Technical Memorandum DRAFT

To:	Angela Johnson, Washington State Department of Ecology
From:	Chad Wiseman, HDR; Malia Bassett, HDR
Copy:	Lisa Dally Wilson (DE) and Bob Montgomery (Anchor QEA)
Date:	December 18, 2020
Subject:	WRIA 10 Permit-Exempt Growth and Consumptive Use Summary (Work Assignment 2, Tasks 2 and 3)

1.0 Introduction

HDR 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) 10, 12, 13, 14, and 15. This memorandum provides a summary of the analytical methods used for Work Assignment 2 Task 2: Consumptive Use (CU) Estimates, and the final estimates of CU per WRIA.

Under RCW 90.94, consumptive water use by permit-exempt connections occurring over the planning horizon must be estimated to establish the water use that watershed restoration plans and plan updates are required to address and offset. This memorandum summarizes permit-exempt connections and related CU of groundwater that is projected to impact WRIA 10 over the planning horizon.

This memorandum includes:

- A summary of WRIA 10 baseline permit-exempt growth and an alternative scenario of permit-exempt growth.
- A summary of WRIA 10 baseline and alternative scenario consumptive use using two different methods.

2.0 WRIA 10 Permit-Exempt Growth Projection Methods

Because WRIA 10 is comprised of two counties, King and Pierce counties, individual county growth projections were combined at the WRIA scale and organized by subbasin. The WRIA growth projection that was composed of the counties' best estimate is considered the baseline.

Portions of the Lower, Middle, and Upper White River subbasins are within King County; the remainder of the WRIA lies within Pierce County.

The WRIA 10 WRE committee agreed to develop high and low growth projection scenarios based on varying Pierce County projections. King County projections remained constant. The WRIA 10 WRE committee agreed to use different time periods in the historical TPCHD well database to project baseline, high, and low permit-exempt connection growth during the 20-year planning horizon in the Pierce County portion of WRIA 10. The 1999–2008 time period was a time of relatively high permit-exempt connection growth and was selected for a "high growth" scenario. The 2009–2018 time

period was a time of relatively low permit-exempt connection growth and was selected to represent the rate of permit-exempt growth for the “low growth” scenario. King County did not vary their growth projection of 81 wells or connections in this area.

2.1 King County

The following methods were used to project growth over the planning horizon:

1) Compile 18 years (2000–2017) of building permit data for new residential structures then subdivide into two periods (2000–2009 and 2010–2017) for high and low growth range.
2) Use GIS to provide location-based information about building permits.
3) Link building permits and parcel data layers to assess percentage of parcels using public versus private water with parcel attribute data.
4) Determine the number of building permits/parcels that have a water source.
5) Calculate the percentage of building permits for each type of water source for the entirety of King County, by WRIA and its subbasins.
6) Use the annual average number of permits per year multiplied by the percentage of permits/parcels on private water to determine a projected number of permit-exempt wells per year. Multiply the number of permit-exempt wells by 20 to calculate the estimated total of permit-exempt wells projected over the 20-year period.

King County growth projections did not change from the initial projections on December 16, 2019 (Attachment C).

2.2 Pierce County

The following methods were used to project growth over the planning horizon:

1) Calculate historical growth rates of permit-exempt connections for each subbasin using the Tacoma-Pierce County Health District (TPCHD) well database (1999–2018).
2) Forecast growth of future permit-exempt connections for the 20-year planning horizon, based on the subbasin-specific historical growth rate.
3) Develop heat map of most likely areas for new permit-exempt connections within each subbasin, based upon spatial analysis of parcels available for development (i.e., parcel must be outside of UGA, not in a water and wastewater system boundary, not already built upon, must have zoning category that allows for domestic use, and outside of commercial forest and federal lands).

3.0 WRIA 10 Consumptive Use Methods

Under RCW 90.94, consumptive water use (consumptive use) by permit-exempt connections that are forecast to be installed over the planning horizon to service rural growth must be estimated to establish the water offsets required under the Streamflow Restoration law. The following definitions from the *Final Guidance for Determining Net Ecological Benefit - ESSB 6091 - Recommendations for Water Use Estimates* (Ecology’s Final NEB Guidance) are used in this memorandum as a guide to estimate consumptive water use by permit-exempt connections (Ecology 2019).

- Consumptive use: water that evaporates, transpires, is consumed by humans, or otherwise removed from an immediate water environment.
- Domestic Use: includes both indoor and outdoor household uses, and watering of a lawn and noncommercial garden.
- New Consumptive Water Use: The consumptive water use from the permit-exempt domestic groundwater withdrawals estimated to be initiated within the 20-year planning horizon (2020–2040) (planning horizon). The required water offset is equal to new consumptive water use.
- Net Ecological Benefit: The outcome that is anticipated to occur through implementation of projects and actions in a plan to yield offsets that exceed impacts within: a) the planning horizon; and, b) the relevant WRIA boundary.
- Water Offsets: Projects that put water back into aquifers or streams that offset new consumptive water use.

Ecology has provided guidance for estimating indoor and outdoor consumptive water use in Ecology's Final NEB Guidance (Ecology 2019).

Consumptive use estimates are divided into two components: the indoor and outdoor portions of use. The use patterns and consumptive portions of indoor versus outdoor use associated with permit-exempt connections are different; therefore, separate approaches within each method that account for these differences are used to estimate consumptive use.

Ecology's indoor consumptive water use guidance includes literature-based assumptions on per-capita indoor water use and the consumptive proportion. Outdoor consumptive water use guidance includes methods for the estimation of irrigated area, assumed irrigation requirements, irrigation efficiency, and the consumptive proportion. Ecology's guidance also recommends local corroboration using water system meter data for both indoor and outdoor estimates (Ecology 2019). For purposes of this technical memorandum, Ecology's method for estimating consumptive use by estimating irrigated area and amount of irrigation is called the Irrigated Area method, and estimation of consumptive use using local water system meter data is called the Water System Data method.

Ecology's guidance also describes using the legal limit to estimate consumptive use, but notes that this method is less accurate because most people do not use 950 gallons per day all year round. This method is referred to as the Legal Limit method.

Consumptive use of water from projected permit-exempt connection growth was estimated using three different methods; 1) the Irrigated Area Method, 2) the Water System Data Method, and the Legal Limit Method.

Consistent with the Final NEB guidance, the Committee assumed impacts from consumptive use on surface water are steady-state, meaning impacts to the stream from pumping do not change over time. This assumption is based on the wide distribution of future well locations and depths across varying hydrogeological conditions.

3.1 Irrigated Area Method

Based on Ecology's Final NEB Guidance (Ecology 2019), estimating indoor and outdoor consumptive water use included literature-based assumptions for both the per capita indoor water use and indoor and outdoor use proportions.

3.1.1 Indoor Consumptive Use – Irrigated Area Method

The following assumptions were used to estimate indoor consumptive water use by occupants of a dwelling unit (Ecology 2018, 2019):

- 60 gallons per day per person within a household
- 2.5 persons per household (or as otherwise defined by the Counties)
- 10 percent of indoor use is consumptively used

Most homes served by a permit-exempt connection use septic systems for wastewater (Ecology 2019). This method assumes 10 percent of water entering the septic system will evaporate out of the septic drain field and the rest will be returned to the groundwater system. The legal limit for water use in WRIA 10 is 950 gallons per day annual average use per connection.[1]

Assuming that there is one permit-exempt connection per dwelling unit, a "per permit-exempt connection" consumptive use factor was applied to the growth projections forecast in each subbasin to determine total indoor consumptive use per subbasin. This method is summarized by the following equation:

$$HCIWU\ (gallons\ per\ year) = 60\ gpd\ x\ 2.5\ people\ per\ household\ x\ 365\ days\ x\ 10\%\ CUF$$

or

$$HCIWU\ (afy) = 60 gpd * \ 2.5\ people\ per\ house * 365\ days * 0.00000307\ AF/gallon * 10\%\ CUF$$

Where:
HCIWU = Household Consumptive Indoor Water Use (gpd)
CUF= Consumptive use factor

This estimate of indoor consumptive water use per household per day can be annualized and converted to gallons per day (gpd) or cubic feet per second (cfs).

Conversion Factors:

gpd = afy / 0.001120

cfs = afy / 723.97

3.1.2 Outdoor Consumptive Use – Irrigated Area Method

Ecology (2019) recommends estimating future outdoor water use based on an evaluation of the average outdoor irrigated area for existing dwelling units served by permit-exempt connections. To calculate the consumptive portion of total outdoor water required per connection, Ecology recommends:

- Estimating the average irrigated lawn area (pasture/turf grass) per parcel in each WRIA (this analysis assumes a single connection per parcel),

[1] This is an enforceable limit, not an estimate of actual water use.
The legal limit in WRIA 10 for indoor and outdoor use is as follows:
Indoor Use = 60 gpd per person * 2.5 people per household= 150 gallons per day
Indoor CU = 60 gpd per person * 2.5 people per household * 10% consumptively used = 15 gallons per day
Outdoor Use = 950 -150 = 800 gallons per day
Outdoor CU = 800 gallons per day * 80% consumptively used = 640 gallons per day

- Applying crop irrigation requirements,
- Correcting for application efficiency (75 percent efficiency recommended by Ecology guidance) to determine the total outdoor water required over a single growing season, and
- Applying a percentage of outdoor water that is assumed to be consumptive (80 percent outdoor consumptive use recommended).

The WRIA 10 Committee was given the opportunity to adjust variables used in the analysis. The WRIA 10 Committee chose to use a 95 percent upper confidence limit of the average irrigated lawn area instead of the average irrigated lawn area.

3.1.3 Estimation of Average Irrigated Area per Connection

HDR conducted an average irrigable area analysis for WRIA 10 to account for the variability in size of irrigated area among parcels in each WRIA. The analysis included 80 parcels identified as containing a dwelling unit served by a permit-exempt well per WRIA. Irrigated areas of the 80 parcels were delineated to estimate a sample distribution. Ultimate selection of irrigated area for the calculation of outdoor consumptive use was based on that sample distribution. To select the 80 parcels in WRIA 10, a parcel "selection pool" of all candidate parcels was developed. The final 80 parcels were determined from the parcel selection pool, as described below.

3.1.4 Parcel Selection

Differing socioeconomic landscapes within and between the WRIAs is a key factor influencing variance in the average irrigable area per dwelling unit (Green 2010). In order to capture those differences, HDR analyzed the range and distribution of property values throughout WRIA 10 and randomly selected 80 parcels representative of the distribution pattern of property values.

3.1.5 Parcel Selection Pool

HDR populated the parcel selection pool for WRIA 10 using direct selection. Direct selection involves joining spatial data of permit-exempt connections to a parcel database, thereby identifying all parcels with known permit-exempt connections (Table 1 and 2).

Pierce and King Counties provided geospatial datasets containing individual permit-exempt connection locations. These points were joined to their respective County parcel datasets to isolate the parcels known to be served by a permit-exempt connection.

Once parcels in each County were added to the selection pool, new parcel datasets were developed to reorganize the selected parcels into WRIA-specific selection pools at the WRIA level.

3.1.6 Parcel Analysis

A single technician conducted the entire irrigated area analysis to standardize the approach and minimize bias. Irrigated areas on each selected parcel were delineated using Google Earth aerial imagery taken during drier summer months (i.e., July and August) from 2000 through 2018. Unirrigated lawns (pasture/turf) go dormant in the dry summer months and turn brown. As such, areas that remain green in the summer imagery were considered irrigated. To aid in this determination, aerial imagery from winter months was reviewed alongside summer imagery to reveal which lawn areas change from green to brown. Those areas that do not change color, or moderately change color but remain green, were considered irrigated. Additionally, the technician reviewed imagery across multiple years (where available) to further corroborate the irrigated area delineation.

Yard areas may be obscured in aerial imagery by tree canopies or shadows; the technician used best professional judgment to interpolate the irrigated area under a tree canopy or across a shadow.

Septic drain fields are a potential non-irrigation source of water that may cause turf to remain green during summer months. Therefore, the technician considered additional indicators of intentional lawn irrigation such as artificially precise boundaries between green and brown grass, and shapes of green grass indicative of an irrigation system. Irregular shapes and mottled grass were included or excluded at the discretion of the technician based on proximity to a visible septic system and similarity to other, more pronounced irrigation signatures. Analyses conducted by other WRE planning groups included areas that appear to be "minimally irrigated," and were also included in this analysis. See Attachment A for additional details concerning the irrigated area delineation analysis.

Upon completion of analysis for 80 parcels, irrigated area was averaged for the WRIA for use in the outdoor consumptive use estimate. The average irrigated area was 0.17 acre. Over 50 percent of the parcels did not have any evidence of irrigation and were assigned a value of zero irrigated acres. To account for potential methodological limitations on detecting irrigation, a minimum value of 0.05 acres of irrigation was assumed to occur, even if there were no indications of irrigation from aerial photo interpretation. This value was approximately the minimum value of detected irrigation in the data set.

The WRIA 10 Committee calculated confidence limits around the average irrigated area to evaluate uncertainty in the estimate. The 95 percent upper confidence limit (UCL) average yielded an irrigated area of 0.27 acre. The 95 percent upper confidence limit represents the upper bound of the average irrigated area, with a 95 percent confidence that the irrigated area is equal to or less than 0.27 acre (Table 1). The irrigated area data set did not have a normal distribution, because over half of the parcels had zero irrigated area (i.e., the data were left-censored). However, when the zero values were replaced with 0.05-acre values (as an imputed detection limit), the data followed a gamma distribution. For gamma distributed detected data, UCLs may be computed using gamma distribution on a Kaplan-Meier (KM) statistic, using a Chi Square approximation (USEPA 2015). The WRIA 10 committee chose to use the 95 percent UCL of 0.27-acre irrigated area for outdoor consumptive use estimates.

3.1.7 Irrigation Requirements and Application Efficiency

Once average irrigable acreage per connection was determined for WRIA 10, water use was calculated based on irrigation requirements and application efficiency. Crop irrigation requirements were estimated for pasture/turf grass from the Puyallup and Buckley weather stations as provided in the Washington Irrigation Guide (NRCS-USDA, 1997). A weighted average of 16.1 inches per year was calculated based on the number of connections closest to the stations. An irrigation application efficiency was applied to account for water that does not reach the turf. Ecology (2019) recommends using a 75 percent application efficiency factor. The consumptive portion of total amount of water used for outdoor use was assumed to be 80 percent. This method is summarized in the following equation:

$$hHCOWU\ (afy) = A\ (acres) * IR(feet) * AE * CUF$$

Where:

HCOWU = Household Consumptive Outdoor Water Use (gpd)
A = Irrigated Area (acres)

IR = Irrigation Requirement over one irrigation season (feet)
AE = Application efficiency; assumed to be 75% (factor expressed as 1/0.75)
CUF= Consumptive use factor; assumed to be 80% (factor expressed as 0.80)

This estimate of outdoor consumptive water use per household per day can be annualized and converted to gallons per day (gpd) or cubic feet per second (cfs).

Conversion Factors:
gpd = afy / 0.001120
cfs = afy / 723.97

Outdoor Use = 950 -150 = 800 gallons per day
Outdoor CU = 800 gallons per day * 80% consumptively used = 640 gallons per day

4.0 Water System Data Method

Consumptive use by permit-exempt connections may also be estimated using metered connections from water systems. HDR requested data from WRE Committee members for water systems that use (or have used) a flat rate billing structure and were similar in character to the rural environments in which households may connect to permit-exempt connections. The Spanaway Water System, which operates under a tiered rate structure in WRIA 12, was used in the WRIA 10 analysis because smaller water system data were unavailable in WRIA 10. The Spanaway Water System may be representative of the rural environments where households typically rely on permit-exempt connection for domestic supply.

4.1 Indoor Use

Average daily use in December, January, and February is representative of year-round daily indoor use. Average daily system-wide use is divided by the number of connections (assuming all connections are residential), to determine average daily indoor use per connection. A 10 percent consumptive use factor was applied to the average daily use in the winter months to determine the consumptive portion of indoor water use per connection.

4.2 Outdoor Water Use

Average daily use in December, January, and February is representative of year-round daily indoor use. Total annual indoor use was subtracted from total annual use by a water system to estimate total annual outdoor use. An 80 percent consumptive factor was applied to determine the consumptive portion of outdoor use.

4.3 Seasonal Outdoor Water Use

Outdoor consumptive use was also estimated on a seasonal basis. The Washington Irrigation Guide reports irrigation requirements between the months of April and September for all weather stations representative of WRIA 10. Therefore seasonal outdoor water use was assumed to occur over a period of six months (April through September). Average daily indoor use was multiplied by the number of days in the irrigation season to calculate total indoor use for the irrigation season. Total irrigation season indoor use was then subtracted from total season use to determine total outdoor use for the irrigation season. The value was proportionally allocated to each month in the irrigation season using the requirements from the Washington Irrigation Guide. An 80 percent consumptive factor was applied to determine the consumptive portion of outdoor use.

5.0 Results

5.1 Permit-Exempt Connection Growth

Baseline permit-exempt connection growth is projected to be 688 connections (Table 1). The alternative "Higher Permit-Exempt Connection Growth" scenario is projected to have 230 additional connections, for a total of 918 permit-exempt connections. Growth is predicted to occur primarily along the midsection of the WRIA between Enumclaw and Orting, and east of Lake Tapps (Figure 1).

Table 1. WRIA 10 Alternative Growth Projection Scenarios (King and Pierce Counties)

Number of Permit-Exempt Connections Added between 2018 and 2038									
Subbasin	Baseline Growth (1999–2018)			High Growth (1999–2008)			Low Growth (2009–2018)		
	King	Pierce	Total	King	Pierce	Total	King	Pierce	Total
Carbon River	--	109	109	--	142	142	--	87	87
Lower Puyallup River	--	102	102	--	153	153	--	53	53
Lower White River	24	52	76	24	67	91	24	42	66
Middle White River	57	--	57	57	--	57	57	--	57
South Prairie Creek	--	167	167	--	229	229	--	122	122
Upper Puyallup River	--	165	165	--	242	242	--	104	104
Upper White River	--	12	12	--	4	4	--	20	20
Total	81	607	688	81	838	919	81	429	510

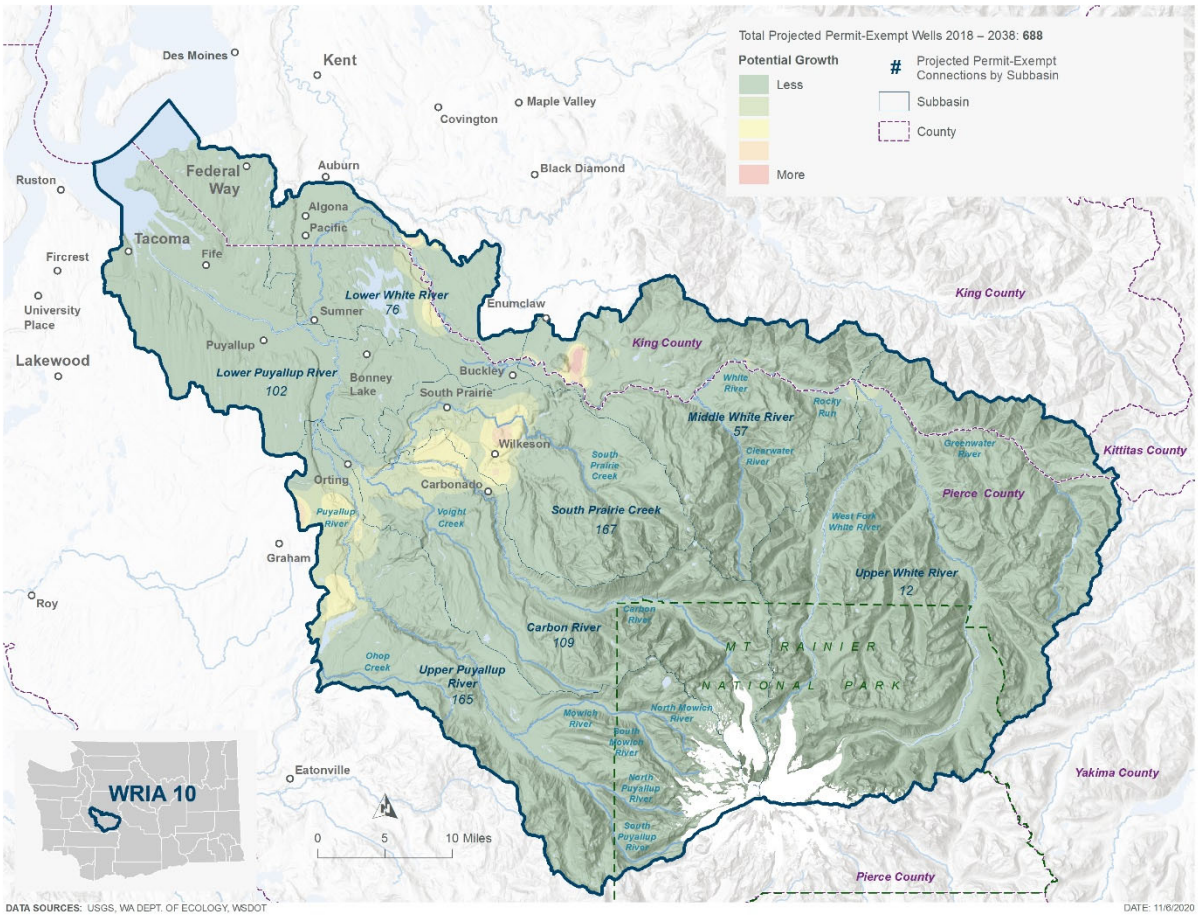


Figure 1. WRIA 10 projected permit-exempt connection growth.

5.2 Consumptive Use

Consumptive water use within WRIA 10 was estimated using the Irrigated Area method, with the Water System Data method serving as comparison. The WRIA 10 committee chose not to modify the irrigation efficiency or indoor and outdoor consumptive factors that Ecology recommends to calculate consumptive use via the Irrigated Area method.

At the November 6, 2019, WRE Committee meeting, the committee agreed to a preliminary consumptive use estimate using an average outdoor irrigation area of 0.27 acre, which is the 95 percent confidence limit based upon the analysis of irrigated area on existing parcels with permit-exempt connections. The 95 percent confidence limit was discussed, and it was generally agreed that the outdoor irrigation area for new permit-exempt connections are likely to be smaller than 0.27 acre. At the April 1, 2020, Committee meeting, the consumptive use estimate based on the Irrigated Area method with an average irrigated area of 0.27 acre was approved. Using this method, indoor, outdoor, and total consumptive use was 150, 210, and 360 gallons per day, respectively. This total consumptive use per permit-exempt connection equates to 0.00056 cubic-feet per second (cfs) and 0.4 acre-feet per year (afy).

Therefore, the consumptive use estimate approved is 0.3838 cfs average annual rate and a total volume of 277 afy. The estimates of annual average consumptive use in WRIA 10 using the Irrigated

Area method range from 0.2839 cfs to 0.5121 cfs between the low and high growth scenarios. The average annual consumptive use for the baseline scenario is 0.3838 cfs. In all growth scenarios, the primary difference in total consumptive use between the water system data method and the Irrigated Area method is due to differences in estimates of the quantity of water used outdoors during months where irrigation occurs. In comparison, consumptive use projections ranged from 0.0418 cfs to 0.0754 cfs between the low and high growth scenarios, when using the Water System Data method. The average annual consumptive use for the baseline scenario is 0.0565 cfs.

For the WRIA 10 scenarios, consumptive use is 35 percent higher in the baseline scenario than the low growth scenario, and 33 percent higher in the high growth scenario than the baseline scenario. The estimates of consumptive use using the Irrigated Area method are approximately seven times higher than the Water System Data estimates.

Table 22, 3, and 4 present the consumptive use projections for WRIA 10.

Table 2. Annualized Average Consumptive Use Estimates for WRIA 10 (2020–2040) – Baseline Growth

Subbasin	Projected Permit-Exempt Connections	Annual Consumptive Use: Water System Estimate			Annual Consumptive Use: Irrigated Area Estimate (per Ecology Guidance)		
		AFY	GPM	CFS	AFY	GPM	CFS
Carbon River	109	6.5	4.0	0.0090	43.9	27.2	0.0608
Lower Puyallup River	102	6.1	3.8	0.0084	41.1	25.5	0.0569
Lower White River	76	4.5	2.8	0.0062	30.6	19.0	0.0424
Middle White River	57	3.4	2.1	0.0047	23.0	14.2	0.0318
South Prairie Creek	167	9.9	6.1	0.0137	67.3	41.7	0.0932
Upper Puyallup River	165	9.8	6.1	0.0136	66.5	41.2	0.0920
Upper White River	12	0.7	0.4	0.0010	4.8	3.0	0.0067
Totals	**688**	**40.8**	**25.3**	**0.0565**	**277.4**	**171.9**	**0.3838**

Table 3. Annualized Average Consumptive Use Estimates for WRIA 10 (2020–2040) – Low Growth

Subbasin	Projected Permit-Exempt Connections	Annual Consumptive Use: Water System Estimate			Annual Consumptive Use: Irrigated Area Estimate (per Ecology Guidance)		
		AFY	GPM	CFS	AFY	GPM	CFS
Carbon River	87	5.2	3.2	0.0071	35.1	21.7	0.0485
Lower Puyallup River	53	3.1	2.0	0.0044	21.4	13.2	0.0296
Lower White River	66	3.9	2.4	0.0054	26.6	16.5	0.0368
Middle White River	57	3.4	2.1	0.0047	23.0	14.2	0.0318
South Prairie Creek	122	7.2	4.5	0.0100	49.2	30.5	0.0681
Upper Puyallup River	104	6.2	3.8	0.0085	41.9	26.0	0.0580
Upper White River	20	1.2	0.7	0.0016	8.1	5.0	0.0112
Totals	**509**	**30.2**	**18.7**	**0.0418**	**205.2**	**127.2**	**0.2839**

Table 4. Annualized Average Consumptive Use Estimates for WRIA 10 (2020–2040) – High Growth

Subbasin	Projected Permit-Exempt Connections	Annual Consumptive Use: Water System Estimate			Annual Consumptive Use: Irrigated Area Estimate (per Ecology Guidance)		
		AFY	GPM	CFS	AFY	GPM	CFS
Carbon River	142	8.4	5.2	0.0117	57.2	35.5	0.0792
Lower Puyallup River	153	9.1	5.6	0.0126	61.7	38.2	0.0854
Lower White River	91	5.4	3.3	0.0075	36.7	22.7	0.0508
Middle White River	57	3.4	2.1	0.0047	23.0	14.2	0.0318
South Prairie Creek	229	13.6	8.4	0.0188	92.3	57.2	0.1277
Upper Puyallup River	242	14.4	8.9	0.0199	97.6	60.5	0.1350
Upper White River	4	0.2	0.1	0.0003	1.6	1.0	0.0022
Totals	**918**	**54.5**	**33.8**	**0.0754**	**370.1**	**229.4**	**0.5121**

6.0 Seasonal Use

Monthly outdoor water use was calculated as part of the consumptive use analysis for the Irrigated Area method. Seasonal water use by month is reported by subbasin and scenario (Table 5). The month of July has the highest irrigation requirement, resulting in the highest monthly consumptive use impact. This information may be used when evaluating projects designed to offset subbasin- and season-specific impacts.

Table 5. WRIA 10 Monthly Consumptive Water Use

Subbasin	Projected No. Permit Exempt Connections (Baseline)	Consumptive Use by Month (cfs)											
		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Carbon River	109	0.0010	0.0010	0.0010	0.0381	0.1004	0.1363	0.1993	0.1413	0.0852	0.0010	0.0010	0.0010
Lower Puyallup River	102	0.0009	0.0009	0.0009	0.0356	0.0939	0.1275	0.1865	0.1322	0.0797	0.0009	0.0009	0.0009
Lower White River	76	0.0007	0.0007	0.0007	0.0265	0.0700	0.0950	0.1390	0.0985	0.0594	0.0007	0.0007	0.0007
Middle White River	57	0.0005	0.0005	0.0005	0.0199	0.0525	0.0713	0.1042	0.0739	0.0445	0.0005	0.0005	0.0005
South Prairie Creek	167	0.0016	0.0016	0.0016	0.0583	0.1538	0.2088	0.3054	0.2164	0.1305	0.0016	0.0016	0.0016
Upper Puyallup River	165	0.0015	0.0015	0.0015	0.0576	0.1519	0.2063	0.3017	0.2139	0.1289	0.0015	0.0015	0.0015
Upper White River	12	0.0001	0.0001	0.0001	0.0042	0.0110	0.0150	0.0219	0.0156	0.0094	0.0001	0.0001	0.0001
Totals	**688**	**0.0064**	**0.0064**	**0.0064**	**0.2402**	**0.6335**	**0.8602**	**1.2581**	**0.8917**	**0.5375**	**0.0064**	**0.0064**	**0.0064**
Subbasin	**Projected No. Permit Exempt Connections (Low Growth)**	**Consumptive Use by Month (cfs)**											
		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Carbon River	87	0.0008	0.0008	0.0008	0.0304	0.0801	0.1088	0.1591	0.1128	0.0680	0.0008	0.0008	0.0008
Lower Puyallup River	53	0.0005	0.0005	0.0005	0.0185	0.0488	0.0663	0.0969	0.0687	0.0414	0.0005	0.0005	0.0005
Lower White River	66	0.0006	0.0006	0.0006	0.0230	0.0608	0.0825	0.1207	0.0855	0.0516	0.0006	0.0006	0.0006
Middle White River	57	0.0005	0.0005	0.0005	0.0199	0.0525	0.0713	0.1042	0.0739	0.0445	0.0005	0.0005	0.0005
South Prairie Creek	122	0.0011	0.0011	0.0011	0.0426	0.1123	0.1525	0.2231	0.1581	0.0953	0.0011	0.0011	0.0011
Upper Puyallup River	104	0.0010	0.0010	0.0010	0.0363	0.0958	0.1300	0.1902	0.1348	0.0812	0.0010	0.0010	0.0010
Upper White River	20	0.0002	0.0002	0.0002	0.0070	0.0184	0.0250	0.0366	0.0259	0.0156	0.0002	0.0002	0.0002
Totals	**509**	**0.0047**	**0.0047**	**0.0047**	**0.1777**	**0.4687**	**0.6364**	**0.9308**	**0.6597**	**0.3977**	**0.0047**	**0.0047**	**0.0047**
Subbasin	**Projected No. Permit Exempt Connections (High Growth)**	**Consumptive Use by Month (cfs)**											
		Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Carbon River	142	0.0013	0.0013	0.0013	0.0496	0.1307	0.1775	0.2597	0.1840	0.1109	0.0013	0.0013	0.0013
Lower Puyallup River	153	0.0014	0.0014	0.0014	0.0534	0.1409	0.1913	0.2798	0.1983	0.1195	0.0014	0.0014	0.0014
Lower White River	91	0.0008	0.0008	0.0008	0.0318	0.0838	0.1138	0.1664	0.1179	0.0711	0.0008	0.0008	0.0008
Middle White River	57	0.0005	0.0005	0.0005	0.0199	0.0525	0.0713	0.1042	0.0739	0.0445	0.0005	0.0005	0.0005
South Prairie Creek	229	0.0021	0.0021	0.0021	0.0799	0.2109	0.2863	0.4188	0.2968	0.1789	0.0021	0.0021	0.0021
Upper Puyallup River	242	0.0023	0.0023	0.0023	0.0845	0.2228	0.3026	0.4425	0.3137	0.1891	0.0023	0.0023	0.0023
Upper White River	4	0.0000	0.0000	0.0000	0.0014	0.0037	0.0050	0.0073	0.0052	0.0031	0.0000	0.0000	0.0000
Totals	**918**	**0.0085**	**0.0085**	**0.0085**	**0.3205**	**0.8453**	**1.1478**	**1.6787**	**1.1898**	**0.7172**	**0.0085**	**0.0085**	**0.0085**

7.0 References

DeOreo, W., P. Mayer, B. Dziegielewski, J. Kiefer. 2016. *Residential End Uses of Water, Version 2*. Water Research Foundation, Report #4309b.

Dunn, A. B., and A. Neff. 2018. *Potential Consumptive Use Impacts of Domestic Groundwater Permit-Exempt Wells Over the Next 20 Years in WRIA 1 – Version 2 Technical Memorandum*. RH2 Engineering.

Ecology. 2019. Final Guidance for Determining Net Ecological Benefit. Washington State Department of Ecology, Publication 19-11-079.

Einberger, C., C. Pitre, and D. Banton. 2014. *Skagit County Exempt Well Metering Program – 2012-2013 Technical Memorandum*. Washington State Department of Ecology.

Green, D. 2010. Water Conservation for Small- and Medium- Sized Utilities. American Water Works Association. Pp. 22

Natural Resource Conservation Service. 1997. Washington Irrigation Guide (WAIG). U.S. Department of Agriculture.

Welch, W.B, L.M. Frans, and T.D. Olsen. 2014. *Hydrogeologic Framework, Groundwater Movement and Water Budget of the Kitsap Peninsula, West-Central Washington*, Scientific Investigation Report 2014-5106.

Attachment A
Irrigated Area Comparability Study

Technical Memorandum

To:	Angela Johnson, Rebecca Brown, Ingria Jones, Stephanie Potts, Stacy Vynne McKinstry, John Covert, and Tom Culhane (Ecology)
From:	Chad Wiseman (HDR) and Bridget August (GeoEngineers)
Date:	January 16, 2020
Subject:	Draft Irrigated Acreage Comparability Study

1.0 Executive Summary

The purpose of this technical memorandum is to summarize the Draft Irrigated Acreage Comparability Study undertaken as a joint exercise by the GEI and HDR technical teams and to provide a recommendation to Ecology on whether variability between GEI and HDR irrigated area delineations warrants data qualification or updates. This study was conducted at the request of the Ecology team indicated as the recipients of this memo. The Ecology team requested we undertake this study as part of on-going quality assurance work associated with development of products for use by the Watershed Restoration and Enhancement (WRE) committees. The need for this specific study was identified because of perceived differences in specific draft, interim results from the two firms related to the analysis of outdoor irrigation area of existing homes served by permit-exempt (PE) wells. The goals of this study were to: 1) to determine if there was a difference in the mean irrigated areas between the HDR and GEI delineations, 2) to identify the reasons for those differences, and 3) to determine the implications, if any, of these differences for the work of the WRE committees. This memorandum details the reasons for the differences and ultimately concludes that the differences will not have an impact on the work of the WRE committees and the WRE committees may accept the irrigated area results completed by the GEI and HDR without qualification. The results of the comparability study, and subsequent review with Ecology, indicate the following:

- It is our recommendation that Ecology and the WRE committees should accept the irrigated area results completed by the GEI and HDR teams. The differences will have no impact on the work of the WRE committees. Furthermore, our analysis and comparability results indicate there is no need for a systematic reevaluation of the primary data sets or methodologies. The GEI and HDR teams have confidence in their completed work and, notably, in each other's work for their respective WRIAs.
- The outdoor irrigation method is conservative because it assigns outdoor watering rates equivalent to those for crops described in the Washington Irrigation Guide such as to produce commercial pasture/turf grass.
- There is inherent subjectivity and variability associated with estimating irrigated areas from manual aerial photo interpretation.
- There are a continuum of possibilities between slightly watered areas and those have been watered at rates similar to those presented in the Washington Irrigation Guide, and because

of this range there are also ranges of "correct" answers to the question of which outdoor watering areas should be counted.

- While it can be relatively straight-forward to delineate the irrigated footprints for parcels on the extreme – either brown lawns or lush, golf-course green lawns- it can be much harder to make delineations for the rest of the parcels.

2.0 Introduction

GeoEngineers, Inc. (GEI) and HDR, Inc., (HDR) are providing technical support to the Washington State Department of Ecology (Ecology) and the Watershed Restoration and Enhancement (WRE) committees. GEI is providing support for Water Resource Inventory Areas (WRIAs) 7, 8, and 9, while HDR is supporting WRIAs 10, 12, 13, 14, and 15.

Under RCW 90.94, consumptive water use by new permit-exempt (PE) domestic wells must be estimated to establish the water use that watershed restoration and enhancement (WRE) plans are required to address and offset. Consumptive use is water that evaporates, transpires, is consumed by humans, or otherwise removed from an immediate water environment. Appendix A in the *Final Guidance for Determining Net Ecological Benefit* (July 2019) recommends using more than one method for calculating consumptive water use: a method based on analysis of outdoor irrigation; and a method based on location-specific small- to medium-sized water system data. GEI and HDR are developing results for both methods in each of the WRIAs. This memo only addresses a quality review for the outdoor irrigation method. The outdoor irrigation method is based, in part, on an estimate of the average irrigated area anticipated for new PE wells. This average irrigated area is estimated by delineating the apparent irrigated area of existing homes served by PE domestic wells.

Both HDR and GEI drew from the recent building permit or well databases in selecting parcels for irrigated area delineations. HDR delineated the irrigated area for 80 parcels in each of its assigned five WRIAs, and GEI delineated 393, 153 and 221 parcels in WRIAs 7, 8 and 9, respectively. One analyst from each firm conducted the delineations for consistency, and each analyst followed the prescribed methodology outlined in their respective consumptive use methodology memoranda (excerpts included in Attachments A and B). Following the delineation for each parcel, the irrigated area was calculated, then the mean irrigated area for each subbasin was calculated. The results of this work for all the WRE WRIAs are summarized in Table 1.

The average irrigated footprint results for WRIAs 7, 8, and 9 were generally higher than those for WRIAs 10, 12, 13, 14, and 15. Because of this difference, Ecology asked GEI and HDR to conduct a blind comparability study on a subset of common parcels. The objectives of the comparison were to determine if there was a difference in the mean irrigated areas between the HDR and GEI delineations and to identify the reasons for those differences, if they occurred. This memo further describes the methods and results of the comparison study and provides a recommendation on how Ecology and the WRE Committees can move forward.

Table 1. Irrigated acreage statistical summary.

WRIA	GEI			HDR				
	7	8	9	10	12	13	14	15
Sample Size (PE Parcels)	393	153	221	80	80	80	80	80
Mean Irrigated Area per Parcel	0.21	0.32	0.30	0.17	0.15	0.06	0.07	0.08

3.0 Methods

All irrigated area delineations were done on the Google Earth platform. HDR and GEI each provided a Google Earth spatial data file (KMZ file) containing a randomly selected subset of 10 PE parcels from one WRIA that had been delineated as part of the original irrigated area analysis. GEI provided HDR a KMZ file with 10 parcels from WRIA 9, and HDR provided GEI a KMZ file with 10 parcels from WRIA 10. Only parcel numbers and boundaries were provided in the KMZ file; the results of the original irrigated area delineations from each analyst were not provided to the other consultant.

Each consultant delineated irrigated areas for the 10 parcels provided by the other consultant, using the same analyst and methods as was used for the original WRIA analyses (Attachments A and B). In general, the irrigated areas included turf (residential lawn or pasture), gardens, and landscaping. Unirrigated lawns go dormant in the dry summer months and turn brown. Consultants used summer and winter imagery publically available in Google Earth to determine which areas of the parcel were dormant in the summer. Two or more years of aerial imagery was used when available. Consultants compared winter imagery, when precipitation turns lawns green naturally, to summer imagery, when the study areas receive little to no precipitation and lawns that are not irrigated typically go brown. Areas that remained green in the summer imagery were considered irrigated. Those areas that did not change color from winter to summer, or moderately changed color but remained green through the summer months, were considered irrigated. Consultants also compared each subject parcel to surrounding parcels with managed turf to differentiate the irrigated versus non-irrigated color signatures. Each analyst took notes detailing the rationale for inclusion or exclusion of an area for each delineation and documented the date(s) of the aerial photography utilized to make that determination.

After the analysts completed the additional delineations, HDR and GEI provided their delineated areas (KMZ files and tabular data) and notes to the other consultant to compare results. A conference call with a shared screen was held with Ecology on November 12, 2019, to discuss the delineated areas on Google Earth and calculated acreage results on a parcel by parcel basis. The rationale for inclusion or exclusion of an area from an irrigated footprint delineation was discussed.

After this initial conference call, analysts from HDR and GEI were each asked to re-delineate all 20 parcels a second time to determine if the delineated acreage from each consultant would be closer in value following this reconciliation of differences in methodology by parcel. A conference call was held with Ecology after this second delineation on November 26, 2019, to compare the new mean irrigated acreage between HDR and GEI.

4.0 Results

On average, GEI delineated larger irrigated areas than HDR during both rounds of comparative analyses. The first round had the largest differences. GEIs irrigated areas were estimated to be 0.27 and 0.14 acre larger than HDRs estimates for WRIAs 10 and 9, respectively (Table 2). While most of the delineated areas were similar (i.e., within 0.10 acre) between analysts, there were large differences (i.e., greater than 0.10 acre difference) in five parcels in WRIA 10 and three parcels in WRIA 9. The complete results table with notes is included in Attachment C. During the November 12, 2019 meeting, the following differences in evaluation accounted for most of these differences in irrigated acreages:

- Per GEI's methods (Attachment A), landscaping outside of but adjacent to irrigated lawn areas were included within irrigated acreage. HDR excluded these areas per their methods (Attachment B).
- GEI was more inclusive of additional acreage under the tree canopy within the irrigated footprint.
- HDR did not identify some gardens that should have been included within the irrigated footprint.
- HDR utilized a more restrictive seasonal range of aerial photography to determine irrigated versus dormant turf (residential lawn and pasture) color signatures. For some parcels, GEI used more recent June and early July imagery, if available, to determine if an area was irrigated. HDR only used imagery from late July to early September to differentiate dormant versus irrigated turf. The different aerial imagery being evaluated by GEI and HDR resulted in some different interpretations of irrigated acreage.
- In some cases, there was a difference in analyst interpretation of areas that would plausibly be managed as irrigated turf (i.e., based off of fence lines and apparent uses).
- In some cases, there was a difference in analyst interpretation of whether or not the turf in the subject parcel was "greener" than turf in the surrounding parcels that was also managed (i.e. as residential yards or pastures) but was not irrigated (assuming that at least some people do not irrigate their lawns and pastures). For example, if the subject parcel had green grass in their yard, but other yards in the area had brown grass (indicating dormancy from no irrigation), the green area in the subject parcel would be delineated. These comparisons and decisions can be subjective.

Following the discussion on November 12, 2019, outlining these differences in methodology and subsequent re-delineation of the 20 parcels, the average irrigated acreages calculated by HDR and GEI were much closer in value, with a difference on average of 0.05 and 0.06 acre in WRIA 9 and 10 respectively (Table 2). GEI reduced the irrigated area, particularly under tree canopies, while HDR slightly expanded irrigated areas for gardens and turf. The GEI mean irrigated areas were reduced by 0.2 and 0.03 acre for WRIAs 10 and 9, respectively. The HDR mean irrigated areas were increased by 0.02 and 0.05 acre for WRIAs 10 and 9, respectively.

Table 2. GEI and HDR irrigated area comparability study results.

Parcel No.	WRIA	Delineated Irrigated Acreage Initial Comparison Analysis			Delineated Irrigated Acreage following Methodology Reconciliation		
		GEI	HDR	Difference	GEI	HDR	Difference
A	10	0.50	0.09	0.41	0.09	0.09	0.00
B	10	0.00	0.00	0.00	0.00	0.00	0.00
C	10	0.00	0.00	0.00	0.00	0.00	0.00
D	10	0.82	0.13	0.68	0.38	0.22	0.16
E	10	0.29	0.31	-0.02	0.23	0.36	-0.13
F	10	0.15	0.15	0.01	0.15	0.15	0.01
G	10	0.10	0.00	0.10	0.10	0.05	0.06
H	10	0.25	0.00	0.25	0.25	0.01	0.24
I	10	0.31	0.00	0.31	0.02	0.01	0.01
J	10	0.91	0	0.91	0.12	0.00	0.12

Parcel No.	WRIA	Delineated Irrigated Acreage Initial Comparison Analysis			Delineated Irrigated Acreage following Methodology Reconciliation		
		GEI	HDR	Difference	GEI	HDR	Difference
K	9	0.23	0.21	0.02	0.23	0.21	0.01
L	9	0.42	0.44	-0.02	0.42	0.54	-0.13
M	9	0.46	0.37	0.09	0.46	0.38	0.09
N	9	0.00	0.00	0.00	0.00	0.00	0.00
O	9	0.65	0.00	0.65	0.48	0.00	0.48
P	9	2.28	1.92	0.36	2.28	1.95	0.34
Q	9	0.18	0.09	0.09	0.18	0.09	0.09
R	9	0.34	0.22	0.12	0.25	0.23	0.02
S	9	0.00	0.00	0.00	0.00	0.00	0.00
T	9	0.11	0.05	0.05	0.11	0.06	0.05
WRIA 10 Average		**0.33**	**0.07**	**0.27**	**0.13**	**0.09**	**0.05**
WRIA 9 Average		**0.47**	**0.33**	**0.14**	**0.44**	**0.38**	**0.06**

5.0 Discussion

What became evident during this exercise is that while it can be relatively straight-forward to delineate the irrigated footprints for parcels on the extreme – either brown lawns or lush, golf-course green lawns- it can be much harder to make delineations for the rest of the parcels. Studies from municipal water suppliers around North America have shown that many homeowners apply outdoor water sparingly, with just enough to prevent landscaping from dying or at least far short of what is needed for maximum growth (DeOreo, et al., 2016. Residential End Uses of Water, Version 2)..

Another important conclusion that can be made from this work is that in many cases using remote sensing to delineate outdoor water areas will not resolve all questions about what outdoor areas were irrigated. This is because that answer depends on how much outdoor watering needs to have occurred in order to be counted. For example, if a lawn has been watered just once during a dry season or just 5 times, and it is not dormant but far from green, is that sufficient to call that area an outdoor watered area? And, if so, is it reasonable to expect a technician to be able to delineate that area using aerial images? In reality, there are a continuum of possibilities between slightly watered areas and those have been watered at rates similar to those presented in the Washington Irrigation Guide (WAIG). Because of this range in watering, there are also ranges of “correct” answers to the question of which outdoor watering areas should be counted.

One important implication of variable watering rates is that the outdoor irrigation method described in Appendix A of the *Final Guidance for Determining Net Ecological Benefit* and the method used by both GEI and HDR for calculating consumptive use is conservative. This is because it assigns outdoor watering rates equivalent to those for crops described in the WAIG, such as for the production of commercial pasture/turf grass. Many of the lawns that are delineated as “irrigated” may not apply water at these rates, resulting in conservatively high consumptive use estimates. At the subbasin and WRIA scale, we are confident that our estimate of the water used for outdoor watering is larger than what is actually being used by permit-exempt domestic well owners. This assumption was corroborated with a comparison of irrigated areas in specific parcels that had metered water use data (HDR 2019).

Based on the above considerations and the results of this comparison exercise, there is inherent subjectivity and variability associated with estimating irrigated areas from manual aerial photo interpretation. Although these results indicate that additional training (or cross-training) may have reduced this variability between analysts, differences are still to be expected. Furthermore, the original differences in mean irrigated areas are generally within the 95 percent confidence interval for the primary data sets. Therefore, these comparability results do not indicate a need for a systematic reevaluation of the primary data sets. The GEI and HDR teams have confidence in their completed work and in each other's work for their respective WRIAs. It is GEI's and HDR's opinion that Ecology and the WRE committees may accept the irrigated area results completed by the GEI and HDR teams without qualification. The WRE committees may consider investigating the sensitivity of consumptive use based on mean irrigated areas for each WRIA and/or at upper or lower 95 percent confidence limits.

Attachment A

GEI Irrigated Footprint Analysis Methods

Irrigated Footprint Analysis Methods

The GEI team conducted an aerial photo-based analysis of irrigated lawn and garden area for 393 parcels in the 16 WRIA 7 subbasins, 153 parcels in seven of the WRIA 8 subbasins, and 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. Permits for accessory dwelling units (ADUs) or reconstruction/remodel were excluded. All new home building permit sites in WRIA 9 were included in the analysis, however, a subset of building permits were selected for WRIAs 7 and 8. The target sample size for WRIAs 7 and 8 was set to provide a 95 percent confidence level (i.e., 95 percent certainty of the sample capturing the true mean of the population). 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.

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 than available orthophotos because it was possible to compare 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. Often, 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 GEI team minimized potential for additional bias to the results by having one GIS analyst evaluate all of the permit 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, and this was included in the calculated results.
- 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.

The following examples illustrate selected delineations.

Figure 1 shows examples of irrigated area delineation for two representative parcels in the Patterson (left) and Upper Skykomish (right) subbasins in WRIA 7. On each photo, the parcel boundary is shown in yellow and the area identified as irrigated in white. Large homes and extensive irrigated lawn and garden areas were much more common in the Patterson, Pilchuck, and Raging subbasins compared to the rest of the WRIA.

Figure 1. Example Irrigated Area Delineations, Patterson subbasin (left) and Upper Skykomish subbasin (right), WRIA 7

Figure 2 shows examples of irrigated area delineation for two parcels in the Bear/Evans subbasin in WRIA 8. 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 2. Example Irrigated Area Delineations, Bear/Evans subbasin, WRIA 8

Figure 3 shows examples of irrigated area delineation for two parcels in the Covington Creek subbasin in WRIA 9. 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 3. Example Irrigated Area Delineations, Covington Creek Subbasin, WRIA 9

Attachment B

HDR Irrigated Area Analysis Methods

Irrigated Area Analysis Methods

1. The GIS technician selected four sample parcels from the WRIA 13 parcel selection pool to draft preliminary delineations. Parcels that displayed a range of potential irrigation situations (e.g., unirrigated lawns, lawns requiring tree/shadow interpolations, minimally irrigated area) were selected for the preliminary analysis.
2. Polygons were created in Google Earth representing the irrigated area within a given tax parcel. The GIS technician made several judgments and assumptions:
    a. Landscaped shrub/flower bed areas within a larger irrigated footprint were included. Shrub and flower bed areas outside of the irrigated footprint were excluded.
    b. If the irrigated area extends beyond the parcel boundary, those areas were included.
    c. Parcels with no visible signs of irrigation were tracked as zero irrigated footprint.
    d. Areas that appeared to be native forest or unmaintained grass were not included in the irrigated footprint.
    e. Parcels with homes under construction in the most recent Google Earth imagery were excluded from the analysis.
    f. New construction due to additional dwelling units (ADUs) were not counted.

    The following examples illustrate example delineations.

Figure 1. No irrigated areas visible in most recent google earth aerial imagery.

Figure 2. Area in white includes maintained grass. Residence constructed between June 2017 and July 2018. Therefore, historical irrigation of property is unavailable in GoogleEarth imagery.

Figure 3. Irrigated area includes landscaped area in driveway, maintained yard around residence, garden area, and maintained grass near garden area.

Figure 4. No irrigated area. Assumption that green vegeation on southern portion of parcel is due to proximity to Spurgeon Creek since clear delineation of irrigated area is not present on aerial. Green area near residence appears to be tree and shrubs, not maintained landscaping and is excluded.

Attachment C

Results Table

Parcel	WRIA	GEI Notes	HDR Notes	Geo Acres	*HDR Acres*	Diff	Geo Adj Acres	*HDR Adj Acres*	Adj Diff	Geo Adjusted Notes	HDR Adjusted Notes
A	10	8/2006 ; 8/2011 - difficult to distinguish if western portion of home are is irrigated	Front yard delineated based on 9/2009 and 8/2011 imagery.	**0.50**	*0.09*	0.41	**0.09**	*0.09*	0.00	tightened lawn area, omitted truck/boat parking	No change
B	10	No apparent irrigation, landscaping not established yet	zero irrigated footprint	**0.00**	*0.00*	0.00	**0.00**	*0.00*	0.00	no change	No change
C	10	No apparent irrigation ; 7/2014 ; 7/2012	zero irrigated footprint (9/2009 and 8/2011)	**0.00**	*0.00*	0.00	**0.00**	*0.00*	0.00	no change	No change
D	10	6/2016 - extensive landscaping and garden area, difficult to discern extent of irrigated lawn ; 7/2014 ; 7/2012	area delineated	**0.82**	*0.13*	0.68	**0.38**	*0.22*	0.16	tightened lawn area to within fenceline, omitted truck/boat area	Garden area SW of home included
E	10	6/27/2016 - areas outside of the riding ring near the house are landscaped and appear irrigated ; 7/2014 - lawn area - compare to western pasture inside parcel	delineated yard area (8/2006 image)	**0.29**	*0.31*	-0.02	**0.23**	*0.36*	-0.13	tightened lawn area to within fenceline, omitted area near garage/barn	reduced front yard area
F	10	7/2014 ; 7/2012 - compare to neighboring lawns	Yard area delineated. 7/2018 image	**0.15**	*0.15*	0.01	**0.15**	*0.15*	0.01	no change	No change
G	10	7/2014 - small hayfield? compare lawn/landscaping (NE of corner of house) area around house to neighbor to the WNW ; 7/2012 - compare to neighbor's lawn to the NW ; 9/2009 - blurry but hayfield area is bright green	zero irrigated footprint. 7/2018 and 7/2006, 9/2009 imagery	**0.10**	*0.00*	0.10	**0.10**	*0.05*	0.06	no change	Added garden bed northwest
H	10	8/2011 - compare lawn to NW portion of property, lawn areas to the NE, particularly the watered lawn to the NE, SW side of house	zero irrigated area 9/2009	**0.25**	*0.00*	0.25	**0.25**	*0.01*	0.24	no change	Added garden area between barn and shop
I	10	7/2014 - garden area and lawn tight to house 6/2016 - compare to house/lawn to the southeast	zero irrigated footprint. 8/2011 and 11/2011	**0.31**	*0.00*	0.31	**0.02**	*0.01*	0.01	only included raised garden bed	Added garden bed northeast of house
J	10	8/2011 - compare to lawn at home 750ft E 7/2012 - home to the NW across street is brown comparatively	zero irrigated footprint	**0.91**	*0*	0.91	**0.12**	*0.00*	0.12	hard to discern lawn area, kept tight to house where grass is green compared to house to west 7/2014	no change
K	9	moderate gardening area	maintained lawn areas and garden area delineated.	**0.23**	*0.21*	0.02	**0.23**	*0.21*	0.01	no change	Addition of garden area on north section of lawn
L	9		area irrigated based on 4/2015 imagery. Although not summer, clear area of irrigation defined.	**0.42**	*0.44*	-0.02	**0.42**	*0.54*	-0.13	no change	Slightly expanded irrigated in the backyard further east.
M	9	includes golf practice green	area delineated 7/13/2017 imagery. Golf bunkers not included. Vegetation on east side of partial either dormant or unmaintained and well as vegetation between irrigated lawn and golf area.	**0.46**	*0.37*	0.09	**0.46**	*0.38*	0.09	no change	Slightly expanded area near golf bunkers. No other change.

Parcel	WRIA	GEI Notes	HDR Notes	Geo Acres	*HDR Acres*	Diff	Geo Adj Acres	*HDR Adj Acres*	Adj Diff	Geo Adjusted Notes	HDR Adjusted Notes
N	9	No apparent irrigation	zero irrigated footprint. Lawn dormant in 7/30/2006, 8/17/2006, 9/10/2009 photo. Green patches of lawn in 7/13/2017 not clearly defined and could be drain field	**0.00**	*0.00*	0.00	**0.00**		0.00	no change	No change
O	9		zero irrigated footprint. Only early July summer imagery available. In HDR analysis, would've selected new parcel.	**0.65**	*0.00*	0.65	**0.48**	*0.00*	0.48	removed western portion of property beyond fenceline	No change
P	9	large 2ac+ landscaped home	area delineated 8/2011 imagery. Eastern portion of parcel excluded, not maintained and vegetation dormant. Landscaping outside of footprint not included	**2.28**	*1.92*	0.36	**2.28**	*1.95*	0.34	no change	Slightly expanded area in backyard to include irrigated area near patio.
Q	9	front half of yard apparently hardscaped	area delineated based on 8/2011 and 5/2018 imagery. Front yard is completely landscaped and not included in irrigated footprint.	**0.18**	*0.09*	0.09	**0.18**	*0.09*	0.09	no change	No change
R	9		Area delineated. However, early 7/2014 was only summer imagery available. Backyard partially obscured by tree canopy. In HDR analysis, would've selected new parcel to delineate due to lack of summer imagery.	**0.34**	*0.22*	0.12	**0.25**	*0.23*	0.02	tightened up area along tree line	Expanded eastern boundary of delineation
S	9	No apparent irrigation	zero irrigated footprint. No maintained vegetation. Drainage ditch appears to traverse southern portion of parcel. Vegetation color matches vegetation on undeveloped parcel adjacent to the east.	**0.00**	*0.00*	0.00	**0.00**	*0.00*	0.00	no change	No Change
T	9		area delineated based on 9/10/2009 imagery showing area of green near front of home and 7/10/2012 imagery of maintained green lawn near home. Area of green south of home looks to be unmaintained.	**0.11**	*0.05*	0.05	**0.11**	*0.06*	0.05	no change	Slightly expanded area in front yard.
			WRIA 10 Total	**3.34**	***0.68***	**2.66**	**1.35**	***0.88***	**0.47**		
			WRIA 9 Total	**4.66**	*3.30*	**1.36**	**4.41**	*3.46*	**0.95**		
			WRIA 10 Average	**0.33**	*0.07*	**0.27**	**0.13**	*0.09*	**0.05**		
			WRIA 9 Average	**0.47**	*0.33*	**0.14**	**0.44**	*0.38*	**0.06**		

	GEI	*HDR*
WRIA 10 Change	**-0.20**	*0.02*
WRIA 9 Change	**-0.03**	*0.05*

Attachment B
Estimation of Average Irrigated Area

Methods

1. 80 parcels representing an existing dwelling served by a permit-exempt well or connection was defined.
    a. A pool of parcels with an existing dwelling served by a permit-exempt well or connection was defined.
    b. The selection pool was classified by property value. The classes were 1) Under $350,000, 2) $350,000 – $600,000, and 3) over $600,000.
    c. 80 parcels were randomly drawn from the selection pool, weighted by the proportion of property value class membership.
    d. Additional parcels were randomly selected as alternates, in case any of the primary (80) samples were able to be interpreted to irrigated area.
    e. All parcels were provided in a Google Earth .kmz file.
2. The irrigated area in each parcel was delineated according to the following procedure:
    a. Used a single technician to minimize operator variability.
    b. Irrigated area delineations were made using Google Earth aerial imagery taken during drier summer months (i.e., July and August). Unirrigated lawns (pasture/turf) go dormant in the dry summer months and turn brown. As such, areas that remain green in the summer imagery were considered irrigated.
    c. Aerial imagery from winter months was reviewed alongside summer imagery to reveal which lawn areas change from green to brown. Those areas that do not change color, or moderately change color but remain green, were considered irrigated.
    d. If available, multiple years of aerial imagery were used to corroborate the irrigated area delineation.
    e. Landscaped shrub/flower bed areas within a larger irrigated footprint were included. Shrub and flower bed areas outside of the irrigated footprint were excluded.
    f. If the irrigated area extended beyond the parcel boundary, those areas were included.
    g. Parcels with no visible signs of irrigation were assumed to have zero irrigated acres.
    h. Areas that appeared to be native forest or unmaintained grass were not included in the irrigated footprint.
    i. Parcels with homes or ADUs under construction in the most recent Google Earth imagery were excluded from the analysis, and an alternate parcel was evaluated.

    Figures B-1 through B-4 illustrate some example delineations.

Figure B-1. No irrigated areas visible in most recent google earth aerial imagery.

Figure B-2. Area in white includes maintained grass. Residence constructed between June 2017 and July 2018. Therefore, historical irrigation of property is unavailable in GoogleEarth imagery.

Figure B-3. Irrigated area includes landscaped area in driveway, maintained yard around residence, garden area, and maintained grass near garden area.

Figure B-4. No irrigated area. Assumption that green vegeation on southern portion of parcel is due to proximity to Spurgeon Creek since clear delineation of irrigated area is not present on aerial. Green area near residence appears to be tree and shrubs, not maintained landscaping and is excluded.

Results

Eighty parcels were evaluated for irrigated acreage (Figure B-5). Average irrigated acreage was 0.15 acre (Table B-1). In all WRIAs evaluated, most of the parcels had zero irrigated acres (Figure B-6). The distribution of irrigated acreages for all WRIAs were skewed, because of the large percentage of parcels that had zero irrigated acres. Some parcels had an irrigated area nearly an order of magnitude larger than the mean, resulting in a large standard deviation. The 95 percent upper confidence limit of the mean could only be fit with a non-parametric distribution and was about two times the quantity of the calculated arithmetic mean.

Figure B-5. Parcels selected in WRIA 10 with existing PE connections that were delineated for apparent irrigated areas.

Table B-1. Irrigated acreage delineation results

Statistic	Units	WRIA 12
PE Parcel Sample Pool	Parcels	978
Sample Size	Parcels	80
Mean (with zero acreage values)	Acres	0.17
Standard Deviation (with zero acreage values)	Acres	0.31
Mean (with minimum 0.5 acre)	Acres	0.20
Standard Deviation (with minimum 0.5 acre)	Acres	0.30
95% UCL (with minimum 0.5 acre)	Acres	0.27

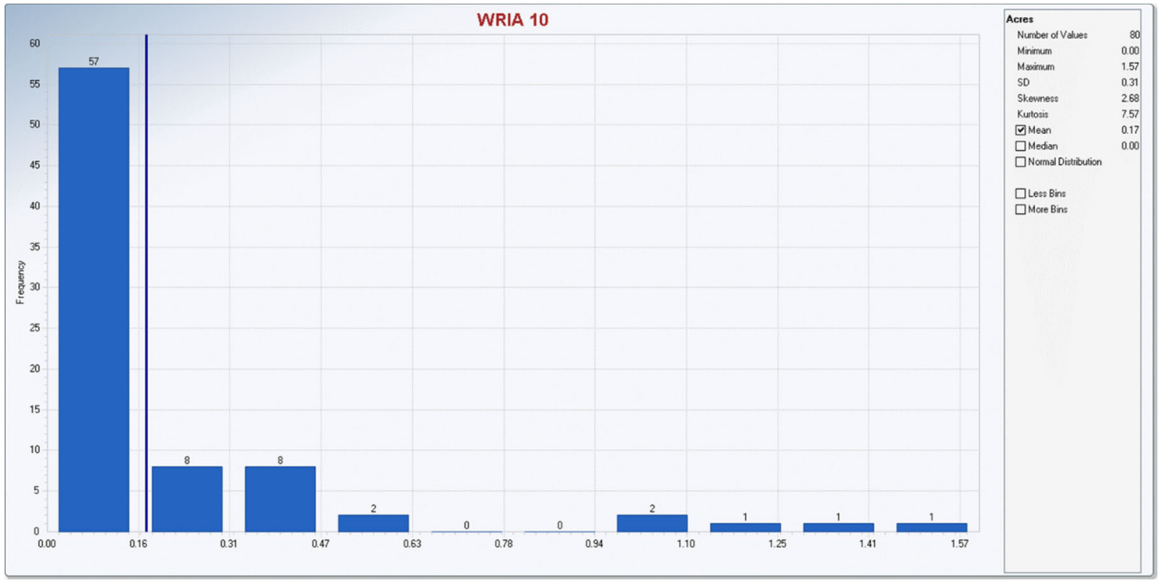


Figure B-6. Histogram of WRIA 10 irrigated acreage delineation results.

Attachment C
King County Growth Projections Memo

King County
Water and Land Resources Division
Department of Natural Resources and Parks
King Street Center
201 South Jackson Street, Suite 704
Seattle, WA 98104-3855
206-477-4800 Fax 206-296-0192
TTY Relay: 711

TECHNICAL MEMORANDUM

December 16, 2019

TO: Stephanie Potts, Ingria Jones, Rebecca Brown, and Stacy Vynne McKinstry, Streamflow Restoration Implementation leads, Water Resources Program, Washington State Department of Ecology

FM: Eric Ferguson, LHG, Science and Technical Support Section, Water and Land Resources Division, Department of Natural Resources and Parks

RE: King County Growth Projections for all Watershed Restorations and Enhancement Committees – WRIAs 7, 8, 9 , 10, and 15

This memorandum summarizes the work that King County did in support of generating 20-year growth projections in the rural areas of the county for Watershed Restoration and Enhancement committee (WREC) work. This effort will be incorporated into another technical memorandum that is area specific for each Watershed Resource Inventory Area (WRIA). The additional memorandum will be authored by consultants working for the Washington State Department of Ecology.

Introduction

King County is participating in five WRECs, one for each of the WRIA within its boundary. King County is providing growth projections for each area that assesses a two-part question:

A. How much potential growth could occur during the 20-year (2018-2038) planning period?

B. Where could that growth occur at a sub-basin/watershed scale within each WRIA?

Principles

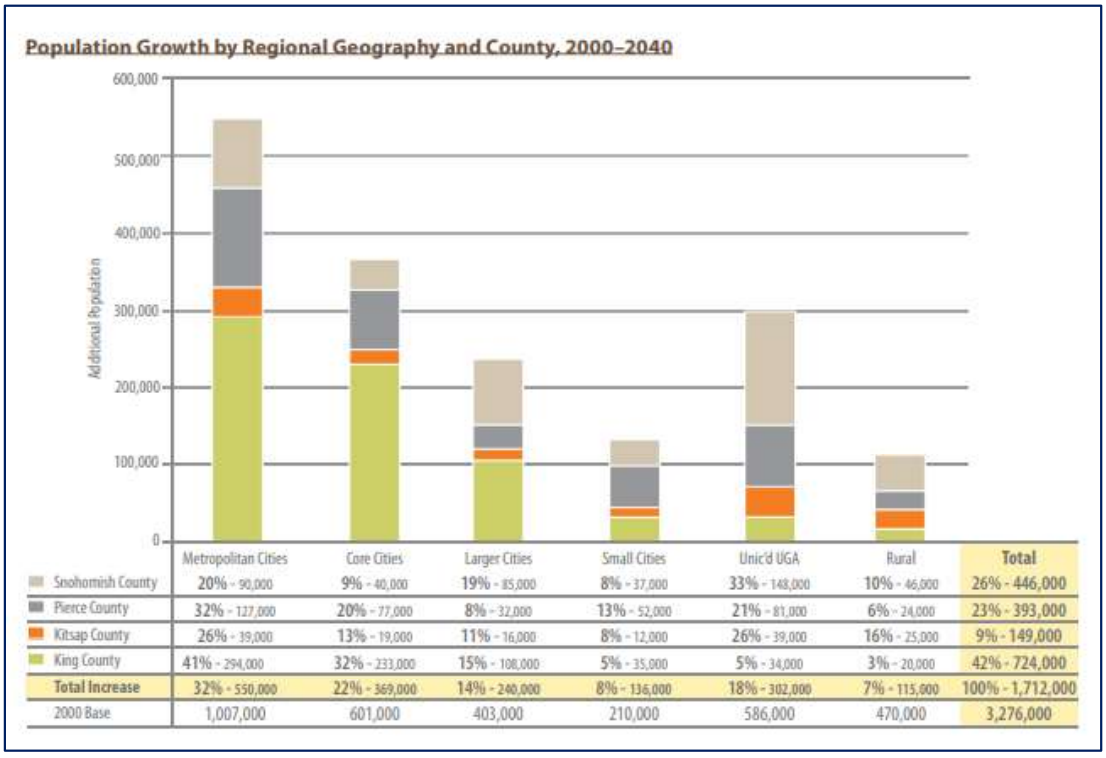
King County does not have growth targets for unincorporated rural areas in the county. All growth targets are for the urban growth area (UGA). No changes to the UGA boundary are intended during the 20-year planning period.

The following are highlights from planning policies:

- Accommodate most recent 20-year population forecast from OFM, and 20-year jobs forecast from Puget Sound Regional Council.
- Plan for growth consistent with Regional Growth Strategy
  - Focus growth in cities with major centers, and in other large cities
  - Limit development in Rural Areas, protect Resource Lands

Source: Policy DP-11 in Countywide Planning Policies, 2012

Population growth in the unincorporated rural area is estimated to be about 20,000 people or ~3% of overall population from Vision2040, Figure 1.



	Metropolitan Cities	Core Cities	Larger Cities	Small Cities	Unic'd UGA	Rural	Total
Snohomish County	20% - 90,000	9% - 40,000	19% - 85,000	8% - 37,000	33% - 148,000	10% - 46,000	26% - 446,000
Pierce County	32% - 127,000	20% - 77,000	8% - 32,000	13% - 52,000	21% - 81,000	6% - 24,000	23% - 393,000
Kitsap County	26% - 39,000	13% - 19,000	11% - 16,000	8% - 12,000	26% - 39,000	16% - 25,000	9% - 149,000
King County	41% - 294,000	32% - 233,000	15% - 108,000	5% - 35,000	5% - 34,000	3% - 20,000	42% - 724,000
Total Increase	32% - 550,000	22% - 369,000	14% - 240,000	8% - 136,000	18% - 302,000	7% - 115,000	100% - 1,712,000
2000 Base	1,007,000	601,000	403,000	210,000	586,000	470,000	3,276,000

Figure 1. Estimated population growth for rural King County from 2000-2040 is 20,000, King County, Vision 2040.

Note: the updated Vision (2050) document is due to be adopted in May 2020. The updated growth for rural King County is planned to be about 1% during 2017–2050 period (or ~6,000 people).

Methods

The first part of the growth projection assessment was performed in order to respond to the question: "How many new single-family permit-exempt well connections will be installed throughout each watershed over the next 20 years?" King County does not have a growth target

for the unincorporated rural area (as noted above) and therefore decided to use building permit data (for new residential structures) as its chosen method to assess future growth potential.

The following is the methodology used to assess the potential growth:

1. Compiled 18 years (2000–2017) of building permit data for new residential structures;
    a. This data was subdivided into two periods: 2000–2009 and 2010–2017, Table 1; each period has a range of low to high growth.

Table 1. Building permits from 2000-2017; new residental structures only

Building permits (unincorporated rural KC)	
2000-2009	4595
2010-2017	1252
Total	5847

2. Used GIS to provide location based information about building permits
    a. Use centroid of the building permit/parcel to assess location relative to other boundaries such as WRIA boundaries, stream basins, water district service areas, sub-basin delineations.
    b. Assess the number of permits per each WRIA, Table 2

Table 2. Building permits by WRIA

WRIA*	Total permits	Permits per year	Percentage of total
7	1864	104	32%
8	1836	102	31%
9	1430	79	24%
10	100	6	2%
15	617	34	11%

* = WRIA boundaries are delineated by Ecology coverage

3. Linked building permits and parcel data layers to assess percentage of parcels using public versus private water with parcel attribute data.
4. Determined the number of building permits/parcels that have a water source as:
    a. Public (pub) water
    b. Private (pvt) water (Permit-Exempt wells)
    c. Other (unknown/null)
        i. “unknown” refers to parcels with no assigned water source (likely unoccupied structure)
        ii. “null” refers to those building permits that did not link to existing parcels.

iii. This category can be used as an "error" since it refers to the amount of information that is undetermined and could potentially be private sourced.

5. Calculated the percentage of building permits for each type of water source (i.e. public, private or other) for entirety of King County as shown in Table 3 below as well as by WRIA and its sub-basin delineations.

Table 3. Water source by parcel/permit

Type of water use	Total permits	Percentage of total
Public	3113	53%
Private	2369	40%
Other -unknown	73	1%
Other - null	292	5%

6. Used the annual average number of permits per year multiplied by the percentage of permits/parcels on private water to determine a projected number of Permit Exempt (PE) wells per year, Table 4.

   Multiplied the number of PE wells per year by 20 to calculate the estimated total of PE wells projected over a 20-year period for unincorporated rural King County, Table 4.

Table 4. Average number of permit exempt well users by WRIA for the planning period.

WRIA*	Permit-exempt well/year^	20-year estimate	Error®
7	46	926	6%
8	35	698	6%
9	29	578	6%
10	4	81	2%
15	18	368	4%

* = WRIA boundaries are delineated by Ecology coverage
^ = WRIA specific percentage of private well users
® = Error calculated from percentage of building permits with "other" water service

Projected number of permit-exempt wells for time period (01/18/2018 to 01/18/2038) for all of King County is 2650. Each WRIA has a series of tables of this specific information, see Tables.

The second part of the growth projection assessment was performed in order to respond to the question: "Where will the well connections be installed?" The PE potential assessment is a GIS assessment of current (2019) parcel data. This work used a series of assumptions to assess potential area of growth within the county, specifically at the sub-basin scale as defined by the WREC for each WRIA.

The following are the assumptions used to refine the parcels:

- Outside Urban Growth Boundary
- Outside Forest Production District
- Outside Agriculture Production District
- Not Encumbered by K`C Parks or TDR conservation easements
- Not enrolled in Farmland Preservation Program
- Not Owned by Public Agencies
- Vacant land (with appraised improvements <$10,000)
- Have at least 1 acres of land outside 100 year Floodway and Severe River Channel Migration Hazard Areas.
- Parcel size – 1 acre or greater.
- Zoning – no exclusion and maximum density allowed by current zoning

7. Used centroid of the refined parcel data to determine location information, similar to step 2 (above).
8. Linked parcel and assessor attribute data to determine total number of parcels and dwelling units per sub-basin. A dwelling unit (DU) is a rough estimate of subdivision potential based on parcel size and zoning (e.g., a 22-acre parcel zoned RA-5 is assumed to have 4 dwelling units).
9. Determined the number of parcels and DUs that are inside or outside water district service boundaries.
10. Calculated water use projections for public connections and PE sourced parcels:
    a. Public connection parcels are located within water district service boundaries and are calculated based on historic rates of connection to public water within each sub-basin, assessed in step 5 (above).

    b. Any remaining number of parcels located within water district service boundaries are assigned to be PE sourced.

    c. PE sourced parcels were calculated based on the number of parcels located outside water district service boundaries plus the remaining parcels from “inside” water district boundaries, as described above, Table 5.

Table 5. Permit exempt (PE) estimate along with PE potential assessment data.

WRIA*	PE 20yr estimate^	Parcel^	DU
7	926	1175	1901
8	698	819	1070
9	578	746	1077
10	81	72	82
15	368	788	888

* = WRIA boundaries are delineated by Ecology coverage
^ = WRIA specific percentage of private well users
DU = Dwelling unit as noted in step 9.

WRIA specific data along with sub-basin assessments can be found in the Tables.

References

King County Countywide Planning Policies
https://www.kingcounty.gov/depts/executive/performance-strategy-budget/regional-planning/CPPs.aspx

https://www.kingcounty.gov/~/media/depts/executive/performance-strategy-budget/regional-planning/CPPs/2012-CPPsAmended062516withMaps.ashx?la=en

Vision 2040 link:
https://www.kingcounty.gov/~/media/depts/executive/performance-strategy-budget/regional-planning/Comp%20Plan/VISION_2040_-_2008.ashx?la=en

King County Growth Projection data tables by WRIA (Watershed Resource Inventory Area)

WRIA 10 - Puyallup-White

WRIA (Ecology Coverage)	(KC building permiting data)				permits
	2000-2009	2010-2017		total	per year
10	92	8		100	6

% of county-wide total
2%

WRIA 10	PE/yr	20 yr est
Future PE wells	**4**	**81**

Water District info	2000-2009	2010-2017		total
total	92	8		100
wtr dst (within water district)	67	7		74
no dst (outside water district)	25	1		26

Ag PD	permits	% of WRIA total
WRIA 10	69	69%

Forest PD	permits	% of WRIA total
WRIA 10	4	4%

Historic Percentages		
	pub	**0.230**
	pvt	**0.730**

Water service info	(derived from KC parcel attribute data)			
public water system (pub)	22	1		23
well - private water (pvt)	68	5		73
other	2	2		4
total	92	8		100

Existing	2000-2009	2010-2017	total
PE wells	68	5	73
error	2%	25%	4%

WRIA 10 - Permit-Exempt Well Potential Assessment

Assessment of potential parcels for future growth

Sub-basins	Number of parcels	Number of Dwelling Units (DU)
Lower White River	18	24
Middle White River	60	64
total	78	88

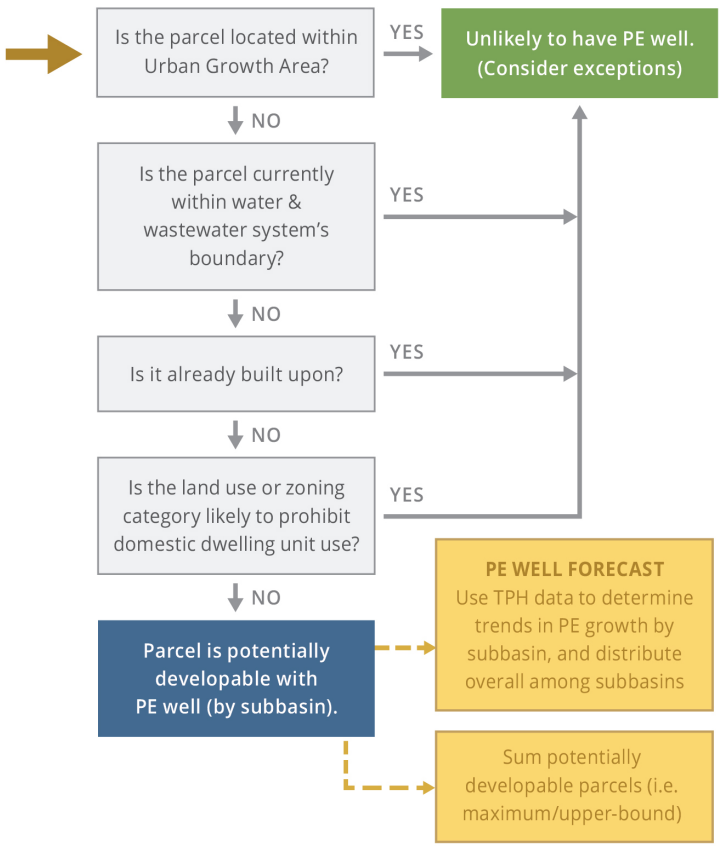
Water district boundaries				subbasin	Water Use Projection					
Inside		Outside			public connection		PE sourced			
parcels	DU	Parcels	DU		parcels	DU	parcels	DU	20 year well total	Shortfall *(red if present)* in 20 year well projection
0	0	18	24	Lower White River	0	0	18	24	24	0
26	28	34	36	Middle White River	6	6	54	58	57	1
26	28	52	60		6	6	72	82	81	----------

total parcels	78	total DU	88		total parcels	78	total DU	88		

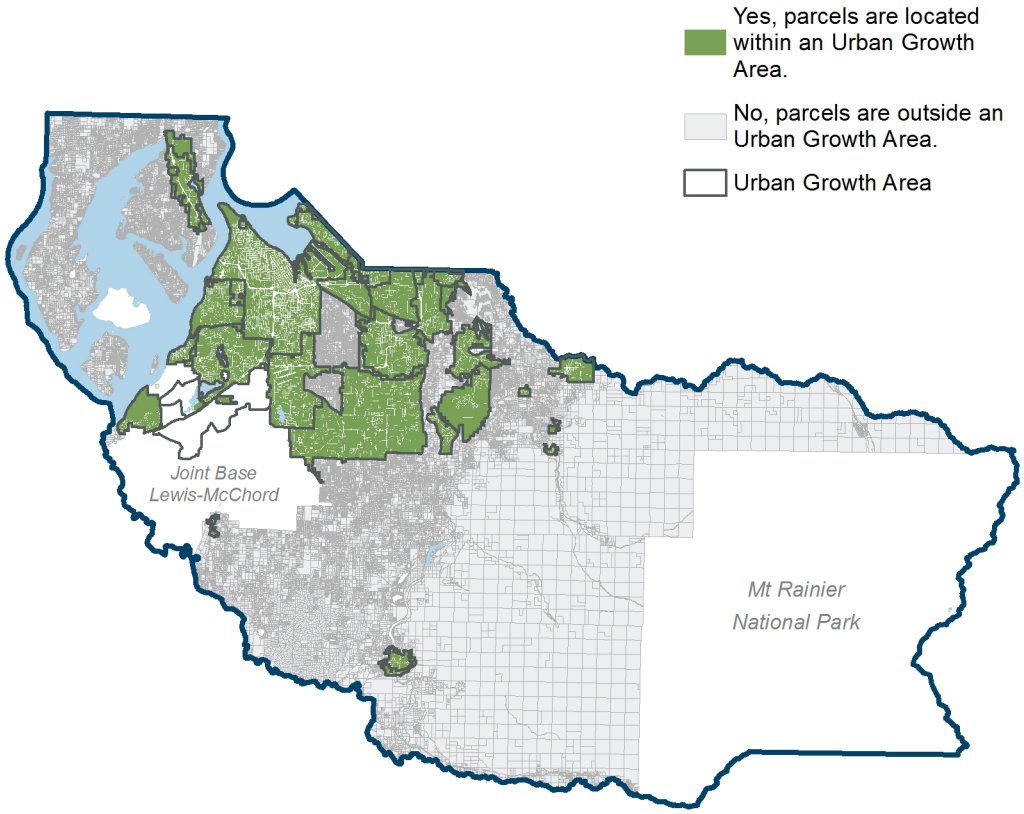
Attachment D

Pierce County PE Growth Methods and Buildable Lands Analysis

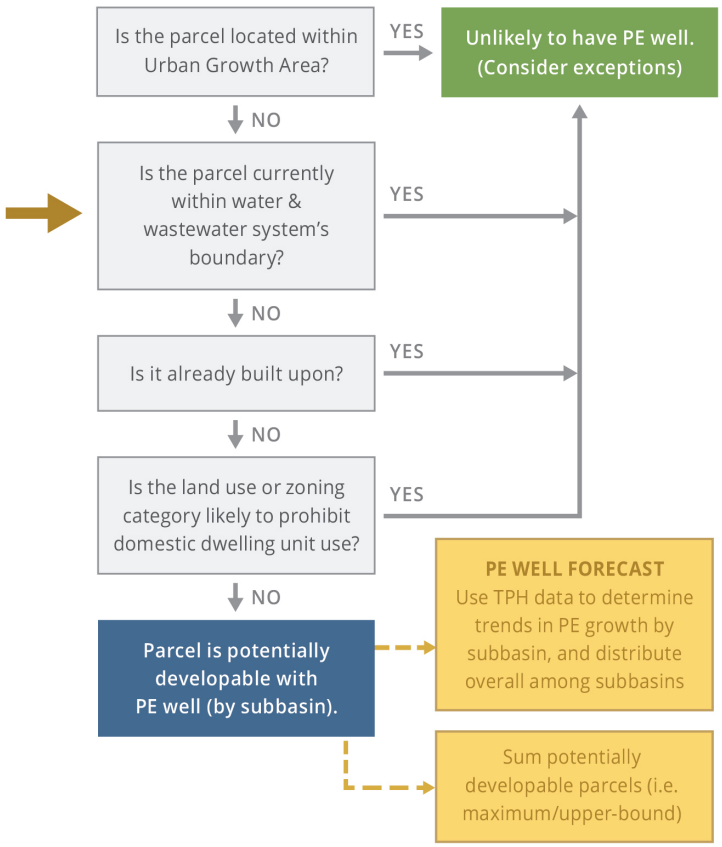
Phase 2: Parcel Inventory



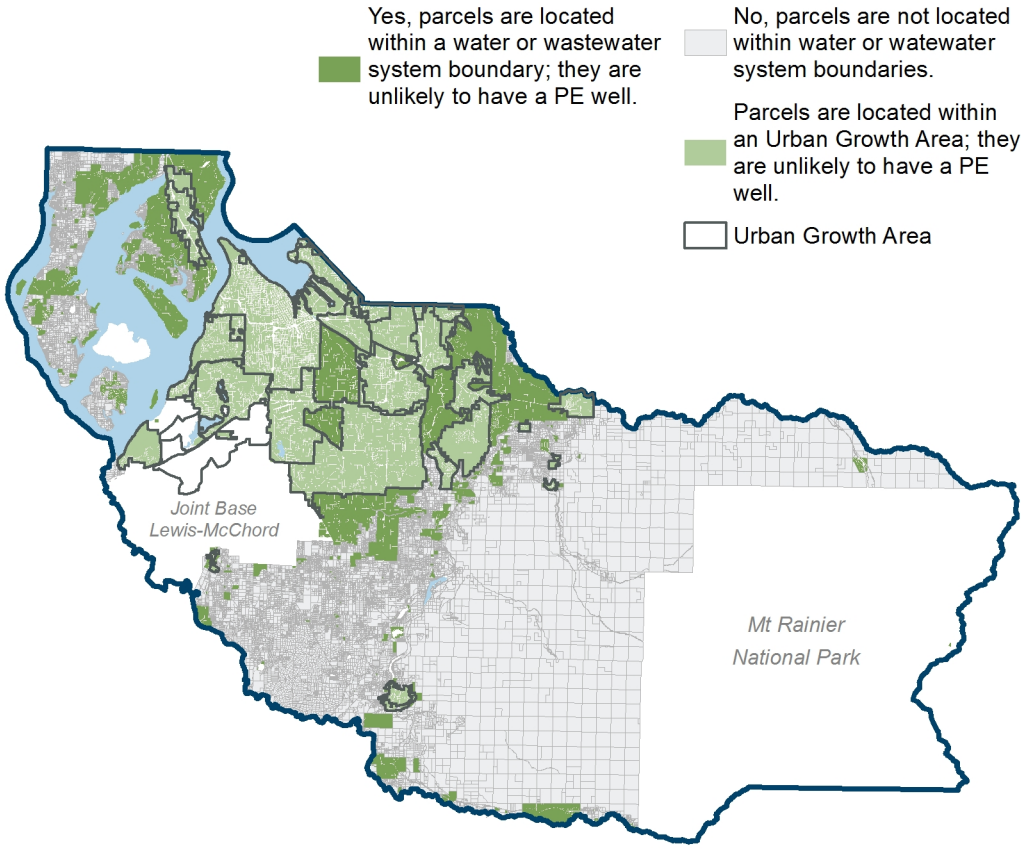
Is the parcel located within an Urban Growth Area (UGA)?



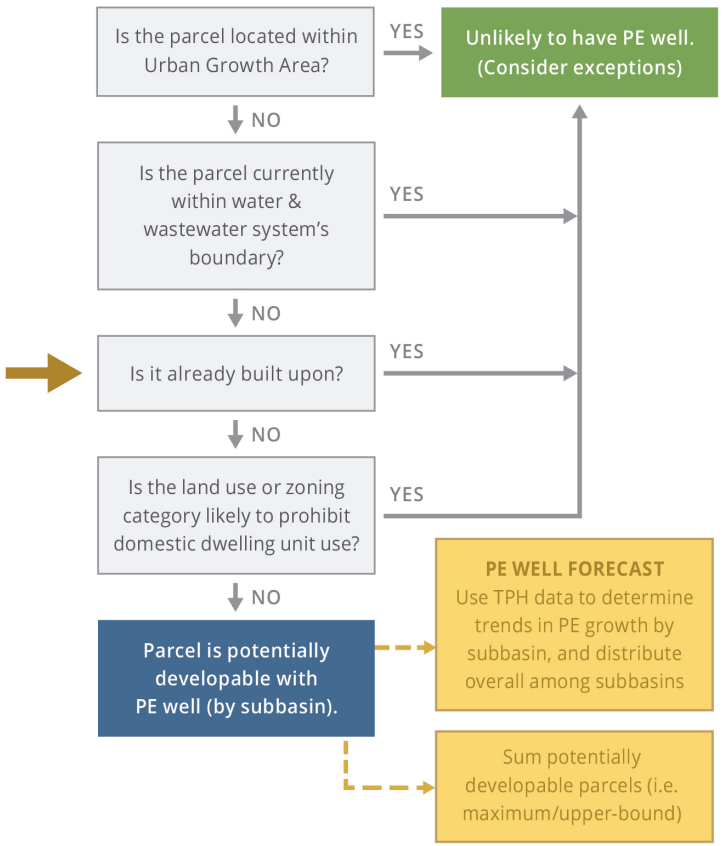
Phase 2: Parcel Inventory



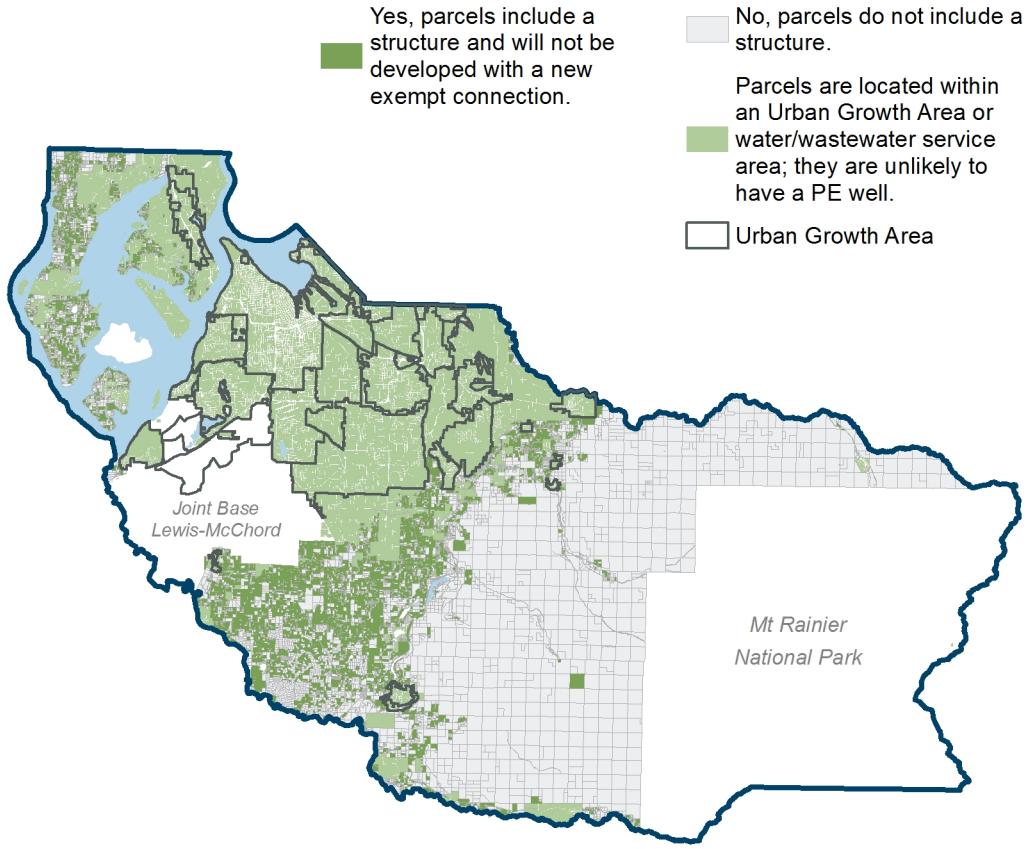
Is the parcel located within a water or wastewater system boundary?



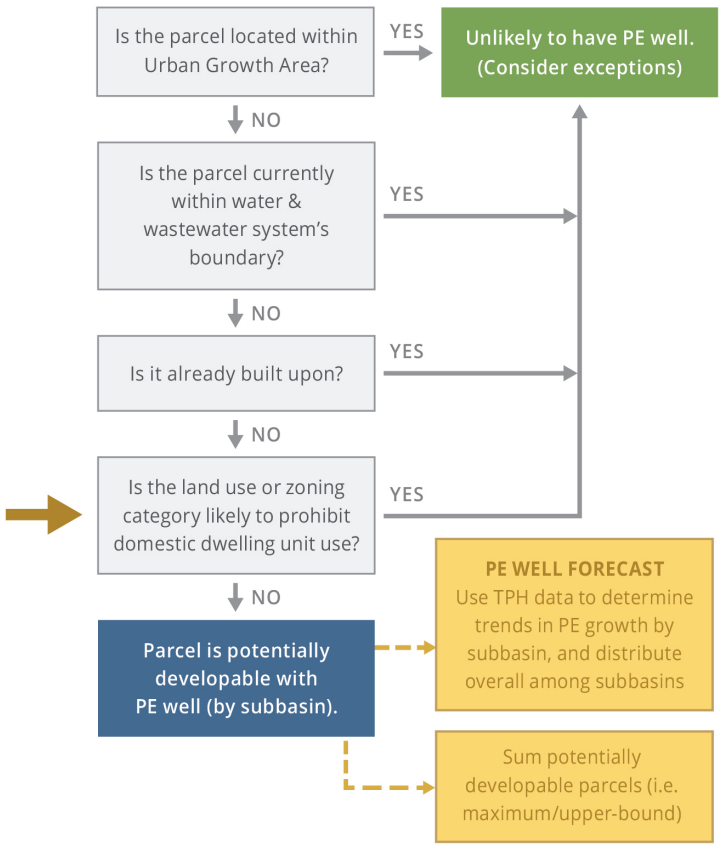
Phase 2: Parcel Inventory



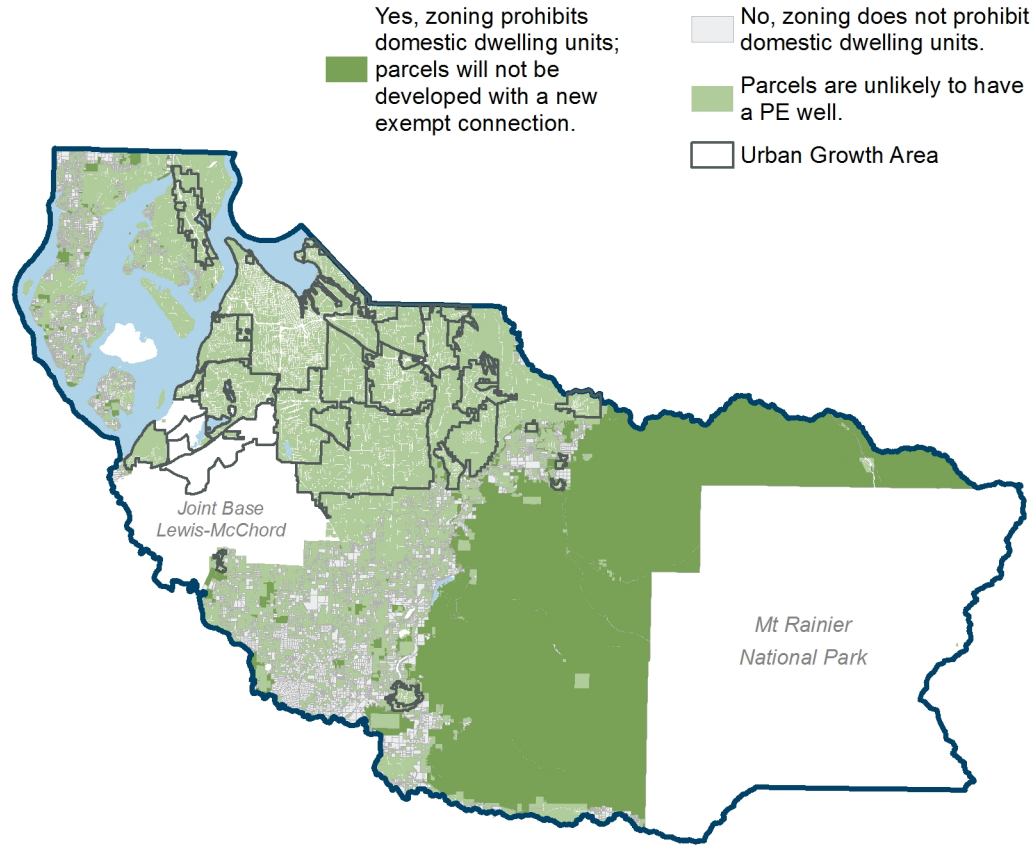
Is the parcel already built upon?

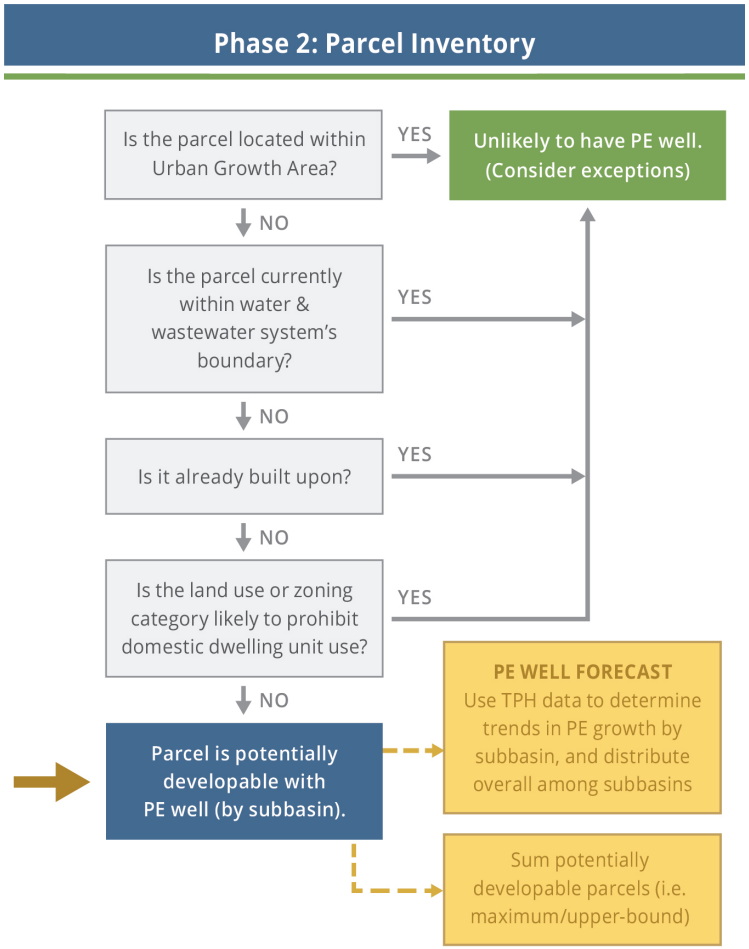


Phase 2: Parcel Inventory

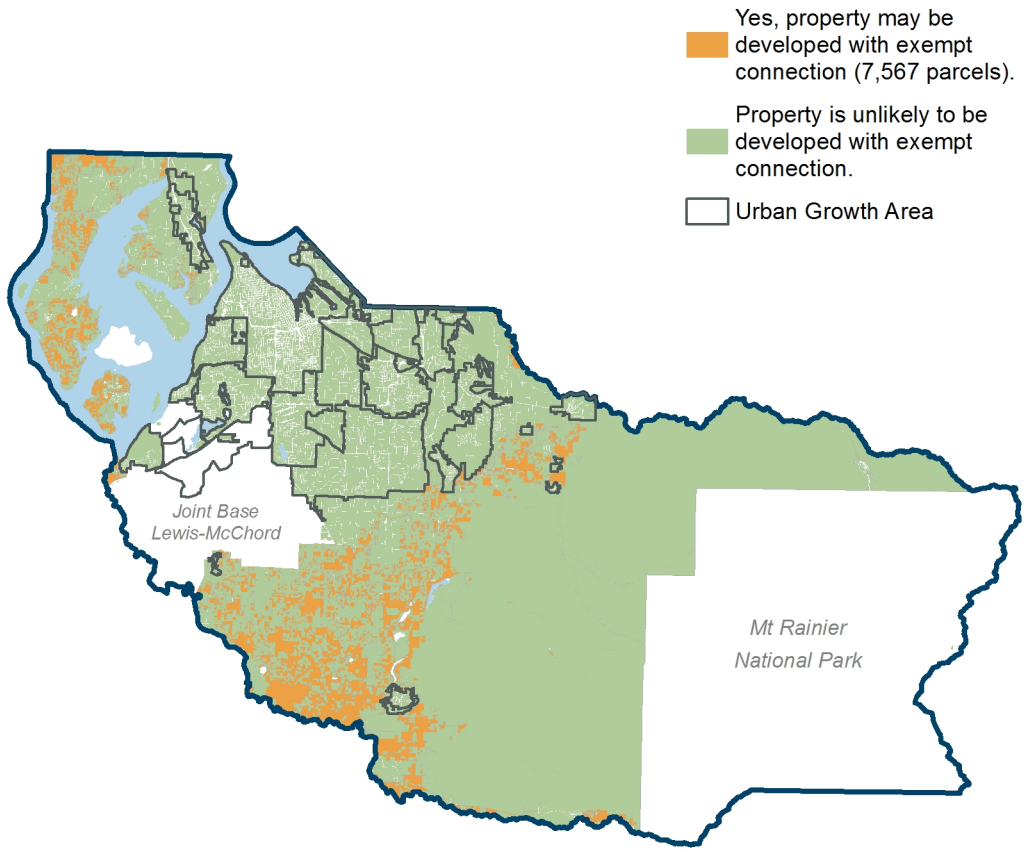


Does the land use or zoning prohibit domestic dwelling units?





Parcel is potentially developable with PE well.



Pierce County Growth Projection Analysis