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GeoEngineers

17245 NE Union Hill Road, Suite 250, Redmond, Washington, 98052 Telephone: 425.861.6000, Fax: 425.861.6050 www.geoengineers.com

Memorandum

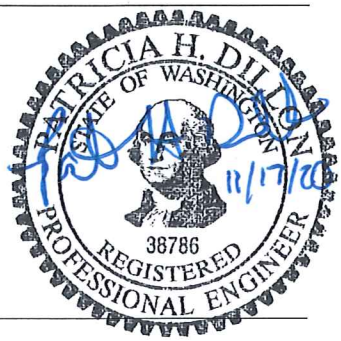
To: Stephanie Potts, Washington State Department of Ecology

From: Patty Dillon, Cynthia Carlstad, NHC;
Bridget August, John Monahan, GeoEngineers

Date: November 17, 2020

File: 0504-161-00

Subject: WRIA 8 Consumptive Use Estimates



INTRODUCTION

GeoEngineers, Inc. (GeoEngineers) is providing technical support to the Washington State Department of Ecology (Ecology) and the Watershed Restoration and Enhancement (WRE) Committees for Water Resource Inventory Areas (WRIAs) 7, 8 and 9. This memorandum provides a summary of the deliverable for Work Assignment GE0102, Task 4, WRIA 8 Consumptive Use Estimates.

BACKGROUND AND CONTEXT

The Streamflow Restoration law (Revised Code of Washington [RCW] 90.94) specifies that by June 30, 2021, Ecology must establish a WRE Committee and adopt a WRE Plan in the Cedar-Sammamish Watershed (WRIA 8). The Cedar-Sammamish (WRIA 8) Watershed Restoration and Enhancement Plan (watershed plan) must include projects and actions that offset new consumptive water use (consumptive use) from future domestic permit-exempt wells (PE wells[1]). Consumptive use is water that is evaporated, transpired, consumed by humans, or otherwise removed from an immediate water environment. For watershed planning purposes, consumptive use is water that is drawn from groundwater via a domestic PE well and not replaced through the septic system, irrigation return flow, or other means.

Projections for number and location of new PE wells within WRIA 8 were developed by King County, Snohomish County, and GeoEngineers (GeoEngineers 2020b) for purposes of the watershed plan. This memorandum summarizes the methods used to estimate consumptive use associated with the new PE well connections and provides results for three water use scenarios. Methodology is based on Appendix A of Ecology's Final Guidance for Determining Net Ecological Benefit (Final NEB Guidance) (Ecology 2019) and documented in further detail in the Consumptive Use Estimates Workplan prepared by the GeoEngineers team (GeoEngineers 2019).

CONSUMPTIVE WATER USE METHODOLOGY

Measurement of consumptive water use in any setting is difficult, and it is virtually impossible for residential groundwater use, which must account for both indoor and outdoor use. PE wells are generally unmetered, so

[1] "PE wells" is used to refer to new homes associated with new permit-exempt wells and also new homes added to existing wells, including homes on group systems relying on permit-exempt wells.

supply to each home is usually unknown, let alone the amount that is lost to the groundwater system. Therefore, we are limited to estimating consumptive use based on projections of future growth, local patterns and trends in water use, and generally accepted and reasonable assumptions. Water use data from local water purveyors may be useful as a check on calculated estimates but must be used with caution. Homes that pay for municipal water tend to exhibit different water use behaviors, including water saving appliances and reduced landscape watering, that reduce usage compared to homes on wells.

The two categories of household consumptive use are indoor water use and outdoor water use. The methodologies used to estimate these quantities for WRIA 8 are described in the following sections.

Indoor Consumptive Use

Indoor consumptive use was estimated using methods and assumptions from the Final NEB Guidance (Ecology 2019), which was based on groundwater monitoring and modeling studies conducted by the U.S. Geological Survey in several areas of Washington. There are two basic elements to estimating indoor consumptive use:

- Amount of total water used. The Final NEB Guidance recommends an assumption of 60 gallons per person per day as a reasonable estimate of indoor water use. To estimate indoor usage per well, the per capita usage was multiplied by the average rural household size, estimated by King County and Snohomish County as 2.73 and 2.75 people per household, respectively. For analysis areas spanning both counties, a weighted value was estimated based on the number of projected PE well connections in each county. Table 1 summarizes the household sizes for each WRIA 8 delineated subbasin with projected PE wells (GeoEngineers 2020a) and for all of WRIA 8.
- Percentage of total water used that is consumptive. The Final NEB Guidance recommends that 10 percent of the total indoor water use is considered consumptive when a home is on a septic system. (All indoor water use is considered consumptive for homes with sewer connections.) Areas projected to be served by PE wells are outside of sewer service areas, so the 10 percent assumption was applied for all projected indoor water use.

TABLE 1. AVERAGE RESIDENTS PER HOUSEHOLD

Subbasin	% Projected Wells by County		Avg. People per Rural Household
	King	Snohomish	
Puget Sound Shorelines		100%	2.75
Swamp/North		100%	2.75
Little Bear		100%	2.75
Sammamish River Valley	100%		2.73
Bear/Evans	59%	41%	2.74
Greater Lake Washington	100%		2.73
May/Coal	100%		2.73
Lake Sammamish Creeks	100%		2.73
Issaquah	100%		2.73
Lower Cedar	100%		2.73
WRIA Total	**77%**	**23%**	**2.73**

Outdoor Consumptive Use

Outdoor water use is typically the larger portion of domestic single-family residential water use, with irrigation of lawn and garden being the dominant outdoor water use component. The GeoEngineers team conducted a subbasin-specific assessment to determine typical outdoor water use patterns, namely the typical size of irrigated lawn, garden, and landscaping areas associated with newer residential development and irrigation water needs, which vary by crop and climate. The consumptive use estimate assumes that current rural residential landscaping practices and outdoor water use will continue over the 20-year planning horizon.

Irrigated Footprint Analysis

The GeoEngineers team conducted an aerial photo-based analysis of irrigated lawn and garden area for 153 parcels in seven of the WRIA 8 subbasins. Parcels used for the irrigated footprint analysis were selected based on recent (2006 to 2017) building permits for new single-family residential homes not served by public water. Permits for accessory dwelling units (ADUs) or reconstruction/remodel were excluded. There were more than 400 permits in WRIA 8 meeting these criteria—more than could be reasonably evaluated for this project. For subbasins with more than 20 applicable building permits, a statistically representative sample size was identified based on statistics from similar analyses in WRIAs 1 and 9 and a pilot study in the Bear/Evans subbasin. The target sample size is sufficient to ensure that the sample mean is representative over the WRIA within a 95 percent confidence limit. Sample parcels were selected by assigning a random number to each building permit, and then evaluating sites in rank order up to the target sample size. Using a random selection from the permit list avoids the bias that could be introduced if selecting from the imagery. Table 2 shows the number of permits by subbasin and the targeted minimum sample size.

TABLE 2. SAMPLE SIZE FOR IRRIGATED FOOTPRINT ANALYSIS

Subbasin	Applicable Building Permits (2006-2017)	Target Minimum Sample Size
Little Bear	98	30
Sammamish River Valley	3	3
Bear/Evans	79	30
May/Coal	7	7
Lake Sammamish Creeks	1	1
Issaquah	108	30
Lower Cedar	150	30
WRIA Total	**446**	**131**

Each parcel was evaluated visually in Google Earth for irrigated lawn areas. Google Earth's historical imagery collection allowed for clearer identification of irrigated areas by comparing aerial photos spanning multiple seasons and years. Late summer imagery was particularly helpful in determining boundaries of irrigated (green) versus non-irrigated (brown) grass areas. More often than not, the parcels did not demonstrate such a clear-cut distinction between green and brown spaces. It appears that many homeowners irrigate enough to keep lawns alive but not lush (or comparable to commercial turf grass/golf course green). Delineating these irrigated spaces is subjective and the GeoEngineers team tried to ensure consistency in the interpretation and results by having one geographic information system (GIS) analyst evaluate all of the selected parcels in the WRIA. The irrigated area was delineated for each parcel based on several key assumptions:

- Landscaped shrub/flower bed areas were included in the irrigated footprint (not just lawn areas).
- Homes that did not show visible signs of irrigation were tracked as zero irrigated footprint.
- Homes or landscaping still under construction in the most recent Google Earth imagery were excluded.
- Native forest or unmaintained grass/pasture were not included in the irrigated footprint.
- Pre-existing agricultural land use was not considered part of the residential irrigation footprint.

Figure 1 shows examples of irrigated area delineation for two parcels in the Bear/Evans subbasin. On each photo, the parcel boundary is shown in light blue and the area identified as irrigated in white. For the example on the left, photos at different times of year showed a clear break between irrigated and non-irrigated grass.

Figure 1. Example Irrigated Area Delineations

Results of the irrigated footprint analysis are summarized in Table 3. The analysis covered seven of the ten subbasins in WRIA 8 with projected PE well connections. Due to small sample sizes, the subbasin-level results for Lake Sammamish Creeks, Sammamish River Valley, and May/Coal subbasins are not considered representative. Parcels in these subbasins were included in the overall average, but average irrigated areas from similar adjacent subbasins (Bear/Evans, Little Bear, and Lower Cedar, respectively) were used for the purpose of subbasin-scale consumptive use estimates. Note that more permit parcels than the target minimum sample were analyzed in four of the subbasins. When identifying the random list for analysis, the GeoEngineers team identified 10 additional sites beyond the target minimum of 30 to allow for dropping parcels that did not meet the analysis criteria (e.g. construction not completed). The full list was analyzed, resulting in a few parcels above the target minimum in each subbasin. Similarly, one of the seven parcels in the May/Coal subbasin had to be dropped, so the analyzed sample is smaller than the projected target.

The Puget Sound Shorelines, Greater Lake Washington, and Swamp/North subbasins (with two, four, and five projected PE well connections, respectively) did not have any recent building permits for sites without purveyor-provided water service from which to estimate subbasin-specific irrigated area. The average irrigated area for the Little Bear subbasin was applied for purposes of subbasin-scale consumptive use estimates. Puget Sound Shorelines, Greater Lake Washington, and Swamp/North subbasins are almost entirely within the Urban Growth Area (UGA) and may have homes on smaller lots with smaller lawns than homes in Little Bear subbasin, which is mostly outside the UGA.

TABLE 3. WRIA 8 IRRIGATED FOOTPRINT SUMMARY

Subbasin	Parcels Analyzed	Total Irrigated Area (ac)	Average Irrigated Area (ac)
Little Bear	37	10.2	0.28
Sammamish River Valley	2	0.3	0.28†
Bear/Evans	39	12.2	0.31
May/Coal	6	1.4	0.23†
Lake Sammamish Creeks	1	1.5	0.31†
Issaquah	33	12.3	0.37
Lower Cedar	35	11.6	0.33
Full Analysis	**153**	**49.4**	**0.32**

† Calculated averages not used due to small sample size. Adjacent subbasins substituted.

Crop Irrigation Requirements

The amount of irrigation water required to grow and maintain vegetation depends on the crop, season, and local climate (temperature and precipitation) and thus varies by location throughout the WRIA. The Washington Irrigation Guide (WAIG) (NRCS 1997) includes an appendix listing net irrigation requirements for various common crops for 89 locations throughout Washington, derived from water use and meteorological data from the 1970s and 1980s. Since lawn is a fairly water-intensive crop and the most common target of residential irrigation, irrigation requirements for turf were used to estimate outdoor water needs.

Using the one WAIG station within WRIA 8 (Seattle-UW) and surrounding stations to the north, south, and east, the GeoEngineers team spatially interpolated crop irrigation requirements (CIRs) across WRIA 8 by creating a triangulated irregular network (TIN) surface between the WAIG station points. Since there are no stations east of Snoqualmie Falls, a lower value was imposed along the Cascade crest to enforce continued reduction in CIR with increasing precipitation. A value of 8 inches per year was used for the boundary value; this is believed to be a conservative value based on nearby Cascade foothill station estimates from an unpublished irrigation data set being developed by Washington State University (Peters et al. 2019). Values from the resulting TIN surface were averaged over each subbasin to estimate the irrigation requirement for each subbasin. This analysis was performed for both annual and summer (June-July-August) irrigation requirements to provide information to compare peak summer water use to annual use estimates. Figure 2 shows the locations of WAIG irrigation data stations and the interpolated distribution of annual turf irrigation requirements across WRIA 8. Table 4 summarizes the average values for both annual and summer CIRs for subbasins with projected PE well connections. Annual values were used for the consumptive use calculations described in this memo.

The CIR is the net amount of external water required by the crop, accounting for precipitation inputs. Since irrigation systems are not 100 percent efficient, additional water must be supplied to ensure that crop needs are met. The application efficiency varies by the type of system (drip irrigation, microsprinklers, pivot sprinklers, etc.). For WRIA 8, the Ecology-recommended value of 75 percent was used to determine the water applied for irrigation (Ecology 2019).

Outdoor water use for each home was then estimated as the applied water for irrigation (computed as a depth) times the average irrigation area. The consumptive use fraction is substantially higher for outdoor use than indoor use (to a septic system) because most of the applied water is taken up by plants or evaporated. Based

on the Final NEB Guidance, a consumptive use fraction of 80 percent was applied to the total outdoor water use, meaning that 80 percent of water used for outdoor watering does not return to the local groundwater system (Ecology 2019).

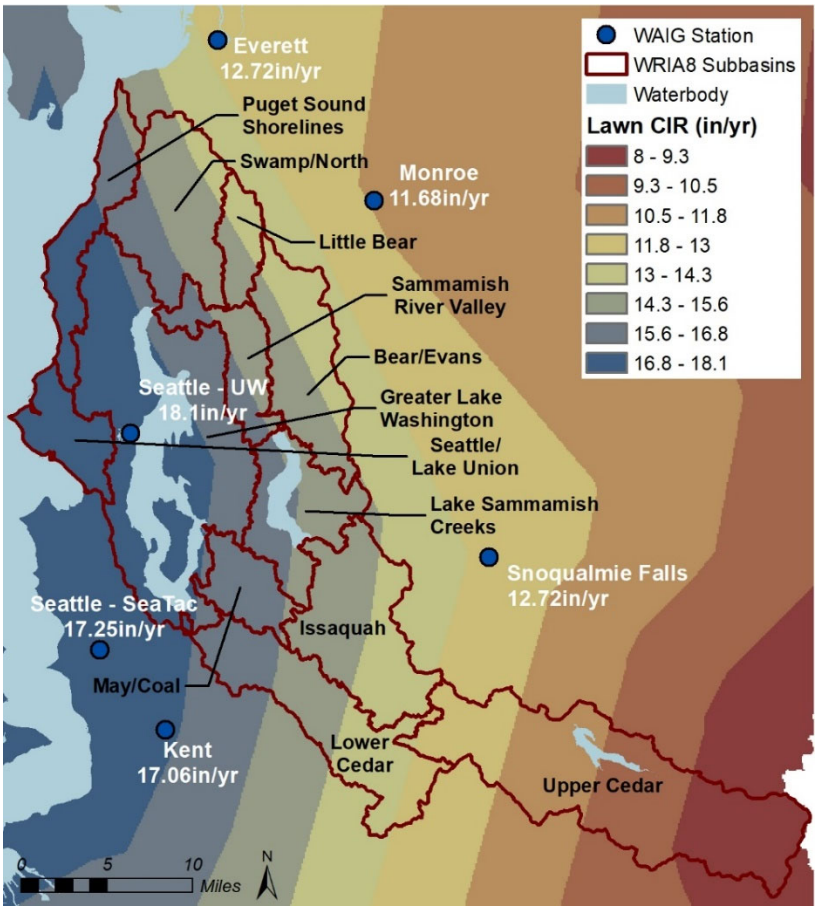


Figure 2. Spatial Distribution of Annual Turf Irrigation Requirement

TABLE 4. WRIA 8 CROP IRRIGATION REQUIREMENTS

Subbasin	Annual Turf CIR (in)	Summer (JJA) Turf CIR (in)
Puget Sound Shorelines	16.78	12.62
Swamp/North	15.22	11.99
Little Bear	14.35	11.51
Sammamish River Valley	15.55	12.31
Bear/Evans	14.33	11.65
Greater Lake Washington	17.15	13.11
May/Coal	16.15	12.67
Lake Sammamish Creeks	15.46	12.28
Issaquah	14.36	11.83
Lower Cedar	14.53	11.89
WRIA Average*	**15.66**	**12.35**

* Spatial average for subbasins with projected PE wells only

TOTAL CONSUMPTIVE USE

The methods described above were used to compute indoor and outdoor consumptive use per PE well connection. Totals for each subbasin were then computed by multiplying per home values by the projected number of PE well connections in each subbasin. The GeoEngineers team developed a consumptive use calculator (Excel spreadsheet) to compute consumptive use for projected PE well connections for each subbasin and the WRIA as a whole. Table 5 summarizes the consumptive use estimate, which assumes one home with the measured subbasin-average yard area per PE well. The consumptive use estimate for WRIA 8 is 425.4 acre-feet per year, as shown on Figure 3.

TABLE 5. ANNUAL CONSUMPTIVE USE FOR ONE HOME WITH SUBBASIN AVERAGE YARD

Subbasin ID	# PE Wells Anticipated in Subbasin	Irrigated Area per Well (ac)	Per Well Consumptive Use (gpd)			Total Consumptive Use (af/yr)
			Indoor	Outdoor	Total	
Puget Sound Shorelines	2	0.28†	16.5	372.8	389.3	0.9
Swamp/North	5	0.28†	16.5	338.2	354.7	2.0
Little Bear	118	0.28	16.5	318.8	335.3	44.3
Sammamish River Valley	8	0.28‡	16.4	345.5	361.9	3.2
Bear/Evans	234	0.31	16.4	352.5	368.9	96.7
Greater Lake Washington	4	0.28†	16.4	381.0	397.4	1.8
May/Coal	15	0.33‡	16.4	422.9	439.3	7.4
Lake Sammamish Creeks	6	0.31‡	16.4	380.3	396.7	2.7
Issaquah	235	0.37	16.4	421.6	438.0	115.3
Lower Cedar	340	0.33	16.4	380.5	396.9	151.2
WRIA 8 Aggregated	**967**	**0.33**	**16.4**	**376.3**	**392.7**	**425.4**

Note: Values in table have been rounded.
† Representative measured value not available; uses Little Bear subbasin average irrigated area.
‡ Calculated average not used due to small sample size. Surrogate subbasin used: Little Bear for Sammamish River Valley, Lower Cedar for May/Coal, and Bear/Evans for Lake Sammamish Creeks.

CONSUMPTIVE WATER USE SCENARIOS

The consumptive use calculator was also used to explore additional consumptive use scenarios. “Default” input parameters and values discussed in the methods section above can be modified to explore the effect of changes or uncertainties in individual assumptions. Based on requests from the technical workgroup and WRIA 8 Committee, two additional scenarios were computed, and annual consumptive use results are summarized in Table 6 and Table 7:

1. One home with legal maximum 0.5-acre irrigated lawn area per PE well. Assumes 60 gallons per day per person indoor use and outdoor use to irrigate 0.5-acre lawn.
2. Legal limit of 950 gallons per day (maximum annual average withdrawal) per well connection for indoor and outdoor household use. Assumes 60 gallons per day per person indoor use and remainder to outdoor use.

TABLE 6. ANNUAL CONSUMPTIVE USE FOR ONE HOME WITH 0.5-AC YARD

Subbasin ID	# PE Wells Anticipated in Subbasin	Irrigated Area per Well (ac)	Per Well Consumptive Use (gpd)			Total Consumptive Use (af/yr)
			Indoor	Outdoor	Total	
Puget Sound Shorelines	2	0.5	16.5	665.7	682.2	1.5
Swamp/North	5	0.5	16.5	603.8	620.3	3.5
Little Bear	118	0.5	16.5	569.3	585.8	77.4
Sammamish River Valley	8	0.5	16.4	616.9	633.3	5.7
Bear/Evans	234	0.5	16.4	568.5	585.0	153.3
Greater Lake Washington	4	0.5	16.4	680.4	696.8	3.1
May/Coal	15	0.5	16.4	640.7	657.1	11.0
Lake Sammamish Creeks	6	0.5	16.4	613.4	629.8	4.2
Issaquah	235	0.5	16.4	569.7	586.1	154.3
Lower Cedar	340	0.5	16.4	576.5	592.9	225.8
WRIA 8 Aggregated	**967**	**0.5**	**16.4**	**574.4**	**590.8**	**640.0**

Note: Values in table have been rounded.

TABLE 7. ANNUAL CONSUMPTIVE USE FOR ANNUAL AVERAGE 950 GPD WATER USE PER CONNECTION

Subbasin ID	# PE Wells Anticipated in Subbasin	Irrigated Area per Well (ac)	Per Well Consumptive Use (gpd)			Total Consumptive Use (af/yr)
			Indoor	Outdoor	Total	
Puget Sound Shorelines	2	0.47	16.5	628.0	644.5	1.4
Swamp/North	5	0.52	16.5	628.0	644.5	3.6
Little Bear	118	0.55	16.5	628.0	644.5	85.2
Sammamish River Valley	8	0.51	16.4	629.0	645.3	5.8
Bear/Evans	234	0.55	16.4	628.6	645.0	169.1
Greater Lake Washington	4	0.46	16.4	629.0	645.3	2.9
May/Coal	15	0.49	16.4	629.0	645.3	10.8
Lake Sammamish Creeks	6	0.51	16.4	629.0	645.3	4.3
Issaquah	235	0.55	16.4	629.0	645.3	169.9
Lower Cedar	340	0.55	16.4	629.0	645.3	245.8
WRIA 8 Aggregated	**967**	**0.55**	**16.4**	**628.7**	**645.1**	**698.9**

Note: Values in table have been rounded.

Daily usage rates shown in Table 5 through Table 7 represent annual average values. While indoor use generally does not vary much from month to month, outdoor water needs range from zero during the winter rainy season to more than three times the annual average during the peak of the summer. Since streamflows are lowest in late summer for most western Washington streams, the WRIA 8 Committee may consider peak summer water use along with annual use when developing the watershed plan. It is important to remember that pumping rates are likely not equivalent to consumptive use impacts on stream depletion. While the Final NEB Guidance recommends considering stream depletion impacts to be a steady-state equivalent, there may be circumstances within a watershed where that is not appropriate.

Total Water Use and Comparison to Water Purveyor Data

Water use data from water purveyors serving rural areas in the central Puget Sound were obtained as one benchmark for comparison with estimated PE well usage. Snohomish County Public Utilities District #1 (Snohomish County PUD), serving about 20,000 customers in central and northern Snohomish County, and Covington Water District, serving about 18,000 customers in southern King County, each provided metered water use data from 2015 and 2017. In addition, Snohomish County compiled annual water demand forecasts from water system plans for 17 water purveyors operating in the county. Table 8 summarizes the available water purveyor data. Reported values are total water use, not consumptive use. For the two metered systems providing data, the average annual use is approximately 220 gallons per day (gpd) per household. About 160 gpd is attributed to indoor uses (year-round) and 50 to 70 gpd (averaged over 12 months) to outdoor uses. Note that outdoor use is typically concentrated over about 3 months during the summer, which equates to rates of 150 to 200 gpd of outdoor watering for those 3 months.[2]

Since most water purveyors charge customers by the amount of water delivered (not just consumptively used)—and in some cases at increased rates as water use goes up—metered water users may exhibit more water conservation behaviors than unmetered users. Total water use breakdowns for the projected PE well scenarios are presented in Table 9. Estimated indoor use of 164 gpd for the PE well scenarios is very consistent with the water purveyor data (based on metered winter water use), between 150 and 170 gpd.

Average annual total use for PE wells estimated from this analysis (see Table 9) are considerably higher, however, due to outdoor use estimates about a factor of 10 greater than average metered use: 470 gpd estimated for PE wells versus 50 to 70 gpd for metered users on an average annual basis or 1,500 gpd estimated for PE wells versus 150 to 200 gpd[3] for metered users on average during the summer. The magnitude of this difference seems unlikely to be accounted for strictly by price pressures and thus suggests that assumptions in this analysis regarding watering behavior are generally conservative. For example, studies have shown that most residential lawn watering is conducted at a deficit level to maintain some growth and green color (Water Research Foundation 2016), versus the assumption of watering for optimal growth of commercial crops (like a sod farm for turf grass) implicit in the WAIG crop irrigation requirements. Because of uncertainty inherent in estimating growth patterns, domestic PE well pumping rates, and potential changes in outdoor watering practices, conservative assumptions for future new household water use, and outdoor water use in particular, are justified.

[2] 50 gpd over 12 months is equivalent to 200 gpd over 3 months, both totaling about 18,000 gallons.
[3] Metered summer usage for several individual homes in the Covington Water District showed outdoor usage ranging from 25 gpd to 2,693 gpd for July-August 2015.

TABLE 8. WATER PURVEYOR HOUSEHOLD WATER USE DATA

Water Purveyor	Average Annual Water Use (gpd)	Average Winter Water Use (gpd)	Average Summer Water Use (gpd)
Metered Water Use Data†			
Snohomish County PUD‡	237	170	370
Covington Water District	200	150	300
Comprehensive Plan Forecast			
Alderwood	169		
Cross Valley*	234		
Edmonds	201		
Gold Bar	171		
Highland*	200		
Marysville	168		
Monroe	170		
Mukilteo	179		
Olympic View	189		
Roosevelt*	383		
Silver Lake	177		
Snohomish	190		
Snohomish County PUD*	190		
Stanwood	282		
Startup*	250		
Sultan	190		
Three Lakes*	191		
*Average Rural Non-City	241		

Note: Reported values are total water use, not consumptive use.
†Data from 2015 and 2017 ‡Average use for parcels ≥1 acre *Rural (non-city) water provider

TABLE 9. ESTIMATED PERMIT-EXEMPT WELL TOTAL WATER USE

Scenario	Average Annual Water Use (gpd)	Average Indoor Use (gpd)	Average Annual Outdoor Use (gpd)	Average Summer Outdoor Use (gpd)
1 home, average measured yard	634	164	470	1,522
1 home, 0.5 ac yard	882	164	718	2,321
1 home using 950 gpd (annual average)	950	164	786	n/a

Note: Reported values are total water use, not consumptive use.

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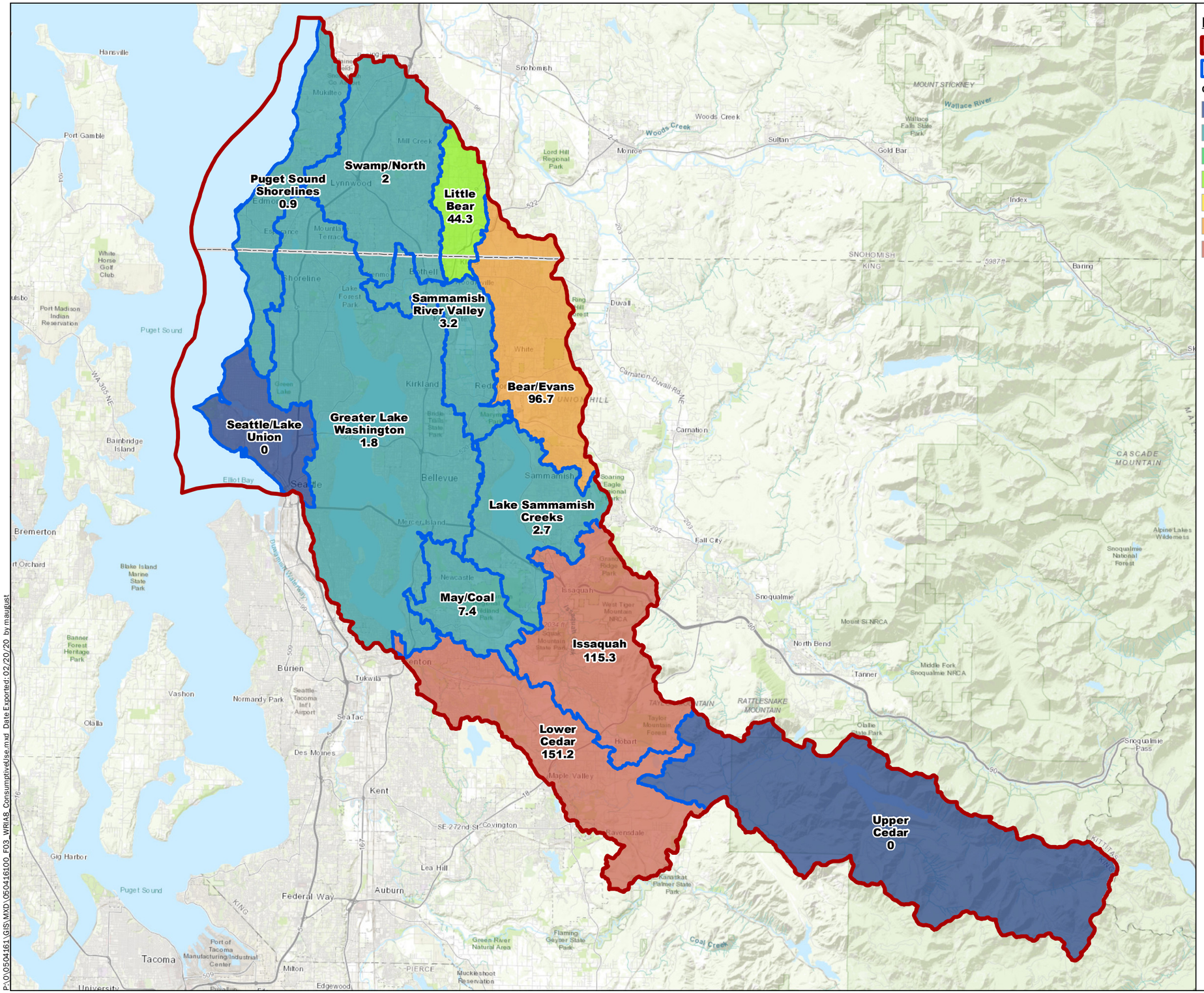
Attachment:
Figure 3. WRIA 8 Estimated Consumptive Use from Projected Permit-Exempt Wells 2018-2038



Notes:
1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: ESRI Topographic Map Base

Projection: NAD 1983 StatePlane Washington North FIPS 4601 Feet

WRIA 8 Estimated Consumptive Use from Projected Permit-Exempt Wells 2018-2038

Watershed Restoration and Enhancement Plan
Snohomish and King Counties, Washington

GeoEngineers

Figure 3

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