# PRELIMINARY
# DRAINAGE REPORT
# FOR
# OAKVIEW PLAT

MARCH 11, 2022

**PRELIMINARY**
**DRAINAGE REPORT**

**FOR**

**OAKVIEW PLAT**

Portions of the NW Quarter, NE Quarter, SE Quarter, and the SW Quarter of Section 03, Township 17 North, Range 02 West, of the Willamette Meridian, City of Roy, Pierce County, Washington

Prepared for:

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File #34816
March 11, 2022

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## CHAPTER 1 – PROJECT OVERVIEW

*Project Description*

The proposed project is located within Section 03, Township 17 North, Range 02 West. Refer to Appendix A for the vicinity map. Access to the proposed project will be from 292$^{nd}$ Street South.

The site is located on parcel 0217036009 and is approximately 38.4 acres. The project site is a proposed single-family residential development that includes the following:

- 79 single-family lots with associated driveways
- Internal plat roads with street parking stalls, vertical curb and gutter, landscaping, and sidewalks
- Stormwater conveyance systems
- Infiltration pond
- Community septic drainfield systems
- Utility installations

*Predeveloped Site Conditions*

The site is generally vegetated with trees, shrubs, and grass. There is an existing non-residential building and concrete pad located in the southwestern portion of the site and a gravel access off of 292$^{nd}$ Street South to the north. The site is bordered to the north by 292$^{nd}$ Street South, Chehalis Western Railroad to the west, and residential developments to the south and east.

Within the central portion of the site, there is an existing ridge. The ridge begins at the northeast corner and cuts diagonally across the site towards the southwestern portion of the site. Within the western portion of the site there are two depressions. The area north of the ridge generally slopes west towards the northernmost depression at approximately 8 percent. The area south of the ridge generally slopes west towards the southernmost depression at approximately 8 percent. Existing site runoff within this portion of the site flows towards the respective low point.

The southeastern flag stem portion of the site consists of rolling slopes that range from approximately 7 to 10 percent. Existing runoff within this portion of the site should either flow to a low point or the existing wetland.

Offsite drainage is assumed to be minimal as 292$^{nd}$ Street South should intercept drainage from the north and the drainage system designed for the residential development to the east should collect a majority of runoff generated from the lots adjacent to the Oakview Plat.

*Developed Site Conditions*

A majority of drainage from the developed plat is proposed to be collected by catch basins and conveyed to an infiltration pond located along the western boundary of the site for water quality/quantity control.

*Soils Analysis*

Per the Natural Resources Conservation Service website for Washington Soil Survey Data (NRCS WSS), the underlaying site soils consist of Everett very gravelly sandy loam (13C and 13D), Nisqually loamy sand (25A), and Spanaway gravelly sandy loam (41A).

Test pits were dug on site on July 16, 2019 by South Sound Geotechnical Consulting (SSGC). Supplemental investigations and testing established a design infiltration rate of 12 inches per hour for soils located in the same vicinity as the proposed infiltration pond. The analysis also included testing to confirm the minimum Cation Exchange Capacity (CEC) of 5 milliequivalents CEC/100 grams dry soil and a minimum of one percent organic content. Per Volume V, Section V-5.6 of the 2019 Washington State Department of Ecology Stormwater Management Manual for Western Washington (SWMMWW), the native soils should meet the criteria for treatment.

In May 2021, Pacific Groundwater Group (PGG) conducted a groundwater study. Using the previous design infiltration rate and a 3-foot separation between the infiltration pond bottom and the seasonal high groundwater level, a design infiltration rate of 0.5 inches per hour was established. This rate was used when sizing the infiltration pond.

Refer to Appendices B-D for the NRCS WSS, SSGC, and PGG reports for additional information.

Per Volume I, Figure I-3.1 from the SWMMWW, all minimum requirements apply to the new impervious surfaces and converted pervious surfaces proposed under this project. The minimum requirements are listed below with a short narrative of how each is being met.

1. *Minimum Requirement #1: Preparation of Stormwater Site Plans*

   Site Development plans and a Drainage Report shall be prepared as part of the Site Development Permit, which should meet Minimum Requirement #1.

2. *Minimum Requirement #2: Construction Stormwater Pollution Prevention*

   A Construction Stormwater Pollution Prevention Plan (CWSPPP) shall be prepared as part of the Site Development Permit, which should meet Minimum Requirement #2.

3. *Minimum Requirement #3: Source Control of Pollution*

   An Operation and Maintenance Manual outlining source control shall be prepared as part of the Site Development Permit, which should meet Minimum Requirement #3.

4. *Minimum Requirement: #4: Preservation of Natural Drainage System and Outfalls*

   The proposed project should not affect any natural drainage systems and is proposed to mimic the existing drainage courses to the maximum extent practicable. No new drainage patterns should be created.

5. *Minimum Requirement: #5: On-site Stormwater Management*

   Per Volume I, Section I-3.4.5, an acceptable compliance method for Minimum Requirement #5 is to meet the LID Performance Standard. To comply with this standard, a majority of drainage from the developed plat is proposed to be collected by catch basins and conveyed to an infiltration pond located along the western boundary of the site for water quality/quantity control. The infiltration pond (BMP T7.10: Infiltration Basins) was designed per Volume V, Section V-5.6 of the SWMMWW.

   Per Volume V, Section V-5.6 of the SWMMWW, infiltration facilities are required to provide a minimum of 5 feet of vertical separation between the bottom of the facility and the seasonal high groundwater level. This separation may be reduced if results from a groundwater mounding analysis, volumetric receptor capacity, and overflow design are found acceptable by a professional. In 2022, Aspect Consulting performed a Groundwater Mounding Analysis to evaluate groundwater levels and influence from the proposed infiltration pond. Aspect Consulting found that groundwater during the wettest year and during the highest 24-hour storm event would not overtop the pond bottom if set at 3 feet above the top of the seasonal groundwater level. Therefore, the proposed reduced vertical separation is acceptable.

   Refer to Appendix E for the Aspect Consulting report for additional information.

   The lots are proposed to handle runoff from a portion of their yards and roofs via individual roof downspout infiltration trenches.

   Landscaped areas are proposed to meet the Post Construction Soil Quality and Depth (BMP T5.13: Post- Construction Soil Quality and Depth) criteria outlined in Volume V, Section V-11.1 of the SWMMWW.

6. *Minimum Requirement: #6: Runoff Treatment*

   A majority of runoff from the developed plat is proposed to be collected by catch basins and conveyed to an infiltration pond. Per Volume V, Section V-5.6 of the SWMMWW, the native soils should meet the criteria for treatment.

   A pretreatment device is proposed to precede the infiltration pond to provide additional treatment.

7. *Minimum Requirement: #7: Flow Control*

   A majority of runoff from the developed plat is proposed to be collected by catch basins and conveyed to an infiltration pond. Per Volume V, Section V-5.2 of the SWMMWW, the infiltration pond should meet the criteria for flow control as it was designed to infiltrate 100 percent of runoff.

8. *Minimum Requirement: #8: Wetlands Protection*

   An existing wetland was identified by Habitat Technologies within the flag stem portion of the site. This area is proposed to be included within Tract "C" and remain undisturbed.

9. *Minimum Requirement: #9: Basin/Watershed Planning*

   There are no known Basin/Watershed Plan requirements more stringent than the minimum requirements.

10. *Minimum Requirement #11 Operation and Maintenance*

    An Operation and Maintenance Manual shall be prepared as part of the Site Development Permit, which should meet Minimum Requirement #10.

**CHAPTER 2 –EXISTING CONDITIONS SUMMARY**

The site is generally vegetated with trees, shrubs, and grass. There is an existing non-residential building and concrete pad located in the southwestern portion of the site and a gravel access off of 292$^{nd}$ Street South to the north. The site is bordered to the north by 292$^{nd}$ Street South, Chehalis Western Railroad to the west, and residential developments to the south and east.

Within the central portion of the site, there is an existing ridge. The ridge begins at the northeast corner and cuts diagonally across the site towards the southwestern portion of the site. Within the western portion of the site there are two depressions. The area north of the ridge generally slopes west towards the northernmost depression at approximately 8 percent. The area south of the ridge generally slopes west towards the southernmost depression at approximately 8 percent. Existing site runoff should flow towards the respective low point.

The southeastern flag stem portion of the site consists of rolling slopes that range from approximately 7 to 10 percent. Existing runoff within this portion of the site should either flow to a low point or the existing wetland.

Offsite drainage is assumed to be minimal as 292$^{nd}$ Street South should intercept drainage from the north and the drainage system designed for the residential development to the east should collect a majority of runoff generated from the lots adjacent to the Oakview Plat.

The project is not located within a known floodplain and/or floodway per FEMA mapping. Refer to Appendix F for the FEMA FIRM for additional information.

In the event the site floods, a majority of runoff should drain west towards Denton Marsh.

## CHAPTER 3 - OFF-SITE ANALYSIS REPORT

A downstream analysis will be prepared during the Site Development Permit.

## CHAPTER 4 – PERMANENT STORMWATER CONTROL PLAN

*Existing Site Hydrology*

Refer to Chapter 2 for existing site information.

The existing site has been modeled as one basin with the following coverage types:

| Coverage Type | Area (sf) | Area (ac) |
|---|---|---|
| Roof | 2,983 | 0.07 |
| Concrete | 1,164 | 0.03 |
| Gravel Access | 340 | 0.01 |
| Pervious | 1,666,446 | 38.26 |
| **TOTAL** | **1,670,933** | **38.36** |

*Developed Site Hydrology*

A majority of drainage from the developed plat is proposed to be collected by catch basins and conveyed to an infiltration pond located along the western boundary of the site for water quality/quantity control.

The developed areas tributary to the plat infiltration pond have been modeled as one basin with the following coverage types:

| Coverage Type | Area (sf) | Area (ac) |
|---|---|---|
| Pond | 33,334 | 0.77 |
| Roadway | 281,145 | 6.45 |
| Driveways | 39,500 | 0.91 |
| Lawn | 201,707 | 4.63 |
| **TOTAL** | **555,686** | **12.76** |

In the event the infiltration pond floods, runoff should flow west towards Denton Marsh.

Individual lot storm management BMPs shall be designed as part of the Site Development Permit.

*Performance Standards and Goals*

The project intends to meet the LID Performance Standard. To comply with this standard, a majority of drainage from the developed plat is proposed to be collected by catch basins and conveyed to an infiltration pond located along the western boundary of the site for water quality/quantity control.

The infiltration pond was designed to infiltrate 100 percent of runoff to satisfy flow control requirements.

Per Volume V, Section V-5.6 of the SWMMWW, the native soils should meet the criteria for treatment.

A pretreatment device is proposed to precede the infiltration pond to provide additional treatment.

*Low Impact Development Features*
The project intends to meet the LID Performance Standard. To comply with this standard, a majority of drainage from the developed plat is proposed to be collected by catch basins and conveyed to an infiltration pond located along the western boundary of the site for water quality/quantity control.

Landscaped areas are proposed to meet the Post Construction Soil Quality and Depth criteria outlined in Volume V, Section V-11.1 of the SWMMWW.

*Flow Control System*
A majority of drainage from the developed plat is proposed to be collected by catch basins and conveyed to an infiltration pond located along the western boundary of the site for water quality/quantity control.

The infiltration pond was designed to infiltrate 100 percent of runoff to satisfy flow control requirements.

*Runoff Treatment System*
Per Volume V, Section V-5.6 of the SWMMWW, the native soils should meet the criteria for treatment.

A pretreatment device is proposed to precede the infiltration pond to provide additional treatment.

*Source Control*
Source Control will be outlined in the Operation and Maintenance Manual as part of the Site Development Permit.

*Conveyance System Analysis and Design*
The conveyance system will be designed and analyzed as part of the Site Development Permit.

**CHAPTER 5 – CONSTRUCTION STORMWATER POLLUTION PREVENTION PLAN**

A CWSPPP shall be prepared as part of the Site Development Permit.

## CHAPTER 6 – SPECIAL REPORTS AND STUDIES

Refer to the following appendices for reports pertaining to the project:

- Appendix B - NRCS WSS
- Appendix C - Geotechnical Report
- Appendix D - Groundwater Study
- Appendix E - Groundwater Mounding Analysis

## CHAPTER 7 – OTHER PERMITS

There are no other known permits with more restrictive drainage-related requirements.

A Construction Stormwater General Permit shall be acquired from the Washington State Department of Ecology prior to construction.

## CHAPTER 8 – OPERATION AND MAINTENANCE MANUAL

An Operation and Maintenance Manual shall be prepared as part of the Site Development Permit.

## CHAPTER 9 – DECLARATION OF COVENANT FOR PRIVATELY MAINTAINED FLOW CONTROL AND RUNOFF TREATMENT BMPS

Required covenants shall be prepared as part of the Site Development Permit.

## CHAPTER 10 – DECLARATION OF COVENANT FOR PRIVATELY MAINTAINED LID BMPS

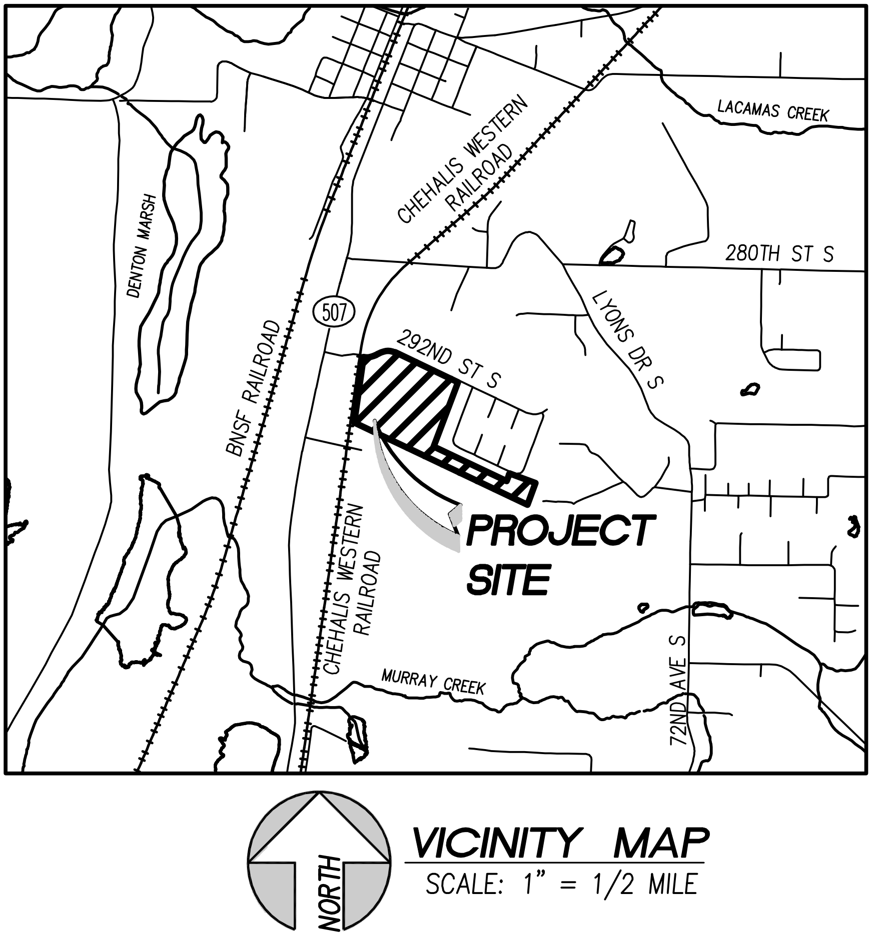
Required covenants shall be prepared as part of the Site Development Permit.

## CHAPTER 11 – BOND QUANTITIES WORKSHEET

A bond quantities worksheet will be prepared as necessary as part of the Site Development Permit.

**APPENDIX A**

VICINITY MAP




## VICINITY MAP

SCALE: 1" = 1/2 MILE

## LEGAL DESCRIPTION

LOT 3, TOWN OF ROY SHORT PLAT RECORDED OCTOBER 11, 2006 UNDER RECORDING NUMBER 200610115003, RECORDS OF PIERCE COUNTY AUDITOR;

SITUATE IN THE CITY OF ROY, COUNTY OF PIERCE, STATE OF WASHINGTON.

Apex Engineering LLC
2601 South 35th, Suite 200
Tacoma, Washington 98409-7479
(253) 473-4494 FAX: (253) 473-0599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I:\34816\Work\34816 VMAP.dwg

**APPENDIX B**

NRCS WSS

United States Department of Agriculture

NRCS

Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

# Custom Soil Resource Report for

# Pierce County Area, Washington


July 2, 2019

# Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (https://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact USDA's TARGET Center at (202) 720-2600 (voice and TDD). To file a complaint of discrimination, write to USDA, Director, Office of Civil Rights, 1400 Independence Avenue, S.W., Washington, D.C. 20250-9410 or call (800) 795-3272 (voice) or (202) 720-6382 (TDD). USDA is an equal opportunity provider and employer.

# Contents

# How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

# Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

## Soil Map

122° 32' 52" W
122° 31' 56" W
46° 59' 36" N
46° 59' 11" N
534400
534500
534600
534700
534800
534900
535000
535100
535200
535300
535400
535500
5204500
5204400
5204300
5204200
5204100
5204000
5203900
5203800
292nd St S
295th St S
81st Ave S
79th Ave S
507
13D
25A
41A
13C
Soil Map may not be valid at this scale.
Map Scale: 1:5,330 if printed on A landscape (11" x 8.5") sheet.
N
Meters
0 50 100 200 300
Feet
0 250 500 1000 1500
Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

## MAP LEGEND

**Area of Interest (AOI)**
- Area of Interest (AOI)

**Soils**
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

**Special Point Features**
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

**Water Features**
- Streams and Canals

**Transportation**
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

**Background**
- Aerial Photography

## MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Pierce County Area, Washington
Survey Area Data: Version 14, Sep 10, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Mar 29, 2016—Oct 10, 2016

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

# Map Unit Legend

| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
|---|---|---|---|
| 13C | Everett very gravelly sandy loam, 8 to 15 percent slopes | 25.0 | 64.1% |
| 13D | Everett very gravelly sandy loam, 15 to 30 percent slopes | 1.9 | 4.8% |
| 25A | Nisqually loamy sand | 4.9 | 12.6% |
| 41A | Spanaway gravelly sandy loam | 7.2 | 18.4% |
| **Totals for Area of Interest** | | **39.0** | **100.0%** |

# Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

# Pierce County Area, Washington

## 13C—Everett very gravelly sandy loam, 8 to 15 percent slopes

**Map Unit Setting**

*National map unit symbol:* 2t62b
*Elevation:* 30 to 900 feet
*Mean annual precipitation:* 35 to 91 inches
*Mean annual air temperature:* 48 to 52 degrees F
*Frost-free period:* 180 to 240 days
*Farmland classification:* Farmland of statewide importance

**Map Unit Composition**

*Everett and similar soils:* 80 percent
*Minor components:* 20 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Everett**

**Setting**

*Landform:* Kames, eskers, moraines
*Landform position (two-dimensional):* Shoulder, footslope
*Landform position (three-dimensional):* Crest, base slope
*Down-slope shape:* Convex
*Across-slope shape:* Convex
*Parent material:* Sandy and gravelly glacial outwash

**Typical profile**

*Oi - 0 to 1 inches:* slightly decomposed plant material
*A - 1 to 3 inches:* very gravelly sandy loam
*Bw - 3 to 24 inches:* very gravelly sandy loam
*C1 - 24 to 35 inches:* very gravelly loamy sand
*C2 - 35 to 60 inches:* extremely cobbly coarse sand

**Properties and qualities**

*Slope:* 8 to 15 percent
*Depth to restrictive feature:* More than 80 inches
*Natural drainage class:* Somewhat excessively drained
*Capacity of the most limiting layer to transmit water (Ksat):* High (1.98 to 5.95 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Low (about 3.2 inches)

**Interpretive groups**

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 4s
*Hydrologic Soil Group:* A
*Forage suitability group:* Droughty Soils (G002XS401WA), Droughty Soils (G002XF403WA), Droughty Soils (G002XN402WA)
*Hydric soil rating:* No

**Minor Components**

**Alderwood**

*Percent of map unit:* 10 percent
*Landform:* Ridges, hills
*Landform position (two-dimensional):* Shoulder
*Landform position (three-dimensional):* Nose slope, talf
*Down-slope shape:* Linear, convex
*Across-slope shape:* Convex
*Hydric soil rating:* No

**Indianola**

*Percent of map unit:* 10 percent
*Landform:* Eskers, kames, terraces
*Landform position (three-dimensional):* Riser
*Down-slope shape:* Linear
*Across-slope shape:* Linear
*Hydric soil rating:* No

## 13D—Everett very gravelly sandy loam, 15 to 30 percent slopes

**Map Unit Setting**

*National map unit symbol:* 2t62c
*Elevation:* 30 to 900 feet
*Mean annual precipitation:* 35 to 91 inches
*Mean annual air temperature:* 48 to 52 degrees F
*Frost-free period:* 180 to 240 days
*Farmland classification:* Farmland of statewide importance

**Map Unit Composition**

*Everett and similar soils:* 80 percent
*Minor components:* 20 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Everett**

**Setting**

*Landform:* Kames, eskers, moraines
*Landform position (two-dimensional):* Backslope
*Landform position (three-dimensional):* Side slope
*Down-slope shape:* Convex
*Across-slope shape:* Convex
*Parent material:* Sandy and gravelly glacial outwash

**Typical profile**

*Oi - 0 to 1 inches:* slightly decomposed plant material
*A - 1 to 3 inches:* very gravelly sandy loam
*Bw - 3 to 24 inches:* very gravelly sandy loam
*C1 - 24 to 35 inches:* very gravelly loamy sand
*C2 - 35 to 60 inches:* extremely cobbly coarse sand

**Properties and qualities**

*Slope:* 15 to 30 percent
*Depth to restrictive feature:* More than 80 inches
*Natural drainage class:* Somewhat excessively drained
*Capacity of the most limiting layer to transmit water (Ksat):* High (1.98 to 5.95 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Low (about 3.2 inches)

**Interpretive groups**

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 4e
*Hydrologic Soil Group:* A
*Forage suitability group:* Droughty Soils (G002XS401WA), Droughty Soils (G002XN402WA)
*Hydric soil rating:* No

### Minor Components

**Alderwood**

*Percent of map unit:* 10 percent
*Landform:* Ridges, hills
*Landform position (two-dimensional):* Backslope
*Landform position (three-dimensional):* Side slope, nose slope, talf
*Down-slope shape:* Linear, convex
*Across-slope shape:* Convex
*Hydric soil rating:* No

**Indianola**

*Percent of map unit:* 10 percent
*Landform:* Eskers, kames, terraces
*Landform position (two-dimensional):* Backslope
*Landform position (three-dimensional):* Side slope
*Down-slope shape:* Linear
*Across-slope shape:* Linear
*Hydric soil rating:* No

## 25A—Nisqually loamy sand

### Map Unit Setting

*National map unit symbol:* 2hq2
*Elevation:* 100 to 590 feet
*Mean annual precipitation:* 40 to 60 inches
*Mean annual air temperature:* 50 degrees F
*Frost-free period:* 150 to 200 days
*Farmland classification:* Prime farmland if irrigated

**Map Unit Composition**

*Nisqually and similar soils:* 85 percent
*Minor components:* 1 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Nisqually**

**Setting**

*Landform:* Terraces
*Parent material:* Sandy glacial outwash

**Typical profile**

*H1 - 0 to 19 inches:* ashy loamy sand
*H2 - 19 to 25 inches:* loamy sand
*H3 - 25 to 60 inches:* sand

**Properties and qualities**

*Slope:* 2 to 6 percent
*Depth to restrictive feature:* More than 80 inches
*Natural drainage class:* Somewhat excessively drained
*Capacity of the most limiting layer to transmit water (Ksat):* High (1.98 to 5.95 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Low (about 4.8 inches)

**Interpretive groups**

*Land capability classification (irrigated):* None specified
*Land capability classification (nonirrigated):* 3s
*Hydrologic Soil Group:* A
*Forage suitability group:* Droughty Soils (G002XS401WA)
*Hydric soil rating:* No

**Minor Components**

**Norma**

*Percent of map unit:* 1 percent
*Landform:* Depressions
*Hydric soil rating:* Yes

## 41A—Spanaway gravelly sandy loam

**Map Unit Setting**

*National map unit symbol:* 2hqw
*Elevation:* 200 to 590 feet
*Mean annual precipitation:* 35 to 65 inches
*Mean annual air temperature:* 50 degrees F
*Frost-free period:* 150 to 200 days
*Farmland classification:* Prime farmland if irrigated

**Map Unit Composition**

*Spanaway and similar soils:* 85 percent
*Minor components:* 8 percent
*Estimates are based on observations, descriptions, and transects of the mapunit.*

**Description of Spanaway**

**Setting**

*Landform:* Outwash plains
*Parent material:* Volcanic ash over gravelly outwash

**Typical profile**

*H1 - 0 to 14 inches:* gravelly medial sandy loam
*H2 - 14 to 18 inches:* very gravelly medial sandy loam
*H3 - 18 to 60 inches:* extremely gravelly sand

**Properties and qualities**

*Slope:* 0 to 6 percent
*Depth to restrictive feature:* More than 80 inches
*Natural drainage class:* Somewhat excessively drained
*Capacity of the most limiting layer to transmit water (Ksat):* High (1.98 to 5.95 in/hr)
*Depth to water table:* More than 80 inches
*Frequency of flooding:* None
*Frequency of ponding:* None
*Available water storage in profile:* Low (about 3.7 inches)

**Interpretive groups**

*Land capability classification (irrigated):* 4s
*Land capability classification (nonirrigated):* 4s
*Hydrologic Soil Group:* A
*Forage suitability group:* Droughty Soils (G002XS401WA)
*Hydric soil rating:* No

**Minor Components**

**Spana**

*Percent of map unit:* 8 percent
*Landform:* Depressions
*Hydric soil rating:* No

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**APPENDIX C**

GEOTECHNICAL REPORT

July 31, 2019

Roy Meadows Development Group, LLC
c/o APEX Engineering, PLLC
2601 S. 35th Street, Suite 200
Tacoma, WA 98409

Attention: Ms. Camille Minogue

Subject: Geotechnical Engineering Report
Oakview Addition – 292nd Street South
Pierce County, Washington
SSGC Project No. 19063

Ms. Minogue,

South Sound Geotechnical Consulting (SSGC) has completed a geotechnical assessment for the planned Oakview development in Pierce County, Washington. Our services have been completed in general conformance with our proposal P19018 (dated June 29, 2018) and authorized per signature of our services agreement. Our scope of services included completion of eighteen test pits, laboratory testing, engineering analyses, and preparation of this report.

## PROJECT INFORMATION

A new residential development is planned on slightly over 38 acres located east of the Chehalis Western Railroad line, south of 292nd Street South in Pierce County. Preliminary plans provided to us show improvements currently include up to 71 single-family lots in the development. Access to the development will be from 292nd Street South with interior roads.

## SITE CONDITIONS

The property is currently undeveloped. The eastern portion is partially wooded with the western portion maintained as field/pasture. A panhandle extension trends east along the southern property boundary Overall, the approximate eastern ¾ of the property is gentle to moderately sloping down to the southwest. A slightly steeper ridge line is in the northern area of the site. Steeper east-facing slopes are in the proposed green belt area of the south east panhandle. The westernmost portion is generally level.

## SUBSURFACE CONDITIONS

Subsurface conditions were characterized by completing eighteen test pits on the site on July 16, 2019. Test pits were advanced to final depths between about 4 and 11 feet below existing ground surface. Approximate locations of the explorations are shown on Figure 1, Exploration Plan. Logs of the test pits are provided in Appendix A. A summary description of observed subgrade conditions is provided below.

### Soil Conditions

Topsoil was observed below the surface and ranged in depth from about 0.5 to 2 feet at the test pit locations. Native soil below the topsoil consisted principally of sand with variable silt to gravelly sand with variable cobbles, silt, and boulders. These soils are interpreted to be glacial outwash. Finer grained outwash extended to the termination depth of the test pits in the flatter western portion of the site, and to depths ranging from about 3 to 5 feet in the upper eastern portion. Glacial till consisting of dense to very dense silty sand with gravel and occasional cobbles was below the outwash in the eastern portions and continued to the bottom of those test pits.

### Groundwater Conditions

Groundwater was not observed in the test pits at the time of excavation. Glacial till in the eastern portion can create perched groundwater conditions during the wetter seasons of the year. Perched groundwater levels will fluctuate during the year based on precipitation and on- and off-site drainage patterns. The permanent groundwater table is at depth and will not affect the proposed development.

### Geologic Setting

Soils within the project area have been classified by the NRCS in the Soil Survey of Pierce County Area, Washington. Surface soils on the site are mapped as several glacial outwash types. Native soils observed in the test pits appear to conform to the mapped soil types, with glacial till below the outwash in the upper eastern portion of the site.

## GEOTECHNICAL DESIGN CONSIDERATIONS

Development for the planned development is considered feasible based on observed soil conditions in the test pits. Properly prepared native soils can be used for support of conventional spread footing foundations, floor slabs, structural fill, and pavements. We anticipate some grading (cuts and fills) will be required for planned road access and individual lot development.

Infiltration to assist in stormwater control is considered feasible in the glacial outwash. However, the presence of shallower glacial till in the eastern portion of the site will restrict infiltration facilities to shallow dispersion systems in this area.

Recommendations presented in the following sections should be considered general and may require modifications at the time of construction. They are based upon the subsurface conditions observed in the test pits and the assumption that finish site grades will not be substantially different than existed grades. It should be noted subsurface conditions across the site can vary from those depicted on the exploration logs and can change with time. It should be expected that other fill of unknown type and thickness may be present due to historic uses of this site. Therefore, proper site preparation will depend upon the weather and soil conditions encountered at the time of construction. We recommend SSGC review final plans and further assess subgrade conditions at the time of construction, as warranted.

**General Site Preparation**

Site grading and earthwork should include procedures to control surface water runoff. Grading the site without adequate drainage control measures may negatively impact site soils, resulting in increased export of impacted soil and import of fill materials, thereby potentially increasing the cost of the earthwork and subgrade preparation phases of the project.

Site grading should include removal (stripping) of topsoil and any fill encountered, or very loose or soft soils in building and pavement areas. Based on observed thickness of topsoil and depth of roots, stripping depths will range from about 1 to 2 feet. However, final stripping depths can only be determined at the time of construction. Subgrades should consist of firm, undisturbed native soils following stripping.

**General Subgrade Preparation**

Subgrades in building footprints and pavement areas should consist of firm, undisturbed native outwash or till. We recommend exposed subgrades in building and conventional pavement areas are proofrolled using a large roller, loaded dump truck, or other mechanical equipment to assess subgrade conditions following stripping. Proofrolling efforts should result in the upper 1 foot of subgrade soils in building and conventional pavement areas achieving a compaction level of at least 95 percent of the maximum dry density (MDD) per the ASTM D1557 test method. Wet, loose, or soft subgrades that cannot achieve this compaction level should be removed (over-excavated) and replaced with structural fill. The depth of over-excavation should be based on soil conditions at the time of construction. A representative of SSGC should be present to assess subgrade conditions during proofrolling.

**Grading and Drainage**

Positive drainage should be provided during construction and maintained throughout the life of the development. Surface water should not be allowed to flow into construction excavations or fill areas.

**Structural Fill Materials**

The suitability of soil for use as structural fill will depend on the gradation and moisture content of the soil when it is placed. Soils with higher fines content (soil fraction passing the U.S. No. 200 sieve) will become sensitive with higher moisture content. It is often difficult to achieve adequate compaction if soil moisture is outside of optimum ranges for soils that contain more than about 5 percent fines.

> Site Soils: Topsoil or organic rich soils are not considered suitable as structural fill. Native outwash and till are considered suitable for structural fill, if properly moisture conditioned. However, the outwash contained variable cobbles and boulders. Particles larger than about 4 inches should be screened from outwash soils prior to their use. Larger particles have a tendency to cluster during earthwork activities and can form voids and non-uniform compaction.

Additionally, glacial till contains sufficient fines to make it difficult to use as structural fill during the wetter seasons of the year.

Import Fill Materials: We recommend import structural fill placed during dry weather consist of material which meets the specifications for *Gravel Borrow* as described in Section 9-03.14(1) of the 2016 Washington State Department of Transportation (WSDOT) Specifications for Road, Bridge, and Municipal Construction (Publication M 41-10). Gravel Borrow should be protected from disturbance if exposed to wet conditions after placement.

During wet weather, or for backfill on wet subgrades, import soil suitable for compaction in wetter conditions should be provided. Imported fill for use in wet conditions should conform to specifications for *Select Borrow* as described in Section 9-03.14(2), or *Crushed Surfacing* per Section 9-03.9(3) of the 2016 WSDOT M-41 manual, with the modification that a maximum of 5 percent by weight shall pass the U.S. No. 200 sieve for these soil types.

Structural fill placement and compaction is weather-dependent. Delays due to inclement weather are common, even when using select granular fill. We recommend site grading and earthwork be scheduled for the drier months of the year. Structural fill should not consist of frozen material.

**Structural Fill Placement**

We recommend structural fill is placed in lifts not exceeding about 10 inches in loose measure. It may be necessary to adjust lift thickness based on site and fill conditions during placement and compaction. Finer grained soil used as structural fill and/or lighter weight compaction equipment may require significantly thinner lifts to attain required compaction levels. Granular soil with lower fines contents could potentially be placed in thicker lifts (1 foot maximum) if they can be adequately compacted. Structural fill should be compacted to attain the recommended levels presented in Table 1, Compaction Criteria.

**Table 1. Compaction Criteria**

| Fill Application | Compaction Criteria* |
|---|---|
| Footing areas | 95 % |
| Upper 2 feet in pavement areas, flatwork, and utility trenches | 95 % |
| Below 2 feet in pavement areas, flatwork, and utility trenches | 92 % |
| Utility trenches or general fill outside of pavement or building areas | 90 % |

*Per the ASTM D 1557 test method.

Trench backfill within about 2 feet of utility lines should not be over-compacted to reduce the risk of damage to the line. In some instances the top of the utility line may be within 2 feet of the surface. Backfill in these circumstances should be compacted to a firm and unyielding condition.

We recommend fill procedures include maintaining grades that promote drainage and do not allow ponding of water within the fill area. The contractor should protect compacted fill subgrades from disturbance during wet weather. In the event of rain during structural fill placement, the exposed fill surface should be allowed to dry prior to placement of additional fill. Alternatively, the wet soil can be removed. We recommend consideration is given to protecting haul routes and other high traffic areas with free-draining granular fill material (i.e. sand and gravel containing less than 5 percent fines) or quarry spalls to reduce the potential for disturbance to the subgrade during inclement weather.

**Earthwork Procedures**

Conventional earthmoving equipment should be suitable for earthwork at this site. Earthwork may be difficult during periods of wet weather or if elevated soil moisture is present. Excavated site soils may not be suitable as structural fill depending on the soil moisture content and weather conditions at the time of earthwork. If soils are stockpiled and wet weather is anticipated, the stockpile should be protected with securely anchored plastic sheeting. If stockpiled soils become wet and unusable, it will become necessary to import clean, granular soils to complete wet weather site work.

Wet or disturbed subgrade soils should be over-excavated to expose firm, non-yielding, non-organic soils and backfilled with compacted structural fill. We recommend the earthwork portion of this project be completed during extended periods of dry weather. If earthwork is completed during the wet season (typically October through May) it may be necessary to take extra measures to protect subgrade soils.

If earthwork takes place during freezing conditions, we recommend the exposed subgrade is allowed to thaw and re-compacted prior to placing subsequent lifts of structural fill. Alternatively, the frozen soil can be removed to unfrozen soil and replaced with structural fill.

The contractor is responsible for designing and constructing stable, temporary excavations (including utility trenches) as required to maintain stability of excavation sides and bottoms. Excavations should be sloped or shored in the interest of safety following local and federal regulations, including current OSHA excavation and trench safety standards. Temporary excavation cuts should be sloped at inclinations of 1.5H:1V (Horizontal:Vertical) or flatter, unless the contractor can demonstrate the safety of steeper cut slopes. It should be noted outwash soils have the tendency to readily cave into open excavations. Shoring may be necessary for deeper utility trenches on this site. Permanent cut and fill slopes should be inclined at 2H:1V, or flatter.

A geotechnical engineer and qualified materials testing firm should be retained during the construction phase of the project to observe earthwork operations and to perform necessary tests and observations during subgrade preparation, placement and compaction of structural fill, and backfilling of excavations.

**Foundations**

Foundations can be placed on firm native soils or on a zone of structural fill above prepared subgrades as described in this report. The following recommendations are for conventional spread footing foundations:

| | |
|---|---|
| Bearing Capacity (net allowable): | 2,000 pounds per square foot (psf) for footings supported on firm native soils or structural fill over native subgrades prepared as described in this report. |
| Footing Width (Minimum): | 16 inches (Strip)<br>24 inches (Column) |
| Embedment Depth (Minimum): | 18 inches (Exterior)<br>12 inches (Interior) |
| Settlement: | Total: < 1 inch<br>Differential: < 1/2 inch (over 30 feet) |
| Allowable Lateral Passive Resistance: | 325 psf/ft* (below 12 inches) |
| Allowable Coefficient of Friction: | 0.40* |

*These values include a factor of safety of approximately 1.5.

The net allowable bearing pressures presented above may be increased by one-third to resist transient, dynamic loads such as wind or seismic forces. Lateral resistance to footings should be ignored in the upper 12-inches from exterior finish grade unless restricted.

**Foundation Construction Considerations**

All foundation subgrades should be free of water and loose soil prior to placing concrete, and should be prepared as recommended in this report. Concrete should be placed soon after excavating and compaction to reduce disturbance to bearing soils. Should soils at foundation level become excessively dry, disturbed, saturated, or frozen, the affected soil should be removed prior to placing concrete. We recommend SSGC observe all foundation subgrades prior to placement of concrete.

**Foundation Drainage**

Ground surface adjacent foundations should be sloped away to facilitate drainage. We recommend footing drains are installed around perimeter footings if place on glacial till or structural fill containing more than 10 percent fines. Footing drains are not considered necessary for foundations placed directly on native outwash soils.

Footing drains should include a minimum 4-inch diameter perforated rigid plastic or metal drain line installed along the exterior base of the footing. The perforated drain lines should be connected to a tight line pipe that discharges to an approved storm drain receptor. The drain line should be surrounded by a zone of clean, free-draining granular material having less than 5 percent passing the No. 200 sieve or meeting the requirements of section 9-03.12(2) "Gravel Backfill for Walls" in the 2016 WSDOT Standard Specifications for Road, Bridge, and Municipal Construction manual (M41-10). The free-draining aggregate zone should be at least 12 inches wide and wrapped in filter fabric. The granular fill should extend to within 6 inches of final grade where it should be capped with compacted fill containing sufficient fines to reduce infiltration of surface water into the footing drains. Alternately, the ground surface can be paved with asphalt or concrete. Cleanouts are recommended for maintenance of the drain system.

**On-Grade Floor Slabs**

On-grade floor slabs should be placed on native soils or structural fill prepared as described in this report. We recommend a modulus subgrade reaction of 200 pounds per square inch per inch (psi/in) for native soil or compacted granular structural fill over properly prepared native soil.

We recommend a capillary break is provided between the prepared subgrade and bottom of slab. Capillary break material should be a minimum of 4 inches thick and consist of compacted clean, free-draining, well graded course sand and gravel. The capillary break material should contain less than 5 percent fines, based on that soil fraction passing the U.S. No. 4 sieve. Alternatively, a clean angular gravel such as No. 7 aggregate per Section 9-03.1(4) C of the 2016 WSDOT (M41-10) manual could be used for this purpose.

We recommend positive separations and/or isolation joints are provided between slabs and foundations, and columns or utility lines to allow independent movement where needed. Backfill in interior trenches beneath slabs should be compacted in accordance with recommendations presented in this report.

A vapor retarder should be considered beneath concrete slabs that will be covered with moisture sensitive or impervious coverings (such as tile, wood, etc.), or when the slab will support equipment or stored materials sensitive to moisture. We recommend the slab designer refer to ACI 302 and/or ACI 360 for procedures and limitations regarding the use and placement of vapor retarders.

**Seismic Considerations**

Recommended seismic parameters and values in Table 2 are based on the 2015 International Building Code (IBC).

**Table 2. Seismic Parameters**

| PARAMETER | VALUE |
|---|---|
| 2015 International Building Code (IBC) Site Classification[1] | D |
| $S_s$ Spectral Acceleration for a Short Period | 1.255 |
| $S_1$ Spectral Acceleration for a 1-Second Period | 0.496g |
| $F_a$ Site Coefficient for a Short Period | 1.00 |
| $F_v$ Site Coefficient for a 1-Second Period | 1.504 |

[1] Note: In general accordance with *2015 International Building Code,* Section 1613.3.1 for risk categories I,II,III. IBC Site Class is based on the estimated characteristics of the upper 100 feet of the subsurface profile. $S_s$, $S_1$, $F_a$, and $F_v$ values based on the OSHPD Seismic Design Maps website.

**Liquefaction**

Soil liquefaction is a condition where loose, typically granular soils located below the groundwater surface lose strength during ground shaking, and is often associated with earthquakes. The Pierce County Potential Liquefaction and/or Dynamic Settlement Hazard map (issued in 2005) does not show the site in an area of high risk to liquefaction. Native soils consist of principally medium dense sand and gravel (outwash) with dense glacial till below. The risk of liquefaction at this site is considered low for the design level earthquake.

**Lateral Earth Pressures**

Below grade walls will be subject to lateral earth pressures. Subgrade walls are typically designed for "active" or "at-rest" earth pressure conditions. Active earth pressure is commonly used for design of free-standing cantilever retaining walls and assumes lateral movement at the top of the wall of around 0.002H to 0.004H, where H is the height of the wall. The at-rest condition assumes no wall movement.

The following recommended earth pressures (Table 3) should be applied as a triangular distribution starting at the top of the wall (for active and at-rest) and bottom of wall (for passive) and assume:

- Backfill behind walls is level and no surcharge loads will be applied;
- Drainage is provided behind the wall to prevent the development of hydrostatic pressures.

**Table 3. Lateral Earth Pressures**

| Soil Type | Earth Pressure Coefficient* | Equivalent Fluid Pressure (pcf)* |
|---|---|---|
| Native Outwash | Active: 0.36<br>At-rest: 0.53<br>Passive: 2.80 | Active: 40<br>At-rest: 55<br>Passive: 300 |
| Native Glacial Till | Active: 0.26<br>At-rest: 0.41<br>Passive: 3.80 | Active: 32<br>At-rest: 45<br>Passive: 350 |

* A factor of safety of about 1.5 should be applied to these values.

Additional lateral pressure should be added to these values to model surcharges such as adjacent buildings, sloped backfill behind the wall, traffic, construction equipment, or seismic loads. We recommend an active seismic pressure of 4H psf (where H is the height of the subgrade wall) and an at-rest seismic pressure of 7H. The effects of other surcharge loads should be accounted for as appropriate.

**Wall Backfill**

Backfill behind retaining walls should consist of granular material that satisfies the criteria of Section 9-03.12(2) "Gravel Backfill for Walls" per the 2018 Washington State Department of Transportation (WSDOT) Specifications for Road, Bridge, and Municipal Construction Manual (Publication M 41-10), or as approved by the engineer.

Wall backfill should be placed in lifts not exceeding 8 inches and compacted with hand-operated compaction equipment. Compaction of wall backfill should be between 90 to 92 percent of the maximum dry density (MDD) per the ASTM D1557 test method within 3 feet of the back of the wall. At a distance greater than 3 feet behind the back of the wall, backfill can be compacted using conventional rollers, with backfill compacted to at least 92 percent of the MDD (ASTM D1557).

**Wall Drainage**

Drainage should be provided behind subgrade walls to reduce the potential for hydrostatic pressure developing against the wall and to reduce the risk of groundwater from entering subgrade floors. We recommend a minimum 12-inch wide zone of free draining granular soil (WSDOT Section 9-03.12(4), or as approved by the engineer) is placed directly behind the wall. Alternatively, a drainage mat can be used behind the wall. A perforated rigid plastic drain pipe at least 6-inches in diameter should be installed behind the base of the wall within 6-inches of the bottom of the footing. The drain line should be surrounded with the free-draining granular soil zone and sloped to provide flow to an approved storm water receptor. The granular fill zone should extend to within 1 foot of final grade of the wall, where it should be capped with compacted low permeable fill containing sufficient fines to reduce infiltration of surface water into the drainage zone. A filter fabric (such as Mirafi 140N, or other approved material) should be placed between native soils and the granular drain material to limit siltation into the drainage zone. Cleanouts are recommended for maintenance of the drain system.

**Infiltration Characteristics**

We understand stormwater control will use infiltration facilities. General assessment of infiltration potential of site soils was completed using gradation correlations based on Massmann's equation per the 2015 Pierce County Stormwater Management and Site Development Manual on three samples of the native outwash from various test pits. Outwash is considered a Type A hydrologic soil. Results of the correlations are provided in Table 3.

**Table 3. Infiltration Rates**

| Test Site and Depth (ft) | Soil Type | Calculated Infiltration Rate (in/hr) | Corrected Infiltration Rate (in/hr) | Correction Factors* (CFg/CFt/CFp) |
|---|---|---|---|---|
| TP-1, 8 ft | Outwash | 12 | 3.8 | (1.0/0.4/0.8) |
| TP-3, 3.5 ft | Outwash | 46 | 16.5 | (1.0/0.4/0.9) |
| TP-7, 4 ft | Outwash | 140 | >50 | (1.0/0.4/0.9) |

* Correction Factors from the 2015 Pierce County Stormwater Management and Site Development Manual.

Calculated infiltration rates are considered appropriate for the outwash soil tested and show the rates are affected by the amount of finer grained particles in the outwash. We recommend using an averaged long-term design rate of 20 inches per hour (in/hr) for design of infiltration facilities located in outwash soils. Correction factors to the above recommended long-term rate should be modified for the type of infiltration system selected, as required.

Infiltration is not considered feasible in the dense glacial till. Infiltration facilities would be limited to shallow dispersion systems in the upper outwash where till is encountered at shallow depth in the upper eastern portion of the site.

Cation Exchange Capacity (CEC) and organic content test were completed on outwash samples from two test pits to assess treatment characteristics of the upper outwash soil. Test results are summarized in Table 4.

**Table 4. CEC and Organic Content Results**

| Test Location, Sample Number, Depth | CEC Results (milliequivalents) | CEC Required* (milliequivalents) | Organic Content Results (%) | Organic Content Required* (%) |
|---|---|---|---|---|
| TP-3, S-1, 3.5 feet | 7.5 | ≥ 5 | 2.68 | ≥1.0 |
| TP-5, S-1, 3.5 feet | 8.1 | ≥ 5 | 2.59 | ≥1.0 |

*Per the 2015 Pierce County Stormwater Management and Site Development Manual.

Organic content and CEC test results satisfy County criteria on the tested samples. However, CEC and organic content can vary significantly in outwash soils depending on depth. Additional testing may be warranted once final depths of proposed infiltration systems have been identified.

**Conventional Pavement Sections**

Subgrades for conventional pavement areas should be prepared as described in the "*Subgrade Preparation*" section of this report. Subgrades below pavement sections should be graded or crowned to promote drainage and not allow for ponding of water beneath the section. If drainage is not provided and ponding occurs, the subgrade soils could become saturated, lose strength, and result in premature distress to the pavement. In addition, the pavement surfacing should also be graded to promote drainage and reduce the potential for ponding of water on the pavement surface.

Minimum recommended pavement sections for conventional pavements are presented in Table 5. These sections are for Pierce County Neighborhood Street designation and private drives. If heavier consistent truck loads or traffic is planned, we should be advised so we can review the section and provide modified sections, as warranted. Pavement sections in public right-of-ways should conform to Pierce County requirements for the road designation.

**Table 5. Preliminary Pavement Sections**

| Traffic Area | Minimum Recommended Pavement Section Thickness (inches) | | | |
|---|---|---|---|---|
| | Asphalt Concrete Surface[1] | Portland Cement Concrete[2] | Aggregate Base Course[3,4] | Subbase Aggregate[5] |
| Access Roads | 2 | 5 | 6 | 12 |
| Driveways | 2 | 5 | 4 | 12 |

[1] 1/2 –inch nominal aggregate hot-mix asphalt (HMA) per WSDOT 9-03.8(1)
[2] A 28 day minimum compressive strength of 4,000 psi and an allowable flexural strength of at least 250 psi
[3] Crushed Surfacing Base Course per WSDOT 9-03.9(3)
[4] Although not required for structural support under concrete pavements, a minimum four-inch thick base course layer is recommended to help reduce potentials for slab curl, shrinkage cracking, and subgrade "pumping" through joints
[5] Native granular soils compacted to 95% of the ASTM D1557 test method, or Gravel Borrow per WSDOT 9-03.14(1) or Crushed Surfacing Base Course WSDOT 9-03.9(3)

**Conventional Pavement Maintenance**

The performance and lifespan of pavements can be significantly impacted by future maintenance. The above pavement sections represent minimum recommended thicknesses and, as such, periodic maintenance should be completed. Proper maintenance will slow the rate of pavement deterioration, and will improve pavement performance and life. Preventative maintenance consists of both localized maintenance (crack and joint sealing and patching) and global maintenance (surface sealing). Added maintenance measures should be anticipated over the lifetime of the pavement section if any existing fill or topsoil is left in-place beneath pavement sections.

**Critical Areas**

Slopes separating the flatter (lower) western portion of the site from the upper eastern have average inclinations of 15 to 20 percent or flatter. Locally steeper inclinations in the northern portion of the west-facing slope approach 40 percent. Some of the steeper slopes along the northern property boundary (bordering 292$^{nd}$ Street South) appear to be cut slopes for original construction of the road. East facing slopes in the eastern panhandle area has slope ranging from about 20 to 30 percent.

We did not observe evidence of recent or historical earth movement on site slopes. Native soils on site slopes consist principally of glacial till, with a relatively thin layer outwash above. Based on provided development plans, the steeper sloped areas (having inclinations steeper than about 20 percent) will remain green space and not subject to development. Construction of the proposed plat should not adversely impact site slopes.

**REPORT CONDITIONS**

This report has been prepared for the exclusive use of Roy Meadows Development Group, LLC and their agents for specific application to the project discussed, and has been prepared in accordance with generally accepted geotechnical engineering practices in the area. No warranties, either express or implied, are intended or made. The analysis and recommendations presented in this report are based on observed soil conditions and test results at the indicated locations, and from other geologic information discussed. This report does not reflect variations that may occur across the site, or due to the modifying effects of construction or weather. The nature and extent of such variations may not become evident until during or after construction. If variations appear, we should be immediately notified so that further evaluation and supplemental recommendations can be provided.

This report was prepared for the planned type of development of the site as discussed herein. It is not valid for third party entities or alternate types of development on the site without the express written consent of SSGC. If development plans change we should be notified to review those changes and modify our recommendations as necessary.

The scope of services for this project does not include any environmental or biological assessment of the site including identification or prevention of pollutants, hazardous materials, or conditions. Other studies should be completed if the owner is concerned about the potential for contamination or pollution.

We appreciate the opportunity to work with you on this project. Please contact us if additional information is required or we can be of further assistance.

Respectfully,

South Sound Geotechnical Consulting

TIMOTHY H. ROBERTS
STATE OF WASHINGTON
43126
REGISTERED
PROFESSIONAL ENGINEER

7-31-19

Timothy H. Roberts, P.E., R.G.
Member/Geotechnical Engineer

Attachments: Figure 1 – Exploration Plan
Appendix A – Field Exploration Procedures and Test Pit Logs
Appendix B – Laboratory Testing and Results
Unified Soil Classification System


**Legend**

**TP - 1**

**Approximate Test Pit Location**

Base map from Google Maps

**Scale: NTS**

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Lakewood, WA 98496
(253) 973-0515

**Figure 1 – Exploration Plan**

**Oakview Addition**
**Pierce County, WA**

SSGC Project #19063

# Appendix A

## Field Exploration Procedures and Test Pit Logs

**Field Exploration Procedures**

Our field exploration for this project included eighteen test pits completed on July 16, 2019. The approximate locations of the explorations are shown on Figure 1, Exploration Plan. The exploration locations were determined by pacing from site features. Test pit locations should be considered accurate only to the degree implied by the means and methods used.

A private backhoe operator subcontracted to SSGC excavated the test pits. Soil samples were collected and stored in moisture tight for further assessment and laboratory testing. Explorations were backfilled with excavated soils and tamped when completed. Please note that backfill in the explorations will likely settle with time. Backfill material located in building areas should be re-excavated and recompacted, or replaced with structural fill.

The following logs indicate the observed lithology of soils and other materials observed in the explorations at the time of excavation. Where a soil contact was observed to be gradational, our log indicates the average contact depth. Our logs also indicate the approximate depth to groundwater (where observed at the time of excavation), along with sample numbers and approximate sample depths. Soil descriptions on the logs are based on the Unified Soil Classification System.

## Test Pit TP-1

| Depth (feet) | Material Description |
|---|---|
| 0 – 0.5 | **Topsoil** |
| 0.5 – 1.5 | SAND with some silt: Loose to medium dense, moist, light brown. (Sample S-1 @ 1 foot) |
| 1.5 - 10 | SAND with trace to some silt: Loose to medium dense, moist, gray. Layer of silty sand between about 7 to 9 feet. (Sample S-2 @ 3.5 feet; Sample S-3 @ 8 feet)(Glacial Outwash) |

Test pit completed at approximately 10 feet on 7/16/19.
Groundwater not observed feet at time of excavation.
Piezometer set in test pit.

## Test Pit TP-2

| Depth (feet) | Material Description |
|---|---|
| 0 – 0.5 | **Topsoil** |
| 0.5 – 1.5 | SAND with some silt: Loose to medium dense, moist, light brown. |
| 1.5 - 9 | SAND with trace silt: Loose to medium dense, moist, brown grading gray at 5 feet. (Glacial Outwash) |

Test pit completed at approximately 9 feet on 7/16/19.
Groundwater not observed at time of excavation.

Test Pit TP-3

| Depth (feet) | Material Description |
|---|---|
| 0 – 0.5 | **Topsoil** |
| 0.5 – 1.5 | SAND with some silt: Loose to medium dense, moist, dark brown. |
| 1.5 – 9 | SAND with trace silt: Loose to medium dense, moist, brownish gray grading gray at 5 feet. (Sample S-1 @ 3.5 feet)(Glacial Outwash) |
| 9 - 11 | Gravelly SAND with trace silt and occasional gravel: Medium dense, moist gray. (Glacial Outwash) |

Test pit completed at approximately 11 feet on 7/16/19.
Groundwater not observed at time of excavation.
Piezometer set in test pit.

Test Pit-4

| Depth (feet) | Material Description |
|---|---|
| 0 – 1 | **Topsoil** |
| 1 – 2 | SAND with some silt: Loose to medium dense, moist, dark brown. |
| 2 – 6 | SAND with trace silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 6 - 10 | Silty SAND with occasional gravel, cobble, boulder: Medium dense, moist, light brown. (Sample S-1 @ 8 feet)(Glacial Outwash) |

Test pit completed at approximately 10 feet on 7/16/19.
Groundwater not observed at time of excavation

Test Pit-5

| Depth (feet) | Material Description |
|---|---|
| 0 – 1.5 | **Topsoil** |
| 1.5 – 10 | Silty gravelly SAND with occasional cobble and boulder: Medium dense, moist, light brown. (Sample S-1 @ 3.5 feet; Sample S-2 @ 7 feet)(Glacial Outwash) |

Test pit completed at approximately 10 feet on 7/16/19.
Groundwater not observed at time of excavation.

Test Pit-6

| Depth (feet) | Material Description |
|---|---|
| 0 – 0.5 | **Topsoil** |
| 0.5 – 2 | SAND with trace to some silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 2 - 4 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |

Test pit completed at approximately 4 feet on 7/16/19.
Groundwater not observed at time of excavation.

Test Pit-7

| Depth (feet) | Material Description |
|---|---|
| 0 – 1.5 | **Topsoil** |
| 1.5 – 6 | Gravelly SAND with trace silt: Medium dense, moist, light brown. (Sample S-1 @ 4 feet)(Glacial Outwash) |
| 6 – 7 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |

Test pit completed at approximately 7 feet on 7/16/19.
Groundwater not observed at time of excavation.

Test Pit-8

| Depth (feet) | Material Description |
|---|---|
| 0 – 2 | **Topsoil** |
| 2 – 4 | SAND with trace to some silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 4 - 6 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |

Test pit completed at approximately 6 feet on 7/16/19.
Groundwater not observed at time of excavation.

Test Pit-9

| Depth (feet) | Material Description |
|---|---|
| 0 – 1 | **Topsoil** |
| 1 – 3 | SAND with trace to some silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 3 – 4.5 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |
| | Test pit completed at approximately 4.5 feet on 7/16/19. Groundwater not observed at time of excavation. |

Test Pit-10

| Depth (feet) | Material Description |
|---|---|
| 0 – 1.5 | **Topsoil** |
| 1.5 – 4 | SAND with trace to some silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 4 - 5 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |
| | Test pit completed at approximately 5 feet on 7/16/19. Groundwater not observed at time of excavation. |

Test Pit-11

| Depth (feet) | Material Description |
|---|---|
| 0 – 1.5 | **Topsoil** |
| 1.5 – 4.5 | SAND with trace to some silt and roots Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 4.5 - 5 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |
| | Test pit completed at approximately 5 feet on 7/16/19. Groundwater not observed at time of excavation. |

## Test Pit-12

| Depth (feet) | Material Description |
|---|---|
| 0 – 1 | **Topsoil** |
| 1 – 2 | SAND with trace to some silt: Loose to medium dense, moist, dark brown. (Glacial Outwash) |
| 2 - 3 | SAND with trace to some silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 3 - 4 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |

Test pit completed at approximately 4 feet on 7/16/19.
Groundwater not observed at time of excavation.

## Test Pit-13

| Depth (feet) | Material Description |
|---|---|
| 0 – 1 | **Topsoil** |
| 1 – 3 | SAND with silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 3 - 4 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |

Test pit completed at approximately 4 feet on 7/16/19.
Groundwater not observed at time of excavation.

## Test Pit-14

| Depth (feet) | Material Description |
|---|---|
| 0 – 1.5 | **Topsoil** |
| 1.5 – 3 | SAND with silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 3 - 5 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |

Test pit completed at approximately 5 feet on 7/16/19.
Groundwater not observed at time of excavation.

Test Pit-15

| Depth (feet) | Material Description |
|---|---|
| 0 – 1 | **Topsoil** |
| 1 – 4 | SAND with silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 4 - 5 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |
| | Test pit completed at approximately 5 feet on 7/16/19. Groundwater not observed at time of excavation. |

Test Pit-16

| Depth (feet) | Material Description |
|---|---|
| 0 – 1 | **Topsoil** |
| 1 – 3 | SAND with silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 3 - 4 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |
| | Test pit completed at approximately 4 feet on 7/16/19. Groundwater not observed at time of excavation. |

Test Pit-17

| Depth (feet) | Material Description |
|---|---|
| 0 – 2 | **Topsoil** |
| 2 – 7 | Gravelly SAND with cobbles and trace to some silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 7 - 8 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |
| | Test pit completed at approximately 5 feet on 7/16/19. Groundwater not observed at time of excavation. |

| Depth (feet) | Test Pit-18<br>Material Description |
|---|---|
| 0 – 1 | **Topsoil** |
| 1 – 5 | Gravelly SAND with cobbles and trace to some silt: Loose to medium dense, moist, light brown. (Glacial Outwash) |
| 4 - 5 | Silty SAND with gravel: Dense to very dense, damp, gray. (Glacial Till) |
| | Test pit completed at approximately 5 feet on 7/16/19. Groundwater not observed at time of excavation. |

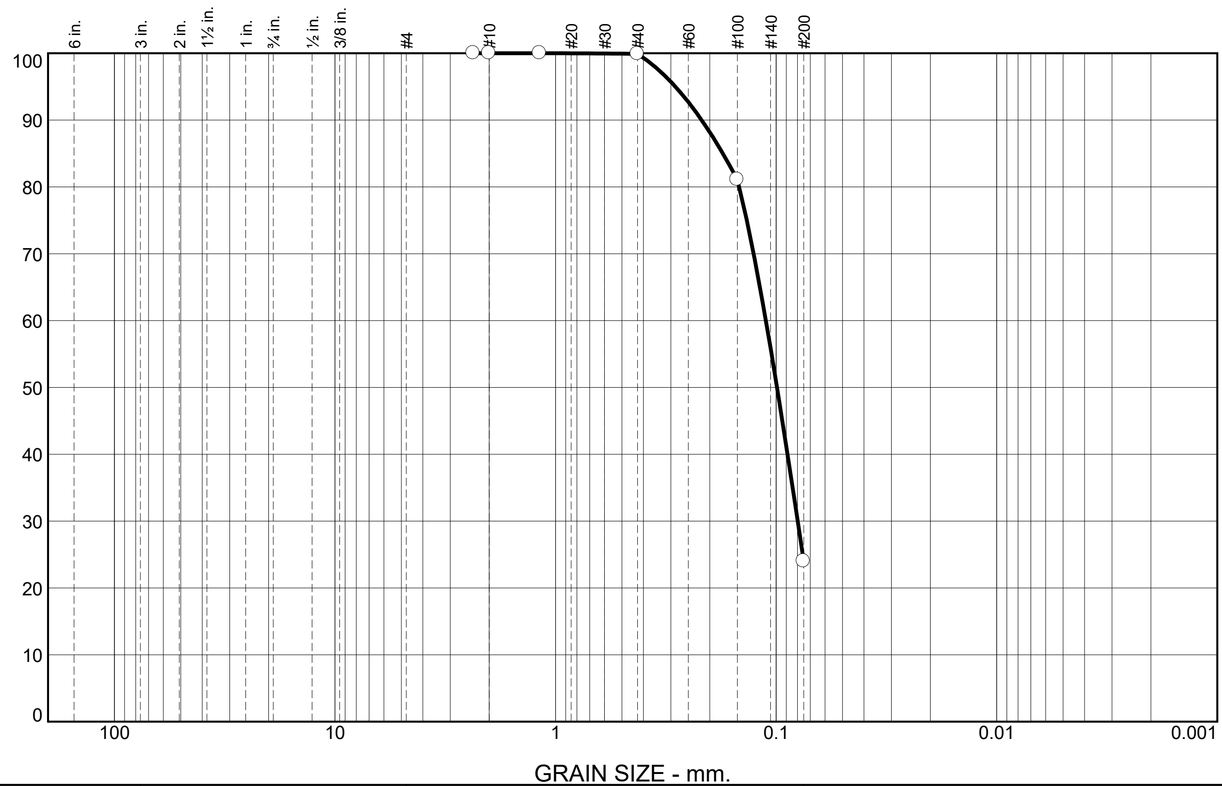
# Appendix B

# Laboratory Testing and Results

## Laboratory Testing

Select soil samples were tested for organic content and cation exchange capacity (CEC) by Northwest Agricultural Consultants of Kennewick, Washington. Gradation tests were completed by Construction Testing Laboratories (CTL) of Puyallup, Washington. Results of the laboratory testing are included in this appendix.

# Particle Size Distribution Report ASTM C-117,C136




| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0 | 0 | 0 | 0 | 0 | 76 | 24 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| #8 | 100 | | |
| #10 | 100 | | |
| #16 | 100 | | |
| #40 | 100 | | |
| #100 | 81 | | |
| #200 | 24 | | |

* (no specification provided)

**Material Description**

Grab Sample, S-3
Sampled at 8'

**Atterberg Limits**

PL= LL= PI=

**Classification**

USCS= AASHTO=

**Remarks**

Report: #02

Sampled by: Client

**Source of Sample:** TP-1
**Sample Number:** 19-1048

**Date:** 07-16-19

**Construction Testing Laboratories**
**400 Valley Ave. NE, Suite #102**
**Puyallup WA, 98372 Tel. (253) 383-8778**

**Client:** South Sound Geotechnical
**Project:** Oak View
19063
**Project No:** 7941 **Figure**

**Tested By:** M Armstrong **Checked By:** C Pedersen

# Particle Size Distribution Report ASTM C-117,C136


| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0 | 0 | 0 | 0 | 19 | 75 | 6 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| #4 | 100 | | |
| #8 | 100 | | |
| #10 | 100 | | |
| #16 | 99 | | |
| #40 | 81 | | |
| #100 | 13 | | |
| #200 | 5.9 | | |

* (no specification provided)

**Material Description**

Grab Sample, S-1
Sampled at 3.5'

**Atterberg Limits**

PL= LL= PI=

**Classification**

USCS= AASHTO=

**Remarks**

Report: #03

Sampled by: Client

**Source of Sample:** TP-3
**Sample Number:** 19-1047

**Date:** 07-16-19

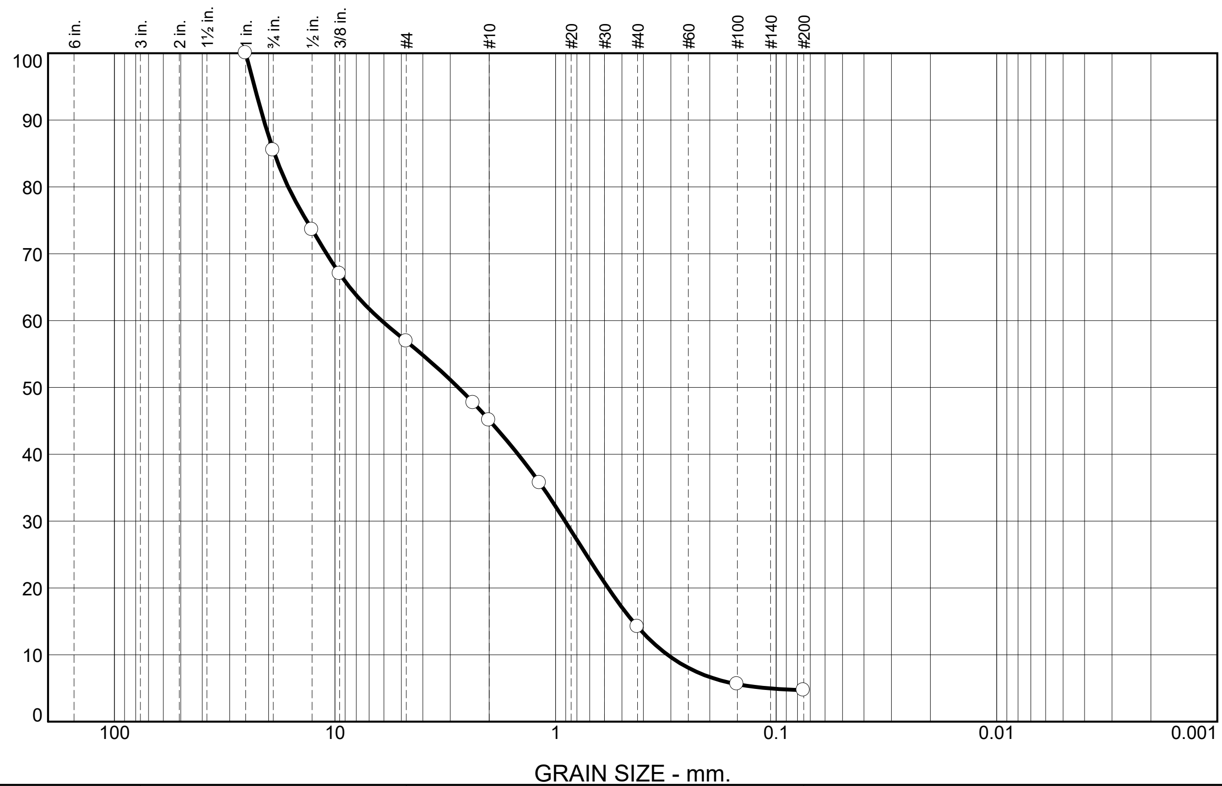

**Construction Testing Laboratories**
**400 Valley Ave. NE, Suite #102**
**Puyallup WA, 98372 Tel. (253) 383-8778**


**Client:** South Sound Geotechnical
**Project:** Oak View
19063
**Project No:** 7941 **Figure**



**Tested By:** M Armstrong **Checked By:** C Pedersen

# Particle Size Distribution Report ASTM C-117,C136




| % +3" | % Gravel | | % Sand | | | % Fines | |
|---|---|---|---|---|---|---|---|
| | Coarse | Fine | Coarse | Medium | Fine | Silt | Clay |
| 0 | 14 | 29 | 12 | 31 | 9 | 4 | |

| SIEVE SIZE | PERCENT FINER | SPEC.* PERCENT | PASS? (X=NO) |
|---|---|---|---|
| 1" | 100 | | |
| 3/4" | 86 | | |
| 1/2" | 74 | | |
| 3/8" | 67 | | |
| #4 | 57 | | |
| #8 | 48 | | |
| #10 | 45 | | |
| #16 | 36 | | |
| #40 | 14 | | |
| #100 | 6 | | |
| #200 | 4.7 | | |

* (no specification provided)

**Material Description**

Grab Sample, S-1
Sampled at 4'

**Atterberg Limits**

PL= LL= PI=

**Classification**

USCS= SP AASHTO=

**Remarks**

Report: #01

Sampled by: Client

**Source of Sample:** TP-7
**Sample Number:** 19-1044

**Date:** 07-16-19


**Construction Testing Laboratories**
**400 Valley Ave. NE, Suite #102**
**Puyallup WA, 98372 Tel. (253) 383-8778**


**Client:** South Sound Geotechnical
**Project:** Oak View
19063
**Project No:** 7941 **Figure**



**Tested By:** M Armstrong **Checked By:** C Pedersen

Northwest Agricultural Consultants

South Sound Geotechnical Consulting
PO Box 39500
Lakewood, WA 98496

2545 W Falls Avenue
Kennewick, WA 99336
509.783.7450
www.nwag.com
lab@nwag.com

PAP-Accredited
NAPT

**Report:** 48535-1
**Date:** July 22, 2019
**Project No:** 19063
**Project Name:** Oakview

| Sample ID | Organic Matter | Cation Exchange Capacity |
|---|---|---|
| TP-3, S-1 @ 3.5’ | 2.68% | 7.5 meq/100g |
| TP-5, S-1 @ 3.5’ | 2.59% | 8.1 meq/100g |
| **Method** | **ASTM D2974** | **EPA 9081** |

# UNIFIED SOIL CLASSIFICATION SYSTEM

| Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A] | | | | Soil Classification: Group Symbol | Soil Classification: Group Name[B] |
|---|---|---|---|---|---|
| Coarse Grained Soils<br>More than 50% retained<br>on No. 200 sieve | Gravels<br>More than 50% of coarse fraction retained on No. 4 sieve | Clean Gravels<br>Less than 5% fines[C] | $Cu \geq 4$ and $1 \leq Cc \leq 3$[E] | GW | Well-graded gravel[F] |
| | | | $Cu < 4$ and/or $1 > Cc > 3$[E] | GP | Poorly graded gravel[F] |
| | | Gravels with Fines<br>More than 12% fines[C] | Fines classify as ML or MH | GM | Silty gravel[F,G,H] |
| | | | Fines classify as CL or CH | GC | Clayey gravel[F,G,H] |
| | Sands<br>50% or more of coarse fraction passes No. 4 sieve | Clean Sands<br>Less than 5% fines[D] | $Cu \geq 6$ and $1 \leq Cc \leq 3$[E] | SW | Well-graded sand[I] |
| | | | $Cu < 6$ and/or $1 > Cc > 3$[E] | SP | Poorly graded sand[I] |
| | | Sands with Fines<br>More than 12% fines[D] | Fines classify as ML or MH | SM | Silty sand[G,H,I] |
| | | | Fines Classify as CL or CH | SC | Clayey sand[G,H,I] |
| Fine-Grained Soils<br>50% or more passes the No. 200 sieve | Silts and Clays<br>Liquid limit less than 50 | inorganic | PI > 7 and plots on or above "A" line[J] | CL | Lean clay[K,L,M] |
| | | | PI < 4 or plots below "A" line[J] | ML | Silt[K,L,M] |
| | | organic | Liquid limit - oven dried / Liquid limit - not dried < 0.75 | OL | Organic clay[K,L,M,N] |
| | | | | | Organic silt[K,L,M,O] |
| | Silts and Clays<br>Liquid limit 50 or more | inorganic | PI plots on or above "A" line | CH | Fat clay[K,L,M] |
| | | | PI plots below "A" line | MH | Elastic Silt[K,L,M] |
| | | organic | Liquid limit - oven dried / Liquid limit - not dried < 0.75 | OH | Organic clay[K,L,M,P] |
| | | | | | Organic silt[K,L,M,Q] |
| Highly organic soils | Primarily organic matter, dark in color, and organic odor | | | PT | Peat |

[A] Based on the material passing the 3-in. (75-mm) sieve

[B] If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C] Gravels with 5 to 12% fines require dual symbols: GW-GM well-graded gravel with silt, GW-GC well-graded gravel with clay, GP-GM poorly graded gravel with silt, GP-GC poorly graded gravel with clay.

[D] Sands with 5 to 12% fines require dual symbols: SW-SM well-graded sand with silt, SW-SC well-graded sand with clay, SP-SM poorly graded sand with silt, SP-SC poorly graded sand with clay

[E] $Cu = D_{60}/D_{10}$ $\quad Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F] If soil contains ≥ 15% sand, add "with sand" to group name.

[G] If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H] If fines are organic, add "with organic fines" to group name.

[I] If soil contains ≥ 15% gravel, add "with gravel" to group name.

[J] If Atterberg limits plot in shaded area, soil is a CL-ML, silty clay.

[K] If soil contains 15 to 29% plus No. 200, add "with sand" or "with gravel," whichever is predominant.

[L] If soil contains ≥ 30% plus No. 200 predominantly sand, add "sandy" to group name.

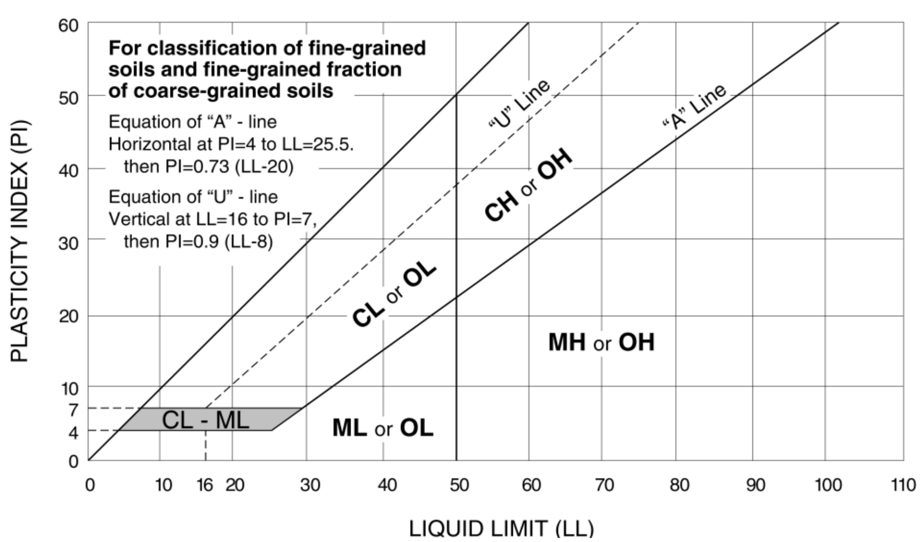
[M] If soil contains ≥ 30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N] PI ≥ 4 and plots on or above "A" line.

[O] PI < 4 or plots below "A" line.

[P] PI plots on or above "A" line.

[Q] PI plots below "A" line.



**APPENDIX D**

GROUNDWATER STUDY

May 13, 2021

Roy Meadows Development Group LLC
1000 Second Ave, Ste 3200
Seattle, WA 98104

Attn: Dan R. Young
Re: Results of Groundwater Study for Proposed Residential Development at 292nd Street South in Roy, Washington, Pierce County

**Dear Dan**:

This letter reports on the results of a groundwater study conducted by Pacific Groundwater Group (PGG) for the above referenced project in Roy, Washington. Specifically, PGG performed the following tasks:

- Oversaw the drilling and installation of three 20-ft deep monitoring wells on February 5, 2021 in the "lowland" area of the site at locations identified by Apex Engineering (Piezo-1, Piezo-2, and Piezo-3 in Figure 1).
- Deployed pressure transducer dataloggers into the new wells to monitor groundwater levels every hour between February 5 and April 23, 2021.
- Estimated seasonal high groundwater elevations and minimum depths to groundwater in the lowland area of the site.
- Estimated preliminary design infiltration rates using methods and equations in the 2019 Stormwater Management Manual for Western Washington (2019 SMMWW[1]) that consider shallow depths to groundwater.

The main results of the study are as follows:

- The lowland area is underlain by a fine silty sand to sandy silt in the upper 2 to 6 feet followed by a medium grained sand 10 to 15 feet thick, which is in turn underlain by a coarse sandy gravel that continues to an unknown depth. Groundwater levels occur within the sand unit suggesting an unconfined aquifer in the lowland; however, the sand unit contains thin (1 to 2 ft thick) discontinuous layers of fine silty sand to sandy silt that, where present, may act as a semi-confining unit and/or limit infiltration capacity.

[1] SMMWW July 2019. Publication Number 19-10-021 Department of Ecology

- The groundwater study captured seasonal high groundwater levels in early March with elevations ranging from about 317.4 to 320.2 feet. This translates to a depth to groundwater of about 9.5 to 14.0 feet below current land surface elevation.
- The groundwater horizontal gradient is 0.017 ft/ft east-to-west and likely discharges towards Denton Marsh. The east-to-west gradient across the lowland suggests the till upland to the east is a source of recharge to the lowland aquifer.
- A preliminary design infiltration rate was estimated to range from 0.25 to 0.63 in/hr. The estimate uses the Massmann (2003) [2] "detailed approach" in the 2019 SMMWW and is based on an estimated saturated hydraulic conductivity of 12 in/hr from previous soil grain-size work conducted by others and a 3-to-5 ft separation between the storm pond bottom and seasonal high groundwater. This calculation does not include reduction factors to account for biofouling or siltation of the pond over time. It also does not account for potential infiltration limitations due to thin layers of fine sandy silt within the sand unit.
- PGG recommends removing the upper 2 to 6 sandy silt at the surface and targeting the middle sand unit for infiltration. We also recommend conducting an infiltration test at the location and depth of the proposed pond to verify the saturated hydraulic conductivity value of the receptor soils and to evaluate possible infiltration limitations due to the discontinuous thin layers of fine sandy silt within the sand unit.
- Finally, given the shallow depths to high groundwater at the site, a mounding analysis will likely be required as part of the final design. The 2019 SMMWW states a mounding analysis is required for infiltration ponds having a contributing area greater than 1 acre and a separation of less than 15 feet to the seasonal high groundwater below the pond[3]. The 2019 SMMWW requires separations greater than 5 feet above the seasonal high groundwater but values as low as 3 feet may be considered if the mounding analysis and other site suitability criteria are met[4].

PGG's tasks and findings are discussed further below and were completed in accordance with our proposed scope of work and authorization with you dated January 25, 2021. Elevations reported in this report use the NAVD88 datum unless stated otherwise. Results of the study are summarized below.

## DRILLING AND INSTALLATION OF MONITORING WELLS

PGG subcontracted with Holocene Drilling of Puyallup, WA to drill and install three 2-inch diameter monitoring wells using a sonic drill rig (Figure 1). Piezo-1 and Piezo-2 were drilled to a total depth of 20 feet below land surface (bls) and Piezo-3 was drilled to a total depth of 21 feet bls. The drill sites were targeted at locations in the lowland area where future stormwater infiltration ponds are being designed for the project development. The "lowland area"

[2] Massmann 2003. A Design Manual for Sizing Infiltration Ponds, Washington Department of Transportation, October 2003.
[3] Vol. V, Chapter 5, Page 725 in 2019 Stormwater Management Manual for Western Washington
[4] Vol. V, Chapter 5, Page 743-744 in 2019 Stormwater Management Manual for Western Washington

occurs on the western third of the site at a fairly uniform elevation of about 330 feet in contrast to the partially forested "upland area" which occurs on the eastern two thirds of the site with elevations rising to as high as 400 feet (Figure 1). Previous test pit excavating by South Sound Geotechnical Consulting (SSGC) across the site identified shallow low-permeability till within a few feet of land surface across much of the upland, making that area unfavorable for managing large volumes of stormwater runoff through focused infiltration (SSGC 2019[5]).

Soil samples were collected with continuous sonic cores during drilling of the wells and logged by PGG's field geologist. The soils encountered at the drill sites are a fine silty sand to sandy silt in the upper 2 to 6 feet followed by a fine to medium sand about 10 to 15 feet thick, which in turn is underlain by a course sandy gravel that continues to an unknown depth below the depth of the borings. At the location of Piezo-1 and 3, thin layers (0.5 to 1 ft thick) of silty fine sand and sandy silt occurs within the fine to medium sand interval. The top of this thin sandy silt layer was observed at a depth of about 12 ft bls at the two well locations. Its absence at Piezo-2 suggests the unit is not laterally continuous beneath the site.

A low permeability till layer was not observed at all three locations; however, the presence of fine sandy silt layers within the sand unit may limit infiltration rates where present. The soil textures observed during the drilling program were similar to the shallow soils described from the previous test pits excavated to depths of 9 to 11 feet in the lowland area (SSGC 2019). The soil textures are consistent with *recessional outwash deposits* as mapped by Washington Department of Natural Resources[6]. They are also consistent with the mapped NRCS surficial soils: Nisqually loamy sand on the west and Spanaway gravelly sandy loam on the east portions of the lowland area[7]. Both soils are group A soils that are somewhat excessively well drained and develop on sandy to gravelly glacial outwash soils.

Final wells were constructed with 10-foot screen lengths extending from approximately 10 to 20 feet bls. Static water levels at the time of drilling were around 10 to 15 feet bls within the sand unit and well below the upper silty sand to sandy silt surface soils. These observations suggest the lowland aquifer is unconfined or possibly semi-confined depending on the influence of the thin fine sandy silt layers within the sand unit.

All three wells were completed with flush-to-grade steel monuments with the top of PVC well casing about 0.3 to 0.5 ft below the top rim of the monument. Final geologic logs and well design as-builts are provided in Figures 2 through 4. Soil intervals recovered during coring are shaded gray in the sample recovery column on the logs. Soil samples collected during drilling were not submitted for soil analysis and were not retained.

Apex engineering surveyed the well locations and elevations of the monument rim and top of PVC well casings so that depth to groundwater measurements could be converted to

[5] SSGC 2019 Geotechnical Engineering Report Prepared for Roy Meadows Development Group, LLC July 31, 2019.
[6] Walsh et al 1987 Geologic Map of Washington Southwest Quadrant. Washington Division of Geology and Earth Resources Geologic Map GM-34.
[7]Natural Resource Conservation Services: https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

groundwater elevations and horizontal hydraulic gradients calculated. Survey information is also provided on the logs.

## GROUNDWATER LEVEL STUDY

Groundwater levels were monitored in the newly installed wells between February 5 and April 23, 2021 with non-vented pressure transducer dataloggers[8] programmed to collect automatic measurements every hour. A barometric datalogger was also deployed at the site to record changes in atmospheric pressure. The non-vented pressure transducers deployed in the wells record both changes in groundwater pressure heads and atmospheric pressure, thus the barometric data are used to subtract atmospheric pressure changes from the groundwater pressure head dataset. In addition to compensating the dataloggers for barometric pressures, we observed groundwater level responses to atmospheric pressure variations in Piezo-2 that required additional correction (see below).

The results were used to develop hydrographs of groundwater level elevations over time at each well location (Figures 5 through 7). Also plotted on the hydrographs is daily precipitation from a Thurston County precipitation station in Yelm[9] (about 5 miles southwest of the site). The main objective of the groundwater study was to document the seasonal high groundwater elevation. The 2019 SWMMWW[1] manual states that seasonal high groundwater elevations generally occur in late winter through mid-spring[10]. Our experience in the area also indicates seasonal groundwater highs tend to occur during the months of February, March, or April and occasionally as late as early May.

The site hydrographs show the following responses in groundwater elevations during the monitoring period:

- Groundwater elevations initially declined in all three wells by about 0.25 to 0.5 feet between February 5th (when the wells were first installed) to February 16th. The decline during this period occurred during a relatively dry period. Except for a few small storm events there was little to no precipitation between mid-January and mid-February.
- After February 16th, groundwater elevations began to steadily increase by about 1.5 to 2 feet through the rest of February reaching their maximum elevations around March 2nd and 3rd. The increase was in response to a series of precipitation events that occurred between February 13th and 26th, resulting in 3.3 inches of total rain fall.
- Following the peak groundwater elevation, and continuing until the end of the monitoring period, groundwater elevations in Piezo-1 and Piezo-3 declined by about 5 feet, while Piezo-2 declined by about 3 feet. As can be seen in the hydrographs, very little precipitation occurred during the remaining monitoring period.

The maximum groundwater level observed at each location in early March was:

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[8] Van Essen Micro-Diver Model DI601with a range of 10 meter/33 feet of pressure head.
[9] Site "05u Yelm WRF Rain" https://www.thurstoncountywa.gov/sw/Pages/monitoring-dashboard.aspx
[10] Vol 1, Chapter 4, Page 167 in 2019 SWMMWW

- Piezo-1 = 316.72 feet elevation (10.6 feet below land surface)
- Piezo-2 = 320.20 feet elevation (9.5 feet below land surface)
- Piezo-3 = 317.35 feet elevation (14.0 feet below land surface)

A "snapshot" of groundwater elevations on March 2, 2021 are contoured on Figure 1 and indicate a horizontal flow direction from east to west across the lowland area with a horizontal gradient of 0.017 ft/ft. Shallow groundwater beneath the lowland area of the site discharges towards Denton Marsh to the west which feeds into Muck Creek (see insert on Figure 1). The east-to-west gradient beneath the lowland suggest the till upland area to the east is a source of recharge. The lack of abrupt groundwater level responses to the individual rain events in mid-to-late February (i.e., smooth rise in groundwater levels throughout late February) also suggests a more regional recharge response.

Groundwater elevations in Piezo-2 are unique in that they display a relatively strong response to atmospheric pressure changes as demonstrated by the short-term variability in groundwater elevations at that location (see uncorrected groundwater elevations in Figure 6). It is not uncommon for groundwater levels in wells to be affected by atmospheric pressure changes, particularly in confined aquifers. The barometric efficiency of a well is a measure of how much water levels fluctuate in a well in response to changes in atmospheric pressure and by definition is the ratio of groundwater level changes caused by atmospheric pressure changes divided by the barometric pressure change. Using a simple graphical method that plots groundwater level changes versus barometric pressure changes, the barometric efficiency at Piezo-2 was estimated to be 46%. This value was used to correct the barometrically effected groundwater elevations at Piezo-2 (see corrected groundwater elevations in Figure 6).

A similar response to atmospheric pressure changes was not observed at Piezo-1 and Piezo-3. Confined aquifers typically have high barometric efficiencies; however, there is no indication of a confining layer in the aquifer at the location of Piezo-2. The unique response at Piezo-2 may be due to its close proximity to the adjacent till upland where groundwater below the till is likely under confined conditions. Confined aquifer responses beneath the till upland likely propagate a short distance into the unconfined aquifer beneath the lowland in the vicinity of Piezo-2.

Although groundwater levels were not monitored over the entire wet season for this study (generally fall to spring), they were monitored over the typical seasonal maximum months of February to March and the highest levels observed in early March are most likely representative of the seasonal maximum. The following additional observations support this assertion.

For comparison, seven manual measurements of groundwater levels were previously collected at the site over a ten-month period between July 16, 2019 and April 7, 2020 (SSGC 2020[11]). The manual measurements were collected from two temporary piezometers installed in previously excavated test pits in the lowland area of the site (TP-1 and TP-3 in

[11] SSGC 2020. Groundwater Monitoring (Winter 2019-2020) Report. Prepared for Roy Meadows Development, LLC October 14, 2020.

Figure 1). That study documented a minimum depth to groundwater of 9 feet bls at TP-1 and 10.5 feet bls at TP-3 on February 12, 2020. Using the topographic survey of the existing site as an estimate of land surface elevation, this results in a maximum groundwater elevation of about 317 feet at TP-1 and 319 feet at TP-3 - similar to the seasonal maximum groundwater elevations observed in this 2021 study.

For another comparison, a groundwater elevation hydrograph for Thurston County's "Thompson Creek" monitoring well located about 5 miles south in the City of Yelm[12] is plotted in Figure 8. Groundwater elevations in this well were monitored throughout the 2020/2021 season. The hydrograph shows groundwater elevations were below the bottom of the well until December 2020, then two maximum groundwater elevations occurred in early 2021. The first occurred in mid-January with an elevation of 323.90 feet (NGVD29) and the other occurred in late February with an elevation of 323.81 feet (NGVD29)[13]. By mid-April, the groundwater elevation was again below the bottom of the well. Although the January peak is 0.09 feet higher than the late February peak, the two maximum elevations are fairly similar suggesting the early March event documented at the Roy project site is representative of seasonal high groundwater levels for the 2020/2021 wet season.

Finally, a chart of the average monthly precipitation from the City of Yelm station[14] is shown in Figure 9. Also shown is the monthly precipitation for the 2021 water year up through April 2021 for comparison. The chart shows that November through March are typically the wettest months of the year. The plot also shows that January and February 2021 had above average rainfall and, while March and April 2021 were below average, it is our opinion that the seasonal high observed on March 2nd is a reasonable estimate of the seasonal high for stormwater design purposes.

## DESIGN INFILTRATION RATE

PGG calculated a preliminary design infiltration rate in the lowland area based on the "detailed approach" for calculating design infiltration rates as outlined in Volume V Chapter 5 (pages 736 to 738) in SMMWW 2019[1]. Under the detailed approach (sites contributing more than 1 acre of runoff), the Massmann (2003)[2] equation is used to calculate a steady-state hydraulic gradient which considers the saturated hydraulic conductivity of the soils (Ksat), the depth to high groundwater beneath the proposed stormwater infiltration pond, pond-size and geometry, and ponding depth.

The Ksat of the soil was assumed to be 12 in/hr for this calculation. This value is the lowest of three Ksat values previously reported by SSGC (2019)[5] using the grain-size method of analysis[15] on soil samples collected from excavated test pits. The grain size method for estimated Ksat is generally acceptable for soils unconsolidated by glacial advance, such as the lowland area of the site. The 12 in/hr value was collected from a "silty sand" at 8-ft

[12] Site "Y03: Thompson Creek @ 93rd Ave (Well)" https://www.thurstoncountywa.gov/sw/Pages/monitoring-dashboard.aspx
[13] Thurston County uses the NGVD29 datum which is different from the NAVD88 datum used in this study.
[14] The record at the Yelm precipitation station goes back to 2009
[15] Option 3, Vol. 5, Chapter 5, Page 733 in SWMMWW 2019

depth at TP-1. Excavation work by SSGC in 2019 did not reach much beyond 10-ft bls and therefore did not extend to the fine sandy silt layer observed at about 12-ft bls in Piezo-1 and Piezo-3. A grain-size analysis of that layer would likely result in lower Ksat value for the calculation.

Based on Apex Engineer's preliminary pond design of an 88-ft x 88-ft with a facility bottom elevation of 322.02 feet, the depth to high groundwater below the pond varies from 3 to 5 feet (based on a high groundwater elevation range of 317 to 319 feet as shown in Figure 1).

Table 1 presents calculated design infiltration rate that ranges from 0.25 to 0.63 in/hr using the above method. The range is based on a range of high groundwater depths (3 to 5 feet) and a range of ponding depths (1 to 5 feet). The correction factors for pond size and aspect are both equal to 1 under the current design as shown in Table 1. The range of results in Table 1 are for preliminary design considerations. Final calculations should be based on final pond design. The results in Table 1 also do not apply any correction factors for bio-fouling or siltation of pond over time.

The minimal separation to high groundwater beneath the proposed infiltration pond indicates a groundwater mounding analysis will be required for the final design. Mounding analyses are typically performed using a simple groundwater flow model that incorporates aquifer properties, observed groundwater levels, and the geometry/loading rates of the proposed infiltration facility. This analysis may require an iterative design process between the engineers and groundwater modeler to develop a functional design that will maintain a minimum separation between the pond bottom and high groundwater.

The potential limitations of the fine sandy silt layer within the sand unit to infiltrate stormwater may also warrant further evaluation in support of the final design. The simplest approach would be to conduct a field infiltration test at the proposed pond location and depth.

Pacific Groundwater Group has performed successful mounding analyses and field infiltration tests in support of stormwater designs for many development projects in the South Sound area in the past and we would be happy to assist you and your team with this effort.

Please contact me with any questions.

Sincerely,
**Pacific Groundwater Group**

Dawn Chapel

Dawn Chapel
Associate Hydrogeologist

*RoyMeadows_GroundwaterStudy_V2.doc*

cc: Camille Minogue – Roy Meadows Development Group LLC
James Kirkebo, Felix Jacob, Maddie Endris – Apex Engineering

**Attachments:**

| | |
|---|---|
| Table 1: | Calculated Design Infiltration Rates (Detailed Approach) |
| Figure 1: | Groundwater Elevations and Flow Direction March 2, 2021 |
| Figure 2: | Geologic Log and As-Built Piezometer 1 |
| Figure 3: | Geologic Log and As-Built Piezometer 2 |
| Figure 4: | Geologic Log and As-Built Piezometer 3 |
| Figure 5: | Piezo-1 Groundwater Elevation Hydrograph |
| Figure 6: | Piezo-2 Groundwater Elevation Hydrograph |
| Figure 7: | Piezo-3 Groundwater Elevation Hydrograph |
| Figure 8: | Thompson Creek Yelm Well – Groundwater Elevation Hydrograph |
| Figure 9: | Monthly Precipitation – Yelm Station |

Table 1. Calculated Design Infiltration Rates (Detailed Approach)
*Preliminlary estimates. To be modified based on final facility design*

| Dwt | Dpond | Ksat | Pond Width | Pond Length | Area | Area | Size Correction Factor ($CF_{size}$) | $gradient_{note 1}$ | $Design Infiltration Rate_{note2}$ (Uncorrected for $CF_{aspect}$) | | $Design Infiltration Rate_{note3}$ (Corrected for $CF_{aspect}$) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ft | ft | ft/day | ft | ft | $ft^2$ | ac | Dimensionless | i (ft/ft) | $I_p$ (ft/day) | $I_p$ (in/hour) | $I_f$ (ft/day) | $I_f$ (in/hr) |
| 5 | 1 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0315 | 0.76 | 0.38 | 0.76 | 0.38 |
| 4 | 1 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0262 | 0.63 | 0.31 | 0.63 | 0.31 |
| 3 | 1 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0210 | 0.50 | 0.25 | 0.50 | 0.25 |
| 5 | 2 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0367 | 0.88 | 0.44 | 0.88 | 0.44 |
| 4 | 2 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0315 | 0.76 | 0.38 | 0.76 | 0.38 |
| 3 | 2 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0262 | 0.63 | 0.31 | 0.63 | 0.31 |
| 5 | 4 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0472 | 1.13 | 0.57 | 1.13 | 0.57 |
| 4 | 4 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0420 | 1.01 | 0.50 | 1.01 | 0.50 |
| 3 | 4 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0367 | 0.88 | 0.44 | 0.88 | 0.44 |
| 5 | 5 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0525 | 1.26 | 0.63 | 1.26 | 0.63 |
| 4 | 5 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0472 | 1.13 | 0.57 | 1.13 | 0.57 |
| 3 | 5 | 24 | 88 | 88 | 7744 | 0.18 | 1.00 | 0.0420 | 1.01 | 0.50 | 1.01 | 0.50 |

See Volume V - Chapter 5 - Pages 736 to 738 in (SWMMWW 2019)

Note1: gradient = i = (Dwt+Dpond)/(138.62*Ksat^0.1)*CFsize

For ponds 0.6 to 6 acres, CFsize = 0.74*(Area)^(-0.76). For ponds less than 0.6 acres, CFsize = 1 and for ponds greater than 6 acres CFsize = 0.2

Note 2: Preliminary Design Infiltration Rate = $I_p$ = Ksat*i

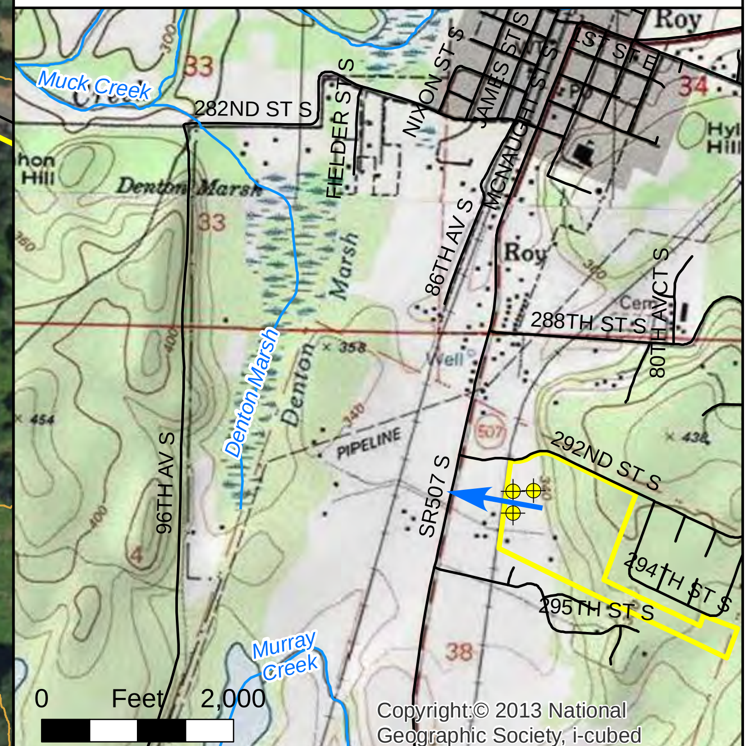
Note 3: Final Design Infiltration Rate = $I_f$ = $I_p$*$CF_{aspect}$, where $CF_{aspect}$ = 0.02*(Length/Width)+0.98

# Figure 1

## Groundwater Elevations and Flow Direction March 2, 2021

Roy Meadows Development

PgG


- Test Pits with Temporary Piezometers
- Piezometer Location
- Groundwater Elevation Contours
- Estimated Flow Path
- Project Boundary
- 10-ft Ground SurfaceContours (Lidar)

N

Elevations in feet NAVD88

| Depth (ft) | Geology | Sample Recovery | Log | Well Construction |
|---|---|---|---|---|

**Log**

- Moist, dark brown, silty, fine SAND. (Organics)
- Moist, dark brown silty, sand and FILL.
- Moist, dense, light brown, fine to medium sandy, SILT.
- Moist, light brown, fine to medium SAND. (Trace silt)
  - Silt lense at 5.5 feet
- Moist to wet, soft, light brown to light gray, very silty, fine SAND.
- Wet, light brown to light gray medium SAND. (Clean)
- Wet, soft, light brown, sandy, SILT.
- Wet, light gray to light brown, medium SAND. (Clean)
- Wet, light gray to light brown, coarse sandy, GRAVEL. (Occasional cobbles, trace silt)

**Well Construction**

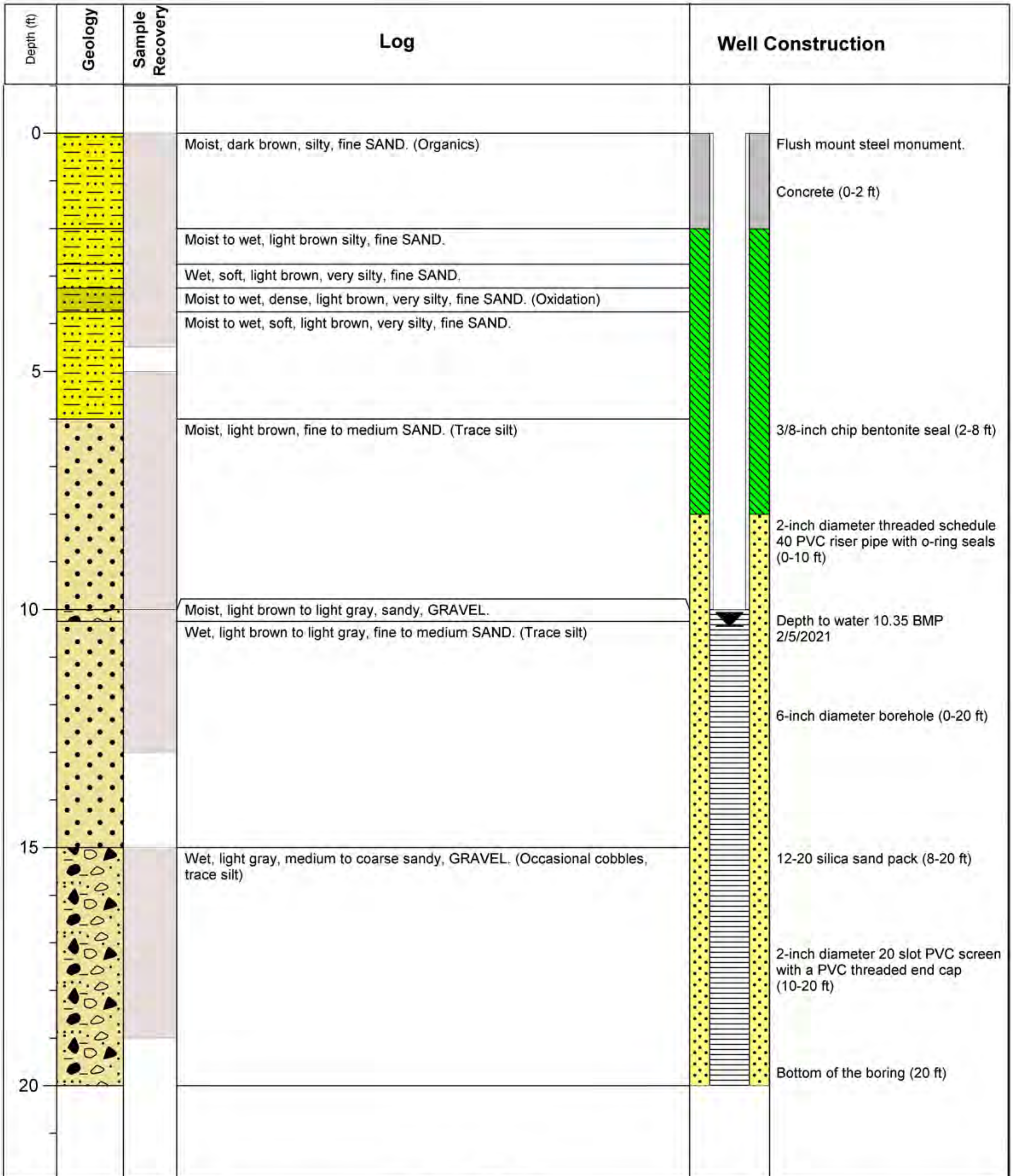
- Flush mount steel monument.
- Concrete (0-2 ft)
- 3/8-inch chip bentonite seal (2-8 ft)
- 2-inch diameter threaded schedule 40 PVC riser pipe with o-ring seals (0-10 ft)
- Depth to water 11.67 BMP 2/5/2021
- 6-inch diameter borehole (0-20 ft)
- 12-20 silica sand pack (8-20 ft)
- 2-inch diameter 20 slot PVC screen with a PVC threaded end cap (10-20 ft)
- Bottom of the boring (20 ft)

Project Name: Roy Meadows
Drilling Firm/ Method: Holocene Drilling/ Sonic
Consultant/ Logged by: PGG/Travis Klaas
Vertical Datum: NAVD 88
Monument Rim Elevation: 327.36 ft
Top of PVC Elevation (measuring point): 327.03 ft

Ecology ID: BMR 873
Drill Date: 2/5/2021
Horizontal Datum: NAD 83/11
Northing: 611346.75
Easting: 1130250.84
BMP = below measuring point

**FIGURE 2:**
**GEOLOGIC LOG AND AS-BUILT**
**Piezometer 1**
Roy Meadows
Roy, WA
JD2108

PGG

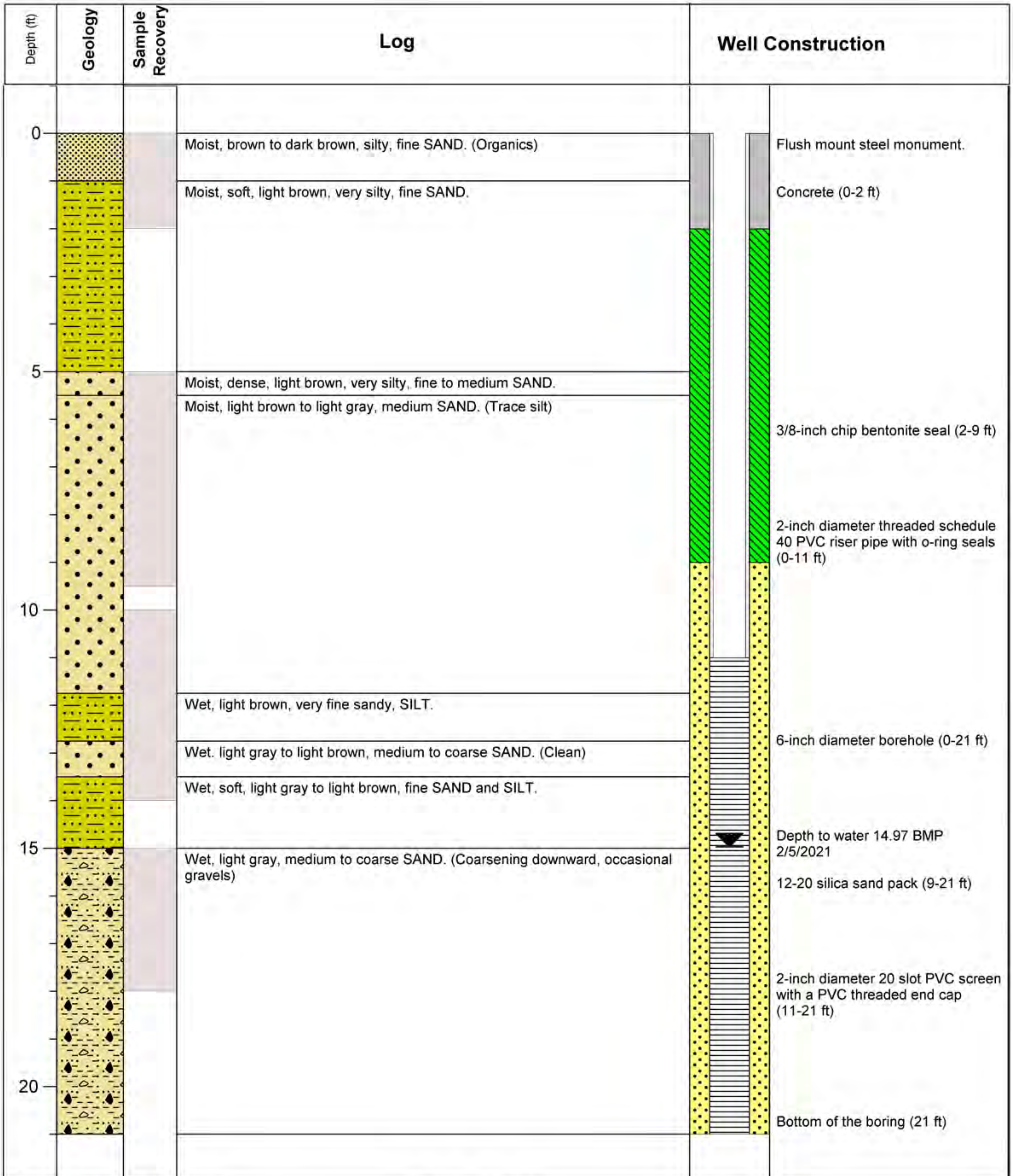



Project Name: Roy Meadows
Drilling Firm/ Method: Holocene Drilling/ Sonic
Consultant/ Logged by: PGG/Travis Klaas
Vertical Datum: NAVD 88
Monument Rim Elevation: 329.68 ft
Top of PVC Elevation (measuring point): 329.26 ft

Ecology ID: BMR 872
Drill Date: 2/5/2021
Horizontal Datum: NAD 83/11
Northing: 611354.54
Easting: 1130457.88
BMP = below measuring point

**FIGURE 3:**
**GEOLOGIC LOG AND AS-BUILT**
**Piezometer 2**
Roy Meadows
Roy, WA
JD2108

PGG

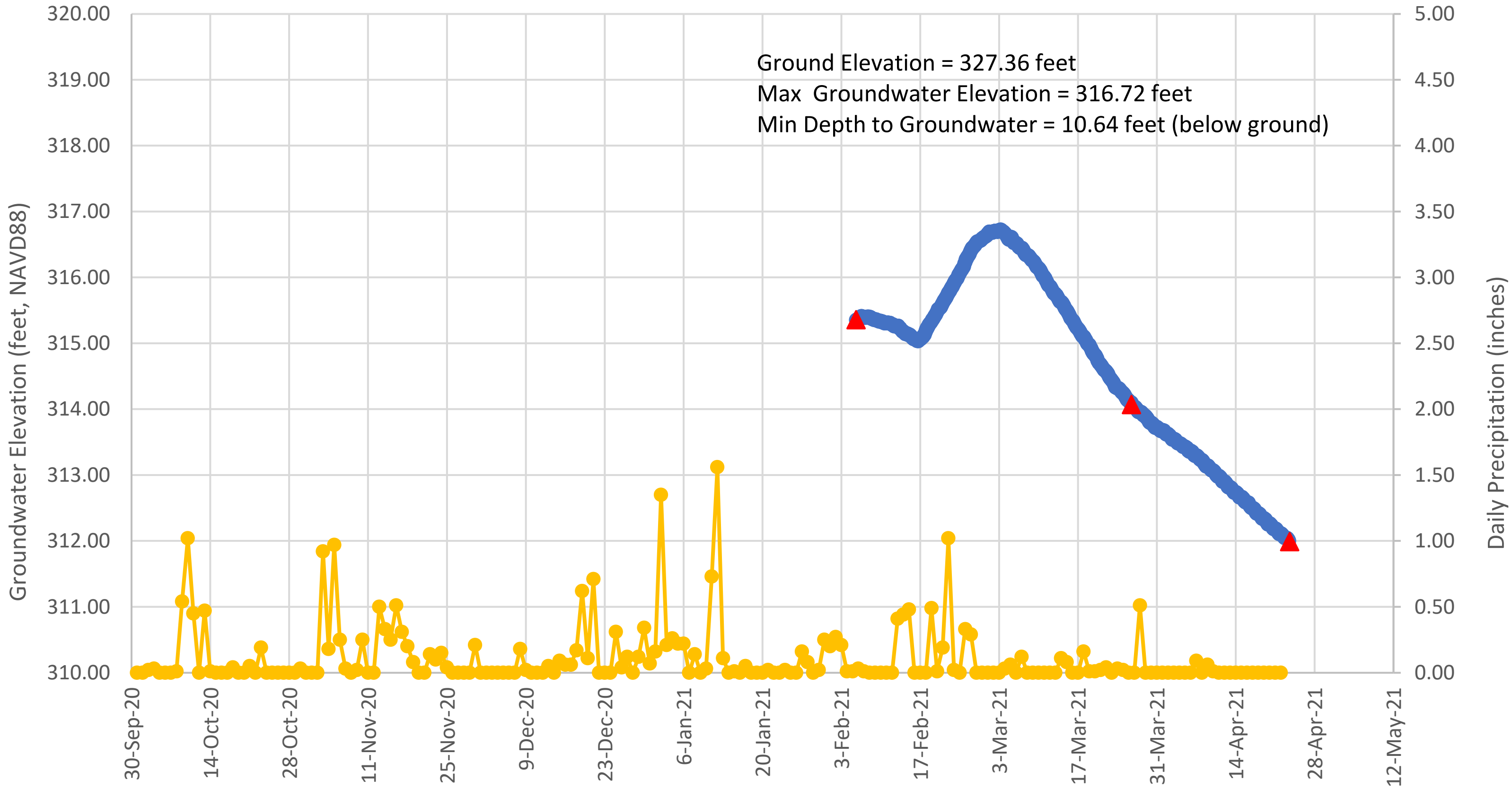



Project Name: Roy Meadows
Drilling Firm/ Method: Holocene Drilling/ Sonic
Consultant/ Logged by: PGG/Travis Klaas
Vertical Datum: NAVD 88
Monument Rim Elevation: 331.31ft
Top of PVC Elevation (measuring point): 330.84 ft

Ecology ID: BMR 871
Drill Date: 2/5/2021
Horizontal Datum: NAD 83/11
Northing: 611121.83
Easting: 1130244.94
BMP = below measuring point

**FIGURE 4:**
**GEOLOGIC LOG AND AS-BUILT**
**Piezometer 3**
Roy Meadows
Roy, WA
JD2108

PGG




Groundwater Elevation (feet)

Manual Measured Groundwater Elevation (feet)

Daily Precipitation - Yelm (inches)

Well Installed February 5, 2021

**Figure 5**
**Piezo-1 Groundwater Elevation Hydrograph**

Roy, WA (Roy Meadows)
JD2108

PgG

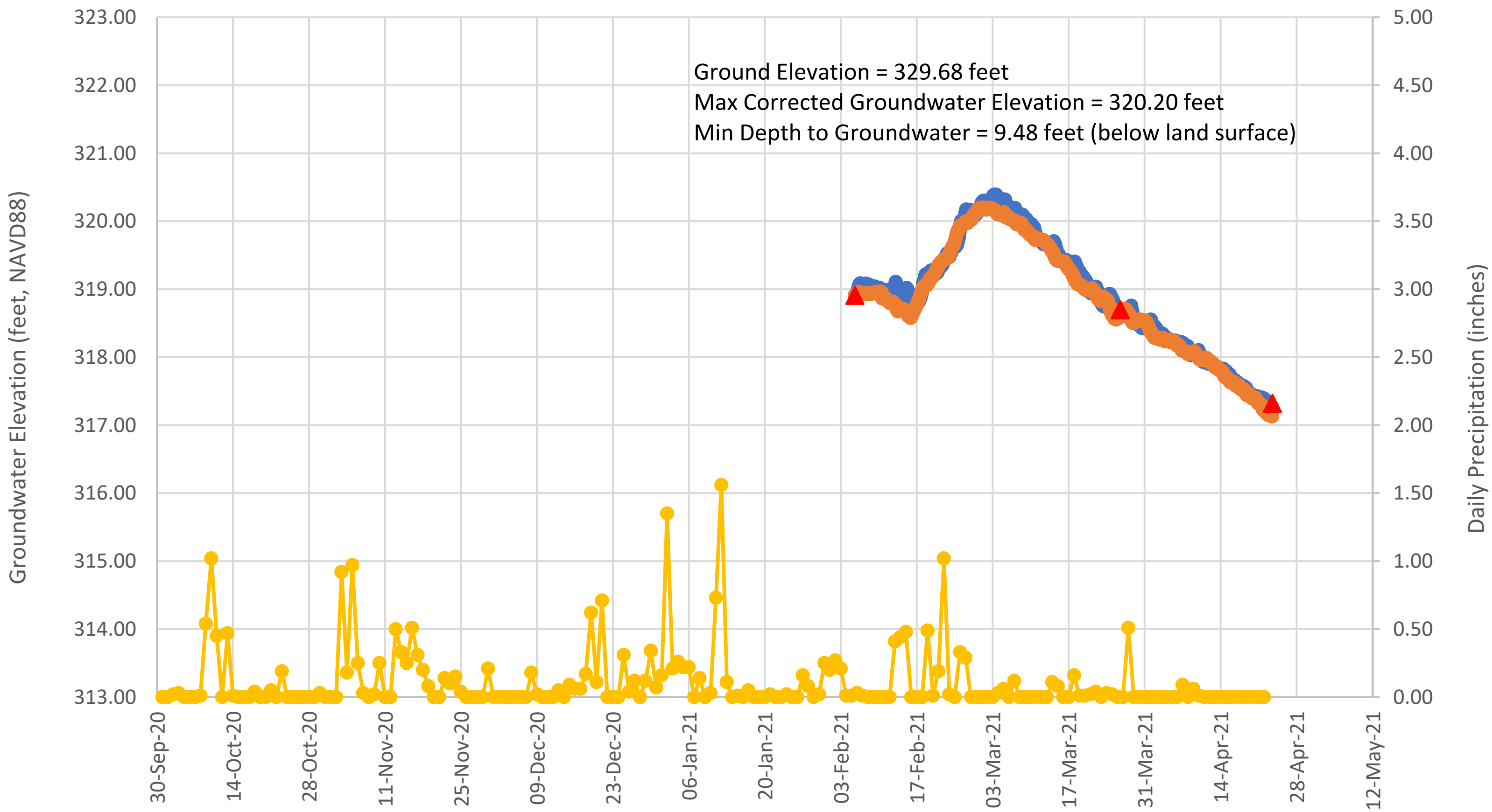
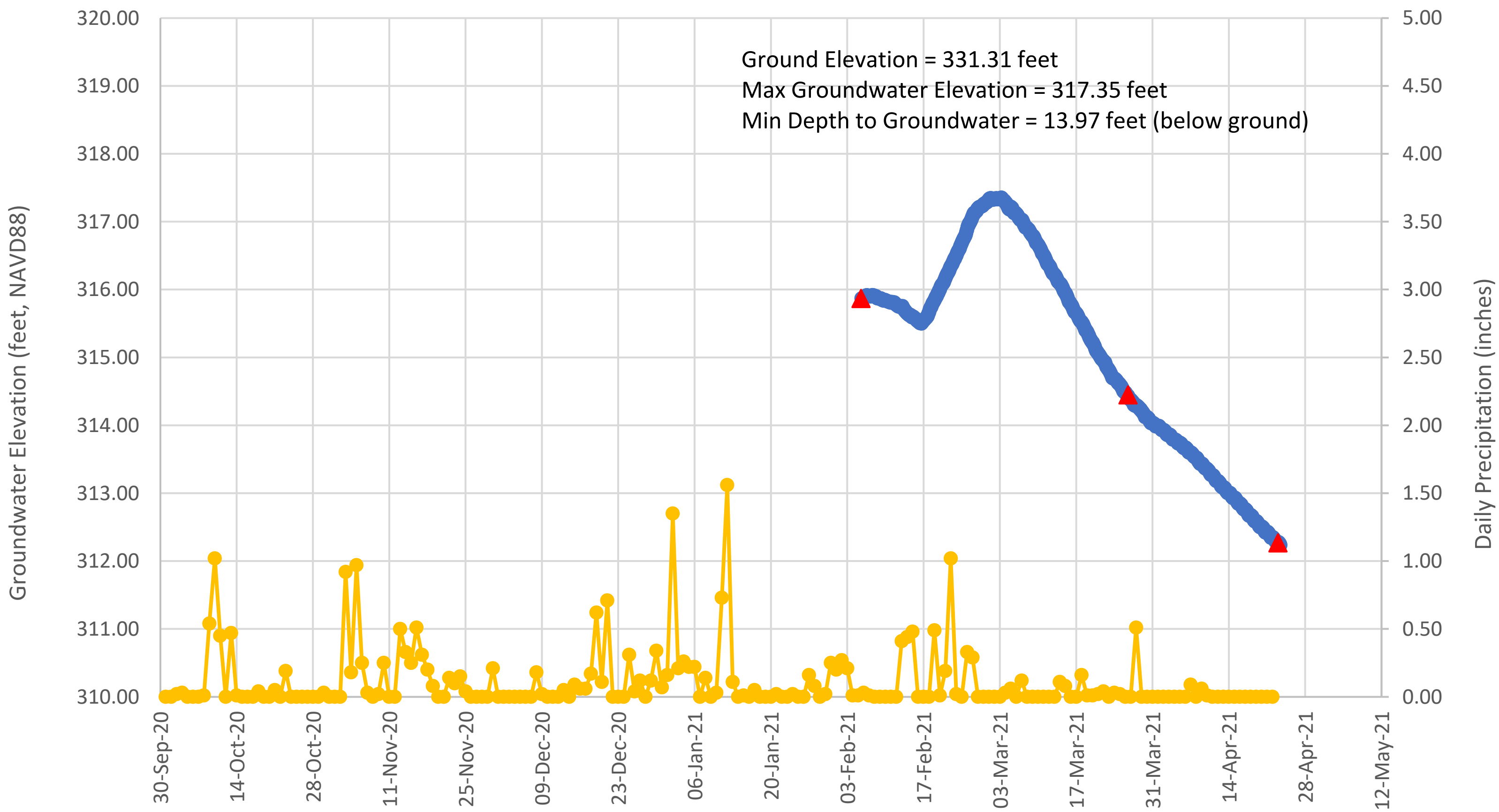



**Figure 6**
**Piezo-2 Groundwater Elevation Hydrograph**

Roy, WA (Roy Meadows)
JD2108

PGG




Groundwater Elevation (feet)

Manual Measured Groundwater Elevation (feet)

Daily Precipitation - Yelm (inches)

Well Installed February 5, 2021

**Figure 7**
**Piezo-3 Groundwater Elevation Hydrograph**

Roy, WA (Roy Meadows)
JD2108

PgG

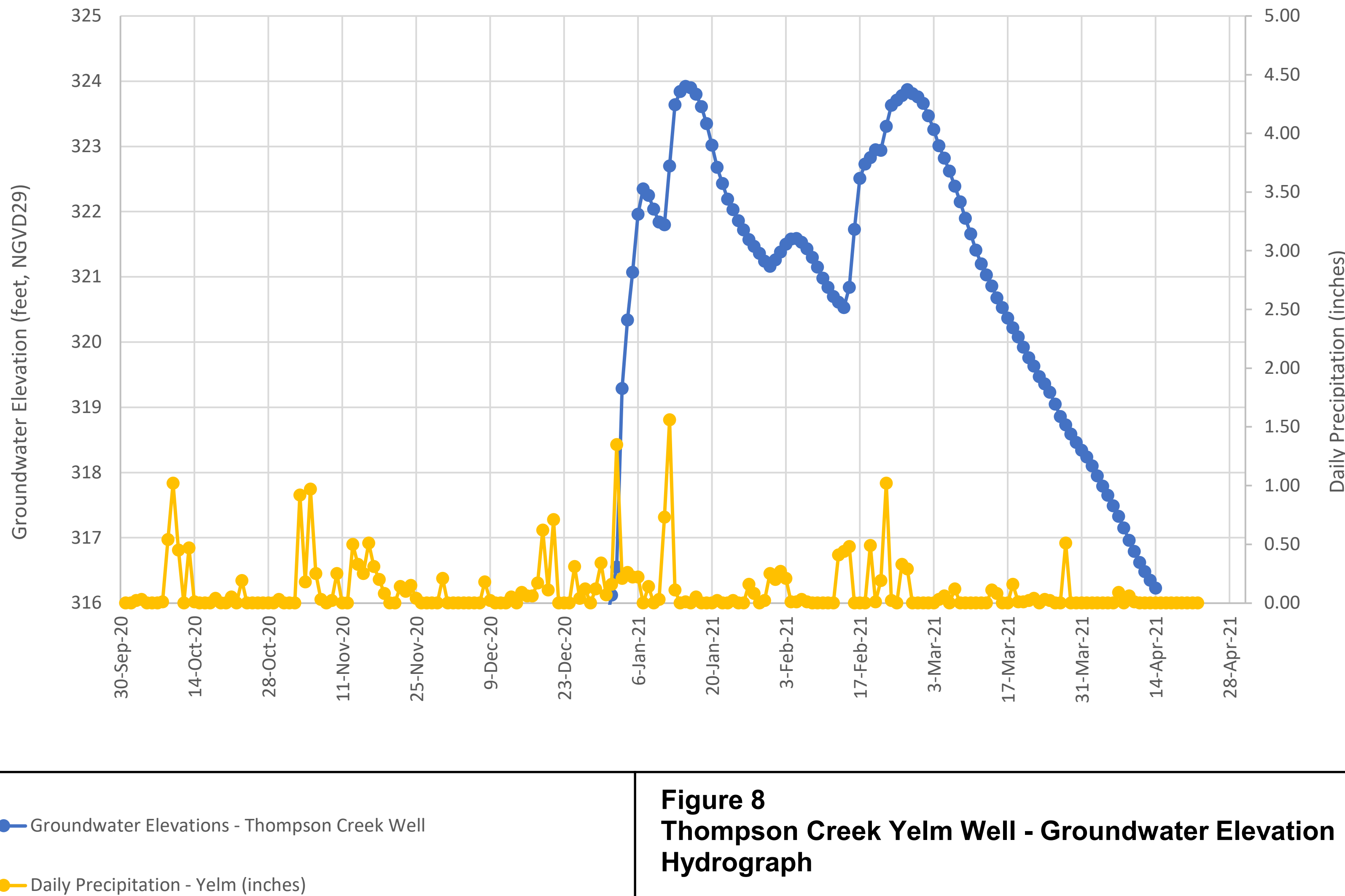
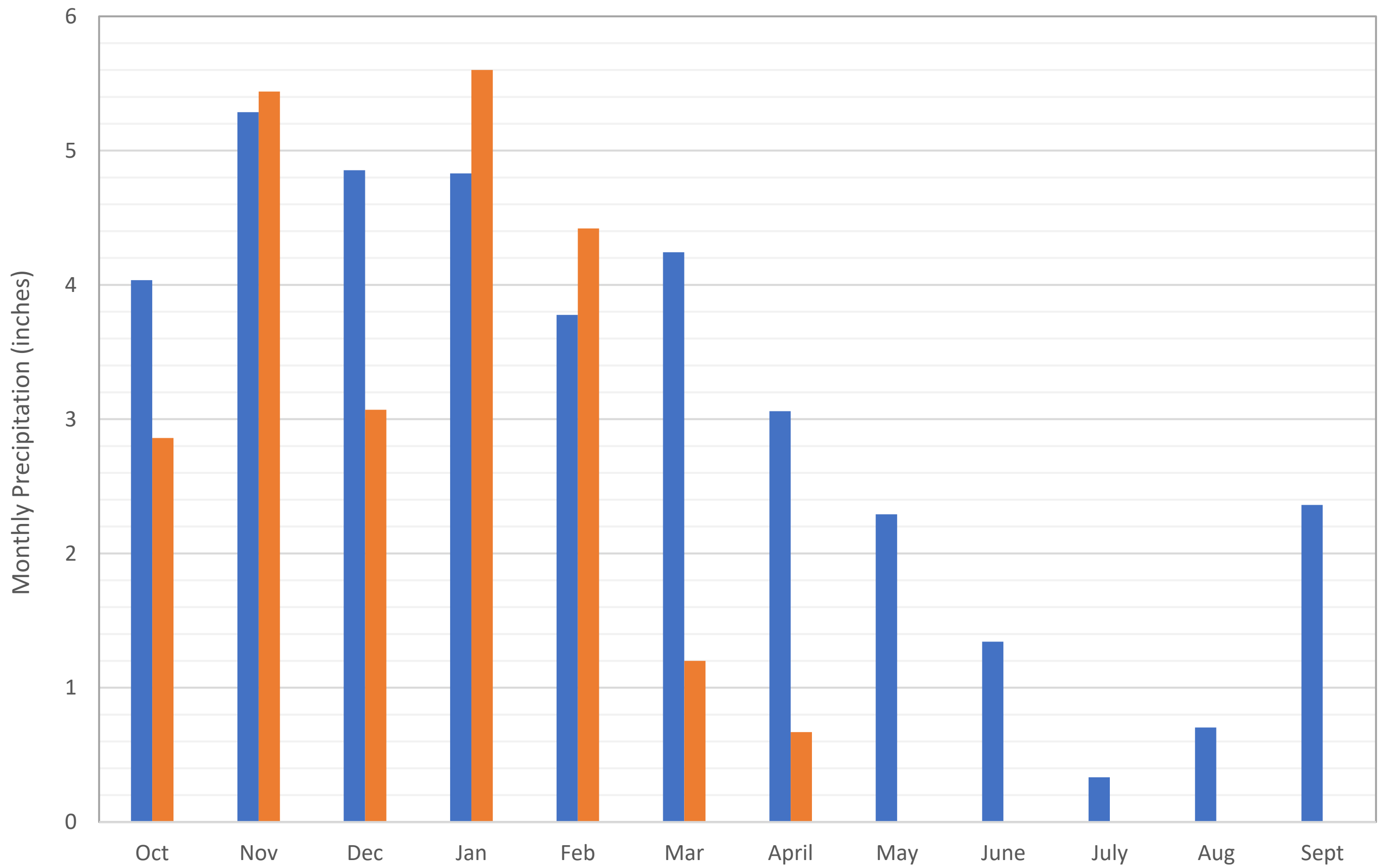



**Figure 8**
**Thompson Creek Yelm Well - Groundwater Elevation Hydrograph**

Roy, WA (Roy Meadows)
JD2108

PgG




Monthly Average Precipitation

2020/2021 Monthly Precipitation (through April 2021)

**Figure 9**
**Monthly Precipition - Yelm Station**

Roy, WA (Roy Meadows)
JD2108

PGG

**APPENDIX E**

GROUNDWATER MOUNDING ANALYSIS

# GROUNDWATER MOUNDING ANALYSIS

## Roy Meadows Development - 292nd Street
## Roy, Washington, Pierce County

Prepared for: Roy Meadows Development Group LLC

Project No. 210496 • February 2022 FINAL

earth + water

Aspect CONSULTING

# GROUNDWATER MOUNDING ANALYSIS

## Roy Meadows Development - 292nd Street
## Roy, Washington, Pierce County

Prepared for: Roy Meadows Development Group LLC

Project No. 210496 • February 2022 FINAL

Aspect Consulting, LLC

February 14, 2022

February 14, 2022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# Executive Summary

This report provides Aspect Consulting, LLC's (Aspect) evaluation of groundwater mounding beneath the proposed infiltration facility for the Roy Meadows development (Site). The proposed development is located on about 38 acres of undeveloped land in Roy, Washington along State Route 507 and includes 79 residential homes, roads, curbs, sidewalks, and open space tracts.

Most of the stormwater runoff from the Site will be managed using a single large infiltration pond designed in the lowland area on the west side of the Site where permeable sandy outwash soils provide more favorable conditions for infiltration. Apex Engineering designed the facility using the 2012 Western Washington Hydrologic Model (WWHM 2012, Clear Creek Solutions, 2016).

The City of Roy (RCC 10-6A-10) has adopted the latest edition of the Washington State Department of Ecology's Stormwater Management Manual for Western Washington (2019 SWMMWW) as the applicable stormwater design manual for development projects. Under the 2019 SWMMWW, the Site Suitability Criteria #5 (SSC-5) for stormwater infiltration facilities requires a separation of five feet or greater between the facility bottom and the seasonal high groundwater level. However, separations of three feet to the high groundwater level can be considered if a groundwater mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures are judged to be adequate to prevent overtopping.

The separation between the Roy Meadows infiltration facility and high groundwater is 3 feet and therefore required an analysis of mounding and volumetric receptor capacity. Aspect did not review the project design of overflow and/or bypass structures or any of the other site suitability criteria in the State's 2019 SWMMWW.

The mounding analysis was conducted using a three-dimensional transient finite-difference groundwater flow model. The model was used to predict two extreme events of groundwater mounding beneath the facility. One during the wettest year and one during the highest 24-hour precipitation event. The modeled recharge beneath the facility was assigned the total runoff flow into the facility predicted by WWHM during these events. This approach results in an over-estimate of the predicted mound because it does not account for surface storage in the facility or the limited infiltration rate of the receptor soils. The results of the two mounding analyses showed a maximum daily mound of 1.86 feet during the wettest year and 2.33 feet during the 24-hour peak storm event. Both predicted maximum mounds are below the bottom of the infiltration facility during ambient[1] high groundwater conditions and both mounds decayed relatively quickly after an extreme event (within a few days).

[1] The ambient groundwater is the level that occurs under current undeveloped conditions without focused infiltration below the stormwater pond.

The total volumetric receptor capacity beneath the facility (i.e., the water holding capacity of the receiving soils) during ambient high groundwater conditions was estimated to be 0.45 cubic feet per square foot of the facility, or about 104,500 gallons total. The ambient groundwater seepage velocity was estimated to be 5.25 in/hr which is ten times higher than the estimated design infiltration rate of 0.5 in/hr for the facility. Together, these estimates indicate the receiving soils and shallow groundwater beneath the facility should have sufficient capacity to receive and convey the infiltrated stormwater away from the site and reduce the chances of flooding.

The potential effect of the proposed septic drainfields on groundwater mounding was also evaluated and the results suggests the distributed design of individual and community drainfields will result in inconsequential groundwater mounding compared to the mounding beneath the much larger onsite infiltration facility.

Based on the result of our analyses, it is our opinion that the soils and ambient groundwater flow field are sufficient to accommodate stormwater infiltration beneath the facility and that the design meets the mounding and receptor capacity criteria under SSC-5 of the 2019 SWMMWW.

# 1 Introduction

This report documents the results of a groundwater mounding analysis conducted by Aspect Consulting, LLC (Aspect) for the Roy Meadows Development on Parcel 0217036009 at 29401 State Route 507 South (Site) in Roy, Washington (see Figure 1). The analysis was performed in support of required site suitability assessments in accordance with the City of Roy's stormwater regulations (Roy City Code 10-6A), which adopt the latest version of the Washington State Department of Ecology's (Ecology) Stormwater Management Manual for Western Washington (RCC 10-6A-10; Ecology, 2019).

The mounding analysis and report were authorized by Roy Meadows Development Group, LLC in a contract with Aspect signed October 20, 2021. The project engineer is Apex Engineering (Apex) of Tacoma, Washington.

This report is broken into the following sections:

- Section 1 provides an introduction
- Section 2 summarizes the project background and previous investigations
- Section 3 presents the results of the groundwater mounding analysis.
- Section 4 provides an analysis on mounding impacts from septic drainfields
- Section 5 provides an estimate of the volumetric receptor capacity

All elevations referenced in this report are reported relative to the North American Vertical Datum of 1988 (NAVD 88).

# 2 Background and Previous Investigations

The proposed Roy Meadows development covers about 38 acres with a preliminary plat by Apex showing 79 residential lots, roads, curbs, and sidewalks and six tracts of open/forest space (Appendix A). The Site is divided into an upland and lowland area. The upland area is located in the middle and eastern portion of the Site and slopes southwest from an elevation of about 400 to 330 feet. The lowland area is situated in the west and southwest portion of the Site and is relatively flat with a gentle westward slope towards Denton Marsh. Denton March occurs at an elevation of about 310 feet[2] within a north-south trending erosional Pleistocene glacial meltwater channel that runs parallel to State Route 507 from City of Roy to the Nisqually River.

In July 2019, South Sound Geotechnical Consulting (South Sound) excavated 17 test pits across the upland and lowland area of the Site at depths ranging from 4 to 11 feet 2019 (SSGC, 2019). Test pitting indicates the upland portion of the Site is underlain by dense glacial till at about 2 to 4 feet below ground surface with a thin veneer of loose sandy outwash above the till. Aspect reviewed well logs from two existing domestic wells about 500 feet north of the Site that indicate the till on the upland extends to about 50 to 60 feet depth.

Test pitting in the lowland indicates loose silty sand to sand grading downward to gravelly sand interpreted as outwash – no till was encountered. Groundwater was not observed in any of the test pits excavated in July 2019. Based on grain-size analyses of samples collected from lowland test pits, South Sound estimated a saturated hydraulic conductivity of 12 inched per hour (in/hr; silty sand) to 46 in/hr (sand).

South Sound installed piezometers into two of the test pits before backfilling in the lowland area to manually monitor groundwater levels between July 2019 and April 2020 (SSGC, 2020). The maximum groundwater level in the piezometers was observed on February 12, 2020, at depths of about 9 to 10 feet below ground surface. Pacific Groundwater Group (PGG) later used Site topographic survey data to estimate the maximum groundwater elevation on February 12, 2020, at 317 feet to 319 feet (PGG 2021).

PGG subsequently installed three shallow monitoring wells (P-1, P-2 and P-3 in Figure 2) at 20-ft depths in the lowland area and instrumented the wells with pressure transducers to continuously monitor groundwater levels between February 5 and April 23, 2021 (PGG 2021). Subsurface geology encountered during the drilling of those wells confirmed loose sand grading to gravelly sand to sandy gravel to at least 20 feet below ground surface. Thin discontinuous layers of fine sandy silt (1 to 2 ft thick) were also described within the upper sand unit.

The 2021 monitoring captured the seasonal high groundwater level in early March with elevations ranging from about 317.4 to 320.2 feet, which are similar to the seasonal high groundwater elevations observed in 2020 by South Sound. PGG estimated the horizontal

[2] All elevations are reported in reference to the North American Datum of 1988 (NAVD88).

groundwater gradient across the lowland was about 0.017 ft/ft east-to-west with discharge towards Denton Marsh (PGG 2021).

## 2.1 Proposed Stormwater Design

Most of the stormwater runoff at the Site will be managed using a single stormwater infiltration facility in the lowland area in the western portion of the Site (Figure 1). Given the presence of dense till at shallow depths, stormwater infiltration on the upland area was considered infeasible[3]. The proposed design by Apex conveys runoff from roads, driveways, and a portion of residential lawns to a single stormwater infiltration pond in the lowland area of the Site (see Appendix A). Runoff from residential roof tops will be infiltrated on each individual lot to mimic distributed recharge under existing conditions.

A design infiltration rate for the lowland area was estimated by PGG (2021) to range from 0.25 to 0.63 in/hr using the Massmann detailed approach in the 2019 SWMMWW (Ecology 2019). The estimate uses a separation of 3 to 5 feet between the proposed pond bottom elevation (322 feet) and the high groundwater level observed in 2021, a ponding depth of 1 to 5 feet, and South Sound's estimated saturated hydraulic conductivity of 12 in/hr for the silty sand. The final design by Apex uses an infiltration rate of 0.5 in/hr based on a separation of 3 feet and ponding depth of 5 feet (i.e., the storage depth in the pond). The infiltration facility size was determined using the WWHM developed by Clear Creek Solutions (2016). The final design dimensions of the infiltration facility are 485 feet by 64 feet with a 3:1 side slope.

[3] The dense till in the upland is described as dense to very dense silty sand with gravel. The till was not tested for infiltration characteristics. However, dense till is generally considered a restrictive layer with very low permeability and is not feasible for focused infiltration of stormwater.

# 3 Groundwater Mounding Analysis

Aspect performed a groundwater mounding analysis to forecast the effects of focused stormwater infiltration at the proposed infiltration facility for the development. To conduct the analysis, Aspect developed a transient three-dimensional finite difference groundwater flow model of the shallow aquifer system to simulate saturated and unsaturated groundwater flow beneath the pond and forecast groundwater mounding responses to recharge. The model is coded in MODFLOW-SURFACT Version 4.0 (HydroGeoLogic, Incorporated, 2001). Groundwater Vistas Version 7.0, a pre- and post-processor for MODFLOW was used to develop and run the model (Environmental Simulations, Incorporated, 2017).

Three model simulations were performed. First, a calibration simulation was performed by adjusting key input parameters to improve the model's ability to reproduce the observed 2021 seasonal fluctuations in groundwater levels in response to natural seasonal recharge. Calibrating the model in this way increases the reliability of model forecasts.

The calibrated model was then used to forecast the mounding response to two extreme runoff events. The two events were selected based on the precipitation time series data in WWHM. One simulation, based on the wettest year (Water Year 1934), was performed to forecast the mounding response to a period of sustained high flows. The other simulation, based on the year with the highest 24-hour precipitation event (Water Year 1953), was performed to forecast the mounding response to extreme short-term flows.

The following sections describe development of the model and input parameters. Results of the calibration and predictive simulations are then presented.

## 3.1 Model Domain, Grid Size, and Layering

The model domain covers approximately 1,734 acres including the Roy Meadows Development and surrounding area (Figure 1). The infiltration facility is located at the center of the model. The model edges estimate the locations of hydrologic boundaries that control the ambient groundwater gradient through the model domain. The western and northern model edges correspond to surface water bodies (the Denton Marsh complex and associated ponds located due west of the development and Lacamas and Muck Creeks to the north). The eastern and southern model boundaries approximate the locations of groundwater flow divides.

The model domain is divided into a three-dimensional grid of 30,185 rectilinear cells arranged into 189 rows (north-south), 117 columns (east-west), and 6 vertical layers (Figure 2). The horizontal spatial dimensions of each cell vary throughout the model domain, ranging from 200 feet wide by 200 feet long near the model edges to 10 feet wide by 10 feet long at the infiltration facility. The horizontal cell dimensions were varied to provide high resolution model results at the pond (the area with the greatest importance) while maintaining efficient model run times.

Six vertical model layers were used to simulate the subsurface to effectively characterize vertical flows and gradients. The uppermost (shallowest) 5 model layers (Layers 1 through 5) are each 12 feet thick throughout the model domain. Layer 6 (the deepest layer) is 100 feet thick throughout the model domain.

## 3.2 Time Discretization

The transient model was constructed using daily stress periods. Stress periods are time periods within a MODFLOW simulation during which time-variant stresses to the groundwater solution are held constant. Daily average recharge was the only time-variant stress applied to the MODFLOW model.

As noted above, the model was configured to perform three separate simulations (calibration, wettest year, and year with the highest 24-hour precipitation event) each simulating a different time period of recharge. The calibration simulation simulates a two-year time between from April 23, 2019 and April 23, 2021. This time period was selected for the calibration simulation to allow adequate time for the simulation to stabilize from user-specified initial conditions before entering the period of calibration in early 2021.The calibration simulation was then re-run using the final conditions of the prior run as the initial conditions of the new run to further stabilize the simulation before attempting calibration. This re-running process was continued until the final conditions of subsequent runs converged to a common solution.

The wettest year simulation simulates a one-year period between October 1, 1933 and September 30, 1934; and the year with the highest 24-hour precipitation event simulation simulates a one-year period between October 1, 1952 and September 30, 1953. Both simulations were subjected to the same run-then-re-run stabilization process as the calibration simulation to achieve convergence in the model solution.

## 3.3 Hydrogeologic Units

Two hydrogeologic units with different hydraulic properties are represented in the model domain (Figure 2) based on site-specific explorations (SSGC, 2019; PGG, 2020), nearby well logs accessed through the Washington State Well Report Viewer (Ecology, 2021), and the surficial hydrogeologic maps developed by the U.S. Geological Survey for the Chambers-Clover Creek Watershed in Pierce County (Savoca et al., 2010):

- **Low permeability diamict (till)** was assigned to the upland areas of the model domain. The till occurs either at land surface or within a few feet of the surface in the upland area and is estimated to reach a maximum thickness of 60 feet before transitioning to higher permeability sandy (outwash) deposits based on review of local drillers' well logs. Model layers 1-5 are used to represent the till thickness in the till uplands.

- **High permeability outwash** was assigned to model layer 6 below the till uplands and to all 6 layers throughout the low-lying areas of the model domain where outwash was mapped by the U.S. Geological Survey at the land surface (Savoca et al., 2010). The thickness of the surficial outwash deposits is highly variable and underlain at depth by older deposits with variable hydraulic properties. For simplicity the thickness was assumed to be uniformly 100 feet below the till in Layer 6 and 160 feet thick (total thickness of Layers 1-6) throughout the rest of the model domain. This estimate is within the ranges reported by the U.S. Geological Survey (Savoca et al., 2010) and information reported on nearby drillers' well logs.

### *3.3.1 Hydraulic Properties*

The hydraulic properties of the till and outwash were assigned both saturated and unsaturated properties at each model cell where the unit is present.

The saturated hydraulic properties assigned to the model include saturated horizontal hydraulic conductivity ($K_h$), saturated vertical hydraulic conductivity ($K_v$), specific yield ($S_y$), and specific storage ($S_s$). Initial values of $K_h$, $K_v$, $S_y$, and $S_s$ were assigned for the till and the outwash based on representative calibrated values for each unit at the Site reported by the U.S. Geological Survey in Savoca et al. (2010).

The unsaturated hydraulic conductivities of the till and the outwash were estimated using the van Genuchten equation (van Genuchten, 1980) that is built into MODFLOW-SURFACT code for simulation of unsaturated flow in the vadose zone. Initial values of the van Genuchten parameters $\alpha$, $\beta$, porosity, and residual saturation were assigned to all model cells based on the corresponding soil types reported by Carsel and Parrish (1988).

The initial hydraulic property values assigned to the till and outwash units were adjusted during the model calibration (Section 3.6).

## 3.4 Constant Head Boundaries

MODFLOW constant head boundaries were assigned to model cells along the western edge of the model to simulate groundwater discharge to the Denton Marsh complex and associated ponds. Constant heads are user-specified groundwater levels that remain constant throughout the simulation and were estimated as one-half foot lower than the LiDAR-derived surface elevation reported by the Puget Sound LiDAR Consortium (2004) at the boundary of the marsh complex and associated ponds.

## 3.5 Recharge

Two zones of groundwater recharge corresponding to the hydrogeologic unit present at ground surface were delineated in the MODFLOW model. Zone 1 represents the high permeability outwash areas and Zone 2 represents the low permeability till areas in the model domain (Figure 2).

Daily recharge rates assigned to the two zones in the MODFLOW model were derived from WWHM recharge output assuming a flat lawn-covered land use type with type A/B soils for Zone 1 (high permeability) and a moderately sloped forested land use type with type C soils for Zone 2 (low permeability)[4].

Recharge rates derived for the calibration simulation applied a user-specified precipitation dataset in WWHM. WWHM by default uses a synthetic precipitation dataset

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[4] The choice of a "flat" sloped lawn-covered land-use type for the modelled outwash area differs from Apex's choice of a "moderate" sloped lawn-covered land use type in their design of the pond. However, the difference in predicted recharge is small (<0.6%) and does not impact the results of the mounding analysis.

for the project area based on interpolation of distant rain gage data and general assumptions on precipitation contours for Pierce County. Since the MODFLOW model was calibrated to observed groundwater responses from rain events in 2021, precipitation data from the nearby City of Yelm rain gage[5] in Thurston County was applied (the Yelm gage is located about 5 miles southwest of the project Site). Figure 3 shows the WWHM daily recharge rates applied to the two zones during the calibration simulation (April 23, 2019 to April 23, 2021).

Recharge rates derived for the predictive simulations applied the long-term default precipitation dataset in WWHM which was used to size the infiltration facility and covers over 100 years of precipitation. Two extreme events (maximum mounding) were chosen for the predictive simulations, the wettest water year (10/1/1933 to 9/30/1934) and the water year with the highest 24-hour precipitation event (10/1/1952 to 9/30/1953). The top half of Figures 4 and 5 show the WWHM daily recharge rates applied to the two zones for the wettest year and the highest 24-hour event simulation respectively.

## 3.6 Model Calibration

Prior to the development of the predictive simulations, the model was calibrated to the observed groundwater fluctuations in three piezometers (P-1, P-2, and P-3) during the winter high groundwater period in early 2021. The model calibration involved systematically adjusting the hydraulic input parameter values to improve the model’s ability to simulate the observed seasonal groundwater fluctuations. Demonstration of a successful calibration provides greater confidence in the model’s use for predictive simulations.

Model calibration was performed in three stages:

1) First, model hydraulic parameter values were systematically manually adjusted in a trial-and-error process. Adjustments that improved the match between observed and model-simulated groundwater fluctuations were incorporated into the model. Adjustments that did not improve the match were not incorporated into the model

2) Following the manual calibration stage, the automated calibration software PEST (Doherty, 2016) was used to further improve the calibration. Similar to manual calibration methods, PEST systematically adjusts parameters and saves adjustments which improve the model’s ability to match observed conditions.

3) Finally, the calibrated parameter values were compared against the initially estimated values and to ranges of values documented in the literature to verify the final calibrated values were within realistic ranges for similar hydrogeologic units.

Table 1 presents the final calibrated hydraulic input parameter values.

[5] Station “05u Yelm WRF Rain” https:www.thurstoncountywa.gov/sw/Pages/monitoring-dashboard.aspx

**Table 1. Calibrated Hydraulic Input Parameters**

| Hydrogeologic Unit | Saturated Hydraulic Properties | | | | Unsaturated Hydraulic Properties | | | |
|---|---|---|---|---|---|---|---|---|
| | $K_h$ (ft/day) | $K_v$ (ft/day) | $S_s$ ($ft^{-1}$) | $S_y$ | Porosity | Residual Moisture Content | Alpha ($ft^{-1}$) | Beta |
| Outwash | 123 | 12.3 | $2 \times 10^{-3}$ | 0.02 | 0.41 | 0.065 | 7.5 | 1.89 |
| Till | 39.5 | 3.95 | $3 \times 10^{-6}$ | 0.1 | 0.41 | 0.065 | 7.5 | 1.89 |

**Notes:**
$K_h$ = saturated horizontal hydraulic conductivity
$K_v$ = saturated vertical hydraulic conductivity
Ss = specific storage
Sy = specific yield
Alpha and Beta are parameters in the van Genuchten (1980) model

Calibrated values for hydraulic parameters generally match documented ranges for the study area, except for the hydraulic conductivity parameters for the till ($K_h$ and $K_v$). Calibrated $K_h$ and $K_v$, for the till are 2 to 3 orders of magnitude greater than the median values developed during calibration of the regional Chambers-Clover Creek Watershed Model (Johnson et al., 2011). The greater calibrated values in this model may reflect heterogeneities in the geologic units being represented by the till in the model area.

Many of the till-like materials present in the study area were deposited during the glacial melt-out period which results in less compaction and less silt and clay compared to lodgement tills deposited beneath the ice during glacial advance. The greater calibrated values may also be an artifact from conceptual model uncertainty related to the boundary conditions upgradient of the facility. This potential bias in hydraulic conductivity of the till is not expected to harm the model's usefulness for forecasting groundwater mounding, as the mound and the outlet boundary (Denton Marsh) occur entirely within the outwash.

Figures 6 and 7 illustrate the calibrated model's ability to reproduce observed groundwater levels and daily changes in groundwater levels, respectively. Because the model is being used to predict groundwater mound heights (e.g., changes from a baseline condition) it is more important that the model be able to simulate the changes in response to recharge rather than the absolute elevation. As shown in Figure 6, the model consistently under-predicted the absolute elevation. However as shown in Figure 7, the model reasonably reproduced the changes over time in response to recharge – particularly during the large storm events in late February 2021.

There are some small differences in daily changes between the observed and simulated values which could be attributed to the model recharge values being derived from precipitation data in Yelm (5 miles from the Site) and/or to local heterogeneities in the hydrogeologic units that influences groundwater responsiveness over small timescales. For the purposes of the predictive mounding analysis, the model was considered reasonably well calibrated.

## 3.7 Predicted Groundwater Mounding Beneath Facility

Each predictive simulation required two model runs to calculate the change in groundwater elevations (mound) due to focused recharge beneath the pond: a pre-development simulation with no focused recharge beneath the pond and a post-development simulation with focused recharge beneath the pond. Calculating mounding in this way increases certainty in the mounding forecasts (Hunt, 2012). The daily recharge assigned to the pond for the post-development simulation used the total daily runoff routed to the pond as predicted by the WWHM model that Apex developed for pond sizing. The total pond flows for the wettest year and highest 24-hour event simulations are shown in the bottom half of Figures 4 and 5 respectively. This approach to assigning recharge for the predictive simulations results in an over-estimate of the predicted mound because:

1. Actual recharge beneath the pond is limited by the infiltration rate of the underlying receptor soils (see bottom hydrographs of Figures 4 and 5).
2. The post-development simulation uses the same recharge as the pre-development recharge across the rest of the Site and does not account for reduced recharge beneath impervious surfaces.

The results of the two mounding analyses are summarized below.

### *3.7.1 Wettest Year*

Groundwater mounding beneath the facility reaches a maximum of 1.86 feet above the predicted ambient groundwater level for one day during the wettest year simulation (Figure 8). At its maximum, the mound exceeds 1 foot in height within 300 feet horizontal distance of the pond (Figure 9). Mounding exceeds 1 foot for a total of 14 days throughout the year. All mounds exceeding 1 foot are associated with storm events during which the mound quickly forms and decays over the span of a few days.

### *3.7.2 Highest 24-hour Storm Event*

Groundwater mounding beneath the facility reaches a maximum of 2.33 feet above the predicted ambient groundwater level for one day during the peak 24-hour storm itself, before decaying to less than one foot over the next two days (Figure 10). At its peak, the mound exceeds one foot in height within a horizontal distance of 100 feet of the pond (Figure 11). Mounding exceeds 1 foot for a total of 11 days throughout the year.

# 4 Assessment of Infiltration from Septic Drainfields

Potable water for the project will be provided by the City of Roy. Wastewater will be managed with on-site septic systems. Apex Septic Design, LLC designed the project septic systems and estimates an average of 360 gallons-per-day (gpd) septic flows to drain fields per residential lot[6]. Based on 79 total lots, total project septic flows are estimated to be 28,440 gpd. All but 15 of the 79 residential lots will use individual drain fields measuring roughly 500 to 600 square feet in area[6]. The other 15 lots will be managed using two community drainfields in the lowland area measuring roughly 4,200 and 4,800 square feet area[6]. The recharge rate beneath each drainfield is estimated to be 0.04 to 0.05 in/hr (Table 2).

These rates were estimated by dividing the total discharge to each drainfield by the drainfield area. These rates are orders of magnitude lower than the recharge rates simulated beneath the proposed infiltration facility for the mounding analysis (see Section 3). Furthermore, the area of the infiltration facility is one to two orders of magnitude larger than the septic drain fields – consequently the *volumetric* recharge to the aquifer beneath the infiltration facility will be several orders of magnitude higher than individual drain fields. This comparison indicates whatever little groundwater mounding may occur beneath individual drain fields will be inconsequential compared to the mounding that is predicted to occur beneath the infiltration facility (Section 3).

**Table 2. Project Septic Flows**

| Location | Number of Lots | Drain Field Area ($ft^2$) | Discharge per Lot (gpd) | Linear Flow (in/hr) |
|---|---|---|---|---|
| Tract B | 8 | 4,800 | 360 | 0.04 |
| Tract D | 7 | 4,200 | 360 | 0.04 |
| Individual Lots | 1 | 500 to 600 | 360 | 0.04-0.05 |

# 5 Volumetric Receptor Capacity

The volumetric receptor capacity of the receiving soils below the infiltration facility was estimated as the total unsaturated pore space below each square foot of pond bottom. Assuming a total porosity (n) of 0.25, a residual volumetric moisture content (s) of 0.1 and a separation (h) of 3 feet between the pond bottom and ambient high groundwater, the unsaturated pore space (P) is estimated to be:

[6] Email communication from Lawrence Purdum of Apex Septic Design, LLC dated 9/15/2021

$$P = (h)(n-s) = (3)(0.25-0.1) = 0.45 \text{ cubic feet per square feet}$$

Assuming pond bottom dimensions of 485 feet by 64 feet, the total unsaturated volume is estimated to be about 14,000 cubic feet or about 104,500 gallons. Assuming a relatively high infiltration of 7 in/hr for a silty sand, it would take about 45 minutes to fill this volume. However, groundwater flow in the underlying shallow outwash aquifer system will convey infiltrated water away from the facility. The ambient groundwater seepage velocity in the shallow outwash aquifer was estimated using Darcy's equation for groundwater flow. Using a horizontal hydraulic conductivity (k) of 123 ft/day for the outwash (based on the results of the model calibration), an estimated effective porosity ($n_e$) of 0.2, and the hydraulic gradient across the Site (i) of 0.017, the groundwater seepage velocity (v) is estimated to be:

$$v = ki/n_e = (123)*(0.017)/0.2 = 10.5 \text{ ft/dy (or 5.25 in/hr)}$$

The groundwater seepage velocity is slightly *lower* than the conservatively high infiltration rate of 7 in/hr used for this analysis, but it is ten times *higher* than the estimated design infiltration rate of 0.5 in/hr which considers the effects of shallow groundwater. Groundwater mounding beneath the facility will also increase the local groundwater gradient (i) resulting in even higher seepage velocities during mounding events. These results together with the mounding analysis presented in Section 3, indicates the ambient groundwater flow field should be sufficient to convey the infiltrated water away from the facility and reduce the chances of flooding.

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# Limitations

Work for this project was performed for the Roy Meadows Development, LLC (Client), and this report was prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

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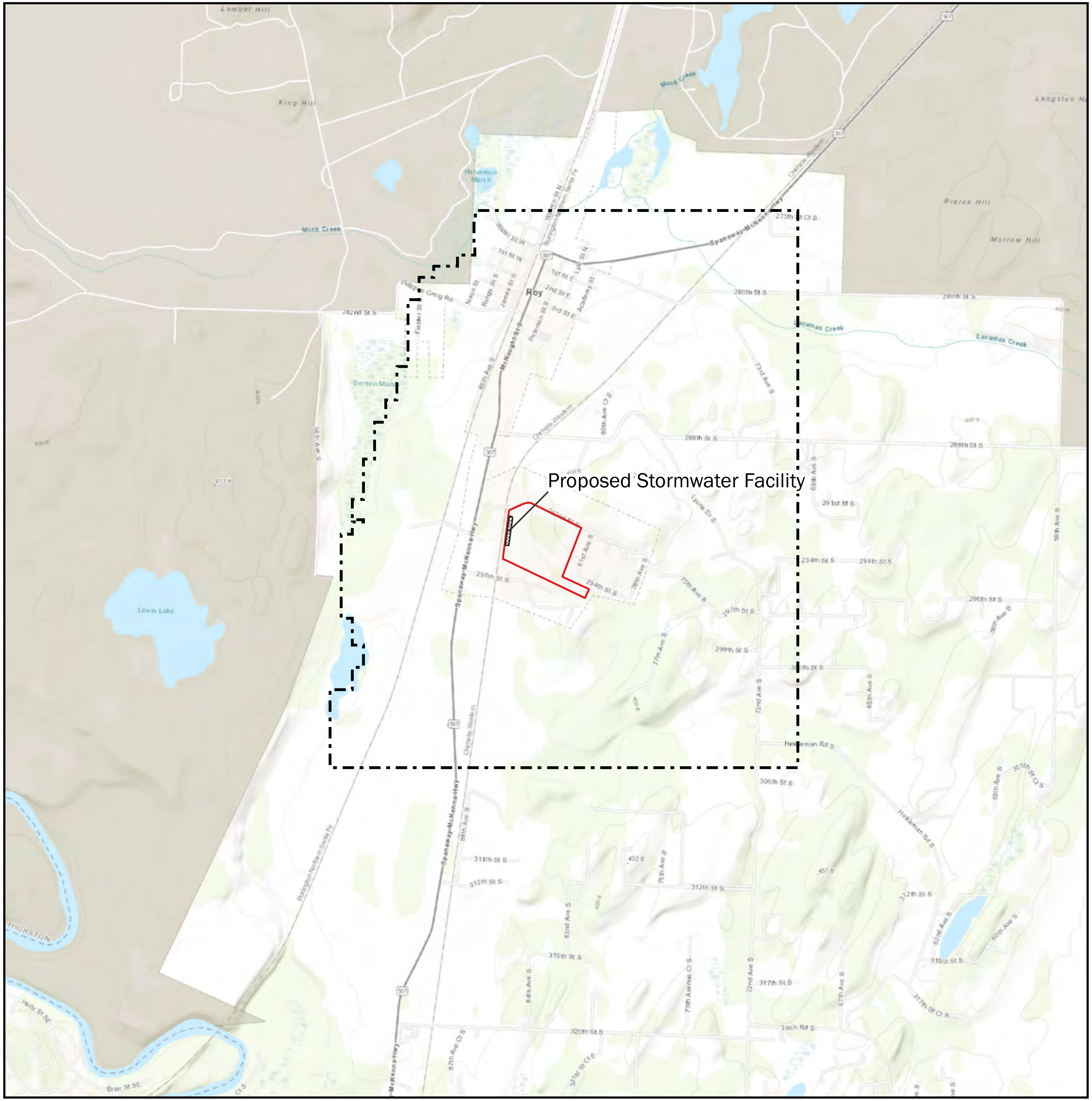
# FIGURES





Comments: Development and proposed stormwater facility extents georeferenced from Oakview Preliminary Plat Map (Apex Engineering PLLC, 02-11-2020).

**LEGEND:**

- Roy Meadows Development Extent
- Proposed Stormwater Facility
- Active MODFLOW Model Extent

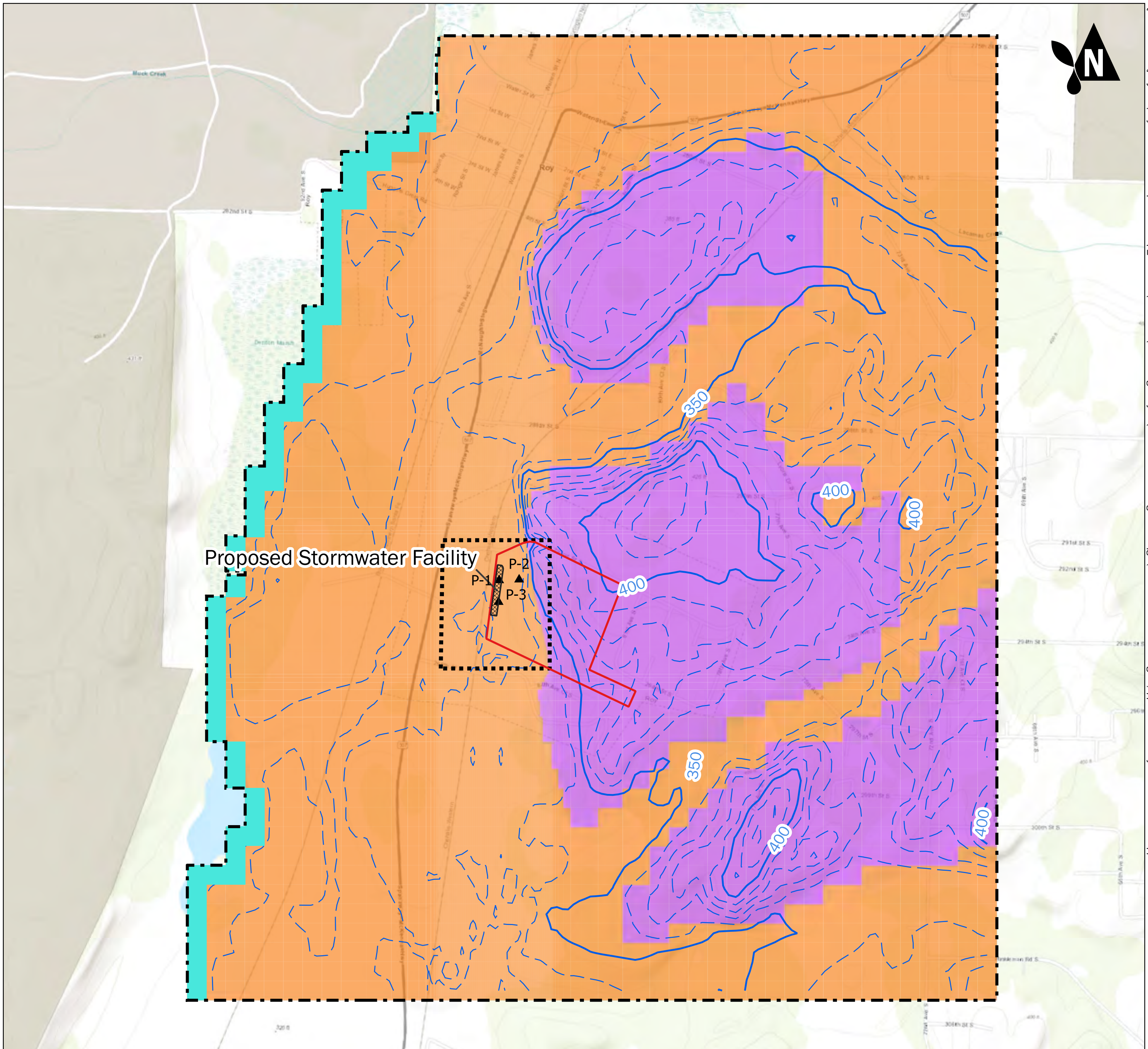
0 1,500 3,000 feet

# Proposed Facility Location

Groundwater Mounding Analysis
Roy Meadows Development
Roy, Washington

| | | | |
|---|---|---|---|
| Aspect CONSULTING | JAN-2022 | BY: JCB | FIG NO. 1 |
| | PROJ NO. 210496 | REV BY: DMC | |

QGIS Path: G:\projects\RoyMeadowsDevelopmentGroup_210496\Delivered\MoundingAnalysis\1 Project Location.qgz (Facility Location) || Coordinate System: EPSG:8791 || Date Printed: 2022-01-21 13:01




- Roy Meadows Development Extent
- Proposed Stormwater Facility
- ▲ Piezometer
- Active MODFLOW Model Extent
- Area of Greatest Grid Refinement (Smallest Cell Size)
- Constant Head Boundary Cell

*Hydrogeologic Units*

- Outwash Deposit (Recharge Zone 1)
- Diamict/Till-like Deposit (Recharge Zone 2)

*Simulated Groundwater Contour (ft)*

- Minor Contour (10-foot interval)
- Major Contour (50-foot interval)

0 750 1,500 ft

# MODFLOW Model Configuration

Groundwater Mounding Analysis
Roy Meadows Development
Roy, Washington

| | | | |
|---|---|---|---|
| Aspect CONSULTING | JAN-2022 | BY: JCB/DMC | FIG NO. 2 |
| | PROJ NO. 210496 | REV BY: OGR | |

QGIS Path: G:\projects\RoyMeadowsDevelopmentGroup_210496\Delivered\MoundingAnalysis\2 MODFLOW Configuration.qgz (MODFLOW Model Config v2) || Coordinate System: EPSG:8791 || Date Printed: 2022-01-21 13:17

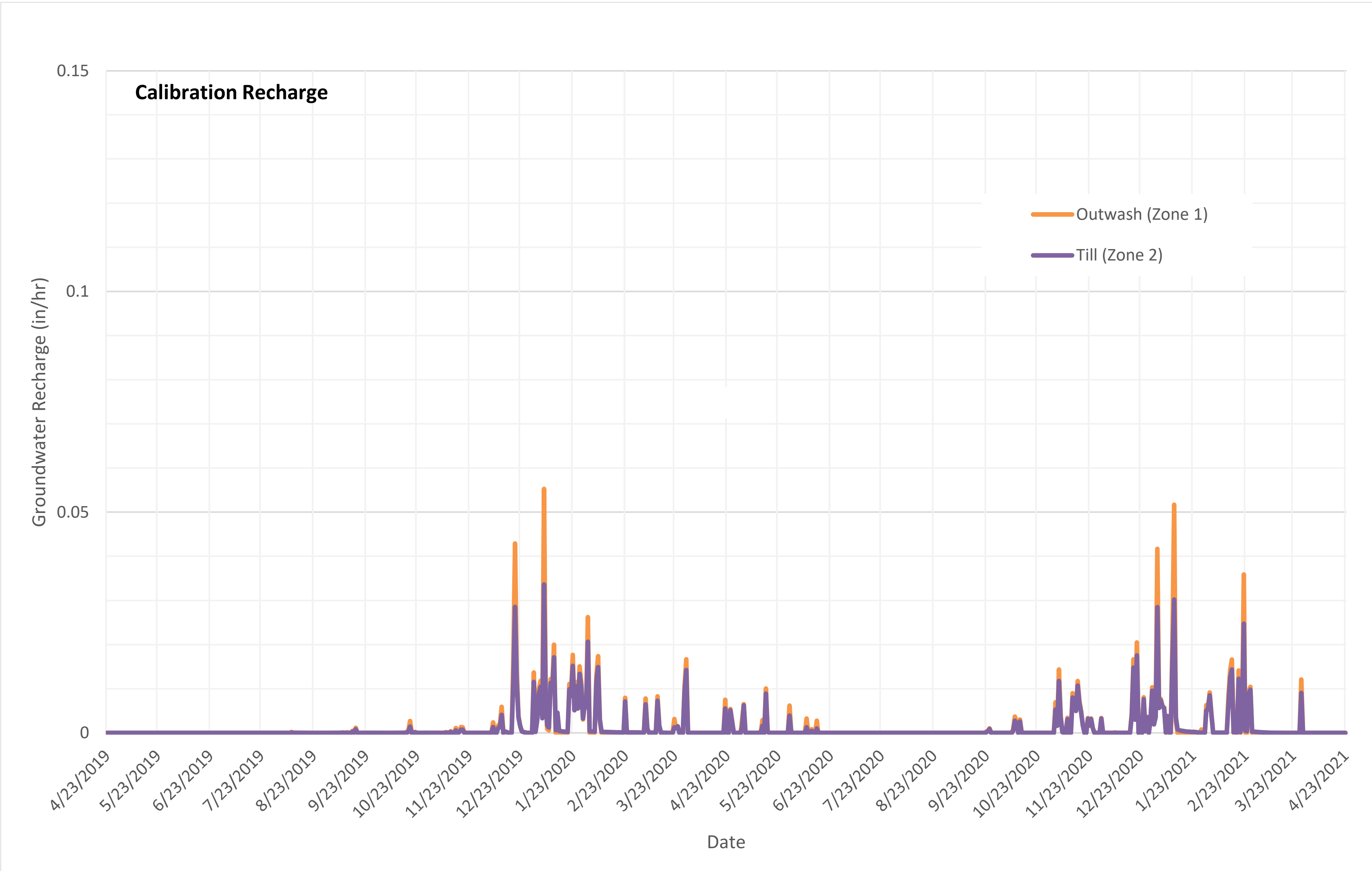
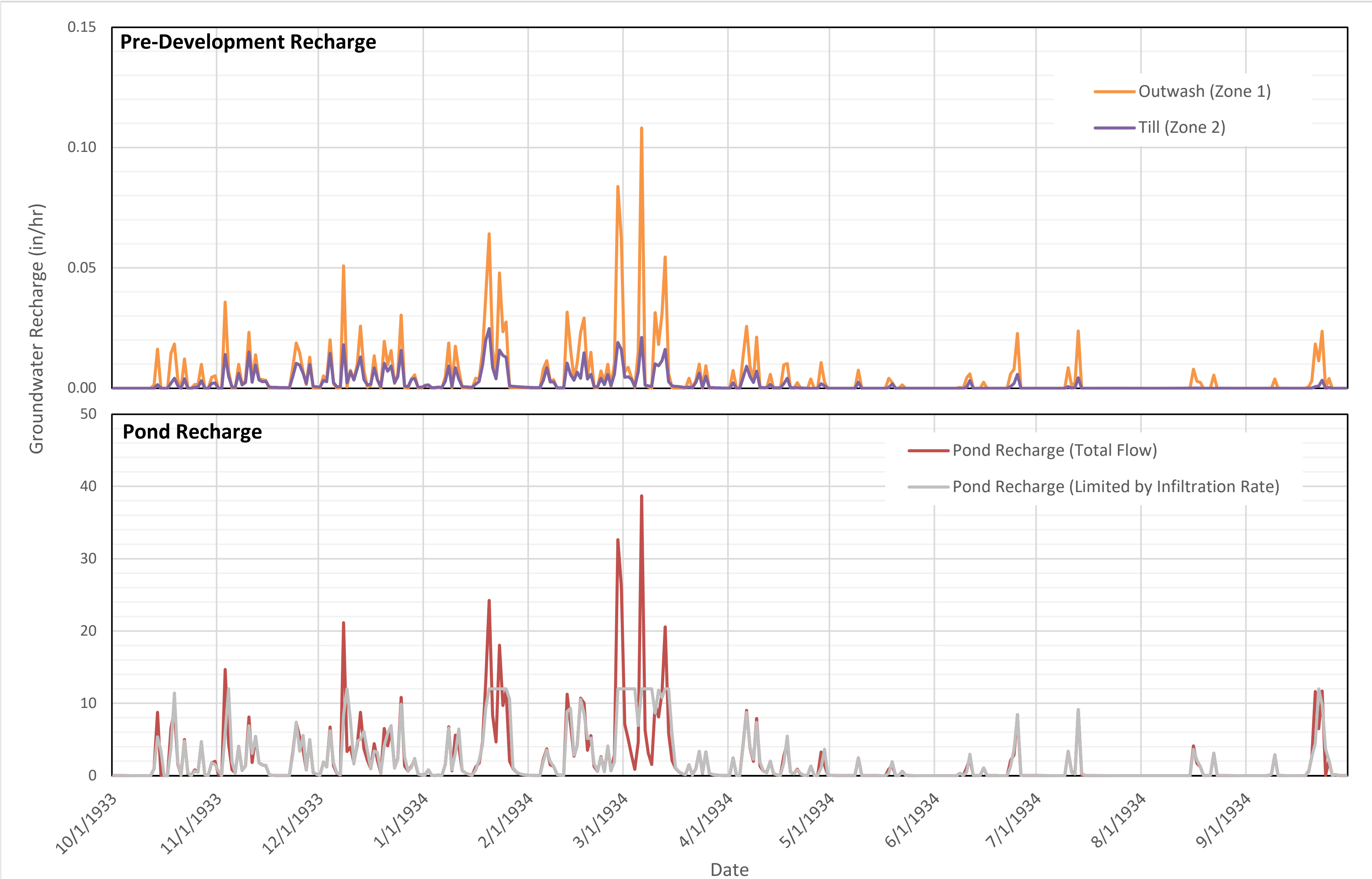


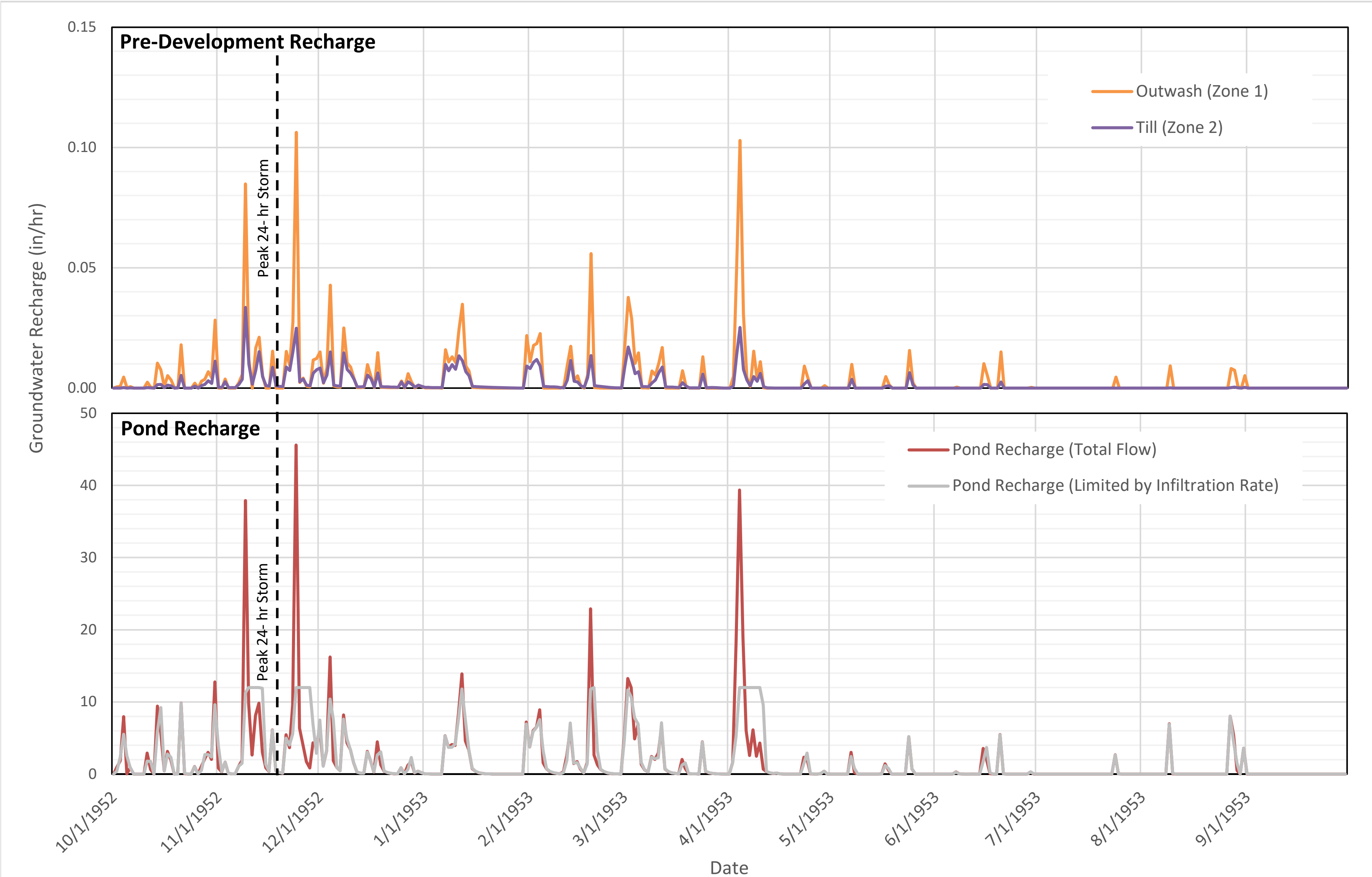

**Figure 3**
**Calibration Period Simulated Recharge**
Groundwater Mounding Analysis
Roy Meadows Development, Roy, WA

**Aspect Consulting**
1/21/2022
*S:\RoyMeadowsDevelopment\Report_MoundingAnalysis\Figures\Hydrographs_RoyMeadows_2022-01-21.xlsx*




**Aspect Consulting**
1/21/2022
*S:\RoyMeadowsDevelopment\Report_MoundingAnalysis\Figures\Hydrographs_RoyMeadows_2022-01-21.xlsx*

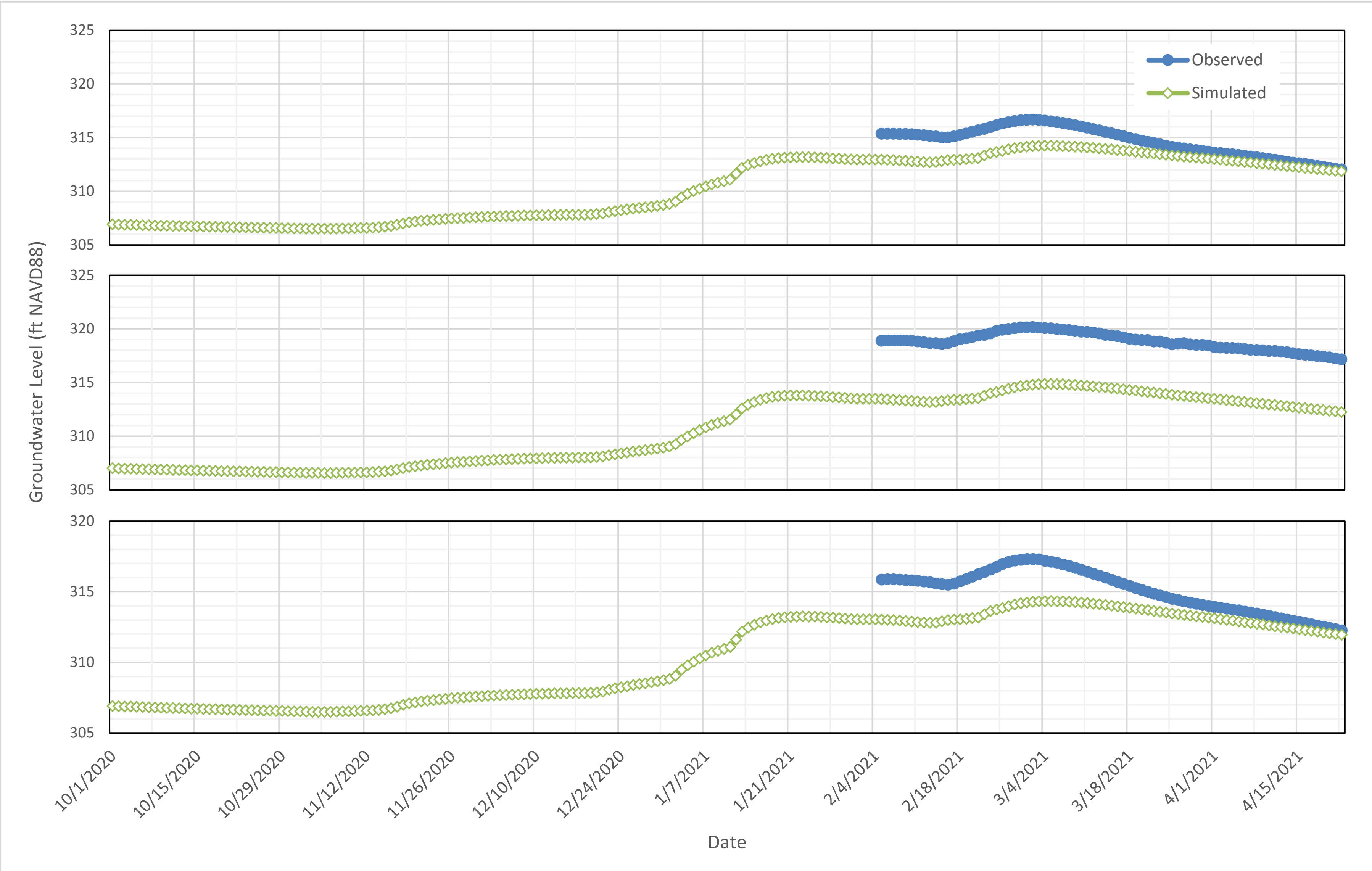
**Figure 4**
**Wettest Year Simulated Recharge**
Groundwater Mounding Analysis
Roy Meadows Development, Roy, WA




**Aspect Consulting**
1/21/2022
*S:\RoyMeadowsDevelopment\Report_MoundingAnalysis\Figures\Hydrographs_RoyMeadows_2022-01-21.xlsx*

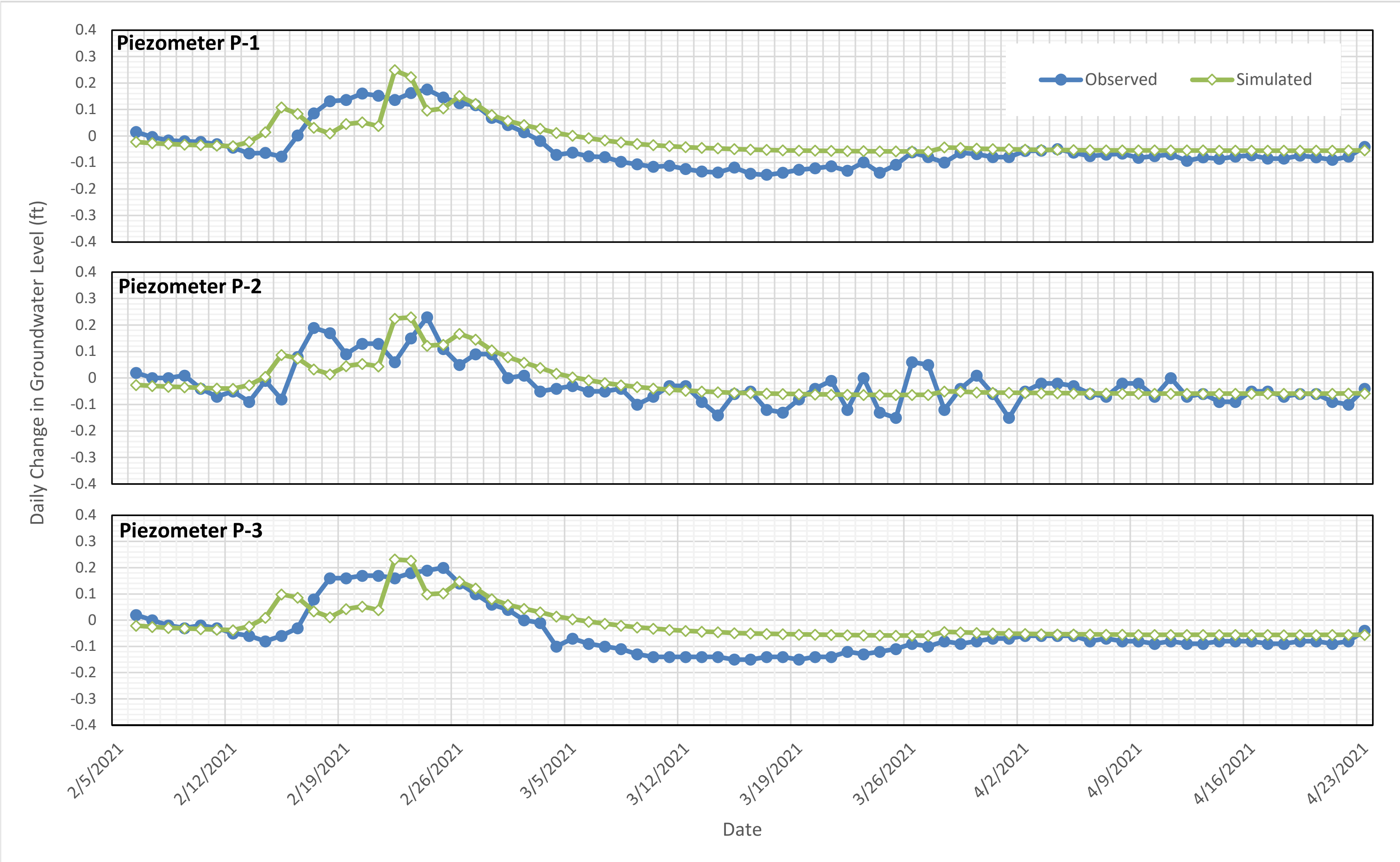
# Figure 5
## Peak Storm Year Simulated Recharge

Groundwater Mounding Analysis
Roy Meadows Development, Roy, WA




**Aspect Consulting**
1/21/2022
*S:\RoyMeadowsDevelopment\Report_MoundingAnalysis\Figures\Hydrographs_RoyMeadows_2022-01-21.xlsx*

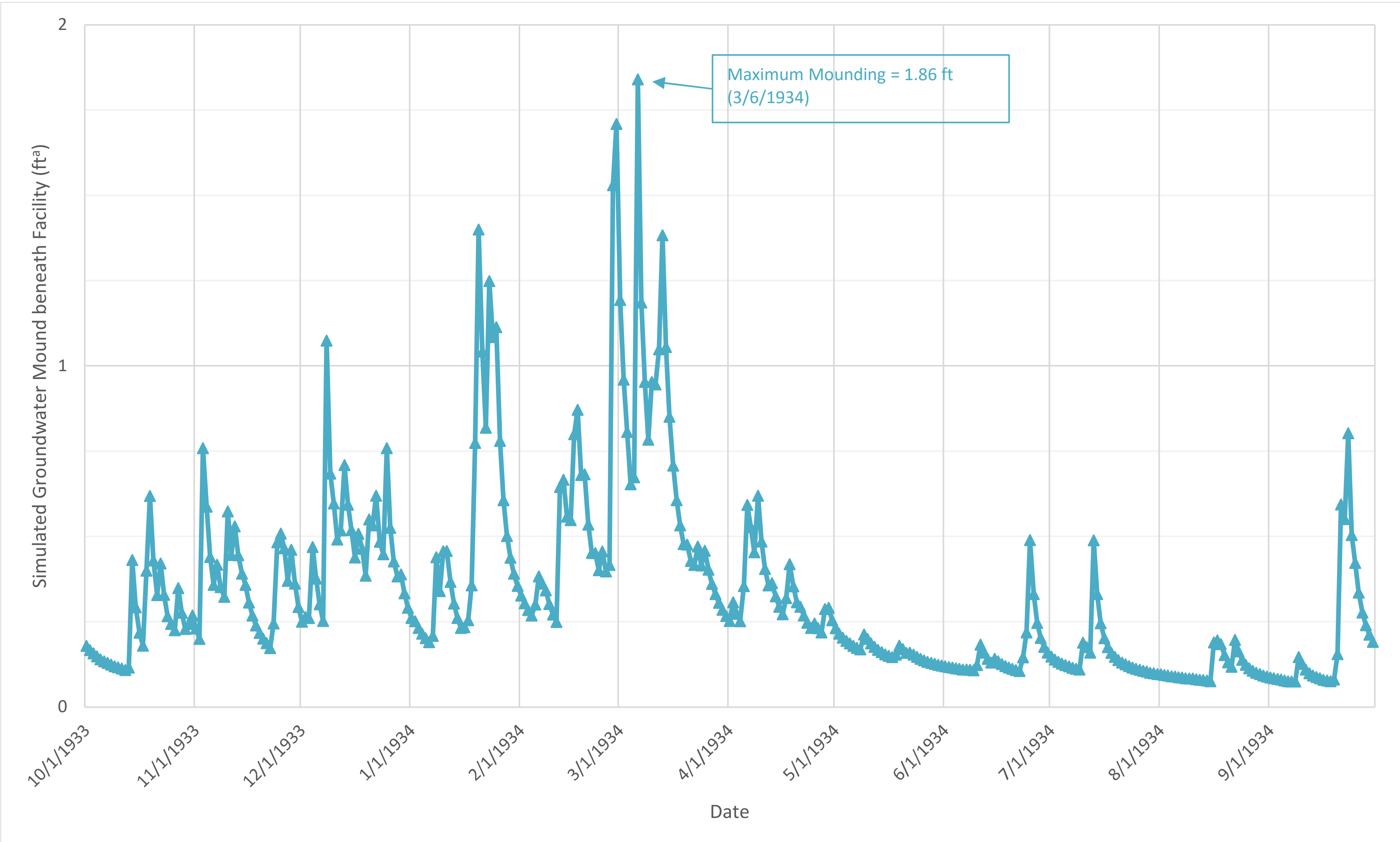
**Figure 6**
**Simulated versus Observed Groundwater Levels (Calibration Period)**
Groundwater Mounding Analysis
Roy Meadows Development, Roy, WA




**Aspect Consulting**
1/21/2022
*S:\RoyMeadowsDevelopment\Report_MoundingAnalysis\Figures\Hydrographs_RoyMeadows_2022-01-21.xlsx*

# Figure 7
## Daily Change in Groundwater Level (Calibration Period)

Groundwater Mounding Analysis
Roy Meadows Development, Roy, WA



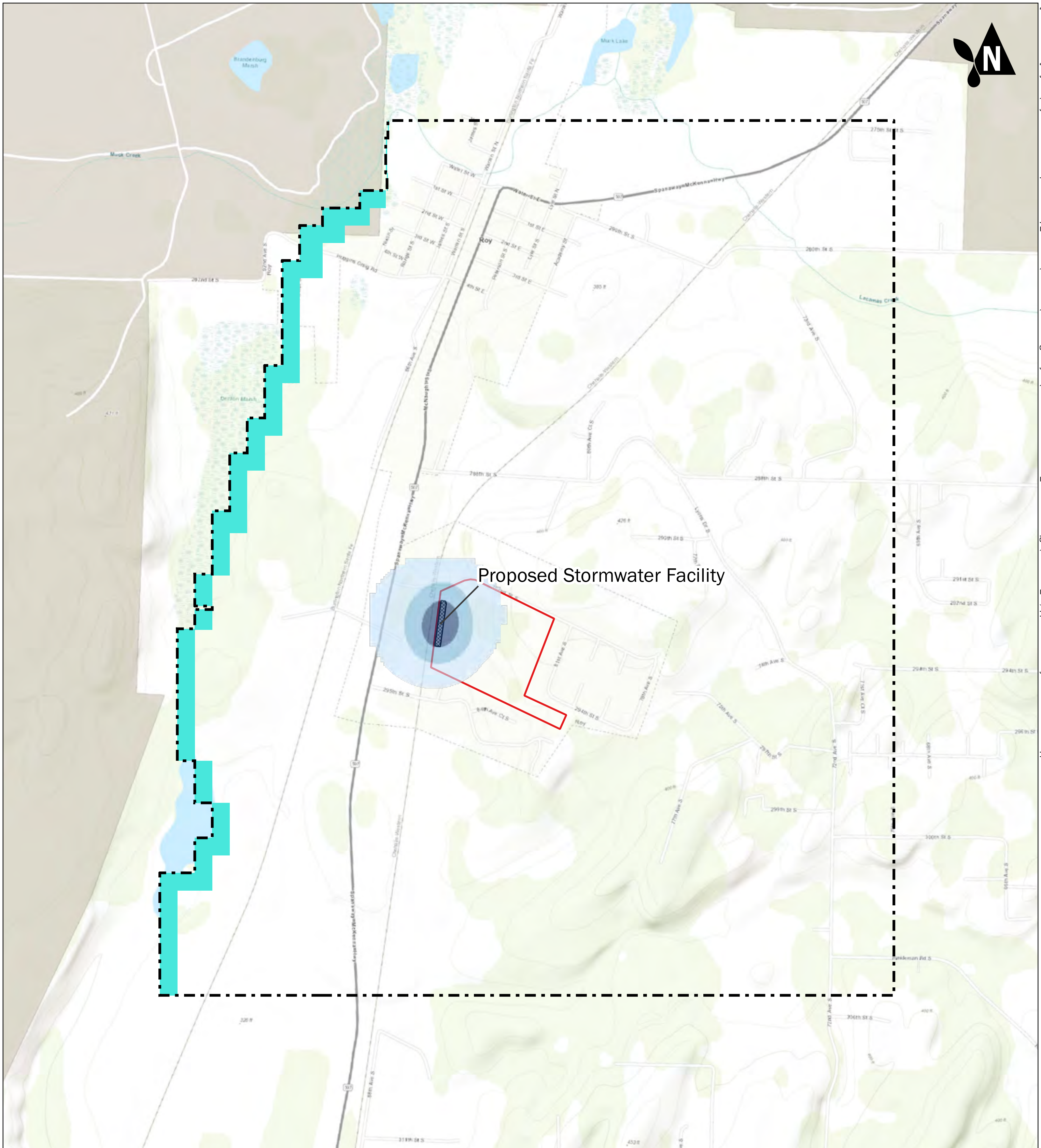

**Notes:**

a. Mounding calculated as the difference in pre- and post-development simulated groundwater levels.

# Figure 8
# Wettest Year Simulated Mounding

Groundwater Mounding Analysis
Roy Meadows Development, Roy, WA

**Aspect Consulting**
1/21/2022
*S:\RoyMeadowsDevelopment\Report_MoundingAnalysis\Figures\Hydrographs_RoyMeadows_2022-01-21.xlsx*




QGIS Path: G:\projects\RoyMeadowsDevelopmentGroup_210496\Delivered\MoundingAnalysis\9 Sim Extent of Mound_WettestYear.qgz (WettestYr_v2) || Coordinate System: EPSG:8791 || Date Printed: 2022-01-21 13:44

Proposed Stormwater Facility

Roy Meadows Development Extent

Active MODFLOW Model Extent

Constant Head Boundary Cell

0 750 1,500 ft

*Simulated Groundwater Mound Height*

<0.1 ft

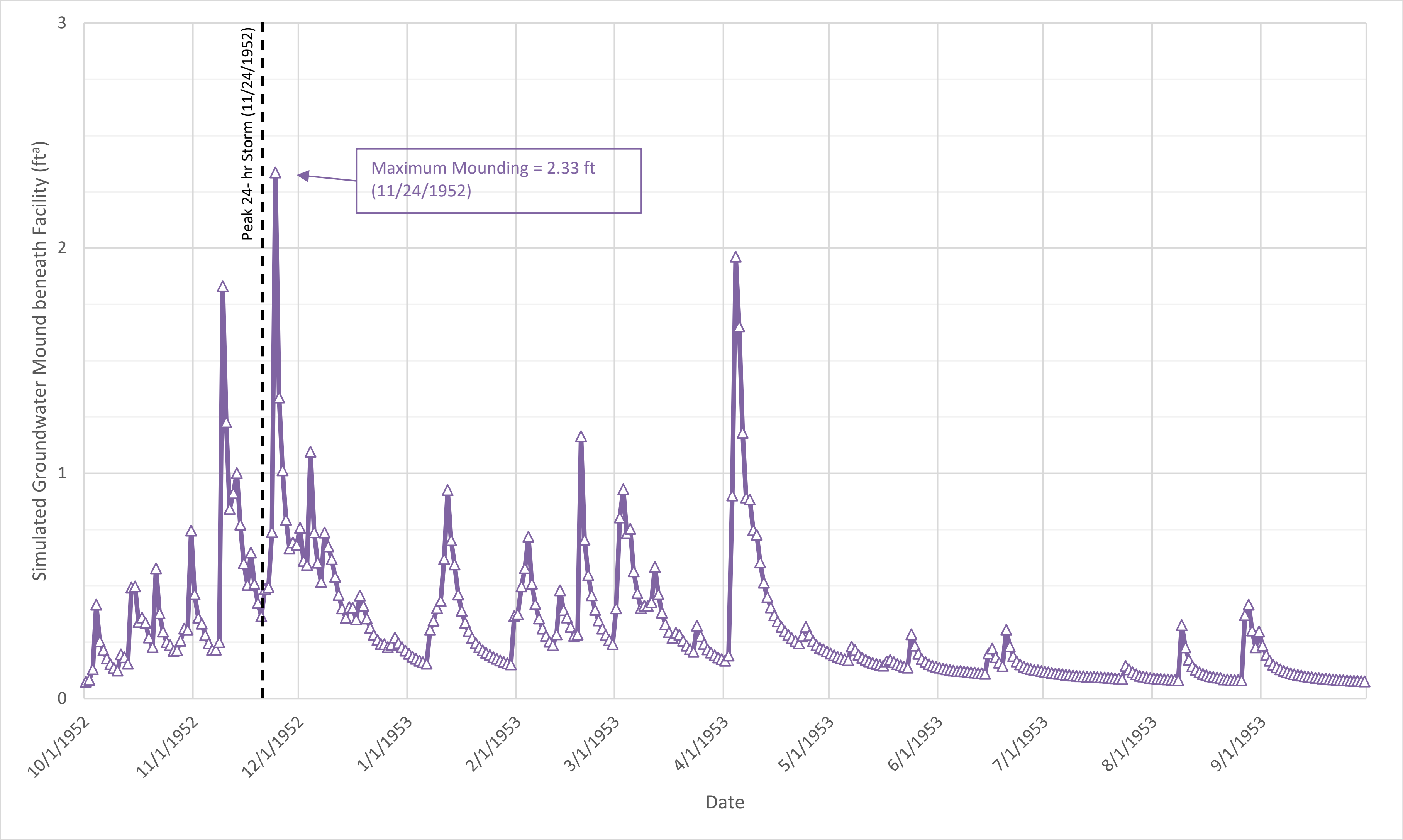
0.5 ft to 1.0 ft

>1.0 ft

# Simulated Maximum Extent of Mounding (Wettest Year)

Groundwater Mounding Analysis
Roy Meadows Development
Roy, Washington

| | | | |
|---|---|---|---|
| Aspect CONSULTING | JAN-2022 | BY: JCB/DMC | FIG NO. 9 |
| | PROJ NO. 210496 | REV BY: OGR | |



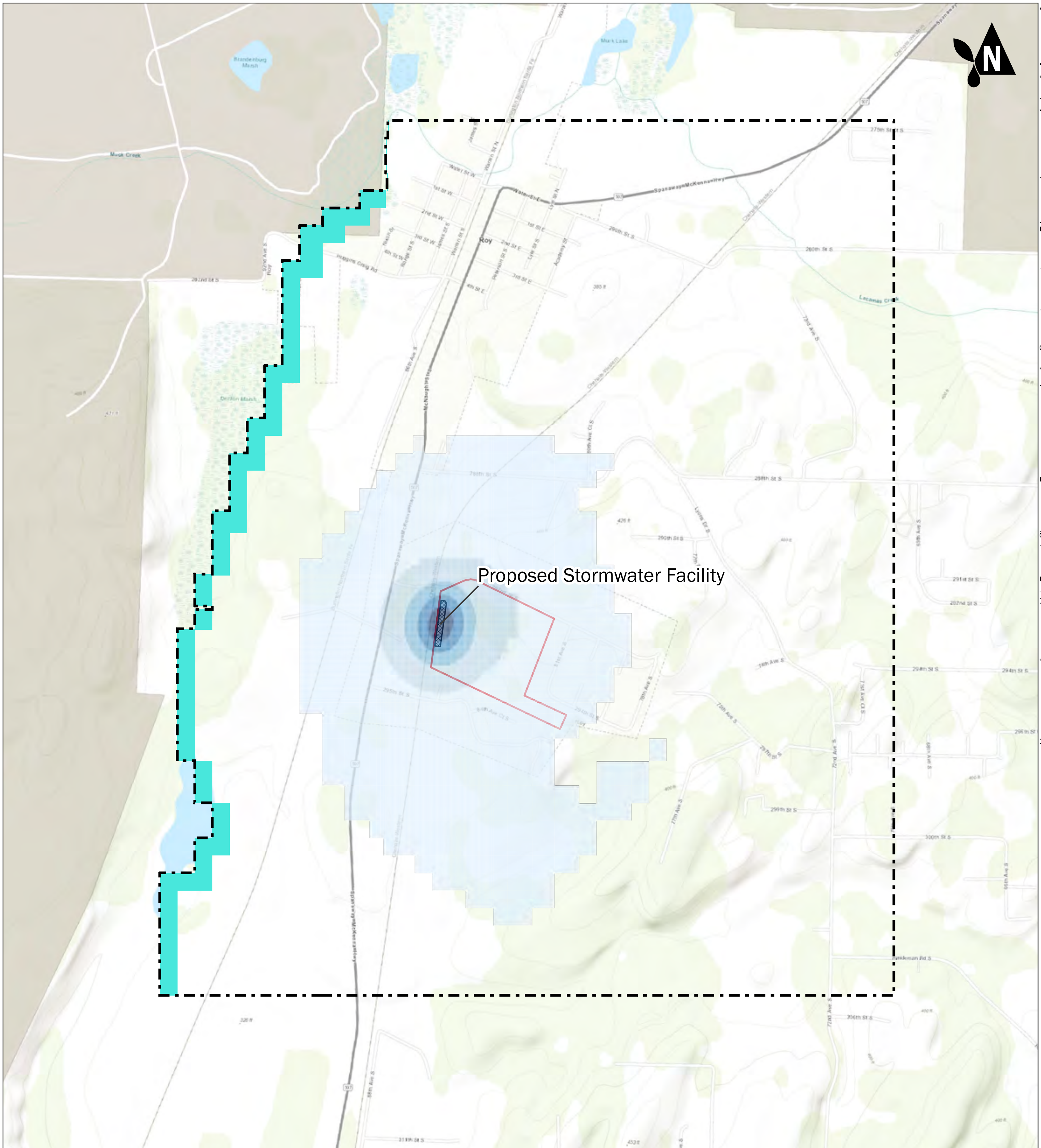

**Notes:**

a. Mounding calculated as the difference in pre- and post-development simulated groundwater levels.

# Figure 10
## Peak Storm Year Simulated Mounding

Groundwater Mounding Analysis
Roy Meadows Development, Roy, WA

**Aspect Consulting**
1/21/2022
*S:\RoyMeadowsDevelopment\Report_MoundingAnalysis\Figures\Hydrographs_RoyMeadows_2022-01-21.xlsx*




Roy Meadows Development Extent

Proposed Stormwater Facility

Active MODFLOW Model Extent

Constant Head Boundary Cell

0 750 1,500 ft

*Simulated Groundwater Mound Height*

- <0.5 ft
- 0.5 to 1.0 ft
- 1.0 to 1.5 ft
- 1.5 to 2.0 ft
- >2.0 ft

# Simulated Maximum Extent of Mounding (Peak Storm Year)

Groundwater Mounding Analysis
Roy Meadows Development
Roy, Washington

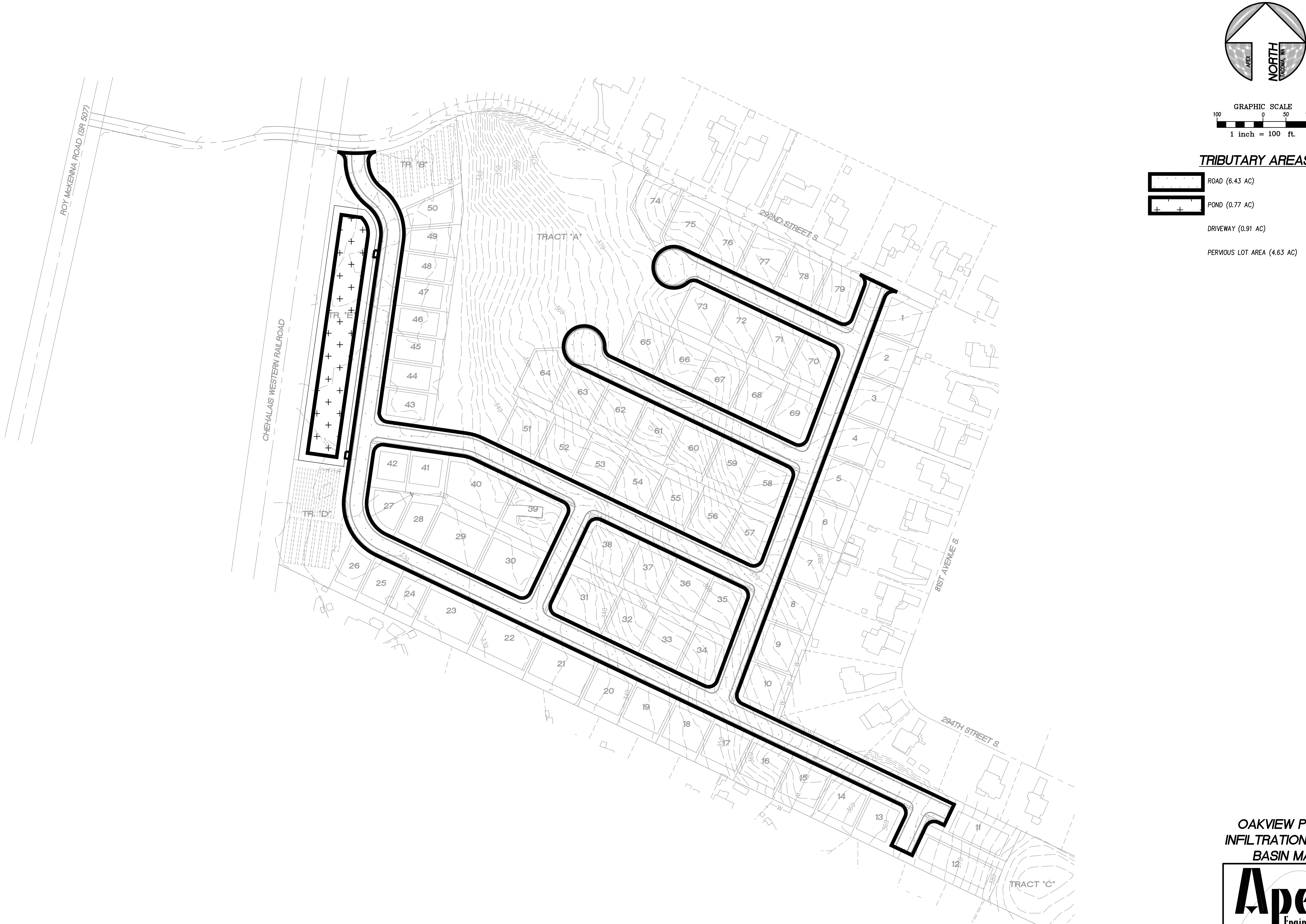
Aspect CONSULTING

| | | | |
|---|---|---|---|
| JAN-2022 | BY: JCB/DMC | FIG NO. | |
| PROJ NO. 210496 | REV BY: OGR | **11** | |

QGIS Path: G:\projects\RoyMeadowsDevelopmentGroup_210496\Delivered\MoundingAnalysis\8 Sim Extent of Mound_PeakStorm.qgz (PeakYR_v2) || Coordinate System: EPSG:8791 || Date Printed: 2022-01-21 13:46

# APPENDIX A

# Proposed Project Design




## TRIBUTARY AREAS

ROAD (6.43 AC)

POND (0.77 AC)

DRIVEWAY (0.91 AC)

PERVIOUS LOT AREA (4.63 AC)

# OAKVIEW PLAT INFILTRATION POND BASIN MAP

Apex Engineering LLC
2601 South 35th, Suite 200
Tacoma, Washington 98409-7479
(253) 473-4494 FAX: (253) 473-0599

**APPENDIX E**

FEMA FIRM MAP

## NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) Report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS Report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

**Coastal Base Flood Elevations** shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study Report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study Report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study Report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Universal Transverse Mercator (UTM) zone 10. The **horizontal datum** was NAD 83, GRS 1980 spheroid. Differences in datum, spheroid, projection or UTM zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713- 3242**, or visit its website at http://www.ngs.noaa.gov.

**Base map** information shown on this FIRM was derived from multiple sources. Base map files were provided in digital format by Pierce County GIS, WA DNR, WSDOT, USFWS, Washington State Department of Ecology, and Puget Sound Regional Council. This information was compiled at scales of 1:1,200 to 1:24,000 during the time period 1996-2012.

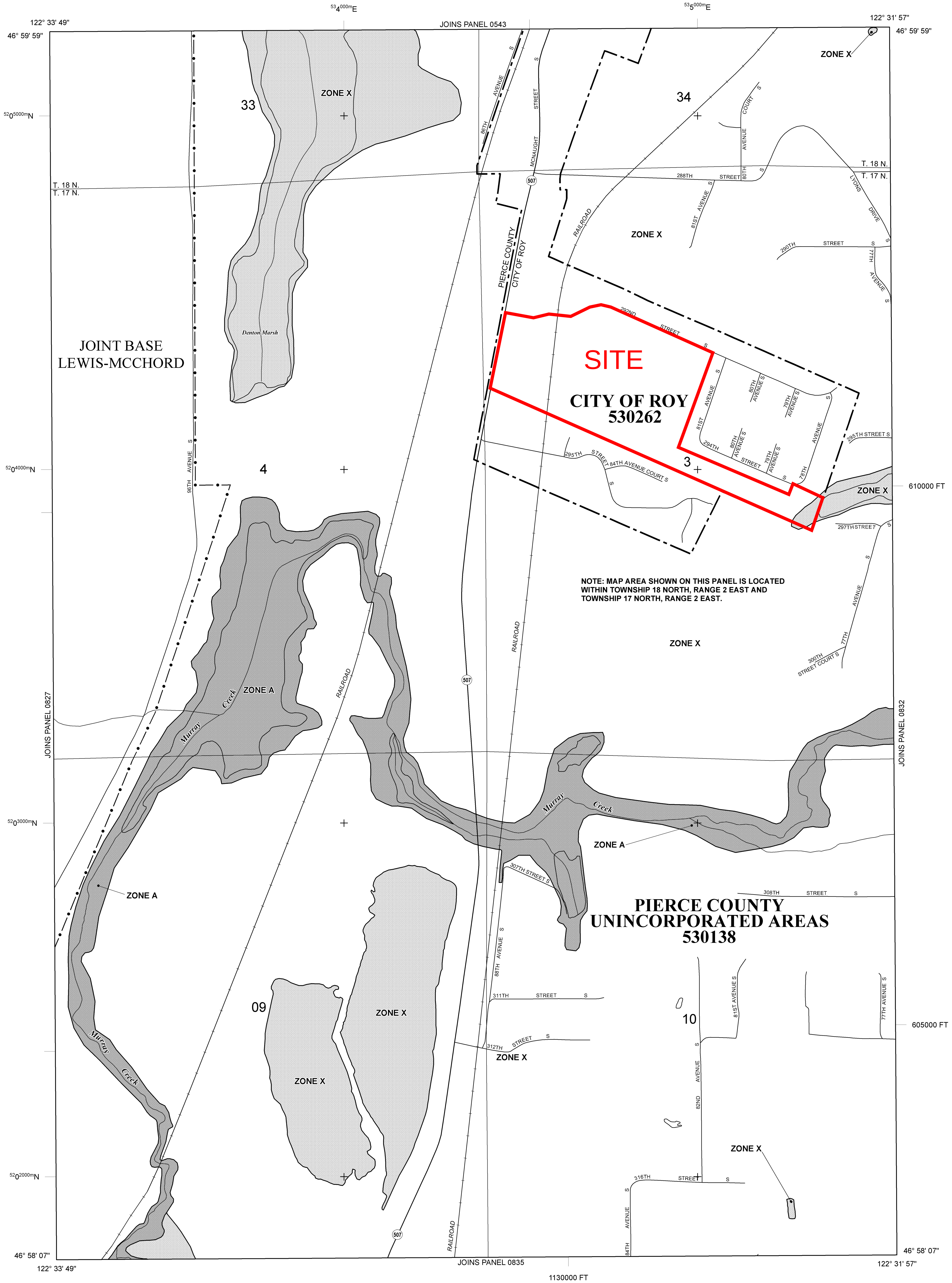
The **profile baselines** depicted on this map represent the hydraulic modeling baselines that match the flood profiles in the FIS report. As a result of improved topographic data, the **profile baseline**, in some cases, may deviate significantly from the channel centerline or appear outside the SFHA.

**Corporate limits** shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

For information on available products associated with this FIRM visit the **Map Service Center (MSC)** website at http://msc.fema.gov. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

If you have **questions about this map,** how to order products, or the National Flood Insurance Program in general, please call the **FEMA Map Information eXchange (FMIX)** at **1-877-FEMA-MAP** (1-877-336-2627) or visit the FEMA website at http://www.fema.gov/business/nfip.




## LEGEND

SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100-year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

| | |
|---|---|
| **ZONE A** | No Base Flood Elevations determined. |
| **ZONE AE** | Base Flood Elevations determined. |
| **ZONE AH** | Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined. |
| **ZONE AO** | Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined. |
| **ZONE AR** | Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood. |
| **ZONE A99** | Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined. |
| **ZONE V** | Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined. |
| **ZONE VE** | Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined. |

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

**ZONE X** Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

**ZONE X** Areas determined to be outside the 0.2% annual chance floodplain.

**ZONE D** Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

1% Annual Chance Floodplain Boundary

0.2% Annual Chance Floodplain Boundary

Floodway boundary

Zone D boundary

CBRS and OPA boundary

Boundary dividing Special Flood Hazard Area Zones and boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths, or flood velocities.

513 — Base Flood Elevation line and value; elevation in feet*

(EL 987) — Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

A — A Cross section line

23 - - - 23 Transect line

Culvert

Bridge

45° 02' 08", 93° 02' 12" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83) Western Hemisphere

$^{49}89^{000m}$ N — 1000-meter Universal Transverse Mercator grid values, zone 10

DX5510 × — Bench mark (see explanation in Notes to Users section of this FIRM panel)

• M1.5 — River Mile

MAP REPOSITORIES
Refer to Map Repositories list on Map Index

EFFECTIVE DATE OF COUNTYWIDE
FLOOD INSURANCE RATE MAP
March 7, 2017

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

**MAP SCALE 1" = 500'**

250 0 500 1000 FEET

150 0 150 300 METERS

NATIONAL FLOOD INSURANCE PROGRAM

NFIP

**PANEL 0831E**

# FIRM

**FLOOD INSURANCE RATE MAP**

**PIERCE COUNTY, WASHINGTON AND INCORPORATED AREAS**

**PANEL 831 OF 1375**

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

| COMMUNITY | NUMBER | PANEL | SUFFIX |
|---|---|---|---|
| PIERCE COUNTY | 530138 | 0831 | E |
| ROY, CITY OF | 530262 | 0831 | E |

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

**MAP NUMBER**
**53053C0831E**

**EFFECTIVE DATE**
**MARCH 7, 2017**

Federal Emergency Management Agency