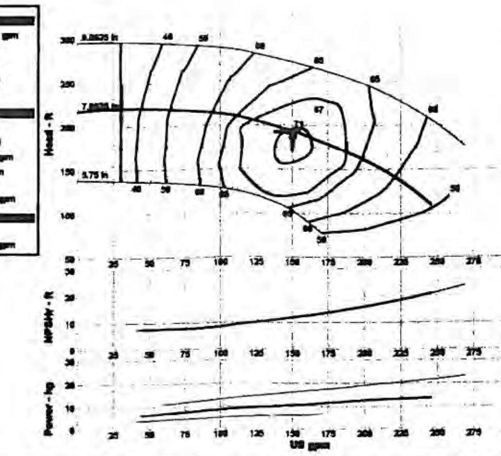
TETHEROW WATER PUMP STATION
PUMP SKID DETAIL
SCALE: N.T.S.
1
C3.0

CONTRACTOR TO SUBMIT SHOP DRAWINGS OF ALL PROPOSED PACKAGE PUMP STATION COMPONENTS TO ENGINEER PRIOR TO MANUFACTURE AND INSTALLATION

GOULDS PUMPS — Small pump

Flow: 150 US gpm
Head: 192 ft
Temperature: 212 °F
Pressure: 175 psi g
Sphere size: 0.3125 in

Flow: 150 US gpm
Head: 194 ft
Eff: 79%
Power: 10.5 hp
NPSHr: 11.9 ft
Shutoff head: 219 ft
Shutoff dP: 94.1 psi
Min flow: 30 US gpm
BEP: 71% @ 150 US gpm
NOL power: 13.5 hp @ 246 US gpm
Max power: 23.1 hp @ 260 US gpm

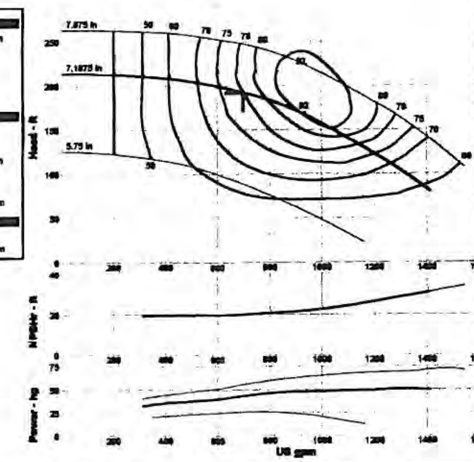


Flow US gpm	Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft
180	3500	175	80	11.7	14.2
150	3500	194	79	10.5	11.9
120	3500	206	68	9.4	8.78
90	3500	215	59	8.28	8.15
60	3500	219	45	[illegible]	7.69

Selected from catalog: Goulds 60.60 Vers: 2

GOULDS PUMPS — Other Pumps

Flow: 700 US gpm
Head: 192 ft



Flow US gpm	Speed rpm	Head ft	Efficiency %	Power hp	NPSHr ft
840	3500	178	81	46.6	21
700	3500	192	78	43.5	20.1
560	3500	201	72	39.4	19.8
420	3500	208	61	36.2	19.6
280	3500	211	47	32	19.4

Selected from catalog: Goulds 60.60 Vers: 2

D'Agostino Parker, LLC
CIVIL ENGINEERING / LAND DEVELOPMENT SERVICES
231 SW SCALEHOUSE LOOP, SUITE 203
BEND, OR 97702
P: (541) 322-8807
F: (541) 322-8827

ARROWOOD DEVELOPMENT, LLC
TETHEROW RESORT
CITY OF BEND WATER PUMP STATION NOTES AND DETAILS
BEND/DESCHUTES OREGON
DRAWING FILE NAME: AWD014-TETHEROW PS-CD01
PROJECT NO. AWD014
SCALE: AS SHOWN

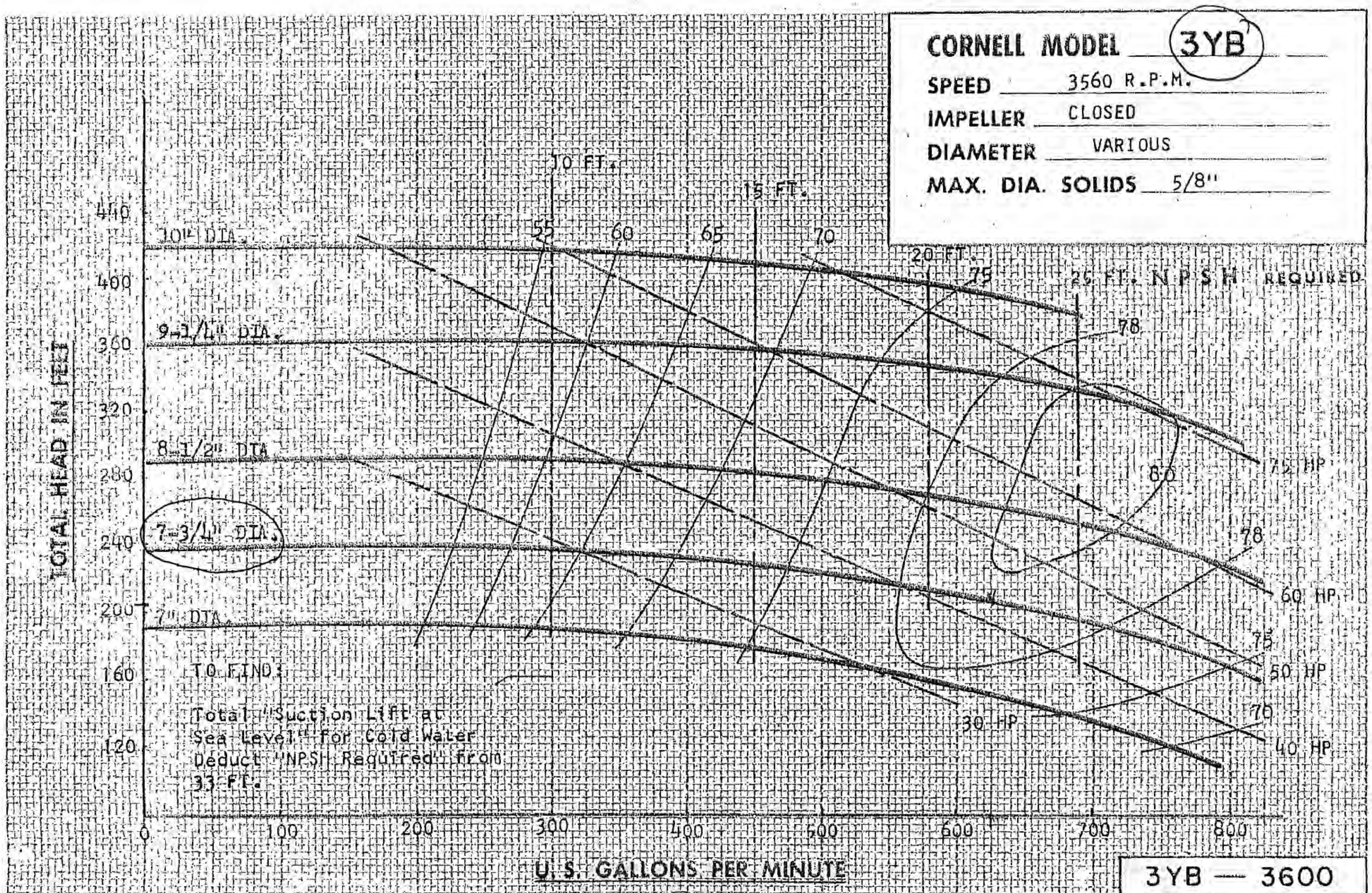
REGISTERED PROFESSIONAL ENGINEER OREGON BRETT A. PARKER

DESIGNED BY: BAP
DRAWN BY: BAP
CHECKED BY: BAP
APPROVED BY: KSD
LAST EDIT: 2/20/2008
PLOT DATE: 2/25/2008

SHEET C3.0

Office: BEND | System: WHP-BND-JF7KC91 | User: BPARKER | Time: 03/22/2007 09:05:57

Westwood Pump 2



CORNELL MANUFACTURING CO. • PORTLAND, OREGON

SUPERSEDES 134-38C DEC, 1961 OR SC1487

NOVEMBER 1970

134-38C

Westwood Pump 3

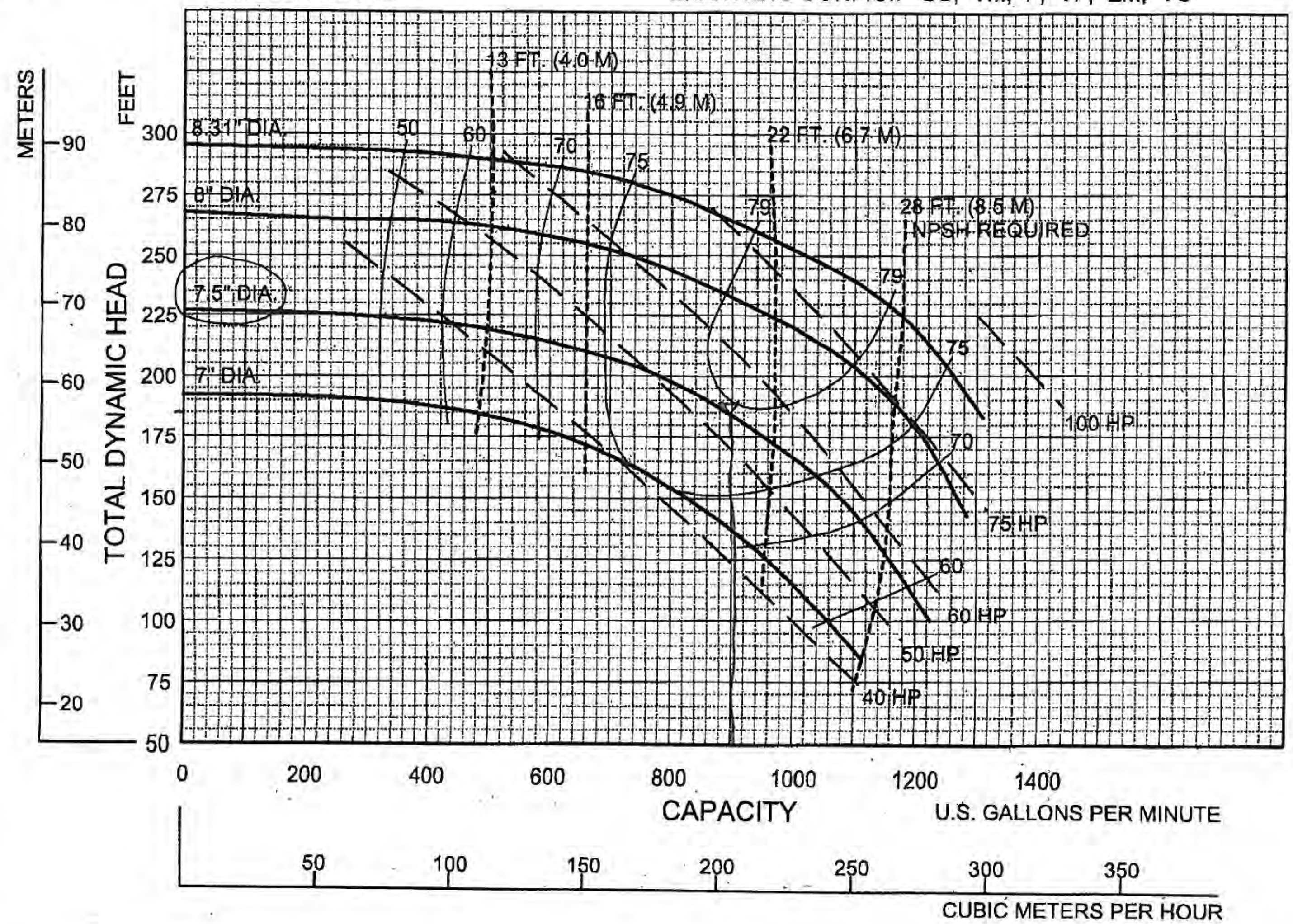
Feet x .305 = Meters
Inches x 25.4 = Millimeters
GPM x .227 = Cubic Meters/Hour
GPM x 3.785 = Liters/Minute
HP x .746 = KW

Speed	Impeller Dia.	Style	Solids Dia.	N_S	Suction	Discharge	No. vanes
3560	VARIOUS	ENCLOSED	.97"	1821	6"	5"	6

NEW PAGE

SINGLE VOLUTE

MOUNTING CONFIG.: CC, VM, F, VF, EM, VC



Performances shown are for cool water, close-coupled electric configuration with packing. Other mounting styles or liquids may require horsepower and/or performance adjustments.

5WB36

7/25/00

CORNELL Efficient by Design

Cornell Pump Company • Portland, Oregon

5WB - 3600 RPM

Westwood Pump 4

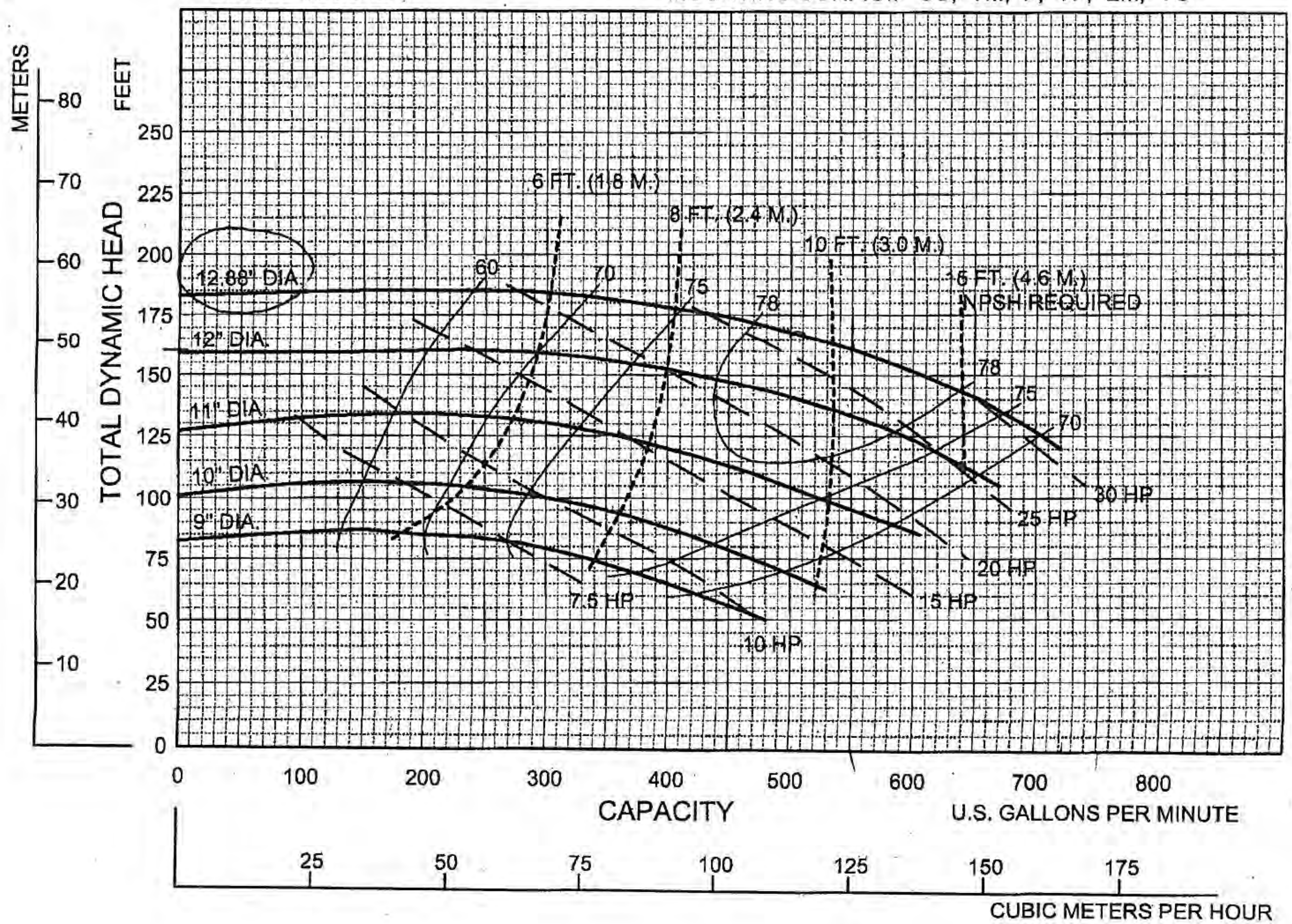
Feet x .305 = Meters
Inches x 25.4 = Millimeters
GPM x .227 = Cubic Meters/Hour
GPM x 3.785 = Liters/Minute
HP x .746 = KW

Speed	Impeller Dia.	Style	Solids Dia.	N_S	Suction	Discharge	No. vanes
1775	VARIOUS	ENCLOSED	.50"	918	5"	3"	7

NEW PAGE

SINGLE VOLUTE

MOUNTING CONFIG.: CC, VM, F, VF, EM, VC



Performances shown are for cool water, close-coupled electric configuration with packing. Other mounting styles or liquids may require horsepower and/or performance adjustments.

3RB18

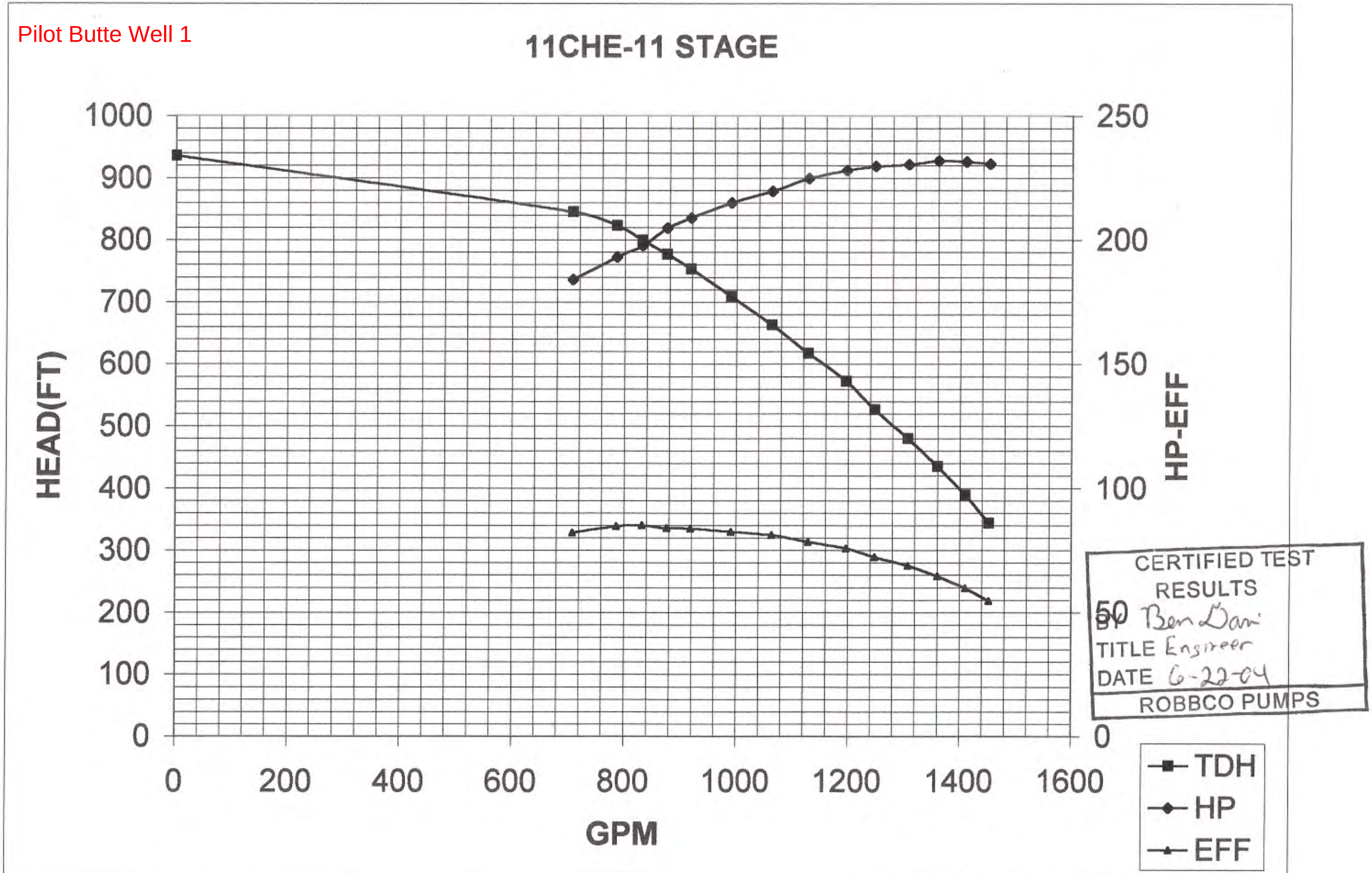
6/99

CORNELL Efficient by Design

Cornell Pump Company • Portland, Oregon

3RB - 1800 RPM

Pilot Butte Well 1



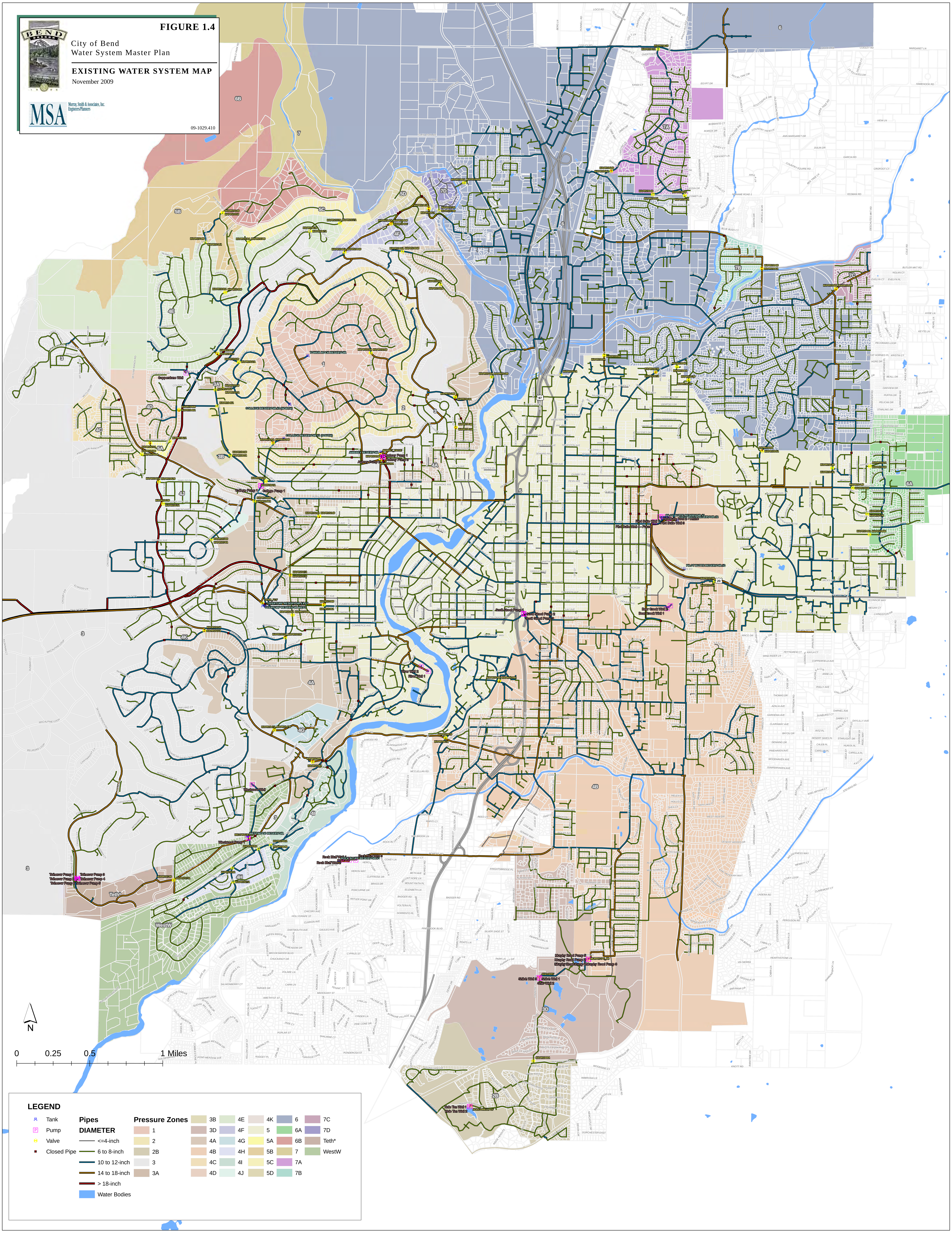


FIGURE 1.4
City of Bend
Water System Master Plan
EXISTING WATER SYSTEM MAP
November 2009
MSA
Murray, Smith & Associates, Inc.
Engineers/Planners
09-1029.410
N
0
0.25
0.5
1 Miles
LEGEND
Tank
Pump
Valve
Closed Pipe
Pipes
DIAMETER
<=4-inch
6 to 8-inch
10 to 12-inch
14 to 18-inch
> 18-inch
Water Bodies
Pressure Zones
1
2
2B
3
3A
3B
3D
4A
4B
4C
4D
4E
4F
4G
4H
4I
4J
4K
5
5A
5B
5C
5D
6
6A
6B
7
7A
7B
7C
7D
Teth*
WestW

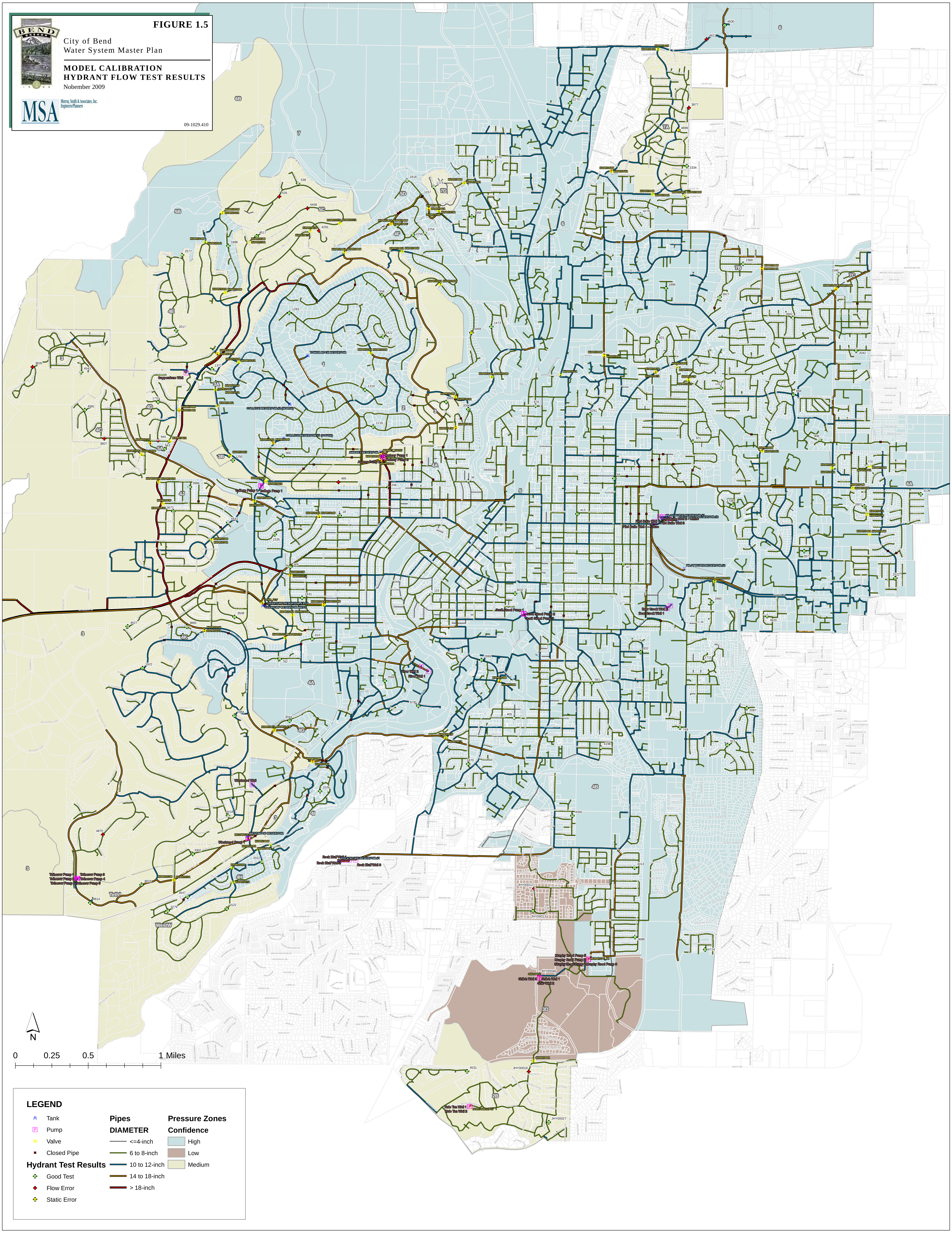


FIGURE 1.5
City of Bend
Water System Master Plan
MODEL CALIBRATION
HYDRANT FLOW TEST RESULTS
Nobember 2009
MSA
Murray, Smith & Associates, Inc.
Engineers/Planners
09-1029.410
N
0
0.25
0.5
1 Miles
LEGEND
Tank
Pump
Valve
Closed Pipe
Hydrant Test Results
Good Test
Flow Error
Static Error
Pipes
DIAMETER
<=4-inch
6 to 8-inch
10 to 12-inch
14 to 18-inch
> 18-inch
Pressure Zones
Confidence
High
Low
Medium

FIGURE 1.26

City of Bend
Water System Master Plan

DRINKNIG WATER DISTRIBUTION SYSTEM

Planning Boundary and Land Development Status

December 2009

Murray, Smith & Associates, Inc.
Engineers/Planners

09-1029.410