City of Bainbridge Island
Groundwater Management Plan

Water Resources
Department of Public Works

Prepared for

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Prepared by

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July 2025
Version: DRAFT, Revision 1
EA Project No. 16409-01

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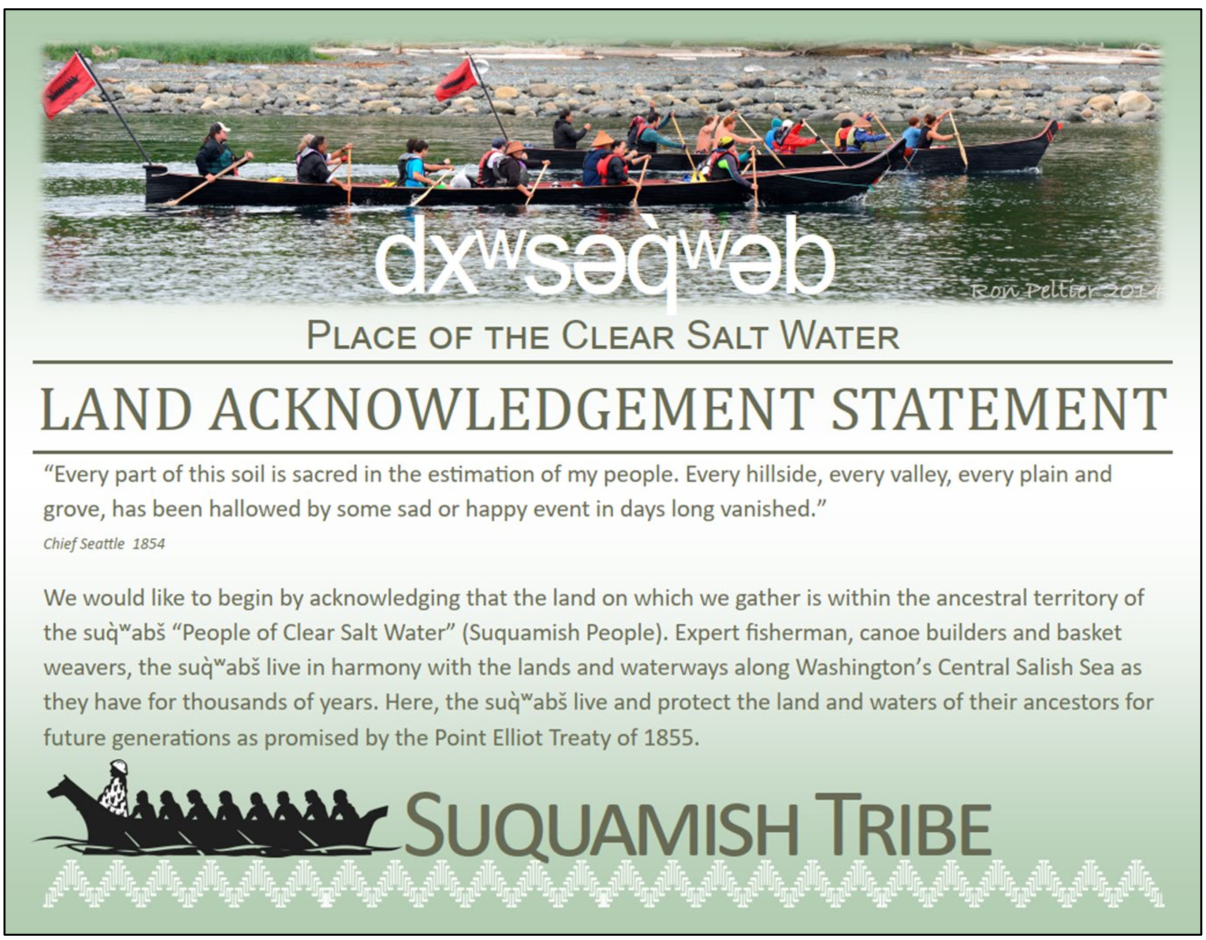
LIST OF ACRONYMS AND ABBREVIATIONS

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
BOD5	biochemical oxygen demand
Carollo	Carollo Engineers, Inc.
CDP	cumulative daily precipitation
CFL	compact fluorescent lamp
COBI	City of Bainbridge Island
DBP	disinfection byproducts
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	Gallons Per Day
GMA	Glaciomarine Aquifer
GSI	green stormwater infrastructure
HB 1220	House Bill 1220
IDDE	Illicit Discharge Detection and Elimination
KPHD	Kitsap Public Health District
KPUD	Kitsap Public Utility District
LID	Low Impact Development
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
ORCI	overriding consideration of the public interest
PA	perched aquifer
PVC	polyvinyl chloride
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
TSS	total suspended solids
UAC	Utility Advisory Committee
USGS	U.S. Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
WA CIG	Washington Climate Impacts Group
WGWA	Washington Growth Management Act
WWTP	wastewater treatment plant

EXECUTIVE SUMMARY

Bainbridge Island is a distinctive landmass approximately 3.5 miles wide and 10.5 miles long, encompassing about 27.5 square miles with 53 miles of scenic coastline. The island's landscape is characterized by rolling hills reaching elevations of up to 400 feet above sea level, with varied coastal features including harbors, coves, and lagoons, as well as steep cliffs particularly along the southern and eastern portions. The island has a population of 24,825 as of 2020. It is primarily residential: 75% of land dedicated to residential use; 15% comprise forest, agriculture, and parks; and the remaining 10% is split between transportation, commercial/industrial, and public facilities. Regarding its water system, Bainbridge Island relies entirely on groundwater for its drinking water supply, with an estimated 1,400 water supply wells across the island. The water system is complex, consisting of multiple aquifer layers, including the Perched Aquifer, Sea Level Aquifer, Glaciomarine Aquifer, and Fletcher Bay Aquifer. City of Bainbridge Island (COBI) maintains a comprehensive Groundwater Monitoring Program, established in 2006, which centralizes various monitoring efforts and maintains a database of groundwater levels and quality data. Water quality and quantity are carefully monitored, with particular attention paid to potential seawater intrusion in coastal areas and ensuring aquifers maintain safe yield levels. This monitoring is crucial as the island's water resources consist of surface water, groundwater, and stormwater, which, while often managed separately, are inextricably linked in maintaining the island's water security.



Purpose/Goals/Objectives

The COBI relies on groundwater for water supply and to support healthy streams and wetlands on the island and was designated in 2013 by the U.S. Environmental Protection Agency (EPA) as a Sole Source Aquifer —meaning the aquifer is the sole or principal source of drinking water for the area and that contamination could pose a significant public health hazard. Consequently, COBI is preparing a Groundwater Management Plan to achieve the following goals and objectives.

Develop community-wide understanding

- Establish advisory sub-committee
- Establish island-wide stakeholder engagement
- Develop on-line platform to share information

Reduce and adapt to climate change impacts

- Identify climate change impacts to groundwater
- Develop and implement strategies to reduce and adapt to climate change impacts
- Improve climate change indicator monitoring

Ensure clean and sufficient groundwater for our natural environment and ourselves

- Produce groundwater models that inform decisions on land-use and population
- Develop and implement water conservation and recharge strategies
- Minimize and mitigate threats to water quality

The concepts of good stewardship today and in the future are inherent to the goals and objectives laid out by the COBI Council. This stewardship is based on community input into land and water management decisions and the best-available science, which evolves over time.

The primary purpose of Bainbridge Island's Groundwater Management Plan is to establish a comprehensive framework for cooperation between regulatory agencies and utilities to protect the island's EPA-designated Sole Source Aquifer system. As Bainbridge Island is entirely dependent on groundwater, the plan emphasizes safeguarding this vital resource through robust protection measures, while also addressing critical data gaps and research needs that influence long-term sustainability.

The plan outlines several key goals, beginning with the protection of groundwater quality and quantity. 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, the COBI, Kitsap Public Utility District, Washington Departments of Ecology and Health, and the Kitsap Public Health District.

Development management is another core goal, as the island must plan to accommodate 1,977 new housing units by 2044 to meet population growth projections mandated under the Washington Growth Management Act (WGMA). The WGMA requires local jurisdictions to ensure adequate housing capacity for future residents while protecting critical areas and natural resources. This balancing act is particularly important on Bainbridge Island, where groundwater is the sole source of drinking water. The plan addresses the impacts of development on both shallow and deep aquifer systems and calls for the implementation of comprehensive stormwater management practices. These are enforced through municipal codes and standards that promote Low Impact Development (LID) and green infrastructure to reduce runoff and enhance groundwater recharge.

The implementation approach prioritizes using existing regulatory frameworks, such as the Western Washington Phase II Municipal Stormwater Permit. It builds upon an established monitoring network of 87 wells across six aquifers and emphasizes 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.

The plan focuses on several specific actions to achieve its objectives. In terms of monitoring and assessment, it calls for regular tracking of groundwater levels and quality through strategically positioned wells, especially in areas at risk of seawater intrusion. It also seeks to evaluate the impacts of development and land use changes on both water availability and aquifer health.

For protection measures, COBI maintains strict development standards under Bainbridge Island Municipal Code 18.15 and 18.18, implements comprehensive stormwater policies, and works to prevent contamination through hazardous material management and careful oversight of known contamination sites. In terms of conservation and management, the plan aims to mitigate a projected 7% increase in water use per house due to the projected longer, drier growing season. This estimate was developed by EA as a best-fit trend line based on prior work by the University of Washington and Seattle Public Utilities. Planning includes preparing for increasing withdrawals, which if done at existing well fields could result in anticipated drawdowns of 40–60 feet in key aquifers over the next century. It also supports local water systems in maintaining adequate supply while minimizing the risk of seawater intrusion.

Altogether, the plan reflects 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, COBI is working to ensure the long-term protection and resilience of its most critical natural resource.

Findings

Bainbridge Island relies entirely on groundwater as its sole source of drinking water. Approximately 1,400 wells—supporting both private and community water systems—draw from a complex system of aquifers that also play a critical role in sustaining the island's streams and wetlands. The island's hydrogeology includes several major aquifers: the Perched and Semi-

Perched Aquifers, which are located at higher elevations (from sea level up to 300 feet) and account for 29% of wells; the Sea Level Aquifer, which is the most widely used with 53% of wells; the Glaciomarine Aquifer, found 300–500 feet below sea level with about 2% of wells; the Fletcher Bay Aquifer, the deepest identified aquifer, which provides approximately 30% of the island's total groundwater production despite only 1% of wells tapping into it; and the Bedrock Aquifer, which has less than 1% of the island's wells.

The island's topography includes twelve watersheds, one natural lake (Gazzam Lake), several small wetlands, and 59 named streams—17 perennial and 42 seasonal. Land use is predominantly residential, making up 75% of the island. An additional 15% is used for forests, agriculture, and parks, while the remaining 10% is dedicated to transportation infrastructure, commercial and industrial development, and public facilities. Bainbridge Island's water budget reflects a dynamic equilibrium, with an estimated total recharge of 13,673 acre-feet per year—primarily from precipitation. Of this recharge, approximately 50-60% discharges to surface waters, 5-10% is withdrawn through well pumping, and 30-40% flows to the marine environment or eastward. This balance is sustained by the interaction of inputs (precipitation and septic and irrigation return flows) and outputs (spring discharge, well withdrawal, and flow to marine waters).

Climate change projections present significant challenges for the island's groundwater system. By mid-century, average annual air temperatures are expected to rise by 4–5.5°F. Precipitation patterns will also shift, with drier summers and more intense winter rainfall, which could lead to increased surface runoff and reduced groundwater infiltration. Sea level rise—projected at 5 inches by 2030, 10 inches by 2050, 28 inches by 2100, and 46 inches by 2150—poses an additional threat to coastal aquifers, increasing the risk of saltwater intrusion. These changes will likely coincide with increased water demand due to warming temperatures, placing further stress on the system.

Groundwater modeling has provided key insights into how the aquifer system functions under these conditions. The simulations indicate that the groundwater system is not in steady state. Shallow aquifers withdraw water that is relatively young—less than 100 years old and close to the wellhead—while deeper aquifers may draw from distant sources, including the Kitsap Peninsula, with some of that water being more than 1,000 years old. These findings emphasize the importance of updated monitoring and management strategies to address both natural variability and the increasing pressures from climate change and development. A summary of the modeling scenarios by aquifer is provided below.

Overall Risk Assessment of Predicted Groundwater Scenarios

Based on the most recent modeling and analysis, Bainbridge Island's groundwater resources face potential risks under a range of predicted scenarios related to climate change, population growth, and land use changes. The modeling considered variations in recharge rates (down by as much as 20%), significant increases in water production (up to 167%), and sea level rise projections up to 6.9 feet over 100 years. Each of these drivers introduces complex, and often compounding, risks for the island's Sole Source Aquifer and related water infrastructure.

Key risks identified include:

Declining Aquifer Levels: Deep aquifers (notably the Fletcher Bay Aquifer, FBA) are expected to experience significant drawdowns—potentially as much as 40 to 60 feet in high-impact scenarios—with increased vulnerability around major production wells. Even shallow aquifers, although more resilient in some models, show modest but persistent declines in water levels across much of the island.

Reduced Groundwater Contribution to Surface Waters: Groundwater drainage to surface water could decrease by as much as 40%, with implications for baseflows in streams and wetlands. This reduction poses a threat to local ecosystems and the island's capacity to maintain healthy surface water systems during dry periods.

Increased Risk of Seawater Intrusion: The risk of saltwater moving into freshwater aquifers will rise because of both declining water tables from over-extraction and sea level rise, particularly in low-elevation coastal wellfields. Model projections show that groundwater elevations may fall below sea level in vulnerable areas within 50-100 years if current trends continue, increasing the likelihood of contamination by seawater.

Infrastructure Stress & Service Reliability: Population growth and increased water demand will place additional stress on existing water infrastructure, requiring substantial upgrades to maintain both service levels and system resilience. The interconnectedness of the island's water systems means that increased use in one area can reduce availability elsewhere.

Uncertainties and Data Gaps: Future risk is compounded by uncertainties in population growth trajectories, climate projections, aquifer connectivity, and recharge rates. Existing gaps in the monitoring network, particularly related to chloride migration and streamflow measurement, limit the ability to foresee and mitigate certain risks effectively.

Implications for Management:

These findings underscore the need for immediate and ongoing adaptive management approaches. Proactive investments in monitoring, infrastructure, conservation measures, and alternative water sources (e.g., expanded rainwater harvesting) are critical to mitigate these risks. Collaborative planning between agencies and robust public engagement will also be necessary to ensure long-term sustainability and resilience of the island's groundwater system

Inclusion of this risk assessment in the Executive Summary will provide stakeholders with a clear understanding of the magnitude and complexity of the challenges ahead, helping to drive informed policy decisions and community actions.

Knowledge/data gaps

Bainbridge Island's Groundwater Management Program has identified several critical knowledge and data gaps that need to be addressed. The program's Early Warning Level (EWL) system requires review and updates, particularly regarding the uniform application of the 0.5 feet/year decline across all aquifers. While COBI's groundwater monitoring network currently includes 87 wells, there are still limitations in the system's ability to track chloride migration and monitor seawater intrusion in all aquifers effectively. The program maintains rigorous monitoring standards and has been particularly successful in identifying areas of concern, such as the Fletcher Bay Aquifer near Eagledale.

The groundwater model serves as a crucial tool for understanding and managing the island's water resources, though it requires continuous updates to remain effective. The model has undergone significant revisions and now incorporates extensive current data, including spatially variable precipitation patterns and detailed extraction records. Future predictions consider three distinct planning scenarios that evaluate various combinations of sea level rise, recharge rates, and production increases applied linearly over the 100-year modeling scenarios as follows:

- Recharge Rates: -20–15% from current values
- Sea Level Rise: 2.8–6.9 feet above current mean sea level
- Production Increases: 122–167% above current pumping rates

The model results have revealed varying impacts across the different aquifers, with deeper aquifers showing significant drawdown near major municipal supply wells.

Table ES-1. Summary of Modeled Planning Scenarios

Low Impact Planning Scenario Summary Table	
Aquifer	**Results**
Vashon Advance Aquifer (Qva)	Negligible changes relative to current conditions. Mean groundwater levels are simulated to increase 0.1 feet after 100 years.
Sea Level Aquifer (SLA)	Groundwater levels are simulated to decrease up to 6 feet after 100 years. Groundwater levels are simulated to be below mean sea level after 50 years around the South Bainbridge Wellfield.
Glaciomarine Aquifer (GMA)	Groundwater levels are simulated to decrease up to 33 feet after 100 years on the southern portion of the island, primarily centered around the Island Ultility Wellfield. This is due to wells set in the FBA creating vertically induced drawdown in the aquitard separating GMA and FBA, ulitmately effecting both aquifers.
Fletcher Bay Aquifer (FBA)	Groundwater levels are simulated to decrease up to 50 feet after 100 years. After 100 years, drawdown of 80-100 feet is projected within 500 feet of Island Utility Wells 1 and 3. The area surrounding that zone is projected to drawdown between 60-80 feet. The nortern side and vast majority of the shoreline of the island has a projected drawdown of 40-60 feet.

Mid Impact Planning Scenario Summary Table	
Aquifer	**Results**
Vashon Advance Aquifer (Qva)	Negligible changes relative to current conditions. Mean groundwater levels are simulated to decrease 0.8 feet after 100 years.
Sea Level Aquifer (SLA)	Groundwater levels are simulated to decrease by 6 feet after 100 years. This is primarily located around the South Bainbridge Wellfield, suggesting the increase in mean sea level offsets effects of decreased recharge and inreased pumping in the SLA.
Glaciomarine Aquifer (GMA)	Groundwater levels are simulated to decreased by 46 feet after 100 years. This is primarily centered around Island Utility Wellfield, due to FBA wells creating drawdown in the aquitard separating GMA and FBA. The portion of the aquifer with groundwater elevations below mean sea level expands past the footprint of the island faster and to a greater overall extent than the Low Impact simulation results.
Fletcher Bay Aquifer (FBA)	Groundwater levels are simulated to decrease by 71 feet after 100 years. 80-100 feet of drawdown are simulated within approximately a 2,000 foot radius around Island Utility Wells 1 and 3 and approximately a 1,000 foot radius around Sands Road wells 1 and 2. The northern part of the island experiences less drawdown, 60 to 80 feet and 40 to 60 feet, due to being less proximate to the Island Utility, Sands Road, and Fletcher Bay wells.

High Impact Planning Scenario Summary Table	
Aquifer	**Results**
Vashon Advance Aquifer (Qva)	Groundwater levels are simulated to decrease 5 feet after 100 years. However, the mean groundwater elevation within the Qva unit will still be projected to be nearly 100 feet above sea level, so the 5 foot decrease is relatively small.
Sea Level Aquifer (SLA)	Groundwater levels are simulated to decrease by 10 feet after 100 years. The decrease by year 100 is primarily due to groundwater levels around the Head of Bay Wellfield dropping below mean sea level and the area of groundwater levels below mean sea level around the South Bainbridge wellfield expanding west.
Glaciomarine Aquifer (GMA)	Groundwater levels are simulated to decrease by 50 feet, 4 feet more than the Mid Impact Planning Scenario. The decrease is due to a sight expansion of the cone of depression around the Island Utility wellfield in thr GMA. Drawdow trends emulate the Mid Impact Planning scenario.
Fletcher Bay Aquifer (FBA)	Groundwater elevations are simulated to decrease by 82 feet, 5 feet more than the Mid Impact Planning Scenario. The decrease is due to the slight deepening of the cones of depression around the production centers in the FBA. Drawdow trends emulate the Mid Impact Planning scenario.

A significant challenge lies in understanding and preparing for climate change impacts on the island's groundwater resources. Climate change poses multiple risks to groundwater processes, including potential reductions in recharge and changes in recharge timing. The situation is complicated by the fact that none of the island's streams, including perennial streams, are continuously gauged or monitored for streamflow or stage, which limits understanding of surface water-groundwater interactions. These knowledge gaps, combined with the need to better link with stormwater management programs and improve monitoring of seawater intrusion, highlight the importance of continuing to evolve and enhance the island's water resource management strategies.

Problem Definition

Bainbridge Island's water infrastructure and management systems represent a complex network of challenges and solutions centered around its Sole Source Aquifer. The island's water demand is met by 33 active Group A and 146 active Group B water systems, collectively serving a population of 28,914. Group A systems—such as the North Bainbridge and South Bainbridge Water Systems operated by Kitsap Public Utility District (KPUD)—serve 15 or more connections or 25 or more people for at least 60 days per year, typically supplying larger communities under more stringent regulatory oversight. In contrast, Group B systems serve fewer than 15 connections or fewer than 25 people per day, generally catering to rural or lower-density areas with less oversight. The island's water infrastructure also includes advanced treatment facilities, including the Bainbridge Island Wastewater Treatment Plant, which currently has capacity for 285 additional Equivalent Residential Units (ERUs). ERUs are a standardized metric used to represent the average water demand or wastewater generation of a single-family household, allowing utilities to consistently compare, manage, and plan for various customer types and usage levels. In addition, historical contamination sites—such as the closed Bainbridge Island Landfill and the Wyckoff/Eagle Harbor Superfund Site—have necessitated robust monitoring and management systems to protect groundwater quality.

The island faces population growth requirements of 1,977 additional housing units by 2044 and significant projected increases in water demand, with the North Bainbridge and South Bainbridge systems—both owned and operated by KPUD—potentially seeing increases of 61–115% and 194–373%, respectively. These trends reflect increasing demand on the COBI system, particularly as more areas transition from individual wells or small systems to centralized service.

However, KPUD does not have the excess pumping capacity or sufficient water rights to meet these projected demands. Meeting future needs will require the development of new wells, acquisition of additional water rights, and expansion of existing infrastructure—alongside aggressive conservation measures and the use of recycled water where feasible.

Climate change further complicates these challenges, with projections indicating temperature increases of 4–5.5°F by mid-century, shifting precipitation patterns, and sea level rise of up to 28 inches by 2100. To address these challenges, COBI has implemented comprehensive management strategies, including stormwater programs, groundwater management plans, and climate action initiatives, while multiple agencies collaborate on water quality monitoring and assessment. These efforts are crucial for maintaining both current service levels and long-term sustainability of the island's water resources, especially given that 90% of land is designated as "conservation area" to minimize development impact.

Management Strategy Alternatives

Together with City staff, a matrix of Groundwater Management Plan Actions was developed to respond to the findings in the Plan - the Actions are categorized as proactive mitigation; prevention; data collection; and information management. A work plan was developed for each action, broken up into three, 3-year increments, and costs for each increment were assigned. In discussions with the GWMP sub-committee and the Technical Advisory Committee, both groups highlighted the need for ranking the actions in accordance with a prioritization criterion so that an overall work plan and budget for the groundwater management plan could be developed.

In response to that request, City staff developed a cost/benefit analysis tool that serves as the prioritization criteria for ranking the actions. The criteria ranked the costs of each action from 1-4, with 1 being the highest relative cost (>$250K) and 4 being the lowest relative cost (<$50K). Only the costs between years 0 and 6 were considered for the analysis, as costs beyond the 6-year timeframe were deemed to be speculative estimates. The benefits of each action were ranked 1-4 according to the directness of their impact: proactive actions were ranked highest at 1, followed by prevention, data collection and information management.

The cost/benefit calculation resulted in actions being assigned a ranking between 4 and 0.33, with the highest priority action being "Promote Water Conservation," and the lowest priority action being "Installing New Groundwater Monitoring Wells." The top 7 actions in the prioritization (ranked between 4 and 1.33) generally align with the team's initial assessment of the programs that should make up the future groundwater management program, while the middle-ranked actions are generally actions that are in progress but have longer-term horizons. These results indicate to the team that the parameters of the cost/benefit analysis is a satisfactory tool for prioritizing actions.

Table ES-2. City of Bainbridge Island Groundwater Management Plan Actions

Actions	Objective	Description	Benefits	Action Category	Notes	Planning Horizon	Work Plan	**Cost** (thousands; supplemental to base cost for 1 FTE @ $150K annual)	Cost/Benefit Analysis (Year 0-6)
Promote Water Conservation	Water usage is reduced, leading to improved aquifer health and longevity, preservation of natural environments, and postponement of the need for infrastructure expansion.	This action involves developing and promoting water conservation, which will minimize water wasting and leakage, improve water use efficiency, and potentially increase recycling and reuse of water. Programs could include measures to change behavior, adopt water-saving technologies, and improve water management practices.	Water conservation will result in reducing energy consumption, lowering water bills, protecting ecosystems, and mitigating the impacts of drought and water shortages. It also helps to maintain the health of aquatic habitats in wetlands and streams. Conservation can lower peak daily demand defering the need for addtional storage.	Proactive Mitigation	The City has a water conservation plan that was included as part of the Water System Plan, developed in 2015. This plan provides a foundation for expanded conservation efforts.	Year 0-3	• Update the water conservation plan outlined in the Water System Plan • Develop a water conservation goal • Develop and implement water conservation pubic outreach plan • Evaluate past conservation measures for effectiveness • Evaluate conservation impacts on water rates • Develop "soft" and "hard" measures; pilot soft measures	$20	**4.00**
						Year 4-6	• Analyze metrics to measure success of the soft trategies • Pilot hard measures • Implement rate changes to reflect conservation targets	$23	
						Year 7-10	Adaptively manage conservation plan and modify as needed	$26	
Manage Storm and Surface Water	Storm and surface water quality and quantities are not damaging to the natural environment, and do not negatively impact groundwater.	This action involves increasing the use the Low Impact Development (LID) in new construction and existing development and ensuring Best Management Practices (BMPs) are implemented at all facilities handling, using and storing hazardous materials	Managing storm and surface water will result in the protection of streams and creeks, including related habitats, postponing the need for infrastructure replacement and/or expansion, and preventing groundwater contamination.	Proactive Mitigation Action	The City has a storm and surface water program that can be tailored or adjusted to meet the needs associated with groundwater protection.	Year 0-3	• Continue to implement source control and IDDE program with a focus on wellhead protection areas and priority recharge areas. • Consider rebate/incentive program to improve retrofit/mitigation implementation.	$50	**3.00**
						Year 4-6	• Examine the current Low Impact Design requirements for stormwater mitigation during development with a focus on clean groundwater recharge. • Create a program to incentivize retrofits to mitigate runoff from existing development.	$50	
						Year 7-10	If needed, refine regulations to improve developed sites' ability to match preexisting hydrology using LID.	$25	
Provide Public Education and Involvement	The public is informed on the wise use of water resources and has a broadened interest in water-related environmental protection.	This action involves development and promoting public involvement/education programs to increase public awareness and participation in groundwater management monitoring, protection and use.	Public education and involvement will result in increased awareness of water conservation, greater community support for sustainable practices, and improved water quality. Educating the public empowers individuals to adopt sustainable habits, participate in decision-making processes, and advocate for environmental protection.	Prevention	Programs should target all age groups, and be tailored to user types.	Year 0-3	• Develop a public education and involvement plan; consider the needs of other plan actions. • Choose 1 audience per year for specific outreach material development. Implement a web-based dashboard to increase data transparency	$20	**2.00**
						Year 4-6	Analyze metrics to measure success of the outreach strategies	$23	
						Year 7-10	Adaptively manage the public education and involvement plan and modify as needed	$26	
Evaluate Limiting New Wells in Shallow Aquifer	Well limitationsin specific areas relieve stress on streams and wetlands during the low flow season.	This action involves evaluating locations and depths where wells should be restricted, and/or where new wells should be at deeper depths.	Restricting some wells will improve conditions for streamflow, riparian habitat, salmonids and other wildlife	Prevention	Any restrictions could be based on existing state-level "Instream flow rules," water management act and ARPA in the Critical Areas Ordinance.	Year 0-3	Examine the process undertaken in the Chimacum watershed to protect instream flows and its relationship to the situation on Bainbridge Island.	$25	**2.00**
						Year 4-6	Develop policy	$25	
						Year 7-10	Implement policy	$52	
Develop Seawater Intrusion Mitigation Strategies	Indications of seawater intrusion are observed early, and mitigation strategies are in place to assist impacted well owners.	This action involves developing policies and management actions to address potential impacts from seawater intrusion.	Having a plan for addressing seawatrer intrusion will benefit homeowners or other well owners, and could provide advanced notice to large water purveyors regarding potential infrastructure expansion needs.	Prevention	One formal response to seawater intrusion has been completed in the Seabold neighborhood. Further investigation may be warranted north and east of the previous extent.	Year 0-3	Reiew ane refine the City's policy for responding to a suspected saltwater intrusion event based on previous investigations.	$0	**2.00**
						Year 4-6	• Develop policy for the City's response to a neighborhood scale intrusion event. • Include in policy the process to protect water quality in existing wells from new nearby extraction (possibly similar to Island or San Juan Counties). Work with KPHD to define roles and responsibilities.	$20	
						Year 7-10	Collaborate with KPUD and other major water purveyors to prepare for policy implementation, as needed.	$20	

Actions	Objective	Description	Benefits	Action Category	Notes	Planning Horizon	Work Plan	Cost (thousands; supplemental to base cost for 1 FTE @ $150K annual)	Cost/Benefit Analysis (Year 0-6)
Manage and Expand Existing Groundwater Well Monitoring Program	The City can identify groundwater trends and risks with a wide and continually expanding groundwater database.	This action involves managing and expanding the existing groundwater well monitoring program through outreach to exsiting well owners and deployment of monitoring equipment.	Managing and expanding the existing groundwater well monitoring program will result in identifying trends and potential risks, and allowing for more regular updates to the groundwater model.	Data Collection	The program should consider locating new monitoring wells with GPS, connect well logs, aquifer IDs, pumping rates, water levels, and quality data. Consider manual vs automated level logging.	Year 0-3	• Maintain existing monitoring well locations where changes in ownership have occurred • Develop and manage an outreach and implementation program aimed at encouraging the installation of monitoring equipment on private wells in highest priority areas. • Goal is to add 5 new monitoring wells to the monitoring network, from preexisting sources, in the Perched and Sea Level aquifers.	$10	**1.33**
						Year 4-6	• Expand existing well monitoring program by up to 3 wells per year;	$12	
						Year 7-10	• Expand existing well monitoring program by up to 3 wells per year or until target number is reached • Begin expanding monitoring program into secondary prioritization areas.	$15	
Manage and Expand Surface Water Monitoring	Ths City can identify surface water trends and risks with a wide and continually expanding surface water database.	This action involves managing and expanding the existing surface water monitoring program through prioritization of surface water locations and variables, and the deployment of monitoring equipment.	Managing and expanding the existing surface water monitoring program will result in the ability to effectively manage island surface water resources, such as streamflow, riparian habitat and salmonid and other wildlife habitat.	Data Collection	This program can provide data for future surface/groundwater interaction modeling, including generating streamflow characteristics. The results from this program can also help inform potential landuse regulations.	Year 0-3	• Analyze the existing surface water monitoring program to identify data gaps and quality of current data sources from the current 5 automated flow gauging stations; Springbrook, Cooper, Ravine, Doe Qud Sake Qub (AKA Murden), and Manzanita Creeks (managed by KPUD).	$22	**1.33**
						Year 4-6	• Develop a plan to expand the surface water monitoring program based on watersheds with greatest modeled impacts and highest priority resources. Possible streams include Issei, Schel Chelb and Sportsman's Club creeks.	$25	
						Year 7-10	• Implement an expansion of the surface water monitoring program with automated stream gauging stations in up to 5 new perennial fish bearing streams.	$50	
Update the Groundwater Model, Test New Scenarios	The City has access to an up-to-date groundwater model that can be used to evaluate current and future conditions.	This action involves updating the groundwater model with the most recently collected data, and running planning scenarios.	Updating the groundwater model and testing new scenarios will result in benefits such as informing policy development and data collection strategies, and identifying risk-management actions.	Information Management	Model scenarios could be used to assess the best locations for new wells or other potential projects such as managed aquifer recharge.	Year 0-3	• No action	$0	**1.00**
						Year 4-6	• At year 6 run 5-10-year modeling scenarios using new data captured from expansion of well monitoring and new monitoring wells • include information from observed and newly predicted conditions	$35	
						Year 7-10	• At year 9 run 5-10-year modeling scenarios using new data captured from expansion of well monitoring and new monitoring wells • Include information from observed and newly predicted conditions. • Recalibrate model based on new well reports and monitoring data. Revisit recharge variables based on best available science.	$40	
Identify Groundwater Recharge Protection Areas	Critical groundwater recharge areas are protected from development impacts.	This action involves evaluating land-use impacts and potential mitigation strategies in key watershed and groundwater recharge areas.	Identifying groundwater recharge protection areas will result in protecting shallow groundwater and surface waters on the island in the short-term, and will protect deep aquifers in the long-term.	Prevention	Some level of work on this effort was performed in 2018 as part of the development of the aquifer recharge protection area regulations. This program should include re-evaluating that work, and also identifying potential off-island areas that could also be protected through work with partner agencies.	Year 0-3	• Building on existing data from the GWMP and the Beneficial Re-use Study, develop a prioritization of recharge protection areas. • Evaluate effectiveness of the current Aquifer Recharge Protection Area regulations (BIMC 16.20.100).	$50	**1.00**
						Year 4-6	• Develop potential land-use changes or other regulations that would implement protection for critical recharge protections areas • Consider implementation as part of the Comprehensive Plan mid-term review process	$150	
						Year 7-10	TBD	TBD	
Spread Out New Production Wells Across the Island	Large water systems in the City are reliant upon wells that provide long-term stability and sustainability for the related aquifers.	This action involves shifting new large production wells further north on island to spread out groundwater extraction and provide longer-term sources for South Island users.	Spreading out production wells will result in relieving the pressure on certain groudnwater systems, and preventing excessive drawdown, saltwater intrusion, and impacts to surface water environments.	Proactive Mitigation Action	This action should be considered as part of a consolidated effort with other management actions, including the evaluation of interties and increases in water storage.	Year 0-3	• Perform evaluation of production well options and cost/benefit along with study of intertie options	$50	**1.00**
						Year 4-6	• Near the end of this planning horizon, begin evaluation of well siting costs and inter-agency agreements	$200	
						Year 7-10	• Complete evaluation of well siting costs and inter-agency agreements; Consider potential for new production well implementation	$100	

Actions	Objective	Description	Benefits	Action Category	Notes	Planning Horizon	Work Plan	Cost (thousands; supplemental to base cost for 1 FTE @ $150K annual)	Cost/Benefit Analysis (Year 0-6)
Evaluate and Implement CIty Water system Interties with KPUD Systems	Large water systems in the City are connected north to south with a series of interties.	This action involves coordinating management (withdrawals, distribution, and monitoring) with KPUD and potentially other water systems on the Island.	Implementing water system interties will result in environmental and economic benefits, shared resources and information, and co-management of surface and groundwater resources on the island.	Proactive Mitigation Action	This action should be considered as part of a consolidated effort with other management actions, including the evaluation of spreading out production wells and increases in water storage.	Year 0-3	• Complete a formal cost/benefit analysis and evaluation of intertie options and consider costs as part of 2027-28 utility rate study	$50	**1.00**
						Year 4-6	• Consider recommendations from analysis and evaluation in the planning and funding of intertie projects; design project	$200	
						Year 7-10	• Complete at least one intertie project	$500	
Consolidate Smaller users with larger water systems	Small water systems are systematically integrated into larger systems over time.	This action involves working to identify small water systems that could incorporate with nearby large public water systems. This would require extension of water lines, installation of meters and connections and decommissioning wells.	Consolidating water systems will result in improved operational efficiency, add enhanced financial stability through economies of scale, leading to lower per-customer costs and the ability to invest in infrastructure improvements and alternative water sources.	Proactive Mitigation Action	A systematic approach to consolidation would allow for grant procurement, and would prevent the need for last-minute management agreements or isolated water system ownership.	Year 0-3	• Complete Water System Business Plan and begin outreach to priority neighborhoods and/or water systems regarding potential consolidation • Consider expansion/consolidation costs as part of 2027-28 utility rate study	$50	**1.00**
						Year 4-6	• Plan and design near-term expansions/ consolidations	$200	
						Year 7-10	• Implement priority expansions/consolidations	$1,000	
Increase Storage for Municipal Water	Large water systems in the City have coordinated storage systems that meet demand.	This action involves increasing storage volume for the municipal water systems to be able to provide enough water during peak demand. This could help spread out withdrawals and costs over a longer time period.	Increasing storage volume in the municipal water system provides several key benefits, including improving water pressure and availability, reducing peak demand costs, and enhancing emergency preparedness.	Proactive Mitigation Action	This action should be considered as part of a consolidated effort with other management actions, including the evaluation of spreading out production wells and implementing water system interties.	Year 0-3	• Study storage issues/benefits as part of evaluation of intertie coordination	$50	**1.00**
						Year 4-6	• Study storage issues/benefits as part of evaluation of intertie coordination; consider storage needs resulting from potential new production wells	$200	
						Year 7-10	• Consider implementation of storage facility resulting from new production wells	TBD	
Evaluate and Implement Managed Aquifer Recharge	Aquifer recharge opportunities are implemented in critical and available locations.	This action involves surface infiltration or injection directly into prioritized aquifers for later recovery. Source water for recharge could include stormwater, reclaimed water, and treated drinking water.	Aquifer recharge could augment stream baseflow, prevent seawater intrusion, increase recharge, and mitigate drawdown in aquifers.	Proactive Mitigation Action	Reference Watershed Assessment of Manzanita as a template.	Year 0-3	• Implement the Manzanita Stormater Recharge Park project, and identify other potential projects within the Mananita watershed for implementation. • Coordinate work with projects and offset goals identified in the WRIA 15 Streamflow Restoration Plan.	$1,200 (grant received)	**1.00**
						Year 4-6	• Expand the model of the Manzanita Watershed project to at least 2 additional priority watersheds.	$250	
						Year 7-10	Identify and implement priority projects from watershed analyses.	TBD	
Evaluate and Implement Wastewater Beneficial Re-Use	Wastewater is re-used in lieu of being discharged to Puget Sound.	Wastewater from the Winslow Wastewater Treatment Plant is processed for re-use in the Winslow area for groundwater recharge, irrigation and other non-potable uses.	Beneficial reuse of wastewater offers several benefits, including drought resilience, reduced reliance on freshwater sources, and support for agriculture and other non-potable uses. It also helps protect ecosystems by reducing the discharge of treated water into Puget Sound.	Proactive Mitigation Action	The City is currently working on a preliminary concept for wastewater beneficial re-use that would serve as irrigation and potentially groundwater recharge.	Year 0-3	• Continue with ongoing wastewater beneficial re-use study and field investigations; Develop 30% design • Begin discussions on agreements with high water users for re-use substitution.	$500	**1.00**
						Year 4-6	Complete 100% design of re-use infrastructure.	$1,000	
						Year 7-10	Implementation	TBD	
Install New Groundwater Monitoring Wells	The City has access to monitoring wells in critical locations.	This action involves expanding the groundwater monitoring network in priority locations and depths to verify model results and identify potential risks.	Installing new monitoring wells will result in comprehensive data collection and management that is critical to effectively managing island groundwater resources and avoiding degradation of the aquifer system.	Data Collection	Existing wells that can be monitored in priority locations is preferred over the expense of new wells.	Year 0-3	• Identify possible locations for new monitoring wells	$10	**0.33**
						Year 4-6	• Install 1 new monitoring well in the Fletcher Bay aquifer	$400	
						Year 7-10	• Install 1 new monitoring well in the Glaciomarine aquifer	$500	

Recommendations

Recommendations/prioritization will be refined throughout the remainder of the public engagement process.

ACKNOWLEDGMENTS

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.

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 Groundwater Management Plan Technical Advisory Committee: Charlie Kratzer (Suquamish Tribe), Douglas Wood (Ecology), John Kiess (KPHD) and Joel Purdy (KPUD) provided significant insights regarding the groundwater quantity and quality on Bainbridge Island.

Thanks are due to Christian Berg, Water Resource Specialist at the COBI for countless hours of technical support and to Chris Wierzbicki, Public Works Director, COBI for overall guidance and review.

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

1. INTRODUCTION

1.1 GROUNDWATER MANAGEMENT PLAN VISION

Our entire community—residents, workers, and visitors alike—depends on groundwater for all water supply needs. Groundwater 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 COBI recognizes that management of this precious resource requires a sustainable, island-wide approach. To meet this need, COBI's 2016 Comprehensive Plan directs that a Groundwater Management Plan (GWMP) be adopted as an adaptive planning tool.

Development of the GWMP began in 2020, when COBI hired Maureen Whalen to lead the initial efforts. This early work laid the foundation for the current plan. In 2023, COBI retained EA Engineering, Science, and Technology, Inc., PBC (EA) as consultants to facilitate development of the GWMP. EA collaborated with COBI staff and the Groundwater Management Subcommittee (comprising members from the Utility Advisory Committee, the Environmental Technical Advisory Committee, and the Climate Change Advisory Committee). Modeling work began with evaluation and revision of the existing groundwater model. This included grid adjustments, recalibration, and scenario testing. Modeling was completed in 2024 and is documented in the modeling report (Appendix A). Updates were shared with the Subcommittee and COBI Council.

1.2 GROUNDWATER MANAGEMENT PLAN GOALS AND OBJECTIVES

The COBI Council has set the following goals and objectives for the GWMP (Figure 1-1).

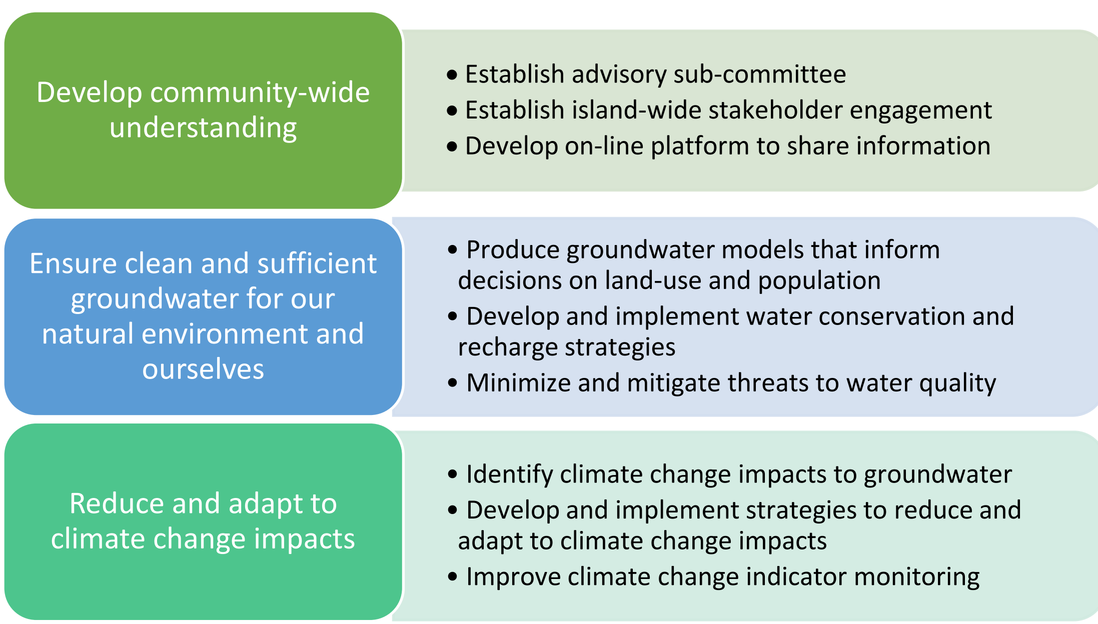


Figure 1-1. Groundwater Management Plan Goals and Objectives

The COBI Council established GWMP goals rooted in the principles of stewardship and science-based decision-making. These goals emphasize managing water resources to protect, restore, and maintain their ecological and hydrological functions, while ensuring clean and sufficient groundwater for future generations. Public input and evolving best-available science remain central to achieving these objectives.

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:

- U.S. Geological Survey (USGS) investigations from the 1950s to 2016
- Groundwater data from COBI and KPUD (1980s to present)
- Hydrogeologic studies by the Washington Department of Ecology (1950s to present)
- Water quality and supply monitoring by the Washington Department of Health and Kitsap Public Health District (1970s to present)
- Cleanup efforts related to the Wycoff/Eagle Harbor Superfund Site (EPA, 1980s to present)
- Consultant reports, including Aspect Consulting's contributions to groundwater modeling and monitoring protocols (2006, 2009, 2015)

GWMP development began in 2021, with EA Engineering engaged in 2023 to update the model and complete the plan. The draft GWMP was finalized in April 2025. A bibliography of supporting reports is provided in Appendix A and accessible via the COBI's Water Resources Library.

COBI's 2016 Comprehensive Plan 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.

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.

1.4 GROUNDWATER MANAGEMENT PLAN PUBLIC ENGAGEMENT

The GWMP was developed through a collaborative process involving residents, water purveyors, businesses, agriculture, local governments, and state and federal agencies. Public input helped shape GWMP policies, milestones, and management initiatives (Section 3.2). Public engagement efforts are detailed in Appendix B.

The GWMP Advisory Subcommittee, composed of members from three COBI Advisory Committees, collaborated with staff to ensure the plan aligns with local needs. Technical expertise was provided by a Technical Advisory Group, which includes representatives from KPHD, KPUD, the Suquamish Tribe, and Ecology. Their focus areas included:

- 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 group's charter is included in Appendix C.

1.5 INTEGRATED GROUNDWATER PROTECTION AND SUSTAINABLE DEVELOPMENT PLANNING IN WASHINGTON STATE

Washington State's groundwater protection policies are designed to safeguard aquifers as essential sources of drinking water and ecological support. These policies are especially critical in areas like Bainbridge Island, which rely entirely on on-island groundwater to meet residential and environmental needs. The state's approach to aquifer protection is grounded in a combination of regulatory oversight, land use planning, and water quality management.

Ecology leads aquifer protection efforts through several key mechanisms. Wellhead Protection Programs, mandated under the federal Safe Drinking Water Act, help identify and safeguard the recharge zones around public drinking water wells. Additionally, the state's Growth Management Act requires local governments to designate Critical Aquifer Recharge Areas, which are highly susceptible to contamination or depletion. These designations influence zoning regulations, permissible land uses, and development density to minimize groundwater impacts. The Water Resources Act (RCW 90.54) further guides water allocation and conservation, emphasizing the integration of environmental needs with land development planning. To support groundwater recharge and prevent pollution, municipalities in western Washington must comply with stormwater regulations such as the Western Washington Phase II Municipal Stormwater Permit, which mandates the use of Low Impact Development (LID) strategies and infiltration-based stormwater practices.

House Bill 1220 (HB 1220), passed in 2021, adds complexity to aquifer protection by requiring local governments to revise their comprehensive plans to meet long-term housing needs. HB 1220 mandates jurisdictions to plan for housing at all income levels and accommodate emergency shelters and supportive housing, with a particular emphasis on equitable development and preventing displacement. While the bill does not directly address groundwater resources, its housing mandates influence land use decisions that can significantly affect aquifer health—especially in communities that rely entirely on groundwater, such as Bainbridge Island. As part of this obligation, Bainbridge Island must plan to accommodate 1,977 new housing units by 2044 while preserving groundwater sustainability, in accordance with the quotas imposed by the Washington Growth Management Act.

To ensure housing growth under HB 1220 aligns with groundwater sustainability goals, cities must integrate land use planning with hydrologic modeling and aquifer monitoring. This includes identifying vulnerable recharge areas, avoiding overdevelopment in Critical Aquifer Recharge Areas, and prioritizing infill and clustered development that reduces impervious surface area. Development standards must incorporate stormwater controls and green infrastructure to promote recharge and reduce runoff-related contamination. Bainbridge Island, for example, enforces development standards through its municipal code (Bainbridge Island Municipal Code [BIMC] Chapters 15.19 and 15.20) and relies on a network of 87 monitoring wells across six aquifers to inform planning decisions.

Moving forward, Washington's groundwater-reliant communities must adopt a collaborative and adaptive approach to land use planning. Coordinating groundwater protection policies with housing growth mandates ensures sustainable development that meets both human needs and environmental constraints. This integrated strategy requires robust cooperation between regulatory agencies, utility providers, and local governments, along with community engagement to build awareness and support for aquifer protection efforts.

2. JURISDICTIONAL, PHYSICAL, AND HYDROLOGICAL SETTING

This section provides a general description of existing conditions including location, government structure, history, land and water management authorities, physical setting, hydrogeology, groundwater quality, and groundwater usage. Projections of future groundwater supply needs using population and climate change projections also are discussed.

2.1 LOCATION

Bainbridge Island is in the Puget Sound lowland of west-central Washington on the east side of the Kitsap Peninsula in Kitsap County. The Bainbridge Island groundwater management area encompasses the entire island. The entire area of Bainbridge Island is encompassed by COBI located within Kitsap County (**Figure 2-1**).

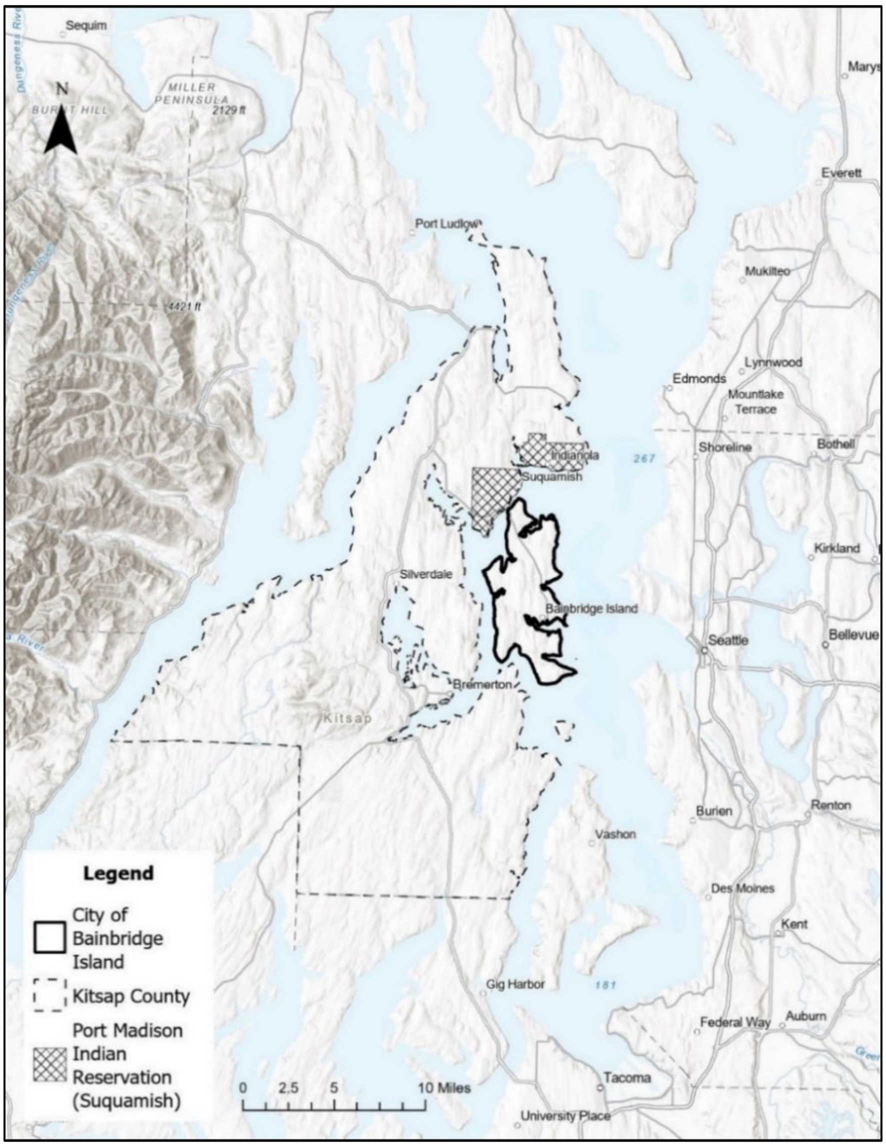


Figure 2-1. City of Bainbridge Island Location

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 23 August 1947). On 28 February 1991, the unincorporated area of Bainbridge Island was annexed into the City of Winslow. On 5 November 1991, voters approved changing the name from City of Winslow to COBI.

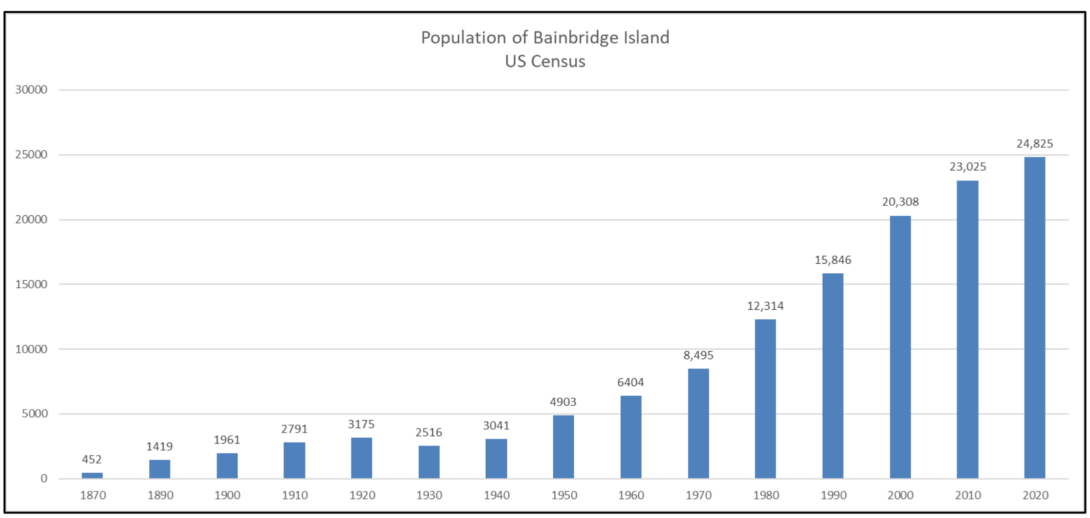


Figure 2-2. Bainbridge Island Population 1870–2020 (U.S. Census)

2.3 CITY OF BAINBRIDGE ISLAND GOVERNMENT

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

2.4 LAND AND WATER MANAGEMENT AUTHORITIES

Preparation of the GWMP follows the outline of Chapter 173-100 WAC, Groundwater Management Areas and Programs. Development of the COBI's GWMP also looks to related plans, policies and regulations ranging from those focusing on other COBI environmental, planning and development concerns to Kitsap County as well as Washington State. The GWMP nests within these plans, policies, and regulations providing a central living document for the community and the COBI to use. These related plans, policies, and regulations are briefly summarized here with a high-level discussion of links to the GWMP.

Water resource development and management is shared between the COBI and public and private Group A (public community water systems serving 15 or more service connections) and Group B water (serving less than 15 service connections and less than 25 people per day or 25 or more people per day during fewer than 60 days per year) purveyors (Section 2.8.2). Wastewater is in specific areas of the island managed by the COBI and a private/public partnership with Kitsap County Sewer District 7 as discussed in Section 2.5.8. Water and wastewater management outside of these service areas is managed by individual property owners.

2.4.1 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:

1. **Mitigation**: Reduce greenhouse gas emissions by 90% by 2045 compared to 2014 levels with interim milestones of 25% reduction by 2025 and 60% by 2035 compared to 2014 levels.

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

3. **Community Engagement**: COBI 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 rising sea levels, increased erosion, potential saltwater intrusion, changes to timing, extent of groundwater recharge and interaction with surface water. 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 COBI will adopt a Groundwater Management Plan that accounts for climate change in its projections, policies, and guidance
  - Steward shorelines to allow for resilience

2.4.2 City of Bainbridge Island Municipal Code

Title 16 (Environment) of the COBI 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 with potential to release pollutants identified as threats to drinking water require a hydrogeologic assessment, the designation of an Aquifer Recharge Protection Area within the project boundary, 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 generous 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.

2.4.3 Kitsap County Code

To give context to the regional approach, it is worth nothing 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. Finally, the ordinance 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 5 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 COBI, 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.

2.4.4 Washington Department of Health

The Washington State Department of Health (DOH) Office of Drinking is responsible for oversight of public water systems. Public water systems are defined as those systems which serve more than one single family residence or more than one industrial plant (WAC 246-293-110). Public water systems are grouped into Group A public water systems and Group B (Washington State DOH, no date).

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 COBI's annual water quality report for the Winslow Water System #97650.

2.4.5 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 3 years (Washington State DOH, no date) (KPHD 2018).

In Kitsap County, Group B well systems are typically 3–15 connections and 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 wells, usually associated with single family homes, are also regulated by KPHD. Property owners of permit exempt wells are responsible for testing their own water quality based on guidance from KPHD.

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 Water Rights

Water rights in Washington state are authorized and regulated by the Washington State Department of Ecology (Ecology) 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 more than 5,000 gallons per day. Groundwater withdrawals less than 5,000 gallons per day for domestic supply, industrial use, stockwater, the irrigation of up to one half acre of non-commercial lawn or garden are authorized without having to get a permit from the Ecology. These withdrawals are commonly referred to as permit-exempt wells. Permit-exempt uses are water rights with a priority date of first use, they just do not have to go through the permit-application process. Because of incomplete records, especially for older wells, the exact number of permit exempt groundwater wells on Bainbridge Island is not known. Further limitations exist in certain parts of the state where water has been over appropriated or to protect surface water resources.

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 water rights have priority over younger rights within the same water source so when supplies are limited, the younger, junior rights can be shut off to satisfy the older, senior rights. Attributes of surface water right certificates can be changed by making application to Ecology.

Groundwater permits and certificates can also be changed using the change 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 what is known as the 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.

There is extensive case law regarding Washington water law that impacts Ecology decisions. All permit decisions by Ecology can be appealed, first to the Pollution Control Hearings Board, Superior Court, and ultimately State Supreme Court. Results of those cases create case law that then influence future permitting decisions. The basic permitting process includes:

- Application to Ecology identifying proposed attributes and establishing a priority date.
- Ecology investigation for compliance with the 4-part test.
- Permit issued or denied by Ecology.
- If the permit is granted, the applicant can proceed to implement the project.
- Applicant "perfects" the water right by putting water to beneficial use within the permit conditions.
- Water right certificate is issued and can be used in perpetuity.

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 1622 claims listed in Ecology's water rights database for Bainbridge Island, 88.5% of all water right documents on the island.

Streams in the Murden Cove and Fletcher Bay watersheds are closed to further water right appropriations by Chapter 173-515 WAC (**Figure 2-3**). 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 before being approved. 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.A summary of water right records for Bainbridge Island is included in Table 2-1. As shown, the number of water right claims, yet to be adjudicated, far out number all other type of water right records.

Table 2-1. 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 2-3. Streams and Watersheds

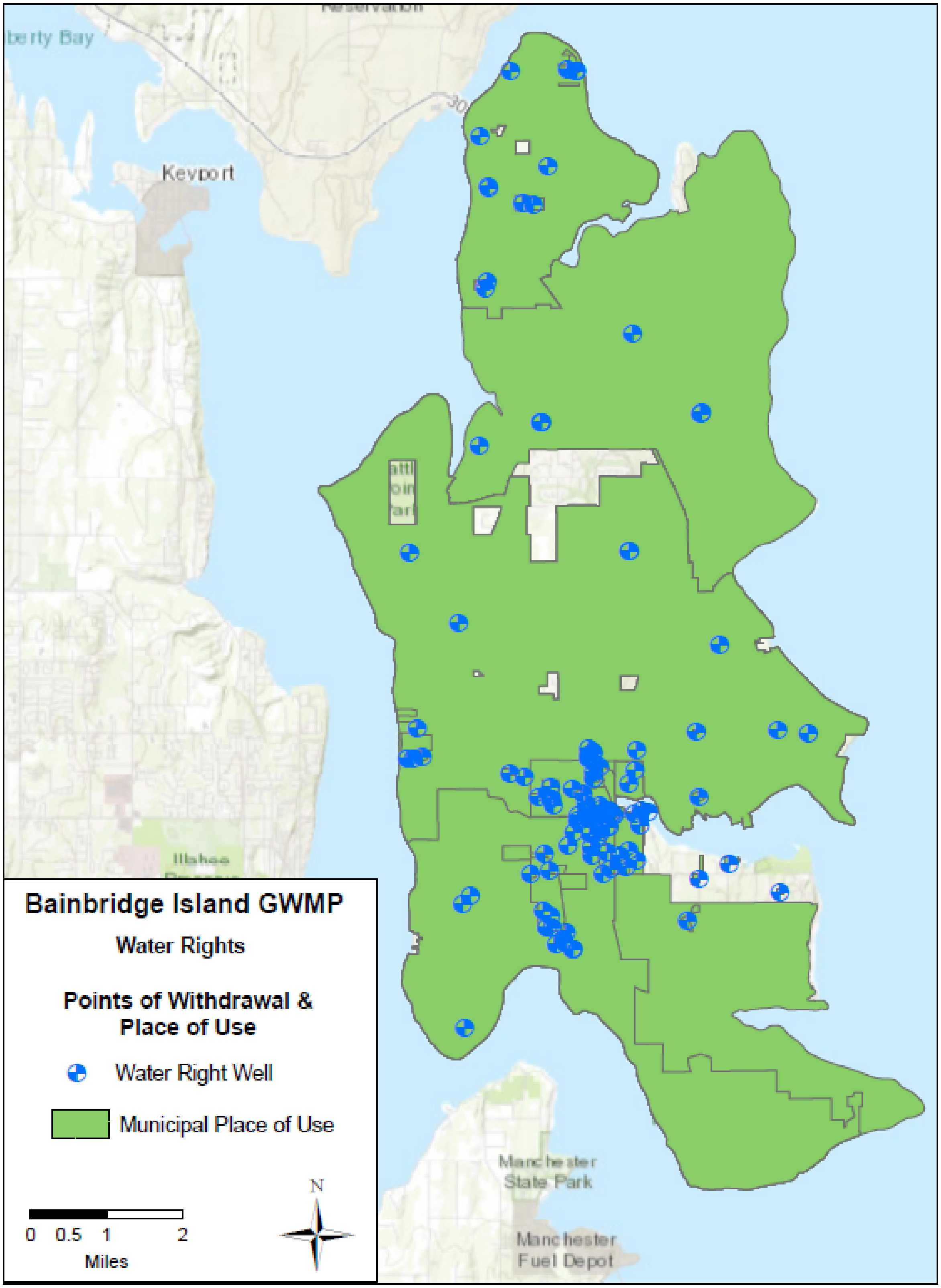


Figure 2-4. Groundwater Rights
Source: Department of Ecology, 2025

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 of 6,810 gpm and an annual quantity of 5,118 acre-ft/yr. Both values are an estimate, and it should be noted that for applications, the quantity eventually allocated may be less than this.

2.4.6.1 City of Bainbridge Island Water Rights

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

COBI also has 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 acre-ft/yr (annual). For the Rockaway Beach Water System, the COBI has one permitted water right: 80 gpm (instantaneous withdrawal) and 34 acre-ft/yr (annual withdrawal). The total annual water rights authorized for the COBI is 4,399 acre-ft/yr.

Table 2-2. Winslow and Rockaway Beach Water Rights Summary

Source	Well Status	Certificate Number	Priority Date	Instantaneous Withdrawal (gpm)	Annual Withdrawal (acre-ft/yr)
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 (S)
Sands					
Well No. 1	Operational	G1-25264C	29 June 1988	300	336 (S)
Well No. 2	Operational	G1-25614P	1 February 1990	500	564 (S)
Head of Bay Wells					
Well Nos. 1 and 2 (Original)	Not used	C-5997-A	21 March 1966	55	88 (S)
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:
acre-ft/yr = acre-foot per year
gpm = gallon(s) per minute
No. = number
Source: Carollo Engineers, Inc. 2017.

The Winslow Water System, shown in **Figure 2-5**, 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 Low Pressure Zone is served by six active pressure reducing valve stations. Storage is provided by the two High School Reservoirs in the High Zone with a total capacity of 2.5 million gallons (MG). A third reservoir, the Grand Reservoir, is currently out-of-service. The High School Reservoirs supply the High 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 million gallons per day (MGD). This is the supply capacity of the system's well sites with the smaller of the two Sands booster pumps pumping (Carollo 2017).

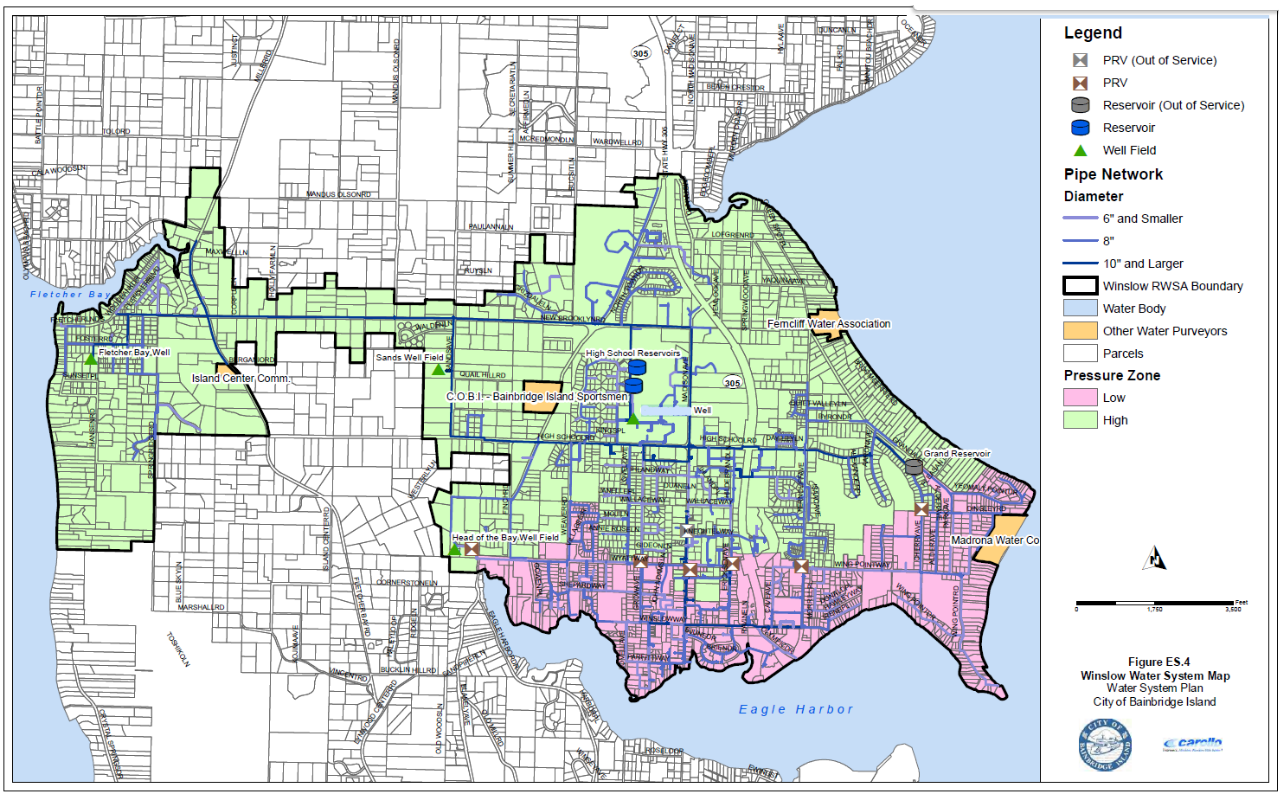


Figure 2-5. Winslow Water System Map
Source: Carollo Engineers, Inc. 2017

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 2-6**. The capacity of the Taylor Avenue well is approximately 43 gpm (Carollo 2017).

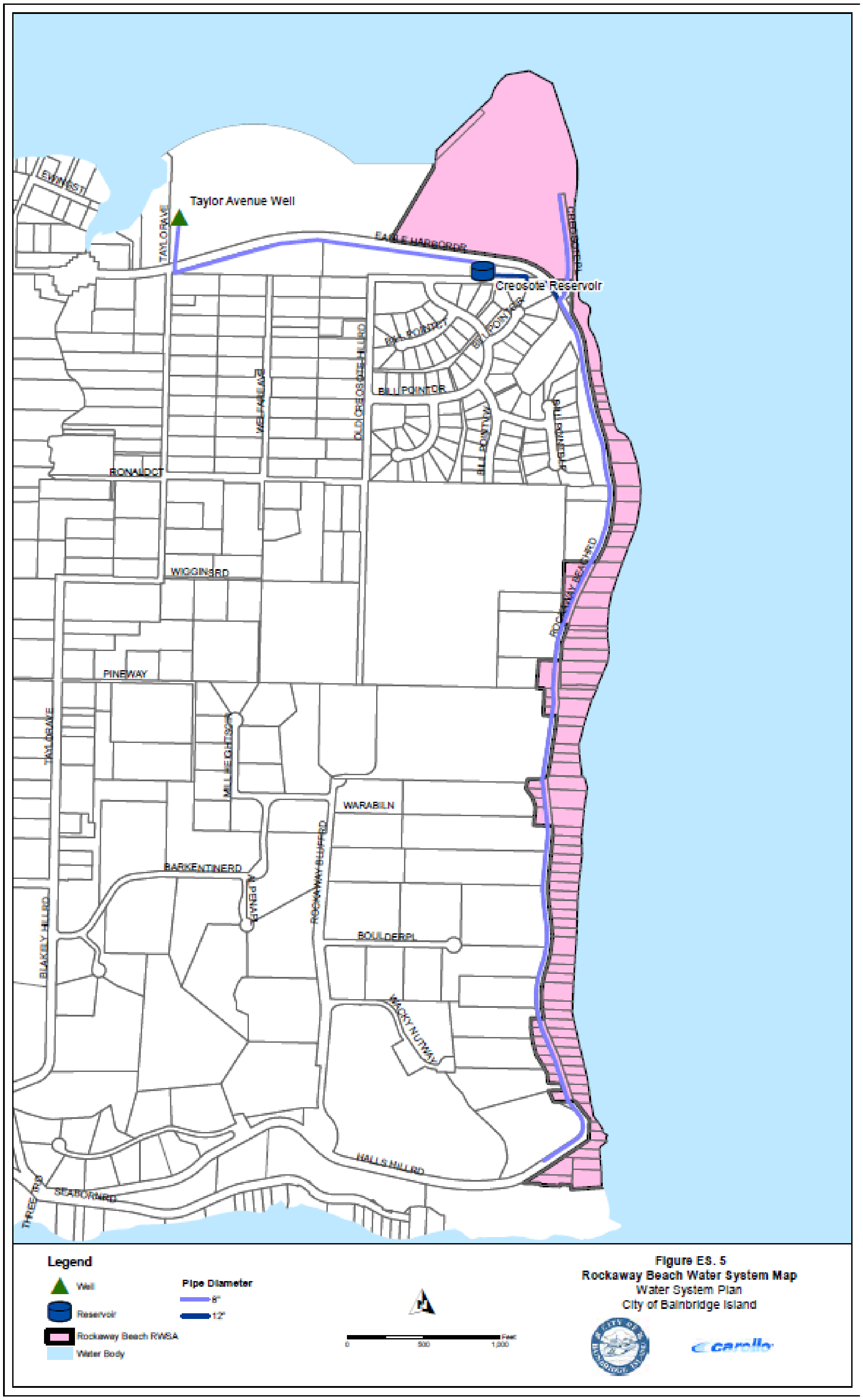


Figure 2-6. Rockaway Beach Water System Map
Source: Carollo Engineers, Inc. 2017

2.4.6.2 KPUD Water Rights

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

- North Bainbridge system (permitted groundwater rights for a total of 1,646 gpm (instantaneous withdrawal) and 507 acre-ft/yr (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 (permitted groundwater rights for a total of 806 gpm (instantaneous withdrawal) and 524 acre-ft/yr (annual withdrawal) for sources currently in use.
- Island Utility system (permitted groundwater rights for a total of 300 gpm (instantaneous withdrawal) and 336 acre-ft/yr (annual withdrawal) for sources currently in use.
- Harbor Crest system (permitted groundwater rights for a total of 60 gpm (instantaneous withdrawal) and 9 acre-ft/yr (annual withdrawal) for sources currently in use.

The Qa for KPUD's water systems is 1,466 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, with technical input from Joel Purdy. The information is considered accurate as of 2025.

2.4.7 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 each county to make decisions 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 and all of Bainbridge Island (Ecology 2019).

The use of new wells that are exempt from water right permitting under RCW 90.44.050 within Watershed Resource Inventory Area (WRIA) 15, including all of Bainbridge Island is limited after 2018 in accordance with the Streamflow Restoration Act (Chapter 90.94 RCW) and HB6091 Section 203 (Washington State 65th Legislature 2018) which requires the following:

- Maximum annual average withdrawal of 950 GPD per connection (346,750 gallons per year) with a possible drought restriction of 350 GPD for indoor use only.

2.4.8 Kitsap County Groundwater Management Plan (1991)

Kitsap County was designated as a Groundwater Management Area in accordance with Chapter 170-100 WAC Groundwater Management Areas and Programs in October 1986. Preparation of a GWMP followed under an Interlocal Agreement between Kitsap County and KPUD (Kitsap County Groundwater Advisory Committee *et al.* 1991).

The goal, as stated by the Kitsap County Groundwater Advisory Committee, was to "…ensure an adequate quantity of high-quality groundwater through conservation and by adopting and enforcing a sensible Groundwater Resource Plan." Bainbridge Island is one of five sub-areas defined by Kitsap County GWMP. Existing information regarding geology/hydrogeology, surface water hydrology, water resource requirements, climate, and land use was analyzed. Perceived problems or issues were identified along with resource management issues leading to recommendations for new or revised policies and ordinances. These recommendations, along with the 2013 Sole Source Aquifer designation and recent improvements in understanding of climate change and groundwater systems, support the need for a Bainbridge Island specific GWMP.

2.4.9 City of Bainbridge Island Water System Plan

The COBI's Water System Plan was updated in 2017 in accordance with WAC 246-290-100 and Washington State DOH requirements. COBI 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 manganese maximum contaminant limit (MCL) during April 2015 field tests. The Sands Avenue wells exceeded MCLs for secondary contaminants: sodium levels (20 mg/L not an MCL but an EPA guideline for those on a restrict diet for sodium) and the color MCL.

In 2015 the Winslow Water System had an average day demand of 0.68 MGD. Growth projections indicate an average day demand of 1.24 MGD by 2035 (medium demand and connect all parcels). 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 is projected to approach the Taylor Avenue Well capacity by 2035. The pumping capacity and water rights are not sufficient to comply with COBI's supply reliability criteria.

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

2.4.10 City of Bainbridge Island Groundwater Monitoring Program

The COBI'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 levels and groundwater quality data. A total of 29 wells (mostly community supply production wells) were monitored by personnel from KPUD and the COBI (Aspect 2006).

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

Primary concerns on Bainbridge are the risk of seawater intrusion, especially in coastal areas, and pumping more than an aquifer's safe yield. The Groundwater Monitoring Program defines EWLs for increasing trends in chloride concentration (as an indicator of potential seawater intrusion) and groundwater level declining trends (as an indicator of potential over-pumping beyond the aquifer's safe yield).

Trends in water levels and chloride concentrations are compared to EWLs to flag potential issues (Aspect 2009). The EWL for water level trends is currently defined as a decline of greater than 0.5 feet per year over a ten-year period (i.e., a decline of 5 feet over 10 years). The EWL should not be set at 0.5 feet per year across the board, but rather be related to the thickness of the aquifer and potentially to the rate at which water levels rebound after pumping ceases in a given well. If an EWL is exceeded, the validity of the data is confirmed and additional analysis of water-level data in nearby wells is conducted to determine whether the issue is well-specific or indicative of broader aquifer conditions. Similarly, if an increasing trend in chloride concentrations is identified—or if the concentration reaches or exceeds 100 milligrams per liter (mg/L), in accordance with Ecology guidelines (Ecology 1990)—then additional sampling and field investigations are performed to examine the nature, extent, and potential causes of the problem.

The COBI's groundwater monitoring network consists of both public and private wells distributed Island-wide across the six Bainbridge Island aquifers. 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 COBI or KPUD. Wells may be monitored for water level only, chloride only, or both water level and chloride.

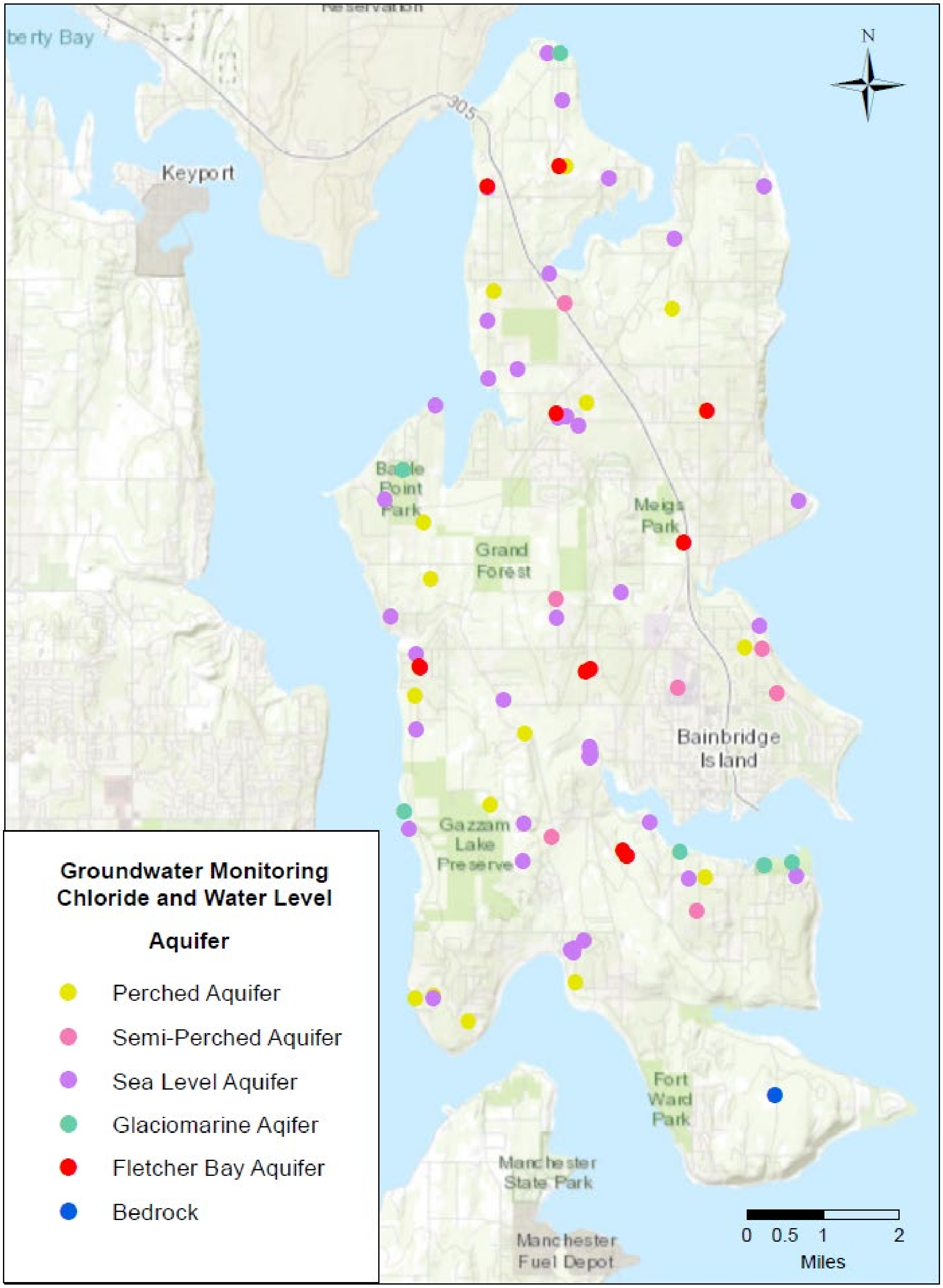


Figure 2-7. City of Bainbridge Island Monitoring Network

The current network includes 87 monitoring wells, and their aquifer distribution is summarized as follows:

- 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

2.5 PHYSICAL SETTING

This section provides details regarding the physical setting of Bainbridge Island including topography, geology, climate, and vegetation. It also provides details regarding land and water use.

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. 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 2-8. 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 Pacific oceanic tectonic plate with the more buoyant North American plate results in a zone of subsidence along 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 is split into two geologic areas. 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 unconsolidated sediments are seen at the surface in different locations throughout Bainbridge Island due to changes in topography and erosion. The abrupt change to shallow bedrock in the southern portion is marked by the extension of the Seattle fault (**Figure 2-8**).

The unconsolidated sediments found at the surface and in the subsurface were deposited by glacial and non-glacial processes. Due to the episodic nature of continental glaciation over the past 300,000 years, these deposits often alternate as the glaciers advanced, overrode, and then retreated from the Puget Sound Lowland, including Bainbridge Island. Sea level also rose and fell, so that most of the island was under a marine environment at some or several points in the past. Glacial advances and retreat, sea-level rise and fall has resulted in deposits that are complex, inter-related and vary in thickness horizontally and vertically throughout the island. Most of the lower layers 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 should be remembered 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).

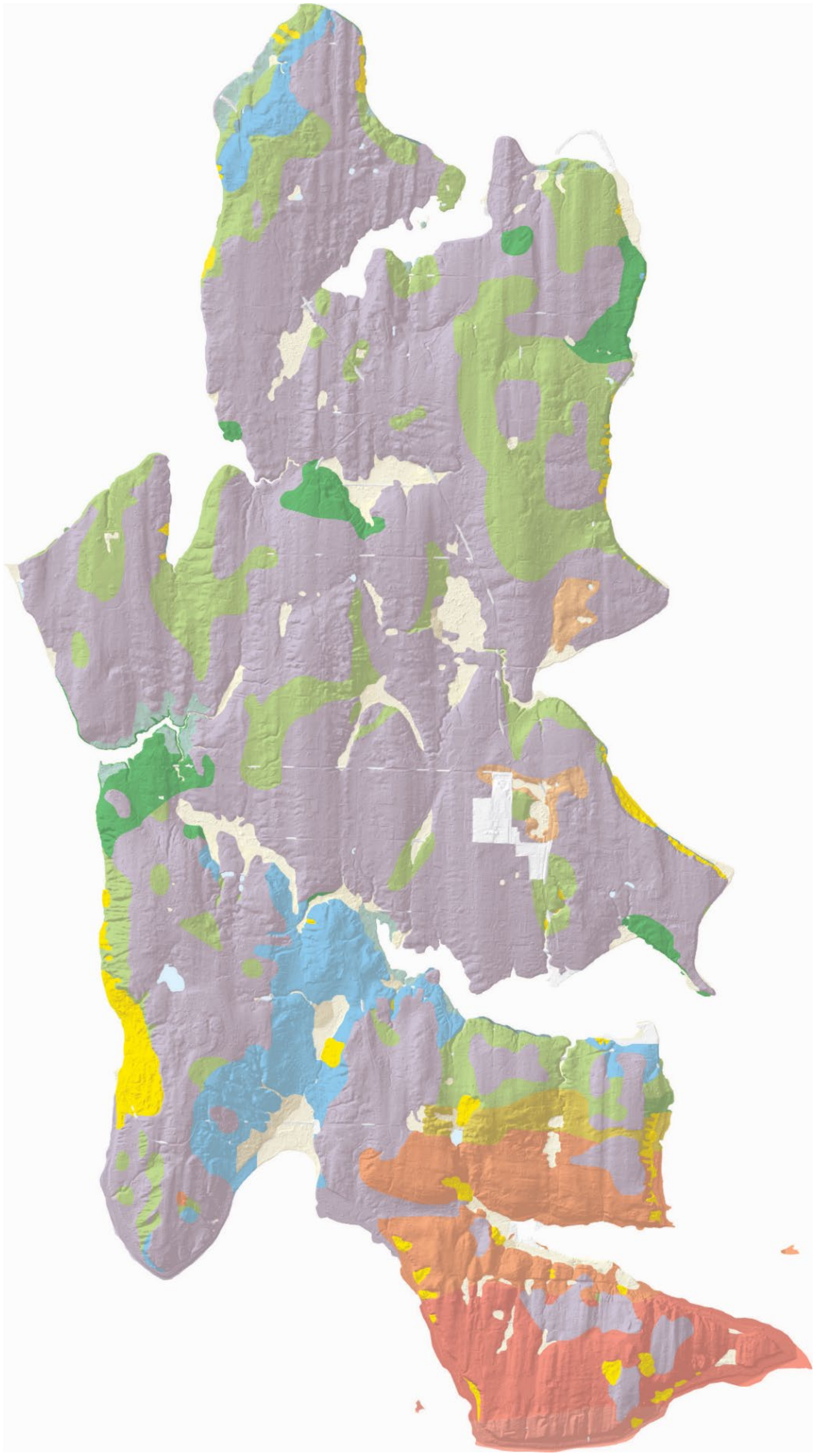


Figure 2-9. Bainbridge Island Surficial Geology (Haugerud, 2005)

Description of Mapped Units (Haugerud, 2005)

Post-Glacial Deposits

m **Modified land (Holocene)**—Sand and gravel as fill, or extensively graded natural deposits. Generally not mapped except where modification is sufficiently extensive that the underlying deposit cannot be inferred. Locally, mapped as:

f **Artificial fill (Holocene)**—Sand, gravel, and wood waste placed as fill. Mapped especially in road prisms where compaction by seismic shaking is a predictable hazard.

Qw **Wetland deposits (Holocene)**—Silt, sand, muck, and peat deposited in wet- lands. Mapped on basis of morphology or presence of surface water and wetland vegetation.

Qal **Alluvium (Holocene)**—Well-sorted sand, gravel, and silt deposited by post- glacial streams. Locally may contain intercalated poorly sorted debris- flow deposits.

Qaf **Alluvial fan deposits (Holocene)**—Stream-deposited sand and gravel deposit- ed in low-angle conical fans. Locally may contain poorly sorted debris- flow deposits.

Qb **Beach deposits (Holocene)**—Sand, gravel, and logs deposited by wave action. Underlies nearshore flats. Beach deposits not mapped seaward of the high water line. Locally, includes mud and peat deposited in wetlands developed inboard of the beach berm.

Qls **Landslide deposits (Holocene)**—Diamict, sand, gravel, silt, and soil trans- ported in deep-seated landslides. Deposits commonly less dense than parent materials. Commonly water-saturated. Largely mapped on basis of morphology. Queried where identity as landslide is uncertain. Some land- slide deposits may be latest Pleistocene in age.

Qtf **Tide-flat deposits (Holocene)**—Sand and gravel gravel deposited in intertidal and shallow subtidal conditions. Mapped only where now landward of the high water line, uplifted by Holocene deformation in the Seattle fault zone.

Glacial and Older Non-Glacial Deposits

Qeg **Emergence gravels (Pleistocene)—**Moderately sorted gravel and sand, 1–3 m thick, that mantles till and older deposits at low elevations. Beach and coextensive stream deposits formed when late-glacial sea level was higher than at present. Mapped from exposures in shoreline bluffs, local artificial exposures (percolation test pits), and morphology.

Vashon Drift (Pleistocene)—divided into:

Qvi **Ice-contact deposits—**Gravel, sand, and diamict deposited against stationary ice. Commonly reworked by slumping. Mapped on basis of morphology.

Qvt **Vashon till—**Dense sandy diamict. Pebbles are matrix-supported; most are well-rounded. Rare clasts larger than 10 cm are commonly sub-angular to angular.

Lenses of bedded sand, silt, and gravel are common. Wave- etched exposures commonly show sub-horizontal foliation in diamict and isoclinal folding of silt and sand lenses. Most Vashon till exposed in shoreline bluffs appears to be subglacial lodgement till.

In many upland locales, till is mapped on basis of silty, pebbly subsoil, commonly with gray to green-gray hue indicative of minimal oxidation.

Qve

Esperance Sand Member—Quartzofeldspathic medium sand, locally with gravelly layers. Little cemented, though locally supports vertical faces. In deep exposures, commonly little oxidized. Sub-soils derived from this unit are mostly loose sand.

Local cross-beds and large foresets suggest deposition in fluvial or deltaic setting; elsewhere, pervasive decimeter-thick planar beds and low- angle cross-beds suggest deposition by prodelta turbidity currents.

Qvlc

Lawton Clay Member—Thin-bedded (5 mm to 15 cm) dark gray silt and clay, locally with dropstones and (or) lenses of ice-rafted sand and gravel. Lacustrine.

Qpv

Pre-Vashon deposits—Sand, gravel, silt, peat, sandstone, mudstone, con- glomerate, and diamict of fluvial, lacustrine, and glacial origin. May in- clude marine deposits. Where outcrop is good, it is evident that much of material mapped as Qpv is interbedded sand and gravel of fluvial origin or thin-bedded fine sand and silt of indeterminate origin.

Mostly mapped where poor outcrop—typically, brown, sandy, pebbly subsoil—does not permit a more detailed classification. In places, mapped as:

Qpvf

Fine-grained deposits—Silt, clay, and local peat.

Qpvu

University Point beds—Fluvial gravel and sand, locally cross-bedded, with interbedded silt and peat. Gravels commonly oxidized. Lithification vari- able; local conglomerate and sandstone.

Gravel has high concentration of dark basaltic sandstone and basalt clasts that suggest an ultimate source in the Olympic Mountains.

North of Fletcher Bay, shoreline bluff exposures display 2–3 m thick fining-upward sequences indicative of meandering stream deposits; silt and peat are overbank facies

Qpog

Older glacial deposits—Till, pebbly mud, and associated silt, sand, gravel, and conglomerate. On Rockaway Beach, till overlain by thin-bedded silt and fine sand, locally disrupted by subaqueous slumping.

Qpor

Rockaway Beach unit—Massive to disrupted silt, clay, and sand. Most dis- ruption appears to be due to soft-sediment deformation.

Tertiary Sedimentary Rocks

Tbh

Blakely Harbor Formation (Miocene)—Volcanic-lithic sandstone, siltstone, conglomerate, and peat. Orange-brown weathering; pervasive clayey alteration. Conglomerate rich in basaltic clasts and without granitic clasts. Abundant wood and, locally, peat as thick as 3 m. Stream and flood-plain deposits.

Tb

Blakeley Formation (Eocene and Oligocene)—Sandstone, siltstone and claystone, plane-bedded, locally calcareous. Thin to medium-bedded, mostly plane-bedded, local load casts and flutes at bases of beds. Moderately common marine shells and charcoal, locally extensive burrowing. Sandstones are rich in volcanic debris; trace white mica. In part mapped as:

Tbt

Tuff-rich beds—Similar to remainder of Blakeley Formation, but with 1- to 3-m thick beds of brown-weathering impure lapilli tuff and minor con- glomerate. Tuff beds locally cross-bedded. Conglomerates polymict, including cobbles and boulders of distinctive black-and-gray welded silicic tuff.

2.5.3 Climate/Rainfall

Bainbridge Island climate is characterized by warm dry summers and cool wet winters with annual 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) Projected impacts from climate change indicate increase in average annual air temperature of 4–5.5°F over the next 30 years which will affect all seasons, with the greatest increase in summers (Hansen *et al.* 2016). Climate models project that the Pacific Northwest will experience wetter winters and drier summers by the mid-21st century. Specifically, most models forecast an average increase in winter precipitation of 2% to 7% (Mote 2013), while summer precipitation is projected to decrease by 6% to 8% for the 2050s (2041–2070) (IPCC 2013), relative to the 1950–1999 baseline. These seasonal shifts are expected to result in shorter, wetter winters with more extreme precipitation events and longer, drier summers.

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. While residential development increased in the 1970s, prompting additional clearing, it did not mark a major turning point; clearing has continued to the present day, sometimes irresponsibly. Even so, 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 and impressive than in the years following the initial clear-cut era.

Rising temperatures from climate change are expected to significantly affect Bainbridge Island's water supply by increasing evapotranspiration (ET), the loss of water from soil and vegetation. With average annual temperatures in the Puget Sound region projected to rise by 4 to 5.5°F by 2050 (University of Washington Climate Impacts Group, 2015), more water will be lost to the atmosphere, especially during spring and summer when plant water use is highest. Because the island relies entirely on a sole source aquifer, higher ET rates will reduce the amount of rainfall that recharges groundwater. Combined with drier summers and increased irrigation demand, this could lower water tables and strain long-term water availability.

2.5.5 Population

The total population of Bainbridge Island in 2020 was 24,825, up from about 8,500 in 1970 (**Figure 2-9**). 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 zones, most residents live outside of them, dispersed across lower-density neighborhoods and rural areas. This is an ongoing planning concern, as current land use patterns do not align with growth management goals for compact, sustainable development. 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 and is zoned for lower-density residential development, could accommodate approximately 4,000 additional residents under current zoning. However, this potential expansion raises critical ecological and economic concerns, including habitat fragmentation, increased infrastructure costs, and challenges to groundwater sustainability. Addressing this imbalance is central to the City's long-range planning efforts.

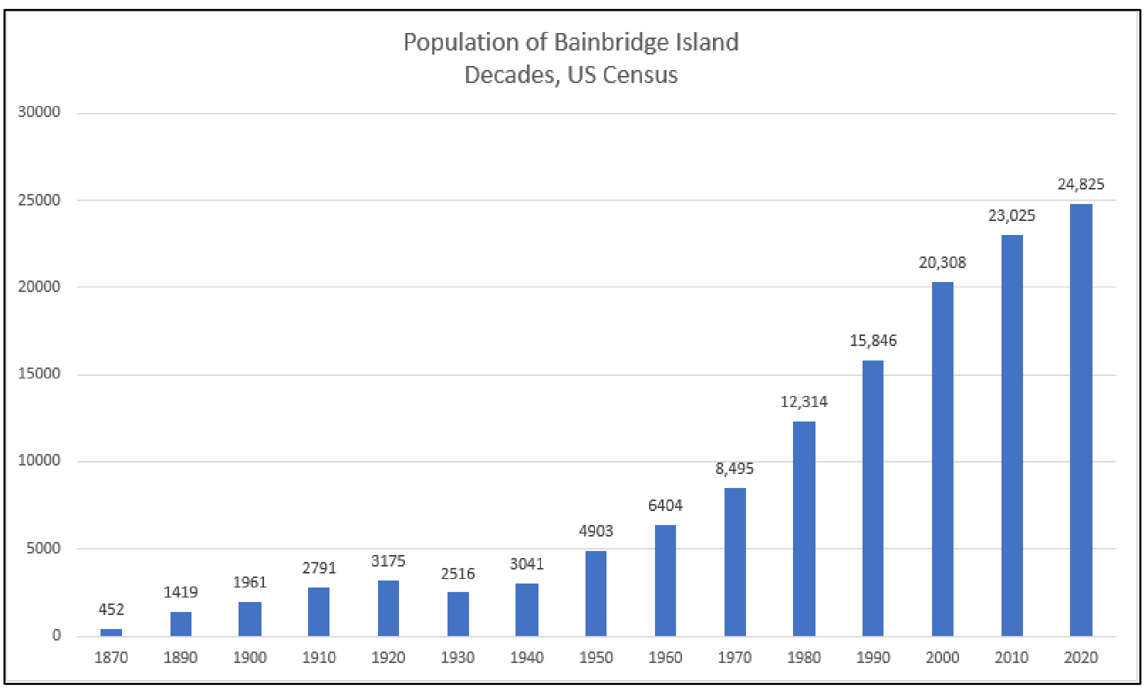


Figure 2-10. Bainbridge Island Population 1870 to 2021 (U.S. Census)

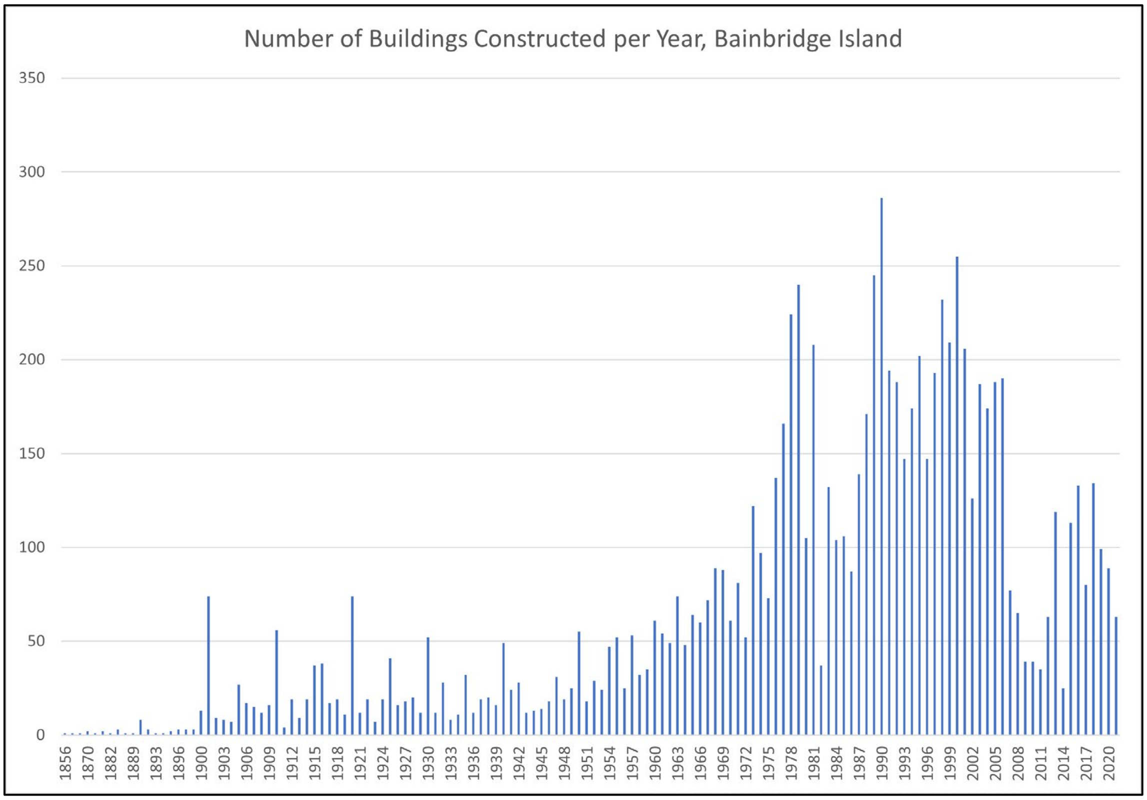


Figure 2-11. Number of Buildings Constructed on Bainbridge Island per Year

2.5.6 Land Use

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 2-10**), indicating a maturing community with limited space for new development and an increasing emphasis on managing growth within existing land use patterns.

2.5.7 Water Resources and Use

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 with no major natural surface water bodies except for one lake (Gazzam Lake) (**Figure 2-11**). Several small wetlands are located throughout the island. Surface water drainage is generally via small spring-fed streams that discharge to Puget Sound. The streams are both permanent (about a dozen) and seasonal (approximately 40), and that permanent 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 historically used for irrigation are also found throughout the island.

Streams in the Murden Cove and Fletcher Bay watersheds are closed to further water right appropriations by Chapter 173-515 WAC (**Figure 2-3**). 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 before being approved.

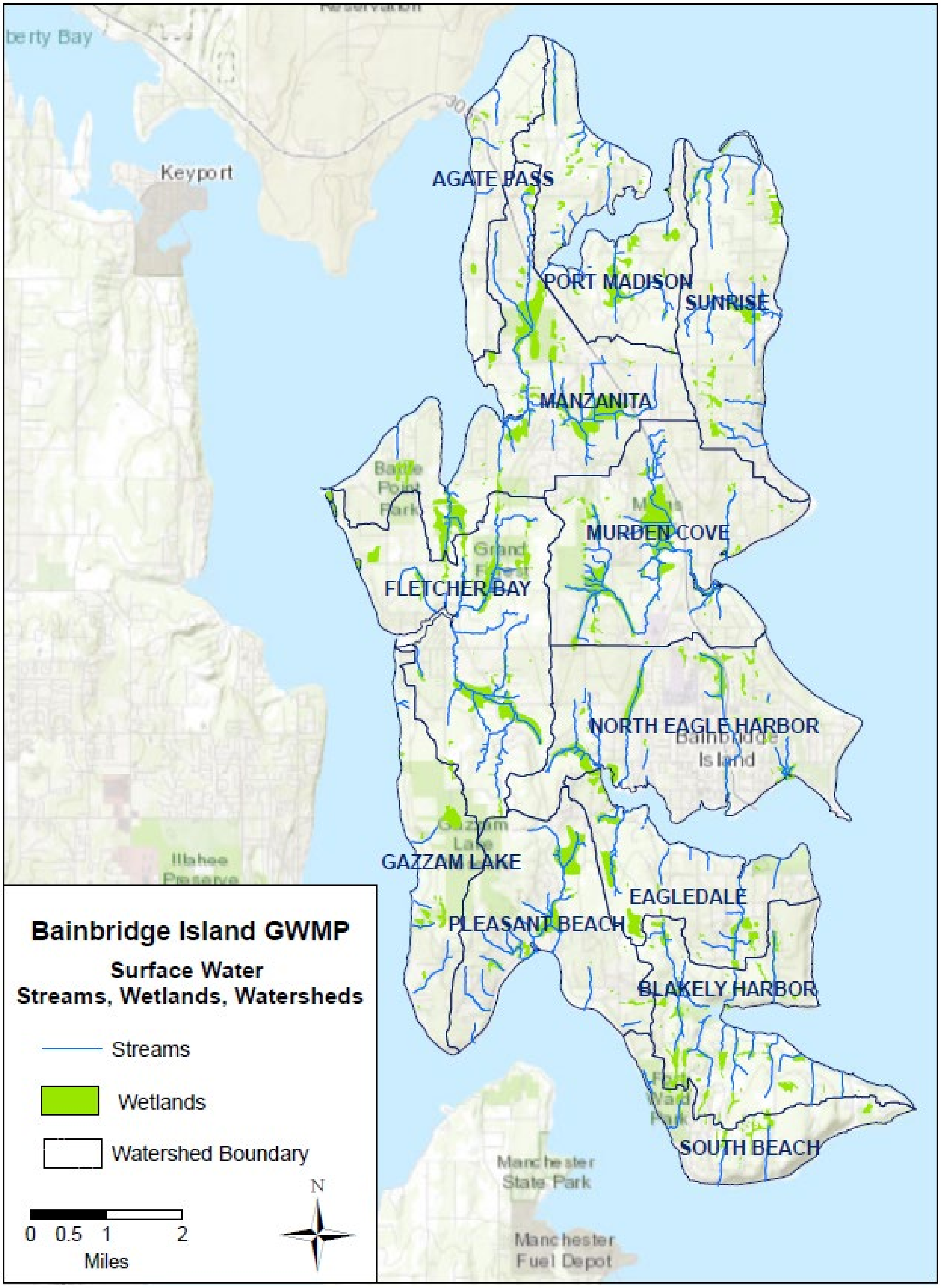


Figure 2-12. Bainbridge Island Surface Water (Streams, Wetlands, and Watersheds)

Groundwater provides the sole source of drinking water and supports surface water health. There are an estimated 1,400 water supply wells located on Bainbridge Island (Frans *et al.* 2011). These wells are split between private water supply, Group B community system (about 135 wells), and Group A community water supply (80 wells). It must be noted that the number of private water supply wells is an approximation because historical records for these wells are incomplete. The wells vary in depth from shallow dug wells (10–20 feet deep) to wells over 1,000 feet deep.

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 COBI while the rest is operated and maintained by private owners and entities (Collier 2021).

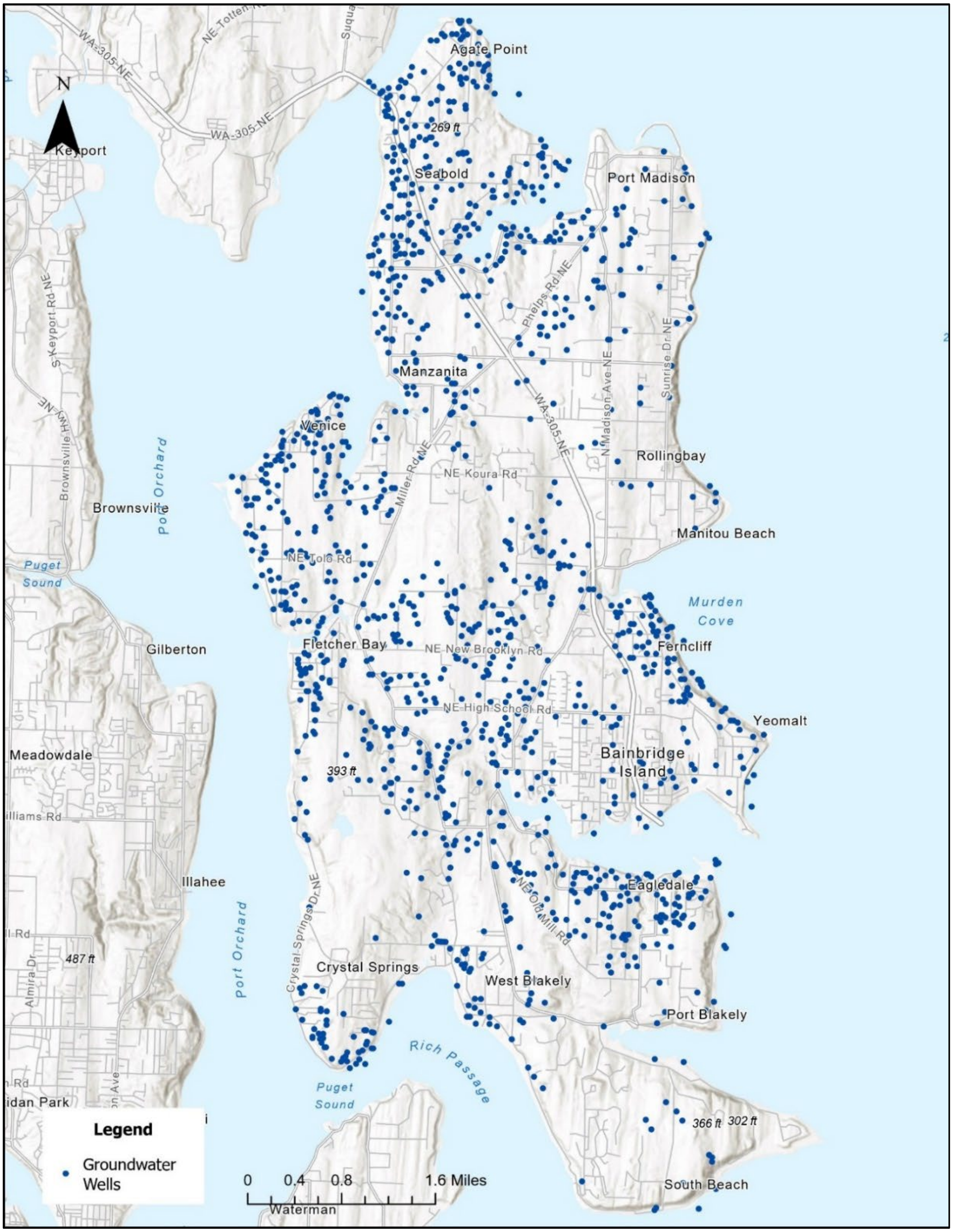


Figure 2-13. Bainbridge Island Water Supply Well Locations

2.5.8 Wastewater

There are two wastewater treatment plants on Bainbridge Island (COBI 2022). The Winslow Wastewater Treatment Plant is maintained and operated by the COBI to serve the Winslow Sewer Service Area (covers about 2.3 square miles). The Winslow Wastewater Treatment Plant discharges to Puget Sound under a National Pollutant Discharge Elimination System (NPDES) Permit WA0020907.The other wastewater treatment plant is maintained and operated by Kitsap County Sewer District #7 and is in the southwest part of the island, near Fort Ward. The Kitsap County Sewer District #7 Wastewater Treatment Plant services about 650 residences and businesses both inside and outside district (Kitsap County Sewer District #7, 2022) and discharges to Rich Passage (Ecology 2022a) The COBI also provides sewer service within the South Island Sewer Service Area (covers about 0.3 square miles) near Lynwood Center and conveys the wastewater to the Kitsap County Sewer District #7 Wastewater Treatment Plant under an interlocal agreement.

The remainder of wastewater on the Island is treated by approximately 6,000 private on-site septic systems. There are also a couple large on-site septic systems that maintain a site-specific discharge permit (Ecology 2025). On-site septic systems contribute to groundwater recharge, with amounts varying across the island. Overall, the contribution is estimated at less than 3 inches per year, equivalent to approximately 4,400 acre-feet annually—more than twice the volume of annual groundwater withdrawals, which total around 2,000 acre-feet (Frans *et al.* 2011).

Figure 2-14. Bainbridge Island Wastewater Service Areas

2.6 HYDROGEOLOGY

The following is a description of the area's hydrogeology, including

- Nature and extent of aquifers and aquitards
- Direction of groundwater flow
- Groundwater recharge and discharge areas
- Surface water
- Groundwater numerical modeling findings

2.6.1 Nature and Extent of Aquifers and Aquitards Underlying the Area

Most of the Kitsap Peninsula is underlain by unconsolidated geologic deposits (loose materials like sand and gravel that allow water to flow in the pore space between grains), similar in hydrogeologic characteristics and sequence to those underlying Bainbridge Island. However, there is no evidence of hydraulic connection of aquifers within these similar geologic deposits. USGS (Frans et al. 2011) examined this question and concluded that at best, only slightly more than 5% of inflow into the Bainbridge Island aquifer system may be attributable to water in the FBA migrating from the Kitsap Peninsula. USGS also concluded that groundwater in the SLA and PA on Bainbridge Island are isolated from the Kitsap Peninsula.

Some of the shallower deposits are found both on the Peninsula and on Bainbridge Island; however, these shallow deposits are not connected because of erosion after they were deposited (Welch et al. 2014).

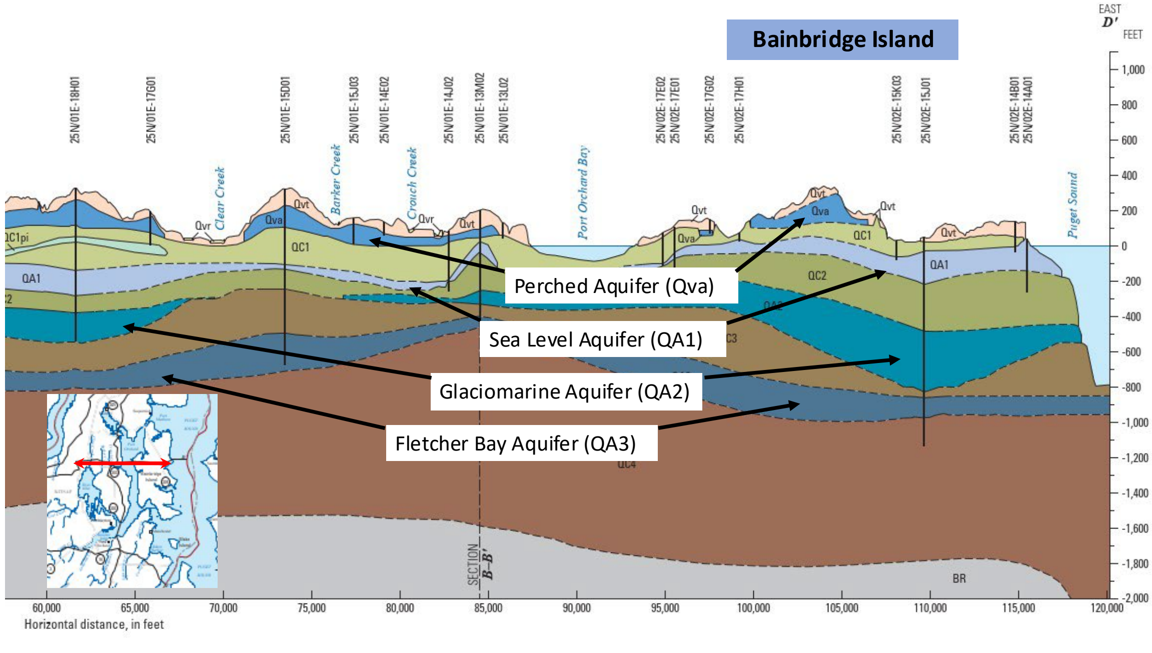


Figure 2-15. Cross-section of Hydrogeologic Deposits underlying Eastern Kitsap County
Source: Modified from Welch, Frans, and Olsen 2014

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 till, which is generally more fine-grained and often compacted.

The major aquifers underlying Bainbridge Island are briefly described below in order of increasing depth and illustrated in illustrates the complex interlayering of aquifers (blue-green color) and confining units (tan and purple color). The red arrow depicts the location of the cross-section or 'slice' through the underlying sediments shown in the diagram.

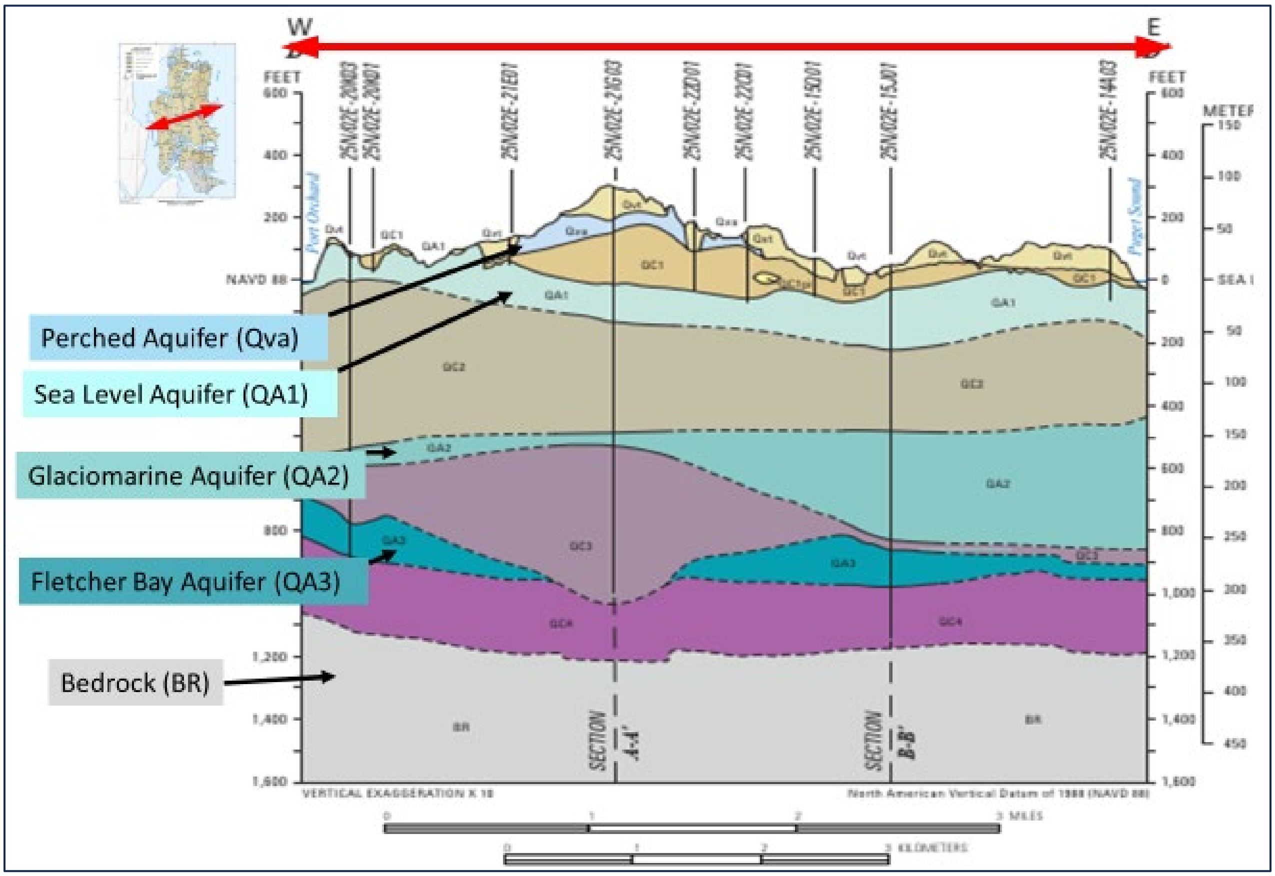


Figure 2-16. Cross-Section of Hydrogeologic Deposits underlying Bainbridge Island
Source: Modified from Frans et al. 2011

PA/SPA (identified as Qva in Figure 2-15) — 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 Kato & Warren and Robinson & Noble (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 percent of wells are completed in these aquifers.

Sea Level Aquifer (identified as QA1 in Figure 2-15) **-** 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 percent of wells are completed in this aquifer.

Glaciomarine Aquifer (identified as QA2 in Figure 2-15) - 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 percent of wells.

Fletcher Bay Aquifer (identified as QA3 in Figure 2-15) - This aquifer (QA3) is the deepest identified aquifer on Bainbridge Island. Several large 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 COBI wells provide approximately 30 percent of the estimated total Island groundwater production.

Bedrock Aquifer (identified as BR in Figure 2-15) - Less than 1 percent of the wells on Bainbridge Island are completed in the sedimentary Blakely Harbor and Blakeley formations on the south end of Bainbridge Island which form this aquifer.

The terminology and characteristics for the geologic/hydrogeologic deposits are summarized in **Table 2-3**.

Table 2-3. Hydrogeologic Layers

Name (s)	Abbreviation	Brief Description	Found
Vashon till	Qvt	Unsorted mixture of clay, silt, sand, gravel and boulders deposited by glacial ice; Confining unit	At surface across most of the island
Vashon advance aquifer, Perched/Semi-Perched Aquifer	Qva, PA/SPA	Well-sorted mix of sand and gravel	Typically, underlying Qvt but can be found at the surface (south-central area and north near Agate Passage)
Upper confining unit	QC1	Thick, low permeability unit made up of glaciolacustrine silt and clay and underlying deposits of interglacial silt, sand, gravel with silt/peat lenses	Underlying Qva, PA/SPA Across the island, absent in Manzanita Bay and Fletcher Bay areas
Sea Level Aquifer	QA1	Glacial sand and gravel with silt interbeds Generally 25 to 200 ft thick	Mostly underlying and confined by QC1 Found at land surface near Fletcher Bay and Manzanita Bay and near part of Eagle Harbor Absent near Port Madison

Name (s)	Abbreviation	Brief Description	Found
Middle confining unit	QC2	Low permeability unit made up of interglacial sandy silty clay and glacial sand and gravel with significant amounts of silt and clay layers Generally 150 to 600 ft thick	Found across most of the island except on southern end where bedrock is at or near the surface Underlying QA1
Glaciomarine Aquifer	QA2, GMA	Consists of sand and gravel to silt Confined Generally lower permeability that Qva or QA1 Generally 20 to 300 ft thick	Absent near Eagle Harbor, Manzanita Bay, southern end of Agate Passage, and southern end where bedrock is at or near the surface
Lower confining unit	QC3	Consists of clay and silt with some gravel Generally 50 to 300 ft thick	Across island, thin near Murden Cove and absent in the southern end where bedrock is at or near the surface. Thickest in the central and north-central areas
Deep aquifer, Flecher Bay Aquifer	QC3, FBA	Consists of sand and gravel with silt interbeds Confined Generally 50 to 300 ft thick	Across island, locally absent east of Fletcher Bay, south of Murden Cove, and in the southern end where bedrock is at or near the surface.
Basal confining unit	QC4	Consists of clay and silt with some gravel. Low permeability and unknown thickness	Across island Absent in the southern end where bedrock is at or near the surface
Bedrock	BR	Consists of marine and non-marine sedimentary rocks and volcanic rocks (Welch et al. 2014)	At or near the surface in the southern end of the island due to faulting and uplift North of the fault line bedrock deep and dept to bedrock is not known

Notes:
BR: bedrock
ft = foot (feet)
PA/SPA: Perched/Semi-Perched Aquifer
QA1: sea level aquifer
QA2: fine-grained glaciomarine deposit
QC1: upper confining unit
QC2: middle confining unit
QC3: deep aquifer
QC4: basal confining unit
Qvt: Vashon till
Qva: Vashon advance aquifer
Source: Modified from Frans, *et al.* 2011, except where noted.

2.6.2 Groundwater Flow including Water Table and Potentiometric Maps

Groundwater flows from areas of higher water levels (greater hydraulic pressure) to areas of lower water levels (lower hydraulic pressure). 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, recharge, and well pumping. In a confined aquifer all the aquifer material is saturated and groundwater flows in response to changes in the confining pressure of overlying layers (which can be of variable thickness and permeability). This response to changes in precipitation, recharge, and pumping are often more subtle than in a water table aquifer. (Frans *et al.* 2011).

The direction and gradient of groundwater flow can be measured by making 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 then can be illustrated on a map, like ground surface elevations on a topographic map. The surface of the water table is not static and can change horizontally vertically over time in response to precipitation, well pumping, etc. In a confined aquifer, this interface is a 'potentiometric surface' reflecting the influence of hydraulic pressure. (Frans *et al.* 2011).

Groundwater flow in the generally unconfined/semi-confined PA/SPA and confined SLA was mapped by the U.S. Geological Survey based on groundwater levels measured in 86 wells during a 2-week period in August 2007 (**Figures 2-16 and 2-17**). There was insufficient information to construct groundwater flow maps for the GMA and FBA, given only a few wells are completed in each aquifer (Frans *et al.* 2011). This method is applicable for wells completed in the same aquifer but would not apply when dealing with wells completed in different aquifers, since water levels in distinct hydrogeologic units may reflect independent pressure systems.

Generally, groundwater in the upper aquifers (PA/SPA and the SLAs) flows from the center of the island towards the shoreline with a downward vertical gradient in the center of the island and upwards at the shoreline.

Groundwater levels across the Kitsap Peninsula were measured in autumn 2010 and used to map groundwater flow direction (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, especially for the shallower Perched and Semi-Perched Aquifers. Groundwater flow in the shallow aquifer (Perched and Semi-Perched) follows a similar pattern noted in the August 2007 data.

The rate of groundwater flow depends on the permeability or interconnectedness of the pore spaces in the sediment or bedrock and the hydraulic pressure exerted by the water in the system. This relationship is characterized as hydraulic conductivity. Given the layered nature of the aquifer and aquitard hydro-stratigraphic units, it can be reasonably assumed that horizontal hydraulic conductivity is much larger than vertical conductivity (Welch *et al.* 2014). Estimated mean hydraulic conductivity values for the hydrogeologic units underlying Bainbridge Island are summarized in Table 2-4.

Table 2-4 shows the range of hydraulic conductivity values for key aquifers on Bainbridge Island, which 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 2-4. Summary of Hydraulic Conductivity Values on Bainbridge Island

Unit	No of Wells	Minimum (ft)	Median (ft)	Maximum (ft)
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:
BR: bedrock
ft = foot (feet) per day
PA/SPA: Perched/Semi-Perched Aquifer
QA1: sea level aquifer
QA2: fine-grained glaciomarine deposit
QC: bedrock
QC1pi: Semi-Perched Aquifer exists within permeable interbeds
Qva: Vashon advance aquifer
Source: Frans et al. 2011.

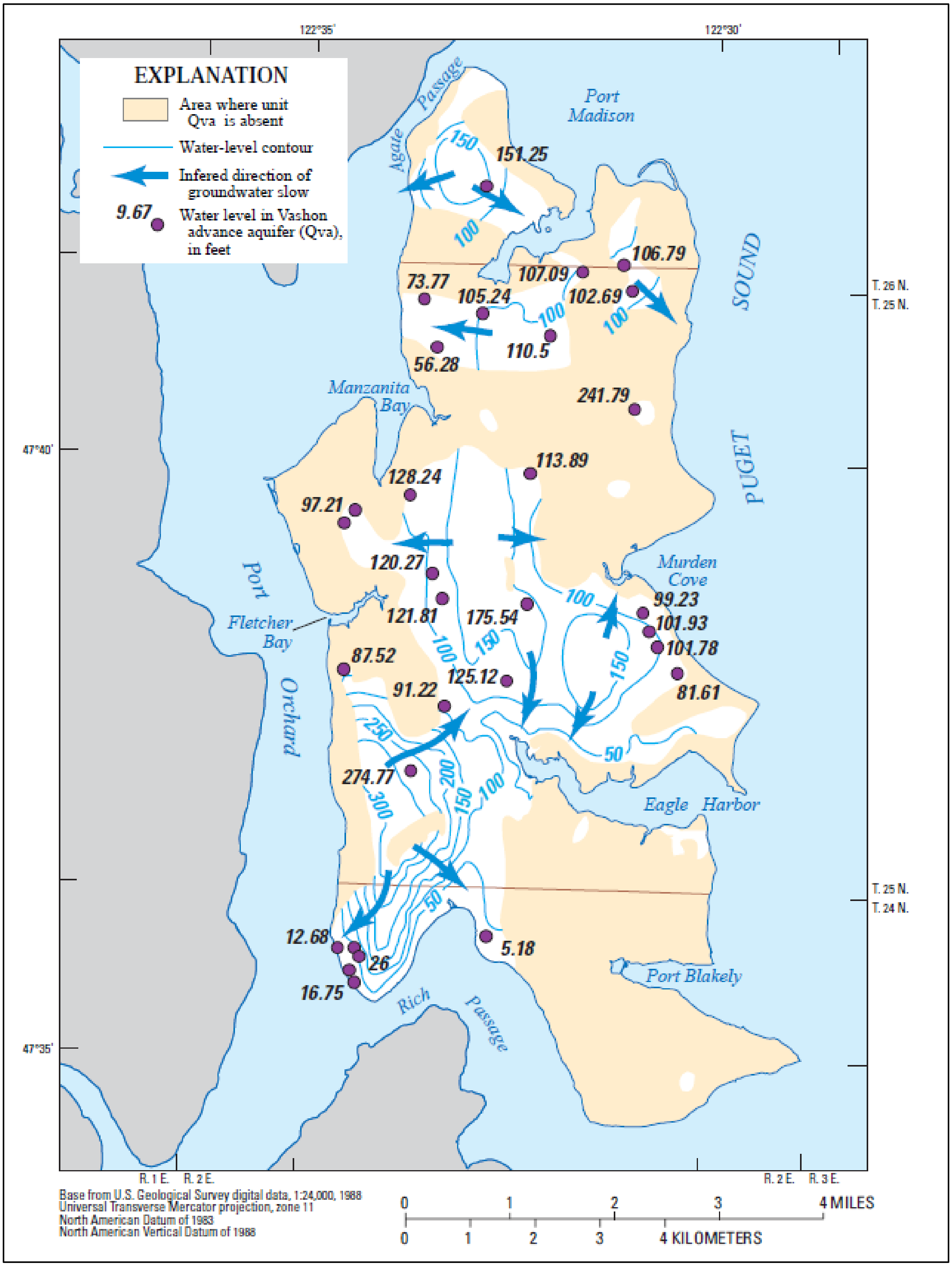


Figure 2-17. Groundwater flow direction, Perched/Semi-Perched Aquifer (Qva)
Source: Welch, Frans, and Olsen 2014

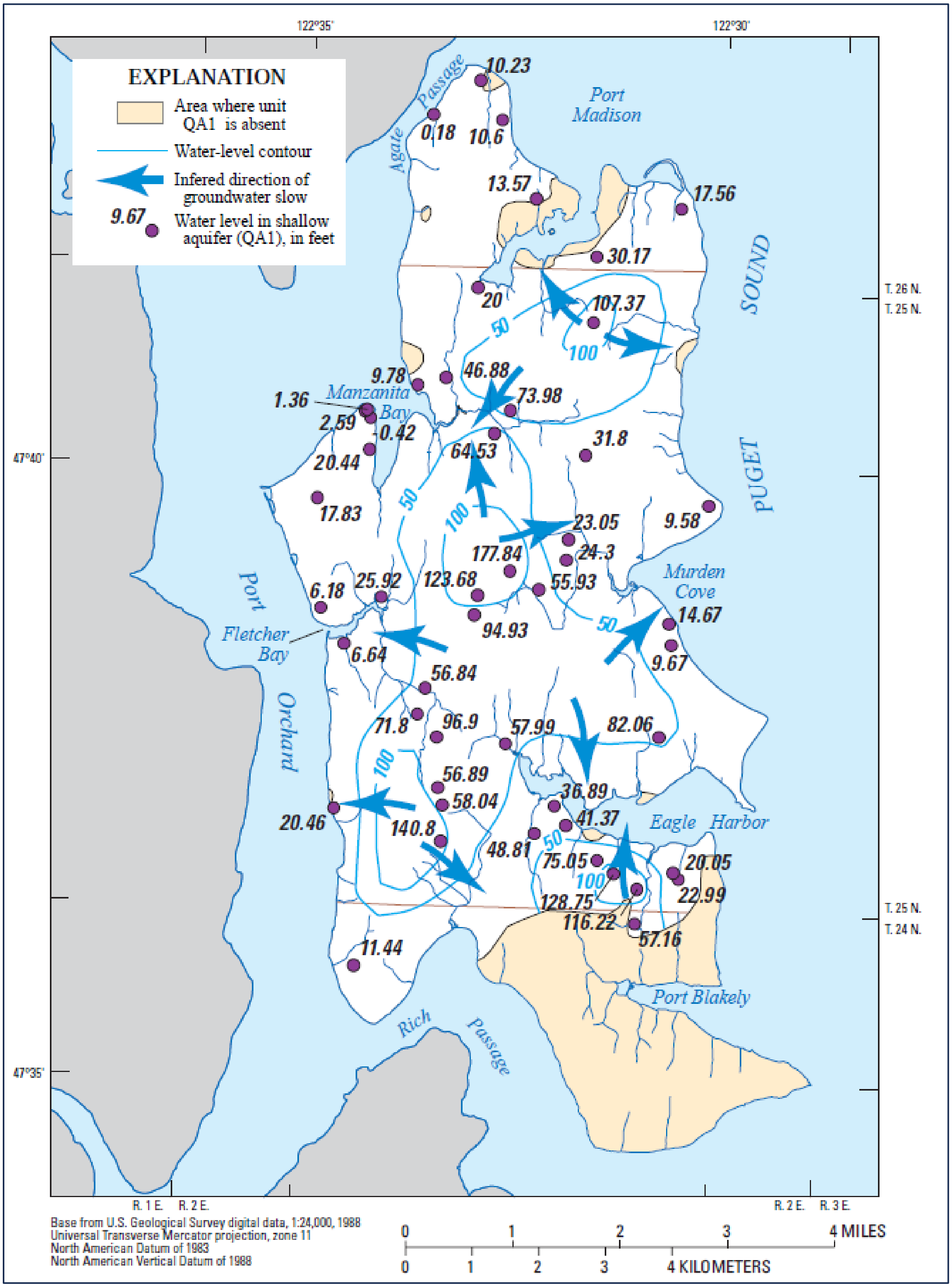


Figure 2-18. Groundwater flow direction, Sea Level Aquifer (QA1)
Source: Welch, Frans, and Olsen, 2014

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

2.6.3 Streams/Springs

The island is divided into twelve watersheds (**Figure 2-3)** consisting of 43 miles of mapped numerous small spring-fed streams that discharge directly into Puget Sound. About 50% of these streams are perennial (flow all or most of the year) and 50% are intermittent (flow only during the wet season or storm events). The largest lake on the island is Gazzam Lake. There also are several smaller lakes and constructed ponds. Gazzam Lake is primarily fed by groundwater and runoff from surrounding forested woodlands and a few single-family residences. Gazzam Lake is perched at an elevation of approximately 320 feet MSL and does not have a surface outlet; water loss occurs primarily through evaporation and leakage rather than overland discharge. The lake is not hydraulically connected to deeper aquifers such as the Qva, SLA, or FBA. In addition to streams, ponds and lakes, wetlands cover an estimated 7% of the island (Kato and Warren 2001).

2.6.4 Location of Recharge/Discharge Areas (Map)

On Bainbridge Island, groundwater recharge from precipitation have been characterized by Welch, Frans, and Olsen (2014). Recharge is correlated with precipitation and thus, varies every year. Monthly recharge values developed by USGS were incorporated into EA's groundwater modeling efforts. Precipitation values in 1982 were close to annual averages. **Figure 2-18.** illustrates the annual recharge values for 1982 that were used in the EA groundwater model. As shown, annual average recharge values range between 0 and 17 inches.

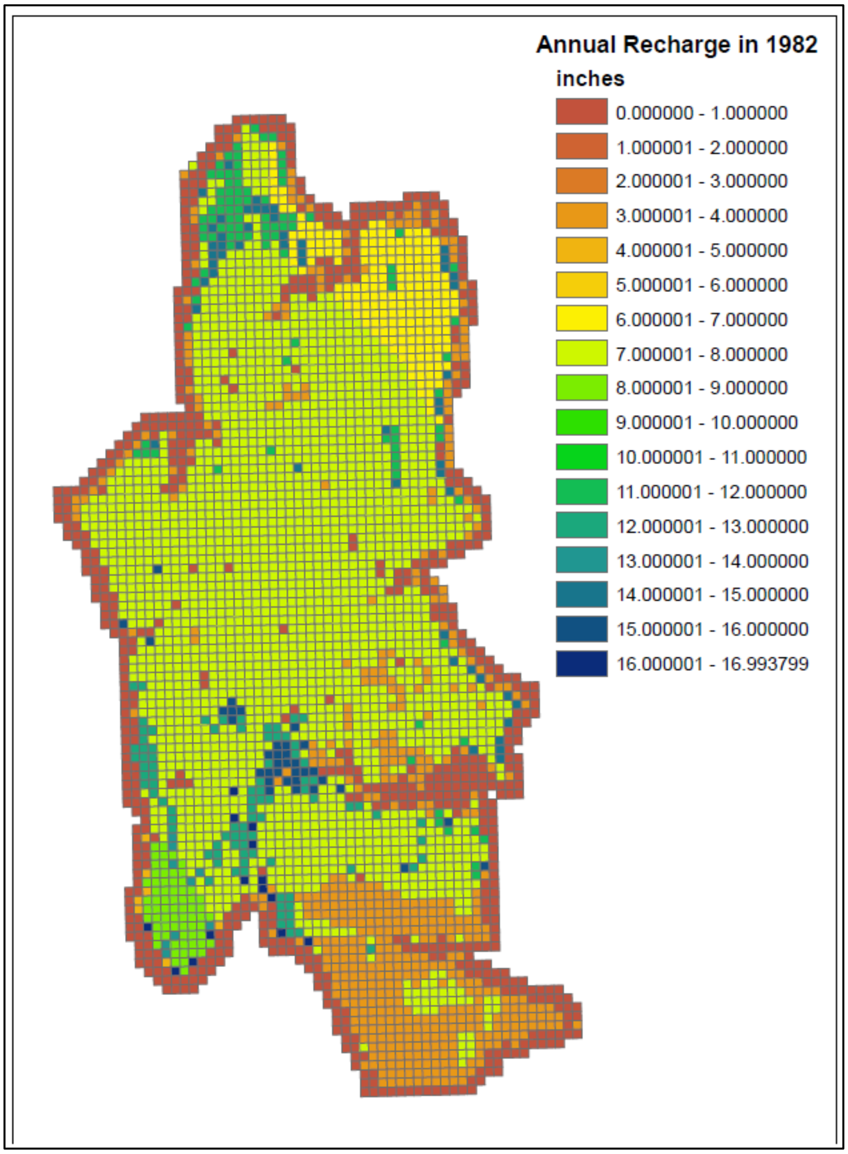


Figure 2-19. Average Annual Recharge from Precipitation, Bainbridge Island, EA 2025

2.6.5 Water Budget

The water budget accounts for water stored in and exchanged between the three principal components of the hydrologic cycle: atmosphere, surface water, and groundwater (Healy *et al.* 2007). A water budget that considers this storage and exchange for surface water and groundwater is a useful tool to aid understanding of the surface water/groundwater system (Healy *et al.* 2007).

A simplified water budget for Bainbridge Island recognizes that over the long term, the aquifer recharge and discharge is in a state of 'dynamic equilibrium' (Welc *et al.* 2014). This means that generally, there is little or no net change in the water stored in the system so changes in observed water levels are in response to changes in inputs (recharge from precipitation and return flow from septic systems and irrigation) and outputs (discharge to surface water, springs, wells, the marine environment, and off-island groundwater systems).

The water budget developed for Bainbridge Island as part of the COBI Level II Basin Assessment estimated average recharge across the island to be about 13 inches/year or 19,000 acre-ft/year (Kato and Warren, Inc. and Robinson and Noble, Inc. 2000). It should be noted that total recharge amount is not the amount of water available for water supply as a portion of recharge supports surface water and maintains hydraulic pressure that keeps the saltwater/freshwater interface offshore.

Total recharge was estimated to be approximately 13,673 acre-ft per year primarily from precipitation for Bainbridge Island (Aspect 2016).

This recharge is balanced by 6,836-8,203 acre-ft per year discharge to surface water (50-60%), approximately 683 acre-ft per year (5%) discharge via well pumping, and approximately 4,101-5,469 acre-ft per year (30-40%) discharging to the marine environment or to the west towards Kitsap Peninsula (2) (USGS, 2011).

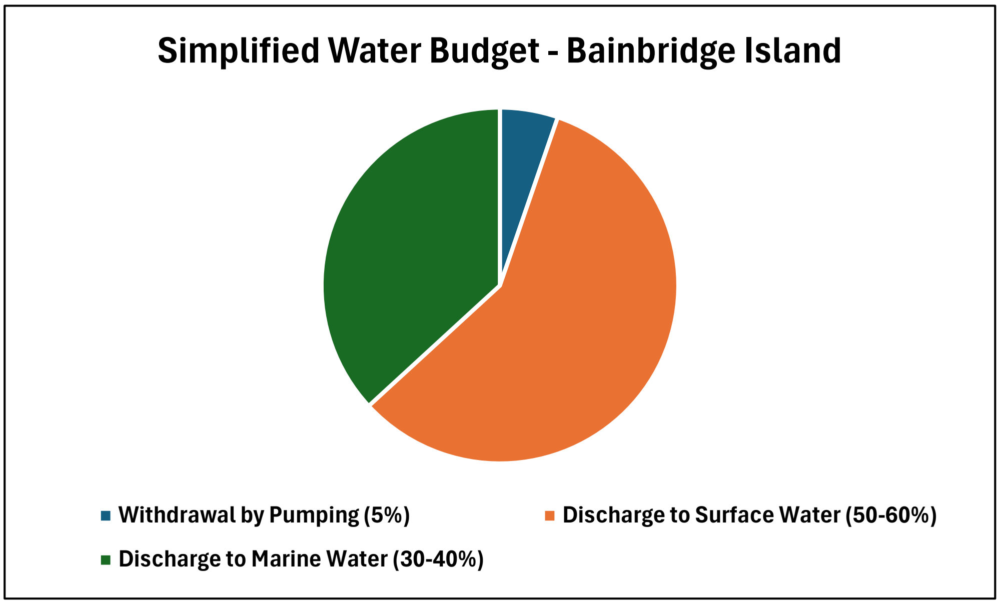


Figure 2-20. Estimated Groundwater Annual Discharge
Source: USGS 2011

Human induced recharge – septic system return was estimated to be 3% regionally (Welch *et al.* 2014) and 5% on Bainbridge Island (Frans *et al.* 2011). The updated Bainbridge Island model did not include septic system return (Aspect 2015).

In simple terms, the hydrologic (surface water and groundwater) system is generally in a state of dynamic equilibrium meaning that inflow equals outflow and the amount of water stored in the system does not change (Welch *et al.* 2014). Inflow includes precipitation and return flow from septic systems and irrigation. Outflow includes water discharged to wells, wetlands, streams, springs, and the marine environment.

Rates of inflow or recharge and rates of outflow or discharge vary seasonally and year to year. Groundwater levels respond to these changes. The amount and timing of these responses depends on the size of the change, the characteristics of the aquifer, and the depth of the aquifer (deeper aquifers tend to respond slower and show a muted response) (Welch *et al.* 2014).

The regional groundwater budget, estimated by Welch *et al.* (2014), characterized the two major sources of recharge to be from precipitation and septic system/irrigation return flows. Discharge from the system was to streams, other natural features (e.g., wetlands, springs, marine environment), and wells. The regional study found recharge to be approximately 97% from precipitation and 3% from septic system/irrigation return flows. Approximately 66% of groundwater discharge was to streams, 30% to other natural features, and 3% to wells.

On Bainbridge Island, the groundwater budget was estimated using an updated version of the 2011 U.S. Geological Survey groundwater model (see discussion in Section 4.6.6).

2.6.6 Numerical Groundwater Models

Groundwater flow can be simulated with the purpose of enhancing understanding of the system and to consider various ‘what if’ scenarios that can inform groundwater management decisions. Numerical groundwater flow models use computers to solve equations that define 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 and cannot replicate this environment with complete accuracy. Errors and uncertainty associated with the approximation, estimates, simplifications, and assumptions necessary due to limitations of data extent, timing, and characteristics impact confidence in model results (Frans *et al.* 2011). Models are calibrated to observed conditions (including groundwater levels derived from fit for purpose monitoring networks) to evaluate the appropriateness of the assumptions and data used to construct the model (Reilly and Harbaugh 2004).

However, the modeling effort can yield useful information if:

- Questions and purpose for building and using the model are clearly defined prior to building the model
- Input data is of the highest quality practicable
- Output data and results are properly contextualized and interpreted
- Looking at different futures, “what if” scenarios to illustrate the magnitude of changes, not necessarily to determine absolute values.

Other critical aspects of the model are as follows (Reilly and Harbaugh 2004):

- Information is only an approximation of reality and subject to error
- Not all processes can be completely represented
- Solutions or outputs from the model may be non-unique, meaning that it is possible for the same solution (e.g., water elevation and simulated groundwater flow) can result from the combination of different input values some of which may not accurately reflect the system.
- There are two basic conditions of the groundwater system that can be used as a basis for modeling the system: steady state or transient flow. A steady state model illustrates conditions once a given set of changes to the system (e.g., changes in precipitation, recharge etc.) have equilibrated. A transient flow model simulates dynamic conditions where inflows, outflows, and groundwater storage vary over time (Frans and Olsen 2016).

Three numerical groundwater flow models have been developed that incorporate the groundwater system on Bainbridge Island. All three models simulate transient flow conditions using the U.S. Geological Survey software package MODFLOW (U.S. Geological Survey 2022). Conceptually, all three models align and have the same basic components:

- Input – water enters the system as recharge from precipitation and septic-system returns
- Output – water exits the system via groundwater pumping, streamflow, and discharge to Puget Sound
- Model boundaries are the same as natural topographic, geologic, hydrologic boundaries where possible

2.6.6.1 U.S. Geological Survey 2011 Groundwater Model

The U.S. Geological Survey, in cooperation with the COBI, 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 to the groundwater system of 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 2-5**.

Table 2-5. Findings 2011 USGS Groundwater Model Bainbridge Island

Simulation (Representation of the Bainbridge Island Groundwater System)		Findings
Baseline simulation – predevelopment groundwater conditions		Simulated groundwater levels/flow direction Location of saltwater/freshwater interface was offshore
2008 simulation – evaluate change from predevelopment groundwater conditions to 2008		Slight increases in water level altitudes in the shallow aquifer are likely due to increased recharge from septic system returns General decline in water level altitudes in deeper aquifers (0–10 feet in Sea Level Aquifer and 10–35 feet in FBA) No change in general radial flow pattern for groundwater in Perched and Sea Level aquifers. Slight change in general west to east groundwater flow direction in the FBA on the western side of the island Saltwater/freshwater interface remains offshore
2035 simulation – evaluate potential groundwater conditions under 4 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 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) could occur if conditions persist beyond 2035

Simulation (Representation of the Bainbridge Island Groundwater System)		Findings
	Protection of recharge areas scenario: Delineated areas contributing recharge for water supply wells combined with expected impact simulation	No changes in land use anticipated in areas identified by the model as recharge areas for COBI wells Change in water levels is the same as the expected impacts scenario

2.6.6.2 U.S. Geological Survey 2016 Groundwater 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. Like 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). Like Bainbridge Island, groundwater is the primary source of drinking water for most of Kitsap Peninsula (Lane 2009).

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 2-6**.

Table 2-6. Key Findings of 2016 USGS Model Kitsap Peninsula

Simulation (representation of the Kitsap Peninsula groundwater system)	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%

Simulation (representation of the Kitsap Peninsula groundwater system)	Findings
3. 15% Increase in current withdrawals in all wells (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% percent to baseline conditions
6. Particle tracking (Assess groundwater flow paths)	Areas contributing to water supply wells were simulated

2.6.6.3 Bainbridge Island Groundwater Model (Aspect)

An update to the 2011 USGS Groundwater Model was completed by Aspect in 2015 (Aspect 2015). 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 2015 Bainbridge Island Groundwater Model 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 2015 Bainbridge Island Groundwater Model included updated monthly water supply well pumping rates as well as revisions to modeling approach and underlying assumptions.

The 2015 Bainbridge Island Groundwater Model 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 2015 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 2015 Bainbridge Island groundwater model are summarized in **Table 2-7**.

Table 2-7. Key Findings 2015 Bainbridge Island Groundwater Model

Simulation (Representation of the Bainbridge Island Groundwater System)	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. 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. 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.
2. Aquifer System Safe Yield (Carrying Capacity) Assessment Simulated 3 stresses concurrently: 50% increase in groundwater withdrawal rates to simulate population growth 20% reduction in recharge rates to simulate effects of climate change 4 foot rise in sea level due to climate change	Wells within the shoreline are predicted to maintain chloride concentrations below 100 mg/L and no trends in chloride concentrations were predicted Approximately 40% decrease in groundwater drainage to surface water The predicted groundwater level changes over a 100-year timeframe were less than the COBI EWLs, but they do not meet the definition of sustainable yield given the measurable annual declines that are predicted. The PA system showed an average 0.10 foot per year of water level decrease at 25 locations simulated across the Island The SPA system showed an average 0.13 foot per year of water level decrease at 12 locations simulated across the Island The SLA system showed an average 0.09 foot per year of water level decrease at 49 locations simulated across the Island The GMA showed an average 0.02 foot per year of water level decrease at 6 locations simulated across the Island The FBA showed an average 0.15 foot per year of water level decrease at 9 locations simulated across the Island.

2.6.6.4 Bainbridge Island Groundwater Model (EA)

As part of the GWMP effort, EA reviewed and updated the existing groundwater flow model and then used the model to run predictive scenarios in aid of the GWMP. The objective of the modeling effort was to provide: (1) a well calibrated groundwater flow that adequately represents subsurface conditions for future use by COBI to evaluate current groundwater flow conditions, (2) reasonable estimates of possible future climatic and aquifer stress conditions (sea levels, groundwater recharge, and extraction rates), and (3) interpretations of the impacts that these possible future conditions will have on groundwater resources on Bainbridge Island.

With the development of the 2025 EA Model, EA has provided COBI with a well calibrated groundwater flow modeling tool that simulates groundwater flow across Bainbridge Island. The structure of the model accurately represents the available aquifer system information and reasonably represents what is known of the aquifer flow properties. The impact scenarios provide reasonable estimates of possible future climatic and water use conditions based on available climate change studies and historic population and production changes.

Based on this information, the Low Impact Planning Scenario probably represents the most likely future conditions, representing the 50% exceedance sea level rise, a minimal change in recharge, and the median population growth estimate. The Mid and High Impact Planning Scenarios represent the most conservative, yet reasonable, future conditions with both simulating the maximum estimated sea level rise and the high population growth estimate, and both simulating recharge reduction beyond what is predicted by CIG.

Impact scenarios show that under all simulated future conditions, the Qva is minimally impacted, primarily due to the absence of large water system extraction and the increase in return water associated with increased production offsetting recharge reduction. The SLA is negatively impacted in two locations centered around water system well fields located close to the shoreline, the Head of the Bay wellfield and the South Bainbridge wellfield.

Groundwater elevations around the South Bainbridge wellfield are estimated to fall below sea level by year 50 in all three impact scenarios. Groundwater elevations around the Head of the Bay wellfield are estimated to fall below sea level by year 100 in the Low and High Impact Scenarios. Groundwater levels below sea level suggest the potential for sea water intrusion exists which may eventually impact water quality for these water systems. The impact scenarios also show a significantly greater drawdown in the deeper GMA and FBA units associated with the estimated increased production for the North Bainbridge, COBI, and South Bainbridge water systems. Drawdown is centered around the Sands Road and Island Utility wellfields.

While the estimated drawdown does not threaten to dewater these units, it does increase the potential for sea water intrusion. However, both hydrogeologic units are separated from Puget Sound sea water by thick aquitards composed of clays and silts that will inhibit the vertical intrusion of sea water. The model cannot simulate the migration of chloride concentrations over time, it only suggests that the potential for sea water intrusion exists under the future conditions.

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, 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 (See Appendix D for a complete list of constituents commonly found in groundwater). 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 COBI Level II Assessment (Kato and Warren, Inc. and Robinson and Noble, Inc. 2000). This assessment included sampling results from over 200 water supply wells (both public and private water) held in the KPUD private 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 Levell 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 (Kato and Warren, Inc. and Robinson and Noble, Inc. 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).

2.7.1.1 Improving Water Quality and Aquatic Habitat

COBI staff completed water quality sampling throughout 2023 to evaluate water quality and aquatic habitat on the Island. Staff completed quarterly sampling events at 17 surface water sites which continue to show that E. coli bacteria levels are impacting the beneficial uses of island streams. Approximately 47% exceed Washington State water quality standards, according to the 2023 Annual Climate Action Plan Progress Report. Targeted and enhanced bacteria monitoring is proposed in the upcoming Stormwater System Plan. The COBI also adopted the salmon monitoring program from the Bainbridge Island Watershed Council this year and successfully monitored four stream reaches with 11 volunteers. Public Works staff will have 2023 data available in early 2024.

2.7.2 Seawater Intrusion

Given that Bainbridge Island is in a marine environment, seawater intrusion into the freshwater aquifers underlying the island is a potential concern (Kato and Warren, Inc. and Robinson and Noble, Inc. 2000). Freshwater is generally less dense than seawater, so the freshwater in an aquifer will be found on top of seawater (U.S. Geological Survey Water Resources 2019). The location and extent of the transition zone between freshwater and seawater depends on the dynamic relationship between water levels in the freshwater aquifer and sea level (**Figure 2-20**). This location of the transition zone fluctuates daily with tidal influences, seasonally and over the years; it also changes based on the amount of fresh groundwater pumped or changes in recharge. Depending on the depth of the freshwater/seawater transition zone, high pumping rates can result in isolated updraw or up-coning of seawater into the well, even in locations not immediately adjacent to the coast. Although this process can be reversed, it requires time and a reduction in pumping (Brzozowski 2017).

According to the Washington State Department of Health guidance (Washington State Department of Health 2020), wells are at risk for seawater intrusion if they are located:

- Within ½ mile of the shoreline and pump water from a depth below sea level
- Within ½ mile of a groundwater source with chloride concentrations over 100 mg/L

Seawater intrusion into freshwater aquifers affects the water quality making unsuitable for use as drinking water without advanced treatment such as reverse osmosis and impacting freshwater coastal environments (USGS Water Resources 2019).

Seawater intrusion can be assessed by measuring specific conductivity and chloride concentrations in groundwater samples. Specific conductivity values provide an indication of the concentration of dissolved ions such as chloride in a water sample.

Currently, 49 wells on Bainbridge Island are assessed annually as part of the COBI's groundwater monitoring program (COBI n.d.). 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.

Seawater intrusion indicated by elevated chloride concentrations has been not been documented but may be possible in various locations on Bainbridge Island between 1957 and 2006.

An example of the COBI'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 COBI, 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 highlights the COBI's commitment to identifying the origin of elevated chloride—whether from seawater intrusion or alternative sources—and to protecting water quality in response to early warning triggers (KPUD 2018).

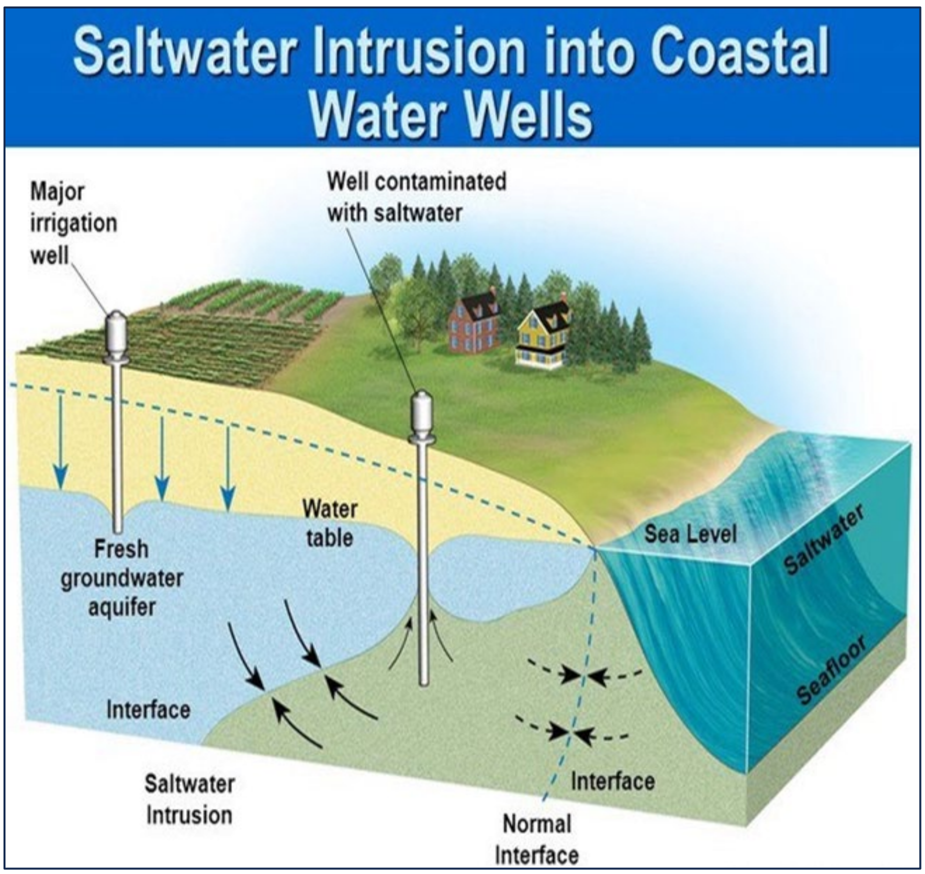


Figure 2-21. Saltwater Intrusion Conceptual Model

2.7.3 Contaminated 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). A complete list is provided in Appendix E. Details regarding 25 sites designated as 'cleanup started' or 'awaiting cleanup' are summarized in **Table 2-8**.

Table 2-8. Contaminated Sites Designated as Cleanup Started or Awaiting Cleanup

Site ID (COBI Map)	Site	Status/Contamination
6	Bainbridge Intermodal Transfer Center	Cleanup started/petroleum hydrocarbon in soil
7	Bainbridge Island Landfill	Cleanup started/soil cleanup action complete and groundwater monitoring in place.
8	Bainbridge Island Sportsman's Club	Cleanup started/lead in soil Note: cleanup is pending.
10	Bainbridge School Bus Maintenance	Cleanup started/contaminated soil associated with (heating oil) Underground Storage Tank (UST) removed
14	Blakely Harbor Park	Awaiting cleanup/Beginning remedial investigation/contaminants in soil and sediment associated with sawmill operations
15	Brown Heating Oil Tank	Cleanup started
18	Chevron 96142	Cleanup started/soil and groundwater contamination petroleum hydrocarbon former USTs/soil removed and groundwater below MTCA cleanup levels
19	Clean Center	Awaiting cleanup /chlorinated solvents in soil and perched groundwater
21	Day Road Industrial Park	Awaiting cleanup/TCE cyanide one time sample 1989
24	Eagle Harbor	Cleanup started/Eagle Harbor Wycoff Site – recognition of the COBI having purchased the site is a PLP (potentially liable person) and is responsible for remedial action in conjunction with the construction, redevelopment, and maintenance of the Park at the Site and not conflict with the EPA remedy at the Site.
26	Eagle Harbor W	Cleanup started/contaminants surface water and sediment metals, PAH, organic contaminants West Harbor Operable Unit (OU-3). Sediment cap and nearshore confined disposal area in intertidal area now used by WA Department of Transportation for ferry maintenance work area
27	Eagle Harbor Wyckoff	Cleanup started/Remedial action cutoff wall for upgradient groundwater flow and ISS (in situ soil stabilization for contaminated soil and groundwater)/contaminants are solvents, creosote, metals in soil and groundwater
28	Fay Bainbridge State Park	Cleanup started/petroleum hydrocarbon gasoline in soil (leaking underground storage tank)
30	Fletcher Bay Mart	Cleanup started/LNAPL + GRO + Benzene in groundwater (shallow + deeper aquifer)
32	FUDS (Formerly Used Defense Site) FORT WARD	Cleanup started/unspecified petroleum products
39	Lynwood Center Corner	Cleanup started/gasoline contaminated soil removed, suspected groundwater cleanup
40	Mac N Jacks Island Service	Cleanup started/leaking underground storage tank gasoline contaminated soil, suspected gasoline contaminated groundwater

Site ID (COBI Map)	Site	Status/Contamination
42	Madison Ave S and Parfitt Way SW (Standard Oil Site)	Awaiting cleanup/petroleum hydrocarbon contaminated soils (low concentrations)
43	Norge Equipped Cleaning Village Store	Awaiting cleanup/chlorinated solvents in groundwater.
55	Stewart Heating Oil Tank	Awaiting cleanup/petroleum - - diesel contaminated soil suspected
57	Strawberry Plant	Awaiting cleanup/PAH, metals (lead and mercury) in soils, arsenic in groundwater
59	Tosco Bainbridge Island Bulk Plant 1784	Cleanup started/petroleum (gasoline, diesel, and oil) contaminated soil/groundwater
60	Unocal 4388	Cleanup started/petroleum hydrocarbon (gasoline) in groundwater
63	Winslow Ravine	Awaiting cleanup/petroleum hydrocarbon in soil/surface water. Possibly originating from Unocal site
64	Winslow Way W and Madison Ave N	Awaiting cleanup/petroleum products unspecified contaminated soil

The location and status of these sites is illustrated by **Figure 2-21**.

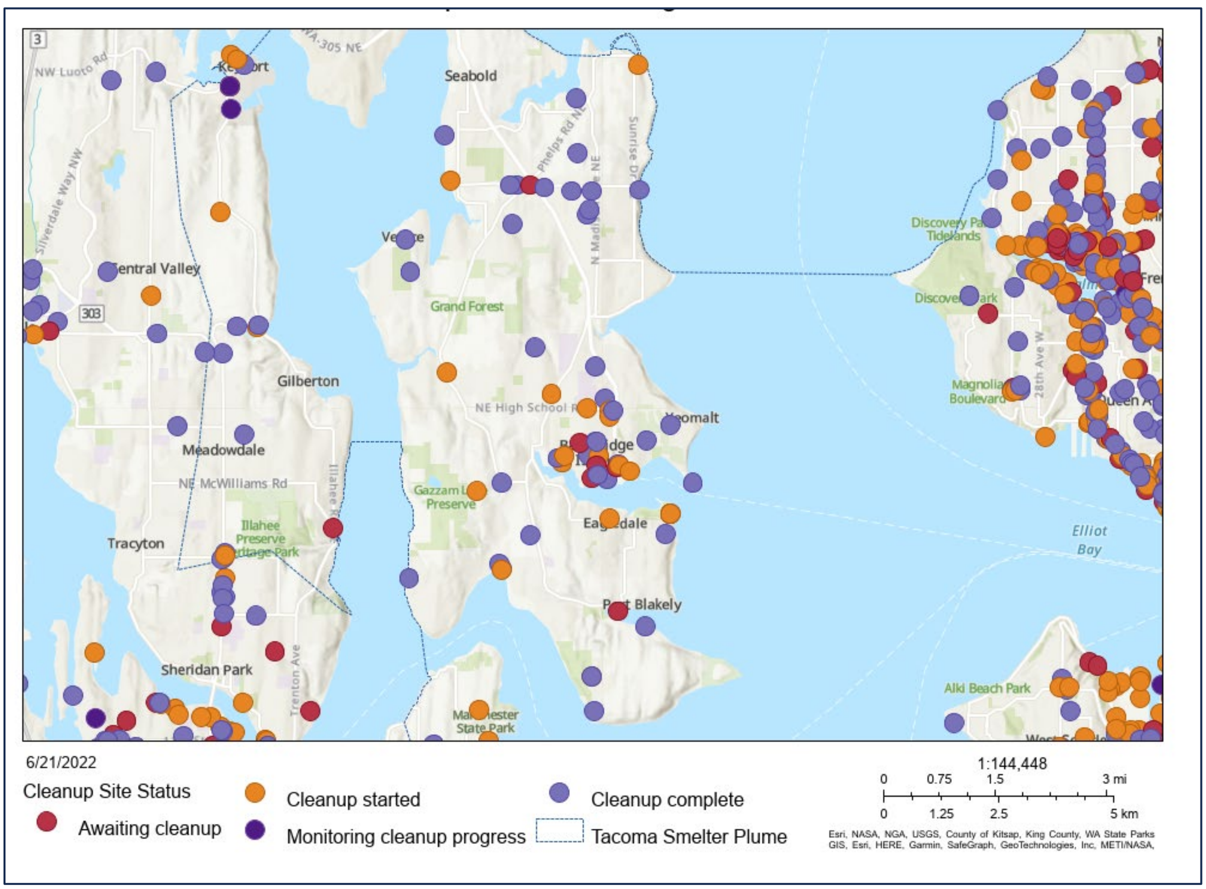


Figure 2-22. Contaminated Sites
Source: WA State Department of Ecology: What's in My Neighborhood: Toxics Cleanup 2024

Of these sites, only a handful (less than 10) have activity recorded in the last 5 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 Wycoff 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.

- **Wycoff Eagle Harbor Superfund Site** (EPA 2022). The Wycoff 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 Wycoff 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 COBI (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 Wycoff facility

- **OU2 – Soils Operable Unit**. Includes contaminated surface soil and structures associated with the Former Process Area of the Wycoff 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 Wycoff 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 Wycoff 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 2-22**). High operating cost and long term needed to reach goal (projected to be 300 years) (EPA 2019).

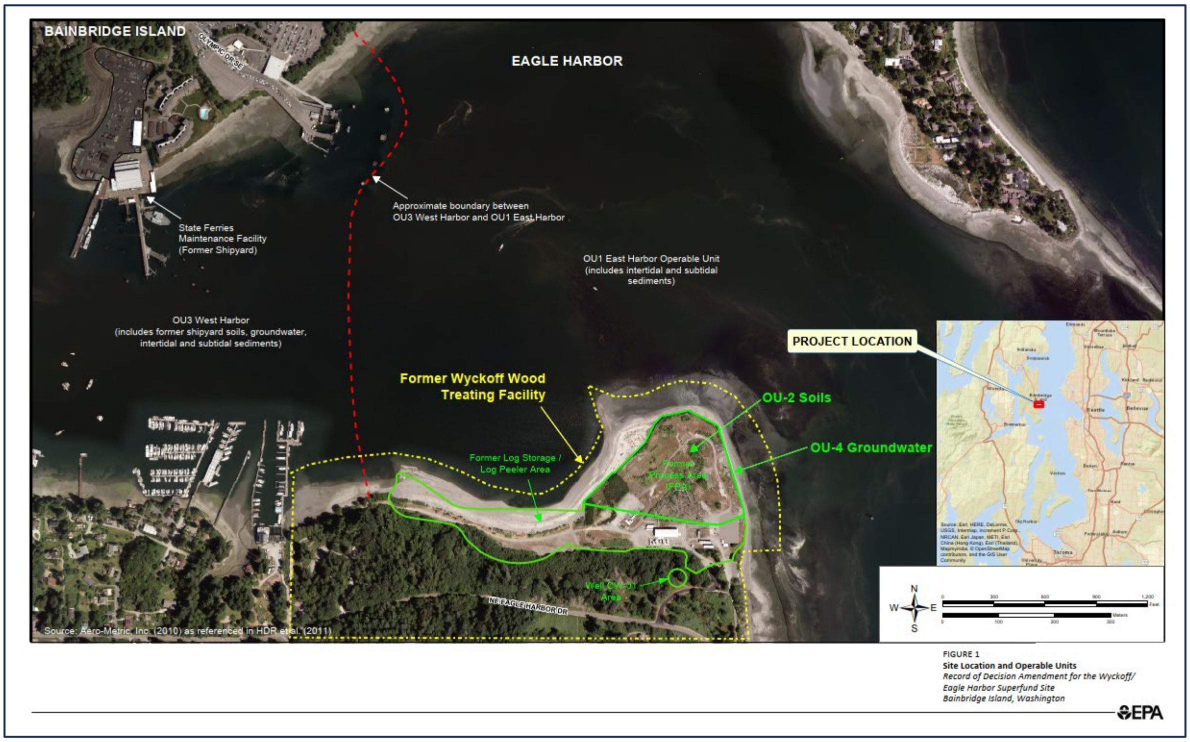


Figure 2-23. Site Location and Operable Units of the Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington.

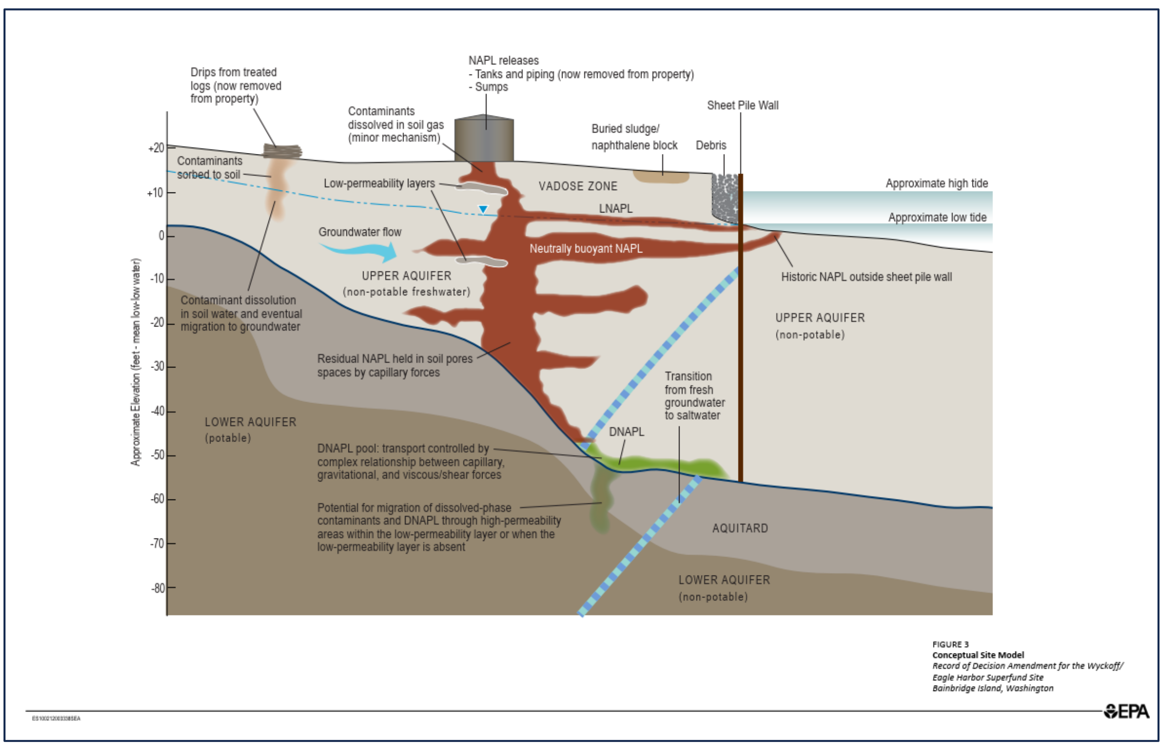


Figure 2-24. Conceptual Site Model of Subsurface Contamination at the Wyckoff/Eagle Harbor Superfund Site, Bainbridge Island, Washington.

The 2022 cleanup plan modifies the earlier "containment" cleanup decision, issued in 2000 (EPA 2022). The next phase of cleanup design is in process. The cleanup will focus on contamination in upper aquifer soil and groundwater impacting Eagle Harbor and lower aquifer (potential drinking water source). Source control will be via In-Situ Solidification/Stabilization of +250,000 cubic yards, groundwater cutoff wall, and low permeability cap/cover. Actions include:

- Replace failing sheet pile wall between site and shoreline
- Dredge and replace with clean materials and cap areas of the beach impacted by continuing creosote contamination from source areas
- Solidification/stabilization of creosote contaminated soils in former process area
- Install passive discharge drains, with treatment as needed, to manage groundwater levels following In Situ Solidification/Stabilization treatment
- Implement institutional controls to prohibit activities that could disturb the cap or result in exposure of contaminated materials that remain below the cap

The selected remedy will be built in two phases over a period of 8–10 years. Construction will start after the existing perimeter wall is replaced. The current schedule is for all cleanup construction to be completed by 2032 (EPA 2022).

2.7.4 Public Water Supplies; Water Quality

COBI (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 level of concern (20 mg/L) 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.

KPUD's estimate of the current population served by its owned systems is 9,254. This total excludes systems no longer managed by KPUD as of 2023—such as Port Madison, Seabold Heights, Onorato, Ferncliff, Blakely, Bainbridge Island Child Care Center, and Agatewood—and does not include the population served by Meadowmeer, which KPUD continues to manage.

Across Bainbridge Island, Group A water systems are owned and operated by various entities, including 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, manganese, and arsenic. These constituents are common in groundwater systems and are generally regulated under SMCLs due to aesthetic concerns rather than health risks.

Iron and manganese, for example, are often present in Island groundwater and can result in discolored water or staining of fixtures. 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 ensures 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.

Several 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 COBI's extension of a new water main to serve the area.

The distinctions between primary and secondary drinking water contaminants, along with State Action Levels (SALs), would help clarify the significance of the 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.

2.8 ESTIMATED HISTORICAL AND CURRENT GROUNDWATER USE

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.

2.8.1 Historical Groundwater Use

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 2-24** 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 Blossum 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 is 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.

In addition, 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.

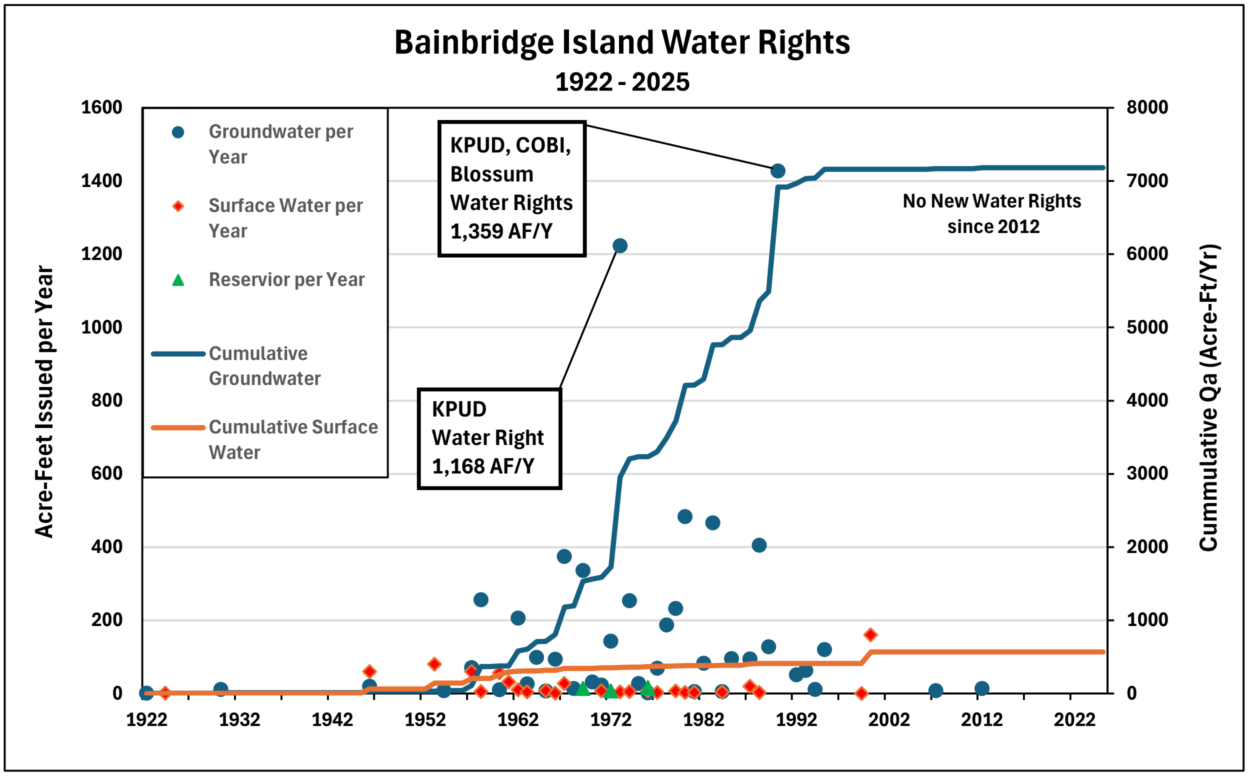


Figure 2-25. Bainbridge Island Water Right Permits and Certificates, 1922–2025
Source: Ecology Water Rights Database 2025

As shown on **Figure 2-24**, 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. Please 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 2-25**.

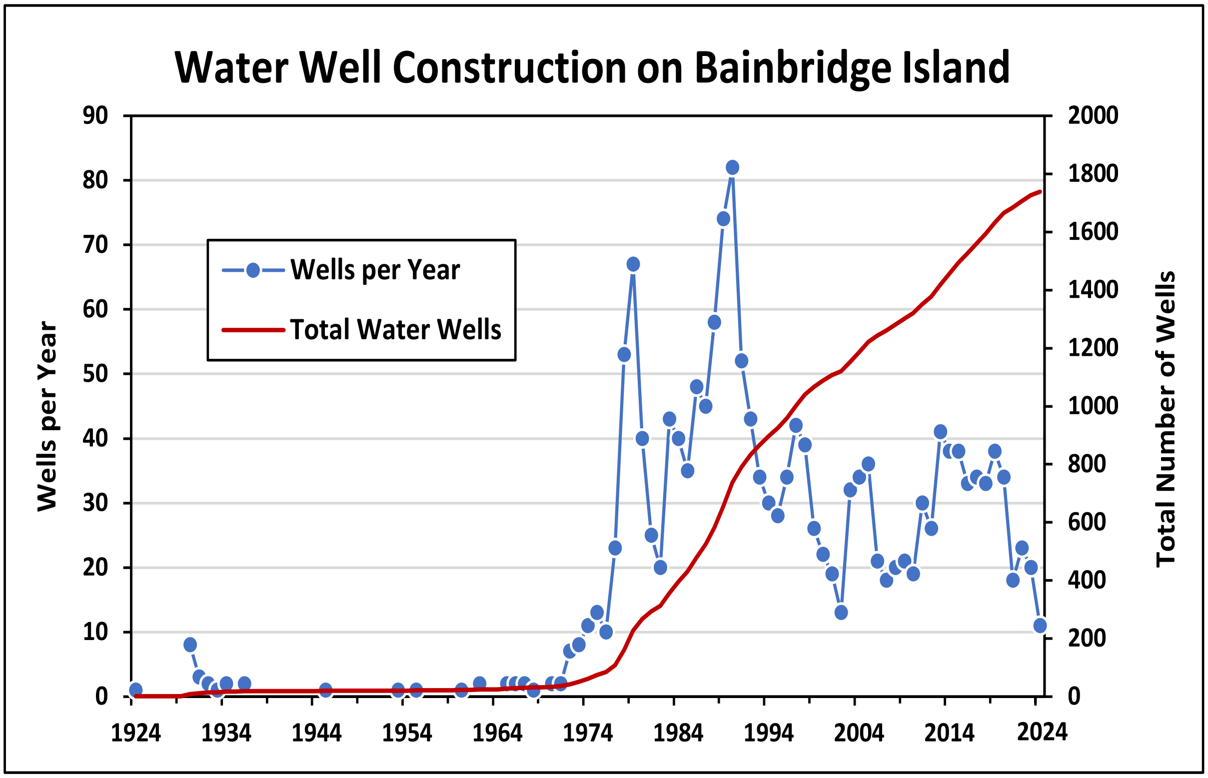


Figure 2-26. Water Well Construction on Banbridge Island 1924-2024
Source: Ecology Well Construction Database 2025.

Figure 2-25 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.

Although it is the best 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.

As noted, this data represents all water supply wells. However, based on experience 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. Most permit-exempt wells used for domestic purposes average around 350-400 gallons per day, with larger amounts during the irrigation season and around 200 gallons per day or less for indoor uses during the winter months.

Figure 2-26 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 ¼ ¼ section (a 40-acre area) the well is reported to be located in. Because there can be multiple wells within a single ¼ ¼ section, locations that include wells are color-coded by the number of wells associated with each location. Although this methods of locating wells is not very precise, patterns of grown and the relative density of wells can be observed plotting the data in this manner.

2.8.2 Current Groundwater Use

Groundwater is used for water supply across the island by public water systems or private water supplies. Public water supply systems are classified based on the number of connections the system provides: Group A Community Water Systems provide water to 15 or more connections and Group B Community Water Systems provide water to 2–14 connections. Private permit-exempt wells typically provide water to one connection, although permit-exempt uses can serve multiple homes up to 5,000 gallons per day.

As expected, more groundwater is used in the summer (in some cases more than twice as much, mostly for irrigation (outside watering for lawns, gardens, landscape vegetation, etc.) as is used in the winter. 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 **Table 2-9**. This data does not account for leaks or irrigation uses. For example, the Derby Downs and Islandwood Estates water system values are not reasonable for water use by ERU and are likely related to errors or other factors.

Table 2-9. Water Use by Public Water System on Bainbridge Island

Water System Name	Water System ID	Res Population	Non-Res Population	Connections	Annual Total Pumping 2022 (Gallons)	Water Use per ERU (Gallons/Day)
Bainbridge Island Child Care Cntrs	05369W	0	45	2	N/A	N/A
BAINBRIDGE ISLAND CITY OF	97650T	7,787	4,642	3,438	255,605,000	204
BAINBRIDGE ISLAND PUB WRKS	07138F	0	36	4	N/A	N/A
BAINBRIDGE IS SADDLE	37950	0	11	1	N/A	N/A
BAINBRIDGE ISLAND SPORTSMENS CLUB	37971	5	10	3	N/A	N/A
BATTLE POINT PARK	47258	0	512	6	N/A	N/A
BILL POINT WATER	06790L	200	3	84	5,606,256	183
BLOEDEL RESERVE	00924Q	2	551	8	N/A	N/A
BUCKLIN	66936L	286	121	121	12,732,200	288
CARDEN COUNTRY SCHOOL	63375	3	0	2		N/A
DERBY DOWNS	70093	30	0	13	4,536,993	956
EAGLE HARBOR MARINA	10327J	17	237	54	N/A	N/A
EAGLEDALE PARK	20809Q	0	51	2	N/A	N/A
EMERALD HEIGHTS	23290U	250	0	112	6,833,376	167
FERNCLIFF	24800B	40	0	18	1,760,240	268
Fieldstone Memory Care Bainbridge	54200N	96	73	1	N/A	N/A
GRAHAM PLACE	25341A	34	0	22	1,403,459	175
HARBOR CREST	01832W	53	0	23	1,419,900	169
HAZEL CREEK MONTESSORI	06916W	0	100	2	N/A	N/A
HIDDEN HEIGHTS	009448	40	0	16	1,723,793	295
ISLAND CENTER COMMUNITY	36098X	0	70	4	N/A	N/A
ISLANDWOOD ESTATES	00588U	40	0	14	4,456,008	871
MANZANITA WATER ASSN	510007	40	0	18	1,044,298	159
MEADOWMEER	532750	897	240	335	28,263,648	231
Montessori Country School AP	086745	0	125	7	N/A	N/A
NORTH BAINBRIDGE WATER CO	599949	4,770	720	1944	147,458,900	208
PHELPS ROAD	63210W	58	0	26	1,326,910	140
PLACE EIGHTEEN HOA	169646	32	0	18	672,200	102
PORT MADISON WATER COMPANY	68750W	233	0	103	11,122,012	296
RAVENS REACH	01031B	42	0	16	1,715,127	293
ROCKAWAY BEACH WATER	734507	175	0	72	7,911,000	301
ROSE AVENUE WATER ASSOCIATION	66932J	53	0	20	1,379,519	189
Seabold Community Hall	AD097J	0	35	1	N/A	N/A
SEABOLD HEIGHTS	769734	36	0	12	N/A	N/A
Seabold United Methodist Church	AC591E	3	187	3	N/A	N/A
SOUTH BAINBRIDGE	81451M	3758	441	1530	163,674,500	293
STRAWBERRY HILL PARK	84623B	0	200	5	N/A	N/A
SUNSET HILLS WATER ASSOC	861209	82	0	35	3,336,500	261
WALDEN WATER	438871	34	0	14	738,100	144

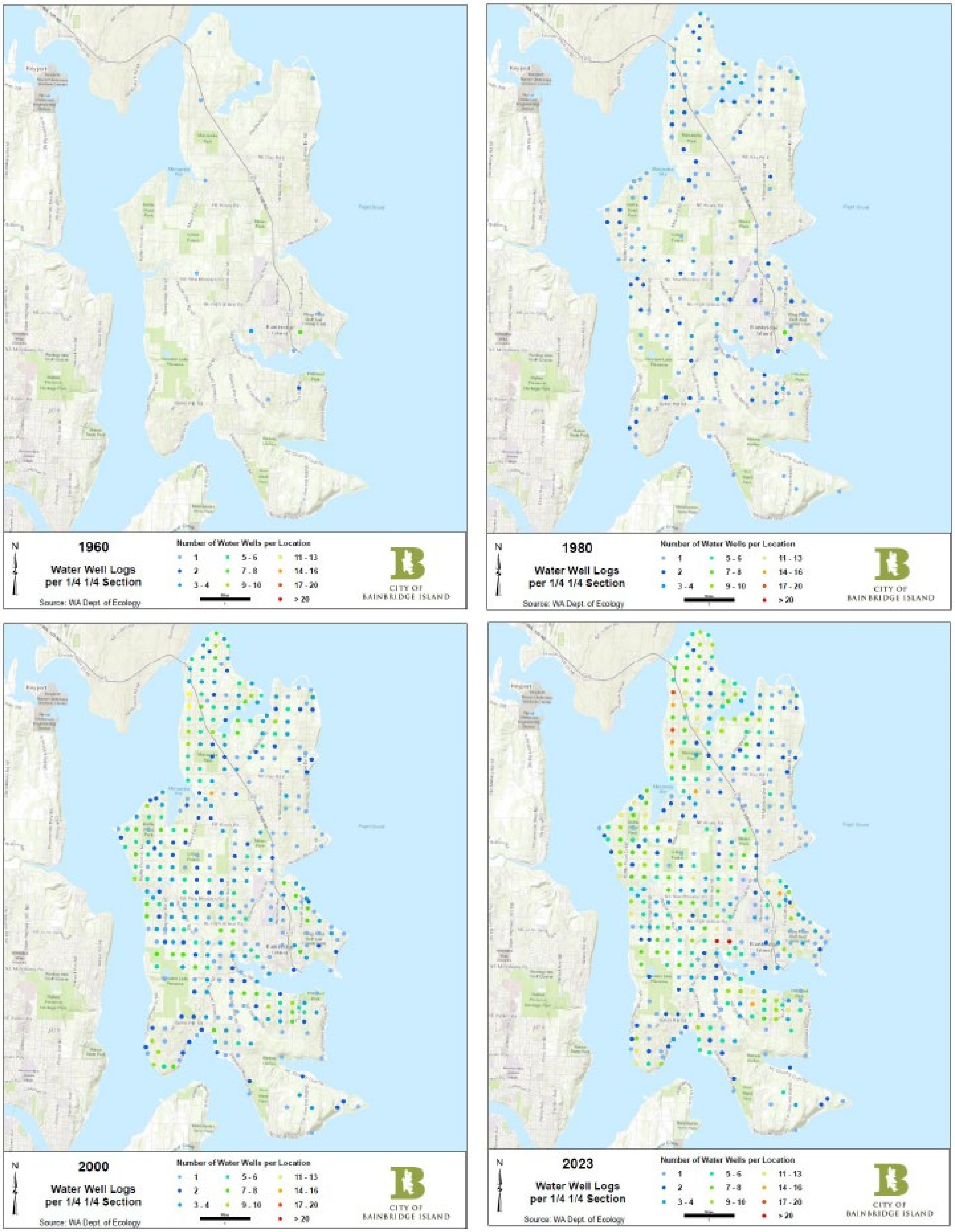


Figure 2-27. Distribution of Water Wells on Bainbridge Island in 1960, 1980, 2000 and 2023
Source: Ecology Well Construction Database 2025

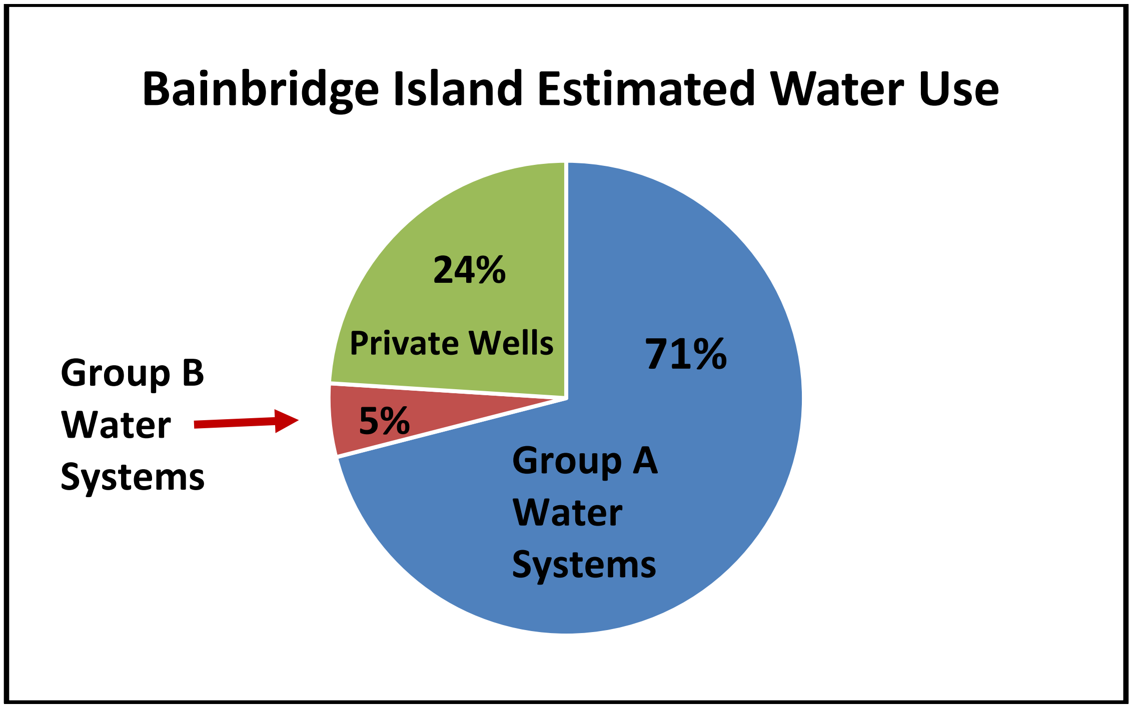


Figure 2-28. Bainbridge Island Estimated Water Use

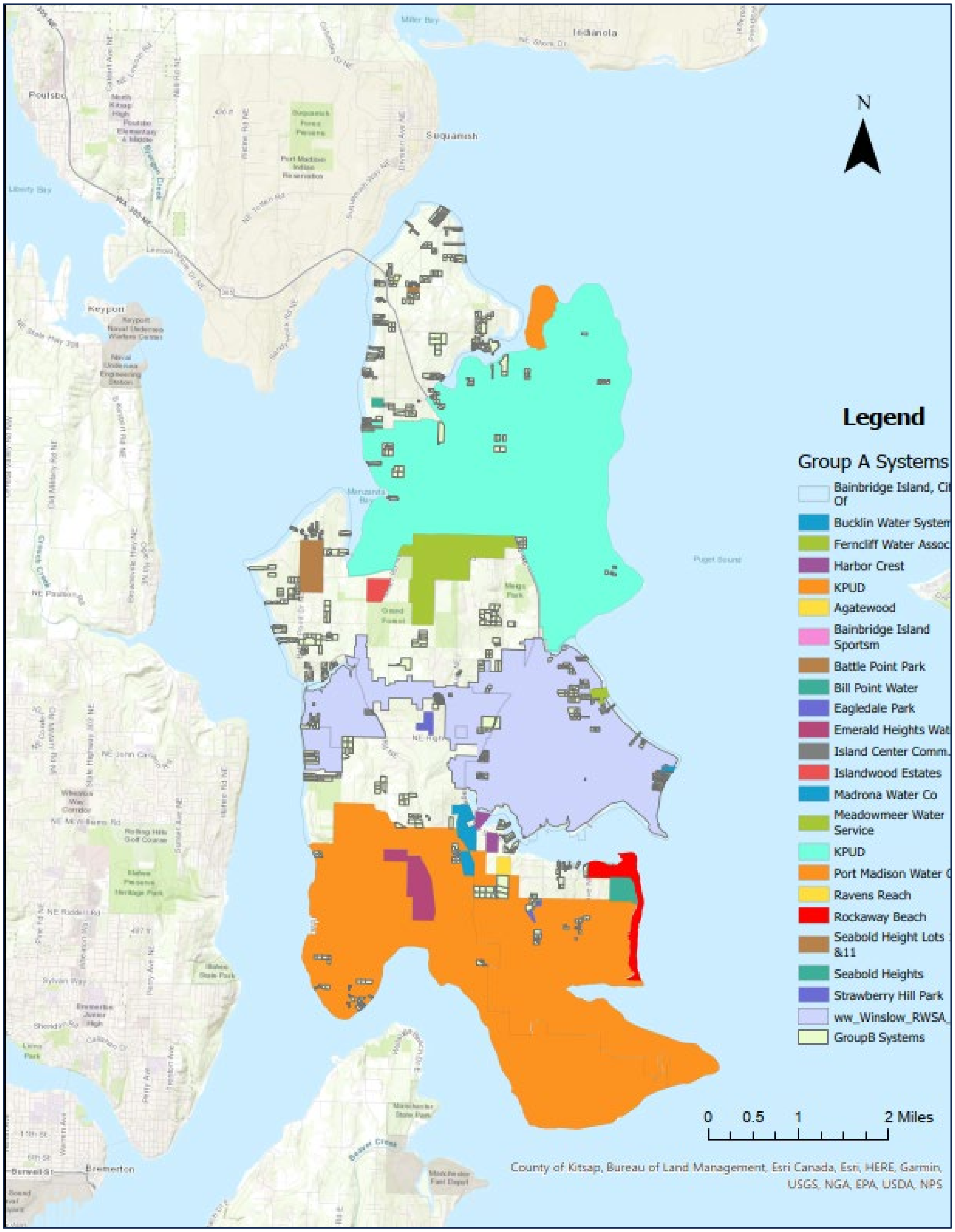


Figure 2-29. Bainbridge Island Water System

Table 2-10. Group A Water Systems

System Name	Number of Wells	Depth (ft bgs)
Bainbridge Island Public Works	1	55
COBI	6	144 to 158
	1	1,014
	2	1,053 to 1058
	1	264
Battle Point Park	1	910
Bill Point Water	4	150 to 161
Bloedel Reserve	1	910
Bucklin Water System	1	244
Carden Country School	1	169
Derby Downs	2	236 to 238
Eagle Harbor Marina	1	140
Eagledale Park	1	185
Emerald Heights Water	6	54 to 84
Ferncliff Water Assoc	1	110
Fieldstone Memory Care (Messenger House)	1	160
Fort Ward Park (inactive, intertie with South Bainbridge)	NA	NA
Graham Place Water System	2	64 to 67
Harbor Crest	1	149
Hazel Creek Montessori	1	48
Hidden Heights	2	77 to 83
Island Center Comm. (inactive)	1	70
Island Utility	3	958to 1015
Islandwood Estates	2	168 to 169
Meadowmeer	4	143 to 213
Montessori Country School Ap	1	306
North Bainbridge Water Co	10	63 to 1342
Phelps Road Water System (Gamble Bay)	2	114 to 133
Place Eighteen	1	140
Port Madison Water Co	3	19 to 79
Ravens Reach	1	180
Rockaway Beach	1	544
Rose Avenue Water Assoc.	2	62 (emergency) 366
Seabold Community Hall	1	214
Seabold Heights	2	74, 259
Seabold United Methodist Church	1	345
South Bainbridge Water	7	143 to 1066
Strawberry Hill Park	1	250
Walden Water System	1	183

Source: Washington State Department of Health Drinking Water Program

2.9 GROUNDWATER SUPPLY NEEDS PROJECTIONS

2.9.1 Population Projections

The 2021 Kitsap County Buildable Lands Report (Kitsap County 2021) provides projections for Bainbridge Island's commercial and industrial employment and housing units in accordance with the Growth Management Act (GMA) requirements outlined in RCW 36.70A.215. The report evaluates development trends from 2013 to 2019, including population growth, by comparing them to Kitsap Countywide Planning Policies and the Bainbridge Island Comprehensive Plan. It projects forward to a 2036 planning horizon to assess available land capacity to accommodate projected growth. The report also distinguishes growth patterns between urban centers and rural areas, estimating that achieving the 2036 residential growth target for Bainbridge Island will require accommodating an additional 3,540 residents, primarily within residential zoning areas.

Building on this, under House Bill 1220 (HB 1220), passed by the Washington State Legislature in 2021, Bainbridge Island is now required to plan for a total additional population of 4,524 residents by 2044. This figure exceeds the 2036 projection in the Kitsap report and reflects the updated growth targets and housing element requirements mandated by HB 1220. To meet this population increase, Bainbridge Island must plan for approximately 1,977 new housing units by 2044. These requirements are driving updates to the City of Bainbridge Island's Comprehensive Plan and the Winslow Subarea Plan, both currently under development, with a Draft Environmental Impact Statement already reviewed by the community.

For additional context, the Kitsap County Coordinated Water System Plan (Kitsap County 2005) projected a 2020 population of 25,747 residents for Bainbridge Island, covering Forecast Analysis Zones 9913 (Winslow) and 9914 (rest of the island), all within a single urban growth area. Although the actual 2020 population was slightly lower at 24,825, the plan projected daily water demand at 3,424,351 gallons based on an assumed per capita use of 133 gallons per day (approximately 1.27 billion gallons annually). These projections remain relevant for understanding infrastructure and resource needs as the island plans for future growth under the GMA and HB 1220 frameworks.

Further analysis of projected growth patterns reveals that population growth on Bainbridge Island will not be evenly distributed across the island. The Winslow area, corresponding to Census Tract 909 (formerly Zone 9913), is expected to capture approximately 56% of the island's total population increase through 2040. This proportion is notably higher than the 14% anticipated in the northern tracts (907/908) and the 30% projected for the southern tract (910). Winslow's designation as the island's principal growth center underlies this trend, reflecting both historical development patterns and its capacity to accommodate denser housing.

Annual growth projections also suggest that, starting from a 2023 baseline of approximately 25,200 residents, the island's total population may reach:

- 28,800 under a low-growth scenario (212 additional residents/year),
- 30,600 under a medium-growth scenario (315/year), and

- 32,300 under a high-growth scenario (419/year) by 2040.

Looking even further ahead, growth is expected to continue steadily beyond 2044. Current long-range regional projections estimate that by 2060, Bainbridge Island could reach a total population of approximately 30,000 residents, assuming a moderate and consistent growth rate. This continued upward trend underscores the need for strategic, coordinated planning to ensure adequate housing, infrastructure, water supply, and resource protection while preserving the island's character and environmental quality (Puget Sound Regional Council, 2023).

2.9.2 Land Use Projections

As discussed in Section 2.5.6, Bainbridge Island is primarily a residential community. Just over 9,600 of the total 17,779 acres (54%) of the Island are developed for residential land uses. Much of the remaining land has been purposely kept undeveloped (City of Bainbridge Island Comprehensive Plan, 2017). With projections of 4,524 more residents by 2044 and up to around 30,000 by 2060, the island will need more housing mainly within existing residential areas. This means growth will likely come from adding homes on smaller lots, infill, or limited expansion, while protecting open spaces and natural areas. This growth will increase demand for infrastructure like roads, water, and services. Because commercial and industrial land is limited (about 3%), Bainbridge will mostly remain a residential community with little new local employment.

City planning efforts will be key to managing growth in a way that balances housing needs and environmental preservation. Current land-use is summarized in **Table 2-11**.

Table 2-11. Current Land Use Bainbridge Island

Land use	Acres	Percentage of total acres
Residential/open	15,882	89%
Commercial/industrial /agricultural	489	3%
Recreational	1,408	8%
Totals	**17,779**	**100%**

Projected land use as described in the COBI is provided in the Future Land Use Map (**Figure 2-29**).

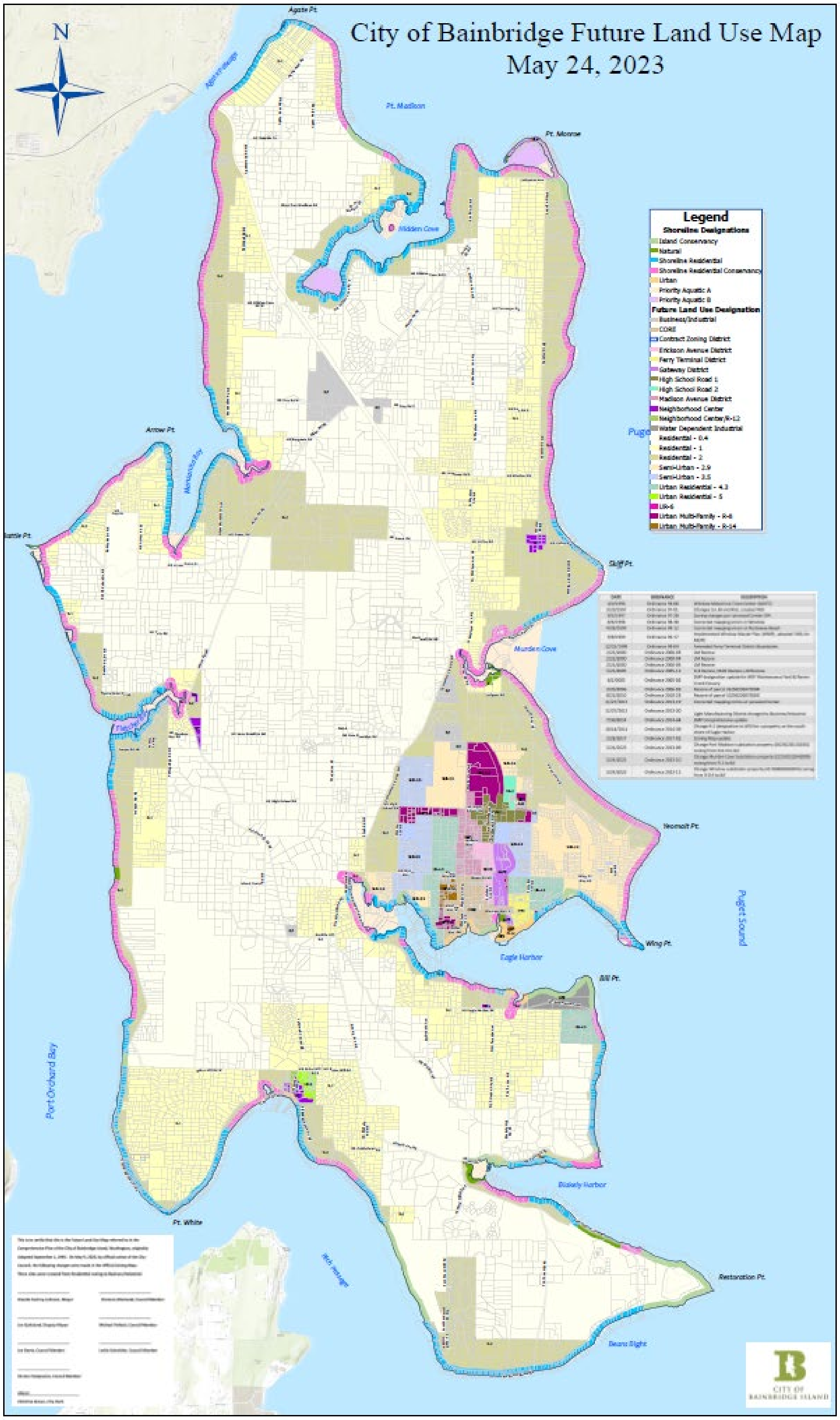


Figure 2-30. Future Land Use
Source: Bainbridge Island 2025

2.9.3 Climate Change Projections

The City of Bainbridge Island Climate Action Plan (COBI 2020) described the impacts of climate change relevant to Bainbridge Island in terms six areas (temperature, precipitation/extreme weather, sea level rise, vegetation changes, ocean acidification, and slope stability). Three of these areas potentially impact the groundwater system: increasing temperature, projected changes in the timing and intensity of precipitation, and sea-level rise.

Average annual air temperatures are projected to increase between 4 and 5.5 °F by mid-century with continuing increases in the following years. The increases are anticipated to impact all seasons with the greatest impact in the summer months. The increased temperatures will likely result in increased demand for water supply for both human and natural systems and will affect terrestrial, freshwater, and marine ecosystems. Precipitation is projected to vary slightly more from year to year with anticipated declining precipitation in summer and more frequent and intense precipitation events in the winter. The more intense events may result in greater runoff and less infiltration (recharge) into the groundwater system.

Climate change predictions for streams within WRIA 15 were not completed. Generally, increasing winter, spring and fall precipitation, decrease in summer with increasing temperature will likely result in decreasing streamflow in summer.

Sea level in Central Puget Sound has risen by more than 8 inches during the past century. Continued warming is expected to accelerate rising sea levels over the next century and beyond. The most likely projections (i.e., central estimates for RCP 8.5 scenario) indicate that relative to average sea level during the period of 1991–2009, Bainbridge Island will experience an additional sea level rise of about:

- 5 inches by 2030
- 10 inches by 2050
- 28 inches by 2100
- 46 inches by 2150

The projected sea level rise could promote saltwater intrusion that could affect groundwater systems, marine riparian vegetation, and low-laying septic systems near the shoreline.

In summary, stresses to water resources include:

- Surface water; greater extremes in flow and runoff, longer dry periods, and higher stormwater flows; aquatic species may experience habitat loss and changes in timing of flows

- Groundwater; reliance on Sole Source Aquifer for water supply. Human development has altered natural recharge patterns which could be further impacted by changes in nature of precipitation. Stressors include:
  - Increased runoff and decreased recharge due to more extreme precipitation events
  - Dryer summer periods, which will particularly impact shallow groundwater and associated surface water
  - Warmer temperatures resulting in increased water demand and evapotranspiration
  - Sea level rise increasing the possibility of saltwater intrusion into shallow aquifers

Note: Climate models project wetter winters (2–7% increase) and drier summers (6–8% decrease) in the Pacific Northwest by mid-century (Mote 2013; IPCC 2013).

2.10 MAPPING SEA LEVEL RISE ON THE ISLAND

In 2023, the COBI selected a consultant to conduct a Sea Level Rise Flooding Vulnerability and Risk Assessment for the Island. This project will result in an online GIS-based map showing existing and future flood vulnerability. The final report will inform capital facilities planning for the 2024 Comprehensive Plan Periodic Update and summarize vulnerabilities for future adaptation efforts. Deliverables from this project are due by June 2024 (CAP 2024).

2.11 ASSESSING SEA LEVEL RISE ADAPTATION STRATEGIES

The COBI applied to the Building Resilient Infrastructure and Communities program to assess sea level rise adaptation strategies for Manitou Beach Drive. This project was advanced to the next stage for potential award by the State in mid-2023. This project was intended to identify mitigation and adaptation strategies for addressing shoreline roads impacted by sea level rise in accordance with best practices for both roadway safety and shoreline management (CAP 2024). The federal government recently canceled the grant.

3. FACTORS EFFECTING MANAGEMENT STRATEGIES

The following knowledge and data gaps have been identified and addressed as part of developing the GWMP:

- COBI EWLs criteria have been reviewed and revised as appropriate.
- Monitoring well network was reviewed for both quality and quantity.
- Groundwater model was updated (latest data, groundwater/surface water interaction, climate change impacts).
- Stormwater management programs and plans have been linked.
  - Annual variations in aquifer recharge have been projected.
  - Investigation was undertaken to determine how climate change poses multiple risks to groundwater processes including changes in quantity and timing of recharge, and other significant hydrogeologic factors.

3.1 COBI EARLY WARNING LEVELS

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 expand previous monitoring efforts (Aspect 2009). The monitoring network has grown substantially from its initial 43 wells to 87 wells, demonstrating the COBI's commitment to comprehensive groundwater surveillance. Currently, 49 wells undergo annual assessment as part of the COBI's groundwater monitoring program, with particular focus on seawater intrusion indicators, while groundwater levels are tracked in 76 of the wells to observe trends in aquifer conditions over time.

The program maintains rigorous monitoring standards, including the original 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 Early Warning indicator (Aspect 2009). These thresholds trigger detailed evaluations and potential management responses when concerning trends emerge.

Historical monitoring has identified several areas that warrant closer attention. In the FBA near Eagledale, significant water level changes have been observed, with some wells showing declining trends (Aspect 2009). These declines may be attributed to ongoing groundwater withdrawals rather than an exceedance of the aquifer's recharge rate. As pumping rates stabilize, the potentiometric surface of the aquifer is also expected to reach equilibrium. High-capacity wells in this aquifer, specifically Sands Road 1, Sands Road 2, and North Bainbridge Well 9, have historically shown declining water level trends, though some have stabilized since 2005.

The COBI's groundwater monitoring now integrates with broader water resource management initiatives. Approximately 28% of groundwater discharge flows to streams, 53% moves to other natural features including the marine environment and deeper aquifers off-island, and 19% is extracted through wells. This understanding of the water budget helps inform sustainable management practices and future planning efforts.

Current monitoring efforts particularly focus on climate change impacts and their implications for groundwater resources. The program recognizes that climate change poses multiple risks to groundwater processes, including potential reductions in recharge and changes in recharge timing. This forward-looking approach helps ensure the program remains responsive to emerging challenges while maintaining its core mission of protecting the island's water resources.

The monitoring program benefits from strong collaboration between multiple stakeholders, including private well owners, water systems operators, KPUD staff, and COBI Public Works. All collected data is centralized in a single database that supports enhanced analysis capabilities and regular updates of water levels, chloride concentrations, production volumes, and rainfall data. This comprehensive approach to data collection and analysis continues to serve as the foundation for ensuring sustainable water resources for the island's future.

Through this integrated monitoring and management approach, Bainbridge Island maintains vigilant oversight of its groundwater resources while adapting to new challenges and incorporating improved understanding of the hydrogeologic system. The program's evolution from its 2006 origins demonstrates both its resilience and its capacity to adapt to changing conditions while maintaining its essential role in protecting the island's water resources.

3.2 MONITORING WELL NETWORK REVIEW (QUANTITY AND QUALITY)

Bainbridge Island’s current groundwater monitoring network includes a combination of dedicated monitoring wells and pumping wells. This network has evolved over time to serve multiple functions, including tracking groundwater levels and assessing water quality conditions across the island’s hydrogeologic systems. As of the most recent update, 93 locations have been regularly monitored since 1984, contributing a robust dataset of over 9,500 water level measurements (EA 2025). These data have been foundational for understanding aquifer behavior, calibrating groundwater models, and informing resource management decisions.

The monitoring network provides especially valuable insights into the island’s deeper aquifers—the Sea Level Aquifer (SLA), Glacial Marine Aquifer (GMA), and Fletcher Bay Aquifer (FBA)—which are key sources for municipal water supply. Major production areas such as the Head of Bay wellfield, Sands Road cluster, and Island Utility wells have benefited from long-term monitoring. Observed declines in groundwater elevations at critical locations, including South Bainbridge and the Head of Bay wellfield, suggest potential vulnerability to seawater intrusion if groundwater levels fall below sea level in the future.

Despite its strengths, the current monitoring network has several important data and knowledge gaps that limit its effectiveness for long-term water resource planning. While water level data coverage is relatively strong, the network lacks sufficient capacity to directly track chloride migration or other indicators of seawater intrusion. This limits the ability to detect or confirm advancing saline fronts in coastal aquifers. Similarly, although five stream gages (Springbrook, Cooper, Ravine, Doe–Quads–Sake–Quub [Murden], and Manzanita) provide limited surface water data, streamflow monitoring remains sparse across the island.

As a result, the understanding of surface water–groundwater interactions—especially seasonal dynamics and baseflow contributions—remains incomplete.

Additionally, the network provides limited spatial resolution in certain areas, particularly within some upland recharge zones and along the island's eastern shoreline, where shallow and intermediate aquifers may be underrepresented. There is also limited water quality monitoring beyond chloride, such as nutrient concentrations or emerging contaminants, which could be important for future assessments of aquifer health and land use impacts.

While the groundwater monitoring data have been critical for developing and calibrating the island's numerical groundwater flow model, the model itself is only as strong as the underlying dataset. Expanding spatial coverage, integrating targeted water quality parameters, and enhancing streamflow monitoring would significantly improve the island's capacity to model future conditions and assess risks under climate change, land use shifts, or increased groundwater demand.

3.3 GROUNDWATER MODEL UPDATE

EA has updated and recalibrated groundwater flow model for COBI that addresses most of the original project objectives with some modifications. The model underwent several key revisions, including a shift from MODFLOW-USG back to MODFLOW-NWT after determining that the unstructured grid was causing unnecessary processing delays without providing additional benefits (EA 2025). While the final model uses a 500 by 500-foot cell spacing rather than the originally proposed 400-foot spacing, this rectilinear grid structure proved effective for the analysis needs (EA 2025).

The model successfully incorporated extensive current data, including spatially variable precipitation patterns from the PRISM dataset and detailed extraction records from public water suppliers (EA 2025). When historical extraction data was not available, the model applied proportional growth rates based on water system trends. The calibration process was particularly robust, utilizing 93 monitoring locations that provided 9,574 individual water level measurements across space and time (EA 2025).

For future predictions, the model evaluated three distinct planning scenarios that considered various combinations of sea level rise, recharge rates, and production increases. These scenarios ranged from conservative to more extreme projections, with sea level rises of 2.8 to 6.9 feet, recharge changes from 0% to -20%, and production increases from 122% to 167% (EA 2025). This comprehensive approach allowed for a thorough assessment of potential future conditions under different climate and population growth scenarios.

The model results revealed varying impacts across different aquifer systems. The Qva aquifer showed minimal impact under all scenarios, largely due to the absence of large water system extraction and the offsetting effect of return water (EA 2025). However, the SLA exhibited negative impacts near shoreline well fields, particularly around the Head of the Bay and South Bainbridge wellfields. The deeper GMA and FBA units demonstrated significant drawdown, especially near major municipal supply wells. While these deeper units showed substantial drawdown, they maintain some protection from seawater intrusion due to thick clay and silt aquitards (EA 2025).

The groundwater model's findings can be further detailed with specific scenario impacts and management recommendations. For the immediate 20-year planning period, the model indicates that aquifers can sustain increased withdrawals, though drawdown is most pronounced in deep aquifers around production wells. This is particularly evident at the Sands Road wells in the FBA, where the High-Mid Impact scenario projects approximately 40 feet of average drawdown. The model's sea level rise projections were based on detailed scenarios, with the High Emissions (RCP 8.5) scenario showing potential rises of 2.8 feet (50% probability) to 6.9 feet (1% probability) over 100 years. Population growth projections were equally comprehensive, with the 2023 baseline population of 25,108 expected to increase to between 46,380 (84% increase) and 70,010 (178% increase) over 100 years, depending on the growth scenario.

Regarding specific aquifer impacts, the Quaternary Vashon Advance Aquifer shows relatively modest changes, with approximately 0–10 foot decreases in groundwater elevation across much of the island. Stream systems are also affected, with baseflow reductions of up to 0.3 cubic feet per second, particularly in the Fletcher Bay and Eagle Harbor watersheds.

To address these projected impacts, several management actions have been recommended. These include exploring new production wells in the northern half of the island and developing interties between larger municipal water systems. Other recommendations involve implementing comprehensive monitoring programs for both groundwater and surface water (quantity and quality), protecting recharge areas, and considering mitigation actions such as stormwater and reclaimed water infiltration. The model suggests that while public water supply appears reliable in the near term, significant infrastructure investment may be required for long-term sustainability. Conservation and public education programs are recommended across all scenarios.

This analysis reinforces the model's value as a management tool while providing more specific details about projected impacts and recommended mitigation strategies. The varying degrees of impact across different aquifers and timeframes highlight the importance of adaptive management approaches based on ongoing monitoring and assessment. The model results also suggest that while seawater intrusion remains a long-term concern, the aquifer systems maintain some resilience, particularly in the shorter 20-year planning horizon. However, this should be confirmed through continued long-term monitoring, especially given the significant drawdown projected for deeper aquifers near major municipal supply wells.

3.4 LINK WITH STORMWATER MANAGEMENT PROGRAMS AND PLANS

COBI's designation as a Sole Source Aquifer underscores the importance of managing stormwater to protect groundwater while supporting natural recharge. While GSI and LID are promoted as essential tools, there remain data gaps in understanding how effectively these systems mimic natural watershed functions under island-specific conditions. More localized performance monitoring is needed to assess long-term infiltration, pollutant removal, and recharge impacts—especially as climate, soils, and development patterns vary across the island. Additionally, uncertainty persists regarding the full hydrologic impacts of widespread GSI implementation over time, particularly in areas with shallow groundwater or limited permeability.

3.4.1 Stormwater Policy Framework and Technical Guidance

COBI has developed a strong regulatory foundation to support LID and GSI, but gaps remain in understanding how well these policies are implemented on the ground and whether they achieve intended outcomes. For example, while the BIMC requires site assessments and LID integration, there is limited data on the frequency and consistency of compliance. Furthermore, although COBI has adopted the SWMMWW as its guiding document, uncertainty exists around how well the manual's assumptions and recommendations translate to the island's unique geology, hydrology, and land use. Ongoing efforts to identify and eliminate regulatory barriers to LID would benefit from more targeted studies on how current permitting and design review processes support or hinder optimal GSI design and placement.

3.4.2 LID Strategies and Benefits

LID practices offer important hydrologic and water quality benefits, but questions remain about how these systems perform under real-world, long-term conditions specific to Bainbridge Island. For instance, there is limited empirical data on infiltration rates across different soil types and how seasonal groundwater fluctuations affect performance. While SWMMWW provides theoretical expectations for processes like evapotranspiration, filtration, and storage, more local data is needed to validate these outcomes, especially for critical features like bioretention and vegetated swales. Understanding how GSI functions during extreme storm events is also a knowledge gap, as many systems are not designed or monitored for high-flow resilience or recovery.

3.4.3 Preserving Natural Systems

Although preserving native vegetation and drainage patterns is a priority, COBI faces challenges in quantifying how much land must remain undisturbed to preserve hydrologic function across different sub-watersheds. The 65–75% undisturbed cover recommendation (SWMMWW 2024) is based on generalized watershed modeling, and more localized studies could help refine what thresholds are appropriate for specific aquifers or recharge zones on the island. There are also data limitations related to mapping and characterizing natural drainage features, depressions, and high-permeability soils. Better geospatial tools and updated inventories are needed to support land use decisions that prioritize natural systems and identify critical recharge areas.

3.4.4 Implementation, Maintenance and Community Incentives

While COBI emphasizes proper implementation and maintenance of GSI and LID, it is not always clear how consistently these practices are maintained after construction, especially on private properties. There is a lack of comprehensive performance tracking or condition assessments for decentralized GSI systems across the island. Additionally, more data is needed on the effectiveness of public outreach, incentives, and rebate programs. Are they reaching the right audiences? Are they driving meaningful adoption? COBI's monitoring well network provides valuable groundwater data, but gaps may exist in spatial coverage, vertical resolution between aquifers, and the integration of water quality monitoring with stormwater source controls. Improved coordination between maintenance tracking, incentive evaluation, and groundwater trends would help strengthen feedback loops.

3.4.5 Climate Change Risks and Groundwater Impacts

Climate change introduces multiple uncertainties that complicate stormwater and groundwater planning. Although COBI recognizes potential threats like more intense rainfall, altered recharge patterns, and saltwater intrusion, the magnitude and timing of these impacts remain poorly constrained. For example, how will changes in evapotranspiration affect vegetation and water demand? Which areas are most vulnerable to reduced recharge or aquifer drawdown? More refined climate-hydrologic models are needed that incorporate island-specific parameters such as vegetation shifts, urban expansion, and soil saturation dynamics. Furthermore, there is insufficient data on groundwater extraction rates, especially from private wells, and how this cumulative use may interact with sea level rise and drought conditions.

3.4.6 Precipitation Patterns and Recharge Insights

While precipitation is known to strongly influence groundwater recharge, the exact relationship between rainfall intensity, duration, and infiltration on Bainbridge Island is not well quantified. The 2007 University of Washington review highlights regional trends, but additional localized modeling and field studies are needed to understand how rainfall becomes runoff versus recharge under current and future conditions. For instance, how much of a storm event infiltrates versus bypasses GSI systems during high-flow events? How do seasonal changes in soil moisture and vegetation affect recharge efficiency? Uncertainty also remains regarding the potential for increased stormwater intrusion or contamination during prolonged wet periods or back-to-back storm events.

3.4.7 Sustainability Outlook

Bainbridge Island's long-term water security depends on fully integrating stormwater management with land use, climate adaptation, and groundwater protection. However, there are key information gaps that limit the ability to make data-driven decisions. These include incomplete understanding of LID effectiveness at scale, limited insight into cumulative aquifer stresses, and uncertainty around the timing and severity of climate impacts. Addressing these gaps will require expanded monitoring, better integration of modeling tools, and ongoing collaboration with researchers, property owners, and regional partners. Without filling these data voids, the community may struggle to ensure that current stormwater strategies are sufficient to protect its Sole Source Aquifer under future conditions.

4. PROBLEM DEFINITION/WATER QUALITY AND QUANTITY ISSUES

Bainbridge Island's groundwater-dependent water supply is increasingly vulnerable to a range of land and water use activities that threaten both water quality and quantity. As the sole source of potable water for residents, the island’s aquifer system faces increased stress from urban development, population growth, and climate-related stressors. Land use practices—including commercial operations, municipal discharges, industrial activities, waste disposal, stormwater runoff, and agricultural practices—can introduce pollutants or alter recharge patterns, directly impacting aquifer health. Additionally, improperly constructed, aging, or abandoned wells may act as direct conduits for surface contamination into groundwater, further complicating management efforts.

Water quality concerns are heightened by potential sources of contamination such as leaking underground storage tanks, pesticide and fertilizer use, failing septic systems, and historical landfills. Stormwater runoff, particularly during high-intensity rain events, can mobilize pollutants across impervious surfaces, increasing the risk of groundwater contamination if not adequately managed through infiltration or treatment systems.

On the water quantity side, declining water table levels and growing seasonal demand—especially during summer months when recharge is limited—are leading to measurable drawdowns in critical aquifers. This is especially concerning in areas where groundwater supports baseflows in streams and wetlands, contributing to ecological health. Seawater intrusion has also emerged as a significant issue in low-elevation coastal wellfields, particularly in southern and northeastern parts of the island, where groundwater elevations are projected to fall below sea level within 50–100 years under current extraction trends.

These issues are compounded by uncertainties in aquifer connectivity and recharge rates, especially under future climate scenarios predicting warmer temperatures and altered precipitation patterns. Together, these risks underscore the urgent need to define and manage threats to groundwater sustainability through integrated land and water resource planning, robust monitoring, and long-term policy coordination.

4.1 LAND USE IMPACTS ON GROUNDWATER QUALITY AND QUANTITY:

4.1.1 Current Water and Sewer Systems

4.1.1.1 Water Systems

Bainbridge Island's public water infrastructure consists of a complex network of systems serving its residential and commercial needs. The island hosts 33 active Group A water systems and 146 active Group B water systems, collectively serving a population of 28,914 residents. Group A systems are the primary water providers, supplying approximately 71% of the island’s total water use, followed by private wells at 24%, and Group B systems at 5% (**Figure 2-28**). 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). South Bainbridge also consolidated the Bill Point water system in 2023, further expanding the reach and capacity of Group A service areas.

4.1.1.2 City of Bainbridge Island Water System

The COBI operates two water systems, the Winslow Water System and the Rockaway Beach Water System. The Winslow Water System service area, shown in **Figure 2-4** 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 Low Pressure Zone is served by six active pressure reducing valve stations. Storage is provided by the two High School Reservoirs in the High Zone with a total capacity of 2.5 MG. A third reservoir, the Grand Reservoir, is currently out of service. The High School Reservoirs supply the High 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).

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 2-5**. The capacity of the Taylor Avenue well is approximately 43 gpm (Carollo 2017).

4.1.1.3 Kitsap Public Utility District Water Systems

Among these systems, two major water providers operated by KPUD stand out. 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).

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).

All drinking water on Bainbridge Island comes from on-island groundwater extraction wells, making these aquifers Sole Source Aquifers (KPUD 2020). This reliance on groundwater highlights the critical importance of sustainable management practices. The systems are designed to handle both current demands and future growth, with careful monitoring of water quality and system capacity (KPUD 2020). Regular water quality testing, infrastructure improvements, and long-term planning ensure these systems can continue to provide reliable water service to the island's growing population.

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).

4.1.1.4 Wastewater Treatment

The Bainbridge Island Wastewater Treatment Plant (WWTP), located in the downtown core area, serves as the primary wastewater treatment facility for the COBI. 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 5. 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 COBI 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, there are 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). The COBI is actively considering these alternatives as part of its water resource management strategy, though careful evaluation of site-specific conditions would be necessary to determine the most appropriate locations for managed aquifer recharge or other reuse applications.

Expanded use of reclaimed water for irrigation and aquifer recharge would directly support groundwater quantity by reducing reliance on groundwater withdrawals, while also offering potential indirect benefits to groundwater quality by sustaining baseflow and minimizing the risk of saltwater intrusion in coastal aquifers. Furthermore, any future implementation of managed aquifer recharge or reclaimed water distribution must be carefully designed to ensure protection of groundwater quality, particularly with respect to nutrient loading, disinfection byproducts, and subsurface geochemical compatibility.

4.1.1.5 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 in the island's northern region, 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.

4.1.1.6 Cleanup Sites

A major contaminated site on Bainbridge Island is the Wyckoff/Eagle Harbor Superfund Site, located at Pritchard Park on the island's southern shoreline. Decades of industrial activity, particularly wood treatment operations, resulted in the release of over 650,000 gallons of toxic chemicals—primarily creosote and other hazardous substances—into the soil and groundwater. This contamination has posed serious threats to both groundwater resources and the surrounding marine ecosystem. The site has a long history of hazardous waste issues, and cleanup efforts by the Environmental Protection Agency (EPA) are ongoing. These efforts have included soil removal, groundwater treatment, and containment measures, with significant federal funding allocated to mitigate remaining contamination and prevent further spread.

4.1.1.7 Commercial/Industrial

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 2025 or early 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 (CFLs). However, they do not accept commercial or other hazardous waste.

4.1.2 Agricultural

Agriculture along with logging were the main industrial activities on Bainbridge Island in the mid-1800s.[1] 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. Similarly, recreational areas and parks present their own challenges through septic systems, fertilizer use, and the handling of various hazardous and non-hazardous materials.

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.2 The Washington State Department of Agriculture has a pesticide waste disposal program where agricultural pesticides are collected and properly disposed of free of charge.

4.1.3 Residential (Water Use, Recharge, On-Site Septic Systems)

Currently, over 90% of land on Bainbridge Island is designated as “conservation area”, intended to minimize the footprint of development, as well as conserve natural open space and ecosystems, including aquifers.[3] The only development permitted in these conservation areas is residential, mostly single family detached housing, and most of which utilize on-site septic systems as opposed to sanitary sewer connections. These septic systems have potential to contaminate groundwater if not managed properly. Maintaining an inventory of these systems and encouraging regular maintenance of on-site septic systems will ensure proper function and minimize risk of leaking or contamination.

Bainbridge Island’s residents depend on the single-source aquifer for all of their potable water needs. With the Growth Management Act and the introduction of HB 1220, the Island’s population is required to increase which will inevitably lead to increased water usage and higher extraction rates. However, current groundwater models show that the Island’s aquifers have sufficient capacity to support increased population growth even beyond the alternatives introduced in the COBI 2024 Draft Comprehensive Plan Update and Winslow Subarea Plan Update.

Bainbridge Island’s current draft Comprehensive Plan update indicates that an increase in residential development will be necessary to accommodate population growth projections, with a legally required 1,977 additional housing units by 2044 including affordable and

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[1] City of Bainbridge Island 2024 Draft Comprehensive Plan Periodic Update and Winslow Subarea Plan Update Environmental Impact Statement, page 3.1-9, 2024.
[2] Chapter 16.30 PEST MANAGEMENT AND. (n.d.). https://www.codepublishing.com/WA/BainbridgeIsland/html/BainbridgeIsland16/BainbridgeIsland1630.html
[3] City of Bainbridge Island 2024 Draft Comprehensive Plan Periodic Update and Winslow Subarea Plan Update Environmental Impact Statement, page 1-1, 2024.

multi-family housing.[4] Increased development adds additional impervious surfaces which can affect groundwater recharge by limiting the amount of rainfall and precipitation that can be absorbed into the ground. However, multi-family housing has a smaller footprint per unit compared to the single-family detached housing that currently makes up the majority of Bainbridge Island's housing supply. Additional multi-family units can assist Bainbridge Island in meeting its housing goals as set by HB 1220 while minimizing additional impervious surfaces introduced to the Island.

4.1.4 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, which oversees over 1,300 acres across the community (SWMMWW, 2024). 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 COBI addresses these risks by discouraging the installation of septic systems in stormwater dispersion areas and requiring proper management of stormwater runoff to avoid contamination near drainfields (SWMMWW, 2024).

To safeguard groundwater, the COBI 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.

4.1.5 Open Space

Open spaces significantly influence water quality and environmental conditions through various mechanisms. Urbanization and development of previously open areas cause substantial changes in water temperature, particularly when trees and shrubs are removed both within and outside riparian areas. This removal allows direct heating of impervious

[4] City of Bainbridge Island 2024 Draft Comprehensive Plan Periodic Update and Winslow Subarea Plan Update Environmental Impact Statement, page 1-2, 2024.

surfaces and exposed water surfaces, raising temperatures above healthy thresholds for aquatic life (SWMMWW 2024).

The conversion of open space to developed areas affects groundwater systems in multiple ways. Urbanization contributes to excessive summer stream temperatures through reduced groundwater recharge due to impervious surfaces. This reduction means cool groundwater inputs to streams are diminished year-round. There's also concern about the replacement of warmer groundwater inputs with colder surface runoff during colder periods, which may have biological impacts (SWMMWW 2024).

Vegetation in open spaces plays a crucial role in environmental protection. Native plants and hardy cultivars, when properly placed, can tolerate local climate and biological stresses without requiring nutrient or pesticide applications in properly designed soil mixes. These plants can be used exclusively or in combination with hardy cultivars that do not require chemical inputs. Natural plant associations often grow well together given specific moisture, sun, soil, and plant chemical interactions (SWMMWW 2024).

The preservation of open spaces requires careful planning and protection measures. For sites with native soil and vegetation protection areas, a survey of existing native vegetation cover must be conducted by a licensed landscape architect, arborist, or qualified biologist to identify forest areas and develop protection plans. These preserved areas should be placed in separate tracts or protected through recorded easements for individual lots (SWMMWW 2024).

Development near open spaces must consider several key factors to minimize environmental impact (SWMMWW 2024):

- Fitting development to the terrain to minimize land disturbance
- Preserving areas with natural vegetation, especially forested areas
- Locating impervious areas over less permeable soil
- Maintaining and utilizing natural drainage patterns
- Clustering buildings to maximize open space preservation

The impact of open space conversion to development can 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.

To protect open spaces and minimize environmental impact, proper management practices must include consideration of (SWMMWW 2024):

- Expected pollutant loadings and plant tolerance
- Adjacent plant communities and invasive species control

- Habitat value for various insects and birds
- Visual buffering and aesthetic considerations
- Long-term maintenance requirements and community involvement

4.1.6 Wetlands/Streams (including Buffers)

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.

The biological impacts are substantial and begin early in the urbanization process. Studies in Puget Sound lowland streams have documented significant changes in biological communities when watershed development reaches just 5-10% total impervious area (SWMMWW 2024). These changes affect both the complex food web and biodiversity, often replacing the natural biological community with one that can tolerate the changes but is typically less complex, less desirable, and unstable due to ongoing rapid changes in the new hydrologic regime.

To protect these vital ecosystems, researchers and regulators suggest preserving a high percentage (65–75%) of land cover and soils in an undisturbed state to maintain proper hydrologic conditions (SWMMWW 2024). This preservation helps prevent stream channel degradation, maintain base flows, and contributes to achieving properly functioning conditions for salmonids. However, current development practices make achieving these preservation goals challenging, particularly in urban and suburban areas.

4.2 EFFECTS OF GROUNDWATER WITHDRAWAL: WATER TABLE DECLINE AND SURFACE WATER DEPLETION

Groundwater extraction impacts the hydrologic system in several ways. Each new withdrawal, even if relatively small, contributes to the cumulative effect on the aquifer system. The primary repercussions include declining water levels in aquifers over time and decreased water discharge from the aquifer system (COBI 2024).

Capture of water from streams resulting from groundwater withdrawals are concerning because streams on Bainbridge Island flow naturally from baseflow discharge from shallower aquifers. Pumping and consuming groundwater from shallow aquifers can directly affect nearby streams and wetlands. This relationship is especially critical during summer months when streamflow is typically at its lowest, as groundwater provides almost all the streamflow and serves as a crucial source of cooler water vital for fish reproduction and survival (COBI 2024).

Modeling studies have revealed potentially concerning trends in water table declines across the island's aquifer systems. Modeling results that account for a range of potential climate change and population growth stresses indicate the following potential impacts:

- The Perched Aquifer system could decline in some areas an average of 0.10 foot per year
- The Semi-Perched Aquifer system could decline in some areas an average of 0.13 foot per year
- The Sea Level Aquifer system could decline in some areas an average of 0.09 foot per year
- The Glaciomarine Aquifer could decline in some areas an average of 0.02 foot per year
- The Fletcher Bay Aquifer may experience the most significant decline near pumping centers of up to 0.15 foot per year

These declines were modeled considering a number of potential future stresses on the groundwater system, as recommended by the groundwater subcommittee. Stresses included:

- Significant increases in groundwater withdrawal rates associated with low, medium and high population growth
- Up to a 20% reduction in groundwater recharge rates due to climate change
- Up to s 4-foot rise in sea level resulting from climate change

Potential impacts extend beyond groundwater level declines. Model simulations predict approximately a 40% decrease in groundwater drainage to surface water. While wells within the shoreline are expected to maintain acceptable chloride concentrations, the predicted groundwater level changes over a 100-year timeframe may not meet the definition of sustainable yield due to measurable annual declines.

To monitor these impacts, the City employs EWLs with a safe yield threshold defined as a decline of 0.5 ft/yr over a ten-year assessment period. However, it's important to note that water level trends alone don't definitively indicate aquifer overdraft or depletion. When evaluating declining trends, several factors must be considered:

- Whether water levels rise during wet years
- If water levels decline during average years
- Whether water level declines are observed in wells accessing the same aquifer in the area or further away

The COBI is actively working to address these challenges through comprehensive monitoring and management strategies. This includes reviewing monitoring well networks, updating groundwater models, and developing a better understanding of the relationship between water withdrawal distribution and water level changes within each aquifer zone.

4.3 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. Managing this threat involves multiple strategies. Monitoring and risk assessment efforts include regular testing of chloride and conductivity in coastal wells, establishing seawater intrusion programs, and implementing reporting requirements for water systems. In terms of well design and management, effective approaches include adopting specific construction standards, strategic placement of wells away from the shoreline, and monitoring both static and pumping water levels. Water use management is also key, with strategies such as water conservation practices, installation of individual usage meters, restrictions on new water connections in high-risk zones, and regulated withdrawal rates to reduce over-pumping.

Regulatory frameworks further support these efforts by establishing special protection areas in coastal zones, evaluating new well developments using objective criteria, and conditioning or denying water right applications in areas deemed high-risk. 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.

Saltwater Intrusion Monitoring in Bainbridge Island Water Systems

Bainbridge Island operates two main water systems: the Winslow Water System on the north side of Eagle Harbor and the Rockaway Beach Water System on the east side of the island.

The Rockaway Beach Water System relies solely on the Taylor Avenue Well, which has an instantaneous withdrawal limit of 80 gpm and an annual withdrawal water right of 34 acre-ft/yr. The system's location, consisting of beachfront property at sea level adjacent to steep hillsides, could potentially make it vulnerable to saltwater intrusion. The monitoring data shows that as of 2015, the Taylor Avenue Well had chloride levels of 4.44 mg/L, which is well below concerning levels for saltwater intrusion.

For the broader Winslow Water System, chloride testing conducted in April 2015 showed levels ranging from 2.15 to 7.76 mg/L across all wells. These levels appear relatively low, suggesting that saltwater intrusion is not currently a significant concern. The Head of Bay wells showed chloride readings between 2.15–4.48 mg/L, while the Sands Avenue wells had slightly higher readings at 7.28–7.76 mg/L.

It is worth noting that the COBI maintains careful oversight of its water resources. The 2015 data shows that both the Winslow and Rockaway Beach Water Systems were in compliance with all primary IOC MCLs. The COBI also regularly monitors water quality parameters and has systems in place to track well performance. While current data doesn't indicate immediate saltwater intrusion concerns, the island's geographic location surrounded by Puget Sound makes ongoing monitoring and management of water resources crucial for preventing future intrusion issues.

4.4 EXTENT AND CROSS-BOUNDARY IMPACTS OF GROUNDWATER PROBLEMS BY LAND USE

Residential Development and Water Extraction — The majority of Bainbridge Island (75%) is residential land use. Much of the residential area is served by private permit-exempt wells. Most of these wells (75% of water wells with recorded depths) are less than 200 feet deep. Thus, most permit-exempt wells tap the Perched or Sea-Level aquifers. These aquifers are interpreted to receive recharge solely from precipitation and recharge on Bainbridge Island. These aquifers discharge primarily to streams and wetlands on the island as well as into marine waters. Therefore, extraction and consumptive use of groundwater by private residential wells is likely to capture water that would otherwise contribute to baseflow discharge to island streams.

Agricultural and Open Space, Forest, and Parks/Recreational Lands — These land uses comprise 15% of the island's land use. These areas are crucial for groundwater recharge, which affects both on and off-island water resources. Changes in vegetation and addition of impervious surfaces can limit aquifer recharge, potentially affecting water availability in connected aquifer systems extending to the Kitsap Peninsula. Agricultural activities involving hazardous and non-hazardous materials, including the storage, use and disposal of fertilizers, pesticides, and herbicides, can impact groundwater quality. These chemicals can enter the groundwater system and affect both water quality and natural processes.

Commercial and Industrial – These land use types comprise only 2% of Bainbridge Island's land use, their potential impact on groundwater resources is substantial through various mechanisms Development activities 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). This impact is particularly concerning because most of the Island's lower aquifer layers extend westward beneath Agate Passage and Port Orchard to the Kitsap Peninsula. While shallow aquifers show limited hydraulic connection between Bainbridge Island and the Kitsap Peninsula, deeper aquifer systems may have greater connectivity. The groundwater system faces additional stress from development-related withdrawals, which can lead to declining aquifer water levels over time. These changes can have cascading effects, including reduced aquifer outflow and negative impacts on streams and wetlands due to increased pumping and consumption. Climate change further compounds these challenges, as changes in precipitation patterns and more intense storms could potentially decrease groundwater recharge rates and increase the risk of stormwater intrusion.

Transportation Infrastructure — Transportation-related land use (6% of total) creates impervious surfaces that affect groundwater recharge patterns. Stormwater runoff from these surfaces is managed through a combination of built infrastructure and natural systems, but changes in recharge patterns can affect groundwater levels in connected aquifer systems extending beyond the island.

Regional Hydrologic Connectivity — The impact of land use extends off-island through several mechanisms:

- Most of the lower aquifer layers extend westward under Agate Passage and Port Orchard to the Kitsap Peninsula
- Groundwater flow in shallower aquifers can affect recharge to deeper regional aquifers (EA 2025)
- Peninsula production in shallower aquifers can intercept recharge that could otherwise migrate downward into the GMA and FBA systems (EA 2025)

Future Development Impacts — Projected development will increase these off-island impacts:

- Population growth will require increased groundwater extraction, potentially affecting regional aquifer systems
- Climate change effects combined with development could increase water use and put more stress on the regional aquatic environment
- Models predict water level decreases in various aquifer systems over time, which could affect regional groundwater availability

Saltwater Intrusion Risk — Land use changes that affect groundwater extraction can increase the risk of saltwater intrusion, which could impact coastal areas beyond the island:

- Wells within ½ mile of the shoreline pumping below sea level are at risk

- Over-pumping can result in saltwater intrusion, even in locations not immediately adjacent to the coast

- While this process can be reversed, it requires time and reduced pumping

The interconnected nature of the aquifer systems means that land use decisions on Bainbridge Island have far-reaching implications for groundwater resources throughout the region. Computer modeling shows that groundwater withdrawals result in impacts to the broader hydrologic system (COBI 2024), affecting not just local water levels but also regional groundwater availability and quality.

4.4.1 Aquifer Over-Utilization causes Seawater Intrusion

Studies indicate that while groundwater levels in certain aquifers, such as the FBA, have declined due to increased pumping, there is currently no substantial evidence of seawater intrusion (Baurick 2010). A 2011 USGS report concluded that, under projected conditions up to 2035, seawater intrusion was not evident. However, localized concerns have emerged. For instance, the Seabold area underwent investigations to assess potential seawater intrusion, highlighting the necessity for ongoing monitoring (COBI 2006).

4.4.2 Sea Level Rise and Repercussions for Saltwater Intrusion

Sea level rise 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. Given Bainbridge Island's extensive shoreline, this underscores the importance of proactive groundwater management strategies.

4.4.3 Historical Trends in Water Quality in Terms of their likely Causes

The historical water quality data reveals several noteworthy trends across the COBI's water systems. The chloride levels have remained consistently low, with 2015 measurements showing concentrations between 2.15-7.76 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 (Carollo 2017).

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 COBI is in the process of evaluating and upgrading systems that manage water quality at all of its well sites. This proactive approach to implement a comprehensive water quality analysis to assess various parameters including iron, manganese, hydrogen sulfide, chlorine residual, arsenic, and disinfection byproducts (Carollo 2017). Additionally, the COBI is evaluating water treatment improvements specifically targeting iron, manganese, and sulfide levels. These ongoing challenges have prompted the COBI to prioritize water quality improvements and treatment solutions for the future.

4.4.4 Documenting Water Table Decline and Addressing Use Conflict

The water resource management challenges on Bainbridge Island present a complex interplay of natural systems and human development. The entire island depends on groundwater wells for domestic potable water, with approximately 1,400 water supply wells currently in operation. This reliance on groundwater has become increasingly challenging as the island's population grows, putting additional strain on the limited water resources. The island's geology plays a significant role in these challenges, with various soil types and geological formations affecting water movement and storage. The predominant soil type is Kapowsin gravelly ashy loam, which is characterized as a deep soil with moderate drainage properties.

Climate change is emerging as a critical factor affecting the island's water resources. Projections indicate that by mid-century, average annual air temperatures will increase by 4 to 5.5° F, with summer months experiencing the greatest warming. This warming trend is expected to be accompanied by significant changes in precipitation patterns, with increased variation in all seasons except summer, which is projected to experience declining precipitation. These changes could significantly impact groundwater recharge rates and affect the types of vegetation that thrive on the island.

The impact of groundwater withdrawals is particularly concerning for the island's ecological systems. When groundwater is pumped for potable water, it typically results in declining water levels in aquifers over time and decreases in the amount of water flowing out of the aquifer. This is especially critical during the summer months when streamflow depends heavily on groundwater discharge. The COBI is actively working to address these challenges through the development of a Groundwater Management Plan, which includes updated modeling to assess potential impacts from anticipated population growth and climate change. This plan will be crucial as the island faces the requirement to accommodate 1,977 additional housing units by 2044.

The COBI has implemented various measures to manage these challenges, including the adoption of the Department of Ecology's 2019 Stormwater Management Manual for Western

Washington and the maintenance of a Storm and Surface Water Management Utility. These programs aim to protect water quality, minimize property damage, and ensure compliance with federal and state regulations while promoting the preservation of natural drainage systems. Additionally, the Washington State Streamflow Restoration Law enacted in 2018 specifically addresses the impact of water withdrawals on streamflows, aiming to ensure adequate water availability for both human use and the environment.

Groundwater Withdrawals and Aquifer Water Level Dynamics on Bainbridge Island

The North Bainbridge Water System's development and withdrawal patterns reflect over a century of evolving water infrastructure on Bainbridge Island. Originally established in 1915 as the Rolling Bay Water Company by Fred F. Weld and Lucas A. Rodal, the system began with modest beginnings, using a spring on Winters Road that gravity-fed water through a 3-inch wood stave main to a 12,000-gallon storage tank (KPUD 2011). The system expanded in 1948 with the addition of a second spring and another 12,000-gallon wood stave tank on Madison Avenue, marking the beginning of significant infrastructure growth (KPUD 2011).

A major expansion phase occurred between 1969 and 1971 when the company drilled three wells (Well #3, #4, and #5) near the Kitsap County gravel pit (KPUD 2011). This expansion continued with the construction of two 120,000-gallon concrete tanks by Mt. Baker Silo Company in 1971, which dramatically increased the system's storage capacity to 240,000 gallons (KPUD 2011). Further improvements came in 1976 with the replacement of the original wood stave tank with a new 120,000-gallon concrete tank, and in 1984 with the installation of Well #7, which boosted source production capacity by 61% (KPUD 2011). The system continued to grow throughout the 1980s and 1990s, with Well #8 being added in 1985 (though producing only 40 gpm) and another 120,000-gallon concrete tank being installed in 1986, bringing total storage to 480,000 gallons (KPUD 2011). A significant addition came in 1994 with Well #9, which could pump 400 gpm with capacity for up to 700 gpm (KPUD 2011). The system's capabilities were further enhanced in 1996 with the addition of a booster pump station, automated controls, and a 211,000 storage-blending tank (KPUD 2011).

Since Kitsap Public Utility District's acquisition in 2002, the system has undergone additional modernization efforts, including the installation of a 200-kW emergency generator, a 700 gpm iron/manganese removal system by ATEC, and the construction of Well #10 (KPUD 2011). Current operations involve ten wells with varying production distributions, with Well #9 handling the majority (51-56%) of production, followed by Well #7 (17-23%), and smaller contributions from Wells #3, #6, and #10 (KPUD 2020).

The relationship between water withdrawal distribution and water level changes across Bainbridge Island's aquifer systems presents a complex hydrogeological scenario that requires careful analysis and management. The island's groundwater system, which serves as the sole source of drinking water, comprises multiple aquifer zones including the Perched Aquifer, Sea Level Aquifer, Glaciomarine Aquifer, and Fletcher Bay Aquifer (KPUD 2011). The South Bainbridge Water System, a major contributor to island withdrawals, demonstrates the intricate balance between extraction and replenishment, with annual average pumping of approximately 488.5 acre-feet from the groundwater system (KPUD 2020).

The system's sustainability is partially maintained through natural return flows, as approximately 86% of properties utilize on-site septic systems, with the USGS groundwater model estimating that 67% of water used by homes with septic systems returns to groundwater (KPUD 2020). This results in about 58% of annual withdrawals returning to the groundwater system, leading to a net consumptive withdrawal of approximately 205 acre-feet per year, which represents only about 1% of the subarea's annual groundwater recharge quantity (KPUD 2020).

The FBA exhibits particularly notable responses to withdrawals, with recent model analysis revealing important insights about its structure. At North Bainbridge Well #9, the FBA extends from 1,125 to 1,394 feet below ground surface, with a total thickness of 270 feet (EA 2025). Previous modeling efforts had overestimated the FBA thickness at 454 feet, which could have led to significant misinterpretations of available water supply. Similarly, the Sea Level Aquifer (SLA) has shown distinct withdrawal impacts, particularly around South Bainbridge Well #8, where issues with well placement and bedrock interactions necessitated model adjustments to accurately represent water level responses to pumping (EA 2025).

The interconnected nature and vertical leakage of the aquifer systems creates additional complexity, as peninsula production in shallower aquifers (Qva and SLA) can intercept vertical recharge that would otherwise migrate downward into the GMA and FBA systems that may contribute to on-island groundwater flow in deeper aquifers (EA 2025). However, the USGS (2011) examined this question of on-island groundwater flow and concluded that at best, only slightly more than 5% of inflow into the Bainbridge Island deep aquifer system may be attributable to water in the Fletcher Bay Aquifer migrating from the Kitsap Peninsula. The USGS also concluded that groundwater in the Sea Level Aquifer (SLA) and Perched Aquifer (PA) on Bainbridge Island are isolated from the Kitsap Peninsula. Therefore, increased groundwater withdrawals from peninsula wells is not considered to be a major factor affecting water availability in island aquifers.

Looking to the future, for groundwater modeling scenarios both systems were modeled to have substantial projected increases in withdrawal rates. The North Bainbridge system's current production of 147.5 MGY is projected to increase by 61% in the low-rate scenario (237.0 MGY) to 115% in the high-rate scenario (317.4 MGY) (EA, 2025, while the South Bainbridge system's current production of 169.3 MGY is expected to increase even more dramatically, ranging from a 194% increase in the low-rate scenario to a 373% increase in the high-rate scenario (KPUD 2020). These projections may not be realistic without major changes in infrastructure (additional wells). In addition, increased withdrawals for the South Bainbridge system must come from areas north of Eagle Harbor where bedrock is not encountered at shallow depths as the aquifers in the southern part of the island are not physically capable of producing large increases in groundwater withdrawals. This underscores the critical importance of understanding and managing these relationships between withdrawals and water levels for the sustainable management of the island's water resources (KPUD 2020).

4.4.5 Predicting Future Groundwater Strain and Potential Conflicts

Bainbridge Island’s groundwater system is under increasing strain due to projected population growth and rising water demand. Over the next 100 years, water extraction rates are expected to rise by 2.2 to 3.3 times, depending on the growth scenario, placing significant pressure on the island’s Sole Source Aquifers. Several areas, such as the South Bainbridge and Head of the Bay wellfields, are at immediate risk of seawater intrusion, with groundwater elevations potentially falling below sea level within 50 to 100 years, depending on how much growth occurs.

Deeper aquifers like the GMA and FBA are also expected to experience notable drawdowns, especially near Sands Road and Island Utility wellfields. Although these aquifers are buffered by thick aquitards, the extent of drawdown raises sustainability concerns. Climate change further complicates the issue, with potential reductions in groundwater recharge of up to 20% over a century and predicted sea-level rise exacerbating stress on the system. Household water usage is also expected to increase by 7% during this time. The interconnectedness of the island's water systems means that increased production in one area can reduce availability in another, while off-island activity, particularly from the Kitsap Peninsula, could further strain local resources due to shared aquifers. Existing infrastructure is already showing signs of stress, and as residential, commercial, and public demands grow, maintaining adequate service and pressure will require significant upgrades. Managing these complex systems—while simultaneously preventing seawater intrusion and ensuring long-term supply—presents mounting challenges. Adding to the difficulty are uncertainties in both population growth and climate change projections, highlighting the need for immediate, proactive measures. The technical memorandum underscores that these are not inevitable outcomes, but stark warnings to inform strategic policy and planning efforts aimed at safeguarding public health, environmental sustainability, and economic stability.

4.4.6 Land and Water Use Policies Effect on Groundwater Quality and Quantity

COBI implements comprehensive land and water use management policies that reflect its unique position as an island community reliant on a Sole Source Aquifer system for drinking water. The foundation of these policies lies in the Western Washington Phase II Municipal Stormwater Permit, which authorizes and regulates the COBI's stormwater discharge activities while ensuring compliance with the Federal Clean Water Act. Central to the COBI's approach are several key municipal codes that govern land and water use. BIMC 15.20 establishes and enforces stormwater management system design and construction standards, while BIMC 15.19 ensures development regulations are understood and followed before any clearing or grading activities begin. Additionally, BIMC 15.16 provides crucial flood damage protection measures (COBI 2025).

The COBI's development standards, as outlined in BIMC 18.15 and 18.18, establish and reinforce specific protections for water quality. These standards are complemented by the COBI's Design and Construction Standards, which may exceed the Department of Ecology's baseline requirements to provide enhanced environmental protection. For existing development, the COBI implements a comprehensive Stormwater Management for Existing Development (SMED) program that focuses on strategic stormwater investments over longer planning timeframes. This program includes specific requirements for managing runoff from various land uses, including streets, parking lots, buildings, parks, and open spaces (COBI 2025).

The COBI's operations and maintenance practices specifically address various land use activities that could impact water quality. These activities include pipe cleaning and maintenance, ditch maintenance, street cleaning and road repair, utility installation, landscape maintenance, sediment and erosion control, and the application of fertilizers, pesticides, and herbicides (Ecology 2024). To minimize environmental impact, the COBI implements specific pollutant control approaches, including spill control plans and careful control of fertilizer and pesticide applications. Additionally, the COBI requires stabilization of access roads and areas of bare ground with gravel or crushed rock to prevent erosion (Ecology 2024).

The COBI maintains robust monitoring and assessment programs to protect water quality, including a voluntary Water Quality and Flow Monitoring Program that conducts quarterly stormwater discharge monitoring at 16 sites (COBI 2025). Field screening for potential contaminants is regularly performed through various programs, including the IDDE Program, OandM Program, and Source Control Program (COBI 2025). This comprehensive monitoring approach helps ensure the effectiveness of the City's land and water use management practices. In addition, KPUD has monitored Manzanita Creek continuously since October 12, 2017. Stage and streamflow data is available on KPUD's website.

Indigenous rights and cultural values are deeply respected in the COBI's land and water management approach, acknowledging the Suquamish People's historical connection to these lands and waterways (COBI 2025). The COBI emphasizes public involvement in land and water use decisions through multiple channels, including the COBI website, Water Resources Listserv, public meetings, and community events (COBI 2025). This comprehensive approach reflects the community's understanding that water plays a vital role in the quality of life on Bainbridge Island. The program recognizes that collective responsibility is essential in protecting water resources, acknowledging that all community members play a role in either helping or hindering water quality through their land and water use practices.

4.4.7 Identifying Data Gaps Affecting Groundwater Problem Assessment

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 critical aquifer systems like the GMA and FBAs, where limited well data prevents accurate mapping of groundwater flow patterns. Additionally, the dynamic nature of the monitoring network, with wells being added or removed as ownership changes, creates challenges in maintaining consistent long-term data collection for trend analysis.

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.

There are also significant knowledge gaps regarding aquifer connectivity, particularly between Bainbridge Island and the rest of the Kitsap Peninsula. The evidence for these connections is not conclusive, especially for the shallower Perched and Semi-Perched Aquifers. This uncertainty affects the understanding of how off-island water usage might impact Bainbridge Island's groundwater resources.

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).

To address these data gaps, several initiatives have been identified. These include conducting comprehensive monitoring well network review for both quality and quantity, updating the groundwater model with the latest data and climate change impacts, improving linkage with stormwater management programs, and developing better understanding of the relationship between water withdrawal distribution and water level changes within each aquifer zone. These efforts are being incorporated into the COBI's Groundwater Management Plan to ensure more comprehensive understanding and management of the island's groundwater resources.

4.4.8 Ensuring Compliance with Water Quality Standards for Aquifer Use

The aquifer system underlying Bainbridge Island requires careful management to ensure both existing and future uses comply with established water quality standards across multiple regulatory agencies. This is particularly critical given that the aquifer has been designated as a Sole Source Aquifer by the United States Environmental Protection Agency (EPA), recognizing it as the only water supply source for the island.

While Bainbridge Island’s designation as a Sole Source Aquifer highlights the importance of protecting its groundwater, the practical implications of this status are relatively limited. The EPA’s review authority under this designation applies only to federally funded projects, where it assesses whether a proposed project poses a risk of aquifer contamination. If such a risk is identified, the EPA may work with project sponsors to modify the design; however, the designation does not affect privately funded or local projects without federal involvement.

The island's groundwater quality is monitored through an extensive network of wells, with specific criteria established for selecting monitoring locations. These wells are strategically positioned to detect early signs of water quality issues, particularly in areas most likely to be affected by seawater intrusion or extensive groundwater withdrawals. The monitoring program includes sampling as close as possible to 'raw' water sources, upstream of treatment facilities, to ensure accurate assessment of aquifer conditions.

Multiple agencies contribute to the ongoing monitoring and assessment of the island's water quality. Historical studies and monitoring efforts have involved collaboration between the U.S. Geological Survey, the COBI, Kitsap Public Utility District, Ecology, Washington Department of Health, Kitsap Public Health District, and the EPA. This multi-agency approach ensures comprehensive oversight of water quality standards and compliance.

To maintain long-term sustainability and compliance with water quality standards, the COBI's 2016 Comprehensive Plan includes specific provisions for groundwater management. These include regular monitoring of groundwater quantity and quality, updating the Island's groundwater model to support management decisions, and implementing water conservation education programs. The plan's vision specifically emphasizes maintaining water resources that are climate resilient and capable of supporting all forms of life on the island while meeting regulatory requirements.

4.5 CLIMATE CHANGE PROJECTIONS

Climate change is projected to have several significant impacts on Bainbridge Island's water resources and environment. Average annual air temperatures are expected to increase between 4 to 5.5°F by mid-century, with summer months experiencing the most dramatic warming. These rising temperatures will likely increase water demand across both human and natural systems, affecting terrestrial, freshwater, and marine ecosystems.

Precipitation patterns are also projected to shift. Winter months will bring more frequent and intense rainfall events, leading to greater surface runoff and reduced groundwater infiltration. In contrast, summer months are expected to become drier. Overall, annual precipitation is projected to rise by 6% to 9% over the next 80 years (EA 2025). Additionally, extreme precipitation events could increase in frequency from two to seven times per year, with their intensity potentially rising by up to 22% (BHC 2024).

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, increased evapotranspiration (ET). In addition, increased impermeable surfaces and an increase in high-intensity storms could reduce groundwater recharge. As such, groundwater modeling scenarios evaluated decreases in groundwater recharge, which would have significant impacts to groundwater supplies on the island. However, whether groundwater recharge will increase or decrease in the future resulting from climate change is not known with any level of certainty as there are factors that could increase recharge as well as some that could decrease recharge. In addition, mitigation measures have been identified to enhance recharge and avoid large decreases.

Groundwater recharge on Bainbridge Island is highly correlated to precipitation which occurs primarily between late fall and early spring. Very little recharge currently occurs from precipitation during the summer and early fall because of the lack of precipitation. Climate models predict an increase in precipitation, thus an increase in recharge is to be expected. Climate models also predict an increase in high-intensity storms, which proportionally have a smaller percentage of recharge compared to the same amount of precipitation over a longer period (Tashie, et. al., 2015). However, these impacts are most pronounced in urban areas, which compose a relatively small percentage of Bainbridge Island where lower amounts of recharge occur because of impervious surfaces.

The increase in ET and longer growing season is not expected to significantly impact groundwater recharge because very little recharge occurs from precipitation during this part of the year. As noted, the amount of precipitation is expected to increase along with a corresponding increase in recharge. This increase will likely occur during the current wet season in western Washington. Although the growing season is also likely to expand, some of the increase precipitation is likely to occur during this period. It is true that an increase in ET is likely to increase the interception of vadose zone water that could contribute to ground water recharge, however this is difficult to predict with a high level of certainty.

These projections underscore the importance of comprehensive planning and adaptive management to safeguard Bainbridge Island's water resources and infrastructure. Proactive measures taken today will be essential in ensuring the long-term sustainability and resilience of the island's environmental and public systems.

5. LAND AND WATER USE MANAGEMENT STRATEGIES

5.1 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 three categories including data collection and information management, actions to prevent undesired impacts, and proactive actions to mitigate and avoid negative impacts. Actions include planning and regulation, coordination between Group A water systems, infrastructure changes, reuse and managed aquifer recharge. Specific mitigation strategies include reuse of treated water, protection of recharge areas, storm water management, land use and well construction issues, prevention of seawater intrusion, public education, hazardous materials, underground storage tank, and septic system management, use of reclaimed water, and managed aquifer recharge.

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.

5.2 MANAGEMENT STRATEGIES

Management Strategies are organized by generally from data collection and administration actions through infrastructure changes and project implementation.

5.2.1 Data Collection and Information Management

A necessity for effective groundwater analysis, including those analyses whose objective is to propose and evaluate alternative management strategies, is the availability of comprehensive high-quality data. To that end, COBI has established its own groundwater monitoring network on Bainbridge Island, separate from KPUD’s efforts. While KPUD shares its water level and production data with COBI annually, they do not coordinate monitoring locations with COBI, and COBI does not receive data from KPUD’s monitoring wells. KPUD maintains its own long-term monitoring network and has collected groundwater data for significantly longer periods—for example, over 45 years of data exist for the Fletcher Bay Observation Well and more than 48 years for the Bloedel Farm Well. This monitoring program currently includes 87 wells, with wells screened in each of the six primary aquifers used on the island for water supply (**Figure 5-1**). 76 wells are monitored for water levels and 49 for chloride concentrations. Data is used to track long-term trends and for comparison to the EWLs.

EWLs were developed in 2006 as a component of the COBI's Groundwater Monitoring Program (Aspect 2006). 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 below.

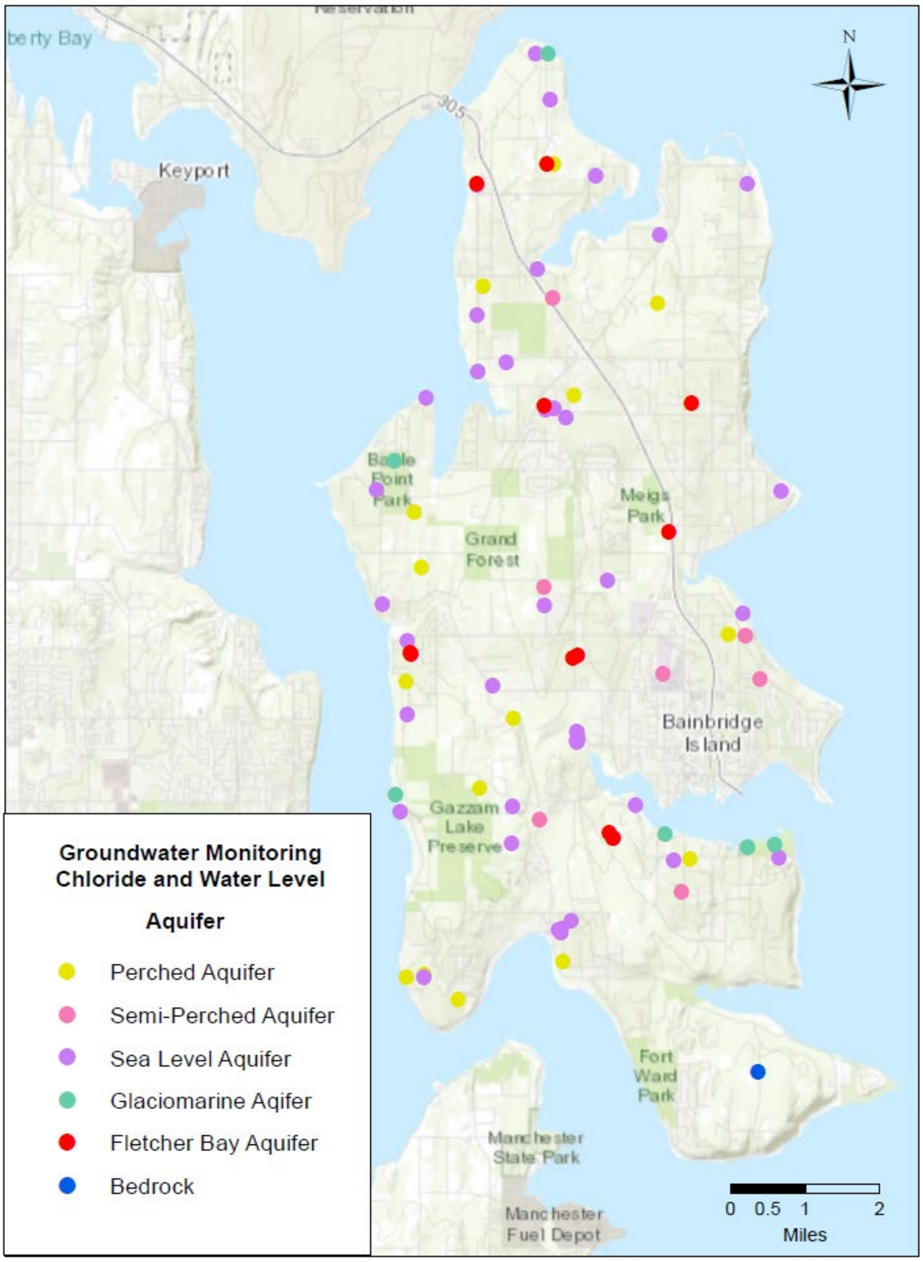

Figure 5-1. Bainbridge Island Groundwater Monitoring Program

Groundwater Levels

The COBI'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 COBI 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:

- 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.

Chloride Concentrations

The COBI's Groundwater Monitoring Program (Aspect 2006) defines the saltwater intrusion EWL 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 COBI separates chloride data by season before comparing concentration trends to the EWL.

The EWLs are applied to data collected for the COBI'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

Primary groundwater-related concerns for the Island are the risk of seawater intrusion (migration of saltwater into the freshwater drinking supply) and pumping rates above the aquifer system's safe yield (amount of water that can be removed from the aquifer system without causing adverse effects). The City of Bainbridge Island (the city) monitors 86 public and private wells Island-wide from all six aquifers in the Bainbridge Island aquifer system. This data used as a comparison of monitoring data collected over the last ten-year period to the EWLs for safe yield and seawater intrusion, any exceedances of which trigger follow-up investigation.

An EWL is a monitoring criterion that, if exceeded, would result in the need for additional sequential monitoring and investigative activities to confirm or rule out a developing problem. an exceedance of the safe yield EWL calls for additional data evaluation, expanded monitoring, problem specific technical review and analysis, or modeling to confirm or rule-out long-term water use exceeding the aquifer's safe yield. The initial exceedance of the safe yield EWL, by itself, is not confirmation of long-term water use exceeding the safe yield (COBI, 2018).

As part of the Bainbridge Island Groundwater Management Plan, EWLs developed earlier by the City of Bainbridge Island were evaluated to assess their appropriateness and ability to identify potential threats to the island's groundwater supply and to contribute to meaningful and effective management of groundwater resources on the island. 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.

Declining groundwater levels and saltwater intrusion are potential threats to long-term sustainability of groundwater withdrawals on Bainbridge Island. In a marine island setting, under natural conditions the seaward flow of fresh groundwater prevents saltwater from encroaching on freshwater aquifers. Groundwater elevations, as measured in wells, are typically higher in the central part of the island and decrease toward the shorelines. The freshwater/saltwater interface, usually through a wide transition zone, is maintained near or beyond the coast or far below the land surface and is partially dependent on the elevation of the groundwater surface. In general, the higher the elevation of fresh groundwater in the aquifer, the lower the potential for saltwater intrusion.

Withdrawal of water by wells lowers groundwater elevations in the aquifer around the well while water is being withdrawn. Over time, increasing groundwater withdrawals can decrease the overall groundwater elevation in the aquifer which raises the risk of saltwater intrusion. Thus, monitoring groundwater elevations and minimizing declines in the aquifer over time is an important way to prevent saltwater intrusion.

Chloride, because of its non-reactive behavior, is used as the indicator parameter for saltwater intrusion. Because of the large difference in chloride concentrations between fresh groundwater (usually less than 20 mg/l) and saltwater (~ 19,000 mg/l), monitoring chloride concentrations in groundwater is another useful way to detect migration of saltwater into coastal aquifers. Slight increases in chloride concentrations above natural conditions may be an indication of the freshwater/saltwater transition zone moving inland. Thus, monitoring chloride concentrations in the aquifer is also an important way for early detection of saltwater intrusion into the aquifer before beneficial uses are degraded.

Groundwater Monitoring

As noted above, reliable and accurate groundwater data is a critical component of effectively managing groundwater resources and the COBI has been building and implementing a groundwater monitoring program for nearly 20 years. Continuation and expansion of this program is an important part of managing and protecting groundwater on the island.

The monitoring program focuses on two primary parameters that are important for assessing and managing groundwater resources in a marine island setting, **groundwater levels (elevations)** and **chloride concentrations**. Under natural conditions precipitation infiltrates and recharges groundwater creating a groundwater gradient from the island interior toward the marine shorelines. This results in groundwater flowing from higher elevations on the island toward the marine shoreline where groundwater discharges into marine waters. If the groundwater elevations in the aquifers remain above MSL, groundwater will flow from the island into Puget Sound. Should pumping or reduced recharge cause sustained groundwater elevations to be below MSL, salt water can flow into the aquifer, resulting in seawater intrusion and degraded water quality. Thus, monitoring groundwater elevations in the aquifer over long periods of time is essential to sustainable management of groundwater on the island.

Fresh groundwater in Bainbridge Island aquifers typically exhibit chloride concentrations below 20 mg/L (parts per million) while seawater exhibits chloride concentrations of around 30,000 mg/L. Because there is typically a mixing zone of varying width between fresh and salt water within an aquifer, early stages of seawater intrusion can be detected when chloride concentrations start to consistently rise above background concentration at any point within an aquifer. Thus, monitoring aquifer water quality for chloride is also an essential element of an effective groundwater monitoring program in a marine island setting.

Because of differences in extent, depth, uses, recharge, discharge, and potential threats between aquifers on the island, existing and potential 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.

Bainbridge Island has six principal aquifers, the extents of which were refined in the U. S. Geological Survey's (USGS) *Conceptual Model and Numerical Simulation of the Groundwater-Flow System of Bainbridge Island, Washington* (Frans et al. 2011). These are shown in **Figure 5-2** below and briefly described in Section 4 of this document and below, from youngest to oldest.

Findings

The City periodically publishes results of their groundwater monitoring program with comparison to EWLs. In general, water levels and water quality on the Island are excellent although there have been a few exceedances of EWLs as described below.

In 2017, the city completed two investigations of exceedances of EWLs. The city observed a small increasing trend in chloride concentration in the Hidden Cove Utilities Shop well (COBI, 2017). Because the concentration increased over four consecutive wet-season sampling events, this triggered an EWL response. However, seawater intrusion is highly unlikely as the chloride concentrations were very low (generally less than 7 mg/L) and the increasing trend was only observed during the wet season. Follow up confirmation sampling indicated chloride concentration appeared to be stabilizing in this well. The city will continue to monitor this well.

The city partnered with the Kitsap Public Utility District (KPUD) and the Kitsap Public Health District (KPHD) to investigate historic elevated chloride concentrations in an inactive Seabold Water Association supply well (KPUD, KPHD, and COBI, 2018). A thorough desktop review of historic and current data and a focused field sampling effort in the Seabold area indicated that elevated chloride concentrations were isolated to the well and no other wells appeared to be impacted. Further, there was strong potential that water treatment by-products could have been the source of chloride contamination in the well rather than seawater intrusion. However, seawater intrusion could not be definitively ruled out. Therefore, monitoring will continue at this well. The final report can be found on the investigation project webpage.

In response to Island Utilities Well 1 water level EWL exceedance, KPUD increased monitoring of Island Utilities wells since taking ownership in 2015 to improve the water level and production datasets to help evaluate trends and to design appropriate responsive actions. It should be noted that the long-term record for this well (1987 – 2016) shows a rate of decline significantly less than the current ten-year period, and recent data appear to indicate a rising trend in 2017 relative to the proceeding four years (email from Joel Purdy, KPUD, dated July 19, 2018). It is unknown if this will be a continuing trend, but KPUD will continue to monitor, assess, and take responsive action.

Summary

Background information on the development and implementation of the City's EWLs was independently reviewed in light of the City's Groundwater Monitoring Program, existing conditions on the island, and EWL Assessment Reports prepared by the City in 2018.

Although additional management actions could be developed to address potential risks related to declining water levels and saltwater intrusion should they occur, current use of the EWLs are an appropriate, meaningful and important groundwater management tool

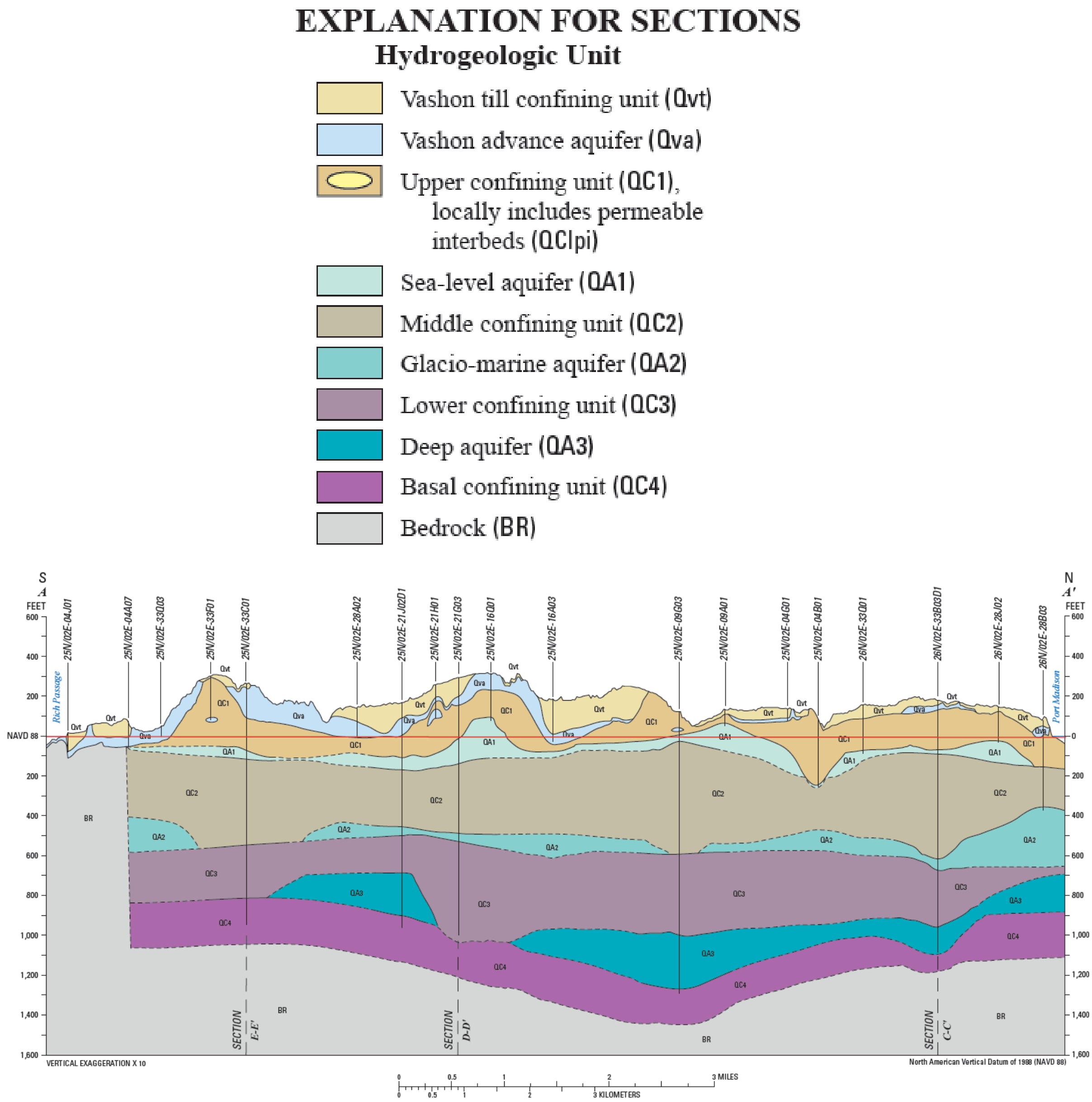

Figure 5-2. Hydrogeologic Cross-Section of Bainbridge Island
Source: USGS SIR 2011–5021

Perched Aquifer

The Perched Aquifer occurs in Vashon Advance glacial outwash (Qva), a glacial sedimentary unit of sand, gravel and clay deposited during the advance of the Vashon glaciation, approximately 18,000 years ago. The top of the unit occurs between 0-300 feet above MSL, with a thickness of 0-200 feet. The thickest portion of the aquifer occurs in the central part of the island. Groundwater elevations in the aquifer range from 280-10 feet above MSL, with higher elevations in the central part of the island and lower values being measured near the marine shoreline.

Groundwater levels in the Qva respond rapidly to precipitation and seasonal changes. Recharge occurs primarily by infiltration of on-island precipitation as well as return flows from septic systems. Existing data show a strong correlation between seasonal precipitation causing groundwater levels to rise and declining groundwater levels during the warmer, drier months. Monitoring data indicates stable groundwater levels over the period of record, with seasonal highs and lows.

Natural discharge from this 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 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.

This 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 COBI 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 5-3**. Also shown in **Figure 5-3** and **5-4** 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 COBI'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 5-3** 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 COBI for chloride concentrations in the Perched Aquifer as shown in **Figure 5-3** and **5-4**. 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 (the red horizontal line on the cross-section in **Figure 5-2**). 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.

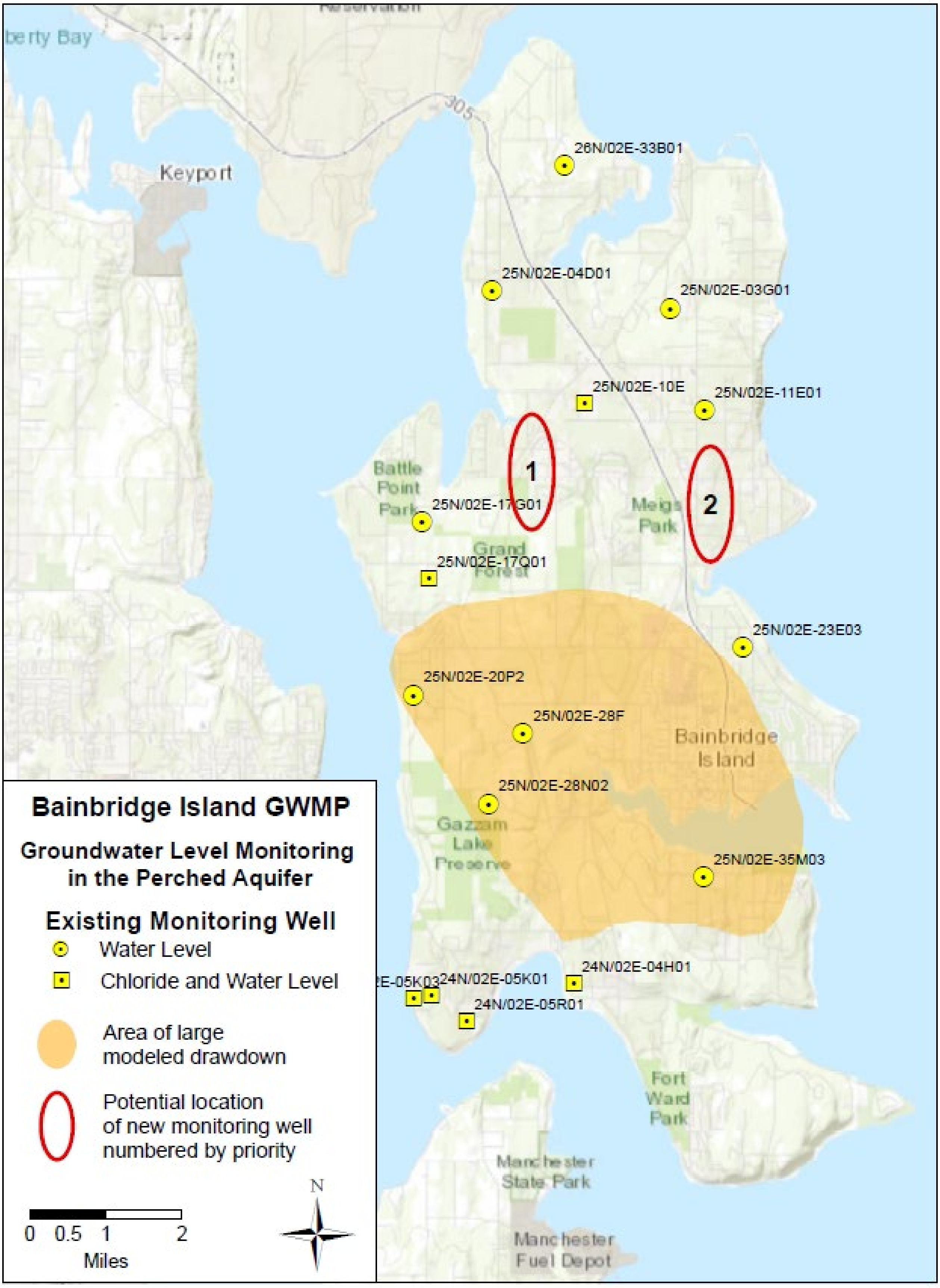

Figure 5-3. Existing and Proposed Water Level Monitoring, Perched Aquifer

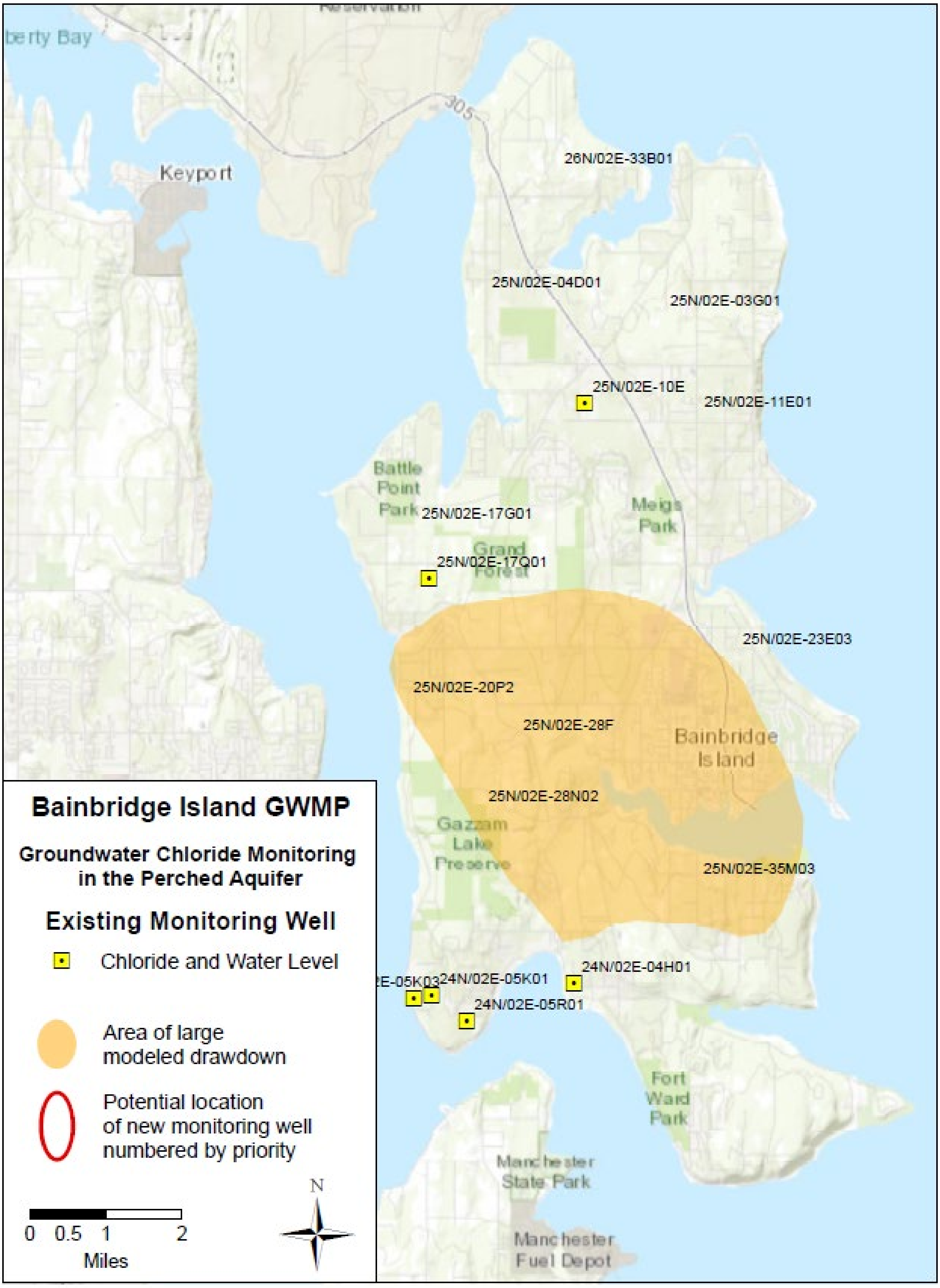

Figure 5-4. Existing and Proposed Chloride Monitoring, Perched Aquifer

Semi-Perched Aquifer

The Semi-Perched Aquifer exists within permeable interbeds (QClpi) of the upper confining unit (QC1). The top of the aquifer ranges 0-200 ft MSL, with a thickness of 10 to 50 feet. The thickest portion of the aquifer occurs in the central part of the island. The unit is generally mapped as discontinuous lenses of permeable material, although this unit was also merged with the Perched Aquifer by the USGS for construction of the Bainbridge Island Groundwater Model. The unit also occurs mostly above MSL and is therefore not very susceptible to sea water intrusion.

Groundwater levels in the QClpi respond rapidly to precipitation and seasonal changes. Recharge occurs primarily by infiltration of on-island precipitation as well as return flows from septic systems. The unit is primarily used by domestic wells and likely provides baseflow to streams and wetlands, as described for the Perched Aquifer. Roughly 29% of all wells on the island are completed in the Perched or Semi-Perched aquifers (COBI 2018).

Natural discharge from this 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 COBI 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 5-5**. 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 5-5** 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 COBI monitors chloride in four wells within the Semi-Confined Aquifer, 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 (the red horizontal line on the cross-section in **Figure 5-2**). 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.

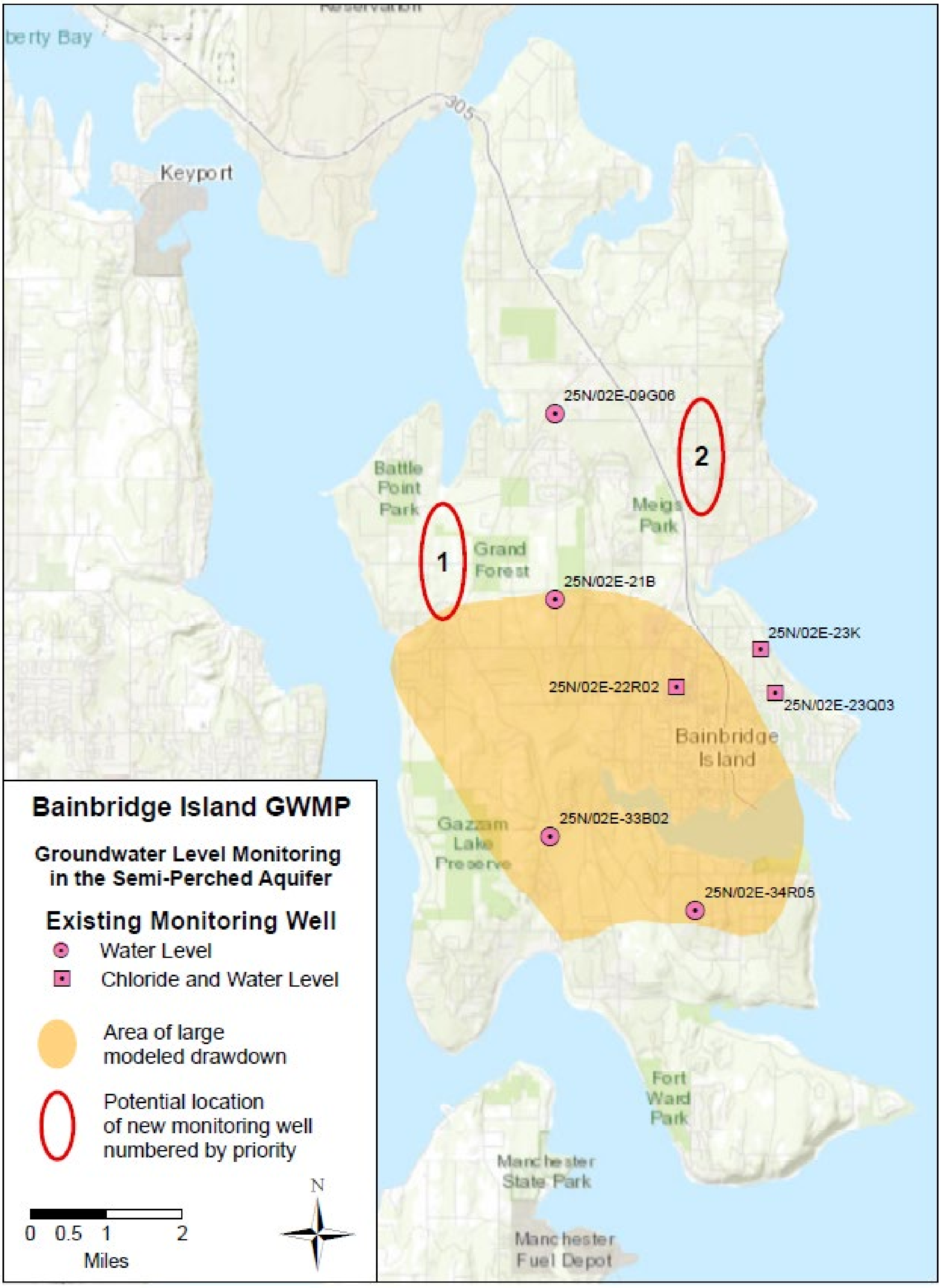

Figure 5-5. Existing and Proposed Water Level Monitoring, Semi-Perched Aquifer

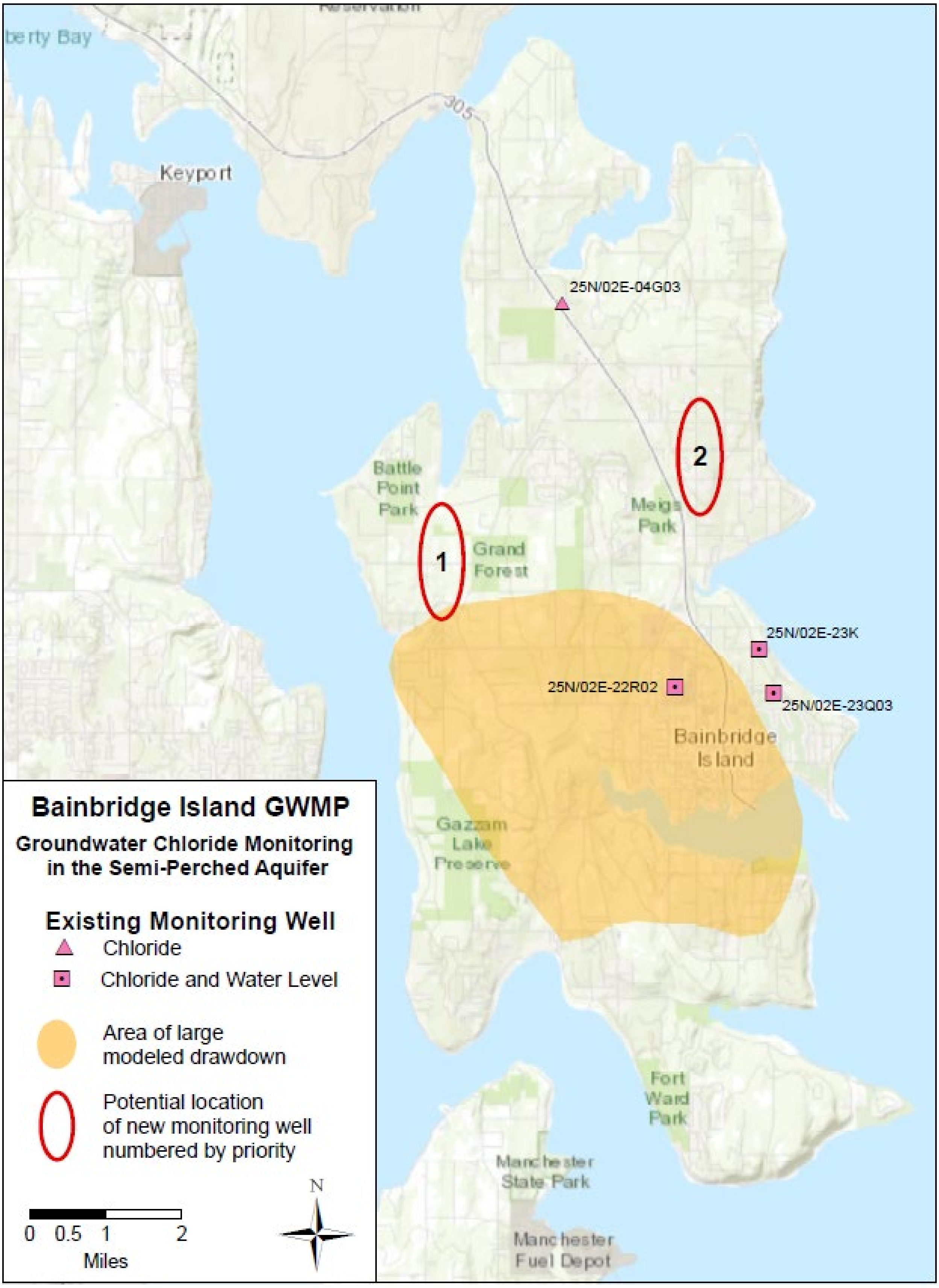

Figure 5-6. Existing and Proposed Chloride Monitoring, Semi-Perched Aquifer

Sea Level Aquifer

The Sea Level Aquifer (QA1) is extensive, widely used, and mostly confined by the upper confining unit (QC1). The aquifer consists mostly of glacial sand and gravel with silt interbeds. The top of the Sea Level Aquifer ranges from more than 200 ft below MSL to around 200 ft above MSL and is interpreted to extend beneath Agate Passage to the Kitsap Peninsula. Thicknesses range from 25 to more than 200 feet. Water levels measured in the Sea Level Aquifer range from about 140 feet above MSL to around 19 feet below MSL, with most measurements being between 20-80 feet above MSL. This aquifer is an important source of municipal water supply for both the COBI and the North Bainbridge Water System, managed by the KPUD.

Recharge to the Sea Level Aquifer occurs by infiltration of precipitation on the island and in areas to the west on the Kitsap Peninsula. Thus, groundwater within the aquifer on the island includes water flowing downward from overlying aquifers and confining units as well as lateral groundwater flow from off-island areas to the west. Discharge from the aquifer is to wells tapping the aquifer and offshore marine waters. The Sea Level Aquifer also occurs at the surface near Fletcher Bay and thus, likely provides baseflow discharge to streams in this area. Additionally, groundwater withdrawals from the Sea Level Aquifer cause drawdown in the aquifer which are likely to cause increased recharge from overlying units, indirectly resulting in capture of baseflow from nearby streams.

The COBI monitors water levels in 26 wells while KPUD monitors 6 wells in the Sea Level Aquifer (**Figure 5-7**). 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 COBI'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.

COBI currently monitors chloride in 24 wells and the KPUD monitors 7 wells in the Sea Level Aquifer. 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 COBI's Head of the Bay wellfield and the north and south Bainbridge Water System wells operated by KPUD.

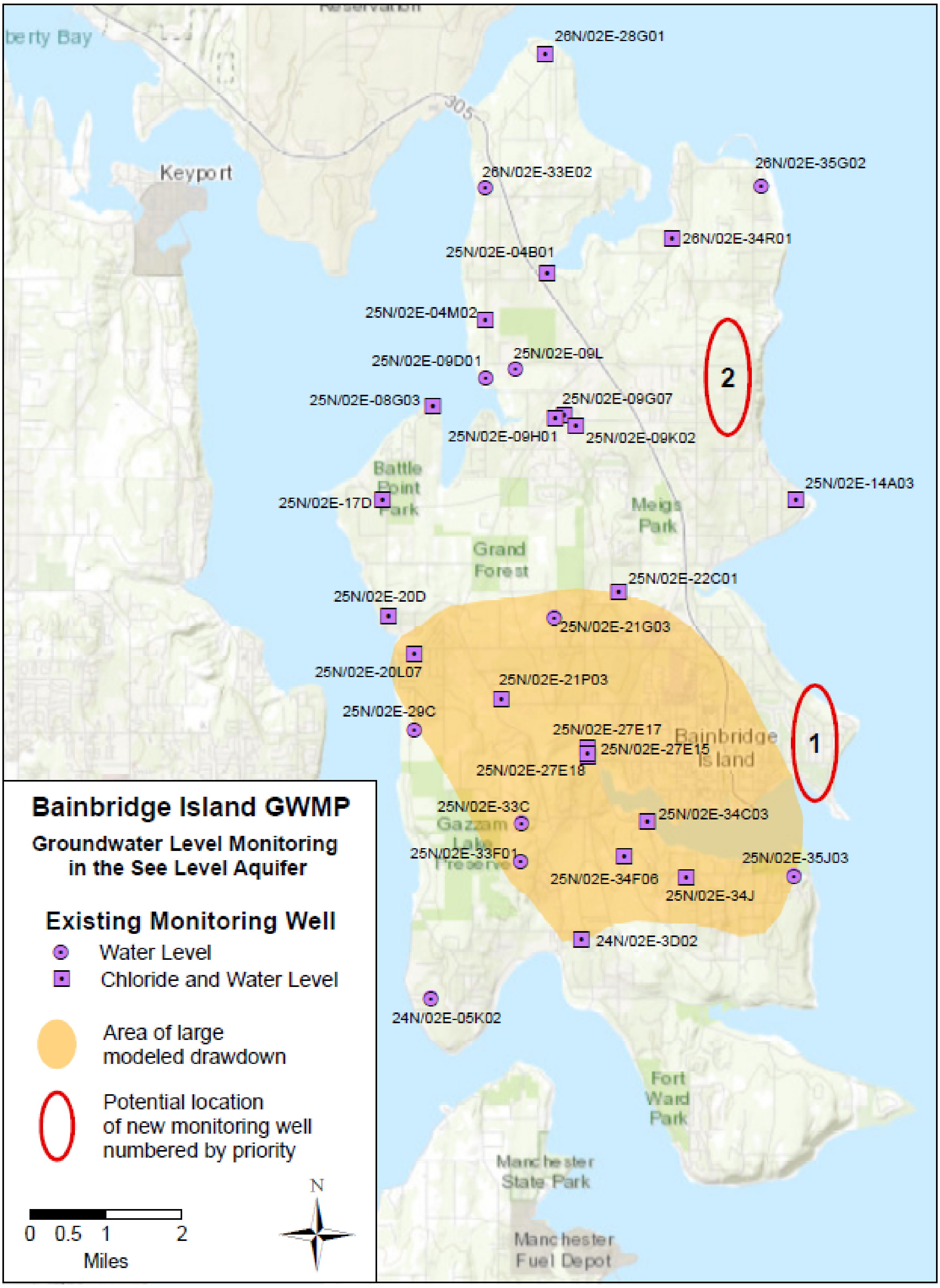

Figure 5-7. Existing and Proposed Water Level Monitoring, Sea Level Aquifer

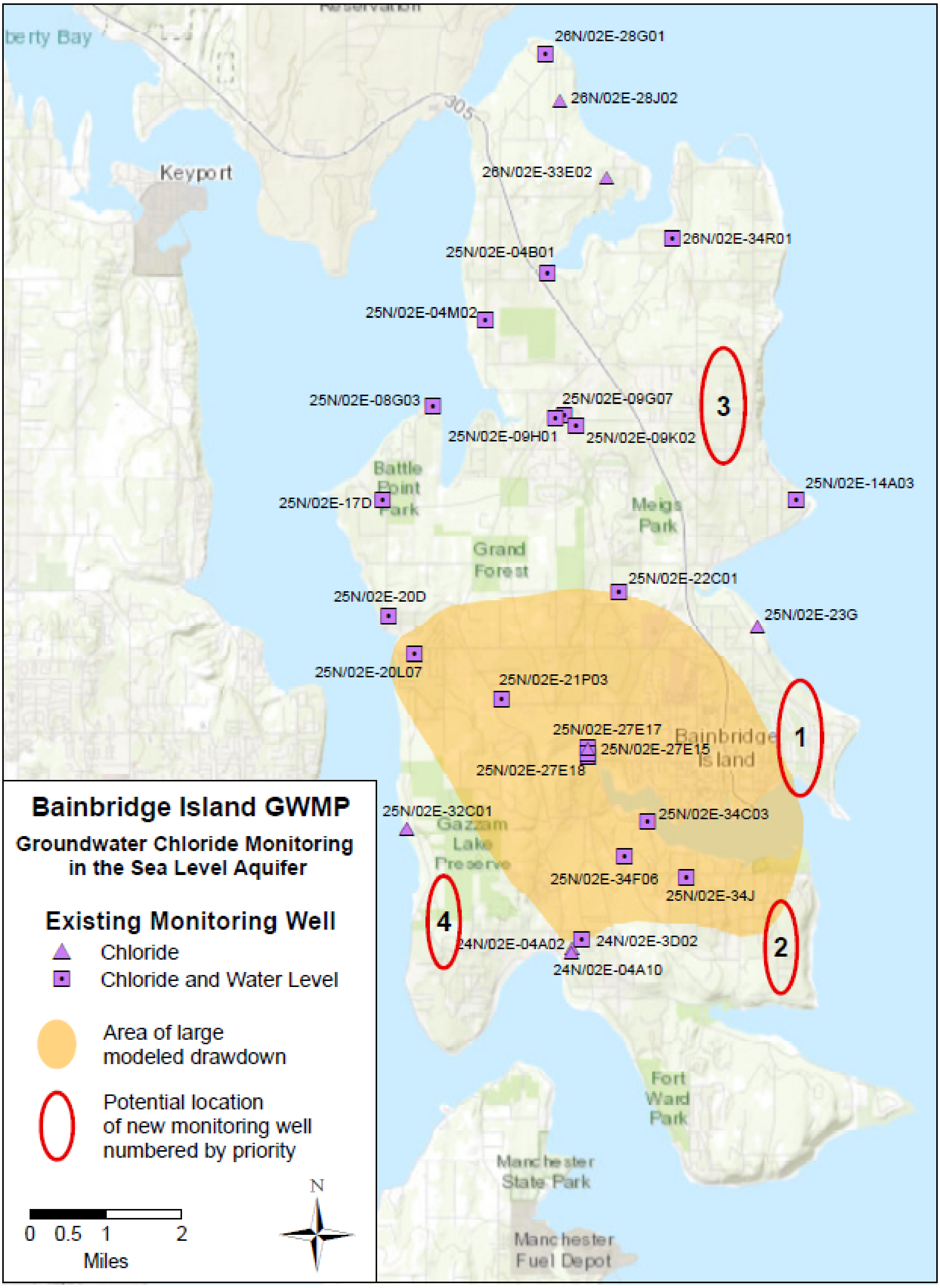

Figure 5-8. Existing and Proposed Chloride Monitoring, Sea Level Aquifer

Glaciomarine Aquifer

The GMA (QA2) is a confined aquifer composed of silt, sand and gravel. The presence of marine fossils in this unit indicates deposition of this aquifer in a marine environment. Relatively few wells use this aquifer due to its depth and generally lower permeability compared to overlying aquifers. The top of the aquifer ranges from less than 300 ft to more than 500 ft below MSL. Aquifer thicknesses range from 0-300 ft. On the island the unit generally is thicker near marine shorelines. The unit is absent near Eagle Harbor, Manzanita Bay, the southern end of Agate Passage, and the southern end of the Island where bedrock is at or near the surface. This aquifer 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 COBI currently monitors water levels in four wells while KPUD monitors one well in the GMA (**Figure 5-9 and 5-10**). 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 COBI monitors chloride in five wells and the KPUD monitors one in the GMA. 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 are a data gap that could be filled by adding additional monitoring locations in the two areas shown in **Figure 5-9 and 5-10**.

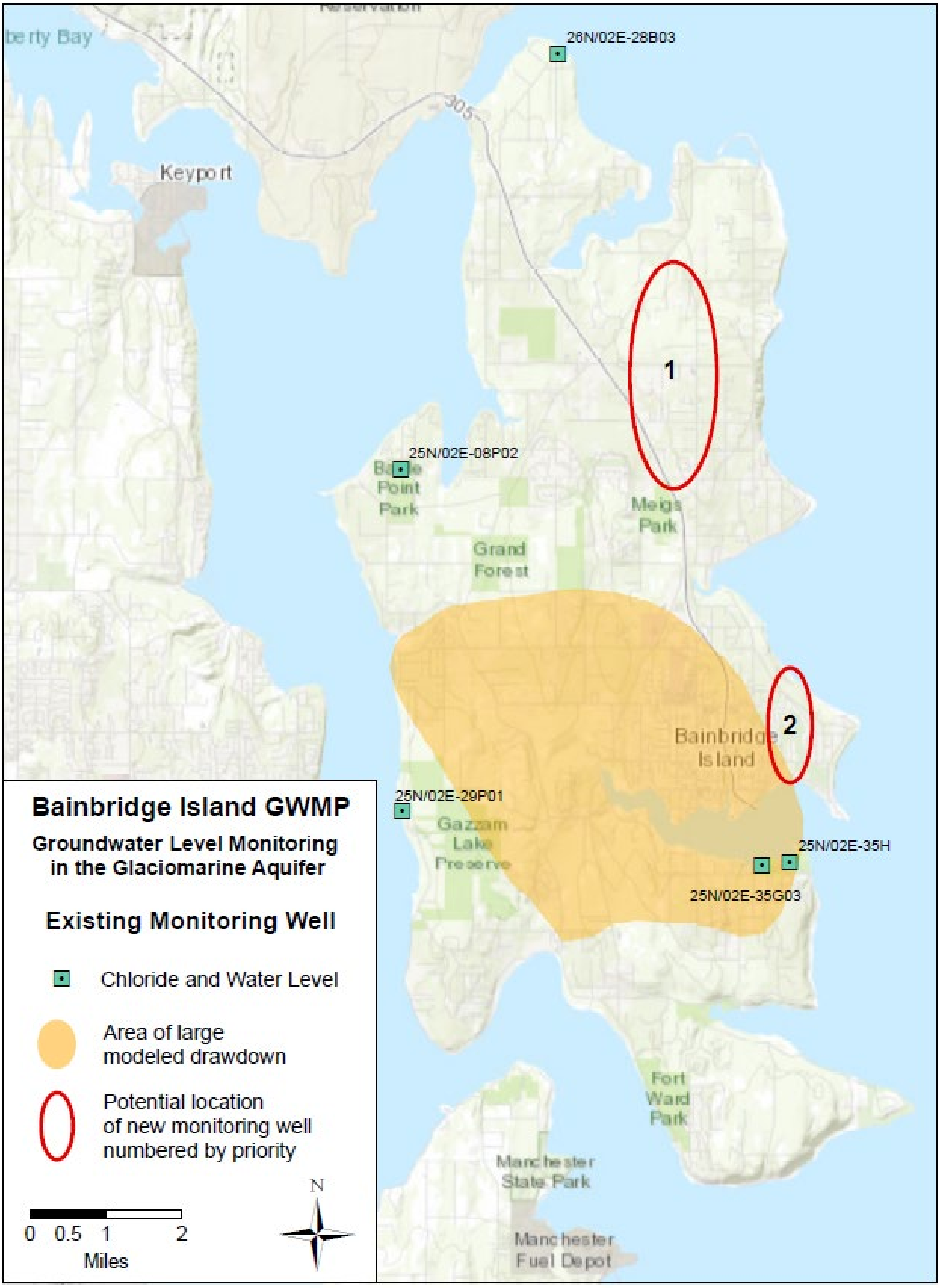

Figure 5-9. Existing and Proposed Water Level Monitoring, Glaciomarine Aquifer

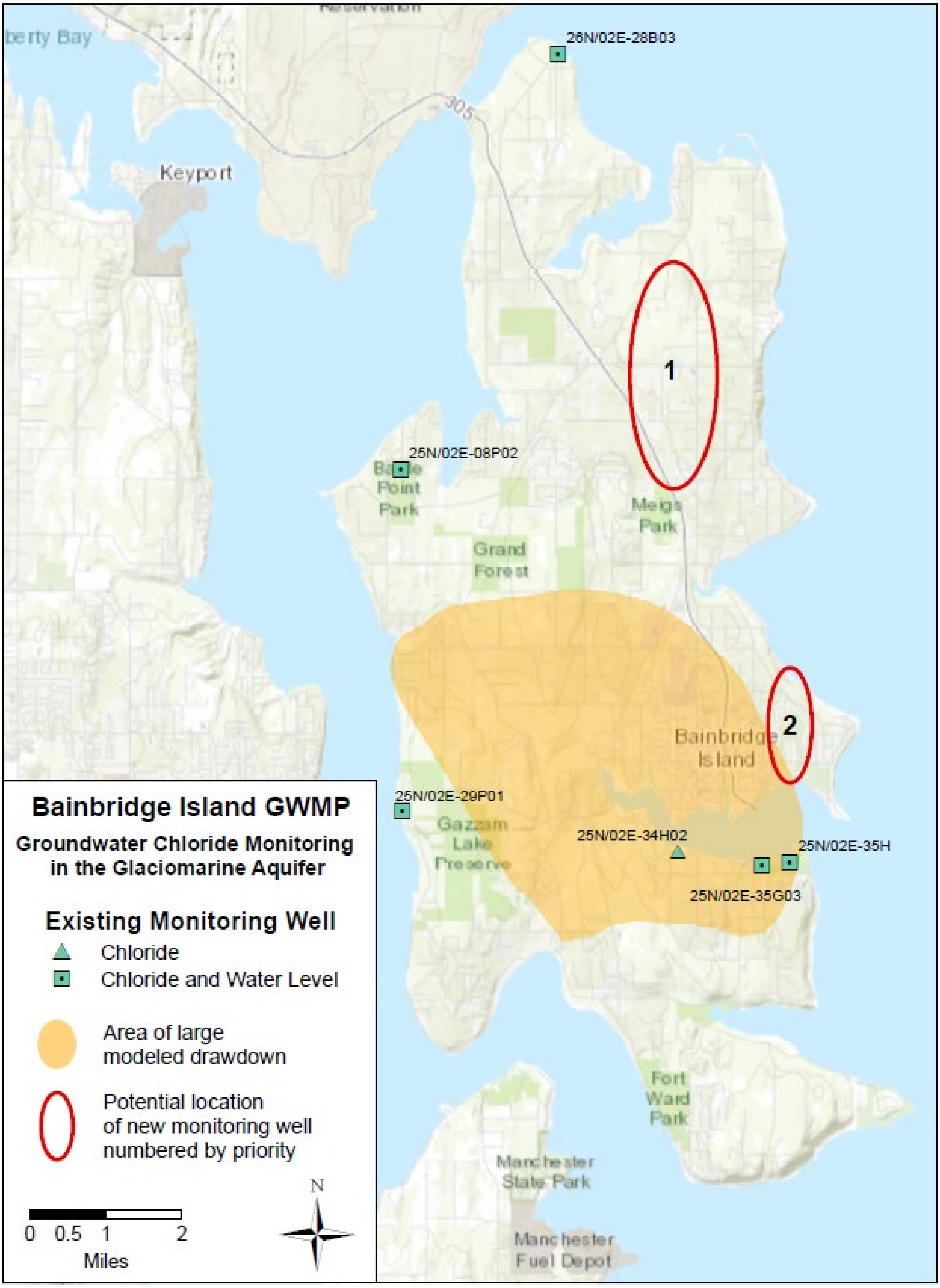

Figure 5-10. Existing and Proposed Chloride Monitoring, Glaciomarine Aquifer

Fletcher Bay Aquifer

The FBA (QA3) is laterally extensive and confined. The aquifer is absent locally east of Fletcher Bay, south of Murden Cove and on the southern end of the Island where bedrock is at or near the surface. The aquifer consists mostly of sand and gravel with silt interbeds. The top of the aquifer ranges from around 600-900 ft below MSL and typically ranges in thickness from 0-300 feet. Typical thicknesses are from 50 to 300 ft. Like the GMA, the FBA 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 COBI currently monitors water levels in three wells (Sands Road and Fletcher Bay wells) while KPUD monitors 6 wells (including the Island Utilities and North Bainbridge Water System wells) in the FBA **(Figure 5-11 and 5-12**). 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. None of the wells have exceeded the EWL criteria.

Three areas have been identified as potential sites to add additional monitoring to fill data gaps (**Figure 5-11**). 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 COBI 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 5-11** and **5-12**). 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 D.

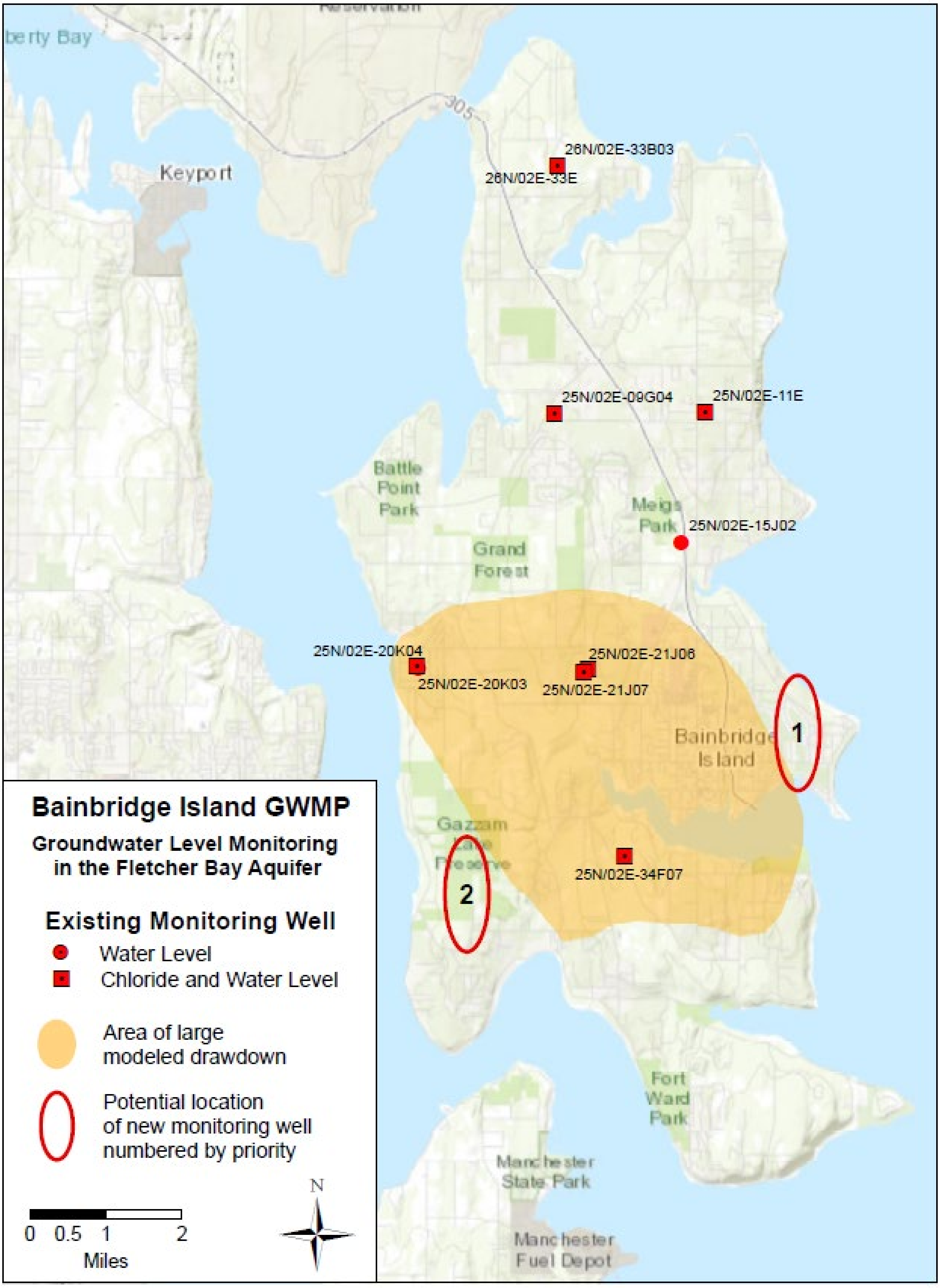

Figure 5-11. Existing and Proposed Water Level Monitoring, Fletcher Bay Aquifer

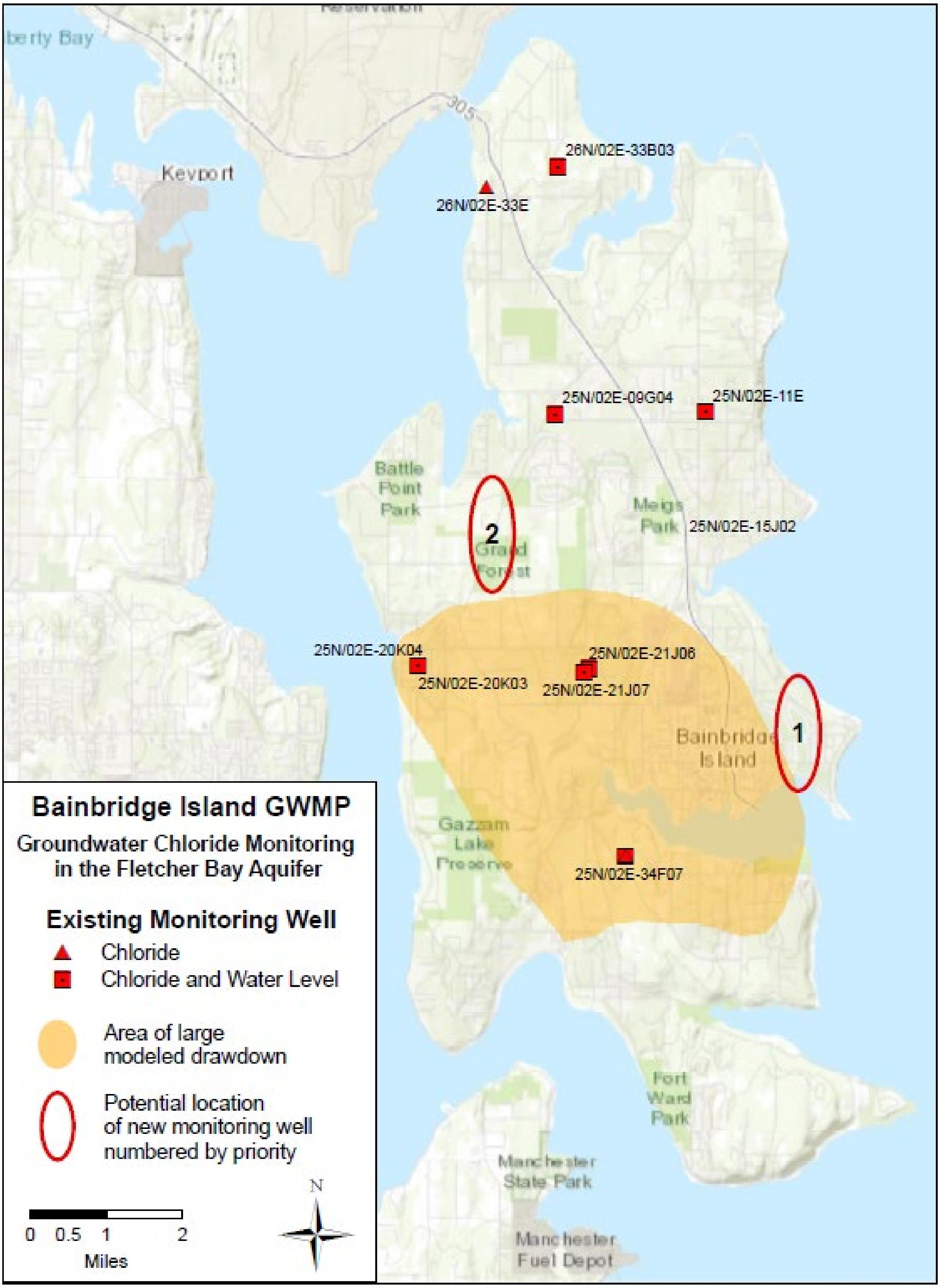

Figure 5-12. Existing and Proposed Chloride Monitoring, Fletcher Bay Aquifer

Bedrock Aquifer

The Bedrock Aquifer (the sedimentary Blakely Harbor and Blakeley formations) is present throughout the island. It occurs at or near the surface on the southern end of the Island due to faulting and uplift, but north of the fault line it lies deep below the units described above. No wells penetrate to bedrock north of the fault line and the altitude of the top of the unit below the glacial deposits is unknown. About one percent 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 COBI 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.

5.2.2 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 (**Figure 5-13**). 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 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.

Streams with the potential to be salmon-bearing (Washington Department of Fish and Wildlife SalmonScape) are also shown in **Figure 5-13**. These streams provide habitat for threatened and endangered salmonids (Coho, Fall Chum and Winter Steelhead) and are priorities for restoration and protection.

The COBI's Water Quality and Flow Monitoring Program has been operating on Bainbridge Island since 2008. Streamflow and water quality data is collected at sixteen locations, with at least one monitoring site within ten of the island's twelve watersheds. In addition, KPUD has monitored Manzanita Creek continuously since October 12, 2017. Stage and streamflow data is available on KPUD's website.

Stream monitoring is necessary to ensure that island streams can continue to support the critical habitat these resources provide. Monitoring is also used to assess protection and mitigation measures and track if they are meeting project objectives. Information gained from monitoring helps to prioritize stream protection and restoration and to select watersheds in which to concentrate, thus helping to ensure cost-effective water-resource management. By implementing the program, the City aims to restore or protect designated beneficial uses, restore 303(d) listed water bodies, and to prevent the degradation of healthy water bodies.

Effective monitoring is regular, long term, and includes biological, physical, and chemical measurements. Long-term data collection, using consistent and comparable methodology, is critical to identify trends and patterns. Water quality is constantly changing, during the day, from day to day, from season to season, and from year to year. To distinguish real trends from short-term fluctuations, consistent and systematic information over the long term is necessary. It is also necessary for evaluating environmental strategies and choosing the most cost-effective strategies for the future.

The monitoring network being operated by the City and KPUD includes monitoring on the highest priority streams, including the closed streams and most of the streams with potential salmon habitat. Additional monitoring stations could be added to the program, as needed and KPUD has expressed an interest in assisting or leading future stream monitoring efforts on the island. 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 have not been identified but should be considered as part of future development and mitigation actions.

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 steam 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.

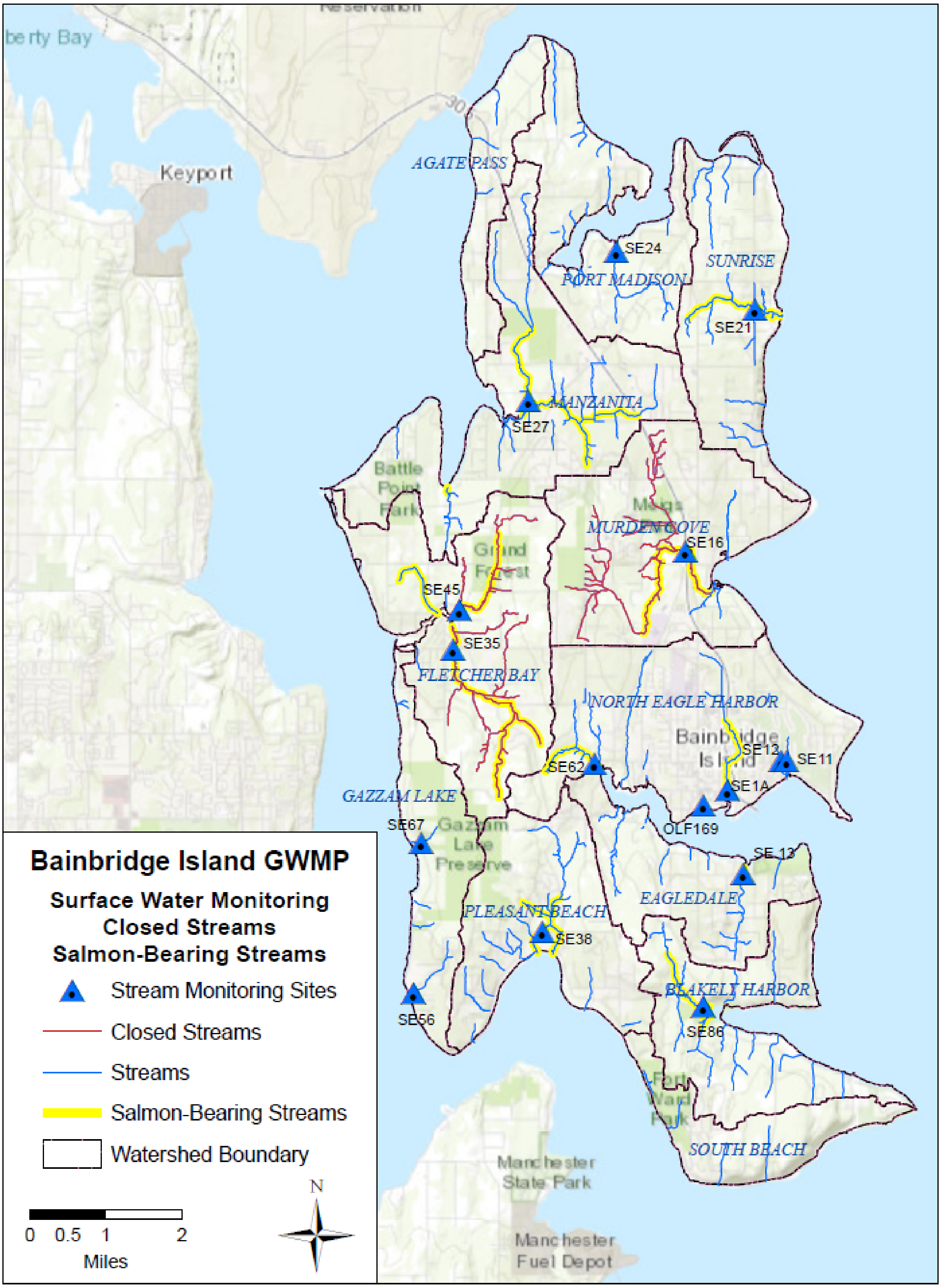

Figure 5-13. Bainbridge Island Watersheds, Salmon-Bearing, and Regulated Streams, and Surface Water Monitoring Network

This includes staff time to enter the station attributes into the COBI's database, equipment and field work to establish the station and collect data, processing and managing the data, and reporting.

5.2.2.1 Well Construction Database

Comprehensive data collection and management provide the foundation for management of Bainbridge Island's groundwater resources. Readily availability, high-quality and up-to-date information provides the data needed for effectively managing groundwater and avoiding degradation of groundwater resources.

Management and regulation of groundwater on Bainbridge Island includes individual well owners, public water systems, and multi levels of government, including COBI, County and State agencies. The COBI operates a groundwater monitoring and data management program, collecting data on water quality and groundwater elevations. This program is intended to monitor groundwater conditions to detect and avoid sea water intrusion and unsustainable declines in groundwater elevations.

The COBI's monitoring and data management program is an excellent tool to track groundwater conditions on the island. However, this program could be enhanced by incorporating additional data which would be very useful for tracking current groundwater withdrawals, planning, adding additional monitoring sites, and providing critical information needed for implementing other groundwater management strategies.

The COBI's groundwater database currently includes data on 146 wells, almost all of which are water supply wells. This is about 7.3% of the water supply wells that have been drilled on Bainbridge Island based on records in Ecology's well construction database (Ecology 2025). Ecology's database includes logs for more than 4,600 wells on the island, including approximately 2,600 resource protection wells (i.e., monitoring wells) and 2,000 water supply wells. The vast majority of the water supply wells are for permit-exempt uses such as single and multiple domestic purposes, and irrigation. Larger withdrawals are used for Group A and B water systems. A summary of the number of well construction records on Bainbridge Island is shown in **Table 5-1**.

Table 5-1. Summary of Well Construction on Bainbridge Island

Well Type	Number of Well Logs	Purpose
Water Wells	2001	Water Supply
Resource	2343	Soil sampling, vapor sampling, heat pump, Geotech soil boring, environmental investigation, monitoring
Dewatering wells	28	Pumping shallow groundwater during construction activities
Decommissioned Wells	333	Wells that have been abandoned per State regulations
Unknown	611	Likely mostly resource protection wells or soil borings
Total Existing Wells	4650	

Notes:
Source: Ecology 2025

The history of water well construction on Bainbridge Island is shown in **Figure 5-14**. This graph illustrates the number of wells constructed per year, as well as the cumulative number of water wells drilled on the island. In addition to the 1,738 wells represented on the graph, there are an additional 263 records for wells in Ecology's database that do not include the year of construction.

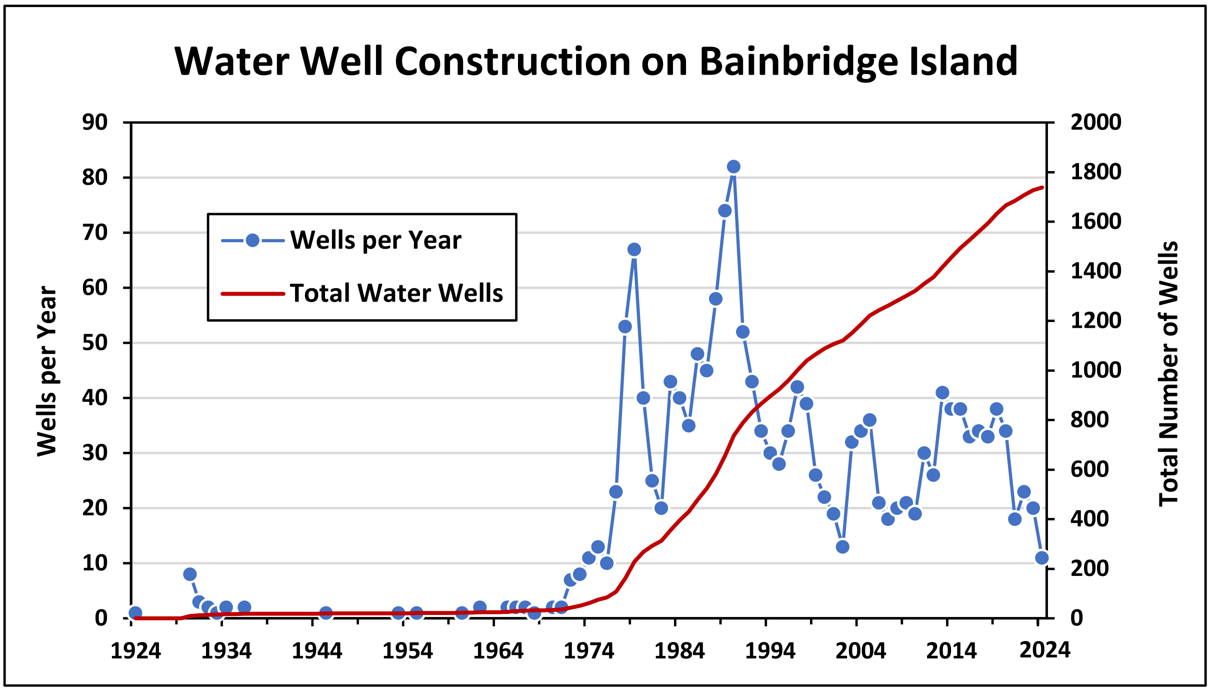

Figure 5-14. History of Water Well Construction on Bainbridge Island

Although it is the best 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. The database is based on well construction records (well logs) provided to Ecology by the well driller. Drillers were not required to provide these records to Ecology prior to 1971 when Chapter 18.104 RCW was codified. Thus, many records for wells drilled prior to 1971 are not in the database. Reported locations for wells are also not precise, as most wells are located by quarter-quarter section, an area the size of 40 acres. However, more recent records typically include parcel number and latitude – longitude (lat-long) coordinates which is a vast improvement.

Tracking future water well construction, as well as incorporating data on the large number of existing water supply wells into the COBI's groundwater database would be helpful in monitoring and tracking current groundwater uses and conditions, as well as assisting in planning and implementing future management strategies on the island.

Useful well data to incorporate includes well ID, lat-long coordinates of the well, parcel number, land surface elevation, depth of well and screened interval, the aquifer being used, static water level at the date and time of construction, any available water quality or water level data, purpose of use, pumping rate (both instantaneously in gallons per minute, and annually in acre-feet per year), water rights associated with the well, and an image of the well log (available on Ecology's web page).

Although it would be ideal to have records for every well on the island, this potential project should include a QA/QC process to verify information, including visiting the well site, so that only high-quality data is entered into the COBI's database. It should include a public information component describing the purpose and importance of tracking well construction on the island. In addition, most wells are located on private property and access to wells would require agreement from the well owner. Wells in locations and within aquifers where data gaps in the COBI's groundwater monitoring program could potentially also be added to the monitoring network. The project should include a plan to incorporate information starting with higher priority wells, such as the largest groundwater withdrawals, then incorporate wells in each aquifer, and within all 16 watersheds on the island. Ideally, any new wells drilled in the future should be incorporated into the database when they are constructed.

The database could be incorporated into a mapping tool and made available as public information. A good example is the publicly available groundwater database maintained by the Island County Health Department. Costs for maintaining the database would include importing data, performing QA/QC, field visits, public involvement and information, and maintenance of the web page.

5.2.2.2 Groundwater Model Updates/Scenarios

The 2025 EA Model represents an updated and refined version of a previously developed model, providing COBI with a well-calibrated groundwater flow modeling tool that simulates groundwater flow across Bainbridge Island. The model structure accurately represents the existing aquifer framework and reasonably reflects known aquifer flow properties. The impact scenarios offer reasonable estimates of potential future climatic and water use conditions, drawing from available climate change studies and historical population and production trends.

The 2025 EA groundwater model delivered to the COBI as part of GWMP was used to simulate potential groundwater conditions under different climate and population growth scenarios. The results of those simulations were presented to improve the understanding of potential future groundwater conditions on Bainbridge Island. However, the model results should not be interpreted as what the actual future conditions will be.

There are large uncertainties both in how climate change will impact the hydrologic cycle (sea level rise and the interactions between precipitation and recharge) and how populations will change on Bainbridge Island over the next 100 years. Even if these parameters could be forecasted without error there would still be uncertainty in the results predicted by the groundwater model itself. The groundwater model is a useful but imperfect representation of reality that inevitably contains errors and generalizations of actual conditions.

Because of this the COBI might periodically update model input using data collected in the future to rerun scenarios using additional data that is not yet available. The model could also be used to simulate potential management strategies, such as evaluating the impacts of artificial recharge such as the rate and timing of beneficial impacts to baseflow from artificial recharge. Another example would be using the model to evaluate potential locations for new water supply wells to avoid well interference and excessive drawdown.

Other potential uses of the model may be to evaluate the impacts of groundwater withdrawals on baseflow discharge to specific streams. This may require changes to the model grid to refine it near streams or editing stream reaches so impacts can be quantified at a much smaller scale than the entire watershed. Depending on the purpose, use of the model may include simple edits to input parameters, or it could include revising the model grid and making changes to layer thickness, extent or other parameters, as new information becomes available which might require recalibration.

Costs to use the model in the future are dependent on the objective of the modeling exercise and if revisions and recalibration would be required. Estimated costs to update the model, run scenarios and report results range from about $25,000 to $250,000 depending on the scope and objectives of the project.

5.2.3 Prevention of Adverse Impacts to Groundwater and Streams

5.2.3.1 Restrict Water Well Completion in the Advance Outwash Aquifer

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. Most permit-exempt wells are used for single or multiple domestic purposes and 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 COBI, 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 sub basins 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 COBI'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.

5.2.3.2 Protection of Critical Aquifer Recharge Areas

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

Section 16.20.100 includes:

- Requirements and review procedures for Critical Area Permits for development
- A list of prohibited activities and uses
- Development standards

Section 16.20.100 is an important and effective management strategy that helps protect groundwater quality on the island.

5.2.3.3 Stormwater Management Program

The Bainbridge Island Municipal Code includes Chapter 15.20 Surface Water and Stormwater Management which also is a Groundwater Management Strategy. The Chapter is intended to establish regulation for all new development, redevelopment or construction activities within the COBI 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 COBI 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 COBI's Stormwater Management Program operates under the Western Washington Phase II Municipal Stormwater NPDES and State Waste Discharge Permit. This 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.

5.2.3.4 Prevention of Seawater Intrusion

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 COBI 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 - Seawater intrusion protection). Island Conty 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 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 COBI to consider drafting and adopting an ordinance in the COBI's Municipal Code to serve a similar purpose. The COBI 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 5-2**.

Table 5-2. Island County Seawater Intrusion Risk Categories

Risk Category	Water Level Elevation[1]	Chloride Concentration[2]
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 5-3**.

Table 5-3. 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 COBI's EWLs are an appropriate and effective Management Strategy for current groundwater conditions on Bainbridge Island. However, the COBI 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.

5.2.3.5 Public Involvement

COBI is actively engaged in public involvement and educational activities on a number of COBI 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. Island residents having a basic understanding of groundwater and why protecting it is important is likely to promote public awareness and support for groundwater management actions on the island.

5.2.4 Proactive Management Strategies

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. Previously noted Management Strategies included monitoring, data management and administrative actions to track, and regulate the resource. Proactive Management Strategies are proposed actions that are intended to physically benefit the resource in quantifiable ways.

5.2.4.1 Expand COBI Production Wells Across the Island

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 COBI'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 COBI wish to pursue this Management Strategy, there are likely many years to plan and fund the project.

5.2.4.2 Intertie and Coordinate Operations and Monitoring with KPUD

Similar to the previous Management Strategy, connecting the COBI'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 COBI'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.

5.2.4.3 Integrate 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.

5.2.4.4 Managed Aquifer Recharge (MAR)

Managed Aquifer Recharge (MAR) is a general term regarding intentionally engineered groundwater recharge. Source water is often captured during flashy events during storms and spring runoff, infiltrated on the surface or using injection wells, 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.

Two types of MAR are summarized here as potential Groundwater Management Strategies.

Surface Infiltration or Shallow Aquifer Recharge (SAR)

Shallow Aquifer Recharge (SAR) typically refers to MAR projects that use surface infiltration in ponds, ditches, lakes, wetlands, etc. Water is diverted to the infiltration sites and typically allowed to flow through the groundwater system without being actively recovery. Common uses of SAR are to increase groundwater recharge during times of higher surface flows, when water is available for diversion so that the recharged water can increase baseflow discharge to streams, ideally in the late summer when natural stream flows are at the lowest period of the water year.

Source water for SAR could be water from irrigation ditches, water diverted from streams, stormwater and reclaimed water from wastewater treatment plants. Groundwater quality standards are required to be met at the water table, but lower quality water can be used for infiltration if it seeps through the unsaturated zone and gets “treated” before reaching the water table. SAR projects are generally cheaper to implement, although property is needed for recharge facilities and source water may be difficult to obtain and infrastructure costs to transport the source water to the infiltration site can be high.

Additionally, the recharge facility must be located in the “right” location for recharged water to provide the intended benefit. For example, if the goal is to enhance baseflow discharge to a stream in the late summer, the infiltration facility must be located up-gradient of the target stream at a distance where groundwater travel time to the intended stream matches the timing between recharge at the facility and baseflow discharge during the low flow period. Increased baseflow discharge typically occurs by ramping up and then decreasing so ideally, a good portion of the increased baseflow discharge occurs during the target period.

SAR projects are typically implemented by first identifying the appropriate infiltration site and source of water. Unless it is reclaimed water, water rights would be needed to access source water so water must be legally and physically available during the intended recharge period. Permits are obtained and field tests are conducted to assess infiltration capacity, water quality, logistical issues and travel times to intended targets. Pilot tests are conducted to perform a large-scale test to check assumptions, monitor aquifer response and to assess water quality. If all still looks good, the project can move into full scale operation. Monitoring and reporting to the state is typically required. The entire process could take several years, but with good planning and the right site conditions, SAR projects can be very beneficial for enhancing baseflow discharge to streams which can increase streamflow and reduce stream temperatures.

SAR is a potential Management Strategy that could be used to mitigate impacts to streams from groundwater withdrawals and increase streamflow and improve habitat during low flow periods.

Aquifer Storage and Recovery (ASR)

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.

Because water is injected directly into the saturated zone of the aquifer, recharged water must meet groundwater quality standards at the point of injection. This eliminates using stormwater, stream water, or water from irrigation ditches as source water for recharge unless it can be treated to meet standards before injection. In several of the permitted ASR projects in Washington, treated municipal drinking water is used for source water. Because treated drinking water typically contains disinfection byproducts (DBPs) such as chloroform, in excess of groundwater quality standards and the anti-degradation policy, it also cannot be used as source water for ASR unless Ecology can make a determination that the project can be permitted because of Overriding Consideration of the Public Interest (OCPI).

ASR projects that store water in an aquifer for later recovery require a Reservoir (ASR) Permit issued by Ecology’s Water Resource Program. However, when the project includes recharging the aquifer with water containing concentrations of contaminants that exceed the Water Quality Standards for Ground Waters of the State of Washington, Ch. 173-200 WAC, the Water Resources Program must consult with Ecology’s Water Quality Program to insure the project is in compliance with state water quality standards, including the anti-degradation policy.

A disinfectant residual is required in the municipal drinking water distribution lines which can also affect the concentration of DBPs in the water. Once recharged in the aquifer, if chlorine is used as the disinfectant, DBP concentrations may also increase if chlorine is present in the recharge water. In most municipal systems, DBPs are present in higher concentrations than the groundwater quality standards specified in WAC 173-200-040. In addition, DBPs are not naturally occurring, and thus, any introduction of these contaminants into an aquifer likely violates the anti-degradation policy in Ch. 90.48 RCW and WAC 173-200-030.

Although introduction of DBPs to the aquifer by injecting treated municipal water for aquifer recharge can be a violation of State water quality standards, using an analysis of all known, available and reasonable methods of prevention, control and Treatment (AKART), proponents of ASR projects may be permitted to inject water containing DBPs if it is determined that the overall project is in the public interest. Ecology can and has authorized the injection of water containing DBPs for ASR projects after the applicant has performed AKART and Ecology has determined that the benefits of implementing ASR override the concerns associated with injecting water containing DBPs at concentrations above the State groundwater quality standards. Ecology has also prepared guidance for ASR AKART analysis and overriding consideration of the public interest to assist ASR permit applicants perform this analysis. Please refer to the guidance document for more background and information regarding the regulatory framework and requirements for demonstrating compliance with the State groundwater quality standards.

The requirements for ASR permitting are outlined in RCW 90.03.370, RCW 90.44.460, and described in Ch. 173-157 WAC, Underground Artificial Storage and Recovery. Ecology has provided guidance documents addressing the ASR permit application requirements and water quality considerations. The process described here summarizes and closely follows the information presented in these documents. Additionally, the ASR permit application is available on-line.

The intent of the guidance documents is to ensure that the applicant provides the information Ecology (or a cost reimbursement contractor) needs to make a permit decision based on the science, laws, and administrative rules related to reservoir permitting in Washington state. A complete *Application for Underground Artificial Storage and Recovery Reservoir Permit* consists of the application form, required fees, an attached report addressing application requirements, and various attachments such as maps and other reports.

Ecology strongly recommends a pre-application consultation prior to filing the ASR permit application. Pre-application consultations offer an opportunity to get questions answered and obtain advice on application requirements to prevent unnecessary work and expense. Ecology requires submitting a Water Right Pre-Application Consultation Form before scheduling a pre-application consultation with Ecology.

Most ASR projects that have been permitted by Ecology include a Pilot Phase of the project. This phase is typically used to test the operation of the system, collection of water quality data and any other information required for a complete ARS application, and a check on the hydrologic conceptual site model. The Pilot Test can be used to ramp up recharged volumes over multiple recharge/storage/recovery cycles which is useful in determining water level and quality changes, storage volumes and recovery efficiency.

Ecology may elect to require a pilot phase of the project under two separate permitting scenarios. Ecology may issue a Preliminary Permit under RCW 90.03.290. Preliminary permits are used by Ecology and water right permit applicants to collect information needed to make a final determination on the permit application. Preliminary permits could be used to conduct pilot tests, when all the information needed for a complete application is lacking. However, beneficial use of recovered water cannot be authorized under a preliminary permit. Thus, preliminary permits should only be used for data collection purposes and are typically limited to a period of 3 years or less. Preliminary permits are appealable Ecology decisions.

Should the water right permit applicant want to beneficially use the water recovered during a Pilot Test, Ecology has the authority under RCW 90.03.250 to authorize beneficial use of recovered water through a Temporary Permit. Ecology must make the determination that the Pilot Test complies with Ecology's 4-part test before the Temporary permit can be issued, but there may be other information needed prior to the issuance of an groundwater storage permit under Chapter 173-157 WAC. Temporary permits can be issued for long-term Pilot Testing and allow the beneficial use of recovered water so are a useful approach to getting Pilot Tests authorized prior to the final decision on the ASR permit application. Temporary permits are also appealable Ecology decisions.

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.

5.2.4.5 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 COBI 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 5-4**.

Table 5-4. Summary of Potential Groundwater Recharge Sites per this Study (Anchor QEA 2024)

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		

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.

5.2.4.6 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. Overall costs for a water conservation program at the COBI are likely equivalent to at least one FTE (around Christian's classification??) plus costs for investigations, equipment, the public education program and fixing leaks.

5.2.4.7 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.

Kitsap County allows 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.

Kitsap County also offers resources and assistance for homeowners looking to implement green stormwater solutions like rain gardens and rainwater harvesting. Collected rainwater often has significant contaminants that must be removed before the water is considered safe for consumption. For regulation purposes, the Washington Department of Health's Office of Drinking Water considers rainwater to be surface water subject to the requirements of the Surface Water Treatment Rule. If you want to use rainwater as your sole water supply when building a new home, contact your local county planning department.

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.

Highlighting this model signals the COBI's openness to exploring a broader adoption of rainwater harvesting as part of its long-term water management strategies. 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.

6. RECOMMENDATIONS

Based on the analysis of potential recommended management strategies will be selected by COBI in coordination with the Groundwater Subcommittee and public input.

Together with City staff, a matrix of Groundwater Management Plan Actions was developed to respond to the findings in the Plan - the Actions are categorized as proactive mitigation; prevention; data collection; and information management. A work plan was developed for each action, broken up into three, 3-year increments, and costs for each increment were assigned. In discussions with the GWMP sub-committee and the Technical Advisory Committee, both groups highlighted the need for ranking the actions in accordance with a prioritization criterion so that an overall work plan and budget for the groundwater management plan could be developed.

In response to that request, City staff developed a cost/benefit analysis tool that serves as the prioritization criteria for ranking the actions. The criteria ranked the costs of each action from 1-4, with 1 being the highest relative cost (>$250K) and 4 being the lowest relative cost (<$50K). Only the costs between years 0 and 6 were considered for the analysis, as costs beyond the 6-year timeframe were deemed to be speculative estimates. The benefits of each action were ranked 1-4 according to the directness of their impact: proactive actions were ranked highest at 1, followed by prevention, data collection and information management.

The cost/benefit calculation resulted in actions being assigned a ranking between 4 and 0.33, with the highest priority action being "Promote Water Conservation," and the lowest priority action being "Installing New Groundwater Monitoring Wells." The top 7 actions in the prioritization (ranked between 4 and 1.33) generally align with the team's initial assessment of the programs that should make up the future groundwater management program, while the middle-ranked actions are generally actions that are in progress but have longer-term horizons. These results indicate to the team that the parameters of the cost/benefit analysis is a satisfactory tool for prioritizing actions.

Table 6-1. City of Bainbridge Island Groundwater Management Plan Actions

Actions	Objective	Description	Benefits	Action Category	Notes	Planning Horizon	Work Plan	**Cost** (thousands; supplemental to base cost for 1 FTE @ $150K annual)	**Cost/Benefit Analysis** (Year 0-6)
Promote Water Conservation	Water usage is reduced, leading to improved aquifer health and longevity, preservation of natural environments, and postponement of the need for infrastructure expansion.	This action involves developing and promoting water conservation, which will minimize water wasting and leakage, improve water use efficiency, and potentially increase recycling and reuse of water. Programs could include measures to change behavior, adopt water-saving technologies, and improve water management practices.	Water conservation will result in reducing energy consumption, lowering water bills, protecting ecosystems, and mitigating the impacts of drought and water shortages. It also helps to maintain the health of aquatic habitats in wetlands and streams. Conservation can lower peak daily demand defering the need for addtional storage.	Proactive Mitigation	The City has a water conservation plan that was included as part of the Water System Plan, developed in 2015. This plan provides a foundation for expanded conservation efforts.	Year 0-3	• Update the water conservation plan outlined in the Water System Plan • Develop a water conservation goal • Develop and implement water conservation pubic outreach plan • Evaluate past conservation measures for effectiveness • Evaluate conservation impacts on water rates • Develop "soft" and "hard" measures; pilot soft measures	$20	**4.00**
						Year 4-6	• Analyze metrics to measure success of the soft trategies • Pilot hard measures • Implement rate changes to reflect conservation targets	$23	
						Year 7-10	Adaptively manage conservation plan and modify as needed	$26	
Manage Storm and Surface Water	Storm and surface water quality and quantities are not damaging to the natural environment, and do not negatively impact groundwater.	This action involves increasing the use the Low Impact Development (LID) in new construction and existing development and ensuring Best Management Practices (BMPs) are implemented at all facilities handling, using and storing hazardous materials	Managing storm and surface water will result in the protection of streams and creeks, including related habitats, postponing the need for infrastructure replacement and/or expansion, and preventing groundwater contamination.	Proactive Mitigation Action	The City has a storm and surface water program that can be tailored or adjusted to meet the needs associated with groundwater protection.	Year 0-3	• Continue to implement source control and IDDE program with a focus on wellhead protection areas and priority recharge areas. • Consider rebate/incentive program to improve retrofit/mitigation implementation.	$50	**3.00**
						Year 4-6	• Examine the current Low Impact Design requirements for stormwater mitigation during development with a focus on clean groundwater recharge. • Create a program to incentivize retrofits to mitigate runoff from existing development.	$50	
						Year 7-10	If needed, refine regulations to improve developed sites' ability to match preexisting hydrology using LID.	$25	
Provide Public Education and Involvement	The public is informed on the wise use of water resources and has a broadened interest in water-related environmental protection.	This action involves development and promoting public involvement/education programs to increase public awareness and participation in groundwater management monitoring, protection and use.	Public education and involvement will result in increased awareness of water conservation, greater community support for sustainable practices, and improved water quality. Educating the public empowers individuals to adopt sustainable habits, participate in decision-making processes, and advocate for environmental protection.	Prevention	Programs should target all age groups, and be tailored to user types.	Year 0-3	• Develop a public education and involvement plan; consider the needs of other plan actions. • Choose 1 audience per year for specific outreach material development. Implement a web-based dashboard to increase data transparency	$20	**2.00**
						Year 4-6	Analyze metrics to measure success of the outreach strategies	$23	
						Year 7-10	Adaptively manage the public education and involvement plan and modify as needed	$26	
Evaluate Limiting New Wells in Shallow Aquifer	Well limitationsin specific areas relieve stress on streams and wetlands during the low flow season.	This action involves evaluating locations and depths where wells should be restricted, and/or where new wells should be at deeper depths.	Restricting some wells will improve conditions for streamflow, riparian habitat, salmonids and other wildlife	Prevention	Any restrictions could be based on existing state-level "Instream flow rules," water management act and ARPA in the Critical Areas Ordinance.	Year 0-3	Examine the process undertaken in the Chimacum watershed to protect instream flows and its relationship to the situation on Bainbridge Island.	$25	**2.00**
						Year 4-6	Develop policy	$25	
						Year 7-10	Implement policy	$52	
Develop Seawater Intrusion Mitigation Strategies	Indications of seawater intrusion are observed early, and mitigation strategies are in place to assist impacted well owners.	This action involves developing policies and management actions to address potential impacts from seawater intrusion.	Having a plan for addressing seawatrer intrusion will benefit homeowners or other well owners, and could provide advanced notice to large water purveyors regarding potential infrastructure expansion needs.	Prevention	One formal response to seawater intrusion has been completed in the Seabold neighborhood. Further investigation may be warranted north and east of the previous extent.	Year 0-3	Reiew ane refine the City's policy for responding to a suspected saltwater intrusion event based on previous investigations.	$0	**2.00**
						Year 4-6	• Develop policy for the City's response to a neighborhood scale intrusion event. • Include in policy the process to protect water quality in existing wells from new nearby extraction (possibly similar to Island or San Juan Counties). Work with KPHD to define roles and responsibilities.	$20	
						Year 7-10	Collaborate with KPUD and other major water purveyors to prepare for policy implementation, as needed.	$20	

Actions	Objective	Description	Benefits	Action Category	Notes	Planning Horizon	Work Plan	Cost (thousands; supplemental to base cost for 1 FTE @ $150K annual)	Cost/Benefit Analysis (Year 0-6)
Manage and Expand Existing Groundwater Well Monitoring Program	The City can identify groundwater trends and risks with a wide and continually expanding groundwater database.	This action involves managing and expanding the existing groundwater well monitoring program through outreach to exsiting well owners and deployment of monitoring equipment.	Managing and expanding the existing groundwater well monitoring program will result in identifying trends and potential risks, and allowing for more regular updates to the groundwater model.	Data Collection	The program should consider locating new monitoring wells with GPS, connect well logs, aquifer IDs, pumping rates, water levels, and quality data. Consider manual vs automated level logging.	Year 0-3	• Maintain existing monitoring well locations where changes in ownership have occurred • Develop and manage an outreach and implementation program aimed at encouraging the installation of monitoring equipment on private wells in highest priority areas. • Goal is to add 5 new monitoring wells to the monitoring network, from preexisting sources, in the Perched and Sea Level aquifers.	$10	**1.33**
						Year 4-6	• Expand existing well monitoring program by up to 3 wells per year;	$12	
						Year 7-10	• Expand existing well monitoring program by up to 3 wells per year or until target number is reached • Begin expanding monitoring program into secondary prioritization areas.	$15	
Manage and Expand Surface Water Monitoring	Ths City can identify surface water trends and risks with a wide and continually expanding surface water database.	This action involves managing and expanding the existing surface water monitoring program through prioritization of surface water locations and variables, and the deployment of monitoring equipment.	Managing and expanding the existing surface water monitoring program will result in the ability to effectively manage island surface water resources, such as streamflow, riparian habitat and salmonid and other wildlife habitat.	Data Collection	This program can provide data for future surface/groundwater interaction modeling, including generating streamflow characteristics. The results from this program can also help inform potential landuse regulations.	Year 0-3	• Analyze the existing surface water monitoring program to identify data gaps and quality of current data sources from the current 5 automated flow gauging stations; Springbrook, Cooper, Ravine, Doe Qud Sake Qub (AKA Murden), and Manzanita Creeks (managed by KPUD).	$22	**1.33**
						Year 4-6	• Develop a plan to expand the surface water monitoring program based on watersheds with greatest modeled impacts and highest priority resources. Possible streams include Issei, Schel Chelb and Sportsman's Club creeks.	$25	
						Year 7-10	• Implement an expansion of the surface water monitoring program with automated stream gauging stations in up to 5 new perennial fish bearing streams.	$50	
Update the Groundwater Model, Test New Scenarios	The City has access to an up-to-date groundwater model that can be used to evaluate current and future conditions.	This action involves updating the groundwater model with the most recently collected data, and running planning scenarios.	Updating the groundwater model and testing new scenarios will result in benefits such as informing policy development and data collection strategies, and identifying risk-management actions.	Information Management	Model scenarios could be used to assess the best locations for new wells or other potential projects such as managed aquifer recharge.	Year 0-3	• No action	$0	**1.00**
						Year 4-6	• At year 6 run 5-10-year modeling scenarios using new data captured from expansion of well monitoring and new monitoring wells • include information from observed and newly predicted conditions	$35	
						Year 7-10	• At year 9 run 5-10-year modeling scenarios using new data captured from expansion of well monitoring and new monitoring wells • Include information from observed and newly predicted conditions. • Recalibrate model based on new well reports and monitoring data. Revisit recharge variables based on best available science.	$40	
Identify Groundwater Recharge Protection Areas	Critical groundwater recharge areas are protected from development impacts.	This action involves evaluating land-use impacts and potential mitigation strategies in key watershed and groundwater recharge areas.	Identifying groundwater recharge protection areas will result in protecting shallow groundwater and surface waters on the island in the short-term, and will protect deep aquifers in the long-term.	Prevention	Some level of work on this effort was performed in 2018 as part of the development of the aquifer recharge protection area regulations. This program should include re-evaluating that work, and also identifying potential off-island areas that could also be protected through work with partner agencies.	Year 0-3	• Building on existing data from the GWMP and the Beneficial Re-use Study, develop a prioritization of recharge protection areas. • Evaluate effectiveness of the current Aquifer Recharge Protection Area regulations (BIMC 16.20.100).	$50	**1.00**
						Year 4-6	• Develop potential land-use changes or other regulations that would implement protection for critical recharge protections areas • Consider implementation as part of the Comprehensive Plan mid-term review process	$150	
						Year 7-10	TBD	TBD	
Spread Out New Production Wells Across the Island	Large water systems in the City are reliant upon wells that provide long-term stability and sustainability for the related aquifers.	This action involves shifting new large production wells further north on island to spread out groundwater extraction and provide longer-term sources for South Island users.	Spreading out production wells will result in relieving the pressure on certain groudnwater systems, and preventing excessive drawdown, saltwater intrusion, and impacts to surface water environments.	Proactive Mitigation Action	This action should be considered as part of a consolidated effort with other management actions, including the evaluation of interties and increases in water storage.	Year 0-3	• Perform evaluation of production well options and cost/benefit along with study of intertie options	$50	**1.00**
						Year 4-6	• Near the end of this planning horizon, begin evaluation of well siting costs and inter-agency agreements	$200	
						Year 7-10	• Complete evaluation of well siting costs and inter-agency agreements; Consider potential for new production well implementation	$100	

Actions	Objective	Description	Benefits	Action Category	Notes	Planning Horizon	Work Plan	Cost (thousands; supplemental to base cost for 1 FTE @ $150K annual)	Cost/Benefit Analysis (Year 0-6)
Evaluate and Implement CIty Water system Interties with KPUD Systems	Large water systems in the City are connected north to south with a series of interties.	This action involves coordinating management (withdrawals, distribution, and monitoring) with KPUD and potentially other water systems on the Island.	Implementing water system interties will result in environmental and economic benefits, shared resources and information, and co-management of surface and groundwater resources on the island.	Proactive Mitigation Action	This action should be considered as part of a consolidated effort with other management actions, including the evaluation of spreading out production wells and increases in water storage.	Year 0-3	• Complete a formal cost/benefit analysis and evaluation of intertie options and consider costs as part of 2027-28 utility rate study	$50	**1.00**
						Year 4-6	• Consider recommendations from analysis and evaluation in the planning and funding of intertie projects; design project	$200	
						Year 7-10	• Complete at least one intertie project	$500	
Consolidate Smaller users with larger water systems	Small water systems are systematically integrated into larger systems over time.	This action involves working to identify small water systems that could incorporate with nearby large public water systems. This would require extension of water lines, installation of meters and connections and decommissioning wells.	Consolidating water systems will result in improved operational efficiency, add enhanced financial stability through economies of scale, leading to lower per-customer costs and the ability to invest in infrastructure improvements and alternative water sources.	Proactive Mitigation Action	A systematic approach to consolidation would allow for grant procurement, and would prevent the need for last-minute management agreements or isolated water system ownership.	Year 0-3	• Complete Water System Business Plan and begin outreach to priority neighborhoods and/or water systems regarding potential consolidation • Consider expansion/consolidation costs as part of 2027-28 utility rate study	$50	**1.00**
						Year 4-6	• Plan and design near-term expansions/ consolidations	$200	
						Year 7-10	• Implement priority expansions/consolidations	$1,000	
Increase Storage for Municipal Water	Large water systems in the City have coordinated storage systems that meet demand.	This action involves increasing storage volume for the municipal water systems to be able to provide enough water during peak demand. This could help spread out withdrawals and costs over a longer time period.	Increasing storage volume in the municipal water system provides several key benefits, including improving water pressure and availability, reducing peak demand costs, and enhancing emergency preparedness.	Proactive Mitigation Action	This action should be considered as part of a consolidated effort with other management actions, including the evaluation of spreading out production wells and implementing water system interties.	Year 0-3	• Study storage issues/benefits as part of evaluation of intertie coordination	$50	**1.00**
						Year 4-6	• Study storage issues/benefits as part of evaluation of intertie coordination; consider storage needs resulting from potential new production wells	$200	
						Year 7-10	• Consider implementation of storage facility resulting from new production wells	TBD	
Evaluate and Implement Managed Aquifer Recharge	Aquifer recharge opportunities are implemented in critical and available locations.	This action involves surface infiltration or injection directly into prioritized aquifers for later recovery. Source water for recharge could include stormwater, reclaimed water, and treated drinking water.	Aquifer recharge could augment stream baseflow, prevent seawater intrusion, increase recharge, and mitigate drawdown in aquifers.	Proactive Mitigation Action	Reference Watershed Assessment of Manzanita as a template.	Year 0-3	• Implement the Manzanita Stormater Recharge Park project, and identify other potential projects within the Mananita watershed for implementation. • Coordinate work with projects and offset goals identified in the WRIA 15 Streamflow Restoration Plan.	$1,200 (grant received)	**1.00**
						Year 4-6	• Expand the model of the Manzanita Watershed project to at least 2 additional priority watersheds.	$250	
						Year 7-10	Identify and implement priority projects from watershed analyses.	TBD	
Evaluate and Implement Wastewater Beneficial Re-Use	Wastewater is re-used in lieu of being discharged to Puget Sound.	Wastewater from the Winslow Wastewater Treatment Plant is processed for re-use in the Winslow area for groundwater recharge, irrigation and other non-potable uses.	Beneficial reuse of wastewater offers several benefits, including drought resilience, reduced reliance on freshwater sources, and support for agriculture and other non-potable uses. It also helps protect ecosystems by reducing the discharge of treated water into Puget Sound.	Proactive Mitigation Action	The City is currently working on a preliminary concept for wastewater beneficial re-use that would serve as irrigation and potentially groundwater recharge.	Year 0-3	• Continue with ongoing wastewater beneficial re-use study and field investigations; Develop 30% design • Begin discussions on agreements with high water users for re-use substitution.	$500	**1.00**
						Year 4-6	Complete 100% design of re-use infrastructure.	$1,000	
						Year 7-10	Implementation	TBD	
Install New Groundwater Monitoring Wells	The City has access to monitoring wells in critical locations.	This action involves expanding the groundwater monitoring network in priority locations and depths to verify model results and identify potential risks.	Installing new monitoring wells will result in comprehensive data collection and management that is critical to effectively managing island groundwater resources and avoiding degradation of the aquifer system.	Data Collection	Existing wells that can be monitored in priority locations is preferred over the expense of new wells.	Year 0-3	• Identify possible locations for new monitoring wells	$10	**0.33**
						Year 4-6	• Install 1 new monitoring well in the Fletcher Bay aquifer	$400	
						Year 7-10	• Install 1 new monitoring well in the Glaciomarine aquifer	$500	

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8. GLOSSARY

Aquifer – An aquifer is a body of porous material, such as sand and gravel or fractured bedrock, that will yield water in a usable quantity to a well or spring.

Acre-ft – volume measurement for example for water this is the volume of water necessary to cover one acre with one foot of water

Confined aquifer – Confined groundwater is under pressure from an overlying confining unit with lower permeability, and its upper limit is the bottom surface of an overlying confining unit.

Baseflow – water seeping into a stream from groundwater

Discharge – volume of water flowing in a stream or through an aquifer past a specific point during a given time period

Dynamic equilibrium – inflow to the system equals outflow from the system and there is little or no net change in the amount of water stored in the system

Hydraulic conductivity – measure of the relative ease of a body of porous material can transmit water under a potential gradient

Hydrogeology – the study of groundwater

Hydrologic cycle – Describes water movement in Earth systems

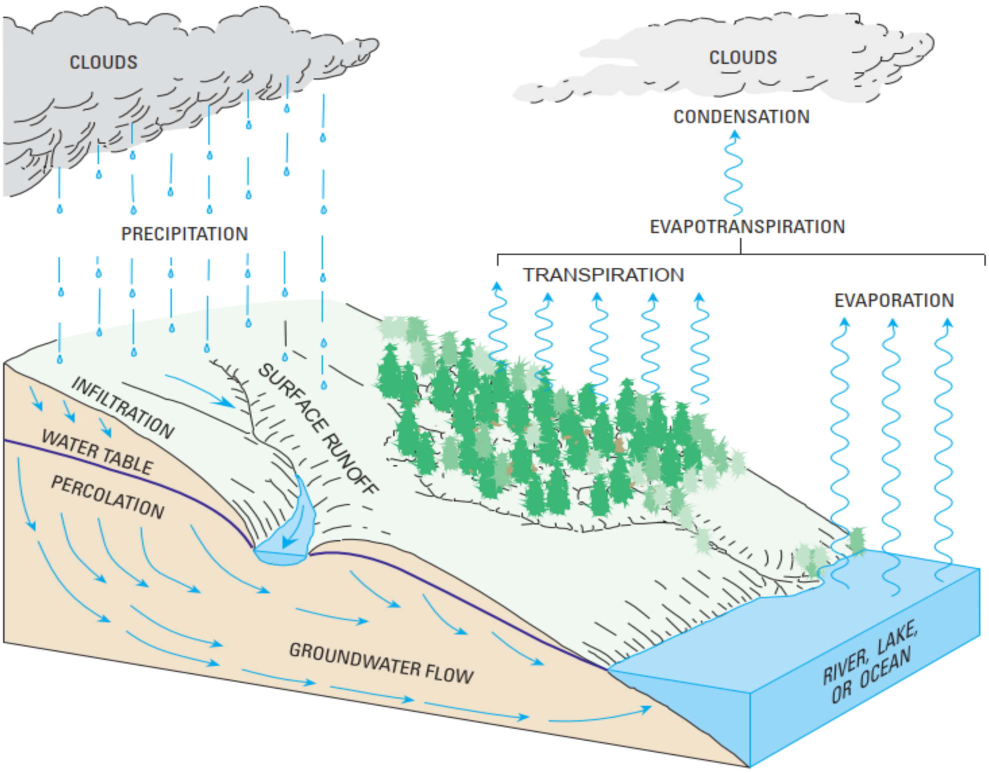


Figure 4. The hydrologic cycle.

Source: Frans, *et al.* 2011

Permeability – describes how easily water can flow through the rock or unconsolidated sediment and how easy it will be to extract the water for our purposes.

Potentiometric surface - areal representation of the hydraulic head or water pressure in an aquifer. For an unconfined aquifer, the potentiometric surface is the water table. For a confined aquifer, the potentiometric surface is above the confining layer.

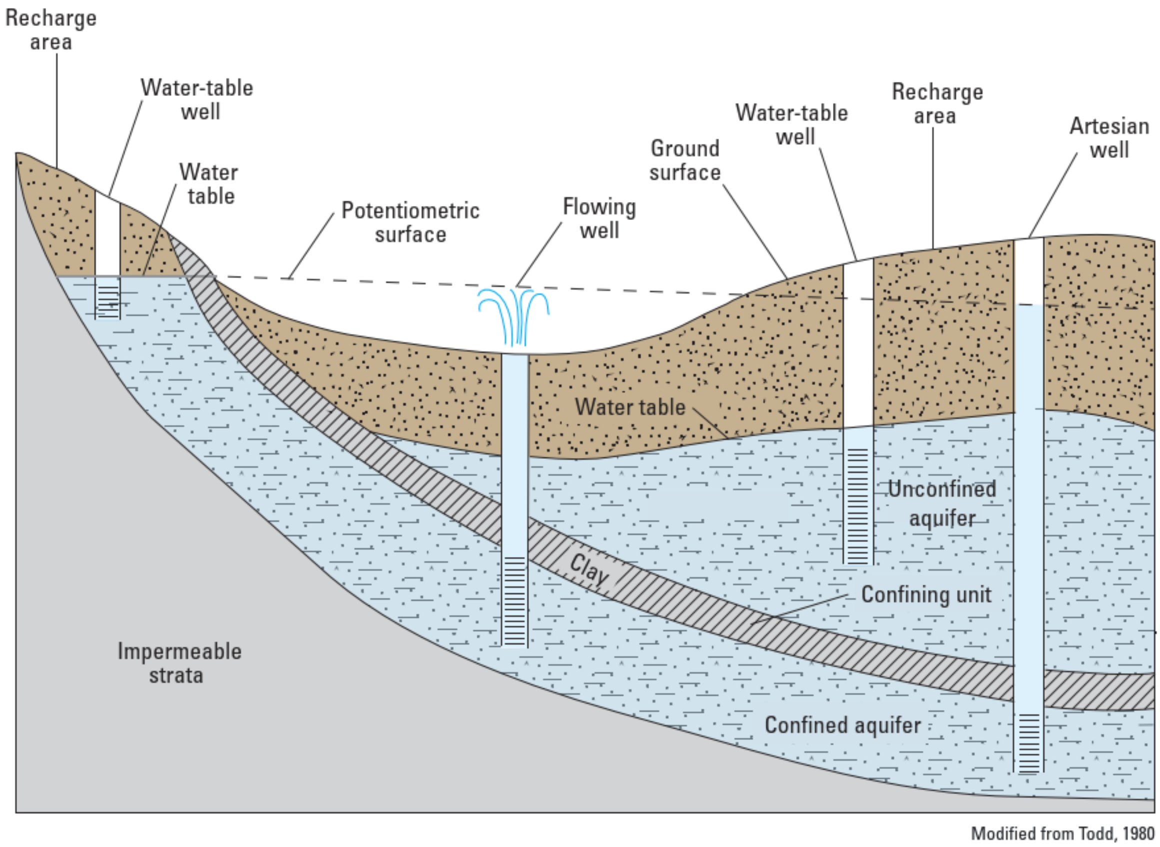


Figure 5. Features of unconfined (water table) and confined groundwater systems.

Source: Frans, *et al.* 2011

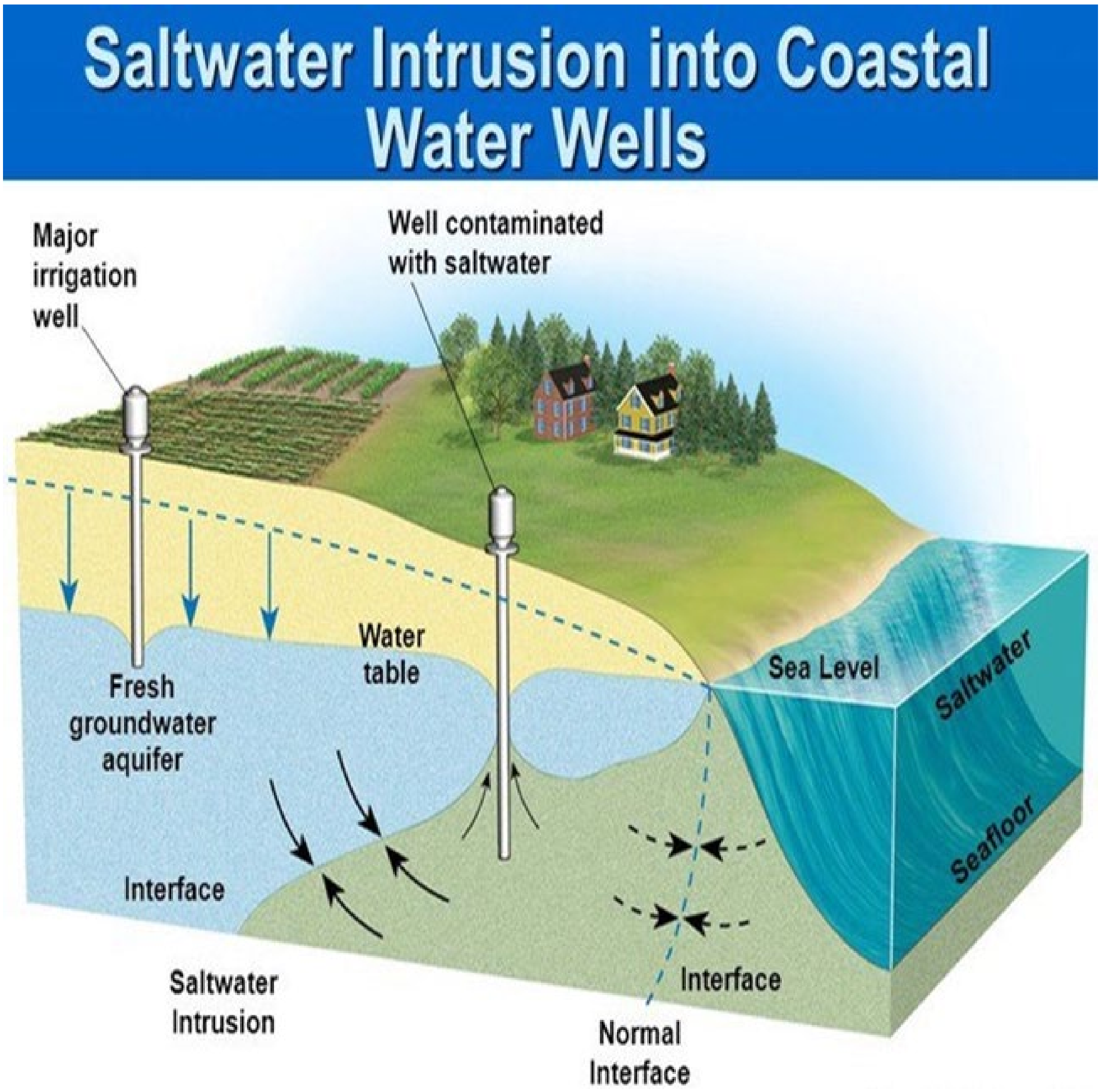
Recharge – water entering the groundwater system, generally from precipitation with secondary recharge from septic systems and/or irrigation.

Safe yield – Safe yield (Fetter, 1980) is the amount of naturally occurring groundwater that can be economically and legally withdrawn (discharged) from an aquifer on a **sustained** basis without impairing the native groundwater quality or creating an undesirable effect such as environmental damage. It cannot exceed the amount of recharge and/or leakage from adjacent strata minus the amount of discharge caused by pumping and natural sources. (Source: Critical Aquifer Recharge Areas Guidance, WA Department of Ecology 2021). the rate at which groundwater can be withdrawn without causing long-term decline of water levels

Safe yield is generally considered equal to the average replenishment rate of the aquifer from natural and artificial recharge. Evaporation, transpiration and basin outflow are also factored in to replenishment rates. Safe yield can be described as the rate at which groundwater can be withdrawn without causing **long-term** decline of water levels. (https://www.watereducation.org/aquapedia/safe-yield)

Essentially, the principle of safe yield can be considered the rate of groundwater withdrawal that is sustainable from multiple perspectives, such as water supply infrastructure, economics, ecological system health, and legal consideration (Aspect 2016). The term ‘carrying capacity’ has been used to describe safe yield for Bainbridge Island aquifers (Aspect 2006).

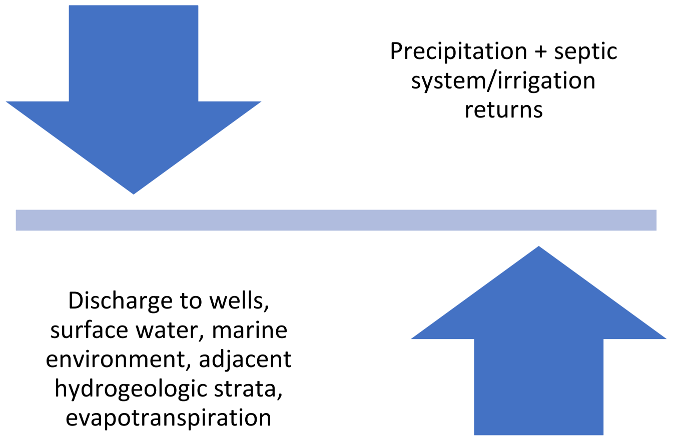
Seawater intrusion - the movement of seawater into freshwater aquifers due to natural processes or human activities. The boundary between seawater and fresh water is usually a zone of mixing between the two.



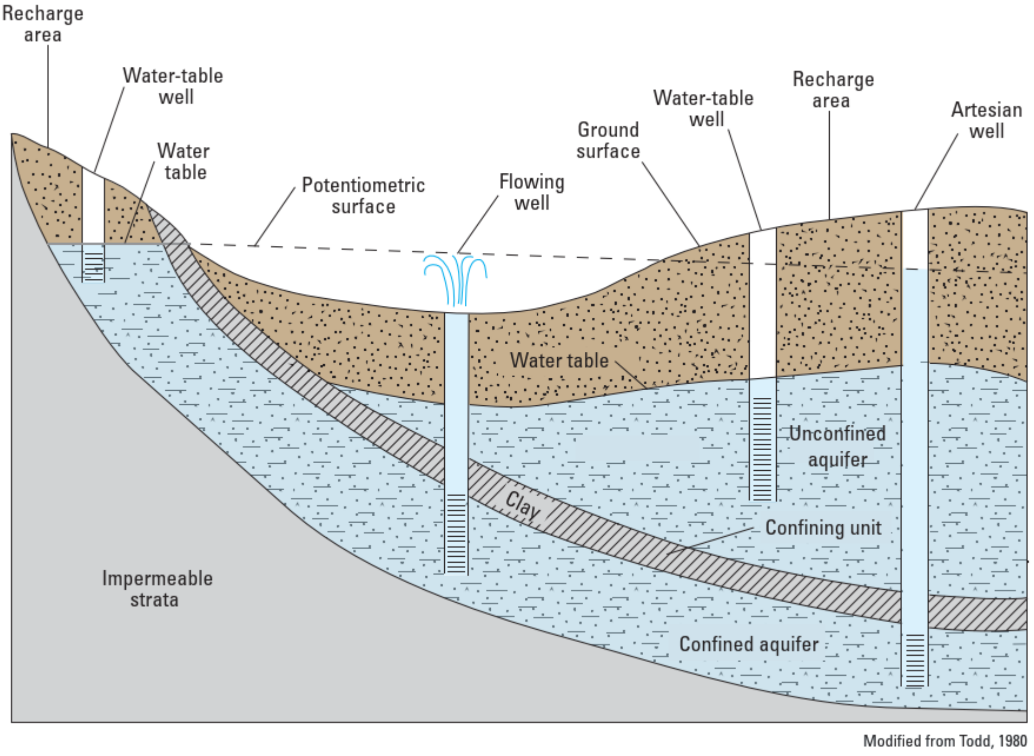
Sole Source Aquifer – Designation by the USEPA where aquifer supplies at least 50 percent of the drinking water for its service area. There are no reasonably available alternative drinking water sources should the aquifer become contaminated.

Sustainable development and use - the development and use of groundwater resources to meet current and future beneficial uses without causing unacceptable environmental or socioeconomic consequences (USGS Circular 1186). It should be noted that definition of ‘unacceptable consequences is subjective. Also, sustainability should be defined within the context of the entire interconnected hydrologic system.

Water budget – mathematical representation of the hydrologic cycle for a given area. Expressed as a water balance:



Unconfined aquifer - groundwater only partly fills an aquifer, and the top surface of the groundwater body is the water table.



From Frans *et al.* 2011 Figure 5.

APPENDIX A
BIBLIOGRAPHY

APPENDIX B
PUBLIC ENGAGEMENT PLAN

APPENDIX C
TECHNICAL ADVISORY GROUP CHARTER

APPENDIX D
EARLY WARNING LEVEL REPORTS 2012–2021

APPENDIX E
COMMON GROUNDWATER CONSTITUENTS

APPENDIX F
CONTAMINATED SITES

Washingtons Department of Ecology Toxic Cleanup (Washington State Department of Ecology 2022)

APPENDIX G
GROUP B WELL DETAILS BAINBRIDGE ISLAND

APPENDIX H
WELL LOGS