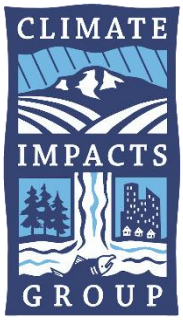
Current Water Use Within the Puget Sound Region: Water Use Patterns and Sources of Data

White Paper #1

Human Use of Water in Puget Sound: Managing Residential Water Demand for Resilient Communities and Healthy Ecosystems in a Changing Climate

Anne Thebo, PhD



ABOUT THIS DOCUMENT

This document is the first in a series of white papers and resources associated with Puget Sound Partnership project '*Human Use of Water in Puget Sound: Managing Residential Water Demand for Resilient Communities and Healthy Ecosystems in a Changing Climate*.' This document provides an overview of public water systems within Puget Sound and the communities they serve. It also compiles regional data on current water use across the region then discusses the utility and relevance of these data in estimating current water use within the region, supporting the development of baseline estimates in subsequent tasks. This white paper was written with a focus on informing subsequent project analyses and white papers. The focus of this white paper is on residential water use. Other uses, such as agriculture and power generation, are discussed as needed to provide context, but are not the focus of this document.

Suggested Citation: Thebo, A. 2025. *Current Water Use Within the Puget Sound Region: Water Use Patterns and Sources of Data*. University of Washington Climate Impacts Group. Seattle, WA. pp.28.

Acknowledgments: Funding for this work was provided by the Puget Sound Partnership. We are grateful for the feedback provided by Laura Rivas and Katherine Wyatt at the Partnership and the many others who provided feedback and answered questions.

CONTENTS

EXECUTIVE SUMMARY

Climate change is fundamentally altering the timing, availability, and quality of freshwater flows in Puget Sound watersheds. Increases in population and urban growth can further exacerbate these challenges. Planning for and adapting to these changes requires accurate, usable projections of future water use. Understanding current water use is foundational in developing estimates of future water use. This whitepaper provides an overview of public water systems within Puget Sound and the data currently available on total and residential water use within Puget Sound, including discussion of the advantages and tradeoffs of each of these sources of information.

The first part of this white paper provides an overview of Puget Sound drinking water systems, geographic variation in system characteristics and how they obtain water. There are nearly 2700 public water systems within the region, serving 86 percent of the region's population (4.6 of 5.4 million people). The characteristics of these systems are as diverse as the population of Puget Sound Region. Residents receive water from a broad range of sources including groundwater, surface water, interties to other systems, and other alternative sources (Figure E1). Public water systems range in size from small Group B water systems serving less than 15 connections through large Group A systems serving millions of connections.

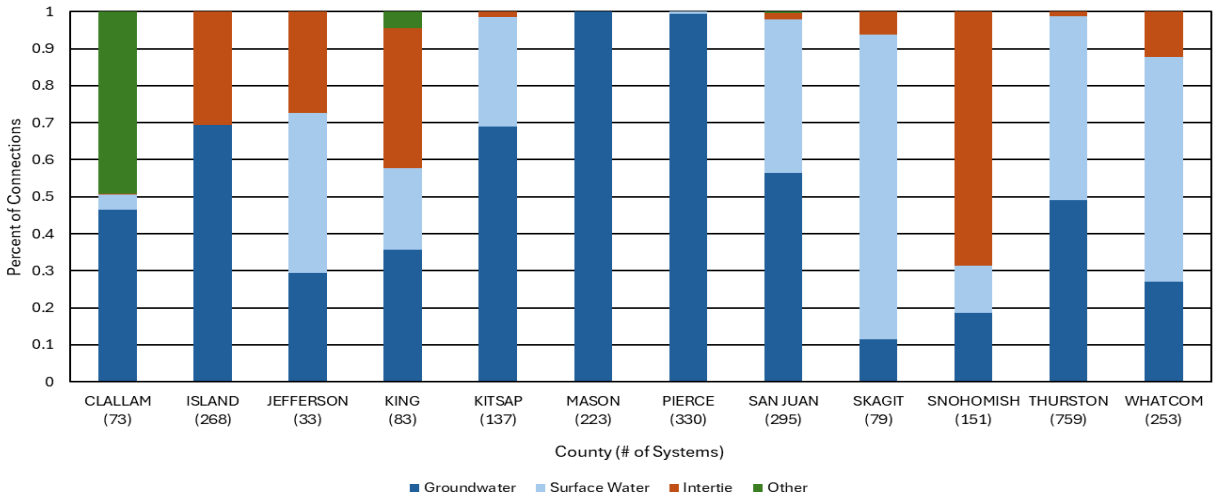


Figure E1. Proportion of connections in each county served by different sources of water. Number indicates the number of public water systems within the county.

The second portion of this white paper discusses sources of data available on current water use within Puget Sound Region, including a summary of the strengths and tradeoffs of different sources of information for estimating current water demand across the region (Table E1).

Table E1. Strengths and limitations of data available to inform regional estimates of water use.

Data	Strengths	Limitations	Next Steps
USGS National Water Use Data	County level estimates of water use by sector. HUC 12 watershed scale estimates of monthly surface and groundwater use for public supply. Estimates over time.	County data drawn from national dataset with known limitations. Most recent comprehensive data from 2015. 2000-2020 reanalysis data include monthly total, surface, and groundwater use for public supply data at the HUC12 watershed scale. Data on water use by sector (beyond public supply, irrigation, and power generation) are not yet available at the HUC12 scale.	Understand more about how these data are used in the Columbia Basin Supply and Demand Forecast. Consider using for regional validation efforts.
DOH Water System Data	Basic system information and spatial data on system boundaries.	Does not include data on water use.	Consider using water system boundaries as geographic unit in demand analysis.
DOH Water System Plans (WSP)	Detailed information on operational context and challenges for all Class A water systems with >1000 connections.	10-year cycle on WSP and recent updates to required content makes direct comparison across plans challenging. Only includes larger Class A systems.	Use WSP data for validation of baseline estimates. Work with DOH (as needed) for access to additional data to support validation efforts
Ecology Water Rights Data	Provides upper bound on instantaneous and annual withdrawals.	Often not reflective of actual use.	Consider development of water rights metric in risk and resilience white paper.
WRIA Watershed Plans	Often provide detailed information on residential water use (e.g., variation in outdoor water use across parcel sizes).	Information varies across WRIAs and not all WRIAs are required to develop a watershed plan. Focus is on water use by permit exempt wells.	Additional consideration on whether permit exempt wells should be included in the residential demand analysis.

Data	Strengths	Limitations	Next Steps
Flume	Wealth of information on water use at device level. With additional data access, could develop more granular sub-regional estimates. Publicly accessible data allows for monthly comparison of indoor/outdoor water use within the Seattle metro area.	Most data are not publicly available. Accessible data are aggregated across the Seattle metro area.	Consider working with Flume on potential access to additional, sub-regional data and current rates of adoption of water efficient devices.
Polebitski et al. Water Demand Studies	Incorporated multiple elements that impact demand for water (climate conditions, demographics, water pricing). Compares relative magnitude of impact of these different drivers.	Age of results (baseline year of 2001, published 2010, most estimates through 2030). Data are not publicly available. Modeled demand exceeds observed demand in the intervening years. Only includes four Puget Sound counties (King, Snohomish, Pierce, and Kitsap)	Methods and findings relevant and useful for informing this project's modeling efforts.

PART 1: OVERVIEW OF PUGET SOUND WATER SYSTEMS

MOTIVATION

Climate change is fundamentally altering the timing, availability, and quality of freshwater flows in Puget Sound watersheds. Increases in population and urban growth can further exacerbate these challenges. Approximately 80 percent of water withdrawals in Puget Sound are through municipal supplies and used for residential purposes.[1] This suggests that strategies such as residential water demand management and managed growth can help build resilience to current and projected changes in water supply for Puget Sound. A key first step in projecting future water demand is understanding current water use and historical trends. This includes factors such as geographic and seasonal variability in water use and adoption of water conservation and efficiency programs. The first part of this white paper provides an overview of Puget Sound drinking water systems, geographic variation in system characteristics and how they obtain water. The second portion of this white paper discusses sources of data available on current water use within Puget Sound, including a summary of the strengths and tradeoffs of different sources of information for estimating current water demand across the region.

PUGET SOUND WATER SYSTEMS

Residential Connections to Public Water Systems

Of the 5.4 million residents of Puget Sound, approximately 86 percent (4.6 million) are connected to public water systems.[2,3,4] The remaining fourteen percent of residents rely on private wells or small community systems. However, connectivity to public systems varies widely across counties (Figure 1), ranging from more than 90 percent in King County to less than 50 percent in San Juan County.

---

[1] Estimated using data from Dieter, Cheryl A., and Kristin S. Linsey. 2017. "Estimated Use of Water in the United States County-Level Data for 2015." U.S. Geological Survey. https://doi.org/10.5066/F7TB15V5.

[2] These values were estimated by dividing the full time residential population served by public water systems[3] by the total population of each county[4] (Office of Financial Management, State of Washington 2023)

[3] Washington State Department of Health. 2022. "Drinking Water System Data". https://doh.wa.gov/data-statistical-reports/environmental-health/drinking-water-system-data/data-download.

[4] Office of Financial Management, State of Washington. 2023. "April 1 Population of Cities, Towns, and Counties." https://ofm.wa.gov/sites/default/files/public/dataresearch/pop/april1/ofm_april1_population_final.pdf.

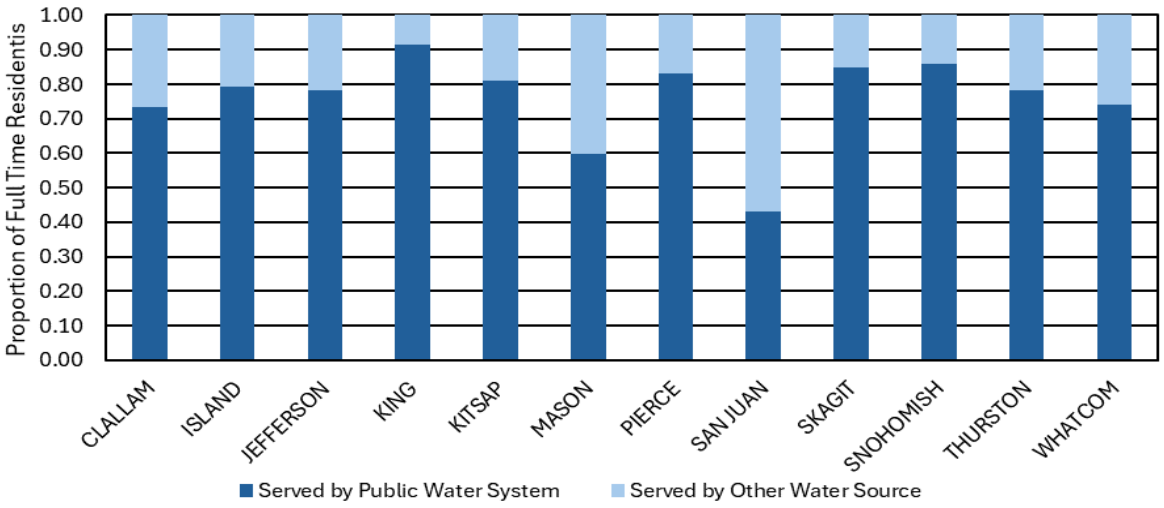


Figure 1. Proportion of full-time residents served by public water systems versus other sources of water (e.g., private wells).

Types of Public Water Systems

Within the Puget Sound Region, there are roughly 2700 public water systems (Figure 2). These systems range from extremely large enterprises such as Seattle Public Utilities that also serve as a regional wholesale agency and have durable access to a diverse range of supplies through very small systems that serve a handful of households with a single supply well.

Public water systems in Washington are classified as 'Group A' or 'Group B' (Table 1). This classification determines planning and reporting requirements applicable to each system and is an important consideration when assessing the availability of water use data associated with different systems. Rural households commonly obtain water through private wells (permit exempt wells).

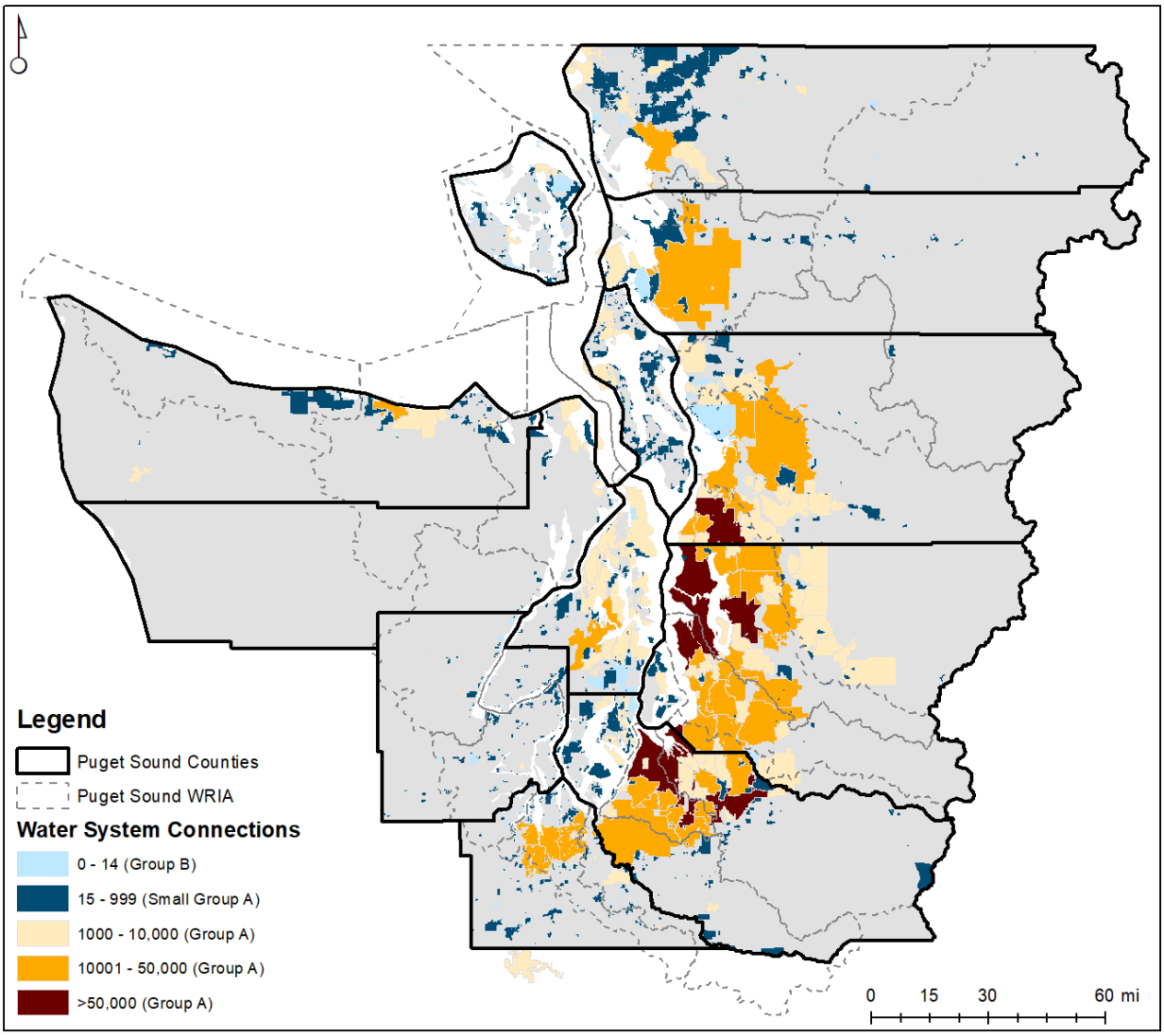


Figure 2. Puget Sound water system locations and number of connections served by each system.

Table 1. Classification of water systems and number of systems serving residential households in Washington State.

System	Definition	Planning Requirements		Number of Puget Sound Systems
Group A	≥ 15 connections OR serve ≥ 25 individuals for ≥ 60 days per year	≥1000 connections	Develop Water System Plan	152
		<1000 connections	Small Water System Management Program	1329
Group B*	<15 connections	Managed by local public health department		1293
Permit Exempt Wells	Domestic wells using less than 5000 gpd	Subject to WRIA specific watershed specific planning requirements[5]		~5540 (estimated number of permit exempt wells)[6]

* Many Group B systems serve communities with transient populations (e.g., seasonal homes, campgrounds, highway rest areas), resulting in highly variable water use.

SOURCES OF WATER

Puget Sound water systems rely on many different sources of water (Figures 3 and 4).[7] Groundwater sources, such as springs and wells, are the most common source of water with 94 percent of systems reporting groundwater use. These systems serve 53 percent of connections[8] within the region. Three percent of systems have interties[9] with other systems and serve 25 percent of connections within the region. Two percent of systems, serving twenty percent of connections within the region, use surface water. Supply diversification is uncommon outside of larger systems with >98% of reporting use of a single source of water (e.g., groundwater, surface water). While groundwater is the predominant source of

[5] Washington State Department of Ecology.2024. "Streamflow Restoration - Domestic Permit-Exempt Withdrawals: New Regulations - RCW 90.94 (ESSB 6091, 2018)". https://waecy.maps.arcgis.com/apps/webappviewer/index.html?id=000d6773daed4deda1c969e0d28f2fda

[6] Washington State Department of Ecology. 2015. "Permit-Exempt Domestic Well Use in Washington State." Olympia, WA. https://apps.ecology.wa.gov/publications/documents/1511006.pdf

[7] Reclaimed water use is tracked through the reclaimed water permitting program and not reported here.

[8] This includes all types of connections (e.g., residential, commercial) reported by the water system. Water use will vary widely across different types of connections.

[9] Interties are permanent physical connections between water systems. These connections can allow for continuous and/or intermittent sharing of water between systems.

water for water systems in aggregate, there is substantial heterogeneity across the region in the number of connections served by different sources of water. For example, in Whatcom County, less than five percent of systems use surface water (Figure 3), but because the City of Bellingham primarily uses surface water, 60 percent of connections within the county rely on surface water (Figure 4). 'Other' includes a range of sources including 'RI Gallery' (aquifer recharge) and desalinated sea water.

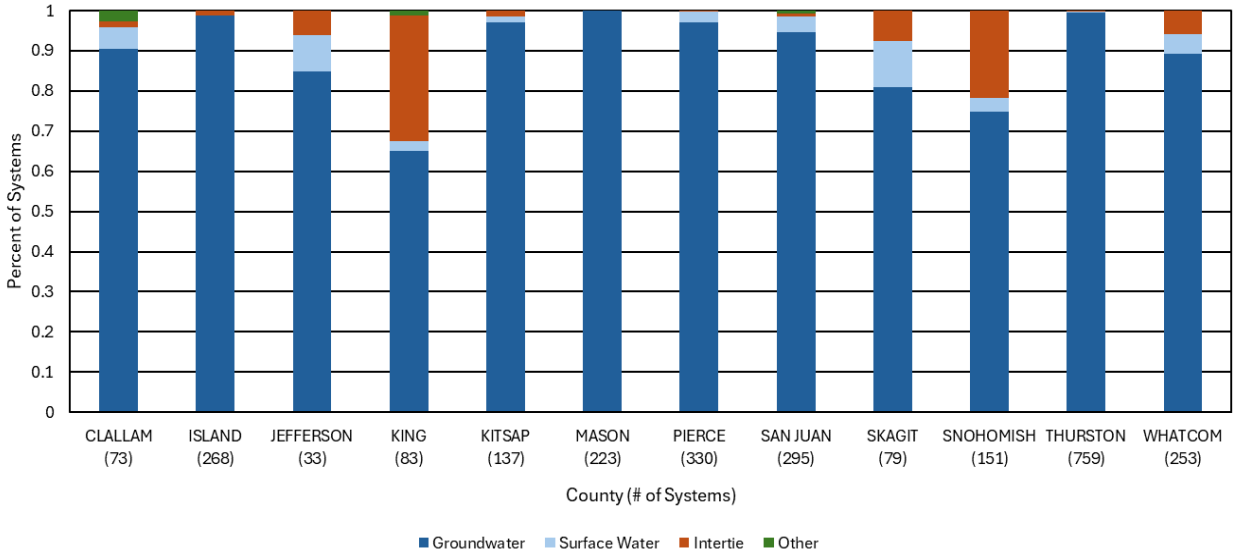


Figure 3. Proportion of water systems in each county served by different sources of water. Number indicates the number of public water systems within the county.

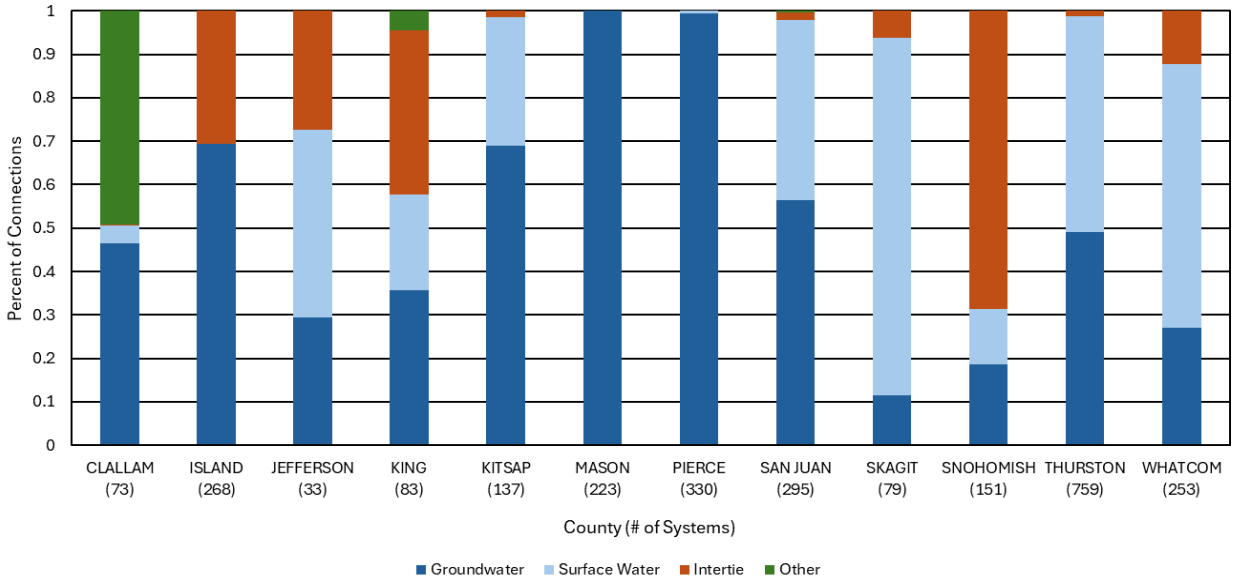


Figure 4. Proportion of connections in each county served by different sources of water. Number indicates the number of public water systems within the county.

IMPACTS OF CLIMATE CHANGE ON PUGET SOUND WATER SUPPLIES

Climate change is expected to impact water supply availability in multiple ways across Puget Sound. Mountain snowpack in the Pacific Northwest essentially serves as a reservoir, making substantive contributions to streamflow and groundwater recharge as it melts during the dry summer months. In the coming decades, most of the basins surrounding Puget Sound are expected to transition to rain dominant basins (Figure 5).[10] These changes are the product of multiple factors, including warmer winter temperatures and changing precipitation patterns. When winter temperatures are warmer, more precipitation falls as rain and the snowpack that is present, melts earlier in the spring leading to earlier peaks in runoff.[11] Already limited summer precipitation is also expected to decline, further decreasing late-summer streamflow. These changes are amplified by projected changes in the intensity, duration, and frequency of drought conditions. Interactions between surface and groundwater are common with changes in surface water hydrology impacting the recharge of groundwater. Changes in water availability impact water systems in myriad ways including water right curtailments, changes in reservoir operations, shifts in regional water demand, and challenges in accessing groundwater. Water availability is also intrinsically linked with a broad range of human behaviors and natural conditions. When coupled with hotter, drier conditions – wildfire risk, agricultural demand, and instream flow needs may all increase concomitantly. These changes impact the quantity and quality of water available across all users.

[10] Mauger, Guillaume, Joseph Casola, Harriet Morgan, Ronda Strauch, Brittany Jones, Beth Curry, Tania Busch Isaksen, Lara Whitely Binder, Meade Krosby, and Amy Snover. 2015. "State of Knowledge: Climate Change in Puget Sound." Seattle, WA: Climate Impacts Group, University of Washington. https://cig.uw.edu/projects/climate-change-in-puget-sound-state-of-knowledge/.

[11] Yoder, John, and Crystal Raymond. 2022. "Climate Change and Streamflow: Barriers and Opportunities." Olympia, WA: Washington State Department of Ecology. https://apps.ecology.wa.gov/publications/documents/2211029.pdf.

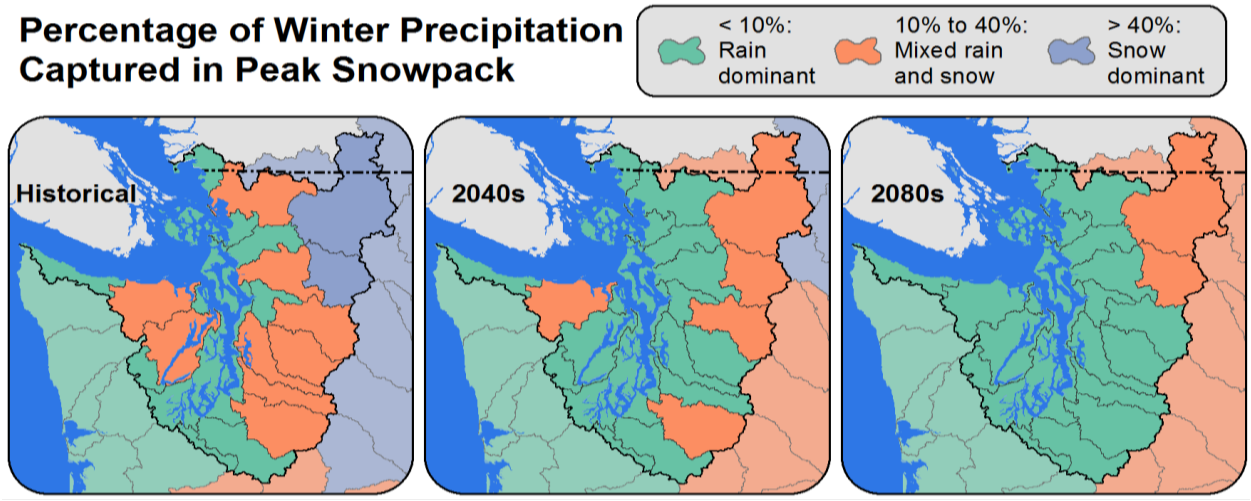


Figure 5. Percentage of winter precipitation captured in peak snowpack in Puget Sound over time. Source: UW Climate Impacts Group, State of Knowledge (2015)

The impacts of climate change on surface waters are the most direct and observable for water systems. However, the realized vulnerability of water systems to changes in surface water availability varies widely across the region. Reservoir storage capacity, water rights seniority, and watershed characteristics all impact realized risks. For example, a large surface water dependent system with multiple reservoirs such as SPU faces very different risks than those of a small surface water system in the San Juan Islands that is dependent on flows from a small, rain dominant watershed.

Climate change will also impact groundwater supplies. However, the impacts are often more indirect and/or related to human responses to climate change impacts such as drought. For example, changes in the intensity and timing of precipitation can impact groundwater recharge while shifts in supply availability can lead to changes in the timing and magnitude of groundwater pumping in a region.

ROLE OF CONSERVATION AND EFFICIENCY IN WATER USE

Water conservation and efficiency are closely related concepts, both relating to reductions in water consumption, albeit via different pathways. Water conservation focuses on changing behaviors around water use (e.g., only running the dishwasher when full) while water use efficiency is a measure of the amount of water needed to accomplish a given task (e.g., water used by the dishwasher per load washed). The 2003 Municipal Water Law (MWL) created flexibility in the administration of municipal water rights in Washington and,

in return, created requirements that municipalities use water efficiently (WAC 246-290).[12] The MWL required Group A water systems (Table 1) to be fully metered by 2017; develop a water use efficiency program, including communication and education programs; and reduce system losses.[13] As of 2020, Group A systems developing a Water System Plan are also required to estimate future water demand with and without expected savings from water use efficiency programs.

With code revisions and technological improvements, water using devices such as dishwashers, washing machines, and toilets are becoming increasingly efficient in their use of water, generally leading to decreasing per capita water use. Many local conservation and efficiency programs subsidize the replacement of older devices with newer, more water efficient models. Improvements in device efficiency are responsible for a large portion of the reductions in per capita water use seen in many water systems across the region (e.g., Figure 6). This trend is likely to continue as older, less efficient devices reach the end of their useful life and are replaced.[14] Whether total regional water use declines in response to water conservation and efficiency programs is a complex interplay between changes in population, housing stock, industry composition, climate, and other factors. The next two examples highlight observed changes in water use at the regional and local scales.

Example: Seattle Public Utilities

SPU acts as both a retail and wholesale water agency, supplying (all or a portion of the) water used by 23 local water agencies across Puget Sound. The amount of water supplied by SPU is 31 percent below its peak (a decline of 172 MGD to 118 MGD per year) despite an increase of more than 500,000 people served by those same supplies (Figure 6).[15] Notably, SPU and the agencies it supplies have also significantly reduced the amount of non-revenue water (e.g., water lost through leaks and other losses). However, the population and geography of each agency and profiles of customers served varies widely. In 7 of 23 water agencies supplied by SPU, per connection water use has actually increased since 1995.[15] The drivers of these differences vary, but, in general, areas where water use is increasing tend to be either high growth and/or located in exurban areas.

---

[12] Washington State Department of Health. 2016. "WUE Rule Background Information". https://doh.wa.gov/community-and-environment/drinking-water/water-system-design-and-planning/water-use-efficiency/wue-background.

[13] Washington State Department of Health. 2017. "Water Use Efficiency Guidebook." Olympia, WA. https://doh.wa.gov/sites/default/files/legacy/Documents/Pubs/331-375.pdf.

[14] DeOreo, William B, Peter Mayer, Benedykt Dziegielewski, and Jack Kiefer. 2016. "Residential End Uses of Water, Version 2: Executive Report." Denver, CO: Water Research Foundation.

[15] Seattle Public Utilities. 2021. "Annual Survey of Wholesale Customers: Summary of Results" https://www.seattle.gov/documents/Departments/SPU/Documents/Reports/Water/Archive/2023-SummaryofSurveyResults.pdf

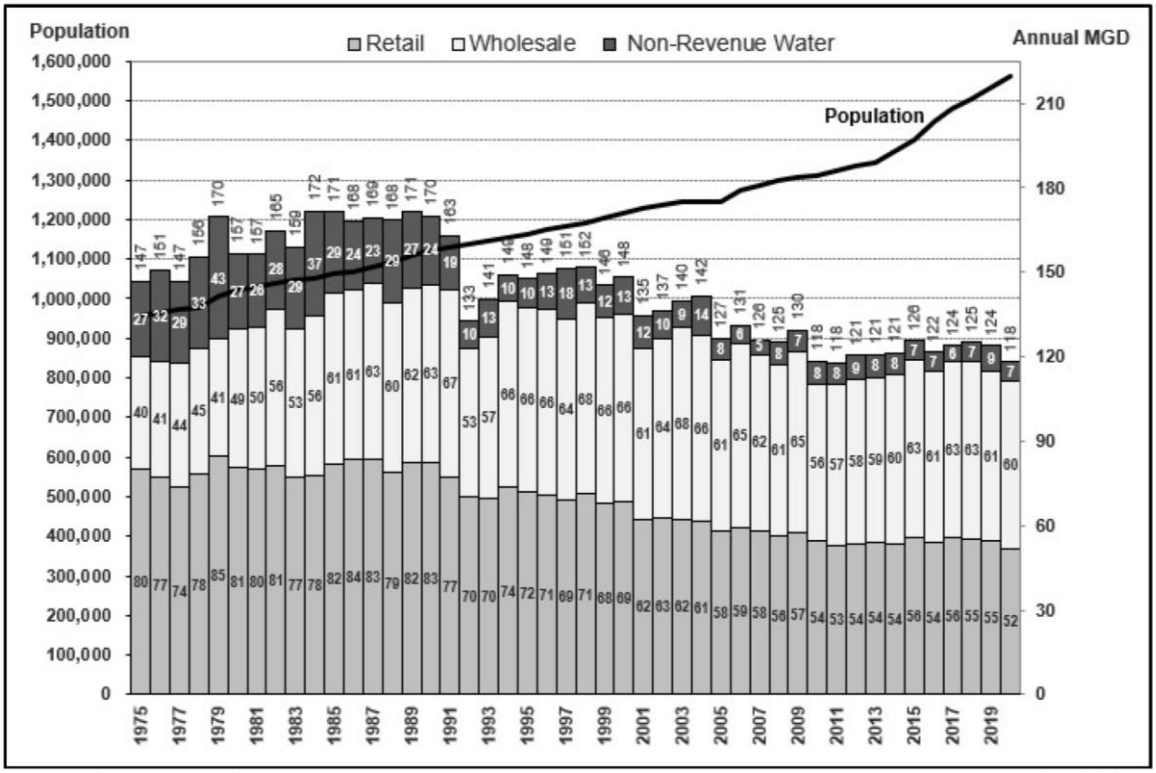


Figure 6. Population* and Components of Annual Water Demand in the Seattle Regional System 1975-2020. Source: SPU (2021)[15]; * Population has been adjusted downwards to reflect that some wholesale customers have other sources of supply in addition to what they purchase from SPU.

Example: Changes in Water Demand in Olympia, WA

The cities of Lacey, Olympia, and Tumwater and the regional wastewater agency, LOTT Clean Water Alliance[16] have made substantial, long-standing investments in water conservation and efficiency programs.[17] The efforts include rebate programs, shared education and outreach, coordination of activities, and collaboration between water and wastewater agencies. These investments were motivated, in part, by a need to reduce wastewater discharges to Budd Inlet to protect sensitive ecosystems and maintain water quality. Reducing municipal water use in the region reduces the volume of wastewater produced and, in turn, the volume of wastewater discharged to Budd Inlet. Water use trends (1996-2019) in Olympia are shown in Figure 7. These efforts have resulted in declines in both per connection use (26% less than 1996) and total water use (12% below

[16] Lacey, Olympia, Tumwater, and Thurston County (LOTT) Clean Water Alliance is the regional wastewater agency https://www.lottcleanwater.org/

[17] City of Olympia. 2021. "2021-2026 Water System Plan". https://www.olympiawa.gov/services/water_resources/water_plans,_regulations___reports/water_system_plan_update.php.

use in 1996). These trends occurred even with a 35 percent increase in the number of connections to Olympia's water system since 1996. While periods of significant drought may be associated with an increase in early conservation and efficiency behaviors (Figure 8), water savings appear to be fairly durable across both wet and dry periods.

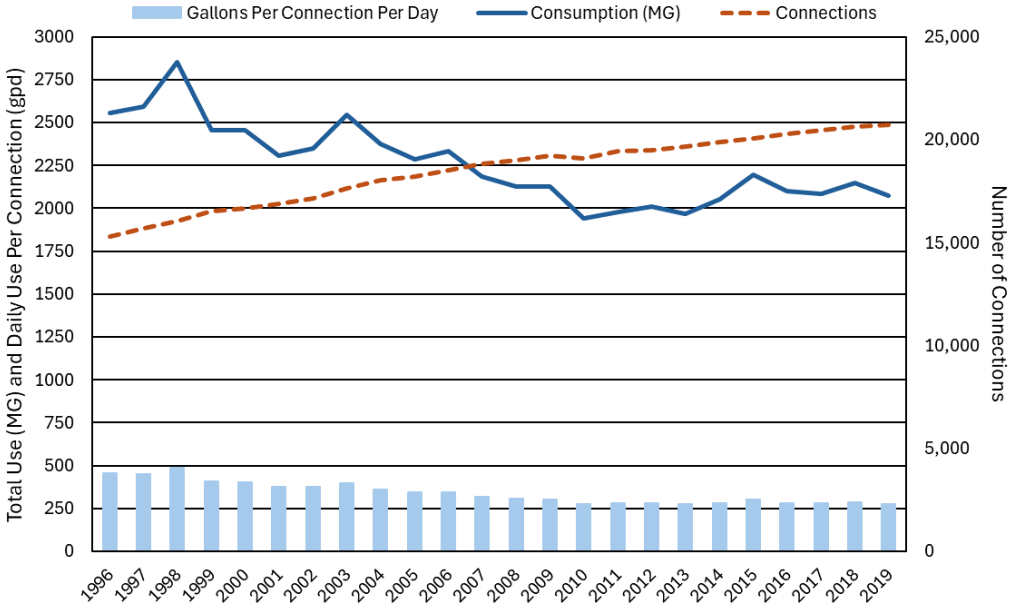


Figure 7. Changes in the Number of Connections, Total Consumption, and Daily Use per Connection in Olympia (1996-2019). Data Source: City of Olympia Water System Plan[17]

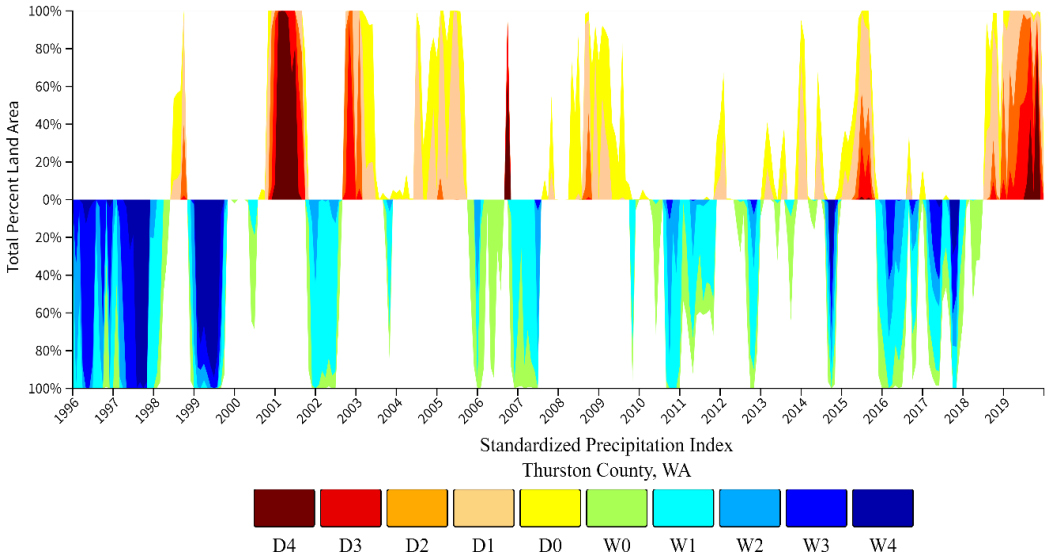


Figure 8. Duration and Severity of Wet (W0-W4) and Dry (D0-D4) Periods in Thurston County (Olympia), 1996-2019. Source: NIDIS Drought Monitor[18]

[18] NOAA National Integrated Drought Information System (NIDIS). 2024. "Conditions for Olympia, WA (Thurston County)". https://www.drought.gov/location/98512.

PART 2: SOURCES OF CURRENT AND HISTORICAL WATER USE DATA

BACKGROUND

Methods of assessing water use are evolving rapidly, facilitating more detailed evaluations of water use by sector and device with increasing levels of granularity and accuracy. However, there are notable gaps in information and differences in reporting that can make estimates of water use in aggregate challenging. This review discusses several sources of information available on water use within Puget Sound and the relative strengths, limitations, and utility of each source.

WATER USE TERMINOLOGY

Classes of water use considered vary with the aims of the assessment. However, some common classes of water use include total water use, consumptive and non-consumptive uses, and use by different customer classes. Some common terms used in water use planning and assessment efforts include:

- **Residential Water Use:** Domestic uses of water (e.g., cooking, bathing) (indoor use) and landscape irrigation (outdoor use) by single and multi-family households.
- **Non-Residential Water Use:** Water use by non-residential customers including businesses, schools, government facilities, manufacturing, hospitals, and other uses. This class of use is also commonly known as 'Commercial, Industrial, and Institutional' (CII) water use.
- **Irrigation Water Use:** Water used for irrigation of croplands, golf courses, and other large irrigation users. Unless the water use is metered separately, water used for landscape irrigation at homes and CII facilities is typically included under those classes of use.
- **Non-Revenue Water:** Water lost to leaks and other system losses.
- **Consumptive Use:** Water that is used and evaporated, transpired, consumed, incorporated into products or crops and no longer available for immediate use.
- **Non-Consumptive Use:** Water that is directly returned to the system after use where it becomes available for other uses. Use for some types of cooling is a common non-consumptive use.
- **Public or Municipal Water System:** Water system supplying residential and non-residential water users for domestic, CII, and other related uses.
- **Self-Supplied:** Water user supply needs are met independent of public systems through sources such as a private well.

USGS 5-YEAR WATER USE ESTIMATES

USGS develops estimates of water use[19] across the entire United States at five-year intervals. These estimates date back to 1950, but the categorization approaches and scales of data reported have varied over the years. Recent efforts estimate water use by sector at the county level. Historically, estimates have been reported by state agencies and compiled by USGS. Approaches for downscaling state water use data to county level estimates varied state-by-state and data are not available for every variable in each state. Acknowledging this limitation, USGS took a different approach with the 2020 data, using a machine learning approach to estimate sector level water use and develop more granular estimates of water use (e.g., HUC12 watersheds).[20] Water use data going back to 2000 were also reanalyzed using the machine learning methodology. Initial data releases from this effort have begun, but the full composite of variables is not yet available.

USGS 2015 Water Use Estimates

In 2015, USGS estimated that the twelve counties surrounding Puget Sound withdrew approximately 880 MG of water per day for a wide variety of consumptive and non-consumptive uses (Figure 9).[21] Across the region, residential water use constituted approximately 80 percent of all water use in the region. Irrigation can be a locally significant water use (e.g., Whatcom and Skagit Counties), but accounts for less than ten percent of water use across the whole region. Self-supplied water for industrial use is another locally significant use (e.g., Snohomish and Whatcom Counties) and typically associated with specific, large industrial users (e.g., refineries, power generating stations, data centers). Aquaculture is another locally significant and typically non-consumptive use of water.

[19] USGS. 2024. "U.S. Geological Survey National Water Use Program". https://www.sciencebase.gov/catalog/item/5e7cb20ee4b01d5092751675.
[20] Luukkonen, Carol L, Ayman H Alzraiee, Joshua D Larsen, Donald Martin, Deidre M Herbert, Cheryl A Buchwald, Natalie A Houston, et al. 2023. "Public Supply Water Use Reanalysis for the 2000-2020 Period by HUC12, Month, and Year for the Conterminous United States." U.S. Geological Survey. https://doi.org/10.5066/P9FUL880.
[21] Dieter, Cheryl A., and Kristin S. Linsey. 2017. "Estimated Use of Water in the United States County-Level Data for 2015." U.S. Geological Survey. https://doi.org/10.5066/F7TB15V5.

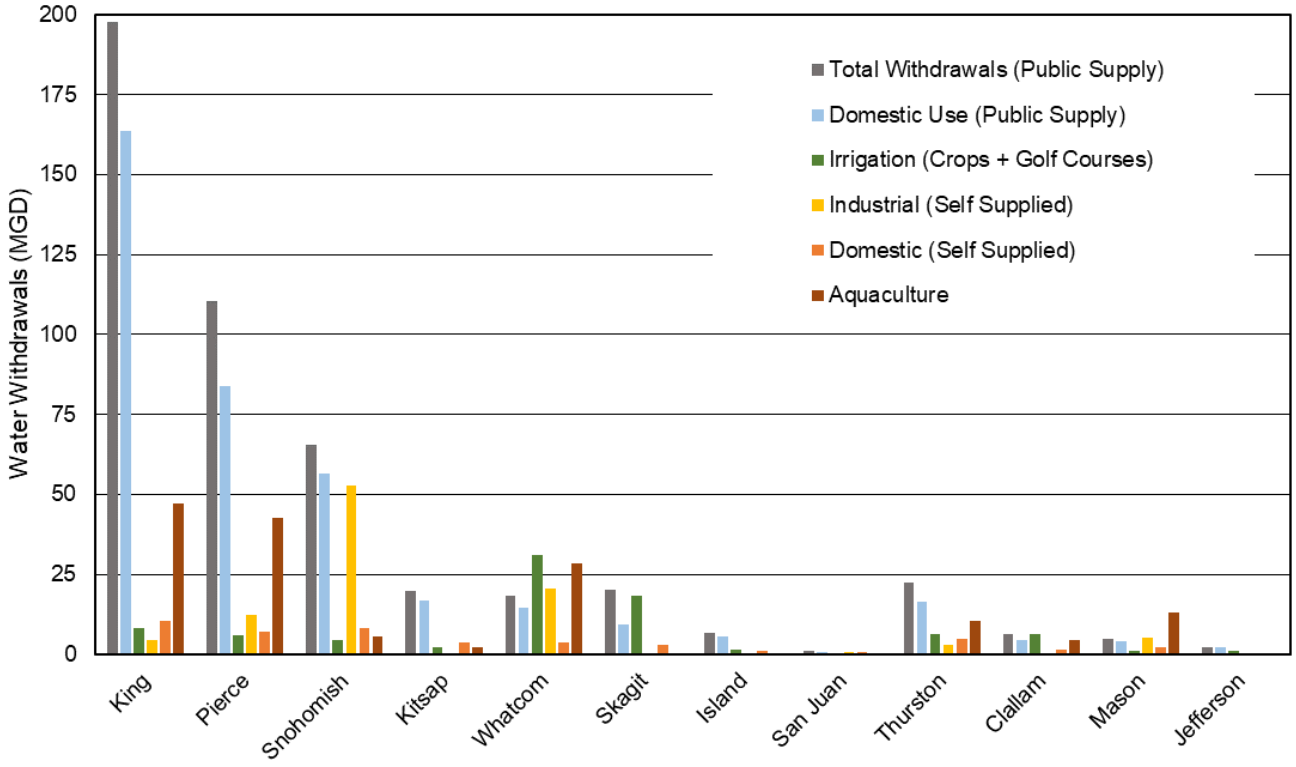


Figure 9. 2015 USGS water use estimates for Puget Sound counties. Data Source: USGS 2017[17]

USGS 2020 Water Use Estimates

In their 2020 estimates and machine learning based reanalysis of the 2000-2020 data, USGS developed monthly estimates of publicly supplied water from surface and groundwater sources at the HUC12 watershed scale.[22] These data are helpful for evaluating trends in water use and understanding regional patterns of water use (Figure 10), including seasonal differences in water use (Figure 11). Public water systems were estimated to use approximately 154,000 MGY in 2020. This estimate is about ten percent lower than the 2015 public supply estimates, but the totals are not directly comparable due to different estimation methodologies. Exploring trends in the 2000-2020 reanalysis data was beyond the scope of the current white paper but could provide additional insights. Watersheds in population centers use the most water though often that water is imported from watersheds in the Cascades. Estimates of use by class (similar to Figure 7) are not yet readily available at the HUC12 scale but are expected to be available in the future.

[22] Estimates of water use for irrigation and thermoelectric power generation are also available in the 2000-2020 reanalysis data but analysis was beyond the scope of this summary.

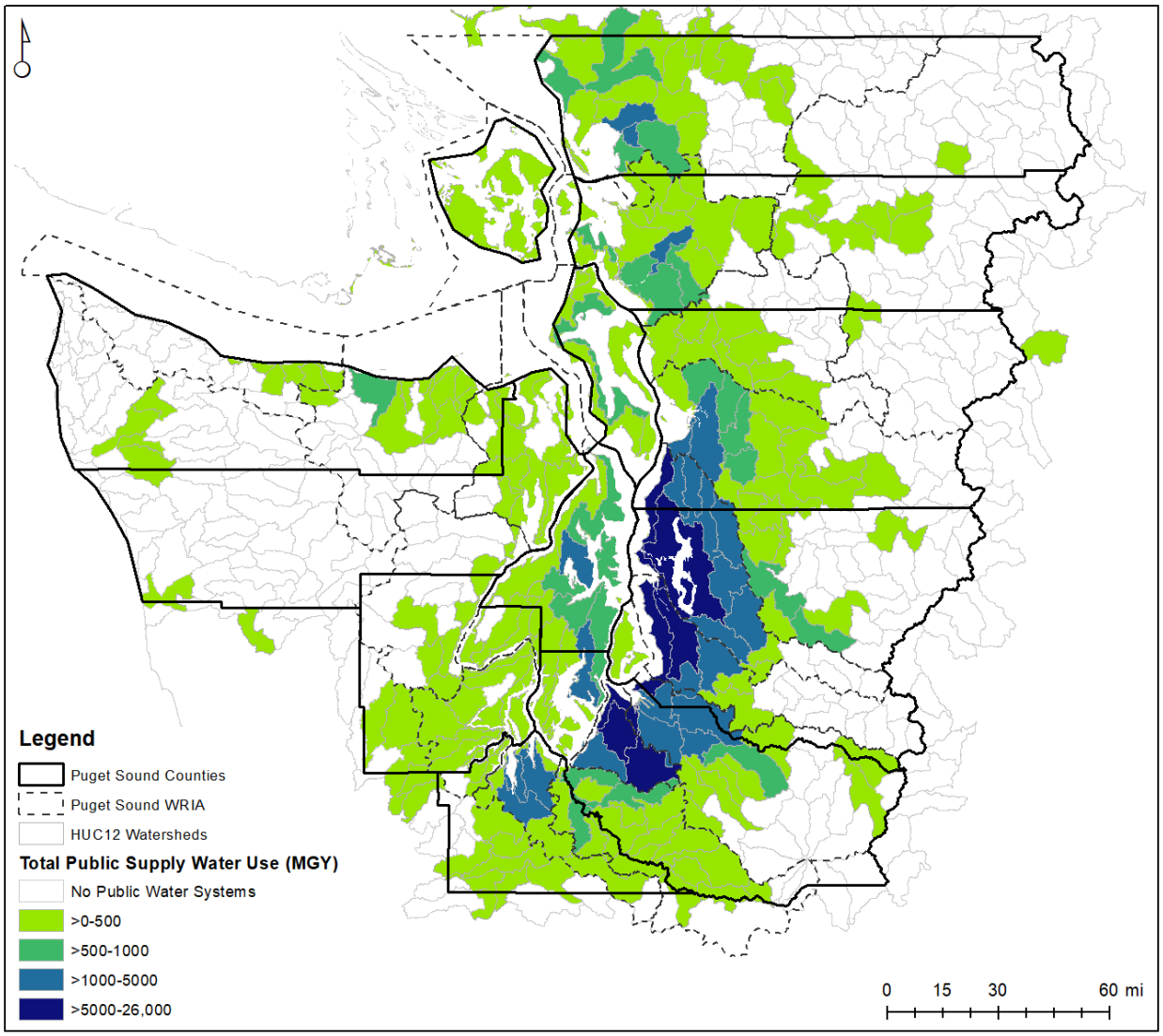


Figure 10. Total public supply water use in 2020. Data Source: USGS 2023[16]

Public supply water use across Puget Sound is at its highest during the dry summer months. However, there are substantial differences in the extent to which summer water use by public systems increases across watersheds. The percent difference between estimated summer and winter water use in 2020 is shown in Figure 11 with watersheds classified by quantile. In the lowest quantile (blue), summer public supply water use is 30-52 percent higher than winter use. In the highest quantile (red), summer water use is 93 to 140 percent higher than winter water use. The summer dry period corresponds with the region's primary growing season and peak use of water for landscape irrigation. Watersheds with higher levels of summer water use are also likely to have larger areas of irrigated landscape area. Water used for agricultural irrigation is typically self-supplied or supplied by an irrigation district and generally not included in estimates of public supply.

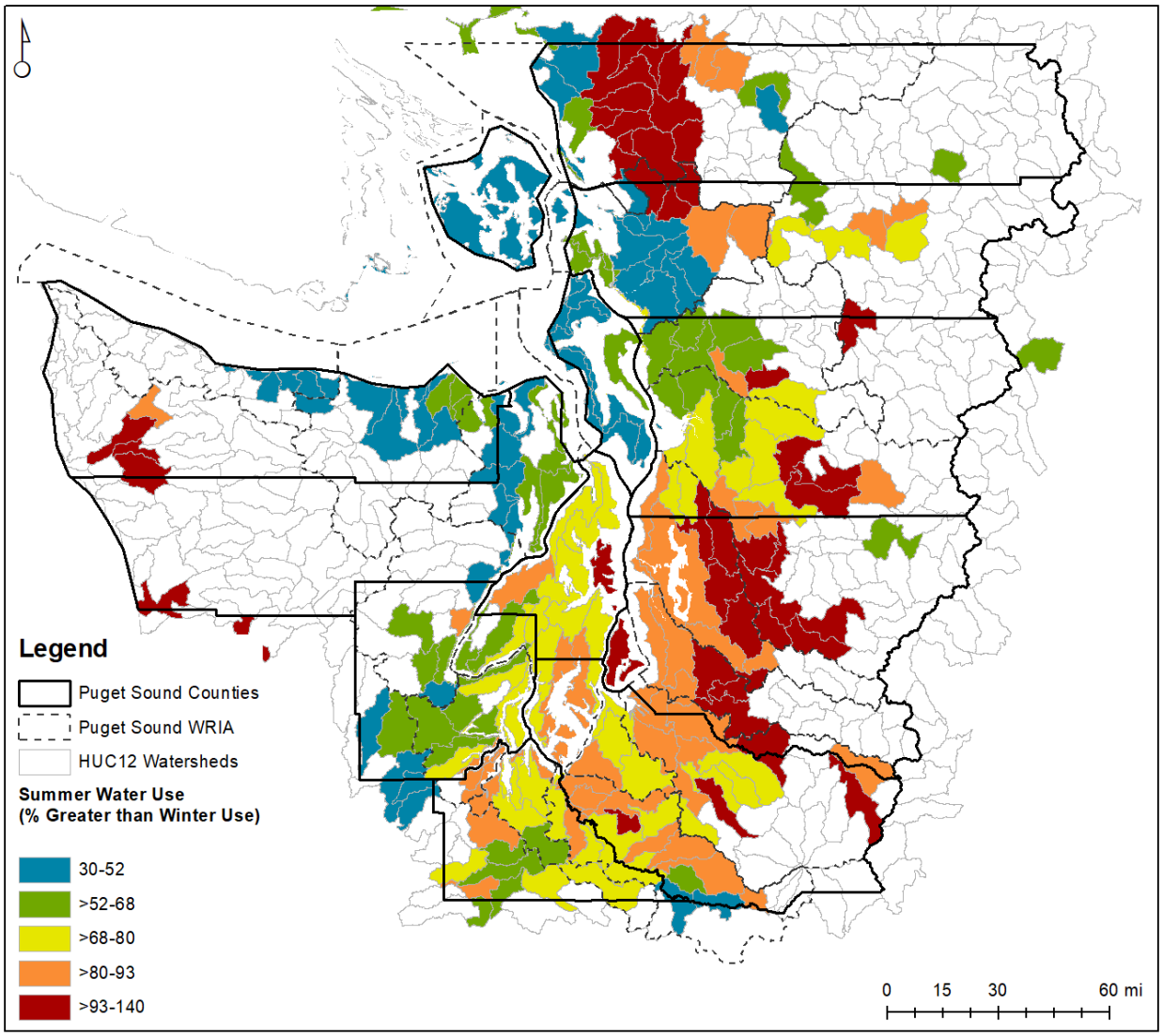


Figure 11. Comparison of winter and summer public supply water use in 2020. Areas where there are large seasonal differences in water use (orange and red watersheds) are often areas where there is more landscape irrigation occurring. Data Source: USGS 2023[16]

WASHINGTON DEPARTMENT OF HEALTH

Water System Data

The Washington Department of Health provides basic information on all Group A and B water systems in the State. These data, provided in a combination of tabular[23] and spatial[24] data formats, include basic information on water systems such as the water system service area, population, number of connections, and contact information for each system. Water system ID can be used to link tabular data with system boundaries. These data were used for mapping and our summary of system characteristics (Figures 1-4), but do not include information on water use by each system.

Water System Plans

The Washington Department of Health (DOH) Office of Drinking Water (ODW) is tasked with state-level implementation of the federal Safe Drinking Water Act as well as management of the State's Water Use Efficiency program, as mandated under the Municipal Water Supply Efficiency Requirements Act (i.e., MWL)[25]. DOH also works in coordination with the Department of Ecology to implement state-level water system planning requirements. Through these programs, ODW compiles a range of information on water systems across the state. Every ten years, Class A Water Systems serving 1000 or more connections are required to submit an updated Water System Plan. Non-expanding, smaller Class A systems follow the requirements of the State Small Water System Management Program (SWSMP).

Water System Plans (WSP) include a broad range of information on each system, including assessments of current use and future demand. The State's Water System Planning Guidebook 331-068[26] and Water System Design Manual 331-123[27] specify what is required in WSPs and details on topics such as demand forecasting and system capacity assessments. At a minimum, water systems are required to report on metrics such as maximum daily demand (MDD), average daily demand (ADD), peak hourly demand (PHD).

[23] Washington State Department of Health. 2022. "Water System Data". https://doh.wa.gov/data-statistical-reports/environmental-health/drinking-water-system-data/data-download.
[24] Washington State Department of Health. 2024. "Drinking Water System Boundaries". https://fortress.wa.gov/doh/base/gis/ServiceAreas.zip.
[25] Washington State Department of Health. 2024. "The Municipal Water Law." https://doh.wa.gov/community-and-environment/drinking-water/water-system-design-and-planning/municipal-water-law.
[26] Washington State Department of Health. 2020. "Water System Planning Guidebook 331-068." Olympia, WA. https://doh.wa.gov/sites/default/files/2022-02/331-068.pdf.
[27] Washington State Department of Health. 2020. "Water System Design Manual 331-123." Olympia, WA. https://doh.wa.gov/sites/default/files/2022-02/331-123.pdf

Water use is normalized (across all uses) to use by 'Equivalent Residential Unit' (ERU).[28] Water systems are also required to conduct a system capacity evaluation comparing current and future water use to constraints such as available water rights and system design capacity. While the overall structure of WSPs is the same across systems, there are differences in how systems present the required information (e.g., units, accounting for loss). Reporting requirements are also updated periodically which leads to some differences in the content and presentation of information in each WSP.

We conducted a preliminary review of eight Water System Plans across six counties and found the plans are a rich source of information on local water system context, system capacity, and challenges. Plans typically included detailed maps of water system service areas and projected expansion of water systems within urban growth areas (UGA). Systems are also required to identify potential capacity constraints by comparing total water use to parameters such as available water rights, storage, and system capacity. Some WSP shared more detailed information on topics such as the specifics on indoor and outdoor use, changes in water use across the year, and water use by locally relevant sectors. In the plans reviewed, average daily demand was 169 gpd/ERU, but ranged from 127 to 267 gpd/ERU. Detailed comparison across plans proved challenging due to differences in data reporting units, methods, and the wide range of time covered by the reviewed plans (2008-2020). While difficult to compare across plans, WSP are still a rich source of information on the characteristics and operations of individual water systems. Moving forward, we feel the information contained in recent plans will prove useful for validation of regional estimates of water use.

WASHINGTON DEPARTMENT OF ECOLOGY

Water Rights Data

The Department of Ecology is responsible for managing Washington's water resources and the administration of permits for surface and groundwater rights. Data on water rights are accessible through Ecology's online Water Rights Search.[29] Water rights typically include limits on both instantaneous withdrawals (e.g., gallons withdrawn per minute) and the total annual quantity of water that can be withdrawn from the source. Water rights are upper limits of how much water can be used and often not necessarily indicative of the actual

[28] From Washington's Water System Design Manual "An ERU is a system-specific unit of measure used to express the amount of water consumed by a typical full-time single-family residence (WAC 246-290-010)".
[29] Washington State Department of Ecology. 2024. "Water Rights Map." https://appswr.ecology.wa.gov/waterrighttrackingsystem/WaterRights/Map/WaterResourcesExplorer.aspx

quantity of water being used currently. Some water rights holders are required to report metering data on actual usage. These data are recorded in the Ecology Metering Database.[30]

WRIA Reports

The Department of Ecology and other state agencies divided Washington into 62 Watershed Resource Inventory Areas (WRIA). WRIA are administrative units based on watershed boundaries and used for watershed planning, water rights permitting, and assessments of water availability. Nineteen of the 62 WRIAs are within Puget Sound. Watersheds subject to instream flow rules (RCW 90.94) are required to develop watershed plans estimating "the cumulative consumptive water use impacts over the subsequent twenty years"[31], including water use by permit exempt wells. Other basins are already adjudicated (with existing limits on use by permit exempt wells) or currently going through the adjudication process (e.g., Upper/Lower Skagit, Nooksack). Watershed plans and details on each WRIA's requirements are available on Ecology's website.[5,32] Information on current and future water use by permit exempt wells can help inform regional estimates of water use in several ways. Patterns of development vary widely across the region ranging from highly urban through rural. In some locations, water use by permit exempt wells may be locally and/or ecologically significant. Information in watershed plans can help make this assessment. Some WRIA's watershed plans also include much more detailed information on outdoor water use (compared to what is available in DOH WSPs). In particular, some plans include information on how outdoor water use varies across different sizes of parcels. For example, in the Snohomish Watershed (WRIA 7), outdoor use scales linearly with lawn size with some small variation attributable to local differences in evapotranspiration and precipitation (Figure 12). Information in WRIA reports may be useful for modeling the nuances of outdoor water use in large lot parcels on the urban periphery.

[30] Washington State Department of Ecology. 2024. "Water Metering Reporting." 2024. https://ecology.wa.gov/regulations-permits/reporting-requirements/water-metering-reporting
[31] RCW 90.94.030(3)(e)
[32] Washington State Department of Ecology. 2024. "Water Availability - In Your Watershed (WRIA)." 2024. https://ecology.wa.gov/water-shorelines/water-supply/water-availability/in-your-watershed.

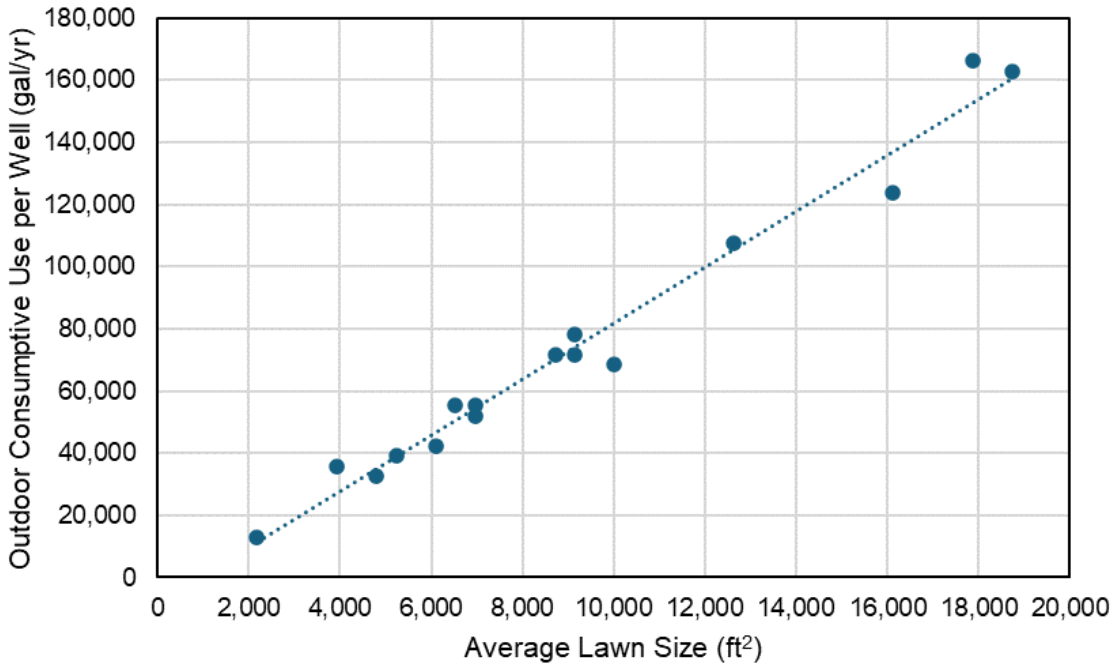


Figure 12. Average lawn size and household outdoor consumptive water use in Snohomish Watershed (WRIA 7) subbasins. Data Source: WRIA 7 Watershed Restoration and Enhancement Plan.[33]

FLUME HOUSEHOLD WATER USE INDEX

Flume is a company that produces devices that attach to existing residential water meters to provide high resolution estimates of water use, including use by device. Most Flume data are not publicly available, but some basic data on indoor and outdoor water use in the fifteen largest metro areas (including Seattle) are available through their data dashboard.[34] Residential water use in the Seattle metro area varies seasonally (Figure 13). From November through April, household water use is relatively consistent—typically about 100 gallons per household per day (assuming a regional average of 2.5 people per household). Household water use increases substantially during the drier May to September months, mostly due to increases in outdoor water use. In 2023, outdoor water use accounted for approximately 50 percent of an average household's water use. Approximately 65 percent of all residential water use in 2023 occurred between May and September. During dry fall seasons, outdoor irrigation can extend into October (Figure 13).

[33] Washington State Department of Ecology. 2022. "Watershed Restoration and Enhancement Plan: WRIA 7 - Snohomish Watershed." 22-11–013. Olympia, WA. https://apps.ecology.wa.gov/publications/documents/2211013.pdf.

[34] Flume Utility and Business Solutions. 2024. "Flume Data Labs Household Water Use Index." 2024. https://flumewater.com/water-index.

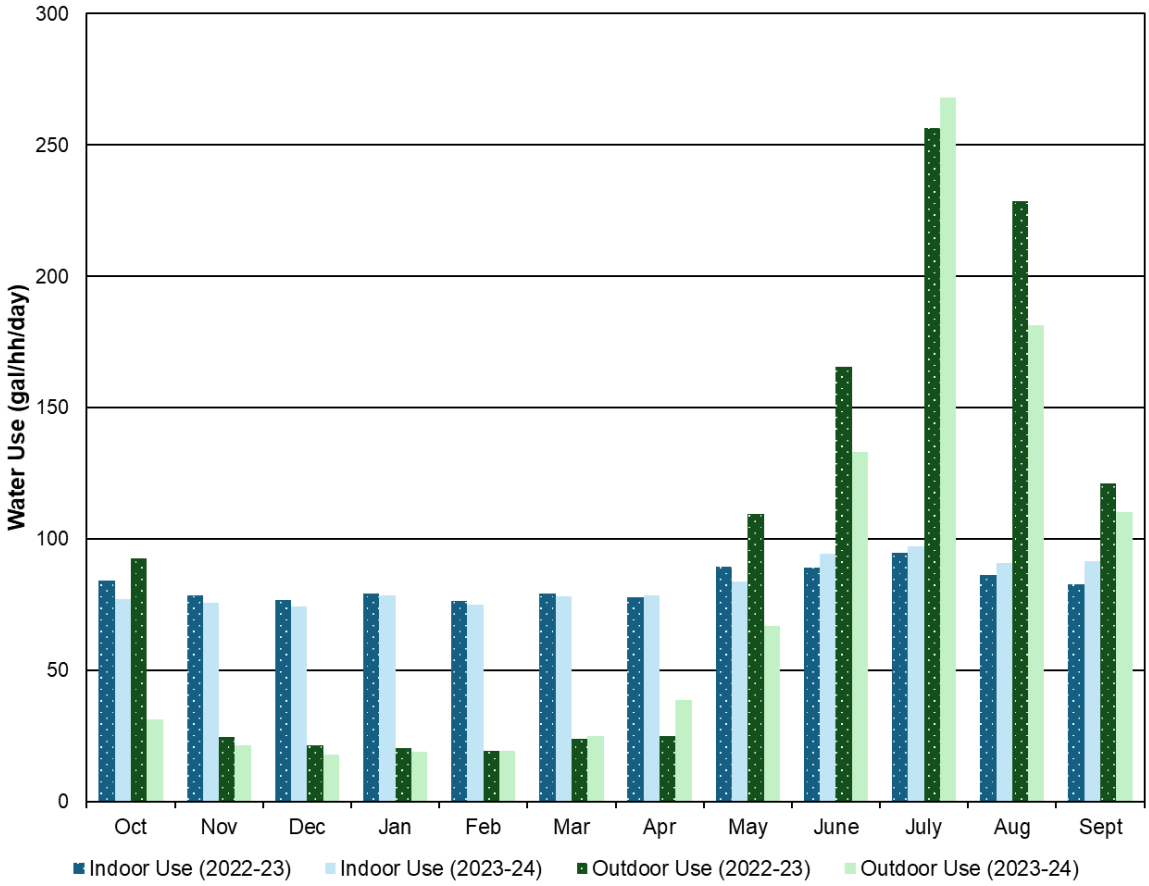


Figure 13. Daily water use per household by month (assuming 2.5 people per household). Data Source: Flume Data Labs[34] Total water use is the sum of indoor and outdoor use in a given month.

POLEBITSKI ET AL. DEMAND STUDIES

The work of Polebitski et al.[35] and Traynham et al.[36] detail findings from related research studies modeling changes in water demand and supply associated with changing climate conditions, water pricing, development, and population within four counties in the Seattle metro area (King, Snohomish, Pierce, Kitsap) and the watersheds supplying the region. The water demand assessment used outputs from the UrbanSim modeling program[31] to assess the sensitivity of water demand to shifts in demographics, development patterns, policy, and climate conditions. 2001 was used as the baseline year to which modeling results were

[35] Polebitski, Austin S., Richard N. Palmer, and Paul Waddell. 2011. "Evaluating Water Demands under Climate Change and Transitions in the Urban Environment." Journal of Water Resources Planning and Management 137 (3): 249–57. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000112.

[36] Traynham, Lee, Richard Palmer, and Austin Polebitski. 2011. "Impacts of Future Climate Conditions and Forecasted Population Growth on Water Supply Systems in the Puget Sound Region." Journal of Water Resources Planning and Management 137 (4): 318–26. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000114.

compared. The region has changed dramatically since this research was conducted, but the researchers' scenarios and findings provide a useful point of comparison for observed water use across the region in the intervening years. The scenarios evaluated by the researchers are summarized in Table 2 with additional details available in Polebitski et al.[31]

Table 2. Summary of Baseline and Future Water Demand Scenarios Evaluated by Polebitski et al.

Scenario	Description
2001 Demand	Observed water demand in 2001.
Baseline	Basic demand forecast assuming constant per capita demand. Future demand estimated using changes in population.
Scenario 1	Uses UrbanSim results to incorporate changes in population demographics and building stock in demand estimate. Pricing, temperature, and precipitation held constant.
Scenario 2	Same as Scenario 1, except incorporates price increases (and their impact on demand).
Scenario 3	Same as Scenario 1, except includes changes in temperature and precipitation between 2001 and 2030, 2060, and 2090.

Polebitski et al.'s work helps to unpack the complex dynamics driving urban water demand. They found that increases in density (resulting in less outdoor irrigated landscape) per household and increases in pricing were likely to contribute to decreases in household water use while increases in summer temperature and decreases in summer precipitation were likely to increase household water use (Table 3). How these dynamics play out at the regional level is spatially heterogeneous with total water use increasing in some areas, but decreasing in others. It is important to note that the study region of Polebitski et al. only includes King, Snohomish, Pierce, and Kitsap counties and, as a result, total demand estimates are not directly comparable to estimates from USGS (which include all twelve Puget Sound counties).

Table 3. Modeled household and total water demand (from Polebitski et al.).

Scenario	Winter Demand (gpd/hh)	Summer Demand (gpd/hh)	Total Demand (MGD)
2001 Demand	155	229	166
Baseline	155	229	203
Scenario 1	148	218	195
Scenario 2	135	161	157
Scenario 3-2030	146	244	208
Scenario 3-2060	147	260	217
Scenario 3-2090	146	272	223

OTHER REGIONAL MODELING EFFORTS

Within Puget Sound there are numerous modeling efforts exploring various socio-ecological connections across the region. The 2023 Puget Sound Modeling Compendium[37] includes briefs on ongoing modeling efforts and programs relevant within the region. Maintaining instream flows and/or water quality for local ecosystems is a common driver in the development of many of these models. Water withdrawals for human use impacts instream flows but can be difficult to account for in many existing modeling frameworks. This is especially true in instances where the impacts are realized via surface-groundwater interactions. Regionally consistent, spatially granular estimates of domestic water use would likely be helpful in understanding the impacts of withdrawals on instream flows and changes in these impacts over time. One such effort in the Columbia Basin is discussed in Box 1.[38]

Box 1: Columbia River Supply and Demand Forecast

The Columbia River Supply and Demand Forecast is one such effort that seeks to develop unified estimates of both supply and demand across a large region. Estimates look forward twenty years and are updated every five years. The effort, led by the Office of the Columbia River (Department of Ecology) and numerous collaborators has, historically, been based on a large, system modeling effort. The primary objective of the most recent forecast (2021) was to "Provide a system-wide quantitative assessment of how future environmental and economic conditions and human responses are likely to influence water supplies and demands over the next 20 years".[1] Water use estimates in the Forecast have historically focused on agricultural water use (the primary water use within the basin) though the most recent version includes more detailed estimates of residential and municipal water use. While patterns of water use and availability in the Columbia Basin are significantly different than those in Puget Sound, there are common sources of data across the regions and

[37] PSEMP Modeling Work Group. 2023. "2023 Puget Sound Modeling Compendium. Status and Gaps in Model Development for the Puget Sound Social-Ecological Ecosystem (Draft)." Olympia, WA. https://pspwa.app.box.com/s/bdx4vewcz7t09t3sduzzwcox881c70hd.

[38] Hall, S.A., J.C. Adam, M.A. Yourek, A.M. Whittemore, G.G. Yorgey, F Scarpare, M Liu, et al. 2022. "2021 Columbia River Basin Long Term Water Supply and Demand Forecast." 21-12–006. Olympia, WA: Washington State Department of Ecology. https://apps.ecology.wa.gov/publications/documents/2112006.pdf

PART 3: STRENGTHS AND LIMITATIONS OF CURRENT WATER USE DATA FOR DEVELOPING REGIONAL BASELINE WATER USE ESTIMATES

SUMMARY OF CURRENT PUGET SOUND WATER USE DATA

Each source of data provides unique insights into water use across Puget Sound. No single source of information tells the whole story, but all provide useful information for developing baseline estimates of current water use. The strengths and limitations of each of the sources reviewed in previous sections are summarized in Table 4. Table 5 also includes a summary of total, residential, and per household water use estimates from each of source of data reviewed. Estimates of total water use are not directly comparable between USGS and Polebitski et al. because of differences in the regions covered. However, estimates of per capita use are roughly comparable and generally on the same order of magnitude as the range reflected in the review of Water System Plans (127-269 gphd).

Table 4. Strengths and limitations of data available to inform regional estimates of water use.

Data	Strengths	Limitations	Next Steps
USGS National Water Use Data	County level estimates of water use by sector. HUC 12 watershed scale estimates of monthly surface and groundwater use for public supply. Estimates over time.	County data drawn from national dataset with known limitations. Most recent comprehensive data from 2015. 2000-2020 reanalysis data include monthly total, surface, and groundwater use for public supply data at the HUC12 watershed scale. Data on water use by sector (beyond public supply, irrigation, and power generation) are not yet available at the HUC12 scale.	Understand more about how these data are used in the Columbia Basin Supply and Demand Forecast. Consider using for regional validation efforts.
DOH Water System Data	Basic system information and spatial data on system boundaries.	Does not include data on water use.	Consider using water system boundaries as geographic unit in demand analysis.
DOH Water System Plans (WSP)	Detailed information on operational context and challenges for all Class A water systems with >1000 connections.	10-year cycle on WSP and recent updates to required content makes direct comparison across plans challenging. Only includes larger Class A systems.	Use WSP data for validation of baseline estimates. Work with DOH (as needed) for access to additional data to support validation efforts
Ecology Water Rights Data	Provides upper bound on instantaneous and annual withdrawals.	Often not reflective of actual use.	Consider development of water rights metric in risk and resilience white paper.
WRIA Watershed Plans	Often provide detailed information on residential water use (e.g., variation in outdoor water use across parcel sizes).	Information varies across WRIAs and not all WRIAs are required to develop a watershed plan. Focus is on water use by permit exempt wells.	Additional consideration on whether permit exempt wells should be included in the residential demand analysis.

Data	Strengths	Limitations	Next Steps
Flume	Wealth of information on water use at device level. With additional data access, could develop more granular sub-regional estimates. Publicly accessible data allows for monthly comparison of indoor/outdoor water use within the Seattle metro area.	Most data are not publicly available. Accessible data are aggregated across the Seattle metro area.	Consider working with Flume on potential access to additional, sub-regional data and current rates of adoption of water efficient devices.
Polebitski et al. Water Demand Studies	Incorporated multiple elements that impact demand for water (climate conditions, demographics, water pricing). Compares relative magnitude of impact of these different drivers.	Age of results (baseline year of 2001, published 2010, most estimates through 2030). Data are not publicly available. Modeled demand exceeds observed demand in the intervening years. Only includes four Puget Sound counties (King, Snohomish, Pierce, and Kitsap)	Methods and findings relevant and useful for informing this project's modeling efforts.

Table 5. Summary of current estimates of total, residential, and per capita water use across Puget Sound.

Data Source	Total Use via Public Supply (MGD)	Residential Use from Public Supply (MGD)	Per Capita Domestic Use (gphd)^	Notes
USGS 2015	475	377	210	Public supply total; Domestic deliveries from public supply; Estimated HH use from per capita use (87.3 gpcd) and median HH size (2.4 ppl)
USGS 2020	423			
Flume			173	Reported as household use
DOH WSP Review			127-269	Units: Use per equivalent residential unit (ERU)[28]; Average daily demand amongst plans reviewed was 169 gal/ERU-day
Polebitski et al.**				
2001 demand	166		155/229	Regional estimates from Polebitski et al. modeling scenarios. Per capita values indicate winter/summer demand.
Baseline (SQ)	203		155/229	
S1	195		148/218	
S2	157		135/161	
S3-2030	208		146/244	
S3-2060	217		147/260	
S3-2090	223		146/272	

* Shading indicates data on metric unavailable from source at the time of review.

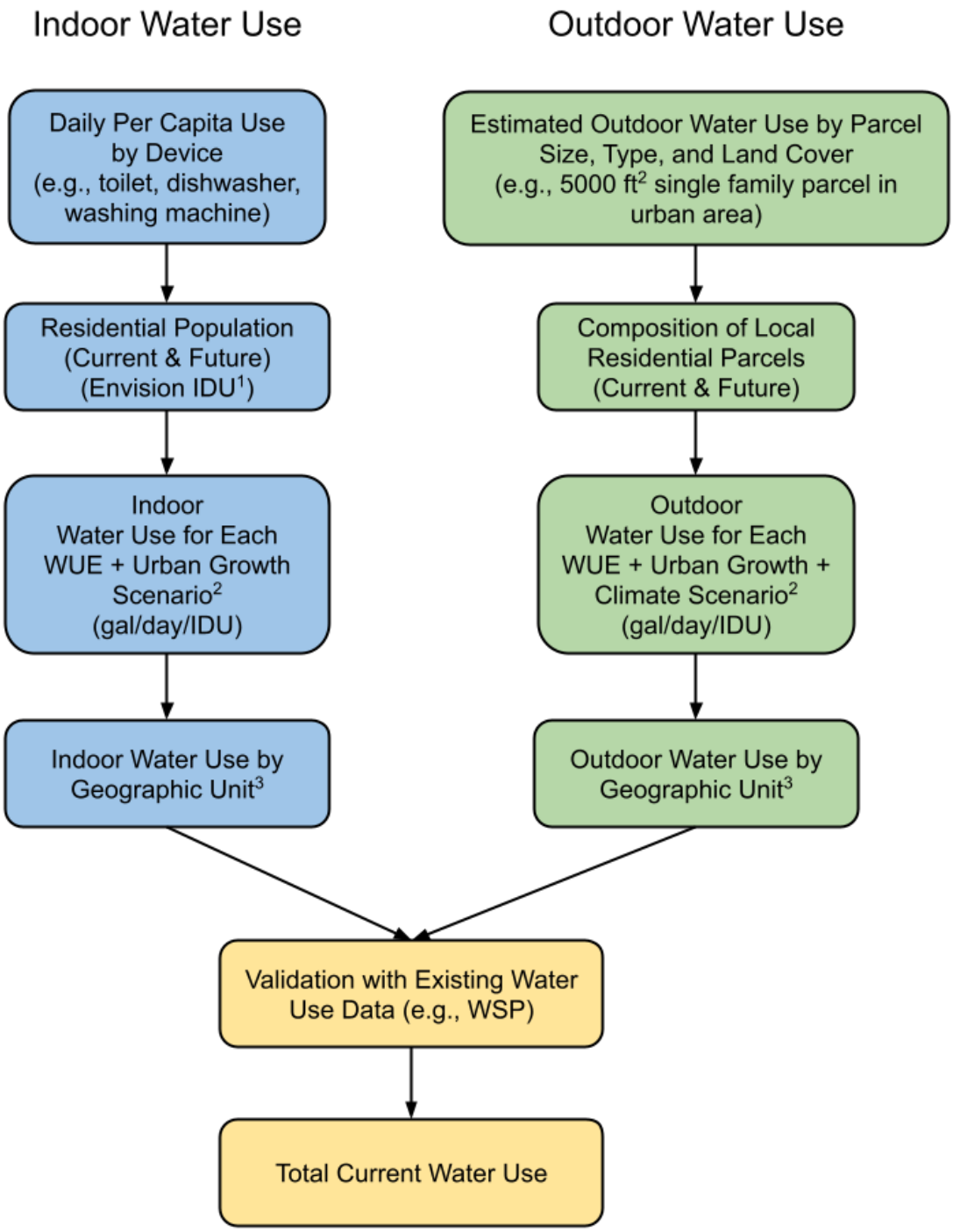
** The study area of Polebitski et al. only includes King, Snohomish, Pierce, and Kitsap as compared to the USGS estimates, which include all 12 Puget Sound counties.

^ gphd: gallons per household per day

DEVELOPING A SPATIALLY EXPLICIT BASELINE ESTIMATE OF CURRENT WATER USE

Each of the sources of data and information evaluated presents unique strengths and tradeoffs. For baseline estimates to be useful in this project, they must also be comparable to modeled estimates of future residential water demand (Task 3). As such, spatially explicit, regional baseline estimates are being developed using a ground-up approach (Figure 14), comparable to the methods being to estimate future residential water demand.

Current indoor and outdoor water use are estimated separately at the per capita (indoor) and household (outdoor) levels. These estimates are then multiplied by household population and number of households (indoor) and estimates of the number of different types of parcels (outdoor) to develop regional estimates of indoor, outdoor, and total water use. Ground-up estimates are being validated using observed data from DOH Water System Plans and (potentially) recent USGS modeling results. These results will be shared in White Paper #2, 'Estimating Future Residential Water Demand in Puget Sound'.



1. Integrated Decision Unit (IDU). Geographic unit of analysis used in Envision modeling.
2. Three water use efficiency (WUE) scenarios are considered - status quo, efficient, highly efficient
3. Level of geographic aggregation will be decided in consultation with PSP, technical advisors, and other stakeholders. Example levels include water system boundary, watershed, county.

Figure 14. Summary of approach for estimating baseline (current) indoor and outdoor water use.