TECHNICAL MEMORANDUM

Signed: 10/19/2023

Client:	City of Camas
Project:	343 Zone Reservoir Siting Analysis
Project File:	CAMA 0220068.00.0002
Project Manager:	Michele Campbell, PE
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Subject:	Pressure Zone Reconfiguration, Reservoir Site Screening and Alternatives Identification
Date:	October 19, 2023

Background

The City of Camas (City) 2019 Water System Plan (WSP) identified the need for a new 1.4 to 1.5 million gallon (MG) 343 Zone Reservoir to replace the existing Butler Reservoir, as it has reached the end of its useful life. The Butler Reservoir is located in the 343 Zone, which serves the Downtown 343 Zone through pressure reducing valve (PRV) stations and the rest of the water system via booster pump stations (BPS).

The Butler Reservoir consists of two adjacent, partially buried concrete structures that share a common wall. The northern half of the reservoir was constructed in 1913, and the southern half of the reservoir was constructed in 1923. The reservoir is covered and has a total storage volume of approximately 1.2 MG. The reservoir has an overflow elevation of 343 feet which establishes the hydraulic grade line of the 343 Zone.

The 343 Zone and Butler Reservoir are crucial to the operation of the City's entire water system. The 343 Zone contains the Washougal Wellfield which is the City's main source of supply. Water from the Washougal Wellfield is pumped directly into the 343 Zone and the Butler Reservoir and then distributed to the rest of the system. Therefore, the Butler Reservoir cannot be easily taken offline while its replacement is being constructed.

The WSP also identified widespread areas of low fire flow and pressure deficiencies in the 343 Zone service area. Improvements to resolve these deficiencies should be considered and coordinated with the design of the new reservoir to optimize the operation of the 343 Zone service area, maximize funding investments in water system infrastructure, and improve level of service to City customers.

Purpose

The City has requested RH2 Engineering, Inc., (RH2) to provide engineering services to support the site selection of the replacement reservoir and distribution system improvements that may be needed to improve the level of service in the 343 Zone. The City has previously identified the existing Butler Reservoir site and the Camas Cemetery as potential reservoir locations. A limited screening is also included in this study to consider other viable properties for reservoir siting alternatives. The reservoir siting project area is shown in **Figure 1**.

This technical memorandum summarizes the results of the reservoir site selection and siting alternatives identification. It also documents the analyses performed to recommend pressure zone reconfiguration improvements to reduce high system pressures and increase available fire flow in the 343 Zone. A subsequent technical memorandum will document the results of the cost estimates for the reservoir siting alternatives and the weighted scoring matrix for the ranking of the reservoir siting alternatives.

Demand Projections

The City's 2019 WSP identified high, medium, and low demand projections through the year 2035 for each of the distribution system's service areas as well as for the system as a whole. The low demand scenario represents future demands with conservation measures, the medium demand scenario is a conservative projection between the low and high projections, and the high demand scenario generally reflects the highest demands in the last eight years analyzed in the City's 2019 WSP. The City opted to size the Butler Reservoir replacement with a longer planning horizon in mind than the 2035 projections provide. Twenty-year projections, (2042) were developed using a constant growth rate determined from the average growth between 2025 and 2035 from the City's 2019 WSP. **Table 1** shows the medium demand projections presented in gallons per minute (gpm) that were used for the reservoir sizing and hydraulic modeling that will be performed to determine distribution system improvements.

Table 1
Medium Demand Projections

	Existing System		2035 System		2042 System	
Demand Type	**System Demand (gpm)**	**343 Zone Service Area Demand (gpm)**	**System Demand (gpm)**	**343 Zone Service Area Demand (gpm)**	**System Demand (gpm)**	**343 Zone Service Area Demand (gpm)**
Average Day Demand (ADD)	3,878	585	5,208	596	6,082	602
Maximum Day Demand (MDD)	8,446	1,275	12,188	1,395	14,760	1,462
Peak Hour Demand (PHD)	14,125	2,156	20,110	2,345	24,191	2,516
Booster Pumping Out of Service Area [1]	-	4,385	-	4,600	-	4,600

1 = From Table 9.1 of the City's 2019 WSP.

Table 1 includes flow rates of water that is projected to be pumped out of the 343 Zone to serve other parts of the City's distribution system. It is important to consider this flow rate when determining the equalizing and standby storage components of the Butler Reservoir replacement.

Supply Analysis

The Washougal Wellfield supplies water directly into the 343 Zone and Butler Reservoir via existing groundwater wells as shown in **Table 2**.

Table 2
343 Zone Service Area Supply Analysis

Description	Base Year 2021	Projected 2032 (+10 years)	Projected 2042 (+20 years)
Existing Available Supply Capacity (gpm)			
Washougal Well 5 [1]	0	500	500
Washougal Well 6	1,000	1,500	1,500
Washougal Well 7	950	950	950
Washougal Well 8	1,350	1,350	1,350
Washougal Well 10	900	900	900
Washougal Well 11	1,200	1,200	1,200
Washougal Well 12	900	900	900
Washougal Well 13	1,325	1,325	1,325
Washougal Well 14	1,000	1,000	1,000
Future Available Supply Capacity (gpm)			
Future additional Washougal Wellfield water rights [2]	1,000	2,000	2,000
Total Supply Capacity	**9,625**	**11,625**	**11,625**

1 = Assumes the Washougal Wellfield Renewal Project will provide backup power to Well 5 and full use of Well 6, and that Well 5 will be reconfigured to pump directly to the 343 Zone dedicated transmission main.
2 = The Future Additional Washougal Wellfield water rights assume the water rights for the Parkers Landing Well and Wastewater Treatment Plant (WWTP) Well will be transferred to the other wells in the Washougal Wellfield and that there is capacity to pump the additional water right.

When operated, Well 5 over-pressurizes the Downtown 343 Zone. To alleviate the high service pressures, the City operates the Forest Home BPS in the Downtown 343 Zone while Well 5 is being operated. Due to the complexity involved with operating Well 5, the City operates this well as a seasonal source. The 2,000 gpm water rights associated with the Parker's Landing Well and Wastewater Treatment Plant (WWTP) Well, identified as Capital Improvement Program (CIP) projects S-2 and S-3 respectively in the 2019 WSP, will be transferred to the Washougal Wellfield because there is not a suitable location for these wells to be constructed. CIP project S-4 was planned to maximize use of the water rights associated with the Washougal Wellfield and is projected to be completed between 2023 and 2026. CIP project S-4 includes resolving the issues associated with operating Well 5, and increasing the yield from Well 6. The Steigerwald Regional Source project, identified as CIP project S-5 in the 2019 WSP, involves obtaining supply from the future Steigerwald Regional Wellfield. It is assumed to supply the 343 Zone directly and is projected to be completed between 2027 and 2036. The City has stated that there is a lot of uncertainty with regard to the future of CIP project S-5 and therefore it has been omitted from the available supply shown in **Table 2**.

Hydraulic Analyses

Hydraulic analyses were performed to determine the capability of the system to meet the pressure and flow requirements, contained in Washington Administrative Code (WAC) 246-290-230, and to identify conceptual water system improvements needed to resolve the widespread areas of low fire flow and pressure deficiencies in the 343 Zone service area.

Existing System Hydraulic Analyses

The first analysis was performed to determine the pressure throughout the system under existing (i.e., 2022) PHD conditions. The results of this analysis were used to identify locations of low and high pressures. To satisfy the minimum pressure requirements, the pressure at all water service locations must be at least 30 psi during PHD conditions. In addition, the system should not have widespread areas with high pressures, generally considered to be more than 100 psi. A summary of the pressure deficiencies identified from the results of this analysis is shown on **Figure 2**. As shown in the figure, there are areas of low pressure in the 343 Zone along NE 22nd Avenue. High pressures exist in the majority of the Downtown 343 Zone area, with some pressures exceeding 120 psi.

The second set of analyses was performed to determine the capability of the existing water system to provide fire flow throughout the system under MDD conditions. The fire flow availability was evaluated based on planning-level fire flow requirements as stated in the City's 2019 WSP.

A separate fire flow analysis was performed for each node in the model where fire flow is provided to determine the available fire flow at a minimum residual pressure of 20 psi at all points throughout the distribution system. No velocity constraint was used for the fire flow analyses per the City's 2019 WSP. Approximately 220 fire flow analyses were performed to comprehensively evaluate the water system. For each node analyzed, the resulting fire flow was compared to its general planning-level fire flow requirement, which was assigned according to its land use classification. As is typical of most water systems, the City's distribution system was constructed to meet fire flow requirements that were in place at the time of construction. Land use classification changes and/or increases in fire flow requirements over time may create deficiencies. A summary of the results of the fire flow analyses for representative system nodes is shown in **Figure 3**. As shown in the figure, the area south of the Washougal Wellfield has limited fire flow availability, with many nodes indicating less than 500 gpm. Fire flow availability varies widely in other areas of the 343 Zone, with some areas meeting the planning-level fire flow requirements.

Pressure Zone Reconfiguration Improvements

The hydraulic analyses performed to develop **Figure 2** identified high service pressures in the Downtown 343 Zone. The portion of the Downtown 343 Zone that is west of the Washougal River has existing service pressures that range between 71 and 113 psi. The portion of the Downtown 343 Zone that is east of the Washougal River has existing service pressures that range between 104 and 127 psi.

To reduce the level of service pressure, a pressure zone reconfiguration is recommended. It is recommended that portions of the existing 343 Zone be converted into a series of three smaller pressure zones in a phased approach. The recommended zones are a 260 Zone, 190 Zone, and 170 Zone. The improvements and suggested phasing are described in the following sections.

Phase 1 – 260 Zone

- Activate the PRVs on NE 6th Avenue and NE 7th Avenue that separate the 343 Zone and the downtown 343 Zone to reestablish this zone boundary and convert the downtown 343 Zone to a 260 Zone. The PRVs located at the following locations are recommended to be set as follows.
    - NE 6th Avenue and NE Joy Street – 64 psi
    - NE 6th Ave and Hayes Street – 36 psi
    - NE 7th Avenue and NE Dallas St – 53 psi
- Upsize approximately 45 feet of 8-inch water main between the 343 Zone dedicated transmission main and the 343 Zone at the intersection of NE 22nd Avenue and NE Everett Street.

Improvements are planned at the Forest Home BPS, but the City has indicated that the timing of these improvements is not yet known. Phase 1 of the pressure zone reconfiguration will alter the suction conditions of the Forest Home BPS. Either a parallel water main should be installed from the 343 Zone to the suction side of the Forest Home BPS (1,800 feet of 12-inch water main), or the design of the proposed BPS improvements should consider pumping from a hydraulic grade of 260 feet to maintain acceptable operating conditions for the Forest Home BPS.

Phase 2 – 260 Zone and 170 Zone

- Install a new 260 Zone to 170 Zone PRV at SE 6th Avenue and SE Polt Street. The recommended PRV setpoint is 53 psi.
- Install approximately 1,000 feet of 8-inch water main from Well 5 to the dedicated 343 Zone transmission main to alleviate existing Well 5 operational concerns, and maintain use of Well 5.

Phase 3 – 260 Zone, 170 Zone, and 190 Zone

- Install a new 260 Zone to 190 Zone PRV at NE 3rd Avenue and NE 3rd Loop. The recommended PRV setpoint is 64 psi.
- Activate PRV-47 with a recommended setpoint of 62 psi.

Table 3 and **Figure 4** show how the service pressures are improved in the project area as the recommended pressure zone reconfiguration phases are implemented.

Table 3
Pressure Zone Reconfiguration

Pressure Zone Reconfiguration Phases	Existing Upper 343		Existing Downtown		260 Zone		170 Zone		190 Zone	
	Min. Pressure	Max. Pressure	Min. Pressure	Max. Pressure	Min. Pressure	Max. Pressure	Min. Pressure	Max. Pressure	Min. Pressure	Max. Pressure
Existing System	38 psi	55 psi	52 psi	127 psi	---	---	---	---	---	---
Phase 1	44 psi	99 psi	---	---	37 psi	95 psi	---	---	---	---
Phase 2	44 psi	99 psi	---	---	36 psi	91 psi	52 psi	61 psi	---	---
Phase 3	44 psi	99 psi	---	---	37 psi	89 psi	52 psi	61 psi	54 psi	72 psi

Figure 5 shows the resultant MDD fire flows following the implementation of the recommended pressure zone reconfiguration. The available fire flows following the pressure zone reconfiguration improvements generally increase across the project area, with many locations that do not currently meet planning level fire flow requirements meeting the requirement following the implementation of Phase 3. The reservoir siting analyses will be evaluated with consideration of the recommended pressure zone reconfiguration.

General Considerations for Reservoir Siting

The existing Butler Reservoir site and the Camas Cemetery have been previously identified for a potential new reservoir. The area of the Camas Cemetery that is being considered for the proposed reservoir is the undeveloped area north of the cemetery plots. Other viable properties for reservoir siting alternatives were also considered through a limited screening of property within the City.

Available Land and Hydraulic Considerations

The following outlines the criteria that was used to help identify parcels that should be included or excluded from consideration based on the development status of the property and hydraulic needs of the system.

- Parcels already owned by the City minimize the cost of purchasing a property for siting a new/replacement reservoir.
- Parcels with existing buildings or otherwise developed were not considered for reservoir siting.
- Parcels significantly far away from existing water system infrastructure that would require significant water main installation were considered less desirable.
- Parcels that would require a significant amount of dead storage to proposed tank sites were considered less desirable.
    - To provide 20 pounds per square inch (psi) residual pressure at the highest service elevation of 239 feet in the 343 Zone without dead storage, the storage volume should be located above an elevation of 285 feet.
    - To provide 20 psi residual pressure at the highest service elevation of 362 feet in the 455 Zone without dead storage, the storage volume should be located above an elevation of 408 feet.
    - To provide 20 psi residual pressure at the highest service elevation of 152 feet in the proposed 260 Zone without dead storage, the storage volume should be located above an elevation of 198 feet.

Figure 6 shows the project area where parcels within the city limits were considered for possible reservoir sites. Property already owned by the City is shown on the figure along with contours to identify sites within preferred elevation ranges.

Environmental and Geologic Considerations

The following sections outline the criteria that will be used to help identify parcels that should be included or excluded from consideration based on environmental or geologic factors.

Natural Resources

Only sites located within the City's jurisdiction were considered; therefore, local permitting is anticipated to be obtained through the City.

Wetlands exist to the east of the City-owned property adjacent to the existing Butler Reservoir site. In addition, Lacamas Creek and associated wetlands can be found to the north and east of the cemetery site.

Lacamas Creek is designated as a shoreline (Type S stream) and flows from Round Lake to its outlet at the Washougal River. Per the City's Critical Areas Code, the creek is a fish and wildlife habitat conservation area. As a result, the creek requires a base buffer width of 150 feet. In addition, the *Camas Shoreline Master Program* (2021) designates the Lacamas Creek shoreline as an Urban Conservancy. Therefore, it is anticipated a Shoreline Conditional Use Permit will be required through the City if the cemetery site is chosen for a future reservoir.

It also is anticipated that critical areas investigations and reporting will be required through the City. Investigations are anticipated to include delineation of the Ordinary High Water Mark (OHWM) of Lacamas Creek and the boundary of any wetlands within 300 feet of the proposed site(s). It is recommended that documentation requirements are confirmed with the City early in the project design phase.

The Butler Reservoir site and the Camas Cemetery sites being considered are not within the 100-year floodplain. Therefore, no floodplain or frequently flooded areas permit reviews are anticipated for these sites. Parcels within the 100-year floodplain have been excluded from the limited site screening for potential reservoir sites. Similarly, parcels with existing mapped wetlands were also excluded from the limited site screening.

Figure 7 shows the natural resource areas in the study area that should be excluded from consideration for siting of the reservoir. None of the Butler Reservoir and Camas Cemetery sites should be excluded from consideration based on this evaluation of natural resources.

Geologic Hazards

The geologic hazards for potential reservoir sites is shown on **Figure 8** and is based on mapping provided by Clark County GIS and the Washington State Department of Natural Resources (DNR). The tectonic setting of the City results in significant seismic activity, including potential fault rupture, earthquake shaking, liquefaction of susceptible sediments, and landsliding. Geologic hazards represented in **Figure 8** consist of severe erosion hazard areas, identified primarily by soil type and topography; landslide susceptibility, identified by geology, topography, and hydrogeology; and liquefaction susceptibility, identified by geology and hydrogeology.

Regionally, the City is located within a bedrock-lined basin, which is part of the larger Puget-Willamette Lowland separating the Cascade Range from the Oregon Coast Range. The basin has been shaped by an active tectonic margin, basin fill from surrounding uplands and volcanic activity, catastrophic glacial flood events, and modern river drainages.

Within the City, Lacamas Lake and Lacamas Creek are located, north of the confluence with the Columbia River. Bedrock, consisting of Tertiary sedimentary and volcanic rocks, is exposed in the upland areas of the City. Unconsolidated to cemented basin fill sediments and volcanic rocks (roughly ½ to 1 million years old) mantle portions of the bedrock and line river valleys, underlying younger unconsolidated sediments. Roughly 13,000 and 15,000 years ago, the majority of the City was inundated by a series of catastrophic floods originating from repeated ice dam failures of Glacial Lake Missoula (Waitt, 1985, Evarts et al., 2009), which deposited layers of boulder-gravel, sandy gravel, and sand with sandy silt. Flood deposits, consisting of sand and gravel, are mapped along Lacamas Creek and Lacamas Lake up to approximately 350 feet elevation and along the Columbia River valley margins. The flood waters triggered landslides along the margins of the uplands. Recent alluvium deposited along and within the modern river channels, exist along Lacamas Lake, Lacamas Creek and the Columbia River, consisting of stratified layers of sand, gravel, silt and clay. Other recent, unconsolidated deposits include landslide deposits, wind-blown sediments, lake sediments and peat (Evarts and O'Connor, 2008).

Landslide mapping by the DNR identifies several large historic or active (less than 150 years old) and pre-historic, deep-seated landslides along the margins of river valleys including Lacamas Lake, Lacamas Creek, Camas Slough and the Columbia River. The DNR also identifies National Earthquake Hazards Reduction Program (NEHRP) seismic site classes and liquefaction susceptibility for the City.

The existing Butler Reservoir site and adjacent parcel consist of gentle slopes, generally less than 15 percent, and soils mapped as Hesson clay loam, 0 to 8 percent slopes and 8 to 20 percent slopes, according to the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture. Hesson clay loam is described as deep, well-drained soils that form in old, mixed alluvium containing varying amounts of gravel. According to geologic mapping, the site is located near the contact of older (Tertiary-age) volcanic rocks consisting of a thick sequence of basaltic and andesitic lava flows and Quaternary-age unconsolidated to cemented basin-fill sediments (Evarts and O'Connor, 2008). Based on soil survey mapping the site is likely underlain by basin-fill sediments. According to DNR, and published geologic hazards mapping, the Butler Reservoir site has very low liquefaction susceptibility, a NEHRP seismic site class of C to D (very dense soil and soft rock to stiff soil), a low risk of erosion, and low landslide susceptibility.

The parcels of the proposed Camas Cemetery site are generally flat-lying and are located immediately west of a steep valley wall of Lacamas Creek. According to NRCS, soils at the site are identified as Vader silt loam, 3 to 8 percent slopes and the Vader series typically consists of well-drained soils underlain by sandstone. Geologic mapping indicates the site is underlain by sandstone of the Troutdale Formation consisting chiefly of coarse volcaniclastic sandstone (Evarts and O'Connor, 2008).

Immediately east of the Camas Cemetery site, a large landslide complex is delineated along the west valley wall of Lacamas Creek, shown on **Figure 8**. The DNR identifies this landslide as a complex, deep-seated rotational earth slide which has been active within the last 150 years. It was field verified by the DNR and identified to have a head scarp height of 50 feet and failure depth of 43 feet. The landslide scarp exceeds slopes of 100 percent, and the landslide height is approximately 170 feet. The high and moderate landslide susceptibility areas mapped by the DNR occupy the eastern portion of the parcels of the proposed cemetery reservoir site (Mickelson et al., 2018).

In addition, the Lacamas Lake fault is mapped within 100 feet to 200 feet of the eastern margin of the proposed Cemetery Reservoir parcels. According to the USGS Quaternary Faults database, the Lacamas Lake Fault is oriented northwest to southeast along Lacamas Lake, Lacamas Creek and continuing into Oregon. It is considered active with the most recent activity uncertain, but occurring less than 750,000 years ago (Personius, 2002).

According to DNR, and published geologic hazards mapping, the proposed Camas Cemetery site has very low liquefaction susceptibility and a NEHRP seismic site class of C to D (very dense soil and soft rock to stiff soil). The eastern and northern portions of the site have a moderate to high landslide susceptibility and a severe risk of erosion (**Figure 8**).

Figure 8 shows the mapped geologic hazards in the study area. Based on this limited review of published site conditions, for the Butler site and adjacent parcel, no geological hazards have been identified to exclude consideration for reservoir siting. For the parcels of the proposed Camas Cemetery site, the identified moderate and high landslide susceptibility areas along the eastern and northern portions of the parcels should be excluded from consideration. Detailed site investigations to evaluate site and soil conditions, potential geological hazards, and potential setbacks and mitigations for identified geological hazards are recommended once a site has been selected.

Cultural Resources

The City is aware that much of the land within the City limits is at risk of encountering cultural resources during construction. Per Washington State Department of Archaeology and Historic Preservation (DAHP) WISAARD mapping, the existing Butler Reservoir site, the adjacent City-owned property, and the Camas Cemetery site have a high to very high risk of encountering cultural resources during project construction. However, DAHP WISAARD mapping also showed that there are no registered historic properties or buildings near any of the proposed reservoir sites.

Figure 9 shows the cultural resources within the study area. Based on the risk of encountering cultural resources during construction, it is recommended that a cultural resources survey be conducted during the design phase.

Shortlisted Viable Reservoir Sites

With consideration given to available land, hydraulic needs, and environmental and geologic conditions, the remaining potential reservoir area is shown in **Figure 10**. Review of the area with the City for the purposes of the limited site screening considered the Fallen Leaf Softball Field and the parcel east of the existing Butler Reservoir site. After further review, the Fallen Leaf Softball Field site was removed from additional consideration.

The remaining shortlisted sites are as follows.

- Existing Butler Reservoir site
- City-owned parcel east of the existing Butler Reservoir site
- Camas Cemetery site

Reservoir Siting Alternatives

The shortlisted sites were considered with the pressure zone reconfiguration recommendations to identify alternative configurations for siting the proposed reservoir. Both ground level and elevated tank styles were evaluated for operation in the various pressure zones adjacent to the shortlisted sites. The following potential reservoir alternatives were selected to maximize the level of service in the water system.

- **Alternative 1 –** Ground level 343 Zone Reservoir on the existing Butler Reservoir site.
- **Alternative 2 –** Buried 343 Zone Reservoir on the City-owned property adjacent to the existing Butler Reservoir Site.
- **Alternative 3 –** Ground level 455 Zone Reservoir on the City-owned property adjacent to the existing Butler Reservoir Site.
- **Alternative 4 –** Ground level 260 Zone Reservoir on the Camas Cemetery site.
- **Alternative 5 –** Elevated 343 Zone Reservoir on the Camas Cemetery site.

Table 4 summarizes the proposed location, reservoir style, and elevation attributes of each evaluated alternative.

Table 4
Proposed Reservoir Alternatives and Reservoir Elevations

Alternative	Proposed Location	Proposed Reservoir Style	Proposed Overflow Elevation (ft)	Proposed Base Elevation (ft)
1	Existing Butler Reservoir site	Ground Level Tank	343	303
2	City-owned property adjacent to the existing Butler Reservoir site	Buried Reservoir	343	328
3	City-owned property adjacent to the existing Butler Reservoir site	Ground Level Tank	455	351
4	Camas Cemetery site	Ground Level Tank	260	200
5 [1]	Camas Cemetery site	Elevated Tank	343	290

1 = The proposed base water level elevation is 290 feet, the ground elevation at the site is 200 feet.

The required storage volume, reservoir diameter and other required distribution system improvements to support each proposed reservoir alternative are evaluated in the following sections.

Reservoir Sizing Analysis

This section evaluates the needed capacity for the proposed reservoir, based on the existing and 20-year water system needs for the pressure zones that will be served by the facility. For the purposes of these analyses, it is assumed that the existing Butler Reservoir will be taken out of service once the proposed reservoir is constructed.

Reservoir Sizing Criteria

Water storage is typically made up of the following components: operational storage; equalizing storage; standby storage; fire flow storage; and dead storage. Each storage component serves a different purpose and will vary from system to system. A definition of each storage component and the criteria used to evaluate the capacity of the City's storage tanks is provided as follows.

Operational Storage – Volume of the reservoir used to supply the water system under normal conditions when the source or sources of supply are not delivering water to the system (i.e., sources are in the off mode). Operational storage is essentially the average amount of drawdown in the reservoir during normal operating conditions, which represents a volume of storage that will most likely not be available for equalizing storage, fire flow storage, or standby storage. The operational storage is based on the amount of storage between the fill, or pump starting setpoint level, and the overflow elevation of the tank. The operational storage component of the proposed reservoir was assumed to be 0.24 MG, as presented in the City's 2019 WSP.

Equalizing Storage – Volume of the reservoir used to supply the water system under peak demand conditions when the system demand exceeds the total rate of supply of the sources. The Washington State Department of Health (DOH) requires that equalizing storage be stored above an elevation that will provide a minimum pressure of 30 psi at all service connections throughout the system under PHD conditions. Because the City's supply sources primarily operate on a "call on demand" basis to fill the reservoirs, the equalizing storage requirements are determined using the standard DOH formula that considers the difference between the system PHD and the combined capacity of the supply sources:

$$\mathbf{ES = (PHD - Q_S)(150\ minutes)}\text{, but in no case less than zero}$$

Where:

ES = Equalizing Storage, in gallons

PHD = Peak Hour Demand, in gpm

Q_S = Sum of all installed and active sources, except emergency supply, in gpm.

If the capacities of the sources that supply each zone are sufficient to meet the peak hour demands of their zones, the equalizing storage requirement for that supply area is zero.

Standby Storage – Volume of the reservoir used to supply the water system under emergency conditions when supply facilities are out of service due to equipment failures, power outages, loss of supply, transmission main breaks, and any other situation that disrupts the supply source. DOH requires that standby storage be stored above an elevation that will provide a minimum pressure of 20 psi at all service connections throughout the system. The criteria for determining the standby storage requirements for the City's system is based on the DOH recommendation that standby storage equals one day of maximum day demands (MDD). This volume may be reduced for pressure zones with multiple sources of supply that each have permanent backup power that starts automatically.

The calculated volume is sufficient to supply the system for a 24-hour period when the primary supply facility is out of service and the system is experiencing maximum day demands:

$$\mathbf{SB = (1\ day)[(ERU_{MDD})(N) - (1\ day)(Q_S\text{-}Q_L)]}$$

Where:

SB = Standby Storage, in gallons

ERU_{MDD} =MDD per equivalent residential unit (ERU), in gallons per day (gpd) per ERU

N = Number of ERUs

Q_S = Sum of all installed and continuously available sources with permanent backup power that starts automatically, except emergency supply, in gpd

Q_L = The capacity of the largest continuously available source with permanent backup power that starts automatically, in gpd.

DOH recommends that the minimum standby storage volume be no less than 200 gallons per ERU.

Fire Flow Storage – Volume of the reservoir used to supply water to the system at the maximum rate and duration required to extinguish a fire at the building with the highest fire flow requirement. The magnitude of the fire flow storage is the product of the fire flow rate and duration of the system's maximum fire flow requirement established by the local fire authority. The maximum fire flow requirement in the project area is 4,000 gpm for 4 hours. DOH requires that fire flow storage be stored above an elevation that will provide a minimum pressure of 20 psi at all points throughout the distribution system under MDD conditions.

If allowed by the local fire authority, the volume of storage reserved for emergencies (fire flow storage and standby storage) may be nested. Nesting uses the largest of the calculated volume of either fire flow or standby storage for the emergency storage volume. Although the 2019 WSP presented the storage capacity analyses with the emergency storage nested, to be conservative, nesting was not considered for the purposes of this analysis.

Dead Storage – Volume of the reservoir that cannot be used because it is stored at an elevation that does not provide system pressures that meet the minimum pressure requirements established by DOH without pumping. This unusable storage occupies the lower portion of most ground-level reservoirs. Water that is stored below an elevation that cannot provide a minimum pressure of 20 psi is considered dead storage for the analyses that follow.

Reservoir Sizing Analysis Results

343 Zone Reservoirs

Alternatives 1, 2, and 5 all target an overflow elevation of 343 feet for the proposed replacement reservoir. **Table 5** shows the existing and future storage calculations for the 343 Zone service area.

Table 5
Alternatives 1, 2, and 5 Reservoir Sizing

Description	Base Year 2022	Projected 2032 (+10 years)	Projected 2042 (+20 years)
Available/Usable Storage (MG)			
Dead (Unusable) Storage	0.00	0.00	0.00
Total Available Storage	**0.00**	**0.00**	**0.00**
Required Storage (MG)			
Operational Storage	0.24	0.24	0.24
Equalizing Storage	0.00	0.00	0.00
Standby Storage	0.58	0.65	0.71
Fire Flow Storage	0.96	0.96	0.96
Total Required Storage	**1.78**	**1.85**	**1.91**

Alternatives 1, 2, and 5 would not require a dead storage component in the proposed replacement reservoir because the highest service elevation in the 343 Zone is at approximately 239 feet. The reservoir base elevation and reservoir style for these alternatives provide enough hydraulic grade for the highest elevation service in the 343 Zone to always have a service pressure of at least 20 psi.

As shown in **Tables 1** and **2**, the supply capacity in the 343 Zone exceeds the PHD required by the 343 Zone service area. Therefore, there is no equalizing storage required.

The recommended reservoir volume for Alternatives 1, 2, and 5 is approximately 1.91 MG. Based on the proposed overflow and base elevations shown in **Table 4**, Alternative 1 would require a tank diameter of 91 feet, Alternative 2 would require a tank diameter of 148 feet, and the elevated tank under Alternative 5 would require a diameter of 79 feet.

455 Zone Reservoir

Table 6 shows the existing and future storage requirements for the Alternative 3 reservoir, which would be a ground level reservoir constructed in the 455 Zone.

Table 6

Alternative 3 Reservoir Sizing

	Base Year	Projected	
Description	**2021**	**2032 (+10 years)**	**2042 (+20 years)**
Available/Usable Storage (MG)			
455 Zone Available Storage	1.30	1.10	1.10
Dead (Unusable) Storage	0.74	0.74	0.74
Total Available Storage	**0.56**	**0.36**	**0.36**
Required Storage (MG)			
Operational Storage	0.24	0.24	0.24
Equalizing Storage	0.00	0.00	0.00
Standby Storage	0.58	0.65	0.71
Fire Flow Storage	0.96	0.96	0.96
Total Required Storage	**1.22**	**1.49**	**1.55**

The available storage for Alternative 3 assumes the surplus storage in the 455 Zone, as calculated in the City's 2019 WSP, is usable in the project area. Alternative 3 requires a dead storage component of approximately 0.74 MG for the proposed replacement reservoir, because the high service elevation in the 455 Zone is at approximately 362 ft.

The equalizing and standby storage calculations assume that supply improvements will be completed such that the full well capacity could be conveyed to the existing and proposed 455 Zone Reservoirs.

The proposed Alternative 3 reservoir would require a diameter of 51 feet with a recommended volume of 1.55 MG.

260 Zone Reservoir

Table 7 shows the existing and future storage requirements for Alternative 4 which would be constructed in the 260 Zone.

Table 7
Alternative 4 Reservoir Sizing

	Base Year	Projected	
Description	**2021**	**2032 (+10 years)**	**2042 (+20 years)**
Available/Usable Storage (MG)			
Dead (Unusable) Storage	0.00	0.00	0.00
Total Available Storage	**0.00**	**0.00**	**0.00**
Required Storage (MG)			
Operational Storage	0.24	0.24	0.24
Equalizing Storage	0.00	0.00	0.00
Standby Storage	0.58	0.65	0.71
Fire Flow Storage	0.96	0.96	0.96
Total Required Storage - No Nesting	**1.78**	**1.85**	**1.91**

Alternative 4 does not require a dead storage component because the highest elevation service in the proposed 260 Zone would be 152.14 feet.

There is no equalizing storage component required for the proposed 260 Zone reservoir because the calculations assume the 343 Zone well capacity will be available to the proposed 260 Zone Reservoir.

The recommended reservoir volume for Alternative 4 is approximately 1.91 MG. Based on the proposed overflow and base elevations shown in **Table 4**, Alternative 4 would require a tank diameter of 74 feet.

A summary of the proposed reservoir volume and dimensions is shown in **Table 8** for each of the alternatives.

Table 8
Proposed Reservoir Alternatives and Reservoir Dimensions

Alternative	Proposed Location	Proposed Reservoir Style	Pressure Zone	Proposed Volume (MG)	Proposed Height (ft)	Proposed Diameter (ft)
1	Existing Butler Reservoir site	Ground Level Tank	343 Zone	1.91	40	91
2	City-owned property adjacent to the existing Butler Reservoir site	Buried Reservoir	343 Zone	1.91	15	148
3	City-owned property adjacent to the existing Butler Reservoir site	Ground Level Tank	455 Zone	1.55	104	51
4	Camas Cemetery site	Ground Level Tank	260 Zone	1.91	60	74
5	Camas Cemetery site	Elevated Tank	343 Zone	1.91	53	79

Proposed Water System Improvements

For each of the proposed reservoir alternatives, additional hydraulic analyses were performed to identify distribution system improvements that would be necessary to incorporate the proposed reservoir into the water system. The required improvements associated with each alternative vary depending on the location, pressure zone, and impacts to the operation of the City's water system.

The required water system improvements for each alternative are described in the following sections and assume that the existing Butler Reservoir would be demolished or taken off line and that the pressure zone reconfiguration improvements will be constructed concurrently with the proposed reservoir.

Alternative 1

- Construct a ground level 1.91 MG 343 Zone Reservoir on the existing Butler Reservoir site.

Alternative 2

- Construct a 1.91 MG buried 343 Zone Reservoir on the City-owned property adjacent to the existing Butler Reservoir site.
- Approximately 500 feet of 12-inch water main to connect the proposed reservoir to the existing BPSs and distribution system main on the Butler Reservoir site.

Alternative 3

- Construct a 1.55 MG ground level 455 Zone Reservoir on the City-owned property adjacent to the existing Butler Reservoir site.

- Approximately 500 feet of 12-inch water main to connect the proposed reservoir to the existing BPSs and distribution system main on the Butler Reservoir site.
- BPS improvements to increase the supply capacity to transfer water from the 343 Zone to the proposed 455 Zone Reservoir.

Alternative 4

- Construct a ground level 1.91 MG 260 Zone reservoir at the Camas Cemetery site.
- Install a PRV/Altitude Valve from the 343 Zone dedicated transmission main to the proposed 260 Zone Reservoir.
- Install approximately 1,700 feet of 12-inch water main to connect the proposed 260 Zone Reservoir to the City's system.
- Install a BPS for transmission of 260 Zone water supply to the 343 Zone.

Alternative 5

- Construct an elevated 1.91 MG 343 Zone reservoir at the Camas Cemetery site.
- Install approximately 800 feet of 12-inch water main to connect the proposed 343 Zone Reservoir to the City's system.

Conclusion

This technical memorandum identifies several options for the City to consider for the replacement of the existing Butler Reservoir that has reached the end of its service life. A pressure zone reconfiguration has also been recommended that will remedy several operational and level of service concerns in the existing Downtown 343 Zone by reducing high system pressures and improving the available fire flow. The proposed reservoir alternatives and recommended pressure zone conversion improvements are shown on **Figure 11** and the pros and cons of each alternative are summarized in **Table 9**.

Table 9
Proposed Reservoir Alternatives Pros and Cons

Reservoir Alternative	Description and Required Improvements [1]	Pros and Cons
1	**Construct a 1.91 MG 343 Zone ground level reservoir on the existing Butler Reservoir site.**	**Pros:** **(1)** In an area of very low to low liquefaction potential. **(2)** Property already owned by the City. **Cons:** **(1)** Existing site would be very difficult to perform any construction on while the existing reservoir is in place. **(2)** Removal of large trees on the site is likely required. **(3)** Cultural resource survey would more than likely be required. **(4)** Existing reservoir will need to be taken offline.
2	**Construct a fully buried 1.91 MG 343 Zone reservoir on the City-owned property adjacent to the existing Butler Reservoir site.** **(1)** Install water main as needed to maintain system configuration at the existing Butler Reservoir site and the proposed reservoir site. (Estimated 500 ft of 12-inch water main)	**Pros:** **(1)** In an area of very low to low liquefaction potential. **(2)** Property already owned by the City. **(3)** Butler Reservoir can stay online during construction. **Cons:** **(1)** Cultural resource survey would more than likely be required. **(2)** This site is small and construction may encroach on the adjacent school property. **(3)** Cost of excavation will be significant for a buried reservoir. **(4)** Maintenance will be challenging for a buried reservoir when compared to a ground level reservoir.
3	**Construct a 1.55 MG 455 Zone ground level reservoir on the City-owned property adjacent to the existing Butler Reservoir site.** **(1)** Install water main as needed to maintain system configuration at the existing Butler Reservoir site and the proposed reservoir site. (Estimated 500 ft of 12-inch water main) **(2)** Increase pumping capacity from the 343/455 Zone BPS.	**Pros:** **(1)** Minimize storage requirement. **(2)** In an area of very low to low liquefaction potential. **(3)** Property already owned by the City. **Cons:** **(1)** Removal of large trees on the site will likely be required. **(2)** Cultural resource survey would more than likely be required. **(3)** The 455 BPS would need to be increased in capacity or a new BPS would need to be constructed. **(4)** This site is small and construction may encroach on the adjacent school property.
4	**Construct a 1.91 MG 260 Zone ground level reservoir at the Camas Cemetery site.** **(1)** Install a PRV/Altitude Valve from the 343 Zone transmission main to the proposed 260 Zone Reservoir. **(2)** Install 1,700 ft of water main as needed to connect the 343 Zone dedicated transmission main to the 260 Zone tank at the Camas Cemetery site. **(3)** Install a BPS for transmission of 260 Zone water to the 343 Zone.	**Pros:** **(1)** In an area of very low to low liquefaction potential. **(2)** Property already owned by the City. **(3)** 343 Zone transmission main alignment is near this site. **(4)** Butler Reservoir will not need to be taken offline during construction. **(5)** Option to utilize the Butler site for future facilities. **Cons:** **(1)** Cultural resource survey would more than likely be required. **(2)** Installation of a new PRV/Altitude valve. **(3)** Adjacent areas of the site are severe erosion hazard. **(4)** No reservoir in the 343 Zone for the Butler BPS to pump out of. **(5)** Additional cost for constructing and maintaining the new 260/343 Zone BPS.

Table 9
Proposed Reservoir Alternatives Pros and Cons (con't)

Reservoir Alternative	Description and Required Improvements [1]	Pros and Cons
5	**Construct an elevated 1.91 MG 343 Zone reservoir at the Camas Cemetery site.** **(1)** Install water main as needed to connect the 343 Zone/343 Zone transmission main to the proposed 343 Zone tank. (Estimated 800 ft of 12-inch water main.	<u>Pros:</u> **(1)** In an area of very low to low liquefaction potential. **(2)** Property already owned by the City. **(3)** 343 Zone transmission main alignment is near this site. **(4)** Butler Reservoir will not need to be taken offline during construction. **(5)** Option to utilize the Butler site for future facilities. <u>Cons:</u> **(1)** Cultural resource survey would more than likely be required. **(2)** Elevated reservoirs are more costly to construct than a ground level reservoir. **(3)** Site surrounded by severe erosion hazard.

1- All reservoir alternatives include the following improvements to facilitate the pressure zone reconfiguration.
(1) Activate PRVs at and convert Downtown 343 Zone to a 260 Zone: NE 6th Ave and NE Joy St, NE 6th Ave and NE Garfield Street, NE Dallas Street near the Highland Nursing Center and upsize approximately 45 feet of 8-inch water main between the 343 Zone dedicated transmission main and the 343 Zone at the intersection of NE 22nd Avenue and NE Everett Street.
(2) Install a new 260 Zone to 170 Zone PRV at SE 6th Ave and SE Polt St.
(3) Install a new 260 Zone to 190 Zone PRV at NE 3rd Ave and NE 3rd Loop.
(4) Install 1,800 ft of 12-inch water main from the 343 Zone in NE Dallas Street to the supply line of the Forest Home BPS. This project assumes the Forest Home BPS will pump from the 343 Zone to the 455 Zone. If the Forest Home BPS improvements are designed to pump from the Proposed 260 Zone to the 455 Zone, then this project will not be needed.
(5) Install 1,000 ft of 8-inch water main to connect Well-5 to the 343 Zone transmission main.
(6) Activate PRV-47.

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Attachments

Figure 1 – Reservoir Siting Project Area

Figure 2 – Existing System PHD Pressures

Figure 3 – Existing System MDD Fire Flows

Figure 4 – Proposed Pressure Zone Reconfiguration - Phase 3 PHD Pressures

Figure 5 – Proposed Pressure Zone Reconfiguration - Phase 3 MDD Fire Flows

Figure 6 – City of Camas Property and Contours

Figure 7 – Natural Resource Areas

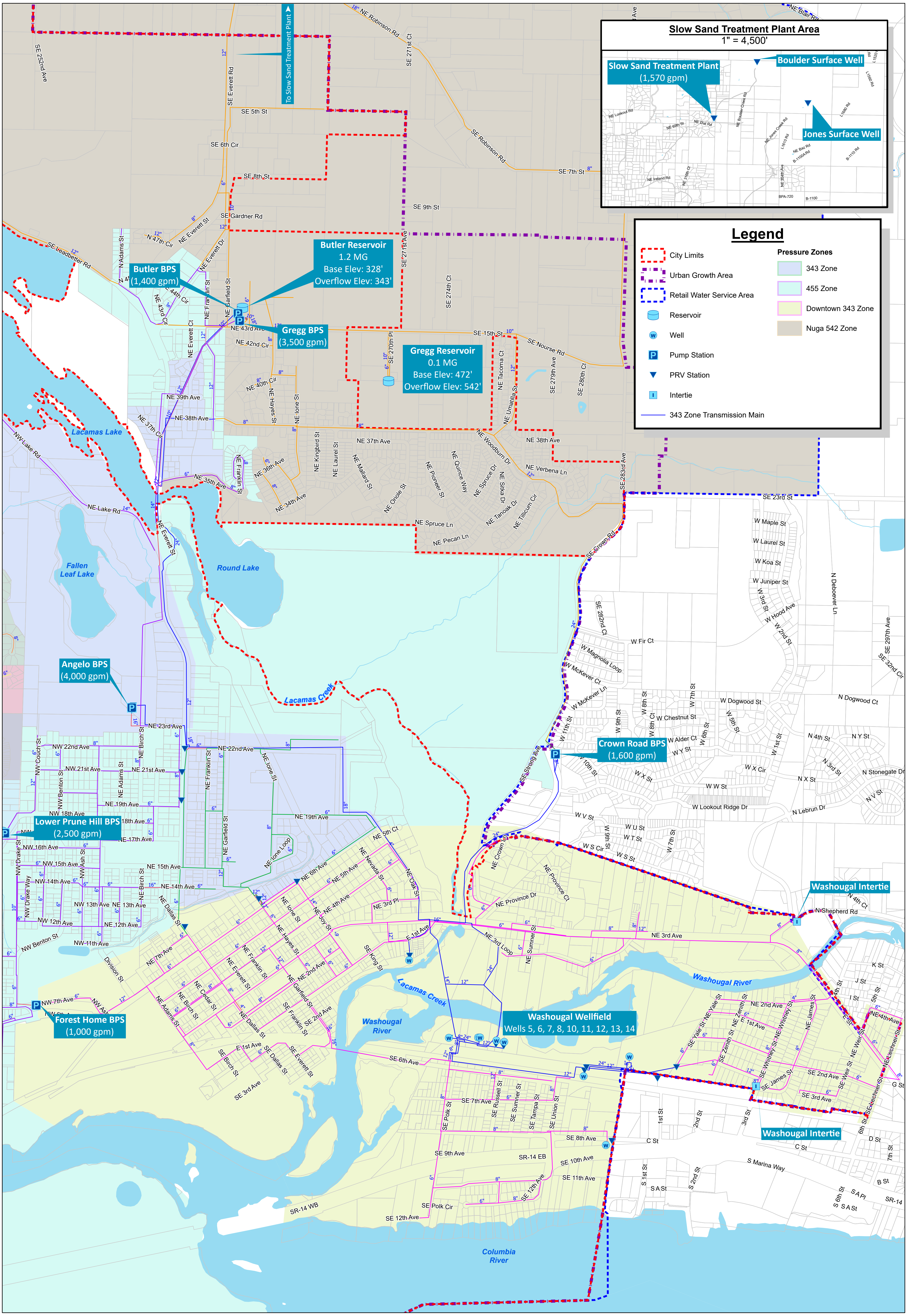
Figure 8 – Geologic Hazard Areas

Figure 9 – Cultural Resource Areas

Figure 10 – Potential Reservoir Areas

Figure 11 – Proposed Reservoir Alternatives and Pressure Zone Reconfiguration Improvements

Attachments



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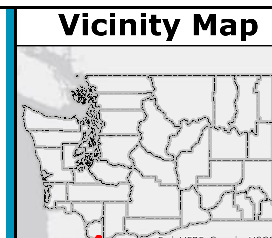
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

City of Camas WASHINGTON

FIGURE 1
Reservoir Siting Project Area
City of Camas
343 Zone Reservoir Siting Analyses

Vicinity Map



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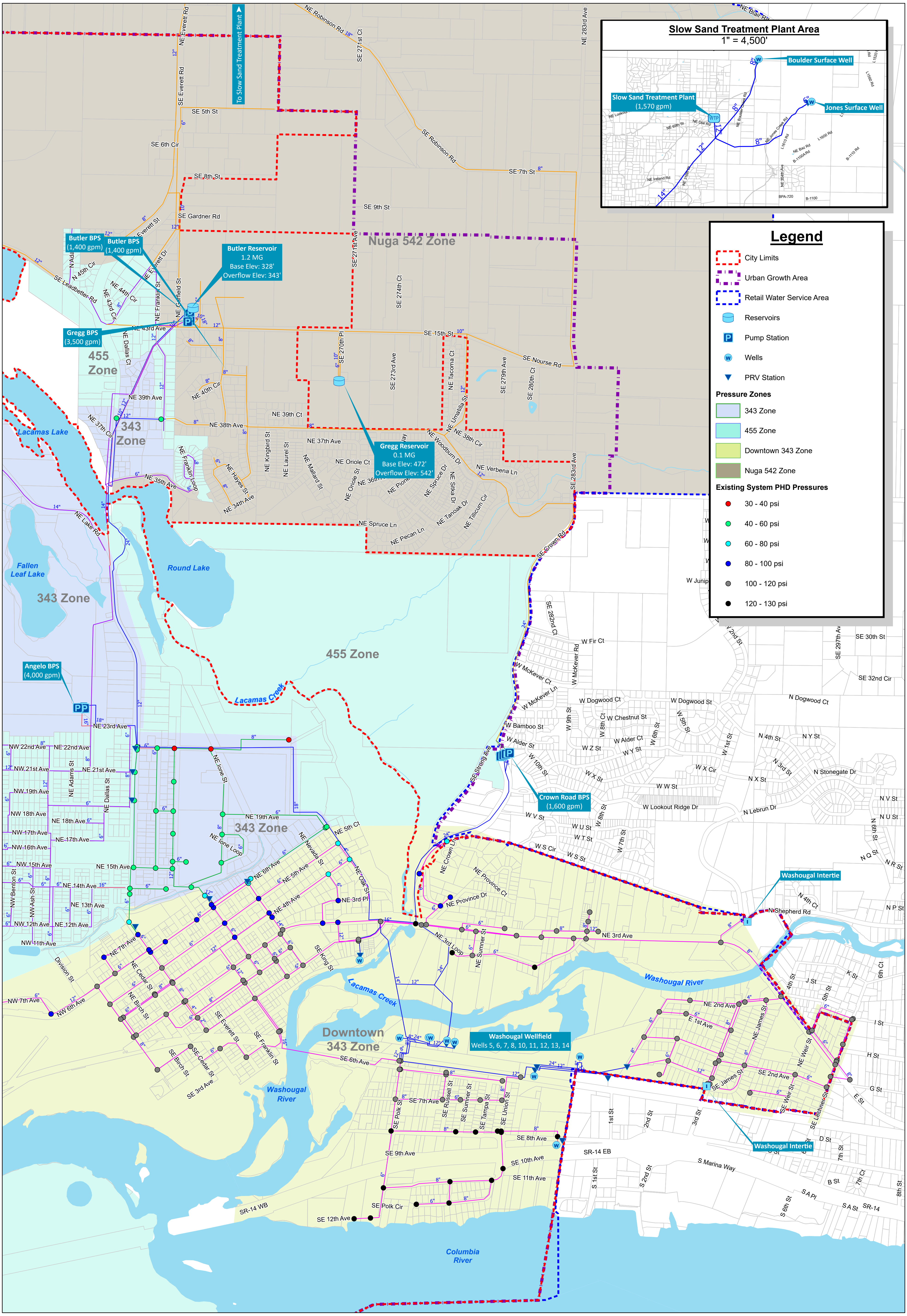

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1 inch : 600 Feet

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City of Camas WASHINGTON

FIGURE 2

Existing System PHD Pressures

City of Camas

343 Zone Reservoir Siting Analyses

Vicinity Map

Esri, HERE, Garmin, USGS, EPA, NPS

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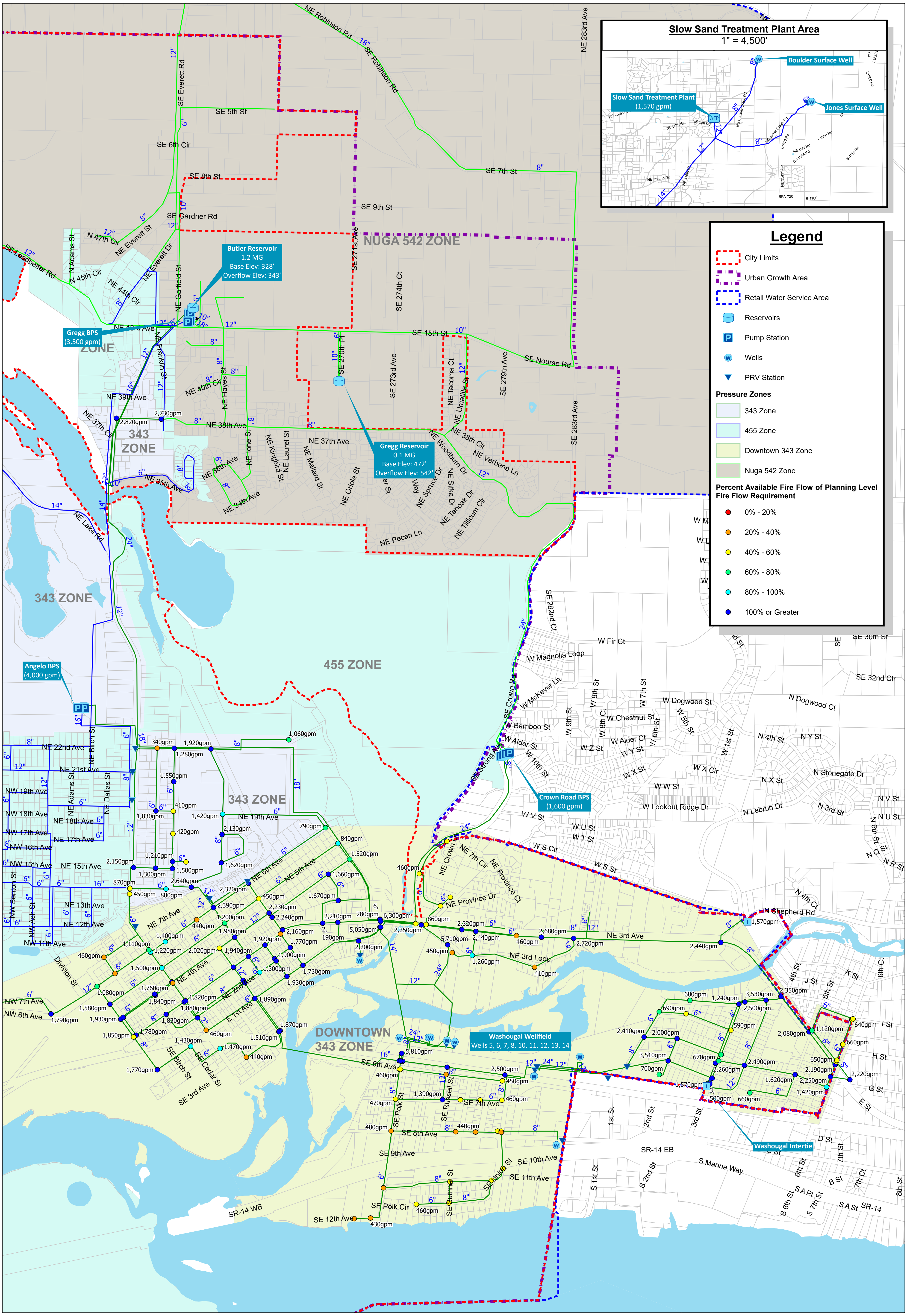

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1 inch : 600 Feet

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DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

City of Camas WASHINGTON

FIGURE 3

Existing System MDD Fire Flows

City of Camas

343 Zone Reservoir Siting Analyses

Vicinity Map

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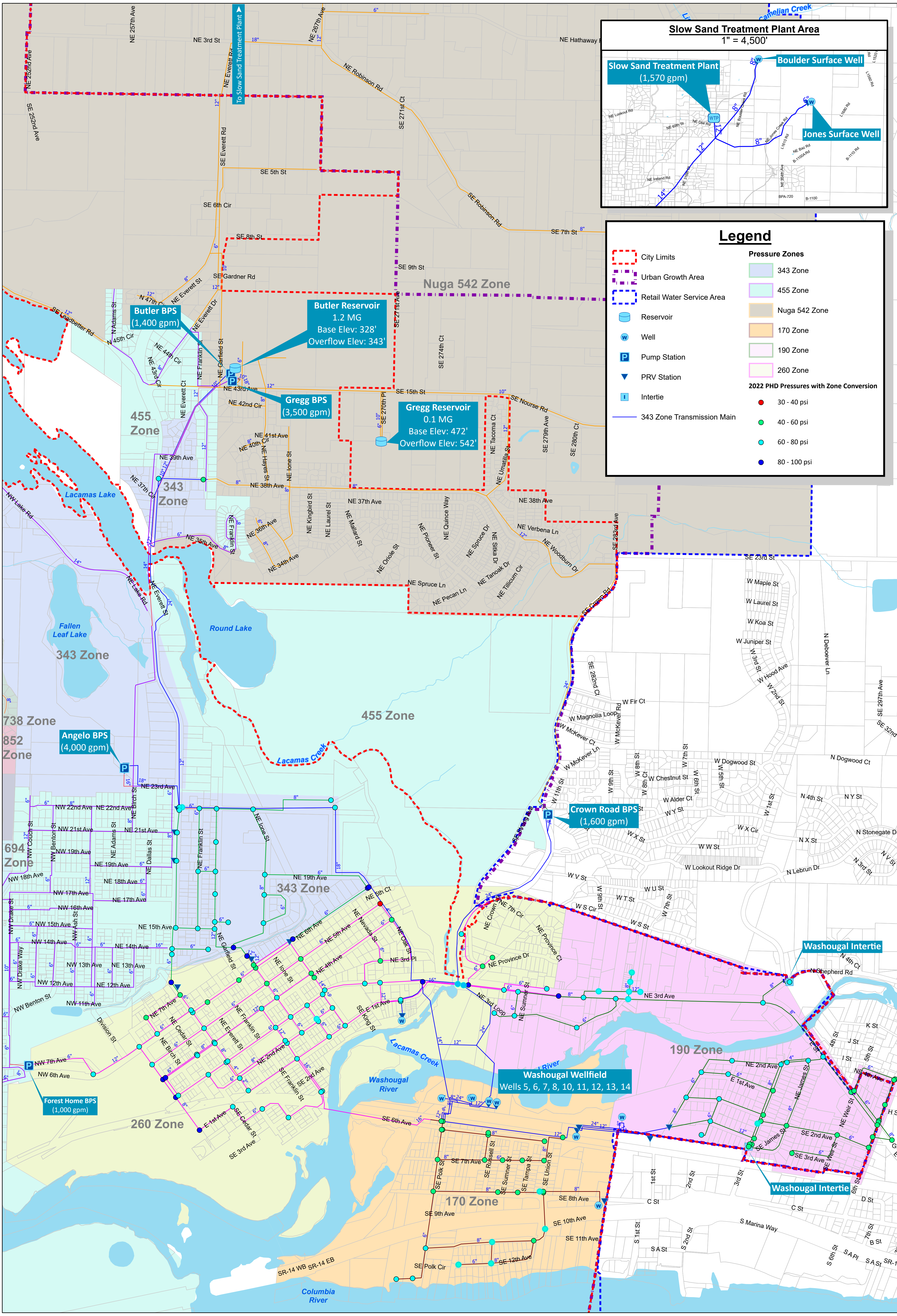

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City of Camas WASHINGTON

FIGURE 4

Pressure Zone Reconfiguration - Phase 3

PHD Pressures

City of Camas

343 Zone Reservoir Siting Analyses

Vicinity Map

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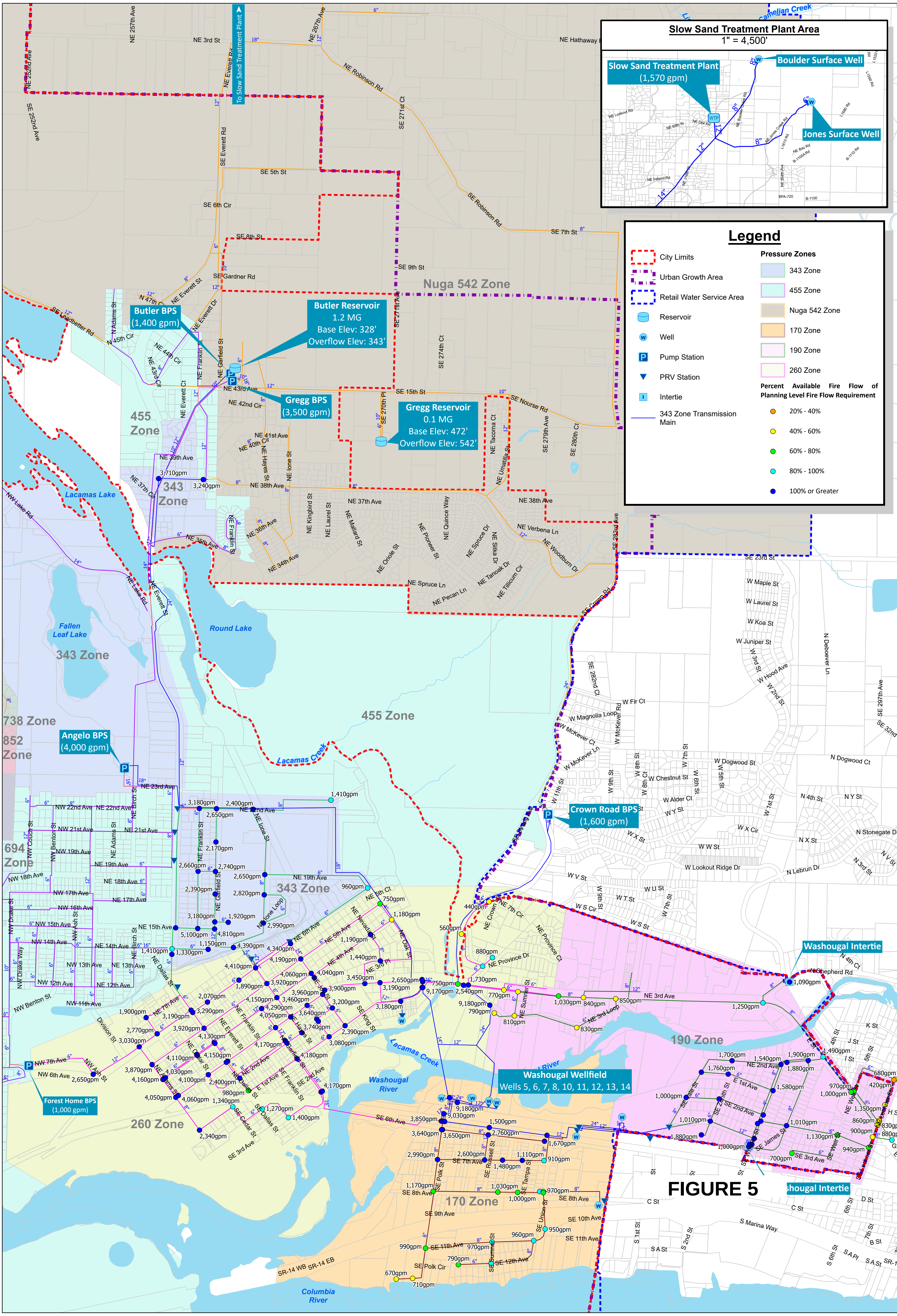

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City of Camas WASHINGTON

FIGURE 5
Pressure Zone Reconfiguration - Phase 3
MDD Fire Flows
City of Camas
343 Zone Reservoir Siting Analyses

Vicinity Map

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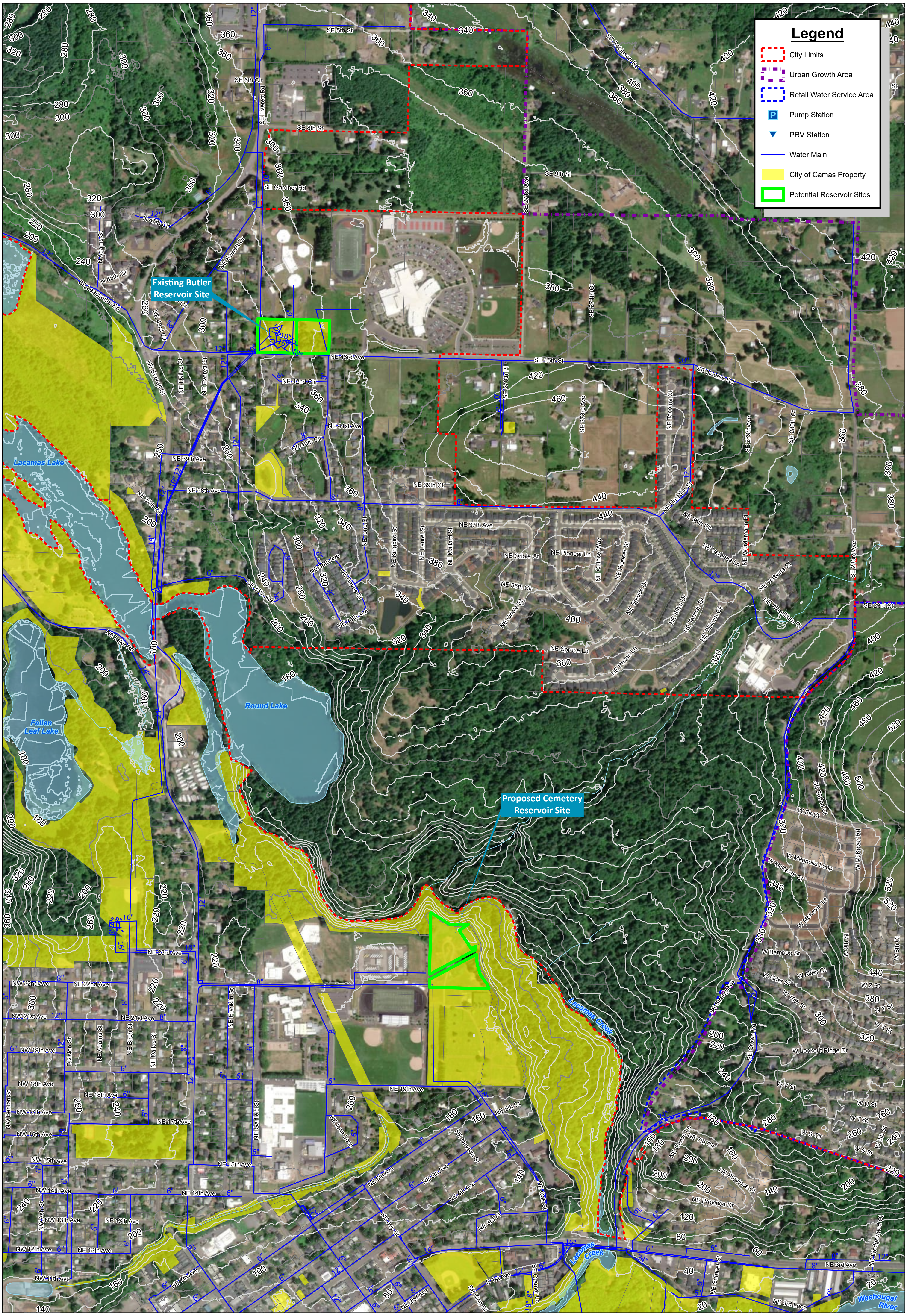

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City of Camas WASHINGTON

FIGURE 6

City of Camas Property and Contours

City of Camas

343 Zone Reservoir Siting Analyses

Vicinity Map

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1 inch : 400 Feet

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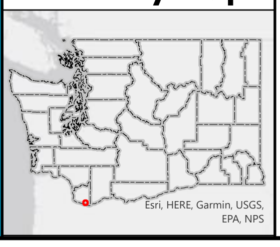
FIGURE 7

Natural Resource Areas

City of Camas

343 Zone Reservoir Siting Analyses

Vicinity Map



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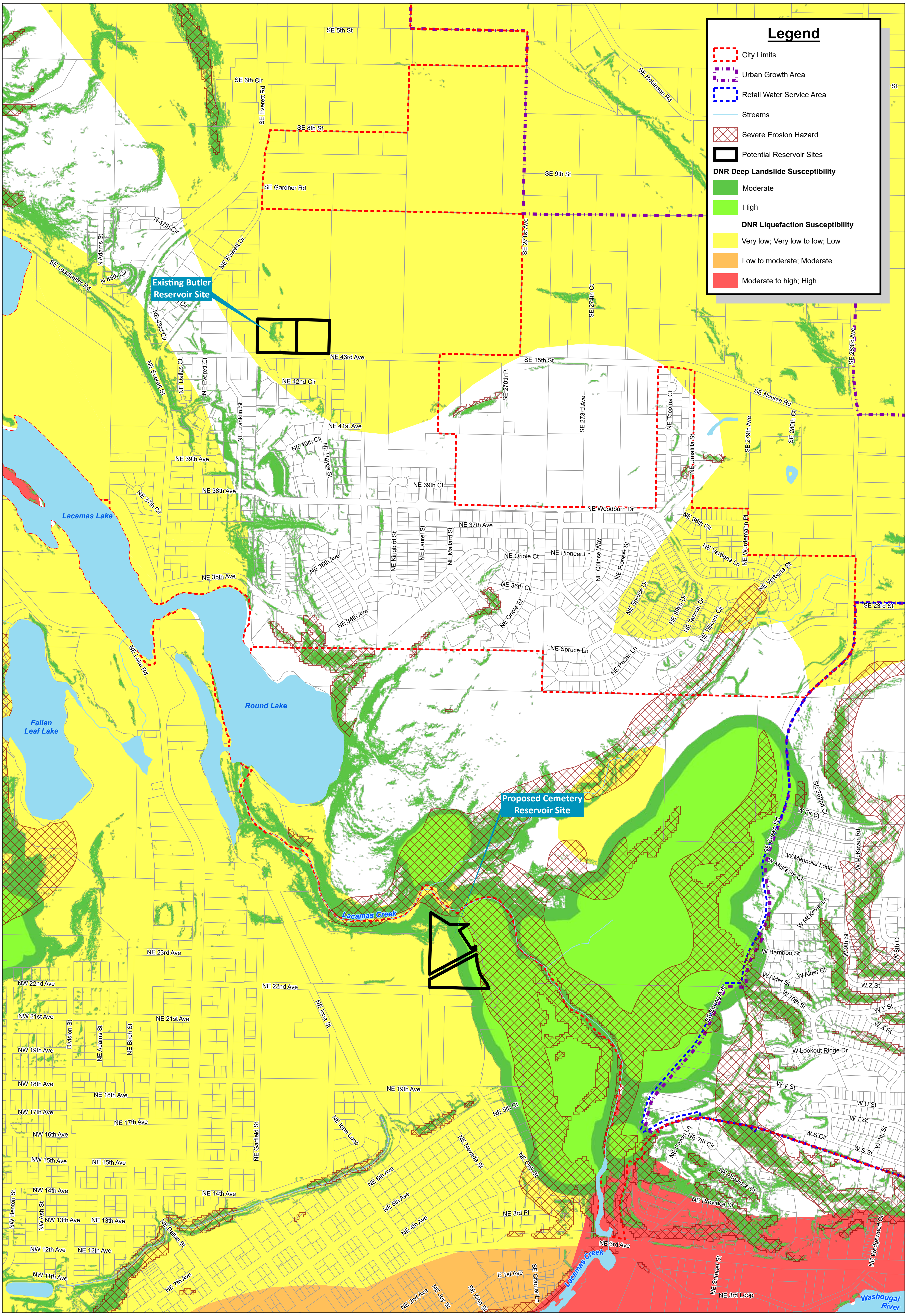

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1 inch : 400 Feet

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FIGURE 8
Geologic Hazards
City of Camas
343 Zone Reservoir Siting Analyses

Vicinity Map

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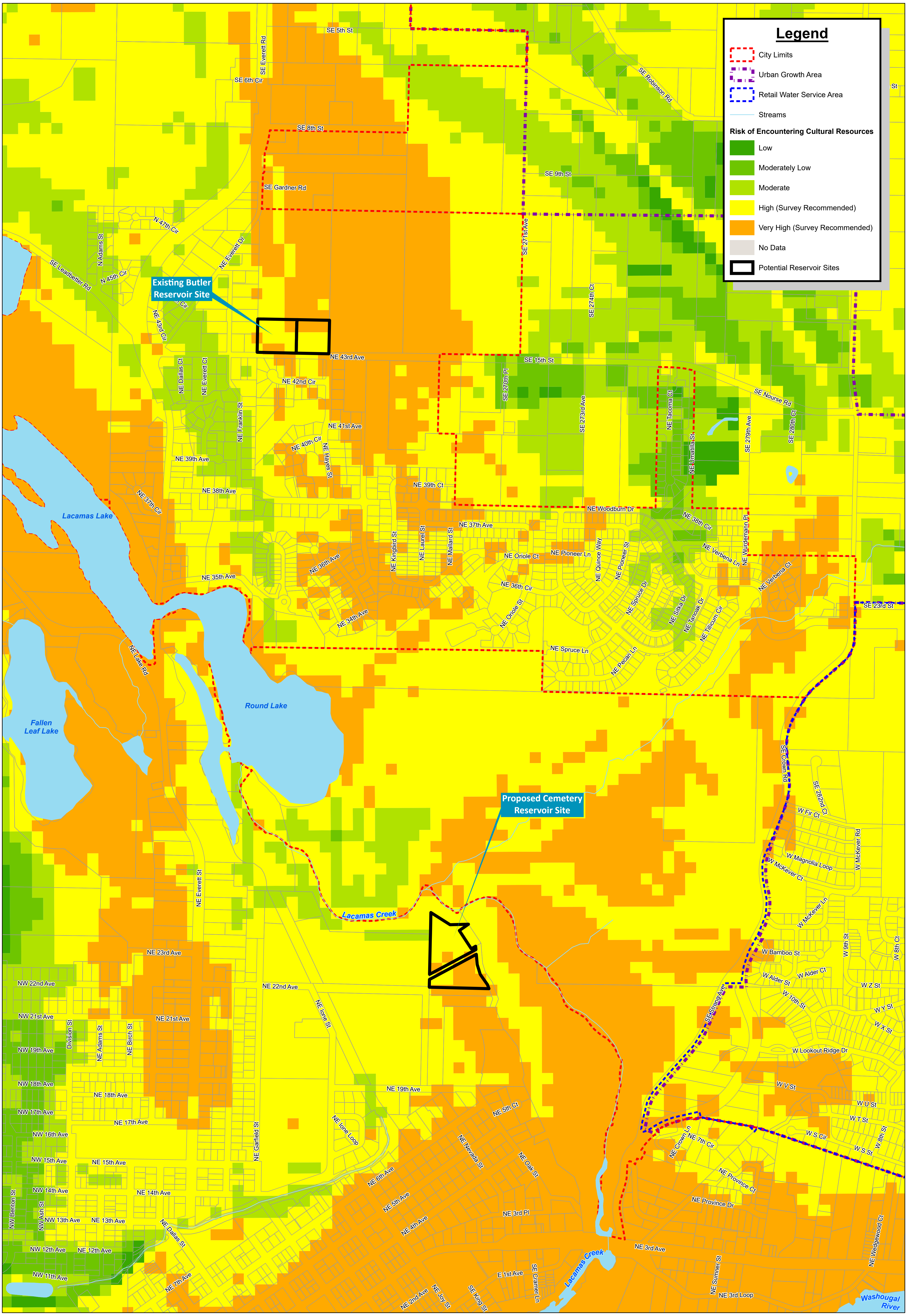

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1 inch : 400 Feet

0 400 800 Feet

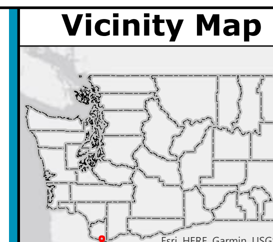
DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

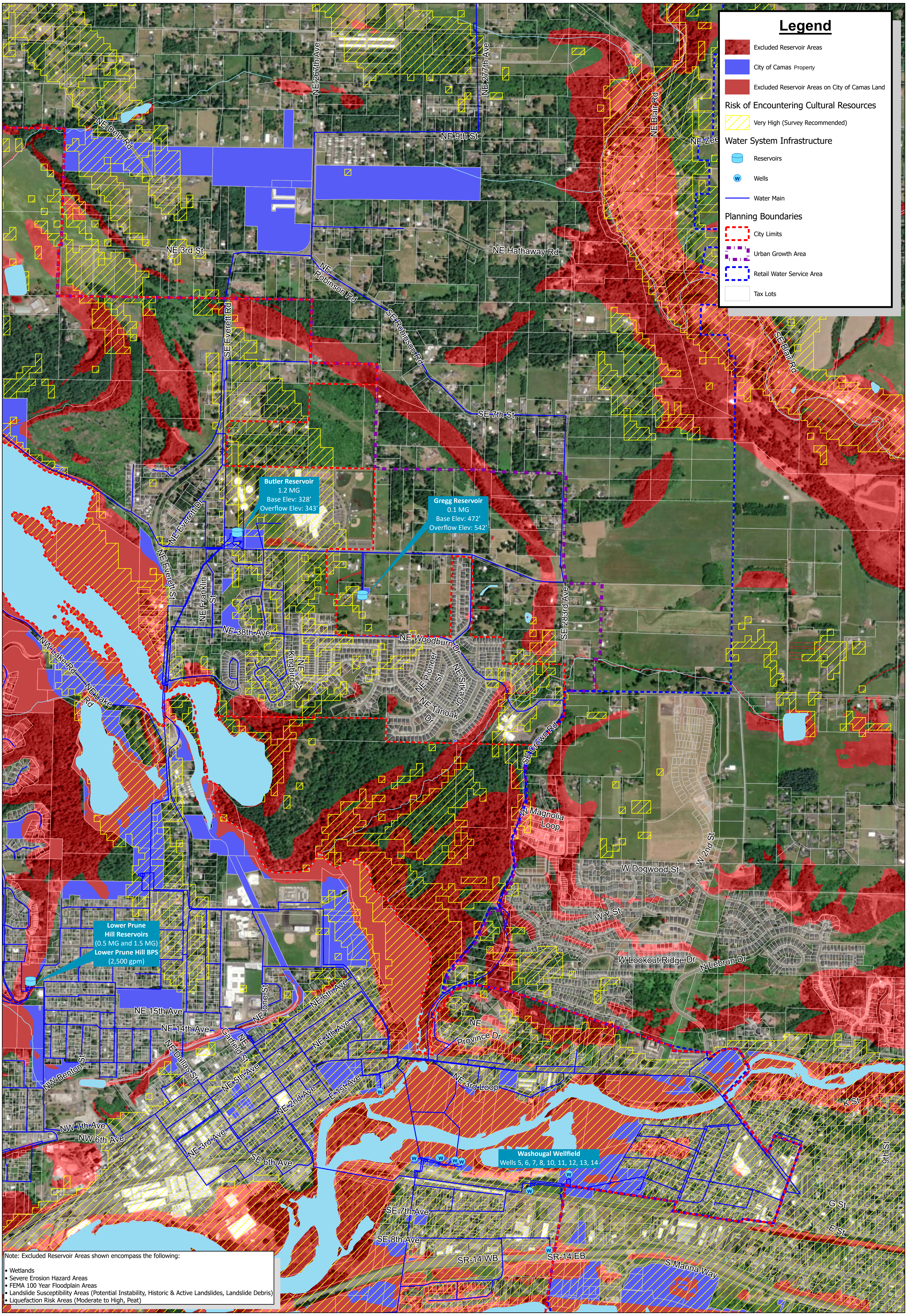
City of Camas WASHINGTON

FIGURE 9

Cultural Resources
City of Camas
343 Zone Reservoir Siting Analyses

Vicinity Map





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1 inch : 700 Feet

0 350 700 1,400 Feet

DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

City of Camas WASHINGTON

FIGURE 10

Potential Reservoir Areas

City of Camas
343 Zone Reservoir Siting Analyses

Vicinity Map

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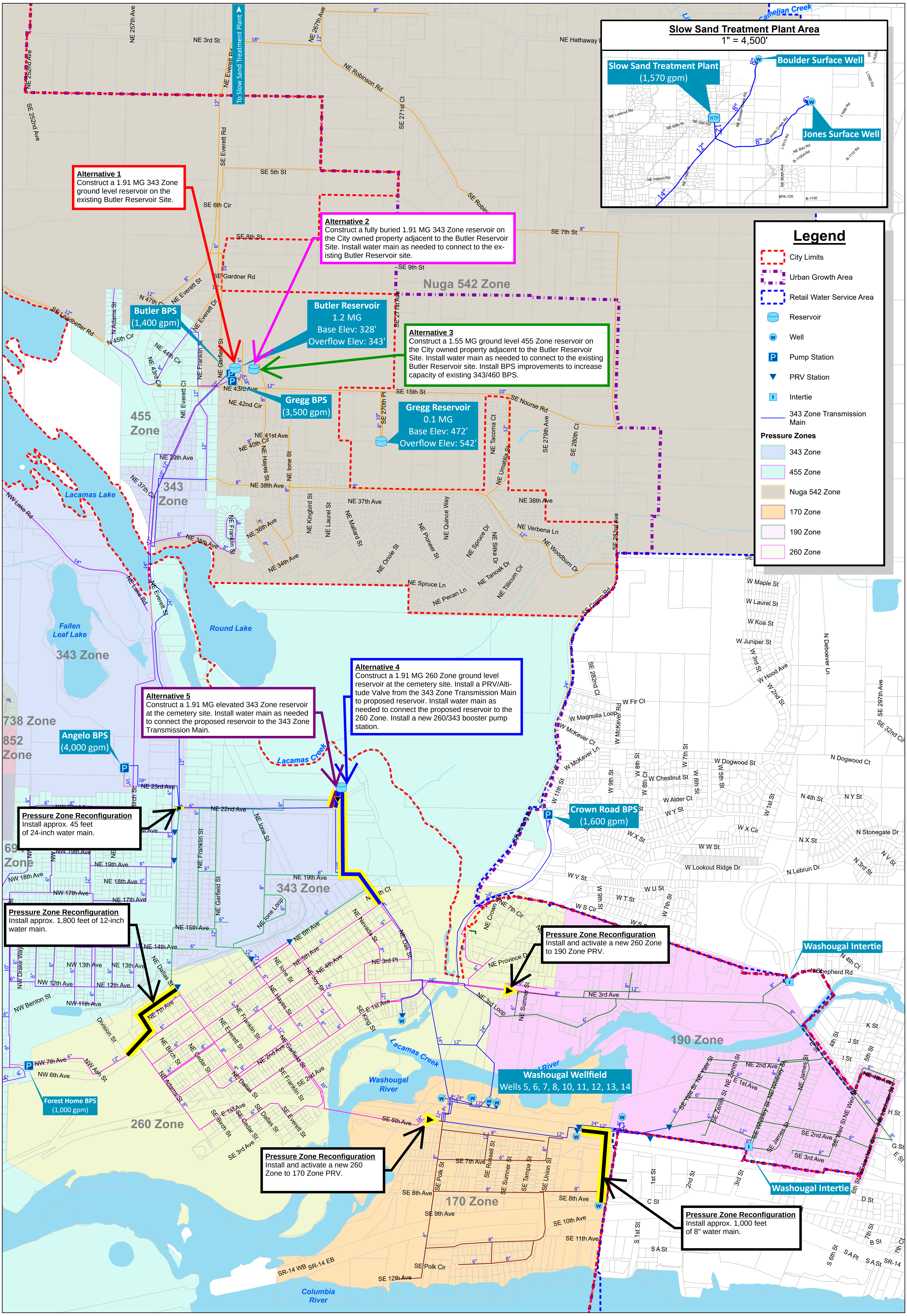

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1 inch : 600 Feet

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DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

City of Camas WASHINGTON

FIGURE 11

Proposed Reservoir Alternatives and Pressure Zone Reconfiguration Improvements

City of Camas

343 Zone Reservoir Siting Analyses

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