

# Technical Memorandum

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To: Maryam Moeinian (City of Tacoma)  
From: HDR and Terraphase  
Project: Tacoma Water Integrated Resource Plan Update  
Date: 3/27/2025  
Subject: South Tacoma Groundwater Protection District Review

## 1.0 Introduction

The City of Tacoma (City) has contracted the HDR/Terraphase team to complete updates to Tacoma Water's Integrated Resource Plan (IRP), which examines future water supply and demand in the context of climate change and regional growth. As part of the update to the IRP, the City requested that the HDR/Terraphase team assess existing groundwater protection and stormwater management codes and regulations to identify recommended changes to bolster protection and sustainability of this resource. This assessment will be informed by results from the broader IRP effort which is evaluating the role groundwater resources will play in meeting future water demands and buffering against climate change impacts on surface water supply.

This groundwater protection code assessment centers on a review of the South Tacoma Groundwater Protection District (STGPD) ordinance (Tacoma Municipal Code [TMC] 13.06.070.D) and related regulations, with the purpose of identifying potential gaps in how existing regulations address redevelopment and stormwater-related impacts to groundwater. This work is part of the STGPD Proposed Work Plan<sup>1</sup>, which the City created in response to an application the South Tacoma Neighborhood Council submitted to the Planning Commission in 2021. This application was aimed at updating the One Tacoma Plan and the TMC applicable to the STGPD, in addition to transforming the South Tacoma Manufacturing/Industrial Center into an Economic Green Zone. The work plan and this effort focus on the former objective. As part of this effort, a review has been conducted of groundwater protection regulations and practices of other jurisdictions that are known to be highly protective and/or have specifically addressed questions/concerns related to redevelopment.

This technical memorandum provides a brief summary of the STGPD, how it relates to multiple State groundwater protection regulations, observations regarding potential gaps, and recommendations for potential updates or modifications.

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<sup>1</sup> City of Tacoma, South Tacoma Groundwater Protection District Proposed Work Plan Update (Dec 2023).

## 2.0 Background

The STGPD was formally established by the City in 1988 through adoption of City of Tacoma Ordinance 24083. This ordinance declared the South Tacoma area (approximately nine square miles in extent) to be environmentally sensitive due to the high potential for contamination of the underlying aquifer system. The ordinance, which has been updated over time, put into place the following:

- Regulations regarding land uses and the handling, storage, and disposal of hazardous substances
- Establishment of technical standards that prescribe best management practices and design requirements (i.e., the document entitled “General Guidance and Performance Standards for the South Tacoma Groundwater Protection District”)
- Identification of prohibited uses
- Regulations pertaining to stormwater infiltration
- Permitting framework for new or substantially modified facilities
- Regulations regarding storage tanks
- Inspection, testing, and enforcement processes

The STGPD was established prior to development of State requirements and guidance related to critical aquifer recharge areas (CARAs) in the Growth Management Act context and Wellhead Protection Programs (WHPPs) as administered by the Washington State Department of Health, (DOH). While the STGPD served as the foundation of Tacoma Water’s approach to protection of its groundwater resources, additional activities have taken place since its inception to maintain compliance with DOH WHPP requirements, including:

- Completion of susceptibility assessments for all Tacoma Water wells, including those located outside of the South Tacoma area
- Coordination between Tacoma Water and the Tacoma-Pierce County Health Department (TPCHD) in implementing wellhead protection activities such as an annual review of potential contaminant sources
- Periodic updates to the City’s wellhead protection area time of travel zones
- Preparation of the Tacoma Wellhead Protection Program (originally developed in 2002, updated in 2015)

The spatial extent of Tacoma-area groundwater resources, as well as the land areas that impact their quantity and quality, is complex. Figure 1 shows the relationship of the STGPD to the South Tacoma wellfield, City of Tacoma municipal boundaries, and the Central Pierce County Sole-Source Aquifer (SSA) that includes the STGPD and other parts of the City of Tacoma. Also depicted are Wellhead Protection Areas (WHPA) mapped by time of travel zones obtained from DOH, some of which are known to not be fully accurate and are currently under review by Tacoma Water. WHPAs mapped include those for the City of Tacoma wells, along with wells in other jurisdictions intersecting with City of Tacoma and/or STGPD boundaries.

Key observations regarding the features depicted in Figure 1 include:

- Tacoma Water's WHPAs for wells located within the City of Tacoma's boundaries extend beyond the STGPD boundary into unincorporated Pierce County and the Cities of Lakewood, University Place, and Fircrest. Tacoma Water wells located outside of the STGPD but still within the City of Tacoma also have WHPAs that extend into the City of Fife. Tacoma wells that were formerly part of the SE Tacoma Mutual Water System are located outside the City of Tacoma boundaries, but these have WHPAs that abut Tacoma municipal boundaries.
- The City of Fircrest's WHPAs extend into the STGPD.

Figures 2 and 3 illustrate other pertinent features in and near the STGPD, including zoning and contamination site locations. Figure 4 provides mapping of the surficial geology throughout the extent of the SSA.

**Recommendation:** Tacoma should coordinate with neighboring jurisdictions regarding the development of policies and regulations protecting groundwater resources because of the overlap between land use jurisdictions and mapped WHPAs. This is a common theme reflected in many of the other recommendations presented throughout this document.

### 3.0 Comparison of STGPD to CARA and WHPP Regulations

There are a number of CARA and WHPP regulations that aim to protect groundwater used for potable uses. The Growth Management Act requires planning jurisdictions to designate critical areas, including CARAs. Best available science (BAS) must be used to designate critical areas as established in RCW 36.70A.172 and to develop policies and development regulations according to WAC 365-195-915. RCW 36.70A.030 defines CARAs as "areas with a critical recharging effect on aquifers used for potable water". WAC 365-190-100 requires cities and counties to use information on aquifers and their recharge areas as the basis for classifying and designating these areas. Existing land use activities and their potential to contaminate the aquifer must also be examined, and recharge areas must be classified according to aquifer vulnerability, defined as the combined effect of hydrogeological susceptibility to contamination and the contamination loading potential. Additionally, this code requires that a classification strategy for aquifer recharge areas maintain the quality and, if needed, quantity of the groundwater and lists data sources which may be used to define an area with a critical recharging effect on the aquifer.

WHPP regulations also apply to areas within the STGPD. WAC 246-290-135 requires that water systems using groundwater sources develop and implement a WHPP. This must be part of the water system plan and is required to include a completed susceptibility assessment and a WHPA delineation for each well, wellfield, or spring with the 6-month and 1-, 5-, and 10-year time of travel boundaries marked. Additionally, this code requires an inventory of all potential groundwater contamination sources with documentation of the water system purveyor's notification to all owners/operators of these known or potential sources of contamination, a notification to regulatory agencies of the boundaries of the WHPAs, a contingency plan in the event of contamination that results in a loss of groundwater supply, and documentation of coordination with local emergency incident responders.

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The Washington State Department of Commerce (Commerce) has published a voluntary Critical Areas Checklist that jurisdictions can use to verify that local codes address comprehensive plan requirements for critical areas. The checklist covers the wide range of elements required within a local jurisdiction’s critical areas regulations, with CARA being one component.

Table 3-1 summarizes a comparison between CARA checklist items and the current STGPD code.

**Table 3-1. Commerce CARA checklist comparison**

| Checklist item <sup>1</sup>   | Addressed in code? | Location in code                         | Notes  |
|---|--------------------|--|--|
| If groundwater is used for potable water, do regulations protect the quality and quantity of groundwater?<br><br>[Referenced regulations include RCW 36.70A.172(1), RCW 36.70A.070(1), and WAC 365-196-485(1)(d)] | Yes                | TMC 13.06.070D (5)<br>TMC 13.06.070D (6) | Stormwater element is tied to STGPD Infiltration Policy, which in turn references the City’s Stormwater Management Manual.   |
| Are the critical aquifer recharge regulations consistent with current mapping of these critical areas?<br>[Referenced regulation: WAC 365-190-100]  | Partially          | TMC 13.06.070D (1-c)                     | The STGPD boundary is not fully in alignment with WHPA and SSA boundaries.   |
| Consider limiting impervious surfaces to reduce stormwater runoff, as required under Phase I and II municipal permits.  | Partially          | TMC 12.08D.150.D                         | Impervious surfaces are not strictly limited, but “effective impervious surfaces” are limited through the use of low impact development and stormwater infiltration BMPs as required in the City’s Stormwater Management Manual. |

1. Source: Washington State Department of Commerce, *Critical Areas Checklist* (May 2024).

While several of the items from the Commerce checklist are addressed in the City’s code, there are opportunities for further alignment. Groundwater quality and pollution prevention is currently addressed in detail in the STGPD code, but groundwater quantity is primarily addressed through the Stormwater Management Manual rather than within the STGPD code. The boundaries of the STGPD are currently not in alignment with WAC 365-190-100, which requires classification of

CARAs based on recharge areas for SSAs and areas designated for wellhead protection in alignment with the Federal Safe Drinking Water Act, among other mapping sources as available. Along these lines, there are some wells (i.e., in the Tideflats) whose WHPAs are outside of, and therefore not subject to, the STGPD. Additionally, the Commerce checklist recommends considering impervious surfaces limitations to reduce stormwater runoff. While impervious surfaces are not strictly limited in the STGPD code, “effective impervious surfaces” are limited through the use of low impact development and stormwater infiltration Best Management Practices (BMPs) as required in the City’s Stormwater Management Manual. Tacoma’s STGPD overlay zone designating the protected aquifer recharge area is also unique compared to other nearby jurisdictions, which instead address these CARA requirements within the critical areas code and apply this to all CARAs within the jurisdictions’ boundaries. These topics are discussed in more detail in Section 4.0.

**Recommendation:** We recommend using the recently produced USGS Southeast Sound groundwater model of the aquifers in the SSA, in conjunction with utility-prepared WHPAs, to better quantify the risks to the aquifers, thereby determining in greater detail which areas should be afforded more or less protection. With that information in hand, work with neighboring jurisdictions to identify the best path to coordinate protections. Seek ways of using common terminology and language in code, which may result in the use of overlay districts, WHPAs, CARAs, and/or other terminology that is found to be most effective at communicating with the broader communities.

## 4.0 Key Technical Topics

Several elements of the STGPD were examined to identify gaps in meeting their intent and to compare the STGPD approach with that of other local jurisdictions.

### 4.1 Protection District Boundary

As noted in Section 3.0, the current STGPD boundary is not fully in alignment with WAC 365-190-100. This code requires a classification strategy for aquifer recharge areas and lists examples of areas with critical recharging effect on aquifers used for potable water. These example data sources are listed in Table 4-1 with corresponding notes on the applicability of this data to Tacoma.

**Table 4-1. Critical recharge areas data sources**

| Data source   | Applicable to Tacoma? | Notes   |
|---|-----------------------|---|
| Recharge areas for SSAs designated pursuant to the Federal Safe Drinking Water Act    | Yes                   | Central Pierce County Aquifer Area SSA                      |
| Areas established for special protection pursuant to a groundwater management program | Yes                   | South Tacoma Groundwater Protection District zoning overlay |

|  |     |   |
|--|-----|---|
| Areas designated for wellhead protection pursuant to the Federal Safe Drinking Water Act | Yes | Washington Department of Health Source Water Assessment Program Mapping |
| Areas near marine waters where aquifers may be subject to saltwater intrusion            | No  |   |

Changing the protection district boundaries to include the SSA would expand the STGPD area to encompass a larger area, impacting future developments in the City and changing regulations around developments which are already in place.

**Recommendation:** Revising the City's CARA regulations to apply to the SSA boundaries, while also maintaining the current STGPD overlay, will allow for the CARA to be in better alignment with Washington State rules while maintaining the integrity of current STGPD protections. The basis for this segregation is the surficial geology of the area occupied by the STGPD compared to the remainder of the SSA located within the City of Tacoma boundary depicted in the attached Figure 4.

## 4.2 Code Location

Theoretically, all elements of the municipal code are equally important and development restrictions or requirements placed anywhere in the code apply in full force. In practice, different chapters of the code are used by different members of the community.

Many developers will review the zoning code as they create a vision for a planned development project. The zoning code is a place where the community's vision is amplified. If the community's priority is to attain a certain look and feel for the community, the zoning code reflects that. Engineering and environmental protection requirements tend to be elsewhere in the code and may not have the attention of developers during that important feasibility stage. The engineers and scientists tasked with implementing those engineering and environmental protections often find a tension between that early developer vision and the more detailed design requirements.

Low impact development standards that came into effect in the early 2000s are a great example of how the location of requirements in code impacts their successful implementation. Zoning codes typically define lot coverage. Low impact development standards are most often placed within stormwater engineering sections of code. This has the effect that a developer may make decisions about where to place buildings on a piece of property and how much of the property to cover with buildings, without regard to low impact development principles that try to mimic natural hydrologic conditions. The outcome of this approach is frequently that developers determine that low impact development is infeasible.

The current zoning code overlay puts the issue of aquifer protection front and center for developers. This unusual placement of these requirements demonstrates a community vision of aquifer protection. Developers see these requirements early in their feasibility process, thanks to code placement. Scientists and engineers hired by developers to implement their vision look for environmental protections and engineering standards in other parts of the code. This is accounted

for in the STGPD by reference to: 1) the STGPD Performance Standards, enforced by the TPCHD, that pertain to requirements for facilities handling hazardous substances; and, 2) the City's Stormwater Management Manual and STGPD Infiltration Policy, which collectively pertain to stormwater infiltration requirements/practices.

Another consideration when determining where development requirements should be placed in code is the process for updating that code. Zoning codes tend to be updated through a process that may include additional public involvement or commissions. Engineering standards and codes tend to be updated through a simpler process. For example, when groundwater protections are within the CARA, anytime additional groundwater resources are discovered, the maps and related restrictions are updated. However, when restrictions are within an overlay, the City needs to go through an additional process to expand the overlay boundaries or create a new zoning classification.

If the STGPD overlay is retained as being separate from the broader CARA code, the CARA regulations could be written to call out that the STGPD overlay is applicable only to the higher risk area proximal to the South Tacoma Channel Wells, thereby requiring additional protections. .

**Recommendation:** The STGPD code as currently located is an effective way of addressing aquifer protection in this area. It is recommended that the overlay continue. However, as noted in Section 4.1, there is value in expanding the City's CARA regulations to apply to the entire SSA. Additional technical analysis or modeling of surficial geology, well use, and groundwater flow patterns, coordinated between the neighboring jurisdictions, would result in a better understanding of land use risk to the aquifers, which could then be used to inform protective measures within the SSA but outside the STGPD.

### 4.3 High Impact Uses

WAC 365-190-100 requires that water system surveyors examine existing land use activities and their potential to contaminate the aquifer. The Washington State Department of Ecology (Ecology) Critical Aquifer Recharge Areas Guidance further suggests that cities can minimize the risk of groundwater contamination by prohibiting high risk uses in critical areas. The STGPD code lists nine high-impact uses which are currently prohibited within the boundaries of STGPD (13.06.070.D(5)). These high-impact uses are:

- Chemical manufacture and reprocessing
- Creosote/asphalt manufacture or treatment
- Electroplating activities
- Manufacture of Class 1A or 1B flammable liquids as defined in the Fire Code
- Petroleum and petroleum products refinery, including reprocessing
- Wood products preserving
- Hazardous waste treatment, storage, or disposal facilities
- Underground storage tanks (temporary moratorium)
- Metal recycling/auto wrecking facilities (temporary moratorium)

Regarding the last two items on the list, a moratorium on new underground storage tanks and metal recycling/auto wrecking facilities is in place by Ordinance No. 28872, passed in March 2023 and currently set to expire in March 2025. This list is intended to adapt over time to changing technology, pollution control, and management, as determined by City Planning and Development Services and the TPCHD. Planning and Development Services, in consultation with TPCHD, may make exceptions to the prohibited uses list when it is conclusively demonstrated that the high-impact use will not threaten the groundwater resource more than a compliant nonprohibited use would. . These prohibited uses are compared against the prohibited uses in ten other nearby jurisdictions in Attachment 1 (see separate Excel file). These jurisdictions were selected for their proximity to Tacoma and for the robustness of their groundwater protection programs, as noted in state regulatory guidance documents. Five of these ten jurisdictions differentiated restrictions in subareas within the recharge area based on the risk of contaminating drinking water. In these cases, the more restrictive designations aligned with WHPP mapping based on time of travel for contaminants. Many of these jurisdictions also distinguish between land uses which are fully prohibited and ones which are permitted with restrictions, such as a mandatory hydrogeological assessment or a permit process.

It is noted that Pierce County recently amended its critical areas code, including its CARA elements, effective February 1, 2025. The approach taken by the County in its proposed CARA updates, as currently reflected in draft documents, is based upon wellhead protection related recommendations made to all local jurisdictions by the Pierce County Water Utility Coordinating Committee (WUCC) in the 2021 Update to the Pierce County Coordinated Water System Plan and Regional Supplement (2021 CWSP).

These prohibited land uses build off any underlying zoning restrictions addressed in other portions of the jurisdictions' codes. These underlying land use codes specify requirements for permitting based on land uses, but CARA codes tend to prohibit more specific land uses due to the risk of groundwater contamination.

Key observations from this comparison which could help inform updates to the prohibited uses specified in Tacoma's STGPD code are:

- Tacoma's restrictions on chemical manufacture and reprocessing, hazardous waste treatment and storage, and underground storage tanks were broadly mirrored in the other jurisdictions' WHPP restrictions. Tacoma's restrictions on wood and wood products preserving, petroleum refining, and metal recycling were also common in the WHPP-based codes included in the comparison.
- The STGPD code allows aboveground and underground storage tanks but subjects them to design, installation, and operational requirements that meet, or exceed current Washington State and Federal criteria.
- Some of Tacoma's restrictions were less common in other high-impact use lists. Class 1A and 1B flammable liquids were restricted in no other jurisdictions, while creosote and asphalt manufacture and electroplating activities were each prohibited in two WHPP-based codes out of the five included in the comparison.
- Wastewater treatment, landfills, mining, and water reuse and infiltration were additionally prohibited or restricted in all five WHPP-based codes.

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- Metal processing, golf courses, funeral facilities, dry cleaning, and vehicle maintenance were all prohibited or restricted in four of the five included WHPP-based codes.
- Three of the WHPP-based codes had blanket restrictions on any additional land uses not listed that pose a risk to groundwater quality in their high-impact uses list.

Guidance for underground injection control from Ecology<sup>2</sup> was also included as part of this comparison. This guidance recommends prohibitions on the following land uses in alignment with Tacoma's code:

- Hazardous waste treatment, storage, or disposal facilities
- Storage of treated lumber
- Asphalt recycling facilities

This guidance additionally recommends prohibiting:

- Solid waste handling facilities
- Concrete recycling facilities
- Industrial or commercial areas that have outdoor processing, handling, or storage of raw materials or finished products unless the facility has specific management plans for proper storage and spill prevention, control, and containment
- Vehicle maintenance, repair, and service
- Process water from the production area of an animal feeding operation
- Fire fighter training facilities

While these land uses are not explicitly prohibited in the STGPD, they are subject to other restrictions, such as permitting, waste handling, and stormwater treatment requirements.

Given that the majority of the STGPD is comprised of WHPAs, the list of prohibited uses in the STGPD is fairly consistent with what is observed in other jurisdictions' codes. Pathways forward for potential modification to this part of the STGPD, and associated pros and cons, include:

1. No change.
  - a. Pros: No shift in current practice.
  - b. Cons: Potential for misalignment with codes of nearby land use jurisdictions whose boundaries intersect with Tacoma Water WHPAs.
2. Follow recommendations of the 2021 CWSP, tying prohibitions/restrictions of certain land uses to WHPA time of travel zones and incorporate the surficial geology of the area.
  - a. Pros: Alignment with WUCC guidance and Pierce County approach. The inclusion of geologic information adds additional information for evaluating the vulnerability of locations with respect to impacting groundwater quality.

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<sup>2</sup> WAC 173-218, and the 2024 Ecology Stormwater Management Manual for Western Washington

- b. Cons: Potential for varied level of prohibition/restriction within STGPD boundary, based on varying time of travel spatial extents. Technically challenging to define/refine time of travel associated with various wells, due to their interactions. Would require additional technical work to refine. The addition of surficial geology into the determination of protective areas can offset some of the issues with time of travel-based restrictions.
  3. Conduct additional technical analysis on specific uses to determine if they should be included in list of prohibited uses.
    - a. Pros: There are two pathways that such analysis can follow. The first pathway is to use the results of additional analysis to expand the list of prohibited uses. The second pathway is to use the results to manage allowed uses, including new or previously/temporarily prohibited by modifying the STGPD Performance Standards to be appropriately protective of groundwater. While these pathways are not unrelated, the City Council will need to determine its political will on the direction any application of results will take.
    - b. Cons: Requires additional time and effort to conduct. Decisions on the application of results will likely divide public comments into opposing groups, and significant education and outreach may be needed to achieve consensus or at least acceptance.

**Recommendation:** We recommend that for CARA regulations that would apply throughout the SSA, surficial geology be used as a primary determinant of risk of impact to groundwater and that the special protections afforded by the STGPD ordinances and its performance standards be maintained. Additionally, some areas of the STGPD with underlying geology indicating lower risk of impact to groundwater (such as the Tacoma Mall area) could be allowed additional uses or less restriction if desired. The same mapping could also be used to establish additional prohibitions/restrictions/performance standards in areas where it is necessary. Existing geologic mapping such as that outlined in the attached Figure 4 are likely sufficient for policy determinations although any implementation may warrant site-specific assessment on a project basis.. For example areas mapped with glacial till as the first surficial layer may, subject to site verification, be considered lower risk.

## 4.4 Stormwater Infiltration

The STGPD Infiltration Policy regulates the use of stormwater infiltration facilities within the STGPD. Infiltration of stormwater runoff from non-pollution-generating surfaces is not regulated by this policy. Infiltration of stormwater runoff from pollution-generating surfaces is subject to several specific requirements at the time of construction and through the life cycle of the facilities.

The STGPD Infiltration Policy provides protection of the groundwater resource through six key elements:

1. Protection Area
2. Permitting
3. Stormwater Runoff Treatment
4. Operation & Maintenance
5. Inspection

## 6. Public Education

### 4.4.1 Protection Area

The most important element of a groundwater aquifer protection strategy is to understand the location of the municipal wells and their relationship to areas nearby where pollutants may migrate from through stormwater runoff. As discussed above, there is substantial overlap in regulations from Ecology, Pierce County, City of Tacoma, and the STGPD Policy. The wells operating in STGPD have the potential to alter groundwater flow patterns and potential contaminant migration from the City of University Place, City of Lakewood, or City of Fircrest, so seeking uniformity in approach to regulations from each of these agencies is important.

### 4.4.2 Permitting

Stormwater infiltration from pollution-generating surfaces is only allowed through a permitting process. This gives the City of Tacoma the ability to impose design requirements. These permits also require granting the City of Tacoma the right to inspect facilities to ensure their appropriate maintenance and continued function. That permitting is limited to facilities within the City of Tacoma, so again seeking uniformity in approach with neighboring jurisdictions is important. The STGPD regulations require coordination between the TPCHD and City of Tacoma Environmental services to ensure that infiltration is implemented meeting the site conditions and permitting regulations set forth in both the STGPD Performance Standards and the City of Tacoma Stormwater Management Manual.

### 4.4.3 Stormwater Runoff Treatment

Stormwater runoff treatment is a primary method for protecting the groundwater resource from contaminants carried in stormwater runoff. Table 4-2 compares the stormwater runoff treatment requirements from comparable jurisdictions with groundwater protection areas. Generally speaking, the Ecology Stormwater Management Manual for Western Washington and the Ecology Underground Injection Control Guidelines provide standards that are broadly used by jurisdictions across western Washington.

In evaluating an individual site, the project proponent and the regulatory agency evaluate both the planned land use and the receiving waters to evaluate the risk of the project impacting water quality. Some receiving waters are known to be impacted for certain pollutants and may have special requirements. Some land uses are known to have a high risk of generating certain pollutants and may have special requirements.

For most sites, stormwater runoff treatment BMPs are categorized by Ecology into one of five different levels, with different goals that are generally applicable to sites based upon their land use and receiving water:

- Pretreatment: Remove larger particles and floatables to protect long term performance of runoff treatment or infiltration BMPs.
- Basic Treatment: Remove 80% of the total suspended solids from stormwater. Many pollutants adhere to those suspended solids, so are removed through this treatment process. This is the baseline level of stormwater runoff treatment for all sites and land uses.

- **Enhanced Treatment:** Provide a higher rate of removal of dissolved metals than basic treatment. Generally targeting removal of 30% of dissolved copper and 60% of dissolved zinc. These BMPs are typically for removal of very low concentrations of dissolved metals that are harmful to fish, but may not be harmful to humans. This is typically only required for sites that discharge into streams or infiltrate close to streams.
- **Phosphorous Treatment:** Remove phosphorous from stormwater to protect sensitive lakes that have been identified as impacted by phosphorous loading.
- **Oil Control:** Remove floatable oil found in land uses that typically generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil. These may include commercial or industrial sites with large numbers of vehicles or oil activities, and also high traffic intersections.

**Table 4-2. Stormwater runoff treatment requirements for infiltration in 5 year time of travel of municipal drinking water wells by land use type**

| Jurisdiction/<br>guidance                         | Non-pollution-<br>generating<br>surfaces  | Residential  | Commercial/<br>multifamily   | Industrial/high<br>vehicle traffic<br>area   |
|---|---|--|--|--|
| Ecology<br>Stormwater<br>Manual & UIC<br>Guidance | Pretreatment  | Ecology also<br>requires that<br>local codes be<br>followed<br><br>Basic treatment | Ecology also<br>requires that<br>local codes be<br>followed<br><br>Basic treatment | Ecology also<br>requires that<br>local codes be<br>followed.<br><br>Basic & oil<br>control |
| Pierce County                                     | Same as Ecology   |  |  |  |
| Fircrest  | Same as Ecology   |  |  |  |
| Lakewood  | Same as Ecology   |  |  |  |
| University Place                                  | Adopted the King County Surface Water Design Manual which is equivalent to the Ecology Stormwater Manual. |  |  |  |
| Tacoma SWMM                                       | Outside STGPD, same as Ecology<br>If in STGPD, follow STGPD Infiltration Policy                           |  |  |  |
| STGPD<br>Infiltration Policy                      | No treatment<br>required  | Basic treatment  | Enhanced<br>treatment  | Enhanced and oil<br>control  |

| Jurisdiction/<br>guidance | Non-pollution-<br>generating<br>surfaces  | Residential     | Commercial/<br>multifamily                                   | Industrial/high<br>vehicle traffic<br>area                                   |
|---------------------------|---|-----------------|--|--|
| Redmond                   | Pretreatment  | Basic treatment | Infiltration prohibited (except in Marymoor – then enhanced) | Infiltration prohibited (except in Marymoor – then enhanced and oil control) |
| Renton                    | Renton’s aquifer is unconfined and as shallow as 23 feet in places. Infiltration is prohibited in Zone 1. The prohibition also requires BMPs like detention ponds to be lined to prevent incidental infiltration. |                 |  |  |

There are minor variations between the STGPD policy and adjacent jurisdictions, as well as broader City of Tacoma requirements that should be coordinated.

#### 4.4.4 Operation and Maintenance

TMC 13.06.070.D includes enforcement mechanisms to ensure proper maintenance of stormwater BMPs, as a requirement of its NPDES permit. Pierce County and the other nearby cities have similar mechanisms in place to ensure proper maintenance.

#### 4.4.5 Inspection

Covenant and easement agreements with the City of Tacoma are required for all new stormwater BMPs within the STGPD.

#### 4.4.6 Public Education

The policy calls for a public education program. The inspection program is a primary source of this public education. Each jurisdiction has public education requirements through their NPDES stormwater permit. Coordination of these efforts makes for more effective messaging.

#### 4.4.7 Potential Areas for Modification

A common theme in the sections above is that there are multiple jurisdictions with independent stormwater infiltration requirements. Pathways for potential modification to this part of the STGPD, and associated pros and cons, are summarized in Table 4-3.

Table 4-3. Stormwater infiltration requirements coordination

| Topic                       | Action  | Pros  | Cons  |
|-----------------------------|---|---|---|
| No change                   |   | No shift in current practice.   | Some areas are more restrictive than others. Higher restrictions limit development and create cost. Lower restrictions create higher risk to the drinking water resource. |
| Protection areas            | Evaluate WHPAs. Perform updated modeling to better define the flow of groundwater during various operating conditions for the existing municipal supply wells. Use that updated modeling to better define WHPAs. Evaluate the appropriate level of risk reduction through operational and structural BMPs for those WHPAs. Coordinate consistent application of those risk reduction strategies for all areas within the WHPAs. | Uniform application of requirements without regard to municipal boundaries reduces risk, optimizes investments, and simplifies communication to the public. | Updating groundwater models is time-consuming and expensive.  |
| Permitting                  | Seek opportunities to align permit requirements among neighboring jurisdictions.  |   |   |
| Stormwater runoff treatment | Note the difference in levels of protection between adjacent jurisdictional areas, such as using enhanced treatment vs basic treatment. Evaluate the cost/benefit of that approach and adopt a uniform approach across the jurisdictions.   | Clarity of requirements for developers.   | There may be differences of opinion in the cost/benefit of various levels of treatment between the jurisdictions.   |

| Topic                   | Action   | Pros  | Cons   |
|-------------------------|--|---|--|
| Operation & maintenance | Seek opportunities to coordinate policies and record keeping related to operation and maintenance requirements.                                |   |  |
| Inspection              | Coordinate inspection programs across the jurisdictions to improve consistency and messaging to businesses and performance of stormwater BMPs. | There may be a grant opportunity for developing a coordinated approach and also for funding inspectors. | Each agency has different resources available and priorities identified for this work. |
| Public education        | Align public education efforts.  | There may be grant opportunities.   |  |

**Recommendation:** We recommend that stormwater regulations between the neighboring jurisdictions should be coordinated for consistent application and protection.

## 4.5 Impervious Surfaces Standards and Aquifer Recharge

Planning policies frequently define the amount of impervious surfaces that should be included in a new development proposal. This parameter in planning policy is selected for many reasons. Some jurisdictions are seeking a certain look and feel for a development. Others are limiting impervious surfaces to support flood protection or protect farmland. Another driver for impervious surface policy may be a desire to support groundwater recharge. This section discusses how impervious surface is addressed in policy and code.

### 4.5.1 Impervious Surfaces

Impervious surface means a hard surface which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development, and/or a hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow than the flow present under natural conditions prior to development. When stormwater runoff lands on impervious surfaces, the stormwater normally runs off of the hard surface, preventing that water from recharging the groundwater below. The stormwater runoff continues to streams where it may contribute to erosion, flooding, and transport of contaminants.

### 4.5.2 Effective Impervious Surfaces

The presence of an impervious surface does not necessarily result in reduction of groundwater recharge or in negative stormwater flow impacts to streams. It is possible to design a development site so that hard surfaces do not “prevent or retard the entry of water into the soil mantle”. In this

case, the hard surface would not be “effective impervious”. An example of this would be a parking lot that is surrounded by a forest. If the forest is large enough, then stormwater runoff flowing off of the parking lot into the forest will infiltrate into the soils of the forest. In that case the forest is acting like an engineered BMP to collect and infiltrate the stormwater. A more engineered example would be that same parking including a collection system that collects all of the water and directs it to an underground chamber designed to infiltrate stormwater.

### 4.5.3 Code Requirements

The TMC requires new development and redevelopment to comply with the requirements within the Tacoma Stormwater Management Manual. These standards derive from the NPDES Municipal Stormwater Permit and so are generally consistent across large and medium sized cities and counties in western Washington. The permit requires application of minimum stormwater requirements. Stormwater management requirements vary based upon the proposed development. The primary driver in determining which stormwater requirements will apply is the amount of new and replaced hard surfaces. Projects with more hard surfaces have more stormwater requirements.

What is significant to this conversation is the extent that stormwater infiltration may be required. When projects exceed 2,000 square feet (SF) of new and replaced hard surfaces, they are required to apply low impact development techniques (also known as on-site stormwater management or green stormwater infrastructure). These techniques are intended to keep stormwater onsite by letting it soak into the ground so that it does not become concentrated stormwater that may cause erosion or flooding offsite. BMPs like pervious pavement, bioretention, or other infiltration practices meet this goal. In addition to meeting the intent of stream protection, they also perform the function of aquifer recharge.

When projects exceed 5,000 SF of new and replaced hard surfaces, they are required to meet flow control standards that try to hold back stormwater flow from larger storms to provide even better stream protection. If soils are highly infiltrative, the standards and economics push projects toward infiltrating stormwater onsite.

As projects trigger those thresholds and develop infiltration BMPs, they are also required to provide protection of surface receiving waters and groundwater from pollution. That requirement means that infiltration system design considers the land uses, the proximity to drinking water wells, and the soil characteristics at the site. They may be required to provide treatment prior to infiltration or may not be allowed to infiltrate based on potential risk to the aquifer of contributing pollution or causing the migration of existing pollution within aquifers.

The TMC also applies stormwater utility rates based on the amount of impervious area on property. Properties with a higher percentage of impervious area pay higher utility rates than less densely developed property. This is intended to more fairly apply utility rates to properties that contribute to stormwater runoff and the costs of managing that stormwater. This also has the effect of providing some incentive to reduce the amount of impervious area on a property.

### 4.5.4 Code Alternatives

Pierce County is currently considering new aquifer recharge and WHPA standards. That proposed code defines “maximum impervious surface coverage” by various land use designations as a way to “ensure sufficient groundwater recharge”. An alternative to meeting the impervious area limits that is

included in the proposed code is to demonstrate that engineered infiltration facilities will result in infiltration “the same or greater for post-development as the pre-development volume”. “The maximum impervious surface coverage is calculated for the total amount of impervious surface per each individual site. The percentage for maximum total impervious surface per lot or site may be exceeded if the applicant can demonstrate that the effective impervious surface on the site is less than or equal to what is allowed for the total impervious surface.”

The City of Redmond addresses this issue through their SEPA authority, routinely requiring development projects to provide stormwater infiltration at least equal to the amount of infiltration on the site prior to a redevelopment project. They also require that proposed development projects identify feasible locations for stormwater infiltration on their properties during the land use entitlement phase of development (RMC 21.17.010.E.1).

**Recommendations:**

- In consideration of standards designed to encourage aquifer recharge through reduction of impervious area, such standards should consider both the benefits of aquifer recharge and the risk to the aquifer that may be presented by stormwater infiltration. The benefits of aquifer recharge from a specific project will depend on the soil characteristics of the site and the path of groundwater flowing from the site and from the larger area serving the aquifer. The risk from stormwater infiltration will also depend on land uses and the potential presence of groundwater or soil contamination at the site and in its vicinity.
- The community should identify where its priorities lie. Code language can be crafted to require developers, during feasibility, to evaluate infiltration potential as a primary variable before selecting the final form of a proposed development. Such language must balance the drivers of growth management with protections of critical resources.
- The community should align aquifer protections with neighboring jurisdictions, applying the watershed approach that is common in river management to protections placed for the underground rivers that make up the drinking water aquifers.

## 5.0 Summary of Recommendations

Recommendations identified in previous sections of this document are summarized below.

1. Tacoma should coordinate with neighboring jurisdictions regarding the development of policies and regulations protecting groundwater resources because of the overlap between land use jurisdictions and mapped WHPAs.
2. We recommend using the recently produced USGS Southeast Sound groundwater model of the aquifers in the SSA, in conjunction with utility-prepared WHPAs, to better quantify the risks to the aquifers, thereby determining in greater detail which areas should be afforded more or less protection. With that information in hand, work with neighboring jurisdictions to identify the best path to coordinate protections. Seek ways of using common terminology and language in code, which may result in the use of overlay districts, WHPAs, CARAs, and/or other terminology that is found to be most effective at communicating with the broader communities.
3. Revising the City’s CARA regulations to apply to the SSA boundaries, while also maintaining the current STGPD overlay, will allow for the CARA to be in better alignment with

Washington State rules while maintaining the integrity of current STGPD protections. The basis for this segregation is the surficial geology of the area occupied by the STGPD compared to the remainder of the SSA located within the City of Tacoma boundary.

4. The STGPD code as currently located is an effective way of addressing aquifer protection in this area. It is recommended that the overlay continue. However, there is value in expanding the City's CARA regulations to apply to the entire SSA. Additional technical analysis or modeling of surficial geology, well use, and groundwater flow patterns, coordinated between the neighboring jurisdictions, would result in a better understanding of land use risk to the aquifers, which could then be used to inform protective measures within the SSA but outside the STGPD.
5. We recommend that for CARA regulations that would apply throughout the SSA, surficial geology be used as a primary determinant of risk of impact to groundwater and that the special protections afforded by the STGPD ordinances and its performance standards be maintained. Additionally, some areas of the STGPD with underlying geology indicating lower risk of impact to groundwater (such as the Tacoma Mall area) could be allowed additional uses or less restriction if desired. The same mapping could also be used to establish additional prohibitions/ restrictions/performance standards in areas where it is necessary. Existing geologic mapping are likely sufficient for policy determinations, although any implementation may warrant site-specific assessment on a project basis.
6. We recommend that stormwater regulations between the neighboring jurisdictions be coordinated for consistent application and protection.
7. In consideration of standards designed to encourage aquifer recharge through reduction of impervious area, such standards should consider both the benefits of aquifer recharge and the risk to the aquifer that may be presented by stormwater infiltration. The benefits of aquifer recharge from a specific project will depend on the soil characteristics of the site and the path of groundwater flowing from the site and from the larger area serving the aquifer. The risk from stormwater infiltration will also depend on land uses and the potential presence of groundwater or soil contamination at the site and in its vicinity.
8. The community should identify where its priorities lie. Code language can be crafted to require developers, during feasibility, to evaluate infiltration potential as a primary variable before selecting the final form of a proposed development. Such language must balance the drivers of growth management with protections of critical resources.
9. The community should align aquifer protections with neighboring jurisdictions, applying the watershed approach that is common in river management to protections placed for the underground rivers that make up the drinking water aquifers.

Additional general observations and recommendations regarding the STGPD and related groundwater and stormwater management regulations are:

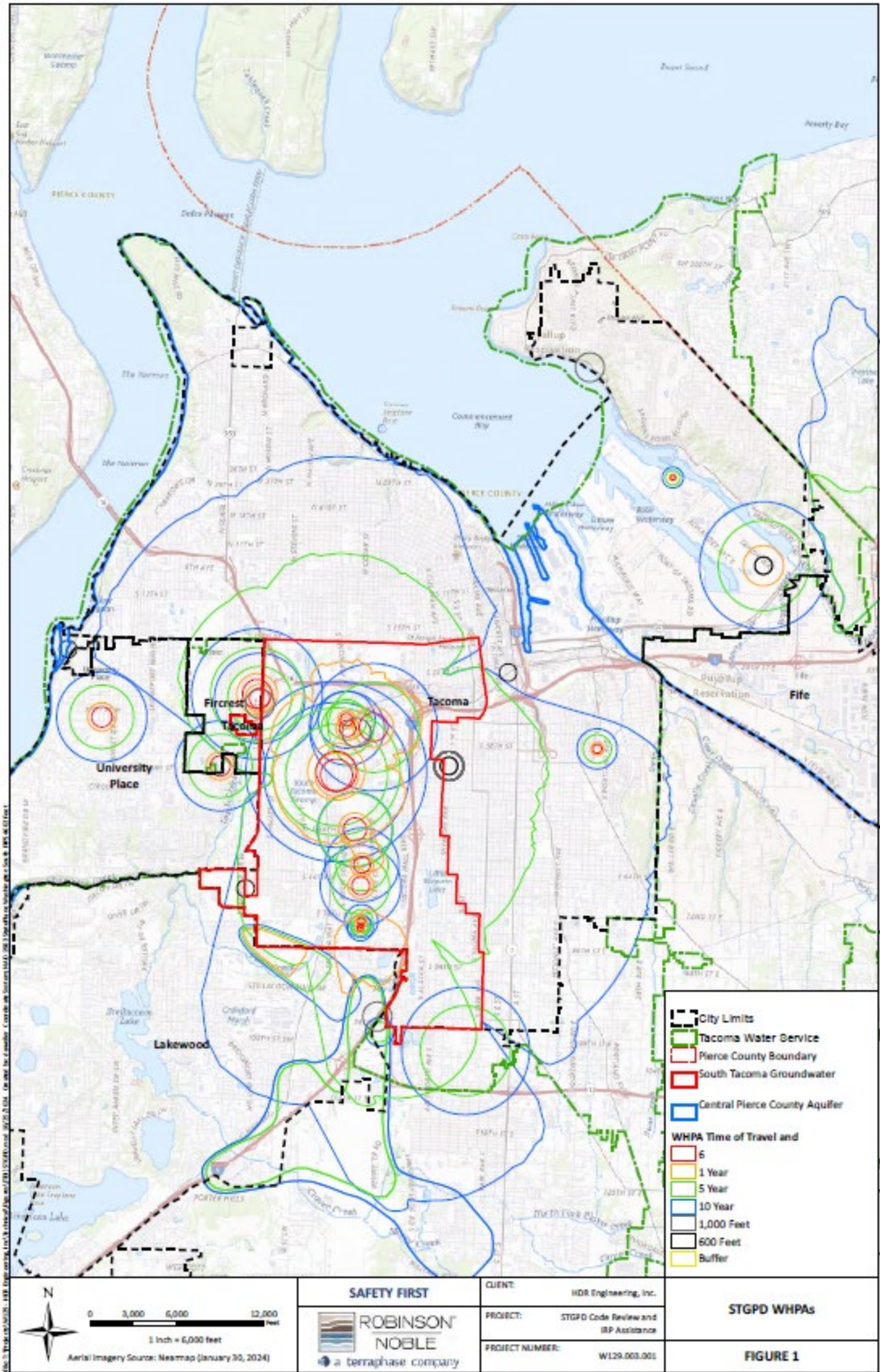
1. Monitoring network. Given the potential vulnerability of the drinking water resource, the feasibility of the creation of a comprehensive groundwater monitoring program should be explored. The benefits of a monitoring program include the ability to gauge the effectiveness of the City's protection measures, establish a data set to evaluate the need for modifying those measures, and the evaluation of potential impacts from upgradient sources of impact in jurisdictions that are beyond the control of the City. It should be noted that the TPCHD,

from 1992-1995, proposed an extensive groundwater monitoring program as part of the Groundwater Management Plan for the Chambers Clover Creek Basin. The City and TPCHD could revisit this as part of coordination efforts with the County on protecting the SSA. Some jurisdictions, such as the City of Issaquah, do not have a formal program of sentinel wells, but do keep track of data from cleanup sites and projects that come to their attention, creating an informal way of monitoring for contaminants.

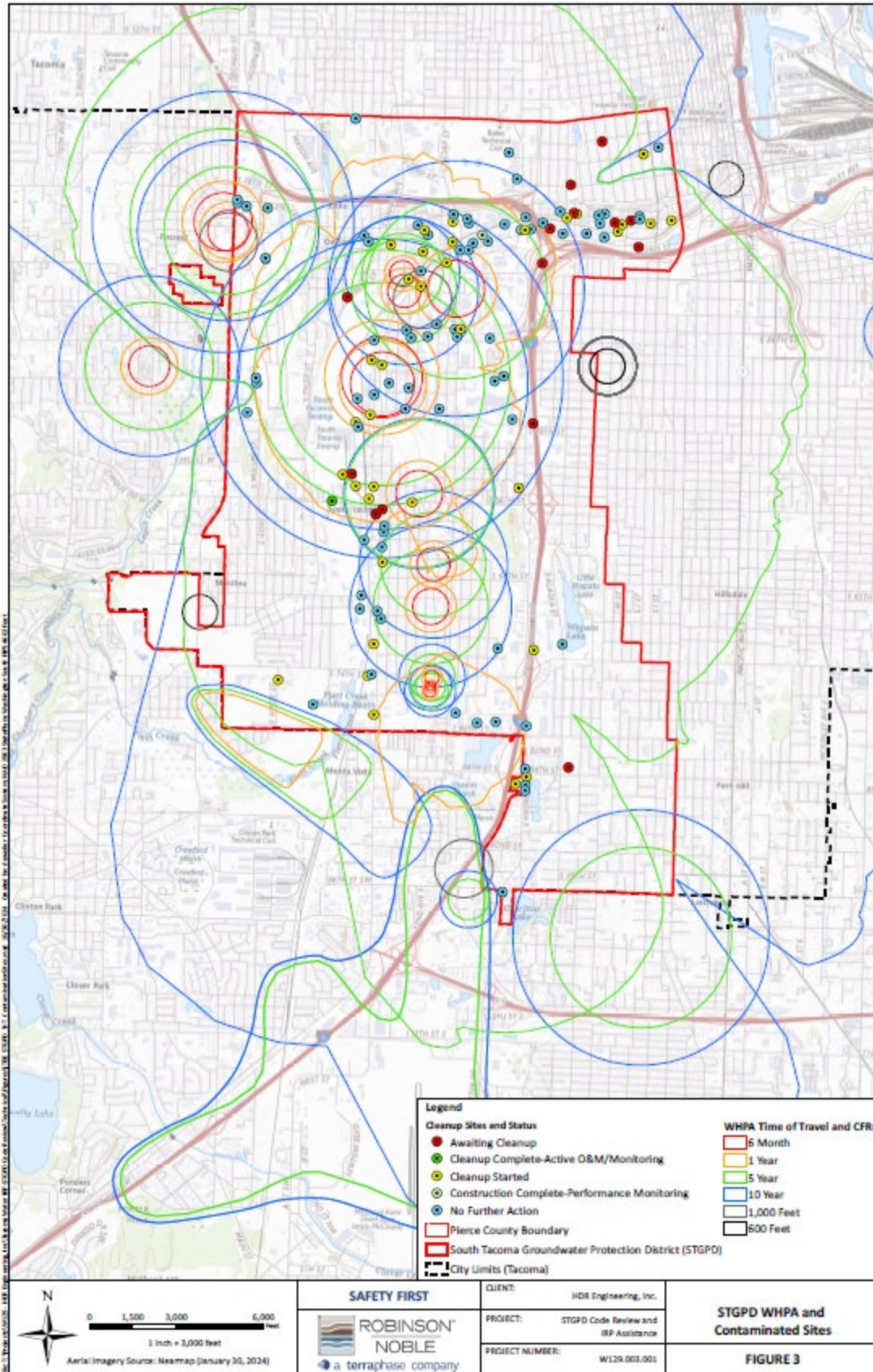
2. Jurisdictional alignment of groundwater protection measures. Ultimately, a single, uniform groundwater management and protection program for the SSA should be enacted. Such a program would ensure uniform land-use controls, protective measures and controls across all jurisdictions within and utilizing the SSA. This would require coordination between the City of Tacoma, Pierce County, and the smaller cities and towns within the SSA boundaries. There is some precedent in underground storage tank and Food/Community Safety regulations administered by TPCHD under concurrent rules codified in City of Tacoma and Pierce County Ordinances and TPCHD Health Codes.
3. Alignment of City land use codes with stormwater management requirements is important. Seek strategies to encourage or require stormwater infiltration where feasible and appropriate early in the development process. Seek strategies to help developers understand these requirements early so they can plan around them instead of being surprised late in their project.

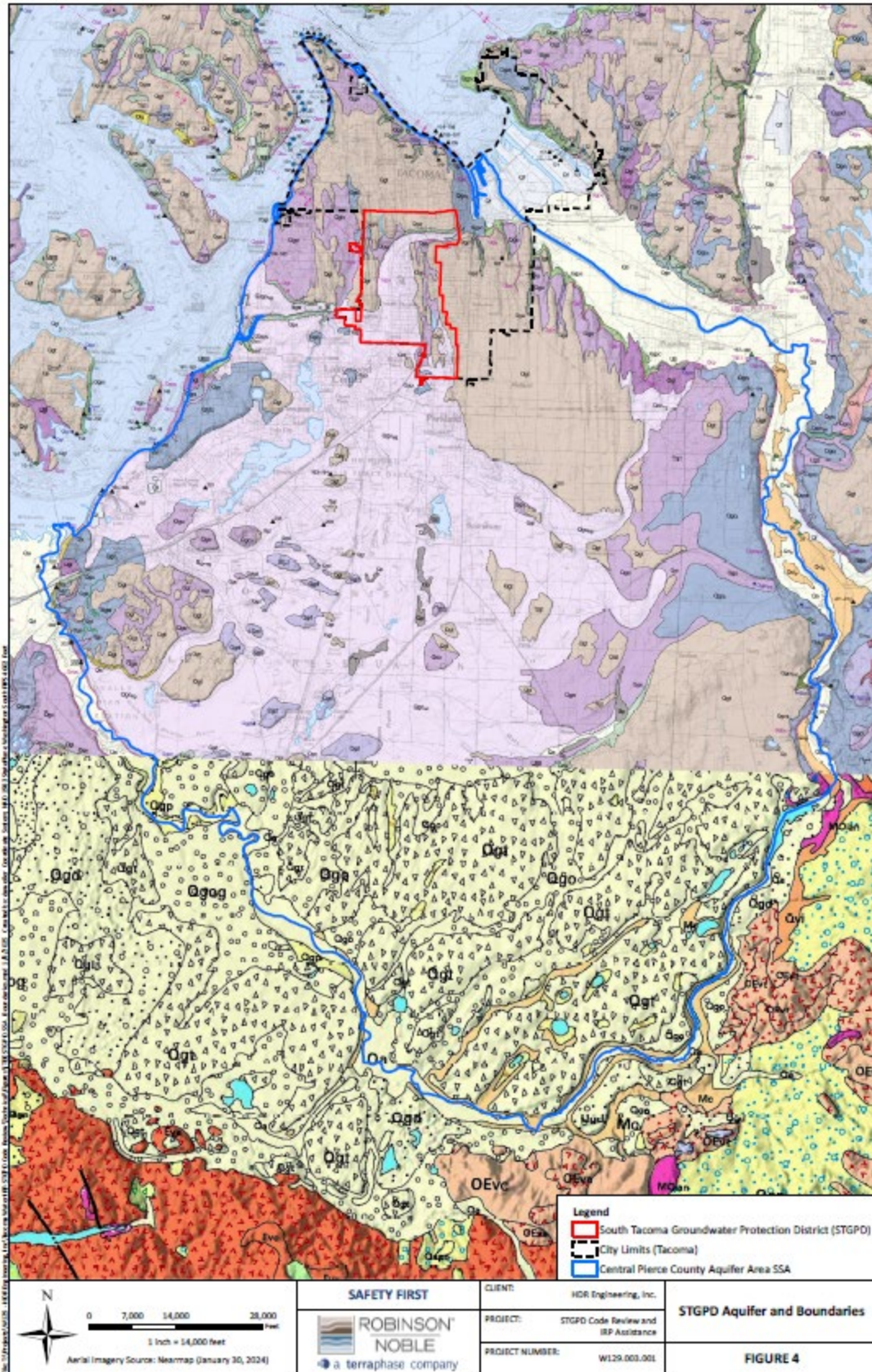
## 6.0 Attachments

1. Table of jurisdictional comparison of high impact use regulations (separate file, Excel)
2. Figures (appended to this TM file)









**DESCRIPTION OF MAP UNITS**

See pamphlet for detailed unit descriptions. Uncolored units (hollow boxes) are too small to show at map scale and are represented solely by geochronology and (or) geochemical sample locations, and (or) line or point geologic units. See Tables 1–4 for supporting analytical data.

**Quaternary Unconsolidated Deposits**


**HOLOCENE TO LATE PLEISTOCENE NONGLACIAL DEPOSITS**

- Qf **Artificial fill (Holocene)**—Modified land and engineered and unengineered fill that obscure or substantially alter the original geologic deposit.
- Qa **Alluvium (Holocene)**—Loose, stratified to massively bedded fluvial silt, sand, and gravel; typically well rounded and moderately to well sorted; locally includes sandy to silty estuarine deposits.
- Qp **Peat (Holocene to late Pleistocene)**—Loose, locally very soft and wet, organic and organic-rich sediment, including muck, silt, and clay.
- Qls **Landslide deposits (Holocene)**—Loose, unsorted, and unstratified clay, silt, soil, and organic matter and angular to rounded sand, gravel, and boulders. Absence of a mapped slide does not imply absence of sliding or hazard.
- Qaf **Alluvial fan deposits (Holocene)**—Stratified and typically poorly sorted silt, sand, gravel, and boulders forming concentric lobes where streams emerge from confining valleys and reduced gradients cause sediment load to be deposited.
- Qvl<sub>o</sub> **Electron Mudflow (Holocene)**—Unsorted mixture of subangular andesitic rock fragments in a purplish-gray, clayey sand matrix; from Mount Rainier.
- Qvl **Lahar deposits (Holocene to late Pleistocene)**—Unsorted mixtures of andesitic rock fragments in a clayey sand matrix; post-glacial; Lahar runoff and overbank deposits of three lahars from Mount Rainier Summerland eruptive period. Unit Qvl is represented on the map by geochronology sample sites no. 178–179 (Table 1).
- Qvl<sub>o</sub> **Osceola Mudflow (Holocene)**—Unstratified mixture of subrounded to subangular andesitic rock fragments in a plastic clayey sand matrix; grayish purple to medium or light gray, oxidizes to mottled yellowish brown; originated as a volcanic mudflow from Mount Rainier.
- Qt **Terrace deposits (Holocene to late Pleistocene)**—Well-sorted, loose, fluvial sand and pebble to boulder gravel along the White and Green Rivers.

**PLEISTOCENE GLACIAL DEPOSITS**

**Deposits of the Vashon Stade of the Fraser Glaciation**

- Qgd **Vashon Drift**—Stratified and unstratified sand, silt, clay, gravel, and diamicton; deposited during glacial advance and retreat; includes undifferentiated advance outwash, recessional outwash, ice-dammed-lake sediment, and ice-contact features.
- Qgo **Recessional outwash**—Silt, clay, sand, and gravel deposited by glacial meltwater; variably sorted; loose to compact; massive to well stratified; horizontal to steeply dipping beds; includes drumlins, eskers, kettles, kames, and deltas. Divided into:
  - Qgl **Recessional glaciolacustrine deposits**—Very fine grained sand, silt, and clay deposited in small ice-enclosed, ice-marginal, and ice-dammed lakes; stratified sand with scattered dropstones and occasional lenses of till or silt.
  - Qgo<sub>1</sub> **Recessional outwash, ice-contact deposits**—Sand, gravel, silt, and clay; tan to gray; loose; moderately to well sorted and rounded; good porosity and permeability; contains a mixture of dynamic-ice and stagnant-ice features, including drumlins, eskers (green lines), kettles, kames, and less-orderly hummocky topography.
  - Qgod **Recessional outwash, delta deposits**—Sand and pebble to cobble gravel, minimal silty sand, and rare boulders; well sorted; predominantly unweathered; deposited beyond retreating ice front by meltwater streams.
  - Qgo<sub>sg</sub> **Recessional outwash, Steilacoom Gravel**—Pebbles with boulders; local crossbedding; kettles and other ice-contact depressions.
  - Qgos **Recessional outwash, sand**—Sand with lenses and beds of pebble gravel and silt; gray to brown; moderate to well sorted; matrix free; loose; moderate to well rounded; commonly associated with eskers and kettles.



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| <p><b>SAFETY FIRST</b></p>  | <p>CLIENT: HDR Engineering, Inc.</p> <p>PROJECT: STGPD Code Review and IRP Assistance</p> <p>PROJECT NUMBER: W129.003.001</p> | <p><b>Geologic Map Legend</b></p> <p><b>FIGURE _</b></p> |
|--|---|--|

|   |   |                            |
|---|---|----------------------------|
| Qgt   | <b>Vashon Till</b> —Clay, silt, sand, and gravel; gray to brown and yellowish brown where oxidized; unstratified and highly compact; angular to subrounded; low permeability and porosity; includes moraines, drumlins, striations, and flutes.   |                            |
| Qga   | <b>Advance outwash</b> —Sand and pebble to cobble gravel; light gray to light brown; poorly to well sorted; very compact. Divided into:   |                            |
| Qgas  | <b>Advance outwash, sand</b> —Fine- to medium-grained sand with lenses of silt or gravel; fluvial and lacustrine facies; typically well rounded and well sorted; prone to deep-seated landslides; locally called Colvos or Esperance Sand.  |                            |
| Qgalc   | <b>Lawton Clay</b> —Laminated to massive silt, clayey silt, and silty clay interbedded with layers of crossbedded sand; light gray to dark blue-gray; local ripple marks.   |                            |
| Qade  | <b>Evans Creek Drift (Fraser Glaciation, Evans Creek Stade)</b> —Till, poorly sorted sand and gravel, and boulders; complexly interbedded; forms moraines and terraces.   |                            |
| Qu  | <b>Fraser-age continental glacial and nonglacial deposits</b> —Undifferentiated glacial and nonglacial deposits of the Fraser Glaciation.   |                            |
| <b>Pre-Vashon Glacial and Nonglacial Deposits</b>                                   |   |                            |
| Qco   | <b>Sediments of the Olympia nonglacial interval</b> —Thin to thick interbedded sand and silt, with localized gravel and some laminated silt and clay sequences; abundant plant material, wood fragments, and shells.  |                            |
| Qcp   | <b>Pre-Fraser continental sedimentary deposits, nonglacial</b> —Silt interbedded with fine sand; blue-gray to yellow-brown; massive to laminated; abundant peat and organic debris and pumice layers.   |                            |
| Qapc  | <b>Pre-Vashon alpine glacial drift and nonglacial deposits</b> —Undifferentiated alpine glacial and nonglacial deposits.  |                            |
| Qgpc  | <b>Pre-Vashon continental glacial drift and nonglacial deposits</b> —Composite geologic unit that includes combinations of all of the continental glacial and nonglacial deposits. Unit Qgpc is widespread in bluffs near Puget Sound and Hood Canal and in valley walls of major rivers. |                            |
| Qgpcpo  | <b>Pre-Olympia continental glacial and nonglacial deposits</b> —Composite geologic unit that includes combinations from among all of the continental glacial and nonglacial geologic units older than Olympia nonglacial interval (Olympia beds, unit Qco).                               |                            |
| Qgdp  | <b>Possession Drift</b> —Sand, gravel, compact sandy till, and glaciomarine drift, with lenses of sand and gravel; gray and oxidized near top of unit; locally contains shells and shell fragments.   |                            |
| Qgp   | <b>Pre-Fraser continental glacial drift</b> —Clay, silt, sand, and gravel; moderately rounded; laminated to poorly bedded; compact to loose; locally oxidized; gravel clasts of northern provenance deposited by glacial ice.   |                            |
| Qcw   | <b>Whidbey Formation</b> —Fluvial sands and gravels and massive to laminated marine and lacustrine silt and clay; wide range of oxidation levels; contains organic material.  |                            |
| Qcpo  | <b>Pre-Olympia continental sedimentary deposits, nonglacial</b> —Silt, clay, gravel, sand, and peat; coarse to fine grained; massive to laminated; predominately volcanic; abundant organic debris and pumiceous deposits.  |                            |
| Qaph  | <b>Hayden Creek Drift</b> —Alpine glacial till and outwash sand and gravel; yellowish to dark brown and oxidized.   |                            |
| Qapw  | <b>Wingate Hill Drift</b> —Alpine glacial till and outwash gravel; dark brown and oxidized, with weathering rinds; very compact; weathering rinds on clasts average 0.2 in. thick.  |                            |
| Qgpd  | <b>Double Bluff Drift</b> —Till, glaciomarine drift, glaciofluvial sand and gravel, and glaciolacustrine silt; wood and shells abundant.  |                            |
| Qgpe  | <b>Salmon Springs Drift</b> —Medium to coarse sand, pebble to cobble gravel, and till, with thin beds and lenses of silt and clay; locally contains peat and volcanic ash; clasts covered with iron-oxide stain, some strongly weathered and decomposed; well sorted.                     |                            |
|  | CLIENT: HDR Engineering, Inc.   | <b>Geologic Map Legend</b> |
|  | PROJECT: STGPD Code Review and IRP Assistance   |                            |
|   | PROJECT NUMBER: W129.003.001  |                            |
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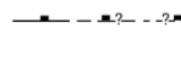
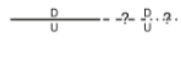
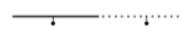






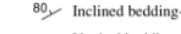


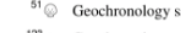
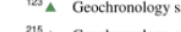
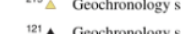
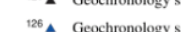
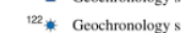






- Qvlic **Lily Creek Formation**—Unconsolidated lahar deposits; sand and gravel interbedded with compact mudflows; mudflows interbedded with ash and silt to very fine sand and white pumice; wholly or partly altered to clay.
- Qgpcpd **Pre-Double Bluff continental glacial and nonglacial deposits**— Composite geologic unit that includes combinations from among all of the continental glacial and nonglacial geologic units older than the Double Bluff (unit Qgpd). Includes portions of Stuck Drift.
- Qgpcps **Pre-Salmon Springs continental glacial and nonglacial deposits**— Composite geologic unit that includes some combination of Puyallup Formation (unit Qcp), Alderton Formation (unit Qca), Stuck Drift, and Orting Drift (unit Qgpo).
- Qcp **Puyallup Formation**—Alluvial and lacustrine silt, sand, and gravel; compact peat beds common; weathered to clay to a depth of ~10 in.; silt is laminated and pinkish-gray; sand is gray and medium to coarse; yellowish-gray pumice common.
- Qca **Alderton Formation**—Alluvial sand, pebble to boulder gravel, mudflows, and peat, with pumice and tuff. Ash deposition is estimated from an Ar-Ar analysis to be 1.6 Ma (Table 1).
- Qgpo **Orting Drift**—Deeply oxidized sand and gravel and minor amounts of till; reversely magnetized; very compact, unsorted, and unstratified.



**Tertiary Sedimentary, Volcanic, and Intrusive Rocks**

- Mci **Hammer Bluff Formation (late Miocene)**—Clayey fluvial sand and gravel, with thin silt and clay lenses, wood fragments, volcanic ash and lignite, and lacustrine sand and clay; cohesive and compact.
- Mvl **Volcanic lahars (middle to late Miocene)**—Pumice gravel, several ash layers, and three lahars containing carbonized wood.
- Mdi **Intrusive latite (Miocene to Oligocene)**—Light gray to creamy tan latite; well jointed and breaks into platy fragments; contorted flow banding, drag folding, and many xenoliths.
- Mdi **Quartz diabase (Miocene to Oligocene)**—Sill of dark gray quartz diabase (diorite), weathered to light greenish gray in places; appears chalky where feldspars have been strongly weathered; holocrystalline and medium grained.
- Mdiad **Intrusive andesite and dacite (Miocene to Oligocene)**—Light-gray massive hornblende dacite porphyry and porphyritic pyroxene andesite sills and dikes; porphyry is deeply weathered in places; irregularly shaped cavities common.
- Eec **Continental sedimentary rocks (Oligocene to Eocene)**—Tuffaceous sandstone and conglomerate, mudstone, and shale; generally poorly indurated; locally cemented by calcite and zeolites; strongly iron-stained; partly weathered to clay.
- Evcn **Ohanapecosh Formation (late Eocene to Oligocene)**—Volcaniclastic conglomerate, sandstone, siltstone, and shale; typically greenish gray, though may be black, brown, red, or white; lower volcanic sandstones are poorly sorted.
- Eida **Intrusive dacite (upper Oligocene)**—Basaltic, andesitic, or dacitic rocks; medium dark gray to dark greenish gray; porphyritic.
- Eian **Intrusive porphyritic andesite (Oligocene to Eocene)**—Irregularly shaped intrusive bodies and a sill of porphyritic andesite, probably emplaced at shallow depth.
- E2sg **Continental sedimentary rocks of the Puget Group (early Eocene to early Oligocene)**—Sandstone, siltstone, shale, carbonaceous shale, claystone, and coal; massive to crossbedded. Divided into:
  - Evcn **Norcraft Formation (Eocene)**—Andesite breccia; generally brownish or yellowish black, but may be brick red, dark gray, greenish gray, or black; includes tuff and lesser amounts of volcanic conglomerate and volcanic sandstone interbedded with mudflow breccia.
  - Ei **Porphyritic intrusive igneous rocks (Eocene)**—Greenish-gray rocks composed of zoned and altered plagioclase and hornblende phenocrysts.
  - Eib **Intrusive porphyritic basalt and andesite (late Eocene)**—Irregular masses of phaneritic igneous rock containing plagioclase and small crystals of mafic minerals; black to varying shades of brown.
  - Evc **Crescent Formation (Eocene)**—Plagioclase-pyroxene tholeiitic basalt with local diabase and gabbro; dark gray with a greenish tint, brown where weathered, and reddish and variegated along altered contact zones.

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|  | CLIENT: HDR Engineering, Inc.   | <b>Geologic Map Legend</b> |
|  | PROJECT: STGPD Code Review and IRP Assistance<br>PROJECT NUMBER: W129.003.001 |                            |
|   |   | <b>FIGURE _</b>            |

**GEOLOGIC SYMBOLS**

-  Contact—Approximately located
-  Fault—Dotted where concealed; short-dashed where inferred; queried where identity or existence questionable
-  Reverse fault—Solid where location accurate; long-dashed where approximate; short-dashed where inferred; queried where identity or existence questionable; rectangles on upthrown block
-  High-angle dip-slip fault—Solid where location approximate; short-dashed where inferred; dotted where concealed; queried where identity or existence questionable; U, upthrown block; D, downthrown block
-  Normal fault—Solid where location approximate; short-dashed where inferred; dotted where concealed; bar and ball on downthrown block
-  Anticline—Solid where location approximate; short-dashed where inferred; dotted where concealed; arrow indicates plunge direction
-  Syncline—Solid where location approximate; dotted where concealed
-  Monocline, synclinal bend—Location concealed; queried where identity or existence questionable; arrows show direction of dip; shorter arrow on steeper limb
-  Monocline, anticlinal bend—Location concealed; queried where identity or existence questionable; arrows show direction of dip; shorter arrow on steeper limb
-  Geologic unit too thin to show as polygon—Location approximate; tic separates units
-  Landslide scarp—Location accurate; identity and existence certain; hatchures point downslope
-  80°/↘ Inclined bedding—showing strike and dip
-  ↖ Vertical bedding—showing strike
-  6°/↘ Inclined bedding in unconsolidated deposits—showing strike and dip
-  51 Ⓞ Geochronology sample, fossil
-  123 ▲ Geochronology sample, argon-argon (<sup>40</sup>Ar/<sup>39</sup>Ar)
-  215 ▲ Geochronology sample, U-Pb, uranium-lead
-  121 ▲ Geochronology sample, radiocarbon (<sup>14</sup>C)
-  126 ▲ Geochronology sample, fission-track
-  122 ★ Geochronology sample, luminescence
-  5 ◆ Geochemistry sample
-  Ogp● Geologic unit too small to be shown as a polygon or line
-  ① Paleomagnetic sample, transitional magnetization
-  ② Paleomagnetic sample, normal magnetization
-  ③ Paleomagnetic sample, reversed magnetization

|  |   |                            |
|--|---|----------------------------|
| <br> | CLIENT: HDR Engineering, Inc.                 | <b>Geologic Map Legend</b> |
|  | PROJECT: STGPD Code Review and IRP Assistance |                            |
|  | PROJECT NUMBER: W129.003.001                  | <b>FIGURE _</b>            |