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GeoEngineers

# Memorandum

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## INTRODUCTION

The WRIA 9 Watershed Restoration and Enhancement Plan (Plan) must include projects and actions that offset the consumptive use from future domestic permit-exempt wells. Consumptive water 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 permit-exempt well and not replaced through the septic system, irrigation return flow, or other means.

Growth projections and projections for number and location of new domestic permit-exempt well connections within WRIA 9 were developed by King County and GeoEngineers (see WRIA 9 Growth Projections Summary of Methods, dated 9/3/19 and presented at the 9/24/19 WRIA 9 WREC meeting) for purposes of the Plan. This memorandum summarizes the methods used to estimate consumptive water use associated with the new well connections and provides results for three water use scenarios. Methodology is based on Appendix A of the Department of Ecology's (Ecology's) Net Ecological Benefit guidance (Ecology, 2019) and documented in further detail in the Consumptive Use Estimates Workplan prepared by the GeoEngineers team.

## 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. Permit-exempt wells are generally unmetered, so 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 water use are indoor use and outdoor use. The methodology used to estimate these quantities for WRIA 9 are described in the following sections.

### Indoor Consumptive Use

Indoor consumptive use was estimated using Ecology guidance, 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. Ecology's 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 as 2.73 people per household.
- Percentage of total water used that is consumptive. Ecology guidance recommends that 10% 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 permit-exempt wells are outside of sewer service areas, so the 10% assumption was applied for all projected indoor water use.

### 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.

### Irrigated Footprint Analysis

The GeoEngineers team conducted an aerial photo-based analysis of irrigated lawn and garden area for 211 parcels in eight of the WRIA 9 subbasins. Parcels used for the irrigated footprint analysis were selected based on recent (2006-2017) building permits for new single-family residential homes not served by public water. All new home building permit sites in WRIA 9 were included in the analysis; permits for accessory dwelling units (ADUs) or reconstruction/remodel were excluded. 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) vs. non-irrigated (brown) grass areas. 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 a couple of parcels in the Covington Creek subbasin. On each photo, the parcel boundary is shown in orange 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 1. The analysis covered eight of the nine subbasins in WRIA 9 with projected permit-exempt well connections. The Lower Green River subbasin (with four projected permit-exempt well connections) did not have any recent building permits for sites without purveyor-provided water service, so the average irrigated area for the adjacent Soos Creek subbasin was applied to the Lower Green subbasin for purposes of consumptive use estimates.

**TABLE 1. WRIA 9 IRRIGATED FOOTPRINT SUMMARY**

| Subbasin | Parcels Analyzed | Total Irrigated Area (ac) | Average Irrigated Area (ac) |
|---|---|---|---|
| Coal/Deep Creek | 21 | 3.6 | 0.17 |
| Covington Creek | 13 | 5.2 | 0.40 |
| Jenkins Creek | 24 | 8.1 | 0.34 |
| Lower Middle Green River | 29 | 12.8 | 0.44 |
| Mid Middle Green River | 21 | 5.2 | 0.25 |
| Newaukum Creek | 38 | 11.7 | 0.31 |
| Soos Creek | 31 | 10.6 | 0.34 |
| Upper Middle Green River | 34 | 7.1 | 0.21 |
| **WRIA Total** | **211** | **64.2** | **0.30** |

### 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 two WAIG stations within WRIA 9 (Seattle-Tacoma and Kent) and surrounding stations to the north, south, and east, the GeoEngineers team spatially interpolated values across WRIA 9 using an inverse distance weighting method. Inverse distance weighting computes a value for any location by weighting surrounding point values based on the square of their distance from the location—so a station one mile away would have four times the influence of a station two miles away. Values from the resulting grid 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 WIG irrigation data stations and the interpolated distribution of annual turf irrigation requirements across WRIA 9. There are no western Washington WIG stations east of Buckley and Snoqualmie Falls, where CIR would be expected to continue to decrease, so the results of the interpolation are likely too high for the Upper Green River subbasin. Since there are no projected permit-exempt well connections in the Upper Green, this uncertainty does not significantly affect consumptive use calculations. Table 2 summarizes the average values for both annual and summer CIRs for subbasins with projected permit-exempt well connections.

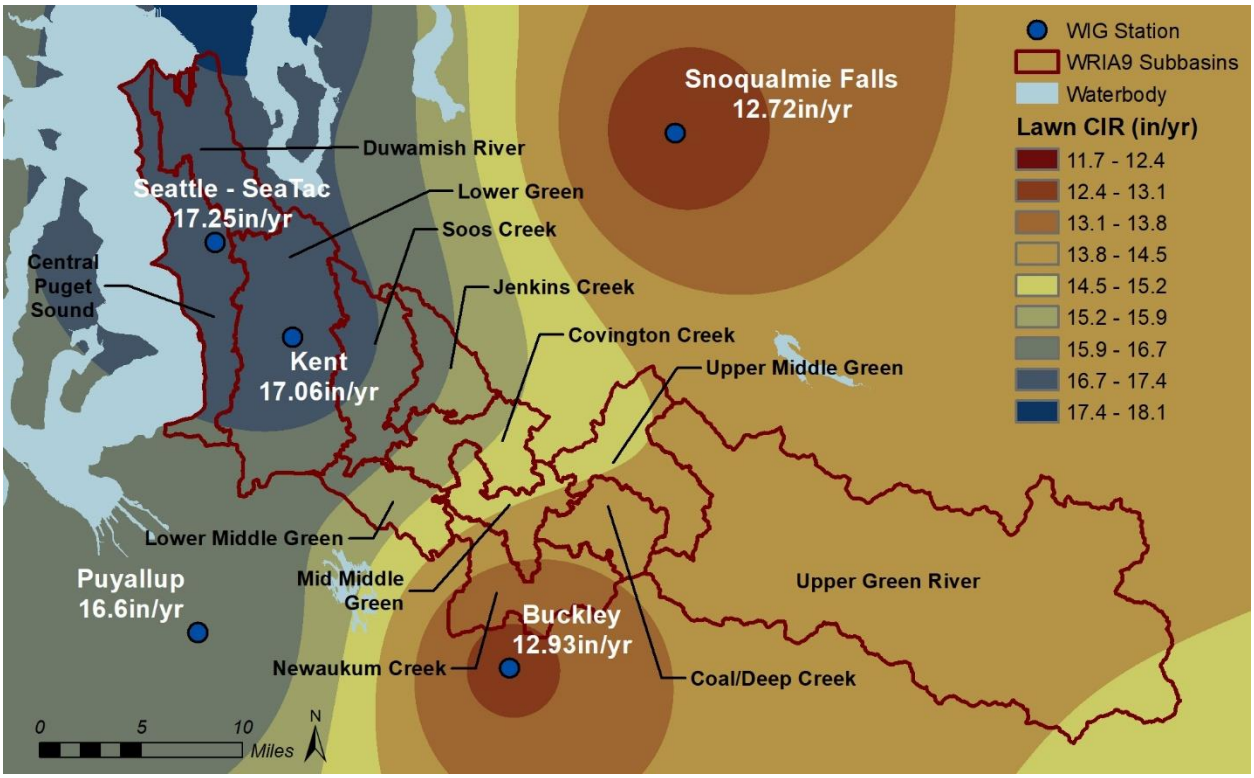


Figure 2. Spatial Distribution of Annual Turf Irrigation Requirement

**TABLE 2. WRIA 9 CROP IRRIGATION REQUIREMENTS**

| Subbasin | Annual Turf CIR (in) | Summer (JJA) Turf CIR (in) |
|---|---|---|
| Coal/Deep Creek | 14.20 | 11.67 |
| Covington Creek | 15.37 | 12.35 |
| Jenkins Creek | 16.02 | 12.74 |
| Lower Green | 16.86 | 13.24 |
| Lower Middle Green River | 15.51 | 12.43 |
| Mid Middle Green River | 14.59 | 11.89 |
| Newaukum Creek | 13.68 | 11.36 |
| Soos Creek | 16.56 | 13.06 |
| Upper Middle Green River | 14.49 | 11.84 |
| **WRIA Average** | **15.25** | **12.29** |

The CIR is the net amount of external water required by the crop, accounting for precipitation inputs. Since irrigation systems are not 100% 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 9, the Ecology-recommended value of 75% was used to determine the water applied for irrigation.

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 Ecology guidance, a consumptive use fraction of 80% was applied to the total outdoor water use, meaning that 80% of water used for outdoor watering does not return to the local groundwater system.

## TOTAL CONSUMPTIVE USE

The methods described above were used to compute indoor and outdoor consumptive use per permit-exempt well connection. Totals for each subbasin were then computed by multiplying per home values by the projected number of permit-exempt well connections in each subbasin. The GeoEngineers team developed a consumptive use calculator (Excel spreadsheet) to compute consumptive use for projected permit-exempt well connections for each subbasin and the WRIA as a whole. Table 3 summarizes the consumptive use estimate, which assumes one home with measured subbasin-average yard area per permit-exempt well. The consumptive use estimate for WRIA 9 is 268.6 acre-feet per year.

**TABLE 3. 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 | |
| Coal/Deep Creek | 62 | 0.17 | 16.4 | 191.5 | 207.9 | 14.4 |
| Covington Creek | 41 | 0.40 | 16.4 | 487.8 | 504.2 | 23.2 |
| Jenkins Creek | 45 | 0.34 | 16.4 | 432.2 | 448.6 | 22.6 |
| Lower Green | 4 | 0.34 | 16.4 | 454.9 | 471.2 | 2.1 |
| Lower Middle Green River | 84 | 0.44 | 16.4 | 541.5 | 557.9 | 52.5 |
| Mid Middle Green River | 100 | 0.25 | 16.4 | 289.4 | 305.8 | 34.3 |
| Newaukum Creek | 103 | 0.31 | 16.4 | 336.5 | 352.9 | 40.7 |
| Soos Creek | 83 | 0.34 | 16.4 | 446.8 | 463.1 | 43.1 |
| Upper Middle Green River | 110 | 0.21 | 16.4 | 241.5 | 257.8 | 31.8 |
| **WRIA 9** | **632** | **0.30** | **16.4** | **363.0** | **379.4** | **268.6** |

## 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 impact of changes or uncertainties in individual assumptions. Based on requests from the technical workgroup and Committee, two additional scenarios were computed, and annual consumptive use results are summarized in Table 4 and Table 5.

1. One home with legal maximum 0.5-acre irrigated yard area per permit-exempt well
2. Legal maximum 950 gallons per day (annual average) combined water use per permit-exempt well

**TABLE 4. 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 | |
| Coal/Deep Creek | 62 | 0.5 | 16.4 | 563.4 | 579.8 | 40.3 |
| Covington Creek | 41 | 0.5 | 16.4 | 609.8 | 626.2 | 28.8 |
| Jenkins Creek | 45 | 0.5 | 16.4 | 635.6 | 652.0 | 32.9 |
| Lower Green | 4 | 0.5 | 16.4 | 668.9 | 685.3 | 3.1 |
| Lower Middle Green River | 84 | 0.5 | 16.4 | 615.4 | 631.7 | 59.4 |
| Mid Middle Green River | 100 | 0.5 | 16.4 | 578.9 | 595.2 | 66.7 |
| Newaukum Creek | 103 | 0.5 | 16.4 | 542.8 | 559.1 | 64.5 |
| Soos Creek | 83 | 0.5 | 16.4 | 657.0 | 673.4 | 62.6 |
| Upper Middle Green River | 110 | 0.5 | 16.4 | 574.9 | 591.3 | 72.9 |
| **WRIA 9** | **632** | **0.5** | **16.4** | **605.0** | **621.4** | **440.0** |

**TABLE 5. ANNUAL CONSUMPTIVE USE FOR 950 GPD WATER USE PER WELL (ANNUAL AVERAGE)**

| 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 | |
| Coal/Deep Creek | 62 | 0.56 | 16.4 | 629.0 | 645.3 | 44.8 |
| Covington Creek | 41 | 0.52 | 16.4 | 629.0 | 645.3 | 29.6 |
| Jenkins Creek | 45 | 0.49 | 16.4 | 629.0 | 645.3 | 32.5 |
| Lower Green | 4 | 0.47 | 16.4 | 629.0 | 645.3 | 2.9 |
| Lower Middle Green River | 84 | 0.51 | 16.4 | 629.0 | 645.3 | 60.7 |
| Mid Middle Green River | 100 | 0.54 | 16.4 | 629.0 | 645.3 | 72.3 |
| Newaukum Creek | 103 | 0.58 | 16.4 | 629.0 | 645.3 | 74.5 |
| Soos Creek | 83 | 0.48 | 16.4 | 629.0 | 645.3 | 60.0 |
| Upper Middle Green River | 110 | 0.55 | 16.4 | 629.0 | 645.3 | 79.5 |
| **WRIA 9** | **632** | **0.52** | **16.4** | **629.0** | **645.3** | **456.9** |

Daily usage rates shown in Table 3 through Table 5 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 Committee may consider peak summer water use along with annual use when developing the watershed restoration and enhancement plan. It is important to remember that pumping rates are not equivalent to consumptive use impacts on stream depletion.

### Comparison to Water Purveyor Data

Covington Water District (CWD) provided water use data for its system from 2015 and 2017 that were compared to calculated usage from the three scenarios. The CWD serves more than 18,000 customers over 55 square miles of southern King County, including areas of Covington, Maple Valley, Black Diamond, and unincorporated King County. Water use varied by year and property type (single-family residential, mobile home, rural subdivision single-family residential) but average total annual water use was approximately 200 gpd per household. Indoor water use (estimated from winter water use values) was consistently between 140 and 160 gpd per household. Outdoor water use (estimated by subtracting typical winter usage from total summer usage) was more variable—about 120 gpd per household in summer 2015 and about 200 gpd per household in summer 2017. This summer usage averages to about 50 gpd on an annual basis.

Indoor water use in the calculated scenarios was very close to the CWD values, as shown in Table 6. (Note that Table 6 compares total water use, not consumptive use.) However, calculated outdoor use is on the order of ten times higher than outdoor use estimated from the CWD numbers. CWD charges its customers on a tiered rate structure, depending on season and level of water use, which may influence summer watering behavior compared to unmetered users. The CWD service area also includes more heavily developed areas in Covington and Maple Valley that would be likely to have smaller lot sizes than the fringe areas where more permit-exempt well connections are anticipated, which also may account for some of the discrepancy. It is likely, however, that assumptions regarding crop water use and application efficiency are also conservative to generate such a significant difference. For example, residential lawn watering is likely more often at a deficit level (to maintain some growth and green color) whereas the WAIG crop irrigation requirements used in the consumptive use estimate assume watering at a level to produce commercial crops (like a sod farm for turf grass).

**TABLE 6. CALCULATED ANNUAL WATER USE VS. WATER PURVEYOR DATA**

| Scenario | Indoor Use per Household (gpd) | Outdoor Use per Household (gpd) | Total Use per Household (gpd) |
|---|---|---|---|
| 1 home, average measured yard | 164 | 454 | 618 |
| CWD Average Water Use | 150 | 50† | 200 |
| Other Scenarios | | | |
| 1 home, 0.5 ac yard | 164 | 756 | 920 |
| 1 home using 950 gpd (annual average) | 164 | 786 | 950 |

†Annualized water use. Summer usage rates are on the order of 150-200 gpd.

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

## REFERENCES

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