



Groundwater Management Plan

May 12, 2026

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EA Technical Memo on Groundwater Modeling, 2025

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Keta Waters Technical Memo on Steady State Modeling, 2026

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List of Acronyms and Abbreviations

AFY	Acre-feet per year
AKART	all known, available and reasonable methods of prevention, control and treatment
ASR	aquifer storage and recovery
BHC	BHC Consultants
BIMC	Bainbridge Island Municipal Code
BIMPRD	Bainbridge Island Metro Parks and Recreation District
BOD5	biochemical oxygen demand 5 day
Carollo	Carollo Engineers, Inc.
CDP	cumulative departure precipitation
COBI	City of Bainbridge Island
DBP	disinfection byproducts
DOH	Department of Health
EA	EA Engineering, Science, and Technology, Inc., PBC
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
ERU	equivalent residential unit
ETAC	Environmental Technical Advisory Committee
EWL	early warning level
FBA	Fletcher Bay Aquifer
GIS	Geographic Information System
GW	groundwater
GWMP	Groundwater Management Plan
GPD	gallon per day
GPM	gallons per minute

GMA	Glaciomarine Aquifer
GSI	green stormwater infrastructure
HB	House Bill
IDDE	Illicit Discharge Detection and Elimination
KPHD	Kitsap Public Health District
KPUD	Kitsap Public Utility District
KW	Keta Waters LP
KWRN	Kato and Warren, Inc. and Robinson and Noble, Inc
LID	Low Impact Development
LOSS	Large On-Site Septic System
MCL	maximum contaminant limit
MFL	million fibers per liter
MG	million gallons
MGD	million gallons per day
mg/L	milligrams per liter
MGY	million gallons per year
MODFLOW	Modular Three-Dimensional Finite-Difference Ground-Water Flow Model
MODFLOW-NWT	Newton-Formulation for Modular Three-Dimensional Finite-Difference Ground-Water Flow Model
MSL	mean sea level
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance
OSS	On-site Septic System
PA	Perched Aquifer
PE	permit-exempt
PVC	polyvinyl chloride

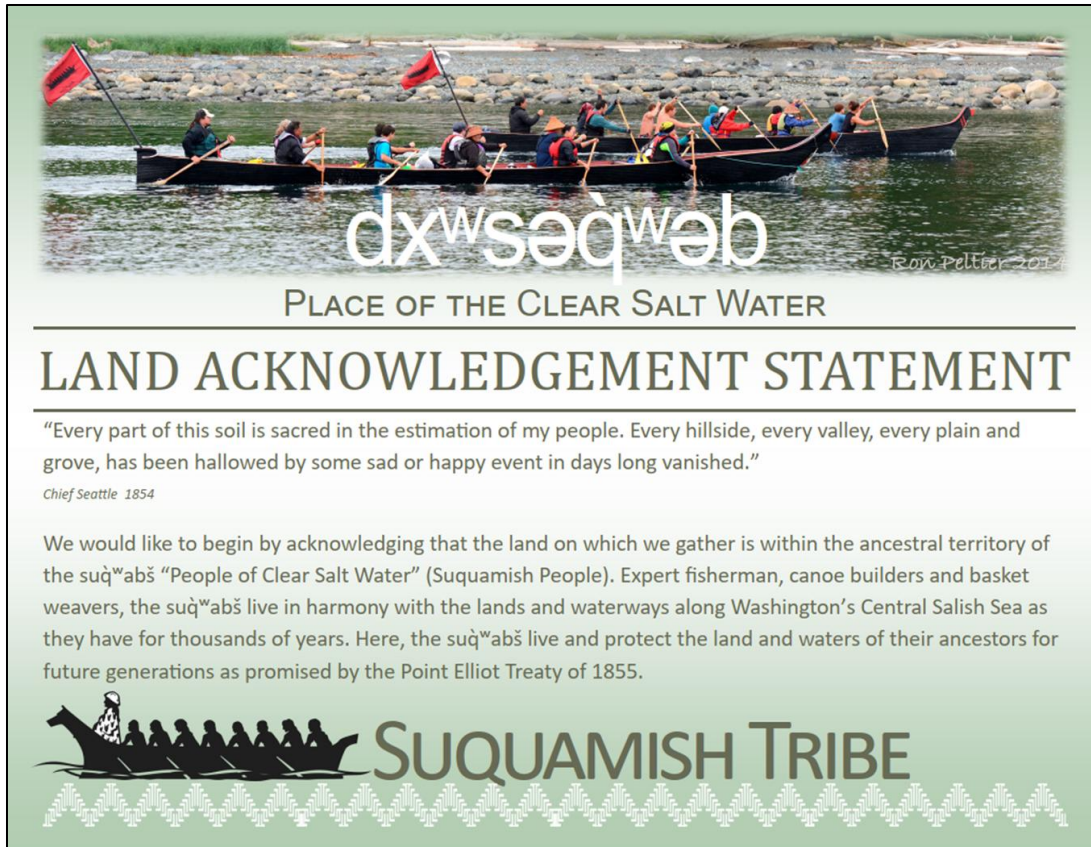
Qa	Annual quantity
Qi	Instantaneous quantity
RCP	Representative Concentration Pathways
RCW	Revised Code of Washington
RWSA	Regional Water Service Area
SALs	State Action Levels
SLA	Sea Level Aquifer
SMED	Stormwater Management for Existing Development
SPA	Semi-Perched Aquifer
SWMP	Stormwater Management Program
SWMMWW	Stormwater Management Manual for Western Washington
TAC	Technical Advisory Committee
TSS	total suspended solids
UAC	Utility Advisory Committee
USGS	U.S. Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
CIG	Climate Impacts Group
GMA	Washington Growth Management Act
WWTP	wastewater treatment plant

Land Acknowledgement

Native American histories indicate that ancestral peoples have lived in the Pacific Northwest since time immemorial. Archaeological evidence supports the deep antiquity of Native peoples in the region by providing material evidence for the local presence of ancestral peoples prior to 12,000 years ago (Carlson 1990; Kopperl, et. al.) and as early as roughly 16,000 years ago. Generally, the earliest known archaeological sites in the Pacific Northwest were occupied shortly after widespread regional deglaciation allowed much of the land to be habitable.

Suquamish tribal members first inhabited Bainbridge Island and the Kitsap Peninsula around 13,000 years ago and continue to live in the area to the present day. The Suquamish People and other People of the Salish Coast Water occupied winter villages and seasonal camps throughout the Island as they fished, hunted, collected shellfish, and gathered plants and other vegetation resources.

With respect to that history, the City of Bainbridge Island offers the following land acknowledgement:



Other Acknowledgements

This groundwater management plan is intended to be a living community document, updated as required. As such, it represents a community-wide effort to assemble, understand, and manage Bainbridge Island’s groundwater. The primary technical analysis was performed by EA Engineering, Inc. and Keta Waters LP.

Special thanks are due to the members of the Groundwater Management Plan Advisory Subcommittee: Andy Maron, Melanie Keenan, Malcolm Gander, Mike Cox, and Ted Jones for their support, advice, and critical input. The members of the Technical Advisory Committee: Charlie Kratzer (Suquamish Tribe), Douglas Wood (Washington State Department of Ecology), John Kiess (Kitsap Public Health District), Joel Purdy (Kitsap Public Utility District), and Tom Colby (Kitsap Public Utility District) provided significant insights regarding the groundwater quantity and quality on Bainbridge Island.

Thanks are due to Christian Berg, Ground and Surface Water Resource Specialist at the City for countless hours of technical support, Gretchen Brown, GIS Specialist for

map design and cartography and to Chris Wierzbicki, Public Works Director, for overall guidance and review.

Finally, thanks are due to the City Council for their vision and support in completing the Groundwater Management Plan and to the residents of the City for their interest and commitment to the process.

Executive Summary

The purpose of the Groundwater Management Plan (GWMP) is to protect the Island's Sole Source Aquifer system. Without a plan, the City of Bainbridge Island (City) runs the risk of overdrawing from groundwater sources, which could lead to dry and unrecoverable drinking water wells, sea-water intrusion, and a host of negative impacts on critical aquatic environments and related species.

The GWMP is based on historical evaluation and monitoring stretching back over 20 years, including updated modeling and analysis performed in 2025 and 2026. The critical findings from this work include the following:

- All models show that impacts of reduced recharge are significantly larger than impacts from increased pumping. In addition, recharge rates have a roughly 1:1 impact on changes in streamflow. Septic return flow contributes to groundwater recharge and reduces the net consumptive use of groundwater pumping.
- In modeling scenarios that reflect anticipated future conditions, groundwater levels remained above sea level in the aquifer system for those scenarios with pumping that was less than 1.5 times current rates. Groundwater levels fell below sea level in some aquifers for scenarios with pumping that was greater than 2.0 times current rates. Groundwater levels that remain below sea level will eventually result in saltwater intrusion.
- A rough estimate of sustainable yield for the aquifer system is in the range of 1,200-3,000 acre-feet/year (AFY). Current consumptive use is estimated to be in the range of 1,000-1,800 AFY (pumping: 2,000-3,000 AFY, minus return flow of 40-50%). This current usage could be sustainable or unsustainable, depending on what the actual values are for sustainable yield and current use. Because these actual values cannot be known with certainty, it is not possible to say definitively if the current usage is sustainable or unsustainable.
- If all allowable water from permitted water rights and ~1,700 private well allowances was put to use, then usage would almost certainly exceed sustainable yield.

It is important to interpret these findings in light of the subjectivity associated with definitions of sustainability. Alley et al. (1999) defined groundwater sustainability as “the development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences.” Ultimately "unacceptable" must be collectively defined, and systems must be measured and monitored to ensure unacceptable thresholds are not crossed.

Given the findings, the GWMP prioritizes management actions that will help the City create a robust measurement and monitoring system, and contribute to the sustainable and responsible use of water resources (see Appendix A for a comprehensive list), including:

- Promoting water conservation, including developing conservation goals, piloting conservation strategies, and evaluating results.
- Enhancing storm and surface water management, including implementing a stormwater source control program and considering rebates for stormwater retrofits.
- Spreading out production wells, evaluating interties between large systems and increasing public water storage. These three actions each have independent benefits but are likely to be pursued together as part of a coordinated effort with KPUD.
- Consolidating smaller water systems and users with larger public systems, which will reduce reliance on shallow aquifers, and ultimately allow more regulation regarding the use of water resources.
- Evaluating and implementing Managed Aquifer Recharge, including following through on the Manzanita Stormwater Recharge Park project, which is currently grant-funded.

Ultimately, the findings from the GWMP indicate that the City is not currently in a groundwater crisis. If managed responsibly, the Island's water supply for human consumption is secure for the 20-year planning horizon given steady population growth combined with changes in climate. Increased water conservation and managed aquifer recharge are necessary to prevent impacts on surface water and

streams, and to provide resiliency for human consumption in the 50-year horizon and beyond.

1. Introduction

1.1 Groundwater Management Plan Vision

The entire Bainbridge Island community—residents, workers, and visitors alike—depends on groundwater for all water supply needs. Groundwater also plays a vital role in supporting healthy streams and wetlands and maintaining the saltwater/freshwater boundary that ensures an ongoing supply of fresh water. The City of Bainbridge Island (City) recognizes that management of this precious resource requires a sustainable, Island-wide approach. To meet this need, the City’s 2016 Comprehensive Plan directs that a Groundwater Management Plan (GWMP) be developed as an adaptive planning tool.

1.2 Groundwater Management Plan Goals and Objectives

In 2021, the City Council established the following high-level goals and objectives for the GWMP (Figure 1).

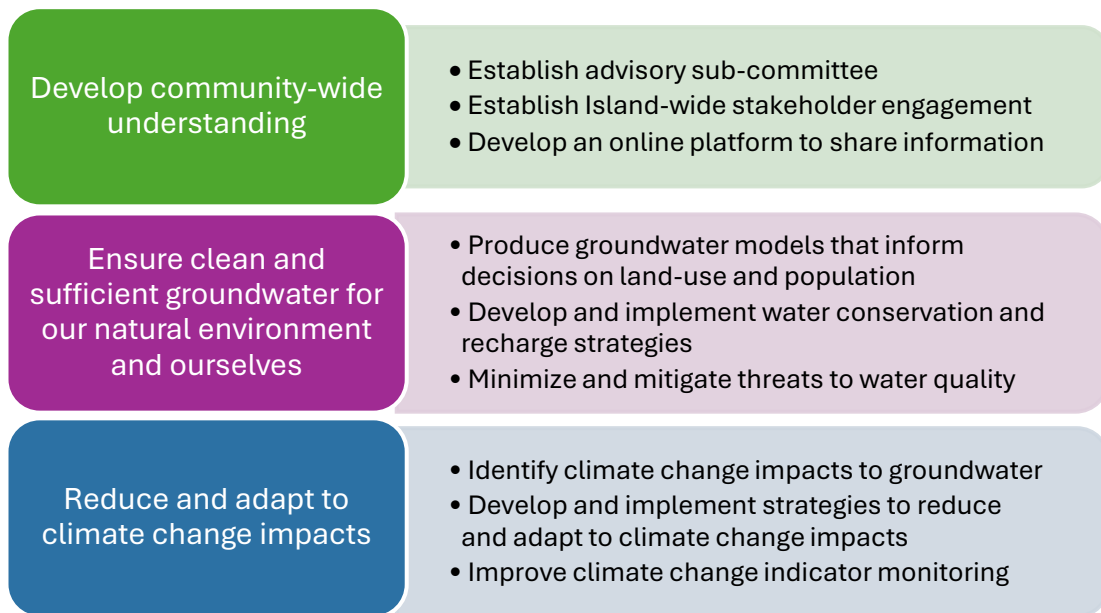


Figure 1 Groundwater Management Plan Goals and Objectives

Beneath the surface of these high-level goals and objectives are some important details regarding emphasis and priorities of the GWMP:

- As Bainbridge Island is entirely dependent on groundwater, the plan goals and objectives emphasize safeguarding this vital resource through robust

protection measures, while also addressing critical data gaps and research needs that influence long-term sustainability. The Island's complex network of aquifers not only supports the drinking water supply for residents, workers, and visitors; it also sustains healthy streams and wetlands throughout the Island. Ensuring the health of this system requires coordination among multiple partners, including the U.S. Geological Survey (USGS), the City, Kitsap Public Utility District (KPUD), Washington State Department of Ecology (Ecology) and Department of Health (DOH), and the Kitsap Public Health District (KPHD).

- Development management is a key issue, as the Island must plan to accommodate additional new housing units by 2044 to meet population growth projections mandated under the Washington Growth Management Act (GMA). The GMA requires local jurisdictions to ensure adequate housing capacity for future residents while protecting critical areas and natural resources. Therefore, the plan goals and objectives seek to address the impacts of development on the aquifer systems.
- The goals and objectives prioritize building upon the established monitoring network of 87 wells across six aquifers and emphasize community involvement through education and volunteer programs. Adaptive management is a guiding principle of this approach, ensuring the plan evolves in response to new data gathered through ongoing assessment.

Altogether, the plan goals and objectives reflect Bainbridge Island's unique position as an Island community entirely reliant on groundwater. It integrates strategies to manage increasing development pressure, climate change impacts, and the technical complexities of maintaining a safe, sustainable aquifer system. Through coordinated, adaptive, and community-focused efforts, the City is working to ensure the long-term protection and resilience of its most critical natural resource.

1.3 Groundwater Management Plan History

Bainbridge Island's groundwater system has been extensively studied for decades by federal, state, and local agencies. Highlights include:

- USGS investigations (1950s to 2016)
- Groundwater data from the City and KPUD (1980s to present)
- Hydrogeologic studies by Ecology (1980s to present)
- Groundwater Management planning by Kitsap County (1991)
- Water quality and supply monitoring by the DOH and KPHD (1970s to present)
- Cleanup efforts related to the Wyckoff/Eagle Harbor Superfund Site (EPA, 1980s to present)
- Consultant reports, including Aspect Consulting's contributions to groundwater modeling and monitoring protocols (2006, 2009, 2015, 2023)

Bainbridge Island's aquifer system is designated as a Sole Source Aquifer by the U.S. Environmental Protection Agency (EPA). This designation, initiated by Island residents in 2009, means all federally funded projects on the Island are subject to EPA review to prevent aquifer contamination. Projects posing potential risks may require modification or face denial of federal funds.

The City's 2016 Comprehensive Plan, which is in the process of being updated in June 2026, also includes Water Resources Element 6, which outlines a vision for climate-resilient water systems supported by groundwater monitoring, model updates, public education, and low-impact development techniques (LID). These measures support long-term sustainability and inform adaptive management.

Development of the formal GWMP began in 2020, when the City hired an in-house hydrogeologist, Maureen Whalen, to lead the initial efforts. Upon her departure in 2022, the City then hired the consulting team, EA Engineering, in 2023 to update the model and complete the plan, a draft of which was finalized in April 2025. Most recently the City worked with Keta Waters, LLC to finalize the Plan. A bibliography of supporting reports is provided in Appendix B and other related information is accessible via the City's [Water Resources Library](#).

1.4 Groundwater Management Plan Public Engagement

The GWMP was developed through a collaborative process involving residents, water purveyors, the Suquamish Tribe, local, state and federal agencies. Public input helped shape GWMP policies, milestones, and management initiatives. Public engagement efforts are detailed in Appendix C.

The GWMP Advisory Subcommittee, composed of members from three City Advisory Committees (Utility Advisory Committee, Environmental Technical Advisory Committee, Climate Change Advisory Committee), collaborated with staff to ensure the plan aligns with local needs. Technical expertise was provided by a Technical Advisory Committee (TAC), which includes representatives from KPHD, KPUD, the Suquamish Tribe, and Ecology. The Subcommittee and TAC focused on the following areas:

- Groundwater system characterization
- Updated numerical groundwater modeling
- Monitoring network evaluation
- Groundwater/surface water interaction
- Impacts of land use, septic systems, and climate change
- Effects of population growth on groundwater

The TAC charter is included in Appendix D.

2. Jurisdictional, Physical, and Hydrological Setting

This section provides a general description of existing conditions including location, history, government structure, land and water management authorities, physical setting, and hydrogeology.

2.1 Location

Bainbridge Island, an all-Island city, is in the Puget Sound lowland of west-central Washington on the east side of the Kitsap Peninsula in Kitsap County (Figure 2). The Bainbridge Island groundwater management area encompasses the entire Island.

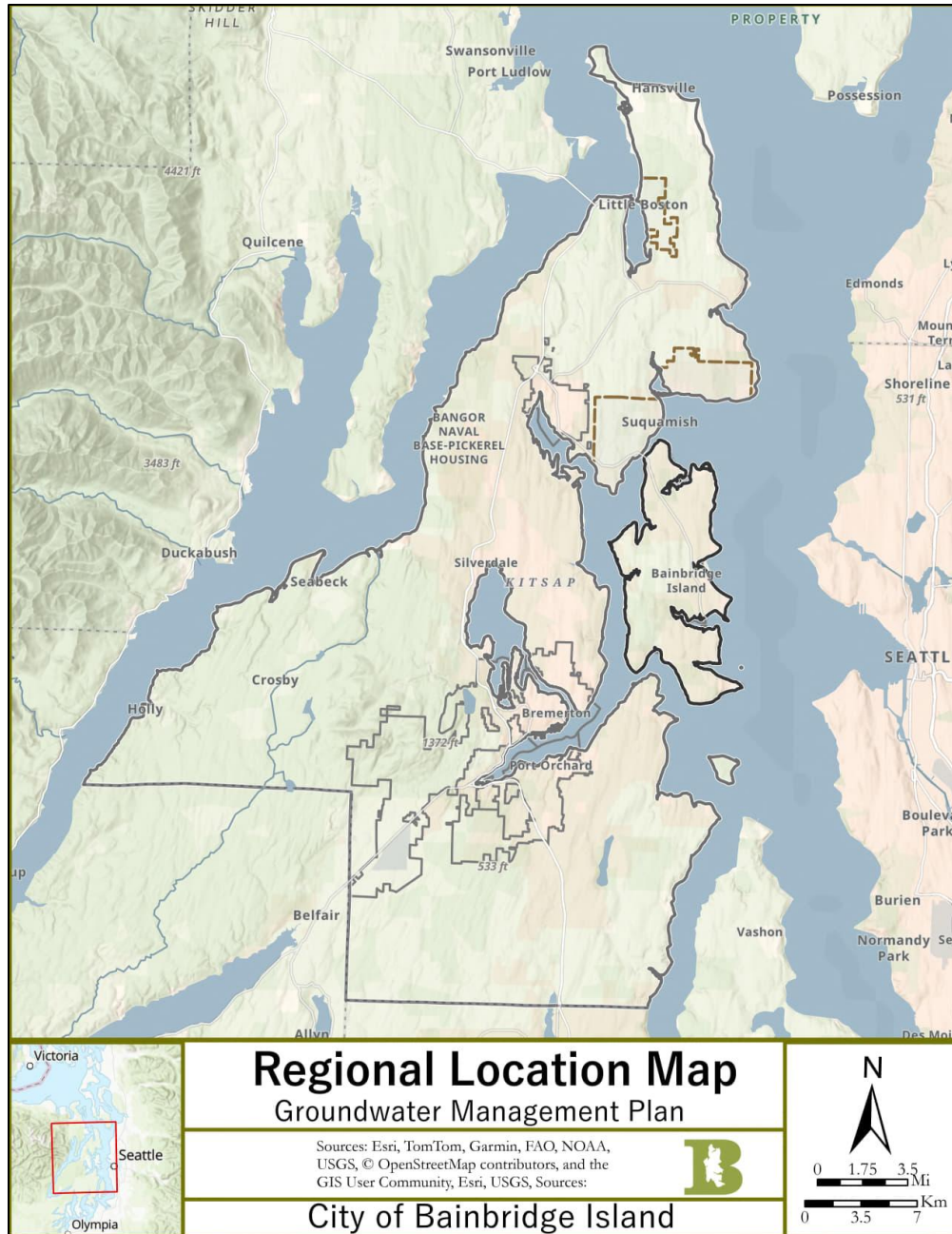


Figure 2 City of Bainbridge Island Location

2.2 Bainbridge Island history

Native American histories indicate that ancestral peoples have lived in the Pacific Northwest since time immemorial. Archaeological evidence supports the deep antiquity of Native peoples in the region by providing material evidence for the local presence of ancestral peoples prior to 12,000 years ago (Carlson 1990; Kopperl, et. al.) and as early as roughly 16,000 years ago. Generally, the earliest

known archaeological sites in the Pacific Northwest were occupied shortly after widespread regional deglaciation allowed much of the land to be habitable.

Suquamish tribal members first inhabited Bainbridge Island and the Kitsap Peninsula around 13,000 years ago and continue to live in the area to the present day. The Suquamish People and other People of the Salish Coast Water occupied winter villages and seasonal camps throughout the Island as they fished, hunted, collected shellfish, and gathered plants and other vegetation resources.

Non-native settlement of the Island began in the mid-1800s primarily to support milling and shipbuilding activities. Commercial agriculture centered on strawberry farms developed in the early 1900s by Japanese immigrants. World War II abruptly altered Bainbridge Island's economy, as Executive Order 9066 ordered West Coast Japanese relocated to internment camps for the war's duration. This resulted in a severe disruption of strawberry farming from which it never fully recovered (COBI 2017).

In 1937, scheduled auto ferry service from the Island to Seattle started and in 1950 the Agate Pass Bridge and State Highway 305 directly linked the Island to the Kitsap Peninsula. With easier access to Seattle and Kitsap Peninsula came an increase in population, especially in the 1960s and 1970s (COBI 2017).

For much of the twentieth century, Bainbridge Island largely consisted of unincorporated areas and the City of Winslow (incorporated on August 23rd, 1947). On February 28th, 1991, the unincorporated area of Bainbridge Island was annexed into the City of Winslow. On November 5th, 1991, voters approved changing the name from City of Winslow to the City of Bainbridge Island (Figure 3).

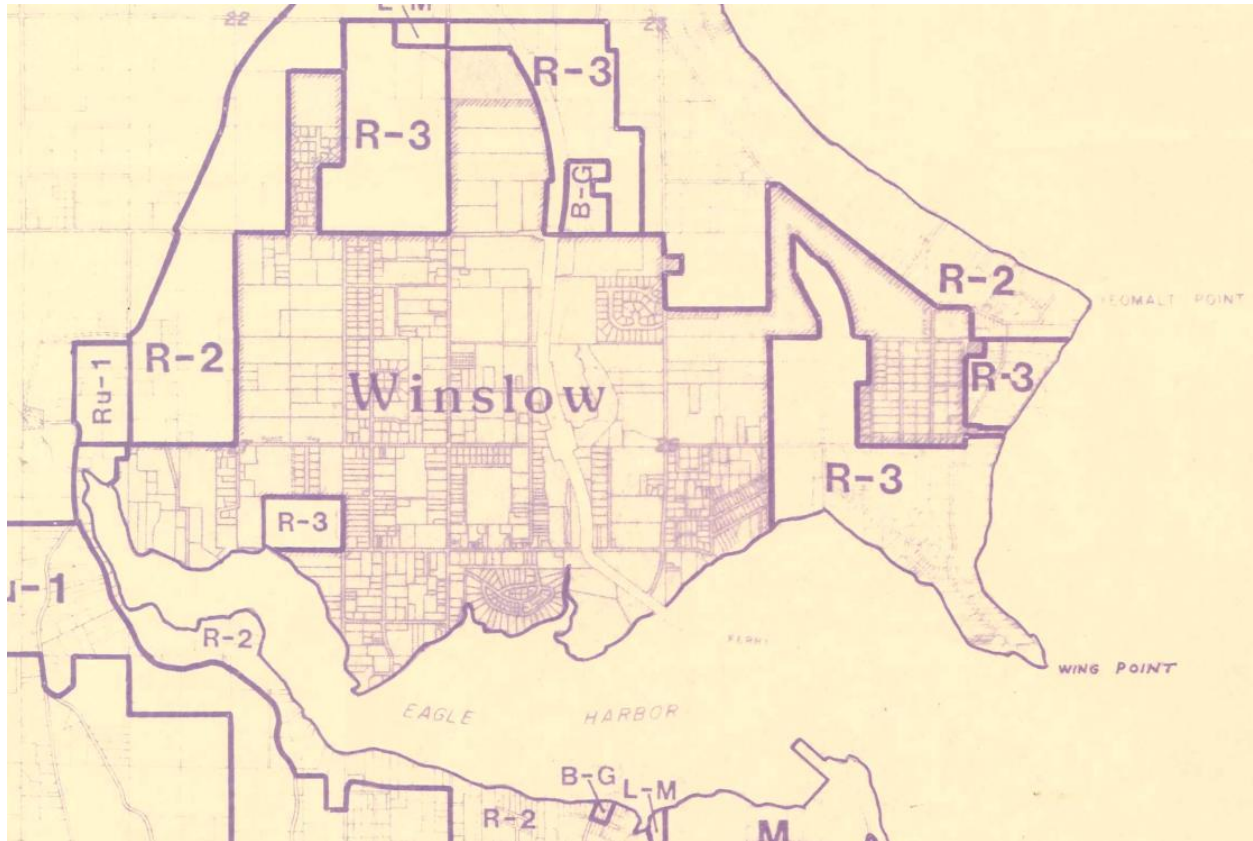


Figure 3 Former City of Winslow Map, 1983

2.3 City of Bainbridge Island Government

The City's government structure employs a non-charter code system with a council/manager. The City Council is an elected body and sets public policy by enacting ordinances, establishing budgetary policies, and defining roles and responsibilities of the City's officers and employees. The City Manager is appointed by and is directly accountable to the City Council. The City Manager is responsible for the execution of City policies and the administration and management of City departments (COBI 2021).

2.4 Land and Water Management Authorities

The GWMP generally follows the requirements of WAC Chapter 173-100, Groundwater Management Areas and Programs, and also looks to related land and water management plans, policies and regulations focusing on other City environmental, planning and development concerns at the local, regional and state

level. The GWMP nests within these plans, policies, and regulations, providing a central living document for the community and the City to use. These related plans, policies, and regulations are briefly summarized in this section with a high-level discussion of links to the GWMP.

Indigenous Treaty Rights

Though the Treaties of Point Elliot and Point No Point do not specifically govern the groundwater resource, the modern understanding of the hydrologic cycle connects the two topics through the relationship of groundwater use and diminished streamflow and thus reduced habitat for salmon. Inherent in the treaties was the continued ability to take fish in the “usual and accustomed grounds and stations.”

Indigenous rights and cultural values are deeply respected in the City's land and water management approach, acknowledging the Suquamish People's historical connection to these lands and waterways (COBI 2025).

2.4.1 City of Bainbridge Island Municipal Code

Title 16 (Environment) of the City Municipal Code provides key protections for groundwater resources, primarily through Chapter 16.20 – Critical Areas. This chapter mandates the designation and protection of ecologically sensitive and hazardous areas, including features that safeguard water quality and groundwater recharge. The purpose is to “protect, maintain and restore these areas and achieve no net loss of their functions and values and allow for reasonable use of public and private property.”

Chapter 16.20.100 (Aquifer Recharge Areas) specifically recognizes that the entire Island is designated as an aquifer recharge area under WAC 365-190-100. This classification is intended to preserve the volume of recharge and prevent groundwater contamination. Projects that meet certain thresholds, such as those that propose the creation of more than 800 square feet of impervious surface may require the designation of an Aquifer Recharge Protection Area, a hydrogeologic assessment, and, if necessary, a mitigation plan to minimize impacts.

BIMC 16.20 is the City's principal regulatory tool for aquifer protection and includes standards such as buffers for wetlands and streams, which help preserve both surface and groundwater quality. However, the City's approach to managing land

and water extends beyond Title 16. Other chapters, particularly BIMC 15.19 and 15.20, which govern water and sewer utilities, also play a critical role in protecting groundwater resources and managing development impacts.

In addition to the Municipal Code, the Bainbridge Island Comprehensive Plan establishes long-range policy direction that shapes how land is used and water resources are managed. While the Comprehensive Plan does not carry the same regulatory authority as the code, several of its elements including Land Use, Housing, Environmental, and Water Resources directly influence the form, location, and cumulative impact of development on natural systems, including groundwater recharge and quality.

Further, the City's Stormwater Management Plan provides operational and planning guidance for reducing nonpoint source pollution and managing runoff in a way that protects both surface water and groundwater. Together, these documents contain statutory regulations, adopted plans, and technical guidance, form a layered and coordinated framework for sustainable land and water management on Bainbridge Island.

2.4.2 City of Bainbridge Island Water System Plan

The City's Water System Plan was updated in 2017 in accordance with WAC 246-290-100 and Washington State DOH requirements. The City owns and operates two water systems, the Winslow Water System and the Rockaway Beach Water System.

The Winslow Water System consists of 11 active wells at four well sites. The seven wells at Head of the Bay supply approximately 25% of the water system. Two wells at the Sands Avenue well site provide 45% and one well at Fletcher Bay provides 30%. There is one other active well (Commodore) that is rarely used due to low production capacity and previous water quality concerns.

Two wells at the Head of the Bay well site and the one well at Commodore well site have been determined by Washington DOH to have moderate to high susceptibility to contamination. Two of the Head of the Bay wells and the Commodore Well tested higher than the maximum contaminant level (MCL) for manganese during April 2015 field tests. The Sands Avenue wells have exceeded limits for two secondary maximum contaminant levels; sodium and color. These exceedances are

primarily due to the geologic conditions where the well is located and are naturally occurring.

In 2015 the Winslow Water System had an average daily demand (ADD) of 0.68 million gallons per day (MGD). Growth projections indicate an average daily demand of 1.24 MGD by 2035 (this assumes a medium level of water demand and all eligible parcels become connected). Current usage consists of 50% single family residential, 15% multi-family residential and 35% other (government, commercial, industrial).

The Rockaway Beach Water System is supplied by one well (Taylor Avenue) which has been designated by the Washington Department of Health as having low susceptibility to contamination. The only exceedances recorded are for the secondary MCL for manganese. The 2007 maximum daily demand (MDD) exceeded the Taylor Avenue well pumping capacity. Although MDD has been significantly lower in recent years, MDD was projected to approach the Taylor Avenue Well capacity by 2035. To correct this, the Taylor Avenue Well was rehabilitated and an intertie was added to KPUD's neighboring water system to increase supply. Since these improvements, further modeling is needed to identify if the current supply capacity for the Rockaway Water system is sufficient to comply with the City's supply reliability criteria which are as follows:

Criterion 1 – **Reliable MDD Supply**. Reliable sources are capable of supplying MDD within a 24-hour period.

Criterion 2 – **Average Daily Demand (ADD) Supply with Largest Source Removed**. Reliable sources are capable of supplying ADD with the largest source out of service.

Criterion 3 – **Fire Storage Replenishment**. Sources are capable of supplying MDD and replenishing fire suppression storage in 72 hours.

Criterion 4 – **Firm Booster Pump MDD Supply**. Booster pump is capable of supplying MDD of the water system with firm, reliable capacity.

Water supply for the rest of the Island is provided by many different water purveyors of both Group A and Group B and permit-exempt wells taking less than 5,000 gallons per day.

The following is a simplified set of definitions of water system types (for more detailed definitions refer to WAC 246):

Group A Systems have more than 14 connections.

Group B Systems have 3 to 14 connections.

Permit-exempt wells have 1-2 connections.

Both Group A and Group B public water systems are required to provide information to the Washington State DOH regarding water source details, water quality monitoring schedule and sampling results, and water use efficiency. Group A water systems are required annually to complete and make publicly available a consumer confidence report (Washington State DOH, no date). The consumer confidence report must include information regarding the source of water, water quality monitoring results, compliance with drinking water regulations, and appropriate educational information. An example of reporting requirements can be found in the City's annual water quality report for the [Winslow Water System #97650](#).

2.4.3 City of Bainbridge Island Climate Action Plan

The [City's Climate Action Plan](#), adopted in November 2020, sets three goals in response to direction given in the Comprehensive Plan to reduce greenhouse gas emissions and increase the Island's climate resilience. Progress reports are available from 2023. The three goals are:

Mitigation: Greenhouse gas emissions are reduced by 90% by 2045 compared to 2014 levels with interim milestones of 25% reduction by 2025 and 60% by 2035 compared to 2014 levels.

Adaptation: Bainbridge Island is climate savvy and can withstand the impacts of climate change.

Community Engagement: the City inspires community action and partners with local and regional organizations to take meaningful and equitable climate change mitigation and adaptation actions.

The Climate Action Plan recognizes several climate impacts that are relevant to groundwater management, including changes to timing and extent of groundwater

recharge, rising sea levels, increased erosion, potential saltwater intrusion, and groundwater/surface water interactions. About water resources, the plan sets the following goals:

- Steward natural resources to function as healthy, resilient ecosystems
- Protect and maintain integrity of Island's surface and groundwater resources in the face of climate change
- By 2025, the City will adopt a Groundwater Management Plan that accounts for climate change in its projections, policies, and guidance
- Steward shorelines to allow for resilience

2.4.4 Kitsap County Code

In most cases, the City's Municipal Code is the primary regulatory authority, however, it is worth noting that the Kitsap County Critical Areas Recharge Ordinance 19.600 provides policy support to identify, preserve, and protect these critical areas, to recognize the connection between surface water and groundwater and to prioritize potable water resource areas per WAC 365-190-100 when undertaking land use planning and regulation. The ordinance also seeks to balance competing needs for water supply while preserving natural functions and processes.

Ordinance 19.600 provides for two categories of Critical Aquifer Recharge Areas. Category I Critical Recharge Areas are defined by the time it takes water to travel from the ground surface to the water supply well (either five years or 10 years if the well takes water from an aquifer at or above sea level with no intervening protective impermeable layer). Category I areas also include significant recharge areas identified as having special circumstances or significant potable supply that is susceptible to groundwater contamination. Category II Critical Aquifer Recharge Areas provide recharge to aquifers that are currently or potentially will become potable water supplies and are vulnerable to contamination based on land use.

Bainbridge Island contains both Category I and II Critical Recharge Areas. Category I areas have been delineated for the City, KPUD and Group A water suppliers. Most of the remaining area on Bainbridge Island is included in Category II Critical Aquifer Recharge Areas. Inclusion in Category I or II indicates that certain land use that can

potentially negatively impact groundwater quality are either prohibited (Category I) or restricted (Category II). A hydrogeologic assessment may be required.

In 1991 Kitsap County and KPUD completed the Kitsap County Groundwater Management Plan that includes recommendations for the Bainbridge Island subarea. See Appendix B for more information on related plans and documents.

2.4.5 Kitsap Public Utility District

KPUD is a municipal corporation serving Kitsap County, with a focus on water resource management, wholesale water supply, and support for local water systems. Established in 1940, the district plays an important role in ensuring reliable water availability across the county, including infrastructure development and coordination with local jurisdictions. KPUD also owns and manages two of the larger water systems on Bainbridge Island. In addition to its operational responsibilities, KPUD contributes to regional groundwater management through monitoring, data collection, and collaboration with other agencies and stakeholders, including the City.

2.4.6 Kitsap Public Health District

KPHD is responsible for the oversight of construction and monitoring of all Group B water systems in Kitsap County as well as assisting the Washington State DOH by inspecting Group A systems with up to 100 connections (KPHD 2018). Larger Group A systems remain under the oversight of the Washington DOH. The oversight of Group B systems by KPHD includes newly required annual operating permits, recordkeeping, and water testing requirements. Sampling requirements for Group B systems include annual bacteria testing and nitrate testing every three years (Washington State DOH, no date) (KPHD 2018). In Kitsap County, Group B well systems are required to apply for an annual operating permit from the KPHD. Kitsap County has an exemption, allowing a two-party water system that meets certain criteria to qualify as a private two party well (KPHD 2018).

Permit-exempt (PE) wells, usually associated with single family homes, are also regulated by KPHD. Property owners of PE wells are responsible for testing their own water quality based on guidance from KPHD. Additional information regarding PE wells is included in the section on the Washington Department of Ecology.

KPHD is also responsible for design review, permitting, and oversight of inspection and maintenance for on-site septic systems that treat wastewater in areas outside of municipal sewer systems (Kitsap County Public Health District 2018).

2.4.6 Washington Department of Health

The Washington State Department of Health (DOH) Office of Drinking Water is responsible for oversight of public water systems. Public water systems are defined as those systems which serve more than one or two single family residence(s) or more than one industrial plant (WAC 246293110). Public water systems are grouped into Group A public water systems and Group B (Washington State DOH, no date). Washington State DOH is also responsible for oversight of large on-site septic systems (LOSS). Bainbridge Island is host to at least four of these systems.

2.4.7 Washington Department of Ecology

The Washington State Department of Ecology (Ecology) is responsible for establishing and managing water rights state-wide under chapters 90.03 RCW and 90.44 RCW, and associated laws and regulations. Chapter 90.03 RCW was adopted for surface water rights in 1917. Chapter 90.44 RCW was adopted for groundwater rights in 1945. Water rights are required for any beneficial use of surface water and for beneficial use of groundwater over 5,000 gallons per day. Permit-exempt wells constructed prior to 2018 are allowed "... any withdrawal of public groundwaters for stock-watering purposes, or for the watering of a lawn or of a noncommercial garden not exceeding one-half acre in area, or for single or group domestic uses in an amount not exceeding five thousand gallons a day, or as provided in RCW 90.44.052, or for an industrial purpose in an amount not exceeding five thousand gallons a day ..." (RCW 90.44.050). Permit-exempt uses are water rights with a priority date of first use, which are not required to undergo the permit-application process. Because of incomplete records, especially for older wells, the exact number of PE wells on Bainbridge Island is not known. The current estimate for the number of these wells on Bainbridge Island is 1,700, but ranges from 1,200-2,400. A compilation of available well logs is included in Appendix G.

All water rights include attributes of priority date, source of water, location of withdrawal or diversion, place of use, purpose of use, period of use, instantaneous withdrawal or diversion rate, annual withdrawal or diversion rate and authorized

beneficial use. Water rights are managed under the prior appropriation system, also known as “first in time, first in right”. This means that older, or senior, water rights have priority over more recent, or junior, rights within the same water source so when supplies are limited, junior rights can be shut off to satisfy the senior rights. Attributes of surface water right certificates can be changed by applying to Ecology. Groundwater permits and certificates can also be changed through an application process. Water rights are issued in perpetuity although they can be relinquished after a 5-year period of non-use.

Water right permits can be issued by Ecology if a 4-part test is satisfied. The 4-part test includes:

- Water is physically and legally available for the intended use.
- Use of the water will not impair a senior water right.
- Water will be put to a beneficial use.
- Use of the water will not be detrimental to the public welfare.

For surface water uses that began prior to 1917 or groundwater uses that began prior to 1945, the water right claim process is used to register that use without specifying quantity or undergoing verification. A water right claim is therefore not the same as a water right. The water right claim must go through an adjudication process in Superior Court to establish validity and confirm attributes. There are currently 1,622 claims listed in Ecology’s water rights database for Bainbridge Island, making up 88.5% of all water right documents on the Island.

Ecology has the authority to review and approve or deny water right permit applications and will issue a water right permit that impacts a closed stream only if it is determined that the impacts to the closed stream will be fully mitigated. Streams that are closed are shown in Figure 4. A summary of water right records for Bainbridge Island is included in Table 1. As shown, the number of water right claims, yet to be adjudicated, far outnumber all other type of water right records. Most claims are for single connection domestic use from either small springs or wells.

Table 1 Water Right Documents on Bainbridge Island

Document Type	Number of Records
Certificate	190
Change Application	1
Claim	1622
New Application	1
Permit	15
Superseding Certificate	1
Superseding Permit	1
Grand Total	1831

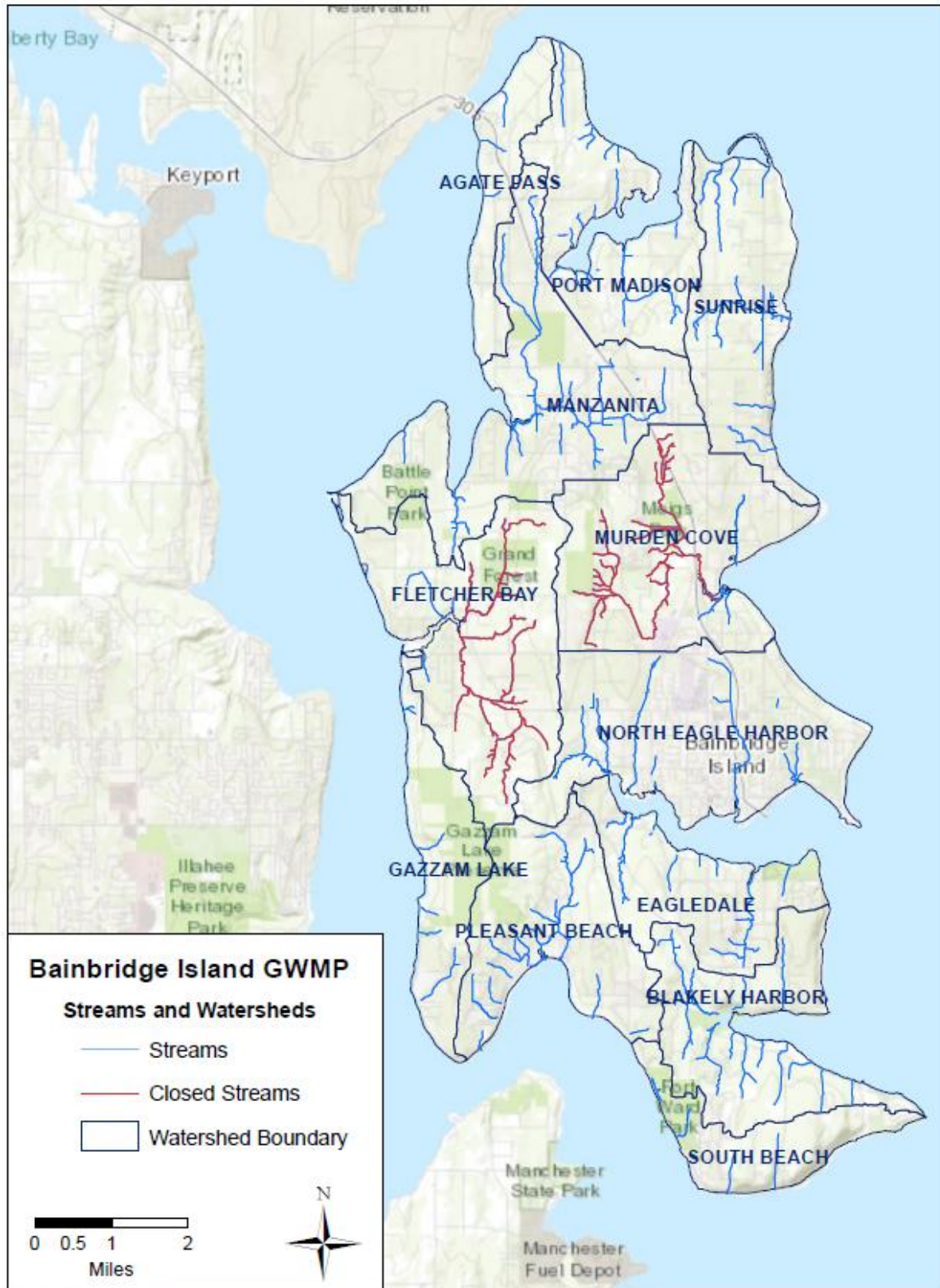


Figure 4 Closed Streams per WAC 173-515

A recent search of the Ecology water rights database (Ecology 2025) indicates about 205 active permitted and certified groundwater rights with a cumulative instantaneous rate (Qi) of 6,810 gallons per minute (gpm) and an annual quantity (Qa) of 5,118 AFY. In 2000 Kato and Warren estimated slightly different permitted and certified groundwater rights totals of 5,378 AFY. They also identified 2,183 AFY for surface water rights.

2.4.8 Washington Streamflow Restoration Act (Chapter 90.94 RCW)

The 2018 Streamflow Restoration Act (Chapter 90.94 Revised Code of Washington (RCW)) codifies the Engrossed Substitute Senate Bill 6091 which provides for response to the 2016 Washington State Supreme Court “Hirst decision.” The “Hirst decision” required counties and cities to make decisions about whether sufficient water was available from both a physical and legal point of view prior to approving a building permit that relied on water provided by a permit-exempt well for domestic water supply. Prior to the “Hirst decision,” counties often relied on Ecology for this determination. The Streamflow Restoration Act recognizes that permit-exempt wells may impact instream flows and requires local watershed planning efforts, including Watershed Resources Inventory Area (WRIA) 15 which encompasses all of Kitsap County, including Bainbridge Island (Ecology 2019).

The use of new PE wells that are exempt from water right permitting under RCW 90.44.050 within WRIA 15, including all of Bainbridge Island is limited after 2018 in accordance with the Streamflow Restoration Act (Chapter 90.94 RCW) and HB 6091 Section 203 (Washington State 65th Legislature 2018) which requires the following:

Maximum annual average withdrawal of 950 gallons per day (GPD) per connection (346,750 gallons per year) with a possible drought restriction of 350 GPD for indoor use only. Applicants must pay a five-hundred-dollar fee to the City prior to well connection and use.

2.4.9 National Pollutant Discharge Elimination System (NPDES) Program

Under Ecology’s NPDES Municipal Stormwater General Permit program, cities that own or operate a small municipal separate storm sewer system (MS4) serving a population of 1,000 to 100,000 (based on the 1990 Census) are required to be

covered under the Phase II Municipal Stormwater Permit. Ecology issues a Western Washington Phase II Municipal Stormwater Permit and an Eastern Washington Phase II Municipal Stormwater Permit.

The City owns and operates an MS4 and discharges stormwater directly into streams, wetlands, and Puget Sound, which are Waters of the United States protected by the Federal Clean Water Act. The City's MS4 discharges have been covered by the Western Washington Phase II Municipal Stormwater Permit (Permit or Phase II Permit) since 2007. The City must comply with all Permit sections and general conditions; principally, to protect water quality, reduce the discharge of pollutants from the MS4 to the maximum extent practicable, and meet Washington State's All Known and Reasonable Treatment (AKART) requirements.

The Permit provides general and prescriptive guidance for accomplishing compliance and requires the City to develop and implement a Stormwater Management Program (SWMP). SWMP requirements continue to grow and become more stringent with each new Permit reissuance every five years.

2.5 Physical Setting

This section provides details regarding the physical setting of Bainbridge Island including topography, geology, climate, vegetation, population and land uses.

2.5.1 Topography

Bainbridge Island is approximately 3.5 miles wide (east to west) and 10.5 miles long (north to south) covering about 27.5 square miles (17,600 acres) with 53 miles of coastline. The Island is bounded by Puget Sound to the east, Port Madison Bay to the north, Port Orchard Bay to the west, and Rich Passage to the south. The Island's topography is characterized by north-south trending rolling hills with a maximum elevation of about 400 feet above sea-level (Figure 5). Eagle Harbor, located on the east side of the Island, is the largest of several bays around the Island. There are also numerous harbors, coves, and lagoons. Coastline topography varies from flat to gently sloping to steep, nearly vertical cliffs particularly on the southern and eastern portions. Offshore topography to the west varies from the relatively shallow (approximately 25 ft deep) Agate Passage to the northwest to Port Orchard Bay (up to 130 ft deep). Puget Sound is the deepest (over 800 ft in some areas).

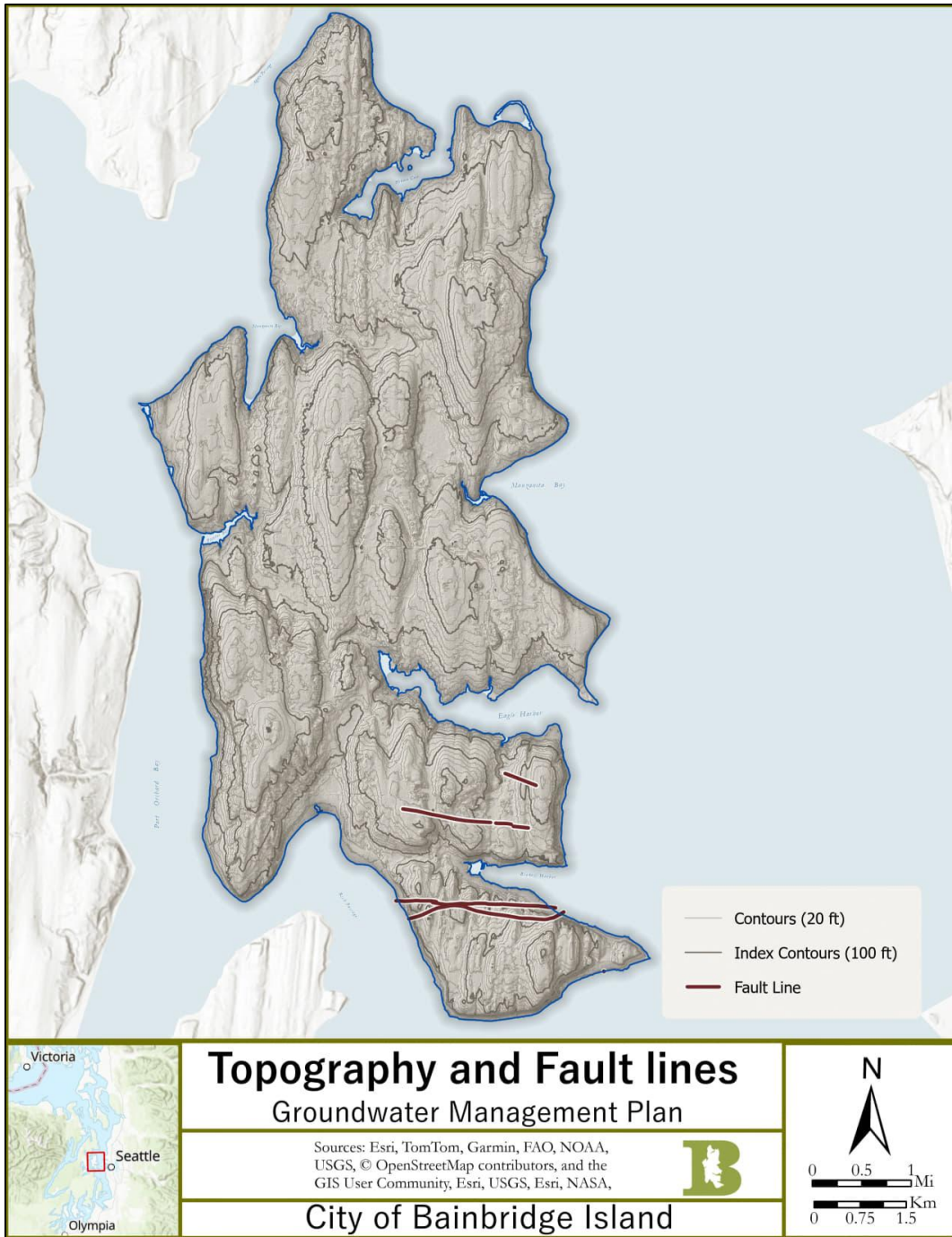


Figure 5 Bainbridge Island Locale and Topography

2.5.2 Geology

The Puget Sound Lowland is a structural basin formed and influenced by tectonic and glacial processes over millions of years. The convergence of the San Juan de Fuca plate with the more buoyant North American plate results in a subduction

zone along portions of the western coast of North America. These tectonic processes have resulted in the uplift of the Cascade Range, the formation of the Olympic Mountains, and major fault zones. Sediments from these areas eroded by water and glacial processes were and continue to be deposited into this lowland area (Jones 1999).

Bainbridge Island can be divided into two distinct geologic regions. The southern portion is composed of sedimentary bedrock approximately thirteen to thirty million years old. The central and northern portion is underlain by a complex sequence of unconsolidated sediments laid down during the last 300,000 years. The abrupt change to shallow bedrock in the southern portion is associated with vertical displacement along the Seattle fault zone (Figure 6).

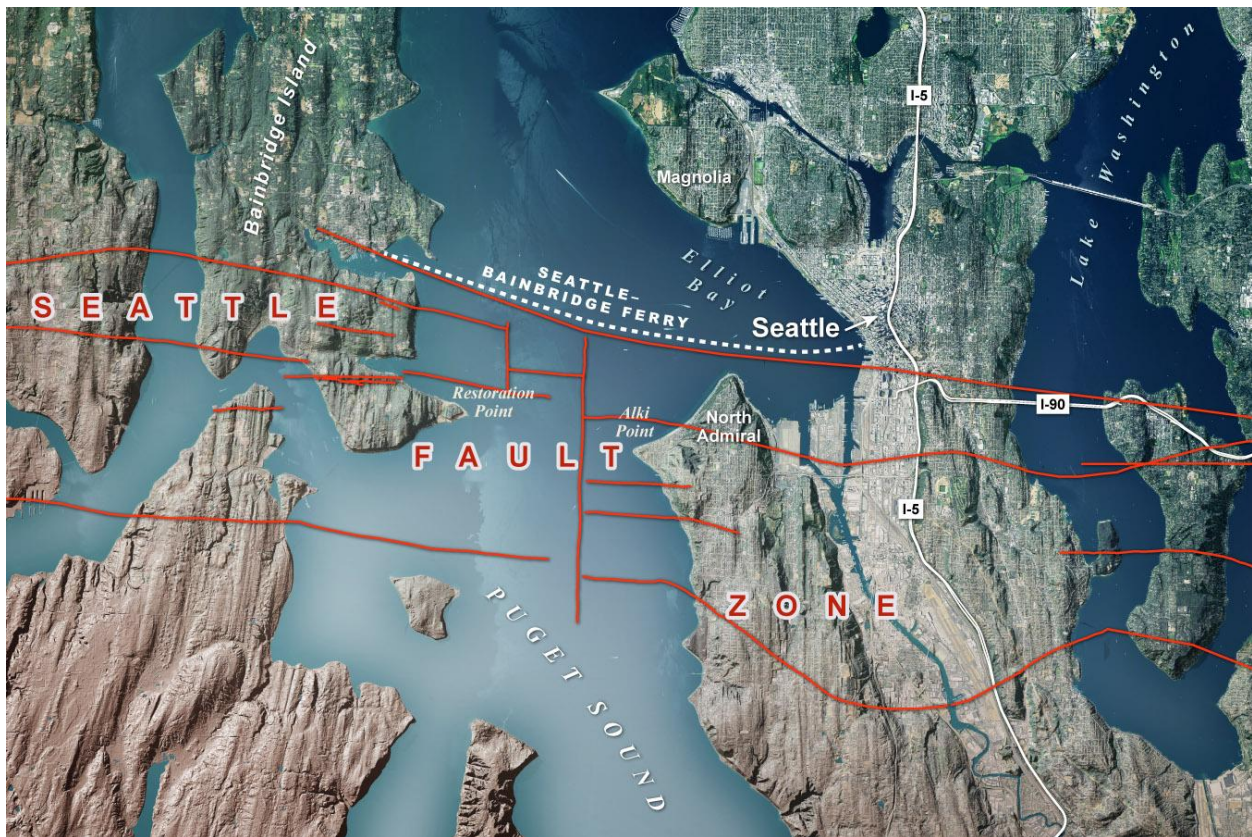


Figure 6 Seattle Fault Map

Source: WA Department of Natural Resources

Glacial advances and retreat coupled with changes in sea level has resulted in a complex mix of unconsolidated deposits. Due to the dynamic nature of glacial

environments, the thickness and lateral continuity of these deposits vary considerably across the Island. Most of the lower layers likely extend further to the west under Agate Passage and Port Orchard to the Kitsap Peninsula (Jones 1999).

The sediments laid down by meltwater from advancing or retreating glaciers tend to be coarse-grained (mostly sand and gravel). Where saturated, these deposits often yield groundwater in sufficient amounts to be considered a “good aquifer”. The other common glacial deposit is till, which is generally composed of a wide range of sediments (silt, sand, and gravel), compacted and is lower in permeability than outwash. Non-glacial deposits are made of up sediments carried and deposited by rivers, streams to and from wetlands, lakes, and ponds, along the coast, in estuaries, and in offshore environments (Frans *et al.* 2011).

Most of the thicker and more extensive non-glacial deposits underlying Bainbridge Island tend to be fine-grained and deposited in offshore environments. Like glacially deposited sediments, sediments in these non-glacial deposits range in size from clay to gravel. The coarser-grained layers also can yield enough water to be considered aquifers. It is worth noting that these are generalizations, and each deposit can contain a wide variety of materials, permeability, connectivity or hydraulic conductivity, and suitability as aquifer material (Frans *et al.* 2011).

2.5.3 Climate/Rainfall

Bainbridge Island is characterized by warm dry summers and cool wet winters with average temperature ranging from 39°F in the winter to 64°F in the summer and annual average precipitation of about 42 inches per year (COBI 2022c).

2.5.4 Vegetation

Prior to logging in the 1850s, Bainbridge Island was likely almost entirely covered in mixed evergreen forest, with pockets of deciduous trees in wetter or previously disturbed areas. Logging began in the 1850s and continued as large-scale clearing and sawmilling operations well into the 1920s, removing most of the Island’s old-growth forests. In the decades that followed, particularly by the early 1920s, much of the cleared land transitioned to agricultural use, including strawberry fields and pastureland. After World War II, as agricultural activity declined, much of this land was left fallow and naturally regenerated, primarily with Douglas-fir, forming the basis of today’s second-growth forests (Sheridan Consulting 2015). These forests

now support a diverse mix of evergreen and deciduous species and a varied understory. Additional residential development continues today, allowing for additional clearing. The forested areas that remain—including large tracts protected by the Bainbridge Island Land Trust and other private holdings—are, in many cases, more ecologically complex than in the years following the initial clear-cut era.

2.5.5 Population

The total population of Bainbridge Island in 2020 was 24,825, up from about 8,500 in 1970 (Figure 7). Winslow, the Island’s designated town center has a population of approximately 3,200, and additional smaller designated centers include Lynwood Center, Island Center, and Rolling Bay. While these areas represent the Island’s higher-density and primary commercial zones, most residents live outside of them, dispersed across lower-density neighborhoods and rural areas. In 2010, single-family housing made up approximately 81% of the Island’s housing units, with multi-family homes at 16% and mobile homes at 3% (COBI 2017). The “Conservation Area,” which comprises roughly 90% of the Island’s land area is zoned for lower-density residential development.

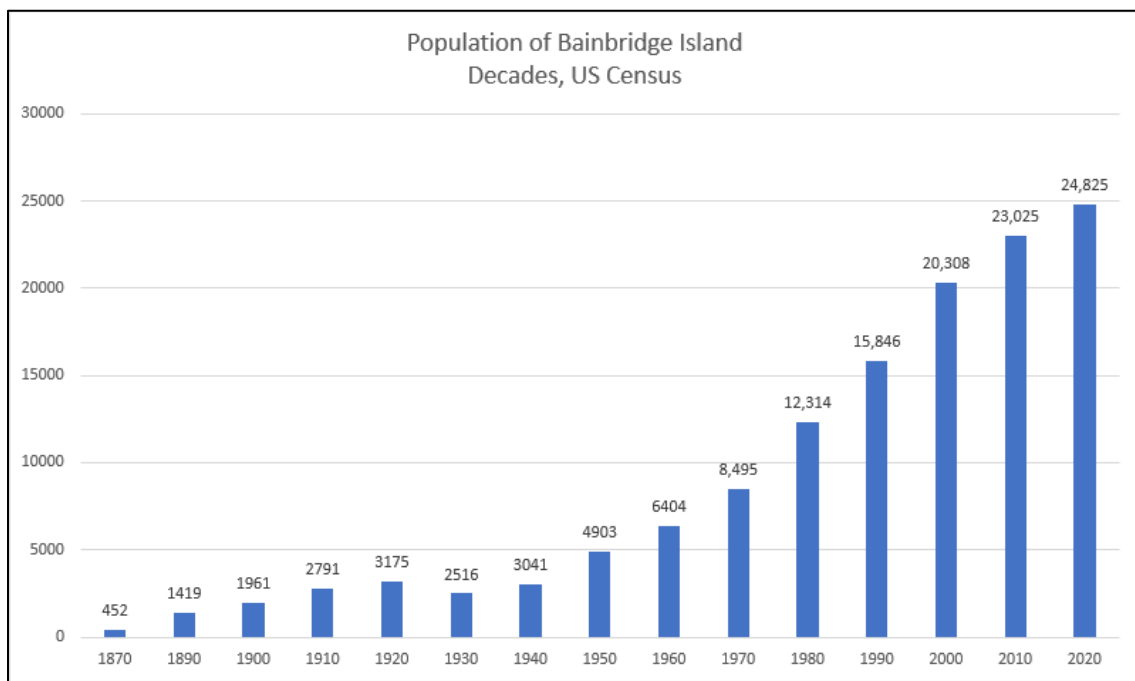


Figure 7 Bainbridge Island Population 1870 to 2020

Source: U.S. Census

Bainbridge Island is primarily a residential community with 75% residential land use; forest, agriculture, parks/recreational lands comprise 15%. The remaining 10% of land is used for transportation (6%), commercial/industrial (2%) and public facilities (2%) (COBI 2017). Building trends on Bainbridge Island reflect its predominantly residential character, with construction peaking in the late 1980s and gradually declining in recent years (Figure 8) indicating a maturing community with limited space for new development and an increasing emphasis on managing growth within existing land use patterns.

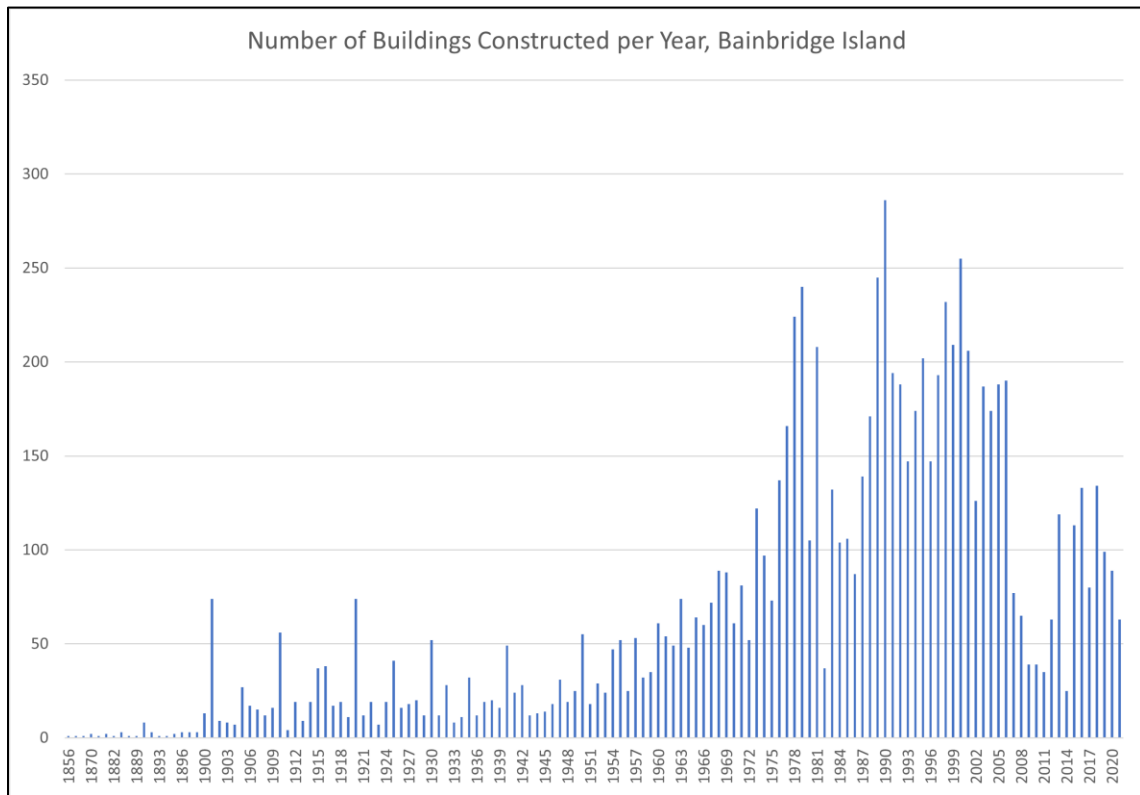


Figure 8 Number of Buildings Constructed on Bainbridge Island per Year

Source: Kitsap Parcel Data

2.5.6 Surface Water Resources

Water resources on Bainbridge Island consist of surface water, groundwater, and stormwater. These resources are often managed and regulated separately; however, they are inextricably linked.

There are 12 watersheds on the Island with wetlands of various sizes located throughout (Figure 9). Surface water drainage generally occurs via small spring-fed streams that discharge to Puget Sound. The streams are both perennial (approximately 30%) and seasonal (approximately 70%), and perennial streams are fed by springs and seeps in the upper watersheds. There are some surface water diversions for irrigation. Small ponds such as Meig's Pond, which was historically used for irrigation, are also found throughout the Island.

Streams in the Murden Cove and Fletcher Bay watersheds (Figure 4) are closed to further water right appropriations by Chapter 173-515 WAC except for a few exemptions. As such, these streams have no water legally available for new water rights and are protected from proposed future groundwater or surface water withdrawals that require water rights. This closure includes proposed water withdrawals directly out of the streams and groundwater withdrawals that would cause a reduction in streamflow. Because of this, any new groundwater rights or changes to existing rights, including adding new wells, or changing the place of use through interties may require mitigation for streamflow impacts before being approved.

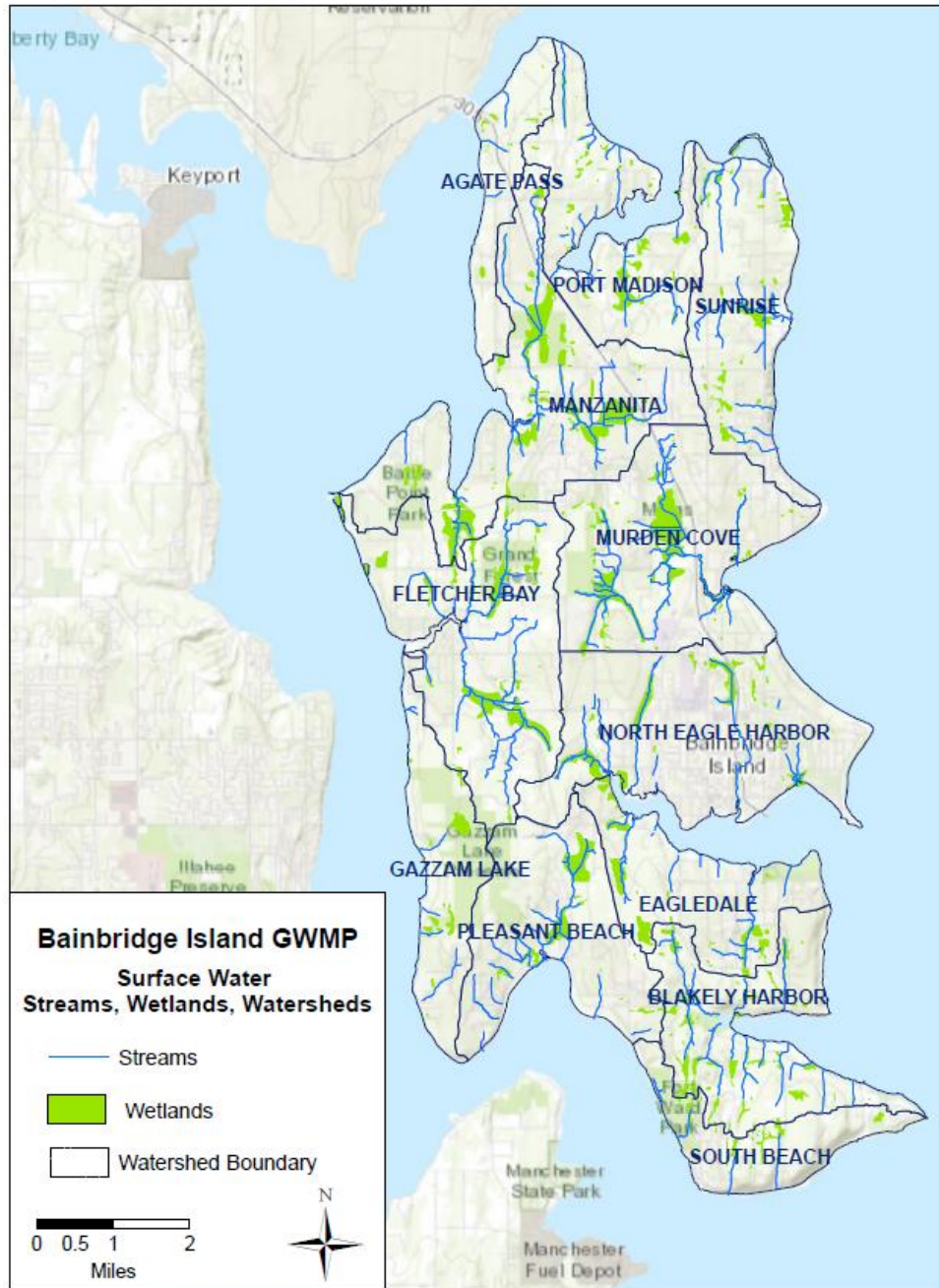


Figure 9 Bainbridge Island Surface Water (Streams, Wetlands, and Watersheds)

Stormwater runoff on Bainbridge Island is managed through a combination of built infrastructure and natural systems, such as wetlands and streams, working together to reduce the discharge of pollutants to Puget Sound. The built infrastructure consists of closed and open conveyances such as pipes and ditches, catch basins, and collection facilities such as detention/retention ponds and bioswales for flow-control and treatment. Most of the built infrastructure is

operated and maintained by the City while the rest is operated and maintained by private owners and entities.

2.6 Hydrogeology

2.6.1 Aquifers and Confining Units Underlying the Area

Most of the Kitsap Peninsula is underlain by unconsolidated geologic deposits similar in hydrogeologic characteristics and sequence to those underlying Bainbridge Island. (Unconsolidated deposits are comprised of clay, silt, sand and gravel that allow water to flow in pore space between grains). The available evidence suggests that deeper aquifers may extend from Bainbridge Island to the Kitsap Peninsula while the shallow aquifers are unconnected, as shown in Figure 10

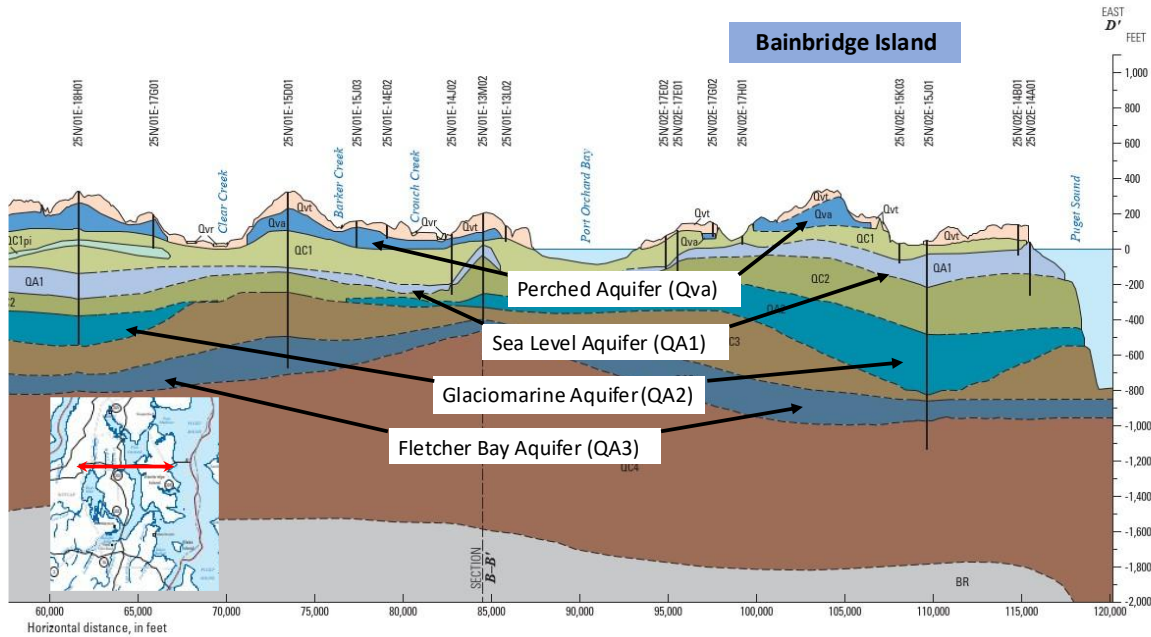


Figure 10 Cross-section of Hydrogeologic Deposits underlying Eastern Kitsap County

Source: Modified from Welch, Frans, and Olsen 2014

Generally, the glacial deposits make up the more productive aquifers underlying Bainbridge Island, and the non-glacial deposits, which are generally finer grained, make up the lower permeability layers or confining units between overlying and

underlying aquifers. The exception to this is glacial till, which is generally more fine-grained and often compacted.

The major aquifers underlying Bainbridge Island are briefly depicted below in order of increasing depth. The illustration (Figure 11) also depicts the complex interlayering of aquifers and confining units. The red arrow depicts the location on the Island of the cross-section or 'slice' through the underlying sediments shown in the diagram.

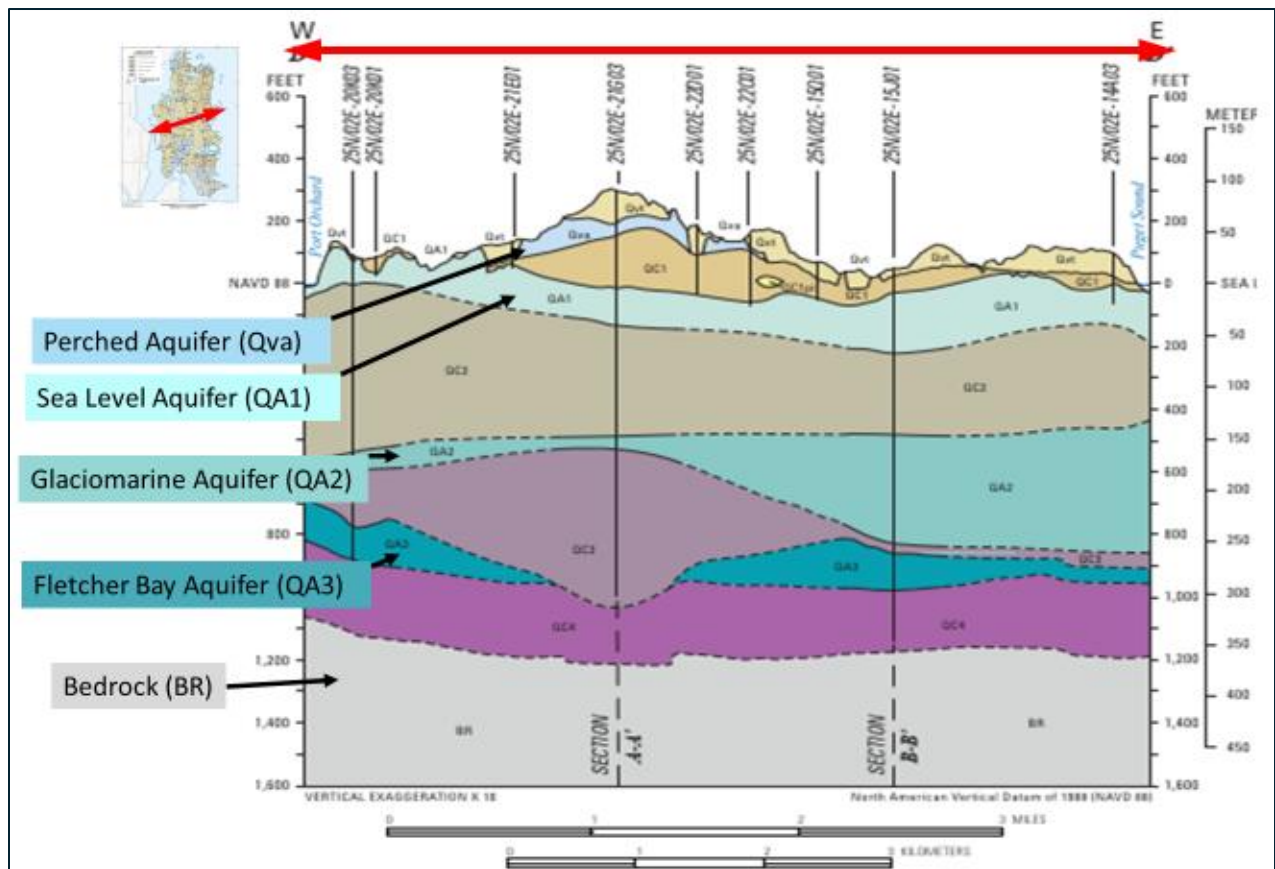


Figure 11 Cross-Section of Hydrogeologic Deposits underlying Bainbridge Island

Source: Modified from Frans et al. 2011

Perched Aquifer (identified as Qva in Figure 11) - The Perched Aquifer is comprised predominantly of Vashon Advance glacial outwash (Qva). The top of the aquifer ranges from sea level to more than 300 feet above mean sea level, with a thickness of 20 to 200 feet. The Semi-Perched Aquifer exists within permeable interbeds (QC1pi) of the upper confining unit (QC1) which is found below the

Perched Aquifer. The top of the Semi-Perched Aquifer ranges from sea level to more than 200 feet above sea level, with a thickness of 10 to 50 feet.

Much of the area previously mapped as SPA by KWRN 2000 was reclassified as PA by USGS when developing the Bainbridge Island groundwater model (Frans *et al.* 2011). These aquifers are utilized by predominantly domestic wells, and about 29% of wells are completed in these aquifers.

Though “Perched Aquifer” is used as a common name for the Vashon Advance Aquifer it should be noted that the terms “Perched Aquifer” and “Semi-Perched Aquifer,” have specific technical definitions in hydrogeology that imply hydraulic disconnection between shallow and deeper layers caused by an underlying unsaturated zone. There is no clear evidence that these layers are perched on Bainbridge Island. None of the groundwater models for Bainbridge Island treat these as perched or semi-perched aquifers. These shallow aquifers are hydraulically connected to deeper aquifers in the groundwater models described in Section 5.

Sea Level Aquifer (identified as QA1 in Figure 11) - The Sea Level Aquifer (QA1) is extensive, widely used, and mostly confined by QC1. The top of the aquifer ranges from 200 feet below to 200 ft above sea level, with a typical thickness of 25–200 feet. About 53% of wells are completed in this aquifer.

Glaciomarine Aquifer (identified as QA2 in Figure 11) - This aquifer consists of water-bearing units within a thick sequence of fine-grained glaciomarine deposits (QA2). The top of the aquifer ranges between more than 500–300 feet below sea level, with a typical thickness of 20–300 feet. Several of Bainbridge Island’s production wells and at least four domestic wells are completed in this aquifer, representing about 2% of wells.

Fletcher Bay Aquifer (identified as QA3 in Figure 11) - This aquifer (QA3) is the deepest identified aquifer on Bainbridge Island. Several high-capacity production wells are completed in this aquifer. The top of the aquifer ranges between more than 900 to slightly less than 600 feet below sea level, with a typical thickness of 50–300 feet. While representing only about 1% of wells on Bainbridge Island, the metered KPUD and City wells provide approximately 30% of the estimated total Island groundwater production.

Bedrock Aquifer (identified as BR in Figure 11) - Less than 1% of the wells on Bainbridge Island are completed in the sedimentary Blakely Harbor and Blakely formations on the south end of Bainbridge Island which form this aquifer.

The simplified terminology for the aquifers is summarized in Table 2.

Table 2 Aquifer Terminology

Name	Abbreviation
Perched Aquifer or Vashon Advance	Qva or PA
Semi-Perched Aquifer or Permeable Interbeds	QC1pi or SPA
Sea Level Aquifer	QA1 or SLA
Glaciomarine Aquifer	QA2 or GMA
Flecher Bay Aquifer	QA3 or FBA
Bedrock Aquifer	BR

2.6.2 Groundwater Flow

In confined aquifers groundwater flows from areas of higher water pressure (greater hydraulic potential) to areas of lower water pressure (lower hydraulic potential). In an unconfined aquifer, the interface between the unsaturated and saturated zone is called the water table. Unconfined groundwater flow is usually more directly influenced by precipitation and recharge. In a confined aquifer, all the aquifer material is saturated and groundwater flows in response to changes in water pressure (Frans *et al.* 2011).

The direction of groundwater flow can be measured by performing water level measurements in wells across an area. The depth to water for each well is converted to altitude above sea level by subtracting the water level measurement from a known measuring point elevation for that well. The water altitude measurements can then be illustrated on a map, like ground surface elevations on a topographic map. In an unconfined aquifer, the map of water altitude measurements identifies the water table. In a confined aquifer, the map of water altitude measurements is termed the 'potentiometric surface' (Frans *et al.* 2011). The surface of the water table and the potentiometric surface in confined aquifers

are not static and can change horizontally and vertically over time in response to precipitation, well pumping, etc.

Groundwater flow directions in the generally unconfined/semi-confined PA/SPA and confined SLA were mapped by the U.S. Geological Survey based on groundwater levels measured in 86 wells during a 2-week period in August 2007 (Figures 12 and 13). This method is applicable for wells completed in the same aquifer but generally does not apply when dealing with wells completed in different aquifers.

There was insufficient information to construct groundwater flow maps for the Glaciomarine Aquifer (GMA) and Fletcher Bay Aquifer (FBA), given only a few wells are completed in each aquifer (Frans *et al.* 2011). Generally, groundwater in the upper aquifers (PA/SPA and the SLAs) flows from the center of the Island towards the shoreline with downward flow in the center of the Island and upward flow at the shoreline.

Groundwater levels across the Kitsap Peninsula were also measured in autumn 2010 and used to map groundwater flow directions (Welch *et al.* 2014). It should be noted that evidence for the connection of these aquifers between Bainbridge Island and the rest of the Kitsap Peninsula is not conclusive. Groundwater flow in the shallow aquifer (PA and SPA) follows a similar pattern noted in the August 2007 data.

The rate of groundwater flow depends on the hydraulic conductivity or permeability of the sediment or bedrock. The hydraulic conductivity or permeability is a measure of the interconnectedness of the pore spaces in the sediment or bedrock. The rate of groundwater flow also depends on the slope or gradient of the water table or potentiometric surface. This relationship is characterized by Darcy's Law. Given the layered nature of the aquifer and confining hydro-stratigraphic units, it can be reasonably assumed that horizontal hydraulic conductivity is much larger than vertical conductivity (Welch *et al.* 2014). Groundwater flow in these types of layered systems is typically horizontal in aquifers and vertical in confining units.

Table 3 shows the range of hydraulic conductivity values for key aquifers on Bainbridge Island. These values reflect how easily groundwater can move through

each unit. The Qva and QA1 aquifers have the highest values, indicating they are the most productive and important for water supply. In contrast, deeper units like QA2 and bedrock (BR) have much lower conductivity, meaning they transmit water more slowly and may have limited yield. These differences help guide water resource planning and groundwater modeling.

Table 3 Summary of Hydraulic Conductivity Values on Bainbridge Island

Unit	No of Wells	Minimum (ft/d)	Median (ft/d)	Maximum (ft/d)
Qva	90	0.70	37	13,000
QC1pi	7	7.4	13	750
QA1	159	0.20	22	8,100
QA2	14	0.18	5.4	87
QA3	7	5.2	26	60
BR	4	0.0043	2.8	5.7
QC	3	3.8	4.9	7.7

Notes:

Ft/d: feet per day

Qva: Perched Aquifer

QC1pi: Semi-Perched Aquifer

QA1: Sea Level Aquifer

QA2: Glaciomarine Aquifer

QA3: Fletcher Bay Aquifer

BR: Bedrock Aquifer

QC: Confining Layer

Source: Frans et al. 2011

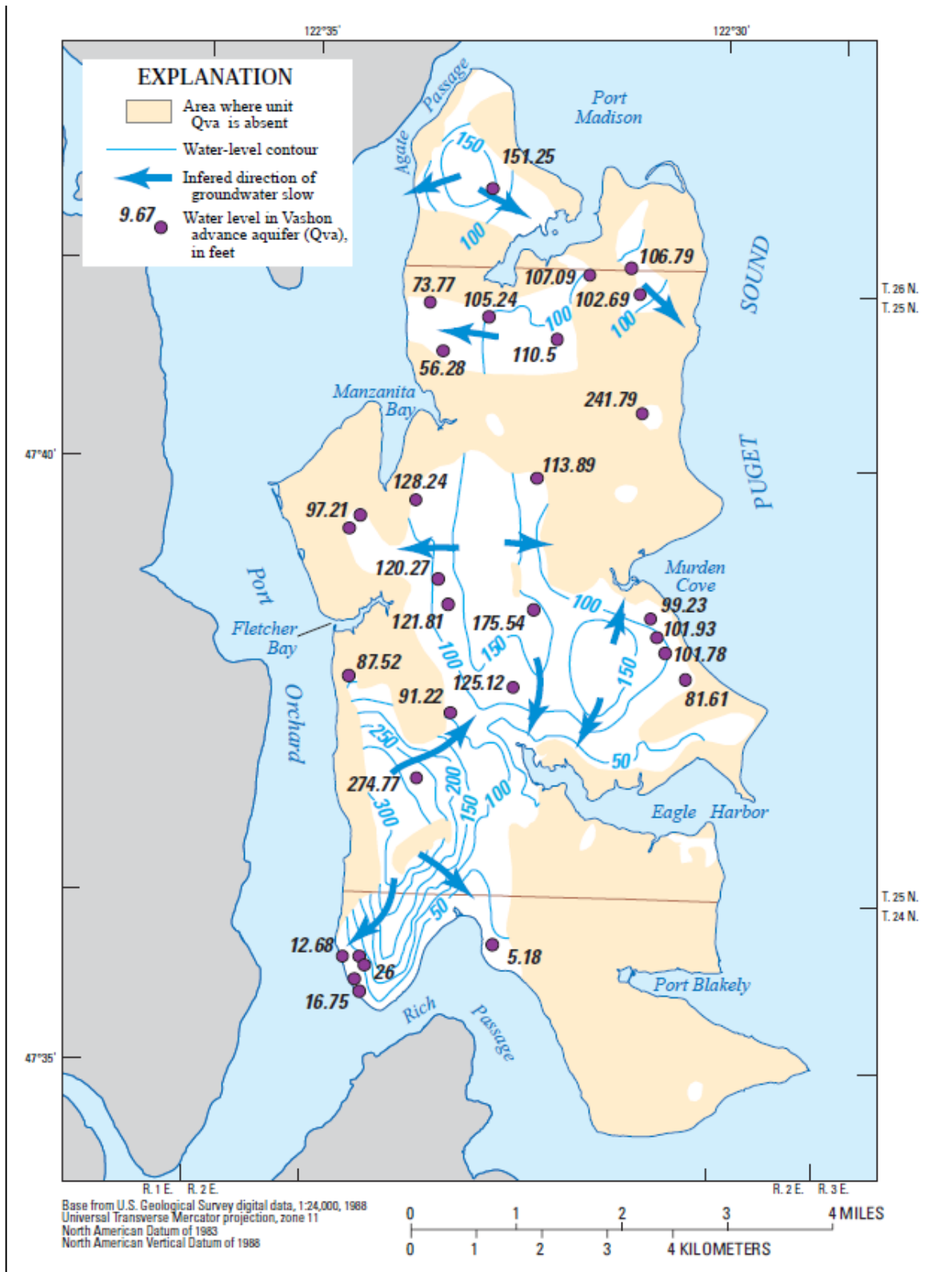


Figure 12 Groundwater flow direction, Perched/Semi-Perched Aquifer (Qva)

Source: Frans et al. 2011

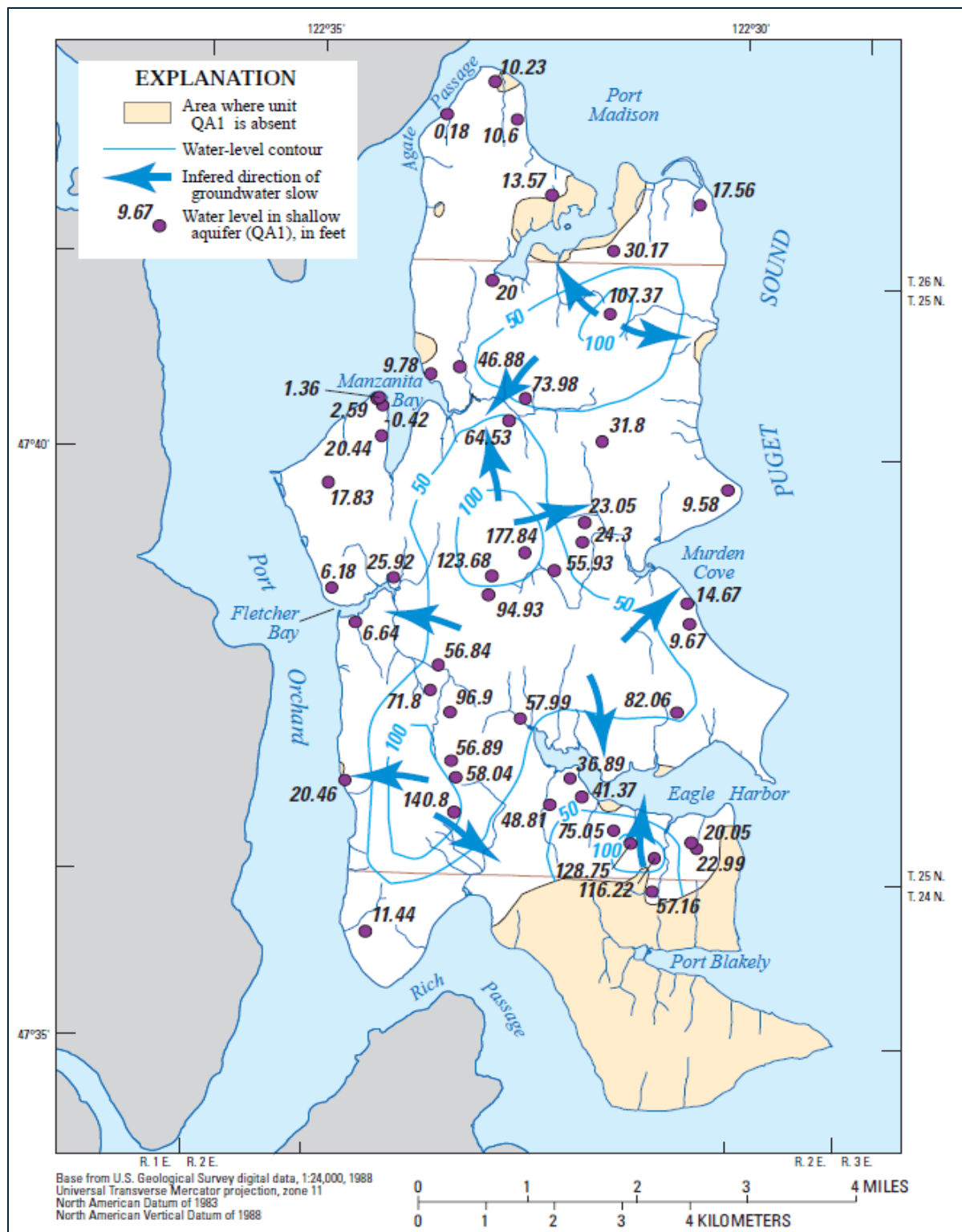


Figure 13 Groundwater flow direction, Sea Level Aquifer (QA1)

Source: Frans et al. 2011

These figures illustrate the extent of each aquifer within a regional perspective; with yellow shading indicating it is not present (Welch *et al.* 2014). The generally radial flow pattern outward from the interior of Bainbridge Island for PAs/SPAs and SLA is similar to what was mapped in 2007.

2.6.2 Location of Recharge/Discharge Areas

On Bainbridge Island, groundwater recharge from precipitation has been characterized by Welch, Frans, and Olsen (2014). Recharge is correlated with precipitation and thus, varies yearly. Monthly recharge values developed by USGS were incorporated into the groundwater models that have been developed for Bainbridge Island, as described in more detail in Section 5. Precipitation values in 1982 were close to annual averages. As an example, Figure 14 illustrates the annual recharge patterns for 1982 that were used in the EA groundwater model (EA, 2025). As shown, annual average recharge values range between 0 and 17 inches with the majority of the Island experiencing 6-8 inches of recharge or 14-19 % of annual rainfall. In Section 6.3 a range of recharge values from various references is presented and it is notable that the values shown in Figure 14 are on the low end of this range.

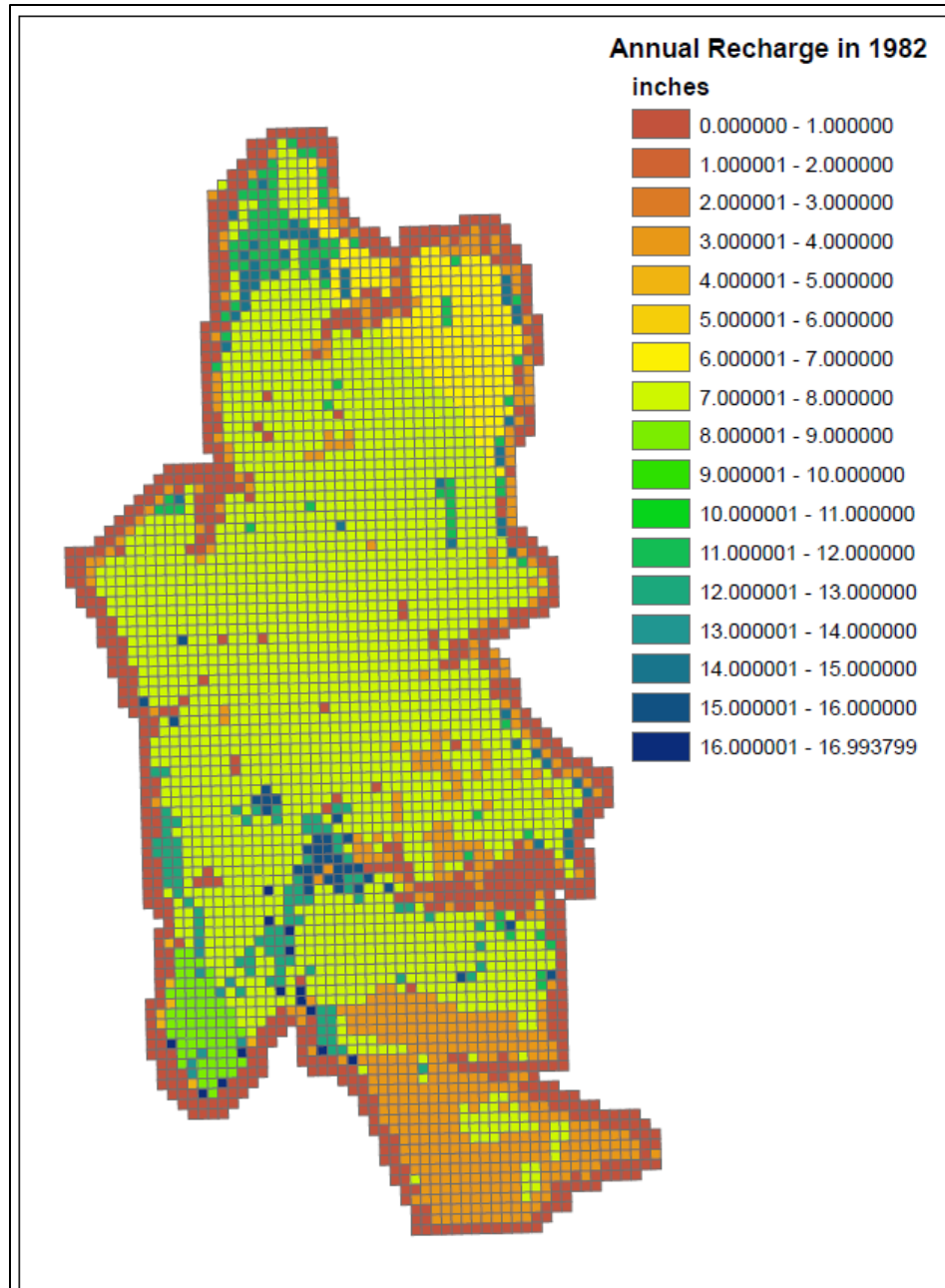


Figure 14 Average Annual Recharge from Precipitation, Bainbridge Island

Source: EA 2025

2.7 Groundwater Quality

2.7.1 General Groundwater Quality

Groundwater contains a variety of naturally occurring dissolved substances.

Generally, sodium, magnesium, calcium, chloride, bicarbonate, silicon, carbonic acid and sulfate constitute the largest concentrations (Freeze and Cherry 1979). Minor

constituents include boron, carbonate, fluoride, iron, nitrate, potassium, and strontium. Trace amounts of metals such as arsenic, copper, lead, and manganese are also commonly found. Minor amounts of dissolved organic matter as measured by dissolved organic carbon also is commonly found in natural groundwater (Freeze and Cherry 1979). Dissolved gasses such as nitrogen, oxygen, carbon dioxide, methane, hydrogen sulfide, and nitrous oxide can also occur in groundwater.

The concentrations of these and other constituents found in Bainbridge Island groundwater depend on characteristics of the precipitation falling on the ground that percolates downward to the groundwater. Additionally, groundwater quality depends on the kinds of materials (sediments and/or bedrock), the chemical and physical properties of those materials that the water flows through as well as the chemical properties of the groundwater itself. These concentrations can vary naturally over time and from location to location. Human-induced changes to groundwater quality can stem from use of fertilizers, malfunctioning on-site septic systems, leachate from landfills, improper storage or disposal of chemicals, waste chemicals, fuel oil and gasoline, among other things.

Groundwater quality for Bainbridge Island was assessed as part of the City's Level II Assessment (KWRN 2000). This assessment included sampling results from over 200 water supply wells (both public and private) held in the KPUD testing program from 1990 to 1994, Bremerton-Kitsap County Health Department, U.S. Geological Survey Bainbridge Island Study ((Dion *et al.* 1988), USGS and Kitsap County Groundwater Management Plan (Kitsap County Ground Water Advisory Committee, and others 1991). General water quality parameters were used in this assessment: chloride, specific conductivity, iron, manganese, and nitrate. Specific conductivity and chloride levels were used as indicators of seawater intrusion. Iron and manganese are naturally occurring and were used to indicate aesthetic quality. Elevated nitrate concentrations can indicate contamination from on-site septic systems, animal waste, and /or fertilizer application. Most samples were taken as a one-time event, so no water quality trends were established.

Based on the data evaluated during the Level II Assessment, the general quality of groundwater on Bainbridge Island was good; most wells met State drinking water standards except for occasional high iron and manganese concentrations (KWRN

2000). A review of water quality data in the State Department of Health's Public Water System Water Quality database, Sentry, indicates that groundwater quality on the Island remains high quality with no major violations in drinking water standards. In general groundwater on Bainbridge Island is characterized as soft to moderately hard, with harder water being higher in dissolved minerals, primarily calcium and magnesium (Dion, Olsen, and Payne 1988).

Chloride concentration and specific conductivity have been monitored by the City of Bainbridge Island's Groundwater Monitoring network since 2008 and is discussed further in section 4.1

2.7.2 Public Water Supplies; Water Quality

Public water supplies are regulated by primary and secondary drinking water contaminants, along with State Action Levels (SALs), that clarify the significance of reported water quality results and regulatory exceedances. Primary contaminants are regulated with enforceable Maximum Contaminant Levels (MCLs) based on potential health risks, and are established to protect public health over both short- and long-term exposure. Secondary contaminants, by contrast, are associated with aesthetic concerns—such as taste, odor, and appearance—and have non-enforceable guidelines known as Secondary MCLs (SMCLs). While not health-based, these standards help ensure water remains palatable and acceptable to consumers. In addition, some contaminants that do not have federal MCLs may be regulated at the state level under SALs, which are often based on emerging health risk assessments or regional water quality concerns. Given that most of the MCL exceedances noted—aside from arsenic and coliform—fall under secondary standards, and some parameters are regulated by SALs.

Across Bainbridge Island, Group A water systems are owned and operated by various entities, including the City, KPUD, Washington Water Service, and Northwest Water Systems. While most systems consistently meet all primary MCLs, several have reported elevated concentrations of naturally occurring elements such as iron and manganese. These constituents are common in groundwater systems and are generally regulated under SMCLs due to aesthetic concerns rather than health risks. While their presence can be problematic for consumers, they are not considered harmful at the concentrations typically observed. Arsenic is another naturally occurring element that may be found at low levels in some wells.

Monitoring helps ensure arsenic levels remain below the MCL of 0.010 mg/L. Sodium, which lacks a formal federal MCL, is evaluated under the EPA's Health Advisory Level of 20 mg/L and Washington's State Action Level. While sodium concentrations above this level may be a concern for individuals on low-sodium diets, they are not generally regulated for the broader population.

The City (as a Group A water system) supplies drinking water to the Winslow and Fletcher Bay areas via the Winslow Water System and the Rockaway Beach area via the Rockaway Beach Water System (COBI 2022a), serving approximately 6,000 residents. These systems meet all federal and state primary Maximum Contaminant Levels (MCLs), which are set to protect public health. However, some sources have shown exceedances of non-health-based secondary MCLs (SMCLs), which are intended to address taste, color, and odor issues. For example, the Sands Avenue wells have exceeded the EPA sodium Health Advisory Level and the color SMCL, and some wells have reported elevated manganese. The Winslow Water System Water Quality Report (2020) also noted low levels of arsenic—below the federal MCL—and potential for lead due to household plumbing, which is typical for many older systems.

Other systems, particularly those using older infrastructure or shallow sources, have historically experienced aesthetic issues or sample exceedances, but in most cases, follow-up monitoring, treatment, or decommissioning has addressed these concerns. For example, the Ferncliff Water System—previously noted for arsenic and manganese—was decommissioned in late 2024 following the City's extension of a new water main to serve the area.

2.8 Water Budget

A water budget is an explicit accounting of the inputs and outputs of the groundwater system. For the Bainbridge Island groundwater system, groundwater outputs include:

- groundwater flow to surface water systems like streams and wetlands
- groundwater flow to Puget Sound
- groundwater pumping from wells.

Groundwater inputs include:

- recharge from precipitation: the portion of rainfall that percolates below the root zone of plants and into the aquifer below.
- return flow from groundwater pumping: some fraction of water pumped out of the ground returns through septic systems, system leakage and downward percolation of excess irrigation.
- groundwater flow from Kitsap Peninsula.

If outputs exceed inputs, then groundwater storage declines. If this state persists, the groundwater system becomes depleted. This is an example of an unsustainable state of the groundwater system. A goal of groundwater management is to manage the groundwater system such that over the long-term outputs from the groundwater system are balanced by inputs, and groundwater levels are maintained such that unacceptable environmental, social, and/or economic consequences are avoided. Past analyses on the water budget and its components are discussed in Chapter 6.

Based on the latest modeling by Keta Waters, this is the current understanding of the most basic water budget components:

Inputs to the aquifer system come from:

- Precipitation on the Island 85%
- Recharge on Kitsap Peninsula 8%
- Septic Systems on the Island 7%

The outputs from the aquifer system are to:

- Wetlands and Streams 51%
- Marine Water, Puget Sound 38%
- Well Pumping 11%

3. Development and Environmental Impacts on Groundwater Quality and Quantity

3.1 Land Uses

The way in which humans alter and use the land affects how water enters the aquifer system to become groundwater and what quality the water is once it reaches the aquifer.

3.1.1 Residential

Residential land uses are divided into two main categories: Single Family and Multi-Family.

Single Family Residential (SFR)

Bainbridge Island is primarily a residential community, currently with 75% of the land developed for residential purposes (COBI 2017). Rural residential zoning is more extensive and allows for a range of housing density, from one house per 2.5 acres up to two houses per acre (R0.4, R1.0 and R2.0 zones) and makes up 90% of the area. The only development permitted in these areas is residential, mostly single family, detached housing, and most of which utilize on-site septic systems for domestic wastewater disposal. These septic systems recharge the aquifer but have potential to contaminate groundwater if not managed properly.

Outdoor irrigation associated with single family residential development is 80-90% consumptive, meaning it does not immediately become recharge but either becomes evaporation or evapotranspiration via plant uptake. In the Kitsap peninsula region, it has been estimated that on average, SFRs irrigate 3,400 square feet of landscaping per parcel (Ecology 2024).

Since the 1990s stormwater mitigation for residential development impacts such as roofs and driveways has been required to help reduce impacts from impervious surfaces inherent in land development. Recent research suggests that current mitigation requirements and low-impact development (LID) techniques have started to achieve the goal of mimicking natural hydrology, including recharge, on developed sites (King County 2023).

Multi-family Residential

Of the residential land use on the Island (75% of the Island) multi-family housing, like apartment and condominium buildings, only make up less than 1% of the Island's area.

Winslow has the highest density of multi-family residential land use, with about 15% of the water system connections designated as multi-family in 2015. In 2010 Island-wide, multi-family housing made up about 16% of total housing units (COBI 2017). Typically, multi-family developments are served by a sewer system that treats wastewater at a wastewater treatment facility, discharging to the Puget Sound.

Water use per multi-family unit is typically about half the use per SFR unit, with multi-family units averaging 77 GPD and SFRs averaging 185 GPD. This difference is largely due to the difference in size of the landscaping per unit with SFR having significantly more landscaping requiring irrigation than multi-family units.

Stormwater flow control and treatment facilities for multi-family residential developments are typically required to be engineered due to their large size and scope. This engineering requirement also triggers an annual inspection requirement via the City's Stormwater Management program. In contrast, SFR development is not typically required to have engineered stormwater mitigation facilities or be inspected annually.

3.1.2 Commercial/Industrial

Commercial and industrial development comprises only 2% of Bainbridge Island's land use, yet their potential impact on groundwater resources is substantial. Development activities associated with commercial and industrial land uses, such as clearing, grading, and the expansion of impervious surfaces significantly alter natural groundwater recharge processes (COBI 2024). When development leads to soil compaction and increased impervious surfaces, it fundamentally changes natural drainage patterns, resulting in higher stormwater runoff rates and volumes while simultaneously reducing groundwater infiltration (COBI 2024). In addition to development impacts, commercial and industrial uses are more likely than residential uses to consume water resources and produce wastewater. Some of

the largest users of water on the City's Winslow water system are commercial grocery stores. Some of the highest concentrated wastewater discharges come from light industrial uses such as wineries and breweries.

Similar to residential development, commercial land uses prior to the 1990's were not required to mitigate stormwater runoff, but since then mitigation requirements have grown more comprehensive. Modern commercial developments do not create the same negative groundwater impacts as older developments that lack stormwater mitigation facilities

3.1.3 Agricultural

Agriculture along with logging were the main industrial activities on Bainbridge Island in the mid-1800s (COBI 2024). While that is no longer the case, groundwater is still utilized for agricultural purposes such as irrigation. Agricultural activities pose potential risks to groundwater through the storage, use, and disposal of various materials including fuel, fertilizers, pesticides, and herbicides. These substances can impact groundwater quality if not properly managed.

Bainbridge Island Municipal Code discourages the use of pesticides and the few that are permitted are subject to regulations ensuring the chemicals do not contain carcinogens and are not hazardous to humans or wildlife as designated by the EPA (BIMC 16.30). The Washington State Department of Agriculture has a pesticide waste disposal program where agricultural pesticides are collected and properly disposed of free of charge.

Currently agricultural uses make up about 5% of the land use on Bainbridge Island (KCD 2024) declining from about 6% in 1999 (Kato 2000). Irrigation for agriculture comes from both groundwater and surface water and is highly variable depending on the crop type. Crops such as grapes require little to no irrigation, while vegetable crops can demand significant amounts. Water right certifications, applications and permits exist for many parcels on the Island including three City-owned farms.

3.1.4 Recreational Parks

Recreational areas and parks form a significant part of Bainbridge Island's landscape, managed mainly by the Bainbridge Island Metro Park and Recreation District (BIMPRD), which oversees over 1,600 acres across the community (BIMPRD,

2026). These areas, including athletic fields, trails, and landscaped open spaces, provide important social and ecological benefits. However, their operation presents notable risks to groundwater quality and quantity, necessitating proactive management strategies to preserve the Island's Sole Source Aquifer.

A primary concern is the use of fertilizers, pesticides, and frequent irrigation needed to maintain sports fields and other park features. Improper application or overuse of these chemicals, particularly ahead of rainfall, can result in runoff or leaching that introduces pollutants to groundwater and surface water. Many of the pollutants present in park maintenance, like certain pesticides or soluble fertilizers, are difficult to remove once they enter the water system and can adversely affect both public health and environmental quality (SWMMWW, 2024).

Additionally, a number of restroom facilities within parks depend on on-site septic systems. If these systems are inadequately maintained or are inappropriately sited, they can fail and allow nutrients or pathogens to seep into the groundwater. The City and KPHD address these risks by requiring proper management of stormwater runoff to avoid contamination near drainfields (SWMMWW, 2024).

To safeguard groundwater, the City and Park District implement best management practices such as minimizing chemical applications, enforcing proper hazardous material storage and disposal, maintaining vegetation buffers, and conducting regular inspections of septic and irrigation systems (SWMMWW, 2024). Ongoing education for park staff and the community reinforces the importance of sustainable landscaping and pollution prevention. These concerted efforts aim to ensure that recreational amenities continue to enhance community well-being without compromising the quality or sustainability of the Island's vital groundwater resources.

3.1.4 Open Space/Passive Recreation Areas

Since the establishment of the all-Island city in 1991, the City and other community stakeholders have made a concerted effort to establish a broad network of dedicated open spaces. To date, 323 acres of open space have been established for the purposes of conservation, preservation, and recreation. These open spaces, and other currently undeveloped open spaces, significantly influence water quality

and environmental conditions through various mechanisms such as infiltration and recharge, reduced runoff and erosion, and natural filtration.

3.1.5 Transportation Infrastructure

The City has approximately 280 lane-miles of paved roads for transportation purposes (6% of total land area) which create over 500 acres of impervious surfaces that affect groundwater recharge patterns. Stormwater runoff from these surfaces is managed through a combination of built infrastructure and natural systems. A majority of the roadways were constructed prior to the establishment of stormwater regulations that require management facilities for flow control and water quality treatment. Therefore, roadways are a significant contributor to increases in runoff and pollution, as well as altered drainage patterns that disrupt natural flow patterns and recharge processes.

3.1.5 Landfills

Bainbridge Island, Washington, has a legacy of landfill and industrial sites that have significantly influenced groundwater and stormwater systems. The most prominent is the closed Bainbridge Island Landfill, where historical waste disposal activities led to the contamination of groundwater with volatile organic compounds (VOCs). Since groundwater serves as a primary source of drinking water on the Island, this posed serious public health concerns. To mitigate these impacts, the site was capped with a landfill cover system to reduce water infiltration, and stormwater control structures—such as ditches and detention ponds—were installed to manage runoff and prevent further leaching of contaminants. Regular monitoring of groundwater, surface water, and landfill gas continues to ensure the site remains stable.

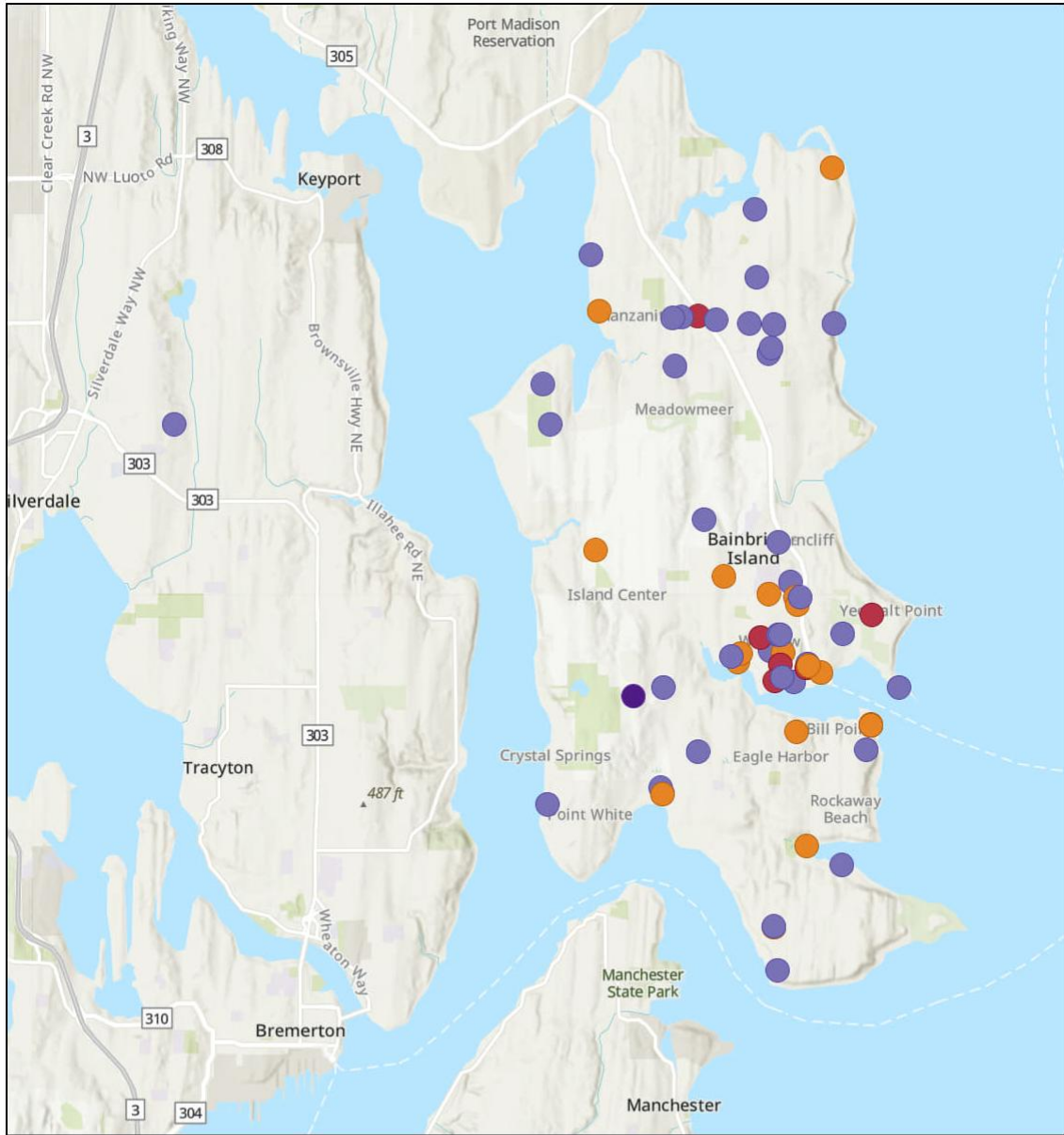
3.1.6 Hazardous Waste Storage

Bainbridge Island does not have permanent facilities for hazardous waste storage. Residents are advised to utilize the Kitsap County Household Hazardous Waste Collection Facility in Bremerton for disposal of items such as adhesives, antifreeze, nail polish, paints, and stains. Previously, Kitsap County held biennial household hazardous waste collection events on Bainbridge Island. However, these events have been discontinued with plans to open a new collection facility in North Kitsap in late 2026. For specific items, the Bainbridge Island Transfer Station accepts certain hazardous materials under their specialty recycling program, including

motor oil, filters, antifreeze, automotive batteries, household batteries, scrap metal, and compact fluorescent lamps. However, they do not accept commercial or other hazardous waste.

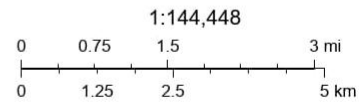
3.1.7 Contaminated and Cleanup Sites

According to the Ecology Toxics Cleanup website (Ecology 2022b) localized areas of soil/groundwater contamination have been identified on Bainbridge Island at 64 sites (as of June 2022) and are mapped on Figure 15. A complete list, including details regarding 25 sites designated as 'cleanup started' or 'awaiting cleanup', are summarized in Appendix J.



4/21/2026

- Cleanup Site Status
- Awaiting cleanup
 - Cleanup started
 - Monitoring cleanup progress
 - Cleanup complete



Esri, NASA, NGA, USGS, WSU Facilities Services GIS, WA State Parks GIS, Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USDA, USFWS

Ecology

Figure 15 Map of Contaminated Sites

Source: WA State Department of Ecology: What's in My Neighborhood Map 2024

Of these sites, less than 10 have activity recorded in the last five years and have potential for significant impact on groundwater. These include:

Bainbridge Island Landfill (Vincent Road). The site was acquired by Kitsap County in 1942 and several parties operated the property as a landfill until 1975 accepting domestic waste as well as waste from Wyckoff wood treatment facility and petroleum products. The site was listed on the Ecology Hazardous Sites List in 1992. Contaminated waste was removed from the site in 1992/93. A 1999 Remedial Investigation determined nature and extent of contamination remaining in soil and groundwater including volatile organic compounds. Additional contaminated material was excavated, and remaining materials were covered with a soil cap in 2001. Groundwater monitoring continues. Manganese concentrations have been identified as the only elevated constituent of concern which may indicate leachate and or landfill gas impacts. An investigation of elevated manganese concentrations is in progress.

Clean Center (290 Madison Avenue N). The site was operated as an on-site dry-cleaning facility from 1982 to approximately 1990 (Environmental Associates, Inc. 2009). Subsurface soil and groundwater investigations have identified chlorinated solvent impacted soil and perched groundwater possibly extending off-site (Environmental Associates, Inc. 2021). The site was enrolled in the Washington State Department of Ecology Voluntary Cleanup Program in 2021 and is awaiting further action.

Fletcher Bay Mart (8800 Fletcher Bay Road). The site has been used for retail service station since 1979 (Environmental Associates, Inc. 2008). The first investigation of the site in 1992 identified petroleum hydrocarbons in soil at concentrations exceeding cleanup levels (Environmental Associates, Inc. 2008). The site was enrolled in the Washington State Department of Ecology Voluntary Cleanup Program and was terminated from the program in 2020 due to inactivity. The latest available report (2018 Annual Groundwater Monitoring and 2019 Semi-Annual Remediation System Report prepared by Environmental Partners, Inc. 2019) indicates that groundwater remediation including removal of non-aqueous phase liquid (petroleum product that is not dissolved in the water) and groundwater remediation to clean up gasoline contaminated groundwater is in progress.

Wyckoff Eagle Harbor Superfund Site (EPA 2022). The Wyckoff Eagle Harbor Superfund Site encompasses 50 acres of nearshore and upland area along the southeastern shoreline of Eagle Harbor extending into Eagle Harbor (approximately 100 acres). The site was operated as a wood-treating facility beginning in the early 1900s; prior to that part of the site was used a brickyard to manufacture wooden tiles in the late 1800s (CH2M HILL 1989). Prior to 1981, site process wastewater was discharged to an onsite seepage basin and sludge was buried on site. Wood treating activities continued at the site until 1988. In 1984, EPA required Wyckoff company to investigate soil and groundwater at the site. Several removal actions of contaminated soil and sediment were undertaken in the 1990s. The property is currently owned by the City (purchased in 2004). The site was added to the National Priorities List (NPL) of Superfund sites in 1987. For remediation purposes, the site is divided into four operable units (OUs):

OU1 – East Harbor Operable Unit. Comprised of intertidal and subtidal sediments of Eagle Harbor contaminated with creosote and other wood-preserving chemicals released from the former Wyckoff facility

OU2 – Soils Operable Unit. Includes contaminated surface soil and structures associated with the Former Process Area of the Wyckoff facility

OU3 – West Harbor Operable Unit. Upland areas, intertidal and subtidal contaminated sediments associated with the former shipyard operations on the north shore of Eagle Harbor

OU4 – Groundwater Operable Unit. Includes contaminated subsurface soil and groundwater associated with operations at the Wyckoff facility.

Cleanup activities have been completed or are ongoing at all four OUs. The remedy for soil and sediment associated with the West Harbor OU3 included placing a cap over the impacted sediments. The remedy is functioning as designed and no further work is planned.

The cleanup activities at the Wyckoff wood treating facility soil and groundwater are in progress. The current cleanup strategy includes groundwater extraction and treatment to address release of contaminants into Eagle Harbor. This strategy includes a perimeter sheet pile wall and groundwater extraction and treatment

system. These remedies have not stopped release of contaminants into the lower aquifer beneath the Former Process Area and into the intertidal sediments along the East Beach and North Shoal (Figure 16).

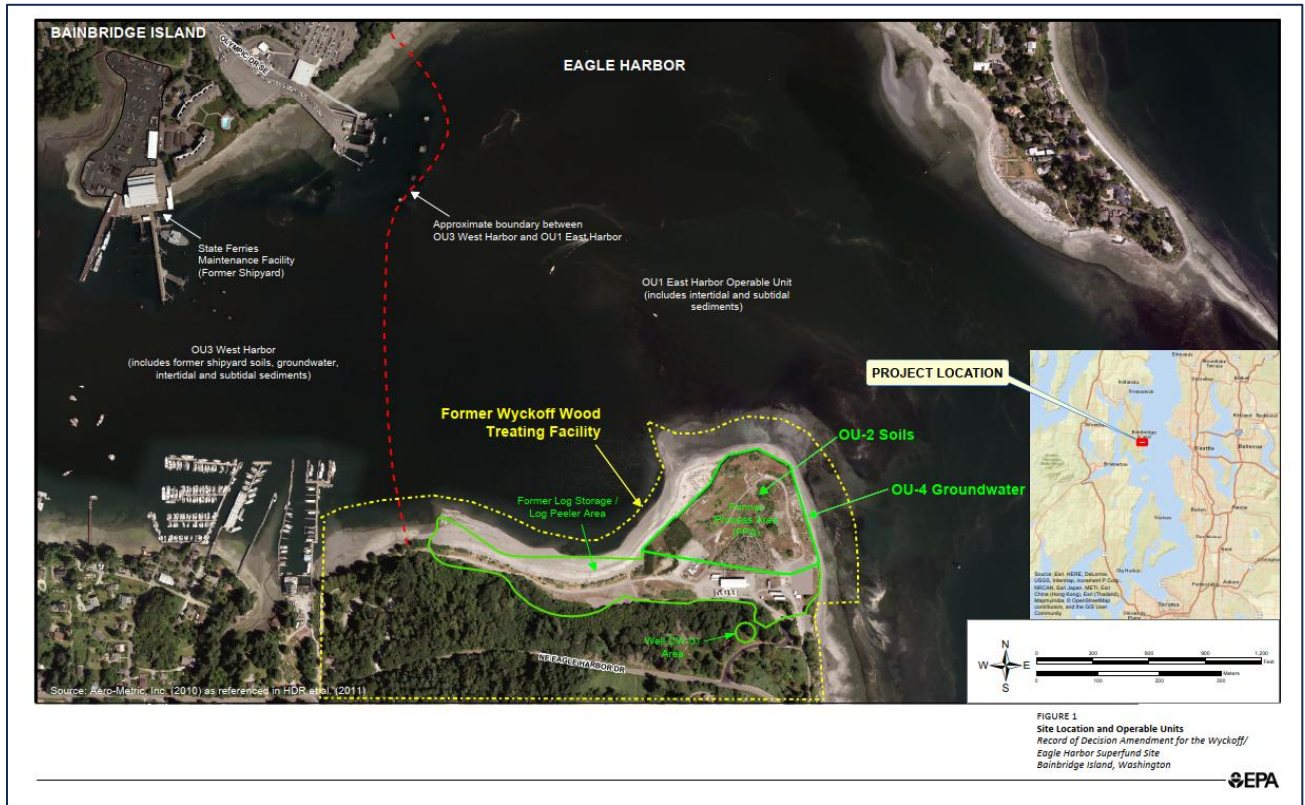


Figure 16 Operable Unit Locations of the Wyckoff/Eagle Harbor Superfund Site

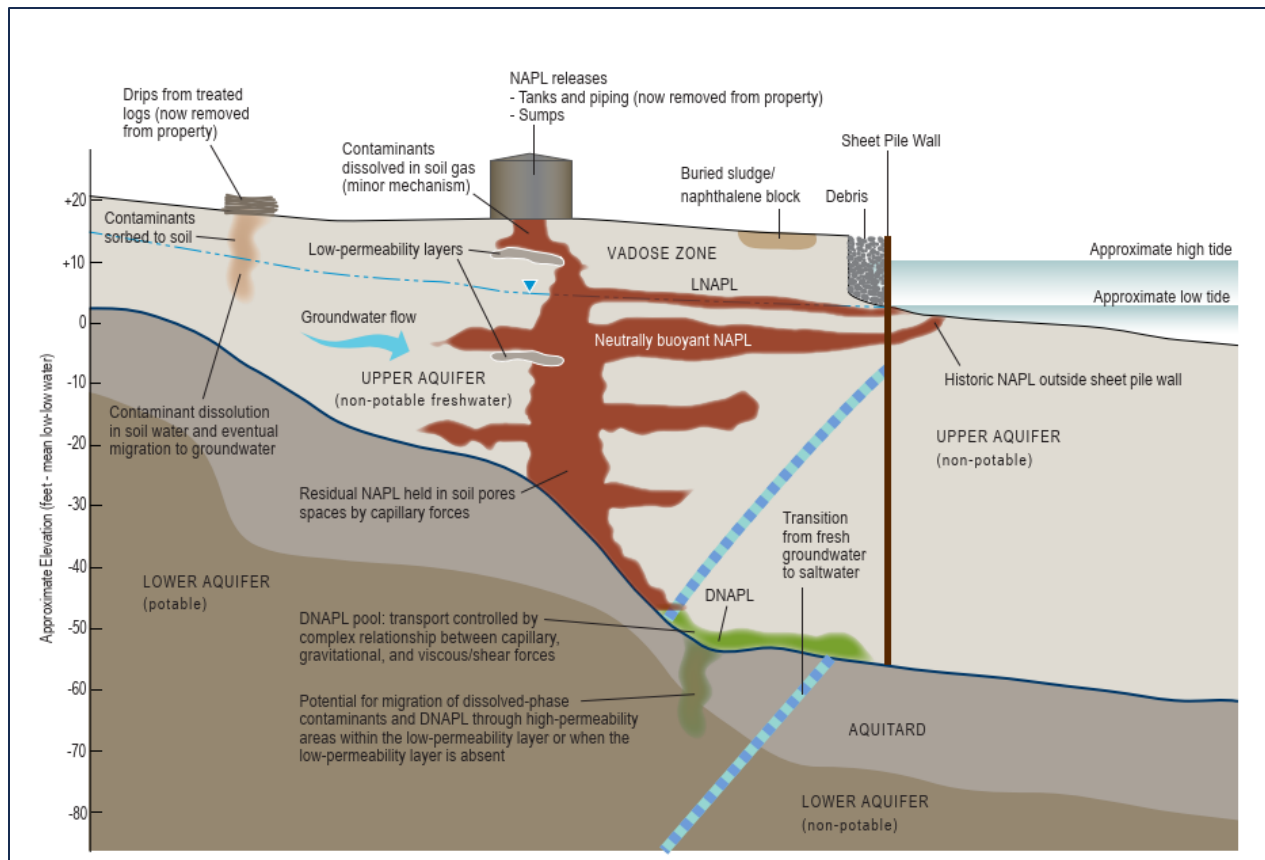


Figure 17 Conceptual Site Model of Contamination at the Wyckoff Superfund Site

3.2 Public Water and Wastewater Systems

3.2.1 Water Systems

Bainbridge Island's public water infrastructure consists of a network of systems serving its residential and commercial needs (Figure 18). The Island hosts 33 active Group A water systems and 146 active Group B water systems, collectively serving a population of 28,914, including Island residents and visitors. Group A systems are the primary water providers, supplying approximately 71% of the Island's total water use, followed by private PE wells at 24%, and Group B systems at 5% (Figure 19). This distribution mirrors the service population, with Group A systems serving the majority and community-type Group A systems alone reaching 71% of the population (EA 2025).

Details on the Group B water sources can be found in Appendix F.

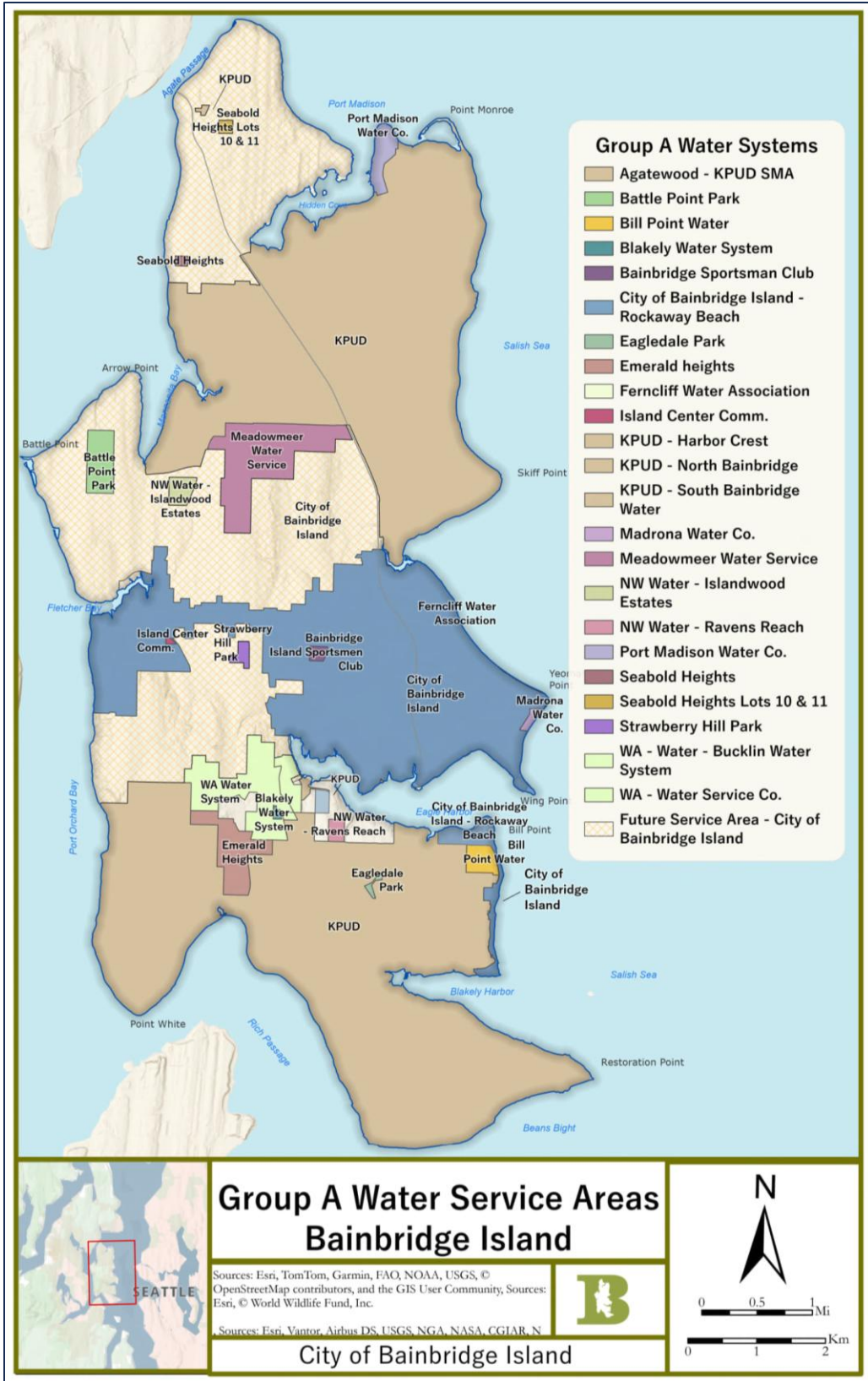


Figure 18 Bainbridge Island Water Systems Map

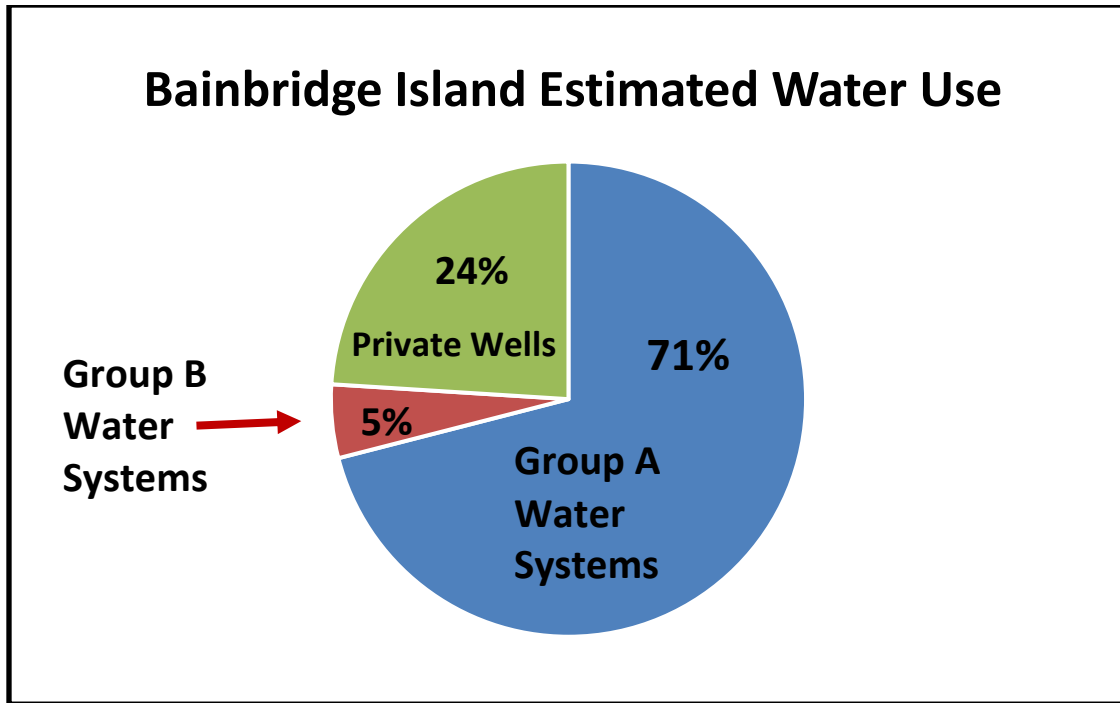


Figure 19 Bainbridge Island Estimated Water Use

3.2.1.1 City of Bainbridge Island Water System

The City operates two group A water systems, the Winslow Water System and the Rockaway Beach Water System. The Winslow Water System service area, shown in Figure 20 serves water to the historic Winslow and Fletcher Bay areas. The system consists of a High Pressure Zone and a Low Pressure Zone. Water is treated with chlorine and fluoride at each well before being pumped into the High Pressure Zone distribution system to supply customers and fill the two active storage reservoirs near the high school.

The system is served by six active pressure reducing valve stations. Storage is provided by one High School Reservoir in the High Zone with a total capacity of 2.5 million gallons (MG). The High School Reservoir supply the High Pressure Zone by gravity when the wells are not operating. The Department of Health has determined eight of the eleven wells have a low risk of contamination while the remaining three have a moderate or high risk of contamination. A wellhead protection plan and an active cross connection control program help protect the water system from contamination. The water system has sufficient water rights to last well into the future. The current limiting source capacity of the water system is approximately 1,750 gpm or 2.52 MG/day. This is the supply capacity of the

system's well sites with the smaller of the two Sands booster pumps pumping (Carollo 2017). It should be noted that by the end of 2026, the smaller and older of the City's two reservoirs will have been demolished, and active storage replaced by a 2.5 MG steel pedestal tank. Implementation of the tank resulted in the creation of a third pressure zone that impacts areas of Winslow and the Fletcher Bay neighborhood.

The Rockaway Beach Water System serves customers along Rockaway Beach Drive NE on the south side of Eagle harbor. The system consists of the Taylor Avenue Well, a treatment facility, the Creosote Reservoir, and distribution system, the locations of which are shown in Figure 21. After rehabilitation in 2022, the capacity of the Taylor Avenue well is approximately 67 gpm.

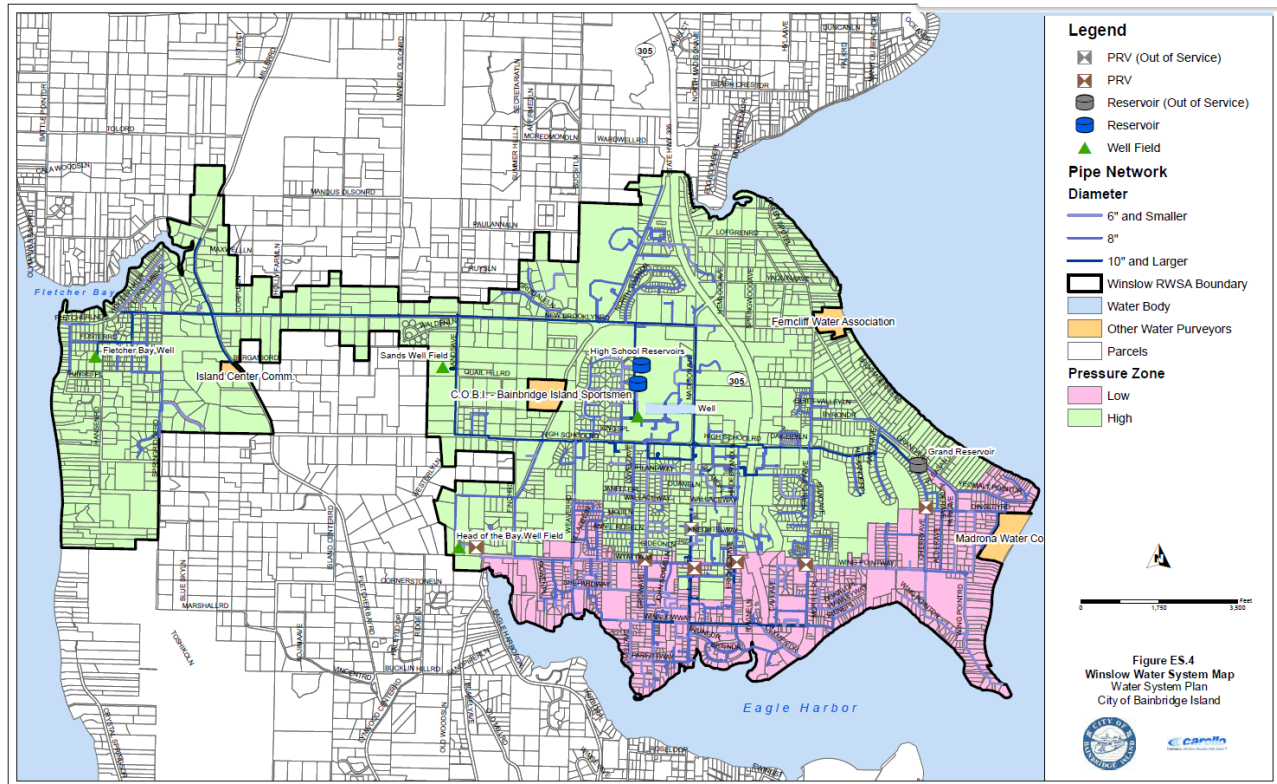


Figure 20 Winslow Water System Map

Source: Carollo Engineers, Inc. 2017

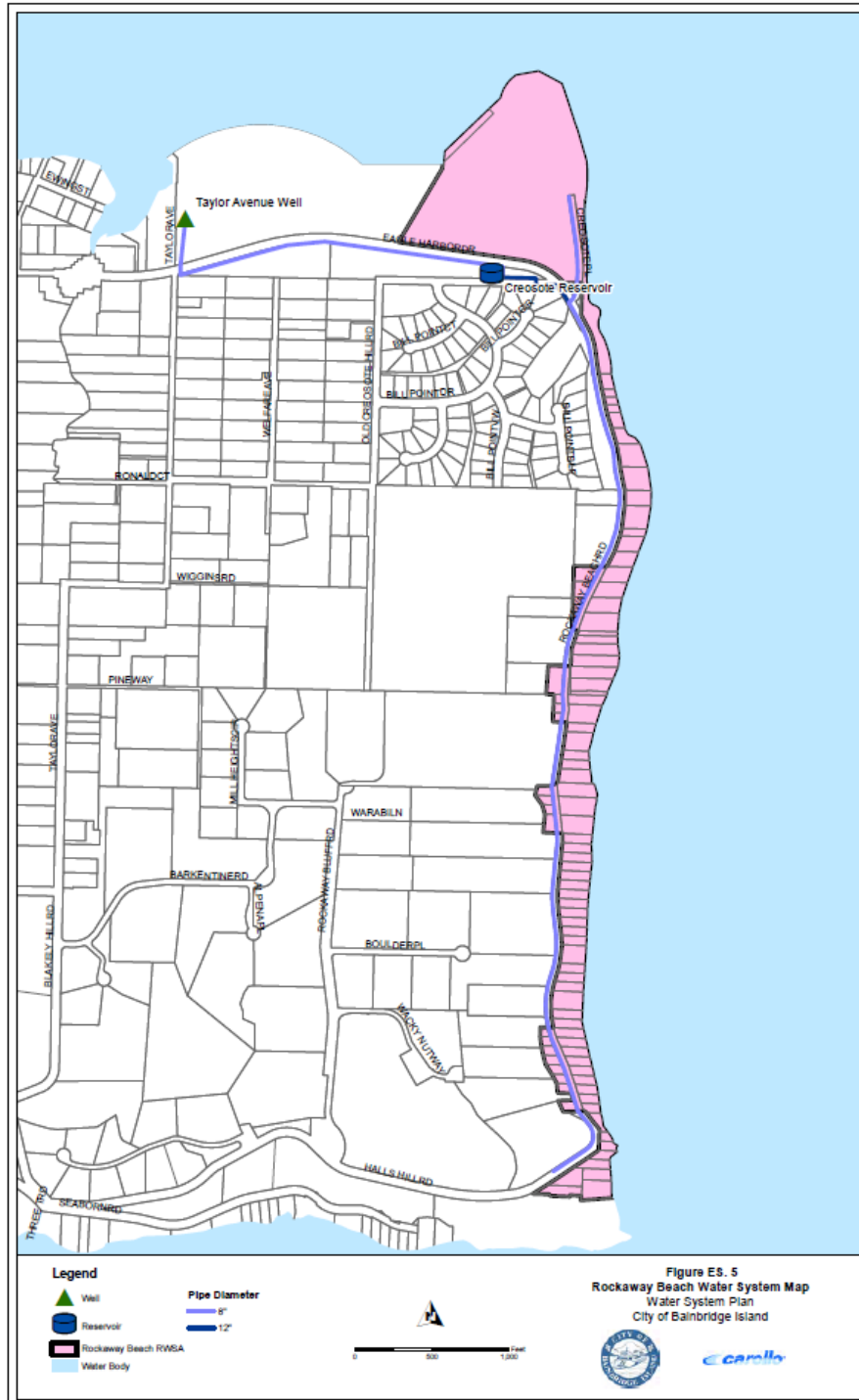


Figure 21 Rockaway Beach Water System Map

Source: Carollo Engineers, Inc. 2017

3.2.1.2 City of Bainbridge Island Water Rights

Existing water rights for the City water systems (Winslow and Rockaway Beach) are summarized in the COBI 2017 Water System Plan (Carollo Engineers, Inc. [Carollo] 2017) and in Table 4. This summary is based on the 2002 Water Rights Analysis and the 2005 Water Resources Management Plan. For the Winslow system, the City has permitted groundwater rights for a total of 2,300 gpm (instantaneous withdrawal) and 1,920 AFY (annual withdrawal) for sources currently in use.

The City's water systems also have permitted water rights for other sources (including one surface water source) that are not in use. This total is 2,657 gpm (instantaneous) and 2,445 AFY (annual). For the Rockaway Beach Water System, the City has one permitted water right: 80 gpm (instantaneous withdrawal) and 34 AFY (annual withdrawal). The total annual water rights authorized for the City is 4,399 AFY.

Table 4 Winslow and Rockaway Beach Water Rights Summary

Source	Well Status	Certificate Number	Priority Date	Instantaneous Withdrawal (gpm)	Annual Withdrawal (AFY)
Primary Sources of Supply					
Fletcher Bay Well	Operational	G1-20706C	14 June 1973	730	1,168
Commodore Wells					
Well No. 1	Not used	C-6025-A	8 April 1968	20	32
Well No. 2	Operational	G1-23678C	15 September 1980	120	32
Sands Ave Wells					
Well No. 1	Operational	G1-25264C	29 June 1988	300	336

Source	Well Status	Certificate Number	Priority Date	Instantaneous Withdrawal (gpm)	Annual Withdrawal (AFY)
Well No. 2	Operational	G1-25614P	1 February 1990	500	564
Head of Bay Wells					
Well Nos. 1 and 2 (Original)	Not used	C-5997-A	21 March 1966	55	88
Well Nos. 1 and 2	Operational	C-7410-A	18 August 1967	300	336
Well No. 3	Operational	G1-22248C	28 June 1974	75	160
Well Nos. 4 and 5	Operational	G1-24349C	8 July 1983	200	224
Total Permitted Water Rights (Primary Sources of Supply)				2,300	1,920

Notes:

AFY= acre-feet per year

gpm = gallon(s) per minute

No. = number

Source: Carollo Engineers, Inc. 2017

3.2.1.3 Kitsap Public Utility District (KPUD) Water Systems

KPUD owns and manages the largest share of public water systems on Bainbridge Island. Among these systems, the two major water providers operated by KPUD are known as North Bainbridge and South Bainbridge. The North Bainbridge Water System, established in 1915 as the Rolling Bay Water Company, has evolved significantly over time. The system operates multiple wells and includes a 120,000 gallon concrete tank that replaced the original wood stave tank in 1976, bringing the total storage capacity to 360,000 gallons. The system features sophisticated

pump controls and monitoring equipment, with digital controllers regulating level control through pressure transducers (KPUD 2011).

The South Bainbridge Water System has recently undergone significant changes through consolidation with the Island Utility system, creating a more robust and reliable water service for residents in the south end of Bainbridge Island. This consolidation has brought several benefits, including greater redundancy for water supply, improved fire flow capabilities, and the elimination of some low-pressure areas. The system includes multiple pressure zones and storage facilities, with plans to construct a new 500,000-gallon storage tank that will help seamlessly combine the two systems (KPUD 2020). KPUD also consolidated the Bill Point water system in 2023, further expanding the reach and capacity of Group A service areas.

Water quality management is a crucial aspect of both systems' operations. The South Bainbridge system has installed water treatment plants by ATEC to address elevated manganese levels, which is a common water quality challenge in the area. The system's distribution infrastructure consists of various materials, including PVC (38%), cast or ductile iron (44%), and asbestos cement (17%) (KPUD 2020).

Looking ahead, both systems face similar challenges related to aging infrastructure, population growth, and water quality management. The consolidation of systems and ongoing improvements demonstrate KPUD's commitment to maintaining and enhancing water service reliability for Bainbridge Island residents. Water conservation and efficiency remain important priorities, with both systems implementing measures to reduce water loss and maintain sustainable operation (KPUD 2020).

3.2.1.4 KPUD Water Rights

Existing water rights for KPUD water systems on Bainbridge Island include:

North Bainbridge system has permitted groundwater rights for 1,713 gpm (instantaneous withdrawal) and 507 AFY (annual withdrawal) for sources currently in use.

Manzanita Heights and Sunset Hills water systems, along with their associated rights, were consolidated into the North Bainbridge system. The combined water rights are included in the totals listed above for North Bainbridge.

South Bainbridge system has permitted groundwater rights for 1,106 gpm (instantaneous withdrawal) and 870 AFY (annual withdrawal) for sources currently in use.

Harbor Crest system has permitted groundwater rights for 60 gpm (instantaneous withdrawal) and 9 AFY (annual withdrawal) for sources currently in use.

See Table 5 Table 5 KPUD Water Rights Details for a breakdown of water rights for all water sources in KPUD’s major systems on the Island.

Table 5 KPUD Water Rights Details

Source	Well Status	Water Right Number	Priority Date	Instantaneous Withdrawal (gpm)	Annual Withdrawal (AFY)
North Bainbridge Water System					
Madison Spring	Not used	S1-*07084 (SWC3556)	04/30/1946	67	456
Wells 1/2	Not used	G1-*07000 (GWC6066)	01/28/1964	150	
Wells 3/4/5	Operational	G1-00531	04/11/1969	250	
Well 6	Operational	G1-23277	12/18/1978	100	
Well 7	Operational	G1-24155	06/29/1982	200	
Wells 8/10	Operational	G1-24627	03/26/1985	75	
Well 9	Operational	G1-25782	0//27/1990	700	
Manzanita Heights	Well replaced	G1-00445	02/10/1971	80	17
Sunset Hills	Well replaced	G1-20239	08/02/1972	60	18
Sunset Hills	Well replaced	G1-*11052 (GWC7136)	07/09/1970	31	16
North Bainbridge Totals				1,713	507
South Bainbridge Water System					
Well 3	Well replaced	G1-23438C	07/16/1979	50	62.5
Well 4	Well replaced	G1-23638C	07/17/1980	30	48
Well 5/9	Operational	G1-23640C	07/17/1980	60	0
Well 6/10	Operational	G1-24392C	09/30/1983	225	229.6
Well 7	Operational	G1-25739C	05/24/1990	300	50
Well 8	Operational	G1-23639C	07/17/1980	50	0
Spring	Not used	S1-*17514CWRIS	06/16/1967	49.4	79.6

Island Utility Wells 1/2/3	Operational	G1-25243P	05/05/1988	300	336
Bill Point Wells 2/3/4	Operational	G1-00315C	02/08/1972	42	64.2
<i>South Bainbridge Totals</i>				<i>1106.4</i>	<i>869.9</i>
Harbor Crest Water System					
Well 1	Operational	G1-24249C	02/14/1983	60	9

The Qa for KPUD’s water systems is 1,376 AFY, based on current water rights across North Bainbridge, South Bainbridge, and consolidated systems such as Manzanita Heights and Sunset Hills.

Water rights data were provided by KPUD in 2025 and 2026, with technical input from Joel Purdy and Tom Colby. The information is considered accurate as of 2026.

3.2.1.5 Other Smaller Water Systems

Apart from the municipal Group A systems like COBI and KPUD, other private Group A systems exist on Bainbridge Island. The two largest private organizations that own and/or operate these systems are Washington Water and Northwest Water Systems who own/operate Bucklin Hill Water and Emerald Heights Water, respectively. Meadowmeer Water System is also a significant Group A system operated by Northwest Water Systems. The service areas for these systems can be found in Figure 18 Bainbridge Island Water Systems Map.

A more complete list of public waters systems can be found in Appendix I.

3.2.2 Wastewater Treatment

3.2.2.1 City Wastewater Treatment Plant (Winslow)

The Bainbridge Island Wastewater Treatment Plant (WWTP), located in the downtown core area, serves as the primary wastewater treatment facility for the City (Figure 22). Originally constructed in 1978, the WWTP has undergone several expansions and upgrades to improve its capabilities. The facility operates as an activated sludge system that provides secondary treatment through multiple processes, including fine screening, biological treatment in five-zone basins, secondary clarification, and UV disinfection (WWTP 2017).

The facility operates under NPDES permit WA0020907, issued by the Department of Ecology, which establishes specific effluent limits for key parameters including biochemical oxygen demand (BOD5), total suspended solids (TSS), pH, fecal coliform bacteria, and total residual chlorine. Currently, the plant has remaining capacity for approximately 285 ERUs (equivalent to about 707 people), though this is limited by the plant's ability to treat biological oxygen demand loads. Planned capital improvements, expected to be completed by 2028, will increase the plant's capacity to serve a population of 10,500 (an additional 2,700 people) in and around the Winslow sewer service area (BHC Consultants [BHC] 2024).

The treated effluent is discharged to Puget Sound through a sophisticated outfall system located on the east side of Bainbridge Island, just east of Wing Point. The 5,370-foot outfall line splits at the end into two 16-inch ports, spaced 14 feet apart and positioned at a depth of -42 feet mean lower low water, approximately 900 feet from the high tide mark (WWTP 2017). The discharge point was strategically selected with consideration for mixing zones and water quality standards, and the infrastructure has been well-maintained, with the most recent improvements completed in 2014 when the City replaced the original ductile iron pipe with high-density polyethylene (WWTP 2017).

Currently, the facility makes limited use of reclaimed water through an in-plant reuse water system, utilizing a portion of the disinfected effluent for wash-down operations, landscape irrigation within the fenced area, scrubber water, and influent screen wash-water (WWTP 2017). However, the City is actively exploring future opportunities for expanded beneficial use of reclaimed water that could help reduce groundwater withdrawals and supplement baseflow to streams and wetlands (BHC 2024). The potential beneficial uses of reclaimed water could include irrigation of golf courses and other landscaping, aquifer recharge, and agricultural purposes. Implementation of such water reuse strategies could help address water conservation needs and reduce pressure on groundwater resources (BHC 2024). This action is discussed further in section 7.4.5.

3.2.2.2 KPUD Wastewater Treatment Plant (Fort Ward)

The Kitsap Public Utility District Fort Ward wastewater treatment plant (formerly owned and operated by Kitsap County Sewer District #7 until late 2025) has its origins in a rudimentary military-era sewer system dating back to the early 1900s at

Fort Ward, where untreated waste was discharged into Rich Passage. Modern wastewater management began after the district was formally created in 1960 and culminated in construction of a secondary treatment facility completed in 1995 to meet federal Clean Water Act standards. The plant treats wastewater not only for local residents of Fort Ward, but also for surrounding areas such as Lynwood Center, Rockaway Beach, Pleasant Beach, Point White, Emerald Heights, and the Blakely School through an inter-local agreement with the City. The City also owns and manages the sewer collection system in those areas. Overall, the system handles wastewater from roughly 700 homes and businesses. In terms of capacity, the facility treats on the order of tens to hundreds of thousands of gallons per day (about 280,000 gallons daily with peak capacity around 140,000 gallons per day for certain service components), making it a relatively small but critical treatment plant designed to provide reliable, environmentally compliant wastewater service for the south Bainbridge Island area.

3.2.2.3 Fieldstone

Fieldstone assisted living facility in the Rolling Bay neighborhood also operates a small wastewater treatment plant with direct discharge to the Puget Sound.

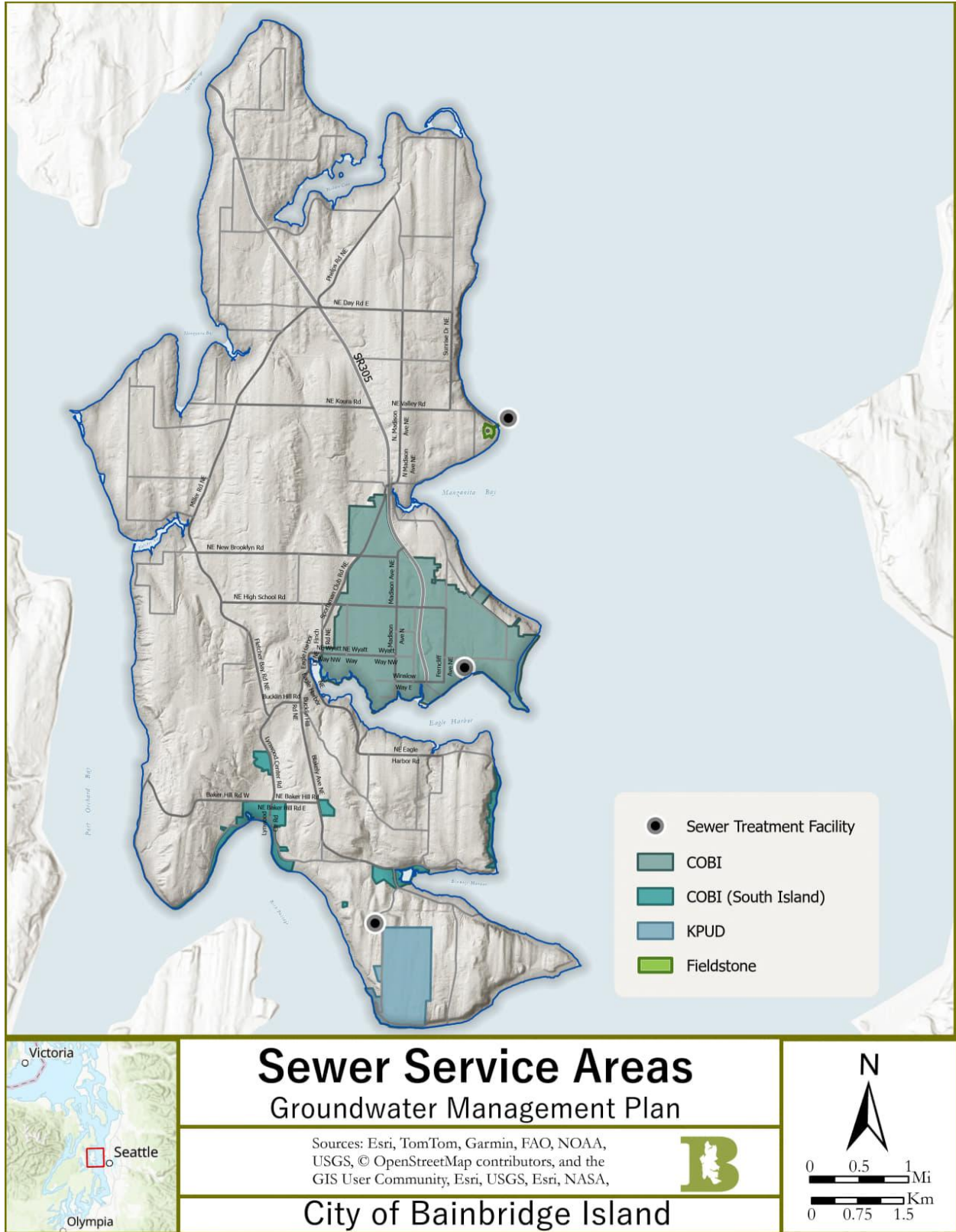


Figure 22 Wastewater Sewer Service Areas Map

3.2.2.4 Septic Systems

The remainder of wastewater on the Island is treated by approximately 6,000 private on-site septic systems. There are also at least four large on-site septic systems (LOSS) that maintain a site-specific discharge permit (Ecology 2025). On-site septic systems contribute to groundwater recharge, with amounts varying across the Island. Average estimates of septic return flow are discussed in Section 6.5.

3.2.3 Water Rights and Well Construction History

Groundwater is withdrawn for use by homeowners, agricultural and commercial users, and by community water supply purveyors. Due to the range of regulations governing groundwater withdrawals and the lack of metering data, providing precise accounting regarding water withdrawals is not possible. Groundwater use can be reasonably estimated for specific types of uses (i.e., indoor domestic use is typically about 60–65 gallons per capita per day COBI 2024)), although actual use for any given system is dependent upon many factors, including regulatory limitations (individual water rights, customers of a water system and permit-exempt uses) and personal choices. Although indoor domestic use typically falls within a fairly narrow range, outdoor uses can vary widely from one house to the next and is heavily dependent on the size of outdoor irrigated area that can be highly variable.

Water rights and water well construction data available from Ecology illustrate the growth in population and water use on Bainbridge Island dating back to the 1920's. Figure 23 illustrates the growth in water right permits and certificates issued by the state for surface water, groundwater, and reservoir rights. In the graph below, the symbols are used to plot the amount of annual water rights issued for each type of permit each year in units of acre-feet per year (left vertical axis). The lines represent cumulative water rights issued over the period of record for both surface and groundwater rights. Cumulative values are relative to the right vertical axis, also in units of acre-feet per year. No new water rights have been issued on Bainbridge Island since 2012.

Years with the largest volume of rights issued were 1973, when KPUD obtained water rights for 1,359 acre-feet per year and 1990 when three large water rights were issued to the City, KPUD and Blossom (former name of the South Bainbridge

Water System) for a total of 1,168 acre-feet per year. The 1973 KPUD water right has subsequently been acquired by the City of Bainbridge Island and is the primary water right utilized in the Fletcher Bay Wellfield. The symbols representing both 1973 and 1990 are higher than the values reported on the graph because other smaller rights were also authorized in each of these years, pushing the total for the year higher than the water rights noted above. It should be noted that the dates used represent priority dates (the date a complete water right permit application was received by Ecology), not the date the rights were granted, which could have been several years later.

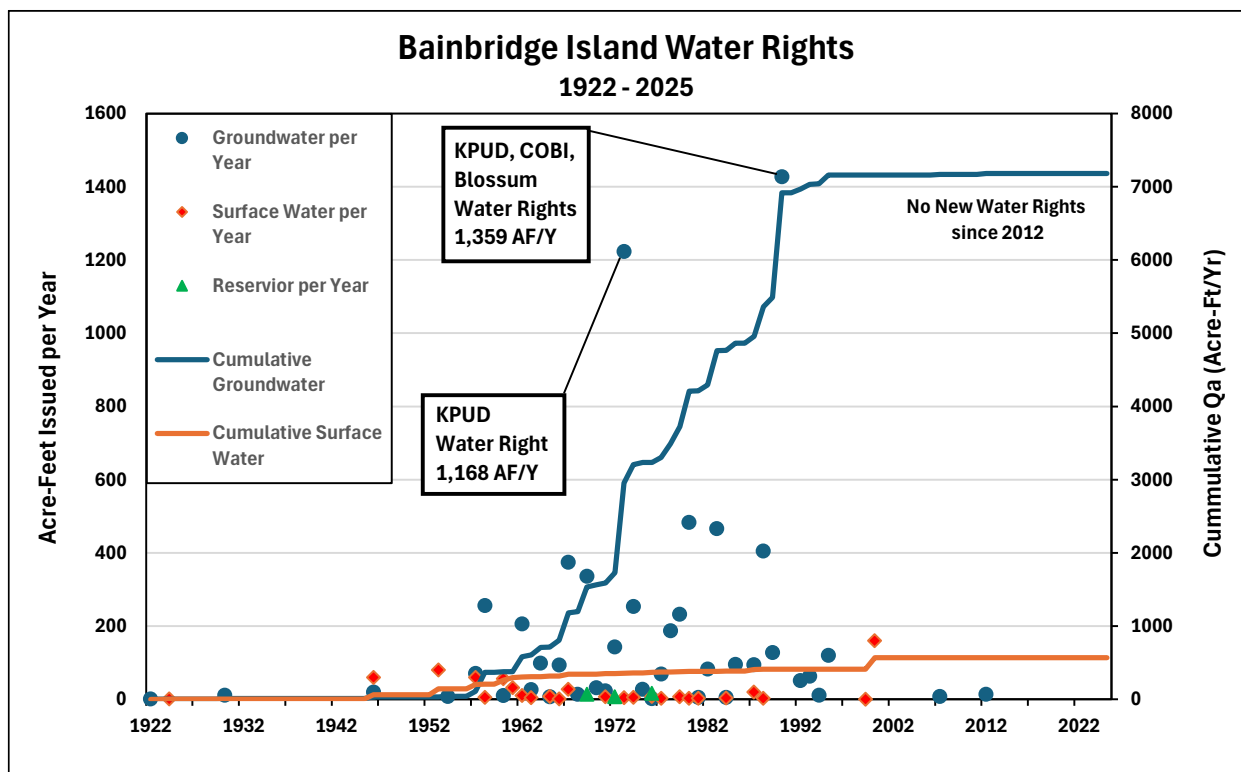


Figure 23 Bainbridge Island Water Right Permits and Certificates, 1922–2025

Source: Ecology Water Rights Database 2025

As shown on Figure 23, most water rights on Bainbridge Island have priority dates between the years 1950 and 2000. Groundwater withdrawals increased dramatically when electricity to power pumps became widely available. Note that permit-exempt uses and claims are not represented in this data. Water use by permit-exempt wells is best illustrated by reviewing the well construction data as

shown in Figure 24 because the majority of the individual wells on the Island are drilled for private use.

A pending water right application submitted by Wing Point Golf Club remains under review by the Washington Department of Ecology. The application seeks additional groundwater withdrawals to support golf course irrigation but has not yet resulted in a permitted water right due to ongoing evaluations of availability and potential impacts on nearby users and resources.

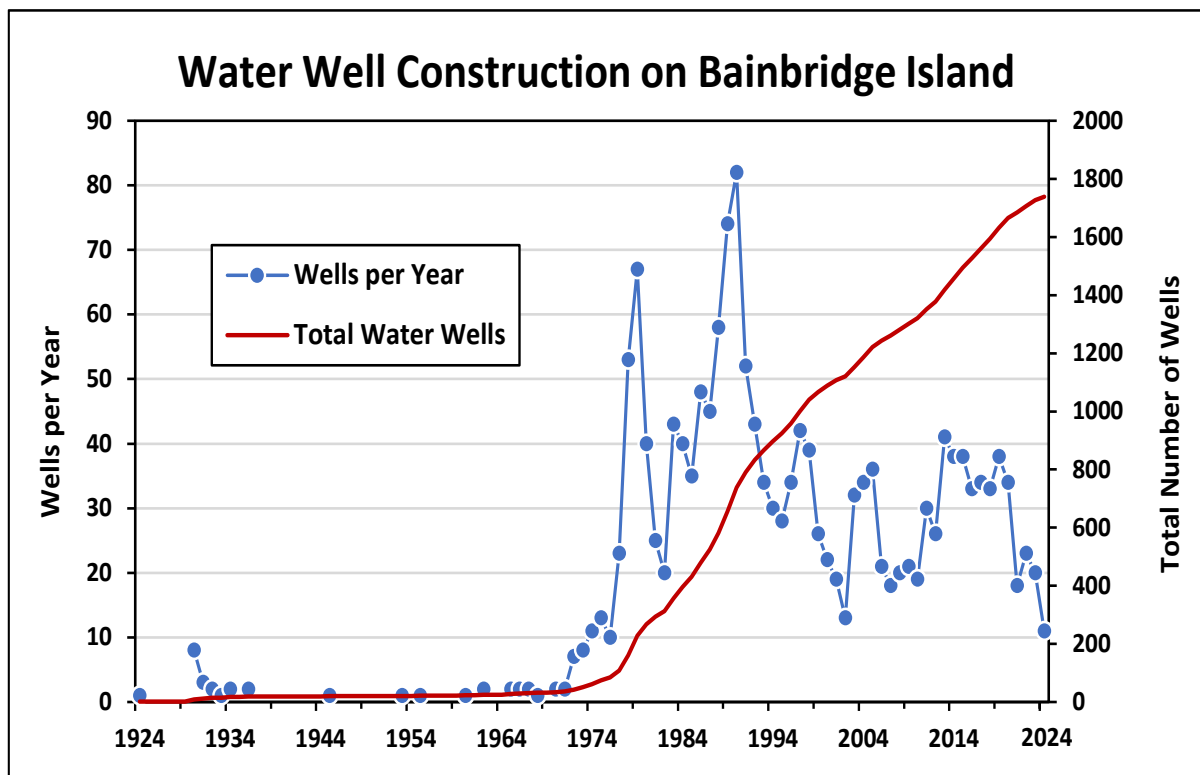


Figure 24 Water Well Construction on Banbridge Island 1924-2024

Source: Ecology Well Construction Database 2025.

Figure 24 illustrates the number of water wells drilled each year as well as the cumulative number of water wells drilled over the period of record based on Ecology records. This data represents records in Ecology's database for all water wells, not only permit-exempt wells. There are nearly 1,800 records that include the date of construction and an additional 260+ well records lacking a date of construction.

Figure 25 illustrates the distribution of water well construction on Bainbridge Island between 1960 and 2023. Ecology's well construction data is presented in four maps showing the number and distribution of water wells on the Island in 1960, 1980, 2000, and 2023. Ecology's well construction data is illustrated by the $\frac{1}{4}$ $\frac{1}{4}$ section (a 40-acre area) the well is reported to be located in. Because there can be multiple wells within a single $\frac{1}{4}$ $\frac{1}{4}$ section, locations that include wells are color-coded by the number of wells associated with each location. Although this method of locating wells is not very precise, patterns of growth and the relative density of wells can be observed plotting the data in this manner.

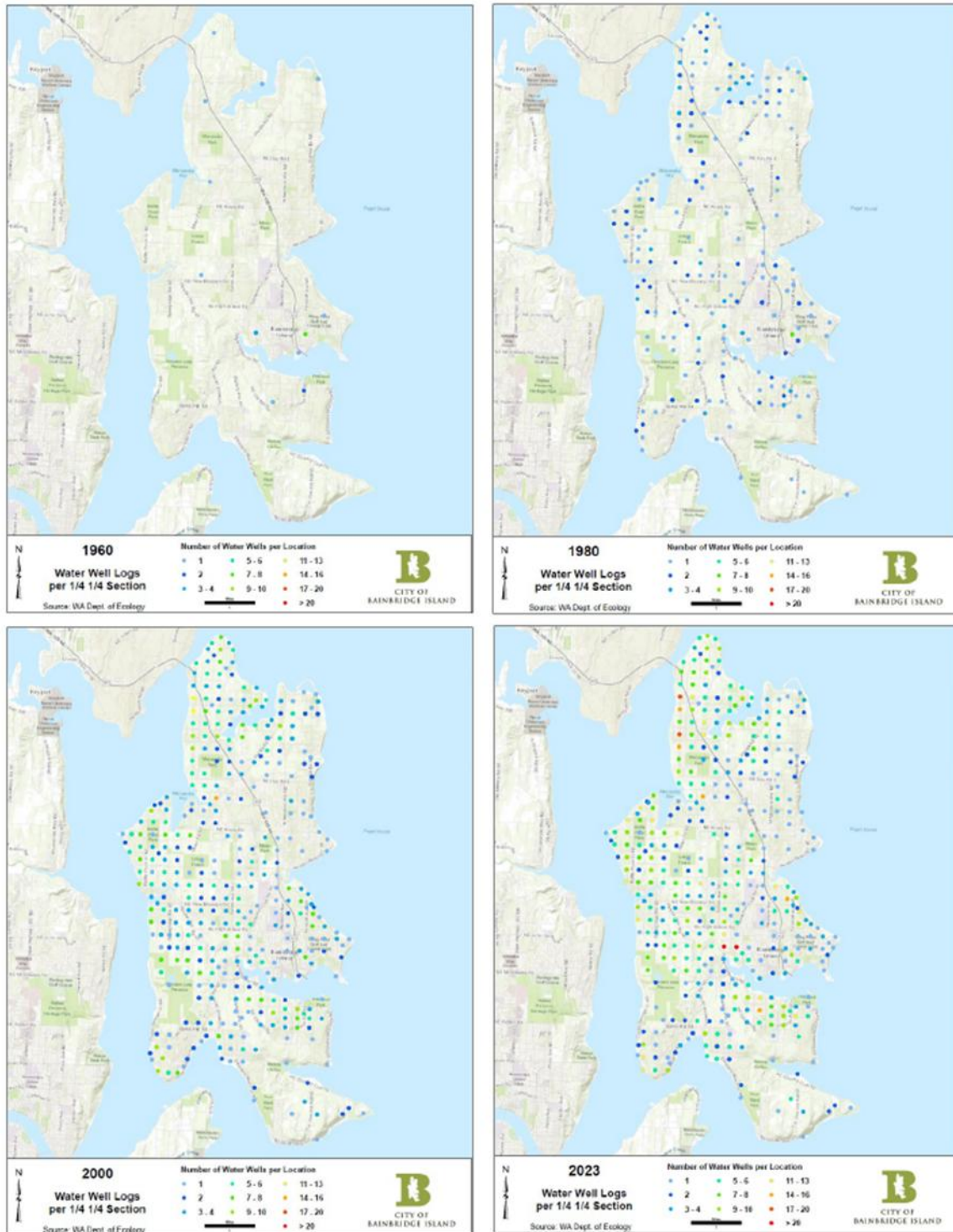


Figure 25 Distribution of Water Wells on Bainbridge Island in 1960, 1980, 2000 and 2023

Source: Ecology Well Construction Database 2025

Although it is the best public source of well construction information available, it should be noted that much of the information in Ecology's well construction database has not undergone a formal quality assurance/quality control (QA/QC) review, and its uncertainties and limitations should be recognized when relying on the data. These number of wells reported do not account for duplicate records, decommissioned wells, and reconstructed wells. In addition, water well reports, were not required to be submitted to the State before 1971 and recordkeeping and tracking have dramatically improved since the late 1990s and early 2000s. This is a factor when comparing well construction data between the 1960s and 1980s. Over the period of record an average of about 20 water wells are drilled each year on Bainbridge Island with the largest number (82 wells) drilled in 1990.

KPUD also hosts a groundwater well database that maintains a more precise location for wells than the Ecology database. By using site plans and other information from the KPHD they can more accurately pinpoint the location of a well on the map. An example of the quantity and locations of well on Bainbridge can be seen in Figure 26.

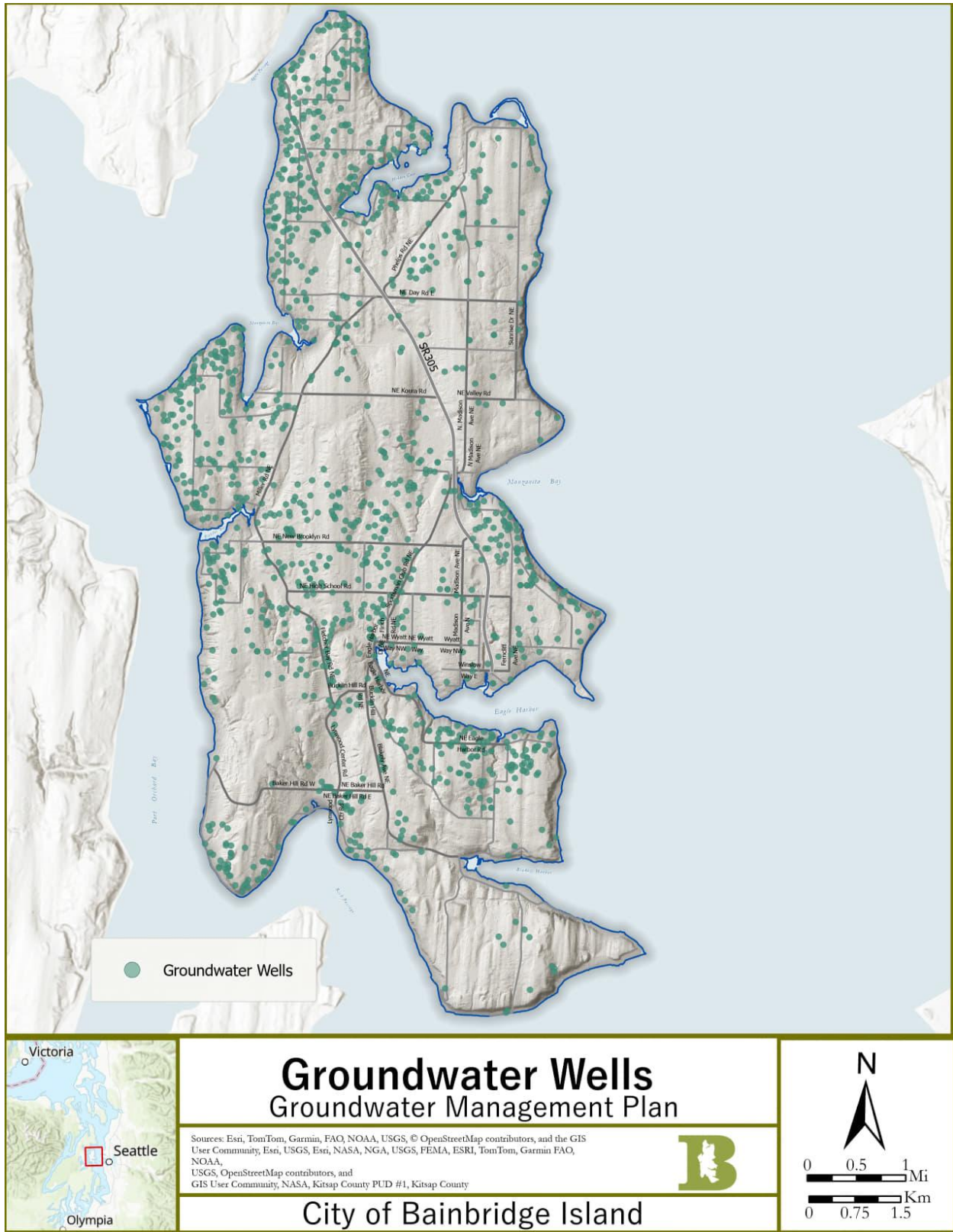


Figure 26 Well Locations from KPUD Well Database

As noted, this data represents all water supply wells. However, it is estimated that at least 90% of water wells drilled in Washington are for permit-exempt uses, most of which are legally limited to no more than 5,000 gallons per day or less. Though wells drilled after 2018 are subject to a limit of 950 gallons per day as described in Section 2.4.8. Most permit-exempt wells used for domestic purposes average around 150-300 gallons per day, with larger amounts during the irrigation season and around 130 gallons per day or less for indoor uses during the winter months (Ecology 2020).

As expected, more groundwater is used in the summer (in some cases more than twice as much as is used in the winter), mostly for irrigation (outside watering for lawns, gardens, landscape vegetation, etc.). Generally, per capita water usage from City and KPUD water systems is higher in the southern part of Bainbridge Island. Available water use data in terms of ERU for 2022 is presented in Appendix I.

3.3 Other Environmental Factors Impacting Groundwater

3.3.1 Development of Open Spaces / Development Near Wetlands and Streams

Development significantly alters natural wetland and stream systems through changes in hydrology, water quality, and habitat structure. After development, these water bodies experience increased frequency and duration of high streamflow during wet weather, while suffering from reduced streamflow and wetland water levels during dry seasons. Consequently, stream channels face both increased flooding and reduced base flows, leading to the alteration or destruction of natural features like riffles, pools, and gravel bars (SWMMWW 2024).

The relationship between development and stream degradation is well documented. Research shows that even at low levels of urban development, significant changes occur in stream stability. These changes begin when developed impervious areas reach just 5% of watershed land cover, creating a direct connection between runoff and channel erosion (SWMMWW 2024). This erosion commonly manifests as channel widening and streambed downcutting, resulting in

habitat damage and reduced biological diversity across arid, semiarid, and humid climate settings.

Smaller water bodies are particularly vulnerable to development impacts. First to third order streams and water bodies with contributing watershed areas less than 100 square miles are most susceptible to changes in runoff patterns caused by development (SWMMWW 2024). The biological communities in wetlands are especially sensitive, where even small changes in natural water elevation fluctuations can cause dramatic shifts in vegetative and animal species composition.

Temperature changes present another significant impact on these ecosystems. Urbanization contributes to excessive summer stream temperatures through two primary mechanisms: direct heating from removal of riparian vegetation and reduced groundwater recharge due to impervious surfaces (SWMMWW 2024). These changes can have direct lethal effects on aquatic life by reducing maximum available dissolved oxygen and potentially causing algae blooms that further reduce oxygen levels.

Construction impacts from open space conversion to development can also be significant. During construction, sediment loads can turn receiving waters turbid and be deposited over natural sediments. Pollutants typically expected in stormwater from construction activity include sediment, pH, nutrients, and petroleum products (SWMMWW 2024). These pollutants can seriously impair beneficial uses of receiving waters if not properly managed.

3.3.2 Saltwater Intrusion

Saltwater intrusion occurs when seawater enters and contaminates freshwater aquifers, leading to elevated chloride levels in well water. This phenomenon typically arises when groundwater is extracted from aquifers that are in hydraulic connection with marine waters such as Puget Sound. As freshwater is pumped out, it creates a pressure imbalance that can draw saltwater inland toward the well. The severity of intrusion depends on factors like local geology, aquifer properties, topography, and the size and capacity of the recharge area. Seasonal variations, especially in the summer when rainfall is low and groundwater usage increases, can exacerbate the problem.

Ecology classifies saltwater intrusion risk levels based on chloride concentrations: levels between 25–100 mg/L indicate a low-risk area; 100–200 mg/L, or under 100 mg/L with a rising trend, signal a medium-risk area; and 200 mg/L or more, or increasing levels between 100–200 mg/L, denote a high-risk area.

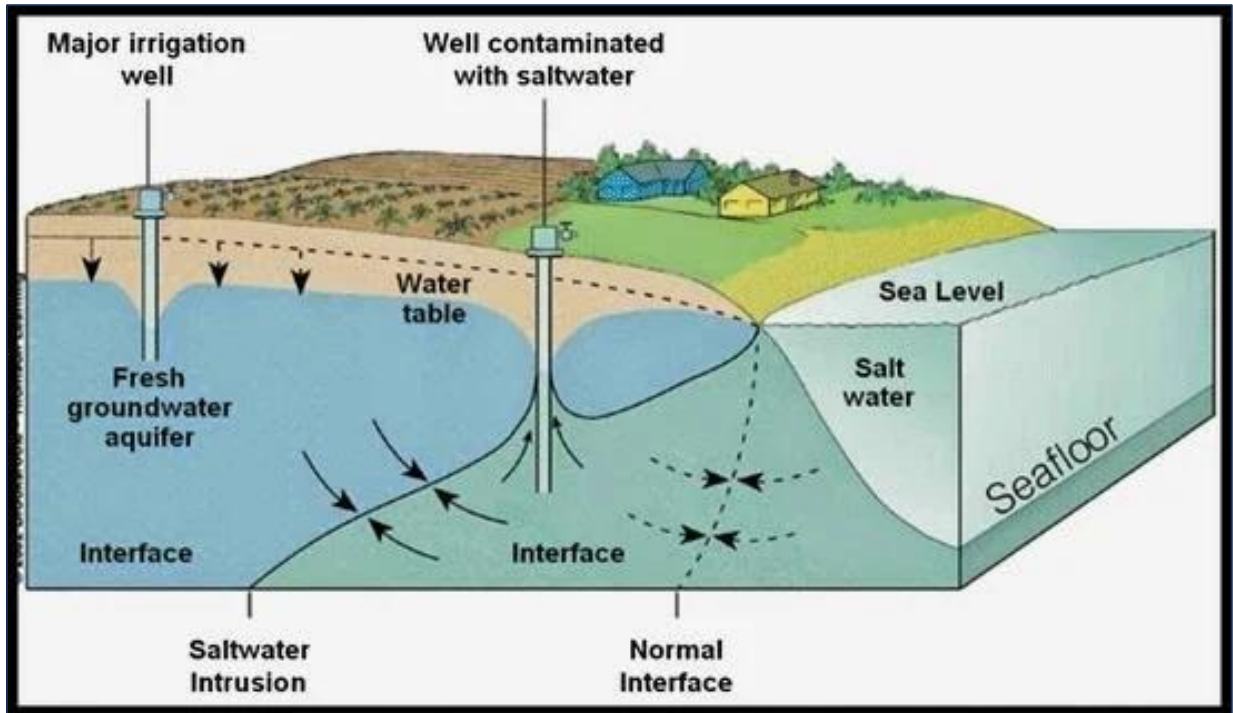


Figure 27 Saltwater Intrusion Conceptual Diagram

Source: Abd-Elaty et al. 2019

Preventing saltwater intrusion is essential, as reversing the process is extremely difficult once contamination occurs. In some cases, wells have had to be permanently closed due to saltwater infiltration, highlighting the importance of proactive management and protection of vulnerable groundwater resources.

3.3.3 Climate Change Variables

Climate change modeling scenarios project several impacts to Bainbridge Island's water resources and environment. Simulated average annual air temperatures increase by between 4 to 5.5°F by 2050, with summer months experiencing the most dramatic warming (Mauger 2015). Rising temperatures will increase water demand across both human and natural systems, affecting terrestrial, freshwater,

and marine ecosystems.

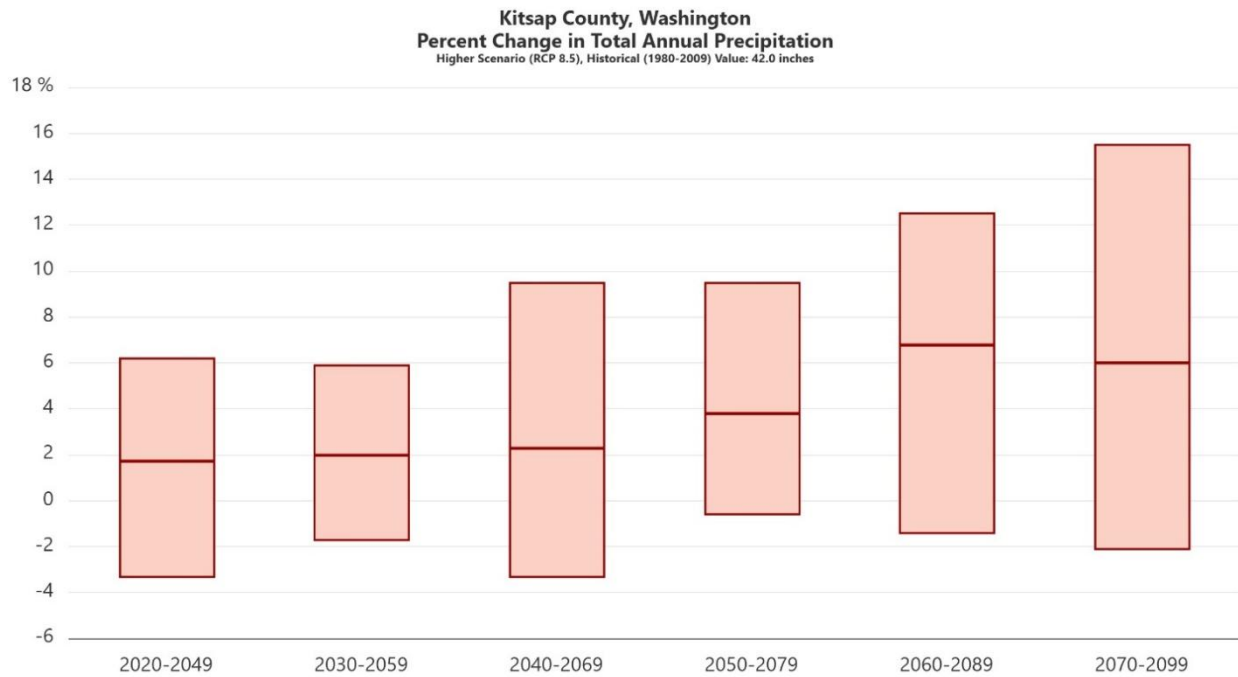


Figure 28 Predicted Precipitation Change

Source: UW CIG Climate Mapping Web Tool 2026

Precipitation patterns are also projected to shift. Overall, annual precipitation is projected to rise by about 3-6% over the next 80 years (Figure 28). Winter months are predicted to bring more frequent and intense rainfall events, which could lead to greater surface runoff and reduced groundwater infiltration. Specifically, most models forecast an average increase in winter precipitation of 4-10%, while summer precipitation is projected to decrease by 2-16% by 2080 relative to the 1950–1999 baseline (Rogers 2021). These seasonal shifts are predicted to result in shorter, wetter winters with more extreme precipitation events and longer, drier summers, but predictions are uncertain.

Intense precipitation events could increase in frequency from two to seven times per year, with their intensity potentially rising by up to 22% (Mauger 2015). However, these projections rely on global climate models and scenarios that may

be so uncertain as to have limited utility for guiding sepecific local management decisions (Keta Waters 2025).

Concerns regarding how changes to climate will impact groundwater recharge have been raised and discussed within the Groundwater Subcommittee and Technical Advisory Committee. The basis of these concerns is that warming temperatures will result in longer growing seasons and increased evapotranspiration (ET). In addition, increased impermeable surfaces and an increase in the intensity of precipitation events could reduce groundwater recharge by increasing the fraction of rain that leaves the Island as surface runoff. However, it is also plausible that overall increases in the total amount of precipitation could offset both of these potential reductions to groundwater recharge, resulting in no significant change to recharge (however it should be noted that relative to temperature change, local precipitation changes are much more uncertain).

The important point is that climate change will continue to impact Bainbridge Island and introduces substantial uncertainty for future planning. To aid planning in light of that uncertainty, the GWMP's equilibrium groundwater modeling considers a range of possible scenarios including relatively strong reductions and increases to recharge and pumping. However, ultimately, management strategies that lead to a more resilient and sustainable system independent of an uncertain and unknowable future should be prioritized (Keta Waters 2025).

Sea level rise associated with climate change also poses a significant risk for saltwater intrusion into coastal aquifers. As sea levels rise, the hydraulic gradient between freshwater and seawater can be altered, increasing the potential for seawater to encroach into freshwater systems (Ecology 2003). Ecology notes that rising sea levels may exacerbate seawater intrusion.

In 2024 the City of Bainbridge Island completed a [Sea-Level Rise Vulnerability and Risk Assessment](#) that focused on mapping hazard areas more precisely. As part of the assessment a mapping tool was created that can show how SLR affects neighborhoods differently based on environmental factors and existing utility locations.

4. Observed Groundwater Trends, Data and Information Gaps

4.1 Historical Trends in City Water System Quality

The historical water quality data reveals several noteworthy trends across the City's water systems. The chloride levels have remained consistently low, with 2026 measurements showing concentrations between 3.5-11.7 mg/L before treatment, well below the secondary MCL of 250 mg/L. Historical post-treatment levels have shown higher concentrations up to 24 mg/L, suggesting that treatment processes may influence chloride content in the finished water.

Manganese has emerged as a significant concern, particularly in the Winslow Water System where the Head of Bay wells demonstrated levels ranging from 0.094 to 0.161 mg/L, substantially exceeding the secondary MCL of 0.05 mg/L (Carollo 2017). The Commodore well also showed elevated manganese at 0.052 mg/L. Recent research has raised additional concerns about manganese, suggesting that the current secondary MCL of 0.05 mg/L may be insufficient for public health protection, with researchers recommending a more stringent target of less than 0.02 mg/L (Carollo 2017). The presence of elevated manganese can lead to multiple issues, including biofilm growth, scale formation, accumulation of toxic trace metals, and potential release of these contaminants into the distribution system (Carollo 2017).

The Rockaway Beach Water System has demonstrated better manganese control through its treatment system. Although raw water testing showed manganese levels of 0.049 mg/L, the treatment process consistently maintains levels below the MCL (Carollo 2017). Iron levels have generally remained low throughout both systems, with only one notable exception at Head of Bay Well, which showed an iron concentration of 0.153 mg/L (Carollo 2017).

Nitrate levels have remained consistently low across all water sources. The 2015 testing revealed minimal concentrations, with Sands Avenue wells showing 0.11-0.12 mg/L and the Taylor Avenue well at 0.14 mg/L, while other wells had non-detectable levels. These values are substantially below the MCL of 10.0 mg/L, indicating no significant nitrate concerns in the water system (Carollo 2017).

In response to these water quality challenges, particularly regarding manganese, the City is in the process of evaluating and upgrading systems that manage water quality at all of its well sites (Carollo 2017).

A report on recent data collection, including chloride and conductivity, by the City's Groundwater Monitoring Program can be found in Appendix E.

4.2 Recent Trends in KPUD Water System Quantity

The South Bainbridge Water System (South Bainbridge) is owned and operated by KPUD and serves the geographic area that stretches from the westernmost portion to the easternmost portion of the south end of the City. The analysis that was prepared for the Department of Health review in November 2021 concluded that the South Bainbridge system had sufficient capacity to meet 20-year growth projections. However, in 2025, KPUD identified that certain source meters had been over-registering. This discovery resulted in a re-evaluation of South Bainbridge's capacity, which was completed in January 2026. The re-evaluation indicates that the South Bainbridge cannot support additional connections due to limited groundwater resources and above average customer summer water usage. To preserve adequate water capacity for existing customers and allow time for development of a water conservation effort and an additional water supply to support future growth, KPUD temporarily suspending the sale of new binding water availability letters.

As a result of the suspension, the City and KPUD are developing an interlocal agreement that identifies areas of water system coordination between the agencies. The coordination areas include a potential near-term inter-tie between the City system and the South Bainbridge Water System, long-term planning for water system coordination and planning across the City – including the potential for new shared supply wells and working together on the development of a city-wide water conservation plan.

4.3 City of Bainbridge Island Groundwater Monitoring Program

The City's Groundwater Monitoring Program was established in 2006 to bring various groundwater monitoring programs across the Island into one centralized program and database. The Groundwater Monitoring Program also expanded the

monitoring network to include areas and aquifers that were inadequately sampled or were of special concern. The associated database contains current and historical groundwater quality (chloride), groundwater levels, and production volumes.

Prior to 2006, monitoring of water quality and levels was undertaken primarily in conjunction with community water supply production by the City, and KPUD. Additionally, from 1984 to 1991 and 2007 to 2009, USGS conducted a water level monitoring program in support of the development of a numerical groundwater model (Frans *et al.* 2011).

The City's current groundwater monitoring network consists of 87 public and private wells distributed Island-wide across the six Bainbridge Island aquifers as follows (Figure 29):

- Perched (PA) and Semi-Perched Aquifer (SPA) - 24 wells
- Sea Level Aquifer (SLA) - 44 wells
- Glaciomarine Aquifer (GMA) - 6 wells
- Fletcher Bay Aquifer (FBA) - 12 wells
- Bedrock Aquifer (BR) - 1 well

Wells may be added or removed from the network over time. For example, well owners may choose to drop out of the monitoring program or public wells may be added as they come under the ownership or management of either City or KPUD. Wells may be monitored for water level only, chloride only, or both water level and chloride.

Along with the development of the monitoring program was the development of Early Warning Levels (EWL). EWLs are quantifiable measures for initial evaluation of data that provide timely warning of a potentially developing groundwater issue before a problem becomes acute. If an EWL is exceeded, additional investigation is conducted to include problem-specific technical data review and analysis to confirm data validity. Additional sampling and field investigation are performed to confirm a potential problem and, if confirmed, identify the extent and potential causes for the exceedance. Ultimately, additional management actions, noted below, could be required to address problems identified by exceedances of the EWLs.

EWLs developed for Bainbridge Island include two components, selected to address Island-specific characteristics that are meaningful measures for protecting groundwater supplies on the Island. The two measures include monitoring groundwater levels and chloride concentrations in wells across the Island. On-going monitoring of groundwater elevations and chloride concentrations in Island aquifers ensure that actions can be taken to protect groundwater supplies from overdraft and saltwater intrusion long before problems occur. Each component is described in more detail in the sections below.

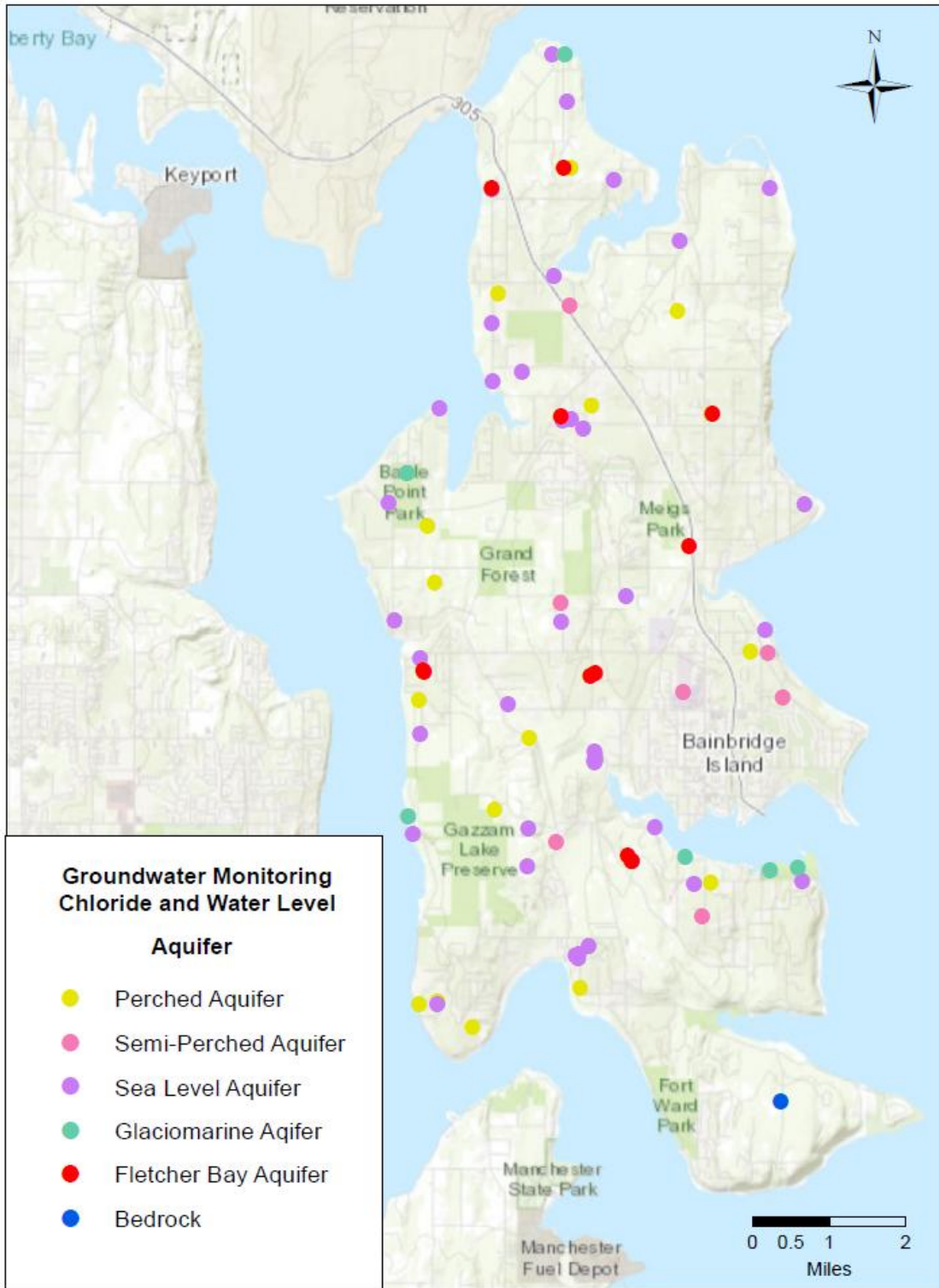


Figure 29 City of Bainbridge Island Monitoring Network

4.3.1 Groundwater Quality (Chloride) Monitoring Network

The City's Groundwater Monitoring Program (Aspect 2006) defines saltwater intrusion as a chloride concentration at or above 100 mg/L or any increasing trend in chloride concentration.

The 100 mg/L level is based on Ecology's draft Seawater Intrusion Policy (Ecology 1990). Although the secondary drinking water standard for chloride is 250 mg/L use of 100 mg/L or an increasing trend in chloride concentration as an EWL is appropriate for early detection. As noted above, natural fresh groundwater on Bainbridge Island typically exhibits chloride concentrations of 20 mg/L or less. Thus, an increasing trend in chloride concentrations or values at or above 100 mg/L are appropriately conservative criteria that warrant additional investigation when a potential problem is initially detected. Because various sources, other than saltwater intrusion can cause elevated chloride concentrations in groundwater, additional investigation is needed to determine whether saltwater intrusion is the cause.

A determination of an increasing trend requires at least four consecutive samples or samples taken over at least a one-year period with seasonality considered. Chloride concentration can vary between the wet season and the dry season. Therefore, to take seasonality into account, the City separates chloride data by season before comparing concentration trends to the EWL.

The EWLs are applied to data collected for the City's Groundwater Monitoring Program and are intended to support long-term sustainable groundwater development and management.

Should the EWL for chloride be exceeded, possible responses include:

- Site investigations
- More frequent chloride samples
- Additional monitoring parameters, such as specific conductivity
- Evaluation of trends over time
- Determining distance from the coast or other wells with elevated chloride concentrations
- Evaluation of nearby pumping and groundwater elevations

Currently, wells in the network are assessed annually as part of the City's groundwater monitoring program. This assessment consists of field measurement of specific conductivity and taking a water sample for laboratory analysis for chloride. The results of the chloride analyses are compared to the chloride EWL response threshold of 100 mg/L or any increasing trend (Aspect 2009). An increasing or decreasing trend in chloride concentrations is characterized by at least four consecutive samples or samples taken over at least a 1-year period with seasonality considered. The groundwater monitoring program provides response actions including confirmation of the data, determine extent, and identification and implementation of appropriate response actions.

An example of the City's response to an elevated chloride level exceeding the EWL can be found in the [Seabold Potential Seawater Intrusion Investigation 2018](#). When the Seabold Water Association's well registered chloride concentrations above the EWL in 2006, the City, along with Kitsap Public Utility District and Kitsap Public Health District, launched a two-phase investigation to determine whether this exceedance was due to regional seawater intrusion or a localized source of contamination. This proactive effort included reviewing water quality data from numerous wells, conducting targeted sampling in the Seabold area, monitoring chloride trends over time, and evaluating possible sources such as well operations and water treatment by-products. The investigation did not indicate seawater intrusion was occurring on a large scale, because others wells in the vicinity did not have similar chloride levels (KPUD 2018).

Recent monitoring results are included in the 2012-2021 EWL report in Appendix E.

4.3.2 Groundwater Quantity (Level) Monitoring Network

The City's Groundwater Monitoring Program (Aspect 2006) defines the aquifer's sustainable groundwater elevation EWL as a declining rate of ½ foot or more per year over a ten-year period that cannot be explained by variations in precipitation.

The target for the groundwater level EWL is long-term changes in the aquifer resulting from groundwater withdrawals. Because the majority of groundwater recharge comes from precipitation and groundwater levels are naturally impacted by precipitation patterns, separating those impacts from changes resulting from groundwater pumping is necessary to determine that EWLs have been reached. As

noted above, increasing withdrawals are expected to lower groundwater levels. However, monitoring and attempting to limit declines resulting from increased groundwater pumping promotes long-term sustainability of the resource.

To determine variations in precipitation, the City uses a Cumulative Departure Precipitation (CDP) curve which represents the running total of differences between monthly rainfall and the average rainfall over any 10-year assessment period. Wetter than normal periods cause groundwater levels to rise, while drier than normal periods cause groundwater levels to fall. Removing those impacts allows for evaluation of groundwater level changes due to groundwater pumping rather than natural variation.

If water level data for a well indicate exceedance of the EWL, the following responses are recommended (to date, these actions have not been implemented in response to EWL findings):

- Analyze the data on an aquifer basis by comparing well hydrographs within the aquifer and with the cumulative rainfall departure curve.
- Compare hydrographs with production data and acquire additional production data as necessary to correlate pumping with groundwater levels.
- Determine the area impacted by water level observations and calculation of the zone of contribution.
- Consider adding additional monitoring wells to the existing network.
- Evaluate long-term impacts with the groundwater model.
- Propose management actions such as limiting or reducing pumping and transferring withdrawals to other areas or aquifers.

Recent monitoring results are included in the 2012-2021 EWL report in Appendix E.

4.4 Groundwater Data Gaps

Several significant data gaps limit our comprehensive understanding of Bainbridge Island's groundwater challenges, including insufficient monitoring well coverage, incomplete aquifer connectivity assessments, and uncertain climate change impacts on the groundwater system. This uncertainty specifically affects our understanding of productive aquifer systems like the GMA and FBAs, where limited well data prevents accurate mapping of groundwater flow patterns.

The monitoring network itself presents certain limitations, as the system is dynamic with wells being added or removed over time when well owners choose to opt out of the monitoring program or as public wells come under new ownership. This variability in monitoring locations can create gaps in long-term trend analysis and understanding of groundwater conditions. Additionally, while EWLs exist for monitoring potential problems, the water level trends alone do not definitively indicate whether aquifer overdraft or depletion is occurring, requiring additional data collection and analysis.

Climate change presents another area where data is insufficient. More comprehensive information is needed to understand annual variations in aquifer recharge, predicted reductions in recharge, changes in recharge timing, and other significant hydrogeologic factors. The groundwater model cannot predict the future with certainty, but it can indicate availability of groundwater in the future when considering climate change impacts. Currently, there are not sufficient data to definitively quantify which portion of increased precipitation is sourced from high-intensity storms versus low- or medium-intensity storms, which affects understanding of potential recharge patterns (EA 2025). Studies are underway by the USGS in San Juan and Thurston counties studying this relationship and will inform future modeling as this plan is adaptively managed.

To address these data gaps, several strategies have been identified and are described in further detail in Chapter 7.

5. Overview of Groundwater Modeling

Groundwater flow models are used to enhance understanding of the groundwater system and to consider various “what if” scenarios that can inform groundwater management decisions. Numerical groundwater flow models use computers to solve equations that describe groundwater flow. Use of commercially-available or publicly-available software packages is a common tool for both groundwater resource management and contaminated groundwater investigations and cleanup.

A groundwater model is a simulation and simplification of a complex environment. These models cannot fully replicate this complex environment with complete

accuracy. Sources of errors and uncertainty include uncertainties in geological conditions, in the extent and amount of groundwater recharge, in the connection between surface water and groundwater, and in the response of groundwater levels to pumping. Models are calibrated to observed conditions (including groundwater levels derived from monitoring networks) to evaluate the appropriateness of the assumptions and data used to construct the model (Reilly and Harbaugh, 2004).

Solutions or outputs from the model may be non-unique, meaning that it is possible that similar solutions (e.g., groundwater elevations and groundwater flow directions) can result from different sets of input values. These different input values may result in different implications for management actions. For example, a model with high recharge rates and high aquifer permeability may give results similar to a model with low recharge rates and low aquifer permeability. These two models may match observed water levels in a similar way, and yet they would result in different estimates of sustainable yield and potentially different management actions.

Bainbridge Island has been included in at least five groundwater flow models that have been developed over the last fifteen years. Table 6 provides a summary of the different models and Appendix O presents more details about the models. These models are closely related and have many similarities in terms of how the hydrogeology of Bainbridge Island is described. In particular, the sequence and layering of aquifers and confining units are similar in all five models and in all five models water enters the system as recharge from precipitation and septic-system returns and exits the system via groundwater pumping, streamflow, and discharge to Puget Sound. The models differ primarily in terms of values assigned to characteristics of aquifers and confining units, groundwater recharge rates, and groundwater pumping rates. The individual models are also used to simulate different time periods and to consider different future scenarios.

The models listed in Table 6 were all used to simulate transient groundwater flow. When used in this mode, the models attempt to describe monthly changes that result from differing pumping rates and recharge rates. The time needed to

complete these simulations is relatively long because the models must be run in one-month timesteps from the past into the future. For example, if a model is used to simulate 20 years in the past and 80 years forward, 1,200 separate timesteps must be simulated to look at one pumping-rate or recharge scenario.

An alternative approach to running the models in transient mode is to use steady-state simulations. These simulations provide estimates of the groundwater system once it reached equilibrium. The advantage of steady-state modeling is that the model is run for one timestep for each scenario, rather than 1,200 times as described above. The disadvantages are that these steady-state applications do not provide information about how long it might take to reach a new equilibrium and the models give only average values for water levels and groundwater flow rates, rather than full seasonal cycles. Keta Waters (2026) used the 2023 Aspect Model and the 2025 EA Model in steady-state mode to evaluate equilibrium conditions for a variety of scenarios.

Table 6 Overview of models describing groundwater flow on Bainbridge Island

Model	Area (sq. mi.)	Layers	Streams included?	Recharge from rainfall (AFY)	Validation parameters	Well pumping (mg/yr)	Flow to surface waters (cfs)
2011 USGS Bainbridge Model (USGS, 2011)	101	33	Yes, as drains	18,000 ¹	Water levels and stream flow	653	22.1
2016 Aspect Bainbridge Model (Aspect, 2016)	101	33	Yes, as drains	13,675	Water levels	836	5.3

2016 USGS Kitsap Model (USGS, 2016)	786	14	Yes, as streams	n.a. ²	Water levels and stream flow	n.a.	n.a.
2023 Aspect Bainbridge Model (Aspect, 2023)	247	14	No	18,726	Water levels	816 ³	13.5 ³
2025 EA Bainbridge Model (EA, 2025)	247	9	No	17,337	Water levels	741	16.3

¹The 2011 USGS model uses 18,000 AFY for 2008 conditions and 30,000 AFY for predevelopment conditions.

²The 2016 Kitsap Model report does not explicitly describe recharge, well withdrawals, or streamflow for Bainbridge Island

³ Well withdrawals and surface water flows were not reported in Aspect (2023) and were calculated from model files.

5.1 Summary of selected model findings

Selected findings from the Bainbridge Island groundwater models listed in Table 6 are summarized below.

5.1.1 2011 U.S. Geological Survey Model for Bainbridge Island

The U.S. Geological Survey, in cooperation with the City, developed a groundwater flow numerical model to characterize the groundwater system and its interaction with surface water (Frans *et al.* 2011). Available data sets of geologic, hydrogeologic including groundwater levels, precipitation, land use, water use, and surface water information were used in support of developing this model. The 2011 Bainbridge Island Groundwater Model was used to develop several “simulations” or representations of the groundwater system that simulate pre-development conditions. These simulations can act as a baseline for comparison to examine effects of current and potential groundwater use on the groundwater and surface water system. Impacts on the groundwater system under projected climate change and land use were also examined.

The model boundaries extend beyond Bainbridge Island in recognition that the aquifers underlying the Island, especially the deeper aquifers, may extend westward to the eastern portion of Kitsap Peninsula. To simulate groundwater flow, the model is divided into a three-dimensional array of cells. Horizontally, the cells were set to represent an area of 800 ft by 800 ft. Vertically, cells were assembled into a total of 33 layers with varying thicknesses that represented the configuration of aquifers and confining units.

The model was used to evaluate pre-development to current (2008) conditions and make some observations of likely future conditions (2035) under a given set of conditions. The results presented in the report focused on the PA, the SLA, and the FBA which provide most of the drinking water supplies on the Island. Key findings of the 2011 U.S. Geological Survey model for Bainbridge Island are summarized in Table 7.

Table 7 Key Findings from 2011 USGS Model Bainbridge Island

Simulation	Findings
2008 simulation – evaluate change from predevelopment groundwater conditions to 2008	<p>Slight increases in water level altitudes in the shallow aquifer are likely due to increased recharge from septic system returns</p> <p>General decline in water level altitudes in deeper aquifers (0–10 feet in Sea Level Aquifer and 10–35 feet in FBA)</p> <p>No change in general radial flow pattern for groundwater in Perched and Sea Level aquifers.</p> <p>Slight change in general west to east groundwater flow direction in the FBA on the western side of the Island</p>

		Saltwater/freshwater interface remains offshore
2035 simulation – evaluate potential groundwater conditions under four scenarios	1. Expected impact scenario: Most probable population growth, change in land use, and climate change projections	General declines between 0 and 5 ft in Perched and Sea Level aquifers and 4–10 ft in FBA
	2. Minimal impact scenario: Lowest projected population growth, increased recharge from minimal changes in land use and climate projections	Slight increase to slight decrease (less than 5 ft) in the Perched and Sea Level aquifers and declines of up to 5 ft in the FBA
	Maximum impact scenario (exaggerated to fully stress system and are not likely to eventuate): Maximum projected population growth and decreased recharge due to changes in land use and climate	Declines less than 10 feet in the Perched and Sea Level aquifers Declines of 10–40 feet (western edge) in FBA may lead to reversal of flow to east to west No saltwater intrusion identified to end of model period (2035), but intrusion could occur if conditions persist beyond 2035
	Protection of recharge areas scenario: Delineated areas contributing recharge for water supply wells combined with	No changes in land use anticipated in areas identified by the model as recharge areas for City wells Change in water levels is the same as the expected impacts scenario

	expected impact simulation	
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5.1.2. 2016 U.S. Geological Survey Model for Kitsap Peninsula

USGS, in cooperation with KPUD and several water purveyors on the Kitsap Peninsula, developed a groundwater flow numerical model to simulate transient conditions in the groundwater systems on the Kitsap Peninsula, including Bainbridge Island. Similar to Bainbridge Island, groundwater is the primary source of drinking water for most of Kitsap Peninsula. The 2016 Kitsap groundwater model expanded and made further refinements to the 2011 Bainbridge Island groundwater model (Frans and Olsen 2016). Use of a transient numerical model allowed for representation of a dynamic system where inflow, outflow, and groundwater storage change with time (Frans and Olsen 2016).

The 2016 Kitsap Peninsula groundwater model was supported by geological, hydrogeological, a water budget, land and water use, and climate (current and projected data) information described by Welch, Frans, and Olsen, 2016.

Groundwater flow in unconfined aquifers underlying Kitsap Peninsula is generally radially from the peninsula towards Hood Canal and Puget Sound. As seen on Bainbridge Island, locally, low permeability layers can influence groundwater flow patterns both vertically and horizontally.

The numerical model was used to simulate groundwater flow and to examine the effects of changes in groundwater withdrawals, consumptive use and recharge on water levels and stream baseflows (Frans and Olsen 2016). A total of six simulations illustrating effects on groundwater levels and stream baseflows from changes in groundwater withdrawals, consumptive use, and recharge.

Key findings of the 2016 U.S. Geological Survey model for Kitsap Peninsula are summarized in Table 8.

Table 8 Key Findings from 2016 USGS Model Kitsap Peninsula

Simulation	Findings
1. Steady-state (Uses average of 2005–2012 pumping rates and 30-year annual average recharge to simulate conditions)	Comparison of steady state simulation to transient simulation indicates system is not in steady state (i.e., has not reached equilibrium)
2. No pumping and return flows (Assess impacts of current pumping on streamflow and water level altitudes)	Rising water level altitudes in many areas Increased baseflow amounts between 1 and 3%
3. 15% Increase in current withdrawals in all wells and in current return flows (simulate population growth)	Overall, there is a smaller effect on the model simulations than decrease in recharge by 15% General water level altitudes in the shallow aquifer decline (0–1 feet) with localized areas of increases (0–2.5 feet) due to increased return flow Water level altitudes in deeper aquifers decline (0–2 feet)
4. Water Conservation (Decrease current outdoor water use by 80% with associated reduction in amount of water pumped)	General rising water level altitudes in shallow aquifer (0–2 feet) with localized areas of declining water level altitudes (0–3.6 ft) due to lower secondary recharge from irrigation General increase in water level altitudes in deeper aquifers (0–6 ft) due to less pumping
5. Climate change drought simulation (Decrease recharge by 15%)	Water-level altitudes decline in all aquifers Baseflow in streams decrease by as much as 18% to baseline conditions

6. Particle tracking (Assess groundwater flow paths)	Areas contributing to water supply wells were simulated
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5.1.3. 2016 Aspect Model for Bainbridge Island

An update to the 2011 USGS Groundwater Model was completed by Aspect in 2016 (Aspect 2016). This update was made concurrently to, but not directly in conjunction with, the 2016 USGS Kitsap Peninsula Groundwater Model. In general, the modeling assumptions and improvements align with the 2016 USGS Kitsap Peninsula Groundwater Model. The 2016 Bainbridge Island Groundwater Model by Aspect incorporated revised recharge rates based on findings in the 2014 USGS Kitsap Peninsula Report (Welch *et al.* 2014) used to support the 2016 USGS Kitsap Peninsula Groundwater Model. Additional updates to the 2016 Bainbridge Island Groundwater Model included updated monthly water supply well pumping rates as well as revisions to modeling approach and underlying assumptions.

The 2016 Bainbridge Island Groundwater Model by Aspect was used to support a Critical Aquifer Recharge Area Assessment to define areas that provide critical recharge to aquifers used for potable water supply (Aspect 2015). The 2016 Bainbridge Island Groundwater Model also was used to assess Aquifer System Safe Yield (Carrying Capacity) (Aspect 2016).

Key findings of these two assessments using the 2016 Bainbridge Island groundwater model are summarized in Table 9.

Table 9 Key Findings from 2016 Aspect Model Bainbridge Island

Simulation	Findings
1. Critical Aquifer Recharge Area Assessment (based on particle tracking analysis of hypothetical particles following model-defined flow paths)	Wells in shallow aquifers (including the SLA and above) may withdraw water that originates as recharge relatively close to the well head and is younger than 100 years old.

	<p>Wells in deep aquifers (including the Glacio-Marine Aquifer and the FBA) may withdraw water that originates as recharge relatively distant from the wellhead and is greater than 100 years old.</p> <p>Not all groundwater on Bainbridge Island comes from recharge on Bainbridge Island. Model results indicate several wells tapping the deeper aquifers withdraw water that originates as recharge from areas on the Kitsap Peninsula and is greater than 1,000 years old.</p>
<p>2. Aquifer System Safe Yield (Carrying Capacity) Assessment</p> <p>Simulated 3 stresses concurrently:</p> <p>50% increase in groundwater withdrawal rates to simulate population growth</p> <p>20% reduction in recharge rates to simulate effects of climate change</p> <p>4 foot rise in sea level due to climate change</p>	<p>Wells within the shoreline are predicted to maintain chloride concentrations below 100 mg/L and no trends in chloride concentrations were predicted</p> <p>Approximately 40% decrease in groundwater drainage to surface water</p> <p>The predicted groundwater level changes over a 100-year timeframe were less than the City EWLs, but they do not meet the definition of sustainable yield given the measurable annual declines that are predicted.</p> <p>The PA system showed an average 0.10 foot per year of water level decrease at 25 locations simulated across the Island</p> <p>The SPA system showed an average 0.13 foot per year of water level decrease at 12 locations simulated across the Island</p>

	<p>The SLA system showed an average 0.09 foot per year of water level decrease at 49 locations simulated across the Island</p> <p>The GMA showed an average 0.02 foot per year of water level decrease at 6 locations simulated across the Island</p> <p>The FBA showed an average 0.15 foot per year of water level decrease at 9 locations simulated across the Island.</p>
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5.1.4. 2023 Aspect Model for Bainbridge Island

Aspect modified the 2016 Kitsap model and then used this model to assess long-term changes in groundwater conditions associated with increased groundwater withdrawal rates. Scenarios included decreased groundwater recharge rates, increased sea level, and a 50-percent increase in groundwater withdrawal across Bainbridge Island. The on-Island groundwater balance (including potential changes in the groundwater discharge to surface water) for the entire aquifer system was evaluated.

Stream boundaries that were used in the 2016 USGS model were converted to drain in the 2023 Aspect model to improve model stability. Drain boundary conditions only allow for gaining conditions in streams and do not fully describe actual groundwater/surface water interactions. Subbasins were delineated across Bainbridge Island to allow for more detailed analysis of groundwater-surface water interactions in watersheds of interest.

The Aspect 2023 model was used to evaluate three primary topics: 1) seawater intrusion, 2) rates of water level decline, and 3) impacts to streamflow. The evaluations were completed using 100-year model simulations.

Key findings from the Aspect 2023 modeling study are summarized in Table 10.

Table 10 Key Findings from 2023 Aspect Model Bainbridge Island

Simulation	Findings
Seawater intrusion	The Sea Level Aquifer system did not show seawater intrusion within the Bainbridge Island shoreline. The deeper aquifer systems (including the Glaciomarine Aquifer and the Fletcher Bay Aquifer) did not show seawater intrusion, because of thick confining units and fresh groundwater flow sourced by off-Island recharge areas.
Rate of groundwater level decline	The Sea Level Aquifer system showed an average 0.04 feet per year of water level decrease across the Island. The Glaciomarine Aquifer showed an average 0.03 feet per year of water level decrease across the Island. The Fletcher Bay Aquifer showed an average 0.05 feet per year of water level decrease across the Island.
Potential changes in streamflow	The percent reduction in streamflow as compared to the historical baseline discharge under 2021 average conditions range from 15 to 58% for the different subbasins. The average reduction was approximately 25%.

5.1.5. 2025 EA Model for Bainbridge Island

The City contracted with EA Consulting to calibrate the Bainbridge Island groundwater model initially created by the USGS and later refined by Aspect Consulting. During EA’s calibration and update of the model with recent monitoring data they also refined parameters in the model such as aquifer thicknesses and locations. Detailed information on the calibration and updates can be found in the Technical Memo provided in Appendix K (EA, 2025).

The EA modeling effort considers three primary variables for evaluating future conditions: well production (pumping); groundwater recharge; and, sea level rise. Three scenarios were considered and described as Low, Mid, and High impact.

The Low Impact Planning Scenario is presented as representing the most likely future conditions.

Key findings of these three scenarios using the 2025 EA Bainbridge Island groundwater model are summarized in Table 11.

Table 11 Key Findings from 2025 EA Model Bainbridge Island

Simulation (Representation of the Bainbridge Island Groundwater System)	Findings
<p>1. Low Impact Scenario with no change in recharge rates, sea level rise of 2.8 feet, and total pumping increased by a factor of 2.22</p>	<p>Negligible changes to the Qva unit water levels relative to current conditions. Mean groundwater levels are simulated to increase 0.1 feet in the Qva after 100 years</p> <p>Mean decreases in groundwater levels in the SLA range from 1 foot after 20 years to 6 feet after 100 years. This decrease is primarily centered around the South Bainbridge Wellfield. Groundwater elevations drop below sea level around the South Bainbridge Wellfield by year 50 of the simulation.</p> <p>Mean decreases in groundwater levels in the GMA range from 5 feet after 20 years to 33 feet after 100 years. This decrease is primarily centered around the Island Utility Wellfield. Groundwater elevations in this unit drop below sea level in the southern portion of the Island between year 50 and year 100 of the simulation.</p> <p>Mean decreases in groundwater levels in the FBA range from 8 feet after 20 years to 50 feet after 100 years. Groundwater levels in the FBA fall below mean sea level across the central portion of the Island at simulation year 75 (corresponding to calendar year</p>

	<p>2097) under the Low Impact Planning Scenario conditions.</p>
<p>2. Mid Impact Scenario with 7.5% decrease in recharge rates, sea level rise of 6.9 feet, and total pumping increased by a factor of 2.67</p>	<p>Negligible changes to the Qva unit water levels relative to current conditions. Mean decreases in groundwater levels in the SLA from 2 feet after 20 years to 6 feet after 100 years. This decrease remains primarily centered around the South Bainbridge Wellfield.</p> <p>Mean decreases in groundwater levels ranging from 10 feet after 20 years to 46 feet after 100 years. The portion of the aquifer unit with groundwater elevations below mean sea level expands past the footprint of the Island quicker (by year 50), and to a greater overall extent (by year 100) in the Mid Impact Planning simulation as compared to the Low Impact Planning simulation results.</p> <p>Mean decreases in groundwater levels in the FBA ranging from 16 feet after 20 years to 71 feet after 100 years. The portion of the aquifer unit with groundwater elevations below mean sea level expands past the footprint of the Island quicker (by year 50), and to a greater overall extent (by year 100) in the Mid Impact Planning simulation as compared to the Low Impact Planning simulation results.</p>
<p>3. High Impact Scenario with 20% decrease in recharge rates, sea level rise of 6.9 feet, and total pumping increased by a factor of 2.67</p>	<p>Water levels in the Qva unit decrease 5 feet by year 100. Mean groundwater levels in the SLA did not show an increased impact due to reduced recharge until year 100, when mean groundwater levels were simulated to be 10 feet below current conditions.</p>

	Reduction in recharge resulted in an additional mean groundwater level decrease relative to the mid-impact scenario of 4 feet and 5 feet in the GMA and FBA, respectively, by year 100. In general, the timing of when the mean groundwater level in the GMA and FBA drops below mean sea level, and the extent of drawdown in the FBA was not significantly impacted by the further reduction in recharge.
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5.1.6. 2026 Keta Water Equilibrium Modeling

The City contracted with Keta Waters to run the 2025 EA model in steady-state mode using a range of annual average recharge rates and annual average withdrawal rates. The 2025 Aspect model was also run in steady-state mode, and the results were compared with the steady-state results from the 2025 EA model.

Key findings using the 2026 equilibrium models are summarized in Table 12.

Table 12 Key Findings from 2026 Keta Waters equilibrium models

Simulation	Findings
Current recharge rates and removal of all wells.	Eliminating all wells results in an increase in stream flow of approximately 4%.
Precipitation recharge ranging from 80% of current estimates to 120% of current estimates	A 20% reduction in recharge results in a decrease in streamflow of 20% to 30%. A 20% increase in recharge results in an increase in streamflow of 20% to 30%.
Removal of existing septic return flow.	Eliminating all septic return flow results in a decrease in stream flow of approximately 7% to 10%.
FBA well withdrawal increased by 50%	Increasing the pumping rates in the FBA by 50% results in water level declines of roughly 8-10 feet in the EA model and 2 to 4 feet in the Aspect model.

FBA well withdrawal increased by 50% and recharge reduced to 80% of current estimates	Combined effects of increased pumping and reduced recharge result in water level declines of roughly 16-18 feet in the EA model and 6-8 feet in the Aspect model, relative to current levels.
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6. Problem Definition / Water Quality and Quantity Issues

One of the primary objectives of the Groundwater Management Plan is to ensure clean and sufficient groundwater for the natural environment and for water supply for future generations. As discussed in Alley et al. (1999), achieving this objective requires estimates of the amount of groundwater that can be developed and used, for an indefinite time, without causing unacceptable environmental, economic, or social consequences. This sustainable yield is controlled in large part by site-specific characteristics of the local groundwater system that typically contain large and inherent uncertainties.

Estimates of sustainable groundwater yields can be derived from site-specific modeling results, from site-specific estimates of water balances, and from a review of past practices at other locations. These approaches are described in the sections that follow.

6.1 Key Analyses from Groundwater Evaluations and Modeling

One of the main objectives behind the development of each of the five models summarized in Section 5 was to provide information to help estimate sustainable groundwater yields and to inform groundwater management actions. It is important to note that groundwater models do not directly calculate sustainable yields. Rather, the models provide information that can help support policy decisions and management actions related to:

- The amount of groundwater that is pumped;
- The amount of human-made recharge that is provided;
- The impacts to surface water habitats that are acceptable; and,
- The degree of risk associated with seawater intrusion that is tolerable.

Specific outputs from the groundwater models that are relevant for estimating sustainable yields include:

- The effects of pumping and groundwater recharge on groundwater contributions to streams and other surface water features; and,
- The effects of pumping and groundwater recharge on groundwater levels.

The models are capable of providing estimates of these effects into the future for a range of pumping and recharge scenarios under varying degrees of sea-level changes. To estimate sustainable yields from model output, decisions must be made regarding acceptable levels of impacts to surface-water habitats and acceptable levels of risk of aquifer depletion and sea water intrusion. These acceptable levels will depend on community values and risk tolerances.

All five models identified in Table 6 and discussed in Section 5 were used to investigate future pumping and recharge scenarios. Table 13 provides an overview of scenarios considered in the different model applications.

Table 13 Overview of scenarios considered in the different model applications

Groundwater Model	Example pumping scenarios	Example recharge scenarios	Sea level scenarios	Future scenario time frame
2011 USGS Bainbridge Model (USGS, 2011)	Water use increases by 1.3x (1%/year for 35 years) and 2.5X (3.75%/year for 25 years).	Approximately 4% reduction to +7% increase	Not considered	2009-2035
2016 Aspect Bainbridge Model (Aspect, 2016)	1.5X increase in groundwater withdrawal rates	20% reduction	4 feet increase	2015-2115
2016 USGS Kitsap Model (USGS, 2016)	1.15X increase in current withdrawals in all wells and in current return flows	15% reduction	Not considered	2005-2012
2023 Aspect Bainbridge Model (Aspect, 2023)	Pumping and septic return increased by 1.5X and held	20% reduction	4 feet increase	2022-2121

	constant for 100 years.			
2025 EA Bainbridge Model (EA, 2025)	2.2X, 2.3X, and 2.4X increase in net production (gross production minus return flow)	Reductions of 0%, 7.5% and 20%	2.8 and 6.9 feet increases	2022-2121
Keta Waters Equilibrium Modeling (Keta Waters, 2026)	Well withdrawal and septic recharge reduced by 50% (0.5X) and increased by 50% (1.5X)	Reductions of 20% and 50% and increases of 20% and 50%	Not considered	Not considered

While the model applications differ in terms of how future scenarios were defined, there are some common findings that can be generalized, as follows.

Model evaluation of impacts on surface water flow.

- All models show that impacts of reduced recharge are significantly larger than impacts from increased pumping.
- Changes in recharge have a roughly 1:1 impact on changes in stream flow. For example, USGS (2016) showed that baseflow in streams decreased by as much as 18% in response to a 15% reduction in recharge. Keta Waters (2026) showed that a 20% reduction in recharge caused groundwater flow to surface waters to be reduced by approximately 25%. Similarly, a 20% increase in recharge caused groundwater flow to surface waters to increase by approximately 25%.
- Combined effects of increased pumping and reduced recharge likely amplify impacts. For example, Aspect (2016) showed that a 50% increase in groundwater withdrawal combined with a 20% reduction in recharge rates resulted in groundwater flow to surface waters to be decreased by approximately 40%. As noted in Table 9, a relatively low recharge rate was used for base-case conditions in this model, so that a 50% increase in water withdrawals represented a larger fraction of recharge than in other models.

- Aspect (2023) showed that a 50% increase in pumping combined with a 20% decrease in recharge results in groundwater flow to surface waters to be reduced by approximately 25%. Although the effects of pumping and recharge were not considered separately, it is likely that most of this impact is from the decrease in recharge.
- Keta Waters (2026) showed that eliminating all septic return flow without changing groundwater withdrawal rates would cause average groundwater flow to surface waters to be reduced by approximately 8-10%.
- Pumping wells in deeper aquifers affects water levels in shallow aquifers and groundwater flow to surface waters. For example, Keta Waters (2026) suggests that the impact on groundwater flow to surface waters was equal to approximately 10% of the pumping rate for wells in the FBA (i.e., increasing the FBA pumping rate by 250 gallons per minute (gpm) reduces groundwater flow to surface waters by approximately 25 gpm.) By comparison, the estimated impact from pumping in more shallow aquifers was 89% for the PA, 72% for the SPA, 60% for the SLA and 14% for the GMA. It should be noted that pumping in the SLA results in smaller water level declines that equilibrate more quickly, compared to pumping in the FBA (T. Colby, KPUD, personal communication).

Model evaluation of Impacts on groundwater levels.

- Saltwater intrusion into aquifers will eventually occur if groundwater levels fall below sea level. In most scenarios that have been considered, groundwater levels in deeper aquifers remain higher than sea level. (It should be noted that the water levels from the model represent average values over an area of approximately 6 acres. The model values do not represent levels in individual wells.)
- Model results suggest groundwater levels fall below sea level for scenarios with groundwater pumping rates that are more than 2x higher than current levels. These include scenarios described in USGS (2011) and EA (2025). As noted in USGS (2011), these scenarios represent extreme stresses, and do not reflect anticipated conditions.
- Groundwater levels remain above sea level for scenarios with groundwater pumping rates that are less than 1.5x higher than current rates. These

include scenarios described in Aspect (2016), USGS (2016), Aspect (2025), and Keta Waters (2026).

- Decreasing recharge rates by 20% while simultaneously increasing pumping rates in the FBA by a factor of 1.5x (from approximately 500 gpm to 750 gpm) results in water level declines in the FBA in the range of 10 to 20 feet (Keta Waters, 2026). Water levels remain above sea level in this scenario.

6.2 Water Budgets

Based on a review of studies from 2000-present, Keta Waters identified two explicit water budgets that fully account for all major sources and sinks of groundwater:

- Frans et al. 2011 reports water budgets for pre-development and 2008 conditions. In addition to total groundwater system water budgets (Table 13), water budgets for individual aquifers are presented (Figure 30 and Figure 31). The pre-development scenario is defined by an Island-wide conifer forest land type, and 1970-2000 climatological precipitation.
- Aspect 2016 reports water budget for current (1995-2014) and projected conditions (Table 13). The “projected” scenario is a hypothetical scenario that very roughly corresponds to a period from 2014-2100; see Aspect 2016 for a complete definition. Aspect 2016 cautions that “[t]hese groundwater balance results should be carefully interpreted, considering that the limited grid resolution may not be sufficient to accurately simulate groundwater discharge to surface water, and that the model has not been calibrated to observed flows.”

Table 14 Water Budget Comparison

Water Balance Component	Frans et al. 2011 “Pre-development” (AFY)	Frans et al. 2011 “2008 Conditions” (AFY)	Aspect 2016 “Current” (AFY)	Aspect 2016 “Projected” (AFY)
Recharge	30,000	18,000	13,675	11,232
GW Underflow	-11,000	-9,000	-7,249	-5,134
SW Drainage	-19,000	-16,000	-3,870	-2,305

Well Pumping	0	-2,000	-2,559	-3,839
GW Change in Storage (=Recharge + GW underflow + SW drainage + well pumping)	N/A	-9,000	N/A	N/A

Notes on sources and modifications:

Reproduced from Table 8 in Frans et al. 2011 and Figure 6 in Aspect 2016.

Units in Figure 6 of Aspect 2016 are converted from million gallons per year to AFY. GW underflow refers to the difference between GW flow coming in primarily from Kitsap County to the west, and GW flow out primarily to Puget Sound. When there is more flow out to the Sound than in from Kitsap County, GW underflow is negative. Data from Table 8 in Frans et al. 2011 is adapted to match the budget components reported in Figure 6 of Aspect 2016. Note that for 2008 conditions, Table 8 in Frans et al. 2011 contains an apparent error: the individual flux components and change in groundwater storage do not balance. To balance the budget we assume that the change in storage was -9,000 AFY rather than the -10,000 AFY reported by Frans et al. 2011.

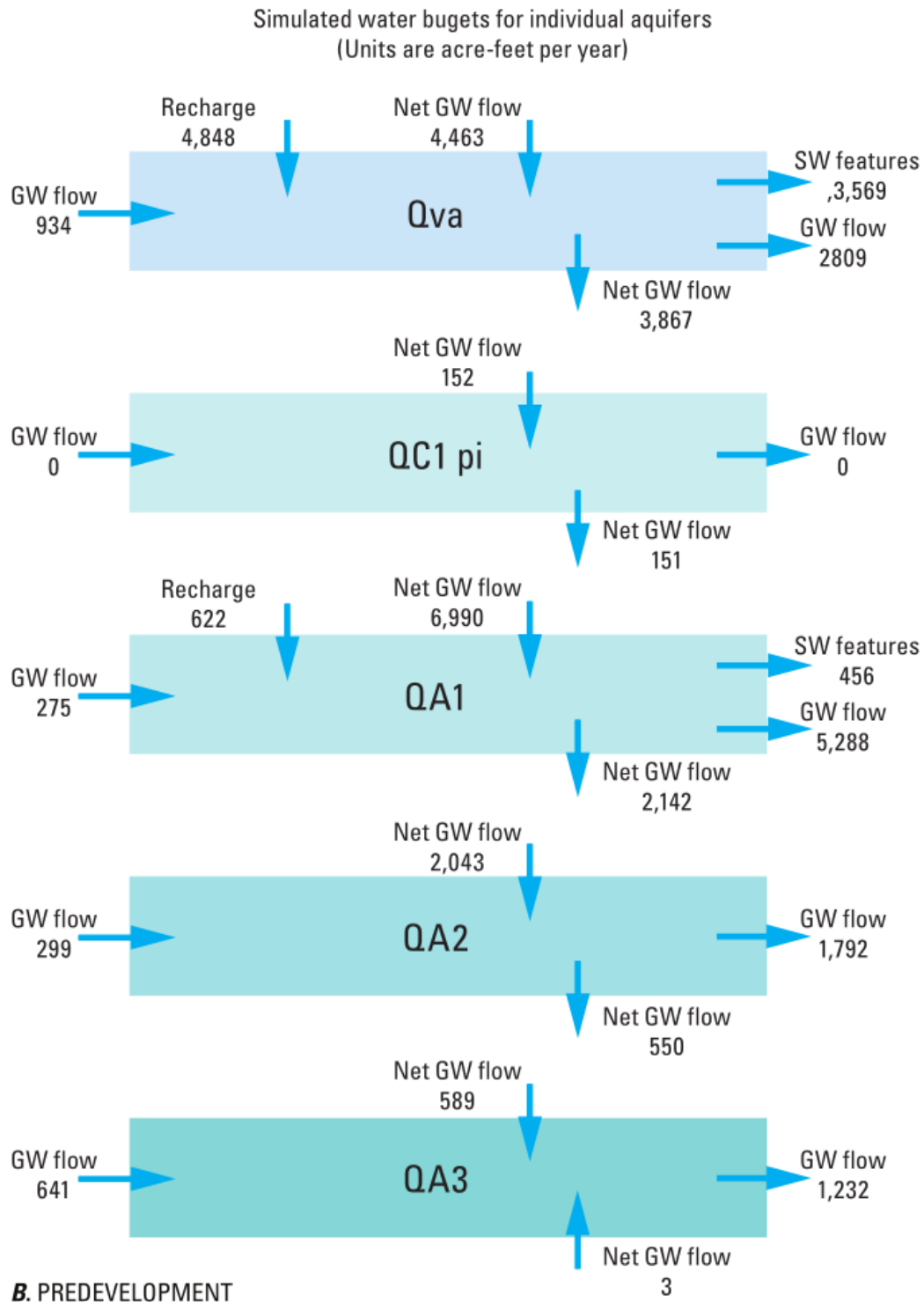


Figure 30 Pre-development water balance for individual aquifers

Source: Frans et al. 2011.

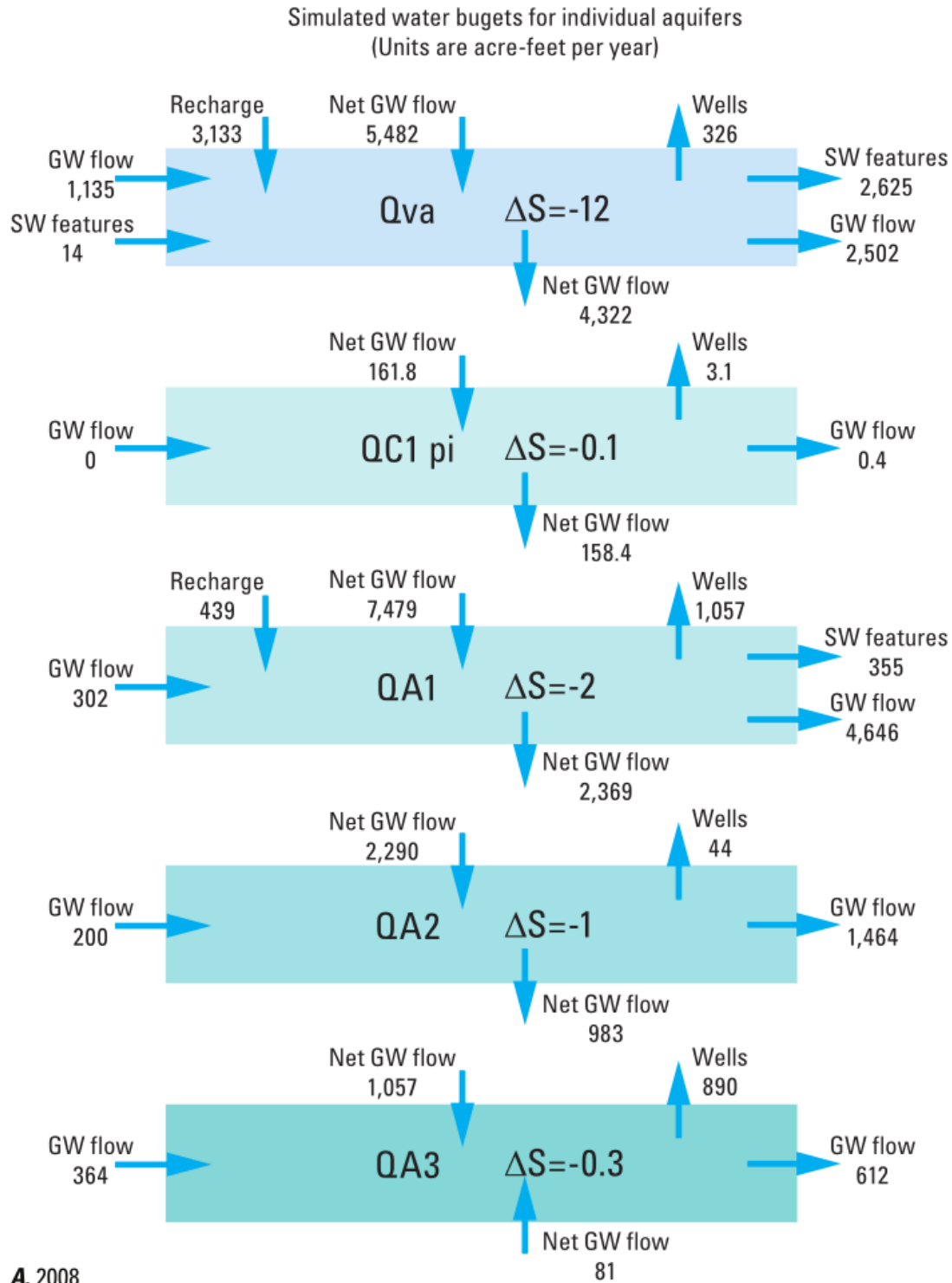


Figure 31 Developed water balance for individual aquifers, 2008

Source: Frans et al. 2011

While these are the only two studies reviewed with fully accounted water budgets, there are more studies with information on specific components of the water budget. Specifically, we focus on recharge (Section 6.3) and pumping (Section 6.4), because recharge is the natural source of water that replenishes the entire groundwater system, and pumping is the primary human process through which the groundwater system is depleted. Any sustainable use of groundwater (Section 6.6) will require a balance between recharge and pumping.

6.3 Recharge from Precipitation

The primary source of water driving the water balance is recharge from precipitation. Recharge is the water that percolates down past the root zone of plants and into the groundwater system. Recharge is the natural source of replenishment for the groundwater system. Unfortunately, in addition to being the quantity that drives water availability in the groundwater system, recharge is also highly uncertain. It is impossible to reliably measure on the scale of Bainbridge Island and estimating it with models is highly uncertain. Recharge estimates in past work varies over a wide range, from 13,675-30,000 AFY (Table 15). This wide range of recharge estimates is consistent with recharge's inherent uncertainty. Analyses for Vashon Island (Table 14) and the broader Pacific Northwest (Li et al. 2001) exhibit a similarly wide range of physically plausible recharge estimates. We cannot rule out any of the estimates in Table 15 and no single recharge estimate is "correct," although it should be noted that the 30,000 AFY estimate is for conceptual "pre-development conditions" rather than for current conditions.

Table 15 Estimates of Recharge

Recharge (AFY)	Source
7,331-24,045	Vashon Island recharge (King County 2026) re-scaled to BI area
13,675	Aspect 2016, based on USGS model
17,337	KW estimate from EA model
18,726	KW estimate from Aspect model
18,000	Pg. 68 of Frans et al. 2011; for 2008 (drier year)
18,920	"Empirical method" of KWRN 2000
19,067	"budget method" of KWRN 2000
23,100	Pg. 39 of Frans et al. 2011; average of 2007-2008

24,053	“regression method” of KWRN 2000
30,000	Pg. 68 of Frans et al. 2011; pre-development: 1970-2000 climatology, developed land replaced with conifer forest.

6.4 Pumping

Table 16 provides pumping estimates from Keta Waters' review and estimates from input files to previously developed groundwater models. A pumping range of 2,000-3,000 AFY appears to be a reasonably conservative range to encompass current and near-future pumping conditions.

Table 16 Estimates of Pumping

Pumping (AFY)	Source
2,000	2008 conditions, pg. 68 of Frans et al. 2011
2,267	KW estimate from EA model
2,560	Aspect 2016, based on USGS model
2,590	KW estimate from Aspect model
2,593	Table 14 of EA 2025
3,329	KWRN 2000-based projection for 2014

6.5 Return Flow

Some fraction of the water pumped out of the ground returns through septic systems, system leakage and downward percolation of excess irrigation. Septic return from about 6,000 septic systems accounts for the majority of return flows on Bainbridge Island.

Keta Waters developed their own estimates of septic recharge, testing the sensitivity of assumptions about indoor water use (Table 15). EA's previous analysis assumes that all water use, up to 162 GPD/ERU is indoor use, and 90% of indoor water use returns to the groundwater or wastewater treatment system for those homes served by sewer (EA 2025). However, there are data to suggest that indoor water use on the Island is less than 162 GPD/ERU: the City of Bainbridge Island Group A system's average water use is 164 GPD, which certainly includes outdoor water use. Additionally, following EA's assumptions 78% of the water used by homes on private wells returns to the groundwater, but in Frans et al. 2011 and Welch et al. 2014 a lower portion is assumed (70%), and an analysis for the South

Bainbridge Island system found the fraction to be ~67%. Keta Waters estimates were based on an assumption of 6,000 on-site septic systems Island-wide, total system pumping of 2,500 AFY, an ERU size of 2.5 people (EA 2025), and a system leakage fraction of 5%. Shifting assumed indoor water use from 162 GPD/ERU to 100 GPD/ERU reduces septic return flow from 1,220 AFY (49% of pumping) to 856 AFY (34% of pumping); this is a hypothetical sensitivity experiment guided by the documented per capita water use of a particularly efficient Group A system (Section 6.6.3) for which it may be safe to assume that the vast majority of water use is indoor use. Based on this sensitivity to indoor water use assumptions, and the high assumed indoor water use in EA's methods, EA/Aspect return flow fractions may be artificially elevated. A return flow fraction of 40-50% strikes a balance between more conservative estimates of indoor water use and EA's approach. Septic return flow substantially reduces the net consumptive use of groundwater pumping. Comparing return flow (Table 17) to recharge (Table 15), return flow is about 4-11% of recharge.

Table 17 Estimates of Return Flow

Return flow (AFY) [% of pumping]	Source
1,360 [68%]	KW estimate from EA model
1,570 [61%]	KW estimate from Aspect model
1,220 [49%]	KW estimate: EA 2025 indoor use (162 GPD/ERU) 80% consumptive outdoor use.
856 [34%]	KW estimate: 100 GPD/ERU indoor use; 90% consumptive outdoor use (WADOE 2009)

6.6 Sustainable Yield

Keta Waters estimated sustainable yield based on ideas in Ponce 2007. Ponce 2007 reviews sustainable yield, acknowledges its subjectivity, and develops pragmatic approaches to quantify sustainable yield based on available data, conceptual models, and diverse case studies. These sustainable yield estimates apply to the total consumptive use of pumping from all aquifers and do not specify which specific aquifers and locations to pump from. As such, they are based on an assumption that wells are thoughtfully located to minimize impacts to surface waters and other systems of social and ecological interest.

All the sustainable yield methods presented are based on the conceptual idea that prior to intensive development, systems (geologic, ecological, etc.) are in a state of dynamic equilibrium with water flows (surface and groundwater). The sustainable yield is a pumping amount that would impact this dynamic equilibrium without having unacceptable impacts to surface water habitats. A sustainable yield relies on an assumption that within a pre-development dynamic equilibrium, there is some portion of water which is "extra" or "unused". For example, deep groundwater flow to the ocean or percolation to deep aquifers may be considered water "lost" to the system: it is not easily accessible by most relevant ecological processes. A sustainable yield is pumping that captures this extra water, while not inducing unacceptable impacts to surface waters. When applying this theory to the Bainbridge Island system, we include outflow to the Puget Sound through the deep aquifers as "deep percolation".

Ponce 2007's theory relies on an assumption that deep percolation is independent of surface waters that support ecological functions. In reality, there will almost always be some hydraulic connection between deep percolation fluxes and fluxes higher up in the water column, including at surface water boundaries (Section 6.1). But the important point is that for sustainable yield, we are interested in the fluxes of water that leave the system, and *that are mostly independent of surface waters*. The more hydraulically disconnected the flux from the surface water, the more confidence we have that the flux of water is extraneous to the surface water system and can be included in the estimate of sustainable yield. For Bainbridge Island, the Fletcher Bay Aquifer (FBA) is the most hydraulically disconnected aquifer from the surface, but the Glaciomarine Aquifer (GMA) is also reasonably disconnected from the surface, given past modeling demonstrating there is limited direct inflow/outflow between surface water bodies and the GMA (Frans et al. 2011). However, the FBA has one more confining layer of hydraulic disconnection from the surface than the GMA, so the FBA is more independent of surface waters, relative to the GMA. Quantifying sustainable yield as deep percolation to and through the FBA is in some sense "safer" than including deep percolation to and through the GMA.

An important consideration is that "[f]or groundwater basins lying in close proximity to the ocean, the capture of all or fractions of deep percolation should be

examined carefully because of the possibility of salt-water intrusion" (Ponce 2007). However, in Section 5.1.5, modeling suggests that hydraulic heads in the deep aquifers are maintained well above sea level, even for elevated pumping scenarios.

We consider three methods of estimating deep percolation and sustainable yield: "precipitation-based", "recharge-based" and "model-based":

- precipitation-based: "On a global basis, deep percolation amounts to about 2% of precipitation. In the absence of basin-specific studies, this figure may be used as a point-of-start on which to base sustainable yield assessments" (Ponce 2007)
- recharge-based: "a reasonably conservative estimate of sustainable yield would be 10% of recharge. Limited experience indicates that average values of this percentage may be around 40%, while less conservative percentages may exceed 70% (Miles and Chambet, 1995; Hahn et al., 1997). The current concept of sustainable yield represents a compromise between theory and practice. In theory, a reasonably conservative estimate of sustainable yield would be about 10% of recharge. In practice, values higher than 10% may reflect the need to consider other factors besides conservation" (Ponce 2007). Keta Waters uses the more conservative estimate of 10% of recharge.
- model-based: Frans et al. 2011's simulations of Bainbridge Island groundwater flow for pre-development conditions provide direct estimates of groundwater outflow to the oceans through deep percolation. However, these estimates are subject to the considerable uncertainties of the groundwater model. "Deep percolation" can be defined at different layers and locations in the model; to test the definition's sensitivity to location, Keta Waters defines deep percolation four ways:
 - "GMA deep percolation": vertical downward flux into the GMA.
 - "FBA deep percolation": vertical downward flux into the FBA.
 - "FBA outflow to Sound": flux from the FBA to Puget Sound.
 - "FBA + GMA outflow to the Sound": flux from both the FBA and GMA to Puget Sound.

Table 18 Estimates of Sustainable Yield

Sustainable yield (AFY)	Method
1,026-1,232	2% of precipitation (35-42 in/yr)
1,367-3,000	10% of recharge (Table 14)
2,043	GMA deep percolation (Figure 30)
589	FBA deep percolation (Figure 30)
1,232	FBA outflow to Sound (Figure 30)
3,024	FBA + GMA outflow to Sound (Figure 30)

Estimates of sustainable yield based on the above methods range from ~600-3,000 AFY (Table 17). However, considering only FBA percolation as deep percolation (589 AFY) is quite conservative, given that overlying GMA percolation is itself separated from surface waters by a confining layer. A more reasonable range of sustainable yield may be ~1,200-3,000 AFY, ignoring the conservative definition of deep percolation as only vertical flux into the FBA. This range is also mostly mutually consistent across precipitation-, recharge-, and model-based estimates of sustainable yield. This sustainable yield estimate applies to total consumptive use, and while it does not specify where water should be sourced (e.g., which aquifer, location, and season), it assumes that water is sourced to minimize, as much as possible, impacts to systems of social and ecological importance. The pre-development estimate of recharge is included in the recharge-based estimate of sustainable yield because of the pre-development concept used in Ponce 2007's guidelines, and because it is consistent with modeled outflow through the FBA and GMA. It is important to interpret all these estimates in light of their subjectivity: "Alley et al. (1999) defined groundwater sustainability as the development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences. The definition of 'unacceptable' is largely subjective, depending on the individual situation" (Ponce 2007). Ultimately "unacceptable" must be collectively defined, and systems must be measured and monitored to ensure unacceptable thresholds are not crossed.

6.6.1 Sustainable Yield and Current Pumping

Assuming current pumping is between 2,000 and 3,000 AFY (Section 6.4) and return flow is 40-50% (Section 6.5) then total consumptive use is ~1,000-1,800 AFY.

Because sustainable yield is ~1,200-3,000 AFY, uncertainty is too high to conclude definitively whether current pumping is sustainable or unsustainable. If sustainable yield is on the high end of the estimated range, then current consumptive water use is almost certainly sustainable. However, if sustainable use is on the low end of the estimated range, and consumptive use is on the mid- to high-end of the estimated range, then current water use is unsustainable.

6.6.2 Sustainable Yield and Legally Allowed Pumping

Currently water rights on Bainbridge Island are over-allocated: as of 2000, permitted groundwater and surface water rights are 7,561 AFY (5,378 groundwater, 2,183 surface water; KWRN 2000). If all these water rights were fully utilized, pumping would almost certainly be unsustainable. This does not include usage from approximately 1,700 (and increasing) private wells. The current state of water rights and private wells limits legal tools to ensure sustainable water use.

6.6.3 Sustainable Yield and a Lower Bound on Residential Pumping

Place 18 HOA, a Group A water system serving 18 townhouses/condos, has successfully reduced per capita water usage to 39 gal/person/day (WADOE WUE reports). This water usage does not include irrigation of common areas, which are counted on a separate meter.

Place 18 HOA water usage can be used to give a rough estimate of an achievable lower bound on residential water use on Bainbridge Island. As a thought experiment, if every resident on Bainbridge Island used as much water as Place 18 residents, total residential pumping would be 1,085 AFY for a 2020 census population of 24,825. If we assume that return flows are maintained at 40-50%, then consumptive use would be ~540-650 AFY, which is almost certainly sustainable with room to grow. In reality return fraction will most likely increase with decreases to water use, because it is usually easier to reduce (highly consumptive) outdoor water use than indoor water use. This effect would further decrease consumptive use relative to this estimate.

6.7 Overall Summary of Analysis

The previous sections present information that can inform estimates of sustainable groundwater yields for Bainbridge Island. This information includes 1) results from groundwater modeling, 2) estimates of water balance components on Bainbridge Island, and 3) information on sustainable yields from past practices at other locations. Sustainable yields will allow development and use of groundwater for water supply without adversely impacting surface water systems and without causing saltwater intrusion into freshwater aquifers.

Modeling results suggest that significant saltwater intrusion is unlikely if groundwater extraction is less than approximately 3,000-4,000 AFY. This rate of withdrawal may or may not be sustainable in terms of acceptable impacts to surface water systems.

The groundwater modeling results also suggest the surface water system is highly sensitive to rates of groundwater recharge from precipitation and from septic return flow. Changes in recharge have a roughly 1:1 impact on changes in groundwater flow to surface waters. For example, a 20% decrease in recharge rates translates into roughly a 20% decrease in groundwater flow to surface waters, based on modeling results from several different studies. On the other hand, pumping in deeper aquifers has a comparatively smaller impact on surface waters. For example, results from equilibrium modeling (Keta Waters, 2026) suggest that the impact on groundwater flow to surface waters is equal to approximately 10% of the pumping rate for wells in the FBA. (Increasing the FBA pumping rate by 250 gpm reduced groundwater flow to surface waters by approximately 25 gpm.)

Maintaining or increasing groundwater recharge while controlling or reducing shallow groundwater withdrawal will limit impacts to surface waters. Additional water supplies may be available through pumping in deeper aquifers. Water balances for deeper aquifers suggest a reasonable range of sustainable yield from these deeper aquifers may be approximately 1,200-3,000 AFY, as discussed in Section 6.6. This range is also consistent with information on sustainable yields from past practices at other locations. As a point of comparison, estimates of current total pumping from both shallow and deep aquifers on Bainbridge Island is

approximately 2,500 AFY, as discussed in Section 6.4, and net consumptive use is 1,000-1,800 AFY (Section 6.6.1).

Current rates of water consumption on Bainbridge Island are significantly higher than what can be achieved through water conservation practices. These conservation practices provide an opportunity for population growth while limiting additional risks to surface water systems. Increasing recharge combined with reducing water consumption through conservation provide the most effective and certain actions for achieving the City's goal of ensuring clean and sufficient groundwater for the natural environment and future generations.

7. Management Actions

7.1 Introduction

This section presents management strategies to address threats to ground water quality and quantity from potential changes to groundwater supply and demand. Changes that could be quantified as input to and output from the Bainbridge Island groundwater model were used to model and quantify potential impacts resulting from those changes. The management strategies presented here are designed to avoid and mitigate these impacts while maintaining beneficial uses and interests. Mitigation strategies are presented in four categories:

- **Proactive** – actions that will have a direct impact on groundwater resources
- **Prevention** – actions that will have an indirect impact on groundwater resources
- **Data Collection** – actions that provide new or more data that informs groundwater resources
- **Information Management** – actions that improve the utility of existing or new data

Management strategies are intended to integrate with existing programs and regulatory structures, building on current efforts rather than replacing or duplicating them. For example, Bainbridge Island has an existing stormwater management permit and program that includes requirements to protect

groundwater. Groundwater management strategies involve using stormwater in ways that mimic and enhance pre-disturbance hydrologic processes, including infiltration. This plan recognizes existing programs with overlapping objectives and actions, and includes additional measures designed to protect groundwater resources and mitigate undesirable impacts. It is acknowledged that many of the management strategies will require several years to implement and adaptive management.

It is also important to recognize that the City and other partners have worked to understand and sustainably manage the groundwater since at least 1956. The following table is an incomplete summary of those efforts.

Table 19 Past Groundwater Management Actions

Who	What	When
U.S. Geologic Survey	8 studies on the water resources of Bainbridge Island	1956-2016
City of Winslow	Ordinance restricting development that adversely impacts aquifer recharge.	1980
Kitsap Public Utility District	Watershed planning for streamflow restoration	1997
City of Bainbridge Island	Winslow Water System Conservation Plan	2005
City of Bainbridge Island	Water Use Efficiency goals set for water system	2015
City of Bainbridge Island	Aquifer Recharge Protection Area added to the BIMC	2017

WA Department of Ecology	Watershed planning for streamflow restoration	2019
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7.2 Proactive Actions

For the purposes of the GWMP, Proactive Management Strategies are defined as Groundwater Management Strategies that proactively implement a project or process to mitigate an impact and/or physically benefit the resource.

7.2.1 Spatially Diversify City Production Wells

Results from the groundwater modeling scenarios indicate large drawdowns in the deeper aquifers may be associated with large increases in groundwater withdrawals over time. Large drawdowns, especially if water levels drop below MSL for extended periods of time, are not a desirable condition in Island aquifers used for municipal water supply because marine water can migrate into the aquifer degrading water quality.

Spreading out municipal production wells across the Island would help minimize well interference and reduce drawdown in the aquifer around major pumping centers which would help reduce the potential for seawater intrusion. In addition, using production wells further north would move large withdrawals further away from the Bedrock Aquifer which acts as a no-flow boundary, increasing drawdown because smaller amounts of groundwater can move from the Bedrock Aquifer toward the production wells, increasing drawdown. The groundwater model could be used to evaluate potential new well sites to optimize pumping while minimizing well interference.

Adding new production wells outside of the City's current service area would be quite expensive, as installation of new water lines, pumps and potentially new storage facilities would likely cost tens of millions of dollars. However, excessive drawdown predicted by the groundwater model is still several decades in the future. Thus, should the City wish to pursue this Management Strategy, there are likely many years to plan and fund the project.

7.2.2 Intertie and Coordinate Operations and Monitoring with KPUD

Similar to the previous Management Strategy, connecting the City's water system with KPUD's North and South Bainbridge water systems would likely aid in spreading out large municipal withdrawals and reduce well interference at the City's pumping centers. However, it would also provide redundancy and increase resiliency as more wells are connected to a common system. It could also allow for increased coordination of pumping between the three largest public water systems on the Island, which could aid in reducing drawdown around pumping centers.

The groundwater model could be utilized to develop optimized groundwater withdrawal scenarios while minimizing well interference across all three systems. In addition, a larger customer base could help spread out shared costs for new infrastructure, which is likely to be very expensive if additional wells, water mains, pumps and storage is needed.

This potential management strategy would likely require years of coordination, planning, permitting, funding and building but it is likely to benefit customers in the three largest water systems as well as reducing risks of excessive drawdown and seawater intrusion.

7.2.3 Consolidate Smaller Water Systems with Larger Water Systems

In addition to the three large municipal water purveyors and several smaller Group A and B water systems, there are hundreds of water wells serving single family and small group domestic users on Bainbridge Island. Each of these wells is independently operated with likely little to no coordination between water users. Each well owner is responsible for operation and maintenance of their well and each well is a potential conduit for contaminants to get into the aquifer from surface sources.

Interties and consolidation of single and small group users with larger water systems could benefit management of groundwater resources on the Island. Over time, poorly constructed, aging wells would likely be decommissioned, water quality sampling will become more reliable and coordination between water users is likely to increase if fewer water systems are operating on the Island. Again, this could minimize or eliminate well interference issues between water users, resources could be combined and systems could be managed and run more efficiently. Larger

water systems are also more likely to be able to develop and implement effective water conservation programs. Although there are likely many individuals who prefer to own and operate their own well, reducing the number of operators and water systems is likely to improve coordination and management of groundwater resources and reduce costs for individual users.

7.2.4 Pursue Managed Aquifer Recharge

Managed Aquifer Recharge (MAR) is a term regarding intentionally engineered groundwater recharge. Source water is often captured during flashy events during storms and spring runoff, infiltrated on the surface, and recovered downgradient, at the recharge location, or used to passively improve stream flows and aquatic habitat. Water storage is provided in the subsurface instead of conventional reservoirs such as dams and water towers.

Aquifer Storage and Recovery (ASR) is a MAR method that recharges water directly into an aquifer through a well. In most ASR projects, water is recharged through a well and allowed to remain in the aquifer, being stored until the water is needed and withdrawn from the same well, or possibly down-gradient wells if the stored water has migrated away from the injection well during the storage period.

ASR is presented as a potential Management Strategy that could potentially provide water stored in an aquifer for use later in the year. This could potentially mitigate declining water levels in an aquifer or be used to create a hydrologic divide in an aquifer to prevent seawater intrusion. However, investigating, testing and permitting an ASR project is expensive and could take several years. And a reliable source of high-quality water is required for recharge, which is not likely to be available on Bainbridge Island unless groundwater is pumped from one location and aquifer and recharged in another.

7.2.5 Evaluate and Implement Reclaimed Water Use

Use of reclaimed water from the Winslow Wastewater Treatment Plant is a potential Management Strategy that could be used for irrigation in lieu of potable water use or infiltrated to provide additional baseflow discharge to streams. In January 2024 the City completed a preliminary groundwater recharge favorability evaluation (Anchor QEA 2024) to support the identification of types and locations for potential reuse with a focus on groundwater recharge via infiltration. Favorable

sites for potential groundwater recharge were identified within the Island core, including the retail water and sewer service area and bands of the Island immediately north and south, in addition to peripheral areas of the Island. A summary of these identified locations, as well as the principal factors driving their selection and further study needs or key uncertainties, is provided in *Table 20*.

Table 20 Summary of Potential Groundwater Recharge Sites

Site Identification		Site Consideration	
Island Area	Site Name	Selection Bias	Key Uncertainties
Island Core (Water and Sewer Area)	Grand Forest East and West	High score; public land	Easements; geohazards
	Sakai Park/Bainbridge High School	Moderate to high score; public land; proximity to existing infrastructure	Till thickness; mapped aquifer characteristics
	Eagle Harbor West	High score; public land; proximity to existing infrastructure	Land use; well field considerations
Island Periphery (North and South)	Manzanita Park	High score; public land	Aquifer thickness/connectivity
	Agate Point		

Source: Anchor QEA 2024

Use of reclaimed water is permitted by Ecology’s Water Quality Program or the Washington State Department of Health (Health) in accordance with Chapter 90.46 RCW and Chapter 173-219 WAC. Health and Ecology are both required to review reclaimed water proposals. The agencies work together to determine if proposed treatment methods and uses will protect public health and the environment, and not affect existing water rights. The lead agency is determined based on the type of facility that will reclaim the water. That agency will only issue a

permit to operate the reclaimed water system after requirements from both agencies are met.

The public has an opportunity to comment on permit conditions during the permitting process. Permits are valid for five years and the facility may renew their permit if they are in compliance (Ecology Reclaimed Water webpage, 2025).

Use of reclaimed water for irrigation could potentially reduce municipal groundwater withdrawals if the reclaimed water is used instead of potable water sources. Use of reclaimed water for infiltration could provide environmental benefits by supplementing baseflow discharge to streams to mitigate impacts from groundwater withdrawals from shallow aquifers.

Investigations, permitting, public involvement and building infrastructure to transport reclaimed water to sites for reuse can be expensive and possibly cost prohibitive.

KPUD has also expressed a long-term goal of treating the discharge from the Fort Ward WWTP and developing an upland discharge area to enhance recharge. (KPUD 2026)

7.2.6 Promote Conservation

Water Conservation is a Management Strategy designed to efficiently use water, minimize waste and ultimately reduce water demands on a water system. A municipal comprehensive water conservation program encompasses a multi-faceted approach, including setting specific goals, educating the public, improving water-efficient technologies and practices, and implementing strategies for water reuse and management. Key elements include leak detection and repair, efficient appliance and fixture usage, responsible landscaping and irrigation, and exploring alternative water sources.

Water conservation plans should address conservation on the supply side as well as on the demand side. Conservation plans for the supply side (i.e., leak detection and repairs, metering, etc.) may require additional financial resources, however there is some potential for reduction in operating costs. Conservation plans for the demand side (i.e. reductions in consumer usage) may result in lost revenues, however, a well-designed pricing program can offset potential losses in revenue. Other

benefits associated with implementing a conservation plan (which include eliminating, downsizing, or postponing the need for capital projects, improving the utilization and extending the life of existing facilities, lowering variable operating costs, avoiding new source development costs, improving drought or emergency preparedness, educating customers about the value of water, improving reliability and margins of safe and dependable yields, and protecting and preserving environmental resources) may also help to balance losses in revenue.

Developing a water conservation plan typically involves the following steps:

- Establish the goals of the water conservation plan.
- Conduct a water system audit.
- Prepare a demand forecast.
- Identify and select potential water conservation measures.

These elements should be included in all water conservation plans:

Metering - Plans should describe the metering method(s) used, and establish protocols for maintaining meter accuracy, conducting calibration and repair, and replacing old or inaccurate meters. Inaccurate meters often result in lost revenue for the utility.

Water Accounting and Loss Control - A well-designed loss-prevention program should target both real and apparent losses. Real losses are physical losses including leaks, bursts, and overflows. Apparent losses are non-physical losses that include meter inaccuracies and unauthorized consumption, such as theft or illegal use.

Pricing - Water conservation will prove to be most cost effective when rate structures are modified to encourage customers to conserve water. There are several pricing strategies that can encourage water conservation.

Information and Education Program - A good information and education program can be very effective in reducing consumer demand. Specific information should be developed for each type of water customer (residential, government, and commercial/industrial).

Pressure Management - Reducing excessive pressures in the distribution system can save water by reducing stresses that could result in leakage, decreasing quantities of water that are currently leaking, and reducing the amount of flow through fixtures.

Water-Use Regulations - Water-use regulations should be designed not only for droughts or emergencies but also to guide responsible consumption during normal times—prompting important questions such as whether we will continue to wash our cars and water lawns or golf courses as if there is no underlying strain on water resources.

Develop an Implementation Strategy - Water utilities should develop a schedule and timetable for implementing the water conservation strategies. Implementation actions should include a timetable for securing budgetary resources, hiring staff, procurement of materials, acquisition of any necessary permits, and activity milestones.

Developing and implementing effective water conservation plans can help minimize waste and reduce overall water demands. Though it is important to temper expectations and recognize that the demand reduction from conservation alone is likely to be limited to about 20% of current use.

7.2.7 Promote Rainwater Harvesting

Rainwater collection, including the use of rain barrels, has become more popular as a supplemental source of water. In 2009, Ecology issued a rainwater use interpretive policy, which clarifies that you may use water collected from your rooftop without a water right permit. However, there are rules on using rainwater as a potable (drinkable) water source.

State and local codes allow rainwater harvesting. Specifically, roof runoff can be directed to cisterns for storage and non-potable uses like irrigation. For potable use in single-family residences, proper design and approval from Kitsap County Public Health District is required.

Bainbridge Island's evolving approach to sustainable water management recognizes the need for innovative alternatives to traditional groundwater reliance. As an

important example, it is notable that at least one residence on Bainbridge Island currently meets all its water needs, including drinking, domestic use, and irrigation—exclusively through rainwater harvesting. This unique case demonstrates the feasibility of rainwater collection systems as a viable alternative for complete household water supply.

Integrating rainwater harvesting could help diversify water sources, reduce pressure on vulnerable aquifers, and enhance resilience to climate change, population growth, and potential future water scarcity. As the Island faces projected increases in water demand and stresses from climate variability, consideration of rainwater harvesting on both individual and community scales—may become an increasingly significant component of Bainbridge Island’s water resource toolkit.

7.2.8 Increase Storage for Municipal Water

The objective is to increase storage volume, typically via above ground water tanks, for the municipal water systems to be able to provide enough water during periods of peak demand. This would help spread out withdrawals and costs over a longer time period which could reduce maximum drawdowns resulting from extended groundwater pumping during peak demand periods.

7.2.9 Enhance Storm and Surface Water Management

The Bainbridge Island Municipal Code includes Chapter 15.20 Surface Water and Stormwater Management is intended to regulate all new development, redevelopment or construction activities within the City that will or may impact surface water, groundwater or stormwater. The purpose of this chapter is listed below:

- Preserve and enhance the suitability of waters for contact recreation, fishing, and other beneficial uses.
- Minimize water quality degradation and sedimentation in streams, ponds, lakes, wetlands and other water bodies.
- Minimize the impact of increased runoff, erosion and sedimentation caused by land development and poor maintenance practices.

- Maintain and protect groundwater resources.
- Minimize adverse impacts from projects on ground and surface water quantities, locations and flow patterns.
- Decrease potential landslide, flood and erosion damage to public and private property.
- Establish site planning and construction practices that are consistent with natural topographical, vegetational and hydrological conditions and that limit the extent of land disturbing activities.
- Maintain and protect the City stormwater management infrastructure and downstream systems and properties.

The purpose of the Stormwater Management Program is consistent with the objectives of the Groundwater Management Plan. Managing stormwater to minimize contaminants while attempting to mimic pre-development hydraulic conditions and recharge is a key objective for groundwater management.

The City's Stormwater Management Program operates under the Western Washington NPDES Phase II Municipal Stormwater Permit. The current permit was issued in July 2024 and effective from August 1, 2024 – July 31, 2029. Components of the Plan include:

- Stormwater planning.
- Public education and outreach.
- Public involvement and participation.
- Municipal separate storm sewer system (MS4) mapping and documentation.
- Illicit discharge detection and elimination.
- Controlling runoff from new development, redevelopment and construction sites.
- Stormwater management from existing development.
- Source control program for existing development.
- Operations and maintenance.

Chapter 15.20 is an important and effective management strategy that helps protect groundwater quality and preserve recharge on the Island.

The City's Stormwater System Plan (COBI 2024a) has many recommendations that would improve stormwater management and increase recharge. The maintenance and retrofit of existing stormwater facilities would ensure that the land set aside for stormwater mitigation is functioning as designed or is improved using the most current science on stormwater mitigation. See Recommendations B7, R1-18 in the Plan for specifics on actions that will reduce the impacts to groundwater from stormwater runoff

7.3 Preventative

Preventative actions are mostly policy actions that the City can take to prevent consequences from occurring that would negatively affect the groundwater resource. Some of these policies could result in direct city action, but many of them would take cooperation from other agencies such as the Kitsap Public Health District or Ecology.

7.3.1 Evaluate Limiting New Wells in the Shallow Aquifers

Groundwater withdrawals can capture water that would contribute to baseflow discharge to streams, thus reducing streamflow. Withdrawals from shallow unconfined aquifers generally capture a larger proportion of baseflow discharge than equivalent withdrawals from deeper confined aquifers.

Results from the Bainbridge Island groundwater model indicate that increased groundwater pumping will decrease groundwater drainage to the surface through springs, wetlands and streams where groundwater discharge to the surface typically occurs. This decrease could be reduced or eliminated from future wells if the wells were required to be drilled and screened in confined aquifers.

Streams in the Murden Cove and Fletcher Bay watersheds are closed to further water right appropriations by Chapter 173-515 WAC. This closure includes proposed water right withdrawals directly out of the streams and groundwater withdrawals that would cause a reduction in streamflow. Ecology has the authority to review and approve or deny water right permit applications and will issue a

water right permit that impacts a closed stream only if it is determined that the impacts to the closed stream will be fully mitigated.

Chapter 90.94 RCW, extends the requirement for mitigating impacts to closed streams to permit-exempt wells. Permit-exempt wells are groundwater uses authorized by RCW 90.44.100 that do not require a water right issued by the State of Washington. Permit-exempt wells are used for single or multiple domestic purposes and those wells drilled since 2018 are limited to withdrawals of 950 gallons per day. Chapter 90.94 RCW defines the requirements for quantifying impacts and developing and implementing mitigation strategies to offset impacts to closed streams from permit-exempt wells. It also established a grant funding program, available to the City, for implementing projects intended to protect instream resources and mitigate impacts from permit-exempt wells.

Although streams in the Murden Cove and Fletcher Bay watersheds are the only subbasins on the Island where surface water is closed to new water rights, there is interest in protecting all streams and wetlands on Bainbridge Island. Therefore, any well drilling requirements intended to minimize impacts to streamflow do not need to be restricted to the Murden Cove and Fletcher Bay watersheds.

Should this potential management strategy be pursued, further assessment should be conducted to define priority watersheds and identify practical options for new well construction. For example, because bedrock is the only unit available in the southern end of the Island, requiring wells to be completed in a deeper aquifer in that area is not practical. Ideally, any watershed with restrictions on shallow well construction should have targeted aquifers identified. And due to variability across the Island, the targeted aquifer may be variable from one watershed to another.

To support the protection of critical hydrologic and ecological functions, well drilling should be managed in a way that minimizes impacts to streamflow, particularly in areas where groundwater and surface water are hydraulically connected. This strategy is consistent with the purpose and intent of Bainbridge Island Municipal Code Chapter 16.20 Critical Areas, which aims to protect, maintain, and restore the functions and values of ecologically sensitive areas. Specifically, limitations on new well drilling or more stringent review processes may be appropriate within or near designated critical areas, such as wetlands, streams, and their associated buffers. In

these areas, restrictions or mitigation requirements may be necessary during periods of low streamflow or where cumulative groundwater withdrawals could impair baseflow or habitat functions. The goal is to ensure no net loss of critical area functions, while still allowing for the reasonable use of public and private property.

Adoption of a new section in Chapter 16.20 would need to go through City's typical process, including public information. Because deeper wells cost more to construct than shallower wells, any requirements must allow for reasonable costs to property owners and not be prohibitively expensive. Public information should include a discussion regarding environmental benefits resulting from a new ordinance compared to the extra costs for well construction.

7.3.2 Reform Critical Aquifer Recharge Area Codes

The Bainbridge Island Municipal Code includes Section 16.20.100 Critical Aquifer Recharge Areas. The entire Island has been designated as a Critical Aquifer Recharge Area and Section 16.20.100 is intended to prevent groundwater contamination and loss of recharge from land use activities within the Critical Aquifer Recharge Area.

In 2017 the Critical Aquifer Recharge Areas section was altered to include a new provision for new developments in the rural residential zoning districts; R0.4, R1 and R2. If more than 800 sq. ft. of impervious surface is proposed as part of a land use action in these zones, then up to 65% of the existing native vegetation on the site is required to be protected with the intent of maintaining aquifer recharge and protecting streams from excess erosion.

This resource protection tool may need reforming to better address the problem. Variables that could be looked at during a reform process include soil type and geology underlying the parcel, type of vegetation being protected, and long-term monitoring and reporting requirements.

Knowing that recharge occurs off the Island for water used on the Island, it may be worthwhile to also work with jurisdictions in Kitsap County to protect recharge for the benefit of Islanders.

7.3.3 Develop Seawater Intrusion Policy

Available information indicates that seawater intrusion is not currently occurring into aquifers supplying water to wells on Bainbridge Island. However, results of groundwater modeling scenarios indicate that large increases in groundwater pumping may result in relatively large drawdowns near pumping centers and there is the potential for groundwater levels to draw down below MSL indicating the potential for seawater intrusion in the future.

As described above, the City operates a groundwater monitoring program and has developed EWLs regarding extended lowering of groundwater elevations and chloride concentrations in groundwater. This program is appropriate for current conditions on the Island. However, should groundwater withdrawals increase as predicted, additional measures to expand and enhance the EWLs may be necessary and appropriate in the future. For example, actions to address specific conditions could be better defined and hard limits for chloride concentrations and/or minimum acceptable static water levels in the aquifer could be appropriate.

Island County has adopted a County Ordinance in 1989 regarding seawater intrusion protection (Island County Code 8.09.099). Island County was already experiencing issues with seawater intrusion so adopted and has been implementing this code with the intent of avoiding additional impacts and protecting existing groundwater users on the Island.

Because Bainbridge Island has not yet experienced significant seawater intrusion, reviewing Island County's ordinance, talking with Island County Health Department staff to discuss the effectiveness of the ordinance and lessons learned would be a useful exercise for the City to consider drafting and adopting an ordinance in the City's Municipal Code to serve a similar purpose. The City could then have more detailed procedures in place if and when seawater intrusion is detected on Bainbridge Island.

A summary of the main parts of Island County's seawater intrusion protection ordinance is provided below:

The Island County Health Department classified all areas of the county into seawater intrusion risk categories based upon groundwater elevation information

and proximity to existing groundwater wells with chloride data. The seawater intrusion risk categorization is provided in Table 21.

Table 21 Island County Seawater Intrusion Risk Categories

Risk Category	Water Level Elevation¹	Chloride Concentration²
Low	Greater than 8.4	Any ³
Medium	Less than or equal to 8.4	Less than 100
High	Less than or equal to 8.4	Between 100 and 250
Very High	Less than or equal to 8.4	Greater than 250

¹ Water level elevation in feet above MSL

² Chloride concentration in milligrams per liter (mg/L) or parts per million (ppm).

³ Where water level elevations are greater than 8.4 feet, chloride concentrations are irrelevant.

Project actions are evaluated for seawater intrusion risk analysis based upon the applicable risk category and proposed activity shown in Table 22.

Table 22 Island County Project Risk Categories

Risk Category	Land Subdivision	New or Expanding Public Water Systems
Low	N/A	N/A
Medium	More than six lots	More than six connections per year
High	All	More than one connection per year (≤ 1.5 acre lot size)
Very High	All	All

All active public water system sources serving more than two (2) residential connections that are located in the medium, high, or very high risk areas shall be sampled for chloride and conductivity in April and August of each year.

A hydrogeologic site evaluation, as defined in section [8.09.097](#), may be required as a result of seawater intrusion risk analysis prior to project review as determined by the health officer.

Based upon available information including that provided by the applicant pursuant to the requirements of this section, the health officer shall have discretion to impose conditions designed to prevent degradation of groundwater quality or quantity. Such conditions may include groundwater monitoring and the development of groundwater quantity management plans. All conditions shall be based on all known, available, and reasonable methods of prevention, control, and treatment.

Projects that cannot mitigate potential impacts to groundwater resources by inducing or contributing to seawater intrusion may be modified, altered or denied by the health officer.

The City's EWLs are an appropriate and effective Management Strategy for current groundwater conditions on Bainbridge Island. However, the City could expand and enhance the EWL's by reviewing Island County's ordinance regarding seawater intrusion protection and consider adopting a similar ordinance before seawater intrusion is detected on the Island.

7.3.4 Public Involvement

The City is actively engaged in public involvement and educational activities on a number of City projects and activities, including groundwater management and monitoring activities. Public involvement and education regarding groundwater issues and management is an important Management Strategy that should continue into the future.

All Island residents rely on groundwater for their potable water supply. Continuing to educate Island residents of the importance of groundwater and protection of the resource can encourage conservation, help protect groundwater quality, and potentially interest volunteers for data collection activities, This program could

include web pages, fact sheets, public meetings, and presentations at schools and other Island organizations. Helping Island residents have a basic understanding of groundwater and why protecting it is important will likely support the other groundwater management actions on the Island.

7.3.5 Support Septic System Monitoring and Maintenance

Support KPHD's existing septic system monitoring and maintenance program and response to concerns about septic system failures and impacts to water quality on the Island. Assisting KPHD in expanding their inventory of these systems will lead to more properly functioning septic systems and consequently more treated recharge reaching the aquifers.

7.4 Data Collection

Groundwater is inherently challenging to monitor and collect data about, but efforts have been ongoing since the 1950s to better understand this valuable resource. Data gaps will always exist, but certain aspects of the resource are worth constraining in order to better measure and monitor for potential trends.

7.4.1 Expand Groundwater Monitoring

A necessity for effective groundwater analysis and evaluation of alternative management strategies, is the availability of comprehensive high-quality data.

Because of differences in extent, depth, uses, recharge, discharge, and potential threats between aquifers on the Island, proposed expansion of groundwater monitoring is presented below by aquifer. Because some wells are monitored for water level, some are monitored for chloride concentration, and some are monitored for both, water level and chloride monitoring are presented separately to identify data gaps and present recommendations for additional monitoring locations for each aquifer.

7.4.1.1 Perched Aquifer

The Perched Aquifer is used primarily by domestic wells. Water level monitoring is important in the Perched Aquifer to assess long-term changes in water levels due to increased pumping, loss of recharge, and impacts from a changing climate. It is

also beneficial for planning and implementing potential management strategies such as managed aquifer recharge.

The City is currently monitoring water levels in 14 wells in the Perched Aquifer and KPUD is monitoring two. Monitoring locations and recommended areas to add additional monitoring sites are shown in Figure 32. Also shown in Figure 32 and Figure 33 and in subsequent figures is the general area where the largest drawdowns were modeling illustrating the impacts of increased future groundwater withdrawals. These areas are related to the City's municipal well fields at Sands Road, Island Utility wells, and Head of the Bay wells where large increases in pumping were used in the modeling scenarios.

Two areas are shown and numbered by relative priority in Figure 32 where additional groundwater level monitoring would be beneficial in the Perched Aquifer. These areas are within the Fletcher Bay and Murden Cove watersheds, both of which contain streams that have been closed to further appropriation by State regulation (Ch. 173-515 WAC). This closure includes proposed water right withdrawals directly out of the streams and groundwater withdrawals that would reduce streamflow. Water rights can be approved if the impacts to the closed streams can be fully mitigated. Adding groundwater monitoring of the Perched Aquifer at these locations would be helpful to assess current conditions as well as assessing the performance of potential future mitigation actions.

Six wells are being monitored by the City for chloride concentrations in the Perched Aquifer as shown in Figure 33. Four of these sites are near the marine shoreline. All samples from the Perched Aquifer had chloride concentrations below 12 mg/L. This is to be expected because the aquifer mostly occurs above MSL. For this reason, no additional sites are recommended for monitoring chloride concentrations in the Perched Aquifer. However, monitoring for other parameters, such as nitrates or other sources of contamination resulting from land use activities, may be appropriate and important for domestic well users down-gradient of potential sources of contamination.

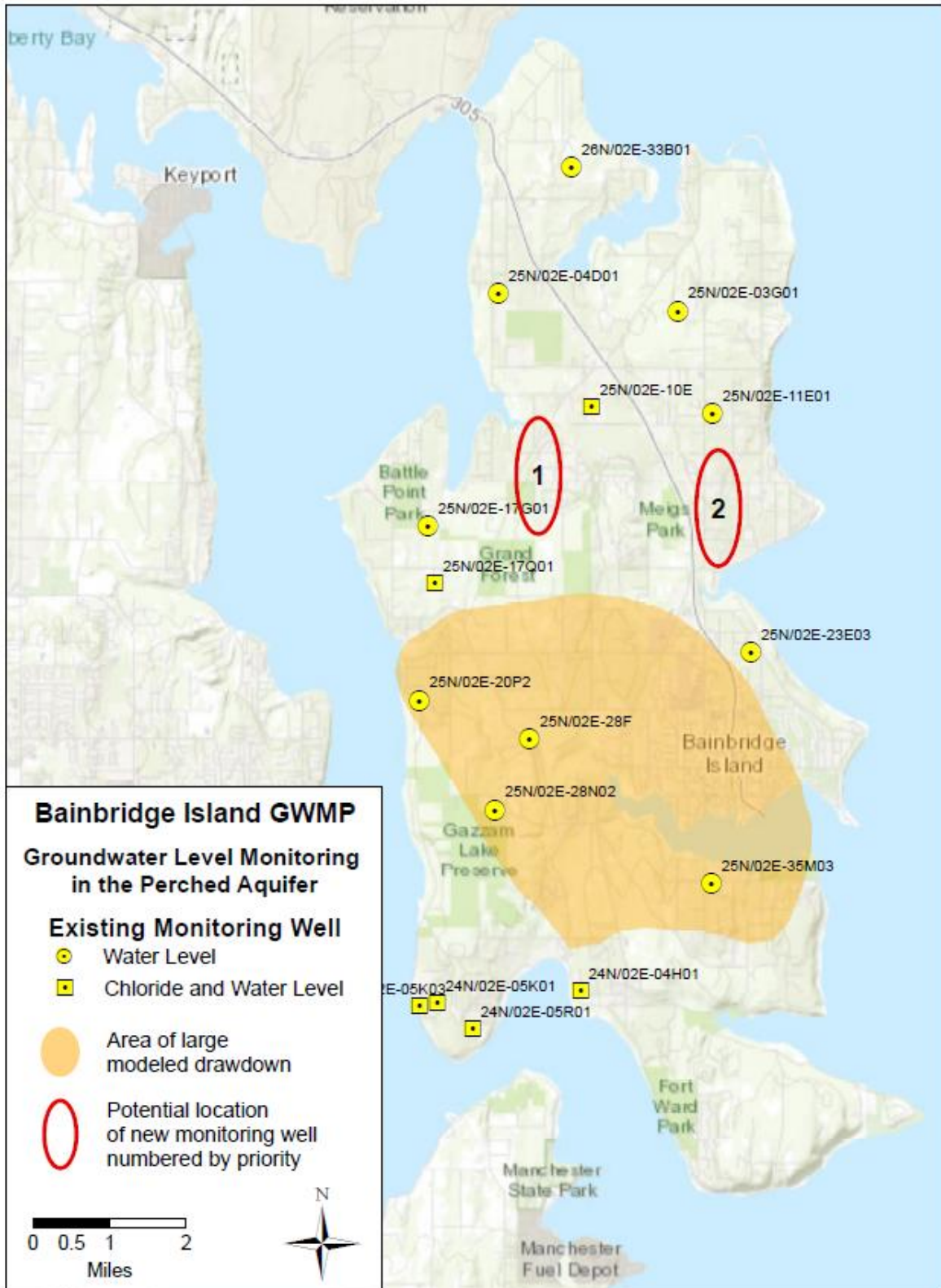


Figure 32 Existing and Proposed Water Level Monitoring, Perched Aquifer

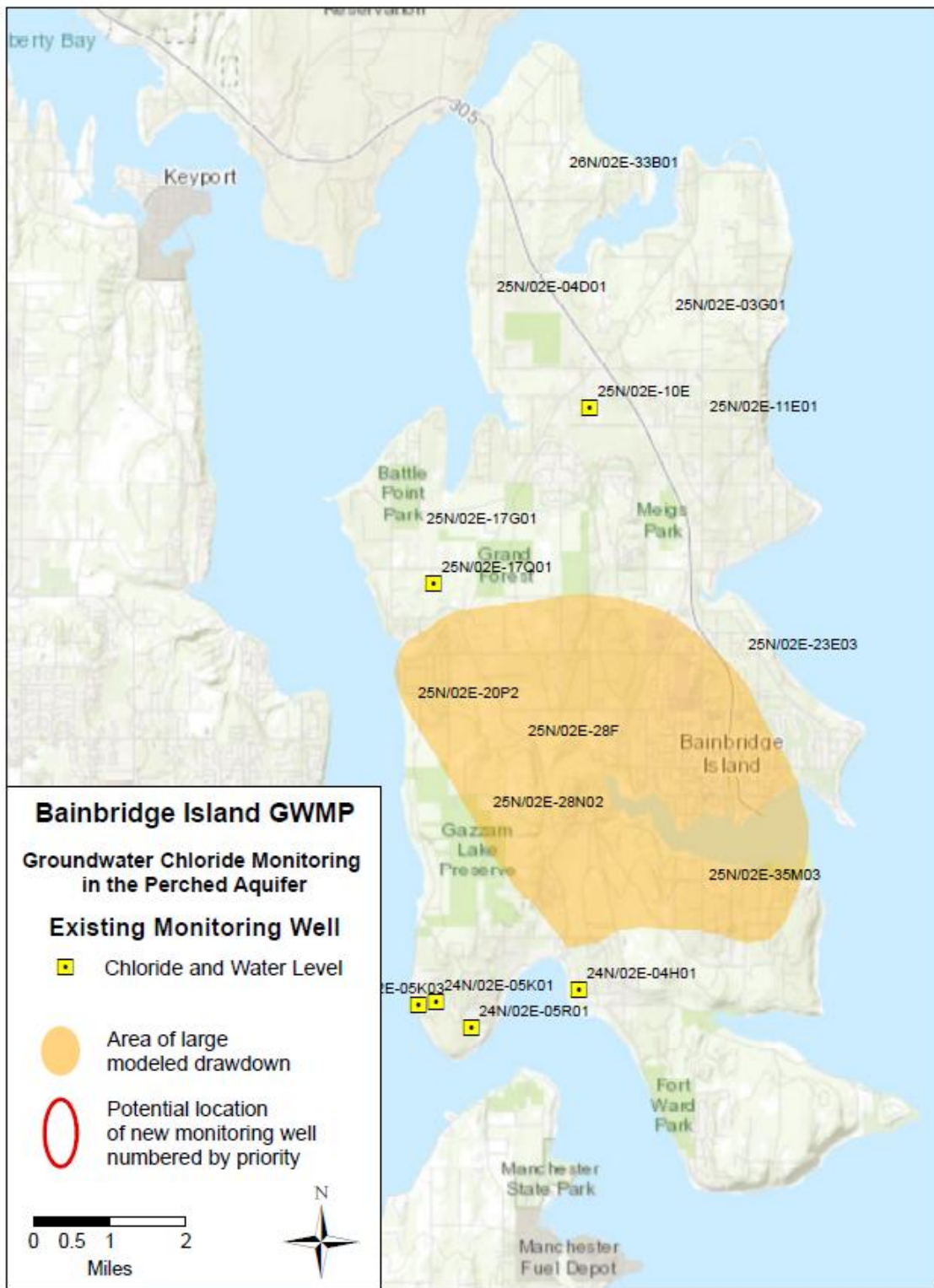


Figure 33 Existing and Proposed Chloride Monitoring, Perched Aquifer

7.4.1.2 Semi-Perched Aquifer

Natural discharge from the Semi-Perched aquifer provides baseflow to streams and wetlands on the Island so increased consumptive use and declines in water levels are likely to reduce baseflow discharge to streams. Conversely, intentional artificial groundwater recharge is likely to increase baseflow to streams and could be an effective streamflow mitigation strategy if implemented at a suitable location. The Semi-Perched Aquifer has a low susceptibility for seawater intrusion because most of the aquifer occurs at an elevation above MSL. However, this unit is susceptible to contamination from septic system discharges and other contaminant sources at the surface. Thus, monitoring for other parameters, such as nitrates may be appropriate in certain areas.

The City is currently monitoring water levels in 6 wells in the Semi-Perched Aquifer and KPUD is monitoring one. Monitoring locations and recommended areas to add additional monitoring sites are shown in Figure 34. Groundwater elevations in the aquifer range from 140-10 feet above MSL, with the higher elevations in the central part of the Island and lower values being measured near the marine shoreline. Water level trends in the Semi-Perched Aquifer remain stable while showing a strong correlation with rainfall both seasonally and long-term.

Two areas are shown and numbered by relative priority in Figure 34 where additional groundwater level monitoring would be beneficial in the Semi-Perched Aquifer. These areas are within the Fletcher Bay and Murden Cove watersheds, both of which contain streams that have been closed to further appropriation by State regulation (Ch. 173-515 WAC). This closure includes proposed water right withdrawals directly out of the streams and groundwater withdrawals that would reduce streamflow. Water rights can be approved if the impacts to the closed streams can be fully mitigated. Adding groundwater monitoring of the Semi-Perched Aquifer (likely within permeable lenses within the upper confining unit (QC1), at these locations would be helpful to assess current conditions as well as assessing the performance of potential future mitigation actions.

The City monitors chloride in four wells within the Semi-Perched Aquifer (Figure 35), all of which have exhibited chloride concentrations below 10 mg/L (COBI 2017). Low chloride concentrations are expected because the aquifer mostly occurs above MSL. For this reason, no additional sites are recommended for monitoring chloride

concentrations in the Semi-Perched Aquifer. However, monitoring for other parameters, such as nitrates or other sources of contamination resulting from land use activities, may be appropriate and important for domestic well users down-gradient of potential sources of contamination.

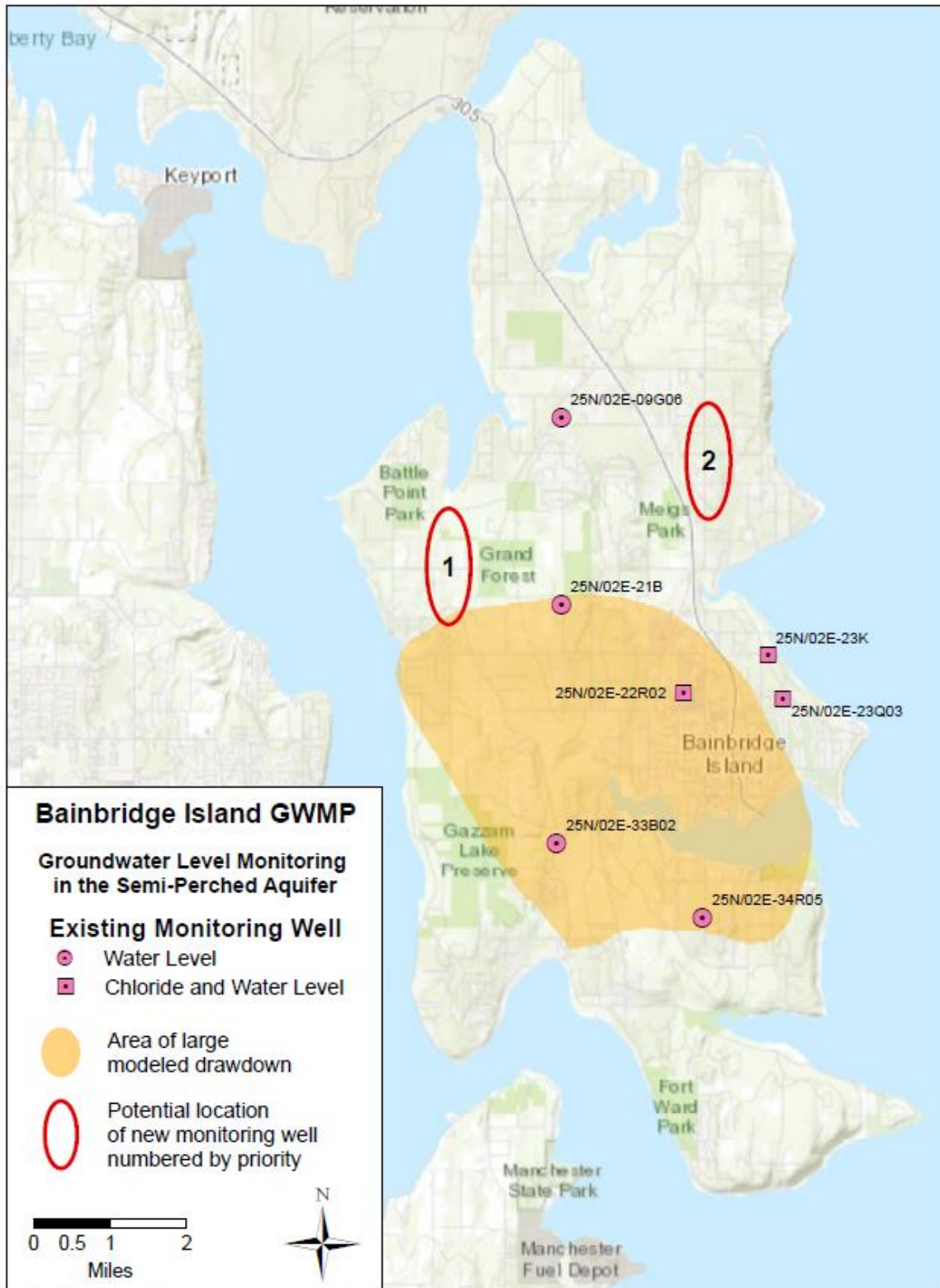


Figure 34 Existing and Proposed Water Level Monitoring, Semi-Perched Aquifer

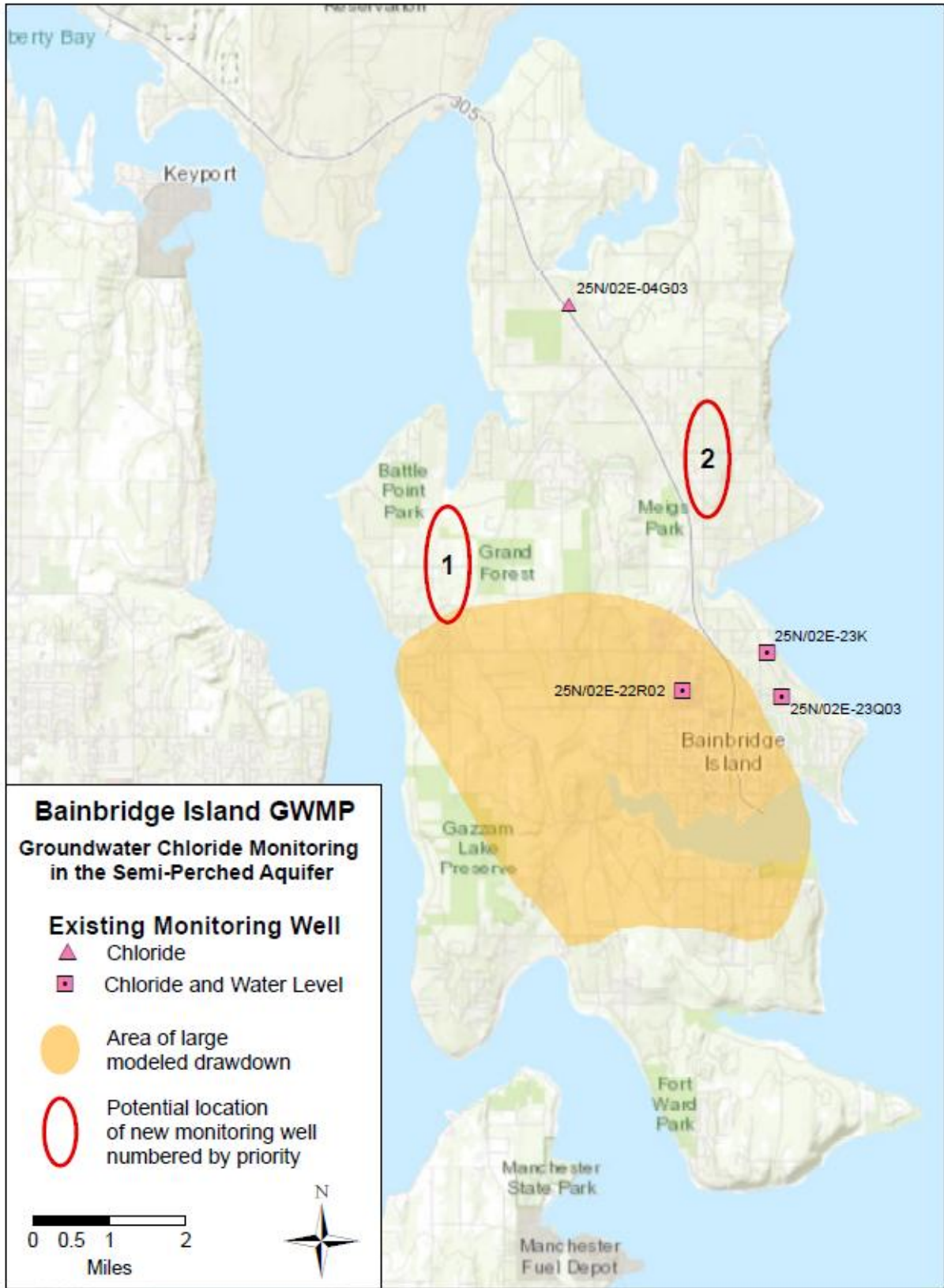


Figure 35 Existing and Proposed Chloride Monitoring, Semi-Perched Aquifer

7.4.1.3 Sea Level Aquifer

The Sea Level Aquifer (QA1) is an important source of municipal water supply for both the City and the North Bainbridge Water System, managed by the KPUD. The City monitors water levels in 26 wells while KPUD monitors 6 wells in the Sea Level Aquifer (Figure 36). Although a few wells show a slight downward trend in water levels over the period of record, none of the wells exceeded the EWL criteria. Water levels in most of the wells monitored are relatively stable over the period of record, although seasonal fluctuations from 5-15 feet are present in most of the wells.

Groundwater model scenarios that included large increases in pumping predict drawdown of up to 10 feet in the Sea Level Aquifer over a large portion of the Island after 100 years of growth. Drawdown of over 30 feet was calculated by the model surrounding the City's Head of the Bay wellfield. This relatively large drawdown is partly due to the Sea Level Aquifer being truncated by bedrock to the south, which acts as a no-flow boundary. However, the potential for large drawdowns associated with increased pumping increases the need for adequate water level monitoring to ensure that excessive drawdown, which may result in seawater intrusion, is not realized in the aquifer in the future.

Although there are currently 32 wells used for monitoring water levels in the Sea Level Aquifer, two areas to the east and northeast of the predicted large drawdown area are proposed for additional water level monitoring locations. These areas were selected because they are located between the current pumping centers and the marine shoreline and there are no wells currently monitored in the Sea Level Aquifer at these locations.

The City currently monitors chloride in 24 wells and the KPUD monitors 7 wells in the Sea Level Aquifer (Figure 37). Four additional locations to the east, southeast, southwest and northeast of the predicted large drawdown area are proposed for additional chloride monitoring. These sites were selected because they are located between the current pumping centers and the marine shoreline and there are no wells currently monitored in these areas. Additional monitoring sites at these locations would provide chloride monitoring on all sides of the predicted large drawdown area for both the City's Head of the Bay wellfield and the north and south Bainbridge Water System wells operated by KPUD.

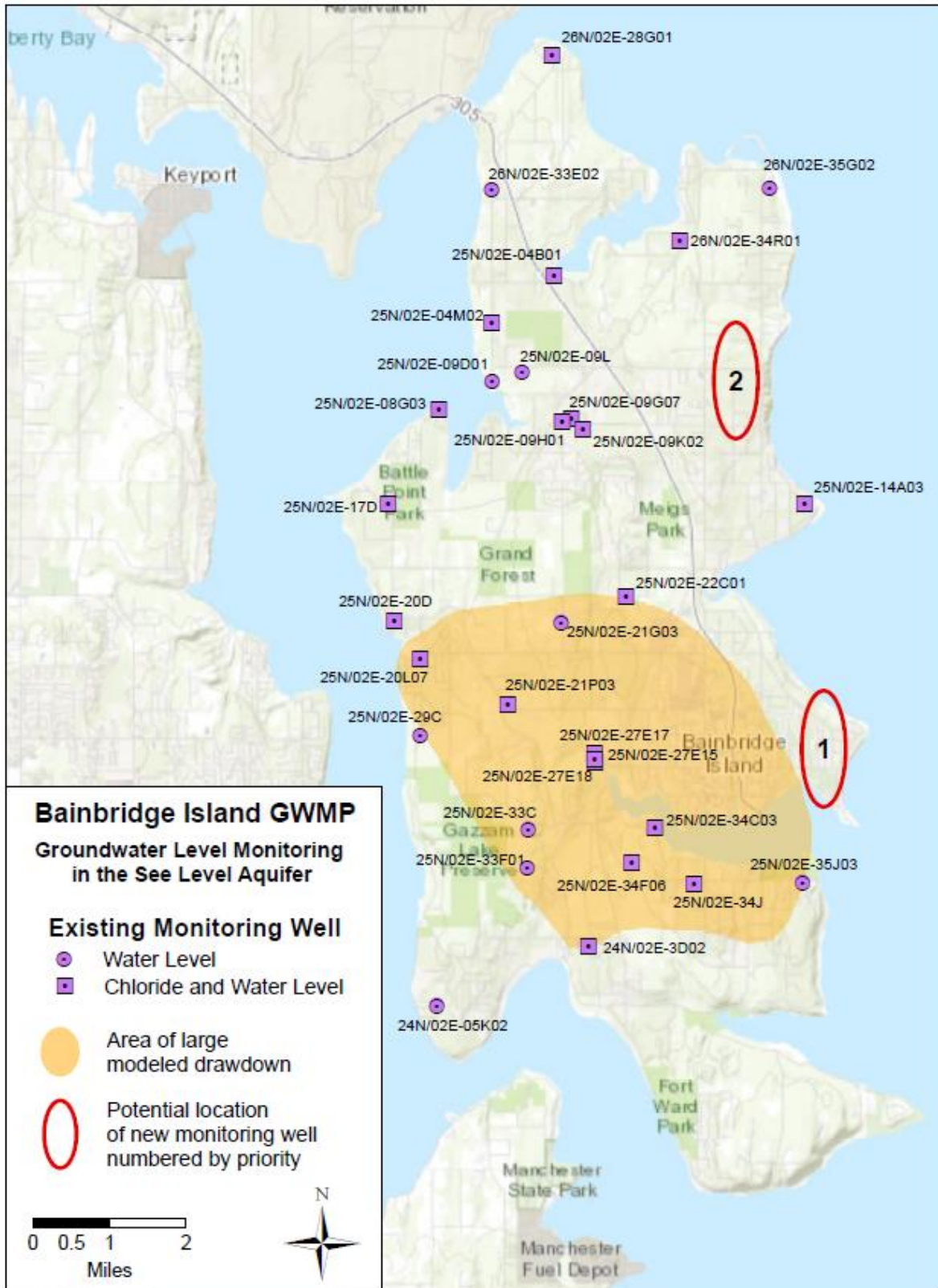


Figure 36 Existing and Proposed Water Level Monitoring, Sea Level Aquifer

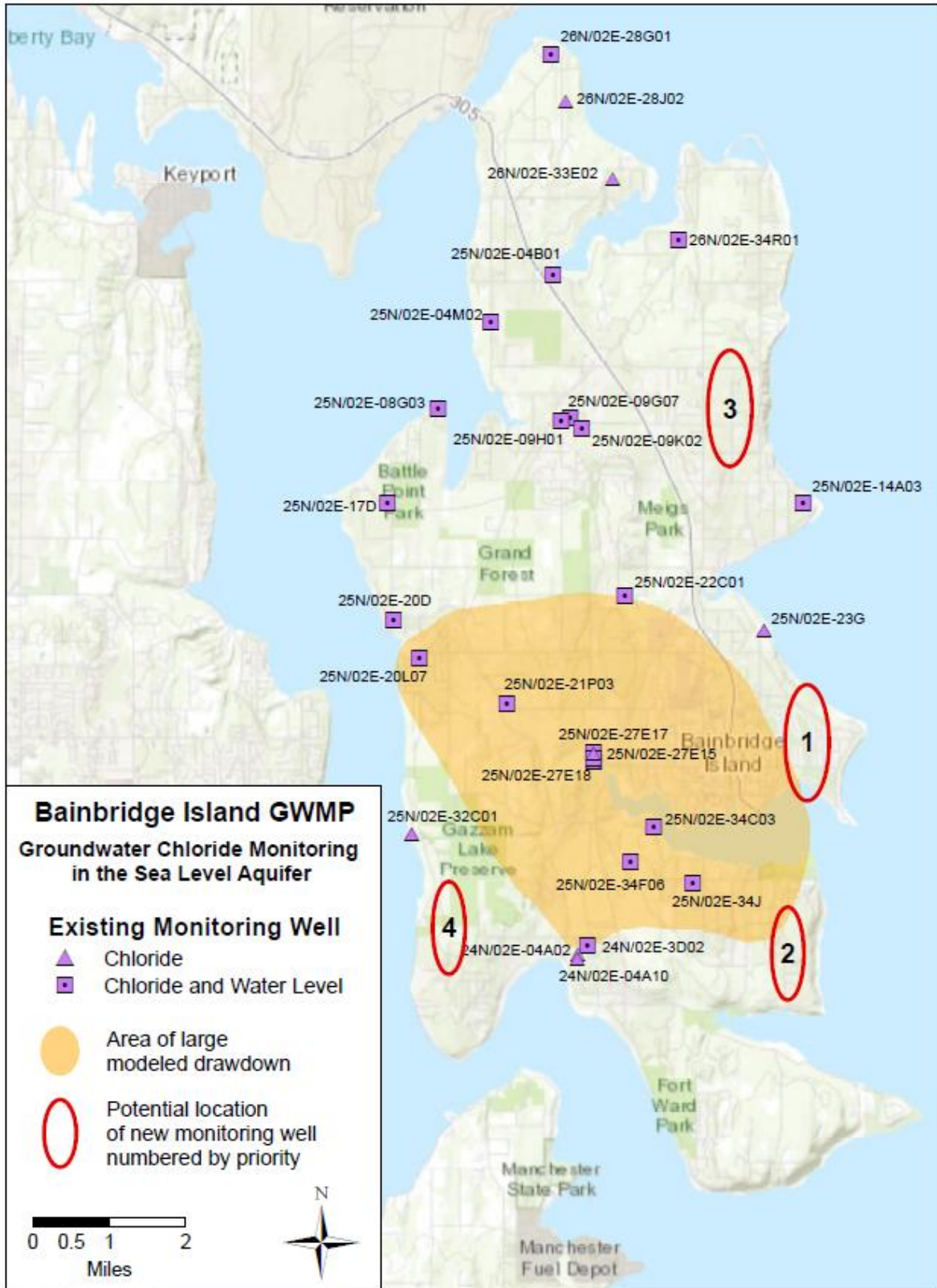


Figure 37 Existing and Proposed Chloride Monitoring, Sea Level Aquifer

7.4.1.4 Glaciomarine Aquifer

The GMA (QA2) is believed to extend beneath Port Orchard onto the Kitsap Peninsula. Recharge to the aquifer occurs through downward groundwater flow from overlying units both on and off the Island on the Kitsap Peninsula. Discharge from the aquifer is likely into marine waters offshore.

The City currently monitors water levels in four wells while KPUD monitors one well in the GMA (Figure 38). Static water levels range between 10-50 feet above MSL, with higher elevations on the western shoreline and the lower elevations just south of Eagle Harbor. Water levels are relatively stable over the period of record with fluctuations of up to 10 feet, likely due to drawdown from pumping. Wells on the western and northwestern parts of the Island indicate a slight upward trend of about 5 feet between 2008 and 2018. None of the wells have exceeded the EWL criteria.

Because of the lack of wells, no groundwater level monitoring of the GMA is occurring in the northwest part of the Island. Thus, it is recommended that additional groundwater level monitoring sites be added in these areas. Additional monitoring would be useful to ensure pumping this aquifer can continue while maintaining groundwater levels above MSL.

The City monitors chloride in five wells and the KPUD monitors one in the GMA (Figure 39). Chloride concentrations have been below 7 Mg/L in all wells except one private well where concentrations up to 43.1 Mg/L have been detected. It is uncertain if the chloride values are an indication of being within the mixing zone between fresh and seawater in the aquifer. Although the well is very close to the marine shoreline, groundwater elevations in this well are around 50 feet above MSL, indicating that chlorides may have originated from a source other than marine water. Further assessment is warranted at this location to evaluate the source of chloride.

The lack of wells in the GMA in the eastern and northeastern part of the Island constitutes a data gap that could be filled by adding additional monitoring locations in the two areas shown in Figure 39.

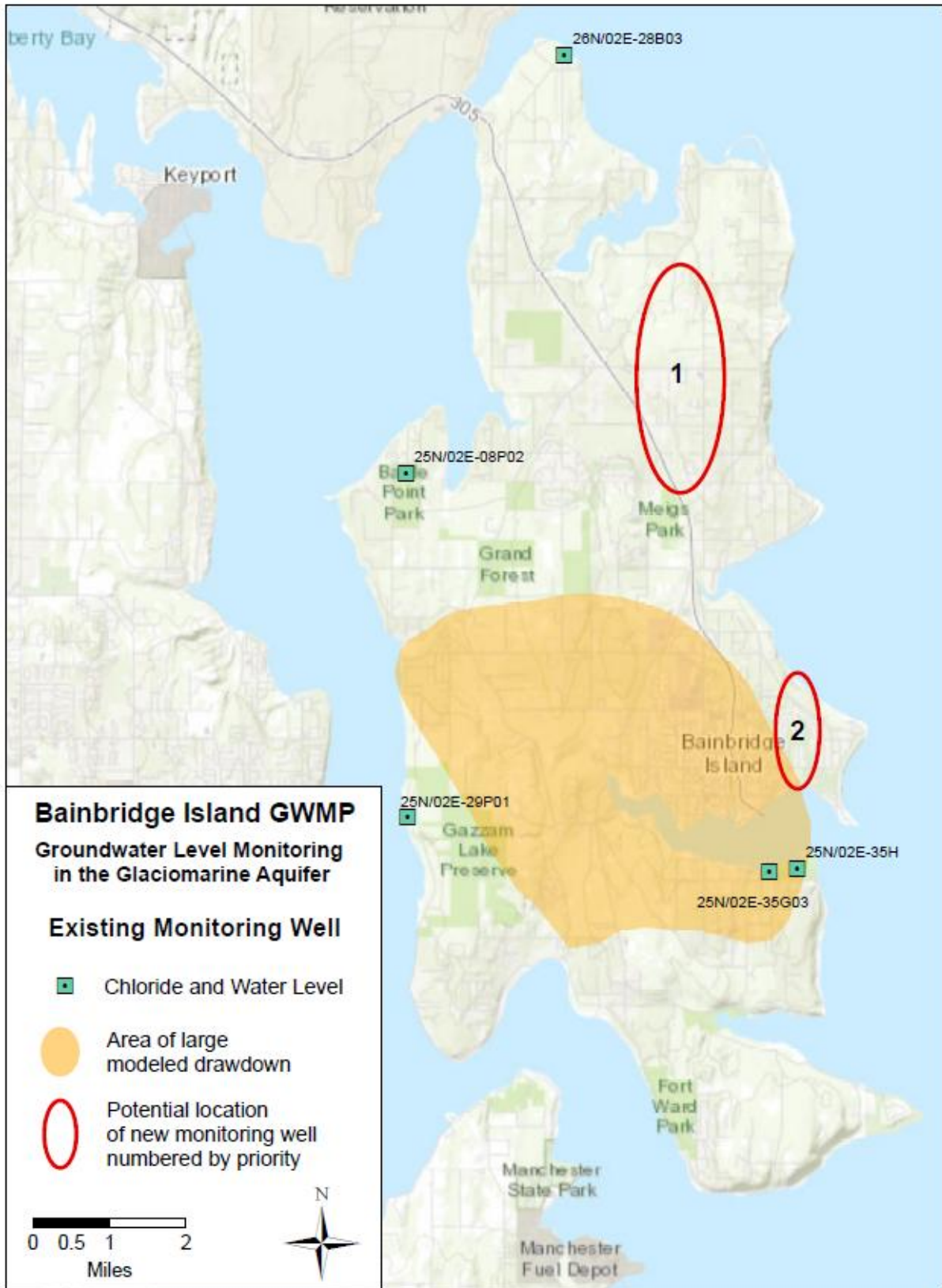


Figure 38 Existing and Proposed Water Level Monitoring, Glaciomarine Aquifer

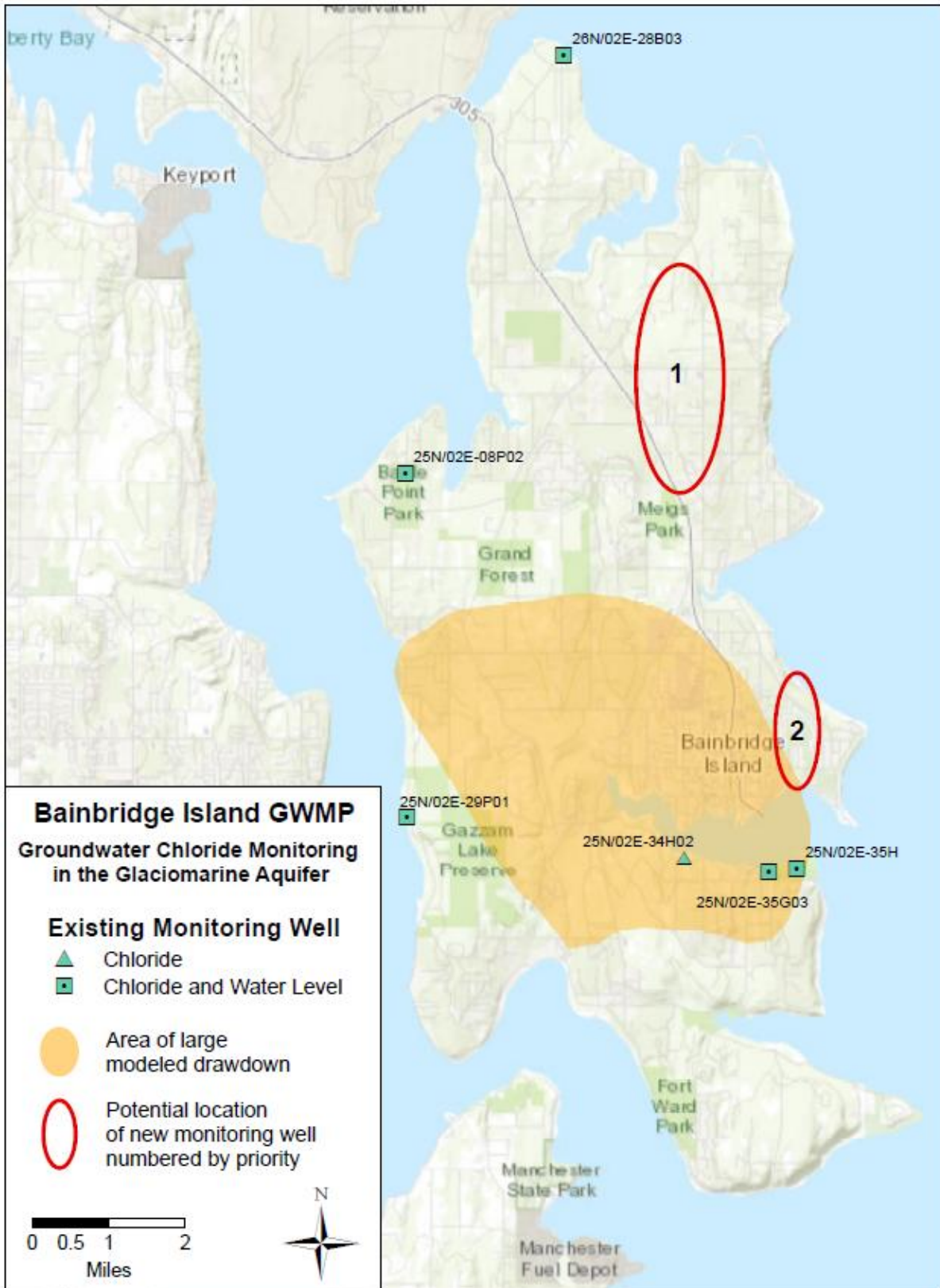


Figure 39 Existing and Proposed Chloride Monitoring, Glaciomarine Aquifer

7.4.1.5 Fletcher Bay Aquifer

Like the GMA, the FBA (QA3) is believed to extend beneath Port Orchard over to the Kitsap Peninsula. Due to its depth, relatively few wells tap into this aquifer and USGS used only 14 wells on the Island to map its extent and thickness (USGS 2011).

The City currently monitors water levels in three wells (Sands Road and Fletcher Bay wells) while KPUD monitors six wells (including the Island Utilities and North Bainbridge Water System wells) in the FBA (Figure 40). Static water levels range between 26 feet above to 35 feet below MSL, with typical fluctuations related to pumping of 15-20 feet. Water levels appear to be relatively constant of the period of record, with groundwater elevations recovering to static water levels after periods of pumping. Island Utility wells have exceeded the EWL criteria.

Three areas have been identified as potential sites to add additional monitoring to fill data gaps (Figure 40). Because of the depth of the aquifer and cost of drilling, it is likely that additional points could be added if additional production wells are added in these areas.

The City monitors chloride in four wells and the KPUD monitors five in the FBA. Chloride concentrations have been below 20 mg/L in all wells with most samples from this aquifer being below 10 mg/L (Figure 41). No exceedances above the EWLs have been detected. Two locations were chosen as potential areas to add additional chloride monitoring sites. These were selected to fill data gaps between pumping centers and surrounding marine waters and could be included if additional production wells are constructed in the FBA in the future.

Refer to Table 1 in Early Warning Level Report 2012–2021 found in Appendix E for specifics on each monitoring well.

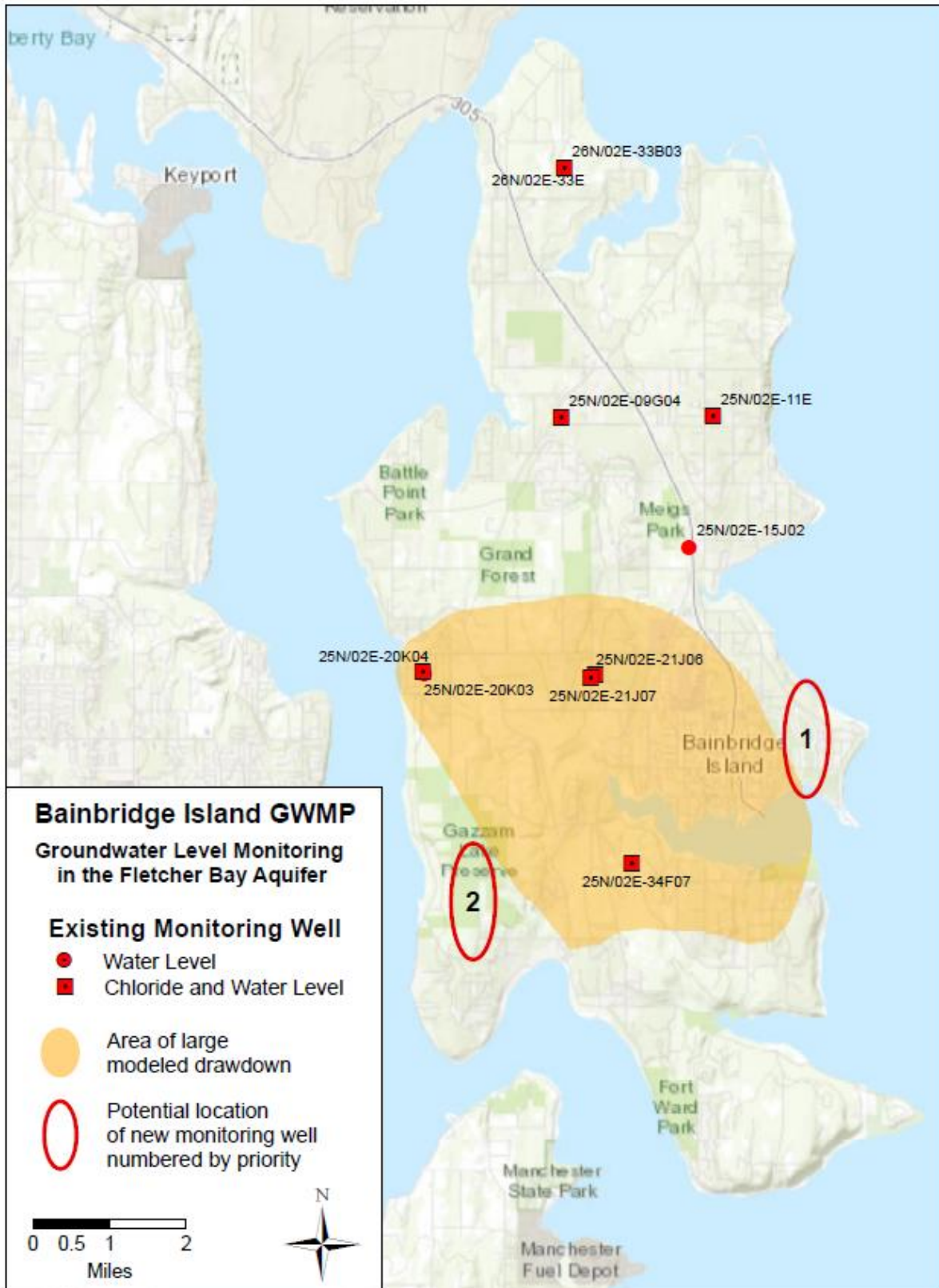


Figure 40 Existing and Proposed Water Level Monitoring, Fletcher Bay Aquifer

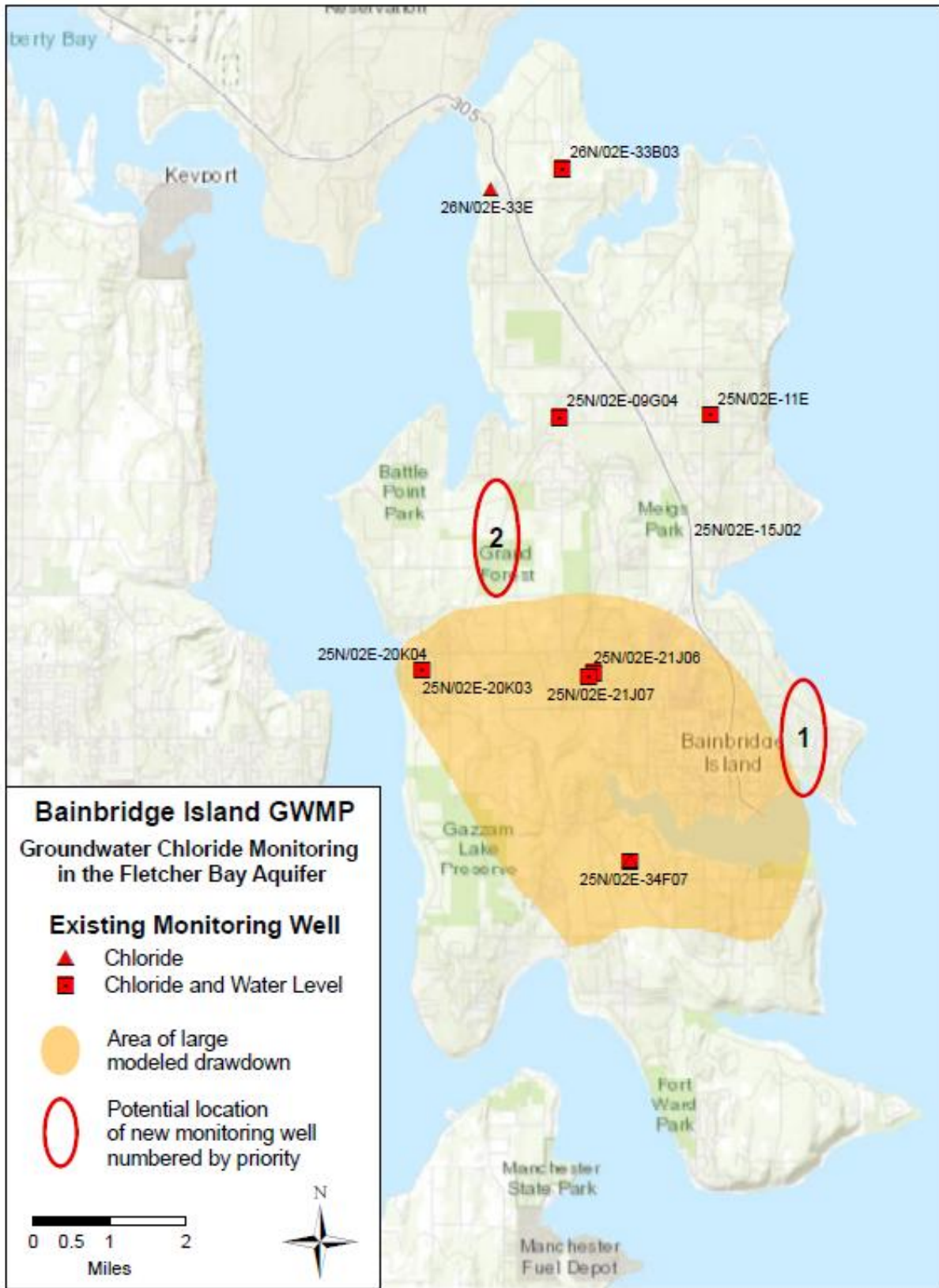


Figure 41 Existing and Proposed Chloride Monitoring, Fletcher Bay Aquifer

7.4.1.6 Bedrock Aquifer

About 1% of the Island's wells use the Bedrock Aquifer. Because of its low permeability and poor ability to store and transmit water, most wells tapping the Bedrock Aquifer can produce only a few gallons per minute, making it unsuitable for large municipal supply wells.

The City currently monitors groundwater levels in one well in the Bedrock Aquifer. Static water levels have been measured around 150 above MSL with fluctuations likely related to pumping and precipitation events of up to 20 feet. Groundwater elevations in the monitoring well appear to be stable over time.

Because static water levels are approximately 150 feet above MSL sea water intrusion into the Bedrock Aquifer is not a concern. Chloride is not monitored in this aquifer. Due to the physical limitations of this unit for supplying water, significant future development of this water source is not possible, although domestic wells could be constructed in no other water sources become available in the south end of the Island where the Bedrock Aquifer occurs near the surface.

For these reasons, no additional monitoring is proposed in the Bedrock Aquifer.

7.4.1.7 Evaluate and Revise Early Warning Levels (EWLs)

EWL assessments have been a cornerstone of Bainbridge Island's groundwater management since 2006, when the COBI established its Groundwater Monitoring Program to centralize and reform previous monitoring efforts (Aspect 2009). Currently, City monitoring wells undergo an annual assessment as part of the COBI's groundwater monitoring program, with particular focus on seawater intrusion indicators, while groundwater levels are tracked in certain wells to observe trends in aquifer conditions over time. The program maintains monitoring standards, including the safe yield EWL threshold of a 0.5 ft/yr decline over a 10-year assessment period. For seawater intrusion monitoring, the program employs a chloride concentration threshold of 100 mg/L or evaluates any increasing trend as an indicator of a potential issue (Aspect 2009). These thresholds trigger detailed evaluations and potential management responses when concerning trends emerge.

Current use of the EWLs are an appropriate, meaningful and important groundwater management tool. As part of the monitoring program efforts moving forward, refinement to the metrics and management responses should be

developed to address potential risks, particularly as they relate to declining water levels, which has yet to be implemented as fully as chloride level evaluations.

7.4.2 Expand Surface Water Monitoring

Groundwater withdrawals can capture water that would contribute to baseflow discharge to streams, thus reducing streamflow. Withdrawals from shallow unconfined aquifers generally capture a larger proportion of baseflow discharge than equivalent withdrawals from deeper confined aquifers. Although not constructed to specifically quantify impacts to streams from groundwater withdrawals, results from the Bainbridge Island groundwater model indicate that increased groundwater pumping will result in a decrease in groundwater drainage to the surface through springs, wetlands and streams where groundwater discharge to the surface typically occurs.

Because groundwater and surface water are connected and one of the objectives of managing groundwater on the Island is to protect and enhance the natural environment on the Island, monitoring streams on the Island is an important component of proposed management strategies. Monitoring can aid in detecting impacts to streams as well as the performance and effectiveness of mitigation and management strategies.

Streams in the Murden Cove and Fletcher Bay watersheds are closed to further water right appropriations by Chapter 173-515 WAC. This closure includes proposed water right withdrawals directly out of the streams and groundwater withdrawals that would reduce streamflow. Water rights can be approved if the impacts to the closed streams can be fully mitigated.

Chapter 90.94 RCW extends the requirement for mitigating impacts to closed streams to permit-exempt wells. Permit-exempt wells are groundwater uses authorized by RCW 90.44.100 that do not require a water right issued by the State of Washington. Most permit-exempt wells are used for single or multiple domestic purposes and wells put into service since 2018 are limited to withdrawals maximum annual average of 950 GPD. Chapter 90.94 RCW also defines the requirements for quantifying impacts and developing and implementing mitigation strategies to offset impacts to closed streams from permit-exempt wells.

The City's Water Quality and Flow Monitoring Program has been operating on Bainbridge Island since 2008. Streamflow data is collected at four locations. In addition, King County in partnership with the City, established a streamflow monitoring site on Manzanita Creek in 2017, see Figure 42. KPUD now operates the equipment and manages the data.

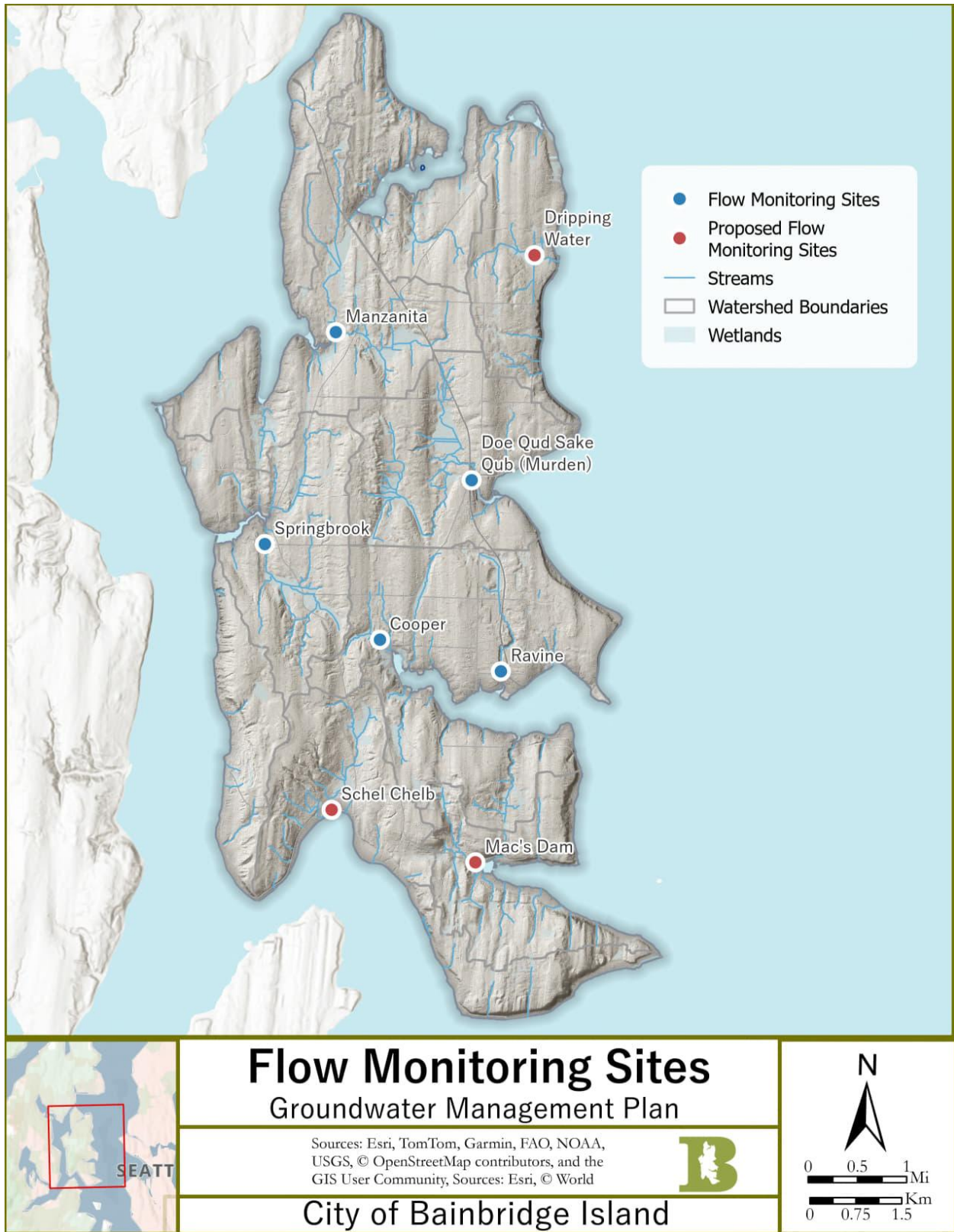


Figure 42 Current and Proposed Stream Monitoring Locations

Monitoring stations could be added to evaluate specific reaches of streams, the effectiveness of mitigation actions, and to evaluate impacts from changing land use and development projects. Specific additional monitoring locations include Schel Chelb, Dripping Water and Macs Dam (Figure 42). These would provide better spatial coverage in the north and south ends of the Island. The sites match with historic flow monitoring sites that the USGS monitored in 2007/2008 (USGS 2011). This will allow comparison to baseline data, albeit at a limited scale. More sites could be added in addition to the three proposed sites if resources become available.

Although stream monitoring is important, several potential obstacles can limit or interfere with monitoring efforts and must be considered as part of future monitoring efforts. These include:

- Most streams on Bainbridge Island have flows that are often too small to accurately measure. Measurements of narrow and shallow streams are highly susceptible to measurement error.
- Major precipitation events rearrange the steep stream channels such that the rating curves must be adjusted often.
- Access to stream channels at locations that are conducive for measurements may be difficult to obtain and may require obtaining access to private property.
- Stream monitoring stations and equipment are susceptible to vandalism and/or damage from high-flow events.

7.4.3 Update Groundwater Model

As groundwater field data continues to be collected it should periodically be reviewed for accuracy and then utilized to update and calibrate the Bainbridge Island groundwater model. This will provide decision makers with a reliable, up-to-date tool that's ready for deployment when new land-use choices are to be made.

7.5 Recommendations

Recommendations for the next 6-year period beginning in 2027 through 2032 (overlapping the timeframe for the City's Capital Improvement Plan planning cycle)

were developed based on a cost/benefit ratio analysis. Costs and benefits were assigned to the management actions in accordance with the following criteria:

- Actions with costs < \$50K were assigned a value of **4**
- Actions with costs between \$51K- \$100K were assigned a value of **3**
- Actions with costs between \$101K-\$250K were assigned a value of **2**
- Actions with anticipated costs >\$251k were assigned a value of **1**

- Proactive actions were assigned a value of **1**
- Preventative actions were assigned a value of **2**
- Data collection actions were assigned a value of **3**
- Information management actions were assigned a value of **4**

Each action was independently evaluated for the years 0-3 and 0-6, and the resulting values were combined for a total cost benefit score. This approach allowed for weighting actions with higher costs in the later years of implementation, given that the City will likely have limited resources to implement large projects or initiatives in a 6-year timeframe.

The analysis resulted in the prioritization of six (6) management actions in the six-year period (a ranking of all the management actions can be found in Appendix A).

- **Promoting water conservation**, including developing conservation goals, piloting conservation strategies, and evaluating results. The City has water conservation plan in the Water System Plan that can be used as a starting point. In addition, KPUD will be piloting conservation measures for the South Bainbridge Water System in the summer of 2026, which could lead to lessons learned.
- **Enhancing storm and surface water management**, including implementing a stormwater source control program and considering rebates for stormwater retrofits. The City has a robust stormwater management program that can be enhanced to address these actions.

- **Promoting rainwater harvesting**, which could help diversify water sources, reduce pressure on vulnerable aquifers, and enhance household resilience to climate change and potential future water scarcity.
- **Spreading out production wells, evaluating interties between large systems and increasing public water storage.** These three actions each have independent benefits but are likely to be pursued together as part of a coordinated effort with KPUD. At the time of development of this plan, the City was considering an Interlocal Agreement with KPUD to explore short and long-term planning for all three of these issues.
- **Consolidating smaller water systems and users with larger public systems**, which will reduce reliance on shallow aquifers, and ultimately allow more regulation regarding the use of water resources. The City's Water System Business Plan, which was in draft at the time of the development of this plan, provides a blueprint for consolidation. There are rolling grant programs available from the state to support consolidation of small systems.
- **Evaluating and Implementing Managed Aquifer Recharge**, including following through on the Manzanita Stormwater Recharge Park project, which is currently grant funded.

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Appendix A

Table of Management Actions

Appendix B

Related Plans and Documents

Appendix C

Public Engagement Plan

Appendix D

Technical Advisory Committee Charter

Appendix E

Early Warning Level Assessment (2021)

Appendix F

Group B Well Details

Appendix G

Water Well Logs

Appendix H

Well Production of Select Municipal Wells

Appendix I

Public Water System Details

Appendix J

Contaminated Sites

Appendix K

EA Technical Memo on Groundwater Modeling, 2025

Appendix L

Keta Waters Peer Review on Draft Groundwater Management Plan, 2025

Appendix M

Keta Waters, Technical Memo on Steady State Modeling 2026

Appendix N

Major Well Site Map

Appendix O

Table of Model Details