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Water System Optimization

DATE: November 11, 2010 (revised from May 2010)

PROJECT: City Ref: WA09FA; Optimatics Ref: 396

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SUBJECT: Review of storage standards and recommended storage guidelines for the City of Bend

1 Introduction

The City of Bend wishes to develop a set of appropriate guidelines to determine storage volume needs in the water system. The recommendations used in the 2007 Master Plan, particularly in relation to standby storage and reliance on groundwater supplies, were not based on a specific standard. The purpose of this memorandum is to develop a defensible set of guidelines for use in the current Water System Master Plan Update Optimization Study, and in the future. The memorandum reviews and summarizes the applicable storage standards in neighboring states and regions, applies the more quantitative standards to the Bend system and recommends guidelines to be adopted.

2 Supply Security and Standby Storage

As the City of Bend grows and additional demands are placed on the system, additional sources will be required to meet those demands. Firm supply capacity is defined as the sum of all available (in service) supply sources, minus the largest single supply source. In the case of the Bend system, the largest supply source is, and will continue to be, the surface water source.

The City is looking to expand the capacity of the surface water system which will help meet near-term demand increases and provide additional benefits through energy cost reduction and hydropower generation. From a supply security point of view, however, it is necessary to also consider the system's groundwater capacity to ensure sufficient supply in the event that the surface water source is not available.

The AWWA *Manual of Water Supply M19 – Emergency Planning for Water Utility Management* provides information related to assessing risks and system vulnerability, and describes methods for mitigation and planning response during an emergency event. From the listed categories of emergency scenarios, forest fires, drought or severe weather events (thunderstorms) are the most likely natural hazards for Bend. Such events would interrupt supply of water and/or power to the system. Other emergencies may be caused by human error or accident with potential consequences being damage to infrastructure or contamination of supply.

Future supply planning must consider these situations and determine how they will be addressed if they affect the system for an extended period of time. Providing back-up power at key groundwater facilities will aid in overcoming a power outage scenario. Ensuring that available groundwater pumping capacity is in excess of the minimum requirements will assist in the event that the surface water source is not able to be used.

In a water distribution system, storage serves a number of purposes. Storages can help reduce peak flows in transmission mains by helping to meet peak demands, allow for more efficient operations through gravity supply, help maintain steady system pressures, provide supply volumes to meet fire suppression needs and provide back-up supply in the event of an emergency.

It must be understood that standby storage simply provides a buffer in the event of an emergency and represents a short-term solution to meet system demands in the event of a water supply or power outage. A system should not be designed such that use of storage is the long-term emergency supply strategy. To meet extended emergency situations, there is a need to provide adequate redundancy in system supplies, otherwise there will be a need for significant curtailments.

3 Review of Available Storage Standards

3.1 General

It is generally agreed that when assessing storage needs for a system, four components need to be considered. These are described below and illustrated in the example in Figure 1.

Equalization and operational storage – required to supply instantaneous demands that are in excess of the system's supply capacity. Volume should be sufficient to meet normal system demands in excess of the maximum day demand, i.e., the difference between peak hour demand and maximum day demand. Operational storage can be defined as the volume between the operational set-points of the supply to the storage (i.e. the pump station that fills the storage). Depending on the standard, operational storage can be a component of equalization storage or a stand-alone requirement.

Note: In an optimization analysis, this component of storage will be determined through analysis of the hydraulic model and is accounted for by ensuring that:

(a) Minimum pressures are met under Maximum Day and Peak Hour demand conditions (minimum pressure constraint)

(b) Standby and fire suppression storage volumes are maintained at all times (minimum storage volume constraint)

The formulation for the Build-out Optimization will include constraints on minimum and maximum allowable storage levels, turnover requirements and comparison of start-of-day and end-of-day levels. A specific volume limit for operational needs will not be applied as a constraint.

Standby storage – to provide water during an emergency event such as a power failure or source outage. There is significant variation in how standards recommend this volume be calculated. Requirements must be determined for any system based on the reliability of supply sources with a view to the type of emergency likely to be encountered, and the likely duration of an emergency event.

Fire Storage – to provide water for fire suppression. The volume of storage that should be maintained for fire suppression is calculated based on the size and duration of fire events typically associated with the building type or land use of a specific location.

Dead Storage – tank level/volume at which 20 psi cannot be maintained at customer connections. This will vary depending on the area served by each tank. Dead storage is also the volume at the top of the tank that is above the overflow or upper (off) set point of a pump filling the tank.

An additional important consideration is water quality; it is inadvisable to install excessive amounts of storage due to potential lack of turnover and the associated potential for water quality degradation.

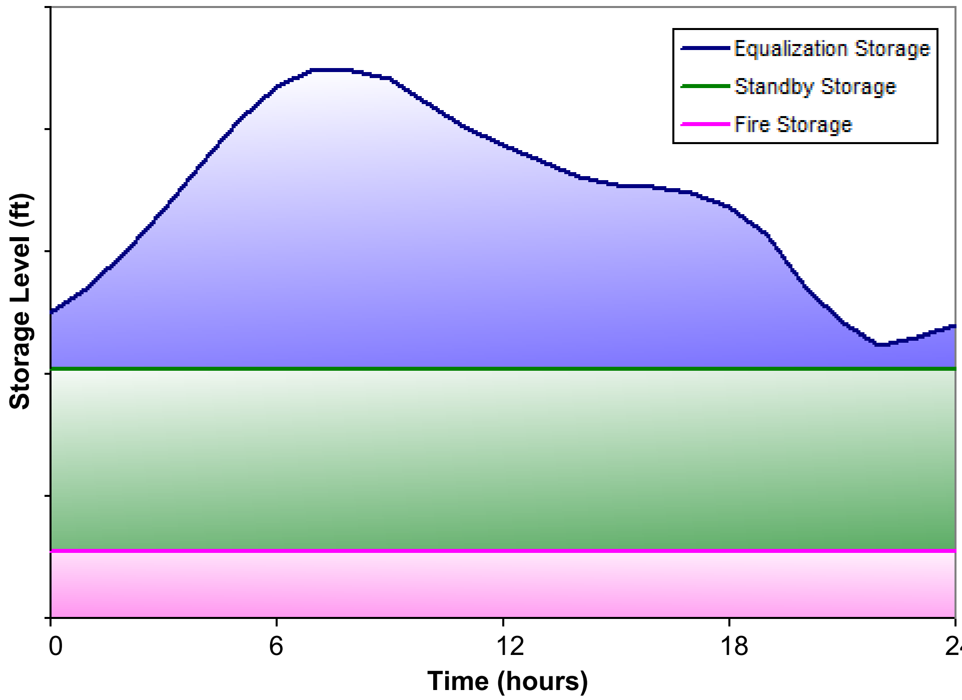


Figure 1 – Typical Components of Storage

3.2 Previous Recommendations – 2007 Master Plan

The 2007 Master Plan proposed the following be used to determine necessary system storage capacity at Build-out:

Operational Storage: 25% of maximum day demand (MDD)

Standby Storage: Two days of average day demands (ADD), met through a combination of above-ground storage and 'aquifer' storage. (Recommended ratio was 'aquifer storage' to meet roughly 55% of the total (i.e. operational, standby and fire) storage requirement by the end of the planning period. This was accompanied by a recommendation that back-up power generation capabilities should be implemented at all groundwater well sites to help minimize risks relating to water supply during power failures.)

Fire Suppression Storage: Table 1 presents the assumed fire flow rates and durations used by MSA in the 2007 Master Plan Update to calculate fire storage requirements. The storage analysis assumed fire flow rates of 3,000 gpm and 5,000 gpm, in lieu of 2,500 gpm and 3,500 gpm for the respective commercial and industrial zoning designations to account for the potential for more than one fire occurring at a time. The resultant fire storage is 180,000 gallons for residential areas, 540,000 gallons for commercial/industrial areas, and 1,500,000 gallons for the commercial highway zone.

Table 1 – Summary of recommended fire storage volumes – 2007 Master Plan

Zone	Zoning Description	Fire Flow Rate for Storage Calculation (gpm)	Duration (hours)	Recommended Fire Storage Volume (MG)
RS	Residential Urban Standard	1,500	2	0.18
RM	Residential Urban Medium	1,500	2	0.18
RH	Residential Urban High	1,500	2	0.18
CN	Commercial Neighborhood	3,000	3	0.54
CC	Commercial Convenience	3,000	3	0.54
CL	Commercial Limited	3,000	3	0.54
CG	Commercial General	3,000	3	0.54
CBD	Industrial Park	3,000	3	0.54
IP	Industrial Light	3,000	3	0.54
IG	Industrial General	3,000	3	0.54
CH	Commercial Highway	5,000	5	1.50

3.3 Summary of available standards from neighboring states/regions

Table 2 summarizes and compares the different storage guidelines from Oregon and neighboring states, AWWA Standards and Manuals, and the Ten States Standards. Appendix A provides a more detailed summary of the relevant sections of each state's/regional body's rules or guidelines; links to the full documents from Oregon, Washington, Idaho and the Ten States Standards have been provided. The rules and guidelines can also be found on the internet by searching for the relevant Rule/Standard reference numbers or titles.

Table 2 – Summary of Storage Guidelines in different states/regions

<table>
<tr><th colspan="2"></th><th>2007 Master Plan Update</th><th>Oregon
Administrative Rules
333-061 Ch 50 & 60</th><th>AWWA
G200 and M32</th><th>Ten States Standards
Part 7, 2007</th><th>Washington
Water System Design Manual
December 2009</th><th>Idaho
IDAPA 58.01.08</th></tr>
<tr><td colspan="2">Dead</td><td></td><td></td><td></td><td></td><td>Volume above maximum pump lift or static hydraulic grade.</td><td>Volume above the overflow.</td></tr>
<tr><td rowspan="4">Effective Storage</td><td>Operating</td><td rowspan="2">25% of MDD</td><td rowspan="3">Master Plans should include an evaluation of storage requirements.

Defer to AWWA Standards</td><td rowspan="2">M32: Typically 10 to 15 percent of the average demand over a 24-hour period.</td><td rowspan="3">Storage level variation not to exceed 30 ft.

Minimum working pressure 35 psi.

Minimum storage requirement for systems not requiring fire protection shall be equal to the average daily consumption.

This may be reduced when sources with standby power have the capacity to supplement peak demands.</td><td>Volume between the on and off set-points of the pump(s) supplying the tank.</td><td>"Operational storage supplies water when, under normal conditions, the sources are off. This is generally the volume between the pump on and pump off levels."</td></tr>
<tr><td>Equalization</td><td>Must be able to maintain 30 psi at service connections.

$ES = (PHD - Q_S) \times 150$ minutes
ES = gallons (>0)
PHD = peak hourly demand (gpm)
Q_S = sum of capacity of all installed and active sources of supply (not including emergency sources)</td><td>"Storage of finished water in sufficient quantity to compensate for the difference between a water system's maximum pumping capacity (with largest pump out of service) and peak hour demand."</td></tr>
<tr><td>Standby</td><td>2 x ADD</td><td>Maintain 20 psi at service connections.

M32: "The amount of emergency storage is a policy decision based on an assessment of the risk of failures and the desired degree of system dependability. An assessment must be made of the type and nature of the emergency condition, including the frequency, intensity and duration."</td><td>Must be able to maintain 20 psi at service connections.

$SB_{TMS} = (2 \text{ days}) \times [N \times ADD - t_m \times (Q_S - Q_L)]$
SB_{TMS} = standby storage for a system with multiple sources (gallons)
N = number of ERUs (equivalent residential units)
ADD = average day demand (gpd/ERU)
Q_S = sum of all installed and continuously available source of supply capacities, except emergency sources (gpm)
Q_L = largest capacity source available to system (gpm)
t_m = time that remaining sources are pumped on the day when the largest source is not available (minutes)

May reduce if community is amenable to lesser capacity (say 1 day of storage).
No less than 200 gallons/ERU.</td><td>"Standby storage provides a measure of reliability or safety factor should sources fail or when unusual conditions impose higher than anticipated demands. Normally used for emergency operation",

8 hours of average day demand if standby power is not provided.</td></tr>
<tr><td>Fire</td><td>Residential: 0.18 MG
Commercial/Industrial: 0.54 MG
Commercial HWY: 1.5 MG</td><td>Storage facilities should be sized to accommodate fire flows if fire hydrants are provided.</td><td>Maintain 20 psi at service connections.
M32: Equals flow duration multiplied by the maximum fire flow in each service area.</td><td>Fire flow requirements should be satisfied where fire protection is provided.</td><td>20 psi at all points in the system under MDD + fire.

FSS (gallons) = Fire Flow x duration</td><td>Volume required by the fire authority to provide fire flows for the fire duration, i.e. X gpm for Y hours.</td></tr>
<tr><td colspan="2">Dead</td><td></td><td></td><td></td><td></td><td>Level of storage below which 20 psi cannot be maintained at all service connections.</td><td>Volume below outlet or substandard flow and pressure.</td></tr>
</table>

Recommended that 55% of total storage needs be allocated to 'aquifer storage'.

WA Note:
The lesser of FSS or SB storage can be excluded from the storage requirement unless prohibited.

A 'continuously available' source must:
- be equipped with functioning pumping equipment (and treatment equipment, if applicable)
- be exercised regularly to ensure integrity
- always have available supply
- be activated automatically based on pre-set parameters

ID Note:
Storage components are additive and their associated volumes cannot be counted for use in more than one component.

4 Additional Considerations

Prior to making a recommendation regarding storage volume guidelines for Bend, it is important to consider additional practical limits and constraints that are likely to be faced. In particular, available land for new storage (which will impact the total maximum storage volume that could be accommodated, regardless of budget considerations) and future supply capacity (specifically groundwater capacity) are important factors to consider.

4.1 Available sites for storage

As part of the Master Plan Update Optimization Study, Optimatics completed a review of existing and potential new storage sites throughout the system (see Appendix B). This includes park areas on the buttes (e.g. placing tanks under tennis courts) and potential vacant lots throughout Level 6 and the eastern portion of Level 5 (for pumped ground storage). The review has shown space for approximately 60 MG of additional storage, and potentially up to 84 MG of additional storage depending on the ability to install new tanks on land that is not currently owned by the City.

Note that pumped ground storage (i.e., storage at ground level which is lifted to system pressure using booster pumps) can only be relied upon to meet standby storage requirements if the associated pump station has:

- back-up power
- capacity to meet peak hour and fire flow requirements
- automatic controls to turn pumps on in emergency conditions (say, pressure below 30 psi)

The Master Plan will assume that such conditions would be met in the design and operation of any pumped ground storage facilities.

4.2 Estimated groundwater supply capacity, existing and Build-out

As mentioned above, the firm supply capacity of a system is the capacity of all sources excluding the largest source. For Bend, the firm supply capacity will be the capacity of in-service groundwater wells (i.e., the total supply capacity without the surface water source).

The Washington Design Manual specifies that only ‘continuously available’ sources should be relied upon to meet standby storage needs. In relation to wells this means the well must be in-service, properly maintained, and able to be activated via SCADA. The manual implies that for sources to be considered equivalent to gravity storage, the sources should have auxiliary power that starts automatically if the primary power feed is disrupted. Additionally, any well that is relied upon to offset standby storage needs should be located proximate to a second well equivalent well – the capacity of the largest well at each site should be discounted.

Bend has advised that generators in their system do start automatically in the event of power loss; however there is a need in some cases for the wells to be restarted manually. In the future it is expected that SCADA would be used to do this remotely, reducing the time when wells are offline.

Table 3 lists the current well facilities (including recently constructed wells) with an indication of whether the pumps can be controlled via SCADA, and whether back-up power is available. By April 2011 there will 32.3 MGD of well capacity in the Bend system (assuming Outback 7, Pilot Butte 4 and Shilo in service; Rock Bluff 2 not in service). Those that are on SCADA and also have back-up power account for 9.0 MGD of capacity.

The Washington Standards also discuss how a system could be equipped with excess supply capacity to help offset equalizing and potentially fire suppression storage requirements. Using wells to offset equalizing storage is likely to increase system operating costs, and also places a higher reliance on groundwater pumping. Relying on wells to offset fire suppression storage could be feasible for Bend, but is not recommended due to the system size and complexity.

Table 3 – Summary of Groundwater Well Capacity, SCADA capability and Back-up Power (April 2011)

Groundwater Production Facility	Zone Supplied	Capacity (MGD)	SCADA Present	Capacity With SCADA	Back-up Power	Capacity With Back-up Power	Redundant Capacity Back-up & SCADA
COPPERSTONE_W	3	1.4	N	0	N	0	0*
OUTBACK_W1	3	1.0	N	0	Y	1.0	0
OUTBACK_W2	3	1.1	N	0	N	1.0	0
OUTBACK_W3	3	1.7	Y	1.7	Y	1.7	1.7
OUTBACK_W4	3	1.7	Y	1.7	Y	1.7	1.7
OUTBACK_W5	3	1.8	Y	1.8	N	1.8	0*
OUTBACK_W6	3	1.8	Y	1.8	Y	1.8	1.8
OUTBACK_W7[1]	3	1.8	Y	1.8	Y	1.8	1.8
OUTBACK_W8	3	*Future*					
WESTWOOD_W	4A	1.0	Y	1.0	N	0	0
BEAR_CREEK_W1	4B	1.5	Y	1.5	N	0	0
BEAR_CREEK_W2	4B	1.6	Y	1.6	N	0	0
ROCK_BLUFF_W1	4B	1.2	Y	1.2	Y	1.2	1.2
ROCK_BLUFF_W2	4B	0.0[2]	N	0	N	0	0
ROCK_BLUFF_W3	4B	1.2	Y	1.2	Y	1.2	0*
PILOT_BUTTE_W1	5	1.2	N	0	N	0	0
PILOT_BUTTE_W2	*5*	*Decommissioned*					
PILOT_BUTTE_W3	5	1.3	N	0	N	0	0
PILOT_BUTTE_W4[3]	5 (4B emerg)	1.6	Y	1.6	Y	1.6	0*
RIVER_W1	5	2.7	N	0	N	0	0
RIVER_W2	5	3.0	N	0	N	0	0
SHILOH_W1	3D	0.0	N	0	N	0	0
SHILOH_W2	3D	0.0	N	0	N	0	0
SHILOH_W3[4]	3D/4B	2.0	Y	2.0	Y	2.0	0*
HOLE_10_W1	2B	0.8	Y	0.8	Y	0.8	0*
HOLE_10_W2	2B	0.8	Y	0.8	Y	0.8	0.8
Total Groundwater Capacity		**32.3**		**20.5**		**18.5**	**9.0**

Notes * Although these wells have back-up power and are connected to SCADA, they are not redundant

1) Outback 7 online by April 2011
2) Rock Bluff 2 is out of service, not expected to be returned to service
3) Pilot Butte 4 online by April 2011 - Generator confirmed but well is not redundant without Pilot Butte 1 or 3
4) Out of service; online April 2011 with portable generator plug in facilities following upgrade, not redundant

Approximately 30% of the existing wells have back-up power currently, and in many cases a single generator has the ability to power one of two, or two of three, wells at an individual site. This is taken into account in the table above. This makes the reliability of the generators a key factor in Bend's 'continuously available' supply.

At Build-out, it is assumed that all new wells will be linked to SCADA. Some will likely be equipped with back-up power. A percentage of these may be less reliable, e.g. Pilot Butte and Bear Creek Wells have exhibited limits in their transmissivity and should not be called upon to deliver supply beyond their stated capacity. However, it seems reasonable to assume that 50% of in-service wells could be relied upon as 'continuously available' sources.

5 Analysis of Required Storage in the Bend System under WA and ID Standards

Table 4 provides a listing of current storage capacity in the Bend system sorted by pressure level.

Table 4 – Existing storage summary (sorted by pressure level)

Reservoir Name	Reservoir Type	Capacity (mg)	Pressure Level Served
Tower	Welded Steel	1.00	1
College I	Welded Steel	0.50	2
College II	Welded Steel	1.00	2
CT Basin	Bolted Steel	1.50	3
Outback I	Bolted Steel	2.00	3
Outback II	Welded Steel	3.00	3
Outback III	Welded Steel	3.63	3
Westwood	Welded Steel	0.50	4A, Westwood (pumped)
Overturf I	Riveted Steel	1.50	4A
Overturf II	Riveted Steel	1.50	4A
Pilot Butte II	Welded Steel	1.00	4B
Rock Bluff	Welded Steel	1.50	4B
Awbrey	Concrete	5.00	5
Pilot Butte I	Welded Steel	1.50	5
Pilot Butte III	Concrete	5.00	5
Total Storage Capacity		**30.13**	

5.1 Lower Dead Storage

An analysis to compare tank elevations to service connection elevations was undertaken to see whether any storages exhibit dead storage (i.e., storage at a level below which 20 psi cannot be maintained in the zone supplied). Based simply on static pressure, no tanks have their base elevation less than 46 ft (i.e. 20 psi) above the highest elevation connection. To be conservative, a 25 psi static level has been used to calculate dead storage. Table 5 lists the tanks in the system and notes which tanks cannot provide a static pressure of 25 psi to all service connections which they supply. The percentage of the total tank volume that is below the 25 psi threshold is given in the final column and has been taken into account in the subsequent storage calculations. Based on this measure, system-wide the dead storage volume is approximately 4% of total storage (1.5 MG).

The limiting node in Zone 4A (JCT-152, elevation 3,794 ft) is directly downstream of the Westwood Well and in close proximity to the Westwood Tank. The Westwood Tank is important to maintain pressure at this node. If this tank is removed from the system in the future it would be advisable to either shift this customer to Level 3 or provide an emergency connection from Level 3 at this location that would activate if pressure dropped below, say, 30 psi.

Table 5 – Analysis of dead storage compared to service pressure of 25 psi under static conditions

Zone	Maximum Ground Elevation	Node ID	Elevation +20 psi	Elevation +25 psi	Tank Name/ID	Base El	Diff. from 25 psi Level	Dead Storage
1	4,160	JCT-3112	4,206	4,218	TOWER_ROCK	4213.0	-4.7	15%
2	4,032	JCT-3086	4,078	4,090	COLLEGE_2	4087.9	-1.8	6%
		Awbrey Butte			COLLEGE_1	4095.8	6.1	-
3	3,910	JCT-3187	3,956	3,968	OUTBACK_CT_BASIN	3980.0	12.3	-
		Awbrey Butte			OUTBACK_1	3976.0	8.3	-
					OUTBACK_2	3976.0	8.3	-
					OUTBACK_3	3982.0	14.3	-
4A[1]	3,794	JCT-152[1]	3,840	3,851	WESTWOOD	3842.0	-9.4	34%[1]
		Near Westwood			OVERTURF_WEST	3844.0	-7.4	26%[1]
					OVERTURF_EAST	3844.0	-7.4	26%[1]
4B	3,774	JCT-1009	3,820	3,832	ROCK_BLUFF_1	3841.0	9.3	-
		Near Rock Bluff			PILOT_BUTTE_2	3840.5	8.8	-
5	3,696	JCT-1960	3,742	3,754	AWBREY	3775.0	21.3	-
		Near Galveston PRV			PILOT_BUTTE_1	3750.0	-3.7	12%
					PILOT_BUTTE_3	3757.3	3.6	-
6	3,586	JCT-4596 Boyd Acres & Ross PRV	3,632	3,644	Planned Juniper Ridge	3673.0	29.3	-

1) Dead storage in Zone 4A governed by single node near Westwood. Next highest elevation node at 3,765 ft. Suggest considering Overturf as having no dead storage.

2) If 20 psi was used as the criterion for Dead storage, no storages would exhibit Lower Dead Storage

5.2 *Operating, Equalizing and Upper Dead Storage*

Each of the standards/guidelines presented in Table 2 have different methods for estimating operating and equalizing storage volumes. For equalizing storage, the two quantitative measures are:

WA Design Manual: *Equalization Storage (ES) = (PHD – Σ Active Sources) x 150 minutes*

Idaho Rules: *Equalization Storage (ES) = (PHD – Maximum Firm Capacity)*

The 2007 Master Plan suggested that *Operating + Equalization Storage (OES) = 25% x MDD*

Existing Conditions

Since the Bend system is designed to have supply greater than or equal to MDD, the WA method can be interpreted as: *(PHD – MDD)*150 minutes*. This results in calculation of 2.4 MG of equalization storage for the existing system.

Idaho's Rules specify that equalizing storage should meet the difference between maximum firm supply capacity and peak hour demand, which is similar to the Washington guidelines. However, this rule is slightly ambiguous as it does not indicate a timeframe or how to convert the difference to a volume.

Figure 2 shows the estimated variation in system demand on a maximum day (29 MGD) and compares this with the firm capacity of the system (i.e. supply capacity without the surface water supply, being the capacity of in-service wells, 30 MG from Table 3 or 20,833 gpm). The volume needed to meet demand during times when demand exceeds supply is calculated as the area between the demand curve and the supply curve. The total volume by this definition is 3.9 MG. This value is conservative, however, as it does not account for recovery of storage volume in the middle period of the day when demands are lower. The necessary volume could be taken as 2.7 MG, based on the period where demand exceeds supply to the greatest extent.

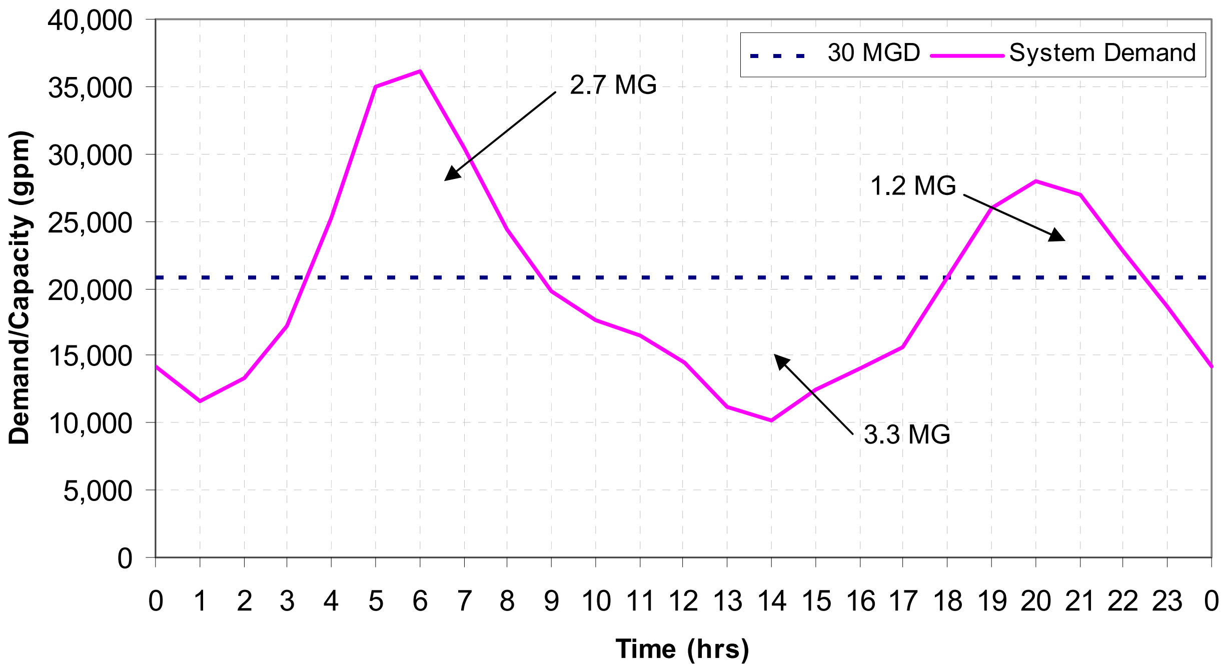


Figure 2 – Estimation of Equalization Storage – Idaho Rules
Comparison of System Demand to Firm Supply Capacity, Existing MDD

For the existing system we can analyze the sum of 'upper' dead storage, operating storage and equalization storage based on the levels in the tanks in the hydraulic model. Table 6 presents an analysis of storage volumes in the existing system under maximum day conditions.

The 2007 Master Plan suggested calculating operating and equalization storage volume as 25% of MDD. Under existing conditions, 25% of MDD (29 MGD) is 7.25 MG. Analysis of storage levels in the existing calibrated hydraulic model indicates an 'actual' system-wide operating, equalization and upper dead storage volume of 10.1 MG (see Table 6) under maximum day demand conditions, or 35% of MDD.

Table 6 – Operating (O), Equalization (E) and Upper Dead (UD) Components of Storage Calibrated EPS Model

Storage	Storage Volume (MG)	Minimum Operating Level, MDD[1]	Volume above Minimum level (O, E + UD, MG)	Lower Dead Storage (< 25 psi)	Reserve Volume (MG)[2]
TOWER_ROCK	1.0	83%	0.17	15%	0.68
COLLEGE_1	0.5	75%	0.12	0%	0.38
COLLEGE_2	1.0	67%	0.34	6%	0.62
OUTBACK_1[3]	2.3	67%	0.75	0%	1.54
OUTBACK_2[3]	3.0	77%	0.70	0%	2.33
OUTBACK_3	3.7	65%	1.28	0%	2.40
WESTWOOD	0.5	51%	0.23	34%	0.08
OVERTURF_EAST	1.4	81%	0.26	26%	0.78
OVERTURF_WEST	1.4	75%	0.35	26%	0.68
ROCK_BLUFF_1	1.5	85%	0.24	0%	1.31
PILOT_BUTTE_2	1.0	67%	0.33	0%	0.66
AWBREY	5.1	73%	1.37	0%	3.76
PILOT_BUTTE_1	1.5	57%	0.63	12%	0.67
PILOT_BUTTE_3	5.0	34%	3.32	0%	1.72
Totals	**29.0**		**10.09**		**17.60**

1) Level is minimum level as a percentage of total height

2) Reserve Volume = (Minimum Operating Level % – Lower Dead Storage %) x Storage Volume

3) Under existing conditions, Outback 1 and 2 are required for chlorine contact time and hence cannot be relied upon to meet standby storage requirements. However, when the surface water treatment has been upgraded, this storage will become available. Note: The CT Basin at Outback has not been included in these calculations

Build-out Conditions

For the Build-out case (37.1 MGD ADD and 83.5 MGD MDD):

- WA method: *(PHD – MDD)*150 minutes*, yields Equalization Storage = 6.6 MG.
- The Idaho Rules: calculation is shown in Figure 3 and yields Equalization Storage = 8.1 MG
- 2007 Master Plan: 25% of MDD yields Operating & Equalization Storage = 20.9 MG

Recommendations for estimating future Operation, Equalization and Upper Dead Storage

Based on the analysis of the existing system, it appears that 25% times MDD gives a reasonable indication of the combined operating and equalization storage needs, however it may not account for dead storage at the top of the tanks. Optimatics suggests the figure be increased to 35% of MDD to account for this unused storage.

As has been mentioned, the estimation of operating and equalization volumes should be considered a guide only. Optimatics recommends that all future storage planning include hydraulic modeling to verify necessary operating and equalization volumes. The optimization analysis will account for operating and equalization storage implicitly, and the constraints applied to storage will ensure that standby and fire suppression storage volumes are maintained (above the dead storage level, if applicable) at all times during maximum day operations.

Table 7 summarizes the different volumes calculated for operating, equalization and upper dead storage under the different guidelines for both existing and Build-out conditions.

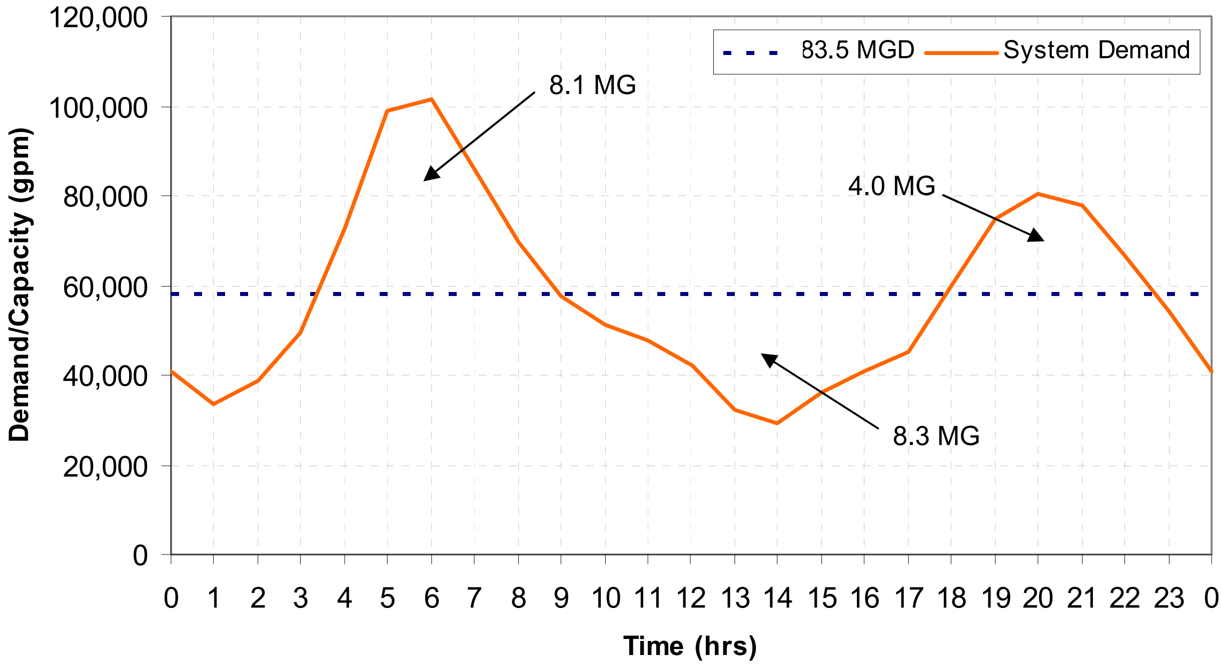


Figure 3 – Estimation of Equalization Storage – Idaho Rules
Comparison of System Demand to Assumed Firm Supply Capacity, Build-out MDD

Table 7 – Summary of Operation, Equalization and Upper Dead Storage Volumes by different methods

Calculation Method	**Existing** (MG)	**Build-out** (MG)
Equalization Storage Volume		
WA Design Manual *(PHD – Σ Active Sources) x 150 mins*	2.4	6.6
Idaho Rules *Maximum firm supply - PHD*	2.7	8.1
Operating & Equalization Storage Volume		
2007 Master Plan *25% x MDD*	7.3	20.9
Operating, Equalization & Upper Dead Volume		
Existing Model Analysis	10.1	TBD
Proposed Estimation 35% x MDD	10.1	29.2

5.3 *Standby Storage*

The methods of estimating standby storage presented in Table 2 are the major point of difference between the standards/guidelines being reviewed. Essentially, three potential calculations are put forward:

1) *2 x ADD – Capacity of continuously available sources* (WA Design Manual)
2) *1 x ADD* (WA Design Manual, subject to public acceptance)
3) *8 hours x ADD* (Idaho Rules)

For (1) above, a source is ‘continuously available’ if it meets the following requirements:

- The source is equipped with functional pumping (and, if necessary, treatment) equipment
- The equipment is exercised regularly to ensure its integrity
- Water is available from the source year round
- The source activates automatically based on pre-set parameters (reservoir level, water system pressure, or other conditions)

In addition, the WA design manual suggests that for sources to be considered equivalent to gravity storage, the sources should have auxiliary power that starts automatically if the primary power feed is disrupted.

For the Bend system, this equates to offsetting the 2 x ADD requirement by the capacity of normally reliable, functioning wells that are on SCADA and can be triggered to turn on automatically. It is recommended that only wells with back-up power should be considered in the calculation of continuously available supply capacity; back-up power should be able to start remotely.

Table 8 shows the estimations of necessary stand-by storage volumes based on the three methods listed above on a system-wide basis.

Table 8 – Estimation of Standby Storage Volumes and Potential Offsets - Existing and Build-out

Standby Volume Criterion	**Existing System** ADD 12.8 MGD	**Existing System** Potential offset (capacity in MGD x 2 days)	**Build-out** ADD 37.1 MGD	**Build-out** Potential offset (capacity in MGD x 2 days)
2 x ADD	25.7 MG	18.0 MG [1]	74.2 MG	83.5 MG [2]
1 x ADD	12.8 MG	n/a	37.1 MG	n/a
8 hours of ADD	4.3 MG	n/a	12.4 MG	n/a

1) The capacity of wells with back-up power and SCADA, running for 2 days, *refer to Table 3*
2) Build-out well capacity calculated assuming:
    a. The capacity of wells at Build-out will be equal to MDD, to ensure firm capacity equals MDD
    b. All wells will be able to be started automatically via SCADA, 50% of wells will have back-up power
    c. Wells can run continuously to meet the 2 x ADD volume requirement

5.4 Fire Suppression Storage

The fire suppression storage volumes used in the 2007 Master Plan Update are somewhat conservative in that they assume a higher fire flow rate than is required for the commercial, industrial and highway zone land use types. The higher flow rate is to account for the possibility of two fires occurring at once. Given the extent of the areas supplied by each of the storages that support the commercial and industrial zones, specifically in Zone 4B and Levels 5, 6 and 7, it seems prudent to be conservative in the calculations.

Optimatics recommends that the same fire flow rates and durations used in the 2007 Plan are used in the current Water System Master Plan Update Optimization Study. In addition to using the higher fire flow rates to estimate storage volumes, because Level 5 storage supports Levels 5, 6 and 7, the needed fire suppression volume has been doubled for the Level 5 storages. The associated system-wide storage volume required for fire suppression in the Bend system is therefore 7.3 MG. This will not change as the system grows, unless the land use classifications change in the future.

Given the size and configuration of the Bend system, using additional groundwater pumping capacity to offset fire suppression storage is not recommended. It should be noted however that the constant pressure pumped areas of the system (Tetherow and South Bend) must be designed such that fire flow rates can be provided at the pump station and that back-up power must be available.

5.5 Total Storage Needs – Existing and Build-out Conditions

Table 9 and Table 10 provide a more detailed analysis, zone by zone, for existing and future Build-out conditions, respectively. In the existing system analysis, the capacity of wells with SCADA and back-up power (refer Table 3) have been used to help meet the necessary storage volumes where applicable, based on the zones in which the wells are located and how supply can be moved through the system via PRVs and booster pump stations. Note that Table 9 shows approximately 7 MG of above-ground storage is available to meet a portion of the total standby storage needs. The existing system therefore has a slight deficit in standby volume when the continuously available supply capacity (2 x 9.0 MGD from Table 3 = 18.0 MG) is combined with the above-ground capacity (total of 25.1 MG compared to a requirement of 25.7 MG as per Table 8).

Storage in Outback 1 and 2, originally designed to meet operational needs, currently are necessary to meet chlorine contact time requirements. Once the surface water supply upgrades are in place, these storages will be able to contribute to standby storage. Also if the River Wells are placed on SCADA and have back-up power available, the deficit in Levels 5, 6 and 7 would be eliminated.

For the Build-out system analysis, an indication of the overall storage deficit has been provided in Table 10, but no offset from wells has been applied. As Table 8 shows, the potential offset could be significant. It should be emphasized, however, that due to the operational needs of the system (i.e. maintaining 40 psi during normal operation) there will always be some volume of emergency storage held above-ground; the potential offset does not imply that all standby storage would be allocated to the aquifer. Section 6 discusses potential well offsets in the different pressure levels.

Table 9 – Available Storage and Required Volumes – Existing System

Storage	A Storage Volume (MG)	B Lower Dead storage (static 25 psi)	C Minimum level - MDD		D Emergency Vol Avail (MG) =(C-B)*A	E Fire suppression (MG) TBC	F Standby Avail (MG) =D-E
TOWER_ROCK	1.0	15%	83%	0.17	0.68	0.18	0.50
COLLEGE_1	0.5	0%	75%	0.12	0.38	0.54	0.46
COLLEGE_2	1.0	6%	67%	0.34	0.62		
OUTBACK_1	2.3	100%	n/a, required for CT			1.50	0.90
OUTBACK_2	3.0	100%	n/a, required for CT				
OUTBACK_3	3.7	0%	65%	1.28	2.40		
OUTBACK_CT_BASIN	1.5	100%	n/a, required for CT				
WESTWOOD	0.5	34%	51%	0.23	0.08	0.54	1.64
OVERTURF_EAST	1.4	0%	75%	0.35	1.05		
OVERTURF_WEST	1.4	0%	75%	0.35	1.05		
ROCK_BLUFF_1	1.5	0%	85%	0.24	1.31	1.50	0.46
PILOT_BUTTE_2	1.0	0%	67%	0.33	0.66		
AWBREY	5.1	0%	73%	1.37	3.76	3.00	3.14
PILOT_BUTTE_1	1.5	12%	57%	0.63	0.67		
PILOT_BUTTE_3	5.0	0%	34%	3.32	1.72		
Totals	**30.5**	**24%**		**8.73**	**14.36**	**7.26**	**7.10**
							28%

G: - - ▸ Pumping; ——▸ Direct/PRV

Zone		H Standby Requirement 2xADD	I Combined Requirement 2xADD (MG) =SUM(H)	J Offset from Wells SCADA + Backup (2 days x MGD)	K Allocation to/from other zones	L Capacity ÷ Requirements =(F+J+K)/I
1		0.76	0.76		0.26 (From 3)	100%
2		0.68	0.81		0.35 (From 3)	100%
2A	Teth PS, 3	0.00	in 3			
2B	South Bend - with 3D	0.14	0.29	*Hole Ten* 1.60	-1.31 (To 4B)	100%
3		2.36	3.70	*Outback, Copperstone* 14.00	-11.20 (To various)	100%
3A		0.02	in 2			
3B		0.10	in 2			
3C	WestW PS, 4A	0.43	0.67		0.67 (From 3)	100%
3D	South Bend - with 4B	0.14	in 2B	*Shilo* 0.00		
4A		1.37	1.37	*Westwood* 0.00	-0.26 (To 5, 6, 7)	100%
4B		3.91	3.91	*Bear Creek, Rock Bluff* 2.40	1.31 (From Hole 10)	107%
4C		0.24	in 3			
4D		0.17	in 3			
4E		0.41	in 3			
4F		0.10	in 3			
4G		0.05	in 3			
4H	Off Westwood	0.14	in 3C			
4I	Off Westwood	0.10	in 3C			
4J		0.14	in 3			
4K		0.03	in 3			
5		8.57	14.17	*River, Pilot Butte* 0.00	10.19 (From 3)	94%
5A		0.02	in 3			
5B		0.04	in 3			
5C	With 4E	0.00	in 3			
5D		0.06	in 3			
6		4.28	in 5			
6A		0.49	in 5			
6B		0.07	in 3			
7A	With 5B	0.50	in 5			
7B		0.22	in 5			
7C		0.11	in 5			
7D		0.02	in 5			
Totals		**25.68**	**25.68**	**18.00**	**0.00**	**98%**
		% of standby storage requirement		70%		

**** Adding back-up power to PB3, or SCADA and back-up power to River Wells will assist***

Notes:

Columns A through F calculate available emergency storage (D) and determine how much standby storage is available (F) once fire suppression needs (E) have been accounted for.

The volume of storage available to meet standby requirements is calculated based on the difference between the minimum tank level observed in the 2009 EPS model under MDD (C) and the calculated dead storage volumes (B), as applicable (see Table 5).

Column G shows how storage can be allocated to zones within the system, either by gravity (solid line) or via a booster pump station (dashed line).

Column H shows the standby requirement, which is 2 x ADD for each zone. Column I combines the requirement for zones which have a common supporting storage.

Column J through L take into account wells that can be operated via SCADA and have back-up power that may offset above-ground storage needs and determines whether there is sufficient supply/storage to meet standby requirements.

Assumptions:

1. Excess storage located in higher pressure levels can be allocated to support the needs of lower pressure levels. Hydraulic model testing would be required to verify that the distribution system can facilitate this in all instances.
2. Wells with back-up power can run for 24 hours at rated capacity to provide a daily volume equal to their rated capacity (in MG).

Table 10 – Available Storage and Required Volumes – Build-out System

Storage	Storage Volume (MG)	Dead storage (assume 5%)	Effective Vol Avail (MG)	Fire suppression (MG) TBC	Standby Avail (MG)	- - ► Pumping ──► Direct/PRV	Zone		Standby Requirement 2xADD	Op/Eq + Dead 0.35xMDD	Effective = Op/Eq + Standby + Fire	Deficit
	A	B	C	D	E	F			G	H	I	J
			=(1-B)*A		=C-D						=SUM(G,H)	=D+E-I
TOWER_ROCK	1.0	15%	0.85	0.18	0.67		1		1.16	0.46	1.80	-0.95
COLLEGE_1	0.5	0%	0.51	0.54	0.92		2		1.21	0.48	2.63	-1.17
COLLEGE_2	1.0	6%	0.96									
							2A	Teth PS, 3	0.31	0.12	*in 3*	
							2B	South Bend - with 3	0.54	0.21	*in 4B*	
OUTBACK_1	2.3	0%	2.29									
OUTBACK_2	3.0	0%	3.03	1.50	7.50		3		10.55	4.15	28.03	-19.03
OUTBACK_3	3.7	0%	3.68									
OUTBACK_CT_BASIN	1.5	100%	(required for CT)				3A		0.19	0.08	*in 2*	
							3B		0.10	0.04	*in 2*	
							3C	WestW PS, 4A	0.99	0.39	*in 3*	*was in 4A*
							7	North Awbrey Butte	0.99	0.39	*in 3*	
							3D	South Bend - with 4	0.88	0.35	*in 2B*	
WESTWOOD	0.5	34%	0.31									
OVERTURF_EAST	1.4	0%	1.40	0.54	2.57		4A		3.17	1.25	4.96	-1.85
OVERTURF_WEST	1.4	0%	1.40									
ROCK_BLUFF_1	1.5	0%	1.54	1.50	1.03		4B		10.82	4.26	18.56	-16.03
PILOT_BUTTE_2	1.0	0%	0.99									
							4C		0.30	0.12	*in 3*	
							4D		0.29	0.11	*in 3*	
							4E		1.63	0.64	*in 3*	
							4F		0.16	0.06	*in 3*	
							4G		0.24	0.10	*in 3*	
							4H	Off Westwood	0.19	0.07	*in 3*	*was in 4A*
							4I	Off Westwood	0.54	0.21	*in 3*	*was in 4A*
							4J		0.23	0.09	*in 3*	
							4K		0.06	0.02	*in 3*	
AWBREY	5.1	0%	5.13									
PILOT_BUTTE_1	1.5	12%	1.30	3.00	8.46		5		16.25	6.40	54.70	-43.24
PILOT_BUTTE_3	5.0	0%	5.04									
							5A		0.02	0.01	*in 3*	
							5B		1.27	0.50	*in 3*	
							5C	With 4E	0.04	0.01	*in 3*	
							5D		0.09	0.04	*in 3*	
							6		15.79	6.22	*in 5*	
							6A		0.77	0.30	*in 5*	
							6B		1.15	0.45	*in 3*	
							6C	Juniper Ridge	3.25	1.28	*in 5*	
							7A	With 5B	0.61	0.24	*in 5*	
							7B		0.22	0.09	*in 5*	
							7C		0.17	0.07	*in 5*	
							7D		0.03	0.01	*in 5*	
Totals	**30.5**		**28.4**	**7.26**	**21.15**				**74.20**	**29.22**	**110.68**	**-82.27**

6 Final Recommended Storage Guidelines

Based on the analysis and calculations presented in Section 5 as well as discussions with Bend staff, the following guidelines are recommended for adoption in future planning activities (Table 11). In an e-mail circulated on April 29, 2010 (see Appendix C), Optimatics presented the storage volume and cost implications of adopting the various guidelines presented above. After reviewing and discussing this information, Bend advised that it wishes to adopt the Washington Design Manual guidelines. In making this decision, Bend considered the following important issues:

- Well reliability: historically the City has experienced problems with a number of wells, particularly on Pilot Butte. In the future it is expected that mechanical equipment will be more reliable; however, it would be undesirable to rely on 100% of the well capacity.
- Availability of back-up power under emergency conditions: relying on wells to meet standby storage needs places increased reliance on back-up power and mechanical infrastructure, and also on fuel supplies to power emergency generators. The City has advised that is entitled to preferential use of diesel supplies in the event of an emergency.
- The reliability of the aquifer: trends show that aquifer levels have declined from previous levels; however, the decline has not been significant. Bend will need to continue to monitor the aquifer levels and may need to revise how much this source is relied upon if levels drop in the future.

If aquifer storage is the preferred option, the required well capacity needs to be evaluated to see if there may be a need for greater capacity than indicated by future supply needs alone.

Table 11 – Recommended storage component definitions for future planning activities

Upper Dead Operating Equalization	Estimate the combined operating, equalization and dead storage volumes as 35% x MDD. Planning Engineers must verify the necessary volume through hydraulic modeling. Modeling must verify that Standby and Fire storage volumes can be maintained under MDD conditions.
Standby	Ensure provisions for a standby volume of 2 x ADD. Wells may be relied on to offset the above-ground storage volume if the following conditions are met: - Only the capacity of wells that are located together with at least one or more reliable wells may be counted, with reliable capacity determined by the concept of firm capacity (largest well out of service) - Wells can be started automatically via SCADA - Wells have back-up power.
Fire	To be determined as per 2007 Master Plan, unless revised requirements are put in force (check with Fire Department): 2 hrs x 1,500 gpm = 0.18 MG Residential 2 hrs x 3,000 gpm* = 0.54 MG Commercial 2 hrs x 5,000 gpm* = 1.5 MG Highway Zone **Higher rates for commercial/highway zones account for chance of more than one fire occurring simultaneously* Given the significant potential to offset Standby storage with well supply, it is recommended that Bend not consider 'nesting' of standby and fire storage volumes.
Lower Dead	Assess based on a static pressure of 25 psi at all service connections.

6.1 Build-out System – Storage requirements

Table 12 lists the existing well facilities in the Bend system, along with potential capacity increases to meet future firm supply capacity needs. These are estimates only based on the distribution of demand in the system and the proposed location of new wells may be influenced by the optimization results. The final four columns of Table 12 compare total well supply capacity in the major pressure levels (3, 4A, 4B and 5, 6 and 7) to MDD (to give firm supply capacity without the surface water source), and firm standby capacity (only wells on SCADA, with back-up power, and with more than one well at a site) to ADD.

Table 13 presents the estimated storage volumes that would be necessary under Build-out conditions in each major pressure level, based on the various guidelines discussed in the previous sections. The final column shows whether wells could be used to offset the requirements, and the potential offset amount. The offset amount is 2 times the firm standby well capacity, assuming wells can operate for 2 days to meet the 2 x ADD standby requirement.

Table 12 – Comparison of Estimated Well Capacity and Demand by Pressure Level under Build-out Conditions

Groundwater Production Facility	Zone Supplied	Pump Size (hp)	Pump Type/ New Well Count	Capacity (MGD)	Total Capacity MGD	Demand MDD MGD	Future Back-up Power	Future SCADA Capability	Capacity Back-up + SCADA	Firm Stb Capacity MGD	Demand ADD MGD
COPPERSTONE_W	3	250	Line Shaft Turbine	1.4			N	N	0.0		
OUTBACK_W1[1]	3	150	Submersible	1.0			Y	N	0.0		
OUTBACK_W2[1]	3	150	Submersible	1.1			N	N	0.0		
OUTBACK_W3[2]	3	250	Line Shaft Turbine	1.7			Y	Y	1.7		
OUTBACK_W4[2]	3	250	Line Shaft Turbine	1.7			Y	Y	1.7		
OUTBACK_W5[2]	3	250	Line Shaft Turbine	1.8			N	Y	0.0		
OUTBACK_W6[3]	3	250	Line Shaft Turbine	1.8			Y	Y	1.8		
OUTBACK_W7[3]	3	250	Line Shaft Turbine	1.8			Y	Y	1.8		
OUTBACK_W8[3, 4]	*3*	*1.8 MGD*	*1*	*1.8*			*Y*	*Y*	*1.8*[10]		
New Level 3 (Outback)	*3*	*1.8 MGD*	*6*	*10.8*	24.9	24.4	*50%*	*Y*	*5.4*	12.4	10.8
WESTWOOD_W	4A	150	Submersible	1.0			N	Y	0.0		
New Level 4 (Overturf)	*4A*	*1.6 MGD*	*2*	*3.2*	4.2	3.6	*50%*	*Y*	*1.6*	1.6	1.6
BEAR_CREEK_W1	4B	350	Line Shaft Turbine	1.5			N	Y	0.0		
BEAR_CREEK_W2	4B	350	Line Shaft Turbine	1.6			N	Y	0.0		
ROCK_BLUFF_W1[5]	4B	150	Line Shaft Turbine	1.2			Y	Y	1.2		
ROCK_BLUFF_W2[5, 6]	4B	150	Submersible	1.1			N	Y	0.0		
ROCK_BLUFF_W3[5]	4B	150	Line Shaft Turbine	1.2			Y	Y	1.2[10]		
SHILOH_W3[7]	4B	250	Line Shaft Turbine	2.0			Y	Y	2.0[10]		
New Level 4 (Rock Bluff)	*4B*	*1.2 MGD*	*8*	*9.6*	18.2	12.2	*50%*	*Y*	*4.8*	6.0	5.4
PILOT_BUTTE_W1	5	250	Line Shaft Turbine	1.2			N	N	0.0		
PILOT_BUTTE_W2[8]	*n/a*	*250*	*Line Shaft Turbine*	*0.0*			*N*	*N*	*0.0*		
PILOT_BUTTE_W3	5	250	Submersible	1.3			Y	Y	1.3		
PILOT_BUTTE_W4[9]	5 (4B emerg)	300	Line Shaft Turbine	1.6			Y	Y	1.6[10]		
New Zone 5 (Pilot Butte, Awbrey)	*5*	*1.6 MGD*	*9*	*14.4*			*50%*	*Y*	*7.2*		
RIVER_W1	5	500	Line Shaft Turbine	2.7			Y	Y	2.7		
RIVER_W2	5	400	Line Shaft Turbine	3.0			Y	Y	3.0[10]		
New Zone 6 (Pumped ground facilities)	*6*	*1.8 MGD*	*6*	*10.8*	35.0	41.7	*50%*	*Y*	*5.4*	16.6	18.5
SHILOH_W1[7]	*3D*	*25*	*Submersible*	*0.0*			*N*	*N*	*0.0*		
SHILOH_W2[7]	*3D*	*25*	*Submersible*	*0.0*			*N*	*N*	*0.0*		
HOLE_10_W1	2B	150	Submersible	0.8			Y	Y	0.8		
HOLE_10_W2	2B	150	Submersible	0.8	1.6	1.6	Y	Y	0.8[10]	0.8	0.7
Total Groundwater Supply Capacity (MGD)				**83.9**	**83.9**	**83.5**				**37.4**	**37.1**

Key:

New Well	Assumed details
Assumed future SCADA/Back-up power status	
Not counted, not redundant	

Notes to Table 12

Well capacities are in line with those detailed in the memorandum *City of Bend Groundwater Rights and Wells – Version 7/1/2010*

1) Outback Well 1 & 2 portable generator has capacity to run one well at a time
2) Two of Outback Wells 3, 4 & 5 can run on one generator
3) Outback Well 6 generator should operate three wells eventually (6, 7 & 8)
4) Outback 8 is a planned future well
5) Generator at Rock Bluff is able to run two of the three wells at once
6) Rock Bluff 2 is always off
7) Shilo Wells are currently out of service. Shilo 3 will have portable generator plug in facilities following upgrade this spring 2010
8) Pilot Butte 2 has been decommissioned
9) Generator confirmed at Pilot Butte 4. Note that Well 3 will need back-up power to be counted as a reliable source.
10) Although the following wells have back-up power and are expected to be on SCADA in the future, they have not been included in the assessment of firm standby well capacity as they are not redundant:
    Outback 8
    Rock Bluff 3
    Shilo 3
    Pilot Butte 4
    River 2
    Hole Ten 2

Table 13 – Estimated Storage Volume Requirements at Build-out and Potential Offset from Wells

Pressure Zone	Dead Storage	Fire (MG)	Standby (MG)	Operating & Equalization (MG)	Total (MG)	Potential Offset
Level 1 [1]	15%	0.18	1.2	0.5	1.8	All above ground
Level 2 [1]	n/a	0.54	1.5	0.6	2.6	All above ground
Level 3 [2], Tetherow, Westwood and Awbrey sub-zones	n/a	1.5	19.0	7.5	28.0	Above-ground storage and well offsets to standby[2]
Zone 4A	34% of Westwood	0.54	3.2	1.3	5.0	Above-ground storage and well offsets to standby (could be met from Level 3)
Zone 4B and South Bend	n/a	1.5	12.2	4.8	18.6	Above-ground storage and well offsets to standby
Level 5, 6 & 7	n/a	3.0	37.1	14.6	54.7	Above-ground storage and well offsets to standby [3]
Totals		**7.3**	**74.2**	**29.2**	**110.7**	

Notes to Table 13

1) It has been assumed that wells will not be used to offset standby storage requirements in Levels 1 and 2, due to their elevation and isolation. New storage is proposed at the Tower Rock and College 1 sites to meet the storage needs in these levels.

2) Level 3 has excess capacity which can be assigned to lower zones.

3) Additional capacity may come from the following sources: planned wells at Pilot Butte, new wells located in Zones 5 and 6, potential acquisition of Pine Nursery well, new wells at Awbrey (if feasible), or additional capacity in higher zones.

6.2 Comparison to the 2007 Master Plan

As a point of comparison, the section related to storage requirements in the 2007 Master Plan (Section 5) is provided below for reference. Table 14 compares the volumes calculated in the 2007 Master Plan and compares them to the values determined using the guidelines in Table 11.

Storage Requirements

Based on water demand forecasts presented in Section 3 and the planning criteria identified in Section 4 the total volume of required storage by the end of the planning period (year 2030) is estimated at approximately 90.8 MG (see Table 5-3, "Storage Requirements").

…

Storage Allocations ("Tank Storage" vs. "Aquifer Storage")

As mentioned previously, a key assumption incorporated into the storage analysis for the City of Bend's water system is the premise that a certain volume of emergency storage may be allocated to the City's subsurface aquifer water supply source. This idea is intended to simply reallocate some of the needed emergency storage capacity, typically provided by constructed storage tanks ("tank storage"), to the existing subsurface aquifer ("aquifer storage"). Emergency storage is that component of storage intended to provide water during emergencies such as pipeline failures, equipment failures, power outages or natural disasters. This approach results in tremendous cost savings to the City by reducing constructed "tank storage" costs. This approach also benefits the City by helping to minimize stagnation of storage water by reducing tank storage and increasing turnover of water in tanks, especially during the low use winter season.

Currently, the City allocates a significant portion of emergency storage capacity to the subsurface aquifer. For example, in the South Bend portion of the City most of the storage is allocated to the subsurface aquifer, as tank storage is only drawn upon periodically through operation of the Murphy Pump Station when needed. Approximately 45% of the City's current total storage needs are allocated to the aquifer. This report recommends increasing that percentage to roughly 55% by the end of the 25-year planning period (see Figure 5-1, "Tank/Aquifer Storage Ratios").

As discussed above, the total volume of required storage by the end of the planning period (year 2030) is estimated at approximately 90.8 MG. As shown in Table 5-4, "Total Storage Allocations", today's storage requirements of approximately 43.3 MG are provided by existing firm "tank storage" capacity of 23.6 MG and existing "aquifer storage" capacity of approximately 19.7 MG. The firm storage capacity assumes that the City's largest storage facility, Awbrey Reservoir, is inoperable."

Figure 5-1
"Tank Storage"/"Aquifer Storage" Ratios

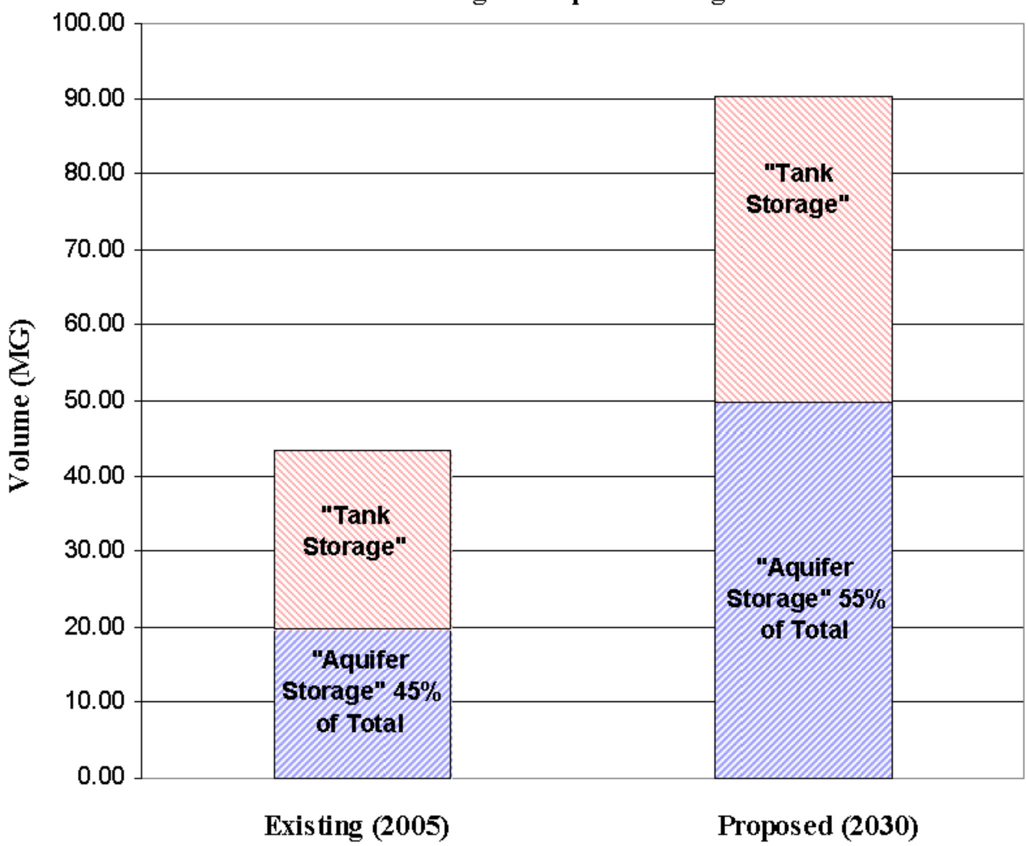


Table 14 – Comparison of recommended storage volumes, 2007 MP vs Table 11

Component	2007 Master Plan (MG)	Recommended Guidelines (MG)
Fire[1]	10.0	7.3
Standby	63.0	74.2
Operating/Equalization	17.8	29.2
Total	**90.8**	**110.7**
% provided by 'aquifer storage'	55% = 50 MG	~55-75 MG 50-70%[2]

1) The recommended volume for fire storage in the 2007 MP was calculated per zone, as they were defined at the time, being 1, 2, 3, Westwood, 4W, 4E, 5, 6, 7, Juniper Ridge and South Bend. The estimate presented in the recommended guidelines groups pressure levels and sub-zones and assigns them to the storage which will support supply in the event of a fire, then determines the worst-case customer class in the zones in question and applies that volume to the storage requirement. The major point of difference in the two calculations is in Pressure Levels 5, 6 and 7. In the 2007 MP a volume of 5 MG was calculated. The current recommendations suggest a volume of 3 MG (a conservative value assuming two simultaneous commercial fires in these zones)

2) Some portion of standby storage will be provided above-ground 'by default' due to the need for storage levels to align with normal system operating pressures (40 psi, compared to 20 psi in an emergency). The exact volume of future standby storage is not known, but initial calculations suggest it may be on the order of 20 MG.

Note that although the 2007 Master Plan suggested that standby storage could be offset by 'aquifer storage' the offset amount is quoted as a percentage of total storage needs. This is slightly misleading; it makes more sense to quote the aquifer storage component as a percentage of standby storage only, which for the 2007 Master Plan Build-out demand case is 80% (50 MG/63 MG).

6.3 Conclusions

As the system grows, the City should monitor maximum day demands and ensure that a firm supply capacity (without the surface water source) equal to MDD is maintained. It is suggested that the City aim to have all new wells linked to SCADA, and able to be operated on back up power. Any combined well/storage/booster pump facilities that are implemented will need to have back up power to the booster pumps to be counted as a reliable source for the purposes of offsetting standby storage requirements.

As mentioned above, necessary above-ground storage to meet operational and equalization needs should be evaluated with the help of a hydraulic model to ensure this component of storage is accounted for appropriately. It is likely that, due to the need to maintain normal operating pressures above 40 psi throughout the system, there will always be some volume of storage available to meet standby needs.

The City should regularly review the above guidelines and revise as necessary, for example if changes are made to the Washington Design standards that form the basis of the recommended guidelines, or if data shows that the aquifer is impacted in such a way that it becomes a less reliable source.

Oregon Administrative Rules – Chapter 333 Division 061

(http://www.oregon.gov/DHS/ph/dwp/docs/pwsrules/61-0050.pdf and /61-0060.pdf)

The Oregon Administrative Rules Chapter 333 Division 061 provides rules for the operation and maintenance of Public Water Systems. The relevant sections pertaining to system storage are outlined below; the full sections have been provided separately. There is little in the way of detail suggesting how storage requirements should in fact be calculated. The Rules refer to the AWWA standards, which are discussed in the following section.

OAR CHAPTER 333
DIVISION 061
PUBLIC WATER SYSTEMS

333-061-0098 References
All standards, listings and publications referred to in these rules are by those references made a part of these rules as though fully set forth. Copies are available from the Department of Human Services.

(1) **American Society for testing and materials (ASTM) specification B32-83 (solder)**
(2) **American Water Works Association (AWWA) Standards**

333-061-0050
Construction Standards

…

(6) Finished water storage:
- (a) Distribution reservoirs and treatment plant storage facilities for finished water shall be constructed to meet the following requirements:
  …
  - (H) The finished water storage capacity shall be increased to accommodate fire flows when fire hydrants are provided;

333-061-0060
Plan Submission and Review Requirements

…

(5) Master plans.
- (a) Community water systems with 300 or more service connections shall maintain a current master plan. Master plans shall be prepared by a professional engineer registered in Oregon and submitted to the Department for review and approval.
- (b) Each master plan shall evaluate the needs of the water system for at least a twenty year period and shall include but is not limited to the following elements:
  …
  - (E) An engineering evaluation of the ability of the existing water system facilities to meet the water quality and level of service goals, identification of any existing water system deficiencies, and deficiencies likely to develop within the master plan period. The evaluation shall include the water supply source, water treatment, storage, distribution facilities, and operation and maintenance requirements. The evaluation shall also include a description of the water rights with a determination of additional water availability, and the impacts of present and probable future drinking water quality regulations.

American Water Works Association (AWWA) Standards

ANSI/AWWA Standard G200-04 pertains to Distribution Systems Operation and Management, but does not provide any quantitative measures for determining storage volumes. The relevant sections are summarized below:

> **AWWA Standard ANSI/AWWA G200-04**
>
> **Distribution Systems Operation and Management**
>
> **4.3 Facility Operations and Maintenance**
>
> 4.3.1 Utility should establish minimum operating levels in storage facilities based on pressure in the distribution system, fire flow requirements, emergency storage requirements, and other site specific conditions.
>
> …
>
> Utility should have written operating procedures, which address water fluctuations in the storage facilities and turnover rates

AWWA's *Manual of Water Supply Practices* is a series of Manuals covering different aspects of water system operations and maintenance. *M19 – Emergency Planning for Water Utility Management* discusses mitigation of emergency situations, but does not provide any quantitative methods for determining necessary storage capacity.

M31 – Distribution System Requirements for Fire Protection has a chapter on Distribution System Storage (Chapter 3). The discussion suggests that equalizing storage will be 30-40 percent of the total storage volume (covering equalization and emergency needs). The only quantitative measure provided is that the system should be able to maintain 20 psi of pressure to customer connections at all times (under fire flow conditions). Storage that is below this level cannot be relied upon to meet emergency needs.

AWWA *Manual of Water Supply Practices M32 – Computer Modeling of Water Distribution Systems*, provides background and discussion of the different components of storage and suggests rules of thumb for calculating the needs based on system size and complexity. The manual makes the following statements regarding the different components of storage (from Chapter 4):

> **Equalizing storage**: "Typically the equalizing storage requirement is 10 to 15 percent of the average demand over a 24-hour period for large systems, but equalizing storage could exceed 30 percent [of ADD] for small service areas or arid climates."
>
> **Fire Storage**: "The fire storage volume is determined by multiplying the required flow duration by the maximum fire flow in each service area of the distribution system ... Typically fire storage is obtained from reservoirs located within the same pressure zone as the fire."
>
> **Emergency Storage**: "The amount of emergency storage is a policy decision based on an assessment of the risk of failures and the desired degree of system dependability. An assessment must be made of the type and nature of the emergency condition, including the frequency, intensity and duration." The Manual refers to M19, or local state regulations, to assist in the estimation of emergency storage requirements.

Ten States Standards (http://10statesstandards.com/waterstandards.html)

The Ten States Standards are policies for the review and approval of plans and specifications for public water supplies. The US member states are Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania and Wisconsin. The Canadian Province of Ontario is also a member. Part 7 discusses storage requirements. The relevant sections are included below:

PART 7 - FINISHED WATER SOURCE

7.0 GENERAL

The materials and designs used for finished water storage structures shall provide stability and durability as well as protect the quality of the stored water. Steel structures shall follow the current AWWA standards concerning steel tanks, standpipes, reservoirs, and elevated tanks wherever they are applicable. Other materials of construction are acceptable when properly designed to meet the requirements of Part 7.

7.0.1 Sizing

Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands, and where fire protection is provided, fire flow demands.

a. Fire flow requirements established by the appropriate state Insurance Services Office should be satisfied where fire protection is provided.

b. The minimum storage capacity (or equivalent capacity) for systems not providing fire protection shall be equal to the average daily consumption. This requirement may be reduced when the source and treatment facilities have sufficient capacity with standby power to supplement peak demands of the system.

c. Excessive storage capacity should be avoided to prevent potential water quality deterioration problems.

…

7.3 DISTRIBUTION SYSTEM STORAGE

The applicable design standards of Section 7.0 shall be followed for distribution system storage.

7.3.1 Pressures

The maximum variation between high and low levels in storage structures providing pressure to a distribution system should not exceed 30 feet. The minimum working pressure in the distribution system should be 35 psi (240 kPa) and the normal working pressure should be approximately 60 to 80 psi (410 - 550 kPa). When static pressures exceed 100 psi (690 kPa), pressure reducing devices shall be provided on mains or as part of the meter setting on individual service lines in the distribution system.

Washington Water System Design Manual (http://www.doh.wa.gov/ehp/dw/publications/331-123.pdf)

The Washington State Department of Health (DOH) has prepared a *Water System Design Manual* (December 2009). This manual contains detailed explanation of how storage volume needs should be calculated. A brief summary is provided below and the full chapter (Chapter 9) has been provided separately.

The WA Design Manual requires storage design to consider five components of storage which can be summarized as follows:

1. Operational Storage – the volume that is used when sources of supply are not operating, i.e., the volume between the on and off set-points of the pump supplying the tank.
2. Equalization Storage – the volume needed to meet demands in excess of source capacity. This storage must be able to maintain 30 psi at all services connections.
3. Standby Storage – to provide reliability of supply in the event of source failure or 'unusual conditions'. The calculation of the necessary volume depends on the nature of the source(s) of supply.
4. Fire Suppression Storage
5. Dead Storage (if any)

Components 1 through 4 can only be applied to the Effective Storage, which is the volume between the Dead Storage level and the highest level that the storage can be filled (i.e. the 'off' set point for pumps filling the tank, or the static hydraulic grade of the zone that fills the storage).

9.0.2 and 9.0.3 Operating and Equalization Storage

As mentioned above, operating storage is defined as "the volume of the reservoir devoted to supplying the water system while, under normal operating conditions, the sources of supply are off". Essentially it represents a factor of safety beyond that provided by the other components of effective storage.

Analysis of the system in a hydraulic model under maximum day conditions can greatly simplify the determination of operational and equalization storage needs; however, the following formula is provided to estimate necessary equalization storage:

Equalizing Storage (ES) = (PHD – Q_S) x 150 minutes

Where *ES* = gallons (must be greater than zero)

PHD = peak hourly demand (gpm)

Q_S = sum of capacity of all installed and active sources of supply (not including emergency sources)

9.0.4 (2) Standby Storage for systems with multiple sources

The WA Design Manual defines standby storage in a system with multiple sources as:

Standby Storage (SB_{TMS}) = (2 days) x [N x ADD – t_m x (Q_S – Q_L)]

Where SB_{TMS} = standby storage for a system with multiple sources (gallons)

N = number of ERUs (equivalent residential units)

ADD = average day demand (gpd/ERU)

Q_S = sum of all installed and continuously available source of supply capacities, except emergency sources (gpm) (see 9.1.1 below)

Q_L = largest capacity source available to system (gpm)

t_m = time that remaining sources are pumped on the day when the largest source is not available (minutes)

9.1.1 Source Definition Used in Sizing New Reservoirs

Engineers may consider any source classified as "permanent" or "seasonal" when designing new reservoir facilities if the source is **continuously available** to the water system and meets, at a minimum, all primary drinking water standards (WAC 246-290-010, 222(3), and 420(2) and (5)).

"Continuously available to the system" means all of the following:

- The source is equipped with functional pumping equipment (and treatment equipment, if required).
- The equipment is exercised regularly to ensure its integrity.
- Water is available from the source year round.
- The source activates automatically based on pre-set parameters (reservoir level, water system pressure, or other conditions).

In addition, the WA Design Manual specifies a number of instances where the Standby Requirements can be reduced:

9.0.4 Standby Storage

…

5. **Reduction in Standby Storage**
The purveyor and water system designer have various options available to decrease the volume of SB in the water system. As Section 9.0.4(2) indicates, they may reduce the volume if they develop additional supply sources. For DOH to consider SB equivalent to gravity storage, the sources must have auxiliary power that starts automatically if the primary power feed is disrupted.

The purveyor may also reduce the volume if community expectations are amenable to a lesser SB capacity. That means they agree that the volume for one average day of service is sufficient for standby purposes instead of two days. A utility may also make better use of dead storage by providing booster pumps at the point where the pressure reaches the minimum established by the community in situations when the SB is used.

9.1.3 Alternate Design Concept

If the water system design includes multiple supply sources and, in some cases, on-site standby power, the engineer may reduce or, in some cases, eliminate the ES and SB components summarized in Section 9.0. The engineer may eliminate ES only if the combined capacity of the supply sources meets or exceeds the PHD for the water system, or the pressure zone, with 30-psi pressure provided at each existing and proposed service connection. The engineer may reduce or, in some cases, eliminate FSS if the water system design includes on-site standby power and the water system has multiple supply sources capable of providing the fire-flow rate in addition to the MDD rate for the water system. The engineer should verify this with the local fire protection authority.

Water systems substituting source capacity for storage volumes must consider and provide appropriate justification for varying from each of the following criteria:

1. Exclude the capacity of the largest producing supply source from the calculations.
2. Equip each supply source used in the calculations with on-site backup power facilities, promptly started by an automatic transfer switch upon loss of utility power.
3. Incorporate provisions for pump protection during low demand periods into the water system design.

9.0.5 Fire Suppression Storage

Similar to other standards and guidelines, the WA Design Manual specifies that fire storage must be able to meet fire flow requirements while maintaining 20 psi throughout the distribution system. The minimum volume is the product of the required flow rate multiplied by the duration, as shown in the following equation:

Fire Suppression Storage FSS (gallons) = FF x t_m

Where *FFS* = fire suppression storage (gallons)

FF = Fire flow rate (gpm)

t_m = Duration of fire flow rate (minutes)

The Manual also states the following:

Consolidating Standby and Fire Suppression Storage (nesting)
Water systems can exclude the SB or FSS component, whichever is smaller, from a water system's total storage requirement unless such practice is prohibited by: (1) a locally developed and adopted coordinated water system plan, (2) local ordinance, or (3) the local fire protection authority or county fire marshal (see WAC 246-290-235(4)).

Idaho Department of Environmental Quality Rules

(http://adm.idaho.gov/adminrules/rules/idapa58/0108.pdf)

The Idaho Rules for Public Drinking Water Systems IDAPA 58.01.08, developed by the Department of Environmental Quality, provide similar definitions of the storage components compared to the Washington Design Manual. The requirements are somewhat less rigorous, specifically with respect to the suggested necessary standby volume.

544. FACILITY AND DESIGN STANDARDS: GENERAL DESIGN OF FINISHED WATER STORAGE.
The materials and designs used for finished water storage structures shall provide stability and durability as well as protect the quality of the stored water. Finished water storage structures shall be designed to maintain water circulation and prevent water stagnation. Steel structures and facilities such as steel tanks, standpipes, reservoirs, and elevated tanks shall be designed and constructed in accordance with applicable AWWA Standards, incorporated by reference into these rules at Subsection 002.01. Other materials of construction are acceptable when properly designed to meet the requirements of Section 544. (5-8-09)

01. **Sizing**. Storage facilities shall have sufficient capacity, as determined from engineering studies that consider peak flows, fire flow capacity, and analysis of the need for various components of finished storage as defined under the term "Components of Finished Water Storage" in Section 003. The requirement for storage may be reduced when the source and treatment facilities have sufficient capacity with standby power to supply peak demands of the system. (3-30-07)

…

16. **Components of Finished Water Storage**. Storage is available to serve the system if the storage structure or facility is elevated sufficiently or is equipped with sufficient booster pumping capability to pressurize the system. Components of finished water storage are further defined as: (5-8-09)

a. Dead Storage. Storage that is either not available for use in the system or can provide only substandard flows and pressures. (3-30-07)

b. Effective Storage. Effective storage is all storage other than dead storage and is made up of the additive components described in Paragraphs c. through f. of this Subsection. (5-8-09)

c. Operational Storage. Operational storage supplies water when, under normal conditions, the sources are off. This component is the larger of; (3-30-07)

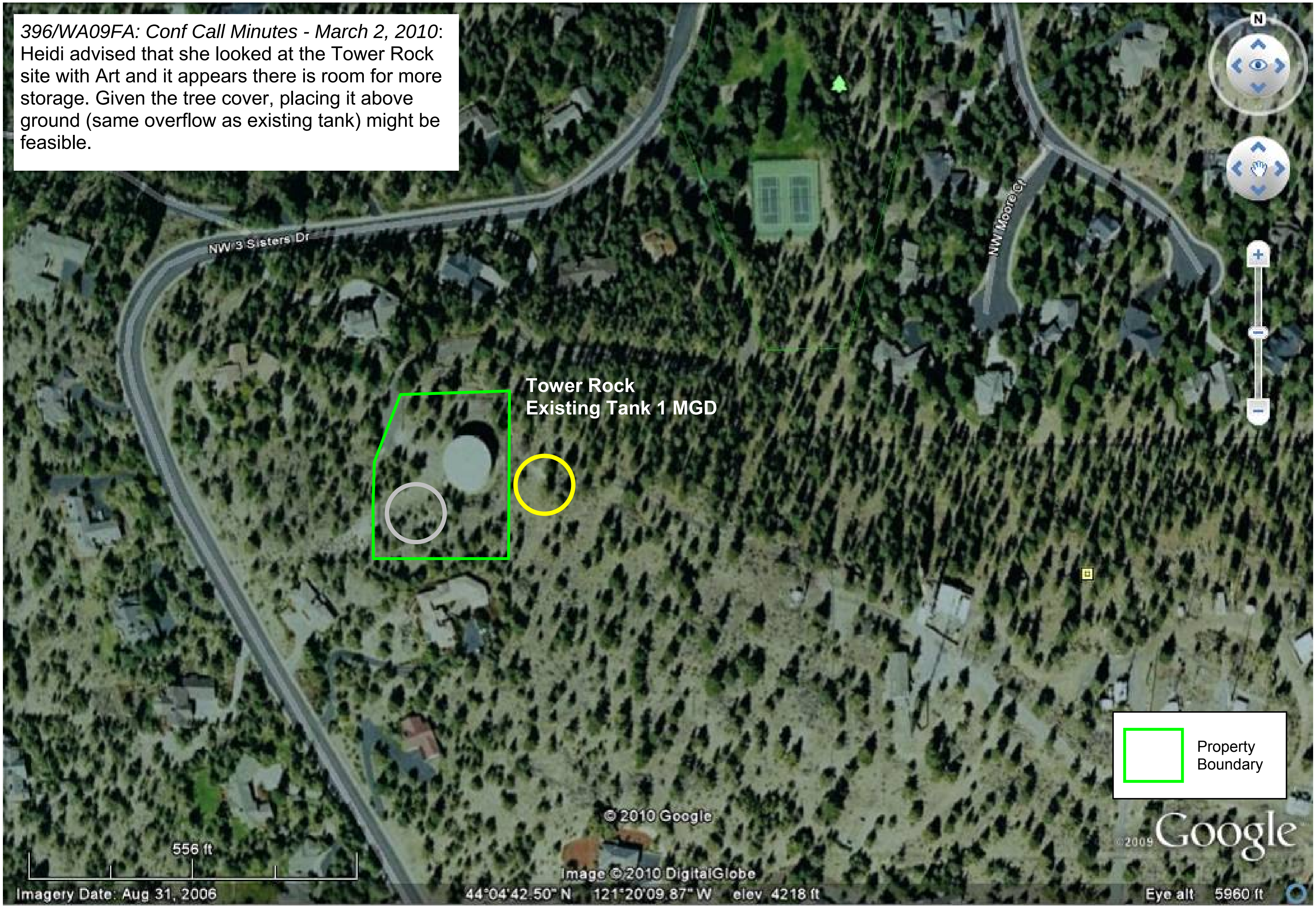
i. The volume required to prevent excess pump cycling and ensure that the following volume components are full and ready for use when needed; or (3-30-07)

ii. The volume needed to compensate for the sensitivity of the water level sensors. (3-30-07)

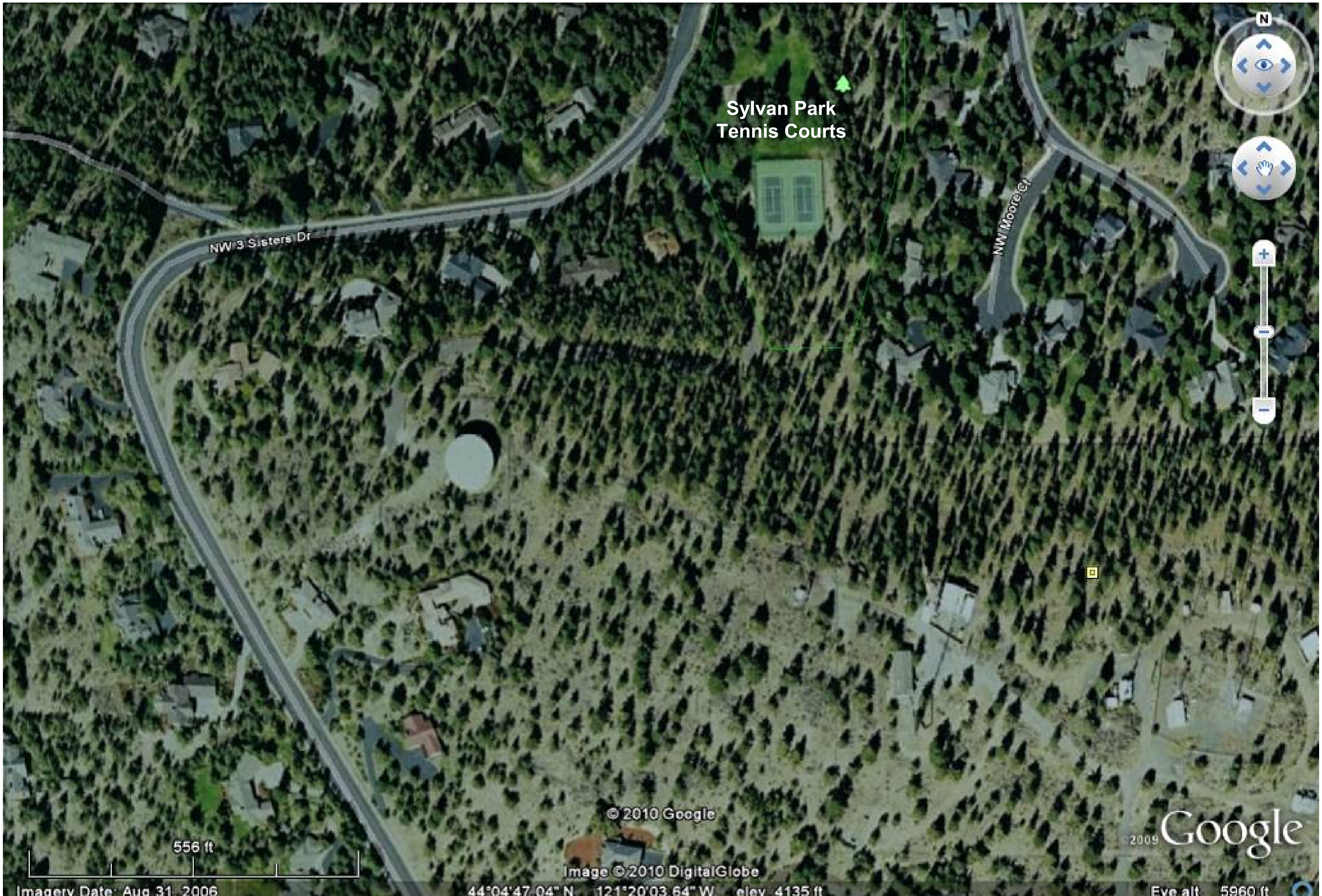
d. Equalization Storage. Storage of finished water in sufficient quantity to compensate for the difference between a water system's maximum pumping capacity and peak hour demand. (3-30-07)

e. Fire Suppression Storage. The water needed to support fire flow in those systems that provide it. (3-30-07)

f. Standby Storage. Standby storage provides a measure of reliability or safety factor should sources fail or when unusual conditions impose higher than anticipated demands. Normally used for emergency operation, if standby power is not provided, to provide water for eight (8) hours of operation at average day demand. (5-8-09)



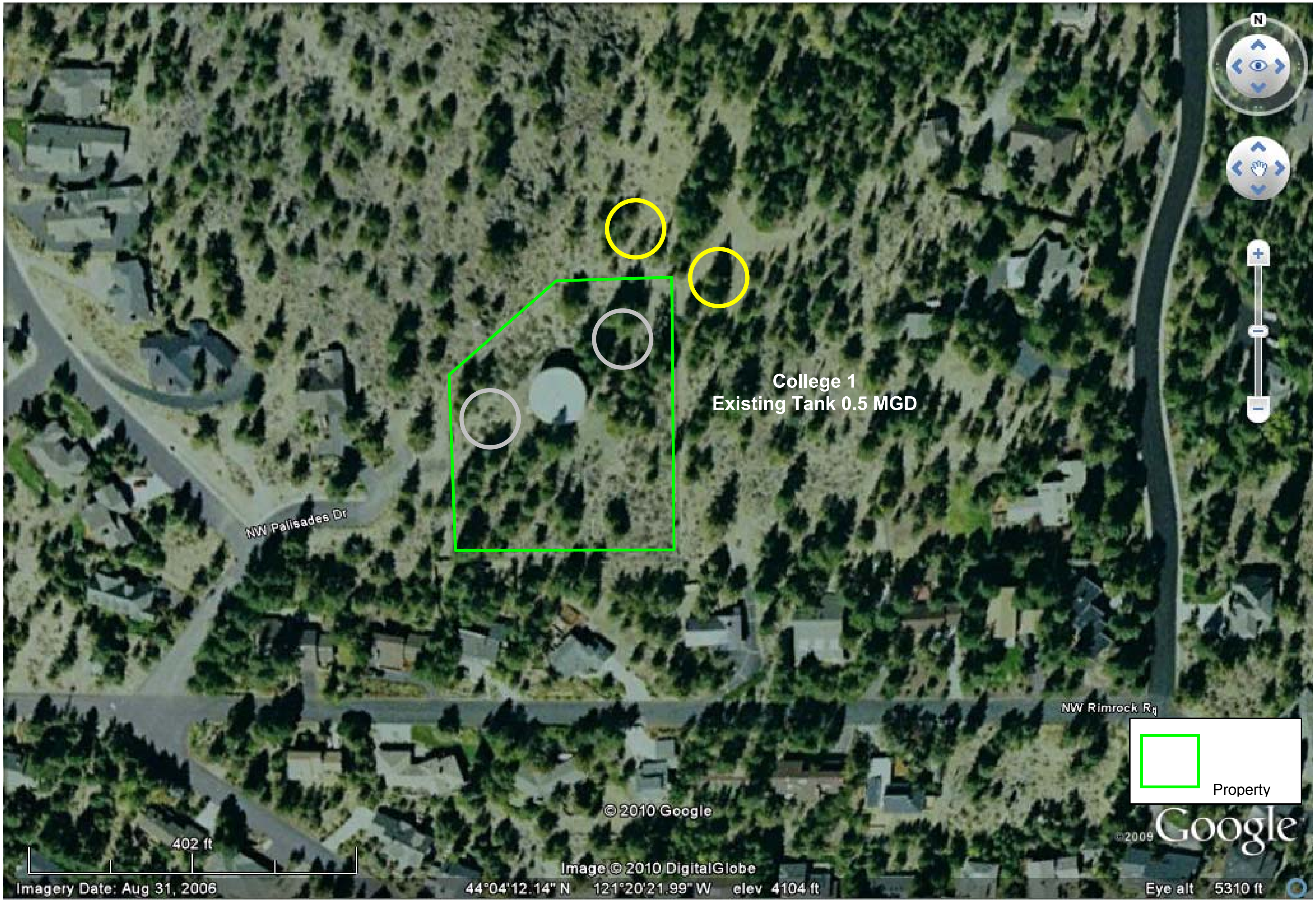
Tower Rock Tank Site – land on site is not level; however space to double existing volume. Space to east looks vacant and may be preferable from a construction and elevation standpoint. Assume maximum additional volume of 2 MG. TWL 4244



Sylvan Park New Tank Site – Assuming tank height 20 ft under the area of the tennis courts (120 ft x 108 ft), maximum volume 259,200 ft^3 = 1.94 MGD. TWL 4130 (ground elevation minus 5 ft) – must be filled from Level 1, serves Level 2 and/or 3.

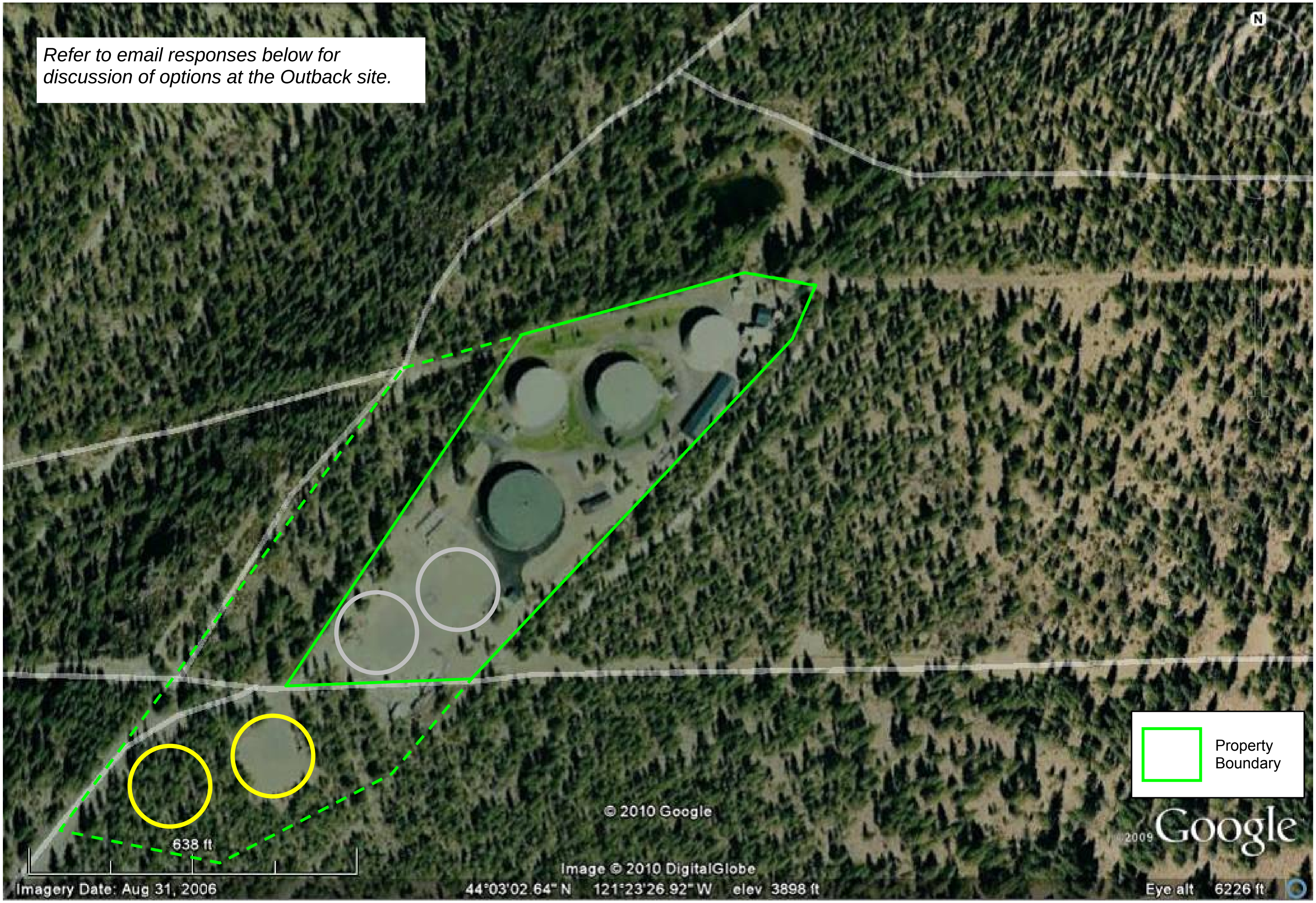
Summit Park New Tank Site – Assuming tank under courts (120 ft x 108 ft x 20 ft) = 1.94 MGD. TWL 4080 (ground elevation minus 5 ft)
Must be filled from Level 2, serves Level 3.

Alternative Tennis Court Tank Site – Assuming tank under courts (120 ft x 108 ft x 20 ft) = 1.94 MGD. TWL 4005 (ground elevation minus 5 ft) Would be filled by gravity and serve Level 3.

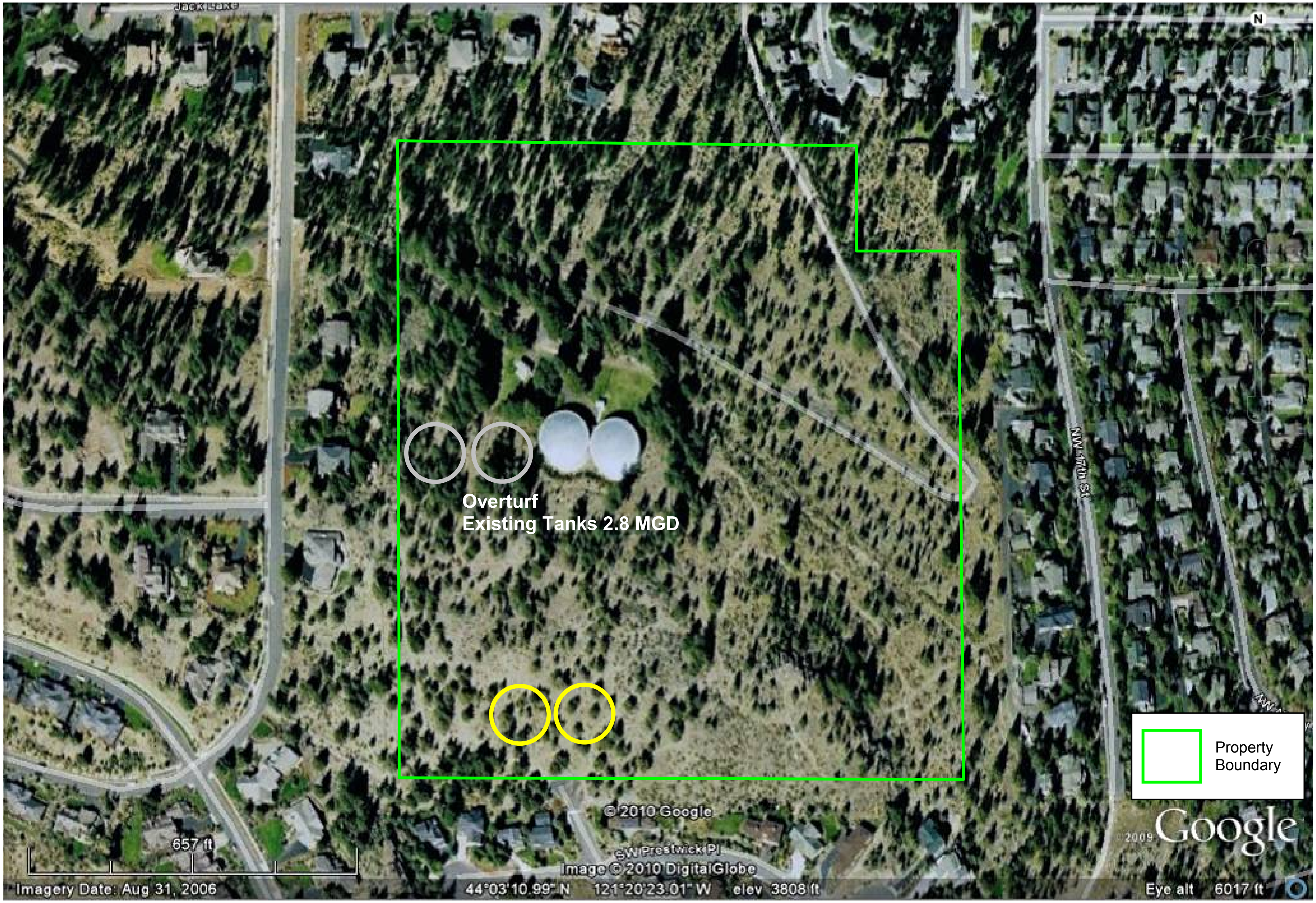


College 1 Tank Site – appears to be plenty of room on site for expansion although maintaining similar elevation is an issue. Two grey circled areas have similar elevation, so could at least triple volume at this site. Yellow circled areas match or exceed the ground elevation at the existing site. Assume maximum additional volume of 2.0 MG. TWL 4119

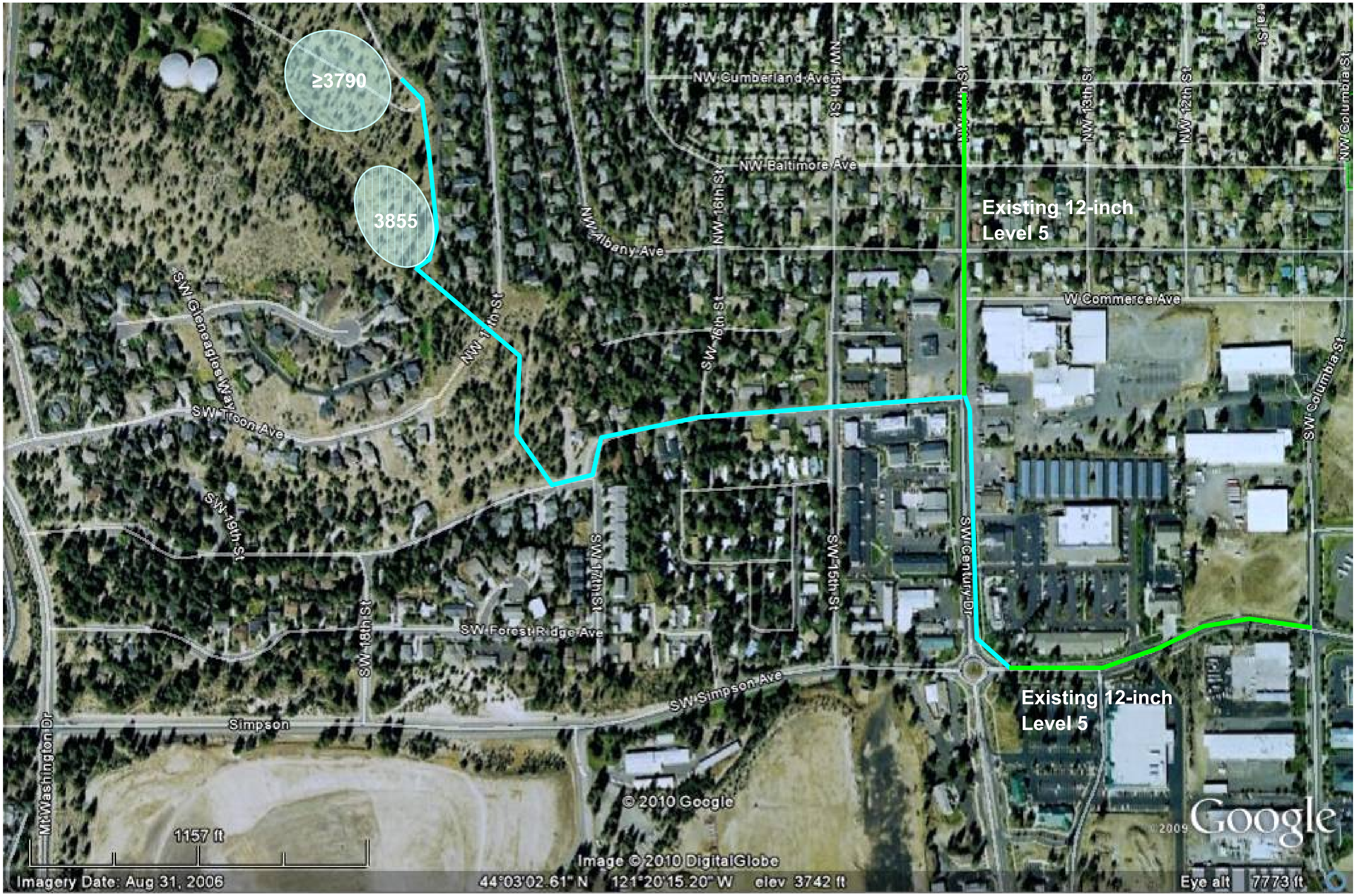
College 2 Tank Site – No room for additional storage



Outback – CT = 1.5 MG, #1 = 2 MG, #2 = 3 MG, #3 = 3.5 MG. 1 & 2 could be replaced with a slightly larger tank, say up to 6 M (+1 MG). Room for additional storage to the south of the site, up to 7 MG. Need to leave room for well infrastructure. Maximum additional on site volume 8 MG. Dotted line shows area with similar elevation. If location outside current boundary is an option, could create an additional 7 MG = 15 MG total additional. TWL 4,011



Overturf Site – Level 4 – To match elevation of existing tanks need to build to the west. Potential additional site to the south, shown in yellow have same elevation. Alternatively could build into the hillside behind the current tanks. Assume Level 4 Maximum additional volume 6 MG. TWL 3,872

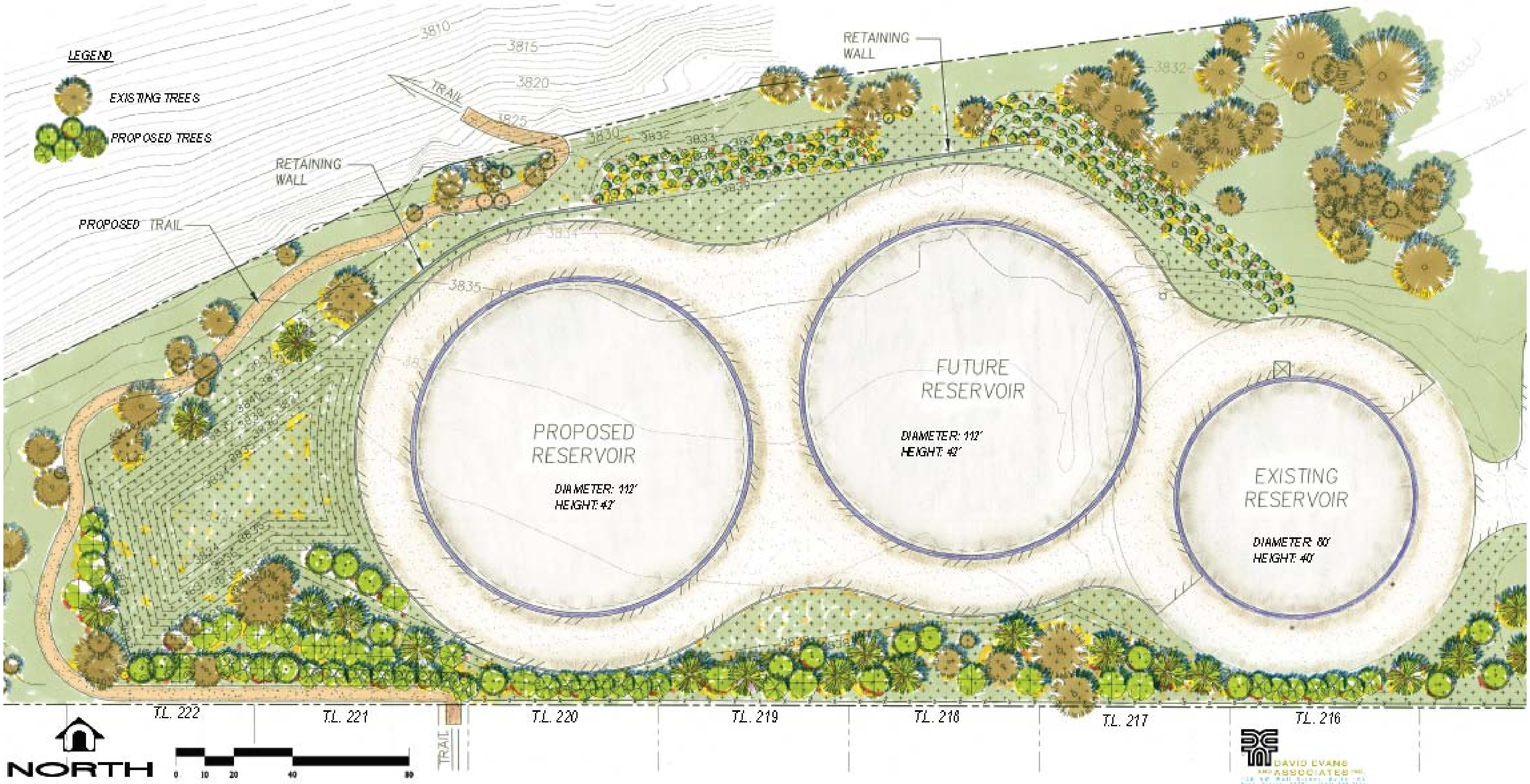


Overturf - Level 5 storage options – Need to consider tying into Level 5 piping. Assume in ground tanks, ground elevations ≈ TWL. Land to the south is higher in elevation which would require filling via Level 3/4 (no option to fill from River Wells). Northern portion of site lower elevation and may be better suited as could float on Level 5.

Connecting via southwest favorable as other routes cross through built-up residential areas. Suggest connecting to 12-inch piping on Simpson and 15th (close proximity to River Wells discharge). Potential route as shown above. Approximately 3,800 ft to Century Drive, 950 ft to Simpson.

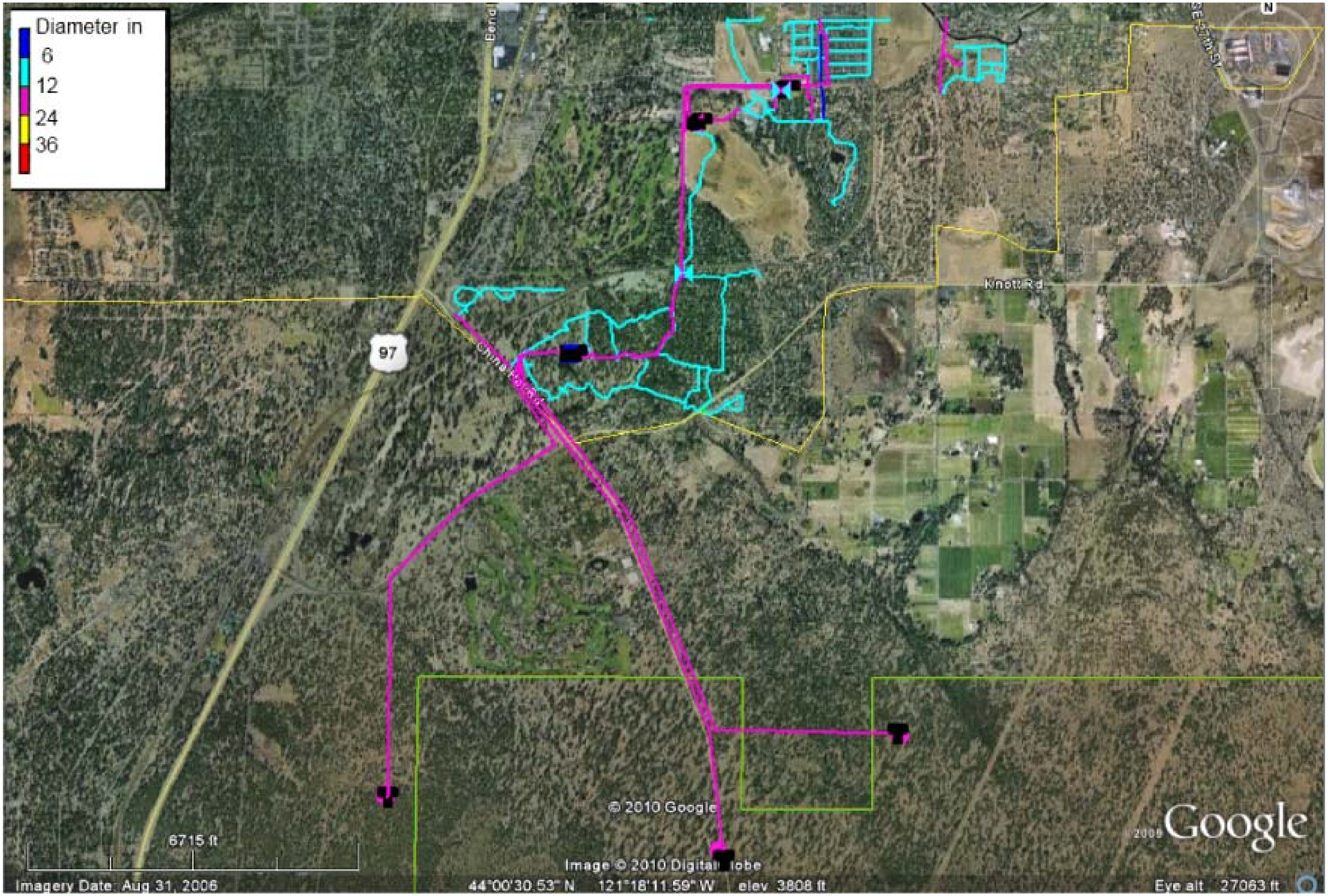
Alternative connection to the north from northern site shown below, ~ 3300 ft to connect to 16-inch main on Galveston.

Westwood – If PS decommissioned, rebuild tank. Existing tank is 0.5 MG. Approx 10 ft of elevation difference across site from north to south. Assume maximum storage potential 5 MG. TWL 3,870.



Plans by David Evans and Associates

Rock Bluff Tank Site – Plans exist for an additional 6 MG of storage. Land to the east is similar elevation (- 5 ft) and could potentially accommodate additional storage. Assume maximum potential additional storage 10 MG? TWL 3,880

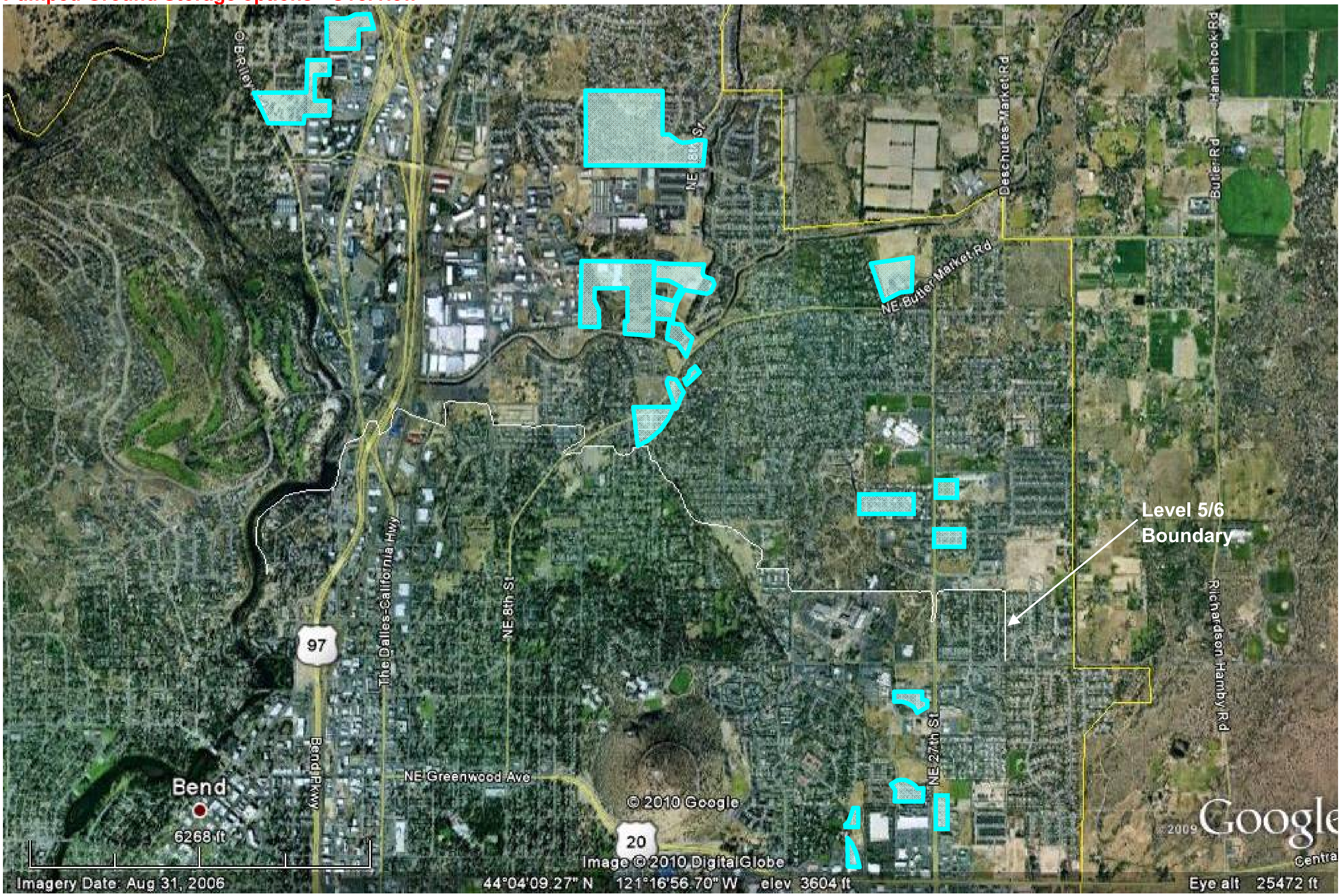


South Bend Tank Site – 3 identified locations at approximately 4,010 ft. Approximately 2 miles of pipe required to connect to the system. Area restrictions unknown, assume up to 5 MG. TWL 4,040

Pilot Butte 2 Extension – Approx 70 ft x 200 ft x 30 ft = 420,000 ft^3 = 3 MG. Additional volume 2 MG. TWL 3,880 ft

Pilot Butte '4' – would involve stabilizing scar and building into the hillside. Base of hillside approximately 3800 ft which is above the necessary TWL 3,780 ft for Level 5. Volume depends on extent of build into hillside. Estimate maximum at 5 MG.

Pumped Ground Storage options - Overview



General Considerations:

Site would need to accommodate a well, the tank and a booster pump station.

Southern locations less likely to be affected by storm water UIC issues

Level 6

KBNW Site – Radio Station is owned by Summit Broadcasting. Lots of space – can it be acquired? Main along Butler Market Road is 12-inches.

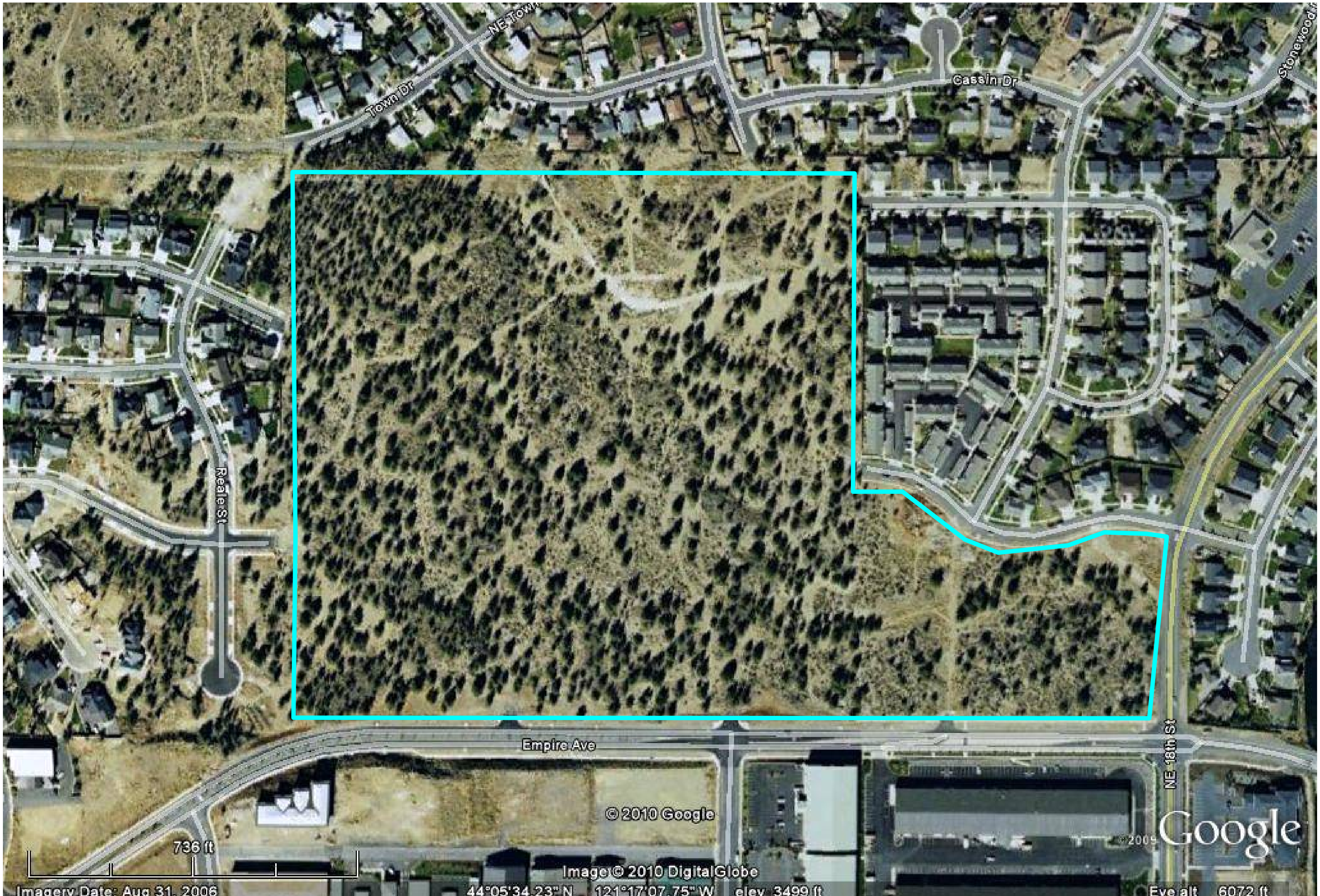
Level 6

Further north along **Butler Market Rd**. Unsure of land availability/ownership. Main along Butler Market Road is 12-inches.

Level 6

Between Empire Ave and Brinson Blvd there is a number of vacant lots. Pipes on 18th St and Brinson Blvd are 12-inches. Presume cleared land is planned for development but could potentially be acquired from a developer.

Level 6



North of Empire, west of 18th. Pipe on Empire Ave is 16-inches. Good proximity to proposed line north to Juniper Ridge along 18th St.

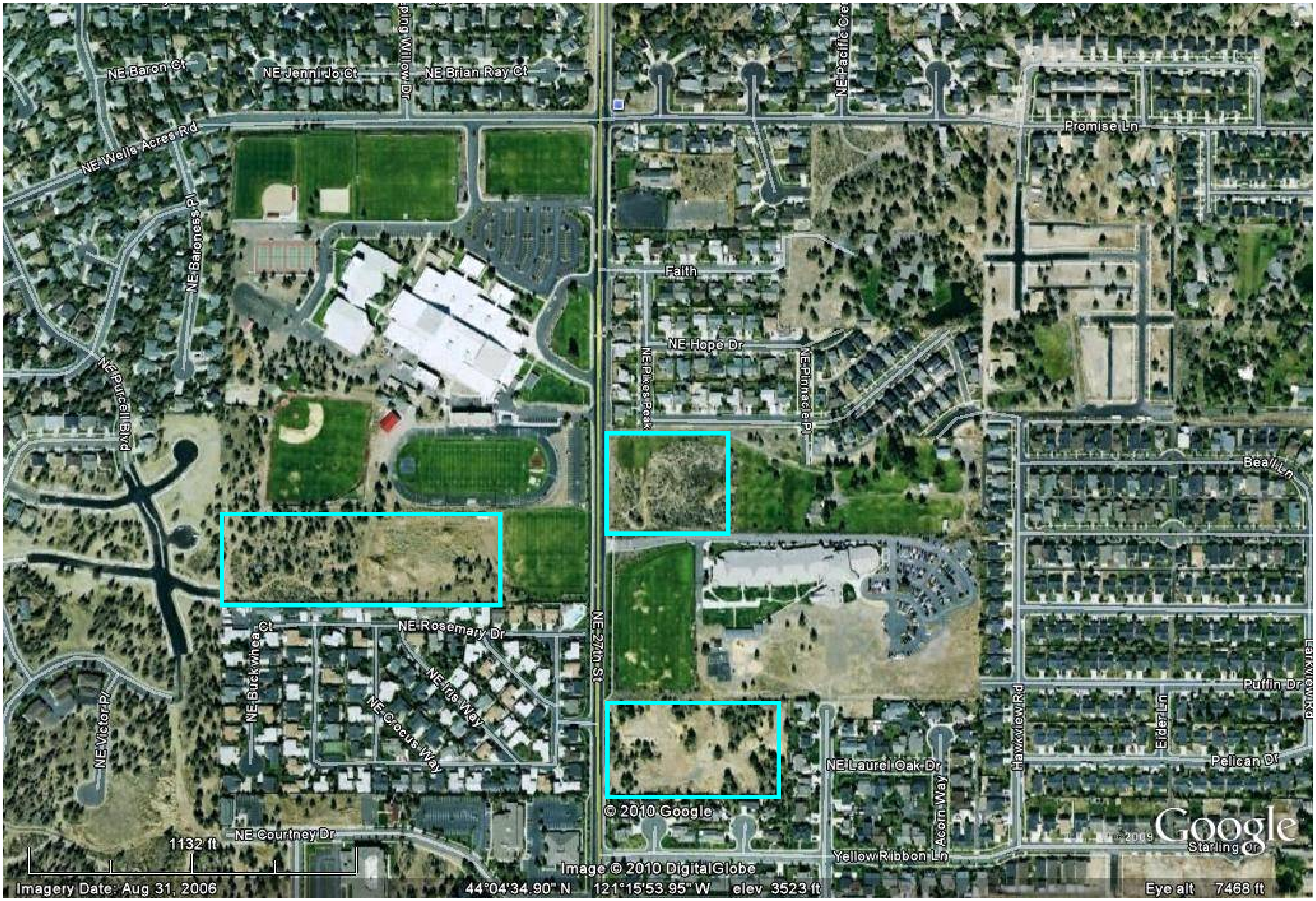
Level 6

West of 97, north of Empire Ave. Some vacant land. Not as favorable as pipes in this area are smaller and not well connected to the east side of Level 6. 12 inch main on Harvest Lane.

Level 6

South of Pine Nursery, north of Butler Market Road. No piping here but would fit in well if the pine nursery well was acquired.

Level 6



Sports complex south of New Wells Acres Rd Underground storage a possibility under playing fields. Some vacant land nearby. There is a 16-inch main on 27th Street.

Level 5 east of Pilot Butte

Corner of Neff and 27th – There are a number of vacant lots along 27th street, but the Neff/27th location is good from a connectivity point of view. 12-inch main on 27th street, 16-inch on Neff Rd. Next best on corner of Purcell Blvd and Paula Dr. 12-inch main on Purcell.

Summary – Maximum Additional Volume

Tank Site	TWL	Existing Volume (MG)	Conservative Maximum Additional Volume (MG)	Sub-total	Upper-limit Maximum Additional Volume (MG)	Total	Estimated Storage Requirement (Fire + Standby + Equalizing) (MG)	Comments
Level 1								
Tower Rock	4,244	1.0	1.0	2.0	2.0	3.0	1.8	Upper limit assumes use of land outside current property boundary
Level 2								
College 1	4,119	0.5	1.0	1.5	2.0	2.5		Upper limit assumes use of land outside current property boundary
College 2	4,119	1.0	0.0	1.0	0.0	1.0		
Proposed Sylvan	4,130	0.0	2.0	2.0	2.0	2.0		Filled from Level 1, serves Level 2/3
Subtotal		**1.5**	**3.0**	**4.5**	**4.0**	**5.5**	2.6	
Level 3, Tetherow, Awbrey Butte Zones								
Outback	4,011	10.1	8.0	18.1	15.0	25.1		Upper limit assumes use of land outside current property boundary
Proposed Summit	4,080	0.0	2.0	2.0	2.0	2.0		Filled from Level 2, serves Level 3
Proposed City View & 12th	4,005	0.0	2.0	2.0	2.0	2.0		Filled by gravity, serves Level 3
Subtotal		**10.1**	**12.0**	**22.1**	**19.0**	**29.1**	28.0	
Zone 4A								
Overturf	3,872	3.0	3.0	6.0	6.0	9.0		Upper limit assumes siting new tanks south of current tanks
Westwood	3,870	0.5	4.5	5.0	4.5	5.0		Assumes replacement of existing tank and use of full property area
Subtotal		**3.5**	**7.5**	**11.0**	**10.5**	**14.0**	4.9	
Zone 4B & South Bend								
Proposed South Bend	4,040	0.0	5.0	5.0	5.0	5.0		Three potential locations, 2 mile pipe connection
Rock Bluff	3,879	1.5	6.0	7.5	10.0	11.5		Upper limit assumes siting new tanks east of current tanks at slightly lower ground elevation
Pilot Butte 2	3,880	1.0	2.0	3.0	2.0	3.0		Assumes cutting into hillside behind existing tank
Subtotal		**2.5**	**13.0**	**15.5**	**17.0**	**19.5**	18.6	
Level 5, 6 & 7								
Awbrey	3,796	5.0	0.0	5.0	0.0	5.0		No expansion considered
Proposed Overturf L5	3,780	0.0	10.0	10.0	15.0	15.0		Check property boundary assumptions.
Proposed Pilot Butte '4'	3,780	6.5	5.0	11.5	5.0	11.5		Assumes in-ground tank, requires stabilization of hill face
Pumped ground storage L5	Pumped	0.0	2.0	2.0	2.0	2.0		Sites could accommodate more storage, this assumes 1 site with a 2 MG ground tank
Proposed Pilot Butte '5' L6	3,688	0.0	5.7	5.7	5.7	5.7		As proposed in Juniper Ridge study
Pumped ground storage L6	Pumped	0.0	4.0	4.0	4.0	4.0		Sites could accommodate more storage, this assumes 2 sites with a 2 MG ground tank
Subtotal		**11.5**	**26.7**	**38.2**	**31.7**	**43.2**	54.7	
TOTALS Existing and Proposed		**30.1**	**63.2**	**93.3**	**84.2**	**114.3**	**110.7**	

From: HLansdowne@ci.bend.or.us [mailto:HLansdowne@ci.bend.or.us]
Sent: Friday, 28 May 2010 1:05 PM
To: Elsie Mann
Subject: Storage sites

Elsie - in the storage site .pdf file provided 3-31-10 you have shown white rings and yellow rings. What is the difference? Also at Outback, there will be no room inside the property owned by the City of Bend for tanks as we are using that space for the treatment plant and hydro (possibly). Sorry if we had not been clear on that.

Also on Level 6, the "sports complex" identified is actually Mountain View High School, south of NW Wells Acre Road. Not sure if we could acquire any property there as it is probably slated for expansion for the high school.

Level 5 east of Pilot Butte - zoned medical (southern sites may be owned by St Charles Medical Hospital) and probably high value for expansion or new medical facilities.

Sorry to provide all of this feedback so late, not sure if you already went through the pluses and minuses of these sites with anyone.

Heidi Lansdowne, P.E.

Date: 05/28/2010 01:08 PM

Heidi,

The white rings were potential sites identified within existing property boundaries and the yellow rings were to indicate that the locations were outside an existing property boundary.

I believe you raised the Level 5 and 6 site issues in a previous conference call, so those particular ones have not been included in the formulation.

Art also commented on Outback, but not in as much detail. With the Outback site, it seemed from my review of the elevations that there were potential sites for storage outside the current property boundary. I think there will be a need for additional storage at this location in the future; do you think it is feasible to consider that the site would expand to encompass a larger area?

Thanks
Elsie

Sent: Friday, 28 May 2010 3:41 PM

Yes - the property outside of the City owned parcel is Forest Service and I believe they would consider giving us a special use permit for a reservoir. We have already drilled a well and plan to construct a well building outside of our property boundary.

Heidi Lansdowne, P.E.
City of Bend Water Utility Division
62975 Boyd Acres Road
Bend, OR 97701
(541)388-5538
(541)317-3046 Fax

From: aeaston@ci.bend.or.us [mailto:aeaston@ci.bend.or.us]
Sent: Wednesday, 7 April 2010 10:10 AM
To: Elsie Mann
Subject: Re: Review of potential for additional storage at existing sites

Hi Elsie, I found your potential water storage very interesting. I did take the time to look at each site. I have no major changes or concerns other than moving them over a bit at certain sites to avoid main lines. Also some sites ill require extensive excavation due to rocky ridges and higher elevations. Other considerations may have to be taken at sites such as Outback where treatment plants or hydro plants may be installed within the next few years.

I noticed one other conflict that may exist with Pilot Butte Two. The underground tank may be a problem as there are more facilities in than the map shows at this time. Hope this is helpful.

Art Easton
Utilities Water Operations Supervisor
(541) 693-2180
Fax (541) 317-3046

From: KVaughan@ci.bend.or.us [mailto:KVaughan@ci.bend.or.us]
Sent: Tuesday, 6 April 2010 3:22 PM
To: Elsie Mann
Cc: HLansdowne@ci.bend.or.us; Mike Canning
Subject: RE: Storage analyses - Current and Build-out

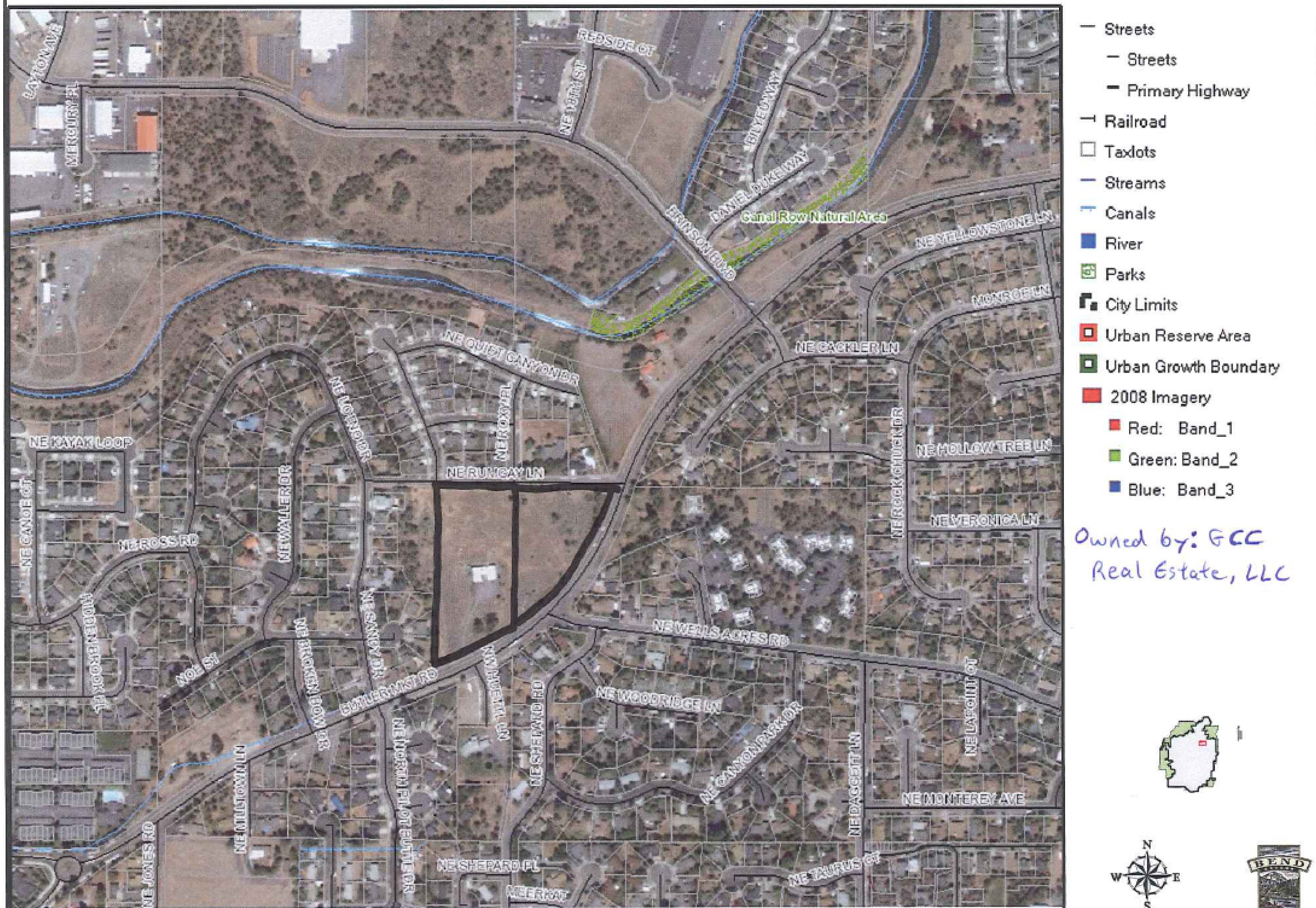
Hello All,

I've gone through all of the potential future storage sites and determined taxlot borders, owners, and whether or not there is any planned development. I've crossed out lots that have planned development or are unsuitable for some other reason (noted where applicable). Let me know if you have any questions about the information I've put together. The sheets I've added are aerial photos from 2008. Thanks.

Ken Vaughan

City of Bend
Utility Services Division
62975 Boyd Acres Road
Bend, OR 97701
(541) 330-4026
kvaughan@ci.bend.or.us

KBNW Site - Butler Mrkt Rd - GCC Real Estate LLC



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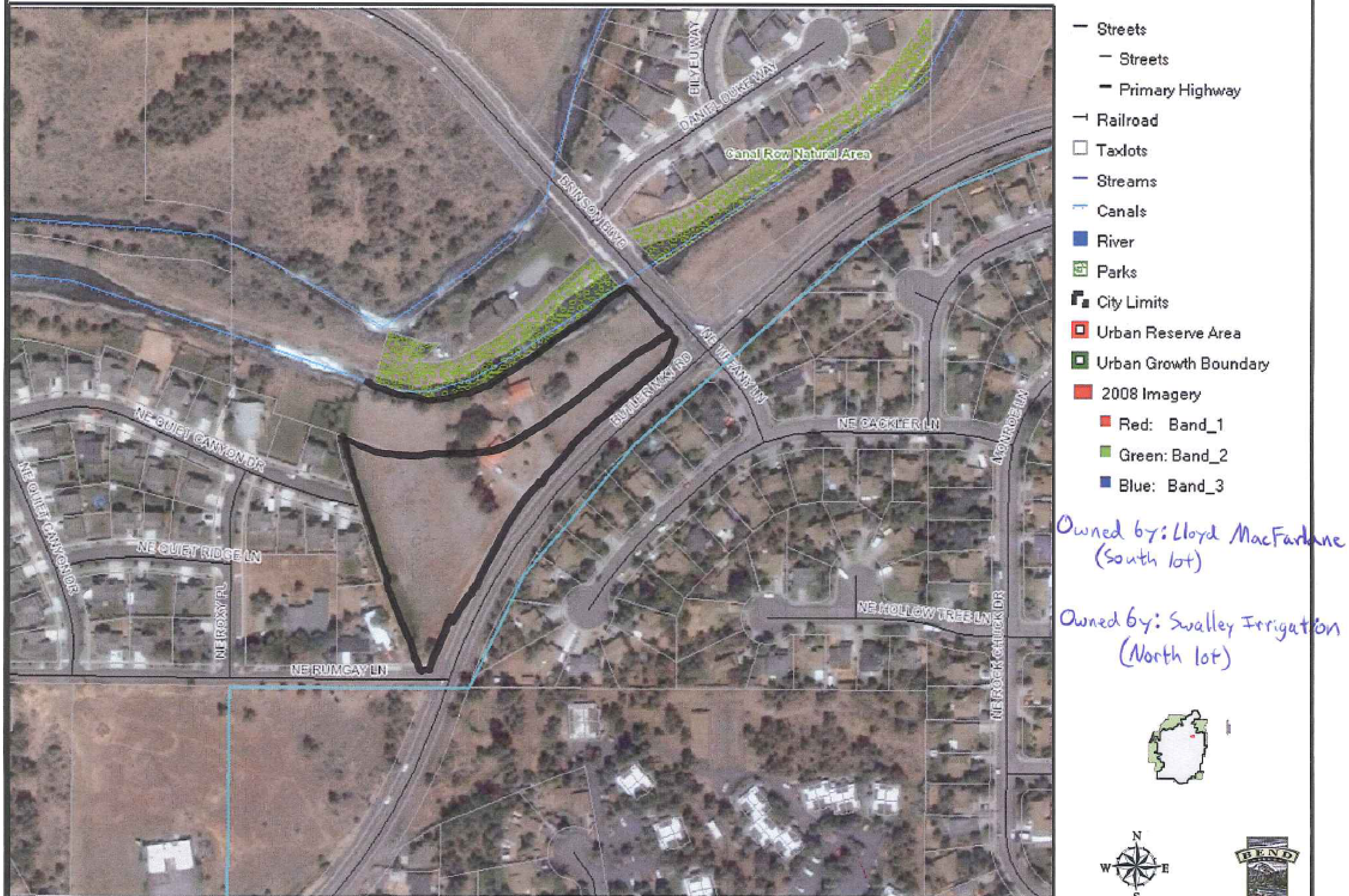
Butler Mrkt Rd - MacFarlane and Swalley Canal



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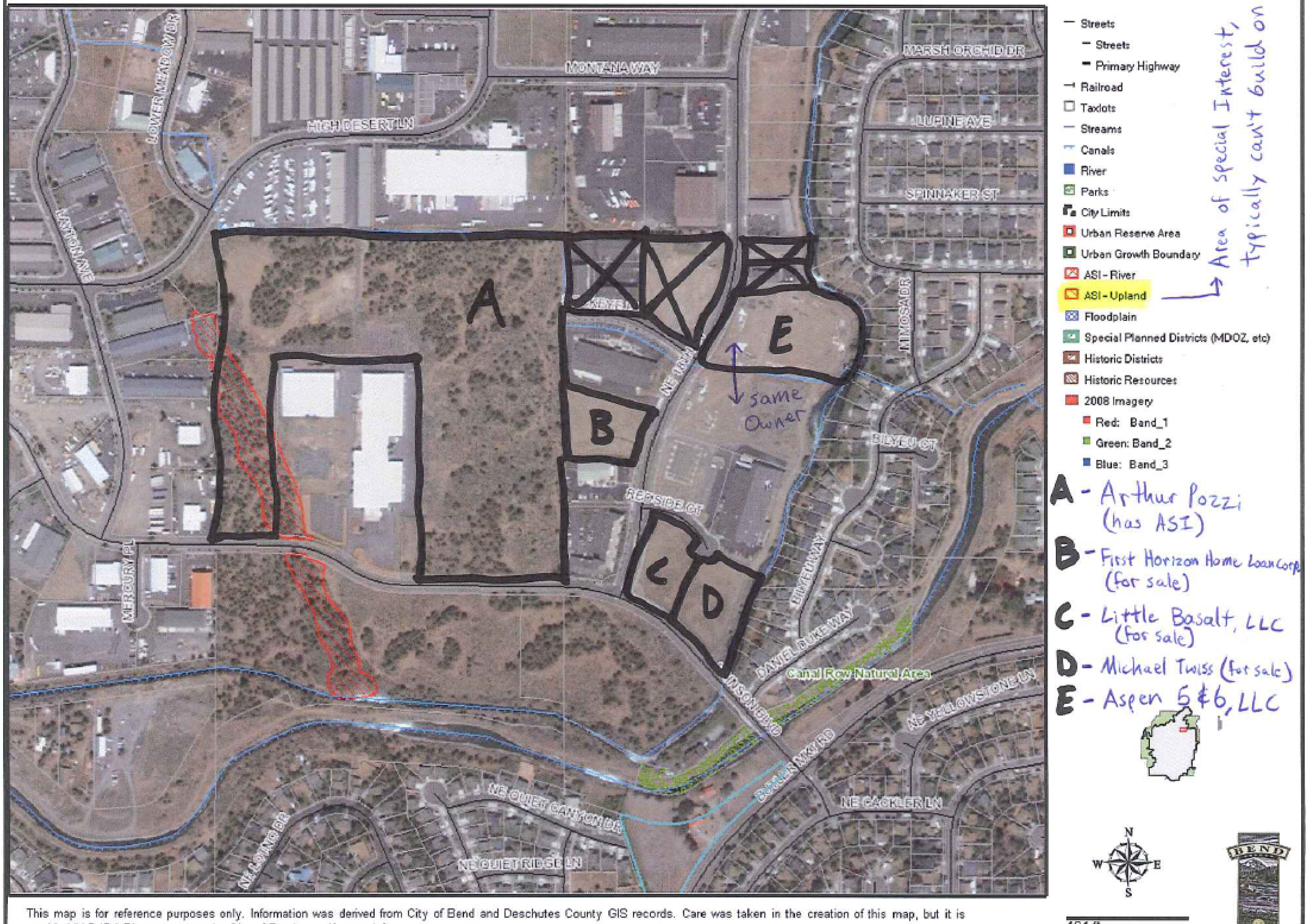
232 ft

Between Empire Avenue and Brinson Blvd



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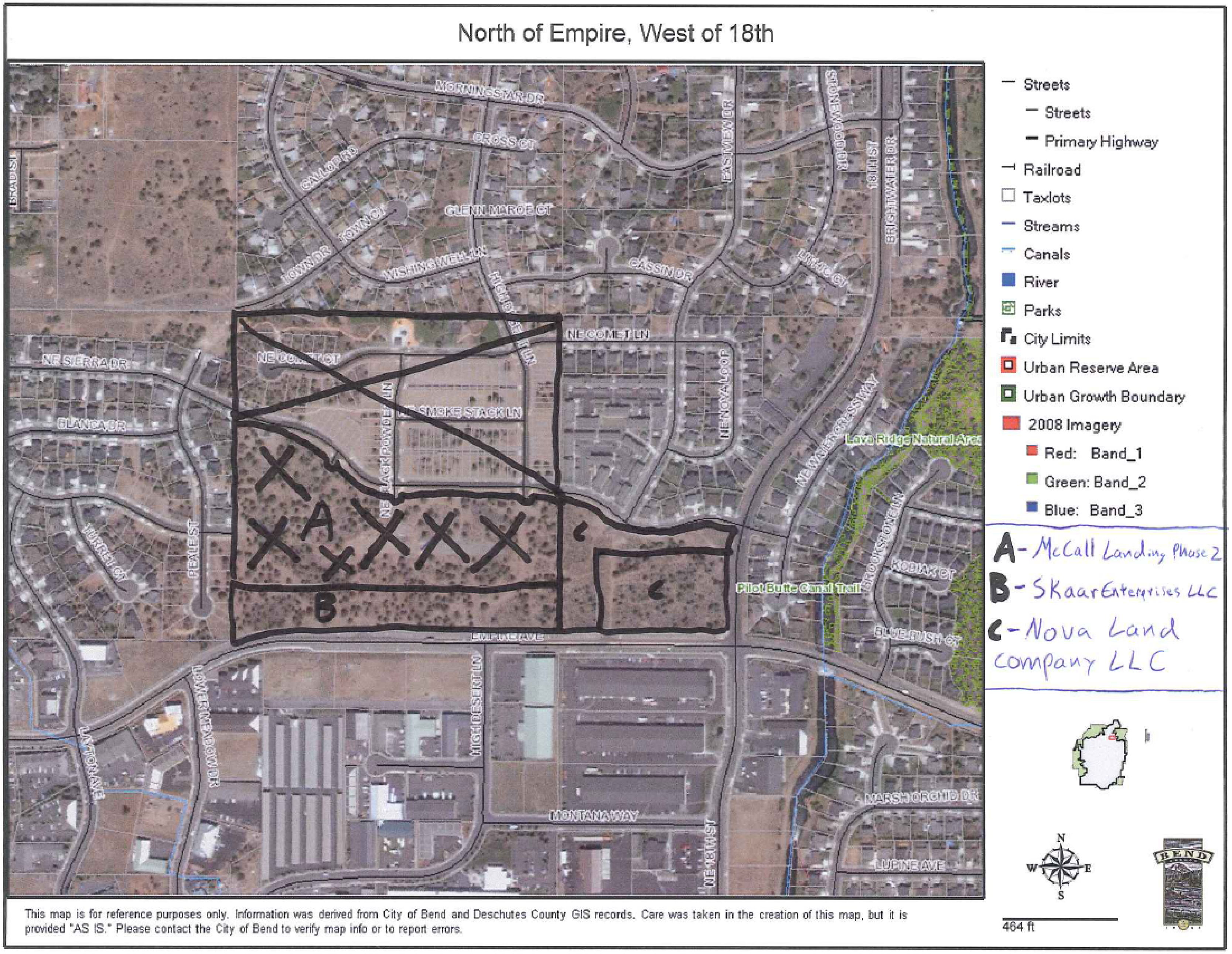
North of Empire, West of 18th
Streets
Streets
Primary Highway
Railroad
Taxlots
Streams
Canals
River
Parks
City Limits
Urban Reserve Area
Urban Growth Boundary
2008 Imagery
Red: Band_1
Green: Band_2
Blue: Band_3
A - McCall Landing Phase 2
B - Skaar Enterprises LLC
C - Nova Land Company LLC
MORNINGSTAR DR
CROSS CT
GALLOP RD
TOWN CT
GLENN MAROE CT
TOWN DR
WISHING WELL LN
CASSIN DR
NE COMET LN
NE COMET CT
NE SIERRA DR
BLANCA DR
SMOKE STACK LN
NE BLACK POWDER LN
NE NOVA LOOP
Lava Ridge Natural Area
Pilot Butte Canal Trail
KODIAK CT
BLUE BUSH CT
PEALE ST
EMPIRE AVE
HIGH DESERT LN
MONTANA WAY
NE 18TH ST
MARSH ORCHID DR
LUPINE AVE
LAYTON AVE
18TH ST
BRIGHTWATER DR
EASTVIEW DR
N
S
W
E
464 ft
BEND
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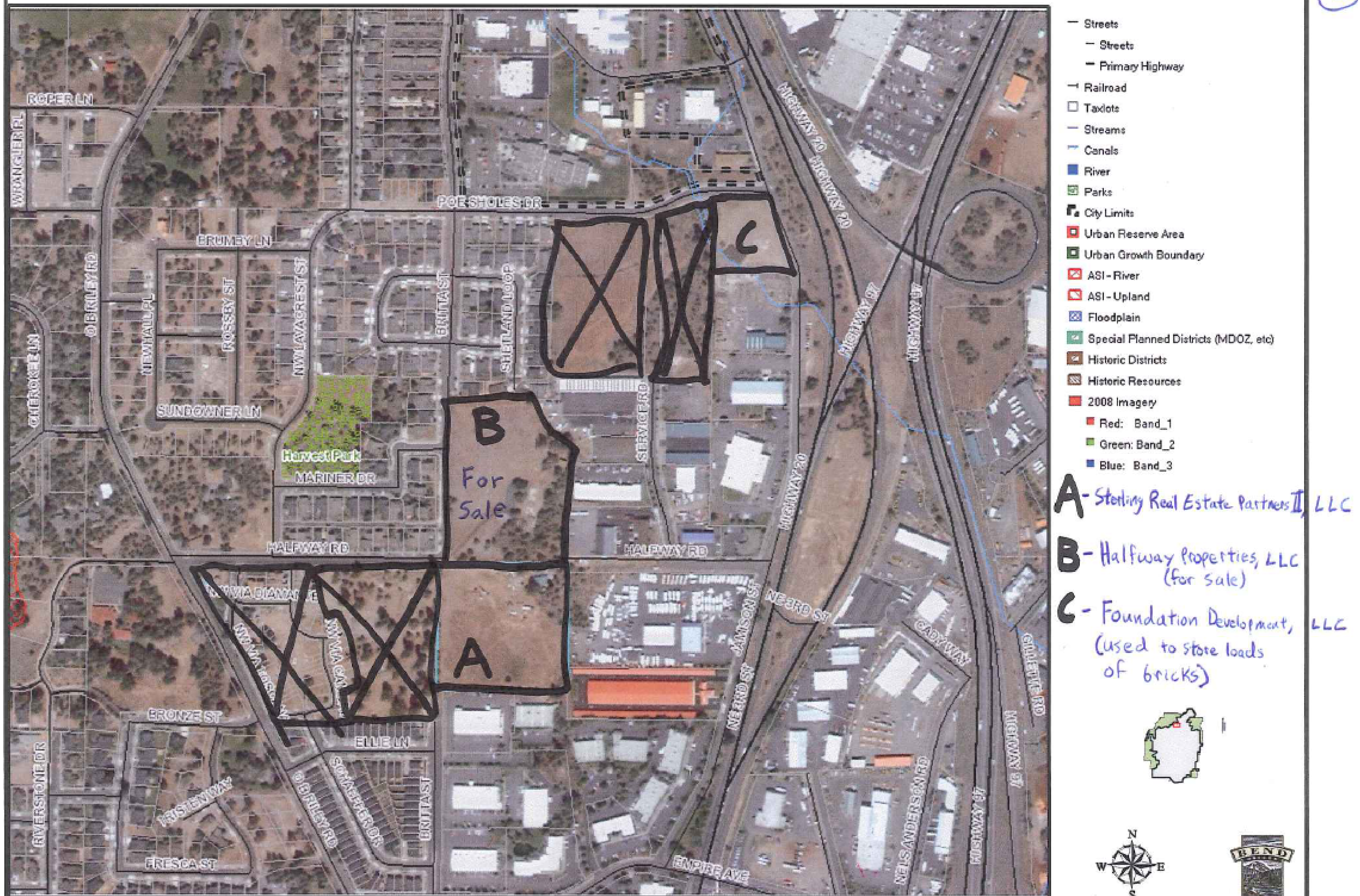
West of 97, North of Empire Ave.



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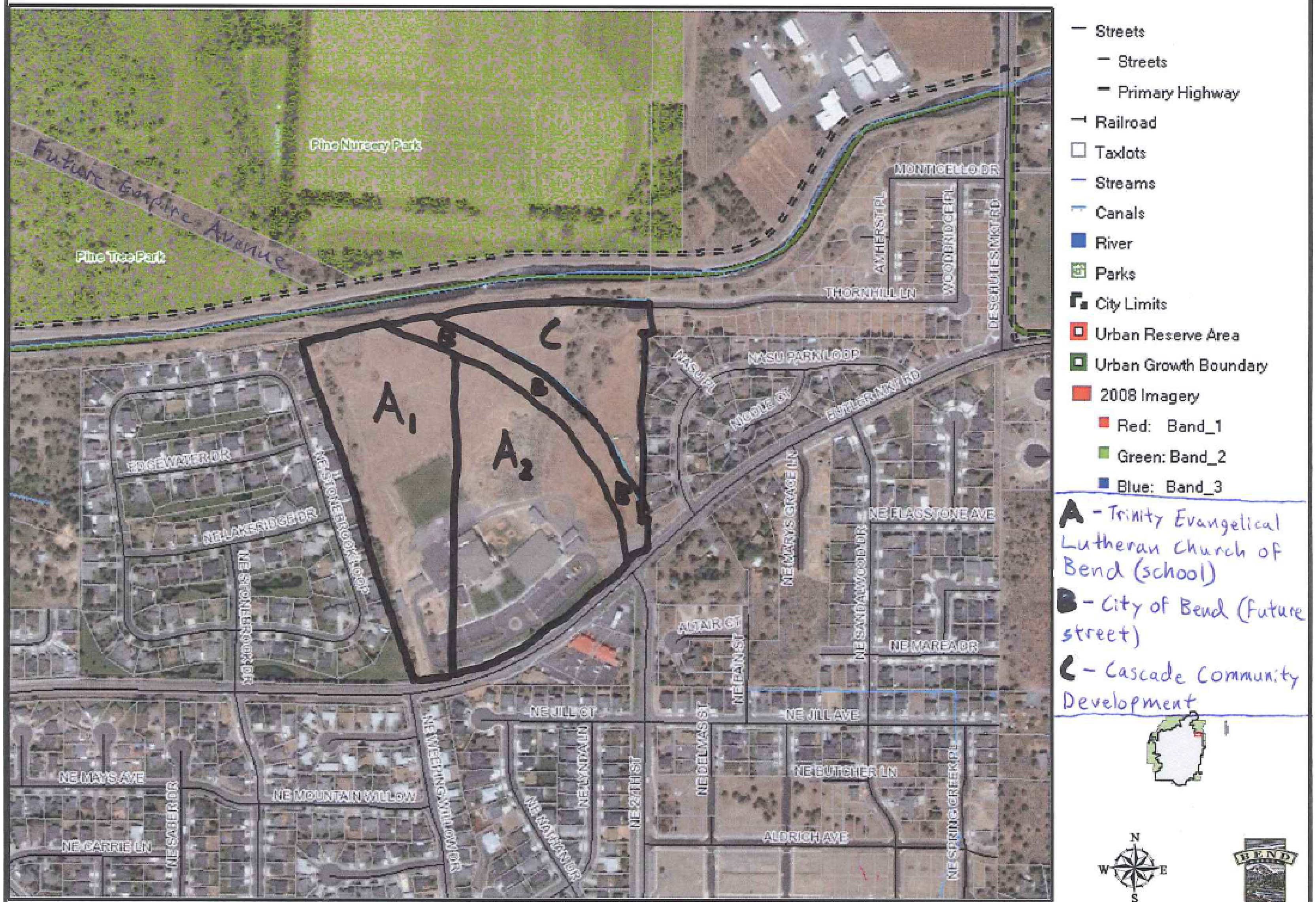
(5)

South of Pine Nursery, North of Butler Mrkt



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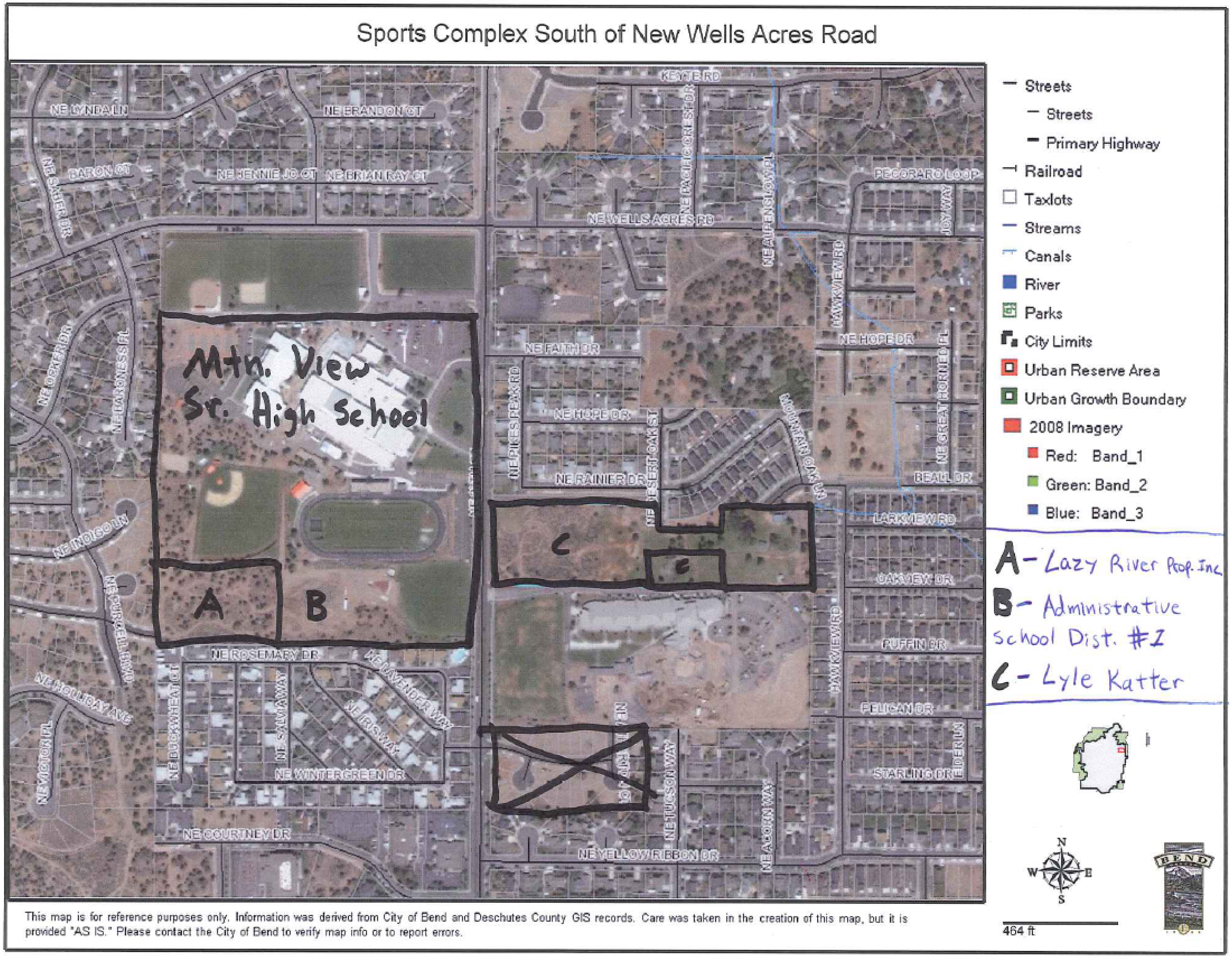

Sports Complex South of New Wells Acres Road
KEYTE RD
NE LYNDA LN
NE BRANDON CT
BARON CT
NE JENNIE JO CT
NE BRIAN RAY CT
NE WELLS ACRES RD
PECORARO LOOP
JOY WAY
NE ALPENGLOW PL
HAWKVIEW RD
NE HOPE DR
NE FAITH DR
NE PIKES PEAK RD
NE RAINIER DR
NE DESERT OAK ST
MOUNTAIN OAK LN
BEALL DR
LARKVIEW RD
OAKVIEW DR
PUFFIN DR
PELICAN DR
STARLING DR
NE GREAT HORNED PL
NE OCKER DR
NE BARONESS PL
NE INDIGO LN
NE PURCELL BLVD
NE HOLLIDAY AVE
NE VICTOR PL
NE ROSEMARY DR
NE LAVENDER WAY
NE IRIS WAY
NE WINTERGREEN DR
NE BUCKWHEAT CT
NE SALVIA WAY
NE COURTNEY DR
NE TUCSON WAY
NE ACORN WAY
NE YELLOW RIBBON DR
Mtn. View Sr. High School
A
B
C
c
Streets
Streets
Primary Highway
Railroad
Taxlots
Streams
Canals
River
Parks
City Limits
Urban Reserve Area
Urban Growth Boundary
2008 Imagery
Red: Band_1
Green: Band_2
Blue: Band_3
A - Lazy River Prop. Inc
B - Administrative School Dist. #1
C - Lyle Katter
N
W
E
S
464 ft
BEND
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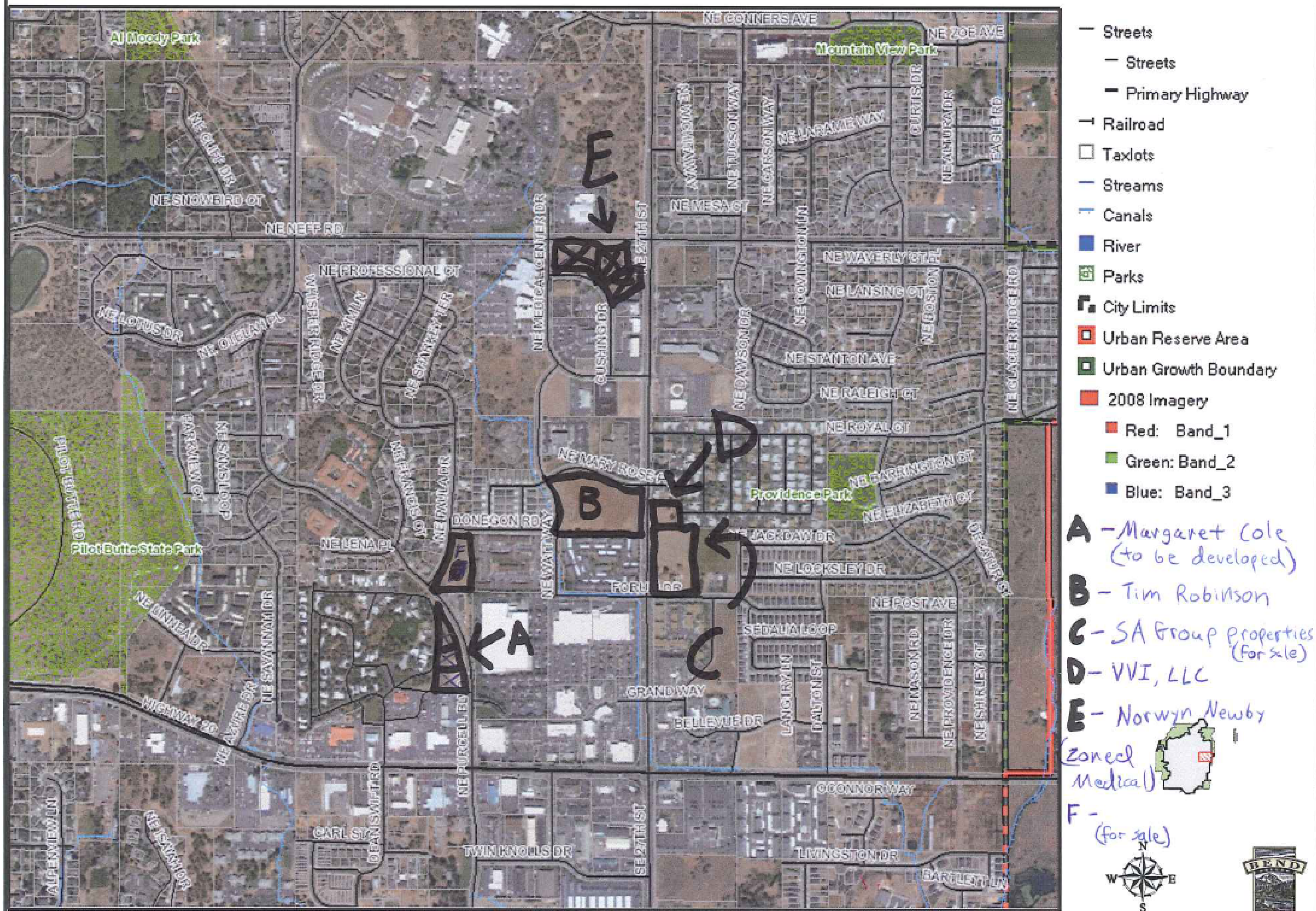
Corner of Neff and 27th



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From: Elsie Mann
Sent: Thursday, 29 April 2010 3:25 AM
To: 'HLansdowne@ci.bend.or.us'; 'THickmann@ci.bend.or.us'
Cc: Mike Canning; 'David Stangel'
Subject: Storage Guidelines - final decision

Heidi, Tom,

Following up from our call with Heidi last Thursday we offered to highlight the key impacts of the different storage standards both system-wide and specifically for Juniper Ridge. The tables below summarize the different options and what they mean in terms of volume and cost. What we need from you is a decision regarding which standard (or customized standard) Bend will be adopting.

To help you make your decision, I want to highlight some key items from our memo (sent April 14):

- Storage needs are broken into 4 major components: operating/equalization, standby, fire, and dead storage.
- Table 2 on page 5 summarizes the different standards that we reviewed.
    - Oregon looks to AWWA standards. These do not provide any quantitative measures for calculating storage requirements
    - The Ten States Standards, which many people refer to, do not apply to the Pacific Northwest, and are also not quantitative
    - Washington and Idaho's rules are quantitative, and are very similar except for their definition of standby storage needs. This is where you really need to make a decision.

Standby Storage

Looking at the Washington Design Manual's definition of 'continuously available sources' (see the note under the WA column in Table 2, and Section 4.2), Bend could look to rely on wells to provide 100% of the standby storage requirement. *Table 3 on Page 7 lists your current wells and the calculation of existing continuously available supply (i.e. the last column of the table) at 12.6 MGD (a little under 50% of total groundwater capacity). 12.6 MGD x 2 days = 25.2 MG which is just shy of the needed 2 x Average Day Demand (ADD) = 25.6 MG. In the future we expect Bend would maintain groundwater capacity equal to maximum day demand; relying on only 50% of this capacity would meet the 2 x ADD requirement.*

Idaho's standby volume requirement is only 8 hours of ADD, but the rules do not allow for offsetting of standby storage with reliable supply. Idaho also does not allow "nesting" (i.e., discounting the smallest) of standby and fire volumes.

As I see it, you have three potential options with respect to standby storage (in order of decreasing above-ground volume requirement):

1) Try to maintain the balance you currently have, where there is *approximately* 1 x ADD in reserve in above-ground storage, after you've accounted for operational and fire storage requirements. I'm calling this 'Modified Washington'.
2) Follow Idaho's rules
3) Follow Washington's Design Manual, taking full credit for your 'continuously available' sources (groundwater wells that are on SCADA and have back up power).

Operating/Equalization storage

It is important to point out that if Bend adopts the Washington Standards/Option #3 (and to a lesser extent if the Idaho rules were adopted) we'd need to look carefully at the estimation of operating and equalization storage volumes and ensure we were accounting for those adequately. As you reduce overall above-ground storage you need to be careful you are not jeopardising the ability to maintain adequate service pressures as storage levels will fluctuate more widely.

In addition, when trying to determine operating/equalization storage volumes needed for new developments, it is difficult to set a generic standard, as the necessary volume will be very dependent on the storage location in the system and how it is supplied, and the total area it supports. Calculating Operational storage needs with reference to demand is misleading when the tank is not solely supplying a particular development. In the case of the Juniper Ridge Tank, with the tank located in Level 6, it will be exposed to a much greater system demand than if it were solely supplying the development. We can talk about this further if need be.

System-wide analysis of storage requirements

Storage Components	**Existing system** *ADD – 12.8 MGD* *MDD – 28.8 MGD*	**Build-out** *ADD – 37.1 MGD* *MDD – 83.5 MGD*		
	Current Situation Refer Memo Table 9 (Compared to SB of 2 x ADD)	**Option #1** **Modified Washington** (SB 2 x ADD 50% above-ground, remainder wells)	**Option #2** **Idaho Rules** (SB 8 hrs x ADD above-ground)	**Option #3** **Washington** (SB 2 x ADD can be met by 'continuously available' supply)
Operation/Equalizing/Dead (MG)*	10.2	29.2	29.2*	29.2*
Standby (MG)	25.7	74.2	12.4	74.2
Offset from wells	*15.7*	*37.1*	*0.0*	*74.2***
Above-ground volume	*10.0*	*37.1*	*12.4*	*0.0*
Fire (MG)	7.3	7.3***	7.3	7.3
Lower Dead % of total	2.8 MG	5%	5%	5%
Total Above-ground Volume (MG)	**30.5**	**77.3**	**51.3**	**38.3**
Volume above Existing (MG)	-	47.3	21.3	8.3
Cost (at $1.35/MG)	**-**	**$63.8 m**	**$28.8 m**	**$11.2 m**

* Operational/equalization volumes are an estimate only and must be verified through hydraulic modeling to ensure that other design constraints (minimum pressures or maximum storage level fluctuations) do not indicate a larger volume requirement.

** This represents less than 50% of anticipated future well capacity operating for 2 days to meet the 2 x ADD volume requirement

*** Could consider 'nesting' this into the standby requirement

Juniper Ridge storage requirements under different standards – see attached spreadsheet.

For Juniper Ridge we have provided estimates of required volumes based on the following:

- MSA's analysis (based on 2007 MP)
- Washington without offset from wells
- Washington with offset from wells
- Idaho

Please let me know if you need more information/clarification. If we can find a time to have a 3 way call to discuss this early next week it would probably be helpful. Look forward to hearing how you and Tom get on with your discussions.

Elsie

Elsinore Mann
Project Engineer

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USA

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Fax: +1 773 792 2677
elsie.mann@optimatics.com

www.optimatics.com

Juniper Ridge Storage Capacity & Cost Estimations

Unit rate $1.925M per MG at Middle School Track
Phase 1 includes $500,000 for replacement of track and field

MSA Analysis

Phase	Acres	Demand			Storage				Estimated
		ADD	MDD	PHD	Fire[1]	Operational/Equalization[2]	Emergency[3]	Total	Cost (rounded)
1	294	643	1,479	2,218	1.50	0.53	1.85	**3.88**	**7,977,000**
2	221	483	1,111	1,666	0.00	0.40	1.40	**1.80**	**3,465,000**
Total	515	1,126	2,590	3,884	1.50	0.93	3.25	**5.68**	**11,442,000**
				1.5 x MDD					

1) Based on highest commercial category, volume as per 2007 Master Plan. Single fire volume assumed since entire area can be served by gravity
2) 25% of MDD
3) 2 x ADD

WA Design Manual (a), Standby 2 x ADD, no offset from wells, but nesting of fire in standby considered

Phase	Acres	Demand			Storage					Estimated
		ADD	MDD	PHD	Fire[1]	Equalization[2]	Operational[3]	Standby[4]	Total[5]	Cost (rounded)
1	294	643	1,479	2,662	1.50	0.18	0.57	1.85	**4.10**	**8,387,000**
2	221	483	1,111	2,000	0.00	0.13	0.43	1.39	**1.95**	**3,756,000**
Total	515	1,126	2,590	4,662	1.50	0.31	0.99	3.24	**6.05**	**12,143,000**
				1.8 x MDD				**With nesting[4]:**	**4.55**	**9,255,000**

1) Based on highest commercial category, volume as per 2007 Master Plan
2) (PHD - MDD) x 150 minutes
3) Calculated make combined Operational and Equalization volume equal 35% MDD, as per existing system MDD evaluation. See note below.
4) 2 x ADD, no offset from wells accounted for.
5) WA Design Manual allows nesting of fire and standby storage volumes. Applying this would reduce the total requirement to 4.55 MG (2.6 at Phase 1)

WA Design Manual (a), Standby 2 x ADD, offset by 'firm' well capacity

Phase	Acres	Demand			Storage					Estimated
		ADD	MDD	PHD	Fire[1]	Equalization[2]	Operational[3]	Standby[4]	Total	Cost (rounded)
1	294	643	1,479	2,662	1.50	0.18	0.57	1.85	**4.10**	**8,387,000**
2	221	483	1,111	2,000	0.00	0.13	0.43	1.39	**1.95**	**3,756,000**
Total	515	1,126	2,590	4,662	1.50	0.31	0.99	3.24	**6.05**	**12,143,000**
				1.8 x MDD				**With offset[4]:**	**2.81**	**5,900,000**

1) Based on highest commercial category, volume as per 2007 Master Plan
2) (PHD - MDD) x 150 minutes
3) Calculated make combined Operational and Equalization volume equal 35% MDD, as per existing system MDD evaluation. See note below.
4) 2 x ADD, offset by 'firm' well capacity. The MSA recommendations include costs for 2,590 gpm/3.7 MG of well capacity by Phase 2 Assuming this would comprise 4 wells at 0.925 MGD/well, firm capacity approxumately 3 x 0.925 = 2.8 MGD. Operating over 2 days gives a credit of 5.6 MG (against standby storage only)

Idaho Rules, Standby 8 hours of ADD

Phase	Acres	Demand			Storage				Estimated
		ADD	MDD	PHD	Fire[1]	Operational/Equalization[2]	Standby[3]	Total	Cost (rounded)
1	294	643	1,479	2,662	1.50	0.75	0.31	**2.55**	**5,417,000**
2	221	483	1,111	2,000	0.00	0.56	0.23	**0.79**	**1,524,000**
Total	515	1,126	2,590	4,662	1.50	1.31	0.54	**3.35**	**6,941,000**
				1.8 x MDD					

1) Based on highest commercial category, volume as per 2007 Master Plan
2) Assume 35% MDD, as per existing system MDD evaluation. See note below.
3) 8 hours x ADD

Note: The Operational volume calculation should be reviewed in light of the fact that a dedicated storage for Juniper Ridge at the Middle School Track Site would likely be operated differently to other tanks in the system. The 35% MDD value is a system-wide average and takes into account the lower operating levels of some reservoirs, e.g. Pilot Butte III. The JR Tank would be filled via a valve from Level 5, and it would be possible to maintain the level quite high, as there would be no restrictions from a supply HGL perspective. This would reduce the operating storage requirement for JR.

Once the site of the JR is confirmed, a more accurate estimation of operational storage requirements can be made.