Naval Facilities Engineering Systems Command Northwest
Silverdale, Washington

Final

Supplemental Site Inspection Report Addendum for Per- and Polyfluoroalkyl Substances Outlying Landing Field Coupeville

Naval Air Station Whidbey Island
Oak Harbor, Washington

January 2022

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Oak Harbor, Washington

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Prepared for NAVFAC Northwest
by CH2M HILL, Inc.
Bellevue, Washington
Contract N62470-16-D-9000
CTO 4405

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Acronyms and Abbreviations

%	percent
3D	three-dimensional
APS	Applied Professional Services Inc.
bgs	below ground surface
CGFM	Coupeville Groundwater Flow Model
CGM	Coupeville Groundwater Model
CH2M	CH2M HILL, Inc.
CSM	conceptual site model
CTO	Contract Task Order
ET	evapotranspiration
f_{oc}	fractional organic carbon
g/cm^3	grams per cubic centimeter
GHB	general head boundaries
gpm	gallon per minute
IDW	investigation-derived waste
K_d	distribution coefficient
K_{oc}	soil organic carbon-water partition coefficient
K_h	horizontal hydraulic conductivity
K_v	vertical hydraulic conductivity
m/d	meters per day
m^2/d	square meters per day
mg/kg	milligrams per kilogram
mL/g	milliliters per gram
mm	millimeters
NAVD88	North American Vertical Datum of 1988
NAVFAC	Naval Facilities Engineering Systems Command
Navy	Department of the Navy
ng/L	nanograms per liter
OLF	Outlying Landing Field
PA	Preliminary Assessment
PEST	parameter estimation
PFAS	per- and polyfluoroalkyl substance
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PVC	polyvinyl chloride
RI	Remedial Investigation
RMS	root mean square
SAP	Sampling and Analysis Plan
SI	Site Inspection
SOP	Standard Operating Procedure
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey

Introduction and Site Description

CH2M HILL, Inc. (CH2M) was contracted by Naval Facilities Engineering Systems Command (NAVFAC) Northwest to perform a supplemental site inspection (SI) for per- and polyfluoroalkyl substances (PFAS) at Outlying Landing Field (OLF) Coupeville in Island County, Washington (**Figure 1-1**). This Supplemental SI Report Addendum presents the data and findings obtained during aquifer testing and groundwater modeling that was developed, calibrated, and updated for the OLF Coupeville site as a part of the analysis associated with the Supplemental SI. This report addends the Supplemental SI Report currently in Draft (CH2M, 2021). This report was prepared for NAVFAC Northwest under the Comprehensive Long-term Environmental Action – Department of the Navy (Navy) 9000, Contract N62470-16-D-9000, Contract Task Order (CTO) 4405.

The field activities discussed in Section 2 of this report addendum were performed in accordance with the *Final Sampling and Analysis Plan, Supplemental Site Inspection, Outlying Landing Field Coupeville, Naval Air Station Whidbey Island* (CH2M, 2019a) and *Final Sampling and Analysis Plan Addendum, Supplemental Site Inspection, Outlying Landing Field Coupeville, Naval Air Station Whidbey Island* (CH2M, 2020a), henceforth referred to as the SAP and SAP Addendum, respectively. Field activities associated with the Supplemental SI were planned and carried out in three phases:

- **Phase 1** – 12 soil borings (8 were completed as new monitoring wells), geotechnical soil sampling (2 locations), depth-discrete groundwater grab sampling for PFAS (7 locations), and soil sampling (11 locations) and monitoring well sampling (8 new wells and 32 existing wells) for PFAS targeting suspected PFAS release areas and data gaps between suspected release areas and on-Base and off-Base areas where PFAS has been detected.
- **Phase 2** – Installation and sampling of 5 new monitoring wells based on Phase 1 data, synoptic water level survey, and aquifer testing.
- **Phase 3** – Installation of one off-base monitoring well northeast of OLF Coupeville.

Details and results of the field investigation for Phase 1 and Phase 2 field investigation are documented in the Supplemental SI Report (CH2M, 2021). This report addendum includes the results for geotechnical sampling (Phase 1), aquifer testing (Phase 2), and installation of one off-base monitoring well (Phase 3). The geotechnical sampling performed during Phase 1 of the Supplemental SI was used in the development of the PFAS solute transport model. The methodology for groundwater flow and PFAS solute transport modeling are described in Section 3.

1.1 Purpose and Objectives

The overall objectives of the Supplemental SI were defined in the SAP (CH2M, 2019a). The objectives were as follows:

- Identify whether there were releases of PFAS-containing compounds to the environment from the on-Base potential release areas that were identified in the Preliminary Assessment (PA) (CH2M, 2018a) as requiring further investigation (these areas are referred to as potential source areas in the PA).
- Refine the understanding of groundwater flow and potential PFAS migration directions between potential release areas and/or on-Base groundwater monitoring wells and off-Base drinking water wells with perfluorooctanoic acid (PFOA) and/or perfluorooctane sulfonate (PFOS) exceedances of the United States Environmental Protection Agency (USEPA) lifetime health advisory.
- Quantify the hydraulic properties of the aquifer system at OLF Coupeville.
- Refine the understanding of the distribution of PFAS within the groundwater system at OLF Coupeville.

The first of these objectives is discussed in the Supplemental SI Report (CH2M, 2021). The latter three of these objectives are further addressed through the recalibration and update of the groundwater flow model developed in 2018, as described in the expedited SI Report (CH2M, 2018b), and the development of solute transport models for two PFAS, PFOS and PFOA. Due to current Navy guidance, which is to focus on PFOS, PFOA, and PFBS, solute transport modeling was not completed for perfluoroheptanoic acid (PFHpA), perfluorohexane sulfonate (PFHxS), and perfluorononanoic acid (PFNA). Due to low concentrations and little-known transport properties, solute transport modeling was not completed for perfluorobutane sulfonate (PFBS). This Supplemental SI Report Addendum outlines the approach taken to achieve the listed objectives and provides conclusions based on data collected and recommendations for further study.

1.2 Site Background and Description

Refer to the OLF Coupeville Supplemental SI Report (CH2M, 2021) for a detailed description of site background and physical setting of OLF Coupeville, including site history, locations of potential PFAS releases, and relevant information on the physical, environmental, and hydrogeologic setting at the site.

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Legend

- City
- Secondary Road
- Local Connecting Road
- Important Local Road
- Base Boundary

N

0 1 2 Miles

1 inch = 2 miles

Figure 1-1
Base Location Map
Supplemental Site Inspection Report Addendum
Naval Air Station Whidbey Island - Outlying Landing Field
Coupeville, Washington

SECTION 2

Investigation Field Activities

This section documents the field activities performed in support of aquifer testing and Phase 3 monitoring well installation at OLF Coupeville in May 2020. This section also summarizes the aquifer testing results and documents the results of geotechnical sampling performed during Phase 1 of the Supplemental SI (July through December 2019).

2.1 Aquifer Test Design

Two aquifer tests were conducted at OLF Coupeville using on-Base monitoring wells. The tests were designed as pumping tests with each test consisting of one pumping well and several observation wells. The pumping well for Test 1 WI-CV-MW31M and the pumping well for Test 2 was WI-CV-MW29M. Both pumping wells were installed during Phase 2 of the OLF Coupeville Supplemental SI and constructed as 4-inch diameter monitoring wells. Each aquifer test consisted of a baseline monitoring period, a step-rate pumping test, a constant-rate pumping test, and a recovery monitoring period. A summary of the design of the aquifer tests is presented in **Table 2-1**. Observation wells were selected as those in closest proximity to the pumping wells, which would demonstrate measurable drawdown, and included wells screened in the shallow, intermediate, and deep elevation intervals. The monitoring networks for the two tests are shown on **Figure 2-1**.

2.1.1 Baseline Water Level Monitoring

Electronic pressure transducers with built-in data loggers were deployed to all pumping and observation wells selected for the aquifer test four days prior to the start of the first pumping test to establish baseline water level conditions. Manual groundwater level measurements were taken at the time of transducer deployment and at the end of the baseline monitoring period. Additionally, a transducer and a barometric pressure logger were deployed to WI-CV-MW08M to record approximated background water level and atmospheric pressure changes throughout the aquifer testing period.

2.1.2 Step-rate and Constant-rate Pumping Tests

The step-rate pumping tests were conducted to determine the maximum sustainable pumping rate for each well. The tests were conducted by pumping the wells at a constant rate for several time-steps of up to 1 hour, increasing the pumping rate for each sequential time step if the water level in the pumping well stabilized.

Each step-rate test was followed by a 14-hour constant-rate pumping test during which the wells were continuously pumped at the highest sustainable pumping rate as determined during the step-rate tests.

During the step-rate and constant-rate tests, water levels in the pumping well and surrounding observation wells were monitored via electronic pressure transducers. Periodic manual water level measurements were made at all pumping and observation wells to verify the accuracy of the transducer readings.

2.1.3 Recovery Monitoring

After the completion of each constant-rate test, well recovery was monitored for 24 hours. Transducers recorded continuous water level readings at all pumping and monitoring wells during the recovery period. Manual water level measurements were taken at the beginning and end of the recovery period.

Table 2-1. Summary of Aquifer Test Design

Test	Pumping Well	Observation Wells	Test Dates	Step-rate Test Procedure	Constant-rate Test Procedure
Test 1	WI-CV-MW31M	WI-CV-MW01M WI-CV-MW01D WI-CV-MW02S WI-CV-MW02M WI-CV-MW20S WI-CV-MW30M	Step rate: 5/18/2020 Constant rate: 5/19/2020	Pump at a constant rate for approximately 1 hour; if water level stabilizes, increase pumping rate by 1 gallon per minute for each sequential 1-hour time step until a pumping rate is reached at which the water level does not stabilize after 1 hour, or the well draws dry.	Pump at constant rate for 14 hours; pumping rate is highest sustainable pumping rate as determined from the step-rate test.
Test 2	WI-CV-MW29M	WI-CV-MW05S WI-CV-MW05M WI-CV-MW13S WI-CV-MW13M WI-CV-MW26D	Step rate: 5/20/2020 Constant rate: 5/21/2020		

2.2 Summary of Aquifer Testing Results

Hydrographs showing pumping rates and transducer data from the WI-CV-MW31M and WI-CV-MW29M aquifer tests are provided in **Appendix A**.

2.2.1 Step-Rate Tests

The initial pumping rate for the Test 1 (WI-CV-MW31M) step-rate test was approximately 20 gallons per minute (gpm). At this rate, the well was drawn dry in approximately 3 minutes. After 90% recovery, the step-rate test was restarted with a pumping rate of approximately 3 gpm. The maximum sustainable pumping rate achieved during the test was approximately 4 gpm. At this pumping rate, the water level stabilized at approximately 16.2 feet of drawdown. No drawdown in response to pumping was observed at any of the observation wells in the Test 2 monitoring network.

The initial pumping rate for the Test 2 (WI-CV-MW29M) step-rate pumping test was approximately 7.2 gpm. At this rate, the well was drawn dry in approximately 2 minutes. After 90% recovery, the step-rate test was restarted with a pumping rate of approximately 2 gpm. The maximum sustainable pumping rate achieved during the test was approximately 2 gpm. At this pumping rate, the water level stabilized at approximately 25.4 feet of drawdown. No drawdown in response to pumping was observed at any of the observation wells in the Test 2 monitoring network.

2.2.2 Constant-Rate Tests

For the Test 1 constant-rate test, WI-CV-MW31M was pumped continuously at approximately 4.1 gpm for 14 hours. The water level at WI-CV-MW31M stabilized at approximately 17 feet of drawdown. No drawdown in response to pumping was observed at any of the Test 1 observation wells during the constant-rate pumping test.

For the Test 2 constant-rate test, WI-CV-MW29M was pumped continuously at approximately 2.2 gpm for 14 hours. The water level at WI-CV-MW29M stabilized at approximately 32 feet of drawdown. No drawdown in response to pumping was observed at any of the Test 2 observation wells during the constant-rate pumping test.

2.2.3 Discussion

The maximum sustainable pumping rates for WI-CV-MW31M and WI-CV-MW29M were insufficient to create drawdown at any of the observation wells, despite the attempt to select observation wells as close to the pumping wells as possible. To calculate estimates of aquifer properties, such as transmissivity and storativity, analyses of pumping test data require drawdown observations at wells at varying distances from the pumping well or at one observation well at multiple time during the pumping period. Because the only discernable drawdown observed during either test was at the pumping wells, attempting to use the data to obtain estimates of aquifer properties would provide minimal value.

However, the aquifer test results were used in the development of the updated groundwater model as an additional check on the validity of the model. Refer to **Section 3** of this report for a full description of aquifer test simulations.

2.3 Geotechnical Sample Results

Soil samples were collected for geotechnical analysis during drilling of soil borings SO05 and SO06 (later completed as monitoring wells WI-CV-MW20S and WI-CV-MW21S, respectively; **Figure 2-2**). Two soil samples were collected from each soil boring. These samples were analyzed for grain size distribution, dry bulk density, total and air-filled porosity, total organic carbon, and fractional organic carbon (f_{oc}). The soil geotechnical results are presented in **Table 2-2** and **Table 2-3**. Laboratory reports with full results are provided in **Appendix B.**

Soil geotechnical properties were used to assign hydraulic and solute transport parameters in the groundwater model as described in **Section 3**.

Table 2-2. Soil Grain Size Distribution

Sample ID	Soil Type	Median Grain Size (mm)	% Gravel	% Very Coarse Sand	% Coarse Sand	% Medium Sand	% Fine Sand	% Very Fine Sand	% Silt	% Clay
WI-CV-BH21-120-0919	Silt	0.0204	0	0	0	0	0.74	8.83	72.29	18.13
WI-CV-BH21-140-0919	Medium Sand	0.3848	0.77	12.98	22.38	34.51	15.15	4.92	7.4	1.89
WI-CV-BH20-120-0919	Silt	0.0248	0	0	0	0	0.98	9.2	73.55	16.27
WI-CV-BH20-186-0919	Silt	0.0144	0	0	0	0	1.25	7.43	69.03	22.29

Notes:
WI-CV-BH21-120-0919 was collected at a depth of 120 feet below ground surface (bgs).
WI-CV-BH21-140-0919 was collected at a depth of 140 feet bgs.
WI-CV-BH20-120-0919 was collected at a depth of 120 feet bgs.
WI-CV-BH20-186-0919 was collected at a depth of 186 feet bgs.
% = percent
mm = millimeters

Table 2-3. Soil Geotechnical Properties

Sample ID	Dry Bulk Density (g/cm^3)	Porosity		Total Organic Carbon (mg/kg)	Fractional Organic Carbon
		Total (%)	Air-filled (%)		
WI-CV-BH21-120-0919	1.68	38.3	<0.01	12,400	0.0124
WI-CV-BH21-140-0919	1.71	36	8.85	2,400	0.0024
WI-CV-BH20-120-0919	1.65	39.6	<0.01	12,400	0.0124
WI-CV-BH20-186-0919	1.67	38.6	<0.01	14,400	0.0144

Notes:
WI-CV-BH21-120-0919 was collected at a depth of 120 feet bgs.
WI-CV-BH21-140-0919 was collected at a depth of 140 feet bgs.
WI-CV-BH20-120-0919 was collected at a depth of 120 feet bgs.
WI-CV-BH20-186-0919 was collected at a depth of 186 feet bgs.
g/cm^3 = grams per cubic centimeter
mg/kg = milligrams per kilogram

2.4 Phase 3 Monitoring Well Installation

Phase 3 field activities were conducted in October 2020 in accordance with the SAP Addendum (CH2M, 2020a), with the drilling and installation of one monitoring well off-Base northeast of OLF Coupeville. The location of the monitoring well, WI-CV-MW18M, is on a parcel owned by Island County, and is shown on **Figure 2-2**. Two additional monitoring wells were proposed in the SAP Addendum; however, property access was not granted for the locations of these wells, and due to the task order schedule, alternate off-Base locations were not pursued in the Supplemental SI.

Due to the timing of the installation of WI-CV-MW18M, survey and water level data from this well were not incorporated into the groundwater flow or solute transport models completed for the Supplemental SI. Hydraulic data from this well will be used in future groundwater evaluation efforts, such as in the upcoming Remedial Investigation (RI) phase.

2.4.1 Property Access

Property access for the off-Base drilling was granted by the parcel owner (Island County) through a Right of Entry and Construction Agreement, executed June 24, 2020, granting Navy access to the parcel on which WI-CV-MW18M is located through 2025.

2.4.2 Archaeological Resources Monitoring

To assess for the presence of cultural or archaeological resources at the off-Base drilling location, the following actions were taken prior to and during the monitoring well installation:

- A National Historic Preservation Act Section 106 consultation was conducted with the Washington State Historic Preservation Officer and/or the Advisory Council on Historic Preservation to identify possible conflicts between historic preservation objectives and the proposed activities in the work area. No conflicts were identified, and a recommendation provided by the Naval Air Station Whidbey Island Cultural Resources Program Manager indicated a Determination of No Historic Properties Affected, with the stipulation for implementation of an unanticipated discovery plan. The Washington State Archaeologist provided concurrence with this recommendation on June 24, 2020.
- An Inadvertent Discovery Plan was generated to establish archaeological resources monitoring and inadvertent discovery protocols to be used during the ground-disturbing activities associated with the well installation.
- On-site monitoring was conducted by a professional archaeologist during ground-disturbing activities associated with the project, observing ground disturbances, examining borehole openings, and retrieving soil samples from the boring for evidence of cultural resource materials. Archaeological monitoring was conducted until drilling was confirmed to be at a depth below any culture-bearing deposits. At WI-CV-MW18M, this depth was approximately 60 feet below ground surface (bgs).
- The archaeological monitor made a determination of no archaeological findings. The results of the archaeological monitoring are described in a technical memorandum prepared and reviewed by CH2M's professional and senior archaeologists, respectively.

The Section 106 consultation record, Inadvertent Discovery Plan, and technical memorandum describing findings during the installation of well WI-CV-MW18M are included in **Appendix C**.

2.4.3 Site Preparation and Utility Location

Prior to the initiation of drilling activities, the proposed drilling location was demarcated, and an 811 call-before-you-dig ticket was submitted for public utility providers. The drilling location was also scanned for utilities by Applied Professional Services Inc. (APS), a licensed third-party utility locating company. APS scanned a 25-feet radius around the well location using a combination of ground-penetrating radar and radio frequency instruments. No conflicts with utilities were identified, and the proposed well location was cleared for drilling.

2.4.4 Soil Boring and Well Installation

The borehole at WI-CV-MW18M was drilled and installed using sonic drilling techniques by a Washington-licensed driller (Yellow Jacket Drilling of Portland, Oregon) in accordance with applicable standard operating procedures (SOPs) included in the SAP and State of Washington well construction standards. The location was hand cleared to a depth of 5 feet bgs using non-invasive methods prior to drilling to ensure that undetected buried utilities were not present. Materials containing PFAS were not used during drilling. Continuous soil cores were collected for lithologic classification and screened for volatile organic compounds using a photoionization detector. Soil cores were closely examined for signs of saturation and the presence of fine-grained beds that could indicate the presence of perched groundwater or confining conditions. Lithology observed in the soil cores was classified according to the Unified Soil Classification System and logged in accordance with applicable SOPs included in the SAP. The soil boring log is included in **Appendix D**. Soil or groundwater samples were not collected for laboratory analysis during drilling.

Monitoring well WI-CV-MW18M was constructed with a 2-inch diameter, Schedule 80 polyvinyl chloride (PVC) riser connected to a 15-foot, factory slotted 0.020-inch PVC screen with a bottom cap installed from 120 to 135 feet bgs. This was a deviation from the 10-foot screen which was originally planned. A longer screen was recommended to increase the chances of installing a productive well across the water table and within water-bearing material based on the lithology observed. The field change request and approval are documented in Field Change Request No. 5, dated October 19, 2020 (**Appendix E**).

A sand filter pack (12/20 washed silica) was placed around the annular space of the well screen from the bottom of the boring extending to a minimum height of 2 feet above the top of the well screen. A bentonite seal, at least 2-feet thick, was placed above the top of the sand pack. After the bentonite had been hydrated, a cement-bentonite grout was placed in the remaining annular space. Well construction materials were free of fluorine. Fluorine containing greases, bentonite, or other materials were not used. The monitoring well was finished with a flush-mount completion that included a metal well vault and concrete pad. A locking watertight cap was placed on the top of the PVC casing, and the well was labeled on the exterior of the well vault with a metal stamp indicating the well identification. A monitoring well completion diagram is provided in **Appendix D**.

2.4.5 Monitoring Well Development

Following construction, monitoring well WI-CV-MW18M was developed by the drilling subcontractor using a combination of bailing, surging, and pumping throughout the well screen in accordance with the applicable SOP included in the SAP. During monitoring well development, the CH2M field staff members measured field water quality parameters, including the potential of Hydrogen (pH), temperature, conductivity, and turbidity with a water quality meter. Well WI-CV-MW18M ran dry during development due to low recharge rates and was allowed to recharge to ensure the full screen interval was surged and bailed and then purged to the extent practicable (two total purges). Development was conducted for approximately 1.5 hours (excluding the surge and bail period). Surge blocks and pumps with Teflon parts were not used during development. Development information, including turbidity, pH, specific conductivity, temperature, and gallons of water removed were recorded as field notes. In addition, the water quality meter was calibrated prior to development, and the calibration results were recorded in the field documentation. The well development log is provided in **Appendix D**.

2.5 Investigation-derived Waste Management and Disposal

2.5.1 Phase 3

Wastes generated during the field activities were characterized as investigation-derived waste (IDW) and managed in accordance with the SAP and applicable SOPs as attached to the SAP. Wastes generated during the Phase 3 field activities included soil cuttings, well development groundwater, and decontamination rinse water from non-disposable development equipment and heavy equipment. Approximately 65 gallons of aqueous IDW were generated and containerized in a 300-gallon polyethylene tote. Approximately 1.75 cubic yards of solid IDW were generated and containerized in stainless-steel 55-gallon drums, which were properly labeled and staged with secondary containment. During off-Base drilling, IDW containers were stored adjacent to the drilling location; following well installation and development, the liquid and solid wastes were staged at OLF Coupeville. IDW containers were inspected weekly prior to the receipt of waste characterization data and have been inspected monthly thereafter.

Following installation and development of WI-CV-MW18M, waste characterization samples were collected from the tote and drums. Solid and aqueous IDW samples were analyzed for PFAS and full Toxicity Characteristic Leaching Procedure analyses (volatile organic compounds, semivolatile organic compounds, pesticides, and inorganic constituents), ignitability, reactive cyanide, reactive sulfide, and corrosivity. The waste characterization profiles are provided in **Appendix F**. Based on the analytical results, IDW generated during Phase 3 was identified as nonhazardous, and PFAS aqueous results were less than the USEPA lifetime health advisory of 70 nanograms per liter (ng/L) for the combined sum of PFOA and PFOS. However, due to increasing difficulty in identifying facilities able to accept any PFAS-containing water for disposal, the aqueous waste required solidification prior to disposal. Transport of waste to an off-site facility in Grand View, Idaho, for solidification and disposal was conducted on August 11, 2021.

\\dc1vs01\GISNavyClean\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Coupeville\Supplemental_SI\SSI_Addendum\Figure_2-1_Aquifer_Test_Layout.mxd11/4/2020DRUCKC

Legend

- Background Observation Well
- Test 1, Observation Well
- Test 1, Pumping Well
- Test 2, Observation Well
- Test 2, Pumping Well
- Base Boundary

Note:
Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.
OLF = Outlying Landing Field

N

0 0.05 0.1 Miles

1 inch = 0.1 mile

Imagery Source: Esri

Figure 2-1
Aquifer Test Layout
Supplemental Site Inspection Report Addendum
Naval Air Station Whidbey Island - Outlying Landing Field
Coupeville, Washington

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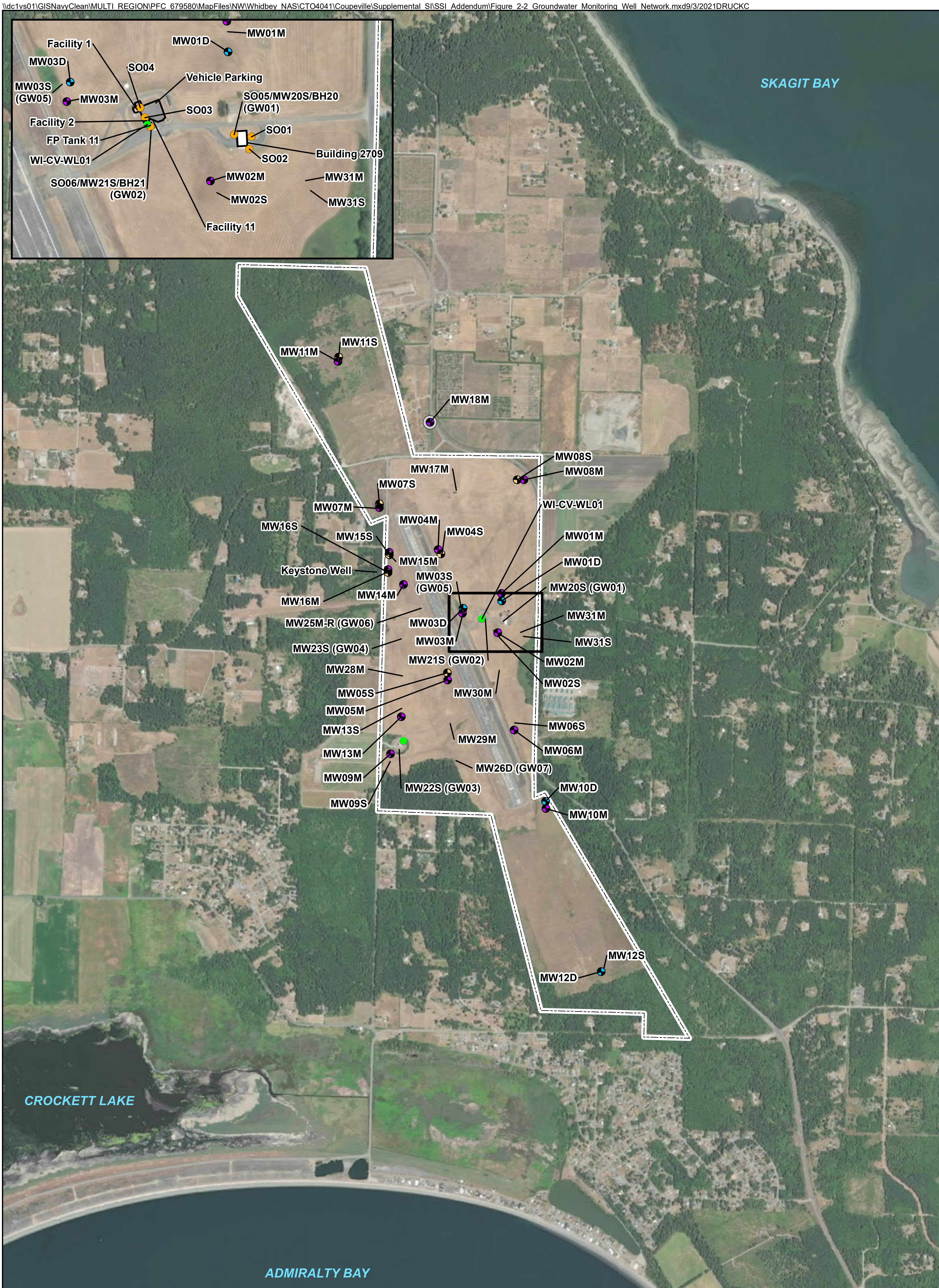


Legend

- Geotechnical Sample Location Co-located with Shallow Elevation Interval Monitoring Well
- Shallow Elevation Interval Monitoring Well
- Middle Elevation Interval Monitoring Well
- Deep Elevation Interval Monitoring Well
- Keystone Well
- Base Supply Well
- Supplemental Site Investigation Monitoring Well Installation
- Soil Boring
- Building/Structure Locations
- Base Boundary

Note:
Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.
Monitoring well MW25M-R is replacement well for MW25M (GW06), which was damaged following construction and required redrilling.
OLF = Outlying Landing Field

N

0 0.15 0.3 Miles

1 inch = 0.3 mile

Imagery Source: Esri

Figure 2-2
Groundwater Monitoring Well Network and Soil Boring Locations
Supplemental Site Inspection Report Addendum
Naval Air Station Whidbey Island - Outlying Landing Field
Coupeville, Washington

Numerical Modeling

The data collected during the OLF Supplemental SI field investigation were used to update and refine the Coupeville Groundwater Flow Model (CGFM), a three-dimensional (3D) numerical groundwater flow model for the OLF Coupeville area (CH2M, 2018b). This section documents the approach used to update and refine the model.

3.1 Previous Groundwater Flow Modeling

The CGFM was developed as part of the 2017-2018 expedited SI (CH2M, 2018b) as a tool to help inform groundwater flow at OLF Coupeville and to potentially assist in the analysis of future alternatives for PFAS remediation. This first iteration was constructed as a five-layer model encompassing the larger Coupeville area, extending to Puget Sound. Each model layer had approximately 86,000 active model cells, ranging in spacing from 40 to approximately 1,200 feet. The model incorporated lithologic data from boreholes at OLF Coupeville and a database of lithologic data throughout the Coupeville area to interpolate a subsurface distribution of hydraulic conductivity zones within the five-layer model.

Hydraulic parameters, including horizontal and vertical hydraulic conductivity values, groundwater recharge rates, evapotranspiration (ET) rates, extinction depth, storativity, specific yield, and conductance at the head-dependent boundaries, were optimized via autocalibration using Model-Independent Parameter Estimation (PEST) (Doherty, 2018). For each PEST iteration, the model underwent both a steady-state and a transient calibration. For the steady-state calibration, the model was calibrated to groundwater elevations measured at OLF Coupeville monitoring wells during a synoptic water level survey conducted April 15-16, 2020 (CH2M, 2021). For the transient calibration, the model was calibrated to drawdown observed at monitoring wells during the Keystone Well aquifer test. The calibration resulted in a model that provided a suitable representation of the groundwater system at OLF Coupeville, based on the understanding of the system and the available data at that time.

The model was used to estimate the effects of planned increases to the Keystone Well pumping rates from 150 to 300 gpm. This first iteration of the CGFM was configured to simulate groundwater flow only and did not include solute transport simulation capabilities. One of the uncertainties remaining following construction and calibration of the CGFM was the location of a groundwater divide on this portion of Whidbey Island. Calibration of the initial model suggested that the groundwater divide was located on OLF Coupeville. This resulted in simulated groundwater flow directions extending radially from this mound at OLF Coupeville, including easterly flow directions from the release areas. Easterly flow from potential release areas at OLF Coupeville was contradictory to the Conceptual Site Model (CSM), given that PFAS was not detected at elevated concentrations in samples collected from residential wells east of the Base.

3.2 Modeling Objectives

As described in the Supplemental SI Report (CH2M, 2021) and in Section 2 herein, field investigations were performed to confirm potential vadose zone PFAS sources and to help resolve uncertainties remaining from the previous CGFM construction/calibration effort. Groundwater level data collected from newly installed monitoring wells located in the eastern and northeastern portions of the Base indicated that the groundwater mound may be located further to the northeast than the original model suggested, and that groundwater flow from potential on-Base PFAS release areas is likely to the south/southwest rather than to the east as indicated by the previous CGFM. Furthermore, the objectives of the Supplemental SI included the development of a numerical model with solute transport capabilities, which the CGFM did not include. The objectives for updating and refining the CGFM were as follows:

- Recalibrate subsurface hydraulic parameters using newly acquired Supplemental SI data to better represent the inferred groundwater flow system at OLF Coupeville.

- Configure the model to support solute transport simulations and project future migration of PFOA and PFOS from their current locations via solute transport simulations.

The following sections describe the activities associated with the modeling effort to achieve these objectives. Because the updated model incorporates transport as well as flow simulation capabilities, the updated model will be referred to as the Coupeville Groundwater Model (CGM) to distinguish it from its predecessor, the CGFM, which simulated groundwater flow only.

3.3 Groundwater Flow Model Design Revisions

The updated CGM covers the same geographic domain and retains most of the design and construction elements of the original CGFM as detailed in the OLF Expedited SI Report (CH2M, 2018b). Furthermore, the CGM was developed using the same MODFLOW-NWT modeling code (Niswonger, et al., 2011; USGS, 2018) in conjunction with Groundwater Vistas (ESI, 2017) pre- and post-processing software package. However, the following revisions to the model design were necessary to accomplish the modeling objectives for the Supplemental SI.

- Increase the number of model layers.
- Refine and recalibrate the subsurface hydraulic parameters (hydraulic conductivity and storage).
- Update boundary conditions (wells and general head boundaries).
- Make minor adjustments to recharge and ET rates.

3.3.1 Updated Model Structure

The horizontal extent and discretization of the model grid (that is, model cell spacing) (**Figure 3-1**) was not altered from the CGFM (CH2M, 2018b). As described herein, the CGFM was constructed with five vertically stacked layers to provide a 3D representation of the subsurface system. Changes to the vertical layering of the updated CGM consisted of adding two layers by subdividing original Model Layers 4 and 5 into two layers for a total of seven model layers. This vertical refinement helped to achieve a better calibration of the groundwater flow system and was also necessary to minimize potential numerical dispersion during solute transport simulations. **Table 3-1** provides a summary of the updated model layering.

Table 3-1. Descriptions of Coupeville Groundwater Model Layers

Layer	Approximate Thickness (feet)	Description
1	90	Mostly dry layer to facilitate transmission of recharge to the lower layers
2	50	Shallow groundwater zone
3	40	Intermediate groundwater zone
4	35	Deep groundwater zone
5	35	
6	35	Basal aquitard
7	65	

3.3.2 Subsurface Hydraulic Parameters

Hydraulic Conductivity

For the CGFM, initial horizontal hydraulic conductivity (K_h) values were assigned based on available lithologic information, provided by Island County, for several hundred wells within the model domain. The details by which lithologic data was translated into hydraulic conductivities are detailed in the expedited SI Report (CH2M, 2018b). Vertical hydraulic conductivity (K_v) was computed on a layer-by-layer basis using an assumed K_h:K_v distribution (that is, the ratio of horizontal to vertical hydraulic conductivity, or anisotropy ratio). K_h values and K_h:K_v were further optimized during the calibration process (CH2M, 2018b).

Autocalibration via PEST included the flexibility to independently vary both K_h and K_h:K_v at a large number of individual points over a wide range of values across the model domain. This process resulted in calibrated K_h and K_h:K_v distributions which exhibited high degrees of variability among model cells, with adjacent model cells often differing by several orders of magnitude. This had the effect of creating sporadic, localized areas of high and low groundwater elevations in the simulated flow field that were not considered representative of the actual flow system at the site (particularly in the shallower model layers). Furthermore, these highly variable K_h and K_h:K_v distributions would likely have led to numerical instability problems when conducting solute transport simulations. To help simplify the K_h and K_h:K_v distributions in the updated CGM, a smoothing process was incorporated to provide smoother transitions between areas of high and low aquifer hydraulic conductivity. K_h and K_h:K_v values were further optimized in the current calibration process, as described in more detail in subsequent sections.

Storage

The calibrated storage parameters for the CGFM were 0.12 for specific yield and 5.3×10^{-5} for specific storage. These parameters were further adjusted during the calibration of the updated CGM. The calibration process (described in more detail below) for the CGM yielded values of 0.2 for specific yield and 7.6×10^{-5} for specific storage.

3.3.3 Boundary Conditions

Boundary conditions in the updated CGM include general head boundaries (GHBs, or head-dependent boundary conditions), specified-flux boundaries, and no-flow boundaries. Changes were not made to the no-flow boundaries; however, updates were made to the GHBs and the specified-flux boundaries.

General Head Boundaries

In the CGFM, head-dependent boundaries were assigned as GHBs to model cells in immediate offshore areas as illustrated on **Figure 3-2**. The reference heads were determined by equivalent freshwater heads of the offshore water column within each head-dependent flux boundary cell. The conductance terms were initially assigned based on assumed hydraulic conductivity values for coastal sediments but were further refined during the model calibration process. For the updated CGM, the GHB reference equivalent freshwater heads were recalculated based on tide levels coinciding with the timing of the April 15-16, 2020 synoptic water level survey at OLF Coupeville. Tidal elevations were obtained from a National Oceanographic and Atmospheric Administration buoy located near Port Angeles, which is the data station nearest to OLF Coupeville for which tide data can be tied to the North American Vertical Datum of 1988 (NAVD88) elevation datum. The equivalent freshwater heads were calculated assuming a salinity of 28,500 ppm (MacCready, 2017).

Well (Specified-Flux) Boundaries

As in the CGFM, pumping wells are simulated in the model as specified-flux boundaries assigned to cells corresponding to the location and depth of operational water supply wells. The CGFM included well boundaries for the Keystone Well and two wells at the Fort Casey Well Field. Recent information from the Town of Coupeville indicates that the Fort Casey Well Field no longer operates on a regular basis and that the large majority of the Town of Coupeville’s water comes from the Keystone Well (Grogan, pers. comm., 2020). Therefore, the Fort Casey Well Field was excluded from the calibration of the updated CGM; however, these wells were implemented in some post-calibration simulations. Updated steady-state pumping rates for the Keystone Well were provided by the Town of Coupeville, which indicated that the well was pumped at rates ranging from 235 to 240 gpm for 16 to 20 hours per day (a time-weighted average [continuous] pumping rate of approximately 185 gpm). Transient pumping rates for the 2018 Keystone Well aquifer test were obtained from ultrasonic flow meter readings collected during the December 2017/January 2018 Keystone Well aquifer test (CH2M, 2018b).

3.3.4 Recharge and Evapotranspiration Properties

As in the CGFM, deep percolation of precipitation (recharge) and ET rates were assigned to cells in Model Layer 1 covering the land surface (**Figure 3-2**) as specified-flux boundaries. Recharge rate zones and initial recharge rate estimates for each zone were obtained from a United States Geological Survey (USGS) study of recharge rates in Island County, Washington for water years 1998 and 1999 (USGS, 2004).The recharge and ET zones were not substantively modified between the CGFM and CGM. Recharge rates, ET rates, and ET extinction depths were refined during calibration of the original CGFM and again during calibration of the CGM.

3.4 Model Flow Recalibration

Model calibration is a process of systematically altering model input parameters to improve agreement between simulated and observed subsurface flow conditions measured in the field. This section discusses the calibration targets and results.

3.4.1 Calibration Targets

Calibration targets are the selected field-measured values that quantify hydrologic conditions of interest with consideration of data quality and reliability. CH2M used both steady-state and transient calibration targets to recalibrate the CGM. This subsection discusses the specific quantitative calibration targets selected for this effort.

Steady-state Groundwater Elevation Targets

Groundwater elevations from the Base-wide synoptic groundwater level survey conducted April 15-16, 2020 during Phase 2 of the Supplemental SI (CH2M, 2021) served as quantitative steady-state calibration targets (**Table 3-2**). Intermediate elevation zone monitoring well WI-CV-MW06M exhibits an anomalous groundwater elevation and was not considered in the calibration. Additionally, due to the complex nature of the groundwater elevation distribution in the discontinuous, perched shallow groundwater zone, accurately matching the groundwater elevations in Model Layer 2 was not considered feasible; therefore, wells in Model Layer 2 were evaluated during calibration, but were not considered when computing calibration statistics. A total of 27 steady-state calibration targets within Model Layers 3 through 5 were used for calibration. **Figure 3-3** shows the locations and groundwater elevations for steady-state calibration targets. These groundwater elevations represent the most current groundwater elevation data available for OLF Coupeville.

Table 3-2. Steady-State Calibration Targets

Well ID[1]	Model Layer	Groundwater Elevation[2] (feet NAVD88)
WI-CV-MW01D	4	53.68
WI-CV-MW01M	3	70.39
WI-CV-MW02M	3	69.56
WI-CV-MW03D	5	51.59
WI-CV-MW03M	3	69.31
WI-CV-MW04M	3	69.29
WI-CV-MW05M	3	66.97
WI-CV-MW06M[3]	3	51.27
WI-CV-MW07M	4	69.45
WI-CV-MW08M	3	82.75
WI-CV-MW09M	3	61.28
WI-CV-MW10D	4	47.03
WI-CV-MW10M	3	52.16

Table 3-2. Steady-State Calibration Targets

Well ID[1]	Model Layer	Groundwater Elevation[2] (feet NAVD88)
WI-CV-MW11M	3	71.11
WI-CV-MW12D	4	26.00
WI-CV-MW13M	3	61.84
WI-CV-MW14M	3	67.44
WI-CV-MW15M	3	66.59
WI-CV-MW15S	3	66.57
WI-CV-MW16M	3	64.67
WI-CV-MW16S	3	64.68
WI-CV-MW17M	3	71.18
WI-CV-MW25M	3	68.11
WI-CV-MW26D	4	47.10
WI-CV-MW28M	3	63.64
WI-CV-MW29M	3	61.48
WI-CV-MW30M	3	67.75
WI-CV-MW31M	3	69.81

Notes:

1 Layer 2 wells are not presented in the table as these wells were not considered in autocalibration.

2 Groundwater elevations refer to the April 15-16, 2020 synoptic groundwater level survey.

3 Groundwater level measured at WI-CV-MW06M is anomalous and was not included in autocalibration.

Groundwater Flow Direction Targets

While not previously used in the calibration of the CGFM, inferred groundwater flow directions in the intermediate elevation interval were used as qualitative calibration targets for the CGM. Groundwater flow direction targets were primarily incorporated to help improve model calibration in areas where quantitative groundwater elevation targets (that is, groundwater level measurements in wells) are unavailable (primarily east of OLF Coupeville). Groundwater flow direction targets were established based on the inferred groundwater elevation contours developed from groundwater elevations from the April 15-16, 2020 synoptic groundwater level survey. Groundwater flow direction targets were placed along transects, at approximate right angles to groundwater elevation contours.

Transient Drawdown Targets

Continuous groundwater level data from ten wells (nine on-Base monitoring wells and the Keystone Well) collected during the 2017/2018 Keystone Well aquifer test (CH2M, 2018b) were used as quantitative targets for the transient CGM recalibration. The locations of the transient target wells are shown on **Figure 3-3**. To replicate the variability in groundwater levels and Keystone Well pumping rates that occurred over the 41-hour transient calibration period, it was necessary to subdivide the 41-hour period into a discrete number of model stress periods. The groundwater elevations and Keystone Well pumping rate were assumed to be constant within each stress period. As shown in **Table 3-3**, the transient conditions were simulated by subdividing the 41 hours into 12 discrete stress periods. Average groundwater elevations were calculated for each stress period and then the cumulative drawdowns from the static groundwater elevation were computed. These computed drawdowns were used as quantitative target values for the transient calibration.

Table 3-3. Transient Calibration Targets – 2017/2018 Keystone Well Aquifer Test

Stress Period	Drawdown (feet)									
	Keystone Well	WI-CV-MW04M	WI-CV-MW04S	WI-CV-MW07M	WI-CV-MW07S	WI-CV-MW14M	WI-CV-MW15M	WI-CV-MW15S	WI-CV-MW16M	WI-CV-MW16S
2	0	0	0	0	0	0	0	0	0	0
3	6.96	0	0	0	0	0.2	0.56	0.57	1.32	1.32
4	7.72	0	0	0	0	0.32	0.69	0.71	1.54	1.54
5	8.16	0	0	0	0	0.35	0.74	0.76	1.63	1.64
6	8.51	0	0	0	0	0.35	0.75	0.77	1.68	1.69
7	8.82	0	0	0	0	0.37	0.8	0.82	1.76	1.76
8	3.45	0	0	0	0	0.33	0.48	0.49	0.88	0.91
9	6.62	0	0	0	0	0.22	0.56	0.58	1.29	1.3
10	7.27	0	0	0	0	0.25	0.64	0.66	1.44	1.45
11	7.73	0	0	0	0	0.29	0.7	0.72	1.54	1.55
12	8.17	0	0	0	0	0.33	0.76	0.78	1.65	1.65
13	8.49	0	0	0	0	0.36	0.79	0.81	1.71	1.71

The results of the 2020 WI-CV-MW31M and WI-CV-MW29M aquifer tests were used to confirm the quality of model calibration. As shown in **Table 3-4a** and **Table 3-4b**, each test was divided into three stress periods representing the baseline period, the 14-hour pumping period, and the recovery period. An average constant pumping rate, based on field-measured values, was assumed over the pumping period for each test (4.1 gpm for WI-CV-MW31M and 2.2 gpm for WI-CV-MW29M).

Table 3-4a. Transient Calibration Targets – WI-CV-MW31M Aquifer Test

Stress Period	Elapsed Time (days)	Drawdown (feet)							
		WI-CV-MW31M	WI-CV-MW30M	WI-CV-MW02M	WI-CV-MW02S	WI-CV-MW20S	WI-CV-MW01M	WI-CV-MW01D	WI-CV-MW08M
1	0.1	0	0	0	0	0	0	0	0
1	0.2	0	0	0	0	0	0	0	0
1	0.276	-0.0012	0	0	0	0	0	0	0
2	0.285	16.51	0	0	0	0	0	0	0
2	0.4	16.63	0	0	0	0	0	0	0
2	0.5	16.76	0	0	0	0	0	0	0
2	0.65	16.78	0	0	0	0	0	0	0
2	0.835	16.88	0	0	0	0	0	0	0
3	0.875	-0.147	0	0	0	0	0	0	0
3	1	-0.1678	0	0	0	0	0	0	0
3	1.2	-0.1736	0	0	0	0	0	0	0
3	1.3	-0.1694	0	0	0	0	0	0	0

Table 3-4b. Transient Calibration Targets – WI-CV-MW29M Aquifer Test

		Drawdown (feet)						
Stress Period	Elapsed Time (days)	WI-CV-MW29M	WI-CV-MW05M	WI-CV-MW05S	WI-CV-MW13M	WI-CV-MW13S	WI-CV-MW26D	WI-CV-MW08M
1	0.1	0	0	0	0	0	0	0
1	0.2	0	0	0	0	0	0	0
1	0.265	0.0082	0	0	0	0	0	0
2	0.285	29.31	0	0	0	0	0	0
2	0.4	31.02	0	0	0	0	0	0
2	0.5	31.32	0	0	0	0	0	0
2	0.65	31.73	0	0	0	0	0	0
2	0.834	32.23	0	0	0	0	0	0
3	0.875	0.0276	0	0	0	0	0	0
3	1	0.0216	0	0	0	0	0	0
3	0.2	0.0195	0	0	0	0	0	0
3	1.3	0.0156	0	0	0	0	0	0

3.4.2 Calibration Procedure

Autocalibration of the updated CGM was performed using the PEST software program (Doherty, 2018). This program was used to refine model parameters to obtain the best set of parameters to match the steady-state and transient calibration targets. Parameters that were allowed to vary within user-defined ranges during the PEST autocalibration effort were: K_h; K_h:K_v; specific yield and storage coefficient; recharge rate; ET rate and extinction depth; and hydraulic conductance at the GHBs along the island perimeter. During each PEST run, the model was run hundreds of times, with the program independently varying the assumed distributions of the model parameters listed above and seeking to minimize the error between the simulated groundwater elevations and the observed steady-state and transient calibration targets.

As described herein, the recalibration process incorporated steps to "smooth" the K_h distributions across the model domain. To accomplish this goal, a base network of pilot points was established. Pilot points are locations that are assigned a specific K_h value that PEST is able to vary over a user-defined range during calibration. In general, pilot points were distributed across the model domain to capture regional-scale variations in lithology based on the Island County and OLF Coupeville boring log information. For example, pilot points were included to represent regions of predominantly sand, silt, gravel, clay, and similar. Pilot points were also included mid-way between quantitative calibration target locations (that is, monitoring wells) to provide PEST flexibility to optimize K_h and improve calibration at a local scale. Initial K_h estimates and reasonable ranges (upper/lower bounds) of K_h values were assigned at each pilot point. During calibration, PEST modified the K_h values at one or more pilot points during a given PEST optimization iteration. Each time K_h values were modified, kriging was performed to interpolate a smooth K_h distribution across the model domain. This process was performed for each model layer independently. The other calibration parameters were optimized as follows:

- K_h:K_v ratios varied layer by layer. That is, a single K_h:K_v was assigned to each model layer (no variability across a given model layer).
- Recharge rate was allowed to vary by recharge zone (generally consistent with the zones identified in USGS, 2004). The upper bound of the recharge rate was that included in the USGS report. The exception was the OLF

Coupeville portion of the model, where PEST was given a slightly higher upper bound to the recharge rate based on the lack of trees that would serve to limit deep percolation of precipitation.

- ET rate and extinction depth were varied during the process within two zones: the OLF Coupeville portion and the remainder of the model domain.
- Specific yield and specific storage were varied on a model-wide basis. That is, a single value for specific yield and/or specific storage was included for all model layers/cells.

Because two calibration data sets (steady-state and transient) were used in the model calibration, it was necessary to run both sets of conditions through the model in a single model run so that a single set of aquifer parameters was obtained from PEST that provided the optimal match to both sets of calibration targets. This was achieved by running an initial stress period in the model that simulated steady-state conditions and attempted to match the steady-state calibration targets. This was followed by 12 stress periods assuming transient conditions that attempted to match the change in groundwater levels (that is, drawdown) that were observed during the 2017/2018 Keystone Well aquifer test.

Drawdown observations from the WI-CV-MW31M and WI-CV-MW29M aquifer tests were not used as targets for autocalibration; however, these observations were used as an additional check on the calibrated model parameters. The calibrated model parameters were implemented into separate transient simulations of the two aquifer tests, and the simulated results were compared to the observed data to verify the overall ability of the calibrated CGM to replicate the tests.

3.4.3 Calibration Results

Steady-State Groundwater Elevations

Mapped steady-state groundwater level residuals for the shallow, intermediate, and deep zones (Model Layers 2, 3, and 4, respectively) are shown on **Figure 3-4** through **Figure 3-6**. Residuals were computed as the simulated groundwater elevation minus the observed groundwater elevation; therefore, positive residuals indicate that the model is simulating high in a given area while negative residuals indicate that the model is simulating low. **Figure 3-5** and **Figure 3-6** also include simulated groundwater elevation contours for the intermediate and deep zones. Overall, strong agreement was achieved between observed and simulated groundwater elevations in the intermediate and deep zones with residuals generally less than ±2 feet at most locations. Residuals in the shallow zone (Model Layer 2) are larger (ranging from approximately 40 feet low to 30 feet high) because the CGM is not configured to simulate the complexity of a discontinuous, perched groundwater system. **Figure 3-7** shows a graph comparing observed versus simulated groundwater levels with the dark line representing a perfect match between observed and simulated levels.

Groundwater elevations in the calibrated CGM are consistent with the CSM in that the area of highest groundwater elevation, referred to as the groundwater mound, is located off-Base to the northeast (**Figure 3-5**). Additionally, to achieve the improved calibration, it was necessary to move the steady-state groundwater elevation targets corresponding to monitoring wells WI-CV-MW09M and WI-CV-MW13M from Model Layer 4 to Model Layer 3. These wells, located in the southwest portion of OLF Coupeville, are screened in a transition zone between the intermediate and deep intervals. These had previously been assigned to Model Layer 4 (deep zone) based on screen elevation; however, the groundwater elevations in these wells are more consistent with intermediate-zone groundwater elevations in Model Layer 3.

Steady-state calibration statistics are provided on **Figure 3-7**. The mean error between simulated and observed groundwater levels is -0.04 foot, and the root mean square (RMS) error is 2.13 feet (excluding WI-CV-MW06M). A key measure of calibration quality often used to evaluate groundwater models is the RMS error divided by the range of measured groundwater level data used in the calibration. For a regional-scale model, such as the CGM, a standard rule of thumb is that the RMS/range value should be less than or equal to 10 percent. The RMS/range value for the calibrated CGM (excluding the shallow zone wells and WI-CV-MW06M) is 3.8 percent, well below the target value of 10 percent, showing that the model is well calibrated.

Transient Response to Keystone Well Pumping

The second portion of calibration consisted of comparing the simulated and observed drawdown in groundwater levels created by the operation of the Keystone Well at the ten instrumented wells during the 41-hour transient calibration period. The comparisons between simulated and observed drawdowns are summarized on **Figure 3-8a** and **Figure 3-8b**. These results clearly indicate that the drawdowns predicted by the model over the transient calibration period are in very close agreement with those measured in the field during the aquifer test. The only well with significant deviation is the Keystone Well, where simulated drawdowns are less than observed drawdowns. This is to be expected as the Keystone Well was pumping during the aquifer test, and due to inefficiencies inherent in well construction, the drawdown measured in the well casing is typically much greater than the drawdown in the aquifer outside of the well. The model forecasts do not account for well inefficiency and the model distributes pumping over the entire cell (40 feet by 40 feet, as opposed to a well diameter of 12 inches); therefore, it would be expected that the model predicts a smaller magnitude of drawdown than what is measured in the well.

Simulation of WI-CV-MW31M and WI-CV-MW29M Aquifer Tests

The WI-CV-MW31M and WI-CV-MW29M aquifer tests were simulated as an additional check on the calibration of the CGM. The simulated drawdown at each well instrumented during the two tests was compared to the observed drawdown at those wells. The comparisons between simulated and observed drawdowns are summarized on **Figures 3-9a-b** and **Figures 3-10a-b**. The observation that no discernable drawdown occurred at any observation well is closely mirrored by the simulated drawdowns. Simulated drawdowns at the pumping wells are much lower than observed; however, as stated in the context of the Keystone Well aquifer test, the model does not account for well inefficiencies or the discrepancy between the well diameter and the size of the model cell to which pumping is assigned. Given that WI-CV-MW31M and WI-CV-MW29M were designed primarily as monitoring wells, a significant degree of inefficiency resulting in greater deviation between observed and simulated drawdown is not unexpected.

Calibrated Hydraulic Parameters

The autocalibration process yielded a single set of aquifer parameters and boundary conditions that provided the comparisons shown between simulated and observed groundwater levels. These sets of aquifer parameters and boundary condition properties are summarized as follows.

Figure 3-11 presents the distribution of aquifer K_h for each of the seven model layers. The K_h value for most of the aquifer material (Model Layers 2 through 4) falls between 1 and 100 feet per day, which is the range for sand to gravelly sand. The figure also shows a trend of decreasing K_h with depth, which is consistent with observations of a greater percentage of fine-grained material deeper within the aquifer system than what is seen at shallower depths.

The distribution of the magnitude of the deep percolation of precipitation (aquifer recharge) across the model domain, ranging from 0 to approximately 14 inches per year, is shown on **Figure 3-12**. This range deviates only slightly from the values reported by the 2004 USGS study (USGS, 2004) which reported a range of between 0 and 12 inches per year. The recharge zones were also not significantly modified from their original geometry as taken from the same USGS study. As expected, the deep percolation rate is higher in areas surrounding OLF Coupeville as most, if not all, of the significant vegetation has been removed in these areas, reducing the canopy interception of precipitation by leaves and allowing for higher recharge rates.

The distribution of active ET of shallow groundwater by plants is depicted on **Figure 3-13**. Due to the significant depth to groundwater over much of the model domain, the only areas where groundwater is shallow enough to be transpired directly by plants is around the model perimeter. The final ET rate simulated in the model where ET is active is approximately 30 inches per year with ET extinction depth (the depth below which ET does not occur) of 10 feet bgs.

3.4.4 Evaluation of Pre-Keystone Well Flow Field

The CGM was used in particle tracking simulations to evaluate past and present potential PFAS transport directions from the release areas east of the OLF Coupeville runway. Two total simulations were run: one under present-day pumping conditions (that is, with only the Keystone Well pumping for the Town of Coupeville municipal supply) and a second under pumping conditions as they were prior to the installation of the Keystone Well in 2008. Updated steady-state pumping rates for the Keystone Well were provided by the Town of Coupeville, which indicated that the well is pumped at rates ranging from 235 to 240 gpm for 16 to 20 hours per day, corresponding to a time-weighted average continuous pumping rate of approximately 185 gpm. Pre-2008 pumping conditions were represented with two wells pumping at the Fort Casey Well Field, southwest of OLF Coupeville. Pumping rates for the Fort Casey Well Field wells provided by the Town of Coupeville were 32 gpm for well 1-06 and 23 gpm for well 1-90. For the purposes of particle tracking, flow paths were started in the mid-point of Model Layer 2 in cells encompassing the approximate geographic area of the PFAS release areas east of the runway. Groundwater flow paths were tracked forward in time to the ultimate discharge point with an assumed effective aquifer porosity of 0.1. **Figure 3-14** shows forward-tracked simulated groundwater flow paths under present-day pumping conditions. **Figure 3-15** shows forward-tracked simulated groundwater flow paths under pre-2008 pumping conditions. Both simulations show that the primary groundwater flow direction from these areas is to the south (consistent with locations where elevated PFAS concentrations are present in residential drinking water wells). The simulations performed with the updated CGM indicate that there is not a significant eastward component of flow in the revised/updated numerical model; however, the model does indicate southeasterly flow toward the southeast end of the Base.

The present-day flow paths on **Figure 3-14** show some flowlines being pulled to the west, presumably due to the influence of pumping at the Keystone Well; however, the flowlines turn back to the south before reaching the Keystone Well which indicates that groundwater from the release areas is not captured by pumping at the Keystone Well, as confirmed by observations during the 2018 Keystone Well aquifer test (CH2M, 2018b). However, the modeled flowlines do indicate that there is a significant westerly component to flow directions from the release areas induced by pumping at the Keystone Well. This would suggest that groundwater flow at the on-Base release areas is influenced but not captured by pumping at the Keystone Well. The pre-2008 flow paths on **Figure 3-15** do not show any flowlines moving to the west toward the Keystone Well. Instead, all flow lines run south, with some flow being captured by the Fort Casey Wells. This would suggest that the westerly component of flow did not exist prior to 2008 and that over most of the timeframe following introduction of PFAS to the subsurface at OLF Coupeville, groundwater flow was predominantly to the south. This interpretation of historic flow direction also supports the hypothesis that the presence of PFAS in wells on the northwest end of the runway and near the Keystone Well are from a potential source separate from the sources east of the runway.

3.5 Vadose Zone Solute Transport

Vadose zone solute transport modeling was performed to simulate loading of PFOA and PFOS from vadose zone soils at on-Base release areas to the groundwater system. These simulations provide estimates of the continuous contribution of these sources to the PFOA and PFOS groundwater plumes to support predictive saturated zone solute transport modeling. The data for the development of the vadose zone model were obtained from soil borings drilled during Phase 1 of the OLF Coupeville Supplemental SI (CH2M, 2021). Data from monitoring well WI-CV-MW20S were used to inform subsurface conditions near the Building 2709 release area, and data from monitoring well WI-CV-MW21S were used in a similar fashion to assign model parameters near the Facilities 1, 2, and 11 release area.

3.5.1 Code Selection

The analysis was performed using HYDRUS-1D for groundwater flow and solute transport (Šimůnek et al., 2013). HYDRUS-1D numerically solves the Richards equation for variably saturated flow and advection-dispersion equations for solute transport in one dimension (1D). The HYDRUS-1D code was selected for the following reasons:

- HYDRUS-1D is in the public domain, a product of more than 10 years of development, is in wide use, and is well supported and documented.
- HYDRUS-1D provides the option of simulating dual-domain transport processes. This allows for the inclusion of the effects of back-diffusion of contaminant mass from hydraulically isolated mass storage zones in the subsurface (dead-end pore space), which tends to prolong the persistence of contaminant source areas.

3.5.2 Grid Construction

1D vertical soil profiles were constructed for each vadose zone source (that is, a single profile for WI-CV-MW20S and a single profile for WI-CV-MW21S). The simulated soil profile lengths represent the depth from ground surface to the water table in each of the release areas, which were 95 and 100 feet bgs for WI-CV-MW20S and WI-CV-MW21S, respectively. The 95 to 100-foot vadose zone profiles were discretized into model cells of equal thickness of 0.1 foot for a total of 950 and 1,000 cells, respectively.

3.5.3 Subsurface Hydraulic Parameters

Lithologic information observed in the soil boring logs for WI-CV-MW20S and WI-CV-MW21S were used to assign soil types (that is, sand, silt, clay, gravel, and similar) within the soil profiles (see CH2M, 2021, for soil boring logs). Soil boring logs indicate that the vadose zone underlying the potential soil source is variable, ranging from clays to gravels. **Table 3-5** summarizes the soil-specific parameters assigned to the vadose zone profiles for general soil classes. These general soil classes encompass variations for the Unified Soil Classification System (that is, sands include well graded, poorly graded, and silty sands, and similar). Soil-specific parameters were derived from site-specific geotechnical samples (**Table 2-3**), the default soil property catalog included in HYDRUS-1D (Carsel and Parrish, 1998), or literature values.

Table 3-5. HYDRUS-1D Soil-Specific Input Parameters

Parameter	Clays	Silts[1]	Sands	Gravels	Source
Residual soil water content, mobile domain (-)	0.068	0.034	0.045 to 0.065	0.01 to 0.02	Carsel and Parrish (1988)
Residual soil water content, immobile domain (-)	0	0	0	0	Carsel and Parrish (1988)
Saturated Hydraulic Conductivity (m/d)	0.048[a]	0.06[a]	1.061 to 7.128[a]	86.4 to 432[b]	[a]Carsel and Parrish (1988) [b]Freeze and Cherry (1979)
Total Porosity (-)	0.45[b]	0.37[a]	0.355[a]	0.30[b]	[a]Laboratory derived (**Table 2-3**) [b]Freeze and Cherry (1979)
Mobile Porosity	0.1	0.1	0.1	0.1	Laboratory derived (**Table 2-3**)
Immobile Porosity	0.35	0.27	0.255	0.2	Computed (total porosity minus mobile porosity)
van Genuchten's alpha (m^{-1})	0.8[a]	1.6[a]	7.5 to 14.5[a]	16 to 20[b]	[a]Carsel and Parrish (1988) [b]Šimůnek (2016)
van Genuchten's n (-)	1.09[a]	1.37[a]	1.89 to 2.68[a]	2.9 to 3.0[b]	[a]Carsel and Parrish (1988) [b]Šimůnek (2016)
Tortuosity (-)	0.5	0.5	0.5	0.5	Carsel and Parrish (1988)
Soil bulk density (g/cm^3)	1.4575[b]	1.67[a]	1.71[a]	1.855[b]	[a]Laboratory derived (**Table 2-3**) [b]Computed from total porosity via Equation 1
Longitudinal dispersivity (m)	1	1	1	1	Assumed
Fraction of organic carbon (-)	0.00773	0.00773	0.00773	0.00773	Laboratory derived (**Table 2-3**), average

Table 3-5. HYDRUS-1D Soil-Specific Input Parameters

Parameter	Clays	Silts[1]	Sands	Gravels	Source
Mass transfer coefficient for moisture (days^{-1})	0.86	0.86	0.86	0.86	Assumed, derived from Šimůnek, J., M.T. et.al. (2008)

Notes:

[a] and [b] designations for a given parameter correlate to the reference for the value in the associated Source column.

[1] Includes sandy silts

g/cm^3 = grams per cubic centimeter

m = meters

m/d = meters per day

Equation (1): Bulk Density = (1 – Total Porosity) * Particle Density (assumed to be 2.65 g/cm^3)

3.5.4 Solute Transport Parameters

HYDRUS-1D was set up to solve the advection-dispersion transport equation with dual-domain mass transfer to simulate PFOA and PFOS transport in the vadose zone within the Building 2709 and Facilities 1, 2, and 11 release areas adjacent to WI-CV-MW20S and WI-CV-MW21S, respectively. The dual-domain transport formulation involves advection-dispersion in the mobile domain and diffusion to/from the immobile domain (that is, dead-end pore space). This formulation was implemented to more accurately account for transport processes with the goal of improving the predictive capabilities over what would have been achieved with a traditional single-domain transport formulation. Solute-specific input parameters are listed in **Table 3-6** and were primarily derived from the literature. Because PFAS constituents are generally conservative (that is, not susceptible to biodegradation) and non-volatile, parameters associated with these processes were omitted from the transport simulations. Additionally, the soil organic carbon-water partition coefficient (K_{oc}) is generally used to simulate the interaction between the solute and the subsurface organic aquifer solids. For the purposes of PFOA and PFOS transport, K_{oc} is considered an “effective” adsorption term, controlling the interaction between the solutes at the air-water interface as well as the interaction between the solutes and the subsurface organic materials. There is still a great deal of uncertainty associated with the adsorptive properties of PFAS which can be important to fate and transport in some lithologies; however the approach described herein uses current estimates of overall K_{oc} values for PFAS in variably saturated conditions developed by the scientific community for modeling PFAS transport.

Table 3-6. HYDRUS-1D Solute-Specific Input Parameters

Parameter	PFOA	PFOS	Source
K_{oc} (mL/g)	108	568	Brusseau (2018)
K_d (mL/g)	0.8352	4.39253	Computed as K_{oc} * f_{oc}
Henry’s Law Constant (-)	0	0	Assumed to be negligible for PFOA/PFOS
Molecular diffusion coefficient in water (m^2/d)	4.67 x 10^{-5}	4.67 x 10^{-5}	Guo, et. al. (2020)
Molecular diffusion coefficient in air (m^2/d)	0	0	Assumed to be negligible for PFOA/PFOS
Biodegradation half-life (days)	0	0	Assumed to be negligible for PFOA/PFOS
Mass transfer coefficient for solute (days^{-1})	4.56 x 10^{-5}	4.56 x 10^{-5}	Computed as 1/emplacement time (assumed to be 60 years [21,915 days])

Notes:

K_d = Distribution coefficient

K_{oc} = Soil organic carbon-water partition coefficient

m^2/d = square meters per day

mL/g = milliliters per gram

3.5.5 Initial Concentrations

Initial PFOA and PFOS soil concentrations in the simulated soil profiles are based on PFAS analytical results of soil samples collected from soil borings SO01 through SO06 (a total of 31 soil samples). For a given release area, the maximum PFOA or PFOS concentration among the three soil borings for a given depth interval was assigned to the HYDRUS-1D profile. For example, the PFOS concentration in the 0.5 to 1.0 foot bgs sample interval at the Facilities 1, 2, and 11 release area (adjacent to WI-CV-MW21S) was 802,000 nanograms per kilogram (ng/kg) at SO04 and 4,920 ng/kg at SO06 (CH2M, 2021). The higher of the two available results for this sample depth interval was assigned to the HYDRUS-1D profile. For computational purposes, non-detect results were assigned a concentration equal to one-half the reporting limit. Assigned concentrations were assumed to extend at a constant concentration from the mid-point between the sample above to the mid-point of the sample below (that is, no interpolation of concentrations between consecutive discrete sample depths). Initial PFOA and PFOS concentrations for the WI-CV-MW20S and WI-CV-MW21S HYDRUS-1D profiles are presented in **Table 3-7** and **Table 3-8**, respectively. The initial concentration profiles indicate that PFOA and PFOS concentrations in the sample intervals directly above the water table (near the bottom of the profiles) are approximately 2 to 3 orders of magnitude lower than the maximum concentrations observed at shallower depths.

Table 3-7. Initial Soil Concentration, WI-CV-MW20S (Building 2709 Release Area)

Depth (feet bgs)	PFOA Concentration (ng/kg)	PFOS Concentration (ng/kg)
0 – 0.9	555	51,300
1.0 – 7.0	4,100	101,000
7.1 – 18.0	560	34,700
18.1 – 24.0	1,075	19,900
24.1 – 31.5	535	535
31.6 – 39.9	505	9,890
40.0 – 44.9	1,085	60,000
45.0 – 59.5	3,850	44,800
59.6 – 72.0	1,090	478,000
72.1 – 76.9	810	20,100
77.0 – 86.0	1,020	1,020
86.1 – 93.5	990	5,370
93.6 – 95.0	1,260	1,260

Table 3-8. Initial Soil Concentration, WI-CV-MW21S (Facilities 1, 2, and 11 Release Area)

Depth (feet bgs)	PFOA Concentration (ng/kg)	PFOS Concentration (ng/kg)
0.0 – 1.5	4,590	802,000
1.6 – 2.9	71,700	23,900
3.0 – 7.5	2,410	936,000
7.6 – 18.0	870	136,000
18.1 – 25.5	520	16,900
25.6 – 33.0	1,900	520
33.1 – 44.4	575	575
44.5 – 53.5	8,340	402,000

Table 3-8. Initial Soil Concentration, WI-CV-MW21S (Facilities 1, 2, and 11 Release Area)

Depth (feet bgs)	PFOA Concentration (ng/kg)	PFOS Concentration (ng/kg)
53.6 – 59.9	74,700	33,100
60.0 – 66.5	23,100	102,000
66.6 – 71.5	1,640	12,500
71.6 – 75.4	2,940	560
75.5 – 85.0	10,900	560
85.1 – 93.9	1,440	550
94.0 - 100	9,470	570

3.5.6 Boundary Conditions

The upper boundary condition of each HYDRUS-1D profile was specified as a constant flux, reflecting the deep percolation of precipitation at the site. The value assigned to each profile (approximately 13.5 inches per year) was obtained from the calibrated CGM model described in Sections 3.1 through 3.4. The bottom boundary of the model was assigned a constant pressure head of 0 feet to represent the water table.

Solute transport boundary conditions at the upper boundaries were set to a concentration flux of zero based on the assumption that additional PFOA and/or PFOS will not be released. The solute transport boundary condition at the lower boundaries was set to a zero-concentration gradient.

3.5.7 Time Discretization

The model was designed to simulate steady-state hydraulic conditions and a 100-year solute transport timeframe. To establish steady-state moisture conditions in the vadose zone, each profile was initially parameterized with the values reported in **Table 3-5** and initial conditions described in Sections 3.5.5 and 3.5.6. The HYDRUS-1D models were then run for a 100-year timeframe. The resultant pressure head profile at the end of this simulation was assumed to represent steady-state conditions in the vadose zone. These pressure head profiles were input as initial conditions to a second simulation for each HYDRUS-1D profile and the simulations were run for a 100-year period to estimate future transport of PFOA and PFOS.

3.5.8 Results

Figure 3-16 and **Figure 3-17** present the simulated PFOA and PFOS concentrations reaching the water table over time within the Building 2709 and Facilities 1, 2, and 11 release areas adjacent to WI-CV-MW20S and WI-CV-MW21S, respectively. Model output based on the parameterization of the HYDRUS-1D profiles suggest a time lag in the arrival of peak PFOA and/or PFOS concentrations at the water table beneath both release areas. As shown in **Table 3-7** and **Table 3-8**, relatively lower concentrations of PFOA and PFOS are in the lower 20 to 30 feet of the soil profiles. As such, a delay exists in the time for the higher PFOA and/or PFOS concentrations at shallower depths to migrate through the vadose zone to the water table. This result is inconsistent with the observation of elevated PFAS concentrations already present in the underlying groundwater in these areas.

As shown on **Figure 3-16**, the maximum concentration of PFOA is simulated as reaching the water table after approximately 10 to 15 years of transport. The simulated maximum concentration reaching the water table at well WI-CV-MW20S (the Building 2709 release area) is estimated to be approximately 3,000 ng/L, while the maximum concentration at well WI-CV-MW21S (the Facilities 1, 2, and 11 release area) is nearly 18,000 ng/L. The differences in the simulated concentrations reaching the water table are a function of lower PFOA concentrations in samples collected at soil borings in the Building 2709 release area adjacent to WI-CV-MW20S as compared to those collected in borings from the Facilities 1, 2, and 11 release area adjacent to WI-CV-MW21S (**Table 3-7** and **Table 3-8**).

HYDRUS-1D simulations show that the maximum PFOS concentrations are forecast to reach the water table after approximately 45 to 70 years of transport (**Figure 3-17**). The longer delay in the arrival of peak PFOS concentrations, as compared to PFOA, is a result of the higher K_{oc} value assigned for PFOS (meaning that PFOS is more strongly adsorbed to organic matter and at air-water interfaces in the vadose zone than PFOA). Maximum concentrations of PFOS of approximately 37,000 and 17,000 ng/L are simulated to reach the water table within the release areas adjacent to WI-CV-MW20S and WI-CV-MW21S, respectively. These higher concentrations are consistent with the higher concentrations of PFOS in soil samples as compared to PFOA. The “plateau” of the simulated PFOS curve for the Facilities 1, 2, and 11 release area adjacent to WI-CV-MW21S is a result of the high PFOS concentrations (over 800,000 ng/kg) within the upper 10 feet of the soil profile. The HYDRUS-1D results suggest that this mass was still reaching the water table after 100 years of transport and that breakthrough had not yet occurred.

3.6 Saturated Zone Solute Transport Model

3.6.1 Code Selection

Fate and transport of PFOA and PFOS in the saturated zone was simulated using MT3D-USGS (USGS, 2016). MT3D-USGS is a modular 3D transport model for the simulation of advection, dispersion, and chemical reactions of dissolved constituents within groundwater systems. MT3D-USGS is used in conjunction with MODFLOW-2005 in a step-wise groundwater flow and transport simulation. Groundwater elevations and cell-by-cell flux terms are computed by MODFLOW-NWT during the flow simulation and are then read by MT3D-USGS and used as the flow field for the transport portion of the simulation.

3.6.2 Model Grid and Parameterization

PFOA and PFOS solute transport was simulated using the CGM grid and revised/recalibrated hydraulic input parameters (that is, K_h, boundary conditions, and similar) described in Sections 3.3 and 3.4. Consistent with the vadose zone modeling described herein, solute transport in the saturated zone was simulated with a dual-porosity formulation assuming no biodegradation or volatilization. Total porosity of 0.355 and mobile porosity of 0.1 (consistent with site-specific geotechnical samples for sand shown in **Table 2-3**) were assigned to the entire model domain. Available literature suggests that the “effective” K_{oc} for PFOS in saturated systems is lower than in the vadose zone due to the absence of processes such as sorption at the air-water interface. The understanding of the transport properties of PFAS is continually evolving as research on the topic continues. As such, a wide range of K_{oc} values is reported in the literature. For the purposes of this evaluation, the K_{oc} of PFOA and PFOS were assigned as 120 milliliters per gram (mL/g) and 370 mL/g, respectively (USEPA, 2017). Using an average site-specific f_{oc} of 0.0077 (derived from the average silt [0.013] and sand [0.0024] f_{oc} values listed in **Table 2-3**), this equates to K_d values of approximately 0.93 mL/g and 2.87 mL/g. A bulk density of 1.71 grams per cubic centimeter was assigned to the entire model domain. The PFAS plume is assumed to have emplaced approximately 60 years ago. Given this assumption, a mass transfer coefficient of 4.56×10^{-5} $days^{-1}$ was computed using the formula: mass transfer coefficient = 1/emplacement time (days) (Haggarty et al., 2004). This estimate of emplacement time was selected to be conservative, reflecting the earliest reasonable time frame for when aqueous film-forming foam containing PFAS would be available for use by the Navy. A formal sensitivity analysis of the influence that the assumed emplacement time (and therefore mass transfer coefficient) has on simulated plume migration rates and extents will be conducted as part of the RI effort planned for OLF. Longitudinal, transverse, and vertical dispersivities were assumed to be 100, 10, and 1 foot, respectively, throughout the model domain. Dispersivity values are based on professional judgement for plumes of similar scale and lithology.

3.6.3 Solute Boundary Conditions and Initial Concentrations

Initial concentration distributions of PFOA and PFOS in groundwater at OLF Coupeville were interpreted based on PFAS concentrations from analytical data from Phase 2 of the OLF Coupeville Supplemental SI (CH2M, 2021). These included PFAS concentrations from depth-discrete groundwater grab samples collected from soil borings and samples from monitoring wells. For locations where a depth-discrete grab sample was collected from an interval coinciding with the monitoring well screen interval, the higher of the two concentrations was used in the interpolation. The initial PFOA and PFOS distributions also incorporated analytical data from off-Base residential well samples. The most recent analytical result (collected between 2016 and 2020) for a given residential well was included (CH2M, 2019b, 2020b).

Analytical results were grouped according to the aquifer elevation interval of the sample (shallow, intermediate, and deep). Two-dimensional interpolation was performed for each of the three aquifer elevation intervals to obtain an initial concentration distribution of both PFOA and PFOS. The shallow zone initial concentrations were applied to Model Layer 2, intermediate-zone initial concentrations were applied to Model Layer 3, and the deep-zone initial concentrations were applied to Model Layers 4 and 5. **Figures 3-18a-c** and **Figures 3-19a-c** show the initial concentrations in Model Layers 2 through 5 for PFOA and PFOS, respectively.

Available data do not suggest the presence of PFOA or PFOS deeper than Model Layer 5; therefore, initial concentrations in Model Layers 6 and 7 were set to zero. Initial concentrations pertain to PFAS concentrations in the saturated zone only; therefore, initial concentrations in Model Layer 1 were also set to zero, as that layer is mostly dry.

To simulate the continuous loading of PFOA and PFOS from vadose zone soils within the release areas, results from the HYDRUS-1D simulations were incorporated in the saturated zone solute transport model as mass-flux boundary conditions. Mass flux of PFOA and PFOS were implemented using the Groundwater Vistas analytic well package. Analytic wells were assigned to each model cell encompassing the assumed approximate geographic extent of the release areas adjacent to WI-CV-MW20S and WI-CV-MW21S (a total of 15 and 20 wells, respectively). The "wells" were simulated as inflow to the groundwater system at a rate equal to simulated flow at the bottom (that is, leaching from the vadose zone) of each HYDRUS-1D profile (approximately 13.5 inches per year). The groundwater recharge property was set to zero over these areas, so as not to double count the amount of deep percolation of precipitation. PFOA and PFOS concentrations assigned to the analytic wells were assigned based on the HYDRUS-1D results presented on **Figure 3-16** and **Figure 3-17**. The HYDRUS-1D outputs were simplified to 5-year time-steps over which concentrations were assumed to be constant using the simulated PFAS concentration at the end of the time period. For example, for simulation years 0 to 5, PFOA concentrations of approximately 2,000 and 7,000 ng/L were assigned to the WI-CV-MW20S and WI-CV-MW21S-adjacent areas, respectively (representing the simulated concentration at the water table at year 5), and years 5 to 10 were assigned concentrations of 3,000 and 13,500 ng/L (the simulated concentration at the water table at year 10). The mass-flux boundary conditions (analytic wells) were assigned to Model Layer 2 to represent leaching of vadose zone release areas to the water table.

3.6.4 Time Discretization

Similar to the vadose zone model, the saturated zone simulations were designed to simulate steady-state hydraulic conditions and a 100-year solute transport timeframe. Each simulation consisted of 20, 5-year stress periods. Hydraulic properties and boundary conditions were constant (to simulate steady-state groundwater flow conditions), while the PFOA and PFOS concentrations varied for each stress period.

3.6.5 Results

Figures 3-18a-c and **Figures 3-19a-c** present the simulated distributions of PFOA and PFOS in the shallow, intermediate, and deep elevation intervals at discrete time periods. Figures for both constituents present the initial (current) concentration distributions, as well as the simulated concentrations after 5, 25, 50, 75, and 100 years of future transport (that is, into the future from current).

As shown on **Figure 3-18a**, PFOA concentrations in the shallow elevation interval underlying the release areas currently exceed 500 ng/L. The impact of ongoing leaching of PFOA from the vadose zone release areas is apparent after 5 years of transport, expressed as increasing PFOA concentrations. As the simulation period progresses, the extent of elevated concentrations emanating from the vadose zone release areas is projected to expand, with concentrations exceeding 100 ng/L extending west of the runway. The footprint of the diffuse plume (exceeding 10 ng/L) expands over time in the general direction of groundwater flow to the south/southwest. The simulated extent of the plume exceeding 10 ng/L is not projected to reach Admiralty Bay after 100 years of transport given the current configuration of hydraulic and solute transport parameters. Similar trends are projected for the intermediate and deep elevation intervals, as presented on **Figure 3-18b** and **Figure 3-18c**.

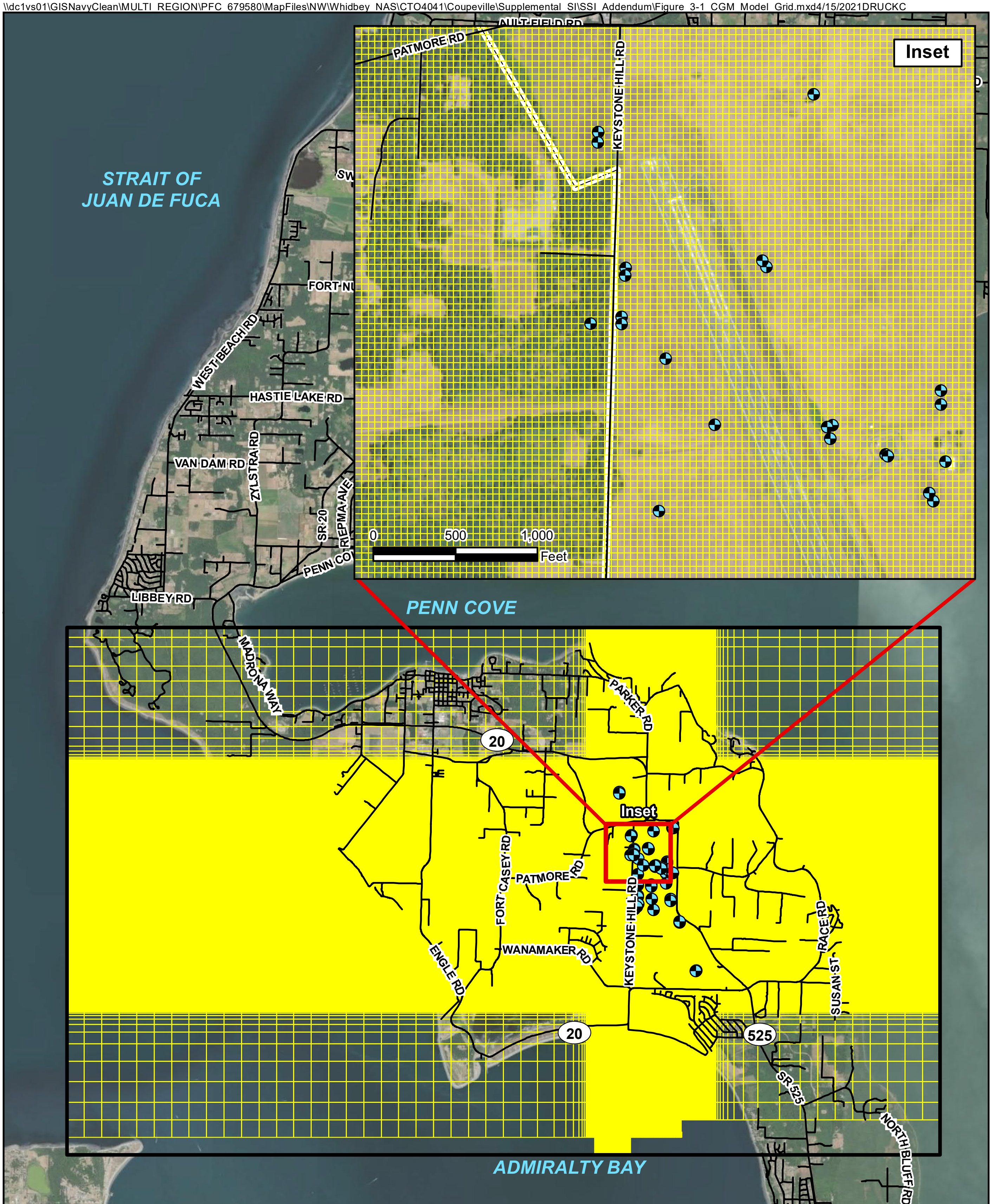
Figure 3-19a presents the simulated distribution of PFOS over time in the shallow elevation interval. These data suggest that mass contribution from vadose zone release areas is not readily apparent until more than 25 years of transport. While PFOS is present in the intermediate and deep elevation intervals throughout the simulation period, reflective of currently observed concentrations, the influx of mass from the release areas does not reach groundwater in the intermediate and deep elevation intervals until 50 and nearly 100 years of transport, respectively (**Figure 3-19b** and **Figure 3-19c**). This highlights a data gap that exists between the observed concentrations in groundwater and the concentrations observed in the soil profiles at release areas. The overall footprint of the PFOS plume exceeding 10 ng/L is not projected to extend beyond the Base boundaries (with the exception of a small area currently present near the western boundary) after 100 years of transport. The lack of PFOS transport is a result of the higher K_{oc} value of the constituent as compared to PFOA, indicating that PFOS is less mobile. The lack of widespread simulated PFOS extents in the groundwater system is consistent with the general lack of elevated concentrations currently observed in both monitoring wells and off-Base residential wells.

3.7 Model Limitations

Models are inherently inexact because the mathematical description of the physical realm is imperfect, and the understanding of interrelated physical processes is incomplete. Mathematical models like the CGM can only approximate subsurface processes, despite their high degree of precision. A major cause of uncertainty in these types of models is the discrepancy between the coverage of measurements needed to understand subsurface conditions and the coverage of measurements generally made under the constraints of limited time and budget. The spatial scale and complex physical environment at and around OLF Coupeville present specific challenges and limitations. A relatively small reservoir of field data has been collected at OLF Coupeville. A significant degree of uncertainty exists in the distribution of subsurface conditions. However, the available data were deemed to be sufficient to provide enough detail of the physical system for the CGM to achieve the modeling objectives described in Section 3.2. It is expected that as more data are collected, the model will be refined and improved.

Additionally, the scientific understanding of the solute transport behavior of PFAS constituents, specifically PFOA and PFOS, is still in its infancy, and much more information is expected to be learned in coming years. The parameterization of solute transport in the CGM is based on the best information currently available; however, as the science develops and understanding improves, the solute transport element of the CGM is expected to be updated, resulting in increased confidence in the results.

Given these assumptions and limitations, numerical groundwater models like CGM should be considered insight tools and qualitative predictors of future conditions. Therefore, important planning decisions that use output from CGM must be made with an understanding of the uncertainty in and sensitivity to model input parameters and should consider other site data, professional judgment, and the inclusion of safety factors. Warranties associated with the forecasts, explicit or implied, are not provided.



Legend

- OLF Monitoring Wells
- Road
- Model Extent
- CGM Model Grid Cell
- Outlying Landing Field

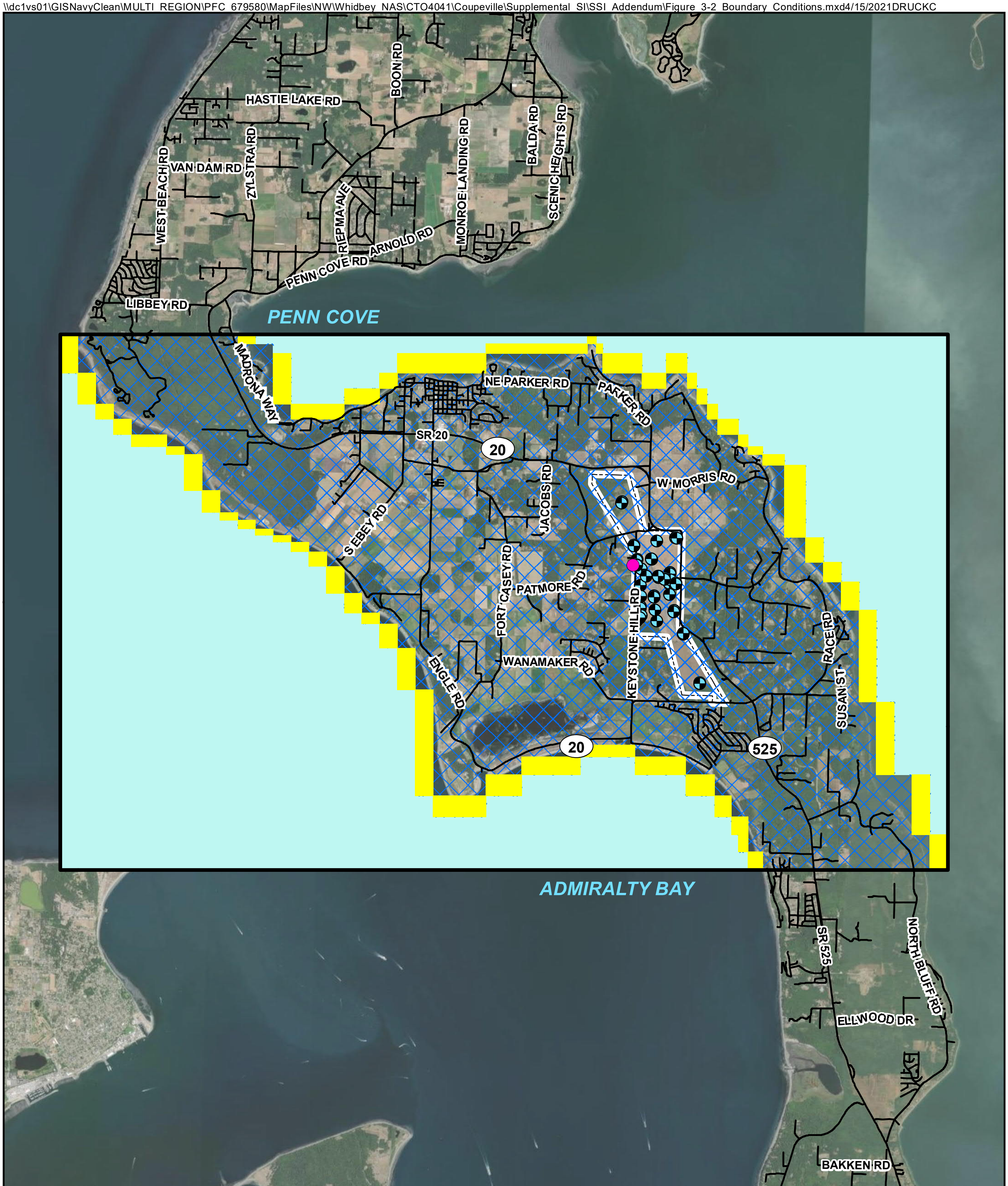
Notes:
CGFM = Coupeville groundwater model
OLF = Outlying Landing Field

N

0 0.75 1.5 Miles

1 inch = 1.5 miles
Imagery Source: ©2018 ESRI

Figure 3-1
Coupeville Groundwater Model Grid
Naval Air Station Whidbey Island
Coupeville, Washington



Legend

- OLF Monitoring Wells
- Well Boundary Cell
- Road
- Model Extent
- No Flow Boundary Cell
- General Head Boundary Cell
- Recharge and Evapotranspiration Cell
- Outlying Landing Field

0 0.75 1.5 Miles
1 inch = 1.5 miles
N

Imagery Source: ©2018 ESRI

Notes:
NAVD88 = North American Vertical Datum of 1988
OLF = Outlying Landing Field

Figure 3-2
Boundary Conditions
Naval Air Station Whidbey Island
Coupeville, Washington

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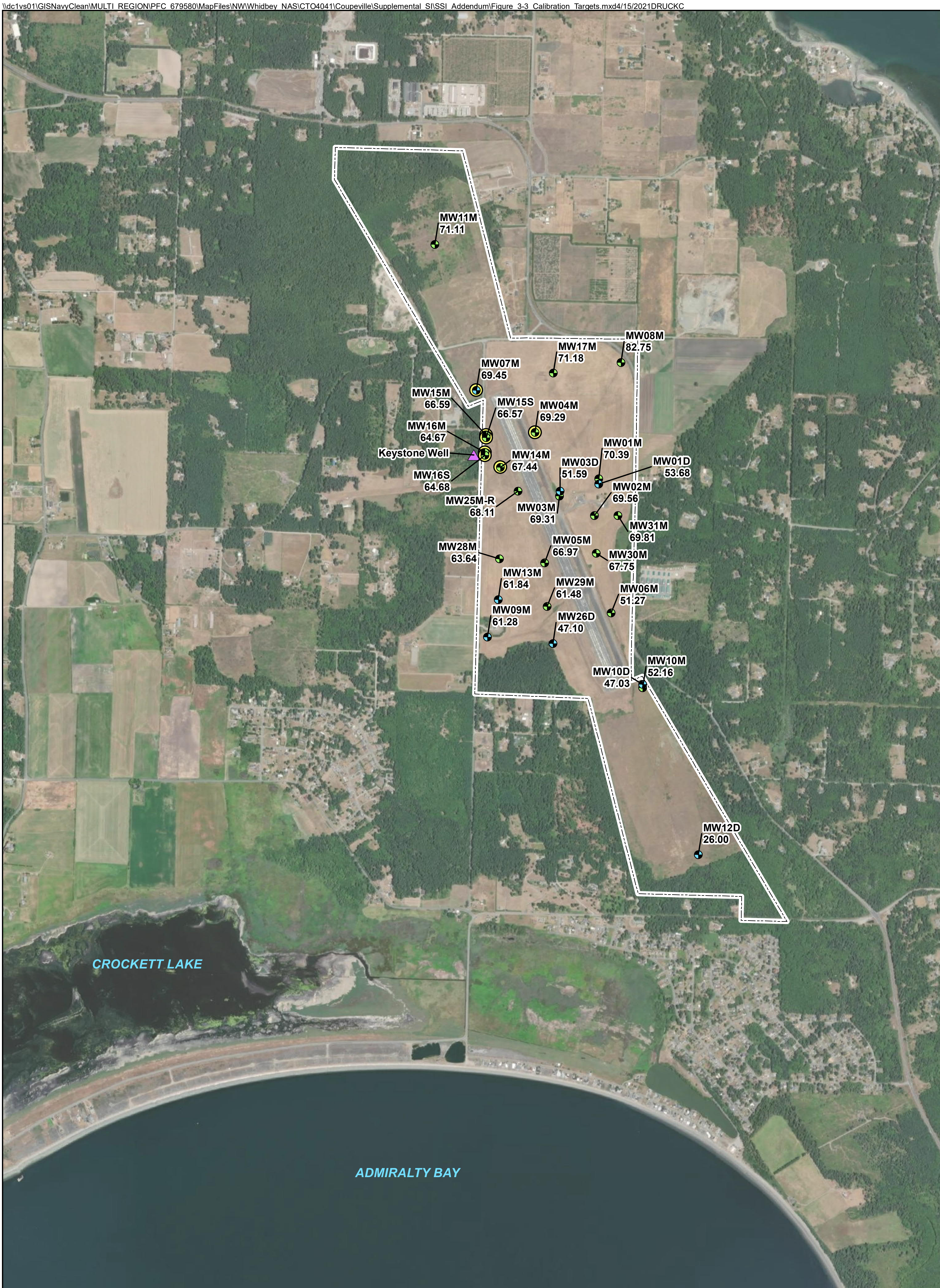

Legend

- Middle Elevation Interval Monitoring Well
- Deep Elevation Interval Monitoring Well
- Community Drinking Water Well
- Keystone Well Aquifer Test Observation Well
- Base Boundary

Notes:
1. Groundwater elevations data are relative to feet above the North American Vertical Datum of 1988
2. Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.

N

0 0.15 0.3 Miles

1 inch = 0.3 mile

Imagery Source: Esri

Figure 3-3
Calibration Targets
Naval Air Station Whidbey Island
Coupeville, Washington

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Legend

Residuals

- -45 to -20
- -19.9 to -10
- -9.9 to -5
- -4.9 to -1
- -0.9 to 0
- 0.1 to 1
- 1.1 to 5
- 5.1 to 10
- 10.1 to 20
- 20.1 to 35

- OLF Coupeville Supply Well
- Community Drinking Water Well
- Building Location
- Base Boundary

Notes:
1. NAVD88 = North American Vertical Datum of 1988
2. Deep elevation interval wells are typically screened near or below 0 feet NAVD88.
3. Groundwater elevations shown in feet NAVD88
4. Posted residuals are calculated as the simulated groundwater elevation minus the measured groundwater elevation.
5. Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.

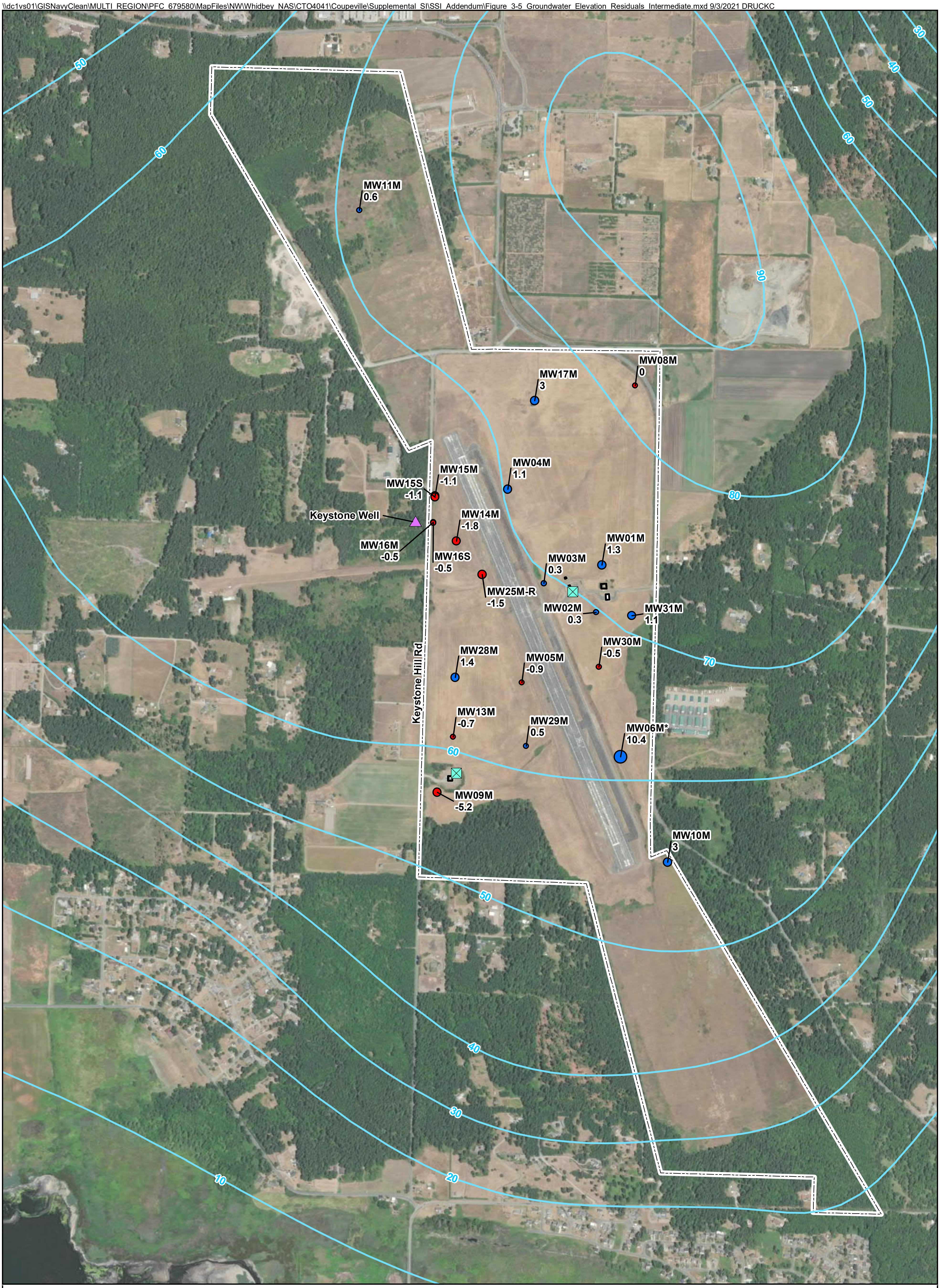
0 0.1 0.2 Miles

N

1 inch = 0.2 mile

Imagery Source: Esri

Figure 3-4
Simulated Steady-State Groundwater Elevation Residuals
Shallow Elevation Interval
Naval Air Station Whidbey Island
Coupeville, Washington



Legend

Residuals
- -5 to -1
- -0.9 to 0
- 0.1 to 1
- 1.1 to 5
- 5.1 to 10.5

- OLF Coupeville Supply Well
- Community Drinking Water Well
- Simulated Groundwater Elevation Contour (10-foot contour interval)
- Building Location
- Base Boundary

Notes:
1. NAVD88 = North American Vertical Datum of 1988
2. Intermediate elevation interval wells are typically screened between approximately 10 and 60 feet NAVD88.
3. Groundwater elevations shown in feet NAVD88
4. Posted residuals are calculated as the simulated groundwater elevation minus the measured groundwater elevation.
5. Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.
* Anomalous water level not used in autocalibration.

0 0.1 0.2 Miles
N
1 inch = 0.2 mile
Imagery Source: Esri

Figure 3-5
Simulated Steady-State Groundwater Elevation and Residuals
Intermediate Elevation Interval
Naval Air Station Whidbey Island
Coupeville, Washington

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Legend

Residuals

- -5 to -1
- -0.9 to 0
- 0.1 to 1
- 1.1 to 5

- OLF Coupeville Supply Well
- Community Drinking Water Well
- Simulated Groundwater Elevation Contour (10-foot contour interval)
- Building Location
- Base Boundary

Notes:
1. NAVD88 = North American Vertical Datum of 1988
2. Deep elevation interval wells are typically screened near or below 0 feet NAVD88.
3. Groundwater elevations shown in feet NAVD88
4. Posted residuals are calculated as the simulated groundwater elevation minus the measured groundwater elevation.
5. Full well names include "WI-CV-" preceding the well number; however names have been abbreviated for figure presentation.
* Well MW03D is located in model layer 5.

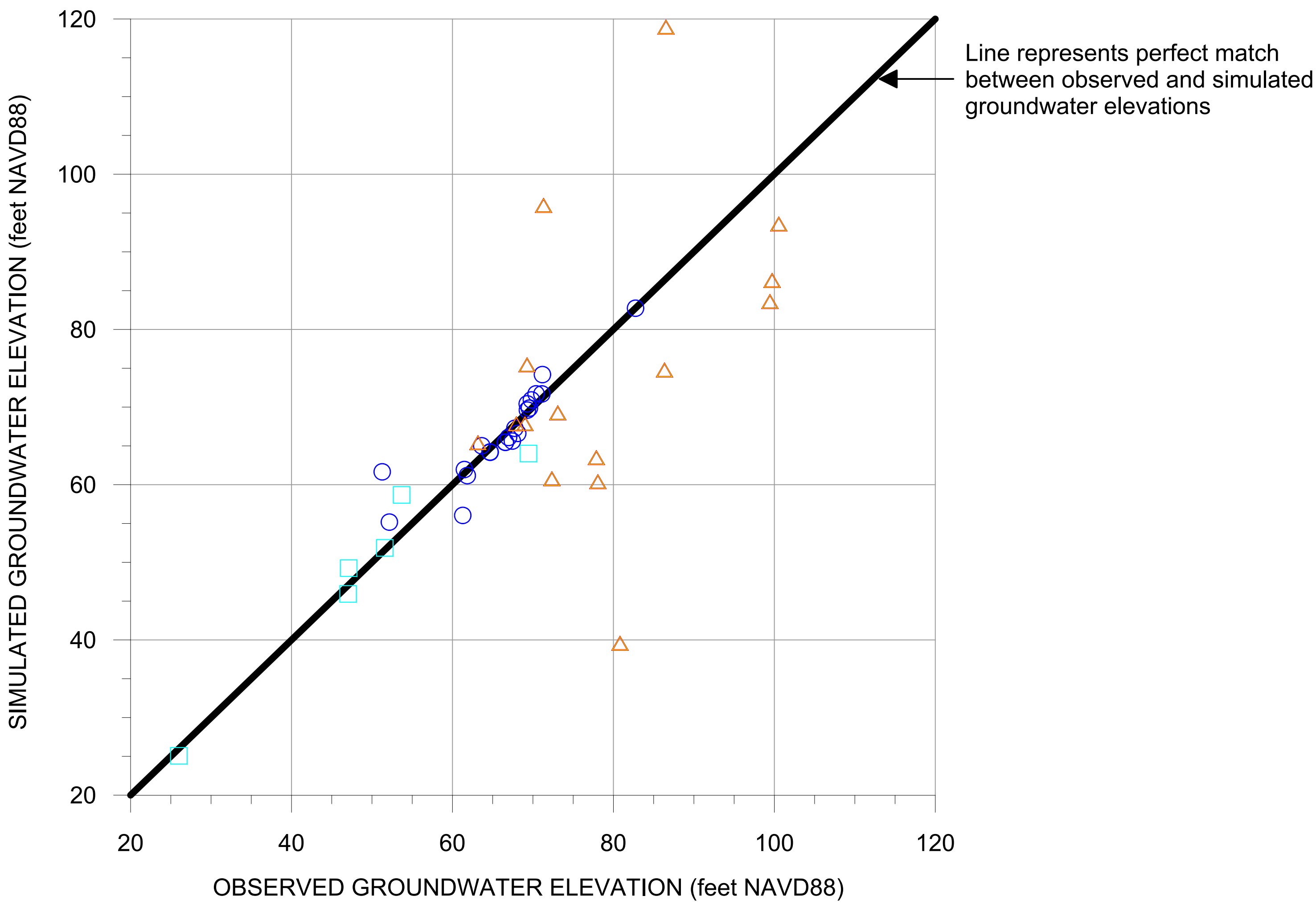
0 0.1 0.2 Miles

N

1 inch = 0.2 mile

Imagery Source: Esri

Figure 3-6
Simulated Steady-State Groundwater Elevation Contours and Residuals
Deep Elevation Interval
Naval Air Station Whidbey Island
Coupeville, Washington



LEGEND

△ Wells in Model Layer 2

○ Wells in Model Layer 3

□ Wells in Model Layers 4 and 5

Notes:

1. NAVD88 = North American Vertical Datum of 1988.
2. Mean Error* = -0.04 foot
3. Range in Observed Elevations* = 56.8 feet
4. Root Mean Squared Error (RMS)* = 2.1 foot
5. RMS/Range* = 3.7%

*Statistics exclude Model Layer 2 targets and MW06M.

Figure 3-7
Steady-State Simulated versus Observed Groundwater Elevations and Calibration Statistics
Naval Air Station Whidbey Island
Coupeville, Washington

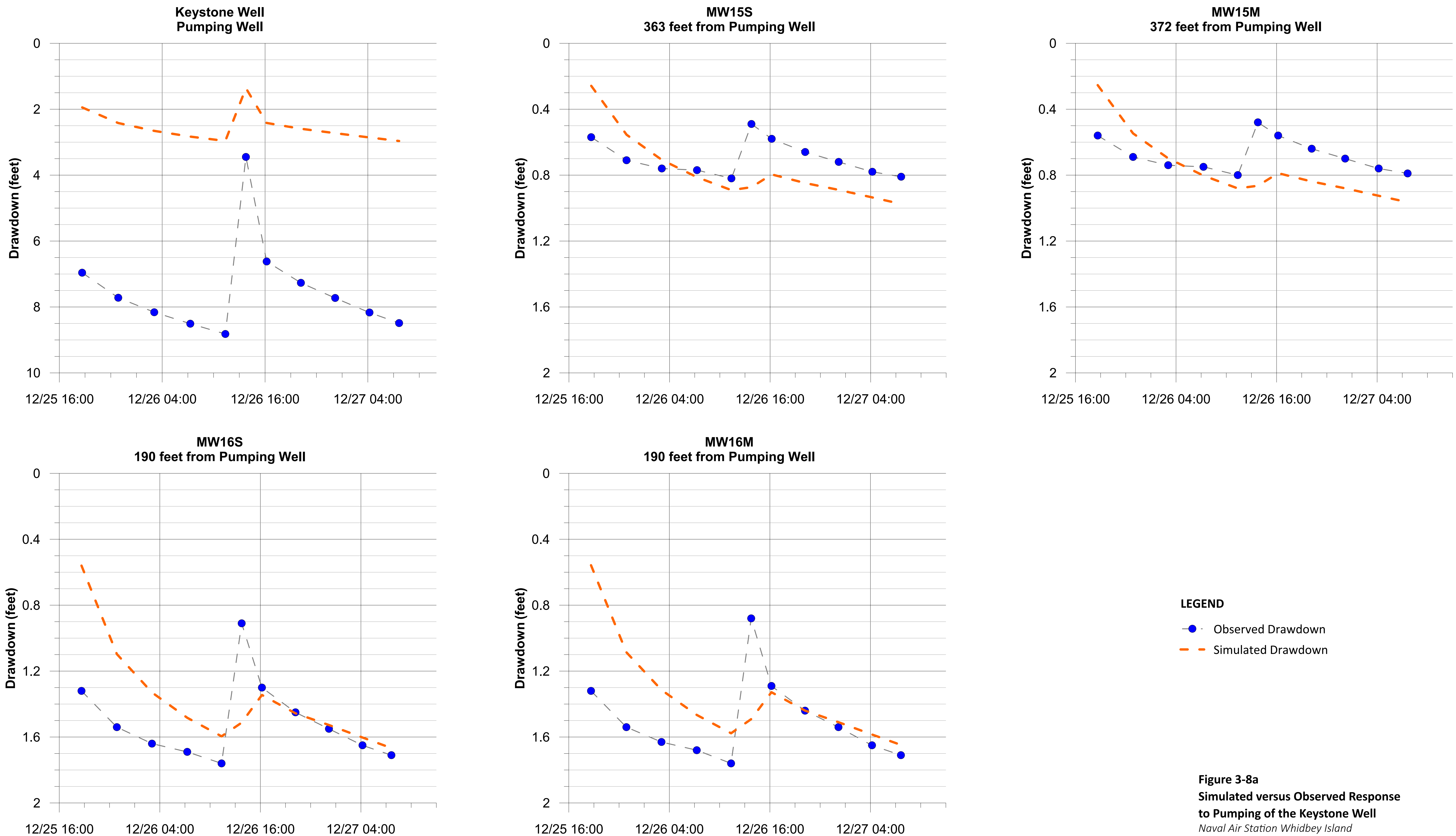


Figure 3-8a
Simulated versus Observed Response to Pumping of the Keystone Well
Naval Air Station Whidbey Island
Coupeville, Washington

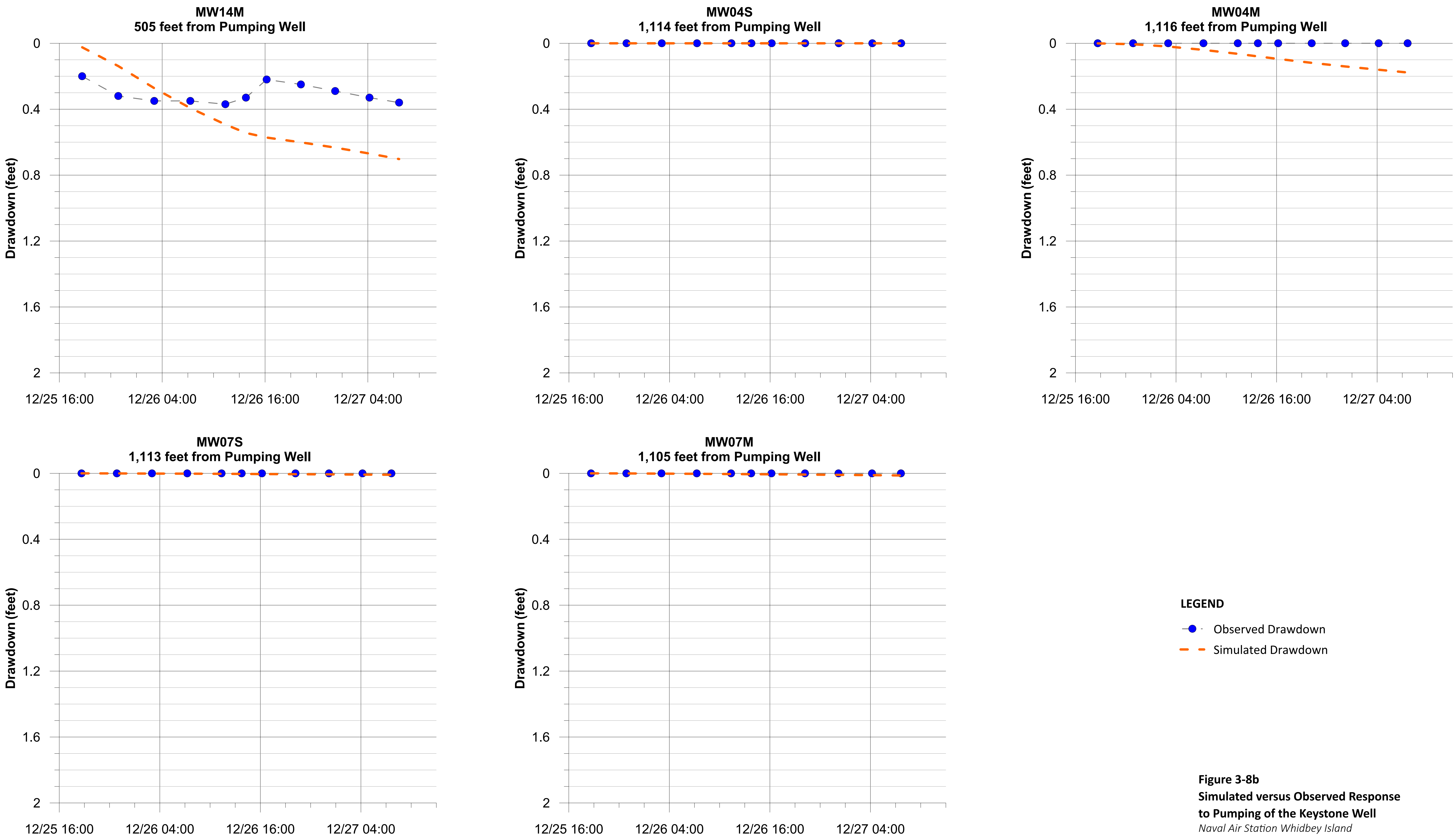


Figure 3-8b
Simulated versus Observed Response to Pumping of the Keystone Well
Naval Air Station Whidbey Island
Coupeville, Washington

ch2m:

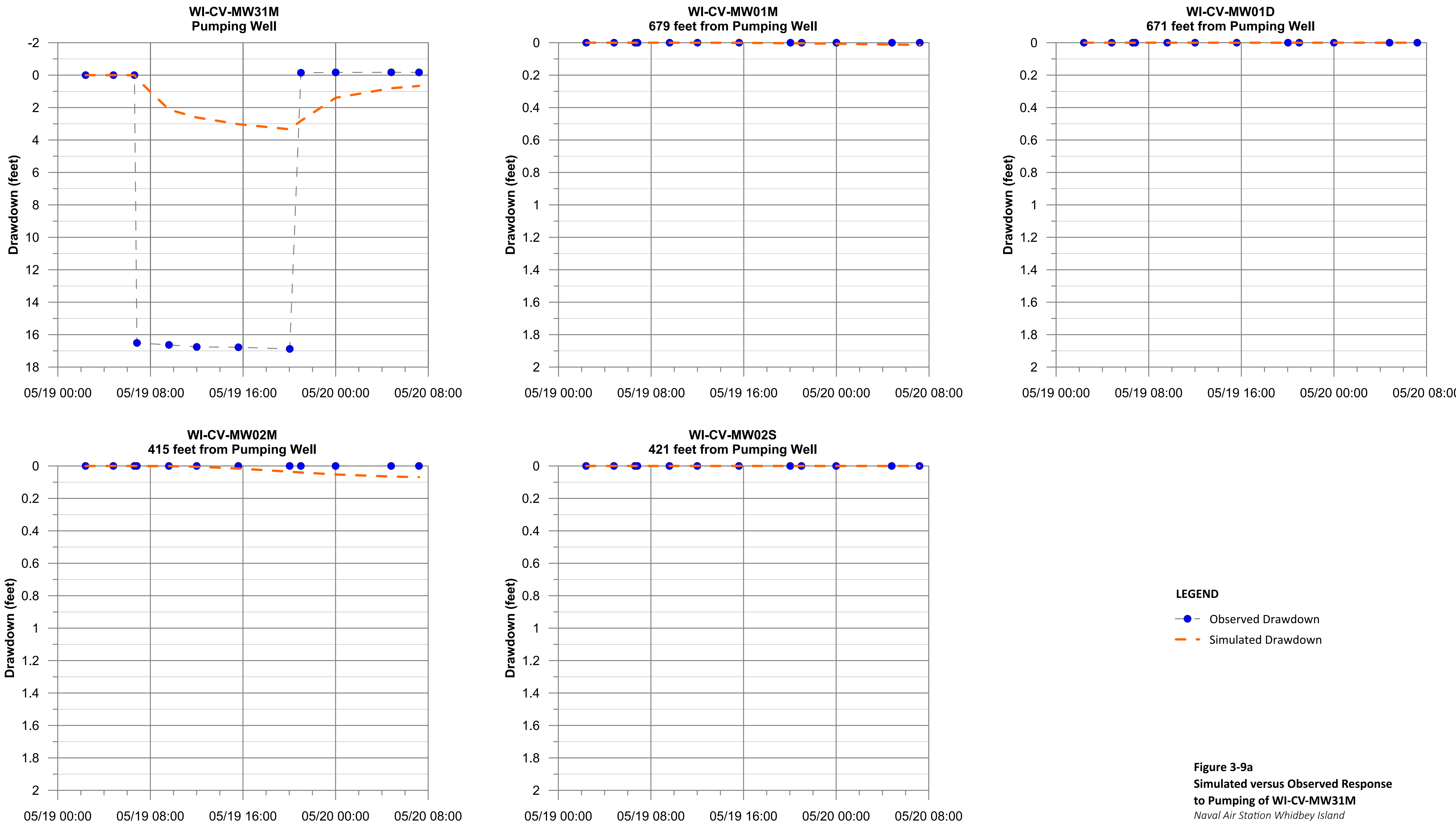


Figure 3-9a
Simulated versus Observed Response to Pumping of WI-CV-MW31M
Naval Air Station Whidbey Island
Coupeville, Washington

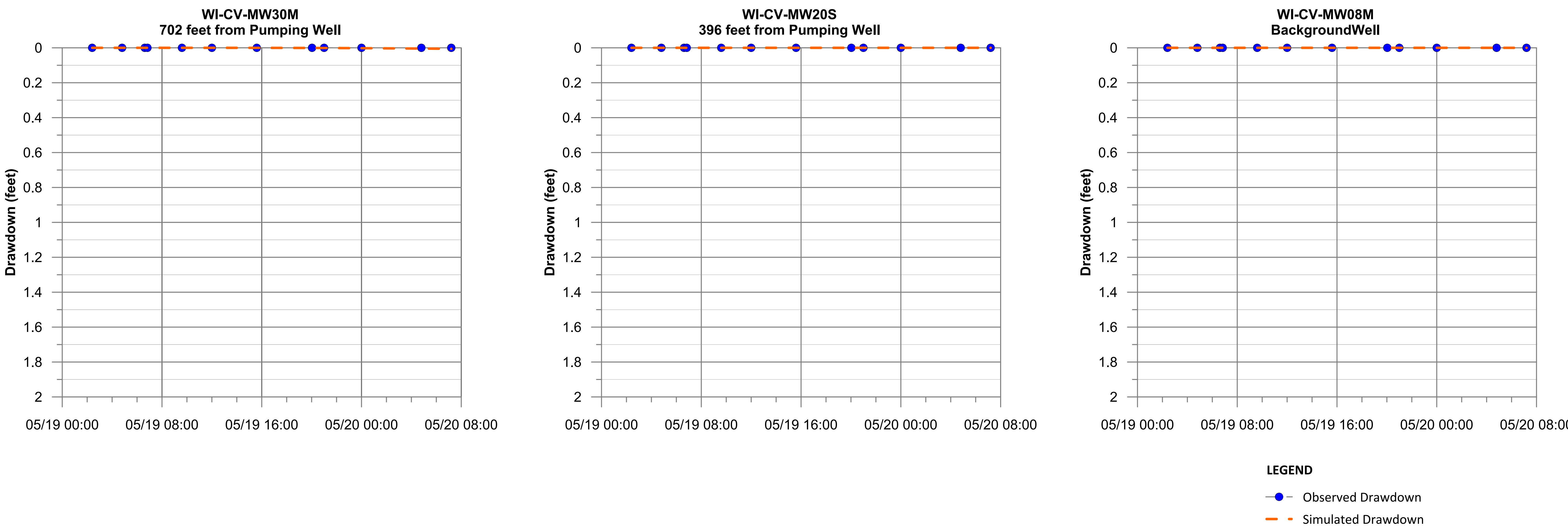


Figure 3-9b
Simulated versus Observed Response to Pumping of WI-CV-MW31M
Naval Air Station Whidbey Island
Coupeville, Washington

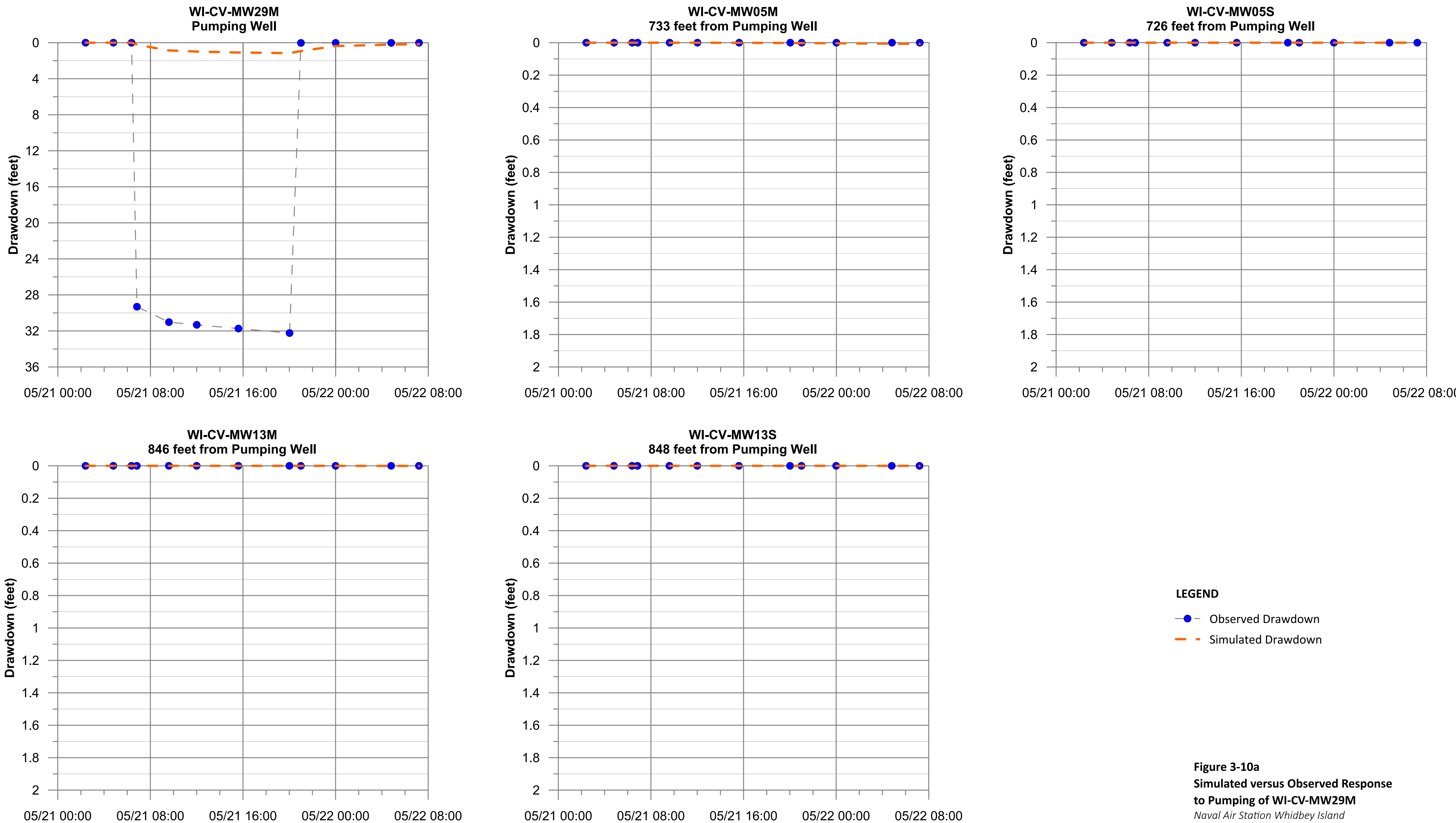
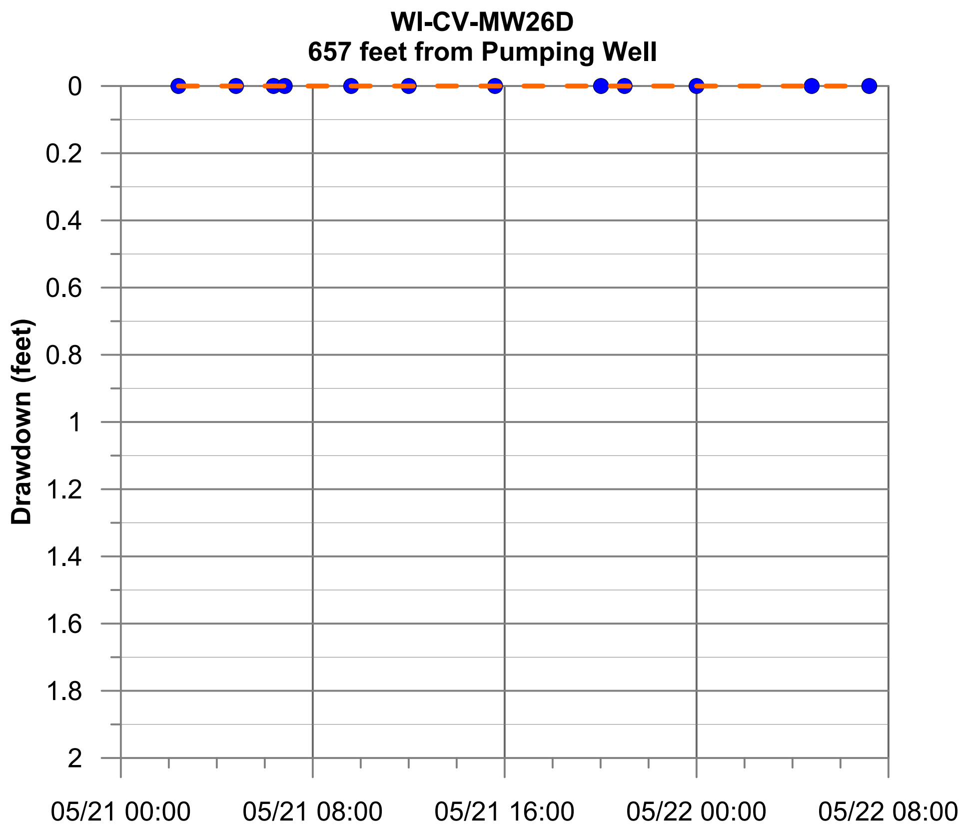
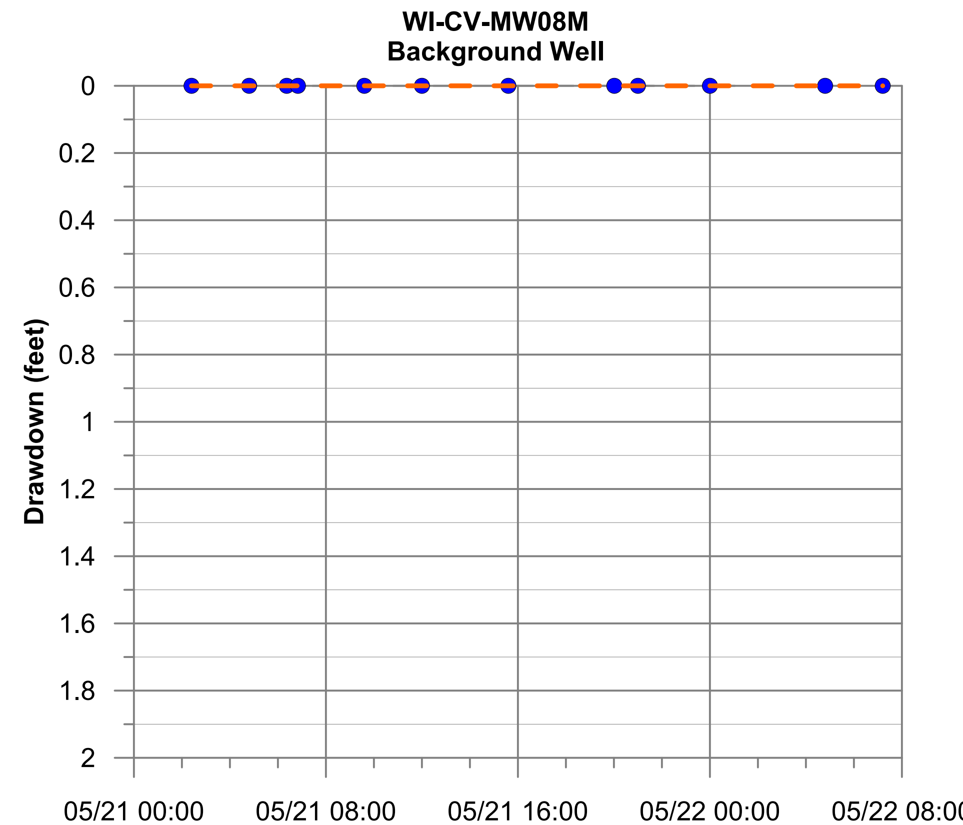


Figure 3-10a
Simulated versus Observed Response to Pumping of WI-CV-MW29M
Naval Air Station Whidbey Island
Coupeville, Washington

ch2m





LEGEND

Observed Drawdown

Simulated Drawdown

Figure 3-10b
Simulated versus Observed Response to Pumping of WI-CV-MW29M
Naval Air Station Whidbey Island
Coupeville, Washington

ch2m

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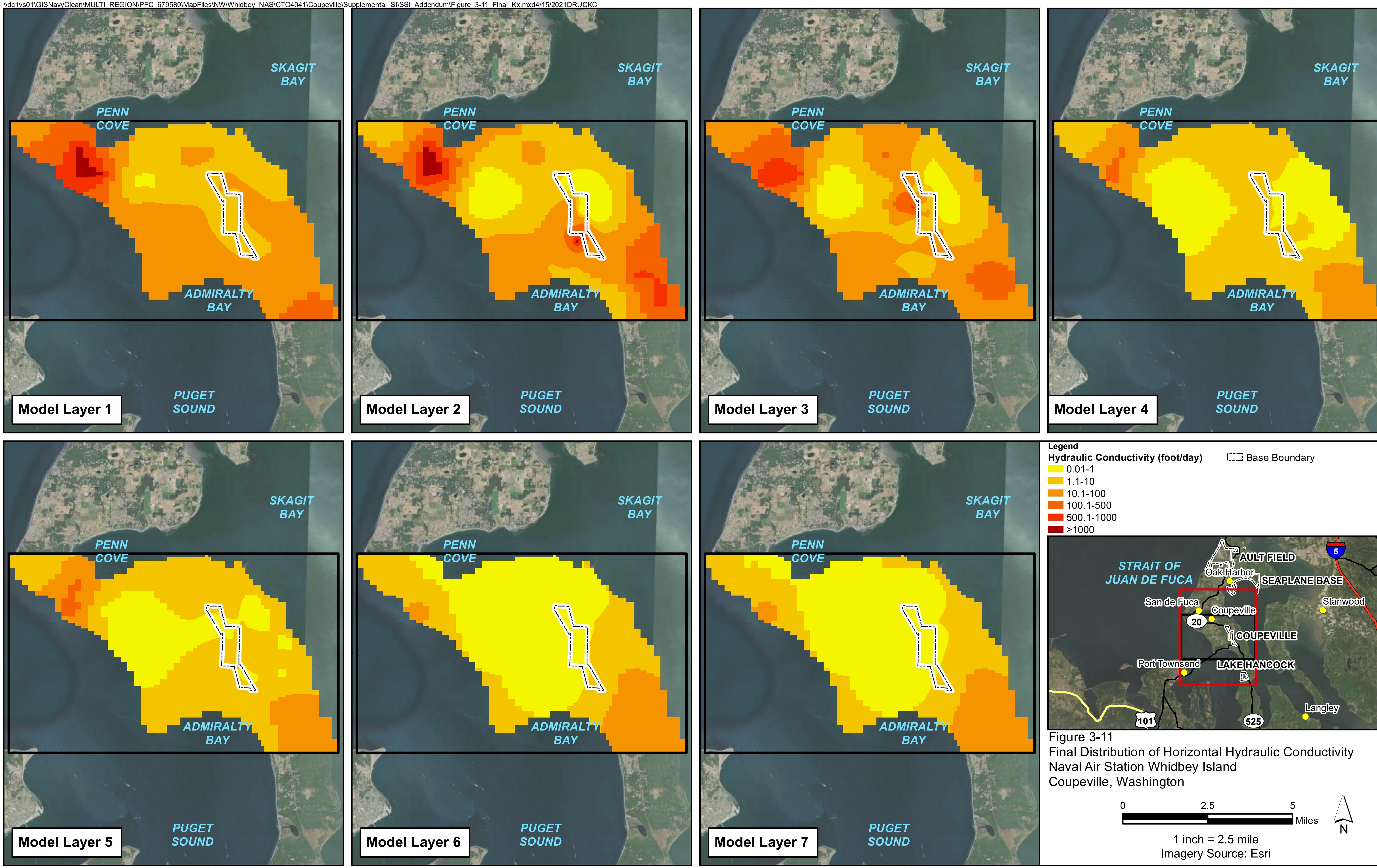

Figure 3-11
Final Distribution of Horizontal Hydraulic Conductivity
Naval Air Station Whidbey Island
Coupeville, Washington

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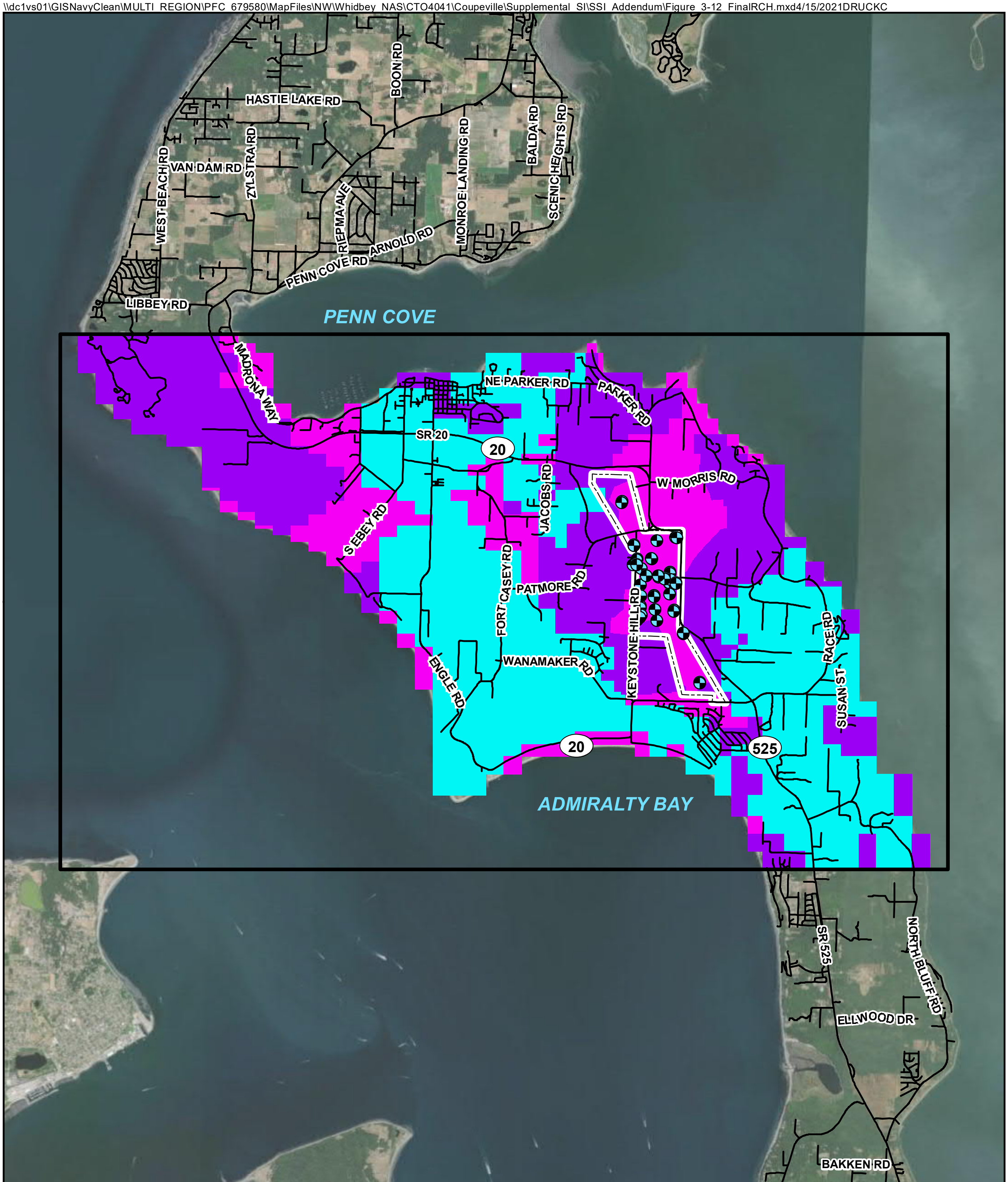


Legend

Simulated Groundwater Recharge (inches per year)

- 0-1
- 1.1 - 2
- 2.1 - 3
- 3.1 - 4
- 4.1 - 5
- 5.1 - 6
- 6.1 - 7
- 7.1 - 8
- 8.1 - 9
- 9.1 - 10
- 10. - 11
- 11.1 - 12
- 12.1 - 13
- 13.1 - 14
- OLF Monitoring Wells
- Road
- Model Extent
- Outlying Landing Field

Note: OLF = Outlying Landing Field

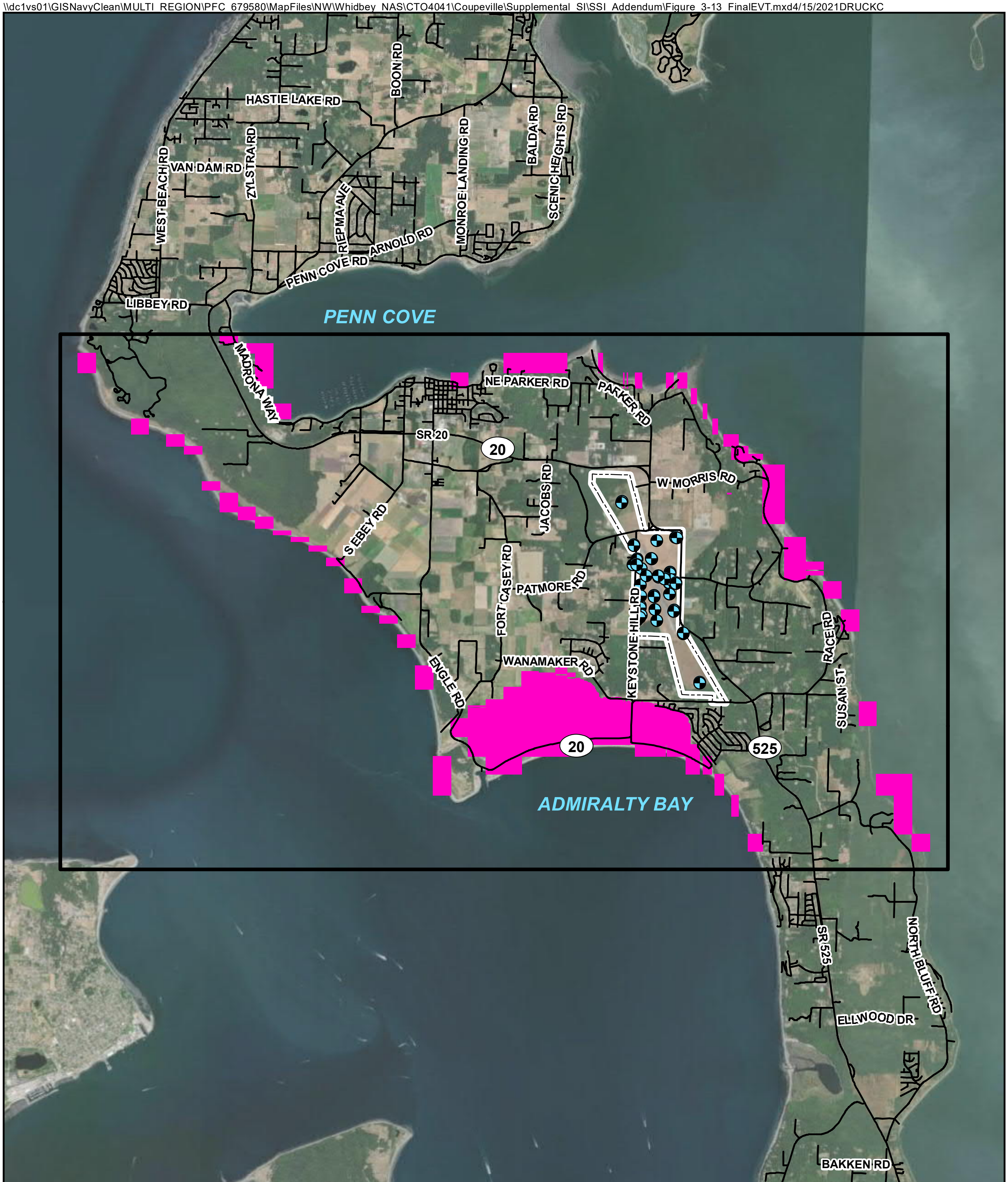
0 0.75 1.5 Miles

1 inch = 1.5 miles

N

Imagery Source: ©2018 ESRI

Figure 3-12
Final Distribution of Deep Percolation of Precipitation
Naval Air Station Whidbey Island
Coupeville, Washington



Legend

- OLF Monitoring Wells
- Active Evapotranspiration Cell
- Road
- Outlying Landing Field
- Model Extent

Figure 3-13
Simulated Distribution of Active Evapotranspiration
Naval Air Station Whidbey Island
Coupeville, Washington

N

0 0.75 1.5 Miles

1 inch = 1.5 miles

Note: OLF = Outlying Landing Field

Imagery Source: ©2018 ESRI

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Outlying Landing Field Coupeville
Naval Air Station Whidbey Island
Oak Harbor, Washington

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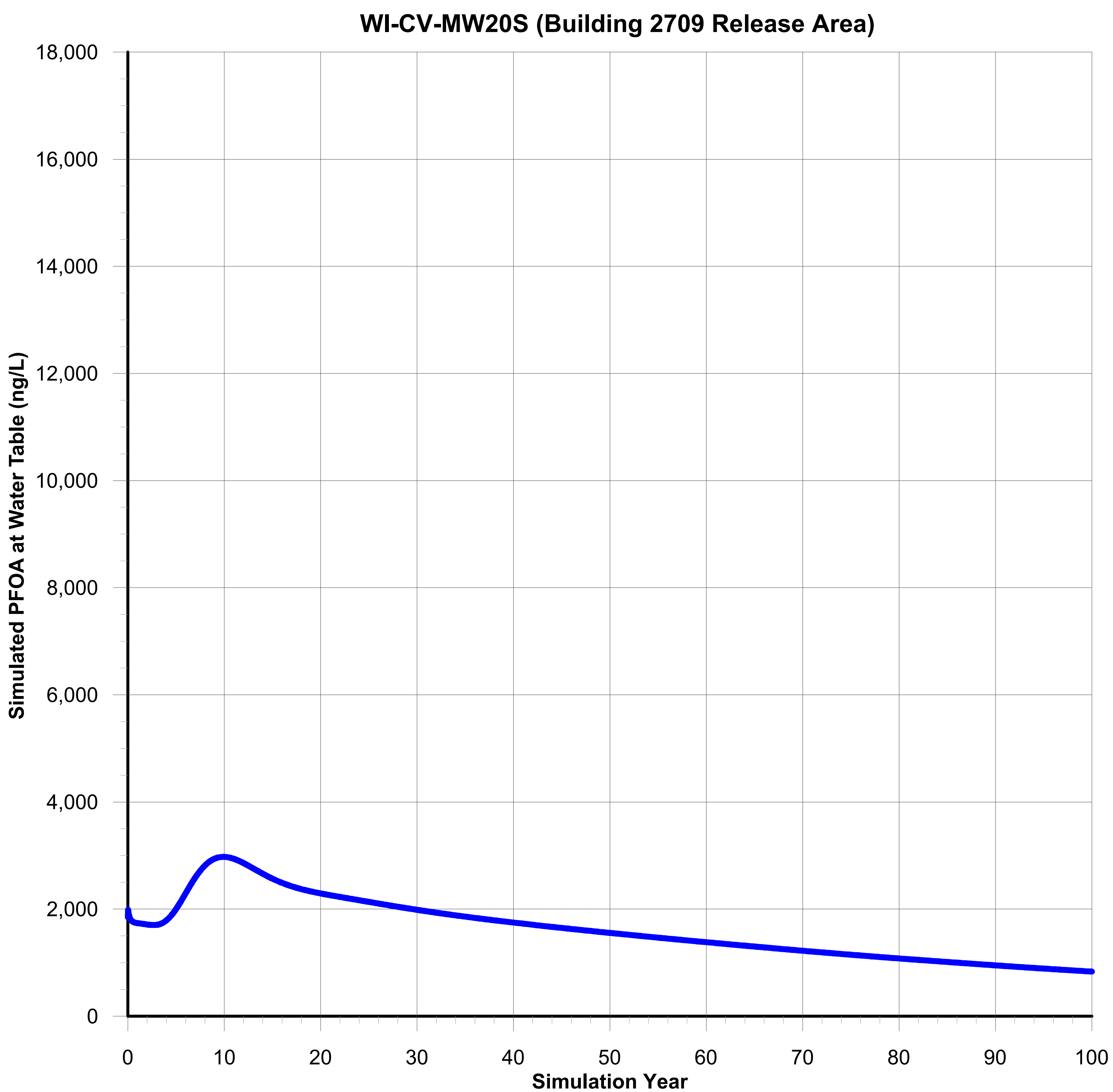
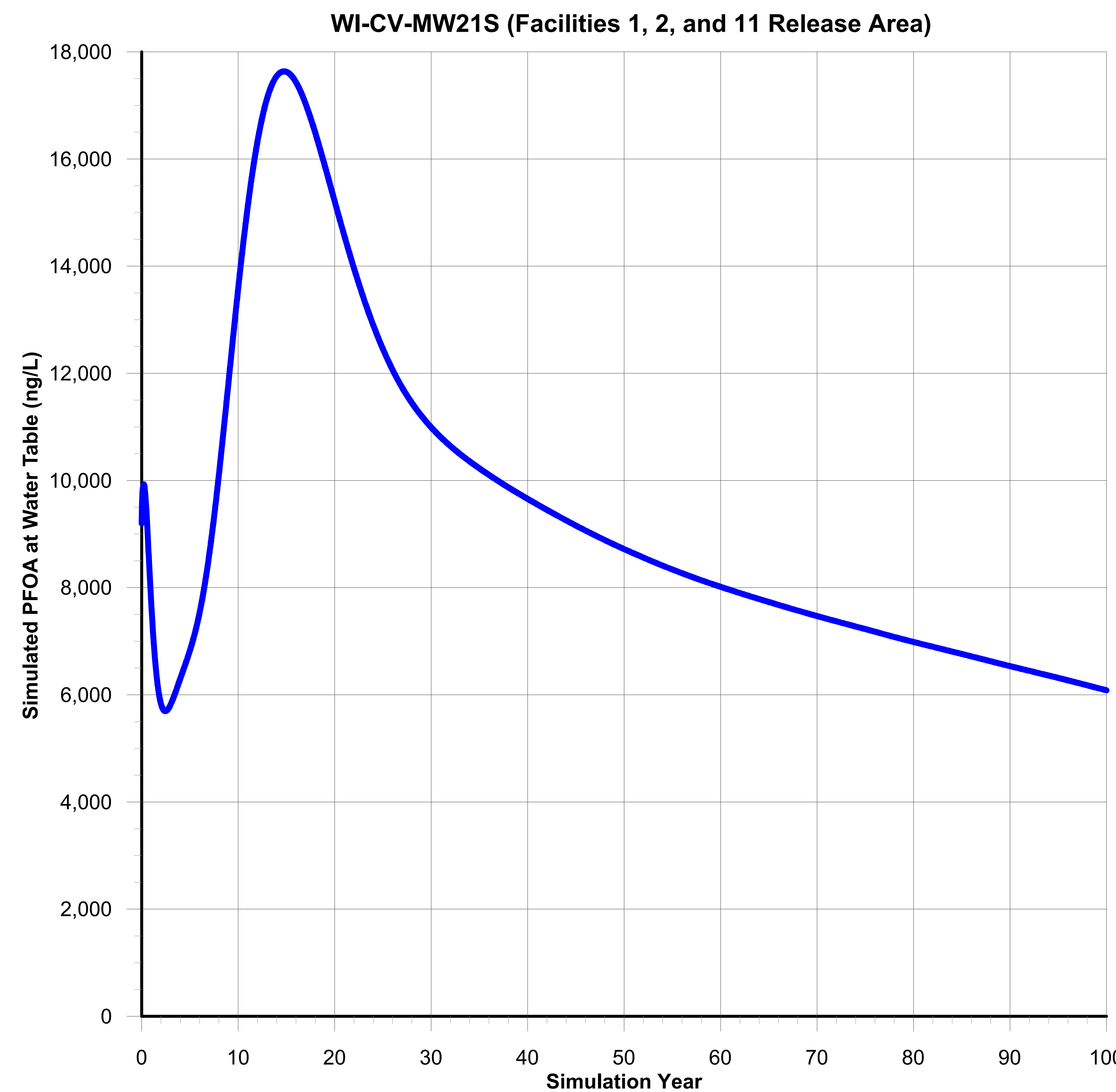
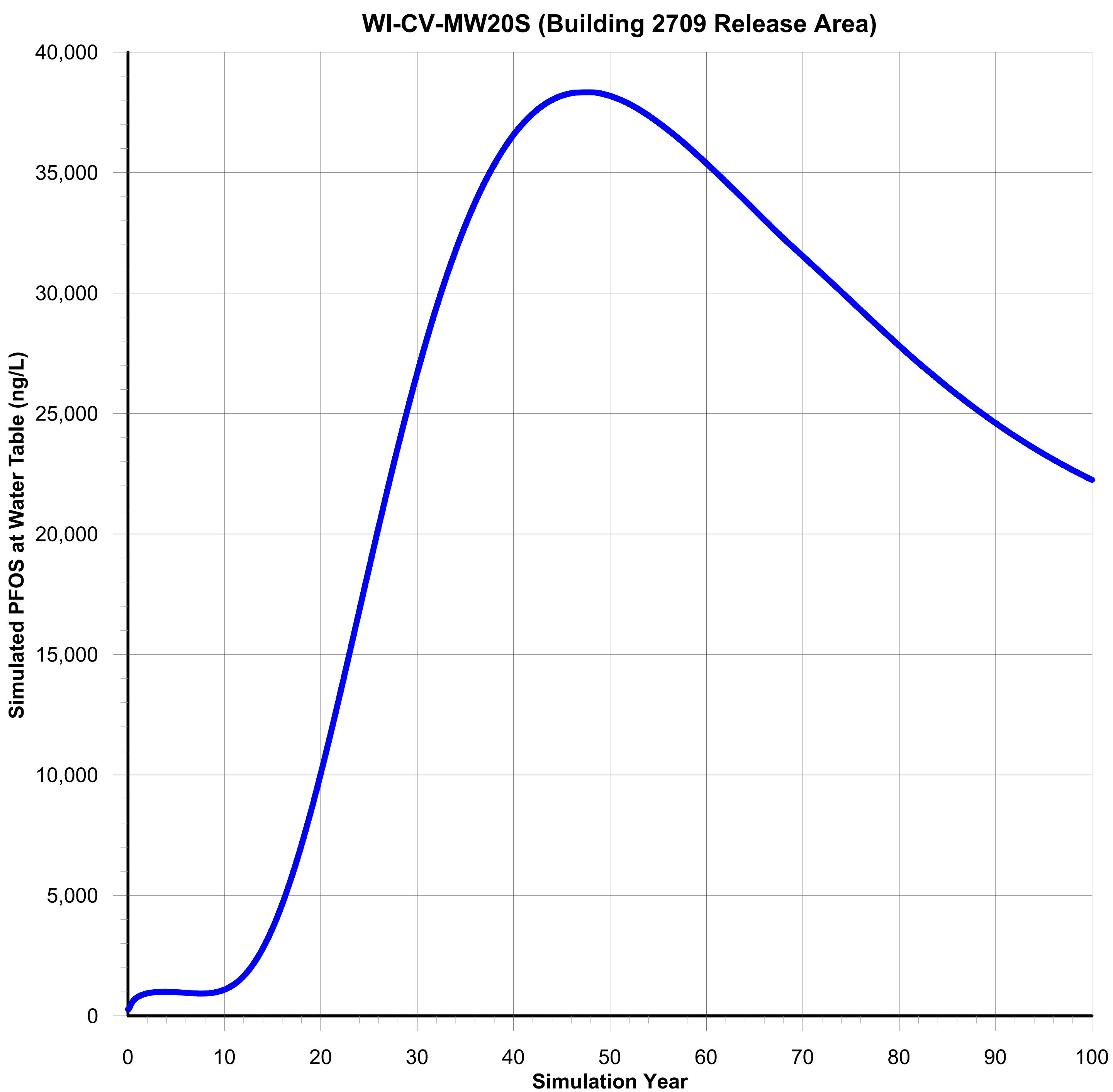
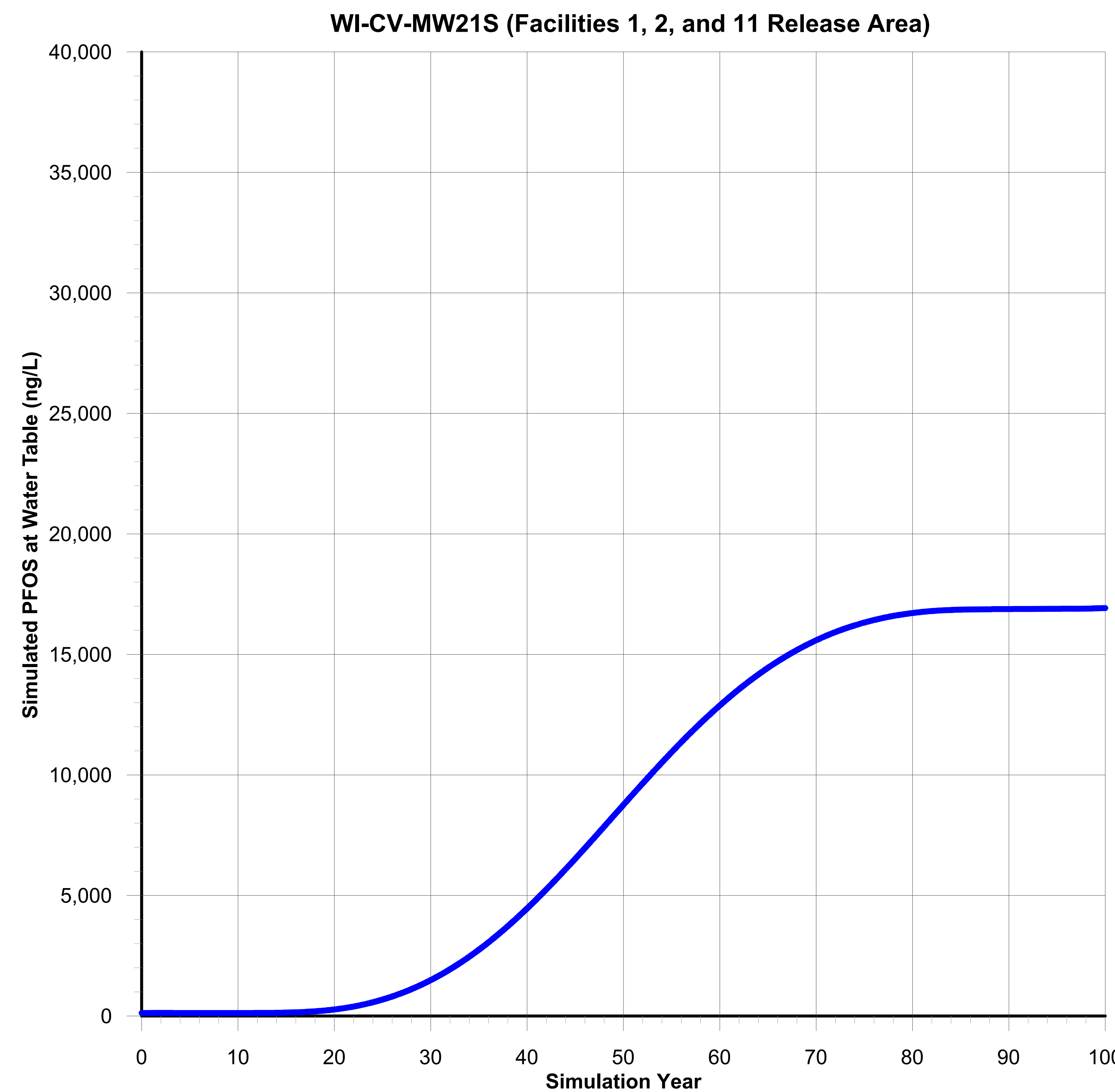




Notes:
1. ng/L = nanograms per liter
2. PFOA = perfluorooctanoic acid

Figure 3-16
Simulated PFOA Transport from the Vadose Zone
Naval Air Station Whidbey Island
Coupeville, Washington





Notes:
1. ng/L = nanograms per liter
2. PFOS = perfluorooctanesulfonic acid

Figure 3-17
Simulated PFOS Transport from the Vadose Zone
Naval Air Station Whidbey Island
Coupeville, Washington

Naval Facilities Engineering Systems Command

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SECTION 4

Conclusions and Recommendations

The groundwater flow model, previously developed during the OLF Coupeville Expedited SI (CGFM), was updated, recalibrated, and configured to simulate solute transport. The effort included a steady-state calibration to more recent groundwater elevations from new and existing monitoring wells and a transient calibration to groundwater elevation data and pumping rates from the 2017-2018 Keystone Well aquifer test (CH2M, 2018b) and the 2020 Supplemental SI Phase 2 aquifer tests. The groundwater flow model is well calibrated, with calibration statistics that meet or exceed all industry standards. The conclusions and recommendations from this effort are summarized herein.

The primary conclusions from the modeling effort described herein are as follows:

- Simulated groundwater elevations in the CGM are consistent with observations at intermediate and deep elevation interval monitoring wells throughout OLF Coupeville.
- Simulated flow directions in the CGM, particularly in the intermediate elevation interval, are to the south/southwest. These flow directions are consistent with groundwater elevation data provided by newly installed wells along the eastern Base boundary which supports the overall CSM for groundwater flow at/near the Base.
- Simulated groundwater flow directions in the CGM are consistent with the current CSM, indicating that pumping at the Keystone Well influences local groundwater flow directions but does not capture groundwater impacted by PFAS from the on-Base release areas east of the runway.
- Simulation results suggest that groundwater flow directions had a more southerly orientation at the time of emplacement of PFAS contamination at OLF Coupeville (before installation of the Keystone Well) than they have currently, and that the current westward component of flow is largely a result of the Keystone Well pumping.
- The calibrated flow model adequately simulates the results of the 2020 Supplemental SI Phase 2 aquifer tests.
- The simulated PFOA and PFOS plume migration is consistent with the CSM and observations of elevated PFOA concentrations in residential drinking water wells south of OLF Coupeville.
- Continued mass flux from vadose zone PFAS releases has a strong influence on future simulated plume migration extent and persistence.

Several uncertainties regarding groundwater flow and PFAS migration at OLF Coupeville remain. Addressing these uncertainties will be one of the primary objectives of the upcoming RI planned for OLF Coupeville. These uncertainties are summarized as follows:

- Groundwater elevations east of OLF Coupeville remain an uncertainty. The CGM was recalibrated, with a primary objective of improving the representation of groundwater flow directions along the eastern boundary of OLF Coupeville in the intermediate elevation interval to be more consistent with the lack of any PFAS detections in drinking water wells east of the Base. While groundwater elevation data from newly installed on-Base monitoring wells suggest that these refined flow directions are reasonable, there remains a lack of off-Base groundwater elevation data to constrain the model calibration. Additionally, the CSM inference that there is not significant flow from OLF Coupeville to the east is largely based on the lack of elevated PFAS in residential well samples east of the Base collected in 2016.
- Groundwater elevations west of OLF Coupeville are uncertain, and additional data in these areas would significantly improve understanding of the groundwater flow regime.
- Vadose zone solute transport simulations suggest a delay in the arrival of peak PFOA and PFOS concentrations at the water table (between 5 and 50 years into the future). This is a result of relatively lower concentrations

of PFOA and PFOS in soil samples near the water table and higher concentrations shallower in the soil profiles (that is, it would take time for the higher concentrations to be leached to the water table). The projected delay in the arrival of PFOA and PFOS at the water table is inconsistent with the current presence of elevated PFOA and PFOS concentrations in groundwater underlying the release areas along with the large spatial extent of groundwater plumes at the site, particularly the PFOA plume. Additional source area characterization is recommended in the upcoming RI.

- Based on model projections and the lack of elevated PFOA in the WI-CV-MW03S/M/D well cluster, elevated concentrations of PFOA near the Keystone Well do not appear to have been transported from the release areas east of the runway. The evaluation of additional potential release areas, such as the area west of the runway near the Keystone Well, requires additional investigation.
- Additional data are needed to reconcile the lower on-Base PFAS concentrations near the southern Base boundary with higher off-Base PFAS concentrations at residential wells to the south.
- The science regarding PFAS solute transport parameters continues to evolve, and projections of future plume migration are expected to need to be refined as more definitive data become available. The simulated persistence and extent of the PFOA and PFOS plumes presented in this report are heavily influenced by the assigned K_{oc} values in the vadose and saturated zones. Large ranges for these parameters are reported in the literature. Assuming lower values than those assumed herein would result in greater simulated migration extents of these constituents, while assuming higher values would result in more limited simulated migration extents. Future solute transport modeling will incorporate PFAS solute transport parameter values based on additional studies/publications as they become available.
- The regulatory environment regarding PFAS is also expected to evolve in the coming years, and these changes will need to be considered as future decisions are made regarding remediation activities, if any, at OLF Coupeville.

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Appendix A
Aquifer Test Hydrographs

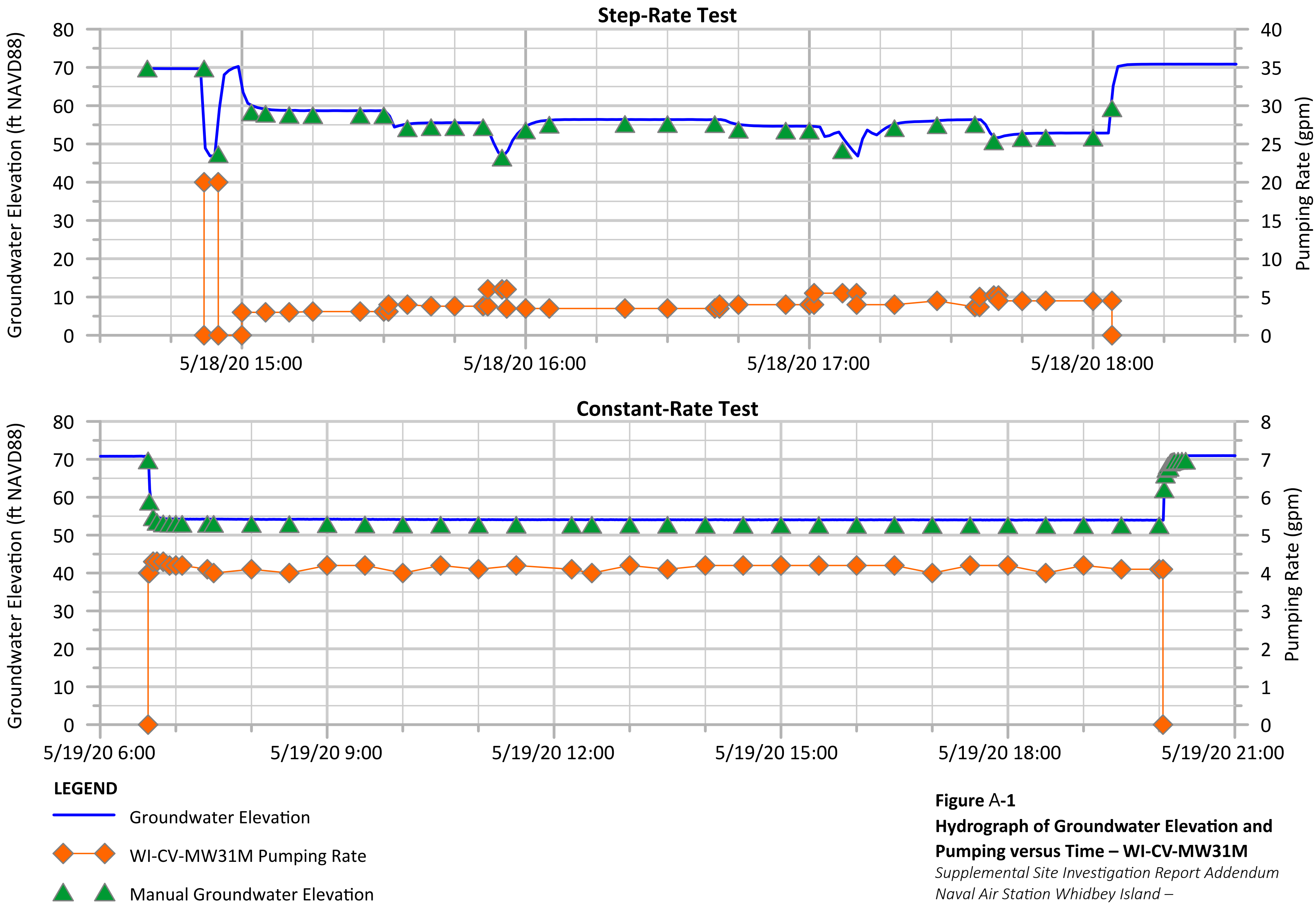

Figure A-1

Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW31M

Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

NG0412170816VBO Figure_A-1_AqTst_Hydrographs

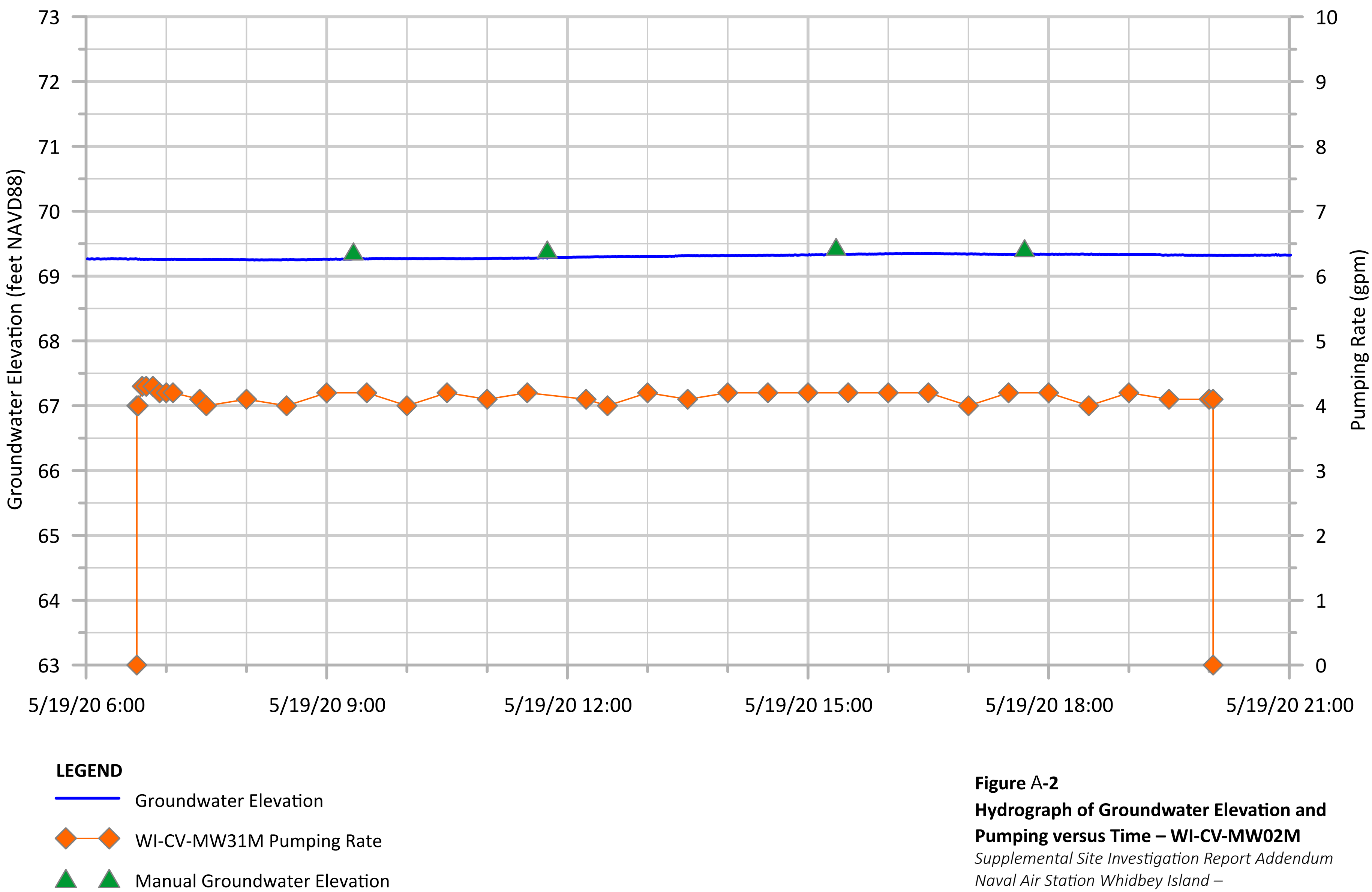

Figure A-**2**
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW02M
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

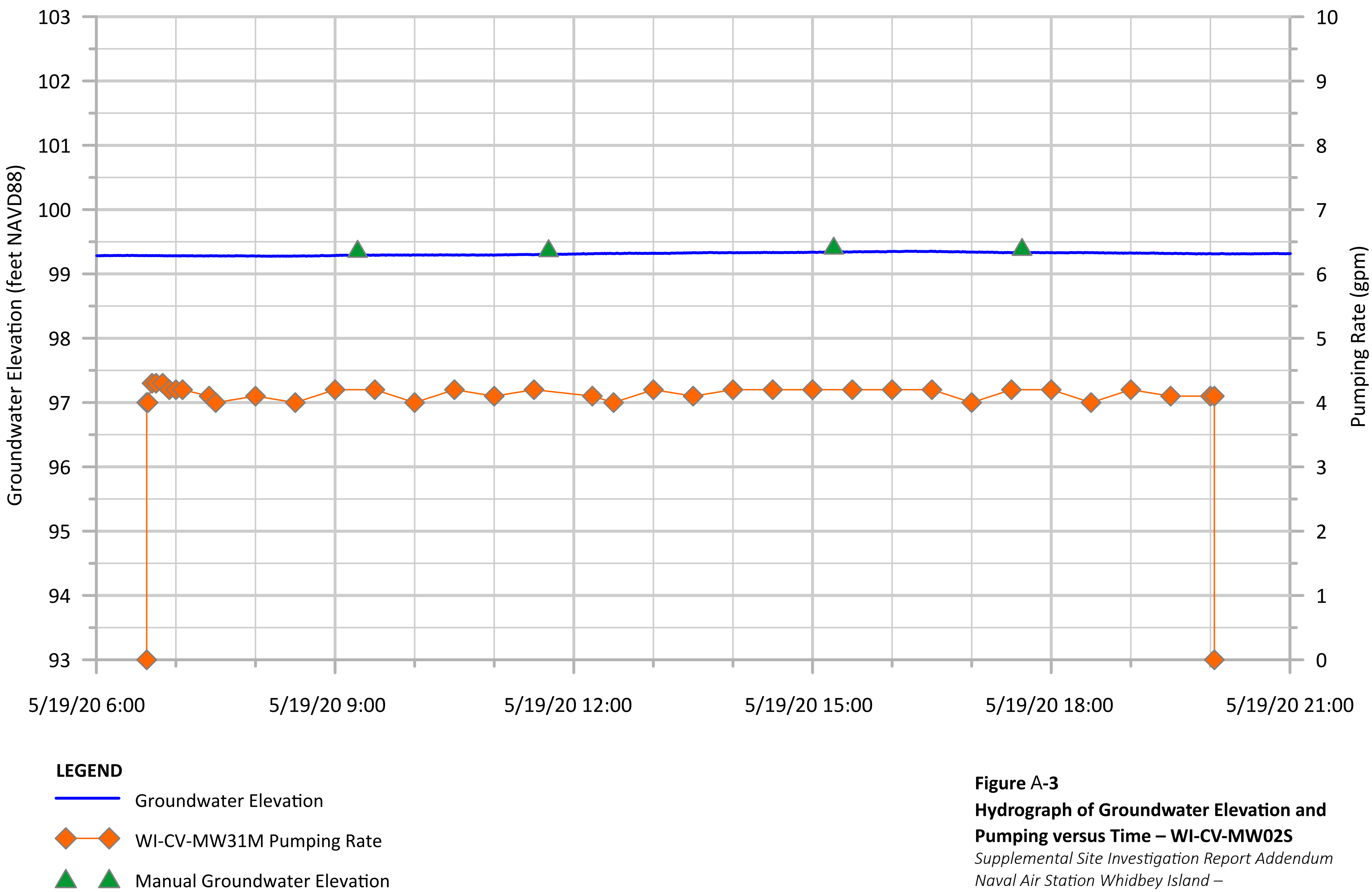

Figure A-3
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW02S
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
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Coupeville, Washington

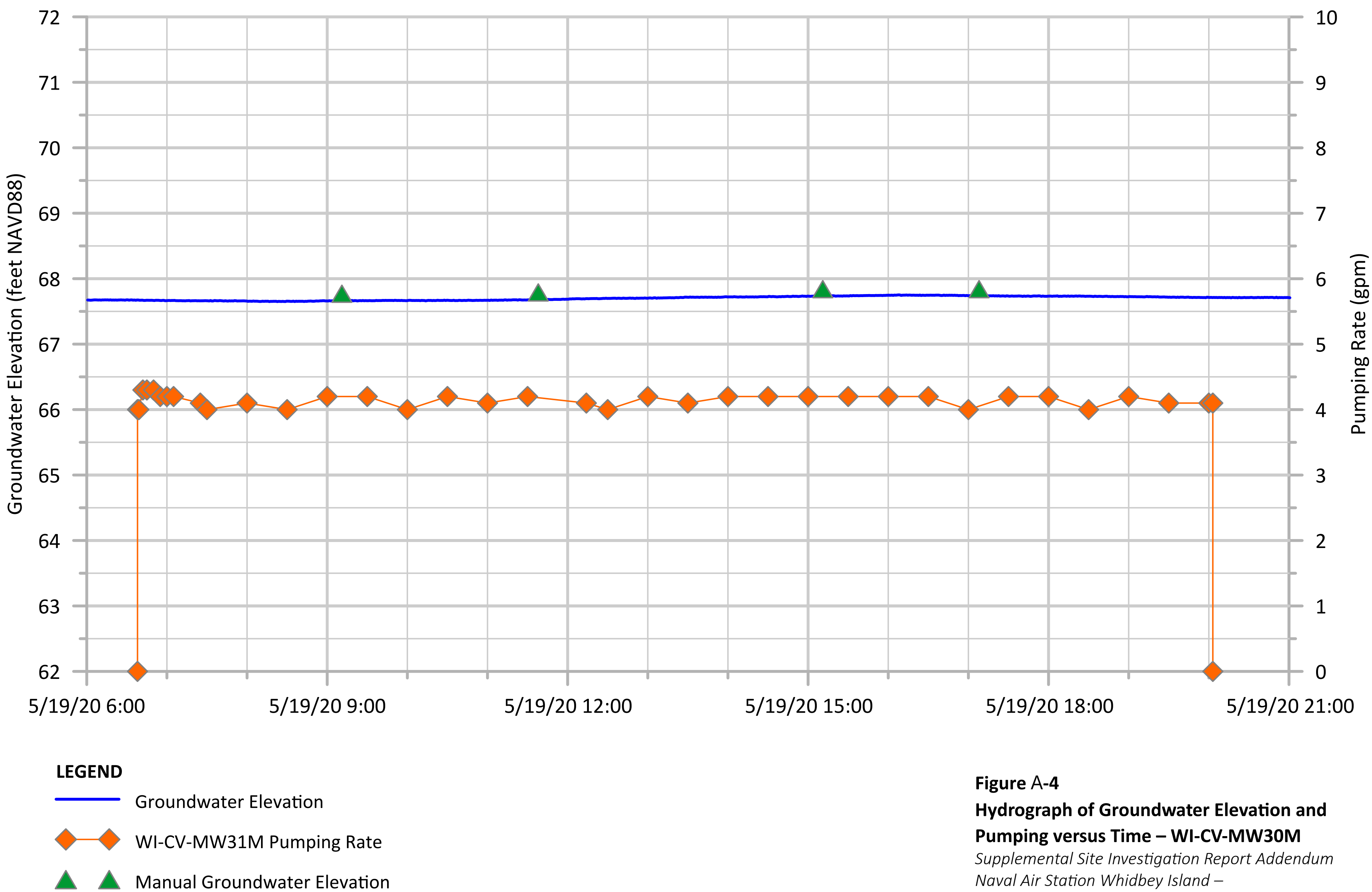

Figure A-4
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW30M
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
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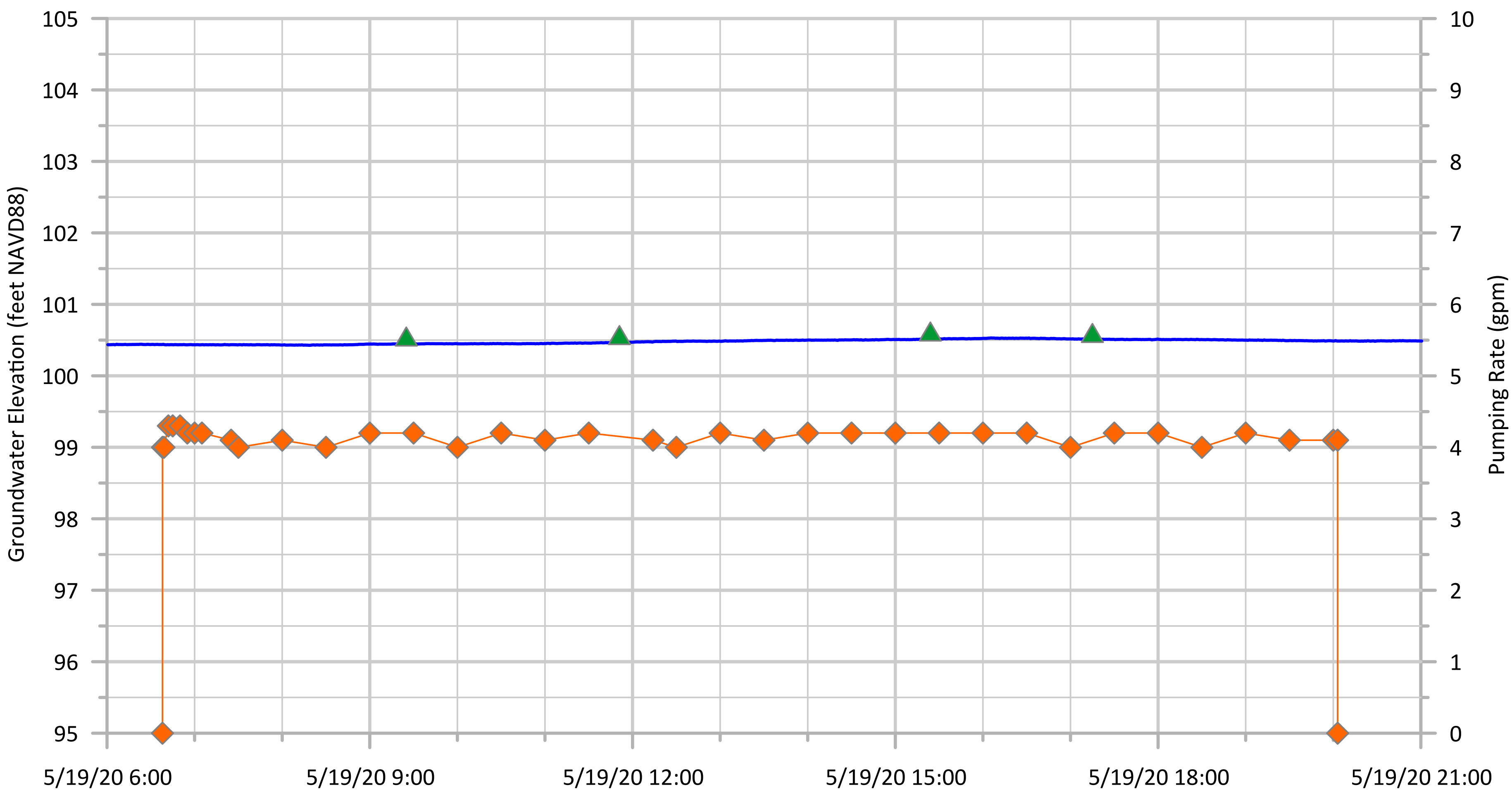
Coupeville, Washington



LEGEND

Groundwater Elevation

WI-CV-MW31M Pumping Rate

Manual Groundwater Elevation

Figure A-5

Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW20S

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Naval Air Station Whidbey Island –
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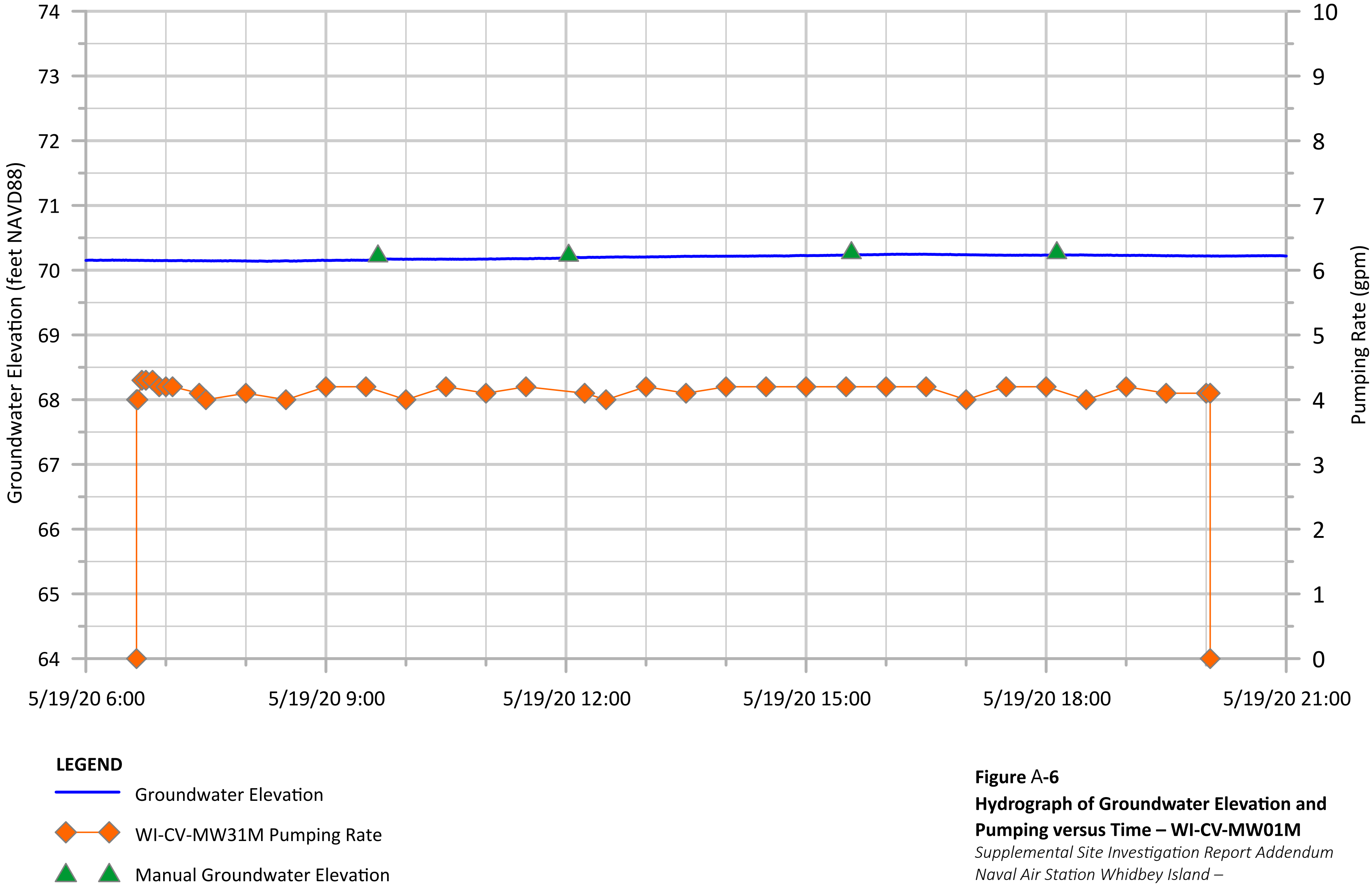
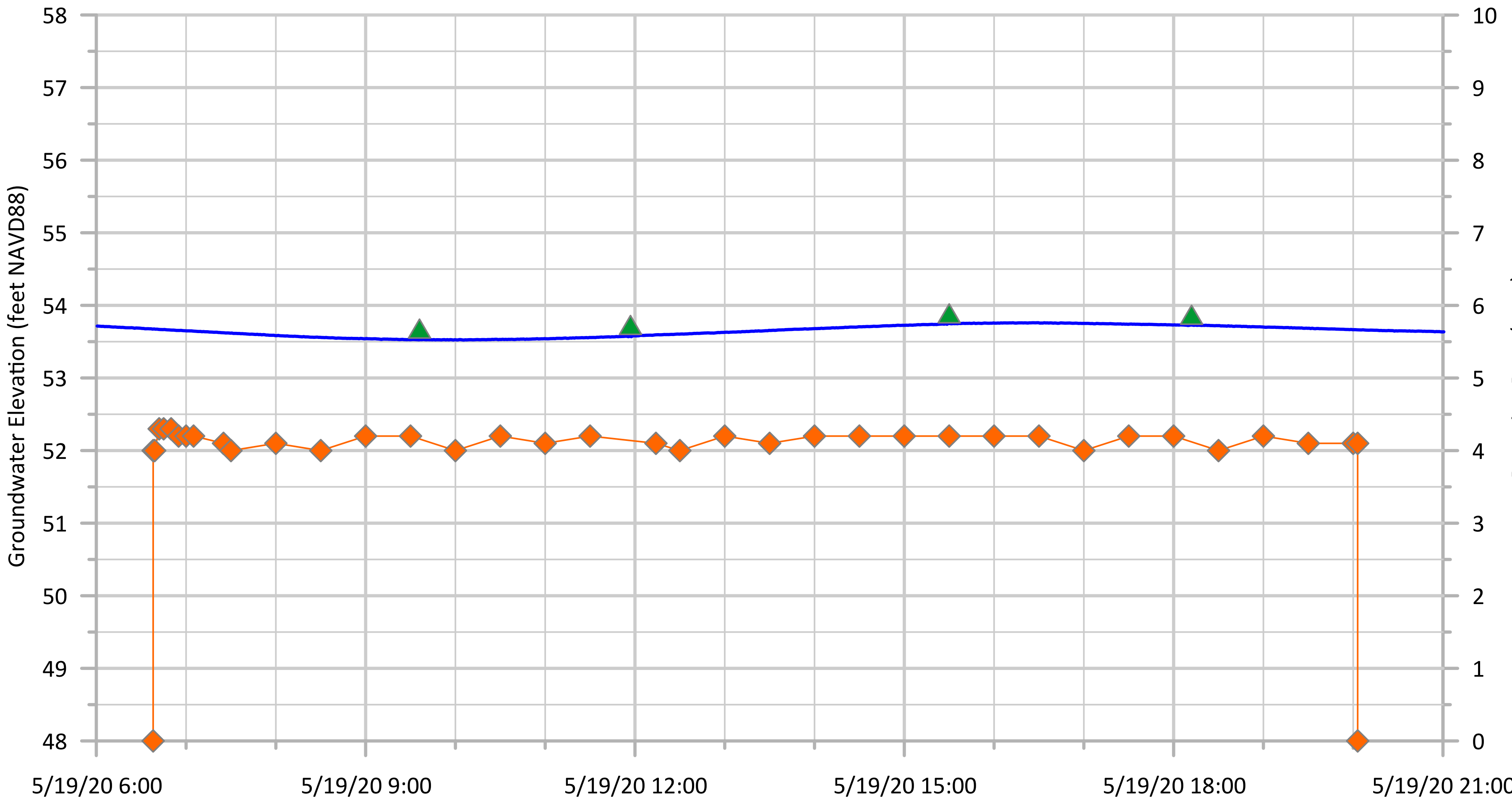


Figure A-6
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW01M
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington



LEGEND

Groundwater Elevation

WI-CV-MW31M Pumping Rate

Manual Groundwater Elevation

Figure A-7

Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW01D

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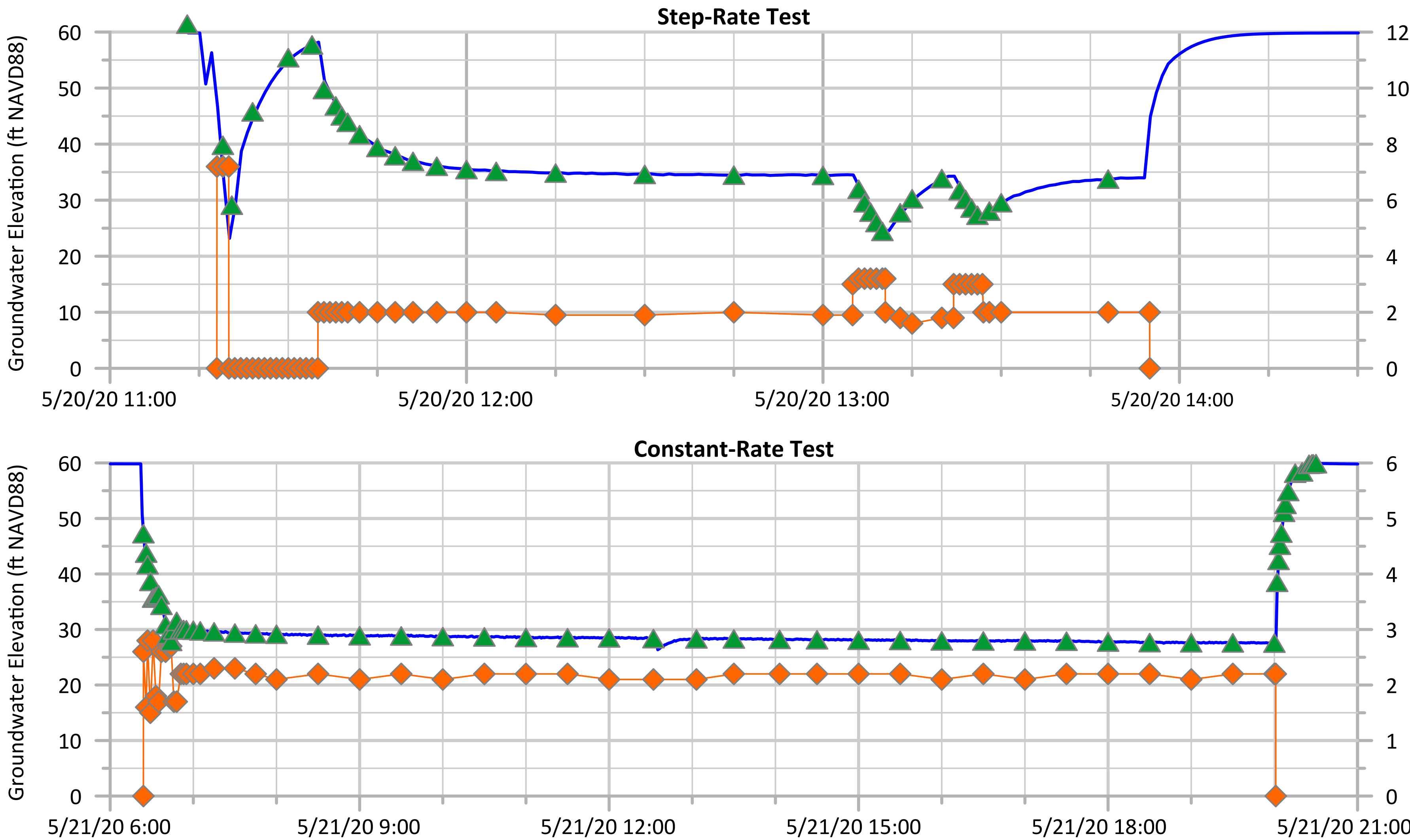
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

ch2m.

NG0412170816VBO Figure_A-7_AqTst_Hydrographs



LEGEND

- Groundwater Elevation
- WI-CV-MW29M Pumping Rate
- Manual Groundwater Elevation

Figure A-8
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW29M
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

ch2m

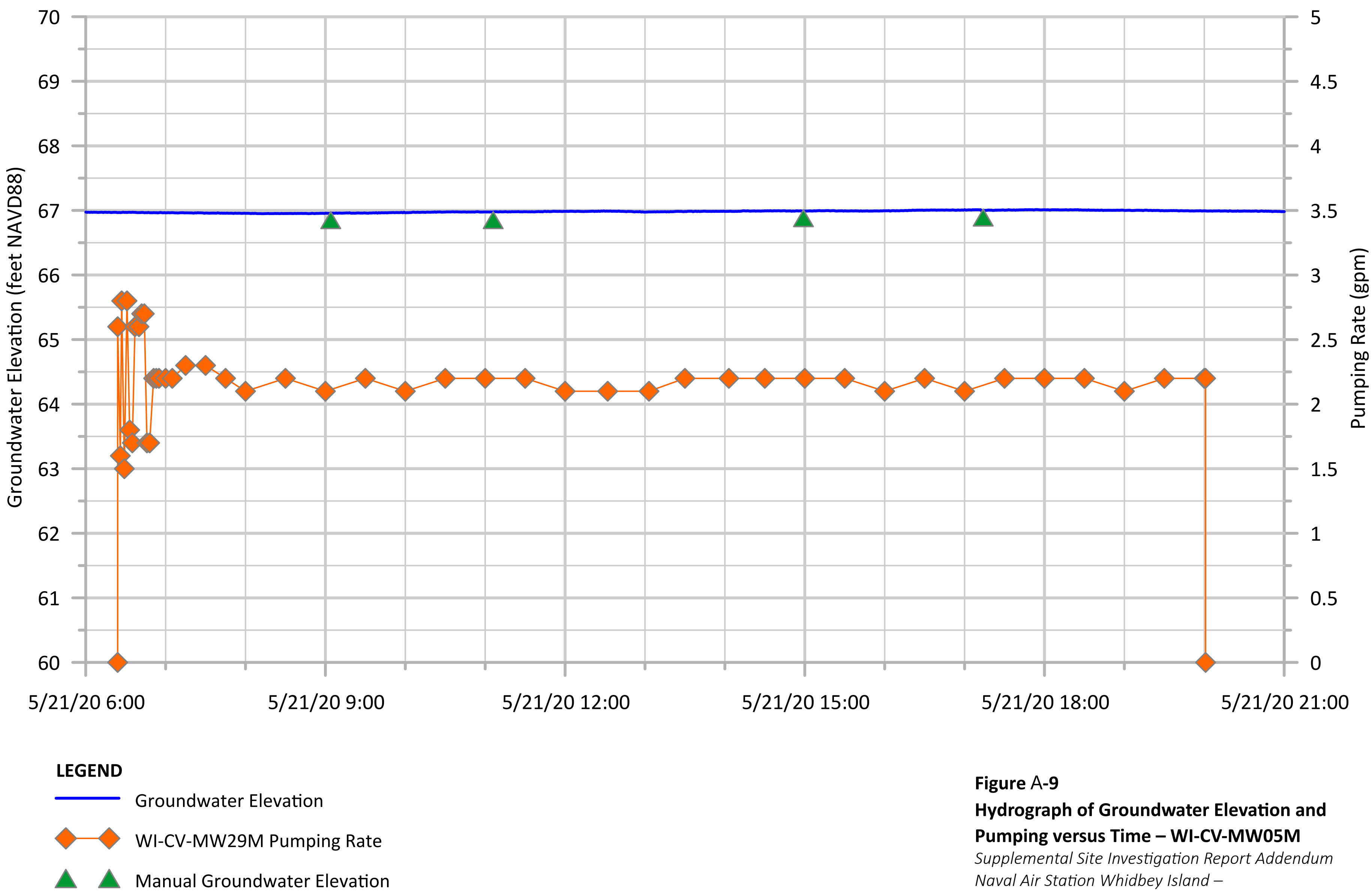


Figure A-9
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW05M
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

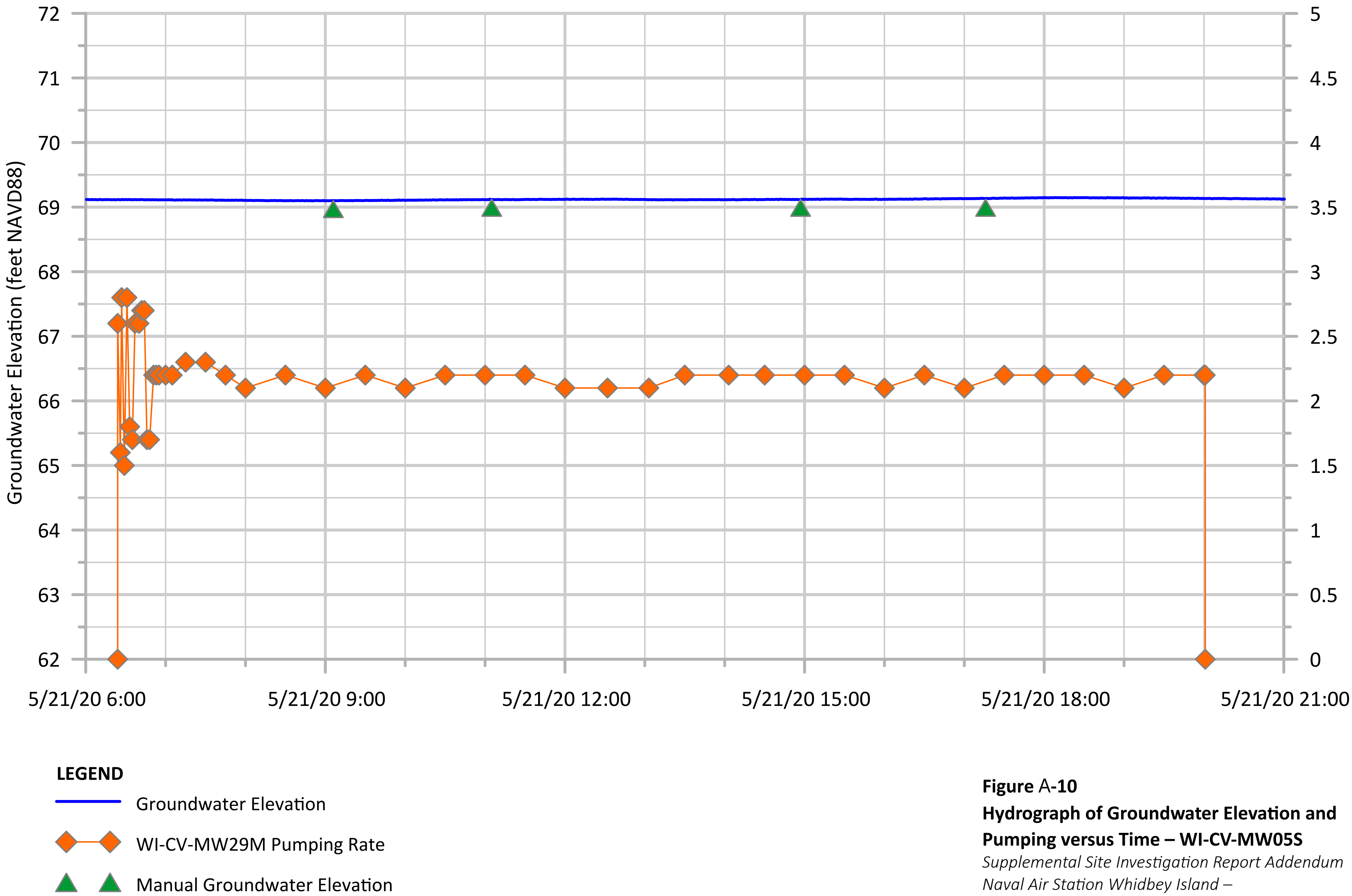


Figure A-10
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW05S
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Naval Air Station Whidbey Island –
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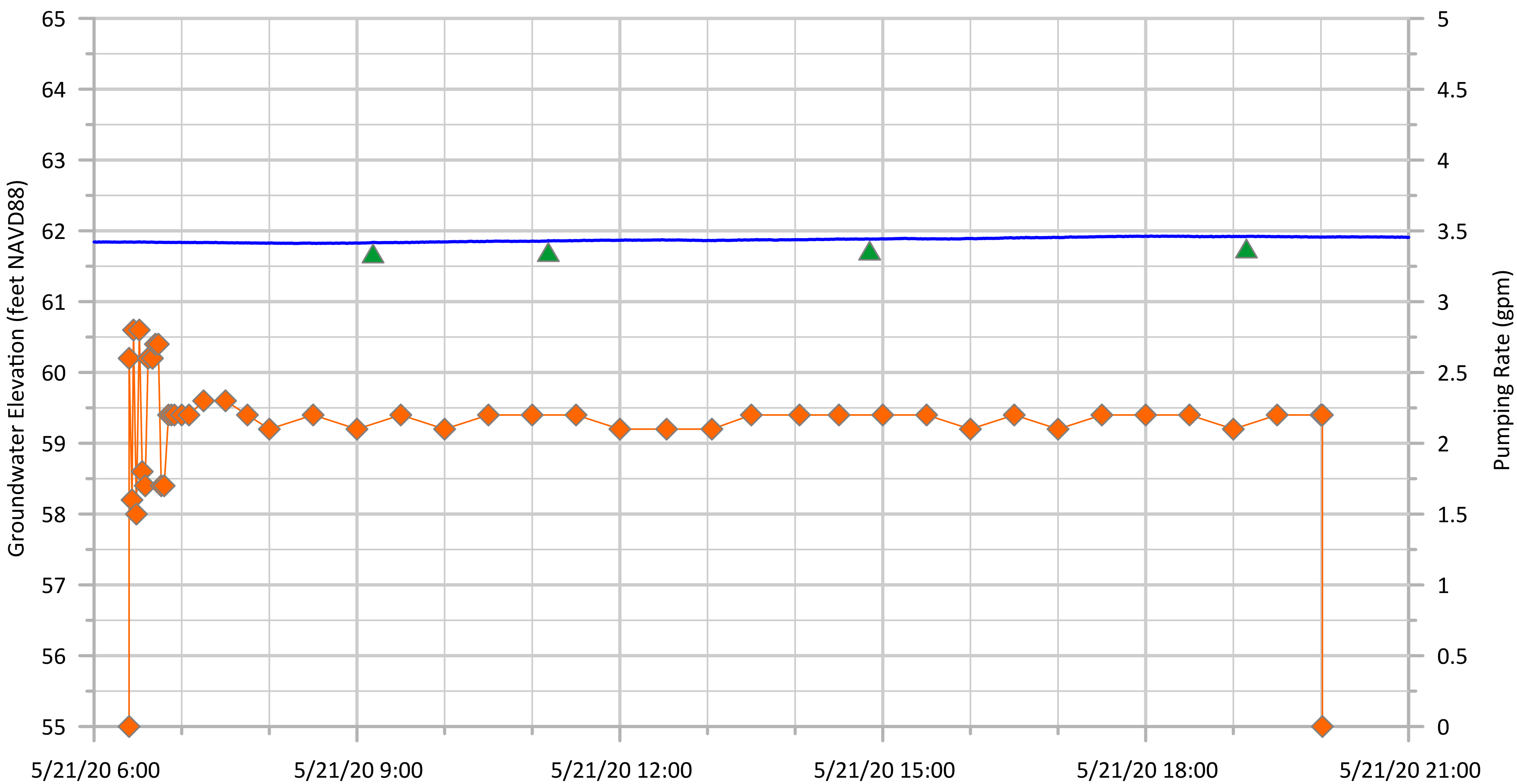
Coupeville, Washington

ch2m.



LEGEND

Groundwater Elevation

WI-CV-MW29M Pumping Rate

Manual Groundwater Elevation

Figure A-**11**
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW13M
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Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

NG0412170816VBO Figure_A-11_AqTst_Hydrographs

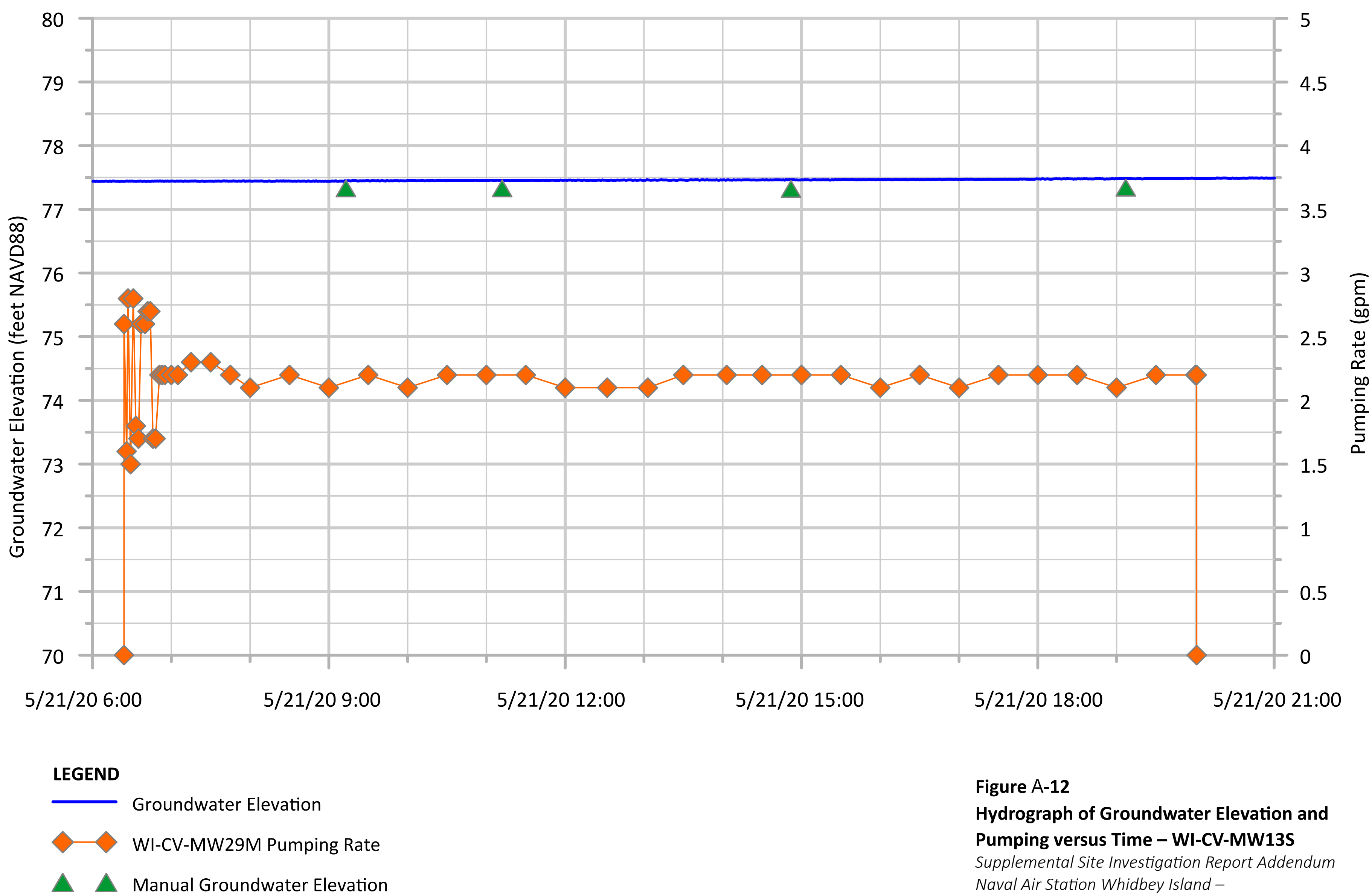


Figure A-12
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW13S
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

ch2m

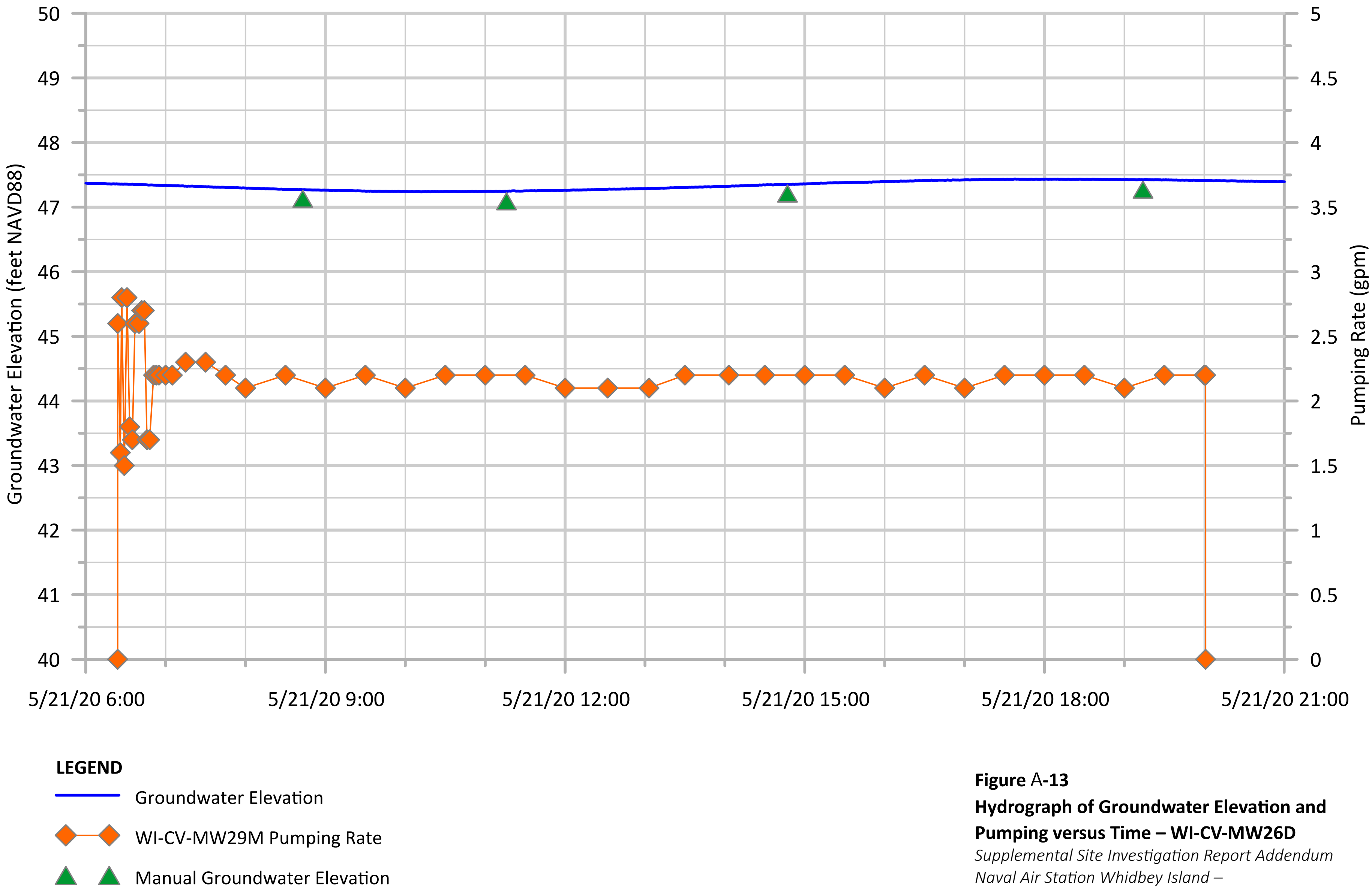


Figure A-13
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW26D
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

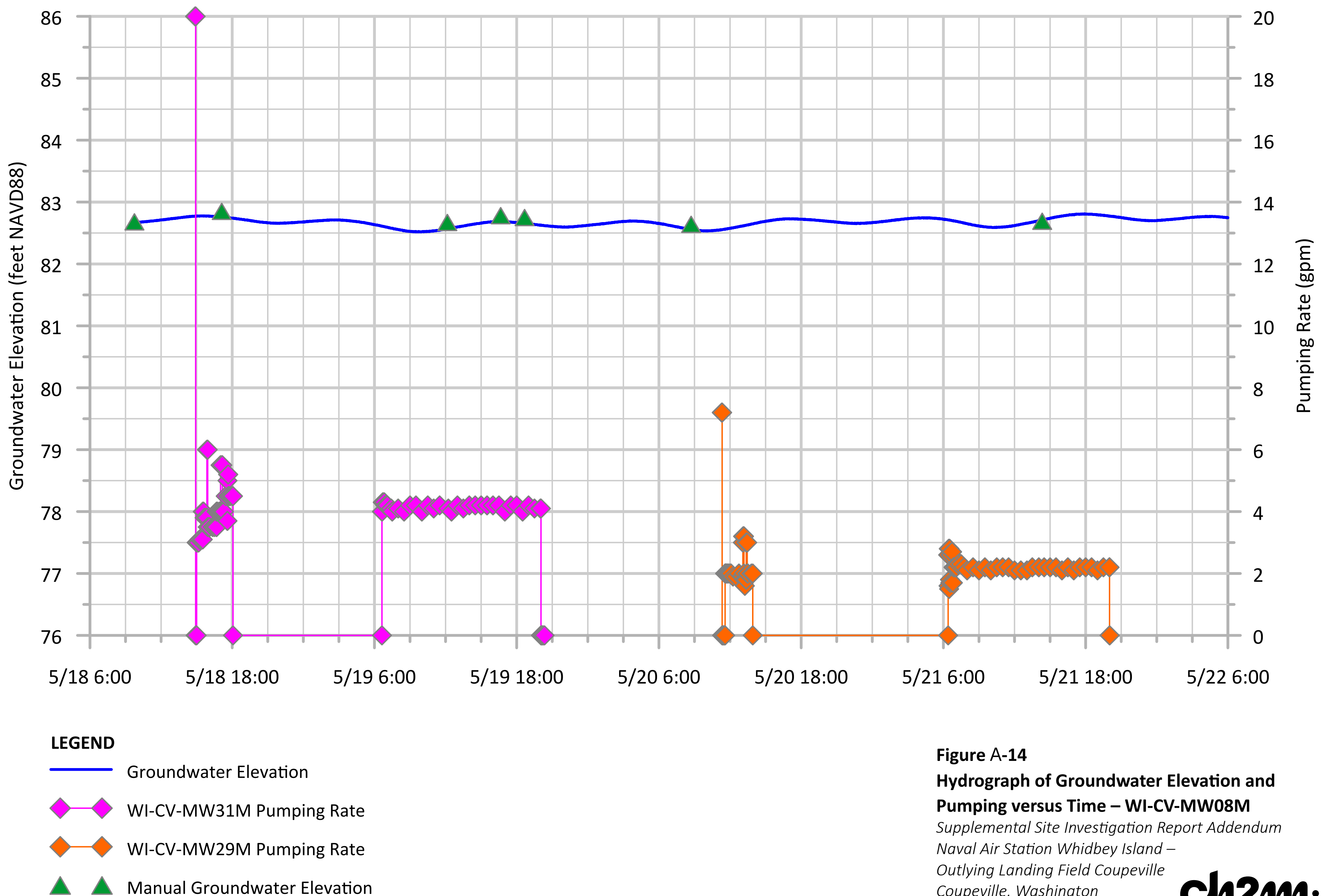


Figure A-**14**
Hydrograph of Groundwater Elevation and Pumping versus Time – WI-CV-MW08M
Supplemental Site Investigation Report Addendum
Naval Air Station Whidbey Island –
Outlying Landing Field Coupeville
Coupeville, Washington

ch2m

Appendix B
Outlying Landing Field Site Inspection
Phase 1 Soil Geotechnical Results

Petroleum Services Division
3437 Landco Dr.
Bakersfield, California 93308
Tel: 661-325-5657
Fax: 661-325-5808
www.corelab.com

November 18, 2019

Rachel Clennon
Jacobs
1100 112th Ave. NE., Suite 500
Bellevue, WA 98004

Subject: OLF Coupeville
Project: OLF SI PHASE 1
CL File No: 1903854

Dear Ms Clennon:

The attached file presents the final physical properties determination results for the soil samples submitted from your OLF SI PHASE 1 Project.

Appropriate ASTM, EPA or API methodologies were used for this project and SOP's are available on request. The samples for this project are currently in storage and will be retained for thirty days past completion of testing at no charge. At the end of thirty days, the samples will be disposed. You may contact me regarding continued storage, disoposal, or return of the samples.

Thank you for this opportunity to be of service to Jacobs . Please do not hesitate to contact us at (661-325-5657) if you have any questions regarding these results or if we can be of any additional service.

Sincerely,
Core Laboratories LP

Eva M. Lopez

Eva Lopez
Core Analyst

Physical Properties Data

Petroleum Services

Jacobs

Core Lab File No.: 1903854

Project Name: OLF SI PHASE 1

Project Number: 9000NVT1

	METHODS:	ASTM D2937	API RP 40		Walkley-Black	
Sample ID.	Sample Orientation [1]	Dry Bulk Density g/cc	Porosity		Total Organic Carbon mg/kg	Fractional Organic Carbon g/g
			Total [2] %Vb [4]	Air Filled [3] %Vb [4]		
WI-CV-BH21-120-0919	V	1.68	38.3	<0.01	12400	1.24E-02
WI-CV-BH21-140-0919	V	1.71	36.0	8.85	2400	2.40E-03
WI-CV-BH20-120-1019	V	1.65	39.6	<0.01	12400	1.24E-02
WI-CV-BH20-186-1019	V	1.67	38.6	<0.01	14400	1.44E-02

(1) Sample Orientation: H = horizontal; V = vertical.

(2) Total Porosity = no pore fluids in place; all interconnected pore channels.

(3) Air Filled Porosity= pore channels not occupied by pore fluids.

(4) Vb = Bulk Volume, cc.

SIEVE and LASER PARTICLE SIZE SUMMARY

(METHODOLOGY: ASTM D422/D4464M)

Petroleum Services

Company: Jacobs
Project Name: OLF SI PHASE 1
Project Number: 9000NVT1

CL File No.: 1903854
Date: 11/18/2019

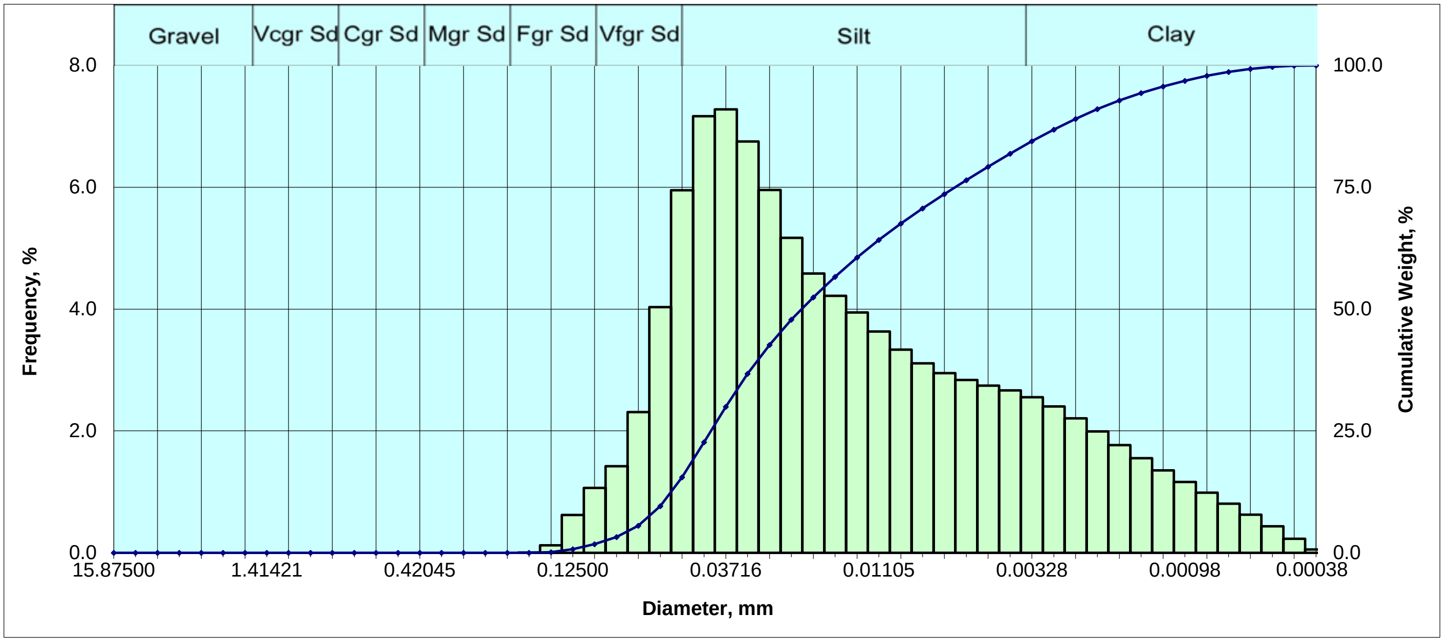
Sample ID	Grain Size Description** (Mean from Folk)	Median Grain Size, mm	Component Percentages								
				Sand Size							
			Gravel	VCoarse	Coarse	Medium	Fine	VFine	Silt	Clay	Silt & Clay
WI-CV-BH21-120-0919	Silt	0.0204	0.00	0.00	0.00	0.00	0.74	8.83	72.29	18.13	90.42
WI-CV-BH21-140-0919	Medium Grain Sand	0.3848	0.77	12.98	22.38	34.51	15.15	4.92	7.40	1.89	9.29
WI-CV-BH20-120-1019	Silt	0.0248	0.00	0.00	0.00	0.00	0.98	9.20	73.55	16.27	89.82
WI-CV-BH20-186-1019	Silt	0.0144	0.00	0.00	0.00	0.00	1.25	7.43	69.03	22.29	91.31

**Wentworth Scale

Company: Jacobs
Project Name: OLF SI PHASE 1
Project Number: 9000NVT1

CL File No.: 1903854
Sample ID: WI-CV-BH21-120-0919

Sieve and Laser Particle Size Analysis



Particle Size Distribution						
	Diameter				Weight %	
	[US Mesh]	[in.]	[mm]	[ϕ]	[Incl.]	[Cum.]
Gravel	5/8 in.	0.625000	15.87500	-4.00	0.000	0.00
	3/8 in.	0.375000	9.50000	-3.25	0.000	0.00
	4	0.187008	4.75000	-2.25	0.000	0.00
	6	0.131890	3.35000	-1.75	0.000	0.00
	8	0.092913	2.36000	-1.25	0.000	0.00
	10	0.078740	2.00000	-1.00	0.000	0.00
V Crse Sand	12	0.066212	1.68179	-0.75	0.000	0.00
	14	0.055678	1.41421	-0.50	0.000	0.00
	16	0.046819	1.18921	-0.25	0.000	0.00
	18	0.039370	1.00000	0.00	0.000	0.00
Coarse Sand	20	0.033106	0.84090	0.25	0.000	0.00
	25	0.027839	0.70711	0.50	0.000	0.00
	30	0.023410	0.59460	0.75	0.000	0.00
	35	0.019685	0.50000	1.00	0.000	0.00
Medium Sand	40	0.016553	0.42045	1.25	0.000	0.00
	45	0.013919	0.35355	1.50	0.000	0.00
	50	0.011705	0.29730	1.75	0.000	0.00
	60	0.009843	0.25000	2.00	0.000	0.00
Fine Sand	70	0.008277	0.21022	2.25	0.000	0.00
	80	0.006960	0.17678	2.50	0.002	0.00
	100	0.005852	0.14865	2.75	0.122	0.12
	120	0.004921	0.12500	3.00	0.621	0.74
V. Fine Sand	140	0.004138	0.10511	3.25	1.067	1.81
	170	0.003480	0.08839	3.50	1.421	3.23
	200	0.002926	0.07433	3.75	2.311	5.54
	230	0.002461	0.06250	4.00	4.033	9.58
Silt	270	0.002069	0.05256	4.25	5.949	15.53
	325	0.001740	0.04419	4.50	7.167	22.69
	400	0.001463	0.03716	4.75	7.279	29.97
	450	0.001230	0.03125	5.00	6.749	36.72
	500	0.001035	0.02628	5.25	5.956	42.68
	635	0.000870	0.02210	5.50	5.169	47.85
		0.000732	0.01858	5.75	4.582	52.43
		0.000615	0.01562	6.00	4.219	56.65
		0.000517	0.01314	6.25	3.945	60.59
		0.000435	0.01105	6.50	3.630	64.22
		0.000366	0.00929	6.75	3.334	67.56
		0.000308	0.00781	7.00	3.111	70.67
		0.000259	0.00657	7.25	2.952	73.62
		0.000217	0.00552	7.50	2.837	76.46
		0.000183	0.00465	7.75	2.746	79.20
		0.000154	0.00391	8.00	2.666	81.87
Clay		0.000129	0.00328	8.25	2.553	84.42
		0.000109	0.00276	8.50	2.400	86.82
		0.000091	0.00232	8.75	2.210	89.03
		0.000077	0.00195	9.00	1.994	91.03
		0.000065	0.00164	9.25	1.769	92.79
		0.000054	0.00138	9.50	1.552	94.35
		0.000046	0.00116	9.75	1.352	95.70
		0.000038	0.00098	10.00	1.163	96.86
		0.000032	0.00082	10.25	0.987	97.85
		0.000027	0.00069	10.50	0.808	98.66
		0.000023	0.00058	10.75	0.624	99.28
		0.000019	0.00049	11.00	0.434	99.71
		0.000016	0.00041	11.25	0.231	99.94
		0.000015	0.00038	11.50	0.056	100.00

Sorting Statistics (Folk)			
Parameter	Trask	Inman	Folk
Median	Silt sized		
(in)	0.0008	0.0008	0.0008
(mm)	0.0204	0.0204	0.0204
Mean	Silt sized		
(in)	0.0009	0.0005	0.0006
(mm)	0.0240	0.0133	0.0153
Sorting	Poor		
	2.631	1.970	1.883
Skewness	Strongly fine skewed		
	0.780	0.527	0.333
Kurtosis	Platykurtic		
	0.301	0.505	0.870

Component Percentages				
Gravel	Sand	Silt	Clay	Silt + Clay
0.00	9.58	72.29	18.13	90.42

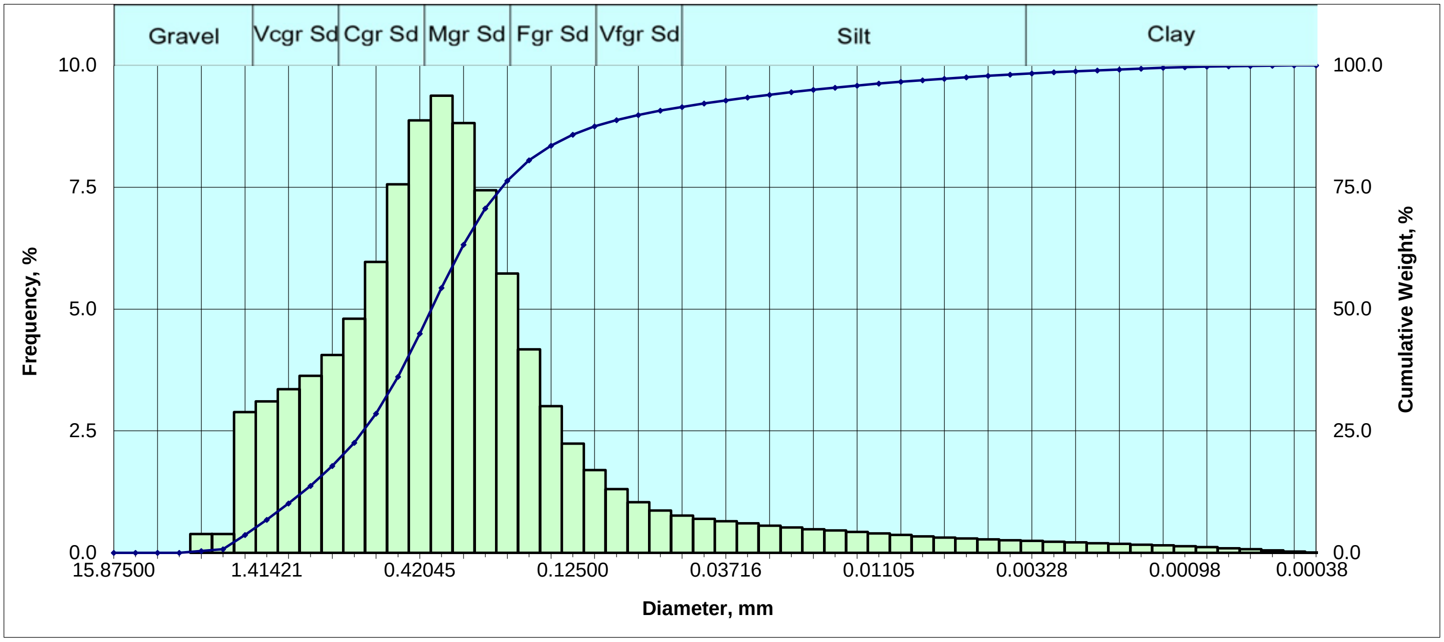
Percentile [Weight, %]	Particle Diameter [in.]	Particle Diameter [mm]	Particle Diameter [phi]
5	0.0031	0.0776	3.6872
10	0.0024	0.0618	4.0164
16	0.0020	0.0520	4.2653
25	0.0017	0.0420	4.5747
40	0.0011	0.0285	5.1323
50	0.0008	0.0204	5.6122
70	0.0003	0.0081	6.9426
75	0.0002	0.0061	7.3663
84	0.0001	0.0034	8.2056
90	0.0001	0.0021	8.8660
95	0.0001	0.0013	9.6155

**All Grain Sizes Classed Using Wentworth Scale

Company: Jacobs
Project Name: OLF SI PHASE 1
Project Number: 9000NVT1

CL File No.: 1903854
Sample ID: WI-CV-BH21-140-0919

Sieve and Laser Particle Size Analysis



Particle Size Distribution

	Diameter [US Mesh]	Diameter [in.]	Diameter [mm]	Diameter [ϕ]	Weight % [Incl.]	Weight % [Cum.]
Gravel	5/8 in.	0.625000	15.87500	-4.00	0.000	0.00
	3/8 in.	0.375000	9.50000	-3.25	0.000	0.00
	4	0.187008	4.75000	-2.25	0.000	0.00
	6	0.131890	3.35000	-1.75	0.000	0.00
	8	0.092913	2.36000	-1.25	0.383	0.38
	10	0.078740	2.00000	-1.00	0.383	0.77
V Crse Sand	12	0.066212	1.68179	-0.75	2.886	3.65
	14	0.055678	1.41421	-0.50	3.105	6.76
	16	0.046819	1.18921	-0.25	3.360	10.12
	18	0.039370	1.00000	0.00	3.629	13.75
Coarse Sand	20	0.033106	0.84090	0.25	4.058	17.81
	25	0.027839	0.70711	0.50	4.801	22.61
	30	0.023410	0.59460	0.75	5.967	28.57
	35	0.019685	0.50000	1.00	7.558	36.13
Medium Sand	40	0.016553	0.42045	1.25	8.873	45.00
	45	0.013919	0.35355	1.50	9.377	54.38
	50	0.011705	0.29730	1.75	8.819	63.20
	60	0.009843	0.25000	2.00	7.437	70.64
Fine Sand	70	0.008277	0.21022	2.25	5.730	76.37
	80	0.006960	0.17678	2.50	4.175	80.54
	100	0.005852	0.14865	2.75	3.008	83.55
	120	0.004921	0.12500	3.00	2.241	85.79
V. Fine Sand	140	0.004138	0.10511	3.25	1.700	87.49
	170	0.003480	0.08839	3.50	1.308	88.80
	200	0.002926	0.07433	3.75	1.040	89.84
	230	0.002461	0.06250	4.00	0.869	90.71
Silt	270	0.002069	0.05256	4.25	0.763	91.47
	325	0.001740	0.04419	4.50	0.700	92.17
	400	0.001463	0.03716	4.75	0.651	92.82
	450	0.001230	0.03125	5.00	0.603	93.43
	500	0.001035	0.02628	5.25	0.558	93.98
	635	0.000870	0.02210	5.50	0.518	94.50
		0.000732	0.01858	5.75	0.486	94.99
		0.000615	0.01562	6.00	0.457	95.44
		0.000517	0.01314	6.25	0.428	95.87
		0.000435	0.01105	6.50	0.396	96.27
		0.000366	0.00929	6.75	0.366	96.63
		0.000308	0.00781	7.00	0.338	96.97
		0.000259	0.00657	7.25	0.314	97.29
		0.000217	0.00552	7.50	0.293	97.58
		0.000183	0.00465	7.75	0.274	97.85
		0.000154	0.00391	8.00	0.259	98.11
Clay		0.000129	0.00328	8.25	0.243	98.36
		0.000109	0.00276	8.50	0.229	98.58
		0.000091	0.00232	8.75	0.214	98.80
		0.000077	0.00195	9.00	0.199	99.00
		0.000065	0.00164	9.25	0.184	99.18
		0.000054	0.00138	9.50	0.168	99.35
		0.000046	0.00116	9.75	0.152	99.50
		0.000038	0.00098	10.00	0.134	99.63
		0.000032	0.00082	10.25	0.115	99.75
		0.000027	0.00069	10.50	0.095	99.84
		0.000023	0.00058	10.75	0.073	99.92
		0.000019	0.00049	11.00	0.050	99.97
		0.000016	0.00041	11.25	0.027	99.99
		0.000015	0.00038	11.50	0.006	100.00

Sorting Statistics (Folk)

Parameter	Trask	Inman	Folk
Median	Medium sand sized		
(in)	0.0152	0.0152	0.0152
(mm)	0.3848	0.3848	0.3848
Mean	Medium sand sized		
(in)	0.0174	0.0143	0.0146
(mm)	0.4408	0.3622	0.3696
Sorting	Poor		
	1.736	1.332	1.636
Skewness	Finely skewed		
	0.991	0.884	0.217
Kurtosis	Very leptokurtic		
	0.197	1.404	1.649

Component Percentages

Gravel	Sand	Silt	Clay	Silt + Clay
0.77	89.94	7.40	1.89	9.29

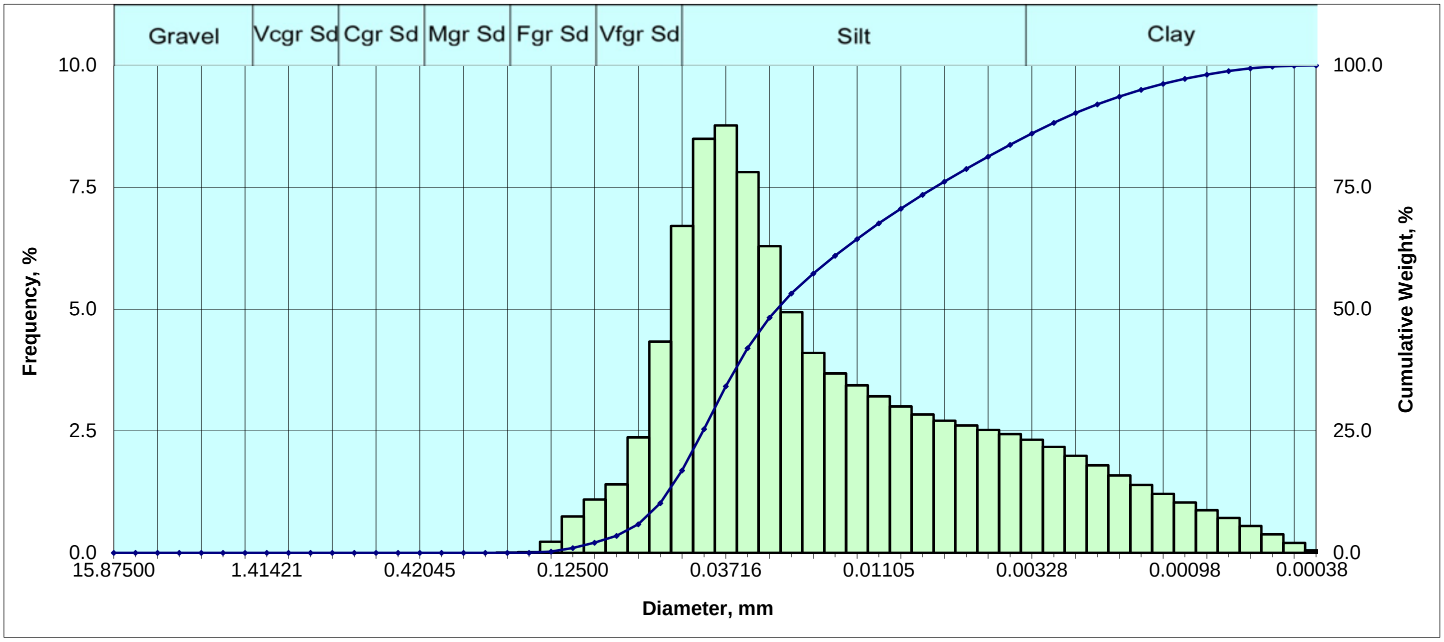
Percentile [Weight, %]	Particle Diameter [in.]	Particle Diameter [mm]	Particle Diameter [phi]
5	0.0616	1.5657	-0.6468
10	0.0471	1.1971	-0.2596
16	0.0359	0.9117	0.1334
25	0.0261	0.6620	0.5951
40	0.0183	0.4653	1.1037
50	0.0152	0.3848	1.3778
70	0.0100	0.2541	1.9768
75	0.0087	0.2197	2.1863
84	0.0057	0.1439	2.7968
90	0.0028	0.0721	3.7930
95	0.0007	0.0185	5.7562

**All Grain Sizes Classed Using Wentworth Scale

Company: Jacobs
Project Name: OLF SI PHASE 1
Project Number: 9000NVT1

CL File No.: 1903854
Sample ID: WI-CV-BH20-120-1019

Sieve and Laser Particle Size Analysis



Particle Size Distribution

	Diameter [US Mesh]	Diameter [in.]	Diameter [mm]	Diameter [ϕ]	Weight % [Incl.]	Weight % [Cum.]
Gravel	5/8 in.	0.625000	15.87500	-4.00	0.000	0.00
	3/8 in.	0.375000	9.50000	-3.25	0.000	0.00
	4	0.187008	4.75000	-2.25	0.000	0.00
	6	0.131890	3.35000	-1.75	0.000	0.00
	8	0.092913	2.36000	-1.25	0.000	0.00
	10	0.078740	2.00000	-1.00	0.000	0.00
V Crse Sand	12	0.066212	1.68179	-0.75	0.000	0.00
	14	0.055678	1.41421	-0.50	0.000	0.00
	16	0.046819	1.18921	-0.25	0.000	0.00
	18	0.039370	1.00000	0.00	0.000	0.00
Coarse Sand	20	0.033106	0.84090	0.25	0.000	0.00
	25	0.027839	0.70711	0.50	0.000	0.00
	30	0.023410	0.59460	0.75	0.000	0.00
	35	0.019685	0.50000	1.00	0.000	0.00
Medium Sand	40	0.016553	0.42045	1.25	0.000	0.00
	45	0.013919	0.35355	1.50	0.000	0.00
	50	0.011705	0.29730	1.75	0.000	0.00
	60	0.009843	0.25000	2.00	0.000	0.00
Fine Sand	70	0.008277	0.21022	2.25	0.000	0.00
	80	0.006960	0.17678	2.50	0.011	0.01
	100	0.005852	0.14865	2.75	0.225	0.24
	120	0.004921	0.12500	3.00	0.745	0.98
V. Fine Sand	140	0.004138	0.10511	3.25	1.093	2.07
	170	0.003480	0.08839	3.50	1.404	3.48
	200	0.002926	0.07433	3.75	2.369	5.85
	230	0.002461	0.06250	4.00	4.333	10.18
Silt	270	0.002069	0.05256	4.25	6.708	16.89
	325	0.001740	0.04419	4.50	8.492	25.38
	400	0.001463	0.03716	4.75	8.770	34.15
	450	0.001230	0.03125	5.00	7.809	41.96
	500	0.001035	0.02628	5.25	6.291	48.25
	635	0.000870	0.02210	5.50	4.937	53.19
		0.000732	0.01858	5.75	4.099	57.29
		0.000615	0.01562	6.00	3.679	60.97
		0.000517	0.01314	6.25	3.436	64.40
		0.000435	0.01105	6.50	3.209	67.61
		0.000366	0.00929	6.75	3.001	70.61
		0.000308	0.00781	7.00	2.837	73.45
		0.000259	0.00657	7.25	2.712	76.16
		0.000217	0.00552	7.50	2.612	78.77
		0.000183	0.00465	7.75	2.523	81.30
		0.000154	0.00391	8.00	2.439	83.73
Clay		0.000129	0.00328	8.25	2.322	86.06
		0.000109	0.00276	8.50	2.172	88.23
		0.000091	0.00232	8.75	1.992	90.22
		0.000077	0.00195	9.00	1.793	92.01
		0.000065	0.00164	9.25	1.588	93.60
		0.000054	0.00138	9.50	1.390	94.99
		0.000046	0.00116	9.75	1.208	96.20
		0.000038	0.00098	10.00	1.035	97.23
		0.000032	0.00082	10.25	0.875	98.11
		0.000027	0.00069	10.50	0.713	98.82
		0.000023	0.00058	10.75	0.548	99.37
		0.000019	0.00049	11.00	0.380	99.75
		0.000016	0.00041	11.25	0.201	99.95
		0.000015	0.00038	11.50	0.049	100.00

Sorting Statistics (Folk)

Parameter	Trask	Inman	Folk
Median	**Silt sized**		
(in)	0.0010	0.0010	0.0010
(mm)	0.0248	0.0248	0.0248
Mean	**Silt sized**		
(in)	0.0010	0.0006	0.0007
(mm)	0.0258	0.0144	0.0172
Sorting	**Poor**		
	2.505	1.906	1.839
Skewness	**Strongly fine skewed**		
	0.717	0.653	0.419
Kurtosis	**Mesokurtic**		
	0.309	0.534	0.904

Component Percentages

Gravel	Sand	Silt	Clay	Silt + Clay
0.00	10.18	73.55	16.27	89.82

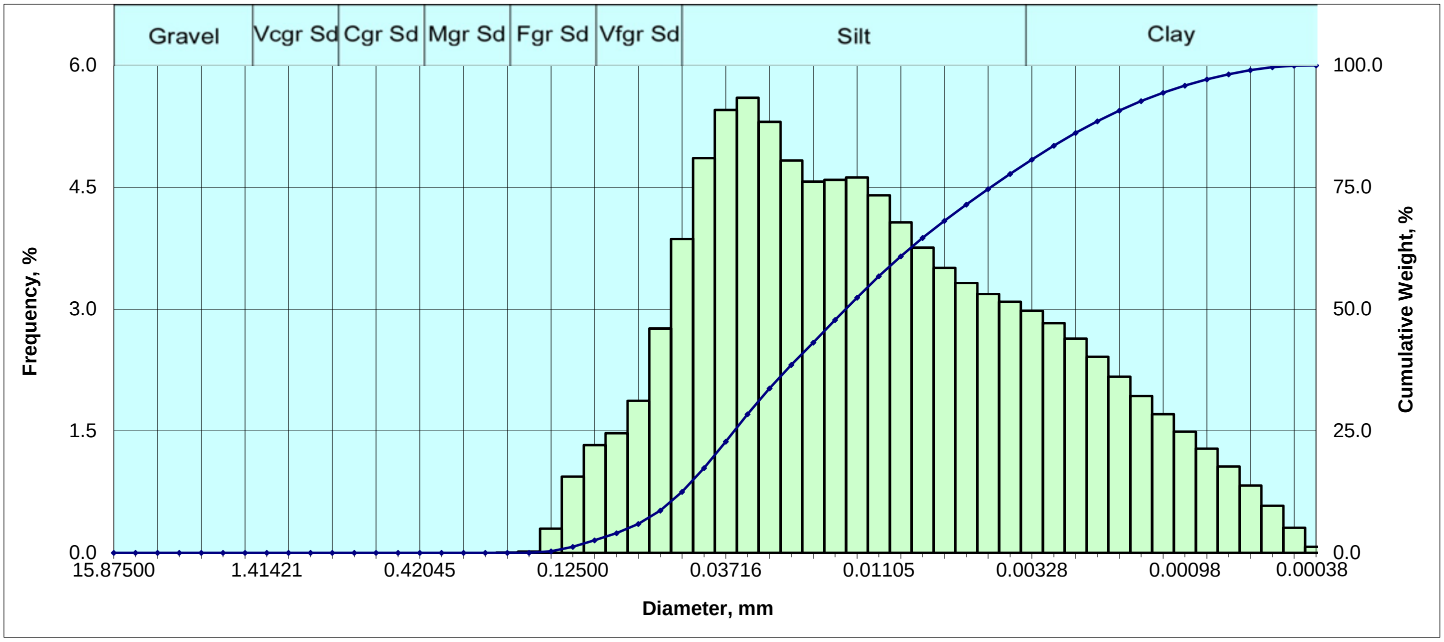
Percentile [Weight, %]	Particle Diameter [in.]	Particle Diameter [mm]	Particle Diameter [phi]
5	0.0031	0.0794	3.6556
10	0.0025	0.0630	3.9887
16	0.0021	0.0539	4.2143
25	0.0018	0.0446	4.4878
40	0.0013	0.0327	4.9331
50	0.0010	0.0248	5.3337
70	0.0004	0.0096	6.6954
75	0.0003	0.0071	7.1377
84	0.0002	0.0038	8.0265
90	0.0001	0.0024	8.7202
95	0.0001	0.0014	9.5016

**All Grain Sizes Classed Using Wentworth Scale

Company: Jacobs
Project Name: OLF SI PHASE 1
Project Number: 9000NVT1

CL File No.: 1903854
Sample ID: WI-CV-BH20-186-1019

Sieve and Laser Particle Size Analysis



Particle Size Distribution

	Diameter [US Mesh]	Diameter [in.]	Diameter [mm]	Diameter [ϕ]	Weight % [Incl.]	Weight % [Cum.]
Gravel	5/8 in.	0.625000	15.87500	-4.00	0.000	0.00
	3/8 in.	0.375000	9.50000	-3.25	0.000	0.00
	4	0.187008	4.75000	-2.25	0.000	0.00
	6	0.131890	3.35000	-1.75	0.000	0.00
	8	0.092913	2.36000	-1.25	0.000	0.00
	10	0.078740	2.00000	-1.00	0.000	0.00
V Crse Sand	12	0.066212	1.68179	-0.75	0.000	0.00
	14	0.055678	1.41421	-0.50	0.000	0.00
	16	0.046819	1.18921	-0.25	0.000	0.00
	18	0.039370	1.00000	0.00	0.000	0.00
Coarse Sand	20	0.033106	0.84090	0.25	0.000	0.00
	25	0.027839	0.70711	0.50	0.000	0.00
	30	0.023410	0.59460	0.75	0.000	0.00
	35	0.019685	0.50000	1.00	0.000	0.00
Medium Sand	40	0.016553	0.42045	1.25	0.000	0.00
	45	0.013919	0.35355	1.50	0.000	0.00
	50	0.011705	0.29730	1.75	0.000	0.00
	60	0.009843	0.25000	2.00	0.000	0.00
Fine Sand	70	0.008277	0.21022	2.25	0.000	0.00
	80	0.006960	0.17678	2.50	0.017	0.02
	100	0.005852	0.14865	2.75	0.298	0.31
	120	0.004921	0.12500	3.00	0.939	1.25
V. Fine Sand	140	0.004138	0.10511	3.25	1.328	2.58
	170	0.003480	0.08839	3.50	1.472	4.05
	200	0.002926	0.07433	3.75	1.872	5.93
	230	0.002461	0.06250	4.00	2.760	8.69
Silt	270	0.002069	0.05256	4.25	3.864	12.55
	325	0.001740	0.04419	4.50	4.860	17.41
	400	0.001463	0.03716	4.75	5.453	22.86
	450	0.001230	0.03125	5.00	5.602	28.46
	500	0.001035	0.02628	5.25	5.303	33.77
	635	0.000870	0.02210	5.50	4.830	38.60
		0.000732	0.01858	5.75	4.570	43.17
		0.000615	0.01562	6.00	4.591	47.76
		0.000517	0.01314	6.25	4.621	52.38
		0.000435	0.01105	6.50	4.402	56.78
		0.000366	0.00929	6.75	4.069	60.85
		0.000308	0.00781	7.00	3.758	64.61
		0.000259	0.00657	7.25	3.507	68.11
		0.000217	0.00552	7.50	3.322	71.44
		0.000183	0.00465	7.75	3.186	74.62
		0.000154	0.00391	8.00	3.090	77.71
Clay		0.000129	0.00328	8.25	2.977	80.69
		0.000109	0.00276	8.50	2.829	83.52
		0.000091	0.00232	8.75	2.637	86.16
		0.000077	0.00195	9.00	2.412	88.57
		0.000065	0.00164	9.25	2.169	90.74
		0.000054	0.00138	9.50	1.930	92.67
		0.000046	0.00116	9.75	1.707	94.37
		0.000038	0.00098	10.00	1.490	95.86
		0.000032	0.00082	10.25	1.283	97.15
		0.000027	0.00069	10.50	1.062	98.21
		0.000023	0.00058	10.75	0.828	99.04
		0.000019	0.00049	11.00	0.579	99.62
		0.000016	0.00041	11.25	0.309	99.92
		0.000015	0.00038	11.50	0.076	100.00

Sorting Statistics (Folk)

Parameter	Trask	Inman	Folk
Median	Silt sized		
(in)	0.0006	0.0006	0.0006
(mm)	0.0144	0.0144	0.0144
Mean	Silt sized		
(in)	0.0008	0.0004	0.0005
(mm)	0.0197	0.0112	0.0122
Sorting	Poor		
	2.768	2.060	1.974
Skewness	Finely skewed		
	0.875	0.301	0.189
Kurtosis	Platykurtic		
	0.265	0.512	0.869

Component Percentages

Gravel	Sand	Silt	Clay	Silt + Clay
0.00	8.69	69.03	22.29	91.31

Percentile [Weight, %]	Particle Diameter [in.]	Particle Diameter [mm]	Particle Diameter [phi]
5	0.0032	0.0813	3.6210
10	0.0023	0.0591	4.0803
16	0.0018	0.0466	4.4230
25	0.0014	0.0349	4.8404
40	0.0008	0.0210	5.5722
50	0.0006	0.0144	6.1159
70	0.0002	0.0060	7.3865
75	0.0002	0.0046	7.7783
84	0.0001	0.0027	8.5426
90	0.0001	0.0017	9.1603
95	0.0000	0.0011	9.8500

**All Grain Sizes Classed Using Wentworth Scale

JACOBS ch2m

CHAIN OF COUSTODY RECORD

10/28/2019 14:16:17

Project Name
Location OLF Coupeville
Project Number 9000NVT1
Project Manager R. Clennon/J. Madsen
Sample Manager Tiffany Hill
(541) 908-3794
Task Order CTO 4405
Project OLF SI PHASE 1
Turnaround Time 28 Days
Shipping Date: 10/28/2019
COC Number: CORE_1028

	DATE	TIME	Matrix	Dry Bulk Density (ASTM D2937)	Fractional Organic Carbon (Walkley Black)	Grain Size (ASTM D422)	Total Porosity (API RP40)	Number of Containers	COMMENTS
Container:				0.5 ft sleeve	0.5 ft sleeve	0.5 ft sleeve	0.5 ft sleeve		
Preservatives:				≤ 6°C	≤ 6°C	≤ 6°C	≤ 6°C		
Filtered:				NA	NA	NA	NA		
Holding Time:				28	28	28	28		
WI-CV-BH21-120-0919	9/10/2019	14:10	Soil	X	X	X	X	1	
WI-CV-BH21-140-0919	9/10/2019	~~17:00~~ 15:00	Soil	X	X	X	X	1	
WI-CV-BH20-120-1019	10/23/2019	17:30	Soil	X	X	X	X	1	
WI-CV-BH20-186-1019	10/24/2019	15:50	Soil	X	X	X	X	1	
TOTAL NUMBER OF CONTAINERS								4	

Samples arrived without ice @ 59°F

	Signatures	Date/Time
Approved by		
Sampled by		
Relinquished by	[signature]	10/28/19 1600
Received by	[signature]	10/29/19 10:00
Relinquished by		
Received by		

Shipping Details

Method of Shipment: FedEx
On Ice: (yes) / no
Airbill No: 7768 3105 7942
Lab Name: Core Laboratories
Lab Phone: (661) 325-5657

ATTN:

Sample Custody
and
Larry Kunkel

Special Instructions:

Email report to:
Rachel.Clennon@jacobs.com;
Tiffany.Hill@jacobs.com
Travis.Pitts@jacobs.com

Report Copy to
Jennifer.Madsen@jacobs.com
(425) 233-3293

Appendix C
State Historic Preservation Office Section 106 Concurrence Letter, Outlying Landing Field Coupeville Archaeological Monitoring and Treatment Plan, and Archaeological Monitoring Technical Memorandum

dahp
protect the past, shape the future

Allyson Brooks Ph.D., Director
State Historic Preservation Officer

June 24, 2020

Ms. Elizabeth Ellis
Naval Air Station Whidbey Island
3730 North Charles Porter Avenue
Oak Harbor, Washington 98278-5000

Re: Groundwater Monitoring Wells Project
Log No.: 2019-04-02954-USN

Dear Ms. Ellis;

Thank you for contacting our department. We have reviewed the materials you provided for the proposed Groundwater Monitoring Wells Project at Outlying Field (OLF) Coupeville, Naval Air Station Whidbey Island, Island County, Washington.

We concur with your Determination of No Historic Properties Affected with the stipulation for for an unanticipated discovery plan.

We would appreciate receiving any correspondence or comments from concerned tribes or other parties that you receive as you consult under the requirements of 36CFR800.4(a)(4).

In the event that archaeological or historic materials are discovered during project activities, work in the immediate vicinity must stop, the area secured, and the concerned tribes and this department notified.

These comments are based on the information available at the time of this review and on the behalf of the State Historic Preservation Officer in conformance with Section 106 of the National Historic Preservation Act and its implementing regulations 36CFR800. Should additional information become available, our assessment may be revised. Thank you for the opportunity to comment and a copy of these comments should be included in subsequent environmental documents.

Sincerely,

Robert G. Whitlam, Ph.D.
State Archaeologist
(360) 586-3080
email: *rob.whitlam@dahp.wa.gov*

Naval Facilities Engineering Command Northwest
Silverdale, Washington

Final

Archaeological Monitoring and Treatment Plan Supplemental Site Investigation Phase 3 Outlying Landing Field Coupeville

Naval Air Station Whidbey Island
Oak Harbor, Washington

October 2020

Naval Facilities Engineering Command Northwest
Silverdale, Washington

Final

Archaeological Monitoring and Treatment Plan Supplemental Site Investigation Phase 3 Outlying Landing Field Coupeville

Naval Air Station Whidbey Island
Oak Harbor, Washington

October 2020

Prepared for NAVFAC Northwest
by CH2M HILL, Inc.
Bellevue, Washington
Contract N62470-16-D-9000
CTO 4405

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4.2 Inadvertent Discovery of Human Remains ... 4-1
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Appendix

A Monitoring Contact Information

Figure

1 Proposed Off-Base Well Location

Acronyms and Abbreviations

CH2M	CH2M HILL, Inc.
CTO	Contract Task Order
DAHP	Department of Archaeology and Historic Preservation
NASWI	Naval Air Station Whidbey Island
NAVFAC	Naval Facilities Engineering Command
Navy	Department of the Navy
NRHP	National Register of Historic Places
OLF	Outlying Landing Field
PFAS	per- and polyfluorinated substances
SAP	Sampling and Analysis Plan
SI	Site Investigation
TBD	to be determined
THPO	Tribal Historic Preservation Office

SECTION 1

Introduction

The purpose of this Archaeological Monitoring and Treatment Plan is to establish archaeological resources monitoring and inadvertent discovery protocols to be used during ground-disturbing activities associated with the Supplemental Site Investigation (SI) Phase 3 field effort, to be conducted adjacent to Outlying Landing Field (OLF) in Coupeville, Washington in Island County. The Supplemental SI will include sections on archaeological monitoring methods, a monitoring plan summary, and an inadvertent discovery plan; and pertinent contact information for monitoring, stakeholder, and Department of the Navy (Navy) personnel.

1.1 Site Description

OLF Coupeville is a military airfield associated with Naval Air Station Whidbey Island (NASWI). It was commissioned for use by the Navy in 1943 and provides support for day and night Field Carrier Landing Practice operations by the Navy for aircraft based out of NASWI. Such operations allow aviators and crew to fly in patterns as well as practice touch-and-go, simulating carrier landings, and take offs. During these practice runs, jet aircraft approach the runway and touch down, immediately taking off again and looping around the field to prepare for another landing and takeoff.

Field efforts described herein are conducted as Phase 3 of the Supplemental SI, as described in the Sampling and Analysis Plan (SAP) Addendum (Navy, 2020), and will consist of installation of one monitoring well on a parcel northeast of OLF Coupeville owned by Island County. The parcel is situated in Section 1 of Township 31, Range 1E, Willamette Base and Meridian (Figure 1). CH2M HILL, Inc. (CH2M) is performing this investigation on behalf of Naval Facilities Engineering Command (NAVFAC) Northwest. As the lead federal agency, NAVFAC Northwest conducted consultation in accordance with Section 106 of the National Historic Preservation Act for the project (State of Washington Department of Archaeology and Historic Preservation [DAHP], 2020).

SECTION 2

Archaeological Monitoring Methods

CH2M will provide oversight of an onsite professional archaeologist during ground-disturbing activities associated with the project. The onsite archaeological monitor will observe ground disturbances, examining borehole opening and retrieved soil samples from the boring for evidence of cultural resource materials while maintaining a safe distance from drilling equipment. The archaeological monitor may request drilling activities be temporarily halted as necessary to allow photography and recovery of materials and data. Any soil sample material may be screened at the discretion of the monitor. The archaeological monitor will be prepared with the basic equipment needed to perform site documentation, evaluation, and recovery of any cultural materials identified. Archaeological monitoring will continue until drilling is confirmed to be at a depth below any culture-bearing deposits. The archaeological monitor will follow all safety protocols required of personnel conducting drilling activities.

The archaeological monitor will prepare daily field monitoring verification reports, noting observations, results, and actions taken, as necessary, concerning the monitoring activities. Photographs will be taken to record the drilling activities as well as the character and provenance of any identified cultural resources. A technical memorandum detailing the results of the archaeological monitoring during the Phase 3 Supplemental SI will be prepared to fully document the results of the monitoring in accordance with Section 106 of the National Historic Preservation Act and the DAHP regulations subsequent to completion of drilling activities.

2.1 Treatment of Cultural Resources

If pre-contact or historic-period archaeological materials and/or features are encountered during the course of monitoring activities, all work will halt, and NAVFAC Northwest and the DAHP will be notified immediately. The treatment of the archaeological materials and their potential National Register of Historic Places (NRHP) eligibility will be determined by NAVFAC Northwest and DAHP through coordination with the consulting parties at that time. If avoidance of the resource is not feasible under project constraints, additional mitigation, including but not limited to NRHP-eligibility test excavations and/or data recovery excavations, may be required. A supplemental treatment plan and/or DAHP Archaeological Excavation Permit may be required if potentially NRHP-eligible cultural resources are encountered and cannot be avoided. The archaeological monitor will ensure that an area large enough to protect the integrity of the resource is avoided by drilling and well construction activities until the appropriate treatment measures are met. Drilling activities will continue in the area once the treatment of the resource is complete.

SECTION 3

Monitoring Plan Summary

- CH2M will provide an archaeological monitor to be on site during ground-disturbing activity (monitoring well drilling) associated with the project.
- The archaeological monitor may request that drilling activities be halted temporarily as necessary to allow photography and recovery of materials and data.
- The archaeological monitor will prepare daily field monitoring verification reports, noting observations, results, and actions taken, as appropriate, concerning the monitoring efforts.
- Digital photographs will be taken to record the construction activity, as well as the character and provenance of any identified cultural resources.
- If potentially NRHP-eligible archaeological materials and/or features are encountered during the course of monitoring activities, all work will halt, and CH2M's archaeological monitor/field team will contact NAVFAC Northwest and DAHP. NAVFAC Northwest and DAHP will determine the treatment of the archaeological materials through coordination with the consulting parties at that time. Drilling may continue in the area once all interested parties have been consulted and consensus of the approach to treatment of the resource is reached.
- CH2M will submit a technical memorandum detailing the results of the archaeological monitoring for dissemination to the consulting parties at the conclusion of the project.
- If potential human remains are encountered during any phase of the project, all work in the area will halt and the protocols described in the following section will be implemented.

SECTION 4

Inadvertent Discovery Plan

The following section details the procedures, which will be followed in the event that drilling activities associated with the Supplemental SI inadvertently encounter cultural resources or human remains.

4.1 Inadvertent Discovery of Cultural Resources

Prior to commencement of project activities, the drilling subcontractor will be prepared for the possibility of encountering prehistoric and/or historic archaeological materials during ground-disturbing activities. In the event that drilling activities associated with the SI encounter cultural resources (that is, intact shell midden deposits, lithic reduction sites, former hearth features, historic-period refuse deposits and/or privy features, or human remains), including archaeological artifacts, features, and/or sites, all work will halt, and NAVFAC Northwest and the DAHP will coordinate the treatment of the materials with the consulting parties. Work will not proceed until notification to proceed is granted by the lead federal agency. Compliance with all applicable laws pertaining to archaeological resources is required. CH2M will complete appropriate DAHP State of Washington Inventory Forms for any identified cultural resources and will submit the completed forms to DAHP for assignment of a Smithsonian Trinomial.

4.2 Inadvertent Discovery of Human Remains

If human remains are encountered during the Supplemental SI field work, CH2M will immediately contact the following entities: NAVFAC Northwest, the Island County Coroner, the Island County Sheriff, and the DAHP State Physical Anthropologist. The following protocol will be applied:

- If ground-disturbing activities encounter human skeletal remains during the course of construction, all activity that may cause further disturbance to those remains will cease. The area of the find will be secured and protected from further disturbance until the State provides notice to proceed. The finding of human skeletal remains will be reported to the county medical examiner/coroner and local law enforcement in the most expeditious manner possible. The remains will not be touched, moved, or further disturbed. The county medical examiner/coroner will assume jurisdiction over the human skeletal remains and make a determination of whether those remains are forensic or non-forensic. If the county medical examiner/coroner determines the remains are non-forensic, they will report that finding to the DAHP), who will then take jurisdiction over the remains. The DAHP will notify any appropriate cemeteries and all affected tribes of the find. The State Physical Anthropologist will make a determination of whether the remains are Indian or Non-Indian and report that finding to any appropriate cemeteries and the affected tribes. The DAHP will then handle all consultation with the affected parties as to the future preservation, excavation, and disposition of the remains.

SECTION 5

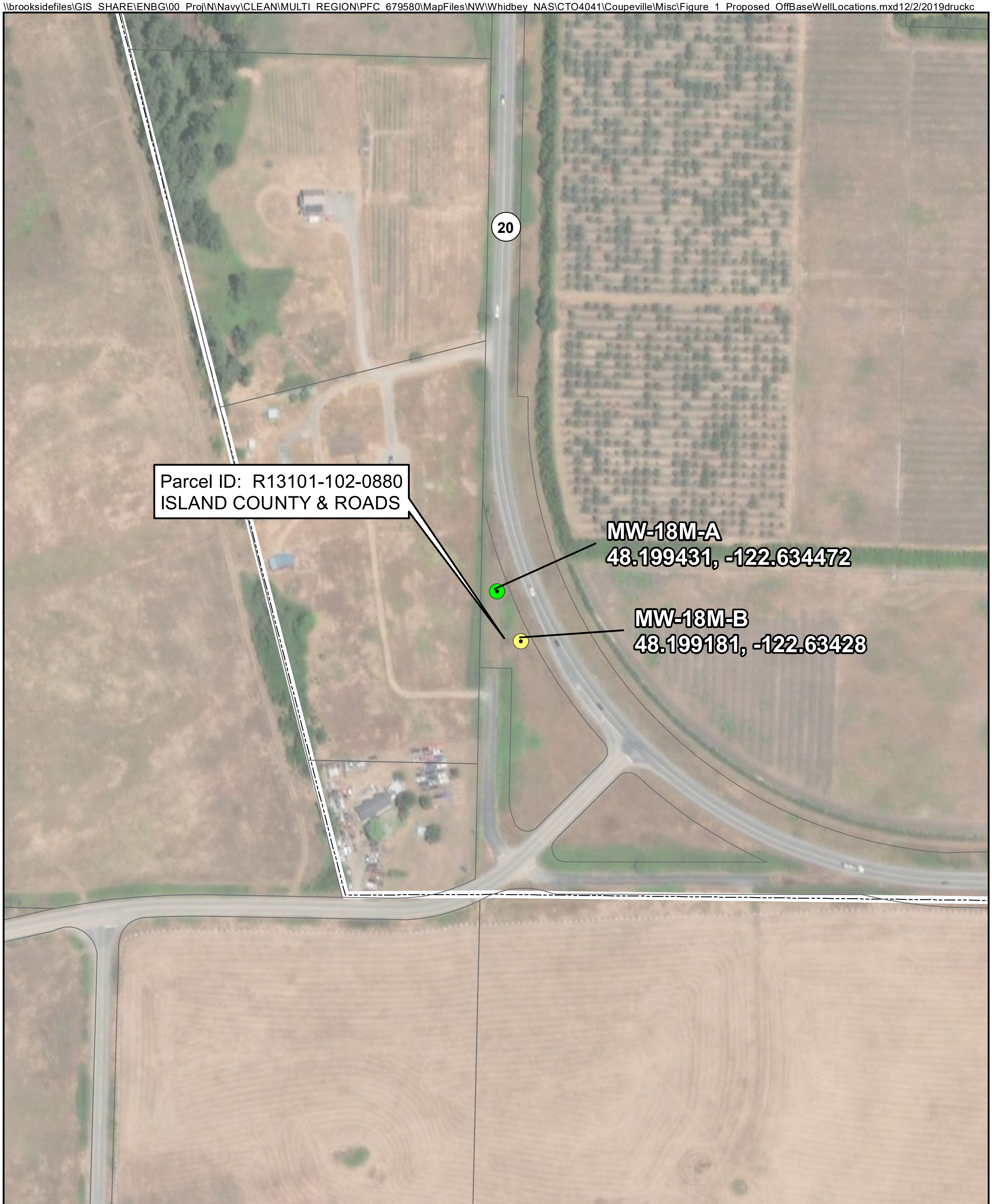
References

State of Washington Department of Archaeology and Historic Preservation (DAHP). 2020. State Historic Preservation Officer concurrence letter. June.

Department of Navy (Navy). 2020. *Sampling and Analysis Plan Addendum, Site Inspection for Perfluorinated Compounds in Groundwater, Outlying Landing Field Coupeville, NAS Whidbey Island, Coupeville, Washington*. August.

Figure

\\brooksidefiles\GIS_SHARE\ENBG\00_Proj\N\Navy\CLEAN\MULTI_REGION\PFC_679580\MapFiles\NW\Whidbey_NAS\CTO4041\Coupeville\Misc\Figure_1_Proposed_OffBaseWellLocations.mxd12/2/2019druckc



Legend

- Primary Proposed New Monitoring Well
- Secondary Proposed New Monitoring Well
- OLF Boundary
- Parcel Boundary

N

0 250 500 Feet

Imagery Source: Esri

Figure 1
Proposed Off-Base Well Locations
OLF Coupeville
Coupeville, Washington

Updated, Site Recon on 11/22/19

Appendix A
Monitoring Contact Information

Supplemental Site Inspection Report Addendum
for Per- and Polyfluoroalkyl Substances
Outlying Landing Field Coupeville
Naval Air Station Whidbey Island
Oak Harbor, Washington

NOTIFICATION: THIS PAGE CONTAINS SENSITIVE BUT UNCLASSIFIED INFORMATION WHICH IS PROTECTED BY THE FREEDOM OF INFORMATION ACT

FOIA Exemption 6 (5 USC 552(b)(6))
Personal Information Affecting an Individual's Privacy

TO REQUEST A COPY OF THE DOCUMENT

PLEASE CONTACT

Department of the Navy
Freedom of Information Act Office

http://www.secnav.navy.mil/foia/Pages/default.aspx

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Jacobs

Memorandum

1100 112th Avenue NE, Suite 500
Bellevue, Washington 98004
425.453.5000
www.jacobs.com

To:	Rachel Clennon, P.G., Jacobs Engineering Group, Inc.
From:	Jane Wiegand, M.A., Jacobs Engineering Group, Inc.
Date:	May 14, 2021
Subject:	**Results of Archaeological Monitoring, Supplemental Site Investigation Phase 3, OLF Coupeville, NAS Whidbey Island, Island County, Washington**

This memorandum summarizes the results of archaeological monitoring completed by Jacobs Engineering Group Inc. (Jacobs) for the Supplemental Site Investigation Phase 3 field effort on Outlying Landing Field (OLF) Coupeville, Naval Air Station (NAS) Whidbey Island in Island County, Washington.

Jacobs archaeologist Jane Wiegand, M.A., a professional archaeologist, conducted the archaeological monitoring for the entire monitoring effort. Matthew Sterner, M.A., RPA, senior archaeologist, served as principal investigator for the monitoring.

PROJECT LOCATION AND DESCRIPTION

Monitoring was completed for the installation of one monitoring well on a parcel northeast of OLF Coupeville owned by Island County. The parcel is situated in Section 1 of Township 31, Range 1E, Willamette Base and Meridian. The project is working to investigate releases of per- and polyfluoroalkyl substances (PFAS) at NAS Whidbey Island, OLF Coupeville. As the lead federal agency, NAVFAC Northwest has been conducting consultation in accordance with Section 106 of the National Historic Preservation Act (NHPA) for the project.

ARCHAEOLOGICAL MONITORING METHODS

A professional archaeologist was on-site during ground-disturbing activities associated with the project. The on-site archaeological monitor observed ground disturbances, examined the borehole opening and retrieval of soil samples from the boring for evidence of cultural resource materials while maintaining a safe distance from drilling equipment. The monitor could request that drilling activities be temporarily halted as necessary to allow photography and recovery of materials and data. Any soil sample material could have been screened at the discretion of the monitor. The archaeological monitor was prepared with the basic equipment needed to perform site documentation, evaluation, and recovery of any cultural materials identified. Archaeological monitoring continued until drilling was confirmed to be at a depth below any culture-bearing deposits.

The archaeological monitor prepared daily field monitoring verification reports, noting observations, results, and actions taken, as necessary, associated with the monitoring activities. Photographs were taken to document the drilling activities and would have also recorded the character and provenance of any identified cultural resources (if encountered).

SUMMARY OF RESULTS

Monitoring was completed on October 13, 2020, at the drill location at 48°11'57.26"N 122°38'3.79"W. The well drilling was anticipated to reach 200 feet (ft) below ground surface (bgs), although glacial drift deposits were anticipated to occur much shallower.

In summary, the monitor observed silty sand transitioning to silty gravel and mixed gravel (0 to 10 ft bgs), gravel and sand (10 to 30 ft bgs), gravel and grey sand inclusions (30 to 40 ft bgs), and course gray sand and sandy gravel (40 to 45 ft bgs). The sediments observed indicated that glacial drift was encountered less than 10 ft bgs; monitoring conservatively continued to a depth of 45 ft bgs to confirm observed conditions.

CONCLUSIONS

No cultural resources, such as historical-period or precontact artifacts, anthropogenic soils, were observed. Similarly, no buried surfaces or soils were observed during the monitoring effort. No archaeological artifacts were collected or removed from the site. In conclusion, no archaeological resources were observed or impacted, and the drilling had no effect to historic properties.

Appendix D
Soil Boring Log, Monitoring Well Construction Diagram, and Development Log

ch2m

WELL DEVELOPMENT DATA SHEET

Client: NAVFAC
Location: ~~Ault Field~~ OLF
Event: Well development
Date: 10/16/20
Weather: 50°'s overcast

Project Number: ~~695610CH.04.FI.WI~~ 9000NVTI
Well ID: ~~WI-AF-~~ MW-18
Sample ID: NA
Sampling Team: T. Chalmers

WL meter: Heron Dipper T - C103374
WQ - Measuring Device: Pro DSS YSI - U94961X
Date and Time: 10/16/20 1016

	Before	After	
Total Depth:	135.25		FT.(BTOC)
Depth to water:	(-) 116.50		FT.(BTOC)
Water Column:	18.75		FT.
	(x) ~~0.3~~ 0.163		GAL/FT.
Well Volume:	3.06		GAL.
3X Total Purge Vol.:	9.17		GAL.

Well Dia. (inches)	Volume (gallons/foot)
1	0.041
1.25	0.064
2	0.163
4	0.653

Purge Device: TC ~~5 ft steel bailer~~ Mega Monsoon Pump

Air Monitoring Equipment: TC ~~N/A~~ PID MinRae 3000

Was well surged and bailed in 2-3 foot intervals along entire screen? No along entire length of screen

Surge and bail equipment: Surge block / 5 ft steel bailer

FIELD PARAMETERS

Time	Purge Vol. (gals)	Temp. °C	Cond. mS/cm	DO mg/L	pH SU	ORP mV	Turbidity NTU	Other: ______	Color / Odor / Comments
Stabilizaton Criteria TC		± 0.1	± 0.01 (if <1) ± 0.02 (if >1)	± 0.05 (if <1) ± 0.2 (if >1)	± 0.1	± 10	< ± 10% or ≤10 NTU		
1016 ~~1010~~	Begin Surge.								
1036	Surge complete.								
1040	Begin bail								
1110	Begin Purge								
1133	0.92	15.0	1.294	6.62	8.93	0.5	12468		Thick/gray/No color
1215	5.0	15.4	0.549	9.70	8.96	24.5	4666		"
1225	5.5	15.1	0.986	8.11	9.08	47.5	12155		"
1235	6.25	15.4	0.855	7.98	8.89	20.4	4457		"
1240	6.5	15.3	0.788	8.36	8.77	-6.1	5292		"
1245	6.75	15.6	0.744	7.89	8.66	-16.9	3136		"
1250	6.95	15.3	0.713	8.16	8.57	-9.8	5175		"
	Development complete based on time spent on well								
Final	6.95	15.3	0.713	8.16	8.57	-9.8	5175		Gray/Murky/No color

Observations/Notes: Purge Start Time: 1110 Purge Rate: 0.18 gal/min

1123: Well pumped dry almost immediately, pump stopped
1128: Pump resumed at ~0.18 gal/min
1150: Pump pulled to fix leak at join, reinstalled at 1200.

Air Monitoring:	HS	BZ
VOC (ppm) =	0.0	0.0
H2S (ppm) =	–	–
LEL (%) =	–	–
CO (ppm) =	–	–
O2 (%) =	–	–

Signature(s):

PROJECT NUMBER:	BORING NUMBER:	
9000NVT1	MW-18	SHEET 1 OF 4

Borehole Log

PROJECT : NASWI OLF Supplemental Site Investigation Phase-3 LOCATION : Outlying Landing Field, Coupeville, WA

COORDINATES : *pending* ELEVATION : *pending*

DRILLING CONTRACTOR : Yellow Jacket DRILLING METHOD AND EQUIPMENT : Rotosonic - 6-inch casing, 4-inch core barrel

WATER LEVEL : 122.0 ft bgs Start : 10/13/20 09:30 END : 10/14/20 12:25 LOGGER : Eric Stokerson

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL / RECOVERY (ft)	GRAPHIC LOG	SOIL DESCRIPTION: Soil name, USCS, color, moisture, density, description	COMMENTS	WELL DETAILS
	5.0		**SILTY SAND (SM)** black (10YR 2/1), dry, very fine to medium grained sand. Some organic roots.		Flush mount 8-inch steel monument; Bentonite grout
5			**SILTY SAND (SM)** dark grayish brown / dark yellowish brown (10YR 4/2), dry, very fine to medium grained sand. Increase in silt concentration. Medium stiff at 5-feet.	Hand auger boring to 5-feet for utility clearance	
10	5.0		**WELL GRADED GRAVEL (GW)** very dark gray (2.5Y 3/1), dry, fine to coarse grained gravel.	Core PID = 0.0 ppm	
15	8.8		**WELL GRADED GRAVEL (GW)** very dark gray (2.5Y 3/1), wet, fine to coarse grained gravel.	Core PID = 0.0 ppm	
20			**WELL GRADED SAND WITH GRAVEL (SW)** very dark gray (2.5Y 3/1), wet, fine to coarse grained sand, with some coarse gravel, and few fines.		
25	6.0		**POORLY GRADED SAND (SP)** dark gray (2.5Y 4/1), dry, loose, fine grained sand, with little fines.	Core PID = 0.0 ppm	
30			**POORLY GRADED GRAVEL (GP)** dark gray (2.5Y 4/1), moist, coarse grained gravel, with few coarse grained sand to fine grained gravel, and few fines		
35	9.8		**POORLY GRADED SAND (SP)** dark gray (2.5Y 4/1), medium to coarse grained sand, with few coarse gravel.	Core PID = 0.3 ppm	
40	6.0		**POORLY GRADED GRAVEL (GW)** dark gray (2.5Y 4/1), slightly moist, coarse grained gravel, with fine to coarse grained sand, and few fines.	Core temperature increasing, drilling 5-foot runs to mitigate	
45	6.0		**POORLY GRADED SAND (SP)** dark gray (2.5Y 4/1), slightly moist, fine grained sand, with trace fines, and trace coarse gravel.		
50					

NEW SOIL BORING LOG; OLF.GLB; OLF FIELD EVENT 3.GPJ; CH2M GEOTECH_12.GDT; 05/04/21

Borehole Log

PROJECT : NASWI OLF Supplemental Site Investigation Phase-3 LOCATION : Outlying Landing Field, Coupeville, WA

COORDINATES : *pending* ELEVATION : *pending*

DRILLING CONTRACTOR : Yellow Jacket DRILLING METHOD AND EQUIPMENT : Rotosonic - 6-inch casing, 4-inch core barrel

WATER LEVEL : 122.0 ft bgs Start : 10/13/20 09:30 END : 10/14/20 12:25 LOGGER : Eric Stokerson

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL / RECOVERY (ft)	GRAPHIC LOG	SOIL DESCRIPTION: Soil name, USCS, color, moisture, density, description	COMMENTS	WELL DETAILS
			POORLY GRADED GRAVEL (GW) dark gray (2.5Y 4/1), fine to medium grained gravel, with fine grained sand, and few fines.	Drilling returns to 10-foot runs	
55	9.4				
				Core very dry and powdery, likely from drilling through cobble or coarse gravel Hard drilling, driller begins using water to aid advancement Core PID = 4.7 ppm Mild odor	
60					
65	9.5		**POORLY GRADED SAND (SM)** dark gray / olive gray (5Y 4/1), slightly moist, fine grained sand, with few fines appearing in non-plastic clumps displaying silt fracturing.		
70					
			POORLY GRADED SAND (SP) very dark grayish brown (2.5Y 3/2), slightly moist, fine grained sand, with little fines.		
75	9.0			Core PID = 0.0 ppm No gravel in SP	
80					
85	9.3				
			SILTY SAND (SM) very dark grayish brown (2.5Y 3/2), slightly moist, fine grained, poorly graded sand, with silt appearing in non-plastic clumps.	Core PID = 29.8 ppm Slight odor	
90				Core PID = 393 ppm Unknown odor	
95	8.5			Core PID = 127 ppm Unknown odor No coarse material in SM Core PID = 29.1 ppm Unknown odor	
100					

PROJECT NUMBER:	BORING NUMBER:
9000NVT1	MW-18 — SHEET 3 OF 4

CH2MHILL

Borehole Log

PROJECT : NASWI OLF Supplemental Site Investigation Phase-3 — LOCATION : Outlying Landing Field, Coupeville, WA

COORDINATES : *pending* — ELEVATION : *pending*

DRILLING CONTRACTOR : Yellow Jacket — DRILLING METHOD AND EQUIPMENT : Rotosonic - 6-inch casing, 4-inch core barrel

WATER LEVEL : 122.0 ft bgs — Start : 10/13/20 09:30 — END : 10/14/20 12:25 — LOGGER : Eric Stokerson

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL / RECOVERY (ft)	SOIL DESCRIPTION: Soil name, USCS, color, moisture, density, description	COMMENTS	WELL DETAILS
105	8.0		Core PID => 400 ppm (maxed-out sensor at 400 ppm) Noticable odor	
110			Core PID => 400 ppm	
			Core PID = 110 ppm	Bentonite seal
115	8.5		Core PID => 400 ppm	
			Core PID => 400 ppm	Filter pack
120		**SILTY SAND (SM)** very dark grayish brown (2.5Y 3/2), moist, fine grained, poorly graded sand, with silt appearing in non-plastic clumps.	Core PID = 4.9 ppm	15-foot 2-inch SCH 80 PVC 0.010-in slot screen
		SILT WITH SAND (ML) very dark grayish brown (2.5Y 3/2), wet, medium plasticity, silt that easily fractures, with little, fine grained sand.	Core PID = 1.7 ppm No clay in ML	
125	9.0		Core PID = 4.8 ppm	
			Core PID = 7.1 ppm	
130		**ELASTIC SILT (MH)** dark gray (GLEY1 4/N), wet, medium plasticity silt that fractures, and clay.	Core PID = 10.0 ppm	
			Core PID = 7.7 ppm	
135	10.0		Core PID = 6.7 ppm	Filter pack
			Core PID = 6.4 ppm	Backfill
140				
145	11.5		Core PID = 0.0 ppm	
150				

PROJECT NUMBER:	BORING NUMBER:
9000NVT1	MW-18 SHEET 4 OF 4

CH2MHILL.

Borehole Log

PROJECT : NASWI OLF Supplemental Site Investigation Phase-3 LOCATION : Outlying Landing Field, Coupeville, WA

COORDINATES : *pending* ELEVATION : *pending*

DRILLING CONTRACTOR : Yellow Jacket DRILLING METHOD AND EQUIPMENT : Rotosonic - 6-inch casing, 4-inch core barrel

WATER LEVEL : 122.0 ft bgs Start : 10/13/20 09:30 END : 10/14/20 12:25 LOGGER : Eric Stokerson

DEPTH BELOW GROUND SURFACE (ft)	INTERVAL / RECOVERY (ft)	GRAPHIC LOG	SOIL DESCRIPTION: Soil name, USCS, color, moisture, density, description	COMMENTS	WELL DETAILS
155	9.0			Core PID = 0.0 ppm	
			ELASTIC SILT (MH) dark gray (GLEY1 4/N), SAME AS ABOVE, slight increase in sand content.		
160			**ELASTIC SILT (MH)** dark gray (GLEY1 4/N), SAME AS ABOVE, dry, becomes hard with strong cementation, sand content decreases.		
165	10.5			Core PID = 0.0 ppm	
170					
175	11.0			Core PID = 0.0 ppm	
180			**ELASTIC SILT (MH)** dark gray (GLEY1 4/N), SAME AS ABOVE, moist, hard with strong cementation, sand content increases.		
185	9.0			Core PID = 0.0 ppm	
190					
195	9.0		**SILTY SAND (SM)** dark gray (GLEY1 4/N), wet, very fine to fine grained sand, with some silt.	Core PID = 0.0 ppm	
200					

Boring terminated at 200 ft bgs.

Appendix E
Sampling and Analysis Plan
Field Change Request

ch2m:

Sampling Analysis Plan Field Change Request (FCR)

(9000-4405-FCR-02 OLF Coupeville SI)

Date of Change: 11/07/2019

FCR No. (assigned by PM): 2

Applicable Sampling Analysis Plan Title:

Supplemental Site Investigation, Outlying Landing Field Coupeville Sampling and Analysis Plan (SAP)

Project Number:	9000NVT1	**Project Location:**	Coupeville, WA
Contract Number:	N62470-16-D-9000, Contract Task Order 4405		

Subject of Change:

1. Change monitoring well development method and sampling criteria.

Recommended Changes:

SAP Worksheet #11 - Project Quality Objectives/Systematic Planning Process Statements and Worksheet #14 - Summary of Project Tasks

- Change monitoring well development, which is conducted in accordance with NAVFAC NW SOP I-C-2 *Monitoring Well Development*, except where conditions warrant change in consultation and approval with the CH2M STC/PM and NAVFAC NW RPM.

If shallow wells are purged dry early in development, and are slow to recharge, in consult with senior technical team it was determined a modified well development approach would be taken to achieve well conditioning:

- Development under SOP I-C-2 would be attempted.
- If significant water drawdown occurred during the swabbing and bailing portion, the well would be allowed to recharge to ensure the full screen interval is completed.
- If significant water drawdown is observed during the over-pumping portion, that well would be purged dry and left to recharge. A total of three well volumes would be purged, if feasible. If turbidity is still extremely high at completion of third purge, the well would be scheduled for sampling towards the end of the sampling event to allow the well to settle. The well will be assessed during groundwater sampling and undergo additional development if warranted.

This change will be described in updated project Field Instructions.

Reason for Change:

1. Adjusted monitoring well development methods due to lithology and well conditions (e.g. WI-CV-MW21S, -MW22S, and -MW23S due to slow recharge rates).

Submitted by:	Mark Endo	**Company**:	CH2M	**Date**:	11/13/2019

Review & Acceptance:			
Activity Manager:	**Jennifer Madsen**	**Date: 11/15/19**	
Project Manager:	**Rachel Clennon**	**Date: 11/13/19**	
Environmental Manager:	**NA**	**Date:**	
Navy RPM/NTR:	**Kendra Clubb (Leibman)**	**Date: 11/18/19**	
Distribution:			
1. Approvers above	2. FTL	3. Field Staff	4.
5.	6.	7.	8.

File Copies: Project File

Appendix F
Investigation-Derived Waste Profiles

US Ecology Nevada (Beatty) 800-239-3943
US Ecology Idaho (Grand View) 800-274-1516
US Ecology Texas (Robstown) 800-242-3209
US Ecology Michigan (Detroit) 800-396-3265

PROFILE #____________________

WASTE/MATERIAL PROFILE FORM

A. GENERATOR INFORMATION

1. Generator: US Navy Air Station Whidbey Island	☐ Billing information is same ☐ P.O. required for payment
2. Facility Address: 18025 WA-20, Coupeville, WA 98239	**12. Billing Company:** Capitol Environmental Services, Inc.
	13. Billing Address: 200 Biddle Ave, Suite 205
3. Mailing Address: 1115 W. Lexington St.	**14. City/State/Zip:** Newark, DE
4. City/State/Zip: Oak Harbor, WA 98277	**15. Billing Contact:** Terri Fort
5. Technical Contact: Amber Derise	**16. Phone:** 540-777-6547 **17. Fax:**
6. Phone: 360-257-1008 **7. Fax:**	**18. Email:** tfort@capitolenv.com

8. Generator Status: ☐ CESQG ☐ SQG ☐ LQG

9. EPA ID #: N/A **10. State ID #:**

11. NAICS CODES:

B. SHIPPING INFORMATION

1. US DOT Shipping name: NonRCRA, NonDOT regulated wastewater

2. Hazard Class: nonhaz **3. UN/NA #:** N/A **4. Packaging Group:** N/A **5. RQ:** N/A

6. Container Type: ☐ Bulk ☐ Totes ☐ Pallet ☐ Boxes ☐ Drums ☐ Other, **Describe:**

7. Frequency: ☐ Year ☐ Quarterly ☐ Monthly ☐ 1 time ☐ Other, **Describe:**

8. Shipment: **Size:** 330 gal **Quantity:** 3

9. Waste Import: ☐ Yes ☐ No
(If yes, complete Waste Import Supplement)

C. GENERAL MATERIAL & REGULATORY INFORMATION

1. Common name: Water for solidification

2. Process generating:
Monitoring wells onsite. See Sample #'s WI-CV-IDW-AQ01-1219, WI-CV-IDW-AQ02-1219, and WI-CV-IDW-AQ03-1219 in Lab report 19-1319 for perfluoroinated compound testing. Sample #'s WI-CV-IDW-AQ01-121419, WI-CV-IDW-AQ02-121419, and WI-CV-IDW-AQ03-121419 in Lab report J91507-1.

3. Describe physical appearance:
Clear/cloudy water, minimal sediment.

4. Odor: ☐ None ☐ Slight ☐ Strong **5. Physical State:** ☐ Liquid ☐ Sludge/Slurry ☐ Solid

6. Describe Color: Clear/cloudy **7. Liquid phases:** ☐ Single ☐ Double Layer ☐ Multi-layer

8. Knowledge is from: ☑ Lab analysis ☐ MSDS ☐ Process/generator knowledge

9. Waste/Material Type (US Ecology Texas customers only): ☐ N/A ☐ Industrial ☐ Non-Industrial

10. Restricted under EPA Land Disposal Restrictions (§268)? ☐ Yes ☐ No

11. If LDR "Yes": ☑ Wastewater ☐ Non-wastewater ☐ Debris (§268.2) **12. Alt. Standards for soil?** ☐ Yes ☐ No

13. Is the material RCRA hazardous waste containing benzene and originating at a Petroleum Refinery (SIC 2911), Chemical Manufacturing Plant (SIC 2800 thru 2899) or Coke by-Product Recovery Plant (SIC 3312)? ***(If yes, complete Benzene Waste/Material Operations Supplement Form and Thermal Supplement Form)***: ☐ Yes ☐ No

14. VO Conc.(§264.1083): ☐ <500 ppmw ☐ ≥500ppmw **15. Has it been treated after point of generation?** ☐ Yes ☐ No

16. CERCLA Regulated (Superfund) Waste: ☐ Yes ☐ No **17. Butadiene waste regulated by §63 Subpart XX:** ☐ Yes ☐ No

18. Waste contains UHC constituent(s) (§268.48), above a treatment standard, other than those for which the waste exhibits a characteristic. ***(If yes, list all UHC's in Section D):*** ☐ Yes ☐ No

19. Waste exempt from definition of "solid waste" or "hazardous waste" ***(If yes, list reference 40CFR ____________________):*** ☐ Yes ☐ No

20. State Waste Codes:	N/A					
21. RCRA Waste Codes:	N/A					

22. Source Code: G19 Other c **23. Form Code:** W119 Other **24. Management Code:** H ________ **(USE only)**

D. COMPOSITION *(use additional form if necessary)*

Constituent	Units	TCLP	Totals	Typical	Min	Max
				Range total ≥ 100%		
Water	%	☐	☐		98	100
Soil/sediment	%	☐	☐		0	2
Perfluorohexanoic acid	ng/L	☐	☐		17.86	29.21
Perfluorooctanoic acid	ng/L	☐	☐		12.39	81.22
Perfluorohexanesulfonate	ng/L	☐	☐		35.60	77.69
Perfluorooctanesulfonate	ng/L	☐	☐		17.32	47.23
Perfluorobutanesulfonate	ng/L	☐	☐		2.68	7.37
		☐	☐			
See reference to analytical in Section C, #2.		☐	☐			
See analytical results for full testing of PFC chemicals.		☐	☐			
		☐	☐			

E. CHARACTERISTICS

1. Oxidizer	☐ Yes	☐ No	**9. Reactive sulfides __________ppm**	☐ Yes	☐ No
2. Explosive	☐ Yes	☐ No	**10. Reactive cyanides__________ppm**	☐ Yes	☐ No
3. Organic peroxide	☐ Yes	☐ No	**11. Water/air reactive**	☐ Yes	☐ No
4. Shock sensitive	☐ Yes	☐ No	**12. Thermally unstable**	☐ Yes	☐ No
5. Tires	☐ Yes	☐ No	**13. TSCA regulated PCB waste** *(control sheet required with shipment)*	☐ Yes	☐ No
6. Pyrophoric	☐ Yes	☐ No	**14. Medical/infectious waste**	☐ Yes	☐ No
7. Compressed gas	☐ Yes	☐ No	**15. Radioactive** (*If yes, complete Profile Supplement for Radioactive Waste)*	☐ Yes	☐ No
8. Halogenated organics	☐ Yes	☐ No	**16. Hazardous Secondary Material (HSM)**	☐ Yes	☐ No

17. Possibility of incidental liquids from transportation? ☐ Yes ☐ No

18. Is waste/material a solid using the paint filter test? ☐ Yes (solid) ☐ No (not solid)

19. pH: ***(If solid, what is pH if mixed with water?)*** **Range** 6 **to** 9 **Typical** ________ ☐ ≤ 2 ☐ 2 < 12.5 ☐ ≥ 12.5

20. Flash Point: > 211 **º F** ☐ < 140 º F

20. Is the waste/material oil bearing from Petroleum Refining, Production or Transportation practices? ☐ Yes ☐ No

F. GENERATOR'S CERTIFICATION

☑ Yes	☐ No	**I certify this waste/material may be disposed without further treatment.**
☐ Yes	☐ N/A	**I certify this waste/material meets all requirements of legitimate recycling of hazardous secondary materials under 40 CFR 260.43 and/or I am complying with the conditions for generators using the verified recycler exclusion.**

I authorize US Ecology to correct inconsistencies on the waste/material profile form that impact management decisions with my oral or written authorization. US Ecology will require re-submittal of the waste/material profile information if substantial changes are determined necessary. I understand waste/material that does not conform to specifications described in this profile may be rejected by US Ecology unless other contractual arrangements have been agreed to by both parties. I certify, under penalty of law, that I am familiar with this waste/material stream through analysis and/or process knowledge, and that all information provided is true, accurate, representative and complete, that all known or suspected hazards have been disclosed, and that this form was completed in accordance with the instructions provided.

Print Name	Signature	Title	Date

US ecology

US Ecology Nevada (Beatty) 800-239-3943
US Ecology Idaho (Grand View) 800-274-1516
US Ecology Texas (Robstown) 800-242-3209
US Ecology Michigan (Detroit) 800-396-3265

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4. City/State/Zip: Oak Harbor, WA 98277	**15. Billing Contact:** Terri Fort
5. Technical Contact: Amber Derise	**16. Phone:** 540-777-6547 **17. Fax:**
6. Phone: 360-257-1008 **7. Fax:**	**18. Email:** tfort@capitolenv.com

8. Generator Status: ☐ CESQG ☐ SQG ☐ LQG

9. EPA ID #: N/A **10. State ID #:**

11. NAICS CODES:

B. SHIPPING INFORMATION

1. US DOT Shipping name: NonRCRA, NonDOT regulated wastewater

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7. Frequency: ☐ Year ☐ Quarterly ☐ Monthly ☐ 1 time ☐ Other, **Describe:**

8. Shipment: **Size:** 330 gal **Quantity:** 3

9. Waste Import: ☐ Yes ☐ No
(If yes, complete Waste Import Supplement)

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1. Common name: Water for solidification

2. Process generating:
Monitoring wells onsite. See Sample #'s WI-CV-IDW-AQ01-1219, WI-CV-IDW-AQ02-1219, and WI-CV-IDW-AQ03-1219 in Lab report 19-1319 for perfluoroinated compound testing. Sample #'s WI-CV-IDW-AQ01-121419, WI-CV-IDW-AQ02-121419, and WI-CV-IDW-AQ03-121419 in Lab report J91507-1.

3. Describe physical appearance:
Clear/cloudy water, minimal sediment.

4. Odor: ☐ None ☐ Slight ☐ Strong **5. Physical State:** ☐ Liquid ☐ Sludge/Slurry ☐ Solid

6. Describe Color: Clear/cloudy **7. Liquid phases:** ☐ Single ☐ Double Layer ☐ Multi-layer

8. Knowledge is from: ☑ Lab analysis ☐ MSDS ☐ Process/generator knowledge

9. Waste/Material Type (US Ecology Texas customers only): ☐ N/A ☐ Industrial ☐ Non-Industrial

10. Restricted under EPA Land Disposal Restrictions (§268)? ☐ Yes ☐ No

11. If LDR "Yes": ☑ Wastewater ☐ Non-wastewater ☐ Debris (§268.2) **12. Alt. Standards for soil?** ☐ Yes ☐ No

13. Is the material RCRA hazardous waste containing benzene and originating at a Petroleum Refinery (SIC 2911), Chemical Manufacturing Plant (SIC 2800 thru 2899) or Coke by-Product Recovery Plant (SIC 3312)? ***(If yes, complete Benzene Waste/Material Operations Supplement Form and Thermal Supplement Form)*:** ☐ Yes ☐ No

14. VO Conc.(§264.1083): ☐ <500 ppmw ☐ ≥500ppmw **15. Has it been treated after point of generation?** ☐ Yes ☐ No

16. CERCLA Regulated (Superfund) Waste: ☐ Yes ☐ No **17. Butadiene waste regulated by §63 Subpart XX:** ☐ Yes ☐ No

18. Waste contains UHC constituent(s) (§268.48), above a treatment standard, other than those for which the waste exhibits a characteristic. ***(If yes, list all UHC's in Section D):*** ☐ Yes ☐ No

19. Waste exempt from definition of "solid waste" or "hazardous waste" ***(If yes, list reference 40CFR ____________________):*** ☐ Yes ☐ No

20. State Waste Codes:	N/A					
21. RCRA Waste Codes:	N/A					

22. Source Code: G19 Other c **23. Form Code:** W119 Other **24. Management Code:** H ________ **(USE only)**

D. COMPOSITION *(use additional form if necessary)*

Constituent	Units	TCLP	Totals	Typical	Min	Max
				Range total ≥ 100%		
Water	%	☐	☐		98	100
Soil/sediment	%	☐	☐		0	2
Perfluorohexanoic acid	ng/L	☐	☐		17.86	29.21
Perfluorooctanoic acid	ng/L	☐	☐		12.39	81.22
Perfluorohexanesulfonate	ng/L	☐	☐		35.60	77.69
Perfluorooctanesulfonate	ng/L	☐	☐		17.32	47.23
Perfluorobutanesulfonate	ng/L	☐	☐		2.68	7.37
		☐	☐			
See reference to analytical in Section C, #2.		☐	☐			
See analytical results for full testing of PFC chemicals.		☐	☐			
		☐	☐			

E. CHARACTERISTICS

1. **Oxidizer**	☐ Yes	☐ No	9. **Reactive sulfides _________ppm**	☐ Yes	☐ No
2. **Explosive**	☐ Yes	☐ No	10. **Reactive cyanides________ppm**	☐ Yes	☐ No
3. **Organic peroxide**	☐ Yes	☐ No	11. **Water/air reactive**	☐ Yes	☐ No
4. **Shock sensitive**	☐ Yes	☐ No	12. **Thermally unstable**	☐ Yes	☐ No
5. **Tires**	☐ Yes	☐ No	13. **TSCA regulated PCB waste** ***(control sheet required with shipment)***	☐ Yes	☐ No
6. **Pyrophoric**	☐ Yes	☐ No	14. **Medical/infectious waste**	☐ Yes	☐ No
7. **Compressed gas**	☐ Yes	☐ No	15. **Radioactive** ***(If yes, complete Profile Supplement for Radioactive Waste)***	☐ Yes	☐ No
8. **Halogenated organics**	☐ Yes	☐ No	16. **Hazardous Secondary Material (HSM)**	☐ Yes	☐ No

17. **Possibility of incidental liquids from transportation?** ☐ Yes ☐ No

18. **Is waste/material a solid using the paint filter test?** ☐ Yes (solid) ☐ No (not solid)

19. **pH:** ***(If solid, what is pH if mixed with water?)*** **Range** 6 **to** 9 **Typical** ________ ☐ ≤ 2 ☐ 2 < 12.5 ☐ ≥ 12.5

20. **Flash Point:** > 211 **º F** ☐ < 140 º F

20. **Is the waste/material oil bearing from Petroleum Refining, Production or Transportation practices?** ☐ Yes ☐ No

F. GENERATOR'S CERTIFICATION

☑ Yes	☐ No	**I certify this waste/material may be disposed without further treatment.**
☐ Yes	☐ N/A	**I certify this waste/material meets all requirements of legitimate recycling of hazardous secondary materials under 40 CFR 260.43 and/or I am complying with the conditions for generators using the verified recycler exclusion.**

I authorize US Ecology to correct inconsistencies on the waste/material profile form that impact management decisions with my oral or written authorization. US Ecology will require re-submittal of the waste/material profile information if substantial changes are determined necessary. I understand waste/material that does not conform to specifications described in this profile may be rejected by US Ecology unless other contractual arrangements have been agreed to by both parties. I certify, under penalty of law, that I am familiar with this waste/material stream through analysis and/or process knowledge, and that all information provided is true, accurate, representative and complete, that all known or suspected hazards have been disclosed, and that this form was completed in accordance with the instructions provided.

Print Name	Signature	Title	Date