STORMWATER TREATMENT SYSTEM IMPROVEMENTS ENGINEERING REPORT

NUSTAR TERMINALS OPERATIONS PARTNERSHIP L.P.

Prepared for

NUSTAR TERMINALS OPERATIONS PARTNERSHIP L.P.

VANCOUVER ANNEX FACILITY

January 17, 2024

Project No. M1866.01.002

Prepared by

Maul Foster & Alongi, Inc.

109 E 13th Street, Vancouver, WA 98660

MAUL FOSTER ALONGI

STORMWATER TREATMENT SYSTEM IMPROVEMENTS ENGINEERING REPORT

NUSTAR TERMINALS OPERATIONS PARTNERSHIP L.P.

The material and data in this report were prepared under the supervision and direction of the undersigned.

MAUL FOSTER & ALONGI, INC.

Kristi Boon, PE
Senior Engineer

Andrea Hand, PE
Project Engineer

This digital seal certifies the signatory and document content.

Neil Alongi, PE
Principal Engineer

CONTENTS

CONTENTS (CONTINUED)

ILLUSTRATIONS

FOLLOWING REPORT:

FIGURES

ACRONYMS AND ABBREVIATIONS

AKART	all known, available, and reasonable methods of prevention and treatment technology
AST	aboveground storage tank
BTEX	benzene, toluene, ethylbenzene, and xylene
Ecology	Washington State Department of Ecology
EFR	external floating roof
the Facility	the existing stormwater management system at the NuStar Terminals Operations Partnership L.P. facility
GAC	granular activated carbon
gpm	gallons per minute
MFA	Maul Foster & Alongi, Inc.
MTCA	Model Toxics Control Act
NuStar	NuStar Terminals Operations Partnership L.P.
OWS	oil/water separator
the Permit	Washington State Waste Discharge Permit number ST 6255
the Property	5420 NW Fruit Valley Road in Vancouver, Washington
Stormwater Detention Pond	the former Fire Pond
SPCC	Spill Prevention, Control, and Countermeasure Plan
TPH	total petroleum hydrocarbons
transmix	transportation mixture
WAC	Washington Administrative Code
WWHM	Western Washington Hydrology Model

SUMMARY

This summary is not intended as a stand-alone document and must be evaluated in context with the entire document.

This engineering report outlines proposed improvements to the existing stormwater management system at the NuStar Terminals Operations Partnership L.P. (NuStar) facility (Facility) located at 5420 NW Fruit Valley Road in Vancouver, Washington (Property) that operates under Washington State Waste Discharge Permit number ST 6255 (Permit).

The Property receives and stores jet fuel (i.e., Jet A) in aboveground storage tanks and exports Jet A by tanker truck and marine vessels to its customers. The Facility's existing system collects stormwater runoff in its various containment areas and allows incident precipitation to either slowly infiltrate into the ground or discharge to an on-site detention pond where stormwater is stored and allowed to evaporate. The on-site detention pond also allows some stormwater to infiltrate. There is no off-site discharge of stormwater to surface waters as the entire Property is either bermed or sloped to contain stormwater.

The existing stormwater management system includes bermed containment areas, one lift station, piping, one detention pond (the former Fire Pond [referred to throughout the remainder of this document as the Stormwater Detention Pond]), one infiltration basin (i.e., Surge Pond), and five permitted water quality monitoring points. The Surge Pond is designed to manage overflows from the Stormwater Detention Pond. A portion of the Surge Pond lies within the boundary of an area being investigated and remediated under the Model Toxics Control Act (MTCA).

In 2022, following the submittal of the "All Known, Available, and Reasonable methods of prevention, control and Treatment" (AKART) report (MFA 2022), additional studies confirmed the feasibility of a new infiltration basin located outside the boundaries of the MTCA site on the Property. Alternative No. 2, as presented in the AKART report (MFA 2022), proposed improvements to the existing stormwater management system to provide Stormwater Detention Pond overflow management.

Alternative No. 2 has been modified slightly from the AKART report description. The proposed system will capture and treat stormwater that collects in several of the containment areas prior to infiltration, either in the Stormwater Detention Pond or in the new infiltration pond. The proposed treatment system (oil/water separation and activated carbon adsorption) meets AKART, i.e. it is no less stringent than what is in place at other petroleum terminals in the state. In addition, the runoff from the aboveground storage tank equipped with external floating roofs (EFRs) will be collected, treated, and tested prior to release to the tank containment areas.

NuStar evaluated the earthen containment areas as part of their spill containment and control planning and determined that the areas meet Ecology's requirements for spill containment and Ecology has concurred in their adequacy by approving NuStar's SPCC plan.

1 INTRODUCTION

1.1 Purpose

This report is submitted to the Washington State Department of Ecology (Ecology) per the Washington State Waste Discharge Permit number ST 6255 (the Permit) special condition S9 requiring approval of engineering documents describing proposed modifications of stormwater control and treatment facilities prior to implementation.

1.2 Facility Description (Washington Administrative Code [WAC] 173-240-130 [2][a])

The NuStar Terminals Operations Partnership L.P. facility (the Facility) is a bulk petroleum terminal located at 5420 NW Fruit Valley Road in Vancouver, Washington (the Property). Figure 1-1 shows the Property location. The Property was first developed in the late 1950s to store and transfer various liquid products. There are two pipelines linking the Property to the Port of Vancouver to convey jet fuel. Property features are shown in Figure 1-2.

The Property is approximately 31 acres and is roughly rectangular, with dimensions of approximately 800 by 1,800 feet. There are seven large aboveground storage tanks (ASTs) at the Property grouped in Containment Areas 1 through 4. The newest of these large AST containment areas (Containment Area 4) is lined with a geomembrane, while the other three use earthen containment systems (Figure 1-2). There is a smaller AST farm for fuel additives located in Containment Area 5 that services the covered Truck Loading Rack in the easterly portion of the Property. A normally empty transportation mixture (transmix) AST and utility shed are located inside Containment Area 6, located south of the Surge Pond. A central piping gallery is located within Containment Area 7. The southeast corner of the Property, located south of Containment Area 5, is not currently used for terminal activities and was historically used as an orchard. The southeast corner area is fenced and contains remnant fruit trees that are not harvested.

NuStar Terminals Operations Partnership L.P. (NuStar) has a Permit authorizing the Facility to discharge stormwater that comes into contact with industrial operations (referred to in the Permit as "wastewater") although there is no off-site discharge of stormwater to surface waters since the entire Property is either bermed or sloped to contain stormwater within the Facility.

Separately, under Ecology's toxics cleanup program, NuStar is in the process of remediating petroleum-impacted soil and groundwater attributed to historical terminal operations (i.e., prior to NuStar's operations) within localized areas of the Model Toxics Control Act (MTCA) site boundaries illustrated in Figure 1-2.

1.3 Industrial Activities (WAC 173-240-130 [2][b])

The Property receives jet fuel (i.e., Jet A[1]) from underground pipelines, stores the petroleum product in seven ASTs, and loads it into tanker trucks beneath the covered Truck Loading Rack for distribution to customers. The Property also loads marine vessels using the same pipeline(s) that terminate at a dock loading facility on the Columbia River within the Port of Vancouver for distribution to customers. NuStar implements non-structural (e.g., good housekeeping and preventative maintenance) and structural (e.g., ASTs designed and constructed to industry standards and automated safety protection systems) best management practices and implements spill prevention and emergency response procedures to prevent and minimize the potential for stormwater contamination. These measures are described in further detail in Section 2.

The following subsections describe the industrial activities conducted at the Property in detail and the associated materials and pollutants to which the stormwater runoff may be exposed.

1.3.1 Jet Fuel Receipt, Storage, and Export

There are seven large ASTs at the Property grouped in Containment Areas 1 through 4 used to store jet fuel. The ASTs range in capacity size from 1,680,000 to 4,599,378 gallons and include both fixed-roof and external floating roof (EFRs) ASTs. Currently, five of the seven ASTs are active and are located in three separate Containment Areas (i.e., 1, 3, and 4). Jet fuel stored in these ASTs is received on-site via two 12-inch diameter underground steel product pipelines that daylight at the west end of the Property. The Property's central pipe run, used for product distribution piping, is generally aboveground, except for short segments beneath berms and roadways, and entirely within secondary containment (i.e., Containment Area 7).

The procedures for receipt, storage, and export of jet fuel at the Property are conducted within an entirely closed system via sealed ASTs and piping, and therefore jet fuel is not exposed to precipitation or runoff during these industrial activities. Accidental spills or leaks from the tanks or conveyance piping and related valves, flanges, and other equipment have the potential to expose stormwater to jet fuel pollutants (e.g., kerosene[2]) and cause a petroleum sheen. Any potential leaks from the tanks and related valves, piping, and appurtenances would be contained within the secondary containment systems and immediately removed in accordance with the Property's Integrated Contingency Plan.

Soil infiltration testing conducted at the Property confirmed that the earthen secondary containment systems meet the "sufficiently contained" and "readily recoverable" requirements of WAC 173-180-320(1)(d). Any incidental stormwater that bypasses the perimeter of the EFR and enters the tank (i.e., tank bottom) is disposed of off-site via a vacuum truck at an approved off-site facility.

[1] Kerosene-based aviation fuel.
[2] Kerosene is a petroleum product made up of hydrocarbons in the C9 to C16 carbon range.

1.3.2 Fuel Additive Storage and Truck Loading Rack

Smaller ASTs containing fuel additives are situated immediately east of the Truck Loading Rack within a concrete lined and walled secondary containment area (Containment Area 5) in the easterly portion of the Property. These smaller ASTs range in size and can store up to a combined total of 9,875 gallons of additive. These additives are stored in sealed ASTs and therefore are not exposed to precipitation or runoff. Any potential leaks from the tanks and related valves, piping, and appurtenances would be contained within the concrete secondary containment, referred to as Containment Area 5. Any incidental stormwater that enters the covered Truck Loading Rack drains to two 3,000-gallon aboveground oil/water separators (OWSs) and is disposed of off-site via a vacuum truck at an approved off-site facility.

1.3.3 Transmix Storage

A 42,000-gallon transmix AST (i.e., Tank 101) is located in Containment Area 6 in the western portion of the Property and is normally empty. If needed, liquids in the OWS can be drained to Tank 101. The purpose of the transmix AST is to supplement secondary containment at the Truck Loading Rack and OWS, should it be needed.

1.3.4 Vehicular Traffic

Vehicles and equipment used to maintain the Property's infrastructure is another potential source of petroleum-related pollutants (e.g., diesel-range total petroleum hydrocarbons and polyaromatic hydrocarbons) and metals (e.g., zinc). The interior access roads are mostly unpaved, so stormwater runoff is minimal. Any runoff from these roads infiltrates along the edge of the roads.

2 EXISTING STORMWATER MANAGEMENT SYSTEM

2.1 Existing Stormwater System

The existing stormwater system is shown in Figure 1-2. The Facility has five permitted water quality monitoring points. The Permit refers to these as Outfall 001, Outfall 002, etc., although none of these monitoring points are outfalls to surface waters. Stormwater is managed on-site primarily via infiltration and evaporation unless evidence of contamination is detected prior to discharge, in which case a vacuum truck is used to remove contaminated water for transport and disposal at an approved off-site facility. There is no off-site discharge of stormwater to surface waters as the entire Property is either bermed or sloped to contain stormwater.

Stormwater conveyance on-site occurs only via manually operated pumps and/or valves. All secondary containment and EFR AST water drain valves are secured in the "closed" position and manually operated pumps remain in the "off" position under normal operating conditions to allow for proper inspection and sampling prior to discharge by NuStar personnel. Accumulated

stormwater upstream of any of NuStar's five Permit water quality monitoring points are inspected prior to discharge to confirm the absence of a petroleum sheen, color, turbidity, or other evidence that a spill or leak occurred. Additionally, each monitoring point with discharge is sampled and analyzed quarterly in accordance with Section S2.A of the Permit.

In the event visual evidence of petroleum impact is identified, the accumulated stormwater is not discharged to the ground and is instead removed by a vacuum truck and transported off-site for disposal at an approved off-site facility. Similarly, if any of the Permit parameters exceed effluent limits upstream of a monitoring point, accumulated stormwater is not discharged to ground and instead is removed by a vacuum truck and transported off-site for disposal at an approved off-site facility.

In addition to pre-discharge inspection and quarterly water quality monitoring, the Facility implements the following BMPs to prevent or minimize the potential for stormwater to come into contact with pollutants:

- **Housekeeping.** Continuous monitoring of pipeline transfers and daily inspections of ASTs, pipes/pipelines, ancillary equipment, truck loading activities, and associated safeguard systems.
- **Preventative Maintenance.** Roadway sweeping, storm drain and detention pond inspections, and removal/repair of any leaking, corroded, or otherwise deteriorating vehicles or equipment.
- **Structural Controls.** ASTs and pipe supports are constructed on concrete foundations, tanks and piping are equipped with electronic pressure sensing and liquid level gauging equipment, redundant automated overflow alarm systems (i.e., audio and visual alarms), and cathodic protection. Secondary containment systems surround all product storage and distribution features, and the Truck Loading Rack is equipped with a canopy and low point drains that are connected to an OWS and transmix tank.

2.1.1 Outfalls (WAC 173-240-130 [2][m])

NuStar has no outfalls of stormwater to surface waters. All stormwater is either infiltrated where the rainfall occurs, is managed by conveying it to the Stormwater Detention Pond or is transferred off-site for disposal at an approved facility.

Stormwater from Containment Area 4, which has a synthetic geomembrane liner, is captured and pumped to the Stormwater Detention Pond in the northwest corner of the Facility. If the water level reaches a specified high level in the Stormwater Detention Pond, the water can be discharged manually via Outfall 001 to the Surge Pond located south of the Stormwater Detention Pond. The discharge from the Detention Pond to the Surge Pond is identified in the Permit as "Outfall 001" and is controlled by a manual valve.

Runoff from Containment Area 7 can also be manually discharged directly to the Surge Pond if the water level in the containment area reaches the level of the valved pipe connecting this area to the

Surge Pond. This is identified in the Permit as "Outfall 005." The Permit was modified on April 6, 2021, to recognize that there are two outfalls (i.e., Outfalls 001 and 005) to the Surge Pond that will be monitored should there be a discharge.

The Surge Pond infiltrates stormwater in excess of the Stormwater Detention Pond and Containment Area 7 capacity into the soil beneath the pond. Should the Surge Pond reach its capacity, it would overflow to the southwest corner of the Property indicated as Containment Area 6. There are no records of any such overflow having occurred in the past.

The three southerly ASTs, in Containment Areas 3 and 4, have fixed roofs that shed runoff to the surrounding ground. The four northerly ASTs in Containment Areas 1 and 2 have EFRs that collect stormwater that is then manually discharged into temporary holding tanks when necessary. Two of the EFRs installed over Tanks 4001 and 5503 are designated stormwater monitoring points in the Permit (i.e., "Outfall 002" and "Outfall 003"). Stormwater that collects on the EFRs is either discharged to the ground after monitoring or disposed of at an approved off-site facility.

Stormwater that accumulates inside Containment Area 5 (fuel additives tank farm containment structure) is manually discharged to the ground via Outfall 004 after inspection and quarterly sampling confirms pollutant concentrations are below Permit effluent limits. If a sheen is observed or monitoring data exceeds the Permit effluent limits, the stormwater is routed to an OWS and then disposed of at an approved off-site disposal facility.

2.1.2 Solids Treatment and Disposal (WAC 173-240-130 [2][r])

NuStar does not currently generate solids that require treatment and disposal.

2.2 Receiving Water (WAC 173-240-130 [2][l])

There is no discharge of Facility stormwater to surface waters. Precipitation is contained on the Property where it either evaporates, or slowly infiltrates through the soil.

Detailed and ongoing groundwater level monitoring data generated using pressure transducers in Containment Area 1 wells MW-5 and MW-5D (see Figure 1-2) confirm that, due to the extremely slow stormwater infiltration rate through the Facility's underlying fine-grained soils, there is no temporary groundwater mounding in response to storm events. The results of groundwater level monitoring conducted at the Facility between February 25, 2022, and November 9, 2022, are provided in Appendix A, Section 9.3.

Precipitation that falls on EFR tanks or in lined containment areas is managed separately but is primarily allowed to infiltrate or naturally evaporate from the Property.

2.3 Quantity of Industrial Stormwater and Bypasses (WAC 173-240-130 [2][c][i and iv])

A water balance study was conducted to estimate the overall quantity of stormwater managed on the Property and to analyze an average annual water year and a peak rainfall water year. The water balance calculations included in Appendix B of the AKART report (MFA 2022) also accounted for evaporation. Monthly pan evaporation rates were exported from Ecology's Western Washington Hydrology Model (WWHM,2012) data set for October 1948 to August 2012, and correction factors were applied to account for seasonal variations to quantify the amount of water lost to evaporation at the Property. These losses were accounted for in the previously completed water balance analysis (see Appendix B of the AKART report) to estimate the volumes and flow rates of runoff generated at the Property that require on-site management.

The results from the water balance study determined that the runoff volume generated in Containment Areas 1, 2, 3, 5, and 6 can be managed via infiltration and evaporation where the precipitation occurs without the need for bypassing flows outside of these areas. Stormwater runoff volumes generated in Containment Area 4 are managed via direct evaporation with the ability to manually bypass flows using an existing pump station, as needed, for discharge to the Stormwater Detention Pond. In the event that the Stormwater Detention Pond capacity is exceeded, a bypass system is in place to convey discharge from the Stormwater Detention Pond to the Surge Pond and subsequently to Containment Area 6 if the Surge Pond capacity is exceeded. There are no records of any such overflow to Containment Area 6 having occurred in the past.

Detailed and ongoing water level monitoring using a pressure transducer in the Stormwater Detention Pond confirms that there is very slow leakage from the detention pond (see Section 9.1 in Appendix A). The results of the Stormwater Detention Pond water level monitoring conducted at the Property between February 25, 2022, and November 9, 2022, are provided in Appendix A. Discrepancies between predicted and actual discharges from the Stormwater Detention Pond are a function of conservative assumptions used in the theoretical water balance model and slow leakage from the pond bottom.

2.4 Quality of Industrial Stormwater (WAC 173-240-130 [2][c][i-iii])

The Permit went into effect on May 1, 2020, and NuStar began monitoring stormwater quality on a quarterly basis starting July 1, 2020. Monitoring results are included in Appendix E of the AKART report; (MFA 2022). The Permit requires NuStar to monitor stormwater quality for total petroleum hydrocarbons (TPH); total benzene, toluene, ethylbenzene, and xylene (total BTEX); total arsenic; barium; copper; lead, zinc; and pH. Outfall 001 that conveys stormwater from the Stormwater Detention Pond to the Surge Pond has been monitored since the fourth quarter of 2020 to the fourth quarter of 2023 with no exceedances of the Permit effluent limits. Outfalls 002 and 003 that convey accumulated stormwater from the EFRs through holding tanks to the ground have been monitored since the fourth quarter of 2020 through the fourth quarter of 2023 with no exceedances of Permit effluent limits. Outfall 004, which conveys accumulated stormwater inside Containment Area 5, was monitored in the fourth quarter of 2020 through the fourth quarter of 2023 with no exceedances of Permit effluent limits. Outfall 005, which conveys stormwater discharge from

Containment Area 7 to the Surge Pond, was monitored in the first quarter of 2021 through the fourth quarter of 2023 with no detections of any of the monitoring parameters for which effluent limits are established in the Permit.

Domestic wastewater does not commingle with industrial stormwater at the Property. All domestic wastewater is discharged to the sanitary sewer. Non-contact cooling water is not generated on-site.

2.5 Discharge through Municipal Sewerage System (WAC 173-240-130 [2][o])

NuStar does not discharge stormwater or non-domestic wastewater to the municipal sewerage system.

2.6 Discharge through Land Application (WAC 173-240-130 [2][p])

There is no land application other than the infiltration previously discussed.

3 AKART ANALYSIS (WAC 173-240-130[2][V])

Several alternatives were evaluated for managing stormwater at the Property as part of the previously completed AKART analysis (MFA 2022). The analysis included stormwater discharge to the City of Vancouver storm sewer, discharge to the City of Vancouver sanitary sewer, direct discharge to surface waters (i.e., the Columbia River and Vancouver Lake), discharge to on-site and off-site infiltration in non-MTCA areas both inside and outside of the Special Wellhead Protection Area, discharge to ground on-site via the existing stormwater disposal system with minor operational changes, and a stormwater management system that includes treatment prior to discharge to an on-site infiltration pond in non-MTCA areas.

In addition to the evaluation of available alternatives, WAC 173-240-130 (2)(v) requires that the engineering report explain why certain alternatives may be unacceptable. As summarized in the previous paragraph, the AKART report evaluated both on-site and off-site stormwater management options. The off-site stormwater management options require approval and/or legal agreements by public and private entities (e.g., the Port of Vancouver, the City of Vancouver, private property owners), including permitting agreements to discharge through existing outfalls, procurement of utility easements, and the purchase of nearby property, or properties, with appropriate zoning requirements for stormwater conveyance infrastructure.

For off-site stormwater management options, multiple risks for project barriers and delays were identified, including the time required for project coordination, review, and approval by outside parties; acquisition of property and easements; permitting requirements that also need time for preparation, review, and approval; land use limitations; and potential restrictions imposed on the project by outside entities. Because of these identified physical and administrative constraints for

off-site options, these alternatives were determined to be not "available" to NuStar under the definition of AKART.

A one-year extension for submittal of the engineering report was requested to conduct additional studies at the Property to further inform the feasibility of on-site stormwater management. During the one-year extension period, additional soil infiltration and groundwater monitoring studies were conducted on-site, the results of which are included in Appendix A. These studies confirm that management of stormwater on-site is viable. Management on-site poses a much lower risk to project schedule and constraints by eliminating the need to acquire easements, property, permits, and agreements (e.g., agreement to utilize an existing outfall) and allows NuStar to monitor the system more closely and to mitigate risk of outside influence on the system facilities located off-site.

Of the on-site alternatives identified in the AKART report, Alternative 2 (Discharge on NuStar Property Outside of MTCA areas) with an OWS and granular activated carbon (GAC) filtration treatment prior to infiltration was selected based on its protection of water resources, its availability to be implemented, and its equivalency to treatment technology in place at other petroleum terminals in the state. This alternative was modified to provide treatment prior to the Stormwater Detention Pond since some infiltration of stormwater does occur at this location.

Several of the other petroleum terminals in Washington state have some form of pre-filtration prior to the GAC filters (Table 11 of the Ecology Fact Sheet). This element of treatment is commonly used to extend the life of the carbon and may or may not be necessary at the NuStar facility. Determination of whether this treatment component is advisable would be made after operation of the treatment system without the pre-filtration step and added later, if needed to extend the carbon life cycle. This pre-filtration component does not impact the level of treatment provided by the system but may, under some conditions, reduce the consumption of activated carbon.

4 PROPOSED SYSTEM IMPROVEMENTS

4.1 Proposed Treatment System Description (WAC 173-240-130 [2][g])

The proposed improvements to the existing stormwater treatment system consist of the following, and the proposed layout is shown in Figures 4-1 and 4-2:

- A treatment system comprised of a coalescing plate OWS to reduce potential TPH in stormwater followed by a GAC filtration system to further reduce TPH, reduce potential benzene, and reduce total BTEX that may be present in stormwater and then discharged to the Stormwater Detention Pond.

- Three lift stations, including piping, valving, control panels, and appurtenances for stormwater conveyance to the various proposed treatment and disposal locations.
  - Pump Station No. 1 will convey accumulated stormwater that is manually discharged from Containment Areas 4 and 7 through the OWS to Pump Station No. 2.
  - Pump Station No. 2 will convey the water treated by the OWS to the GAC filtration system for further treatment prior to discharge to the Stormwater Detention Pond.
  - Pump Station No. 3 will convey stormwater from the Stormwater Detention Pond to the infiltration pond located in the former orchard area. The pump station will maintain the water level in the Stormwater Detention Pond at a low level to minimize infiltration while providing detention storage for large storm events.
- An infiltration pond in the southeast corner of the Property for management of treated water from the Stormwater Detention Pond.
- Treatment with GAC filters for all EFR runoff prior to infiltration

Reducing or eliminating the earthen containment areas was evaluated as required by S9.B in the Permit via soil infiltration studies conducted on-site. The soil infiltration testing results (Appendix C of the AKART report and summarized in Appendix D of this report) confirmed that the earthen secondary containment systems meet the "sufficiently contained" and "readily recoverable" requirements of WAC 173-180-320(1)(d).

4.2 Treatment Process (WAC 173-240-130 [2][h] and [n])

The process of the stormwater management system with the proposed improvements is outlined below:

- Containment Areas 1, 2, 3, and 6 will continue to infiltrate incidental precipitation. Accumulated stormwater from tanks with EFRs will be treated with GAC filters prior to discharging the treated stormwater to the surrounding ground within the containment areas, as needed, or disposed of off-site at an approved off-site facility.
- Stormwater from Containment Area 4 is collected and manually pumped, as needed, via an existing lift station to the proposed OWS and GAC filtration system for treatment prior to discharge to the Stormwater Detention Pond.
- Stormwater from Containment Area 5 will continue to be manually discharged to the surrounding ground after inspection and quarterly sampling confirms pollutant concentrations are below Permit effluent limits, or the stormwater will be disposed of off-site at an approved facility if the water quality testing does not meet the Permit effluent limits.
- Stormwater in Containment Area 7 sheet flows from the eastern area of Containment Area 7 to the low point at the western end of Containment Area 7. A new catch basin will be installed at the low point to collect stormwater, which will be manually discharged via an isolation valve, as needed, to gravity drain to Pump Station No. 1 and

subsequently to the OWS, then to Pump Station No. 2 for conveyance to the GAC filtration system, and then will be discharged into the Stormwater Detention Pond. Monitoring for Outfall 001 will be relocated to the discharge of treated water into the Stormwater Detention Pond. Outfall 005 from Containment Area 7 will be abandoned and removed from further monitoring under the Permit.

- The treated stormwater stored in the Stormwater Detention Pond will flow to Pump Station No. 3 and then be pumped to the proposed infiltration pond in the southeast corner of the Property. Floats or other level monitoring devices will automatically maintain the water level in the Stormwater Detention Pond at a low level to minimize infiltration and provide detention storage for large storm events.
- The proposed infiltration pond installed in the southeast corner of the Property will serve as the final step in the treatment process and infiltrate stormwater from the Stormwater Detention Pond.

See Figure 4-3 for the flow diagram.

4.3 Basic Design Data and Calculations (WAC 173-240-130 [2][e])

The proposed improvements were sized using results from the water balance calculations for a peak rainfall year included in the AKART report (MFA 2022) to manage the stormwater on a seasonal basis rather than using runoff volumes and flow rates estimated in the WWHM. The use of the water balance results as a design basis is a conservative approach to sizing the system as it overestimates the volume of stormwater, based on actual site observations, that has to be managed. Sizing the treatment system components to manage stormwater in this manner allows 100 percent of collected stormwater to be managed and treated versus the minimum 91 percent of runoff volume estimated in the WWHM.

The results from the water balance study determined that the runoff volume generated in Containment Areas 1, 2, 3, 5, and 6 can be managed via infiltration and evaporation, as currently operated, without the need for bypassing flows outside of these areas, and therefore volumes from these areas are not accounted for in the sizing of the proposed treatment system. Stormwater discharges from Containment Areas 4 and 7 will be treated via an OWS and GAC filtration system prior to discharge to the Stormwater Detention Pond and subsequent transfer to the infiltration pond.

The design treatment flowrate is 310 gallons per minute (gpm) for the OWS and the GAC filtration system based on the maximum recorded discharge from Containment Area 7 plus the pumping rate capacity of the existing pump station for conveyance of accumulated stormwater from Containment Area 4. Design calculations are included in Appendix B.

Preliminary equipment selected for the treatment system (Appendix B) is based on the design treatment flowrate and the target pollutants (i.e., those which have established Permit effluent limits) and includes a coalescing plate OWS that has a maximum treatment capacity of 420 gpm and an adsorptive GAC pressure filter comprised of two pressure vessels operated in series in a lead/lag configuration. The GAC filter system will have a wash water source tank and a wash water decant

tank to accommodate the occasional backwash of the lead filter unit. Each tank will be approximately 15,000 gallons. Details of system operations will be included in a separate Operations and Maintenance Manual.

A pump station will convey treated stormwater from the Stormwater Detention Pond to the proposed infiltration pond located in the former orchard area of the Property where relatively high permeability rates were determined during infiltration testing conducted on-site (see Appendix A for infiltration testing results). The pump station will maintain the water level in the Stormwater Detention Pond at a low level to minimize infiltration while providing detention storage for large storm events.

The design flowrate to convey treated stormwater from the Stormwater Detention Pond to the infiltration pond is 72 gpm and is based on runoff volumes generated during a peak rainfall water year (i.e., 2016–2017) that are managed in the pond (see Appendix B for design calculations). The proposed infiltration pond was sized based on the design flowrate of 72 gpm and the design infiltration rate determined during soil infiltration testing (Appendix A) plus an added safety factor of 1.5 to accommodate variations in pump station mode of operation.

4.4 Discharge through Land Application (WAC 173-240-130 [2][p])

4.4.1 Infiltration Pond

The proposed stormwater treatment system improvements include an infiltration pond in the southeastern portion of the Property, also known as the former orchard area. Because discharge of treated stormwater through subsurface disposal is proposed, a geohydrologic evaluation was conducted for the Property. The observations, collected data, and conclusions are included in the Additional Soil Infiltration Testing and Stormwater Detention Monitoring report by GeoEngineers, Inc., included in Appendix A.

Evaluation of the area proposed for stormwater infiltration included the installation of two piezometers equipped with transducers to inform the overall effects of the proposed infiltration pond on the groundwater and additional soil infiltration testing to confirm suitability of the former orchard area for infiltration. The two piezometers (i.e., INF-1 and INF-2) were monitored over an approximately eight-month period, along with the Columbia River stage and monthly precipitation rates. Water level data (see Figures 4 through 8 in Appendix A) were collected over both a wet and dry season as well as the transitional period between the two seasons to understand the primary factors influencing the seasonal water table fluctuations beneath the Property. The infiltration testing results for the Property, including the former orchard area, are summarized in Table 4 of Appendix A. The infiltration rates will be checked again during the construction phase to confirm the results and, if necessary, the final footprint of the infiltration pond may be adjusted.

The infiltration pond is preliminarily sized to accommodate the flow rate from Pump Station No. 3 conveying treated stormwater from the Stormwater Detention Pond. The infiltration pond size is approximately 0.4 acres but is situated to accommodate a larger pond if required. There will be a

forebay cell as part of the infiltration pond to allow energy dissipation and settling of any solids that may come from the Stormwater Detention Pond intake.

4.4.2 Stormwater Detention Pond

The Stormwater Detention Pond will also allow some infiltration although the rate of infiltration is significantly slower than the infiltration pond. The amount of infiltration will be minimized by normally operating the Stormwater Detention Pond at a low water level thereby reducing the amount of infiltration it experiences.

4.5 Chemicals Used in the Treatment Process (WAC 173-240-130 [2][d])

The existing and proposed treatment processes do not use chemical treatment.

4.6 Suitability of the Proposed Site for the Facility (WAC 173-240-130 [2][f])

The proposed treatment system improvements will be located within the existing Property boundary as shown in Figures 4-1 and 4-2. The proposed treatment system is located in the most suitable area for stormwater treatment based on the existing facilities layout and infiltration testing results (Appendix A).

4.7 Results to be Expected from the Treatment Process and Engineering Justification (WAC 173-240-130 [2][k] and [q])

Based on the use of similar treatment technologies (i.e., OWS and GAC adsorption filtration) at seven of eight other bulk petroleum terminals throughout Washington State with active National Pollutant Discharge Elimination System individual permits and the scientific evidence from the literature provided in Appendix C for the removal of pollutants (i.e., TPH, benzene and BTEX) for which the Permit establishes effluent limits, it is expected that the proposed treatment system will achieve the Permit effluent limits. The treatment system operation will actually utilize lower setpoints than the Permit effluent limits to trigger system maintenance as detailed in the Operations and Maintenance Manual.

4.8 Compliance with Water Quality Standards (WAC 173-240-130 [2][l])

There is no off-site discharge of stormwater to surface water as the entire Property is either bermed or sloped to contain stormwater and the proposed treatment system maintains on-site management of stormwater that may come into contact with pollutants.

Stormwater sampling results from NuStar's current practices indicate that stormwater is capable of meeting Permit effluent limits without treatment. The proposed treatment system is being put in place so that ongoing stormwater discharges to the Stormwater Detention Pond and proposed infiltration pond continue to meet Permit effluent limits and do not fall under the City of Vancouver code definition of "Direct Infiltration."

4.9 Compliance with Other Plans (WAC 173-240-130 [2][t])

There are no state or local water quality management plans or any other plans adopted under the Federal Water Pollution Control Act that apply to NuStar discharges.

The City of Vancouver has adopted, and amended as recently as 2023, a Water Resources Protection code that applies to the City in general and to Special Protection Areas in which NuStar is located. The code restricts the use of infiltration facilities within the Special Protection Areas (VMC 14.26.135.D.1) by specifying that "New direct infiltration facilities, and replacement of existing direct infiltration facilities shall not be allowed for Class I and Class II operations in Special Protection Areas." The definition of "direct infiltration facility" is clarified in the Water Resources Protection code to mean "any mechanism that is intended to direct stormwater or process wastewater directly into the ground without providing treatment in accordance with Chapters 14.10 and 14.25 VMC. Examples include, but are not limited to, drywells, ponds, trenches, and perforated pipe systems."

For the proposed stormwater management system, all collected stormwater will be treated above and beyond the requirements of Chapters 14.10 and 14.25 VMC prior to infiltration which means there is no new direct infiltration contemplated in this report. Existing infiltration, which occurs when rainfall falls naturally across the site, is not considered within the definition of "direct infiltration facility" because the stormwater is not directed into a facility like the examples provided in the definition (i.e., drywells, ponds, trenches, perforated pipes) but rather the rainfall evaporates or slowly infiltrates into the ground within the containment areas where it falls.

In summary, no new direct infiltration facilities and no replacement of existing direct infiltration facilities are proposed in this report. All other applicable sections of the Water Resources Protection code have been complied with in this report.

4.10 Operation and Maintenance (WAC 173-240-130 [2][s])

NuStar owns, operates, and maintains the existing stormwater treatment system and will own, operate, and maintain the proposed system improvements described in this report. An operation and maintenance manual will be submitted to Ecology with the required conceptual plans by May 1, 2024 in accordance with the requested permit schedule.

4.11 Implementation Schedule (WAC 173-240-130 [2][w])

Implementation of the proposed improvements will begin after local agencies (City of Vancouver and Clark Public Utilities) and Ecology have approved the AKART and Engineering Reports. The

plans and specifications will be a conceptual level submittal as provided for in WAC 173-240-110(5). Following Ecology's approval of the submittals, NuStar will begin the permit process which includes the development of construction plans and application to the City of Vancouver for a grading permit. The grading permit application also addresses stormwater and erosion control for the construction phase.

Infiltration pond construction will be weather dependent so completion of this work may extend into Summer 2025. After the treatment system is completed, the system will undergo a startup and troubleshooting phase that is typical for treatment systems and requires precipitation in order to be completed.

The proposed implementation schedule is provided below:

- Submitted engineering report—May 2023
- Submit revised engineering report, conceptual plans—May 1, 2024
- Submit operation and maintenance manual—May 1, 2024
- Final design, bid documents, and permitting—October 2024 to March 2025
- Procure and install treatment system—April to September 2025
- System startup and troubleshooting— September to December 2025

4.12 Spill Control or Accidental Discharge Prevention (WAC 173-240-130[2][j] and Sections S7, S8, and S9.B of the Permit)

In June 2020, in accordance with Section S7 of the Permit, NuStar implemented a stormwater pollution prevention plan to identify potential stormwater pollution sources, establish controls to reduce or eliminate the potential for contaminated stormwater being released to the environment, and ensure compliance with the terms and conditions of the Permit. Since stormwater quality monitoring began on July 1, 2020, all discharges through compliance monitoring points have met Permit effluent limits.

In September 2020, in accordance with Section S8 of the Permit, NuStar updated its existing spill prevention control and countermeasure plan to further minimize the potential for accidental releases of oil and hazardous materials in stormwater (i.e., ensure consistency with the stormwater pollution prevention plan) and outline spill response procedures and roles. Both plans will be updated to reflect the stormwater management system as proposed in this report.

Section S9.B of the permit contains several requirements that have been addressed in the Engineering Report. The first requirement regarding proposing treatment technology "no less stringent than that in place at other petroleum terminals in the state" has been addressed in Section 3 - AKART Analysis above.

Section S9.B of the Permit requires the permittee to evaluate and propose improvements to "intercepting and diverting product spills." As part of NuStar's response to Section S8, the SPCC Plan has been updated to meet the permit requirements as well as those of Ecology's Spill Prevention Group. In addition, NuStar proposes improvements to managing the runoff from their

tanks with EFRs which can have some exposure to the tank contents as the roofs float up and down with the product levels within the tanks. These improvements will allow NuStar to capture all the roof runoff and hold the runoff for treatment and monitoring prior to infiltration. The roof runoff managed in this manner avoids the definition of "direct infiltration" by treating all the runoff prior to infiltration.

Section S9.B of the Permit requires the permittee "to reduce or eliminate unlined containment areas." NuStar conducted soil infiltration testing within the Facility's earthen secondary containment areas to confirm that they met the "sufficiently contained" and "readily recoverable" requirements of WAC 173-180-320(1)(e), which specifically allows soil for secondary containment systems. NuStar revised its SPCC plan and the completed plan was reviewed and approved by Ecology in December 2022. The plan included evaluations of the containment areas and their performance.

Precipitation that falls within the earthen lined containment areas infiltrates into the ground at a very slow rate of 3.5×10^{-5} centimeters per second (0.1 feet per day) on average. These soil infiltration testing results, included in Appendix C of the AKART report (MFA 2022) and summarized in Appendix D of this report, confirm that the earthen secondary containment systems meet the "sufficiently contained" and "readily recoverable" requirements of WAC 173-180-320(1)(e). Ecology has concurred with NuStar's evaluation by their approval of the NuStar SPCC plan.

Based on the work completed by NuStar as part of their response to Section S8 of the Permit, NuStar has evaluated the containment areas and determined that they all meet the requirements of WAC 173-180-320 as "sufficiently contained" by way of their earthen containment structures or other containment structures. Earthen secondary containment areas are not considered "unlined" if they meet Ecology's definition of "sufficiently contained" systems.

4.13 Compliance with State Environmental Policy Act and National Environmental Policy Act (WAC 173-240-130 [2][x])

The improvements outlined in this report include modifications to the existing stormwater management system. As such, checklists under either the State Environmental Policy Act or the National Environmental Policy Act are not required.

LIMITATIONS

The services undertaken in completing this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this report.

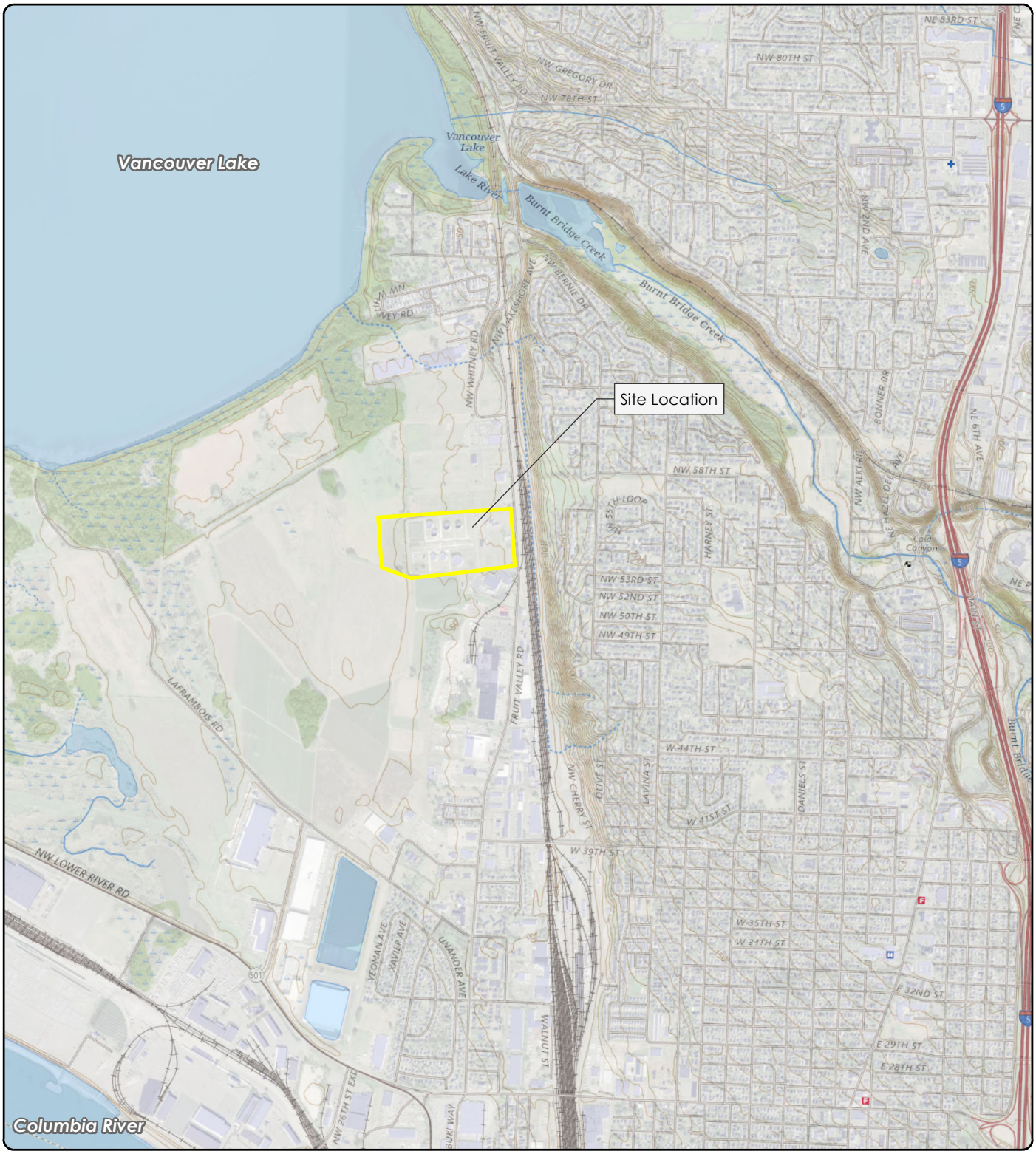
REFERENCES

Ecology. 2012. "Western Washington Hydrology Model." Washington State Department of Ecology.

MFA. 2022. *NuStar Terminals AKART Report*. Prepared for NuStar Terminals Operations Partnership L.P. Maul Foster & Alongi, Inc.: Vancouver, WA. January 10.

Ecology, 2020. "Fact Sheet for NuStar Terminals Operations Partnership L.P.

FIGURES



Notes
US Geological Survey 7.5-minute topographic quadrangle (2020): Vancouver.
Township 2 North, Range 1 East, Sections 54 and 55.

Data Source
Property boundary obtained from Clark County GIS.

Legend

Site Boundary

Figure 1-1
Property Location

NuStar Terminals Operations Partnership LP
Vancouver Annex Facility
5420 NW Fruit Valley Road
Vancouver, WA 98660

0 1,000 2,000
Feet

MAUL FOSTER ALONGI
p. 971 544 2139 | www.maulfoster.com

Path: X:\1866.01_02\Projects\Fig1_1_Property_Location.mxd
Print Date: 4/6/2023
Reviewed By: ahlatky
Produced By: jroberts
Project: M1866.01.002

Figure 1-2
Property Features

NuStar Terminals Operations Partnerhip LP
Vancouver Annex Facility
5420 NW Fruit Valley Road
Vancouver, WA 98660

Legend

- Monitoring Well
- Piezometer with Pressure Transducer
- Low-Point Drain
- Oil/Water Separator
- Stormwater Monitoring Point/Outfall
- Stormwater Pipe and Flow Direction
- Process Water Pipe and Flow Direction
- MTCA Site Boundary
- Building Footprint
- Tank
- Containment Area
- Property Boundary

Note
Washington State Department of Ecology Agreed Order No. 08-TC-S DE5250.
MTCA = Model Toxics Control Act.

0 75 150
Feet

Data Sources
Aerial photograph obtained from Mapbox; property boundary data obtained from Clark County GIS.

MAUL FOSTER ALONGI
p. 971 544 2139 | www.maulfoster.com

Path: X:\1866.01_02\Projects\Fig1_2_Property_Features.mxd
Print Date: 4/6/2023
Reviewed By: ahlaky
Produced By: jroberts
Project: M1866.01.002

PLOTTED ON: 2024-01-17 11:15 AM
PLOTTED BY: Loraine Daniel
FILENAME: G:\00_MFA Civil 3D\00_PROJECTS\1866.01 NuStar\EXHIBIT\Prop Treatment System_FIGURE 4.dwg

MAUL FOSTER ALONGI
971.544.2139 | www.maulfoster.com

0 120' 240'

NOTE: BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALE ACCORDINGLY.

Figure 4-1
Proposed Treatment System Improvements
NuStar Terminals Operations Partnership, L.P.
Vancouver, Washington

LEGEND:

- EXISTING STORM PIPE (ABANDON IN PLACE) — SD_x SD_x
- EXISTING STORM PIPE — SD_x SD_x
- PROPERTY BOUNDARY
- FACILITY BOUNDARY
- PROPOSED GRAVITY STORM PIPE
- PROPOSED FORCE MAIN STORM PIPE — FM FM
- CONTAINMENT AREA
- BUILDING FOOTPRINT

STORMWATER DETENTION POND (FORMER FIRE POND)

EXTG LOW POINT DRAIN AND PIPING MAY BE USED TO GRAVITY DRAIN STORMWATER DETENTION POND TO PUMP STATION NO. 3 IN LIEU OF INSTALLING NEW DISCHARGE PIPING AS SHOWN. TBD DURING FINAL DESIGN.

FILTER EFFLUENT FORCEMAIN

GAC FILTERS

PUMP STATION NO. 2

ABANDON EXTG PIPELINE IN PLACE

CONTAINMENT AREA 7

WASH WATER DECANT TANK

FIRE POND PUMP HOUSE

GRAVITY PIPELINE

WASH WATER SOURCE TANK

ABANDON EXTG PIPELINE IN PLACE

EXTG SURGE POND

OIL AND WATER SEPARATOR

LOW-POINT CATCH BASIN CONTAINMENT AREA 7

PUMP STATION NO. 1

FORCEMAIN PIPELINE

PUMP STATION NO. 3

TIE-IN TO EXTG PIPELINE

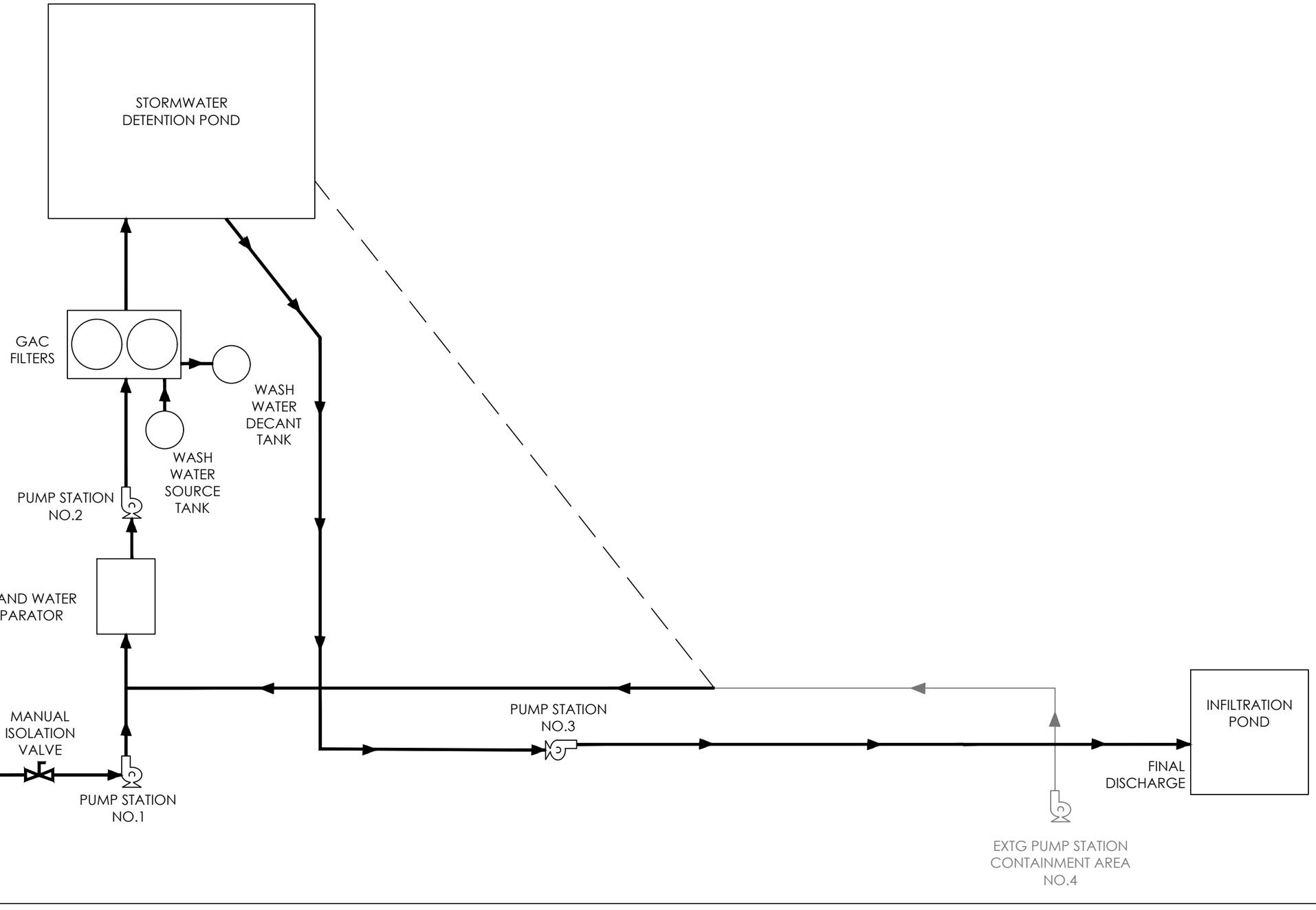
PLOTTED ON: 2024-01-17 11:16 AM PLOTTED BY: Loraine Daniel FILENAME: G:\00_MFA Civil 33\00_PROJECTS\1866.01 NuStar\EXHIBIT\Prop Treatment System_FIGURE 4.dwg

MAUL FOSTER ALONGI
971.544.2139 | www.maulfoster.com

0 20' 40'

NOTE: BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALE ACCORDINGLY.

Figure 4-2
Proposed Treatment System
NuStar Terminals Operations Partnership, L.P.
Vancouver, Washington



MAUL FOSTER ALONGI
971.544.2139 | www.maulfoster.com

DRAWING NOT TO SCALE

LEGEND:

PROPOSED STORM PIPE
EXISTING STORM PIPE
EXISTING STORM PIPE TO BE ABANDONED IN PLACE
DIRECTION OF FLOW

Figure 4-3
Proposed Treatment System Schematic
NuStar Terminals Operations Partnership, L.P.
Vancouver, Washington

APPENDIX A

ADDITIONAL SOIL INFILTRATION TESTING AND STORMWATER DETENTION MONITORING REPORT

Additional Soil infiltration Testing and Stormwater Detention Monitoring

NuStar Vancouver Annex
5420 NW Fruit Valley Road
Vancouver, Washington

for
NuStar Energy, L.P.

December 5, 2023

GeoEngineers
Earth Science + Technology

Additional Soil infiltration Testing and Stormwater Detention Monitoring

NuStar Vancouver Annex
5420 NW Fruit Valley Road
Vancouver, Washington

for
NuStar Energy, L.P.

December 5, 2023

GeoEngineers

5820 South Kelly Avenue, Suite B
Portland, Oregon 97239
503.906.6577

Additional Soil Infiltration Testing and Stormwater Detention Monitoring

NuStar Vancouver Annex
5420 NW Fruit Valley Road
Vancouver, Washington

File No. 19001-008-04

December 5, 2023

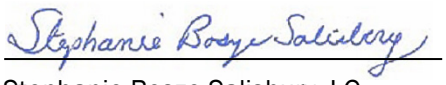
Prepared for:

NuStar Energy, L.P.
9280 West Stockton Boulevard, Suite 220
Elk Grove, California 95758

Attention: Houston Keck

Prepared by:

GeoEngineers, Inc.
5820 South Kelly Avenue, Suite B
Portland, Oregon 97239
503.906.6577



Stephanie Bosze Salisbury, LG
Associate Geologist

Kurt Harrington, PE
Principal

JMW:SBS:KH:cdb

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

1.0 INTRODUCTION AND PURPOSE

GeoEngineers, Inc. (GeoEngineers) has prepared this report for NuStar Terminals Operations Partnership L.P. (NuStar) to summarize additional soil infiltration testing and stormwater detention pond monitoring data collected at the NuStar Vancouver Annex facility located at 5420 NW Fruit Valley Road in Vancouver, Washington (the Facility or Property). To support this study, piezometers and a stilling well were installed, soil samples were collected and analyzed, pressure transducers were deployed to monitor water levels across the Facility, and additional soil infiltration testing was completed at the southeastern portion of the Property. The Facility location is shown on Figure 1, and the Facility layout is shown on Figure 2.

The southeastern (2.5-acre) portion of the Property, also known as the former orchard area, is being considered for stormwater infiltration discharge as presented as Alternative No. 2 in the January 10, 2022 All Known, Available, and Reasonable Method of Prevention, Control, and Treatment (AKART) report prepared by Maul Foster & Alongi, Inc. (MFA, 2022) on behalf of NuStar Terminals Operations L.P. During preparation of the AKART report, a Facility water balance was prepared, calculating the volume of stormwater infiltrated annually at the Facility as well as the volume of water pumped into the stormwater detention pond. It was understood that at times of heavy rainfall, the stormwater detention pond was allowed to overflow into an adjacent infiltration basin (aka, surge pond). A portion of the surge pond is located within a Washington State Department of Ecology (Ecology) Model Toxics Control Act (MTCA) program Site boundary which might limit its use for infiltrating stormwater overflow (Figure 3). The purpose of this study was to evaluate the inputs, water levels, and potential discharge from the stormwater detention pond, and to evaluate the suitability of the former orchard area for infiltrating stormwater detention pond overflow.

Soil infiltration rates were measured across the Facility in 2020, including the former orchard area, using a single ring falling head test method approved by the City of Vancouver. The former orchard area is outside of any known and inferred areas of residual soil and groundwater contamination as determined separately under the Ecology MTCA program (Supplemental Remedial Investigation and Feasibility Study; Cascadia,2020). The results of the 2020 infiltration testing indicated that shallow soil (i.e., depths ranging between 0 and 3 feet below ground surface [bgs]) beneath the former orchard area are more permeable than elsewhere beneath the Facility. In February 2022, additional soil infiltration testing was conducted within the orchard area at depths of 3 and 5 bgs using a double-ring infiltrometer in accordance with ASTM Standard Test Method D03385-9 to confirm the results of the 2020 single-ring infiltration testing. This report summarizes the results and conclusions of the February 2022 double-ring infiltration test and evaluates the future suitability of infiltrating stormwater detention pond overflow in the orchard area.

2.0 FACILITY DESCRIPTION

The Vancouver Annex jet fuel storage terminal is approximately 31 acres and is roughly rectangular, with dimensions of approximately 800 by 1,800 feet. The Facility receives jet fuel from underground pipelines, stores the petroleum product in seven aboveground storage tanks (ASTs), and loads it into tanker trucks at the Truck Loading Rack for distribution to customers in Oregon and Washington. The jet fuel ASTs are grouped in four tank farm containments (Containment Areas 1 through 4), as shown on the layout of the Facility presented on Figure 2, Facility Map. The newest of these large AST containment areas (Containment

Area 4) is lined with a geomembrane, while the other three use earthen containment systems. Precipitation that falls within the earthen lined containment areas infiltrates into the ground at a very slow rate of 3.5×10^{-5} centimeters per second (0.1 feet per day) on average. These soil infiltration testing results were included in Appendix C of the AKART report (MFA 2022). Stormwater from Containment Area 4, which has a synthetic geomembrane liner, is captured and pumped to the stormwater detention pond in the northwest corner of the Facility. The stormwater detention pond was understood to be fully or partially lined; however, no as-built information could be obtained to verify the presence of the liner. Therefore, an evaluation of pond leakage was part of the scope of this study.

Smaller ASTs containing fuel additives are situated next to the Truck Loading Rack inside a concrete containment area (#5). Any stormwater that enters the covered Truck Loading Rack drains to a below ground oil/water separator (OWS) and is disposed of offsite via a vacuum truck. A surge pond located immediately next to the stormwater detention pond is used for stormwater storage and infiltration during heavy rain events. An empty transmix AST and utility building are located inside Containment Area 6 (earthen), located south of the surge pond. An aboveground pipeline manifold area and vapor recovery unit are present within Containment Area 7 (earthen). The southeast corner of the property, located south of Containment Area 5, is not used for terminal activities and was historically used as an orchard. The area currently is fenced and contains remnant fruit trees that are not harvested. Except for the eastern portion of the Facility where the entrance and office building are located, the Facility is surrounded by a perimeter berm (i.e., no off-site stormwater runoff).

3.0 GEOLOGY AND HYDROGEOLOGY

The following sections describe both the regional geology and hydrogeology for the Vancouver lowlands area as well as the geology/hydrogeology documented at the Facility.

3.1. Regional Geology

The regional geology is summarized below and is based on reports prepared by Pacific Groundwater Group (PGG, 2001) and AMEC Earth and Environmental, Inc. (AMEC, 2002a and 2002b). The Site and surrounding area are dominated by three primary geologic units: Recent Alluvial deposits, the Pleistocene Alluvial deposits, and the Troutdale Formation.

The Recent Alluvial deposits are the upper unit with deposits approximately 55 feet thick and consisting of fine-grained silt and sand within the areas investigated near Vancouver Lake. The Pleistocene Alluvial deposits, located below the Recent Alluvial deposits, are approximately 95 to 115 feet thick and consist of coarse-grained sand and gravel. The Pleistocene Alluvial deposits originate from alluvial deposits from the Columbia River and deposits from the catastrophic Missoula Floods. The Troutdale Formation underlies the Pleistocene Alluvial deposits and can be more than 1,000 feet thick. It is made up of cemented sandy gravels and semi-consolidated sands, silts, and clays.

3.2. Local Soil Conditions and Site Topography

Numerous investigations have been conducted at the Facility since 2001. Soil borings have been advanced to depths of up to 72 feet below ground surface (bgs) as a part of environmental investigations conducted at the Facility by SECOR International Inc. (SECOR, 2003), Ash Creek Associates, Inc. (Ash Creek, 2008), Cascadia Associates, LLC (Cascadia, 2020), and GeoEngineers, Inc. (GeoEngineers, 2022a). The Recent

Alluvial deposits underlying the western portion of the Facility consist of clayey silt, silt with some fine sand, and sandy silt to depths of approximately 28 to 35 feet bgs. In some areas, localized sand layers, which appear to be laterally discontinuous, are observed within the silt. Below 28 to 35 feet bgs, the Recent Alluvial deposits consist of fine- to medium-grained sand to a depth of at least 65 feet bgs. On the eastern portion of the Facility, the base of the silt layer is generally shallower, with fine- to medium-grained sand encountered at approximately 10 feet bgs.

While the Facility is generally flat, there is some variability in surface topography as depicted by the isocontour lines on Figure 2. The stormwater detention pond elevation ranges from 26 to 36 feet North American Vertical Datum of 1988 (NAVD88)[1], which is consistent with the elevations of the secondary containment areas. The only exception being Containment Area 2, with a base elevation of 32 feet NAVD88 and the southern portion of Containment Area 6, with a base elevation of 16 feet NAVD88. The elevation at the base of the surge pond ranges from 16 to 18 feet NAVD88. A review of boring logs from boreholes advanced in Containment Areas 1 and 6 indicate that the surface soils are comprised of silt, with sandy lenses or silty sand layers observed beginning 8-10 feet below ground surface. The topography maps and boring log information would suggest that native soils below the stormwater detention pond are comprised of silt, while the soils at the base of the surge pond and lower portion of Containment Area 6, while silty, contain more fine sand and are generally more permeable than the overlying soil.

3.3. Regional Hydrogeology

The regional aquifers, Recent Alluvial Aquifer (RAA); Pleistocene Alluvial Aquifer (PAA); and the aquifers of the Troutdale Formation, follow the regional geology discussed above. The regional hydrogeology summarized below is based on reports prepared in support of Clark Public Utilities (CPU) Carol Curtis Wellfield (PGG, 2001; PGG, 2009), and by Ash Creek (2008a and 2008b).

The RAA is unconfined and receives recharge directly from the land surface and/or surface water features. The PAA directly underlies the RAA and is a productive aquifer with high well yields (several thousand gallons per minute [gpm] without significant drawdown). The groundwater flow system is highly influenced by local surface water bodies. The Columbia River, Vancouver Lake, Vancouver Lake Flushing Channel, and Lake River form natural hydrologic boundaries to the groundwater flow system. Tidal influences and seasonal variations in surface water runoff cause dynamic variation in the stage of the Columbia River, and results in adjustments in the water levels within the other three connected surface water bodies. The groundwater flow system is also influenced by tidal and seasonal variations in the surface water bodies. Regionally, it is anticipated that groundwater within the RAA and PAA in the vicinity of the Facility would have a net gradient towards Vancouver Lake and the Columbia River.

The Troutdale Gravel Aquifer has been observed at a depth of approximately 200 feet at the CPU wellfield located 500 feet north of the Facility. It is approximately 50 feet thick and is underlain by a 100-foot-thick clay confining layer. The Sand and Gravel Aquifer (SGA) of the Troutdale Formation is found beneath the confining layer.

[1] North American Vertical Datum of 1988 (NAVD 88) consists of a leveling network on the North American Continent, ranging from Alaska, through Canada, across the United States, affixed to a single origin point on the continent.

3.4. Local Hydrogeology

A total of 16 groundwater monitoring wells have been installed at Facility with 10- to 15-foot-long screened intervals located at depths ranging between 14.5 and 45 feet bgs. Locations of the wells are shown on Figure 3. Groundwater monitoring, including water level gauging, has been conducted in some of the Facility's wells since 2002, while facility-wide routine quarterly monitoring has been ongoing since February 2019. First encountered groundwater is found in the silt of the RAA. In the western portion of the Facility, depth to first encountered groundwater ranges from approximately 8 to 22 feet bgs, and in the eastern portion of the Facility, near the Truck Loading Rack and where the ground surface elevation is approximately 10 to 12 feet higher, depth to groundwater has ranged from approximately 20 to 32 feet bgs. Depth to first groundwater varies seasonally, with the shallower depths generally encountered between December and June and the deeper depths encountered between July and November. On average, depth to groundwater is approximately 11 feet beneath the undeveloped grass and shrub covered land west of the bermed containment areas; approximately 15 feet beneath the large AST containment areas; and approximately 30 feet beneath the Truck Loading Rack and the grass and orchard land southeast of the rack. Shallow groundwater flow at the Facility has remained, under static conditions, relatively flat with a slight gradient (typically ranging between 0.0001 to 0.0005 foot per foot) predominantly to the southeast (GeoEngineers, 2022b) but at times to the east/northeast.

3.5. Nearby Municipal Pumping in Regional Aquifer

CPU owns and operates a series of groundwater production wells (Carol Curtis Wellfield) approximately 500 feet north of the Facility. CPU currently pumps 7,000 gallons per minute from the deeper, confined SGA and has plans to pump from wells in the shallower PAA, with a proposed production rate of 5,000 gpm as early as 2024. Currently, CPU has a small pump in the PAA well and is conducting short term aquifer tests. CPU is contacted routinely for updates on their projected production schedule in the PAA.

4.0 REGULATORY FRAMEWORK AND PERMITTING

4.1. Status of Environmental Investigation and Cleanup

Petroleum hydrocarbon constituents were identified in soil and groundwater in 2001, and since that time, a number of subsurface investigations and interim cleanup actions (contaminated soil removal and in-situ chemical oxidation and enhanced bioremediation injections) have been conducted at the Facility in accordance with the protocols in MTCA and pursuant to Agreed Order No. 09-TC-S-DE5250 ("Agreed Order").

There are four areas of soil and/or groundwater with concentrations of petroleum hydrocarbon constituents above MTCA cleanup levels at the Facility; the locations are shown on Figure 3 (the Truck Loading Rack and the Vapor Recovery areas are contiguous, as shown on the figure). The nature and extent of the impacted areas and the proposed remedy for each of these areas are detailed in the Supplemental Remedial Investigation and Feasibility Study (SRI/FS) report (Cascadia, 2020) and are summarized below:

- Truck Loading Rack Area—Soil in the Truck Loading Rack area is impacted by gasoline-range hydrocarbons (TPHg) and diesel-range hydrocarbons (TPHd) in a localized area approximately 40 feet by 90 feet in extent and located west of the Truck Loading Rack. Vertically, the TPH are limited to the depth interval between 6 and 16 feet bgs. Comparison of soil data collected from this area in 2002 to data collected in 2019 indicates that petroleum hydrocarbon concentrations have attenuated

significantly with time. Seasonally high groundwater is encountered at approximately 22 feet bgs; therefore, soil containing petroleum hydrocarbons is at least 6 feet above the water table. Groundwater is not impacted in this area and the residual hydrocarbons in soil are not leachable. A site use restriction will be placed on soil in this area to ensure its proper management if accessed and removed.

- Vapor Recovery Unit Area—Shallow groundwater contains TPHg, benzene, ethylbenzene, xylenes, and naphthalene in an approximately 50- by 50-foot area near the vapor recovery unit. The extent of this impacted groundwater has decreased significantly between the initial investigation of this area in 2002 (AMEC, 2002) and 2022. The proposed cleanup plan is to inject bio-stimulants and plume stabilization compounds to stabilize and remediate the limited impacted groundwater in this area. This area is west of the Truck Loading Rack as shown on Figure 3.
- MW-5 Area (East of the stormwater detention pond)—TPHg and TPHd are present in shallow groundwater in an approximately 100- by 200-foot area and in vadose zone soil below a depth of 7 feet in an approximately 50- by 75-foot area. The vertical extent of impacted groundwater is primarily confined to fine-grained silt at depths above 30 feet below grade. Ethylbenzene, xylenes, and naphthalene are also found in this area, although the extent of these constituents is more limited than TPH. Benzene and toluene are not found in this area. The excavation and removal of accessible impacted soil and the implementation of a groundwater extraction, treatment, and re-injection system (i.e., groundwater recirculation) is being planned to address elevated hydrocarbon concentrations in this area.
- MW-6 Area (South of the Surge Pond)—TPHg and TPHd are present in shallow groundwater in an oblong area approximately 125 feet by 225 feet. Benzene, toluene, ethylbenzene and xylenes (BTEX) and naphthalene are also present in this area but are more limited in extent. The vertical extent is limited to the fine-grained silt and does not extend below 40 feet below grade. Soil between 3 and 21 feet contains TPH and BTEX in a localized area of approximately 50 by 50 feet. A second groundwater recirculation system is being planned to address the limited groundwater impacted by petroleum hydrocarbons in this area.

Groundwater is monitored quarterly and demonstrates that the extent of TPH and related constituents in the MW-5 and MW-6 areas is stable (GeoEngineers, 2022b).

In addition, in 2003, SECOR collected soil and groundwater samples from the former orchard area in the southeast corner of the Facility.. The samples were submitted for laboratory analysis of pesticides, herbicides, triazines, and nitrogen. Pesticides, herbicides, and triazines were not detected in soil or groundwater (SECOR, 2003). Nitrates were not detected at concentrations that would be indicative of a source (Ash Creek, 2010).

4.2. Permit Conditions and Status of Compliance

In April 2017, the Pollution Control Hearing Board concluded that a stormwater discharge permit was required by the Facility due to the infiltration of stormwater through soil that contains residual hydrocarbons. Ecology issued the State Waste Discharge Permit Number ST 6255 (Permit) to NuStar on March 30, 2020. The Permit requires preparation of a Stormwater Pollution Prevention Plan (SWPPP), spill

control plan (i.e., SPCC[2]), and stormwater/groundwater monitoring, as well as preparation of both an AKART report and an Engineering report.

The SWPPP, originally prepared in June 2020 (NuStar, 2020) and then updated in October 2020 and July 2021 (NuStar, 2021), identifies potential sources of stormwater contamination from industrial activities and how the Facility plans to manage these sources of contamination to prevent and minimize contamination of stormwater and the degradation of groundwater.

The Permit requires quarterly stormwater quality monitoring and discharge monitor reporting. Per the permit, the stormwater monitoring occurs at the following discharge points (a.k.a., outfalls):

- Manual controlled discharges/overflow from the stormwater detention pond to the surge pond (labeled Outfall 001);
- Manual controlled discharges from the external floating roofs on ASTs #4001 and #5503 (Outfalls 002 and 003, respectively);
- Manual controlled discharges from the fuel additive tank farm (Outfall 004); and
- Manual controlled discharges from the Containment Area 7 to the surge pond (Outfall 005).

Stormwater quality monitoring began in July 2020 with quarterly sampling occurring at each outfall with stormwater discharges. The location of site features, including the outfalls, are shown on Figure 3. To date, the results of quarterly stormwater sampling confirm that the Facility's storm discharges to ground have been below the Permit's effluent limits.

The Permit also requires quarterly monitoring of groundwater. Quarterly groundwater is currently being conducted as a part of the MTCA cleanup of soil and groundwater that is ongoing at the Facility and the scope of this groundwater monitoring is consistent with the requirements of the stormwater permit.

Discharge permits issued by Ecology specify conditions requiring facilities to use AKART before discharging to "Waters of the State". "Waters of the State" is defined in Title 90.48 of the Revised Code of Washington (RCW 90.48) and includes all surface water and groundwater within the jurisdiction of the State of Washington. In accordance with the Permit, an AKART report prepared by MFA was submitted to Ecology on April 30, 2021. Based on the results of the AKART analysis, the following stormwater discharge options were carried forward to the Engineering report for further evaluation:

- Alternative 1a. Discharge to Vancouver Lake
- Alternative 1b. Discharge to Columbia River (Port Outfall)
- Alternative 2. Discharge on NuStar Property (Outside MTCA Site boundary)
- Alternative 3. Off-site Infiltration, in Special Wellhead Protection Area (SWPA)
- Alternative 4. Off-site Infiltration, outside SWPA
- Alternative 5. Existing Condition

[2] Spill Prevention, Control, and Countermeasure plan

Following submittal of the AKART report, NuStar received the following general comments from Ecology and local jurisdictions in August and October 2021:

1. A permanent stormwater treatment system consistent with other fuel terminals in Washington (e.g., oil/water separation followed by sorption polishing) will be required regardless of existing stormwater quality monitoring data;
2. The Facility is not considered an "existing facility" that predates Wellhead Protection Area requirements and therefore it must comply;
3. Stormwater infiltration options near MTCA Site Boundaries need to include a containment fate and transport analysis under a steepened downward vertical gradient condition (i.e., towards the aquifer tapped by CPU's Carol Curtis Wellfield future production wells);
4. Stormwater infiltration options outside MTCA Site Boundaries need to include a groundwater mounding and gradient analysis (i.e., Geohydrologic Evaluation) in response to increased pumping of PAA production wells (55 to 180 feet bgs); and
5. NuStar must engage the City and County directly about preferred stormwater treatment and disposal options and attempt to find common ground.

The Permit requires that NuStar submit an Engineering report that evaluates and proposes installation of control and treatment technology that is equivalent to those present at other petroleum terminals within the State of Washington and consistent with the findings of the AKART. The Engineering report is due to Ecology by May 1, 2023.

The following sections summarize Property investigation activities and data collected to evaluate stormwater storage in the detention pond and to evaluate potential stormwater infiltration options outside of the Facility's MTCA Site boundaries.

5.0 STILLING WELL AND PIEZOMETER INSTALLATION AND SHALLOW SOIL SAMPLING

Two shallow groundwater piezometers (INF-1 and INF-2) were installed in the southeastern portion of the Facility at the locations shown on Figure 2. The piezometers were screened across first encountered groundwater to monitor the seasonal changes in the depth of shallow groundwater beneath the former orchard area. Because this portion of the Property was once an orchard, shallow soil from the piezometer boreholes was also sampled for pesticides and herbicides.

A stilling well was installed inside the southern end of the stormwater detention pond as shown on Figure 3. The purpose of the stilling well was to allow the collection of accurate water levels without being subject to any turbulence of flow that might be present in the pond.

Details of the stilling well and piezometer installations, as well as the soil sampling activities, are provided below.

5.1. Stilling Well Installation

A stilling well was installed by GeoEngineers field staff at the southern end of the stormwater detention pond in February 2022. The stilling well consisted of 2-inch diameter schedule 40 polyvinyl chloride (PVC) casing with a 15 foot (0.010-inch) slotted screen at the bottom and an additional 10 feet of solid PVC

casing above the slotted screen. The stilling well was manually installed inside the pond at an approximately 30-degree angle to the bank and the top of the well was fastened to a small tree for stability. The stilling well was installed so that the top of casing could be accessed from the side of the berm for the installation of transducers or other monitoring equipment.

5.2. Preparatory Activities for Piezometer Well Installation

Prior to field work, the public utility locating notification center was contacted and representatives from the various utilities marked the presence of any buried utilities entering the site. On January 27, 2022, a private utility locator was checked for the presence of buried utilities or infrastructure in the Facility work area. At each boring location, the borehole was also cleared with hand auger equipment, down to 8 feet bgs. The hand augers were completed to confirm that no utilities or other buried infrastructure were present in the proposed piezometer locations, prior to continuing work with the direct push drilling equipment.

Per Chapter 173-160 WAC (Minimum *Standards for the Construction and Maintenance of Wells),* the state of Washington requires a variance to install wells deeper than 30 feet bgs using direct push technology. Because the total depth of the piezometers was anticipated to be approximately 35 feet bgs, NuStar submitted a variance request to the Department of Ecology Water Resources Program prior to the field event. On January 27, 2022, the Department of Ecology Water Resources Program issued NuStar a letter approving the variance request. A copy of the variance request and approval letter are provided in Appendix A.

5.3. Soil Boring Activities

From February 1 to 2, 2022, borings were advanced by a Washington state licensed driller from Cascade Drilling, Inc. of Clackamas, Oregon, using a direct-push drill rig. A field scientist from GeoEngineers oversaw the drilling activities and piezometer installations. The soil borings were advanced in general accordance with standard operating procedures (SOP) for direct-push explorations, which are included in Appendix A.

5.4. Field Screening

Field scientists with GeoEngineers collected continuous soil samples during hand auger and push-probe activities for the purpose of documenting lithologic descriptions and for field screening for the potential presence of petroleum hydrocarbons. Field screening consisted of water sheen testing and the use of a photoionization detector (PID); these procedures are detailed in the field screening SOP, also included in Appendix A. No field indications of petroleum hydrocarbons or other soil contaminants were observed.

5.5. Soil Sampling and Analysis

Soil samples were collected from borings INF-1 and INF-2 for chemical analysis. In each borehole, a sample was at collected at three feet bgs and five feet bgs using a hand auger. The hand auger was decontaminated between sample depths to mitigate cross contamination.

The soil samples were collected in accordance with sampling procedures outlined in the sampling SOPs, provided in Appendix A. The soil samples were submitted to Apex Laboratories of Tigard, Oregon, a Washington accredited laboratory, for chemical analysis of the following:

- Organochlorine pesticides by U.S. Environmental Protection Agency (EPA) Method 8081B; and
- Organophosphorous pesticides by EPA Method 8270E and;

- Chlorinated herbicides by EPA Method 8151A.

The analytical results are summarized in Tables 1 through 3 and are discussed in Section 8.1. The laboratory analytical report is provided in Appendix B.

5.6. Piezometer Installation

Piezometers were installed in the two boreholes by a Washington state-licensed driller in accordance with Washington Administrative Code (WAC) 173-160-400. Each piezometer was constructed with 2-inch PVC casing with a 0.010-inch slot PVC well screen. Ten feet of well screen was installed for each casing; piezometer INF-1 was screened from 25 to 35 feet bgs, and piezometer INF-2 was screened from 30 to 40 feet bgs. Locking well caps were placed on the top of casing to secure each piezometer. The surface of each piezometer was completed with a traffic-rated flush monument set in a concrete pad. The driller filed a well report with Ecology for each piezometer and attached a Washington state well ID tag inside each well monument. Three, 3-foot-tall bollards were installed around each well monument for protection and were painted yellow for high visibility. Lithologic and piezometer construction logs for each piezometer are included in Appendix C.

5.7. Piezometer Development

On February 8, 2022, after the piezometer monuments were allowed to set for 72 hours after pouring concrete, the new piezometers were developed using a downhole pump and surge block. Water quality parameters, including temperature and pH, were measured during well development activities. Development was considered complete after the extracted water was clear, at least 5 casing volumes of groundwater had been removed, and when the temperature and pH readings had stabilized. The piezometer development water was contained in 55-gallon drums, profiled, and transported from the Facility for disposal as investigation-derived waste at a recycling facility.

5.8. Piezometer and Stilling Well Survey

On February 10, 2022, the top of the piezometer and stilling well casings were surveyed for lateral and vertical position relative to Washington State Plane Coordinate System and NAVD88 by a Washington state licensed surveyor (Mackay Sposito). The surveyor identified the location of the survey point on the top of the casing with a permanent mark to allow groundwater elevation data to be collected from a consistent point. A copy of the survey is provided in Appendix D.

6.0 ADDITIONAL SOIL INFILTRATION TESTING

In accordance with ASTM D3385, double-ring infiltration testing was conducted near piezometers INF-1 and INF-2 on February 24 and 25, 2022. Prior to beginning work, a private utility locator checked for the presence of buried utilities or infrastructure in the work area. No buried infrastructure was identified, and two test pits were excavated near each piezometer by representatives of Telluric Enterprises LLC using a CAT 306 mini-excavator. Two test pits were excavated to three and five feet bgs near each piezometer (a total of four), and the five-foot pits were benched at 1.5 feet to permit safe entry. The test pits (labeled IT-1 through IT-4) were located approximately 20 feet from each piezometer to target similar infiltration conditions without compromising the piezometer casing installation. Approximate locations of the double-ring infiltration test pits and piezometers are illustrated on Figure 1.

The double-ring infiltrometer method consists of driving two open cylinders, one inside the other, into the ground, partially filling the rings with water and then measuring the level of the water within the inner ring over a set period of time (60 minutes for these tests). The ground surface within inner ring was lined with filter fabric and weighted with pea gravel to prevent disturbance of fines which might affect infiltration rate. Prior to installing the liners and double ring infiltrometers in test pits, the soil within the test pits were pre-saturated (soaked). Water level monitoring conducted during the soaking period in INF-1(3) and INF-1(5) indicates that the soils were approaching steady state prior to conducting the 60-minute infiltration tests. Water level monitoring was not conducted during the pre-saturation of INF-2(3) and INF-2(5) because these test pits were soaked overnight.

The change in water level in the inner ring was measured to calculate an infiltration rate of the soil. The water level in the ring was measured and recorded at 60-second intervals using an Onset HOBO pressure transducer and visually confirmed every 20 minutes using a ruler fixed to the inner ring. The volume infiltrated during timed intervals was converted to an incremental infiltration velocity, expressed in inch per hour and plotted versus elapsed time. The average of the incremental infiltration velocity for each measurement (approximately 60 per test) is the infiltration velocity for the test. The coefficient of permeability was calculated by the equation recommended in the Review of Infiltration Standard and Practices in Clark County (American Society of Civil Engineers, 2009):

$$k = \frac{L}{t} ln \frac{h_1}{h_2}$$

In which k is the coefficient of permeability, L is the length of flow through the soil, t is time per measurement, and h_1 and h_2 are the change in the water height.

The only deviation from the above-referenced configuration was that the native fine-grained soils at all test locations were too compact and stiff to manually embed the 12- and 24-inch-diameter metal rings a full 6 inches. Despite hours of soaking, the rings could only be driven into the soil 2 to 4 inches using a wood block and sledgehammer. This site-specific modification to the standard test configuration was considered acceptable because an adequate seal around the embedded pipe was established and maintained throughout the duration of testing. Details regarding test configuration, pre-saturation, and water level measurements at each test location are provided in Appendix E.

7.0 TRANSDUCER INSTALLATION AND MONITORING

On February 25, 2022, pressure transducers (Seametrics LevelSCOUT® absolute [non-vented] water level and temperature sensors) were installed in monitoring wells MW-5, MW-5D, piezometer INF-1, and the stormwater detention pond stilling well. On March 10, 2022, a similar pressure transducer was installed in piezometer INF-2. The pressure transducers were suspended from protective well caps using a nylon cord and the length of the cord was measured to determine the distance of the pressure transducer below the well's top of casing (the surveyed reference elevation for each well).

Prior to deploying the transducers, each of the units were programmed to record pressures and temperature measurements in synchronized 10-minute intervals. The thickness of the water column was calculated using the overlying pressure that was recorded by the transducer. Water elevations were calculated for each 10-minute measurement interval by subtracting the transducer cable length from the

well top of casing elevation to determine the elevation at which the transducer was suspended, then the water column thickness above the transducer was added to determine the groundwater or surface water elevation.

The pressure measurements recorded by the transducers represent a total pressure measurement. For transducers submerged in water, the total pressure includes barometric pressure and overlying water pressure. In order to evaluate the barometric pressure component, a separate transducer (Seametrics BaroSCOUT®) was placed in the study area to record ambient barometric pressure at the same time as the LevelSCOUT® water pressure readings. The barometric pressure data were subsequently subtracted from the total pressure data so that the resulting dataset only represented water pressure and could be used to accurately calculate water elevation.

The pressure data were periodically downloaded from the transducers using dataloggers attached to a tablet equipped with the Seametrics Aqua4Plus (version 2.2) software. Once the barometric data were subtracted from the dataset, the pressure data were compared to the reference elevation point and water elevation data (in feet) were calculated for each 10-minute reading.

8.0 RESULTS

The results of the soil sampling, additional infiltration testing, and water level monitoring conducted at the Facility between February and November 2022, are summarized in the sections below.

8.1. Soil Analytical Results

No organochlorine pesticides, organophosphorous pesticides, or chlorinated herbicides were detected above the laboratory method reporting limit (MRL) in the samples collected from the piezometer boreholes. The results of the analysis along with the results of previously mentioned 2003 SECOR analysis in the former orchard area, are presented in Tables 1 through 3.

8.2. Transducer Results

The water level data collected from the stormwater detention pond, well MW-5, well MW-5D, and piezometers INF-1 and INF-2, are depicted on Figures 4 through 8, respectively. For each location, water levels are plotted in 10-minute intervals from the time period between February 25, 2022 and November 9, 2022. For each plot, the daily rainfall (in inches) is plotted for the Hayden Island rain gauge, located at 1704 Jantzen Beach Center, Portland, Oregon, approximately 3.3 miles south of the Facility. The transducer study period includes a seasonal rainfall period between February and late June, followed by a seasonal dry period between late June and late October, with only a few isolated rainfall events occurring in the dry season.

A fluid totalizer was installed on the discharge pipe between Containment Area 4 and the stormwater detention pond. The monthly water volumes shown on Figure 4 depict all transfers of stormwater from the lined Containment Area 4 to the detention pond. From the last storm event on June 13, 2022 until October 20, 2022, there were only minimal additions of water to the pond from Containment 4 or via rain events, and the water level in the pond decreased by an average of 0.025 feet per day.

8.3. Infiltration Testing Results

The results of the infiltration testing (e.g., depth of trench, length of flow, measured drawdown rate, and calculated coefficient of permeability) are summarized on Table 4. The unfactored coefficients of permeability at the test locations ranged from 0.13 to 1.94 inches per hour (in/hr), 0.27 to 3.89 feet per day (ft/day), and 0.000097 to 0.0013 centimeters per second (cm/sec). However, the coefficient of permeability in the three-foot test pit at INF-1 and the three- and five-foot test pits at INF-2 only ranged from 0.13 to 0.49 in/hr (0.26 to 0.99 ft/day and 0.000090 to 0.00035 cm/sec). Some variability in infiltration rate is expected due to heterogeneities in soil, but the measured infiltration rate in the five-foot test pit at INF-1 is an order of magnitude higher than measured at the other site locations.

The coefficient of permeability is defined as the quantity of flow through a unit cross-sectional area of a porous media (i.e., soil) under a unit hydraulic gradient. Under saturated soil conditions, the infiltration rate is essentially equivalent to the soil coefficient of permeability. It should be noted that the infiltration rate is not the true velocity, but an average velocity over the length of discharge (e.g., silt vadose zone). Furthermore, voids in soil are not regular, uniform, or continuous in the flow direction, and the actual seepage velocity changes in both magnitude and direction from one point to another in the soil. Water, when flowing downward, can change direction by as much as 90 degrees, depending on the availability of the soil particle size, shape, texture, density, and layering. As such, a soil correction factor between 2 and 5 is normally applied to the unfactored infiltration rate (coefficient of permeability) to account for basic soil variability. In Table 4, a correction factor of 2.5 was used to calculate the design infiltration rate in ft/day. The average infiltration rate in the former orchard area is 0.23 ft/day at the 3-foot depth and 0.85 ft/day at the 5-foot depth.

Infiltration rate data were collected across the Facility to support preparation of the AKART report (MFA, 2021) in August 2020 and are provided in a summary table in Appendix E for comparison. Infiltration tests were conducted in Containment Areas 1, 2, 3 and 7, the surge pond, west of the tank farm containment areas, in the unused contained area east of Containment Area 2, and in the former orchard area. The infiltration rates in the Facility's Containment Areas ranged from 0.01 to 0.15 ft/day. The average infiltration rate at depths of 6 inches in the surge pond was 0.34 ft/day and the average infiltration rate in the Orchard area at depths of 2 and 3 feet was 0.10 ft/day.

9.0 EVALUATION OF DATA AND CONCLUSIONS

The scope of this study included the installation of two piezometers and one stilling well, additional soil infiltration testing, and the installation of transducers in two monitoring wells, two piezometers, and the stormwater detention pond stilling well. The water levels in the stilling well, monitoring wells, and piezometers, were monitored over an approximately 8-month period, along with Columbia River stage and monthly precipitation rates. Water level data were collected over both a wet season and a dry season as well as the transitional period between the two seasons.

During the AKART report preparation process, a Facility water balance was prepared that included inputs and assumptions for local precipitation and evaporation, as well as estimates of collected runoff and infiltration at each of the Containment Areas at the Facility. Using historical peak precipitation rates, the annual stormwater volume discharged from lined Containment Area 4 was estimated, and the estimated discharge to the stormwater detention pond was calculated. Based on historical reports, it was believed

that the stormwater detention pond was partially lined, and some level of leakage occurred when the pond was full above the liner level. However, the elevation of the top of the liner was unknown. The data collected in this study were used to refine those assumptions and to evaluate actual water levels and leakage in the stormwater detention pond, and the potential water level response in nearby monitoring wells. Soil infiltration data for the former orchard area as well as across the Facility were used to provide more information on areas of the Facility most suitable for future engineered infiltration. Specific conclusions from this study area are summarized in the sections below.

9.1. Stormwater Detention Pond

As previously discussed, a water balance was prepared for the AKART report, which utilized precipitation rates from a peak discharge year (2016/2017 water period) to estimate discharge rates from the stormwater detention pond. During that peak water year the annual rainfall was 51.45 inches. The annual rainfall during the 2021/2022 water year was 43.41 inches, which is higher than the average rainfall over the past 20 years, of 37.54 inches per year. Using the water balance model developed during the AKART, an estimated 325,600 gallons of stormwater should have overflowed from the stormwater detention pond into the surge pond in April 2022. However, as shown on Figure 4, the maximum water level height in the stormwater detention pond was approximately 34.2 feet NAVD88 or approximately 0.3 foot below the lowest point in the top of berm surrounding the pond. Subsequently, water was not discharged from the detention pond to the surge pond in 2021/2022. It is important to note, that the water balance model (i.e., spreadsheet) developed to predict discharge volumes from the lined Containment Area 4 and detention pond relies on limited data regarding the actual size of the detention pond and too many assumptions to accurately predict overflow (when and how much) to the surge pond. This has been confirmed through pond water level monitoring and totalizer readings on the discharge from Containment Area 4. The spreadsheet does not account for the fact that the timing and volume of water pumped from Containment Area 4 to the detention pond varies depending on site conditions (e.g., the terminal will hold water in Containment Area 4 when the pond is reaching capacity) and that there is some infiltration through the base of the pond as described below.

During the 2021/2022 water year, after the heavy rainfall between April and June, there was nearly a three-month dry period from July through September with a total rainfall of only 0.57 inches. These precipitation data suggest that the 2021/2022 water year (and spring/summer 2022 in particular) was an ideal time window for evaluating water levels, potential overflow, and potential leakage from the stormwater detention pond as conditions were being monitored under the most extreme precipitation levels followed by an extreme dry period. Because the stormwater detention pond was believed to have been partially lined, the conditions during spring and summer 2022 were ideal for evaluating leakage rates from the pond and to identify the elevation of the top of the pond liner.

Based on the recent investigation, the following conclusions can be made about the stormwater detention pond.

- Between the last storm event on June 13, 2022 and the end of the study period on October 11, 2022, the water level in the pond decreased by an average of 0.026 ft/day. As shown on Figure 4, while there were minor inputs from Containment Area 4 transfers and minor precipitation events, the pond elevation decreased by a nearly uniform rate after the last storm event.
- In the summer months, much of the reduction in pond water levels can be explained by evaporation. As calculated for the Facility water balance, evaporation rates for the months of July, August, and

September are 0.017 ft/day, 0.015 ft/day, and 0.011 ft/day, respectively. When subtracting out evaporation rates from the average pond decrease of 0.026 ft/day, the resulting decrease in water levels is 0.009 to 0.015 ft/day. Observed water level decline during the winter months when evaporation rates are low (e.g., 0.001 – 0.004 ft/day) appears to range between 0.007 and 0.01 ft/day, although it's difficult to plot in between discharges from Containment Area 4.

- Based on water level monitoring in the stormwater detention pond, the average daily infiltration rate through the native fine-grained soils underlying the pond appears to range between 0.007 and 0.015 ft/day after correcting for evaporation.
- As discussed in Section 3.0 (Local Soil Conditions and Site Topography), a review of boring logs collected from site investigations in Containment Areas 1 and 6, indicate that the soils encountered between 26 and 36 feet NAVD88, the elevation range between the base of the pond and the top of the pond berm, are silty and are generally absent of sands.
- As shown on Figure 3, the inferred lateral extent of petroleum-impacted soil and groundwater extends beneath the eastern berm of the stormwater detention pond. Residual petroleum contamination beneath this portion of the Facility resides within the seasonal fluctuation of the water table where the biodegradation of petroleum hydrocarbons by indigenous microbes through aerobic and/or anaerobic respiration is slowed by the absence of electron acceptors. During microbial respiration, electrons are transferred from an electron donor (petroleum hydrocarbons) to an electron acceptor. In the process, naturally abundant electron acceptors in the aquifer are reduced (e.g., dissolved oxygen, nitrate, and sulfate) while products of biodegradation increase (dissolved manganese and methane). Measured concentrations of field parameters and analytical results of natural attenuation constituents, as well as the stable lateral extent and concentration of petroleum hydrocarbons in sampled wells, suggest that biodegradation processes continue at the site. However, the restoration timeframe is limited by the flat hydraulic gradient and inability to replenish electron acceptors in areas of residual contamination. Subsequently, the site's approved remediation plan is designed to speed up (i.e., enhance) the biodegradation process by replenishing electrons within the source areas. The slow infiltration of stormwater with dissolved oxygen from the detention pond only supports plans to enhance the biodegradation process as described in Section 4.1.

9.2. Orchard Area Infiltration

As previously stated, conservative calculations using the best information available were used to estimate the volume of water managed in the tank farm areas, either through slow infiltration (in the earthen containment areas) or by pumping to the stormwater detention pond, as in the case of Containment Area 4. The hydrologic monitoring conducted between February and November 2022 indicate that it would take a rare, intense series of rainfall events to warrant using the surge pond for stormwater detention pond overflow.

The proposed stormwater management plan includes maintaining a low water level in the detention pond by routinely pumping clean stormwater to the Property's orchard area for infiltration outside the MTCA Site boundaries. The following conclusions can be made about the soils in the orchard area, and the potential use of the area for an engineered infiltration system.

- The orchard area is nearly 200 feet southeast of the nearest MTCA Site boundary. Based on initial testing, the soils do not appear to be impacted with herbicides and pesticides from the historical use of the area as an orchard. As requested by the consultant working on behalf of the Clark Public Utilities,

soil within the proposed infiltration area will be tested further for arsenic and lead before construction of the pond.

- Infiltration testing was conducted using a double-ring infiltration test which is believed to be more accurate than the single-ring falling head tests completed in August 2020. The results from the 2022 investigation confirm that the soils in the former orchard area are more permeable than the remainder of the Property and are suitable for managing treated stormwater from the detention pond.

9.3. Monitoring Wells MW-5 and MW-5D

Wells MW-5 and MW-5D are located in Containment Area 1, an earthen containment area immediately to the east of the stormwater detention pond. Transducers recorded water level data in both wells and the adjacent stormwater detection pond from February 25 through November 9, 2022. Local precipitation was plotted along with water stage data during that time period (see Figures 5 and 6). The following conclusions can be made about site conditions in the vicinity of wells MW-5 and MW-5D during the monitoring period:

- As discussed in Section 3.3, regional water levels are directly influenced by local water bodies including Vancouver Lake and the Columbia River. Figure 9 depicts water levels in wells MW-5 and MW-5D along with water elevation in the Columbia River. The water levels in the monitoring wells are consistent with that understanding and water levels in both the shallow (MW-5) and deeper (MW-5D) wells correlated with river stage during the monitoring period.
- The water levels in both MW-5 and MW-5D decreased after mid-June and the water elevation plots suggest no evidence of water table mounding in response to the slow infiltration of water from the stormwater detention pond.

10.0 LIMITATIONS

This report has been prepared for the exclusive use of NuStar Energy, LP. This report is not intended for use by other entities, and the information contained herein is not applicable to other properties. Our report was prepared for the exclusive use of our Client and their affiliated entities. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. In addition, the information contained herein is not applicable to other sites.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted environmental science practices in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

Any electronic form, facsimile or hard copy of the original document (email, text, table and/or figure), if provided, and any Appendices are only a copy of the original document. The original document is stored by GeoEngineers, Inc.

Our interpretations of subsurface conditions are based on field observations and chemical analytical data from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface

conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

11.0 REFERENCES

AMEC Earth & Environmental, Inc. (AMEC), 2002a. Phase II Environmental Site Assessment, Cenex Harvest State Cooperatives. May 2002.

AMEC 2002b. Subsurface Investigation and Soil Removal Report, Cenex Harvest States Cooperatives. December 2002.

Ash Creek, 2008a. Results of Direct-Push Groundwater Assessment. January 28, 2008.

Ash Creek, 2008b. Groundwater Monitoring Report – Quarterly Monitoring 2007. January 28, 2008.

Ash Creek Associates, Inc. (Ash Creek), 2010. Remedial Investigation/Risk Assessment Report. December 29, 2010.

American Society of Civil Engineers (ASCE), 2009. A Review of Infiltration Standards and Practices in Clark County, July 31, 2009.

ASTM, D3385-09. Standard Test Method for Infiltration Rate of Soils in Field Using Double-Ring Infiltrometer. Current edition approved March 1, 2009.

Cascadia Associates LLC (Cascadia), 2019a. Pilot Study Results Report. NuStar Vancouver Annex Facility. January 17, 2019.

Cascadia, 2019b. Additional Investigation Results Report. NuStar Vancouver Annex Facility. July 1, 2019.

Cascadia, 2020. Supplemental Remedial Investigation and Revised Feasibility Study. October 23, 2020.

GeoEngineers, Inc. (GeoEngineers), 2022a. 2021 Annual Groundwater Monitoring Report. January 31, 2022.

GeoEngineers, 2022b. Additional Monitoring Well Installation and Sampling Report. April 15, 2022.

Maul Foster & Alongi, Inc. (MFA), 2022. NuStar Terminals All Known, Available, and Reasonable Methods of Prevention, Control, and Treatment (AKART) Report. January 10, 2022.

NuStar Terminal Operations Partnership LP (NuStar), 2020. Stormwater Pollution Prevention Plan (SWPPP) for State Waste Discharge Permit No. ST 6255. Originally prepared on June 30, 2020. Updated October 27, 2020.

NuStar, 2021. SWPPP for State Waste Discharge Permit No. ST 6255. Updated July 20, 2021.

Pacific Groundwater Group (PGG), 2009. Hydrogeologic Evaluation for Clark Public Utilities South Lake Wellfield, SGA Production Wells PW-2 and PW-3. July 2009.

PGG, 2021. Clark Public Utilities Lakeshore Wellfield Exploration and Testing Program, February 2021.

SECOR International, Inc. (SECOR), 2003. Results of Phase II Environmental Site Assessment. June 6, 2003.

TABLES

GeoEngineers

Table 1
Organochlorine Pesticide Analysis
NuStar Energy, L.P. – Vancouver Annex Terminal
Vancouver, Washington

	Sample No.	Date Sampled	Depth (feet bgs)	Aldrin	alpha-BHC	beta-BHC	delta-BHC	gamma-BHC (Lindane)	gamma-Chlordane	alpha-Chlordane	Chlordane (tech)	4,4'-DDD	4,4'DDE	4'4-DDT	Dieldrin	Endosulfan I	Endosulfan II	Endosulfan sulfate	Endrin	Endrin aldehyde	Endrin ketone	Heptachlor	Heptachlor epoxide	Methoxychlor	Toxaphene	Method
				µg/kg dry																						
Organochlorine Pesticides	HA-11	4/15/2003	--	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<150	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<200	EPA 8081A
	HA-12	4/15/2003	--	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<150	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<200	EPA 8081A
	SB-3-8	4/18/2003	8	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<150	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<200	EPA 8081A
	SB-3-28	4/18/2003	28	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<150	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<6.70	<200	EPA 8081A
	INF1-3	2/3/2022	3	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<35.0	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<1.17	<3.50	<35.0	EPA 8081B
	INF1-5	2/3/2022	5	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<37.9	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<1.26	<3.79	<37.9	EPA 8081B
	INF2-3	2/3/2022	3	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<40.6	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<1.35	<4.06	<40.6	EPA 8081B
	INF2-5	2/3/2022	5	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<41.3	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<1.38	<4.13	<41.3	EPA 8081B
Screening Levels:																										
Method B Direct Contact Non-cancer				2,400				24,000			40,000	2,400	24,000	40,000	4,000			480,000	24,000			40,000	1,000	400,000	7,200	
Method B Direct Contact Cancer				59				910			2,900	4,200	2,900	2,900	63							220	110		910	
Soil Protective of GW Vadose @13 deg C				2.50				6.20			1,300	340	220	3,500	2.8			19,000	440			19.00	9.90	64,000	1,500	
Soil protective of GW saturated				0.13				0.33			64	17	11	170	0.14			970	22			0.95	0.50	3,200	76	
All screening levels expressed in micrograms per kilogram				µg/kg																						

Notes
1. < = Not detected at or above the specified laboratory method reporting limit (MRL).

Data from "Master Excel" here: https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables

Table 2
Organophosphorus Pesticide Analysis
NuStar Energy, L.P. – Vancouver Annex Terminal
Vancouver, Washington

	Sample No.	Date Sampled	Depth (feet bgs)	Azinphos methyl	Bolstar	Chlorpyrifos	Coumaphos	Demeton	Demeton, total	Diazinon	Dichlorvos	Dimethoate	Disulfoton	Ethoprop	Fensulfothion	EPN	Fenthion	Malathion	Mevinphos	Parathion-methyl	Paration-ethyl	Phorate	Ronnel	Stirophos (Tetrachlorvinphos)	Tokuthion (Parothiofos)	Trichloronate	Method
				µg/kg dry																							
Organophosphorus Pesticides	HA-11	4/15/2003	--	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	EPA 8141A
	HA-12	4/15/2003	--	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	EPA 8141A
	SB-3-8	4/18/2003	8	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	EPA 8141A
	SB-3-28	4/18/2003	28	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	<40.0	EPA 8141A
	INF1-3	2/3/2022	3	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	<58.9	EPA 8270E
	INF1-5	2/3/2022	5	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	<62.8	EPA 8270E
	INF2-3	2/3/2022	3	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	<69.2	EPA 8270E
	INF2-5	2/3/2022	5	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	<68.7	EPA 8270E
Screening Levels:																											
Method B Direct Contact Non-cancer						80,000		3,200	3,200	56,000	40,000	180,000	3,200			1		1,600,000		480,000	480,000	16,000		2,400,000			
Method B Direct Contact Cancer						0					3,400													42,000			
Soil Protective of GW Vadose @13 deg C						2,400				720	1.5	150	13			0.05		1,500		5,000	5,000	42	37,000	110			
Soil protective of GW saturated						120				37	0.1	11	0.72			0.0025		100		260	260	2	1,900	6.1			
All screening levels reported in micrograms per kilogram (µg/kg)																											

Notes
1. < = Not detected at or above the specified laboratory method reporting limit (MRL).

Data from "Master Excel" here: https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables

Table 3
Chlorinated Herbicide Analysis
NuStar Energy, L.P. – Vancouver Annex Terminal
Vancouver, Washington

	Sample No.	Date Sampled	Depth (feet bgs)	2,4-D	2,4-DB	2,4,5-T	2,4,5-TP (Silvex)	Dalapon	Dicamba	Dichloroprop	Dinoseb	MCPA	MCPP	Pentachlorophenol	Picloram	Method
				µg/kg dry												
Chlorinated Herbicides	HA-11	4/15/2003	--	<50.0	<50.0	<50.0	<50.0	<100	<50.0	<50.0	<50.0	<5000	<5000	<50.0	--	EPA 8151A
	HA-12	4/15/2003	--	<50.0	<50.0	<50.0	<50.0	<100	<50.0	<50.0	<50.0	<5000	<5000	<50.0	--	EPA 8151A
	SB-3-8	4/18/2003	8	<50.0	<50.0	<50.0	<50.0	<100	<50.0	<50.0	<50.0	<5000	<5000	<50.0	--	EPA 8151A
	SB-3-28	4/18/2003	28	<50.0	<50.0	<50.0	<50.0	<100	<50.0	<50.0	<50.0	<5000	<5000	<50.0	--	EPA 8151A
	INF1-3	2/3/2022	3	<0.18	<0.35	<0.089	<0.089	<0.18	<0.18	<0.18	<0.089	<18	<18	<0.089	<0.089	EPA 8151A
	INF1-5	2/3/2022	5	<0.20	<0.39	<0.098	<0.098	<0.20	<0.20	<0.20	<0.098	<20	<20	<0.098	<0.098	EPA 8151A
	INF2-3	2/3/2022	3	<0.19	<0.38	<0.095	<0.095	<0.19	<0.19	<0.19	<0.095	<19	<19	<0.095	<0.095	EPA 8151A
	INF2-5	2/3/2022	5	<0.20	<0.40	<0.099	<0.099	<0.20	<0.20	<0.20	<0.099	<20	<20	<0.099	<0.099	EPA 8151A
Screening Levels:																
	Method B Direct Contact Non-cancer			800,000	2,400,000	800,000		2,400,000	2,400,000		80,000	40,000	80,000	400,000		
	Method B Direct Contact Cancer													2,500		
	Soil Protective of GW Vadose @13 deg C			320	5,500	980		810	2,200		630	37	80	16		
	Soil protective of GW saturated			22	320	63		58	150		32	2.5	5.4	0.88		

All screening levels reported in micrograms per kilogram (µg/kg)

Notes
1. < = Not detected at or above the specified laboratory method reporting limit (MRL).

Data from "Master Excel" here: https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Contamination-clean-up-tools/CLARC/Data-tables

Table 4
Soil Infiltration Testing
NuStar Energy, L.P. – Vancouver Annex Terminal
Vancouver, Washington

Test Location [1]	Date	Depth below ground surface (feet)	Length of flow (*L*) (inches)	Time (*t*) (hour)	Initial head (h_1) (inches)	Final head (h_2) (inches)	Coefficient of Permeability (in/hr) [2]	Coefficient of Permeability (ft/day) [2]	Coefficient of Permeability (cm/sec) [2]	Design Infiltration Rate (ft/day) [3]		
East of Tank Containment Areas (Orchard)												
INF-1(3)	2/24/2022	3	4	1	12.46	11.01	0.49	0.99	3.49E-04	0.4		
				1	12.45	11.15	0.44	0.88	3.11E-04	0.4		
				1	12.56	11.30	0.42	0.85	2.99E-04	0.3	Ave =	0.36
INF-1(5)	2/24/2022	5	4	1	15.25	9.40	1.94	3.87	1.37E-03	1.5		
				1	15.33	9.63	1.86	3.72	1.31E-03	1.5		
				1	15.54	9.56	1.94	3.89	1.37E-03	1.6	Ave =	1.53
INF-2(3)	2/25/2022	3	3	1	15.78	15.08	0.14	0.27	9.61E-05	0.109		
				1	15.59	14.89	0.14	0.28	9.73E-05	0.110		
				1	15.38	14.74	0.13	0.26	9.00E-05	0.102	Ave =	0.11
INF-2(5)	2/25/2022	5	2	1	14.08	12.68	0.21	0.42	1.48E-04	0.168		
				1	14.81	13.25	0.22	0.45	1.57E-04	0.178		
				1	13.93	12.65	0.19	0.39	1.36E-04	0.154	Ave =	0.17

3-foot Ave =	0.23	ft/day
5-foot Ave =	0.85	ft/day

Notes:

[1] Refer to Figure 2 for test locations.

[2] Coefficient of Permeability (k) = L / t * ln (h_1/h_2)

[3] The design infiltration rate is determined by dividing the calculated coefficient of permeability by a correction factor of 2.5 (0.4) to account for layered soil conditions.

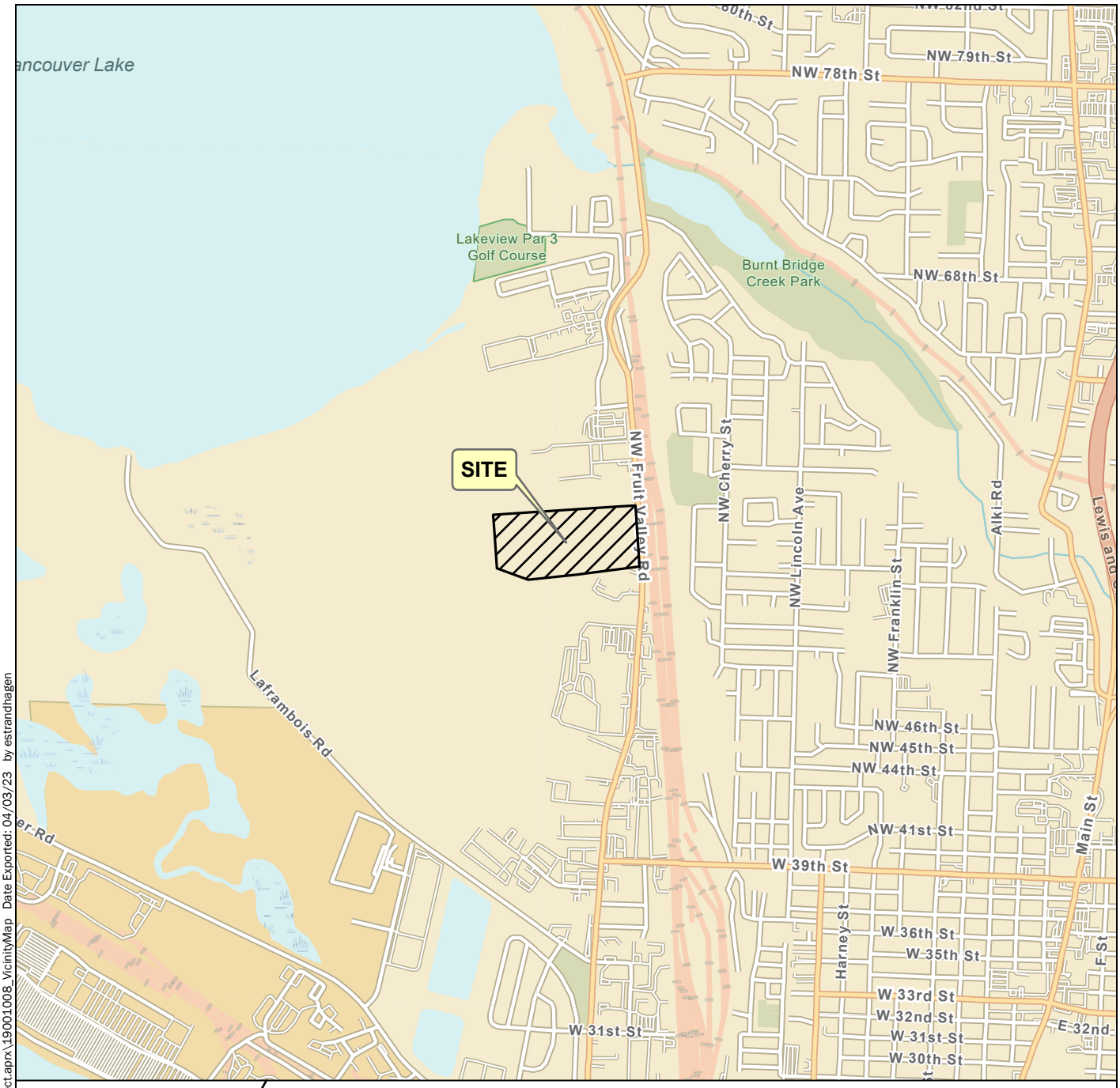
in/hr = inches per hour

ft/day = feet per day

cm/sec = centimeters per second

FIGURES

GeoEngineers



N
W E
S

2,000 0 2,000

Feet

Notes:

1. The locations of all features shown are approximate.
2. This drawing is for information purposes. It is intended to assist in showing features discussed in an attached document. GeoEngineers, Inc. cannot guarantee the accuracy and content of electronic files. The master file is stored by GeoEngineers, Inc. and will serve as the official record of this communication.

Data Source: ESRI

Projection: NAD 1983 StatePlane Washington South FIPS 4602 Feet

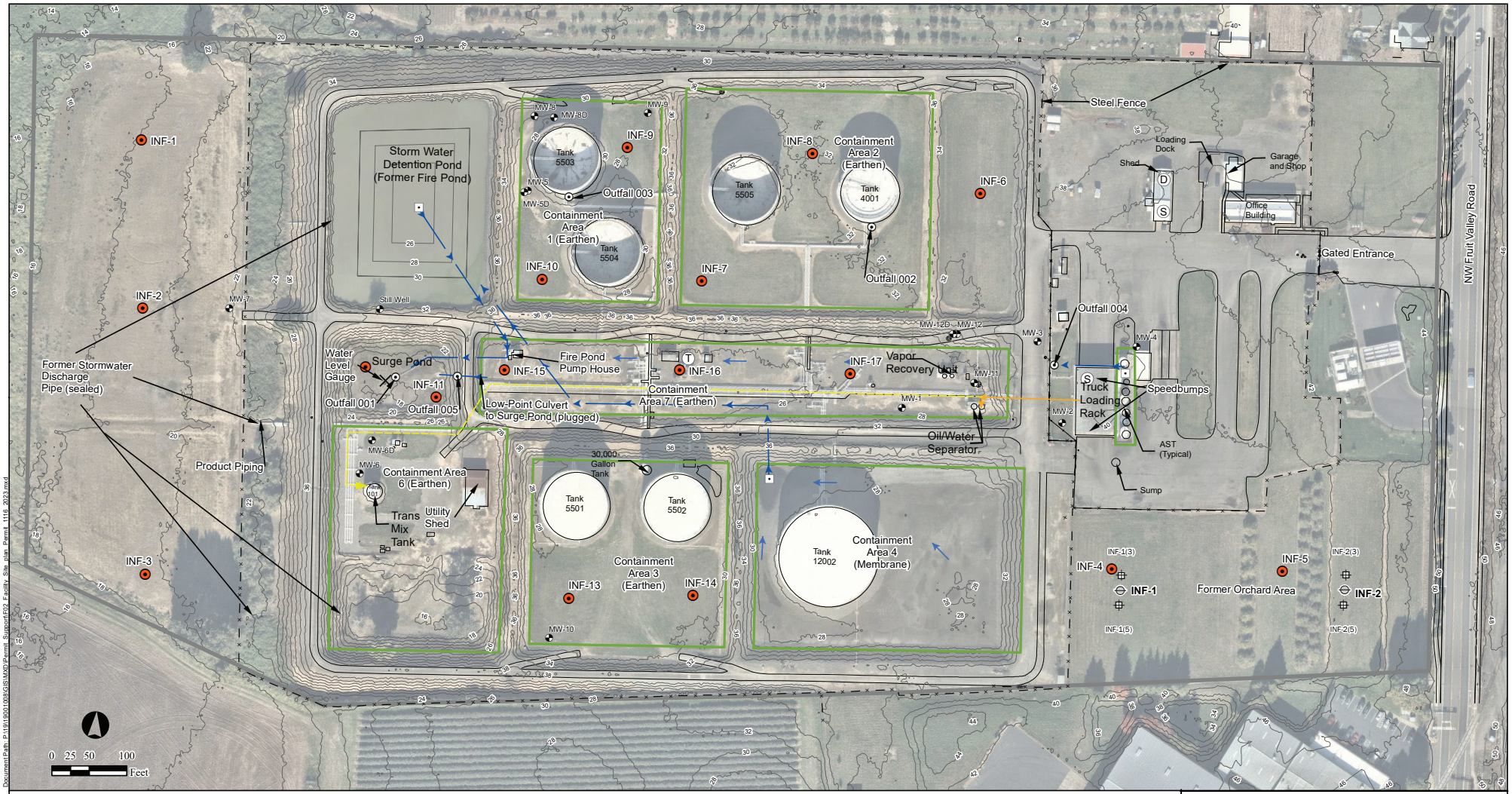
Vicinity Map

NuStar Terminals Operations Partnership L.P. - Annex Terminal
Vancouver, Washington

GeoEngineers

Figure 1

P:\19\19001008\GIS\19001008_Project\19001008_Project\19001008_Project.aprx\19001008_VicinityMap Date Exported: 04/03/23 by estrandhagen



Notes:
Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and monitoring wells surveys by Statewide Land Surveying, Inc. (10/30/2007), bluedot group (12/06/2017), and MacKay Sposito (02/07/2022).

Locations of roads and containments are approximate.

Source:
Aerial from Mapbox.

- Groundwater Monitoring Well Location (MW-5D, MW-6D, MW-8D, and MW-12D are Deep Monitoring Well Locations)
- 2020 Infiltration Test Location
- 2022 Infiltration Test Pits
- Low Point Drain
- Stormwater Monitoring Point/Outfall
- (D) Drum Storage
- (S) Spill Kit
- (T) Transformer
- Piezometer
- Buried Stormwater Conveyance Piping and Flow Direction
- Direction of Process Water Drainage
- Direction of Stormwater Drainage
- Direction of Process Water Drainage in the Event of a Spill
- Steel Fence
- 2-Foot Contour (NAVD88)
- Facility Boundary
- Secondary Containment

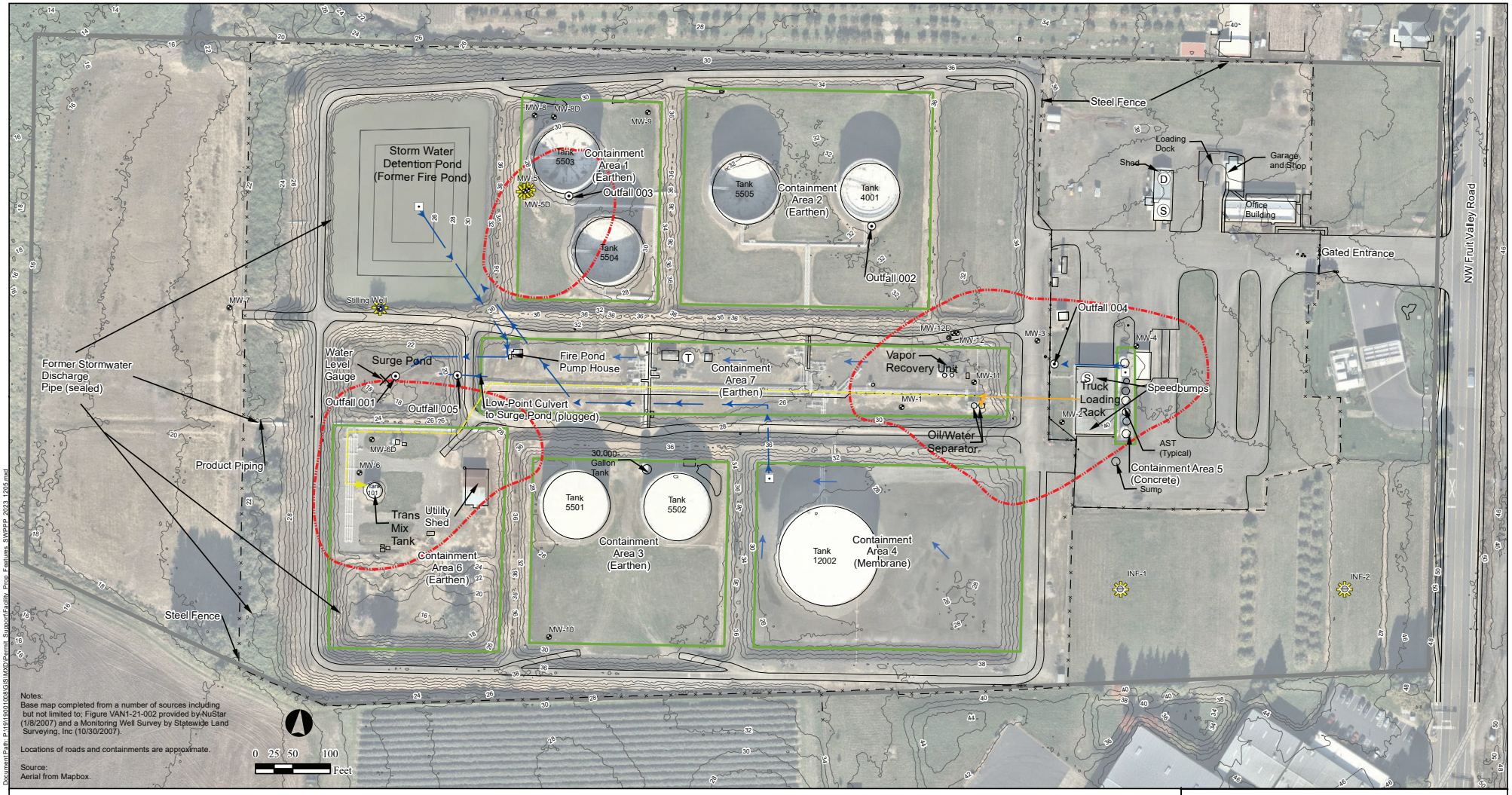
11/16/2023 | Drawn by: ES | Checked by: IM

Facility Map

NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

GeoEngineers

Figure 2



Notes:
Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and a Monitoring Well Survey by Statewide Land Surveying, Inc (10/30/2007).

Locations of roads and containments are approximate.

Source:
Aerial from Mapbox.

Groundwater Monitoring Well Location (MW-5D, MW-6D, MW-8D, and MW-12D are Deep Monitoring Well Locations)

2-Foot Contour (NAVD88)

Surface Water Level Monitoring Location

Piezometer Location

Pressure Transducer Location

Low Point Drain

Stormwater Monitoring Point/Outfall

(D) Drum Storage Area

(S) Spill Kit

(T) Transformer

Buried Stormwater Conveyance Piping and Flow Direction

Direction of Process Water Drainage

Direction of Stormwater Drainage

Direction of Process Water Drainage in the Event of a Spill

Secondary Containment Area

Facility Boundary

MTCA Site Boundaries

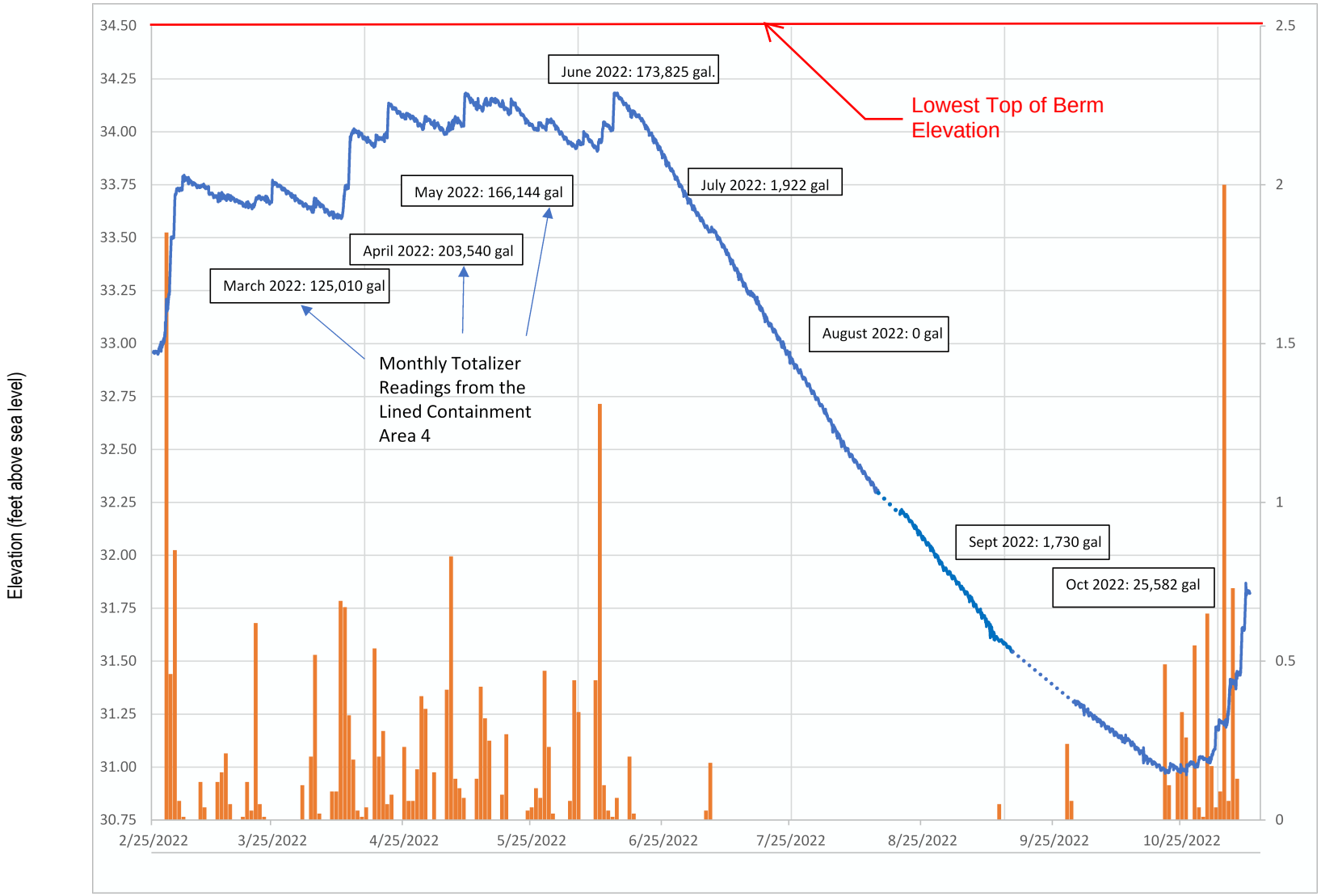
Property Features

NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

GeoEngineers

Figure 3

12/5/2023		Drawn by: ES	



Legend:

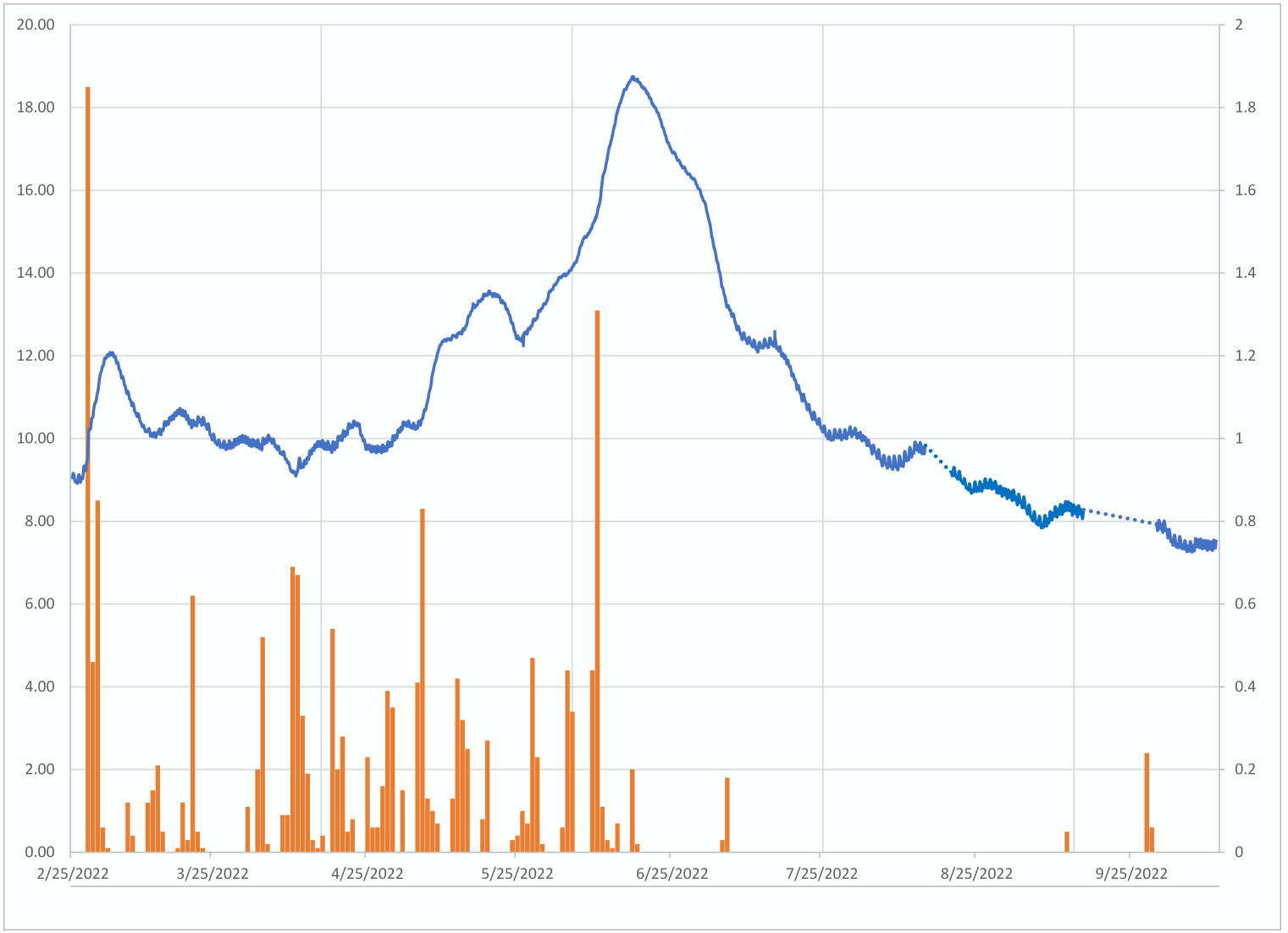
- Hayden Island Rain Gage
- Stormwater Pond Elevation Estimated
- Stormwater Pond Elevation

Stormwater Detention Pond - Water Elevation and Daily Precipitation

Additional Soil Infiltration Testing and Stormwater Detention Monitoring Report
NuStar Vancouver Annex Facility
Vancouver, Washington

GeoEngineers

Project Number	19001-008-04	Figure
November 2022		4



Legend:

- Hayden Island Rain Gage
- Groundwater Elevation
- Estimated Groundwater Elevation

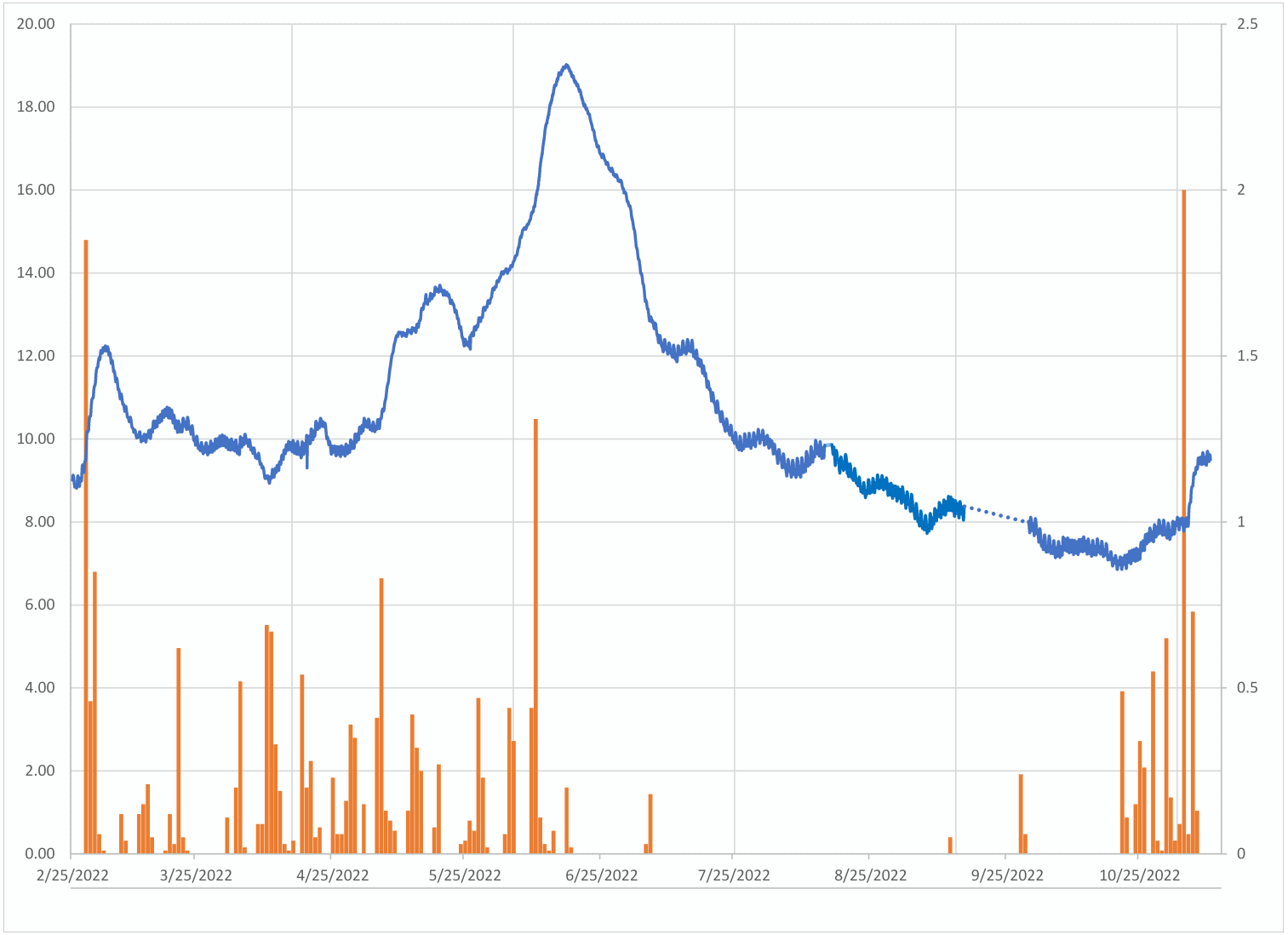
Well MW-5 Water Elevation and Daily Precipitation

Additional Soil Infiltration Testing and Stormwater Detention Monitoring Report

NuStar Vancouver Annex Facility
Vancouver, Washington

GeoEngineers

Project Number	19001-008-04	Figure
November 2022		5



Legend:

- Hayden Island Rain Gage
- Groundwater Elevation
- Estimated Groundwater Elevation

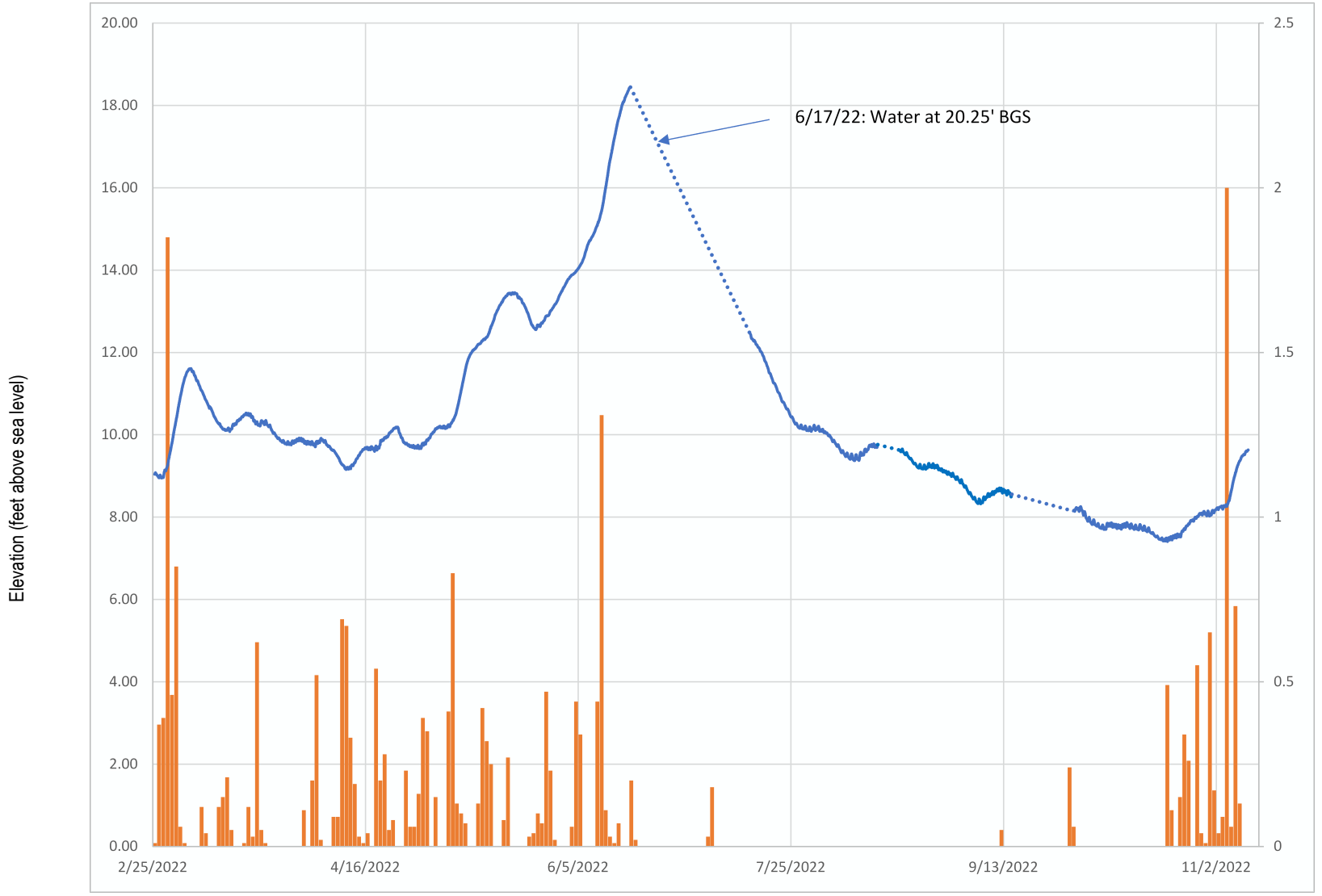
Well MW-5D Water Elevation and Daily Precipitation

Additional Soil Infiltration Testing and Stormwater Detention Monitoring Report

NuStar Vancouver Annex Facility
Vancouver, Washington

GeoEngineers

Project Number	19001-008-04	Figure
November 2022		6



Legend:

- Hayden Island Rain Gage
- Groundwater Elevation
- Estimated Groundwater Elevation

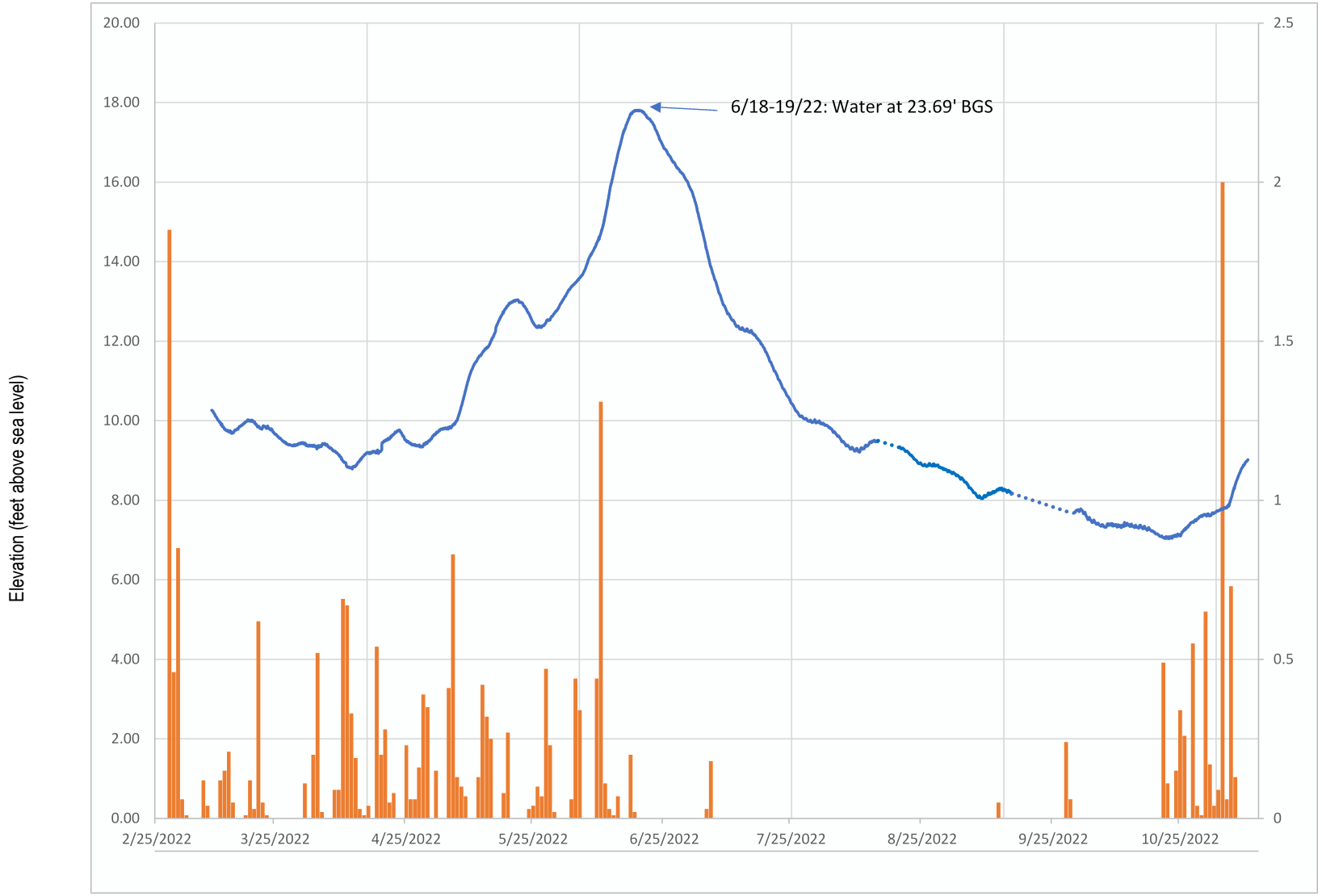
Piezometer INF-1 Water Elevation and Daily Precipitation

Additional Soil Infiltration Testing and Stormwater Detention Monitoring Report

NuStar Vancouver Annex Facility
Vancouver, Washington

GeoEngineers

Project Number	19001-008-04	Figure
November 2022		7



Legend:

- Hayden Island Rain Gage
- Groundwater Elevation
- Estimated Groundwater Elevation

Piezometer INF-2 Water Elevation and Daily Precipitation

Additional Soil Infiltration Testing and Stormwater Detention Monitoring Report

NuStar Vancouver Annex Facility
Vancouver, Washington

GeoEngineers

Project Number	19001-008-04	Figure
November 2022		8

Legend:

- Well MW-5 Groundwater Elevation
- Well MW-5D Groundwater Elevation
- Columbia River Elevation

Wells MW-5/MW-5D and Columbia River

Additional Soil Infiltration Testing and Stormwater Detention Monitoring Report

NuStar Vancouver Annex Facility
Vancouver, Washington

GeoEngineers

Project Number	19001-008-04	Figure
November 2022		9

APPENDICES

GeoEngineers

APPENDIX A
Standard Operating Procedures (SOP)

STANDARD OPERATING PROCEDURE 2.1

STANDARD FIELD SCREENING PROCEDURES

1.1. Purpose and Scope

This Standard Operating Procedure (SOP) provides instructions for standard field screening. Field screening results are used to aid in the selection of soil samples for chemical analysis. This procedure is applicable during soil sampling operations.

Standard field screening techniques include the use of a photoionization detector (PID) to assess for volatile organic compounds (VOCs) and for the presence of separate-phase petroleum hydrocarbons using a sheen test. These methods will not detect all potential contaminants, so selection of screening techniques shall be based on an understanding of the site history. The PID is not compound or concentration-specific, but it can provide a qualitative indication of the presence of VOCs. PID measurements are affected by other field parameters such as temperature and soil moisture. Other field screening methods, such as screening for dense non-aqueous phase liquid (DNAPL) using dye or ultraviolet (UV) light, are not considered "standard" and will be detailed in the site-specific sampling and analysis plan (SAP).

1.2. Equipment and Materials

The following materials are necessary for this procedure:

- PID with calibration gas (record daily calibration/calibration check in field notes);
- Plastic resealable bags (for PID measurement); and
- Glass jars or stainless steel bowls (for sheen testing).

1.3. Methodology

Each soil sample will be field screened for VOCs using a PID and for the presence of separate-phase petroleum hydrocarbons using a sheen test.

PID lamps come in multiple sizes, typically 9.8, 10.6, and 11.7 electron volts (eV). The eV rating for the lamp must be greater than the ionization potential (in eV) of a compound for the PID to detect the compound. For petroleum hydrocarbons, a lamp of at least 9.8 eV should be used. For typical chlorinated alkenes (dichloroethene, trichloroethene, tetrachloroethene, or vinyl chloride), a lamp of at least 10.6 eV should be used. The compatibility of the lamp size with the site constituents should be verified prior to the field event and will be detailed in the site-specific SAP.

PID Calibration Procedure: The PID used on-site should be calibrated daily or more frequently if needed. Calibration of the PID should be documented in field notes. Calibrations procedures should be conducted per the manufacturer's instructions.

PID Screening Procedure

- Place a representative portion (approximately one ounce) of freshly exposed, uncompacted soil into a clean resealable plastic bag.

- Seal the bag and break up the soil to expose vapors from the soil matrix.
- Allow the bag to sit to reach ambient temperature. Note: Ambient temperature and weather conditions/humidity should be recorded in field notes. Changes in ambient temperature and weather during the field work should also be recorded, as temperature and humidity can affect PID readings.
- Carefully insert the intake port of the PID into the plastic bag.
- Record the PID measurement in the field notes or boring logs.

Sheen Test Procedure

- Following the PID screen, place approximately one ounce of freshly exposed, uncompacted soil into a clean glass jar or stainless steel bowl.
- Add enough water to cover the sample.
- Observe the water surface for signs of discoloration/sheen and characterize based on the descriptions below.

No Sheen (NS)	No visible sheen on the water surface.
Biogenic Film (BF)	Dull, platy/blocky or foamy film.
Slight Sheen (SS)	Light sheen with irregular spread, not rapid. May have small spots of color/iridescence. Majority of water surface not covered by sheen.
Moderate Sheen (MS)	Medium to heavy coverage, some color/iridescence, spread is irregular to flowing. Sheen covering a large portion of water surface.
Heavy Sheen (HS)	Heavy sheen coverage with color/iridescence, spread is rapid, entire water surface covered with sheen. Separate-phase hydrocarbons may be evident during sheen test.

STANDARD OPERATING PROCEDURE 2.2

EPA METHOD 5035A SOIL SAMPLING PROCEDURES

1.1. Purpose and Scope

This Standard Operating Procedure (SOP) describes the methods used for obtaining soil samples for chemical analysis for volatile organic compounds (VOCs) by EPA Method 5035A. Samples collected using the 5035A protocols are not exposed to the atmosphere after sampling thereby reducing the potential for loss of VOCs during sample transport, handling, and analysis. This procedure assumes the use of the PowerStop Handle sampler with disposable EasyDraw Syringes or Terra Core Samplers. This procedure is applicable during soil sampling activities where the 5035A protocols are employed.

1.2. Equipment and Materials

The following materials are necessary for this procedure:

- Sampling equipment (PowerStop Handle, disposable EasyDraw Syringes, Terra Core Samplers)
- Laboratory-supplied sample containers (pre-weighed 40 milliliter [ml] volatile organics analysis (VOA) vials including labels, preservative, stir bars, etc. [number and type as specified by the lab], 2-ounce jars)
    - Vials used from stock must be weighed to confirm loss of reagents is less than 0.02 grams. Record vial tare weight in field notes. Discard vials with dates over 6 months old.
- Field documentation materials
- Decontamination materials
- Personal protective equipment (as required by Health and Safety Plan)

1.3. Methodology

The project-specific sampling and analysis plan (SAP) will define the specific requirements for 5035A methodology required for a particular site or by a regulatory agency.

Analytical Requirements

- VOCs must be analyzed within 14 days of collection.
- Field preserved samples (e.g., sodium bisulfate or methanol) must be maintained at 4 degrees Celsius.
- Sample collected without preservative (e.g., reagent water) must be frozen or analyzed within 48 hours.

Collection of Samples

- When using the PowerStop Handle, clip the syringe into the handle in one of the three 5-gram positions. Use the heavy position for dense clay, the light position for dry sandy soil, and the medium position for all others.
- Using the handle, push the sampler into the soil to collect the sample. Continue pushing until the soil column has forced the plunger in the syringe to the stopping point or filled the sampler.

- Wipe all debris from the outside of the sampler. The soil plug should be flush with the mouth of the sampler. Remove any excess soil that extends beyond the mouth of the sampler.
- Extrude the 5-gram sample into vial and cap vial immediately. Hold vial at an angle when extruding to minimize splashing. Gently swirl vial for 10 seconds to break up soil particles (do not shake).
- When capping the vial, be sure to remove any soil or debris from the threads of the vial.
- Repeat process for each additional vial.
- Fill a 2-ounce container (to capacity) for percent total solids determination.

Additional Considerations

- Methanol contamination can occur from adjacent activities (e.g., exhaust from running equipment or vehicles, hot tar roofing, facility operations, etc.). Collection and analysis of methanol field blank (e.g., additional methanol vial left open during period of sampling) is recommended.
- Acidification of carbonaceous soils with sodium bisulfate can cause effervescence and loss of VOCs.
- Certain volatile compounds such as 2-chloroethylvinyl ether may be lost by acidification.
- Acidification of certain soils with sodium bisulfate may cause the formation of acetone through oxidation of soil waxes and humic material (e.g., organic materials such as roots).

STANDARD OPERATING PROCEDURE 2.3

LOW FLOW GROUNDWATER SAMPLING PROCEDURES

1.1. Purpose and Scope

This Standard Operating Procedure (SOP) describes the methods for collection of groundwater samples from monitoring wells applying low flow protocols. Low flow sampling is a method of collecting samples that does not require the removal of large volumes of water and therefore does not overly agitate the water, suspend particles, or potentially aspirate VOCs. Typical flow rates for low flow sampling range from 0.1 liters per minute (L/min) to 0.5 L/min depending on site characteristics. The groundwater monitoring activities will consist of measuring water levels, purging and sampling groundwater, and measuring groundwater field parameters. This procedure is applicable during all low flow groundwater sampling activities.

1.2. Equipment and Materials

The following materials are necessary for this procedure:

- Traffic cones, tools, keys, and buckets/drums
- Water quality meter with calibration solutions (record daily calibration/calibration check in field notes)
- Sampling equipment (water level probe, pumps, tubing) and laboratory-supplied sample containers
- Field documentation materials
- Decontamination materials
- Personal protective equipment (as required by project Health and Safety Plan)

1.3. Methodology

Water Levels

Water levels in the wells will be measured and recorded for the purpose of determining groundwater elevations and gradient. The wells will be opened, and the water level allowed to equilibrate before the measurements are taken. Measurements of the depth to water will be made to the nearest 0.01 foot using an electronic probe.

Purging

Purge using low-flow sampling equipment (e.g., bladder pump) at a rate no greater than the recharge rate of the groundwater to prevent water table drawdown. Unless specified otherwise in the project-specific sampling and analysis plan (SAP) the sample tubing/pump will be lowered to the middle of the screened interval. To assess the effectiveness of purging, groundwater field parameters (pH, electrical conductivity, and temperature) will be measured using a flow cell connected to the discharge tubing of the sample pump. Purging will be considered complete when the water quality parameters (i.e., pH, temperature, and specific conductance) stabilize within 10 percent for three consecutive 3-minute intervals. Consult the project-specific SAP for additional parameters and stabilization criteria. Purge water will be placed in Washington State Department of Transportation (WSDOT) approved drums.

Sample Collection

After the purging of each well is complete, collect groundwater samples for chemical analyses using the same pump used for the well purging.

Low Yield Sampling Procedure

If a well pumps dry during purging discontinue measurement of water quality parameters. Collect groundwater samples once the water level recovers to 90 percent of the pre-purge water column. Contact project manager in the event of slow recharge conditions. Always collect samples for VOC analysis as soon after recharge as possible.

STANDARD OPERATING PROCEDURE 2.4

PUSH-PROBE EXPLORATION PROCEDURES

1.1. Purpose and Scope

This Standard Operating Procedure (SOP) describes the methods for observing and sampling from push-probes (i.e., GeoProbe™, AMS PowerProbe™, or similar). Subsurface soil cores may be obtained using this system for purposes of determining subsurface soil conditions and for obtaining soil samples for physical and/or chemical evaluation. Grab groundwater samples may be collected using temporary well screens. Soil vapor samples may be obtained using temporary well points. Shallow (less than 50 feet), small-diameter (2-inch max) pre-packed wells may also be installed using push-probe equipment. This procedure is applicable during push-probe activities.

1.2. Equipment and Materials

The following materials are necessary for this procedure:

- Traffic cones, tools, keys, and buckets/drums
- Water quality meter with calibration solutions (record daily calibration/calibration check in field notes)
- Sampling equipment (water level probe, pumps, tubing) and laboratory-supplied sample containers
- Field documentation materials
- Decontamination materials
- Personal protective equipment (as required by project Health and Safety Plan)

1.3. Methodology

Coring Procedure (Conducted by Drilling Subcontractor)

The sampling procedure includes driving a 2-inch outside-diameter, 5-foot-long, push-probe soil sampler to the desired depth using a combination of hydraulic pressure and mechanical hammer blows. When the sampling depth is reached, the pin attaching the sampler's tip is released (if a tip is used), which allows the tip to slide inside the sampler (Macro-Core Sampler with removable plastic liner). The sampler is driven the length of the sampler to collect a soil core, which is then withdrawn from the exploration. When the sampler is retrieved from the borehole the drive head/cutting shoe is detached and the liner is removed, and the liner is cut open to expose the recovered soil core. Soil cores are collected continuously to the full depth of the exploration unless otherwise specified in a project-specific sampling and analysis plan (SAP). Verify that the subcontractor decontaminates the sampling device prior to its initial use and following collection of each soil sample.

Logging and Soil Sample Collection

Remove the soil core from the sampler for field screening, description, and placement into sample jars. Soil samples will be collected for field screening and possible chemical analysis on 2-foot intervals unless otherwise specified in a project-specific SAP. The sampling interval will be determined in the field based on recovery, soil variability, and evidence of contamination. Complete field screening as specified in SOP 2.1. Soil samples should be collected using different procedures for volatile on non-volatile analyses, as follows.

- Volatile Analyses. Sampling for volatile organics analysis (VOA) is different than other routine physical or chemical testing because of the potential loss of volatiles during sampling. To limit volatile loss, the soil sample must be obtained as quickly and as directly as possible. If a VOA sample is to collected as part of a multiple analyte sample, the VOA sample portion will be obtained first. The VOA sample should be obtained from a discrete portion of the entire collected sample and should not be composited or homogenized. Sample bottles should be filled to capacity, with no headspace. Specific procedures for collecting VOA samples using the EPA Method 5035 are discussed in SOP 2.2.
- Other Analyses. Soil samples for non-volatile analyses will be thoroughly homogenized in a stainless steel bowl prior to bottling. Sample homogenizing is accomplished by manually mixing the entire soil sample in the stainless steel bowl with a clean sampling tool until a uniform mixture is achieved. The sample jar should be filled completely.

Any extra soil generated during probing activities will be placed in Washington State Department of Transportation (WSDOT) approved drums. At a minimum, the drum should be properly labelled with the generator (client – if appropriate), Site address, and contents.

Grab Groundwater Sample Collection

Collect grab groundwater samples using a sampling attachment with a 4- to 5-foot-long temporary screen (specify to drillers whether to use decontaminated stainless steel or disposable polyvinyl chloride [PVC]. Also, specify whether a filter pack is necessary based on field observations). Obtain samples using a peristaltic pump unless otherwise specified in the SAP with new tubing for each boring. Record field parameters (e.g., temperature, conductivity, and pH) prior to sampling.

Backfilling the Excavation (Conducted by Drilling Subcontractor)

After sampling activities are completed, abandon each exploration in accordance with Washington Department of Ecology regulations and procedures. The abandonment procedure typically consists of filling the exploration with granular bentonite and hydrating the bentonite with water. Match the surface completion to the surrounding materials.

1. PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) provides instructions for standard field screening. Field screening results are used to aid in the selection of soil samples for chemical analysis. This procedure is applicable during soil sampling operations.

Standard field screening techniques include the use of a photoionization detector (PID) to assess for volatile organic compounds (VOCs) and for the presence of separate-phase petroleum hydrocarbons using a sheen test. These methods will not detect all potential contaminants, so selection of screening techniques shall be based on an understanding of the site history. The PID is not compound or concentration-specific, but it can provide a qualitative indication of the presence of VOCs. PID measurements are affected by other field parameters such as temperature and soil moisture. Other field screening methods, such as screening for dense non-aqueous phase liquid (DNAPL) using dye or UV light, are not considered "standard" and will be detailed in the site-specific sampling and analysis plan (SAP).

2. EQUIPMENT AND MATERIALS

The following materials are necessary for this procedure:

- PID with calibration gas (record daily calibration/calibration check in field notes);
- Plastic resealable bags (for PID measurement); and
- Glass jars or stainless steel bowls (for sheen testing).

3. METHODOLOGY

Each soil sample will be field screened for VOCs using a PID and for the presence of separate-phase petroleum hydrocarbons using a sheen test.

PID lamps come in multiple sizes, typically 9.8, 10.6, and 11.7 electron volts (eV). The eV rating for the lamp must be greater than the ionization potential (in eV) of a compound for the PID to detect the compound. For petroleum hydrocarbons, a lamp of at least 9.8 eV should be used. For typical chlorinated alkenes (dichloroethene, trichloroethene, tetrachloroethene, or vinyl chloride), a lamp of at least 10.6 eV should be used. The compatibility of the lamp size with the site constituents should be verified prior to the field event and will be detailed in the site-specific SAP.

PID Calibration Procedure: The PID used on-site should be calibrated daily or more frequently if needed. Calibration of the PID should be documented in field notes. Calibrations procedures should be conducted per the manufacturer's instructions.

PID Screening Procedure:

- Place a representative portion (approximately one ounce) of freshly exposed, uncompacted soil into a clean resealable plastic bag.
- Seal the bag and break up the soil to expose vapors from the soil matrix.
- Allow the bag to sit to reach ambient temperature. Note: Ambient temperature and

weather conditions/humidity should be recorded in field notes. Changes in ambient temperature and weather during the field work should also be recorded, as temperature and humidity can affect PID readings.

- Carefully insert the intake port of the PID into the plastic bag.
- Record the PID measurement in the field notes or boring logs.

Sheen Test Procedure:

- Following the PID screen, place approximately one ounce of freshly exposed, uncompacted soil into a clean glass jar or stainless steel bowl.
- Add enough water to cover the sample.
- Observe the water surface for signs of discoloration/sheen and characterize based on the descriptions below.

No Sheen (NS)	No visible sheen on the water surface
Biogenic Film (BF)	Dull, platy/blocky or foamy film.
Slight Sheen (SS)	Light sheen with irregular spread, not rapid. May have small spots of color/iridescence. Majority of water surface not covered by sheen.
Moderate Sheen (MS)	Medium to heavy coverage, some color/iridescence, spread is irregular to flowing. Sheen covering a large portion of water surface.
Heavy Sheen (HS)	Heavy sheen coverage with color/iridescence, spread is rapid, entire water surface covered with sheen. Separate-phase hydrocarbons may be evident during sheen test.

1. PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) describes the methods used for obtaining soil samples for chemical analysis for volatile organic compounds (VOCs) by EPA Method 5035A. Samples collected using the 5035A protocols are not exposed to the atmosphere after sampling thereby reducing the potential for loss of VOCs during sample transport, handling, and analysis. This procedure assumes the use of the PowerStop Handle sampler with disposable EasyDraw Syringes or Terra Core Samplers. This procedure is applicable during soil sampling activities where the 5035A protocols are employed.

2. EQUIPMENT AND MATERIALS

The following materials are necessary for this procedure:

- Sampling equipment (PowerStop Handle, disposable EasyDraw Syringes, Terra Core Samplers)
- Laboratory-supplied sample containers (pre-weighed 40ml VOA vials including labels, preservative, stir bars, etc. [number and type as specified by the lab], two ounce jars)
    - Vials used from ACA stock must be weighed to confirm loss of reagents is less than 0.02 grams. Record vial tare weight in field notes. Discard vials with dates over 6 months old.
- Field documentation materials
- Decontamination materials
- Personal protective equipment (as required by Health and Safety Plan)

3. METHODOLOGY

The project-specific sampling and analysis plan (SAP) will define the specific requirements for 5035A methodology required for a particular site or by a regulatory agency.

Analytical Requirements

- VOCs must be analyzed within 14 days of collection.
- Field preserved samples (e.g., sodium bisulfate or methanol) must be maintained at 4° C.
- Sample collected without preservative (e.g., reagent water) must frozen or analyzed within 48 hours.

Collection of Samples

- When using the PowerStop Handle, clip the syringe into the handle in one of the three 5 gram positions. Use the heavy position for dense clay, the light position for dry sandy soil, and the medium position for all others.
- Using the handle, push the sampler into the soil to collect the sample. Continue pushing until the soil column has forced the plunger in the syringe to the stopping point or filled the sampler.
- Wipe all debris from the outside of the sampler. The soil plug should be flush with the mouth of the sampler. Remove any excess soil that extends beyond the mouth of the sampler.
- Extrude the 5 gram sample into vial and cap vial immediately. Hold vial at an angle when extruding to minimize splashing. Gently swirl vial for 10 seconds to break up soil particles (do not shake).
- When capping the vial, be sure to remove any soil or debris from the threads of the vial.
- Repeat process for each additional vial.
- Fill a two ounce container (to capacity) for percent total solids determination.

Additional Considerations

- Methanol contamination can occur from adjacent activities (e.g., exhaust from running equipment or vehicles, hot tar roofing, facility operations, etc). Collection and analysis of methanol field blank (e.g., additional methanol vial left open during period of sampling) is recommended.
- Acidification of carbonaceous soils with sodium bisulfate can cause effervescence and loss of VOCs.
- Certain volatile compounds such as 2-chloroethylvinyl ether may be lost by acidification.
- Acidification of certain soils with sodium bisulfate may cause the formation of acetone through oxidation of soil waxes and humic material (e.g., organic materials such as roots.

1. PURPOSE AND SCOPE

2. This Standard Operating Procedure (SOP) describes the methods for collection of groundwater samples from monitoring wells applying low flow protocols. Low flow sampling is a method of collecting samples that does not require the removal of large volumes of water and therefore does not overly agitate the water, suspend particles, or potentially aspirate VOCs. Typical flow rates for low flow sampling range from 0.1 L/min to 0.5 L/min depending on site characteristics. The groundwater monitoring activities will consist of measuring water levels, purging and sampling groundwater, and measuring groundwater field parameters. This procedure is applicable during all low flow groundwater sampling activities.

3. EQUIPMENT AND MATERIALS

The following materials are necessary for this procedure:

- Traffic cones, tools, keys, and buckets/drums
- Water quality meter with calibration solutions (record daily calibration/calibration check in field notes)
- Sampling equipment (water level probe, pumps, tubing) and laboratory-supplied sample containers
- Field documentation materials
- Decontamination materials
- Personal protective equipment (as required by project Health and Safety Plan)

4. METHODOLOGY

Water Levels:

Water levels in the wells will be measured and recorded for the purpose of determining groundwater elevations and gradient. The wells will be opened and the water level allowed to equilibrate before the measurements are taken. Measurements of the depth to water will be made to the nearest 0.01 foot using an electronic probe.

Purging:

Purge using low-flow sampling equipment (e.g., bladder pump) at a rate no greater than the recharge rate of the groundwater to prevent water table drawdown. Unless specified otherwise in the project-specific sampling and analysis plan (SAP) the sample tubing/pump will be lowered to the middle of the screened interval. To assess the effectiveness of purging, groundwater field parameters (pH, electrical conductivity, and temperature) will be measured using a flow cell connected to the discharge tubing of the sample pump. Purging will be considered complete when the water quality parameters (i.e., pH, temperature, and specific conductance) stabilize within 10 percent for three consecutive 3-minute intervals. Consult the project- specific SAP for additional parameters and stabilization criteria. Purge water will be placed in Department of Transportation (DOT) approved drums.

Sample Collection:

After the purging of each well is complete, collect groundwater samples for chemical analyses using the same pump used for the well purging.

Low Yield Sampling Procedure:

If a well pumps dry during purging discontinue measurement of water quality parameters. Collect groundwater samples once the water level recovers to 90 percent of the pre-purge water column. Contact project manager in the event of slow recharge conditions. Always collect samples for VOC analysis as soon after recharge as possible.

PUSH-PROBE EXPLORATION PROCEDURES

1. PURPOSE AND SCOPE

This Standard Operating Procedure (SOP) describes the methods for observing and sampling from push-probes (i.e., GeoProbe™, AMS PowerProbe™, or similar). Subsurface soil cores may be obtained using this system for purposes of determining subsurface soil conditions and for obtaining soil samples for physical and/or chemical evaluation. Grab groundwater samples may be collected using temporary well screens. Soil vapor samples may be obtained using temporary well points. Shallow (less than 50 feet), small-diameter (2-inch max) pre-packed wells may also be installed using push-probe equipment. This procedure is applicable during push-probe activities.

2. EQUIPMENT AND MATERIALS

The following materials are necessary for this procedure:

- Traffic cones, tools, keys, and buckets/drums
- Water quality meter with calibration solutions (record daily calibration/calibration check in field notes)
- Sampling equipment (water level probe, pumps, tubing) and laboratory-supplied sample containers
- Field documentation materials
- Decontamination materials
- Personal protective equipment (as required by project Health and Safety Plan)

3. METHODOLOGY

Coring Procedure (Conducted by Drilling Subcontractor):

The sampling procedure includes driving a 2-inch outside-diameter, 5-foot-long, push-probe soil sampler to the desired depth using a combination of hydraulic pressure and mechanical hammer blows. When the sampling depth is reached, the pin attaching the sampler's tip is released (if a tip is used), which allows the tip to slide inside the sampler (Macro-Core Sampler with removable plastic liner). The sampler is driven the length of the sampler to collect a soil core, which is then withdrawn from the exploration. When the sampler is retrieved from the borehole the drive head/cutting shoe is detached and the liner is removed and the liner is cut open to expose the recovered soil core. Soil cores are collected continuously to the full depth of the exploration unless otherwise specified in a project-specific sampling and analysis plan (SAP). Verify that the subcontractor decontaminates the sampling device prior to its initial use and following collection of each soil sample.

Logging and Soil Sample Collection:

Remove the soil core from the sampler for field screening, description, and placement into sample jars. Soil samples will be collected for field screening and possible chemical analysis on two foot intervals unless otherwise specified in a project-specific SAP. The sampling interval will be determined in the field based on recovery, soil variability, and evidence of contamination. Complete field screening as specified in SOP-2.1. Soil samples should be collected using different procedures for volatile on non-volatile analyses, as follows.

- Volatile Analyses. Sampling for volatile organics analysis (VOA) is different than other routine physical or chemical testing because of the potential loss of volatiles during sampling. To limit volatile loss, the soil sample must be obtained as quickly and as directly as possible. If a VOA sample is to collected as part of a multiple analyte sample, the VOA sample portion will be obtained first. The VOA sample should be obtained from a discrete portion of the entire collected sample and should not be composited or homogenized. Sample bottles should be filled to capacity, with no headspace. Specific procedures for collecting VOA samples using the EPA Method 5035 are discussed in SOP 2.2.
- Other Analyses. Soil samples for non-volatile analyses will be thoroughly homogenized in a stainless steel bowl prior to bottling. Sample homogenizing is accomplished by manually mixing the entire soil

sample in the stainless steel bowl with a clean sampling tool until a uniform mixture is achieved. The sample jar should be filled completely.

Any extra soil generated during probing activities will be placed in Department of Transportation (DOT) approved drums. At a minimum, the drum should be properly labelled with the generator (client – if appropriate), Site address, and contents.

Grab Groundwater Sample Collection:

Collect grab groundwater samples using a sampling attachment with a 4 to 5-foot-long temporary screen (specify to drillers whether to use decontaminated stainless steel or disposable PVC. Also, specify whether a filter pack is necessary based on field observations). Obtain samples using a peristaltic pump unless otherwise specified in the SAP with new tubing for each boring. Record field parameters (e.g., temperature, conductivity, and pH) prior to sampling.

Backfilling the Excavation (Conducted by Drilling Subcontractor):

After sampling activities are completed, abandon each exploration in accordance with Oregon Water Resources Department (OWRD) regulations and procedures (or other regulatory authority if work is completed outside of the State of Oregon. The abandonment procedure typically consists of filling the exploration with granular bentonite and hydrating the bentonite with water. Match the surface completion to the surrounding materials.

DEPARTMENT OF ECOLOGY
State of Washington

Water Resources Program
Variance Request- Minimum Standards for Well Construction

WAC173-160-106(1) allows you to request a variance from the Department of Ecology when strict compliance with state well construction standards is impractical. The variance request must propose comparable alternative specifications that will provide equal or greater human health and resource protection than the minimum standards. You must apply for a variance in writing and receive approval before constructing or decommissioning the well. (All fields must be completed.)

Requested by: Stephanie Salisbury

Mailing Address: 5820 S Kelly Ave Suite B City: Portland State: OR Zip: 97239

Daytime Phone: 503-807-3835 Date: 1/19/22

Property Owner (if different): NuStar Terminal Operations Partnership L.P.

Site Location: NE ¼ NW ¼ Section: 16 Township: 2N Range: 1 ■E or □WWM

Tax Parcel Number: 147360

Well Address: 5420 NW Fruit Valley Road, Vancouver, WA, 98660

Well Driller/Company (if known): Cascade Drilling

Check one: □ Water Well ■ Resource Protection Well □ Dewatering Well

What construction standard cannot be met?

WAC 173-160-451(d) - Direct-push wells shall not be greater than 30-feet in depth.

Describe the reason why standard cannot be met. Include site map and distances from all known potential sources of contamination if setback variance is being requested.

Wells MW-6D, MW-12, and MW-12D are proposed using direct push and have been approved by the Ecology Toxics Cleanup Group (Andrew Smith, Project Manager; see attached map). Wells MW-6D and MW-12D will be installed to up to 55 feet bgs, consistent with a well for which a variance was approved in 2017 at this site. Well MW-12 will be installed up to 35 ft and will also require a variance. A track mounted direct push rig has been used at this site in the past and is safest technology to access the site in muddy conditions. It is narrow and the safest method to navigate a rig on the narrow tank farm berm roads. A variance has been approved by Ecology for similar wells at the site, and no issues were encountered.

Describe the alternative construction method that will provide equal or greater protections than those provided by the minimum standard.

The construction methods are in-line with regulatory code. Only the drilling method is being modified from the minimum standard.

A modified drilling method is needed to access the borehole locations safely.

The wells will be installed consistent with all other regulations.

(Attach additional pages if necessary.) Complete and return with your site map to the appropriate regional office:

Northwest Regional Office	Southwest Regional Office	Eastern Regional Office	Central Regional Office
ATTN: Noel Philip	ATTN: John Pearch	ATTN: Mark Ader	ATTN: Avery Richardson
3190 160th Avenue SE	PO Box 47775	N 4601 Monroe	1250 W Alder St.
Bellevue, WA 98008	Olympia, WA 98504	Spokane, WA 99205	Union Gap, WA 98903
425-649-7044	360-407-0297	509-329-3544	509-575-2639
Fax: 425-649-7098	Fax: 360-407-6305	Fax: 509-329-3529	Fax: 509-454-7830
nphi461@ecy.wa.gov	jope461@ecy.wa.gov	made461@ecy.wa.gov	aric461@ecy.wa.gov

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47775 • Olympia, Washington 98504-7775 • (360) 407-6300
711 for Washington Relay Service • Persons with a speech disability can call 877-833-6341

January 27, 2022

Jeff Hibner
NuStar Energy, L.P.
19003 IH-10 West
San Antonio, Texas 78257
jeff.hibner@nustarenergy.com

Re: Variance request to Chapter 173-160 Washington Administrative Code (WAC) for drilling deeper than the 30 foot requirement for direct push resource protection wells to be constructed near 5420 NW Fruit Valley, Washington in the NE ¼, NW ¼, Section 16, Township 2 North, Range 1 East, Clark County (Tax Parcel # 147360000)

Dear Jeff Hibner:

This letter is in response to your request for a variance (dated January 25, 2022) from the *Minimum Standards for the Construction and Maintenance of Wells*, Chapter 173-160 WAC. Specifically, your request is to drill a direct push resource protection well deeper than is required under Chapter 173-160-451 (d) WAC. The monitoring well will allow NuStar Energy, LP (remedial investigation) to comply with an agreed order from the Washington State Department of Ecology, Toxic Cleanup Program. The complete proposal is described in your variance request for the following monitoring and eventual remediation wells: INF-1 and INF-2 (copy attached).

After an investigation, interview, and review of information available, a variance is hereby **granted** to Chapter 173-160 WAC. Ecology will allow the wells to be constructed as soon as workers and equipment are available and using the method you have proposed. This variance is granted under the following conditions:

1. The construction must be completed within 1 year receipt of this variance.

2. All well construction work shall be performed by a licensed driller as set forth by WAC 173-162.

3. A notice of intent to construct a resource protection well must be filed and the fee paid in accordance with WAC 173-160-151.

4. If conditions change while constructing this well and variance conditions cannot be met, an additional variance is required. Alternate methods must be approved before constructing the well further.

5. According to WAC 173-160-451 (d) “Direct push wells shall not be constructed through more than one water bearing formation and the seal shall be from the top of the sand pack to land

surface." However, this variance grants that the direct push well may drill to a maximum of 35 feet or penetrate through one water bearing formation (whichever comes first). All other requirements of WAC 173-160-451 must be met :

WAC 173-160-451 What are the minimum standards for direct push resource protection wells?

(1) Resource protection wells that are installed using direct push technology shall comply with the applicable standards in these rules for reporting, casing, screening, development, surface protection, cleaning, tagging, and completion.

(2) Resource protection wells that are installed using direct push technology shall also comply with the following standards:

(a) Prepacked or sand packed screens shall be used. The sand pack or filter pack shall not extend more than three feet above the top or one foot below the bottom of the well screen; and

(b) The outside diameter of the bore hole shall be a minimum of one inch greater than the outside diameter of the well casing; and

(c) Granular bentonite shall not be used in the sealed interval below the static water level. Prepacked or slurry sealant is required below static level. Any sealing method used must result in a continuous and effective seal meeting the minimum sealing standards of this chapter; and

(d) Direct push wells shall not be constructed through more than one water bearing formation and the seal shall be from the top of the sand pack to land surface. Direct push wells shall not be greater than thirty feet in depth unless a variance is obtained. A request for a variance must be accompanied by a site-specific plan; and

(e) If the total probe depth exceeds the depth of the bottom of the screen it must be properly decommissioned to the bottom of the screen.

6. The driller must submit a Water Well Report describing the decommissioning to Ecology (Southwest Regional office) within 30 days after completion of the work. Attach a copy of this variance to that well report. Borehole diameter, casing diameter, annular seal, static water level and lithology must also be included on the well report. **Note: Latitude and longitude in decimal degrees (to fifth decimal place) is now required to be included for each well on all well reports.**

7. When this well is no longer necessary for project work at this site, the property owner must decommission these wells using proper methods, material, licensed personnel, and notice to Ecology (per WAC 173-160-460).

8. The driller must inform Ecology (John Pearch, 360-407-0297) 2 business days before any work begins. The driller must make the site accessible to Mr. Pearch to inspect any and/or all work.

9. With the exception of the provisions set forth (above) in this variance, all federal, state, and local requirements shall apply.

YOUR RIGHT TO APPEAL

You have a right to appeal this variance to the Pollution Control Hearing Board (PCHB) within 30 days of the date of receipt of this variance. The appeal process is governed by Chapter 43.21B RCW and Chapter 371-08 WAC. "Date of receipt" is defined in RCW 43.21B.001(2).

To appeal you must do the following within 30 days of the date of receipt of this variance:

- File your appeal and a copy of variance with the PCHB (see addresses below). Filing means actual receipt by the PCHB during regular business hours.
- Serve a copy of your appeal and this variance on Ecology in paper form - by mail or in person. (See addresses below.) E-mail is not accepted.

You must also comply with other applicable requirements in Chapter 43.21B RCW and Chapter 371-08 WAC.

ADDRESS AND LOCATION INFORMATION

Street Addresses	Mailing Addresses
Department of Ecology Attn: Appeals Processing Desk 300 Desmond Drive SE Lacey, WA 98503 **Pollution Control Hearings Board** 1111 Israel RD SW STE 301 Tumwater, WA 98501	**Department of Ecology** Attn: Appeals Processing Desk PO Box 47608 Olympia, WA 98504-7608 **Pollution Control Hearings Board** PO Box 40903 Olympia, WA 98504-0903

For additional information visit the Environmental Hearings Office Website: http://www.eho.wa.gov. To find laws and agency rules visit the Washington State Legislature Website: http://www1.leg.wa.gov/CodeReviser.

SIGNATURE

Michael J. Gallagher

_____ January 27, 2022

Michael J. Gallagher
Section Manager
Water Resources Program

John Pearch

_____ January 27, 2022

John Pearch, LHG
Well Construction Coordinator
jope461@ecy.wa.gov

cc: Stephanie Bosze-Salisbury, GeoEngineers, Inc., ssalisbury@geoengineers.com
Heidi D. Celorie, Cascade Drilling of Clackamas Oregon, hcelorie@cascade-emv.com
Andrew Smith, TCP

APPENDIX B
Apex Labs Analytical Report

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

Thursday, March 10, 2022

Kurt Harrington
GeoEngineers
4000 Kruse Way Place, Bldg 3 Suite 200
Lake Oswego, OR 97035

RE: A2B0215 - NuStar Vannex Piezo Install - 019001-008-01

Thank you for using Apex Laboratories. We greatly appreciate your business and strive to provide the highest quality services to the environmental industry.

Enclosed are the results of analyses for work order A2B0215, which was received by the laboratory on 2/3/2022 at 4:00:00PM.

If you have any questions concerning this report or the services we offer, please feel free to contact me by email at: DAuvil@apex-labs.com, or by phone at 503-718-2323.

Please note: All samples will be disposed of within 30 days of sample receipt, unless prior arrangements have been made.

Cooler Receipt Information

(See Cooler Receipt Form for details)

Cooler #1	5.1 degC

This Final Report is the official version of the data results for this sample submission, unless superseded by a subsequent, labeled amended report.
All other deliverables derived from this data, including Electronic Data Deliverables (EDDs), CLP-like forms, client requested summary sheets, and all other products are considered secondary to this report.

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

ANALYTICAL REPORT FOR SAMPLES

SAMPLE INFORMATION

Client Sample ID	Laboratory ID	Matrix	Date Sampled	Date Received
INF1-3	A2B0215-01	Soil	02/02/22 10:45	02/03/22 16:00
INF1-5	A2B0215-02	Soil	02/02/22 11:15	02/03/22 16:00
INF2-3	A2B0215-03	Soil	02/02/22 13:50	02/03/22 16:00
INF2-5	A2B0215-04	Soil	02/02/22 14:15	02/03/22 16:00
INF1-3 (2/3/22)	A2B0215-05	Soil	02/03/22 09:20	02/03/22 16:00
INF1-5 (2/3/22)	A2B0215-06	Soil	02/03/22 09:40	02/03/22 16:00
INF2-3 (2/3/22)	A2B0215-07	Soil	02/03/22 10:10	02/03/22 16:00
INF2-5 (2/3/22)	A2B0215-08	Soil	02/03/22 10:30	02/03/22 16:00

Apex Laboratories

Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

ANALYTICAL SAMPLE RESULTS

Organochlorine Pesticides by EPA 8081B

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF1-3 (2/3/22) (A2B0215-05)				**Matrix: Soil**		**Batch: 22B0539**		
Aldrin	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
alpha-BHC	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
beta-BHC	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
delta-BHC	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
gamma-BHC (Lindane)	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
cis-Chlordane	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
trans-Chlordane	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
4,4'-DDD	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
4,4'-DDE	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
4,4'-DDT	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Dieldrin	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Endosulfan I	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Endosulfan II	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Endosulfan sulfate	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Endrin	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Endrin Aldehyde	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Endrin ketone	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Heptachlor	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Heptachlor epoxide	ND	---	1.17	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Methoxychlor	ND	---	3.50	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Chlordane (Technical)	ND	---	35.0	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Toxaphene (Total)	ND	---	35.0	ug/kg dry	1	02/18/22 15:18	EPA 8081B	
Surrogate: 2,4,5,6-TCMX (Surr)		*Recovery:*	*61 %*	*Limits: 42-129 %*	*1*	*02/18/22 15:18*	*EPA 8081B*	
Decachlorobiphenyl (Surr)			*71 %*	*55-130 %*	*1*	*02/18/22 15:18*	*EPA 8081B*	
INF1-5 (2/3/22) (A2B0215-06)				**Matrix: Soil**		**Batch: 22B0539**		
Aldrin	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
alpha-BHC	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
beta-BHC	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
delta-BHC	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
gamma-BHC (Lindane)	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
cis-Chlordane	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
trans-Chlordane	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

APEX LABORATORIES

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

ANALYTICAL SAMPLE RESULTS

Organochlorine Pesticides by EPA 8081B

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF1-5 (2/3/22) (A2B0215-06)				**Matrix: Soil**		**Batch: 22B0539**		
4,4'-DDD	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
4,4'-DDE	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
4,4'-DDT	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Dieldrin	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Endosulfan I	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Endosulfan II	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Endosulfan sulfate	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Endrin	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Endrin Aldehyde	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Endrin ketone	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Heptachlor	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Heptachlor epoxide	ND	---	1.26	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Methoxychlor	ND	---	3.79	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Chlordane (Technical)	ND	---	37.9	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Toxaphene (Total)	ND	---	37.9	ug/kg dry	1	02/18/22 15:52	EPA 8081B	
Surrogate: 2,4,5,6-TCMX (Surr)		*Recovery:*	*67 %*	*Limits: 42-129 %*	*1*	*02/18/22 15:52*	*EPA 8081B*	
Decachlorobiphenyl (Surr)			*76 %*	*55-130 %*	*1*	*02/18/22 15:52*	*EPA 8081B*	
INF2-3 (2/3/22) (A2B0215-07)				**Matrix: Soil**		**Batch: 22B0539**		
Aldrin	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
alpha-BHC	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
beta-BHC	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
delta-BHC	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
gamma-BHC (Lindane)	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
cis-Chlordane	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
trans-Chlordane	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
4,4'-DDD	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
4,4'-DDE	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
4,4'-DDT	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Dieldrin	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Endosulfan I	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Endosulfan II	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Endosulfan sulfate	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

ANALYTICAL SAMPLE RESULTS

Organochlorine Pesticides by EPA 8081B

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF2-3 (2/3/22) (A2B0215-07)				**Matrix: Soil**		**Batch: 22B0539**		
Endrin	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Endrin Aldehyde	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Endrin ketone	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Heptachlor	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Heptachlor epoxide	ND	---	1.35	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Methoxychlor	ND	---	4.06	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Chlordane (Technical)	ND	---	40.6	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Toxaphene (Total)	ND	---	40.6	ug/kg dry	1	02/18/22 16:09	EPA 8081B	
Surrogate: 2,4,5,6-TCMX (Surr)		*Recovery:*	*76 %*	*Limits: 42-129 %*	*1*	*02/18/22 16:09*	*EPA 8081B*	
Decachlorobiphenyl (Surr)			*88 %*	*55-130 %*	*1*	*02/18/22 16:09*	*EPA 8081B*	
INF2-5 (2/3/22) (A2B0215-08)				**Matrix: Soil**		**Batch: 22B0539**		
Aldrin	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
alpha-BHC	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
beta-BHC	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
delta-BHC	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
gamma-BHC (Lindane)	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
cis-Chlordane	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
trans-Chlordane	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
4,4'-DDD	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
4,4'-DDE	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
4,4'-DDT	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Dieldrin	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Endosulfan I	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Endosulfan II	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Endosulfan sulfate	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Endrin	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Endrin Aldehyde	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Endrin ketone	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Heptachlor	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Heptachlor epoxide	ND	---	1.38	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Methoxychlor	ND	---	4.13	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Chlordane (Technical)	ND	---	41.3	ug/kg dry	1	02/18/22 16:27	EPA 8081B	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

ANALYTICAL SAMPLE RESULTS

Organochlorine Pesticides by EPA 8081B

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF2-5 (2/3/22) (A2B0215-08)				**Matrix: Soil**		**Batch: 22B0539**		
Toxaphene (Total)	ND	---	41.3	ug/kg dry	1	02/18/22 16:27	EPA 8081B	
Surrogate: 2,4,5,6-TCMX (Surr)		*Recovery:*	*71 %*	*Limits: 42-129 %*	*1*	*02/18/22 16:27*	*EPA 8081B*	
Decachlorobiphenyl (Surr)			*87 %*	*55-130 %*	*1*	*02/18/22 16:27*	*EPA 8081B*	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

ANALYTICAL SAMPLE RESULTS

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF1-3 (2/3/22) (A2B0215-05RE1)				**Matrix: Soil**		**Batch: 22B0538**		
Azinphos methyl (Guthion)	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Chlorpyrifos	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Coumaphos	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Demeton O	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Demeton S	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Diazinon	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Dichlorvos	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Dimethoate	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Disulfoton	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
EPN	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Ethoprop	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Fensulfothion	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Fenthion	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Malathion	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Merphos	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Methyl parathion	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Mevinphos (Phosdrin)	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Monocrotophos	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Naled (Dibrom)	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Parathion, ethyl	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Phorate	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Ronnel (Fenchlorphos)	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Sulfotep	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Sulprofos (Bolstar)	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
TEPP	ND	---	235	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Tetrachlorvinphos (Rabon)	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Tokuthion (Prothiofos)	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Trichloronate	ND	---	58.9	ug/kg dry	1	02/15/22 18:18	EPA 8270E OPPs	
Surrogate: Tributyl phosphate (Surr)		*Recovery:*	*47 %*	*Limits: 10-136 %*	*1*	*02/15/22 18:18*	*EPA 8270E OPPs*	
Triphenyl phosphate (Surr)			*52 %*	*34-121 %*	*1*	*02/15/22 18:18*	*EPA 8270E OPPs*	
INF1-5 (2/3/22) (A2B0215-06)				**Matrix: Soil**		**Batch: 22B0538**		
Azinphos methyl (Guthion)	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

ANALYTICAL SAMPLE RESULTS

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF1-5 (2/3/22) (A2B0215-06)				**Matrix: Soil**		**Batch: 22B0538**		
Chlorpyrifos	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Coumaphos	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Demeton O	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Demeton S	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Diazinon	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Dichlorvos	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Dimethoate	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Disulfoton	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
EPN	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Ethoprop	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Fensulfothion	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Fenthion	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Malathion	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Merphos	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Methyl parathion	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Mevinphos (Phosdrin)	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Monocrotophos	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Naled (Dibrom)	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Parathion, ethyl	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Phorate	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Ronnel (Fenchlorphos)	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Sulfotep	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Sulprofos (Bolstar)	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
TEPP	ND	---	251	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Tetrachlorvinphos (Rabon)	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Tokuthion (Prothiofos)	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Trichloronate	ND	---	62.8	ug/kg dry	1	02/15/22 19:27	EPA 8270E OPPs	
Surrogate: Tributyl phosphate (Surr)		*Recovery:*	*62 %*	*Limits: 10-136 %*	*1*	*02/15/22 19:27*	*EPA 8270E OPPs*	
Triphenyl phosphate (Surr)			*68 %*	*34-121 %*	*1*	*02/15/22 19:27*	*EPA 8270E OPPs*	
INF2-3 (2/3/22) (A2B0215-07)				**Matrix: Soil**		**Batch: 22B0538**		
Azinphos methyl (Guthion)	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Chlorpyrifos	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

ANALYTICAL SAMPLE RESULTS

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF2-3 (2/3/22) (A2B0215-07)				**Matrix: Soil**			**Batch: 22B0538**	
Coumaphos	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Demeton O	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Demeton S	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Diazinon	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Dichlorvos	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Dimethoate	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Disulfoton	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
EPN	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Ethoprop	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Fensulfothion	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Fenthion	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Malathion	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Merphos	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Methyl parathion	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Mevinphos (Phosdrin)	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Monocrotophos	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Naled (Dibrom)	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Parathion, ethyl	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Phorate	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Ronnel (Fenchlorphos)	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Sulfotep	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Sulprofos (Bolstar)	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
TEPP	ND	---	277	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Tetrachlorvinphos (Rabon)	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Tokuthion (Prothiofos)	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Trichloronate	ND	---	69.2	ug/kg dry	1	02/15/22 20:02	EPA 8270E OPPs	
Surrogate: Tributyl phosphate (Surr)		*Recovery:*	*71 %*	*Limits: 10-136 %*	*1*	*02/15/22 20:02*	*EPA 8270E OPPs*	
Triphenyl phosphate (Surr)			*69 %*	*34-121 %*	*1*	*02/15/22 20:02*	*EPA 8270E OPPs*	
INF2-5 (2/3/22) (A2B0215-08)				**Matrix: Soil**			**Batch: 22B0538**	
Azinphos methyl (Guthion)	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Chlorpyrifos	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Coumaphos	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

ANALYTICAL SAMPLE RESULTS

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF2-5 (2/3/22) (A2B0215-08)				**Matrix: Soil**		**Batch: 22B0538**		
Demeton O	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Demeton S	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Diazinon	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Dichlorvos	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Dimethoate	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Disulfoton	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
EPN	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Ethoprop	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Fensulfothion	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Fenthion	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Malathion	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Merphos	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Methyl parathion	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Mevinphos (Phosdrin)	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Monocrotophos	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Naled (Dibrom)	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Parathion, ethyl	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Phorate	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Ronnel (Fenchlorphos)	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Sulfotep	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Sulprofos (Bolstar)	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
TEPP	ND	---	275	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Tetrachlorvinphos (Rabon)	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Tokuthion (Prothiofos)	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Trichloronate	ND	---	68.7	ug/kg dry	1	02/15/22 17:08	EPA 8270E OPPs	
Surrogate: Tributyl phosphate (Surr)			*Recovery: 74 %*	*Limits: 10-136 %*	*1*	*02/15/22 17:08*	*EPA 8270E OPPs*	
Triphenyl phosphate (Surr)			*69 %*	*34-121 %*	*1*	*02/15/22 17:08*	*EPA 8270E OPPs*	

Apex Laboratories

Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

ANALYTICAL SAMPLE RESULTS

Percent Dry Weight

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF1-3 (2/3/22) (A2B0215-05)				**Matrix: Soil**		**Batch: 22B0266**		
% Solids	**80.1**	---	1.00	%	1	02/08/22 10:32	EPA 8000D	
INF1-5 (2/3/22) (A2B0215-06)				**Matrix: Soil**		**Batch: 22B0266**		
% Solids	**74.3**	---	1.00	%	1	02/08/22 10:32	EPA 8000D	
INF2-3 (2/3/22) (A2B0215-07)				**Matrix: Soil**		**Batch: 22B0266**		
% Solids	**71.8**	---	1.00	%	1	02/08/22 10:32	EPA 8000D	
INF2-5 (2/3/22) (A2B0215-08)				**Matrix: Soil**		**Batch: 22B0266**		
% Solids	**69.7**	---	1.00	%	1	02/08/22 10:32	EPA 8000D	

Apex Laboratories

Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

Weck Laboratories, Inc.

ANALYTICAL SAMPLE RESULTS (Subcontracted)

Chlorinated Herbicides by GC/ECD

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF1-3 (A2B0215-01)				**Matrix: Soil**		**Batch: W2B0841**		
Batch: W2B0841								
2,4-D	ND	---	0.18	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
2,4-DB	ND	---	0.35	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
2,4,5-T	ND	---	0.089	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
2,4,5-TP (Silvex)	ND	---	0.089	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
Dalapon	ND	---	0.18	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
Dicamba	ND	---	0.18	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
Dichloroprop	ND	---	0.18	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
Dinoseb	ND	---	0.089	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
MCPA	ND	---	18	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
MCPP	ND	---	18	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
Pentachlorophenol	ND	---	0.089	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
Picloram	ND	---	0.089	mg/kg dry	1	02/27/22 18:40	EPA 8151A	M-02
Batch: W2B0841								
Surrogate: 2,4-DCAA		*Recovery: 61 %*		*Limits: 13-119 %*	*1*	*02/27/22 18:40*	*EPA 8151A*	
INF1-5 (A2B0215-02)				**Matrix: Soil**		**Batch: W2B0841**		
Batch: W2B0841								
2,4-D	ND	---	0.20	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
2,4-DB	ND	---	0.39	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
2,4,5-T	ND	---	0.098	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
2,4,5-TP (Silvex)	ND	---	0.098	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
Dalapon	ND	---	0.20	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
Dicamba	ND	---	0.20	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
Dichloroprop	ND	---	0.20	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
Dinoseb	ND	---	0.098	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
MCPA	ND	---	20	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
MCPP	ND	---	20	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
Pentachlorophenol	ND	---	0.098	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
Picloram	ND	---	0.098	mg/kg dry	1	02/27/22 19:12	EPA 8151A	M-02
Batch: W2B0841								
Surrogate: 2,4-DCAA		*Recovery: 58 %*		*Limits: 13-119 %*	*1*	*02/27/22 19:12*	*EPA 8151A*	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

Weck Laboratories, Inc.

ANALYTICAL SAMPLE RESULTS (Subcontracted)

Chlorinated Herbicides by GC/ECD

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF2-3 (A2B0215-03)				**Matrix: Soil**		**Batch: W2B0841**		
Batch: W2B0841								
2,4-D	ND	---	0.19	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
2,4-DB	ND	---	0.38	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
2,4,5-T	ND	---	0.095	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
2,4,5-TP (Silvex)	ND	---	0.095	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
Dalapon	ND	---	0.19	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
Dicamba	ND	---	0.19	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
Dichloroprop	ND	---	0.19	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
Dinoseb	ND	---	0.095	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
MCPA	ND	---	19	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
MCPP	ND	---	19	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
Pentachlorophenol	ND	---	0.095	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
Picloram	ND	---	0.095	mg/kg dry	1	02/27/22 19:43	EPA 8151A	M-02
Batch: W2B0841								
Surrogate: 2,4-DCAA			*Recovery: 59 %*	*Limits: 13-119 %*	*1*	*02/27/22 19:43*	*EPA 8151A*	
INF2-5 (A2B0215-04)				**Matrix: Soil**		**Batch: W2B0841**		
Batch: W2B0841								
2,4-D	ND	---	0.20	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
2,4-DB	ND	---	0.40	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
2,4,5-T	ND	---	0.099	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
2,4,5-TP (Silvex)	ND	---	0.099	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
Dalapon	ND	---	0.20	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
Dicamba	ND	---	0.20	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
Dichloroprop	ND	---	0.20	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
Dinoseb	ND	---	0.099	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
MCPA	ND	---	20	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
MCPP	ND	---	20	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
Pentachlorophenol	ND	---	0.099	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
Picloram	ND	---	0.099	mg/kg dry	1	02/27/22 20:15	EPA 8151A	M-02
Batch: W2B0841								

Apex Laboratories

Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

Weck Laboratories, Inc.

ANALYTICAL SAMPLE RESULTS (Subcontracted)

Chlorinated Herbicides by GC/ECD

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF2-5 (A2B0215-04)				**Matrix: Soil**		**Batch: W2B0841**		
Surrogate: 2,4-DCAA			*Recovery: 59 %*	*Limits: 13-119 %*	*1*	*02/27/22 20:15*	*EPA 8151A*	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

Weck Laboratories, Inc.

ANALYTICAL SAMPLE RESULTS (Subcontracted)

Conventional Chemistry/Physical Parameters by APHA/EPA/ASTM Methods

Analyte	Sample Result	Detection Limit	Reporting Limit	Units	Dilution	Date Analyzed	Method Ref.	Notes
INF1-3 (A2B0215-01)				**Matrix: Soil**		**Batch: W2B0974**		
Batch: W2B0974								
% Solids	**79.5**	---	0.100	% by Weight	1	02/15/22 18:00	EPA 160.3M	
INF1-5 (A2B0215-02)				**Matrix: Soil**		**Batch: W2B0974**		
Batch: W2B0974								
% Solids	**73.5**	---	0.100	% by Weight	1	02/15/22 18:00	EPA 160.3M	
INF2-3 (A2B0215-03)				**Matrix: Soil**		**Batch: W2B0974**		
Batch: W2B0974								
% Solids	**71.5**	---	0.100	% by Weight	1	02/15/22 18:00	EPA 160.3M	
INF2-5 (A2B0215-04)				**Matrix: Soil**		**Batch: W2B0974**		
Batch: W2B0974								
% Solids	**73.7**	---	0.100	% by Weight	1	02/15/22 18:00	EPA 160.3M	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

QUALITY CONTROL (QC) SAMPLE RESULTS

Organochlorine Pesticides by EPA 8081B

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0539 - EPA 3546							Soil					
Blank (22B0539-BLK1)			Prepared: 02/15/22 07:38 Analyzed: 02/18/22 14:43									
EPA 8081B												
Aldrin	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
alpha-BHC	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
beta-BHC	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
delta-BHC	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
gamma-BHC (Lindane)	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
cis-Chlordane	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
trans-Chlordane	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
4,4'-DDD	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
4,4'-DDE	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
4,4'-DDT	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Dieldrin	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Endosulfan I	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Endosulfan II	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Endosulfan sulfate	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Endrin	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Endrin Aldehyde	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Endrin ketone	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Heptachlor	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Heptachlor epoxide	ND	---	0.909	ug/kg wet	1	---	---	---	---	---	---	
Methoxychlor	ND	---	2.73	ug/kg wet	1	---	---	---	---	---	---	
Chlordane (Technical)	ND	---	27.3	ug/kg wet	1	---	---	---	---	---	---	
Toxaphene (Total)	ND	---	27.3	ug/kg wet	1	---	---	---	---	---	---	
Surr: 2,4,5,6-TCMX (Surr)			*Recovery: 86 %*			*Limits: 42-129 %*			*Dilution: 1x*			
Decachlorobiphenyl (Surr)			*105 %*			*55-130 %*			*"*			
LCS (22B0539-BS1)			Prepared: 02/15/22 07:38 Analyzed: 02/18/22 15:01									
EPA 8081B												
Aldrin	42.4	---	1.00	ug/kg wet	1	50.0	---	85	45-136%	---	---	
alpha-BHC	49.7	---	1.00	ug/kg wet	1	50.0	---	99	45-137%	---	---	
beta-BHC	45.5	---	1.00	ug/kg wet	1	50.0	---	91	50-136%	---	---	
delta-BHC	54.2	---	1.00	ug/kg wet	1	50.0	---	108	47-139%	---	---	
gamma-BHC (Lindane)	49.4	---	1.00	ug/kg wet	1	50.0	---	99	49-135%	---	---	Q-41
cis-Chlordane	45.3	---	1.00	ug/kg wet	1	50.0	---	91	54-133%	---	---	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

APEX LABORATORIES

ANALYTICAL REPORT

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

QUALITY CONTROL (QC) SAMPLE RESULTS

Organochlorine Pesticides by EPA 8081B

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0539 - EPA 3546							**Soil**					
LCS (22B0539-BS1)			Prepared: 02/15/22 07:38		Analyzed: 02/18/22 15:01							
trans-Chlordane	46.8	---	1.00	ug/kg wet	1	50.0	---	94	53-135%	---	---	
4,4'-DDD	55.3	---	1.00	ug/kg wet	1	50.0	---	111	56-139%	---	---	Q-41
4,4'-DDE	51.8	---	1.00	ug/kg wet	1	50.0	---	104	56-134%	---	---	Q-41
4,4'-DDT	57.4	---	1.00	ug/kg wet	1	50.0	---	115	50-141%	---	---	Q-41
Dieldrin	50.4	---	1.00	ug/kg wet	1	50.0	---	101	56-136%	---	---	
Endosulfan I	48.2	---	1.00	ug/kg wet	1	50.0	---	96	53-132%	---	---	
Endosulfan II	51.9	---	1.00	ug/kg wet	1	50.0	---	104	53-134%	---	---	
Endosulfan sulfate	53.4	---	1.00	ug/kg wet	1	50.0	---	107	55-136%	---	---	Q-41
Endrin	55.3	---	1.00	ug/kg wet	1	50.0	---	111	57-140%	---	---	Q-41
Endrin Aldehyde	49.4	---	1.00	ug/kg wet	1	50.0	---	99	35-137%	---	---	
Endrin ketone	54.6	---	1.00	ug/kg wet	1	50.0	---	109	55-136%	---	---	Q-41
Heptachlor	50.5	---	1.00	ug/kg wet	1	50.0	---	101	47-136%	---	---	Q-41
Heptachlor epoxide	48.2	---	1.00	ug/kg wet	1	50.0	---	96	52-136%	---	---	
Methoxychlor	55.2	---	3.00	ug/kg wet	1	50.0	---	110	52-143%	---	---	Q-41
Surr: 2,4,5,6-TCMX (Surr)			*Recovery: 85 %*		*Limits: 42-129 %*				*Dilution: 1x*			
Decachlorobiphenyl (Surr)			*102 %*		*55-130 %*				*"*			
Duplicate (22B0539-DUP1)			Prepared: 02/15/22 07:38		Analyzed: 02/18/22 15:35							
QC Source Sample: INF1-3 (2/3/22) (A2B0215-05)												
EPA 8081B												
Aldrin	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
alpha-BHC	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
beta-BHC	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
delta-BHC	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
gamma-BHC (Lindane)	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
cis-Chlordane	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
trans-Chlordane	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
4,4'-DDD	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
4,4'-DDE	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
4,4'-DDT	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Dieldrin	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Endosulfan I	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Endosulfan II	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Endosulfan sulfate	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

QUALITY CONTROL (QC) SAMPLE RESULTS

Organochlorine Pesticides by EPA 8081B

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0539 - EPA 3546							**Soil**					
Duplicate (22B0539-DUP1)			Prepared: 02/15/22 07:38		Analyzed: 02/18/22 15:35							
QC Source Sample: INF1-3 (2/3/22) (A2B0215-05)												
Endrin	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Endrin Aldehyde	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Endrin ketone	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Heptachlor	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Heptachlor epoxide	ND	---	1.22	ug/kg dry	1	---	ND	---	---	---	30%	
Methoxychlor	ND	---	3.65	ug/kg dry	1	---	ND	---	---	---	30%	
Chlordane (Technical)	ND	---	36.5	ug/kg dry	1	---	ND	---	---	---	30%	
Toxaphene (Total)	ND	---	36.5	ug/kg dry	1	---	ND	---	---	---	30%	
Surr: 2,4,5,6-TCMX (Surr)			*Recovery: 67 %*		*Limits: 42-129 %*				*Dilution: 1x*			
Decachlorobiphenyl (Surr)			*81 %*		*55-130 %*				*"*			
Matrix Spike (22B0539-MS1)			Prepared: 02/15/22 07:38		Analyzed: 02/18/22 16:44							
QC Source Sample: INF2-5 (2/3/22) (A2B0215-08)												
EPA 8081B												
Aldrin	53.8	---	1.35	ug/kg dry	1	67.3	ND	80	45-136%	---	---	
alpha-BHC	60.5	---	1.35	ug/kg dry	1	67.3	ND	90	45-137%	---	---	
beta-BHC	56.3	---	1.35	ug/kg dry	1	67.3	ND	84	50-136%	---	---	
delta-BHC	64.7	---	1.35	ug/kg dry	1	67.3	ND	96	47-139%	---	---	
gamma-BHC (Lindane)	62.0	---	1.35	ug/kg dry	1	67.3	ND	92	49-135%	---	---	Q-41
cis-Chlordane	56.4	---	1.35	ug/kg dry	1	67.3	ND	84	54-133%	---	---	
trans-Chlordane	55.4	---	1.35	ug/kg dry	1	67.3	ND	82	53-135%	---	---	
4,4'-DDD	67.7	---	1.35	ug/kg dry	1	67.3	ND	101	56-139%	---	---	Q-41
4,4'-DDE	63.0	---	1.35	ug/kg dry	1	67.3	ND	94	56-134%	---	---	Q-41
4,4'-DDT	74.6	---	1.35	ug/kg dry	1	67.3	ND	111	50-141%	---	---	Q-41
Dieldrin	62.2	---	1.35	ug/kg dry	1	67.3	ND	92	56-136%	---	---	
Endosulfan I	61.7	---	1.35	ug/kg dry	1	67.3	ND	92	53-132%	---	---	
Endosulfan II	62.1	---	1.35	ug/kg dry	1	67.3	ND	92	53-134%	---	---	
Endosulfan sulfate	66.2	---	1.35	ug/kg dry	1	67.3	ND	98	55-136%	---	---	Q-41
Endrin	68.6	---	1.35	ug/kg dry	1	67.3	ND	102	57-140%	---	---	Q-41
Endrin Aldehyde	62.7	---	1.35	ug/kg dry	1	67.3	ND	93	35-137%	---	---	
Endrin ketone	70.9	---	1.35	ug/kg dry	1	67.3	ND	105	55-136%	---	---	Q-41
Heptachlor	65.2	---	1.35	ug/kg dry	1	67.3	ND	97	47-136%	---	---	Q-41
Heptachlor epoxide	57.5	---	1.35	ug/kg dry	1	67.3	ND	85	52-136%	---	---	

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

QUALITY CONTROL (QC) SAMPLE RESULTS

Organochlorine Pesticides by EPA 8081B

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0539 - EPA 3546							**Soil**					
Matrix Spike (22B0539-MS1)			Prepared: 02/15/22 07:38		Analyzed: 02/18/22 16:44							
QC Source Sample: INF2-5 (2/3/22) (A2B0215-08)												
Methoxychlor	72.7	---	4.04	ug/kg dry	1	67.3	ND	108	52-143%	---	---	Q-41
Surr: 2,4,5,6-TCMX (Surr)			*Recovery: 77 %*		*Limits: 42-129 %*			*Dilution: 1x*				
Decachlorobiphenyl (Surr)			*95 %*		*55-130 %*			*"*				

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

QUALITY CONTROL (QC) SAMPLE RESULTS

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0538 - EPA 3546							**Soil**					
Blank (22B0538-BLK1)			Prepared: 02/15/22 07:36		Analyzed: 02/15/22 14:03							
EPA 8270E OPPs												
Azinphos methyl (Guthion)	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Chlorpyrifos	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Coumaphos	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Demeton O	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Demeton S	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Diazinon	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Dichlorvos	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Dimethoate	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Disulfoton	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
EPN	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Ethoprop	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Fensulfothion	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Fenthion	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Malathion	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Merphos	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Methyl parathion	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Mevinphos (Phosdrin)	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Monocrotophos	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Naled (Dibrom)	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Parathion, ethyl	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Phorate	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Ronnel (Fenchlorphos)	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Sulfotep	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Sulprofos (Bolstar)	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
TEPP	ND	---	182	ug/kg wet	1	---	---	---	---	---	---	
Tetrachlorvinphos (Rabon)	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Tokuthion (Prothiofos)	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Trichloronate	ND	---	45.5	ug/kg wet	1	---	---	---	---	---	---	
Surr: Tributyl phosphate (Surr)			*Recovery: 72 %*		*Limits: 10-136 %*			*Dilution: 1x*				
Triphenyl phosphate (Surr)			*87 %*		*34-121 %*			*"*				
LCS (22B0538-BS1)			Prepared: 02/15/22 07:36		Analyzed: 02/15/22 14:38							
EPA 8270E OPPs												

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

APEX LABORATORIES

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

QUALITY CONTROL (QC) SAMPLE RESULTS

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0538 - EPA 3546							**Soil**					
LCS (22B0538-BS1)			Prepared: 02/15/22 07:36		Analyzed: 02/15/22 14:38							
Azinphos methyl (Guthion)	395	---	50.0	ug/kg wet	1	400	---	99	38-156%	---	---	
Chlorpyrifos	384	---	50.0	ug/kg wet	1	400	---	96	47-140%	---	---	
Coumaphos	379	---	50.0	ug/kg wet	1	400	---	95	37-160%	---	---	
Demeton O	92.8	---	50.0	ug/kg wet	1	97.6	---	95	66-127%	---	---	
Demeton S	244	---	50.0	ug/kg wet	1	268	---	91	70-121%	---	---	
Diazinon	377	---	50.0	ug/kg wet	1	400	---	94	42-134%	---	---	
Dichlorvos	372	---	50.0	ug/kg wet	1	400	---	93	39-142%	---	---	
Dimethoate	404	---	50.0	ug/kg wet	1	400	---	101	16-139%	---	---	
Disulfoton	355	---	50.0	ug/kg wet	1	400	---	89	28-145%	---	---	
EPN	402	---	50.0	ug/kg wet	1	400	---	101	44-137%	---	---	
Ethoprop	412	---	50.0	ug/kg wet	1	400	---	103	47-128%	---	---	
Fensulfothion	389	---	50.0	ug/kg wet	1	400	---	97	27-147%	---	---	
Fenthion	401	---	50.0	ug/kg wet	1	400	---	100	44-134%	---	---	
Malathion	381	---	50.0	ug/kg wet	1	400	---	95	46-137%	---	---	
Merphos	365	---	50.0	ug/kg wet	1	400	---	91	66-131%	---	---	
Methyl parathion	380	---	50.0	ug/kg wet	1	400	---	95	49-138%	---	---	
Mevinphos (Phosdrin)	407	---	50.0	ug/kg wet	1	400	---	102	12-176%	---	---	
Monocrotophos	465	---	50.0	ug/kg wet	1	400	---	116	10-153%	---	---	
Naled (Dibrom)	427	---	50.0	ug/kg wet	1	400	---	107	10-174%	---	---	
Parathion, ethyl	377	---	50.0	ug/kg wet	1	400	---	94	50-139%	---	---	
Phorate	419	---	50.0	ug/kg wet	1	400	---	105	23-142%	---	---	
Ronnel (Fenchlorphos)	384	---	50.0	ug/kg wet	1	400	---	96	45-138%	---	---	
Sulfotep	438	---	50.0	ug/kg wet	1	400	---	110	52-126%	---	---	
Sulprofos (Bolstar)	374	---	50.0	ug/kg wet	1	400	---	93	48-139%	---	---	
TEPP	301	---	200	ug/kg wet	1	400	---	75	16-126%	---	---	
Tetrachlorvinphos (Rabon)	377	---	50.0	ug/kg wet	1	400	---	94	54-129%	---	---	
Tokuthion (Prothiofos)	382	---	50.0	ug/kg wet	1	400	---	95	45-136%	---	---	
Trichloronate	375	---	50.0	ug/kg wet	1	400	---	94	37-140%	---	---	
Surr: Tributyl phosphate (Surr)			*Recovery: 89 %*		*Limits: 10-136 %*			*Dilution: 1x*				
Triphenyl phosphate (Surr)			*91 %*		*34-121 %*			*"*				
Duplicate (22B0538-DUP1)			Prepared: 02/15/22 07:36		Analyzed: 02/15/22 18:53							

QC Source Sample: INF1-3 (2/3/22) (A2B0215-05RE1)

EPA 8270E OPPs

Apex Laboratories

Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

QUALITY CONTROL (QC) SAMPLE RESULTS

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0538 - EPA 3546							**Soil**					
Duplicate (22B0538-DUP1)			Prepared: 02/15/22 07:36 Analyzed: 02/15/22 18:53									
QC Source Sample: INF1-3 (2/3/22) (A2B0215-05RE1)												
Azinphos methyl (Guthion)	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Chlorpyrifos	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Coumaphos	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Demeton O	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Demeton S	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Diazinon	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Dichlorvos	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Dimethoate	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Disulfoton	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
EPN	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Ethoprop	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Fensulfothion	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Fenthion	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Malathion	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Merphos	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Methyl parathion	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Mevinphos (Phosdrin)	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Monocrotophos	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Naled (Dibrom)	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Parathion, ethyl	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Phorate	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Ronnel (Fenchlorphos)	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Sulfotep	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Sulprofos (Bolstar)	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
TEPP	ND	---	237	ug/kg dry	1	---	ND	---	---	---	30%	
Tetrachlorvinphos (Rabon)	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Tokuthion (Prothiofos)	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Trichloronate	ND	---	59.3	ug/kg dry	1	---	ND	---	---	---	30%	
Surr: Tributyl phosphate (Surr)			*Recovery: 66 %*		*Limits: 10-136 %*				*Dilution: 1x*			
Triphenyl phosphate (Surr)			*65 %*		*34-121 %*				*"*			
Matrix Spike (22B0538-MS1)			Prepared: 02/15/22 07:36 Analyzed: 02/15/22 17:43									
QC Source Sample: INF2-5 (2/3/22) (A2B0215-08)												

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

QUALITY CONTROL (QC) SAMPLE RESULTS

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0538 - EPA 3546							Soil					
Matrix Spike (22B0538-MS1)			Prepared: 02/15/22 07:36 Analyzed: 02/15/22 17:43									
QC Source Sample: INF2-5 (2/3/22) (A2B0215-08)												
EPA 8270E OPPs												
Azinphos methyl (Guthion)	474	---	70.6	ug/kg dry	1	565	ND	84	38-156%	---	---	
Chlorpyrifos	441	---	70.6	ug/kg dry	1	565	ND	78	47-140%	---	---	
Coumaphos	469	---	70.6	ug/kg dry	1	565	ND	83	37-160%	---	---	
Demeton O	91.4	---	70.6	ug/kg dry	1	138	ND	66	66-127%	---	---	
Demeton S	309	---	70.6	ug/kg dry	1	379	ND	82	70-121%	---	---	
Diazinon	389	---	70.6	ug/kg dry	1	565	ND	69	42-134%	---	---	
Dichlorvos	471	---	70.6	ug/kg dry	1	565	ND	83	39-142%	---	---	
Dimethoate	477	---	70.6	ug/kg dry	1	565	ND	84	16-139%	---	---	
Disulfoton	420	---	70.6	ug/kg dry	1	565	ND	74	28-145%	---	---	
EPN	495	---	70.6	ug/kg dry	1	565	ND	88	44-137%	---	---	
Ethoprop	475	---	70.6	ug/kg dry	1	565	ND	84	47-128%	---	---	
Fensulfothion	520	---	70.6	ug/kg dry	1	565	ND	92	27-147%	---	---	
Fenthion	459	---	70.6	ug/kg dry	1	565	ND	81	44-134%	---	---	
Malathion	452	---	70.6	ug/kg dry	1	565	ND	80	46-137%	---	---	
Merphos	409	---	70.6	ug/kg dry	1	565	ND	72	66-131%	---	---	
Methyl parathion	461	---	70.6	ug/kg dry	1	565	ND	82	49-138%	---	---	
Mevinphos (Phosdrin)	478	---	70.6	ug/kg dry	1	565	ND	85	12-176%	---	---	
Monocrotophos	546	---	70.6	ug/kg dry	1	565	ND	97	10-153%	---	---	
Naled (Dibrom)	479	---	70.6	ug/kg dry	1	565	ND	85	10-174%	---	---	
Parathion, ethyl	432	---	70.6	ug/kg dry	1	565	ND	76	50-139%	---	---	
Phorate	501	---	70.6	ug/kg dry	1	565	ND	89	23-142%	---	---	
Ronnel (Fenchlorphos)	438	---	70.6	ug/kg dry	1	565	ND	78	45-138%	---	---	
Sulfotep	492	---	70.6	ug/kg dry	1	565	ND	87	52-126%	---	---	
Sulprofos (Bolstar)	427	---	70.6	ug/kg dry	1	565	ND	76	48-139%	---	---	
TEPP	299	---	283	ug/kg dry	1	565	ND	53	16-126%	---	---	
Tetrachlorvinphos (Rabon)	451	---	70.6	ug/kg dry	1	565	ND	80	54-129%	---	---	
Tokuthion (Prothiofos)	458	---	70.6	ug/kg dry	1	565	ND	81	45-136%	---	---	
Trichloronate	430	---	70.6	ug/kg dry	1	565	ND	76	37-140%	---	---	
Surr: Tributyl phosphate (Surr)			*Recovery: 75 %*		*Limits: 10-136 %*			*Dilution: 1x*				
Triphenyl phosphate (Surr)			*70 %*		*34-121 %*			*"*				

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

QUALITY CONTROL (QC) SAMPLE RESULTS

Percent Dry Weight

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch 22B0266 - Total Solids (Dry Weight)							Soil					
Duplicate (22B0266-DUP1)			Prepared: 02/07/22 13:16		Analyzed: 02/08/22 10:32							
QC Source Sample: Non-SDG (A2B0171-01)												
% Solids	**83.8**	---	1.00	%	1	---	83.5	---	---	0.3	10%	
Duplicate (22B0266-DUP2)			Prepared: 02/07/22 13:16		Analyzed: 02/08/22 10:32							
QC Source Sample: Non-SDG (A2B0194-02)												
% Solids	**85.5**	---	1.00	%	1	---	84.8	---	---	0.8	10%	
Duplicate (22B0266-DUP3)			Prepared: 02/07/22 13:16		Analyzed: 02/08/22 10:32							
QC Source Sample: Non-SDG (A2B0200-01)												
% Solids	**95.3**	---	1.00	%	1	---	94.8	---	---	0.6	10%	
Duplicate (22B0266-DUP4)			Prepared: 02/07/22 18:32		Analyzed: 02/08/22 10:32							
QC Source Sample: Non-SDG (A2B0236-02)												
% Solids	**87.2**	---	1.00	%	1	---	86.5	---	---	0.8	10%	

No Client related Batch QC samples analyzed for this batch. See notes page for more information.

Apex Laboratories

Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

Weck Laboratories, Inc.

QUALITY CONTROL (QC) SAMPLE RESULTS

Chlorinated Herbicides by GC/ECD

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch W2B0841 - EPA 3550/Sonication							**Solid**					
Blank (W2B0841-BLK1)			Prepared: 02/11/22 09:10 Analyzed: 02/27/22 16:34									
EPA 8151A												
2,4-D	ND	---	0.040	mg/kg wet	1	---	---	---	---	---	---	
2,4-DB	ND	---	0.080	mg/kg wet	1	---	---	---	---	---	---	
2,4,5-T	ND	---	0.020	mg/kg wet	1	---	---	---	---	---	---	
2,4,5-TP (Silvex)	ND	---	0.020	mg/kg wet	1	---	---	---	---	---	---	
Dalapon	ND	---	0.040	mg/kg wet	1	---	---	---	---	---	---	
Dicamba	ND	---	0.040	mg/kg wet	1	---	---	---	---	---	---	
Dichloroprop	ND	---	0.040	mg/kg wet	1	---	---	---	---	---	---	
Dinoseb	ND	---	0.020	mg/kg wet	1	---	---	---	---	---	---	
MCPA	ND	---	4.0	mg/kg wet	1	---	---	---	---	---	---	
MCPP	ND	---	4.0	mg/kg wet	1	---	---	---	---	---	---	
Pentachlorophenol	ND	---	0.020	mg/kg wet	1	---	---	---	---	---	---	
Picloram	ND	---	0.020	mg/kg wet	1	---	---	---	---	---	---	
Surr: 2,4-DCAA			*Recovery: 69 %*	*Limits: 13-119 %*				*Dilution: 1x*				
LCS (W2B0841-BS1)			Prepared: 02/11/22 09:10 Analyzed: 02/27/22 17:06									
EPA 8151A												
2,4-D	0.0740	---	0.040	mg/kg wet	1	0.100	---	74	53-130%	---	---	
2,4-DB	0.101	---	0.080	mg/kg wet	1	0.200	---	50	28-119%	---	---	
2,4,5-T	0.0365	---	0.020	mg/kg wet	1	0.0500	---	73	40-108%	---	---	
2,4,5-TP (Silvex)	0.0409	---	0.020	mg/kg wet	1	0.0500	---	82	38-108%	---	---	
Dalapon	0.0586	---	0.040	mg/kg wet	1	0.100	---	59	17-122%	---	---	
Dicamba	0.0651	---	0.040	mg/kg wet	1	0.100	---	65	48-107%	---	---	
Dichloroprop	0.0727	---	0.040	mg/kg wet	1	0.100	---	73	45-117%	---	---	
Dinoseb	ND	---	0.020	mg/kg wet	1	0.0500	---	36	0.1-83%	---	---	
MCPA	6.82	---	4.0	mg/kg wet	1	10.0	---	68	33-107%	---	---	
MCPP	7.23	---	4.0	mg/kg wet	1	10.0	---	72	34-117%	---	---	
Pentachlorophenol	0.0369	---	0.020	mg/kg wet	1	0.0500	---	74	40-102%	---	---	
Picloram	0.0437	---	0.020	mg/kg wet	1	0.0500	---	87	22-139%	---	---	
Surr: 2,4-DCAA			*Recovery: 60 %*	*Limits: 13-119 %*				*Dilution: 1x*				
Matrix Spike (W2B0841-MS1)			Prepared: 02/11/22 09:10 Analyzed: 02/27/22 17:37									

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project:	NuStar Vannex Piezo Install
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number:	019001-008-01
Lake Oswego, OR 97035	Project Manager:	Kurt Harrington

Report ID: A2B0215 - 03 10 22 1001

Weck Laboratories, Inc.

QUALITY CONTROL (QC) SAMPLE RESULTS

Chlorinated Herbicides by GC/ECD

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch W2B0841 - EPA 3550/Sonication							**Solid**					
Matrix Spike (W2B0841-MS1)			Prepared: 02/11/22 09:10 Analyzed: 02/27/22 17:37									
QC Source Sample: A2B0215-01 (A2B0215-01)												
EPA 8151A												
2,4-D	0.293	---	0.18	mg/kg dry	1	0.458	ND	64	21-126%	---	---	M-02
2,4-DB	0.444	---	0.37	mg/kg dry	1	0.917	ND	48	13-133%	---	---	M-02
2,4,5-T	0.135	---	0.092	mg/kg dry	1	0.229	ND	59	17-123%	---	---	M-02
2,4,5-TP (Silvex)	0.144	---	0.092	mg/kg dry	1	0.229	ND	63	15-126%	---	---	M-02
Dalapon	0.232	---	0.18	mg/kg dry	1	0.458	ND	51	9.6-101%	---	---	M-02
Dicamba	0.233	---	0.18	mg/kg dry	1	0.458	ND	51	11-107%	---	---	M-02
Dichloroprop	0.270	---	0.18	mg/kg dry	1	0.458	ND	59	44-133%	---	---	M-02
Dinoseb	ND	---	0.092	mg/kg dry	1	0.229	ND	23	0.1-72%	---	---	M-02
MCPA	24.1	---	18	mg/kg dry	1	45.8	ND	53	23-123%	---	---	M-02
MCPP	26.9	---	18	mg/kg dry	1	45.8	ND	59	24-120%	---	---	M-02
Pentachlorophenol	ND	---	0.092	mg/kg dry	1	0.229	ND	19	10-103%	---	---	M-02
Picloram	0.165	---	0.092	mg/kg dry	1	0.229	ND	72	17-155%	---	---	M-02
Surr: 2,4-DCAA			*Recovery: 65 %*		*Limits: 13-119 %*				*Dilution: 1x*			
Matrix Spike Dup (W2B0841-MSD1)			Prepared: 02/11/22 09:10 Analyzed: 02/27/22 18:08									
QC Source Sample: A2B0215-01 (A2B0215-01)												
EPA 8151A												
2,4-D	0.401	---	0.19	mg/kg dry	1	0.465	ND	86	21-126%	**31**	**25%**	M-02, R-02
2,4-DB	0.599	---	0.37	mg/kg dry	1	0.929	ND	64	13-133%	**30**	**25%**	M-02, R-02
2,4,5-T	0.179	---	0.093	mg/kg dry	1	0.232	ND	77	17-123%	**28**	**25%**	M-02, R-02
2,4,5-TP (Silvex)	0.195	---	0.093	mg/kg dry	1	0.232	ND	84	15-126%	**31**	**25%**	M-02, R-02
Dalapon	0.238	---	0.19	mg/kg dry	1	0.465	ND	51	9.6-101%	3	25%	M-02
Dicamba	0.289	---	0.19	mg/kg dry	1	0.465	ND	62	11-107%	22	25%	M-02
Dichloroprop	0.350	---	0.19	mg/kg dry	1	0.465	ND	75	44-133%	**26**	**25%**	M-02, R-02
Dinoseb	0.0956	---	0.093	mg/kg dry	1	0.232	ND	41	0.1-72%	**56**	**25%**	M-02, R-02
MCPA	30.9	---	19	mg/kg dry	1	46.5	ND	67	23-123%	25	25%	M-02
MCPP	39.2	---	19	mg/kg dry	1	46.5	ND	84	24-120%	**37**	**25%**	M-02, R-02
Pentachlorophenol	ND	---	0.093	mg/kg dry	1	0.232	ND	35	10-103%	**62**	**25%**	M-02, R-02
Picloram	0.175	---	0.093	mg/kg dry	1	0.232	ND	75	17-155%	6	25%	M-02

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

Weck Laboratories, Inc.

QUALITY CONTROL (QC) SAMPLE RESULTS

Chlorinated Herbicides by GC/ECD

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch W2B0841 - EPA 3550/Sonication							**Solid**					
Matrix Spike Dup (W2B0841-MSD1)				Prepared: 02/11/22 09:10 Analyzed: 02/27/22 18:08								
QC Source Sample: A2B0215-01 (A2B0215-01)												
Surr: 2,4-DCAA				*Recovery: 79 %*	*Limits: 13-119 %*		*Dilution: 1x*					

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

Weck Laboratories, Inc.

QUALITY CONTROL (QC) SAMPLE RESULTS

Conventional Chemistry/Physical Parameters by APHA/EPA/ASTM Methods

Analyte	Result	Detection Limit	Reporting Limit	Units	Dilution	Spike Amount	Source Result	% REC	% REC Limits	RPD	RPD Limit	Notes
Batch W2B0974 - _NONE (METALS)							Solid					
Duplicate (W2B0974-DUP1)			Prepared: 02/14/22 11:48		Analyzed: 02/15/22 18:00							
QC Source Sample: Non-SDG (2A20064-01)												
% Solids	**34.2**	---	0.100	% by Weight	1	---	31.7	---	---	7	20%	

Apex Laboratories

Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

SAMPLE PREPARATION INFORMATION

Organochlorine Pesticides by EPA 8081B

Prep: EPA 3546

Lab Number	Matrix	Method	Sampled	Prepared	Sample Initial/Final	Default Initial/Final	RL Prep Factor
Batch: 22B0539							
A2B0215-05	Soil	EPA 8081B	02/03/22 09:20	02/15/22 07:38	10.7g/5mL	10g/5mL	0.94
A2B0215-06	Soil	EPA 8081B	02/03/22 09:40	02/15/22 07:38	10.66g/5mL	10g/5mL	0.94
A2B0215-07	Soil	EPA 8081B	02/03/22 10:10	02/15/22 07:38	10.28g/5mL	10g/5mL	0.97
A2B0215-08	Soil	EPA 8081B	02/03/22 10:30	02/15/22 07:38	10.42g/5mL	10g/5mL	0.96

Organophosphorous Pesticides (OPPs) by EPA 8270E (GC/MS)

Prep: EPA 3546

Lab Number	Matrix	Method	Sampled	Prepared	Sample Initial/Final	Default Initial/Final	RL Prep Factor
Batch: 22B0538							
A2B0215-05RE1	Soil	EPA 8270E OPPs	02/03/22 09:20	02/15/22 07:36	10.6g/5mL	10g/5mL	0.94
A2B0215-06	Soil	EPA 8270E OPPs	02/03/22 09:40	02/15/22 07:36	10.72g/5mL	10g/5mL	0.93
A2B0215-07	Soil	EPA 8270E OPPs	02/03/22 10:10	02/15/22 07:36	10.06g/5mL	10g/5mL	0.99
A2B0215-08	Soil	EPA 8270E OPPs	02/03/22 10:30	02/15/22 07:36	10.44g/5mL	10g/5mL	0.96

Percent Dry Weight

Prep: Total Solids (Dry Weight)

Lab Number	Matrix	Method	Sampled	Prepared	Sample Initial/Final	Default Initial/Final	RL Prep Factor
Batch: 22B0266							
A2B0215-05	Soil	EPA 8000D	02/03/22 09:20	02/07/22 18:32			NA
A2B0215-06	Soil	EPA 8000D	02/03/22 09:40	02/07/22 18:32			NA
A2B0215-07	Soil	EPA 8000D	02/03/22 10:10	02/07/22 18:32			NA
A2B0215-08	Soil	EPA 8000D	02/03/22 10:30	02/07/22 18:32			NA

Apex Laboratories

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: OR100062

ANALYTICAL REPORT

GeoEngineers	Project: NuStar Vannex Piezo Install	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: 019001-008-01	Report ID:
Lake Oswego, OR 97035	Project Manager: Kurt Harrington	A2B0215 - 03 10 22 1001

Weck Laboratories, Inc.

SAMPLE PREPARATION INFORMATION

Chlorinated Herbicides by GC/ECD

Prep: EPA 3550/Sonication

Lab Number	Matrix	Method	Sampled	Prepared	Sample Initial/Final	Default Initial/Final	RL Prep Factor
Batch: W2B0841							
A2B0215-01	Soil	EPA 8151A	02/02/22 10:45	02/11/22 09:10	8.51g/10ml	30g/10ml	3.53
A2B0215-02	Soil	EPA 8151A	02/02/22 11:15	02/11/22 09:10	8.36g/10ml	30g/10ml	3.59
A2B0215-03	Soil	EPA 8151A	02/02/22 13:50	02/11/22 09:10	8.88g/10ml	30g/10ml	3.38
A2B0215-04	Soil	EPA 8151A	02/02/22 14:15	02/11/22 09:10	8.21g/10ml	30g/10ml	3.65

Conventional Chemistry/Physical Parameters by APHA/EPA/ASTM Methods

Prep: _NONE (METALS)

Lab Number	Matrix	Method	Sampled	Prepared	Sample Initial/Final	Default Initial/Final	RL Prep Factor
Batch: W2B0974							
A2B0215-01	Soil	EPA 160.3M	02/02/22 10:45	02/14/22 11:48	1g/1ml	1g/1ml	NA
A2B0215-02	Soil	EPA 160.3M	02/02/22 11:15	02/14/22 11:48	1g/1ml	1g/1ml	NA
A2B0215-03	Soil	EPA 160.3M	02/02/22 13:50	02/14/22 11:48	1g/1ml	1g/1ml	NA
A2B0215-04	Soil	EPA 160.3M	02/02/22 14:15	02/14/22 11:48	1g/1ml	1g/1ml	NA

Apex Laboratories

Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

QUALIFIER DEFINITIONS

Client Sample and Quality Control (QC) Sample Qualifier Definitions:

Apex Laboratories

Q-41 Estimated Results. Recovery of Continuing Calibration Verification sample above upper control limit for this analyte. Results are likely biased high.

Weck Laboratories, Inc.

M-02 Due to the nature of matrix interferences, sample was diluted prior to preparation. The MDL and MRL were raised due to the dilution.

R-02 The RPD was outside of QC acceptance limits due to possible matrix interference.

Apex Laboratories

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

REPORTING NOTES AND CONVENTIONS:

Abbreviations:

DET Analyte DETECTED at or above the detection or reporting limit.

ND Analyte NOT DETECTED at or above the detection or reporting limit.

NR Result Not Reported

RPD Relative Percent Difference. RPDs for Matrix Spikes and Matrix Spike Duplicates are based on concentration, not recovery.

Detection Limits: Limit of Detection (LOD)

Limits of Detection (LODs) are normally set at a level of one half the validated Limit of Quantitation (LOQ).
If no value is listed ('-----'), then the data has not been evaluated below the Reporting Limit.

Reporting Limits: Limit of Quantitation (LOQ)

Validated Limits of Quantitation (LOQs) are reported as the Reporting Limits for all analyses where the LOQ, MRL, PQL or CRL are requested. The LOQ represents a level at or above the low point of the calibration curve, that has been validated according to Apex Laboratories' comprehensive LOQ policies and procedures.

Reporting Conventions:

Basis: Results for soil samples are generally reported on a 100% dry weight basis.
The Result Basis is listed following the units as " dry", " wet", or " " (blank) designation.

" dry" Sample results and Reporting Limits are reported on a dry weight basis. (i.e. "ug/kg dry")
See Percent Solids section for details of dry weight analysis.

" wet" Sample results and Reporting Limits for this analysis are normally dry weight corrected, but have not been modified in this case.

" " Results without 'wet' or 'dry' designation are not normally dry weight corrected. These results are considered 'As Received'.

QC Source:

In cases where there is insufficient sample provided for Sample Duplicates and/or Matrix Spikes, a Lab Control Sample Duplicate (LCS Dup) may be analyzed to demonstrate accuracy and precision of the extraction batch.

Non-Client Batch QC Samples (Duplicates and Matrix Spike/Duplicates) may not be included in this report. Please request a Full QC report if this data is required.

Miscellaneous Notes:

" --- " QC results are not applicable. For example, % Recoveries for Blanks and Duplicates, % RPD for Blanks, Blank Spikes and Matrix Spikes, etc.

" *** " Used to indicate a possible discrepancy with the Sample and Sample Duplicate results when the %RPD is not available. In this case, either the Sample or the Sample Duplicate has a reportable result for this analyte, while the other is Non Detect (ND).

Blanks:

Standard practice is to evaluate the results from Blank QC Samples down to a level equal to ½ the Reporting Limit (RL).
-For Blank hits falling between ½ the RL and the RL (J flagged hits), the associated sample and QC data will receive a 'B-02' qualifier.
-For Blank hits above the RL, the associated sample and QC data will receive a 'B' qualifier, per Apex Laboratories' Blank Policy.
For further details, please request a copy of this document.

Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

REPORTING NOTES AND CONVENTIONS (Cont.):

Blanks (Cont.):

Sample results flagged with a 'B' or 'B-02' qualifier are potentially biased high if the sample results are less than ten times the level found in the blank for inorganic analyses, or less than five times the level found in the blank for organic analyses.

'B' and 'B-02' qualifications are only applied to sample results detected above the Reporting Level.

Preparation Notes:

Mixed Matrix Samples:

Water Samples:

Water samples containing significant amounts of sediment are decanted or separated prior to extraction, and only the water portion analyzed, unless otherwise directed by the client.

Soil and Sediment Samples:

Soil and Sediment samples containing significant amounts of water are decanted prior to extraction, and only the solid portion analyzed, unless otherwise directed by the client.

Sampling and Preservation Notes:

Certain regulatory programs, such as National Pollutant Discharge Elimination System (NPDES), require that activities such as sample filtration (for dissolved metals, orthophosphate, hexavalent chromium, etc.) and testing of short hold analytes (pH, Dissolved Oxygen, etc.) be performed in the field (on-site) within a short time window. In addition, sample matrix spikes are required for some analyses, and sufficient volume must be provided, and billable site specific QC requested, if this is required. All regulatory permits should be reviewed to ensure that these requirements are being met.

Data users should be aware of which regulations pertain to the samples they submit for testing. If related sample collection activities are not approved for a particular regulatory program, results should be considered estimates. Apex Laboratories will qualify these analytes according to the most stringent requirements, however results for samples that are for non-regulatory purposes may be acceptable.

Samples that have been filtered and preserved at Apex Laboratories per client request are listed in the preparation section of the report with the date and time of filtration listed.

Apex Laboratories maintains detailed records on sample receipt, including client label verification, cooler temperature, sample preservation, hold time compliance and field filtration. Data is qualified as necessary, and the lack of qualification indicates compliance with required parameters.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

LABORATORY ACCREDITATION INFORMATION

ORELAP Certification ID: OR100062 (Primary Accreditation) - EPA ID: OR01039

All methods and analytes reported from work performed at Apex Laboratories are included on Apex Laboratories' ORELAP Scope of Certification, with the exception of any analyte(s) listed below:

Apex Laboratories

Matrix	Analysis	TNI_ID	Analyte	TNI_ID	Accreditation

All reported analytes are included in Apex Laboratories' current ORELAP scope.

Secondary Accreditations

Apex Laboratories also maintains reciprocal accreditation with non-TNI states (Washington DOE), as well as other state specific accreditations not listed here.

Subcontract Laboratory Accreditations

Subcontracted data falls outside of Apex Laboratories' Scope of Accreditation.
Please see the Subcontract Laboratory report for full details, or contact your Project Manager for more information.

Field Testing Parameters

Results for Field Tested data are provded by the client or sampler, and fall outside of Apex Laboratories' Scope of Accreditation.

Apex Laboratories

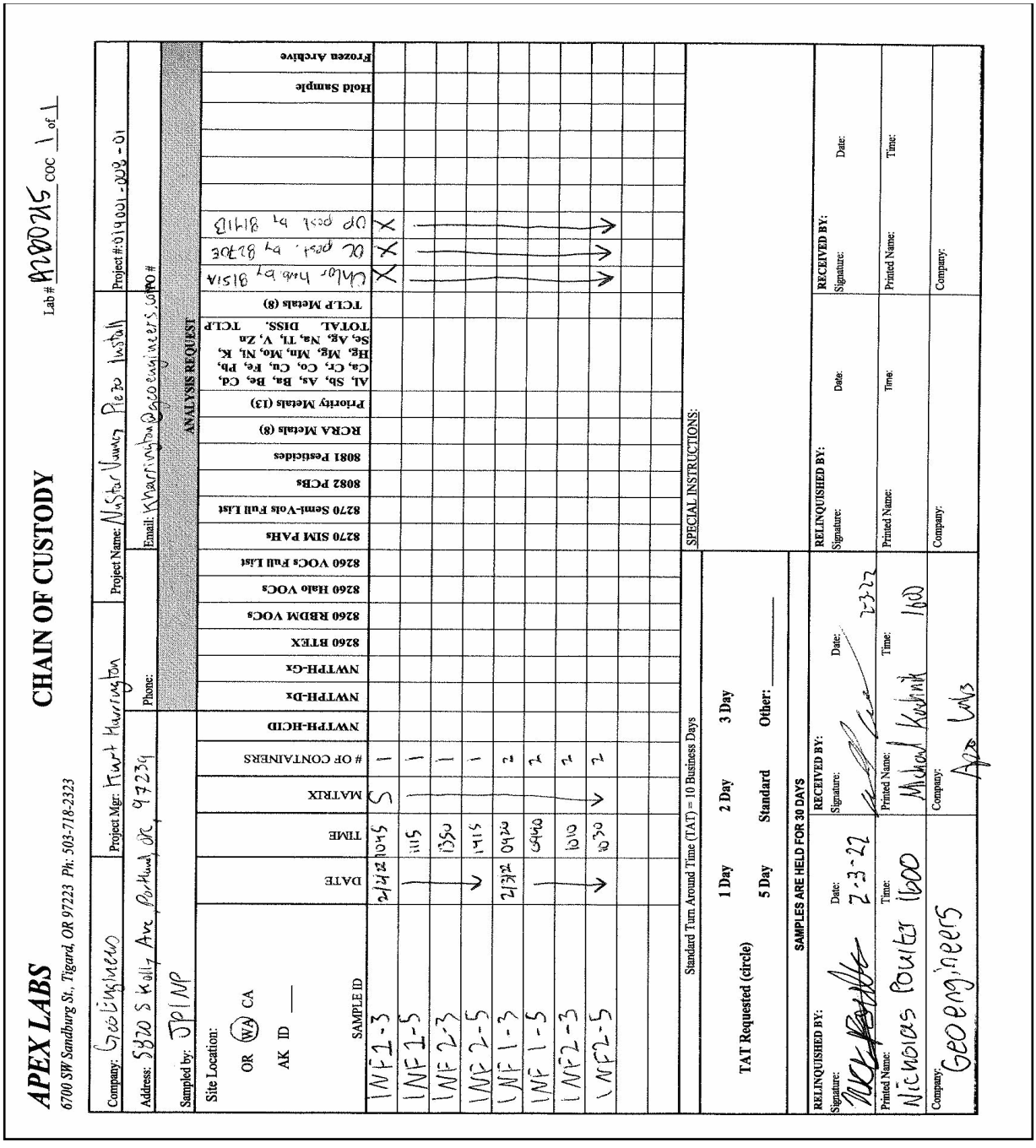
Darrell Auvil, Client Services Manager

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**



Apex Laboratories

The results in this report apply to the samples analyzed in accordance with the chain of custody document. This analytical report must be reproduced in its entirety.

Darrell Auvil, Client Services Manager

Apex Laboratories, LLC
6700 S.W. Sandburg Street
Tigard, OR 97223
503-718-2323
ORELAP ID: **OR100062**

ANALYTICAL REPORT

GeoEngineers	Project: **NuStar Vannex Piezo Install**	
4000 Kruse Way Place, Bldg 3 Suite 200	Project Number: **019001-008-01**	**Report ID:**
Lake Oswego, OR 97035	Project Manager: **Kurt Harrington**	**A2B0215 - 03 10 22 1001**

APEX LABS COOLER RECEIPT FORM

Client: GeoEngineers Element WO#: A2B0215

Project/Project #: NuStar Vannex Piezo Install / 019001-008-01

Delivery Info:

Date/time received: 2-3-22 @ 1600 By: MK

Delivered by: Apex X Client ESS FedEx UPS Swift Senvoy SDS Other

Cooler Inspection Date/time inspected: 2-3-22 @ 1655 By: MK

Chain of Custody included? Yes X No Custody seals? Yes No X

Signed/dated by client? Yes X No

Signed/dated by Apex? Yes X No

	Cooler #1	Cooler #2	Cooler #3	Cooler #4	Cooler #5	Cooler #6	Cooler #7
Temperature (°C)	5.1						
Received on ice? (Y/N)	Y						
Temp. blanks? (Y/N)	Y						
Ice type: (Gel/Real/Other)	Real						
Condition:	good						

Cooler out of temp? (Y/N) Possible reason why:

Green dots applied to out of temperature samples? Yes/No

Out of temperature samples form initiated? Yes/No

Sample Inspection: Date/time inspected: 2/3/22 @ 1845 By: AKK

All samples intact? Yes X No Comments:

Bottle labels/COCs agree? Yes X No Comments: IDs listed twice on COC, matched by sampling dates.

COC/container discrepancies form initiated? Yes No X

Containers/volumes received appropriate for analysis? Yes X No Comments: INF 1-3 + INF 1-5 + INF2-3 + INF2-5 40z provided for 8151 + OCP + OPP.

Do VOA vials have visible headspace? Yes No NA X

Comments

Water samples: pH checked: Yes No NA X pH appropriate? Yes No NA X

Comments:

Additional information:

Labeled by: AKK Witness: JS Cooler Inspected by: AKK

Darrell Auvil, Client Services Manager

APPENDIX C
Boring Logs

SOIL CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES
				GP	POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES
MORE THAN 50% RETAINED ON NO. 200 SIEVE	SAND AND SANDY SOILS	CLEAN SANDS (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS
				SP	POORLY-GRADED SANDS, GRAVELLY SAND
	MORE THAN 50% OF COARSE FRACTION PASSING ON NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND - SILT MIXTURES
				SC	CLAYEY SANDS, SAND - CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY
				OH	ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

ADDITIONAL MATERIAL SYMBOLS

SYMBOLS GRAPH	SYMBOLS LETTER	TYPICAL DESCRIPTIONS
	AC	Asphalt Concrete
	CC	Cement Concrete
	CR	Crushed Rock/ Quarry Spalls
	SOD	Sod/Forest Duff
	TS	Topsoil

Groundwater Contact

Measured groundwater level in exploration, well, or piezometer

Measured free product in well or piezometer

Graphic Log Contact

Distinct contact between soil strata

Approximate contact between soil strata

Material Description Contact

Contact between geologic units

Contact between soil of the same geologic unit

Sampler Symbol Descriptions

2.4-inch I.D. split barrel / Dames & Moore (D&M)

Standard Penetration Test (SPT)

Shelby tube

Piston

Direct-Push

Bulk or grab

Continuous Coring

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

"P" indicates sampler pushed using the weight of the drill rig.

"WOH" indicates sampler pushed using the weight of the hammer.

Laboratory / Field Tests

%F	Percent fines
%G	Percent gravel
AL	Atterberg limits
CA	Chemical analysis
CP	Laboratory compaction test
CS	Consolidation test
DD	Dry density
DS	Direct shear
HA	Hydrometer analysis
MC	Moisture content
MD	Moisture content and dry density
Mohs	Mohs hardness scale
OC	Organic content
PM	Permeability or hydraulic conductivity
PI	Plasticity index
PL	Point lead test
PP	Pocket penetrometer
SA	Sieve analysis
TX	Triaxial compression
UC	Unconfined compression
UU	Unconsolidated undrained triaxial compression
VS	Vane shear

Sheen Classification

NS	No Visible Sheen
SS	Slight Sheen
MS	Moderate Sheen
HS	Heavy Sheen

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

Key to Exploration Logs

GeoEngineers

Figure A-1

Drilled	Start	End	Total Depth (ft)	Logged By	Checked By	Driller	Drilling Method
	2/2/2022	2/3/2022	35	NP/JP			Hand Auger/ Direct Pursh

Hammer Data	N/A	Drilling Equipment	Hand Auger/ GeoProbe 3230 DT
Surface Elevation (ft) Vertical Datum	Undetermined NAVD88	Top of Casing Elevation (ft)	
Easting (X) Northing (Y)		Horizontal Datum	NAD83 (feet)

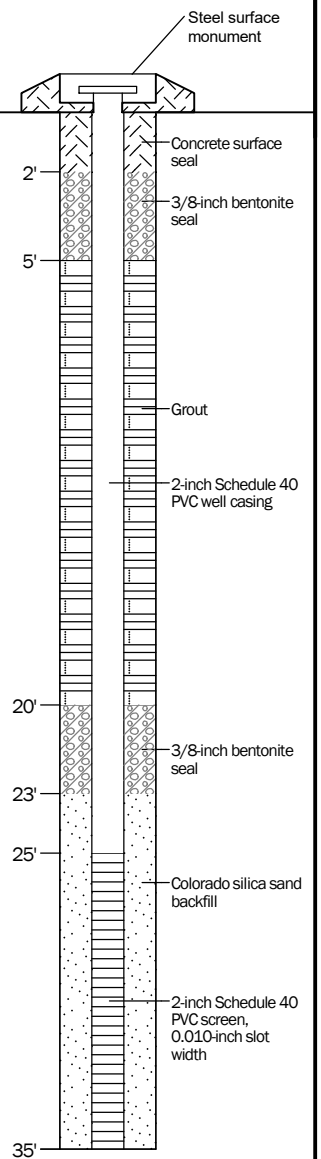
A 2-in well was installed on 2/3/2022 to a depth of 35 ft.

Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)

Notes: Hand augered to approximately 8 feet

Elevation (feet)	Depth (feet)	FIELD DATA: Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	0								OL	Brown organic silt (medium stiff, moist)	NS	<1
											NS	<1
											NS	<1
										Oxidation staining observed		
	5					INF1-5					NS	<1
											NS	<1
			24								NS	<1
									ML	Brown silt with trace sand (medium stiff, moist)	NS	<1
	10		60									
											NS	<1
									SP	Increased sand content		
	15		36						NR	Black and white fine to medium sand (medium dense, moist) No recovery		
									SP	Black and white fine to medium sand (medium dense, moist)	NS	<1
									SW	Black and white fine to medium sand with trace silt (medium dense, moist)	NS	<1
	20		36						NR	No recovery		
									SP	Black and fine to medium sand (medium dense, moist)	NS	<1
										Becomes brown Becomes black and white	NS	<1
	25		42						NR	No recovery	NS	<1
									SP	Black and fine to medium sand (medium dense, moist) Becomes wet	NS	<1
	30		48						NR	No recovery		
									SP	Black and fine to medium sand (medium dense, wet)		
	35											

WELL LOG



Note: See Figure A-1 for explanation of symbols.
Coordinates Data Source: Horizontal approximated based on . Vertical approximated based on .

Log of Monitoring Well INF-1

GeoEngineers

Project: NuStar Energy - Vancouver Annex - Stormwater Permit Support
Project Location: Vancouver, Washington
Project Number: 19001-008-01

Figure A-2
Sheet 1 of 1

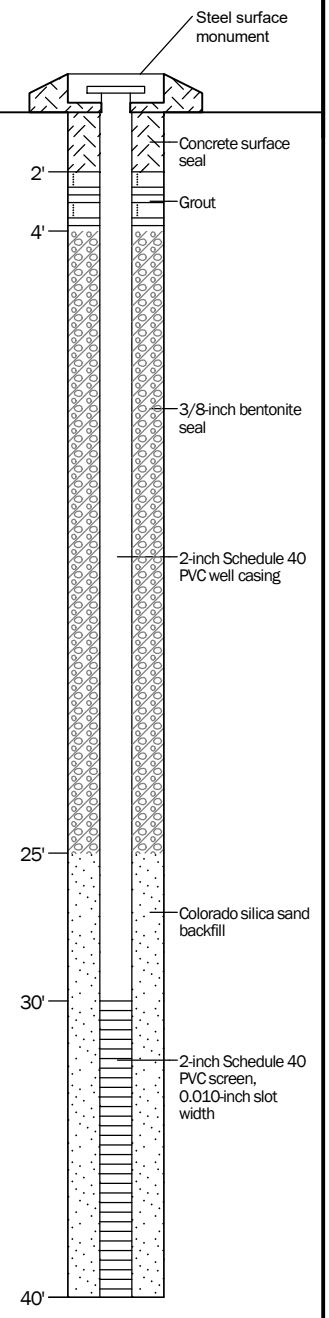
Date:3/29/22 Path:P:\19\19001008\GINT\19001008G1.GPJ DBLibrary/Library:GEOENGINEERS_DF_STD_US_JUNE_2017.GLB/GEI8_ENVIRONMENTAL_WELL

Drilled Start 2/2/2022 End 2/4/2022	Total Depth (ft) 40	Logged By NP/JP Checked By	Driller	Drilling Method Hand Auger/ Direct Pursh	
Hammer Data N/A		Drilling Equipment Hand Auger/ GeoProbe 3230 DT	A 2-in well was installed on 2/4/2022 to a depth of 40 ft.		
Surface Elevation (ft) Undetermined Vertical Datum NAVD88		Top of Casing Elevation (ft)	Groundwater Date Measured	Depth to Water (ft)	Elevation (ft)
Easting (X) Northing (Y)		Horizontal Datum NAD83 (feet)			

Notes: Hand augered to approximately 8 feet

Elevation (feet)	Depth (feet)	Interval	Recovered (in)	Blows/foot	Collected Sample	Sample Name Testing	Water Level	Graphic Log	Group Classification	MATERIAL DESCRIPTION	Sheen	Headspace Vapor (ppm)
	0								OL	Brown organic silt (soft)	NS	<1
									ML	Silt with trace organic matter (medium stiff)	NS	<1
						INF2-3					NS	<1
										Becomes without organic matter		
	5					INF2-5				Becomes with trace organic matter, soft	NS	<1
											NS	<1
			24						ML	Silt with trace sand (stiff)	NS	<1
	10		48						NR	No recovery	NS	<1
									ML	Gray-brown silt with sand (soft, damp)		
											NS	<1
									SP	Gray fine sand (loose, damp)		
	15		48						NR	No recovery		
									SP	Brown-gray sand with little silt	NS	<1
									SP-SM	Gray sand with silt (medium dense, damp)		
	20		60						SP	Gray fine sand with trace silt (medium dense, moist)	NS	<1
											NS	<1
											NS	<1
	25		60							Becomes wet		
										Becomes dark gray, fine to medium grained sand	NS	<1
	30		30								NS	<1
	35		60								NS	<1
											NS	<1
	40											

WELL LOG



Note: See Figure A-1 for explanation of symbols.
Coordinates Data Source: Horizontal approximated based on . Vertical approximated based on .

Log of Monitoring Well INF-2

GeoEngineers

Project: NuStar Energy - Vancouver Annex - Stormwater Permit Support
Project Location: Vancouver, Washington
Project Number: 19001-008-01

Figure A-3
Sheet 1 of 1

APPENDIX D
Survey Data

MacKay Sposito

Vancouver Office

18405 SE Mill Plain Boulevard, Suite 100 Vancouver, WA 98683
360.695.3411 www.mackaysposito.com

FEBRUARY 10, 2022

MONITORING WELL SURVEY DATA

NUSTAR VANCOUVER ANNEX FACILITY, CLARK COUNTY, WASHINGTON

WELL	NORTHING	EASTING	RIM	TOP OF PVC	GROUND
STILLING WELL	127541.19	1078902.50	N/A	40.48	N/A
MW-1	127470.61	1079608.23	27.04	26.73	26.68
MW-6D	127365.71	1078907.36	28.03	27.59	24.88
MW-11	127511.87	1079701.42	27.87	27.41	27.44
MW-12	127575.18	1079672.99	33.40	33.12	33.41
MW-12D	127574.17	1079668.19	32.77	32.06	32.80
INF-1	127253.32	1079919.82	41.88	41.52	38.69
INF-2	127279.78	1080218.12	44.78	44.55	41.49

SURVEYOR'S NOTES:

1. SURVEY DATA WAS COLLECTED ON 2/7/2022.
2. ELEVATIONS ARE BASED ON CONTROL POINT 10 AS SHOWN ON THE BLUEDOT GROUP SURVEY DATED DECEMBER 6, 2017. ELEVATION = 39.02 NAVD88.
3. COORDINATES SHOWN ARE GRID, BASED ON THE WASINGTON STATE PLANE COORDINATE SYSTEM, SOUTH ZONE (4602), NAD83(2011) (EPOCH 2010.0), U.S. SURVEY FOOT. COORDINATES WERE DERIVED FROM CONTROL POINT 10 AS SHOWN ON THE BLUEDOT GROUP SURVEY DATED DECEMBER 6, 2017. NORTHING: 127383.412 EASTING: 1080070.211

2-10-2022

APPENDIX E
2022 Infiltration Test Summary and Measurements

Table E-1
Summary Soil Infiltration Testing
NuStar Energy, L.P. – Vancouver Annex Terminal
Vancouver, Washington

	Test Location	Depth (ft)	Starting Head (in)	Coefficient of Permeability (in/hr)	Design Infiltration Rate (ft/day)	Notes
Initial 2020 Testing Throughout Facility	INF-1	2	15	0.05	0.04	
	INF-2	3	15	0.00	0	
	INF-3	2	15	0.10	0.081	
	INF-4	3	15	0.36	0.292	In test area depth of 3 ft in low area
	INF-5	2	15	0.32	0.253	In test area at depths of 2ft on bench
	INF-6	2	15	0.05	0.04	
	INF-7	0.5	15	0.13	0.102	
	INF-8	0.5	15	0.03	0.02	
	INF-9	0.5	15	0.03	0.02	
	INF-10	0.5	15	0.10	0.081	
	INF-11	0.5	15	0.28	0.221	
	INF-12	0.5	15	0.07	0.054	
	INF-13	0.5	15	0.08	0.061	
	INF-14	0.7	15	0.03	0.02	
	INF-15	0.5	15	0.00	0	
	INF-16	0.7	15	0.02	0.013	
	INF-17	1	15	0.00	0	

	Test Location	Depth (ft)	Starting Head (in)	Test Run Number	Raw Rate (in/hr)	Coefficient of Permeability (in/hr)	Design Infiltration Rate (ft/day)
Additional 2022 Testing In Orchard	IT-1 Labeled "INF-1(5)" on Figure 1	5	15.25-15.54	1	7.05	1.94	1.50
				2	5.75	1.86	1.50
				3	6.06	1.94	1.60
				average	**6.28**	**average**	**1.53**
	IT-2 Labeled "INF-1(3)" on Figure 1	3	12.45-12.56	1	1.50	0.49	0.40
				2	1.40	0.44	0.35
				3	1.32	0.42	0.34
				average	**1.41**	**average**	**0.36**
	IT-3 Labeled "INF-2(5)" on Figure 1	5	17.25	1	0.72	0.21	0.17
				2	0.73	0.22	0.18
				3	0.61	0.19	0.15
				average	**0.68**	**average**	**0.17**
	IT-4 Labeled "INF-2(3)" on Figure 1	3	16.5	1	1.50	0.14	0.11
				2	1.75	0.14	0.11
				3	1.29	0.13	0.10
				average	**1.52**	**average**	**0.11**

Table E-2
IT-1 Soak Data

Data Group/ Refill	Rate (in/hr)	#	Date-Time (PST)	Ch: 1 - Differential Pressure (kpa)	Ch: 2 - Absolute Pressure (kpa)	Ch: 3 - Temperature (°C)	Water Level (m)	Water Level (in)	Barometric Pressure (kpa)
1		1	02/24/2022 10:25:57	-0.142	102.986	7.29	-0.00129	-0.05071	103.128
1		2	02/24/2022 10:26:57	3.519	106.645	7.49	0.37208	14.64880	103.126
1	10.92960406	3	02/24/2022 10:27:57	3.474	106.597	7.79	0.36745	14.46664	103.123
1	17.13780741	4	02/24/2022 10:28:57	3.402	106.533	7.99	0.36020	14.18101	103.131
1	14.99569631	5	02/24/2022 10:29:57	3.340	106.468	8.09	0.35385	13.93108	103.128
1	13.87727511	6	02/24/2022 10:30:57	3.283	106.416	8.19	0.34797	13.69979	103.133
1	10.48981274	7	02/24/2022 10:31:57	3.239	106.365	8.19	0.34353	13.52496	103.126
1	14.44581772	8	02/24/2022 10:32:57	3.179	106.306	8.19	0.33742	13.28420	103.127
1	10.67674409	9	02/24/2022 10:33:57	3.135	106.260	8.19	0.33290	13.10625	103.125
1	13.6679903	10	02/24/2022 10:34:57	3.078	106.205	8.19	0.32711	12.87845	103.127
1	13.40084483	11	02/24/2022 10:35:57	3.022	106.152	8.29	0.32144	12.65511	103.130
1	12.75549201	12	02/24/2022 10:36:57	2.969	106.093	8.29	0.31604	12.44252	103.124
1	8.355792561	13	02/24/2022 10:37:57	2.935	106.060	8.29	0.31250	12.30325	103.125
1	11.98070326	14	02/24/2022 10:38:57	2.885	106.005	8.29	0.30743	12.10357	103.120
1	14.92446394	15	02/24/2022 10:39:57	2.823	105.946	8.29	0.30111	11.85483	103.123
1	12.36094547	16	02/24/2022 10:40:57	2.772	105.900	8.29	0.29588	11.64882	103.128
1	13.90891447	17	02/24/2022 10:41:57	2.714	105.845	8.29	0.28999	11.41700	103.131
1	9.178032605	18	02/24/2022 10:42:57	2.676	105.803	8.29	0.28611	11.26404	103.127
1	13.13573423	19	02/24/2022 10:43:57	2.621	105.752	8.29	0.28055	11.04511	103.131
1	12.70160665	20	02/24/2022 10:44:57	2.569	105.698	8.29	0.27517	10.83341	103.129
1	6.616180109	21	02/24/2022 10:45:57	2.541	105.668	8.29	0.27237	10.72314	103.127
1	10.91132588	22	02/24/2022 10:46:57	2.496	105.622	8.29	0.26775	10.54129	103.126
1	14.43961059	23	02/24/2022 10:47:57	2.436	105.563	8.29	0.26164	10.30063	103.127
1	8.541174286	24	02/24/2022 10:48:57	2.401	105.534	8.29	0.25802	10.15828	103.133
1	10.91442802	25	02/24/2022 10:49:57	2.355	105.487	8.29	0.25340	9.97637	103.132
1	7.874156249	26	02/24/2022 10:50:57	2.323	105.454	8.29	0.25007	9.84513	103.131
1	11.92371575	27	02/24/2022 10:51:57	2.273	105.403	8.29	0.24502	9.64640	103.130
1	9.125755763	28	02/24/2022 10:52:57	2.235	105.365	8.29	0.24116	9.49431	103.130
1	10.61978195	29	02/24/2022 10:53:57	2.191	105.323	8.29	0.23666	9.31731	103.132
1	10.37580421	30	02/24/2022 10:54:57	2.148	105.281	8.29	0.23227	9.14438	103.133
1	12.89175649	31	02/24/2022 10:55:57	2.095	105.231	8.29	0.22681	8.92952	103.136
1	5.893725642	32	02/24/2022 10:56:57	2.070	105.201	8.29	0.22431	8.83129	103.131
1	11.09986719	33	02/24/2022 10:57:57	2.024	105.159	8.29	0.21962	8.64629	103.135
1	12.6461415	34	02/24/2022 10:58:57	1.972	105.109	8.29	0.21426	8.43552	103.137
1	5.600630644	35	02/24/2022 10:59:57	1.948	105.083	8.29	0.21189	8.34218	103.135
1	10.18884269	36	02/24/2022 11:00:57	1.906	105.037	8.29	0.20758	8.17237	103.131
1	10.27759842	37	02/24/2022 11:01:57	1.863	105.003	8.29	0.20323	8.00107	103.140
1	8.686888802	38	02/24/2022 11:02:57	1.827	104.961	8.29	0.19955	7.85629	103.134
1	5.839869005	39	02/24/2022 11:03:57	1.803	104.936	8.29	0.19708	7.75896	103.133
1	8.645699246	40	02/24/2022 11:04:57	1.767	104.898	8.29	0.19342	7.61487	103.131
1	6.559163883	41	02/24/2022 11:05:57	1.740	104.873	8.29	0.19064	7.50555	103.133
1	10.61978195	42	02/24/2022 11:06:57	1.696	104.831	8.29	0.18615	7.32855	103.135
1	9.312717283	43	02/24/2022 11:07:57	1.657	104.797	8.29	0.18220	7.17334	103.140
1	9.412531583	44	02/24/2022 11:08:57	1.618	104.755	8.29	0.17822	7.01646	103.137
1	7.335474988	45	02/24/2022 11:09:57	1.588	104.726	8.29	0.17511	6.89420	103.138
1	6.323085111	46	02/24/2022 11:10:57	1.562	104.701	8.29	0.17244	6.78882	103.139
1	7.332286675	47	02/24/2022 11:11:57	1.531	104.671	8.29	0.16933	6.66662	103.140
1	6.129804413	48	02/24/2022 11:12:57	1.506	104.642	8.29	0.16674	6.56445	103.136
1	8.347864864	49	02/24/2022 11:13:57	1.471	104.608	8.29	0.16320	6.42532	103.137
1	8.347864864	50	02/24/2022 11:14:57	1.436	104.574	8.29	0.15967	6.28619	103.138
1	5.114226224	51	02/24/2022 11:15:57	1.415	104.549	8.29	0.15750	6.20095	103.134
1	8.542725357	52	02/24/2022 11:16:57	1.380	104.520	8.29	0.15389	6.05857	103.140
1	10.08270921	53	02/24/2022 11:17:57	1.338	104.482	8.29	0.14962	5.89053	103.144
1	5.646559583	54	02/24/2022 11:18:57	1.314	104.452	8.29	0.14723	5.79642	103.138
1	6.031569908	55	02/24/2022 11:19:57	1.289	104.431	8.29	0.14468	5.69589	103.142
1	8.349444659	56	02/24/2022 11:20:57	1.255	104.398	8.29	0.14114	5.55674	103.143
1	7.569945241	57	02/24/2022 11:21:57	1.223	104.368	8.29	0.13794	5.43057	103.145
1	4.824290816	58	02/24/2022 11:22:57	1.203	104.347	8.29	0.13589	5.35017	103.144
1	5.841448799	59	02/24/2022 11:23:57	1.179	104.322	8.29	0.13342	5.25281	103.143
1	8.054769866	60	02/24/2022 11:24:57	1.146	104.293	8.29	0.13001	5.11856	103.147
1	6.331496279	61	02/24/2022 11:25:57	1.119	104.265	8.19	0.12733	5.01304	103.146
1	7.62377147	62	02/24/2022 11:26:57	1.088	104.232	8.19	0.12410	4.88597	103.144
1	2.218043247	63	02/24/2022 11:27:57	1.079	104.228	8.19	0.12316	4.84901	103.149
1	5.065069685	64	02/24/2022 11:28:57	1.058	104.207	8.19	0.12102	4.76459	103.149
1	6.899742823	65	02/24/2022 11:29:57	1.029	104.173	8.19	0.11810	4.64959	103.144

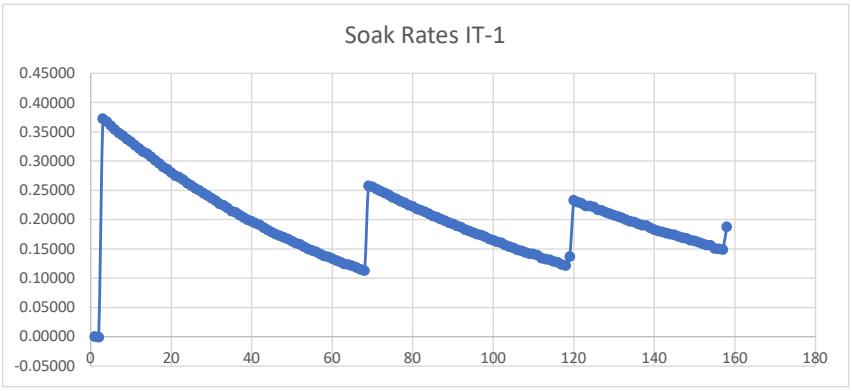
Table E-2
IT-1 Soak Data

1	8.247972229	66	02/24/2022 11:30:57	0.995	104.148	8.19	0.11461	4.51213	103.153
1	5.114186557	67	02/24/2022 11:31:57	0.973	104.122	8.19	0.11244	4.42689	103.149
2		68	02/24/2022 11:32:57	2.398	105.544	8.39	0.25777	10.14832	103.146
2	4.827710653	69	02/24/2022 11:33:57	2.378	105.523	8.59	0.25572	10.06786	103.145
2	9.12611595	70	02/24/2022 11:34:57	2.340	105.485	8.79	0.25186	9.91575	103.145
2	7.125074406	71	02/24/2022 11:35:57	2.311	105.454	8.89	0.24884	9.79700	103.143
2	7.552903291	72	02/24/2022 11:36:57	2.279	105.426	8.99	0.24565	9.67112	103.147
2	8.324590153	73	02/24/2022 11:37:57	2.245	105.395	9.09	0.24212	9.53238	103.150
2	10.09446911	74	02/24/2022 11:38:57	2.203	105.357	9.09	0.23785	9.36414	103.154
2	6.424907308	75	02/24/2022 11:39:57	2.176	105.323	9.09	0.23513	9.25705	103.147
2	9.077243342	76	02/24/2022 11:40:57	2.138	105.289	9.09	0.23129	9.10577	103.151
2	6.084223428	77	02/24/2022 11:41:57	2.113	105.264	9.09	0.22871	9.00436	103.151
2	8.858904507	78	02/24/2022 11:42:57	2.076	105.228	9.19	0.22496	8.85672	103.152
2	5.843498638	79	02/24/2022 11:43:57	2.052	105.203	9.19	0.22249	8.75932	103.151
2	9.609726351	80	02/24/2022 11:44:57	2.012	105.165	9.19	0.21842	8.59916	103.153
2	5.360188583	81	02/24/2022 11:45:57	1.990	105.140	9.19	0.21615	8.50983	103.150
2	6.326722516	82	02/24/2022 11:46:57	1.964	105.115	9.19	0.21347	8.40438	103.151
2	8.833327887	83	02/24/2022 11:47:57	1.927	105.081	9.19	0.20973	8.25716	103.154
2	7.873171062	84	02/24/2022 11:48:57	1.894	105.047	9.19	0.20640	8.12594	103.153
2	6.130238666	85	02/24/2022 11:49:57	1.869	105.018	9.19	0.20380	8.02377	103.149
2	7.339188857	86	02/24/2022 11:50:57	1.838	104.988	9.19	0.20070	7.90145	103.150
2	6.806815291	87	02/24/2022 11:51:57	1.810	104.963	9.19	0.19782	7.78800	103.153
2	7.822470186	88	02/24/2022 11:52:57	1.778	104.934	9.19	0.19450	7.65763	103.156
2	5.409309546	89	02/24/2022 11:53:57	1.755	104.904	9.19	0.19221	7.56747	103.149
2	7.336029029	90	02/24/2022 11:54:57	1.725	104.875	9.19	0.18911	7.44520	103.150
2	4.781882608	91	02/24/2022 11:55:57	1.705	104.858	9.19	0.18708	7.36551	103.153
2	9.896495105	92	02/24/2022 11:56:57	1.664	104.816	9.19	0.18289	7.20057	103.152
2	5.550352777	93	02/24/2022 11:57:57	1.641	104.795	9.19	0.18054	7.10806	103.154
2	6.615099909	94	02/24/2022 11:58:57	1.613	104.765	9.19	0.17774	6.99781	103.152
2	7.14589356	95	02/24/2022 11:59:57	1.584	104.732	9.19	0.17472	6.87871	103.148
2	3.864469639	96	02/24/2022 12:00:57	1.568	104.711	9.19	0.17308	6.81430	103.143
2	6.513698156	97	02/24/2022 12:01:57	1.541	104.690	9.19	0.17033	6.70574	103.149
2	8.397616332	98	02/24/2022 12:02:57	1.506	104.652	9.19	0.16677	6.56578	103.146
2	5.553512605	99	02/24/2022 12:03:57	1.483	104.631	9.19	0.16442	6.47322	103.148
2	5.892590875	100	02/24/2022 12:04:57	1.458	104.601	9.19	0.16193	6.37501	103.143
2	4.533117968	101	02/24/2022 12:05:57	1.440	104.585	9.19	0.16001	6.29946	103.145
2	8.592491543	102	02/24/2022 12:06:57	1.404	104.551	9.19	0.15637	6.15625	103.147
2	5.838701444	103	02/24/2022 12:07:57	1.380	104.526	9.19	0.15390	6.05894	103.146
2	6.325142602	104	02/24/2022 12:08:57	1.353	104.500	9.19	0.15122	5.95352	103.147
2	6.852776425	105	02/24/2022 12:09:57	1.325	104.471	9.19	0.14832	5.83931	103.146
2	3.766256439	106	02/24/2022 12:10:57	1.309	104.458	9.19	0.14672	5.77654	103.149
2	6.389680533	107	02/24/2022 12:11:57	1.283	104.427	9.09	0.14402	5.67004	103.144
2	5.046886012	108	02/24/2022 12:12:57	1.262	104.408	9.19	0.14188	5.58593	103.146
2	1.597149423	109	02/24/2022 12:13:57	1.255	104.395	9.19	0.14121	5.55931	103.140
2	6.050489379	110	02/24/2022 12:14:57	1.230	104.372	9.09	0.13865	5.45847	103.142
2	10.85658412	111	02/24/2022 12:15:57	1.185	104.330	9.09	0.13405	5.27752	103.145
2	4.536266184	112	02/24/2022 12:16:57	1.166	104.313	9.09	0.13213	5.20192	103.147
2	2.127895427	113	02/24/2022 12:17:57	1.158	104.297	9.09	0.13123	5.16646	103.139
2	6.510451709	114	02/24/2022 12:18:57	1.130	104.275	9.09	0.12847	5.05795	103.145
2	3.864464	115	02/24/2022 12:19:57	1.114	104.254	9.09	0.12684	4.99354	103.140
2	8.638375862	116	02/24/2022 12:20:57	1.079	104.217	9.09	0.12318	4.84957	103.138
2	4.295403255	117	02/24/2022 12:21:57	1.061	104.200	9.09	0.12136	4.77798	103.139
NA		118	02/24/2022 12:22:57	1.212	104.349	8.99	0.13680	5.38575	103.137
3		119	02/24/2022 12:23:57	2.154	105.289	9.09	0.23292	9.17004	103.135
3	7.869912527	120	02/24/2022 12:24:57	2.122	105.256	9.09	0.22959	9.03888	103.134
3	4.588546509	121	02/24/2022 12:25:57	2.103	105.235	9.09	0.22765	8.96240	103.132
3	10.38287266	122	02/24/2022 12:26:57	2.060	105.193	9.09	0.22325	8.78935	103.133
3	-0.141041977	123	02/24/2022 12:27:57	2.060	105.184	9.09	0.22331	8.79171	103.124
3	4.753711986	124	02/24/2022 12:28:57	2.040	105.169	9.19	0.22130	8.71248	103.129
3	11.63939878	125	02/24/2022 12:29:57	1.992	105.123	9.19	0.21637	8.51849	103.131
3	2.848843469	126	02/24/2022 12:30:57	1.980	105.106	9.19	0.21516	8.47101	103.126
3	7.047651636	127	02/24/2022 12:31:57	1.951	105.081	9.19	0.21218	8.35355	103.130
3	5.845049826	128	02/24/2022 12:32:57	1.927	105.056	9.19	0.20971	8.25613	103.129
3	6.131847305	129	02/24/2022 12:33:57	1.901	105.026	9.19	0.20711	8.15393	103.125
3	4.346171054	130	02/24/2022 12:34:57	1.883	105.005	9.19	0.20527	8.08149	103.122
3	5.070231276	131	02/24/2022 12:35:57	1.862	104.984	9.19	0.20312	7.99699	103.122
3	8.353263838	132	02/24/2022 12:36:57	1.828	104.951	9.19	0.19959	7.85777	103.123
3	6.348018742	133	02/24/2022 12:37:57	1.801	104.923	9.09	0.19690	7.75197	103.122

Table E-2
IT-1 Soak Data

3	3.040531814	134	02/24/2022 12:38:57	1.789	104.911	9.09	0.19561	7.70129	103.122
3	6.855875289	135	02/24/2022 12:39:57	1.760	104.881	9.09	0.19271	7.58703	103.121
3	5.841838051	136	02/24/2022 12:40:57	1.736	104.856	9.09	0.19024	7.48967	103.120
3	1.012457338	137	02/24/2022 12:41:57	1.732	104.852	9.09	0.18981	7.47279	103.120
3	9.608032274	138	02/24/2022 12:42:57	1.692	104.814	9.09	0.18574	7.31266	103.122
3	7.386664221	139	02/24/2022 12:43:57	1.661	104.780	9.09	0.18261	7.18955	103.119
3	5.070214916	140	02/24/2022 12:44:57	1.640	104.759	9.09	0.18047	7.10504	103.119
3	4.536237458	141	02/24/2022 12:45:57	1.621	104.742	9.09	0.17855	7.02944	103.121
3	4.105298203	142	02/24/2022 12:46:57	1.604	104.721	9.09	0.17681	6.96102	103.117
3	4.002288727	143	02/24/2022 12:47:57	1.588	104.709	9.09	0.17512	6.89431	103.121
3	3.384375494	144	02/24/2022 12:48:57	1.574	104.688	9.09	0.17368	6.83791	103.114
3	5.597815322	145	02/24/2022 12:49:57	1.550	104.662	9.09	0.17131	6.74461	103.112
3	5.261928593	146	02/24/2022 12:50:57	1.529	104.646	9.09	0.16909	6.65691	103.117
3	2.799697611	147	02/24/2022 12:51:57	1.517	104.633	9.09	0.16790	6.61025	103.116
3	8.350001033	148	02/24/2022 12:52:57	1.482	104.599	9.09	0.16437	6.47108	103.117
3	2.508162982	149	02/24/2022 12:53:57	1.472	104.591	9.09	0.16330	6.42928	103.119
3	4.636087135	150	02/24/2022 12:54:57	1.453	104.566	9.09	0.16134	6.35201	103.113
3	6.325086357	151	02/24/2022 12:55:57	1.426	104.540	9.09	0.15866	6.24659	103.114
3	5.597815322	152	02/24/2022 12:56:57	1.403	104.515	9.09	0.15629	6.15330	103.112
3	0.964945438	153	02/24/2022 12:57:57	1.399	104.515	9.09	0.15589	6.13721	103.116
3	12.45369061	154	02/24/2022 12:58:57	1.348	104.461	9.09	0.15061	5.92965	103.113
3	1.54482617	155	02/24/2022 12:59:57	1.341	104.452	9.09	0.14996	5.90391	103.111
3	2.508162982	156	02/24/2022 13:00:57	1.331	104.444	9.09	0.14890	5.86210	103.113
3		157	02/24/2022 13:01:57	1.709	104.822	9.09	0.18752	7.38258	103.113

Table E-2
IT-1 Soak Data



Water Level (m)

Time (min)

Refill	Average Rate	Beginging to End Average
1	9.435611966	9.435611966
2	6.575930054	6.575930054
3	5.364230026	5.364230026

Table E-3
IT-1 Test Data

Data Group/Refill	Rate (in/hr)	#	Date-Time (PST)	Ch: 1 - Differential Pressure (kpa)	Ch: 2 - Absolute Pressure (kpa)	Ch: 3 - Temperature (°C)	Water Level (m)	Wate Level (in)	Barometric Pressure (kpa)	
1		159	02/24/2022 13:03:57	3.704	106.820	9.19	0.39099	15.39348	103.116	
1	8.362743	160	02/24/2022 13:04:57	3.669	106.786	9.19	0.38745	15.25410	103.117	8.362743322
1	7.397847	161	02/24/2022 13:05:57	3.639	106.753	9.19	0.38432	15.13081	103.114	7.397846755
1	-30.214	162	02/24/2022 13:06:57	3.764	106.879	9.19	0.39711	15.63437	103.115	-30.213988
1	10.97713	163	02/24/2022 13:07:57	3.718	106.828	9.19	0.39247	15.45142	103.110	10.97712755
1	7.587953	164	02/24/2022 13:08:57	3.687	106.799	9.19	0.38925	15.32496	103.112	7.587953497
1	8.895088	165	02/24/2022 13:09:57	3.650	106.761	9.19	0.38549	15.17670	103.111	8.895088162
1	8.60358	166	02/24/2022 13:10:57	3.614	106.727	9.19	0.38185	15.03331	103.113	8.603579666
1	6.382221	167	02/24/2022 13:11:57	3.588	106.698	9.19	0.37914	14.92694	103.110	6.382220585
1	8.411864	168	02/24/2022 13:12:57	3.553	106.660	9.19	0.37558	14.78674	103.107	8.411864284
1	9.085252	169	02/24/2022 13:13:57	3.515	106.626	9.19	0.37174	14.63532	103.111	9.085252356
1	5.17959	170	02/24/2022 13:14:57	3.494	106.597	9.19	0.36954	14.54900	103.103	5.17959005
1	9.135925	171	02/24/2022 13:15:57	3.456	106.559	9.19	0.36568	14.39673	103.103	9.135924506
1	6.813164	172	02/24/2022 13:16:57	3.428	106.534	9.19	0.36279	14.28318	103.106	6.813163673
1	4.34936	173	02/24/2022 13:17:57	3.409	106.512	9.19	0.36095	14.21069	103.103	4.349359607
1	11.64575	174	02/24/2022 13:18:57	3.361	106.466	9.19	0.35602	14.01659	103.105	11.64574716
1	8.372926	175	02/24/2022 13:19:57	3.326	106.430	9.29	0.35248	13.87704	103.104	8.372925585
1	7.106345	176	02/24/2022 13:20:57	3.297	106.401	9.29	0.34947	13.75861	103.104	7.106344867
1	6.572387	177	02/24/2022 13:21:57	3.270	106.376	9.29	0.34669	13.64907	103.106	6.572386574
1	8.890457	178	02/24/2022 13:22:57	3.233	106.338	9.29	0.34292	13.50089	103.105	8.890457287
1	9.413887	179	02/24/2022 13:23:57	3.194	106.298	9.19	0.33894	13.34399	103.104	9.413887464
1	8.373347	180	02/24/2022 13:24:57	3.159	106.262	9.29	0.33539	13.20444	103.103	8.373346824
1	4.143881	181	02/24/2022 13:25:57	3.142	106.239	9.19	0.33364	13.13537	103.097	4.143880895
1	9.580755	182	02/24/2022 13:26:57	3.102	106.203	9.29	0.32958	12.97569	103.101	9.580754642
1	8.359659	183	02/24/2022 13:27:57	3.067	106.169	9.29	0.32604	12.83637	103.102	8.359658851
1	2.511396	184	02/24/2022 13:28:57	3.057	106.161	9.29	0.32498	12.79451	103.104	2.511396478
1	10.23271	185	02/24/2022 13:29:57	3.014	106.112	9.19	0.32065	12.62396	103.098	10.23270518
1	9.528807	186	02/24/2022 13:30:57	2.975	106.081	9.29	0.31661	12.46515	103.106	9.528807437
1	4.35095	187	02/24/2022 13:31:57	2.957	106.060	9.29	0.31477	12.39264	103.103	4.350950017
1	8.35805	188	02/24/2022 13:32:57	2.922	106.026	9.29	0.31123	12.25333	103.104	8.358050196
1	6.329939	189	02/24/2022 13:33:57	2.896	106.001	9.29	0.30856	12.14784	103.105	6.329939404
1	7.344024	190	02/24/2022 13:34:57	2.865	105.971	9.29	0.30545	12.02544	103.106	7.344023526
1	7.290134	191	02/24/2022 13:35:57	2.835	105.946	9.29	0.30236	11.90393	103.111	7.29013361
1	9.370583	192	02/24/2022 13:36:57	2.796	105.908	9.29	0.29839	11.74776	103.112	9.370583116
1	5.846654	193	02/24/2022 13:37:57	2.772	105.883	9.29	0.29592	11.65031	103.111	5.846653718
1	5.604264	194	02/24/2022 13:38:57	2.749	105.858	9.29	0.29355	11.55691	103.109	5.604264
1	4.834236	195	02/24/2022 13:39:57	2.729	105.837	9.29	0.29150	11.47634	103.108	4.834235702
1	10.62861	196	02/24/2022 13:40:57	2.684	105.794	9.29	0.28700	11.29919	103.110	10.62860816
1	8.166333	197	02/24/2022 13:41:57	2.651	105.757	9.29	0.28354	11.16309	103.106	8.166333086
1	5.021184	198	02/24/2022 13:42:57	2.630	105.740	9.29	0.28142	11.07940	103.110	5.021184302
1	5.361874	199	02/24/2022 13:43:57	2.608	105.715	9.29	0.27915	10.99004	103.107	5.361874282
1	10.86945	200	02/24/2022 13:44:57	2.562	105.672	9.29	0.27455	10.80888	103.110	10.86944667
1	4.01026	201	02/24/2022 13:45:57	2.546	105.660	9.29	0.27285	10.74204	103.114	4.010260036
1	8.110892	202	02/24/2022 13:46:57	2.512	105.626	9.29	0.26941	10.60686	103.114	8.110891968
1	3.333763	203	02/24/2022 13:47:57	2.498	105.609	9.29	0.26800	10.55130	103.111	3.33376349
1	9.904484	204	02/24/2022 13:48:57	2.457	105.567	9.29	0.26381	10.38622	103.110	9.904483958
1	4.590237	205	02/24/2022 13:49:57	2.438	105.546	9.29	0.26187	10.30972	103.108	4.59023733
1	6.810008	206	02/24/2022 13:50:57	2.410	105.521	9.29	0.25898	10.19622	103.111	6.810007781
1	3.572993	207	02/24/2022 13:51:57	2.395	105.504	9.29	0.25747	10.13667	103.109	3.572993351
1	4.35095	208	02/24/2022 13:52:57	2.377	105.483	9.29	0.25563	10.06415	103.106	4.350950017
1	9.850651	209	02/24/2022 13:53:57	2.336	105.445	9.29	0.25146	9.89998	103.109	9.850651494
1	7.340864	210	02/24/2022 13:54:57	2.306	105.416	9.29	0.24835	9.77763	103.110	7.34086367
1	7.442209	211	02/24/2022 13:55:57	2.275	105.378	9.29	0.24520	9.65359	103.103	7.442208885
1	0	212	02/24/2022 13:56:57	2.275	105.378	9.29	0.24520	9.65359	103.103	0
1	8.597338	213	02/24/2022 13:57:57	2.239	105.344	9.29	0.24156	9.51030	103.105	8.59733751
1	4.105343	214	02/24/2022 13:58:57	2.222	105.323	9.29	0.23982	9.44188	103.101	4.10534299
1	2.074072	215	02/24/2022 13:59:57	2.213	105.310	9.29	0.23895	9.40731	103.097	2.074072341
NA		216	02/24/2022 14:00:57	2.176	105.281	9.29	0.23512	9.25679	103.105	0
2		217	02/24/2022 14:01:57	3.700	106.805	9.29	0.39062	15.37872	103.105	0
2	2.818572	218	02/24/2022 14:02:57	3.689	106.791	9.39	0.38943	15.33175	103.102	2.818572473
2	7.396372	219	02/24/2022 14:03:57	3.658	106.757	9.39	0.38630	15.20848	103.099	7.39637236
2	9.378597	220	02/24/2022 14:04:57	3.619	106.719	9.39	0.38232	15.05217	103.100	9.378597164
2	5.025941	221	02/24/2022 14:05:57	3.598	106.702	9.39	0.38020	14.96840	103.104	5.025941277
2	3.096113	222	02/24/2022 14:06:57	3.585	106.685	9.39	0.37889	14.91680	103.100	3.096113116
2	9.13609	223	02/24/2022 14:07:57	3.547	106.647	9.39	0.37502	14.76453	103.100	9.136090327
2	8.312222	224	02/24/2022 14:08:57	3.513	106.618	9.39	0.37150	14.62599	103.105	8.312222038
2	8.118895	225	02/24/2022 14:09:57	3.479	106.584	9.39	0.36806	14.49068	103.105	8.118894507
2	9.083866	226	02/24/2022 14:10:57	3.441	106.550	9.39	0.36422	14.33928	103.109	9.08386604
2	3.576128	227	02/24/2022 14:11:57	3.427	106.534	9.39	0.36270	14.27968	103.107	3.576128427
2	7.641982	228	02/24/2022 14:12:57	3.395	106.500	9.39	0.35947	14.15231	103.105	7.64198163
2	2.562092	229	02/24/2022 14:13:57	3.384	106.487	9.39	0.35838	14.10961	103.103	2.562092492
2	12.42076	230	02/24/2022 14:14:57	3.333	106.437	9.39	0.35313	13.90260	103.104	12.42076242
2	1.788897	231	02/24/2022 14:15:57	3.325	106.428	9.39	0.35237	13.87278	103.103	1.788897274
2	4.488818	232	02/24/2022 14:16:57	3.307	106.416	9.39	0.35047	13.79797	103.109	4.48881822
2	5.848373	233	02/24/2022 14:17:57	3.282	106.390	9.39	0.34799	13.70050	103.108	5.848373254
2	8.844577	234	02/24/2022 14:18:57	3.246	106.357	9.39	0.34425	13.55309	103.111	8.844576541
2	5.848316	235	02/24/2022 14:19:57	3.221	106.331	9.39	0.34177	13.45561	103.110	5.848315801
2	7.635604	236	02/24/2022 14:20:57	3.190	106.298	9.39	0.33854	13.32835	103.108	7.635604407
2	5.075121	237	02/24/2022 14:21:57	3.169	106.277	9.39	0.33639	13.24377	103.108	5.075120583
2	3.631628	238	02/24/2022 14:22:57	3.154	106.256	9.39	0.33485	13.18324	103.102	3.631627504
2	6.757846	239	02/24/2022 14:23:57	3.126	106.235	9.39	0.33199	13.07061	103.109	6.757845709
2	8.600576	240	02/24/2022 14:24:57	3.090	106.201	9.39	0.32835	12.92727	103.111	8.600575939

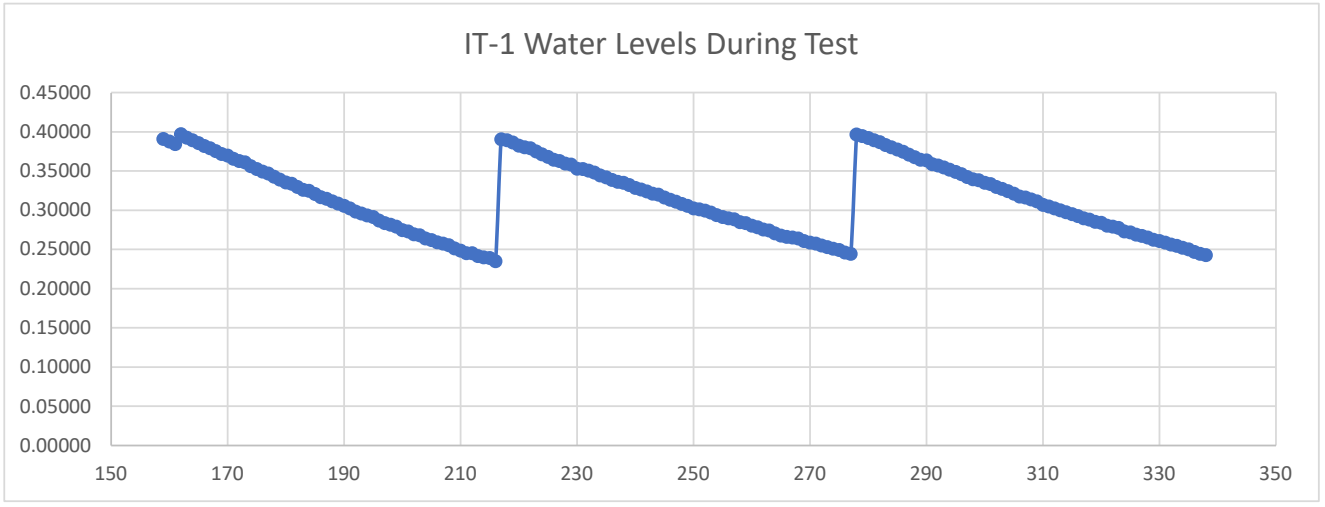
Table E-3
IT-1 Test Data

2	4.061027	241	02/24/2022 14:25:57	3.073	106.184	9.39	0.32663	12.85959	103.111	4.061027196
2	6.569229	242	02/24/2022 14:26:57	3.046	106.159	9.39	0.32385	12.75010	103.113	6.56922928
2	6.040092	243	02/24/2022 14:27:57	3.021	106.138	9.39	0.32130	12.64943	103.117	6.040092116
2	3.386018	244	02/24/2022 14:28:57	3.007	106.117	9.39	0.31986	12.59300	103.110	3.386018234
2	8.598967	245	02/24/2022 14:29:57	2.971	106.083	9.39	0.31622	12.44968	103.112	8.59896727
2	6.621568	246	02/24/2022 14:30:57	2.943	106.053	9.39	0.31342	12.33932	103.110	6.621568472
2	6.328446	247	02/24/2022 14:31:57	2.917	106.028	9.39	0.31074	12.23385	103.111	6.328446017
2	5.848316	248	02/24/2022 14:32:57	2.893	106.003	9.39	0.30826	12.13637	103.110	5.848315801
2	6.569287	249	02/24/2022 14:33:57	2.866	105.978	9.39	0.30548	12.02689	103.112	6.569286733
2	7.586483	250	02/24/2022 14:34:57	2.834	105.948	9.39	0.30227	11.90045	103.114	7.586482553
2	2.321252	251	02/24/2022 14:35:57	2.825	105.936	9.39	0.30129	11.86176	103.111	2.321251776
2	3.815475	252	02/24/2022 14:36:57	2.809	105.919	9.39	0.29967	11.79817	103.110	3.815475379
2	6.328389	253	02/24/2022 14:37:57	2.782	105.893	9.39	0.29699	11.69269	103.111	6.328388564
2	7.825772	254	02/24/2022 14:38:57	2.750	105.864	9.39	0.29368	11.56226	103.114	7.825772052
2	5.555193	255	02/24/2022 14:39:57	2.727	105.843	9.39	0.29133	11.46968	103.116	5.555193346
2	3.764745	256	02/24/2022 14:40:57	2.711	105.830	9.39	0.28974	11.40693	103.119	3.764744856
2	3.096056	257	02/24/2022 14:41:57	2.698	105.813	9.39	0.28843	11.35533	103.115	3.096055664
2	8.358184	258	02/24/2022 14:42:57	2.664	105.780	9.39	0.28489	11.21603	103.116	8.358184007
2	3.043774	259	02/24/2022 14:43:57	2.651	105.767	9.39	0.28360	11.16530	103.116	3.043773924
2	7.342482	260	02/24/2022 14:44:57	2.621	105.738	9.39	0.28049	11.04292	103.117	7.342481951
2	5.605924	261	02/24/2022 14:45:57	2.597	105.712	9.39	0.27812	10.94949	103.115	5.605923869
2	6.567678	262	02/24/2022 14:46:57	2.570	105.687	9.39	0.27534	10.84003	103.117	6.567678064
2	2.270579	263	02/24/2022 14:47:57	2.561	105.679	9.39	0.27438	10.80219	103.118	2.270578706
2	8.595807	264	02/24/2022 14:48:57	2.525	105.645	9.39	0.27074	10.65892	103.120	8.595807385
2	6.911531	265	02/24/2022 14:49:57	2.496	105.611	9.39	0.26781	10.54373	103.115	6.911531042
2	4.057867	266	02/24/2022 14:50:57	2.480	105.595	9.39	0.26609	10.47610	103.115	4.057867311
2	2.319643	267	02/24/2022 14:51:57	2.470	105.582	9.39	0.26511	10.43744	103.112	2.319643107
2	3.091345	268	02/24/2022 14:52:57	2.457	105.565	9.39	0.26380	10.38592	103.108	3.091344562
2	7.29336	269	02/24/2022 14:53:57	2.427	105.540	9.39	0.26071	10.26436	103.113	7.293360097
2	4.880242	270	02/24/2022 14:54:57	2.407	105.515	9.39	0.25865	10.18302	103.108	4.880241836
2	2.752203	271	02/24/2022 14:55:57	2.395	105.506	9.39	0.25748	10.13715	103.111	2.752202685
2	5.363474	272	02/24/2022 14:56:57	2.373	105.481	9.39	0.25521	10.04776	103.108	5.363474484
2	5.311193	273	02/24/2022 14:57:57	2.351	105.460	9.39	0.25296	9.95924	103.109	5.311192745
2	4.783549	274	02/24/2022 14:58:57	2.331	105.443	9.39	0.25094	9.87952	103.112	4.783549344
2	3.862989	275	02/24/2022 14:59:57	2.315	105.422	9.39	0.24930	9.81513	103.107	3.862988564
2	7.825772	276	02/24/2022 15:00:57	2.282	105.392	9.39	0.24599	9.68471	103.110	7.825772052
2	3.283063	277	02/24/2022 15:01:57	2.269	105.380	9.39	0.24460	9.62999	103.111	3.283063424
3		278	02/24/2022 15:02:57	3.760	106.871	9.39	0.39667	15.61711	103.111	0
3	4.835889	279	02/24/2022 15:03:57	3.740	106.850	9.39	0.39463	15.53652	103.110	4.835888536
3	5.846707	280	02/24/2022 15:04:57	3.715	106.824	9.39	0.39215	15.43907	103.109	5.846707133
3	6.575607	281	02/24/2022 15:05:57	3.688	106.799	9.39	0.38937	15.32948	103.111	6.575606504
3	5.799251	282	02/24/2022 15:06:57	3.664	106.778	9.39	0.38691	15.23282	103.114	5.7992514
3	8.464299	283	02/24/2022 15:07:57	3.629	106.736	9.39	0.38333	15.09175	103.107	8.464298702
3	6.868729	284	02/24/2022 15:08:57	3.600	106.706	9.39	0.38042	14.97727	103.106	6.868728959
3	7.396372	285	02/24/2022 15:09:57	3.570	106.673	9.39	0.37729	14.85400	103.103	7.39637236
3	6.092316	286	02/24/2022 15:10:57	3.544	106.647	9.39	0.37471	14.75246	103.103	6.092316403
3	8.844577	287	02/24/2022 15:11:57	3.508	106.614	9.39	0.37097	14.60505	103.106	8.844576541
3	7.396372	288	02/24/2022 15:12:57	3.477	106.580	9.39	0.36784	14.48178	103.103	7.39637236
3	8.361344	289	02/24/2022 15:13:57	3.442	106.546	9.39	0.36430	14.34242	103.104	8.361343892
3	1.837962	290	02/24/2022 15:14:57	3.435	106.534	9.39	0.36352	14.31179	103.099	1.837961676
3	11.3576	291	02/24/2022 15:15:57	3.387	106.491	9.39	0.35871	14.12250	103.104	11.35760463
3	4.10854	292	02/24/2022 15:16:57	3.370	106.470	9.39	0.35697	14.05402	103.100	4.108540381
3	6.090765	293	02/24/2022 15:17:57	3.345	106.445	9.39	0.35439	13.95251	103.100	6.090765186
3	6.572447	294	02/24/2022 15:18:57	3.318	106.420	9.39	0.35161	13.84297	103.102	6.572446618
3	6.572447	295	02/24/2022 15:19:57	3.291	106.395	9.39	0.34883	13.73343	103.104	6.572446618
3	6.963755	296	02/24/2022 15:20:57	3.262	106.357	9.39	0.34588	13.61736	103.095	6.963755329
3	8.551512	297	02/24/2022 15:21:57	3.226	106.327	9.39	0.34226	13.47484	103.101	8.551511538
3	6.280875	298	02/24/2022 15:22:57	3.200	106.306	9.39	0.33960	13.37016	103.106	6.280875379
3	2.853664	299	02/24/2022 15:23:57	3.188	106.289	9.39	0.33839	13.32260	103.101	2.853663731
3	7.878054	300	02/24/2022 15:24:57	3.156	106.256	9.39	0.33506	13.19130	103.100	7.878053791
3	4.251137	301	02/24/2022 15:25:57	3.138	106.243	9.39	0.33326	13.12044	103.105	4.251137389
3	8.649698	302	02/24/2022 15:26:57	3.102	106.205	9.39	0.32960	12.97628	103.103	8.649697793
3	5.556802	303	02/24/2022 15:27:57	3.079	106.184	9.39	0.32725	12.88367	103.105	5.556802015
3	7.103192	304	02/24/2022 15:28:57	3.050	106.155	9.39	0.32424	12.76528	103.105	7.103192452
3	7.394821	305	02/24/2022 15:29:57	3.019	106.121	9.39	0.32111	12.64204	103.102	7.394821143
3	9.083809	306	02/24/2022 15:30:57	2.981	106.087	9.39	0.31726	12.49064	103.106	9.083808588
3	2.07886	307	02/24/2022 15:31:57	2.973	106.075	9.39	0.31638	12.45599	103.102	2.078859844
3	6.517005	308	02/24/2022 15:32:57	2.945	106.053	9.39	0.31362	12.34737	103.108	6.517004993
3	5.125794	309	02/24/2022 15:33:57	2.924	106.028	9.39	0.31145	12.26194	103.104	5.125793654
3	11.11039	310	02/24/2022 15:34:57	2.878	105.986	9.39	0.30675	12.07677	103.108	11.11038669
3	4.832671	311	02/24/2022 15:35:57	2.858	105.965	9.39	0.30470	11.99623	103.107	4.832671198
3	5.607475	312	02/24/2022 15:36:57	2.835	105.940	9.39	0.30233	11.90277	103.105	5.607475086
3	5.314353	313	02/24/2022 15:37:57	2.813	105.919	9.39	0.30008	11.81420	103.106	5.31435263
3	6.087605	314	02/24/2022 15:38:57	2.787	105.893	9.39	0.29750	11.71274	103.106	6.087605301
3	6.325229	315	02/24/2022 15:39:57	2.761	105.868	9.39	0.29483	11.60732	103.107	6.325228679
3	5.417365	316	02/24/2022 15:40:57	2.739	105.839	9.39	0.29253	11.51703	103.100	5.417364892
3	7.050968	317	02/24/2022 15:41:57	2.709	105.813	9.39	0.28955	11.39951	103.104	7.050968165
3	3.577737	318	02/24/2022 15:42:57	2.695	105.797	9.39	0.28803	11.33988	103.102	3.577737096
3	7.052519	319	02/24/2022 15:43:57	2.665	105.771	9.39	0.28505	11.22234	103.106	7.052519381
3	2.077251	320	02/24/2022 15:44:57	2.657	105.759	9.39	0.28417	11.18772	103.102	2.077251175
3	8.890539	321	02/24/2022 15:45:57	2.620	105.721	9.39	0.28040	11.03954	103.101	8.890538509
3	3.525513	322	02/24/2022 15:46:57	2.605	105.708	9.39	0.27891	10.98079	103.103	3.525512809
3	3.623699	323	02/24/2022 15:47:57	2.590	105.687	9.39	0.27738	10.92039	103.097	3.623699064
3	10.04562	324	02/24/2022 15:48:57	2.548	105.653	9.39	0.27313	10.75296	103.105	10.04562023
3	3.094504	325	02/24/2022 15:49:57	2.536	105.637	9.39	0.27182	10.70139	103.101	3.094504447
3	6.859192	326	02/24/2022 15:50:57	2.507	105.607	9.39	0.26891	10.58707	103.100	6.85919185

Table E-3
IT-1 Test Data

3	3.623757	327	02/24/2022 15:51:57	2.492	105.586	9.39	0.26738	10.52667	103.094	3.623756517
3	5.265231	328	02/24/2022 15:52:57	2.470	105.569	9.39	0.26515	10.43892	103.099	5.265230776
3	6.859192	329	02/24/2022 15:53:57	2.442	105.540	9.39	0.26224	10.32460	103.098	6.85919185
3	3.384467	330	02/24/2022 15:54:57	2.428	105.519	9.39	0.26081	10.26819	103.091	3.384467017
3	4.811027	331	02/24/2022 15:55:57	2.408	105.500	9.29	0.25878	10.18801	103.092	4.811026746
3	6.085998	332	02/24/2022 15:56:57	2.383	105.475	9.29	0.25620	10.08657	103.092	6.085998484
3	3.574545	333	02/24/2022 15:57:57	2.368	105.458	9.29	0.25469	10.02700	103.090	3.574544554
3	6.035211	334	02/24/2022 15:58:57	2.343	105.437	9.29	0.25213	9.92641	103.094	6.035210972
3	5.124196	335	02/24/2022 15:59:57	2.321	105.411	9.29	0.24996	9.84101	103.090	5.124195623
3	7.339255	336	02/24/2022 16:00:57	2.291	105.382	9.29	0.24685	9.71869	103.091	7.339255015
3	6.136671	337	02/24/2022 16:01:57	2.265	105.352	9.29	0.24426	9.61641	103.087	6.136671091
3	3.279816	338	02/24/2022 16:02:57	2.252	105.340	9.29	0.24287	9.56175	103.088	3.279816122

Table E-3
IT-1 Test Data



Run	Average Rate (in/hr)	Difference from previous (%)	Derivation from Average
1	7.049505053		12.2
2	5.7487394	22.6	-8.5
3	6.055369959	-5.1	-3.6

Table E-4
IT-2 Soak Data

Run	Rate	#	Date-Time (PST)	Ch: 1 - Differential Pressure (kpa)	Ch: 2 - Absolute Pressure (kpa)	Ch: 3 - Temperature (°C)	Water Level (m)	Water Level (in)	Barometric Pressure (kpa)
NA	NA	1	02/24/2022 10:24:43	-0.282	102.974	3.90	-0.00163	-0.06412	103.256
NA	NA	2	02/24/2022 10:25:43	-0.275	102.973	4.11	-0.00099	-0.03910	103.248
NA	NA	3	02/24/2022 10:26:43	-0.283	102.970	4.22	-0.00181	-0.07144	103.253
NA	NA	4	02/24/2022 10:27:43	-0.261	102.988	4.32	0.00048	0.01906	103.249
NA	NA	5	02/24/2022 10:28:43	-0.247	102.972	4.43	0.00191	0.07532	103.219
NA	NA	6	02/24/2022 10:29:43	-0.286	102.967	4.32	-0.00213	-0.08367	103.253
NA	NA	7	02/24/2022 10:30:43	-0.298	102.955	4.43	-0.00331	-0.13050	103.253
NA	NA	8	02/24/2022 10:31:43	-0.291	102.956	4.53	-0.00257	-0.10128	103.247
NA	NA	9	02/24/2022 10:32:43	-0.282	102.966	4.63	-0.00166	-0.06548	103.248
NA	NA	10	02/24/2022 10:33:43	-0.283	102.964	4.84	-0.00174	-0.06850	103.247
NA	NA	11	02/24/2022 10:34:43	-0.297	102.953	4.94	-0.00324	-0.12738	103.250
NA	NA	12	02/24/2022 10:35:43	-0.291	102.960	5.15	-0.00263	-0.10370	103.251
NA	NA	13	02/24/2022 10:36:43	-0.288	102.949	5.36	-0.00226	-0.08906	103.237
1		14	02/24/2022 10:37:43	1.258	104.498	5.87	0.15535	6.11633	103.240
1	4.171395	15	02/24/2022 10:38:43	1.240	104.478	6.68	0.15359	6.04681	103.238
1	10.11253	16	02/24/2022 10:39:43	1.198	104.446	7.19	0.14931	5.87826	103.248
1	-2.872	17	02/24/2022 10:40:43	1.210	104.456	7.59	0.15052	5.92613	103.246
1	9.326844	18	02/24/2022 10:41:43	1.171	104.421	7.89	0.14658	5.77068	103.250
1	1.717926	19	02/24/2022 10:42:43	1.164	104.411	8.09	0.14585	5.74205	103.247
1	3.749556	20	02/24/2022 10:43:43	1.149	104.400	8.19	0.14426	5.67956	103.251
1	1.908543	21	02/24/2022 10:44:43	1.141	104.397	8.29	0.14345	5.64775	103.256
1	7.428441	22	02/24/2022 10:45:43	1.110	104.368	8.39	0.14031	5.52394	103.258
1	-2.09135	23	02/24/2022 10:46:43	1.119	104.364	8.39	0.14119	5.55880	103.245
1	5.296461	24	02/24/2022 10:47:43	1.097	104.351	8.39	0.13895	5.47052	103.254
1	2.301547	25	02/24/2022 10:48:43	1.087	104.339	8.49	0.13798	5.43216	103.252
1	0.483224	26	02/24/2022 10:49:43	1.085	104.339	8.49	0.13777	5.42411	103.254
1	4.168455	27	02/24/2022 10:50:43	1.068	104.322	8.49	0.13601	5.35464	103.254
1	0.719306	28	02/24/2022 10:51:43	1.065	104.322	8.49	0.13570	5.34265	103.257
1	5.771829	29	02/24/2022 10:52:43	1.041	104.296	8.49	0.13326	5.24645	103.255
1	0.161601	30	02/24/2022 10:53:43	1.040	104.300	8.49	0.13319	5.24376	103.260
1	1.12173	31	02/24/2022 10:54:43	1.035	104.292	8.49	0.13272	5.22506	103.256
1	2.563502	32	02/24/2022 10:55:43	1.025	104.283	8.49	0.13163	5.18234	103.258
1	5.427616	33	02/24/2022 10:56:43	1.002	104.258	8.59	0.12933	5.09188	103.256
1	3.926085	34	02/24/2022 10:57:43	0.986	104.241	8.59	0.12767	5.02644	103.255
1	-1.76341	35	02/24/2022 10:58:43	0.993	104.245	8.59	0.12842	5.05583	103.252
1	2.241883	36	02/24/2022 10:59:43	0.984	104.241	8.59	0.12747	5.01847	103.257
1	0.080801	37	02/24/2022 11:00:43	0.984	104.237	8.59	0.12743	5.01712	103.253
1	3.287574	38	02/24/2022 11:01:43	0.970	104.228	8.59	0.12604	4.96233	103.258
1	1.842631	39	02/24/2022 11:02:43	0.962	104.219	8.59	0.12526	4.93162	103.257
1	0.803273	40	02/24/2022 11:03:43	0.959	104.215	8.59	0.12492	4.91823	103.256
1	4.406139	41	02/24/2022 11:04:43	0.941	104.198	8.59	0.12306	4.84479	103.257
1	4.01322	42	02/24/2022 11:05:43	0.924	104.189	8.59	0.12136	4.77791	103.265
1	4.48536	43	02/24/2022 11:06:43	0.906	104.168	8.59	0.11946	4.70315	103.262
1	-2.00581	44	02/24/2022 11:07:43	0.914	104.172	8.59	0.12031	4.73658	103.258
1	4.011626	45	02/24/2022 11:08:43	0.897	104.163	8.59	0.11861	4.66972	103.266
1	3.202019	46	02/24/2022 11:09:43	0.884	104.146	8.59	0.11726	4.61635	103.262
1	-1.52259	47	02/24/2022 11:10:43	0.890	104.150	8.59	0.11790	4.64173	103.260
1	5.691074	48	02/24/2022 11:11:43	0.867	104.129	8.59	0.11549	4.54688	103.262
1	-1.84263	49	02/24/2022 11:12:43	0.874	104.137	8.59	0.11627	4.57759	103.263
1	5.207832	50	02/24/2022 11:13:43	0.853	104.116	8.59	0.11407	4.49079	103.263
1	-0.72405	51	02/24/2022 11:14:43	0.856	104.116	8.59	0.11437	4.50286	103.260
1	-0.24082	52	02/24/2022 11:15:43	0.857	104.116	8.59	0.11447	4.50687	103.259
1	-1.12332	53	02/24/2022 11:16:43	0.861	104.111	8.59	0.11495	4.52560	103.250
1	2.487461	54	02/24/2022 11:17:43	0.851	104.107	8.59	0.11390	4.48414	103.256
1	2.485881	55	02/24/2022 11:18:43	0.841	104.103	8.59	0.11284	4.44271	103.262
1	3.444423	56	02/24/2022 11:19:43	0.826	104.085	8.59	0.11139	4.38530	103.259
1	0.481648	57	02/24/2022 11:20:43	0.824	104.085	8.59	0.11118	4.37727	103.261
1	2.489055	58	02/24/2022 11:21:43	0.814	104.081	8.59	0.11013	4.33579	103.267
1	3.224185	59	02/24/2022 11:22:43	0.801	104.067	8.49	0.10876	4.28205	103.266
1	0.321623	60	02/24/2022 11:23:43	0.799	104.062	8.49	0.10863	4.27669	103.263
1	2.725103	61	02/24/2022 11:24:43	0.788	104.058	8.49	0.10747	4.23127	103.270

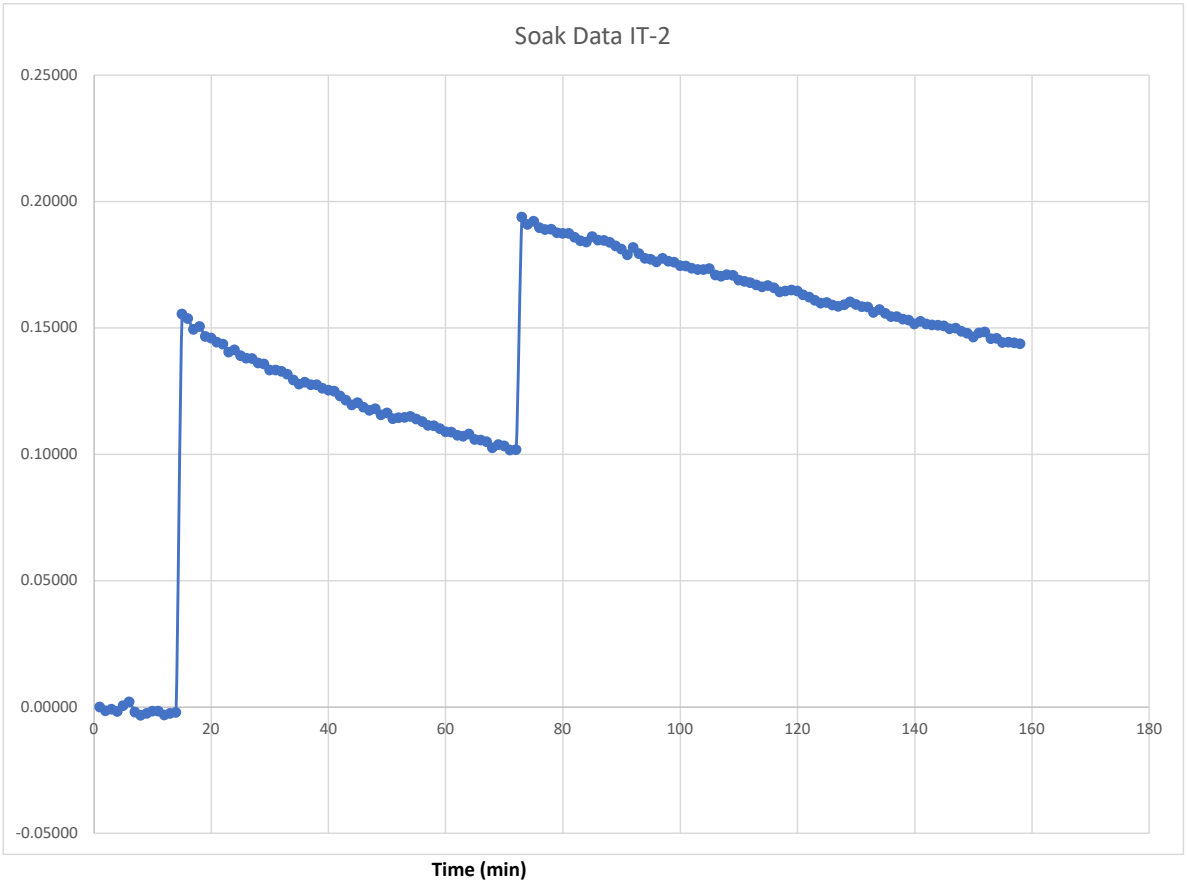
Table E-4
IT-2 Soak Data

1	0.880893	62	02/24/2022 11:25:43	0.784	104.049	8.49	0.10710	4.21659	103.265
1	-2.00896	63	02/24/2022 11:26:43	0.793	104.054	8.49	0.10795	4.25007	103.261
1	5.052522	64	02/24/2022 11:27:43	0.772	104.041	8.49	0.10581	4.16587	103.269
1	0.564024	65	02/24/2022 11:28:43	0.769	104.036	8.49	0.10557	4.15647	103.267
1	1.600214	66	02/24/2022 11:29:43	0.763	104.028	8.49	0.10490	4.12980	103.265
1	5.76706	67	02/24/2022 11:30:43	0.739	104.002	8.49	0.10246	4.03368	103.263
1	-3.2004	68	02/24/2022 11:31:43	0.752	104.019	8.49	0.10381	4.08702	103.267
1	1.359377	69	02/24/2022 11:32:43	0.746	104.010	8.49	0.10323	4.06436	103.264
1	3.767612	70	02/24/2022 11:33:43	0.731	104.002	8.49	0.10164	4.00157	103.271
1		71	02/24/2022 11:34:43	0.732	104.002	8.49	0.10174	4.00558	103.270
2		72	02/24/2022 11:35:43	1.634	104.903	8.59	0.19375	7.62780	103.269
2	6.738331	73	02/24/2022 11:36:43	1.606	104.877	8.59	0.19089	7.51549	103.271
2	-2.99928	74	02/24/2022 11:37:43	1.618	104.878	8.69	0.19216	7.56548	103.260
2	6.017517	75	02/24/2022 11:38:43	1.593	104.865	8.69	0.18962	7.46519	103.272
2	1.817234	76	02/24/2022 11:39:43	1.586	104.854	8.79	0.18885	7.43490	103.268
2	-0.31844	77	02/24/2022 11:40:43	1.587	104.858	8.79	0.18898	7.44021	103.271
2	3.259035	78	02/24/2022 11:41:43	1.574	104.847	8.89	0.18760	7.38589	103.273
2	0.801713	79	02/24/2022 11:42:43	1.570	104.842	8.89	0.18726	7.37253	103.272
2	-0.07764	80	02/24/2022 11:43:43	1.571	104.847	8.89	0.18730	7.37382	103.276
2	3.446104	81	02/24/2022 11:44:43	1.556	104.829	8.89	0.18584	7.31639	103.273
2	3.290817	82	02/24/2022 11:45:43	1.543	104.821	8.89	0.18444	7.26154	103.278
2	1.283373	83	02/24/2022 11:46:43	1.537	104.816	8.89	0.18390	7.24015	103.279
2	-4.97663	84	02/24/2022 11:47:43	1.558	104.825	8.89	0.18601	7.32309	103.267
2	3.287657	85	02/24/2022 11:48:43	1.544	104.816	8.89	0.18461	7.26830	103.272
2	0.318474	86	02/24/2022 11:49:43	1.543	104.812	8.89	0.18448	7.26299	103.269
2	1.766613	87	02/24/2022 11:50:43	1.536	104.808	8.89	0.18373	7.23355	103.272
2	3.12763	88	02/24/2022 11:51:43	1.523	104.795	8.89	0.18241	7.18142	103.272
2	3.051567	89	02/24/2022 11:52:43	1.510	104.786	8.89	0.18112	7.13056	103.276
2	5.451967	90	02/24/2022 11:53:43	1.487	104.764	8.89	0.17881	7.03970	103.277
2	-6.89853	91	02/24/2022 11:54:43	1.516	104.786	8.89	0.18173	7.15467	103.270
2	5.772021	92	02/24/2022 11:55:43	1.492	104.760	8.89	0.17929	7.05847	103.268
2	4.252557	93	02/24/2022 11:56:43	1.474	104.751	8.89	0.17748	6.98760	103.277
2	1.044123	94	02/24/2022 11:57:43	1.470	104.747	8.89	0.17704	6.97019	103.277
2	2.324337	95	02/24/2022 11:58:43	1.460	104.738	8.89	0.17606	6.93145	103.278
2	-3.28924	96	02/24/2022 11:59:43	1.474	104.747	8.89	0.17745	6.98627	103.273
2	2.64439	97	02/24/2022 12:00:43	1.463	104.734	8.89	0.17633	6.94220	103.271
2	0.934917	98	02/24/2022 12:01:43	1.459	104.731	8.99	0.17594	6.92662	103.272
2	3.235257	99	02/24/2022 12:02:43	1.446	104.717	8.89	0.17457	6.87270	103.271
2	0.529353	100	02/24/2022 12:03:43	1.444	104.710	8.99	0.17434	6.86388	103.266
2	2.007461	101	02/24/2022 12:04:43	1.435	104.705	8.99	0.17349	6.83042	103.270
2	1.120197	102	02/24/2022 12:05:43	1.431	104.697	8.99	0.17302	6.81175	103.266
2	-0.05407	103	02/24/2022 12:06:43	1.431	104.691	8.89	0.17304	6.81265	103.260
2	-0.66843	104	02/24/2022 12:07:43	1.434	104.697	8.99	0.17332	6.82379	103.263
2	5.856035	105	02/24/2022 12:08:43	1.409	104.679	8.99	0.17085	6.72619	103.270
2	1.044132	106	02/24/2022 12:09:43	1.405	104.675	8.99	0.17040	6.70879	103.270
2	-1.37054	107	02/24/2022 12:10:43	1.411	104.671	8.99	0.17098	6.73163	103.260
2	0.514702	108	02/24/2022 12:11:43	1.408	104.673	8.89	0.17077	6.72305	103.265
2	4.620445	109	02/24/2022 12:12:43	1.389	104.653	8.99	0.16881	6.64604	103.264
2	1.284964	110	02/24/2022 12:13:43	1.384	104.649	8.99	0.16827	6.62463	103.265
2	1.118588	111	02/24/2022 12:14:43	1.379	104.640	8.99	0.16779	6.60599	103.261
2	2.007489	112	02/24/2022 12:15:43	1.371	104.636	8.99	0.16694	6.57253	103.265
2	1.768209	113	02/24/2022 12:16:43	1.364	104.632	8.99	0.16619	6.54306	103.268
2	-1.04413	114	02/24/2022 12:17:43	1.368	104.636	8.99	0.16664	6.56046	103.268
2	1.921917	115	02/24/2022 12:18:43	1.360	104.623	8.99	0.16582	6.52843	103.263
2	4.003834	116	02/24/2022 12:19:43	1.343	104.601	8.99	0.16413	6.46170	103.258
2	-1.03939	117	02/24/2022 12:20:43	1.348	104.606	8.99	0.16457	6.47902	103.258
2	-0.72092	118	02/24/2022 12:21:43	1.351	104.606	8.99	0.16487	6.49103	103.255
2	0.798561	119	02/24/2022 12:22:43	1.347	104.601	8.99	0.16453	6.47773	103.254
2	3.609322	120	02/24/2022 12:23:43	1.332	104.588	8.99	0.16301	6.41757	103.256
2	2.086685	121	02/24/2022 12:24:43	1.324	104.580	8.99	0.16212	6.38279	103.256
2	2.96289	122	02/24/2022 12:25:43	1.311	104.562	8.99	0.16087	6.33341	103.251
2	2.807601	123	02/24/2022 12:26:43	1.300	104.554	8.99	0.15968	6.28662	103.254
2	-0.72408	124	02/24/2022 12:27:43	1.303	104.554	8.99	0.15999	6.29869	103.251
2	2.325937	125	02/24/2022 12:28:43	1.293	104.545	8.99	0.15900	6.25992	103.252
2	1.468269	126	02/24/2022 12:29:43	1.287	104.535	8.89	0.15838	6.23545	103.248

Table E-4
IT-2 Soak Data

2	-1.76661	127	02/24/2022 12:30:43	1.294	104.539	8.89	0.15913	6.26489	103.245
2	-2.64439	128	02/24/2022 12:31:43	1.305	104.552	8.89	0.16025	6.30897	103.247
2	2.566747	129	02/24/2022 12:32:43	1.295	104.544	8.89	0.15916	6.26619	103.249
2	1.9219	130	02/24/2022 12:33:43	1.287	104.531	8.89	0.15835	6.23415	103.244
2	0.405596	131	02/24/2022 12:34:43	1.285	104.535	8.89	0.15818	6.22739	103.250
2	4.968728	132	02/24/2022 12:35:43	1.264	104.513	8.89	0.15607	6.14458	103.249
2	-2.72677	133	02/24/2022 12:36:43	1.276	104.518	8.89	0.15723	6.19003	103.242
2	3.606131	134	02/24/2022 12:37:43	1.261	104.505	8.89	0.15570	6.12993	103.244
2	3.126022	135	02/24/2022 12:38:43	1.248	104.492	8.89	0.15438	6.07783	103.244
2	0.080803	136	02/24/2022 12:39:43	1.247	104.487	8.89	0.15434	6.07648	103.240
2	2.243534	137	02/24/2022 12:40:43	1.238	104.483	8.89	0.15339	6.03909	103.245
2	1.044123	138	02/24/2022 12:41:43	1.234	104.479	8.89	0.15295	6.02169	103.245
2	3.609319	139	02/24/2022 12:42:43	1.219	104.466	8.89	0.15142	5.96153	103.247
2	-2.59309	140	02/24/2022 12:43:43	1.230	104.472	8.99	0.15252	6.00475	103.242
2	2.593092	141	02/24/2022 12:44:43	1.219	104.466	8.89	0.15142	5.96153	103.247
2	0.880908	142	02/24/2022 12:45:43	1.215	104.457	8.89	0.15105	5.94685	103.242
2	0.318474	143	02/24/2022 12:46:43	1.214	104.453	8.89	0.15092	5.94154	103.239
2	0.559304	144	02/24/2022 12:47:43	1.212	104.449	8.89	0.15068	5.93222	103.237
2	2.726774	145	02/24/2022 12:48:43	1.200	104.444	8.89	0.14952	5.88677	103.244
2	-0.72091	146	02/24/2022 12:49:43	1.203	104.444	8.89	0.14983	5.89879	103.241
2	3.048407	147	02/24/2022 12:50:43	1.191	104.436	8.89	0.14854	5.84798	103.245
2	1.605007	148	02/24/2022 12:51:43	1.184	104.427	8.89	0.14786	5.82123	103.243
2	3.708349	149	02/24/2022 12:52:43	1.169	104.413	8.79	0.14629	5.75942	103.244
2	-3.84535	150	02/24/2022 12:53:43	1.184	104.425	8.79	0.14792	5.82351	103.241
2	-0.88567	151	02/24/2022 12:54:43	1.188	104.421	8.79	0.14829	5.83828	103.233
2	6.095182	152	02/24/2022 12:55:43	1.163	104.404	8.79	0.14571	5.73669	103.241
2	-0.24083	153	02/24/2022 12:56:43	1.164	104.404	8.79	0.14581	5.74070	103.240
2	3.851667	154	02/24/2022 12:57:43	1.148	104.391	8.79	0.14418	5.67651	103.243
2	-0.24083	155	02/24/2022 12:58:43	1.149	104.391	8.79	0.14429	5.68052	103.242
2	0.635362	156	02/24/2022 12:59:43	1.146	104.382	8.79	0.14402	5.66993	103.236
2	0.964892	157	02/24/2022 13:00:43	1.142	104.382	8.79	0.14361	5.65385	103.240

Table E-4
IT-2 Soak Data



Refill	Rate
1	2.265817
2	1.393374

Table E-5
IT-2 Test Data

Run	Rate	#	Date-Time (PST)	Ch: 1 - Differential Pressure (kpa)	Ch: 2 - Absolute Pressure (kpa)	Ch: 3 - Temperature (°C)	Water Level (m)	Water Level (in)	Barometric Pressure (kpa)
1	NA	158	02/24/2022 13:01:43	2.837	106.070	8.79	0.31649	12.46032	103.233
1	-1.20414	159	02/24/2022 13:02:43	2.842	106.070	8.79	0.31700	12.48039	103.228
1	2.327448	160	02/24/2022 13:03:43	2.832	106.061	8.79	0.31602	12.44160	103.229
1	5.576437	161	02/24/2022 13:04:43	2.809	106.038	8.69	0.31366	12.34866	103.229
1	0.363488	162	02/24/2022 13:05:43	2.808	106.040	8.79	0.31350	12.34260	103.232
1	-1.4884	163	02/24/2022 13:06:43	2.814	106.047	8.69	0.31413	12.36741	103.233
1	3.694771	164	02/24/2022 13:07:43	2.799	106.030	8.69	0.31257	12.30583	103.231
1	2.00583	165	02/24/2022 13:08:43	2.790	106.025	8.69	0.31172	12.27240	103.235
1	3.370012	166	02/24/2022 13:09:43	2.776	106.012	8.69	0.31029	12.21623	103.236
1	-0.16005	167	02/24/2022 13:10:43	2.777	106.008	8.69	0.31036	12.21890	103.231
1	3.610838	168	02/24/2022 13:11:43	2.762	105.995	8.69	0.30883	12.15872	103.233
1	-1.20413	169	02/24/2022 13:12:43	2.767	105.995	8.69	0.30934	12.17879	103.228
1	1.685782	170	02/24/2022 13:13:43	2.760	105.982	8.69	0.30863	12.15069	103.222
1	1.522627	171	02/24/2022 13:14:43	2.754	105.978	8.69	0.30798	12.12531	103.224
1	1.924999	172	02/24/2022 13:15:43	2.746	105.965	8.69	0.30717	12.09323	103.219
1	3.536327	173	02/24/2022 13:16:43	2.731	105.956	8.69	0.30567	12.03429	103.225
1	3.2068	174	02/24/2022 13:17:43	2.718	105.939	8.69	0.30431	11.98084	103.221
1	-0.4832	175	02/24/2022 13:18:43	2.720	105.939	8.69	0.30452	11.98890	103.219
1	-0.07606	176	02/24/2022 13:19:43	2.720	105.943	8.69	0.30455	11.99016	103.223
1	5.058953	177	02/24/2022 13:20:43	2.699	105.930	8.69	0.30241	11.90585	103.231
1	-0.96491	178	02/24/2022 13:21:43	2.703	105.930	8.69	0.30282	11.92193	103.227
1	4.570982	179	02/24/2022 13:22:43	2.684	105.904	8.69	0.30088	11.84575	103.220
1	1.448115	180	02/24/2022 13:23:43	2.678	105.904	8.69	0.30027	11.82161	103.226
1	1.044134	181	02/24/2022 13:24:43	2.674	105.900	8.69	0.29983	11.80421	103.226
1	0.318439	182	02/24/2022 13:25:43	2.672	105.895	8.69	0.29969	11.79890	103.223
1	2.215934	183	02/24/2022 13:26:43	2.663	105.888	8.79	0.29875	11.76197	103.225
1	-2.25305	184	02/24/2022 13:27:43	2.673	105.893	8.79	0.29971	11.79952	103.220
1	4.898999	185	02/24/2022 13:28:43	2.652	105.875	8.79	0.29763	11.71787	103.223
1	1.283363	186	02/24/2022 13:29:43	2.647	105.871	8.79	0.29709	11.69648	103.224
1	2.409831	187	02/24/2022 13:30:43	2.637	105.858	8.79	0.29607	11.65632	103.221
1	0.400882	188	02/24/2022 13:31:43	2.635	105.862	8.79	0.29590	11.64964	103.227
1	1.286522	189	02/24/2022 13:32:43	2.630	105.858	8.79	0.29536	11.62819	103.228
1	0.076063	190	02/24/2022 13:33:43	2.630	105.854	8.79	0.29532	11.62693	103.224
1	4.578891	191	02/24/2022 13:34:43	2.611	105.841	8.79	0.29339	11.55061	103.230
1	4.414126	192	02/24/2022 13:35:43	2.592	105.823	8.79	0.29152	11.47704	103.231
1	-1.76657	193	02/24/2022 13:36:43	2.600	105.828	8.79	0.29226	11.50649	103.228
1	4.092467	194	02/24/2022 13:37:43	2.583	105.815	8.79	0.29053	11.43828	103.232
1	0.079223	195	02/24/2022 13:38:43	2.582	105.810	8.79	0.29050	11.43696	103.228
1	-0.6401	196	02/24/2022 13:39:43	2.585	105.819	8.79	0.29077	11.44763	103.234
1	-0.16	197	02/24/2022 13:40:43	2.586	105.815	8.79	0.29084	11.45029	103.229
1	5.375887	198	02/24/2022 13:41:43	2.563	105.797	8.79	0.28856	11.36070	103.234
1	-0.64171	199	02/24/2022 13:42:43	2.566	105.793	8.79	0.28883	11.37139	103.227
1	2.970767	200	02/24/2022 13:43:43	2.554	105.789	8.79	0.28758	11.32188	103.235
1	2.327448	201	02/24/2022 13:44:43	2.544	105.780	8.79	0.28659	11.28309	103.236
1	2.888384	202	02/24/2022 13:45:43	2.532	105.767	8.79	0.28537	11.23495	103.235
1	-1.76663	203	02/24/2022 13:46:43	2.539	105.771	8.79	0.28612	11.26439	103.232
1	6.904846	204	02/24/2022 13:47:43	2.511	105.750	8.79	0.28319	11.14931	103.239
1	-4.49657	205	02/24/2022 13:48:43	2.529	105.758	8.79	0.28510	11.22425	103.229
1	2.329114	206	02/24/2022 13:49:43	2.520	105.750	8.79	0.28411	11.18543	103.230
1	-1.60818	207	02/24/2022 13:50:43	2.526	105.758	8.79	0.28479	11.21224	103.232
1	-0.88409	208	02/24/2022 13:51:43	2.530	105.754	8.79	0.28517	11.22697	103.224
1	5.138218	209	02/24/2022 13:52:43	2.509	105.737	8.79	0.28299	11.14134	103.228
1	1.768178	210	02/24/2022 13:53:43	2.501	105.732	8.79	0.28224	11.11187	103.231
1	-0.96492	211	02/24/2022 13:54:43	2.505	105.732	8.79	0.28265	11.12795	103.227
1	1.605022	212	02/24/2022 13:55:43	2.499	105.724	8.79	0.28197	11.10120	103.225
1	2.487502	213	02/24/2022 13:56:43	2.488	105.706	8.79	0.28092	11.05974	103.218
1	2.485894	214	02/24/2022 13:57:43	2.478	105.702	8.79	0.27987	11.01831	103.224
1	-0.88409	215	02/24/2022 13:58:43	2.482	105.698	8.79	0.28024	11.03304	103.216
1	1.444968	216	02/24/2022 13:59:43	2.476	105.698	8.79	0.27963	11.00896	103.222
2		217	02/24/2022 14:00:43	2.854	106.076	8.89	0.31821	12.52791	103.222
2	4.415715	218	02/24/2022 14:01:43	2.836	106.059	8.89	0.31634	12.45432	103.223
2	1.284982	219	02/24/2022 14:02:43	2.830	106.054	8.89	0.31580	12.43290	103.224
2	-2.88996	220	02/24/2022 14:03:43	2.842	106.067	8.89	0.31702	12.48107	103.225
2	1.323425	221	02/24/2022 14:04:43	2.837	106.056	8.99	0.31646	12.45901	103.219
2	5.217473	222	02/24/2022 14:05:43	2.815	106.034	8.99	0.31425	12.37205	103.219
2	2.010649	223	02/24/2022 14:06:43	2.807	106.030	8.99	0.31340	12.33854	103.223
2	0	224	02/24/2022 14:07:43	2.807	106.030	8.99	0.31340	12.33854	103.223
2	-1.04571	225	02/24/2022 14:08:43	2.811	106.034	8.99	0.31384	12.35597	103.223
2	2.649153	226	02/24/2022 14:09:43	2.800	106.021	8.99	0.31272	12.31182	103.221
2	2.568378	227	02/24/2022 14:10:43	2.789	106.012	8.99	0.31163	12.26901	103.223
2	0.483215	228	02/24/2022 14:11:43	2.787	106.012	8.99	0.31143	12.26096	103.225
2	1.364217	229	02/24/2022 14:12:43	2.782	106.004	8.99	0.31085	12.23822	103.222
2	-0.5625	230	02/24/2022 14:13:43	2.784	106.008	8.99	0.31109	12.24760	103.224
2	2.009098	231	02/24/2022 14:14:43	2.776	106.004	8.99	0.31024	12.21411	103.228
2	4.97509	232	02/24/2022 14:15:43	2.755	105.982	8.99	0.30813	12.13119	103.227
2	0.96488	233	02/24/2022 14:16:43	2.751	105.982	8.99	0.30772	12.11511	103.231
2	3.050042	234	02/24/2022 14:17:43	2.738	105.973	8.99	0.30643	12.06428	103.235

Table E-5
IT-2 Test Data

2	-3.77409	235	02/24/2022 14:18:43	2.754	105.982	8.99	0.30803	12.12718	103.228
2	1.286544	236	02/24/2022 14:19:43	2.749	105.978	8.99	0.30749	12.10574	103.229
2	2.246713	237	02/24/2022 14:20:43	2.739	105.973	8.99	0.30653	12.06829	103.234
2	1.845881	238	02/24/2022 14:21:43	2.732	105.965	8.99	0.30575	12.03753	103.233
2	1.365768	239	02/24/2022 14:22:43	2.726	105.956	8.99	0.30518	12.01476	103.230
2	-0.32006	240	02/24/2022 14:23:43	2.727	105.960	8.99	0.30531	12.02010	103.233
2	1.925048	241	02/24/2022 14:24:43	2.719	105.947	8.99	0.30450	11.98801	103.228
2	2.80921	242	02/24/2022 14:25:43	2.708	105.939	8.99	0.30331	11.94119	103.231
2	3.853313	243	02/24/2022 14:26:43	2.692	105.926	8.99	0.30168	11.87697	103.234
2	-0.56244	244	02/24/2022 14:27:43	2.694	105.930	8.99	0.30191	11.88635	103.236
2	0.803272	245	02/24/2022 14:28:43	2.691	105.926	8.99	0.30157	11.87296	103.235
2	1.044161	246	02/24/2022 14:29:43	2.686	105.921	8.99	0.30113	11.85556	103.235
2	2.405161	247	02/24/2022 14:30:43	2.676	105.908	8.99	0.30011	11.81547	103.232
2	0.724047	248	02/24/2022 14:31:43	2.673	105.908	8.99	0.29981	11.80340	103.235
2	0.724105	249	02/24/2022 14:32:43	2.670	105.908	8.99	0.29950	11.79133	103.238
2	-1.68582	250	02/24/2022 14:33:43	2.677	105.908	8.99	0.30021	11.81943	103.231
2	3.772481	251	02/24/2022 14:34:43	2.662	105.900	8.99	0.29862	11.75656	103.238
2	-1.68582	252	02/24/2022 14:35:43	2.669	105.900	8.99	0.29933	11.78465	103.231
2	6.02402	253	02/24/2022 14:36:43	2.644	105.887	8.99	0.29678	11.68425	103.243
2	-2.73315	254	02/24/2022 14:37:43	2.655	105.891	8.99	0.29794	11.72981	103.236
2	4.57897	255	02/24/2022 14:38:43	2.636	105.878	8.99	0.29600	11.65349	103.242
2	-3.05159	256	02/24/2022 14:39:43	2.649	105.887	8.99	0.29729	11.70435	103.238
2	4.895866	257	02/24/2022 14:40:43	2.628	105.869	8.99	0.29522	11.62275	103.241
2	1.963827	258	02/24/2022 14:41:43	2.620	105.859	8.89	0.29439	11.59002	103.239
2	-0.35878	259	02/24/2022 14:42:43	2.622	105.861	8.99	0.29454	11.59600	103.239
2	2.728377	260	02/24/2022 14:43:43	2.610	105.856	8.99	0.29338	11.55053	103.246
2	4.257362	261	02/24/2022 14:44:43	2.593	105.835	8.99	0.29158	11.47957	103.242
2	1.16043	262	02/24/2022 14:45:43	2.588	105.829	8.89	0.29109	11.46023	103.241
2	-2.68942	263	02/24/2022 14:46:43	2.599	105.839	8.99	0.29223	11.50506	103.240
2	5.577825	264	02/24/2022 14:47:43	2.576	105.816	8.89	0.28987	11.41209	103.240
2	-0.3185	265	02/24/2022 14:48:43	2.577	105.820	8.89	0.29000	11.41740	103.243
2	0.318502	266	02/24/2022 14:49:43	2.576	105.816	8.89	0.28987	11.41209	103.240
2	0.682259	267	02/24/2022 14:50:43	2.573	105.813	8.99	0.28958	11.40072	103.240
2	1.606601	268	02/24/2022 14:51:43	2.567	105.805	8.99	0.28890	11.37394	103.238
2	1.722868	269	02/24/2022 14:52:43	2.559	105.794	8.89	0.28817	11.34523	103.235
2	2.809128	270	02/24/2022 14:53:43	2.548	105.786	8.89	0.28698	11.29841	103.238
2	-1.52575	271	02/24/2022 14:54:43	2.554	105.790	8.89	0.28763	11.32384	103.236
2	0.560883	272	02/24/2022 14:55:43	2.552	105.786	8.89	0.28739	11.31449	103.234
2	4.29795	273	02/24/2022 14:56:43	2.534	105.770	8.99	0.28557	11.24286	103.236
2	0.884104	274	02/24/2022 14:57:43	2.530	105.761	8.99	0.28519	11.22812	103.231
2	1.320356	275	02/24/2022 14:58:43	2.525	105.760	8.89	0.28464	11.20612	103.235
2	3.370069	276	02/24/2022 14:59:43	2.511	105.747	8.89	0.28321	11.14995	103.236
		277	02/24/2022 15:00:43	2.787	106.024	8.89	0.31138	12.25896	103.237
		278	02/24/2022 15:01:43	2.869	106.103	8.99	0.31979	12.59010	103.234
3	1.966573	279	02/24/2022 15:02:43	2.861	106.096	9.09	0.31896	12.55732	103.235
3	0	280	02/24/2022 15:03:43	2.861	106.096	9.09	0.31896	12.55732	103.235
3	0.564053	281	02/24/2022 15:04:43	2.859	106.092	9.09	0.31872	12.54792	103.233
3	-1.7268	282	02/24/2022 15:05:43	2.866	106.102	9.19	0.31945	12.57670	103.236
3	2.327529	283	02/24/2022 15:06:43	2.856	106.093	9.19	0.31846	12.53791	103.237
3	0.242445	284	02/24/2022 15:07:43	2.855	106.093	9.19	0.31836	12.53387	103.238
3	3.691771	285	02/24/2022 15:08:43	2.840	106.076	9.19	0.31680	12.47234	103.236
3	3.208489	286	02/24/2022 15:09:43	2.827	106.059	9.19	0.31544	12.41886	103.232
3	-1.04257	287	02/24/2022 15:10:43	2.831	106.063	9.19	0.31588	12.43624	103.232
3	0	288	02/24/2022 15:11:43	2.831	106.063	9.19	0.31588	12.43624	103.232
3	-1.52263	289	02/24/2022 15:12:43	2.837	106.067	9.19	0.31653	12.46162	103.230
3	4.976787	290	02/24/2022 15:13:43	2.817	106.046	9.19	0.31442	12.37867	103.229
3	2.690084	291	02/24/2022 15:14:43	2.806	106.036	9.09	0.31328	12.33383	103.230
3	1.84584	292	02/24/2022 15:15:43	2.798	106.027	9.09	0.31250	12.30307	103.229
3	1.847449	293	02/24/2022 15:16:43	2.790	106.018	9.09	0.31172	12.27228	103.228
3	-1.28656	294	02/24/2022 15:17:43	2.796	106.023	9.09	0.31226	12.29372	103.227
3	2.327566	295	02/24/2022 15:18:43	2.786	106.014	9.09	0.31128	12.25493	103.228
3	3.210069	296	02/24/2022 15:19:43	2.773	105.997	9.09	0.30992	12.20143	103.224
3	-1.84429	297	02/24/2022 15:20:43	2.780	106.005	9.09	0.31070	12.23217	103.225
3	1.525781	298	02/24/2022 15:21:43	2.774	106.001	9.09	0.31005	12.20674	103.227
3	-1.04411	299	02/24/2022 15:22:43	2.778	106.005	9.09	0.31049	12.22414	103.227
3	4.577458	300	02/24/2022 15:23:43	2.759	105.992	9.09	0.30856	12.14785	103.233
3	0.32161	301	02/24/2022 15:24:43	2.758	105.988	9.09	0.30842	12.14249	103.230
3	3.690187	302	02/24/2022 15:25:43	2.743	105.971	9.09	0.30686	12.08098	103.228
3	1.768224	303	02/24/2022 15:26:43	2.735	105.966	9.09	0.30611	12.05151	103.231
3	-0.24083	304	02/24/2022 15:27:43	2.736	105.966	9.09	0.30621	12.05553	103.230
3	2.327566	305	02/24/2022 15:28:43	2.727	105.958	9.09	0.30523	12.01674	103.231
3	-1.60667	306	02/24/2022 15:29:43	2.733	105.966	9.09	0.30591	12.04351	103.233
3	4.175015	307	02/24/2022 15:30:43	2.716	105.949	9.09	0.30414	11.97393	103.233
3	-2.24828	308	02/24/2022 15:31:43	2.725	105.953	9.09	0.30509	12.01140	103.228
3	2.810786	309	02/24/2022 15:32:43	2.714	105.945	9.09	0.30390	11.96455	103.231
3	-0.48328	310	02/24/2022 15:33:43	2.716	105.945	9.09	0.30410	11.97261	103.229
3	2.088283	311	02/24/2022 15:34:43	2.707	105.936	9.09	0.30322	11.93780	103.229
3	3.371736	312	02/24/2022 15:35:43	2.693	105.923	9.09	0.30179	11.88161	103.230
3	1.765064	313	02/24/2022 15:36:43	2.686	105.919	9.09	0.30105	11.85219	103.233
3	3.612513	314	02/24/2022 15:37:43	2.671	105.906	9.09	0.29952	11.79198	103.235
3	-2.48918	315	02/24/2022 15:38:43	2.681	105.910	9.09	0.30057	11.83347	103.229

Table E-5
IT-2 Test Data

3	3.373287	316	02/24/2022 15:39:43	2.667	105.897	9.09	0.29914	11.77725	103.230
3	3.932572	317	02/24/2022 15:40:43	2.651	105.880	9.09	0.29748	11.71170	103.229
3	3.612513	318	02/24/2022 15:41:43	2.636	105.867	9.09	0.29595	11.65150	103.231
3	0.961786	319	02/24/2022 15:42:43	2.632	105.867	9.09	0.29554	11.63547	103.235
3	-2.48757	320	02/24/2022 15:43:43	2.642	105.871	9.09	0.29659	11.67693	103.229
3	0.560893	321	02/24/2022 15:44:43	2.640	105.867	9.09	0.29636	11.66758	103.227
3	1.044113	322	02/24/2022 15:45:43	2.635	105.862	9.09	0.29591	11.65018	103.227
3	2.89001	323	02/24/2022 15:46:43	2.623	105.849	9.09	0.29469	11.60201	103.226
3	1.844289	324	02/24/2022 15:47:43	2.616	105.841	9.09	0.29391	11.57127	103.225
3	0	325	02/24/2022 15:48:43	2.616	105.841	9.09	0.29391	11.57127	103.225
3	1.768224	326	02/24/2022 15:49:43	2.608	105.836	9.09	0.29316	11.54180	103.228
3	3.129293	327	02/24/2022 15:50:43	2.595	105.823	9.09	0.29184	11.48965	103.228
3	0.803336	328	02/24/2022 15:51:43	2.592	105.819	9.09	0.29150	11.47626	103.227
3	3.930963	329	02/24/2022 15:52:43	2.576	105.802	9.09	0.28983	11.41074	103.226
3	-2.24673	330	02/24/2022 15:53:43	2.585	105.806	9.09	0.29078	11.44819	103.221
3	2.086732	331	02/24/2022 15:54:43	2.576	105.797	9.09	0.28990	11.41341	103.221
3	0.080776	332	02/24/2022 15:55:43	2.576	105.793	9.09	0.28987	11.41206	103.217
3	3.371679	333	02/24/2022 15:56:43	2.562	105.780	9.09	0.28844	11.35587	103.218
3	-0.80644	334	02/24/2022 15:57:43	2.565	105.784	9.09	0.28878	11.36931	103.219
3	1.608166	335	02/24/2022 15:58:43	2.559	105.776	9.09	0.28810	11.34250	103.217
3	5.696085	336	02/24/2022 15:59:43	2.535	105.754	9.09	0.28569	11.24757	103.219
3	-2.89001	337	02/24/2022 16:00:43	2.547	105.767	9.09	0.28691	11.29574	103.220

Table E-5
IT-2 Test Data

Run	Average Rate	Difference from previous (%)	Derivation from Average
1	1.501408833		6.8
2	1.401319106	7.1	-0.4
3	1.316299113	6.5	-6.4

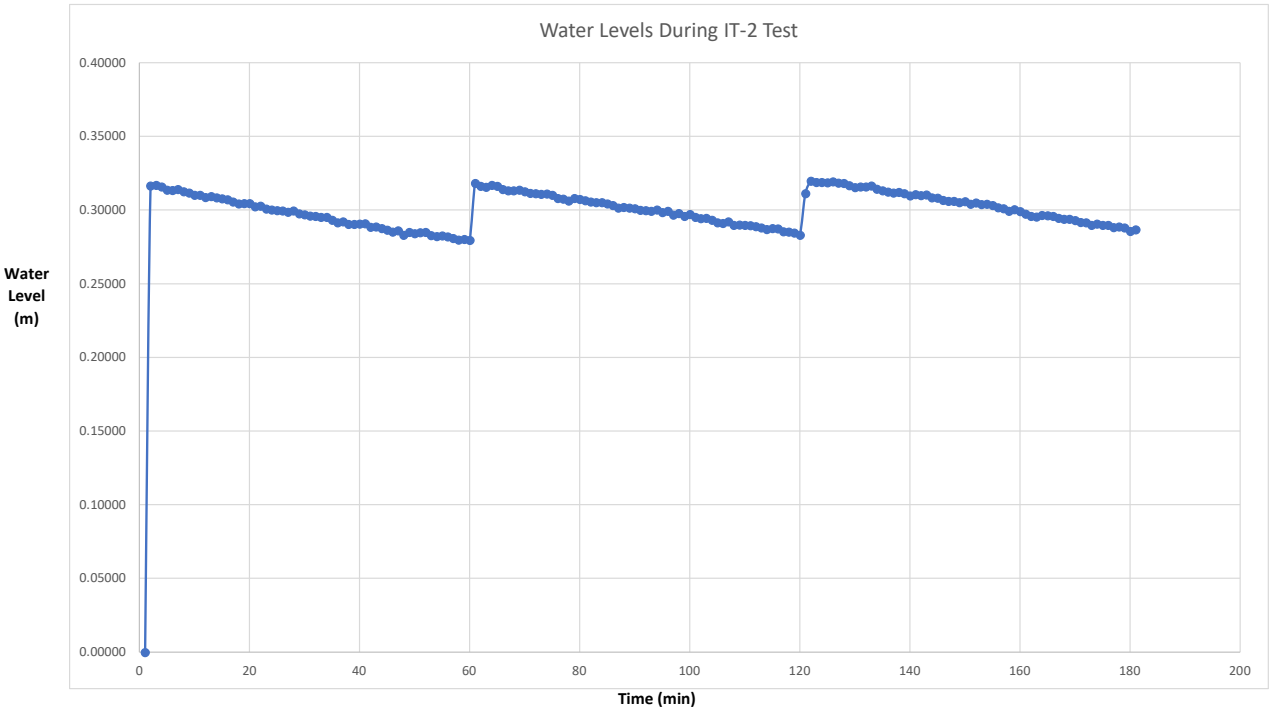


Table E-6
IT-3 Test Data

Run	Rate	#	Date-Time (PST)	Ch: 1 - Differential Pressure (kpa)	Ch: 2 - Absolute Pressure (kpa)	Ch: 3 - Temperature (°C)	Water Level (m)	Water Level (in)	Barometric Pressure (kpa)
		1361	02/25/2022 09:05:57	3.801	106.817	3.69	0.40074	15.77732	103.016
1	-0.19511	1362	02/25/2022 09:06:57	3.801	106.818	4.43	0.40083	15.78057	103.017
1	2.276345	1363	02/25/2022 09:07:57	3.792	106.812	4.94	0.39986	15.74263	103.020
1	-0.26612	1364	02/25/2022 09:08:57	3.793	106.816	5.36	0.39998	15.74707	103.023
1	-3.17371	1365	02/25/2022 09:09:57	3.806	106.820	5.56	0.40132	15.79996	103.014
1	1.985017	1366	02/25/2022 09:10:57	3.798	106.816	5.77	0.40048	15.76688	103.018
1	-1.46938	1367	02/25/2022 09:11:57	3.804	106.818	5.87	0.40110	15.79137	103.014
1	4.055332	1368	02/25/2022 09:12:57	3.787	106.801	5.87	0.39938	15.72378	103.014
1	-5.06912	1369	02/25/2022 09:13:57	3.808	106.822	5.87	0.40153	15.80827	103.014
1	3.021429	1370	02/25/2022 09:14:57	3.796	106.812	5.97	0.40025	15.75791	103.016
1	3.443276	1371	02/25/2022 09:15:57	3.781	106.805	5.87	0.39879	15.70052	103.024
1	0.481565	1372	02/25/2022 09:16:57	3.779	106.805	5.87	0.39859	15.69249	103.026
1	0.532225	1373	02/25/2022 09:17:57	3.777	106.801	5.87	0.39836	15.68362	103.024
1	-1.73774	1374	02/25/2022 09:18:57	3.784	106.805	5.87	0.39910	15.71259	103.021
1	2.612189	1375	02/25/2022 09:19:57	3.773	106.788	5.87	0.39799	15.66905	103.015
1	0.532283	1376	02/25/2022 09:20:57	3.771	106.784	5.87	0.39777	15.66018	103.013
1	4.269979	1377	02/25/2022 09:21:57	3.754	106.770	5.77	0.39596	15.58901	103.016
1	-2.02763	1378	02/25/2022 09:22:57	3.762	106.778	5.77	0.39682	15.62281	103.016
1	4.194659	1379	02/25/2022 09:23:57	3.745	106.770	5.77	0.39504	15.55290	103.025
1	-1.68547	1380	02/25/2022 09:24:57	3.752	106.770	5.77	0.39576	15.58099	103.018
1	2.50764	1381	02/25/2022 09:25:57	3.741	106.761	5.77	0.39470	15.53919	103.020
1	1.355945	1382	02/25/2022 09:26:57	3.735	106.748	5.77	0.39412	15.51659	103.013
1	-2.02763	1383	02/25/2022 09:27:57	3.744	106.757	5.77	0.39498	15.55039	103.013
1	-0.24078	1384	02/25/2022 09:28:57	3.745	106.757	5.77	0.39508	15.55440	103.012
1	0.289891	1385	02/25/2022 09:29:57	3.744	106.753	5.77	0.39496	15.54957	103.009
1	2.081505	1386	02/25/2022 09:30:57	3.735	106.740	5.77	0.39408	15.51488	103.005
1	1.444687	1387	02/25/2022 09:31:57	3.729	106.740	5.77	0.39347	15.49080	103.011
1	1.303676	1388	02/25/2022 09:32:57	3.724	106.732	5.77	0.39291	15.46907	103.008
1	-0.47995	1389	02/25/2022 09:33:57	3.726	106.732	5.77	0.39312	15.47707	103.006
1	3.492012	1390	02/25/2022 09:34:57	3.711	106.721	5.67	0.39164	15.41887	103.010
1	1.359156	1391	02/25/2022 09:35:57	3.706	106.709	5.67	0.39106	15.39622	103.003
1	-2.0815	1392	02/25/2022 09:36:57	3.714	106.721	5.67	0.39195	15.43091	103.007
1	2.702459	1393	02/25/2022 09:37:57	3.703	106.717	5.67	0.39080	15.38587	103.014
1	1.97851	1394	02/25/2022 09:38:57	3.695	106.713	5.67	0.38996	15.35289	103.018
1	1.303728	1395	02/25/2022 09:39:57	3.689	106.704	5.67	0.38941	15.33116	103.015
1	2.99074	1396	02/25/2022 09:40:57	3.677	106.696	5.67	0.38815	15.28132	103.019
1	-6.70543	1397	02/25/2022 09:41:57	3.705	106.713	5.67	0.39098	15.39308	103.008
1	2.320668	1398	02/25/2022 09:42:57	3.695	106.700	5.67	0.39000	15.35440	103.005
1	-1.20551	1399	02/25/2022 09:43:57	3.700	106.700	5.67	0.39051	15.37449	103.000
1	1.394021	1400	02/25/2022 09:44:57	3.694	106.704	5.67	0.38992	15.35126	103.010
1	5.792968	1401	02/25/2022 09:45:57	3.670	106.683	5.67	0.38747	15.25471	103.013
1	0.24078	1402	02/25/2022 09:46:57	3.669	106.683	5.67	0.38737	15.25069	103.014
1	0	1403	02/25/2022 09:47:57	3.669	106.683	5.67	0.38737	15.25069	103.014
1	2.268457	1404	02/25/2022 09:48:57	3.660	106.675	5.67	0.38641	15.21289	103.015
1	-4.0553	1405	02/25/2022 09:49:57	3.677	106.692	5.67	0.38812	15.28047	103.015
1	5.843686	1406	02/25/2022 09:50:57	3.652	106.666	5.67	0.38565	15.18308	103.014
1	-2.51073	1407	02/25/2022 09:51:57	3.663	106.675	5.67	0.38671	15.22492	103.012
1	2.02917	1408	02/25/2022 09:52:57	3.654	106.666	5.67	0.38585	15.19111	103.012
1	4.055296	1409	02/25/2022 09:53:57	3.638	106.650	5.67	0.38414	15.12352	103.012
1	-2.99235	1410	02/25/2022 09:54:57	3.650	106.658	5.67	0.38540	15.17339	103.008
1	0.24078	1411	02/25/2022 09:55:57	3.649	106.658	5.67	0.38530	15.16938	103.009
1	3.282238	1412	02/25/2022 09:56:57	3.635	106.645	5.67	0.38391	15.11467	103.010
1	-2.45691	1413	02/25/2022 09:57:57	3.646	106.650	5.67	0.38495	15.15562	103.004
1	5.49992	1414	02/25/2022 09:58:57	3.623	106.633	5.67	0.38262	15.06396	103.010
1	-1.20235	1415	02/25/2022 09:59:57	3.628	106.633	5.67	0.38313	15.08400	103.005
1	-2.2684	1416	02/25/2022 10:00:57	3.637	106.641	5.67	0.38409	15.12180	103.004
		1417	02/25/2022 10:01:57	3.759	106.763	5.67	0.39654	15.61189	103.004

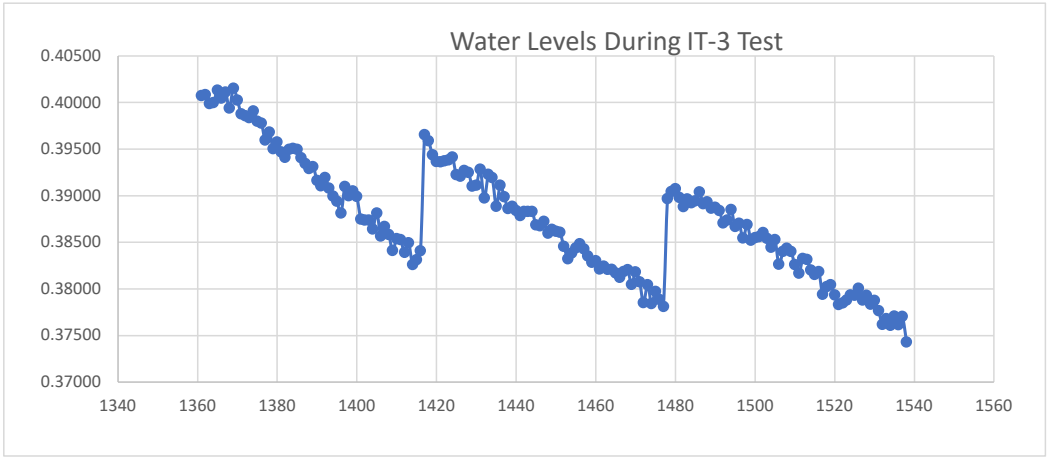
Table E-6
IT-3 Test Data

2	1.52316	1418	02/25/2022 10:02:57	3.753	106.757	5.77	0.39590	15.58650	103.004
2	3.552286	1419	02/25/2022 10:03:57	3.738	106.742	5.87	0.39439	15.52730	103.004
2	1.713051	1420	02/25/2022 10:04:57	3.731	106.740	5.97	0.39367	15.49875	103.009
2	0.052269	1421	02/25/2022 10:05:57	3.731	106.736	5.97	0.39365	15.49788	103.005
2	-0.24078	1422	02/25/2022 10:06:57	3.732	106.736	5.97	0.39375	15.50189	103.004
2	-0.21495	1423	02/25/2022 10:07:57	3.733	106.734	6.07	0.39384	15.50547	103.001
2	-0.72396	1424	02/25/2022 10:08:57	3.736	106.734	6.07	0.39415	15.51754	102.998
2	4.490987	1425	02/25/2022 10:09:57	3.717	106.721	6.07	0.39224	15.44269	103.004
2	0.338948	1426	02/25/2022 10:10:57	3.716	106.713	6.07	0.39210	15.43704	102.997
2	-1.4431	1427	02/25/2022 10:11:57	3.722	106.713	6.07	0.39271	15.46109	102.991
2	0.481569	1428	02/25/2022 10:12:57	3.720	106.713	6.07	0.39251	15.45307	102.993
2	3.523082	1429	02/25/2022 10:13:57	3.705	106.700	6.07	0.39102	15.39435	102.995
2	-0.29305	1430	02/25/2022 10:14:57	3.706	106.704	6.07	0.39114	15.39923	102.998
2	-4.00626	1431	02/25/2022 10:15:57	3.723	106.717	6.07	0.39284	15.46600	102.994
2	7.291716	1432	02/25/2022 10:16:57	3.693	106.692	6.07	0.38975	15.34447	102.999
2	-5.9832	1433	02/25/2022 10:17:57	3.717	106.708	6.07	0.39228	15.44419	102.991
2	0.771464	1434	02/25/2022 10:18:57	3.714	106.704	6.07	0.39196	15.43134	102.990
2	7.29005	1435	02/25/2022 10:19:57	3.684	106.679	6.07	0.38887	15.30984	102.995
2	-5.31311	1436	02/25/2022 10:20:57	3.706	106.700	6.07	0.39112	15.39839	102.994
2	2.903717	1437	02/25/2022 10:21:57	3.694	106.679	6.07	0.38989	15.34999	102.985
2	2.992345	1438	02/25/2022 10:22:57	3.682	106.671	6.07	0.38862	15.30012	102.989
2	-0.53068	1439	02/25/2022 10:23:57	3.684	106.675	6.07	0.38885	15.30896	102.991
2	1.013857	1440	02/25/2022 10:24:57	3.680	106.671	6.07	0.38842	15.29207	102.991
2	1.303694	1441	02/25/2022 10:25:57	3.674	106.662	6.07	0.38787	15.27034	102.988
2	-1.06291	1442	02/25/2022 10:26:57	3.679	106.671	6.07	0.38832	15.28805	102.992
2	0.04911	1443	02/25/2022 10:27:57	3.678	106.666	6.07	0.38830	15.28724	102.988
2	0	1444	02/25/2022 10:28:57	3.678	106.666	6.07	0.38830	15.28724	102.988
2	3.332959	1445	02/25/2022 10:29:57	3.664	106.649	6.07	0.38688	15.23169	102.985
2	0.291503	1446	02/25/2022 10:30:57	3.663	106.645	6.07	0.38676	15.22683	102.982
2	-1.15326	1447	02/25/2022 10:31:57	3.668	106.641	6.07	0.38725	15.24605	102.973
2	2.992402	1448	02/25/2022 10:32:57	3.656	106.633	6.07	0.38598	15.19618	102.977
2	-0.96475	1449	02/25/2022 10:33:57	3.660	106.633	6.07	0.38639	15.21225	102.973
2	0.483177	1450	02/25/2022 10:34:57	3.658	106.633	6.07	0.38619	15.20420	102.975
2	0.240785	1451	02/25/2022 10:35:57	3.657	106.633	6.07	0.38608	15.20019	102.976
2	3.575351	1452	02/25/2022 10:36:57	3.642	106.616	6.07	0.38457	15.14060	102.974
2	3.18086	1453	02/25/2022 10:37:57	3.629	106.612	6.07	0.38322	15.08759	102.983
2	-1.49382	1454	02/25/2022 10:38:57	3.635	106.616	6.07	0.38386	15.11248	102.981
2	-1.25458	1455	02/25/2022 10:39:57	3.640	106.620	6.07	0.38439	15.13339	102.980
2	-1.06768	1456	02/25/2022 10:40:57	3.644	106.628	6.07	0.38484	15.15119	102.984
2	1.254584	1457	02/25/2022 10:41:57	3.639	106.624	6.07	0.38431	15.13028	102.985
2	1.78848	1458	02/25/2022 10:42:57	3.632	106.616	6.07	0.38355	15.10047	102.984
2	1.688651	1459	02/25/2022 10:43:57	3.625	106.616	6.07	0.38284	15.07232	102.991
2	-0.43401	1460	02/25/2022 10:44:57	3.627	106.612	6.07	0.38302	15.07956	102.985
2	2.079926	1461	02/25/2022 10:45:57	3.618	106.599	6.07	0.38214	15.04489	102.981
2	-0.72396	1462	02/25/2022 10:46:57	3.621	106.599	6.07	0.38245	15.05696	102.978
2	0.822183	1463	02/25/2022 10:47:57	3.618	106.591	6.07	0.38210	15.04326	102.973
2	0	1464	02/25/2022 10:48:57	3.618	106.591	6.07	0.38210	15.04326	102.973
2	0.876003	1465	02/25/2022 10:49:57	3.614	106.578	6.07	0.38173	15.02866	102.964
2	1.153204	1466	02/25/2022 10:50:57	3.609	106.582	6.07	0.38124	15.00944	102.973
2	-1.4431	1467	02/25/2022 10:51:57	3.615	106.582	6.07	0.38185	15.03349	102.967
2	-0.48318	1468	02/25/2022 10:52:57	3.617	106.582	6.07	0.38206	15.04154	102.965
2	3.713205	1469	02/25/2022 10:53:57	3.602	106.574	6.07	0.38048	14.97965	102.972
2	-3.18092	1470	02/25/2022 10:54:57	3.615	106.578	6.07	0.38183	15.03267	102.963
2	2.509225	1471	02/25/2022 10:55:57	3.604	106.570	6.07	0.38077	14.99085	102.965
2	5.259235	1472	02/25/2022 10:56:57	3.583	106.553	6.07	0.37854	14.90319	102.970
2	-4.53527	1473	02/25/2022 10:57:57	3.601	106.570	6.07	0.38046	14.97878	102.968
2	4.776057	1474	02/25/2022 10:58:57	3.582	106.553	6.07	0.37844	14.89918	102.971
2	-3.04146	1475	02/25/2022 10:59:57	3.594	106.565	6.07	0.37973	14.94987	102.971
2	2.027656	1476	02/25/2022 11:00:57	3.586	106.557	6.07	0.37887	14.91608	102.971
2	1.786872	1477	02/25/2022 11:01:57	3.578	106.548	6.07	0.37811	14.88630	102.970
		1478	02/25/2022 11:02:57	3.692	106.658	6.07	0.38968	15.34176	102.966

Table E-6
IT-3 Test Data

3	-1.75952	1479	02/25/2022 11:03:57	3.699	106.664	6.18	0.39043	15.37108	102.965
3	-0.74907	1480	02/25/2022 11:04:57	3.702	106.666	6.28	0.39074	15.38357	102.964
3	2.21625	1481	02/25/2022 11:05:57	3.693	106.662	6.28	0.38980	15.34663	102.969
3	2.323892	1482	02/25/2022 11:06:57	3.683	106.649	6.28	0.38882	15.30790	102.966
3	-1.92945	1483	02/25/2022 11:07:57	3.691	106.649	6.28	0.38964	15.34005	102.958
3	0.915588	1484	02/25/2022 11:08:57	3.688	106.654	6.28	0.38925	15.32479	102.966
3	-0.48312	1485	02/25/2022 11:09:57	3.690	106.654	6.28	0.38945	15.33285	102.964
3	-2.22096	1486	02/25/2022 11:10:57	3.699	106.658	6.28	0.39039	15.36986	102.959
3	2.993983	1487	02/25/2022 11:11:57	3.686	106.649	6.28	0.38913	15.31996	102.963
3	-0.48312	1488	02/25/2022 11:12:57	3.688	106.649	6.28	0.38933	15.32801	102.961
3	1.599981	1489	02/25/2022 11:13:57	3.682	106.637	6.28	0.38865	15.30135	102.955
3	-0.24079	1490	02/25/2022 11:14:57	3.683	106.637	6.28	0.38876	15.30536	102.954
3	0.771472	1491	02/25/2022 11:15:57	3.680	106.633	6.28	0.38843	15.29250	102.953
3	3.233162	1492	02/25/2022 11:16:57	3.666	106.624	6.28	0.38706	15.23862	102.958
3	-0.72075	1493	02/25/2022 11:17:57	3.669	106.624	6.28	0.38737	15.25063	102.955
3	-2.7532	1494	02/25/2022 11:18:57	3.681	106.633	6.28	0.38853	15.29652	102.952
3	4.29769	1495	02/25/2022 11:19:57	3.663	106.616	6.28	0.38671	15.22489	102.953
3	-0.77147	1496	02/25/2022 11:20:57	3.666	106.620	6.28	0.38704	15.23775	102.954
3	3.760745	1497	02/25/2022 11:21:57	3.650	106.607	6.28	0.38545	15.17507	102.957
3	-3.42174	1498	02/25/2022 11:22:57	3.665	106.612	6.28	0.38690	15.23210	102.947
3	3.957188	1499	02/25/2022 11:23:57	3.648	106.603	6.28	0.38522	15.16614	102.955
3	-0.67486	1500	02/25/2022 11:24:57	3.651	106.599	6.28	0.38551	15.17739	102.948
3	-0.24079	1501	02/25/2022 11:25:57	3.652	106.599	6.28	0.38561	15.18140	102.947
3	-1.01381	1502	02/25/2022 11:26:57	3.656	106.603	6.28	0.38604	15.19830	102.947
3	1.455807	1503	02/25/2022 11:27:57	3.650	106.582	6.28	0.38542	15.17404	102.932
3	2.220903	1504	02/25/2022 11:28:57	3.641	106.578	6.28	0.38448	15.13702	102.937
3	-1.9263	1505	02/25/2022 11:29:57	3.649	106.578	6.28	0.38530	15.16913	102.929
3	6.271603	1506	02/25/2022 11:30:57	3.623	106.557	6.28	0.38264	15.06460	102.934
3	-3.28233	1507	02/25/2022 11:31:57	3.636	106.569	6.28	0.38403	15.11931	102.933
3	-0.77308	1508	02/25/2022 11:32:57	3.640	106.574	6.28	0.38436	15.13219	102.934
3	0.77308	1509	02/25/2022 11:33:57	3.636	106.569	6.28	0.38403	15.11931	102.933
3	3.3346	1510	02/25/2022 11:34:57	3.623	106.553	6.28	0.38262	15.06373	102.930
3	2.219352	1511	02/25/2022 11:35:57	3.613	106.548	6.28	0.38168	15.02674	102.935
3	-3.71634	1512	02/25/2022 11:36:57	3.629	106.557	6.28	0.38325	15.08868	102.928
3	0.242338	1513	02/25/2022 11:37:57	3.628	106.557	6.28	0.38315	15.08464	102.929
3	2.634029	1514	02/25/2022 11:38:57	3.617	106.538	6.18	0.38203	15.04074	102.921
3	1.182145	1515	02/25/2022 11:39:57	3.612	106.540	6.28	0.38153	15.02104	102.928
3	-0.72236	1516	02/25/2022 11:40:57	3.615	106.540	6.28	0.38184	15.03308	102.925
3	5.73931	1517	02/25/2022 11:41:57	3.591	106.523	6.28	0.37941	14.93742	102.932
3	-1.97541	1518	02/25/2022 11:42:57	3.599	106.527	6.28	0.38025	14.97035	102.928
3	-0.4598	1519	02/25/2022 11:43:57	3.601	106.525	6.18	0.38044	14.97801	102.924
3	2.536591	1520	02/25/2022 11:44:57	3.591	106.515	6.28	0.37937	14.93573	102.924
3	2.510858	1521	02/25/2022 11:45:57	3.580	106.506	6.28	0.37830	14.89388	102.926
3	-0.48318	1522	02/25/2022 11:46:57	3.582	106.506	6.28	0.37851	14.90194	102.924
3	-0.72236	1523	02/25/2022 11:47:57	3.585	106.506	6.28	0.37882	14.91398	102.921
3	-1.2562	1524	02/25/2022 11:48:57	3.591	106.511	6.28	0.37935	14.93491	102.920
3	0.102989	1525	02/25/2022 11:49:57	3.590	106.502	6.28	0.37930	14.93320	102.912
3	-1.83606	1526	02/25/2022 11:50:57	3.598	106.515	6.28	0.38008	14.96380	102.917
3	2.989273	1527	02/25/2022 11:51:57	3.585	106.506	6.28	0.37882	14.91398	102.921
3	-1.15322	1528	02/25/2022 11:52:57	3.590	106.502	6.28	0.37930	14.93320	102.912
3	2.220903	1529	02/25/2022 11:53:57	3.581	106.498	6.28	0.37836	14.89618	102.917
3	-0.9647	1530	02/25/2022 11:54:57	3.585	106.498	6.28	0.37877	14.91226	102.913
3	2.607472	1531	02/25/2022 11:55:57	3.574	106.481	6.28	0.37767	14.86880	102.907
3	3.475557	1532	02/25/2022 11:56:57	3.560	106.473	6.28	0.37620	14.81088	102.913
3	-1.44788	1533	02/25/2022 11:57:57	3.566	106.473	6.28	0.37681	14.83501	102.907
3	1.736228	1534	02/25/2022 11:58:57	3.558	106.468	6.28	0.37607	14.80607	102.910
3	-2.40793	1535	02/25/2022 11:59:57	3.568	106.468	6.28	0.37709	14.84620	102.900
3	2.21941	1536	02/25/2022 12:00:57	3.559	106.464	6.28	0.37615	14.80921	102.905
3	-2.11797	1537	02/25/2022 12:01:57	3.568	106.460	6.28	0.37705	14.84451	102.892
3	6.466381	1538	02/25/2022 12:02:57	3.541	106.443	6.28	0.37431	14.73674	102.902

Table E-6
IT-3 Test Data



Run	Average Rate	Difference From Previous	Difference from Average
1	0.71511094		-0.7
2	0.725593956	1.5	6.4
3	0.60501672	-16.6	-9.1

Table E-7
IT-4 Test Data

Run	Rate	#	Date-Time (PST)	Ch: 1 - Differential Pressure (kpa)	Ch: 2 - Absolute Pressure (kpa)	Ch: 3 - Temperature (°C)	Water Level (m)	Water Level (in)	Barometric Pressure (kpa)
		1359	02/25/2022 09:02:43	3.158	106.323	7.09	0.34915	13.74598	103.165
		1360	02/25/2022 09:03:43	3.161	106.321	6.99	0.34951	13.76029	103.160
1		1361	02/25/2022 09:04:43	3.247	106.403	6.99	0.35831	14.10665	103.156
1	1.310128	1362	02/25/2022 09:05:43	3.242	106.402	6.89	0.35775	14.08481	103.160
1	0.402378	1363	02/25/2022 09:06:43	3.240	106.406	6.89	0.35758	14.07811	103.166
1	5.083429	1364	02/25/2022 09:07:43	3.219	106.383	6.79	0.35543	13.99338	103.164
1	2.566358	1365	02/25/2022 09:08:43	3.209	106.375	6.79	0.35435	13.95061	103.166
1	-0.48159	1366	02/25/2022 09:09:43	3.211	106.375	6.79	0.35455	13.95864	103.164
1	2.8322	1367	02/25/2022 09:10:43	3.199	106.356	6.68	0.35335	13.91143	103.157
1	2.892664	1368	02/25/2022 09:11:43	3.187	106.343	6.68	0.35213	13.86322	103.156
1	0.237633	1369	02/25/2022 09:12:43	3.186	106.343	6.68	0.35203	13.85926	103.157
1	2.407921	1370	02/25/2022 09:13:43	3.176	106.330	6.68	0.35101	13.81913	103.154
1	2.887897	1371	02/25/2022 09:14:43	3.164	106.317	6.68	0.34978	13.77100	103.153
1	2.246397	1372	02/25/2022 09:15:43	3.155	106.313	6.68	0.34883	13.73356	103.158
1	0.563954	1373	02/25/2022 09:16:43	3.152	106.321	6.68	0.34859	13.72416	103.169
1	3.692643	1374	02/25/2022 09:17:43	3.137	106.304	6.68	0.34703	13.66261	103.167
1	-4.81739	1375	02/25/2022 09:18:43	3.157	106.317	6.68	0.34907	13.74290	103.160
1	5.375029	1376	02/25/2022 09:19:43	3.135	106.287	6.68	0.34679	13.65332	103.152
1	2.485581	1377	02/25/2022 09:20:43	3.124	106.269	6.68	0.34574	13.61189	103.145
1	5.135845	1378	02/25/2022 09:21:43	3.103	106.252	6.68	0.34357	13.52630	103.149
1	0.184782	1379	02/25/2022 09:22:43	3.102	106.259	6.58	0.34349	13.52322	103.157
1	3.29186	1380	02/25/2022 09:23:43	3.089	106.251	6.58	0.34210	13.46835	103.162
1	2.327146	1381	02/25/2022 09:24:43	3.079	106.242	6.58	0.34111	13.42957	103.163
1	-3.77028	1382	02/25/2022 09:25:43	3.095	106.251	6.58	0.34271	13.49240	103.156
1	2.244719	1383	02/25/2022 09:26:43	3.085	106.233	6.58	0.34176	13.45499	103.148
1	3.049518	1384	02/25/2022 09:27:43	3.073	106.225	6.58	0.34047	13.40417	103.152
1	2.162349	1385	02/25/2022 09:28:43	3.064	106.212	6.58	0.33955	13.36813	103.148
1	-0.72392	1386	02/25/2022 09:29:43	3.067	106.212	6.58	0.33986	13.38019	103.145
1	5.780529	1387	02/25/2022 09:30:43	3.043	106.186	6.58	0.33741	13.28385	103.143
1	1.603165	1388	02/25/2022 09:31:43	3.036	106.177	6.58	0.33673	13.25713	103.141
1	-0.88395	1389	02/25/2022 09:32:43	3.040	106.186	6.58	0.33711	13.27186	103.146
1	-0.48158	1390	02/25/2022 09:33:43	3.042	106.186	6.58	0.33731	13.27989	103.144
1	5.295846	1391	02/25/2022 09:34:43	3.020	106.160	6.58	0.33507	13.19163	103.140
1	-0.40398	1392	02/25/2022 09:35:43	3.021	106.155	6.58	0.33524	13.19836	103.134
1	-4.01107	1393	02/25/2022 09:36:43	3.038	106.164	6.58	0.33694	13.26521	103.126
1	3.928703	1394	02/25/2022 09:37:43	3.022	106.147	6.58	0.33527	13.19973	103.125
1	-0.63684	1395	02/25/2022 09:38:43	3.024	106.155	6.58	0.33554	13.21035	103.131
1	0.877634	1396	02/25/2022 09:39:43	3.021	106.147	6.58	0.33517	13.19572	103.126
1	4.494263	1397	02/25/2022 09:40:43	3.002	106.125	6.58	0.33327	13.12082	103.123
1	2.40314	1398	02/25/2022 09:41:43	2.992	106.112	6.58	0.33225	13.08076	103.120
1	1.604774	1399	02/25/2022 09:42:43	2.985	106.103	6.58	0.33157	13.05402	103.118
1	-1.5224	1400	02/25/2022 09:43:43	2.992	106.108	6.58	0.33222	13.07939	103.116
1	2.084747	1401	02/25/2022 09:44:43	2.983	106.099	6.58	0.33133	13.04464	103.116
1	4.007914	1402	02/25/2022 09:45:43	2.966	106.077	6.58	0.32964	12.97785	103.111
1	0.481581	1403	02/25/2022 09:46:43	2.964	106.077	6.58	0.32943	12.96982	103.113
1	-0.96471	1404	02/25/2022 09:47:43	2.968	106.077	6.58	0.32984	12.98590	103.109
1	3.13028	1405	02/25/2022 09:48:43	2.955	106.064	6.58	0.32852	12.93373	103.109
1	2.327146	1406	02/25/2022 09:49:43	2.946	106.056	6.58	0.32753	12.89494	103.110
1	3.128671	1407	02/25/2022 09:50:43	2.933	106.043	6.58	0.32621	12.84280	103.110
1	-3.85265	1408	02/25/2022 09:51:43	2.949	106.056	6.58	0.32784	12.90701	103.107
1	3.451889	1409	02/25/2022 09:52:43	2.934	106.038	6.58	0.32638	12.84948	103.104
1	3.12712	1410	02/25/2022 09:53:43	2.921	106.025	6.58	0.32505	12.79736	103.104
1	-0.64638	1411	02/25/2022 09:54:43	2.924	106.021	6.58	0.32533	12.80813	103.097
1	0.242399	1412	02/25/2022 09:55:43	2.923	106.021	6.58	0.32522	12.80409	103.098
1	6.259009	1413	02/25/2022 09:56:43	2.897	105.995	6.58	0.32257	12.69977	103.098
1	-1.52711	1414	02/25/2022 09:57:43	2.903	105.999	6.58	0.32322	12.72523	103.096

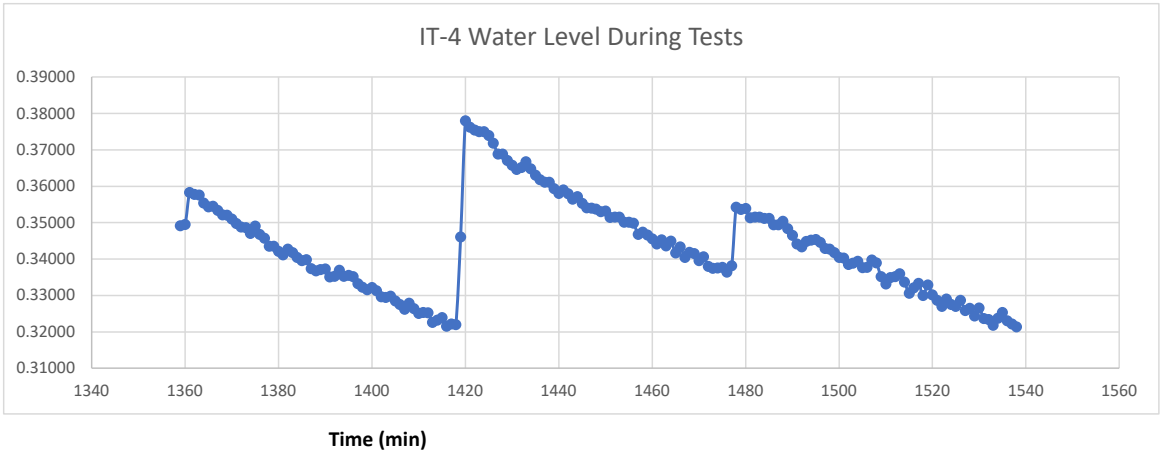
Table E-7
IT-4 Test Data

1	-1.7648	1415	02/25/2022 09:58:43	2.911	106.004	6.58	0.32397	12.75464	103.093
1	5.695057	1416	02/25/2022 09:59:43	2.887	105.982	6.58	0.32156	12.65972	103.095
1	-1.44474	1417	02/25/2022 10:00:43	2.893	105.982	6.58	0.32217	12.68380	103.089
1	0.318393	1418	02/25/2022 10:01:43	2.892	105.978	6.58	0.32203	12.67849	103.086
		1419	02/25/2022 10:02:43	3.127	106.210	6.48	0.34603	13.62335	103.083
		1420	02/25/2022 10:03:43	3.441	106.528	6.58	0.37801	14.88218	103.087
2	4.251864	1421	02/25/2022 10:04:43	3.423	106.506	6.58	0.37621	14.81132	103.083
2	1.739514	1422	02/25/2022 10:05:43	3.416	106.499	6.68	0.37547	14.78233	103.083
2	1.043988	1423	02/25/2022 10:06:43	3.411	106.494	6.68	0.37503	14.76493	103.083
2	0	1424	02/25/2022 10:07:43	3.411	106.494	6.68	0.37503	14.76493	103.083
2	2.567951	1425	02/25/2022 10:08:43	3.401	106.486	6.68	0.37394	14.72213	103.085
2	4.978974	1426	02/25/2022 10:09:43	3.380	106.477	6.68	0.37183	14.63914	103.097
2	7.060631	1427	02/25/2022 10:10:43	3.351	106.460	6.68	0.36885	14.52147	103.109
2	0.08237	1428	02/25/2022 10:11:43	3.350	106.455	6.68	0.36881	14.52009	103.105
2	4.091915	1429	02/25/2022 10:12:43	3.333	106.442	6.68	0.36708	14.45190	103.109
2	3.128689	1430	02/25/2022 10:13:43	3.320	106.429	6.68	0.36575	14.39975	103.109
2	2.732692	1431	02/25/2022 10:14:43	3.309	106.425	6.68	0.36460	14.35421	103.116
2	-1.28472	1432	02/25/2022 10:15:43	3.314	106.429	6.68	0.36514	14.37562	103.115
2	-3.77352	1433	02/25/2022 10:16:43	3.330	106.438	6.68	0.36674	14.43851	103.108
2	4.655869	1434	02/25/2022 10:17:43	3.311	106.421	6.68	0.36477	14.36091	103.110
2	4.172677	1435	02/25/2022 10:18:43	3.294	106.404	6.68	0.36300	14.29137	103.110
2	2.808743	1436	02/25/2022 10:19:43	3.282	106.395	6.68	0.36181	14.24456	103.113
2	1.603174	1437	02/25/2022 10:20:43	3.275	106.386	6.68	0.36113	14.21784	103.111
2	0	1438	02/25/2022 10:21:43	3.275	106.386	6.68	0.36113	14.21784	103.111
2	4.256655	1439	02/25/2022 10:22:43	3.258	106.378	6.68	0.35933	14.14689	103.120
2	3.128689	1440	02/25/2022 10:23:43	3.245	106.365	6.68	0.35801	14.09475	103.120
2	-2.40792	1441	02/25/2022 10:24:43	3.255	106.365	6.68	0.35903	14.13488	103.110
2	2.566343	1442	02/25/2022 10:25:43	3.244	106.356	6.68	0.35794	14.09211	103.112
2	3.53112	1443	02/25/2022 10:26:43	3.229	106.347	6.68	0.35644	14.03326	103.118
2	-1.68715	1444	02/25/2022 10:27:43	3.236	106.347	6.68	0.35716	14.06137	103.111
2	4.415077	1445	02/25/2022 10:28:43	3.218	106.330	6.68	0.35529	13.98779	103.112
2	2.810294	1446	02/25/2022 10:29:43	3.206	106.321	6.68	0.35410	13.94095	103.115
2	0.318452	1447	02/25/2022 10:30:43	3.205	106.317	6.68	0.35397	13.93564	103.112
2	0.479976	1448	02/25/2022 10:31:43	3.203	106.304	6.68	0.35376	13.92764	103.101
2	1.845575	1449	02/25/2022 10:32:43	3.195	106.295	6.68	0.35298	13.89688	103.100
2	-0.56556	1450	02/25/2022 10:33:43	3.198	106.287	6.68	0.35322	13.90631	103.089
2	4.256655	1451	02/25/2022 10:34:43	3.180	106.278	6.68	0.35142	13.83537	103.098
2	-0.32161	1452	02/25/2022 10:35:43	3.181	106.282	6.68	0.35155	13.84073	103.101
2	0	1453	02/25/2022 10:36:43	3.181	106.282	6.68	0.35155	13.84073	103.101
2	3.372698	1454	02/25/2022 10:37:43	3.167	106.269	6.68	0.35013	13.78452	103.102
2	0	1455	02/25/2022 10:38:43	3.167	106.269	6.68	0.35013	13.78452	103.102
2	0.640006	1456	02/25/2022 10:39:43	3.165	106.274	6.68	0.34986	13.77385	103.109
2	7.299815	1457	02/25/2022 10:40:43	3.134	106.243	6.68	0.34677	13.65218	103.109
2	-1.52396	1458	02/25/2022 10:41:43	3.141	106.248	6.68	0.34741	13.67758	103.107
2	2.007156	1459	02/25/2022 10:42:43	3.132	106.243	6.68	0.34656	13.64413	103.111
2	2.406313	1460	02/25/2022 10:43:43	3.122	106.230	6.68	0.34554	13.60403	103.108
2	3.369538	1461	02/25/2022 10:44:43	3.108	106.217	6.68	0.34412	13.54787	103.109
2	-2.80398	1462	02/25/2022 10:45:43	3.120	106.226	6.68	0.34530	13.59460	103.106
2	3.928725	1463	02/25/2022 10:46:43	3.104	106.209	6.68	0.34364	13.52912	103.105
2	-3.13191	1464	02/25/2022 10:47:43	3.117	106.209	6.68	0.34497	13.58132	103.092
2	7.702188	1465	02/25/2022 10:48:43	3.085	106.183	6.68	0.34170	13.45295	103.098
2	-3.93344	1466	02/25/2022 10:49:43	3.101	106.187	6.68	0.34337	13.51851	103.086
2	6.82139	1467	02/25/2022 10:50:43	3.073	106.170	6.68	0.34048	13.40482	103.097
2	-3.21112	1468	02/25/2022 10:51:43	3.086	106.174	6.68	0.34184	13.45834	103.088
2	0.803196	1469	02/25/2022 10:52:43	3.083	106.170	6.68	0.34150	13.44495	103.087
2	4.57505	1470	02/25/2022 10:53:43	3.064	106.157	6.68	0.33956	13.36870	103.093
2	-2.41108	1471	02/25/2022 10:54:43	3.074	106.157	6.68	0.34059	13.40888	103.083
2	6.179833	1472	02/25/2022 10:55:43	3.048	106.135	6.68	0.33797	13.30589	103.087
2	1.283171	1473	02/25/2022 10:56:43	3.043	106.131	6.68	0.33743	13.28450	103.088
2	-0.31845	1474	02/25/2022 10:57:43	3.044	106.135	6.68	0.33756	13.28981	103.091
2	-0.48314	1475	02/25/2022 10:58:43	3.046	106.135	6.68	0.33777	13.29786	103.089
2	3.128689	1476	02/25/2022 10:59:43	3.033	106.122	6.68	0.33644	13.24572	103.089
		1477	02/25/2022 11:00:43	3.050	106.148	6.68	0.33817	13.31389	103.098

Table E-7
IT-4 Test Data

3		1478	02/25/2022 11:01:43	3.208	106.304	6.68	0.35427	13.94774	103.096
3	1.604783	1479	02/25/2022 11:02:43	3.201	106.295	6.68	0.35359	13.92099	103.094
3	-0.80635	1480	02/25/2022 11:03:43	3.205	106.287	6.68	0.35393	13.93443	103.082
3	6.1846	1481	02/25/2022 11:04:43	3.179	106.278	6.68	0.35132	13.83135	103.099
3	-0.40237	1482	02/25/2022 11:05:43	3.181	106.274	6.68	0.35149	13.83806	103.093
3	-0.08398	1483	02/25/2022 11:06:43	3.181	106.265	6.68	0.35152	13.83946	103.084
3	0.887117	1484	02/25/2022 11:07:43	3.177	106.269	6.68	0.35115	13.82467	103.092
3	-0.00316	1485	02/25/2022 11:08:43	3.177	106.256	6.68	0.35115	13.82473	103.079
3	4.088755	1486	02/25/2022 11:09:43	3.160	106.243	6.68	0.34942	13.75658	103.083
3	0.085529	1487	02/25/2022 11:10:43	3.160	106.252	6.68	0.34938	13.75516	103.092
3	-2.41108	1488	02/25/2022 11:11:43	3.170	106.252	6.68	0.35040	13.79534	103.082
3	4.814234	1489	02/25/2022 11:12:43	3.150	106.226	6.68	0.34836	13.71510	103.076
3	4.416685	1490	02/25/2022 11:13:43	3.132	106.222	6.68	0.34649	13.64149	103.090
3	5.455848	1491	02/25/2022 11:14:43	3.109	106.200	6.68	0.34418	13.55056	103.091
3	2.005548	1492	02/25/2022 11:15:43	3.101	106.196	6.68	0.34334	13.51713	103.095
3	-3.53112	1493	02/25/2022 11:16:43	3.115	106.204	6.68	0.34483	13.57599	103.089
3	-0.88396	1494	02/25/2022 11:17:43	3.119	106.200	6.68	0.34520	13.59072	103.081
3	-0.40714	1495	02/25/2022 11:18:43	3.121	106.183	6.68	0.34538	13.59751	103.062
3	1.845575	1496	02/25/2022 11:19:43	3.113	106.174	6.68	0.34460	13.56675	103.061
3	3.935044	1497	02/25/2022 11:20:43	3.097	106.170	6.68	0.34293	13.50116	103.073
3	0.399214	1498	02/25/2022 11:21:43	3.095	106.161	6.68	0.34276	13.49451	103.066
3	2.327159	1499	02/25/2022 11:22:43	3.085	106.152	6.68	0.34178	13.45572	103.067
3	3.046319	1500	02/25/2022 11:23:43	3.073	106.144	6.68	0.34049	13.40495	103.071
3	0.483193	1501	02/25/2022 11:24:43	3.071	106.144	6.68	0.34028	13.39690	103.073
3	4.174227	1502	02/25/2022 11:25:43	3.053	106.126	6.68	0.33851	13.32733	103.073
3	-0.88074	1503	02/25/2022 11:26:43	3.057	106.135	6.68	0.33889	13.34201	103.078
3	-1.20557	1504	02/25/2022 11:27:43	3.062	106.135	6.68	0.33940	13.36210	103.073
3	4.171068	1505	02/25/2022 11:28:43	3.045	106.118	6.68	0.33763	13.29258	103.073
3	-0.32316	1506	02/25/2022 11:29:43	3.046	106.109	6.68	0.33777	13.29797	103.063
3	-4.57821	1507	02/25/2022 11:30:43	3.065	106.109	6.68	0.33971	13.37427	103.044
3	1.847126	1508	02/25/2022 11:31:43	3.057	106.100	6.68	0.33892	13.34348	103.043
3	8.909365	1509	02/25/2022 11:32:43	3.020	106.087	6.68	0.33515	13.19500	103.067
3	4.814234	1510	02/25/2022 11:33:43	3.000	106.074	6.68	0.33311	13.11476	103.074
3	-4.17584	1511	02/25/2022 11:34:43	3.018	106.079	6.68	0.33488	13.18436	103.061
3	-0.64161	1512	02/25/2022 11:35:43	3.020	106.074	6.68	0.33515	13.19505	103.054
3	-1.84868	1513	02/25/2022 11:36:43	3.028	106.070	6.68	0.33594	13.22586	103.042
3	5.299034	1514	02/25/2022 11:37:43	3.006	106.070	6.68	0.33369	13.13754	103.064
3	7.222155	1515	02/25/2022 11:38:43	2.976	106.044	6.68	0.33064	13.01717	103.068
3	-3.45346	1516	02/25/2022 11:39:43	2.991	106.049	6.68	0.33210	13.07473	103.058
3	-2.81029	1517	02/25/2022 11:40:43	3.002	106.044	6.68	0.33329	13.12157	103.042
3	7.702188	1518	02/25/2022 11:41:43	2.970	106.018	6.68	0.33003	12.99320	103.048
3	-6.66142	1519	02/25/2022 11:42:43	2.998	106.027	6.68	0.33285	13.10422	103.029
3	6.260652	1520	02/25/2022 11:43:43	2.972	106.014	6.68	0.33020	12.99988	103.042
3	3.529511	1521	02/25/2022 11:44:43	2.957	106.005	6.68	0.32870	12.94105	103.048
3	3.931884	1522	02/25/2022 11:45:43	2.941	106.001	6.68	0.32704	12.87552	103.060
3	-4.65587	1523	02/25/2022 11:46:43	2.960	106.005	6.68	0.32901	12.95312	103.045
3	3.53267	1524	02/25/2022 11:47:43	2.946	105.997	6.68	0.32751	12.89424	103.051
3	1.120039	1525	02/25/2022 11:48:43	2.941	105.988	6.68	0.32704	12.87558	103.047
3	-3.85273	1526	02/25/2022 11:49:43	2.957	105.988	6.68	0.32867	12.93979	103.031
3	6.740628	1527	02/25/2022 11:50:43	2.929	105.975	6.68	0.32582	12.82744	103.046
3	-1.60788	1528	02/25/2022 11:51:43	2.936	105.971	6.68	0.32650	12.85424	103.035
3	4.972655	1529	02/25/2022 11:52:43	2.915	105.949	6.68	0.32439	12.77136	103.034
3	-5.05347	1530	02/25/2022 11:53:43	2.936	105.962	6.68	0.32653	12.85559	103.026
3	6.82139	1531	02/25/2022 11:54:43	2.908	105.945	6.68	0.32364	12.74190	103.037
3	0.559244	1532	02/25/2022 11:55:43	2.905	105.940	6.68	0.32341	12.73258	103.035
3	3.852674	1533	02/25/2022 11:56:43	2.889	105.927	6.68	0.32178	12.66837	103.038
3	-4.73663	1534	02/25/2022 11:57:43	2.909	105.936	6.68	0.32378	12.74731	103.027
3	-3.69431	1535	02/25/2022 11:58:43	2.924	105.927	6.68	0.32535	12.80888	103.003
3	5.457456	1536	02/25/2022 11:59:43	2.902	105.919	6.68	0.32304	12.71793	103.017
3	2.005548	1537	02/25/2022 12:00:43	2.893	105.914	6.68	0.32219	12.68450	103.021
3	1.840807	1538	02/25/2022 12:01:43	2.886	105.893	6.68	0.32141	12.65382	103.007

Table E-7
IT-4 Test Data



Run	Average Rate (in.hr)	Difference from previous (%)	Derivation from Average
1	1.503320454		-0.9
2	1.753358883	16.6	15.6
3	1.293918613	-26.2	-14.7

GeoEngineers

APPENDIX B
DESIGN CALCULATIONS

Confidential

OWS and GAC Filtration System Treatment Flowrate Calculations
NuStar Terminals Operations Partnership LP
Vancouver, Washington

MAUL FOSTER ALONGI

Containment Area 4 Treatment Flowrate

Containment Area 4 - Treatment flowrate[(a)]: 230 gpm

Containment Area 7 Treatment Flowrate

Runoff volume discharged[(b)]: 191,000 gallons

Flowrate (gpm)[(c)]
79.6

Containment Area 7 Treatment Flowrate: 79.6 gpm

Combined Treatment Flowrate: 310 gpm

Notes

GAC = granular activated carbon.

gpm = gallons per minute.

OWS = oil/water seperator.

[(a)]The treatment flowrate for Containment Area 4 is based on the pumping rate capacity of the existing pump used to convey accumulated stormwater from Containment Area 4 to the existing Stormwater Detention Pond.

[(b)]The runoff volume of 191,000 gallons is based on the maximum recorded discharge volume of accumulated stormwater from Containment Area 7 via Outfall 005 since the third quarter of 2020 through the first quarter of 2023.

[(c)]The treatment flowrate calculated for Containment Area 7 is the minimum flowrate required to evacuate Containment Area 7 of 191,000 gallons of accumulated stormwater over a standard work week (i.e., 8 hours per day, 5 days per week).

Water Year (October 1–September 30)	Fire Pond Volume at Beginning of Water Year	October	November	December	January	February	March	April	May	June	July	August	September	Annual Total
Monthly Rainfall (inches) [1]		8.31	6.83	4.61	4.13	10.36	7.26	4.51	1.92	1.08	0.00	0.06	2.38	51.45
Assumed Capture (percentage)		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Evaporation (inches) [2]		1.81	0.78	0.52	0.55	0.92	1.64	2.75	4.28	5.04	6.25	5.62	3.95	34.11
Runoff by Basin														
Containment Area 1 (unlined)		276,848	227,542	153,583	137,591	345,144	241,868	150,251	63,965	35,980	-	1,999	79,290	
Containment Area 1 EFR		51,571	48,001	32,450	28,404	74,897	44,589	13,964	-	-	-	-	-	293,875
Containment Area 1, plus EFR Runoff		328,419	275,543	186,033	165,995	420,041	286,457	164,215	63,965	35,980	-	1,999	79,290	2,007,936
Containment Area 2 (unlined)		508,891	418,258	282,309	252,914	634,429	444,590	276,185	117,578	66,137	-	3,674	145,747	
Containment Area 2 EFR		46,159	42,964	29,045	25,423	67,037	39,910	12,498	-	-	-	-	-	263,037
Containment Area 2, plus EFR Runoff		555,050	461,222	311,354	278,337	701,467	484,500	288,683	117,578	66,137	-	3,674	145,747	3,413,750
Containment Area 3 (unlined)		446,150	366,691	247,503	221,733	556,211	389,777	242,134	103,082	57,983	-	3,221	127,778	2,762,264
Containment Area 4 (lined)		444,255	406,011	274,416	240,983	631,053	384,731	138,995	-	-	-	-	-	2,520,445
Containment Area 5 (lined)		14,315	13,324	9,007	7,884	20,789	12,377	3,876	-	-	-	-	-	81,571
Containment Area 6 (unlined)		351,620	288,997	195,062	174,752	438,361	307,191	190,831	81,241	45,698	-	2,539	100,705	2,176,996
Containment Area 7 (unlined)		349,918	287,598	194,118	173,906	436,239	305,704	189,907	80,847	45,477	-	2,526	100,217	2,166,458
CA7 Volume after Evap. and Infiltration		121,702	102,754	20,222	(1,253)	245,500	84,647	(77,890)	(251,375)	(318,748)	(415,175)	(386,121)	(218,110)	
Stormwater Detention Pond (former Fire Pond)		287,184	261,976	177,062	155,541	407,021	248,746	91,065	(75,204)	(138,799)	(229,098)	(203,453)	(43,538)	938,504
Total gallons Infiltrated		2,045,471	1,693,374	1,143,077	1,022,608	2,573,109	1,786,006	1,079,647	446,712	251,276	-	13,960	553,737	12,608,976
Total gallons managed in Stormwater Detention Pond	1,091,259	1,822,698	667,987	451,478	396,525	1,038,074	633,477	230,061	(75,204)	(138,799)	(229,098)	(203,453)	(43,538)	5,240,299
Cumulative Stormwater Detention Pond (gal)		1,822,698	2,490,686	2,942,164	3,338,688	4,376,762	5,010,239	5,240,299	5,165,095	5,026,297	4,797,198	4,593,746	4,550,207	

Stormwater Detention Pond Estimated Overflow Volumes														
Excess water to be pumped to prevent overflow of Stormwater Detention Pond (gal) [a]		-	-	-	-	1,038,074	633,477	230,061	(75,204)	(138,799)	(229,098)	(203,453)	(43,538)	1,901,611
Required pumping rate (gpm)						72	44	16	(5)	(10)	(16)	(14)	(3)	

Design flowrate for Pump Station No. 3, Stormwater Detention Pond to Infiltration Pond [b]: 72 gpm

Notes

Light gray cells indicate volume infiltrated.

Dark gray cells indicate volume in excess of Stormwater Detention Pond capacity.

The rainfall data in the table above is a reproduction of the original table from the water balance study and is included in Appendix B of the AKART report.[3]

Rainfall, evaporation and runoff volumes for peak rainfall year (i.e., NOAA 2016-2017) are reflected in the table above from the AKART report.[3]

Only CA4 and CA7 discharge to the Stormwater Detention Pond; therefore only the accumulated stormwater volumes from CA4 and CA7 were taken into account in the design flowrate calculation.

AKART = all known, available, and reasonable methods of prevention and treatment technology.

CA4 = Containment Area 4.

CA7 = Containment Area 7.

EFR = External Floating Roof.

Evap. = Evaporation.

gal = gallons.

gpm = gallons per minute.

NOAA = National Oceanic and Atmospheric Administration.

[a]The excess volumes of water managed in the Stormwater Detention Pond to prevent overflow are based on the anticipated monthly runoff volume, excluding cumulative storage in the pond, and assumes that the pond will have an estimated 1,091,259 gallons of dead storage at the start of each new water year.

[b]The design flowrate calculated is the pumping rate required to manage stormwater volumes in excess of the existing Stormwater Detention Pond capacity and assumes active pumping during a standard work week (i.e., 8 hours per day, 5 days per week).

References

[1]Pan Evaporation Data Source is from Ecology. 2012. "Western Washington Hydrology Model" 1948–2012. Washington State Department of Ecology.

[2]Rainfall Data Source is from NOAA/WSU 1/1/2009 - 12/31/2017

[3]MFA. 2022. *NuStar Terminals AKART Report.* Prepared for NuStar Terminals Operations Partnership LP. Maul Foster & Alongi, Inc.: Vancouver, WA. January 10.

Infiltration Pond Sizing Calculations
NuStar Terminals Operations Partnership LP
Vancouver, Washington

MAUL FOSTER ALONGI

Design Flowrate

Design flowrate for Pump Station No. 3: 72 gpm

Native Infiltration[(a)]

Design Infiltration Rate (ft/day)
0.401
1.545
0.109
0.168

Overall average (ft/day): 0.56

Table 4
Soil Infiltration Testing
NuStar Energy, L.P. – Vancouver Annex Terminal
Vancouver, Washington

Test Location [1]	Date	Depth below ground surface (feet)	Length of flow (L) (inches)	Time (t) (hour)	Initial head (h_1) (inches)	Final head (h_2) (inches)	Coefficient of Permeability (in/hr) [2]	Coefficient of Permeability (ft/day) [2]	Coefficient of Permeability (cm/sec) [2]	Design Infiltration Rate (ft/day) [3]
East of Tank Containment Areas (Orchard)										
INF-1(N)	2/24/2022	3	4	1	12.48	11.01	0.50	1.00	3.54E-04	0.401
INF-1(S)	2/24/2022	5	4	1	15.25	9.41	1.93	3.86	1.36E-03	1.545
INF-2(N)	2/25/2022	3	3	1	15.78	15.08	0.14	0.27	9.61E-05	0.109
INF-2(S)	2/25/2022	5	2	1	14.08	12.68	0.21	0.42	1.48E-04	0.168

Overall Ave = 0.56 ft/day
3-foot Ave = 0.25 ft/day
5-foot Ave = 0.86 ft/day

Notes:
[1] Refer to Figure 2 for test locations.
[2] Coefficient of Permeability (k) = L/t * ln (h_1/h_2)
[3] The design infiltration rate is determined by dividing the calculated coefficient of permeability by a correction factor of 2.5 (0.4) to account for layered soil conditions.
in/hr = inches per hour
ft/day = feet per day
cm/sec = centimeters per second

Stormwater Volume

Pumping duration: 8 hrs assumes pumping during standard working hours only (i.e., 8-hr work day)
Stormwater volume managed in Infiltration Pond: 34,602 gallons
4,625 ft^3 per working day

Infiltration Pond Dimensions

Required bottom area for infiltration pond: 8,323 square feet

Bottom width: 91 ft
Bottom length: 91 ft
Depth: 2 ft assumes 1 foot ponding depth + 1 foot freeboard
Sidewall slopes: 3 Horizontal
1 Vertical

Total width: 103 ft
Total length: 103 ft

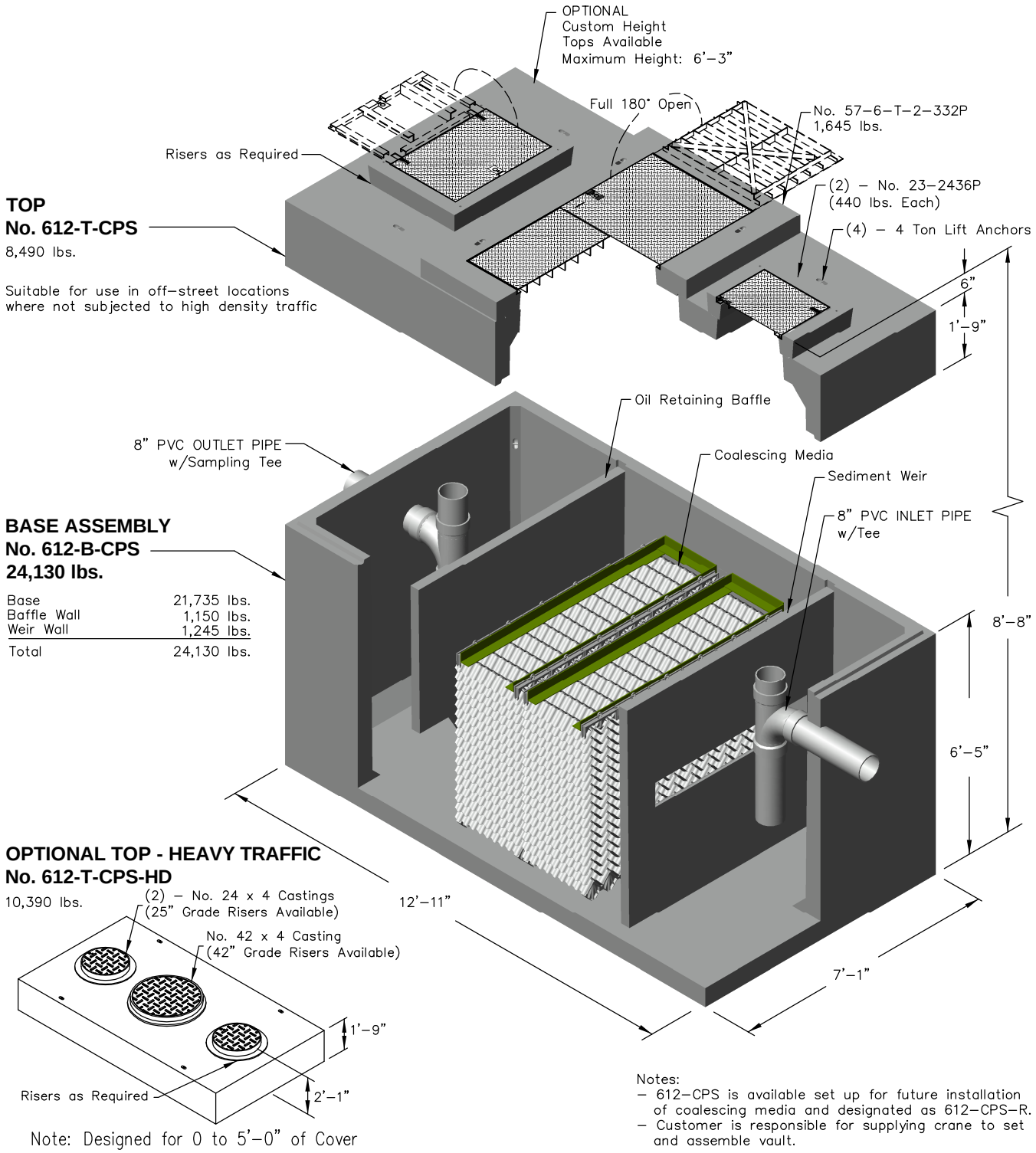
Pond Factor of Safety 1.5

Required total area for Infiltration Pond[(b)]: 15,984 square feet

Notes

ft = feet.
ft^3 = cubic feet.
gpm = gallons per minute.
hr = hour.
[(a)]The design infiltration rate is from soil infiltration testing results in the former orchard area. These results are included in Appendix A of this report.
[(b)]For reference, the existing Surge Pond has a total surface area of approximately 9,200 square feet and, historically, has proven sufficient capacity to manage overflow volumes from the Stormwater Detention Pond.

612-2-CPS



TOP
No. 612-T-CPS
8,490 lbs.

Suitable for use in off–street locations where not subjected to high density traffic

BASE ASSEMBLY
No. 612-B-CPS
24,130 lbs.

Base	21,735 lbs.
Baffle Wall	1,150 lbs.
Weir Wall	1,245 lbs.
Total	24,130 lbs.

OPTIONAL TOP - HEAVY TRAFFIC
No. 612-T-CPS-HD
10,390 lbs.

Note: Designed for 0 to 5'–0" of Cover

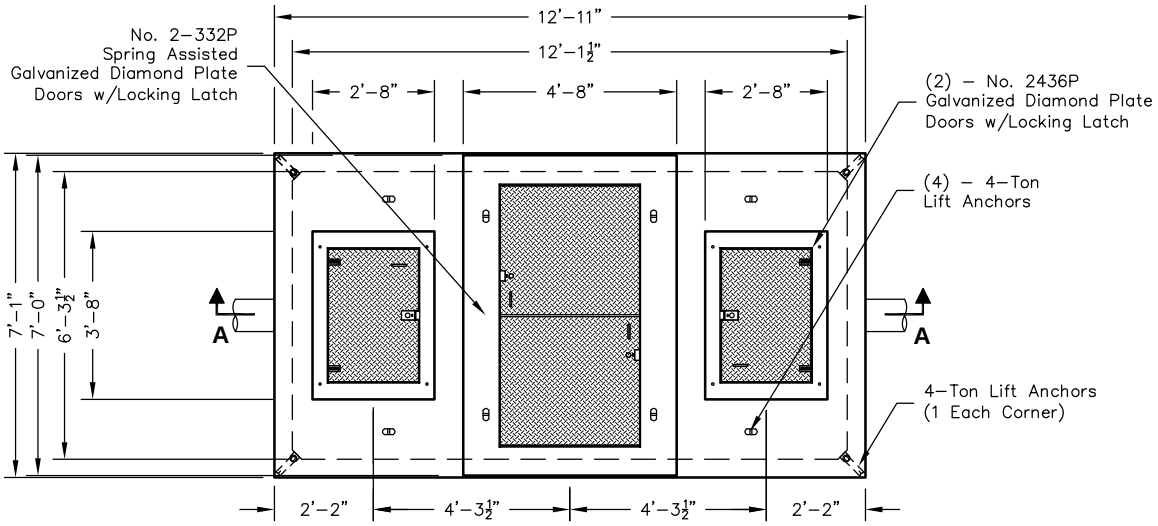
Notes:
- 612–CPS is available set up for future installation of coalescing media and designated as 612–CPS–R.
- Customer is responsible for supplying crane to set and assemble vault.

Oldcastle Precast®
PO Box 323, Wilsonville, Oregon 97070-0323
Tel: (503) 682-2844 Fax: (503) 682-2657

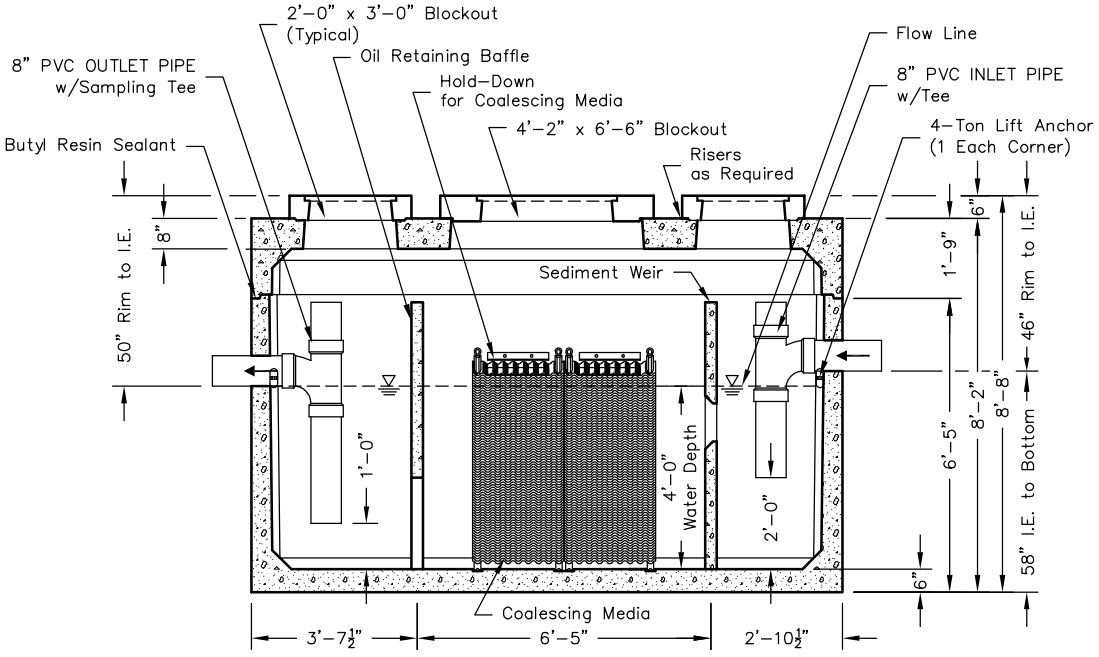
612-2-CPS	612-2-CPS OIL / WATER SEPARATOR COALESCING - 420 GPM
File Name: 020-612CPS2	
Issue Date: 2018	
oldcastleprecast.com/wilsonville	

612-2-CPS

Projected Coalescing Plate Area = 1,776 Sq.Ft.
*Design Flow Rate = 420 GPM
Maximum Process Flow = 1,130 GPM



PLAN VIEW



SECTION AA

*DESIGN FLOW RATE	EFFLUENT QUALITY	100% COLLECTED SIZE
420 GPM	10 ppm	60 Micron

Basic Design Information: *
Influent Characterics
- Oil Specific Gravity = 0.88
- Operating Temperature = 50°
- Influent Oil Concentration = 100 ppm
- Mean Oil Droplet Size = 130 Microns
- .033 ft/min. Critical Oil Droplet Predicted Rise Rate

*Basic Design Information per Washington State Department of Ecology; User to Adjust Estimates for Variations in Real Conditions.

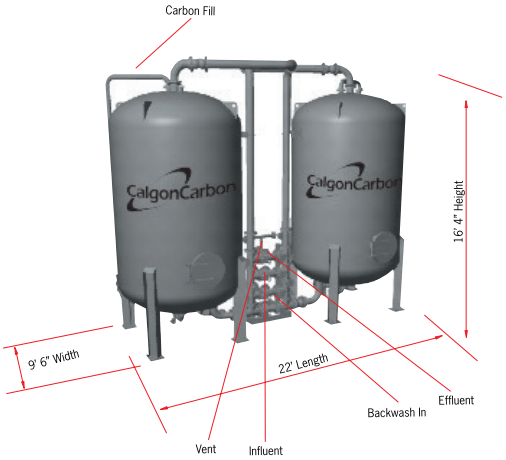
Notes:
- Static Water Depth = 4'–0"
- Prior to "Startup" of system, fill with clean water to bottom of outlet pipe. For best results, fill to flow line.
- Follow Regular Inspection, Cleaning, & Maintenance Schedule (See Clean Out & Maintenance).

Oldcastle Precast®
PO Box 323, Wilsonville, Oregon 97070-0323
Tel: (503) 682-2844 Fax: (503) 682-2657

612-2-CPS	612-2-CPS OIL / WATER SEPARATOR COALESCING - 420 GPM
File Name: 020-612CPS2	
Issue Date: 2018	
oldcastleprecast.com/wilsonville	

MODEL 8

Modular Carbon Adsorption System



Description

The Calgon Carbon Model 8 is an adsorption system designed for the removal of dissolved organic compounds from water or other liquids using granular activated carbon. The modular design concept allows for selection of options or alternate materials to best meet the requirements of the site and treatment application.

The Model 8 system is delivered as two adsorbers and a separate compact center piping network and interconnecting piping requiring minimal space and field assembly. The pre-engineered Model 8 design assures that adsorption system functions can be performed with the system as provided. The design has the benefit of Calgon Carbon's extensive expertise and has been proven in numerous applications. The engineering package can be provided quickly and the system expedited through Calgon Carbon's production capabilities.

The process piping network for the Model 8 offers operation of the two adsorbers in parallel or two-stage series flow, with either adsorber in the lead position. The piping can also isolate either adsorber for carbon exchange or backwash operations, while maintaining flow through the other adsorber. In addition, the Calgon Carbon underdrain design provides for efficient use of the carbon through uniform collection of water at the bottom of the bed, and even distribution of backwash water to minimize carbon bed disturbance.

The Model 8 system is designed for use with Calgon Carbon's closed loop carbon exchange service. Using specially designed carbon transport trailers, the spent carbon can be removed from the adsorber via a pressurized carbon-water slurry, and fresh carbon refilled in the same manner. This closed loop transfer is accomplished without exposure of personnel to either spent or fresh carbon. Calgon Carbon can also manage the disposition of the spent carbon. It is typically returned to Calgon Carbon for reactivation, avoiding the need for the site to arrange for disposal.

Carbon Adsorbers	MODEL 8
Carbon steel ASME code stamped pressure vessels	
Internal vinyl ester lining (25-35 mils) to protect carbon steel surfaces	
Suitable for potable water and most liquid applications	
Internal underdrain with stainless steel slotted septa for water collection and backwash distribution	
Standard Adsorption System Piping	
Schedule 40 carbon steel piping with cast iron fittings	
Cast iron or steel wafer butterfly valves in process piping	
Polypropylene lined steel pipe for resin discharge pipe	
Full bore stainless steel ball valves for carbon and discharge piping	
Pressure gages to measure pressure drop across system and each adsorber	
Rupture discs open to each vessel for emergency pressure relief	
System External Coating	
High solids epoxy paint system	
Typical System Options	
In-bed water sample collection probes	
System skid, shipped separately, upon which system components can be assembled	

Safety Message

Wet activated carbon can deplete oxygen from air in enclosed spaces. If use in an enclosed space is required, procedures for work in an oxygen deficient environment should be followed.

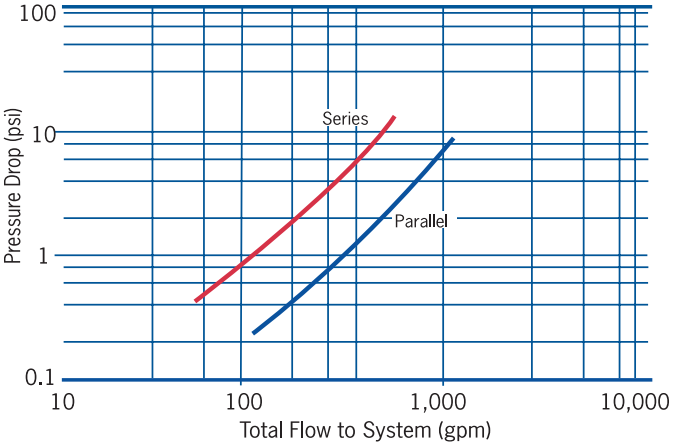
1.800.4CARBON calgoncarbon.com

Dimensions and Field Conditions	MODEL 8
Adsorber Vessel Diameter	8' (2,440 mm)
Process and Backwash Piping	6" (4" option)
Influent/Effluent Connections	6" 125# ANSI flange
Backwash/Vent Connections	6" 125# ANSI flange
Utility Water Connection	3/4" hose connection
Utility Air Connection	3/4" hose connection
Carbon Hose Connections	4" Kamlock type
Adsorber Side Manway	20" round flanged with davit
Adsorber Shipping Weight	16,000 lbs empty (7,300 kg)
System Operating Weight	92,000 lbs (41,800 kg)

Operating Conditions	MODEL 8
Carbon per Adsorber	10,000 lbs (4,536 kg)
Pressure Rating	125 psig (862 kPa)
Temperature Rating	140°F maximum (60°C)
Pressure Relief	Graphite rupture disc
Backwash Rate	Typical 500 gpm (25% expansion)
Carbon Transfer	Air pressurized slurry transfer
Utility Air	100 scfm at 30 psig (reduce to 15 psig for trailer)
Utility Water	100 gpm at 30 psig
Freeze Protection	None provided; enclosure or protection recommended

Pressure Drop Curve

F300 Carbon, 55°F, 4" Steel Pipe



Calgon Carbon Systems and Services

The Model 8 system is designed for a variety of higher pressure water or process liquid applications at moderate flowrates. Calgon Carbon Corporation offers a wide range of carbon adsorption systems and services for a range of water or liquid flow rates and carbon usages to meet specific applications.

Calgon Carbon also provides additional services for support of water treatment systems, including supply of virgin and reactivated grades of granular activated carbon, or exchange of carbon in the treatment system, including disposal or reactivation of the spent activated carbon.

Safety Message

Wet activated carbon can deplete oxygen from air in enclosed spaces. If use in an enclosed space is required, procedures for work in an oxygen deficient environment should be followed.

1.800.4CARBON calgoncarbon.com

DS-MODEL817-EIN-E1

APPENDIX C

OWS AND GAC FILTRATION SYSTEM PERFORMANCE INFORMATION

scientific reports

Check for updates

OPEN

Removal of benzene, MTBE and toluene from contaminated waters using biochar-based liquid activated carbon

F. Alshahrani[1], B. Tawabini[1]✉, T. Saleh[2], M. Alrayaan[3], S. Alaama[3], R. Nasser[3], P. Soupios[1], P. Kirmizakis[1], M. Mahmoud[4], T. Oyehan[1] & E. Safi[1]

Fuel components such as benzene, toluene, and methyl tertiary-butyl ether (MTBE) are frequently detected pollutants in groundwater resources. Ex-situ remediation technologies by activated carbon have been used for treatment for many years. However, due to high cost of these technology, more attention has been given to the in-situ remediation methods of contaminated groundwaters using liquid carbon adsorbents. Literature search showed limited studies on using adsorbents in liquid form for the removal of such contaminants. Therefore, this lab-scale study investigates the capacity of using raw biochar-based liquid activated carbon and iron-modified biochar-based liquid activated carbon to remove these pollutants. The adsorption efficiency of the synthesized liquid activated carbon and iron-modified liquid activated carbon mixed with sand, limestone, and 1:1 mixture of sand/limestone, was tested using batch suspension experiments. Adsorption by granular activated carbon was also investigated for comparison with liquid activated carbon. Results of the study revealed that mixing of liquid activated carbon or LAC-Fe on subsurface materials had not improved the removal efficiency of MTBE. At the same time, it showed a slight improvement in the adsorption efficiency of benzene and toluene. In all cases, the removal by GAC was higher with around 80% and 90% for MTBE and BT, respectively. Results also showed that benzene and toluene were better removed by liquid activated carbon and iron-modified liquid activated carbon (~ 40%) than MTBE (~ 20%). It is also found that water chemistry (i.e., salinity and pH) had insignificant effects on the removal efficiency of pollutants under the study conditions. It can be concluded that more research is needed to improve the capacity of biochar-based liquid-activated carbon in removing MTBE, benzene and toluene compounds that will lead to improve the utilization of liquid activated carbon for the in-situ remediation of contaminated groundwaters.

Fuel compounds such as benzene, toluene, ethylbenzene, and xylene (a.k.a BTEX) and fuel additives such as methyl tertiary-butyl ether (a.k.a MTBE) are well-known pollutants that may cause serious environmental and health issues if not removed from the water before use. BTEX and MTBE are highly mobile and soluble in groundwater, regulated up to 5 µg/L and 13 µg/L in drinking water[1,2]. MTBE is substantially more soluble than BTEX, sorbs less, is less likely to volatilize out of groundwater, and is less likely to be biodegraded[3,4]. For the last decades, BTEX removal has become a focus as it is toxic and carcinogenic even at low concentrations[5]. In the 2000s, the United States and Canada banned MTBE use[6] after a study reported its widespread occurrence in shallow groundwater[7]. However, the recent call for reducing carbon emissions appears to favor the increased use of MTBE, and its production is predicted to continue growing through 2050[8]. Wide treatment applications have been applied for MTBE & BTEX remediation, including physical, chemical and biological methods[9–15]. MTBE adsorption by activated carbon (AC) was studied, and it found high solubility of MTBE in water is a disadvantage of granular activated carbon (GAC) adsorption and took around 15 h for total removal[16]. Thermally modified diatomite was investigated[17] to adsorb MTBE & BTEX and found the highest adsorption by modified diatomite

[1]Department of Geosciences, College of Petroleum Engineering & Geosciences, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia. [2]Department of Chemistry, King Fahd University of Petroleum & Minerals, Dhahran 31263, Saudi Arabia. [3]Saudi Arabian Oil Company, Dhahran, Saudi Arabia. [4]Department of Petroleum Engineering, College of Petroleum Engineering & Geosciences, King Fahd University of Petroleum & Minerals, Dhahran 31261, Saudi Arabia. ✉email: bassamst@kfupm.edu.sa

CalgonCarbon

Pipeline treats hydro-test water on site with carbon adsorption

carbon adsorption

Several years ago, a pipeline company in the northeast U.S. used an activated carbon-adsorption system to make pipeline hydro-test water acceptable for surface discharge.

A Project Dilemma

The pipeline company has more than 3,400 miles of pipeline to serve 80 locations in 10 states, linking major U.S. petroleum refiners with petroleum supply regions. This company is a major shipper of gasoline, heating oil, kerosene, turbine and diesel fuels and, to a lesser extent, of naphtha, liquefied petroleum gases (LPGs), and refinery feedstocks.

Supplying airports, commercial marketing terminals, and connecting pipelines, the company receives petroleum products into its pipeline system from refineries, deepwater marine terminals, and connecting pipelines.

A five-year forecast outlined a need to handle an estimated 795,000 bbl (more than 33 million gal) of hydro-test water from its system. The number of trucks needed to transport this amount of water and the high cost for disposal at a treatment, storage, and disposal facility, made disposal economically and logistically prohibitive.

The challenge was to find a suitable treatment system capable of treating large amounts of water on site in a short period. Additionally, the system had to be mobile and sturdy enough to be moved anywhere within the 3,400 mile system.

Defining Requirements

The environmental affairs department evaluated several technologies to find a solution capable of treating hydro-test water with benzene, toluene, ethylbenzene, and xylene (BTEX) concentrations ranging between 10 and 150 ppm. The system had to be capable of achieving greater than 99% removal of BTEX compounds to achieve the low parts-per-billion levels required for surface-water discharge, while maintaining a consistently high flow rate (150-175 gpm).

To ensure operation and approval throughout a 10-state service area, the selected treatment system had to use best demonstrated available technology (BDAT). In addition, the system needed to be easy to maintain, durable, intrinsically safe, readily available on short notice, compact, and mobile.

With cost effectiveness and portability as the major goals, the pipeline company evaluated four possible treatment technologies from several vendors and consultants. The company compared the costs (Table 1), advantages and disadvantages of **biological treatment, air stripping** followed by vapor and liquid-phase carbon polish, **advanced oxidation,** and **activated carbon adsorption.**

Biological Treatment

Biological treatment can providecost-effective multi-phase remediation, but ultimately proved to be an unattractive or inconvenient option. To meet the flow requirements set by the customer while still providing sufficient retention time, the biological treatment system would have been required to be mounted on two separate trailers. Additionally, constant monitoring for bioactivity would have been needed. And, finally, the company was concerned that a bio-system could not consistently handle a wide range of hydrocarbon concentrations.

Air Stripping

The volatility of the light aromatic hydrocarbons in gasoline made remediation that utilized air stripping appear to be the most effective means for treating hydro-test water. The cost of having to treat off-gas with vapor-phase carbon or thermal combustion would generally place the stripping/off-gas treatment combination at two to three times the cost of straight liquid phase carbon treatment.

Advanced Oxidation Systems

The major advantage of an advanced oxidation system is that it reduces or eliminates a hazard rather than transferring it to a different medium. The disadvantage is the technology's dependence on light penetrating the wastewater. Generally, this process requires the water to be relatively free of suspended particles, oils, and anything else that may hamper ultraviolet light penetration.

An advanced oxidation system would require a feeder mechanism for introducing an oxidant (ozone and/or hydrogen peroxide), a reactor tank fitted with ultraviolet lights, and follow-up devices for preventing ozone from entering the atmosphere. The durability of an advanced oxidation system when being transported throughout the pipeline was also a concern.

Activated Carbon Adsorption

Liquid-phase purification with carbon adsorption has long been cost-effectively applied to process streams, drinking water, and municipal and industrial wastewater. Activated carbon is a relatively inert, highly porous material, which adsorbs organic compounds via physical attractive forces.

Liquid Phase Adsorption Equipment (CalgonCarbon Model 8 shown).

Making Water and Air Safer and Cleaner

carbon adsorption

Treatment Options

Options	$/gal
Air stripping followed by vapor or liquid phase	0.03 to 0.04
Carbon polish	
Biological treatment	0.025 to 0.035
Carbon adsorption	0.01 to 0.02
Chemical oxidation	
Ozonation	
Transporting waste-water for disposal	0.20 to 0.60

Method, Vendor Choice

Information supplied by vendors and consultants in water treatment led to the environmental affairs department to choose activated carbon for treating hydro-test water and Calgon Carbon as the supplier.

Activated-carbon treatment is based on adsorption in which molecules of a liquid or gas adhere to the surface of an adsorbent. Activated carbon offers a high internal surface area (porosity), and much of the surface area exists at the angstrom level (10 m in pore size) in which adsorption forces are additive and strong.

Adsorption works because the attraction of the carbon structure for molecules is stronger than the forces that keep the molecules in solution. Organic molecules such as benzene, xylene, and toluene, adsorb more readily than inorganic chemicals because they tend to be non-polar in nature, have low solubility in water (which is polar), and are attracted to the non-polar surface of the carbon.

Activated carbon is also cost-effective because the same high-temperature process that is used to manufacture the product can also be used to reactivate the carbon for reuse. In reactivation, adsorbed organic chemicals are thermally destroyed, and the carbon can then be recycled for reuse.

Calgon Carbon's Model 7.5 adsorption system was chosen because of its ability to operate in series at 150 to 175 gpm while achieving greater than 99% removal of BTEX compounds to meet the stringent surface-water discharge effluent limits stipulated under federal and various states' programs for the National Pollutant Discharge Elimination System.

The system was also simple to operate, easy to maintain, and mobile. The Model 7.5 is an adsorption system designed for the removal of dissolved organic contaminants from liquids using granular activated carbon (GAC). The pre-piped, skid mounted configuration is designed for on-site treatment where the need is periodic or where a permanent system would be uneconomical.

The Model 7.5 system is delivered as two pre-piped adsorbers on a skid. Installation, piping connections and startup are supervised by Calgon Carbon personnel. When the carbon becomes exhausted, the Model 7.5 is designed for fresh carbon replacement utilizing Calgon Carbon's closed loop carbon exchange service. Using a special designed trailer, spent carbon is removed from the adsorbers and returned to Calgon Carbon for reactivation. The trailer can also provide fresh carbon to recharge the adsorbers, minimizing downtime.

The spent carbon is then shipped to a fully permitted Calgon Carbon reactivation facility as a RCRA, D018-benzene hazardous waste. There it can be thermally reactivated and recycled for reuse.

The reactivation process ensures complete destruction of the adsorbed organics and reduces environmental liability.

Project Payback

The pipeline company considered two options for the use of Calgon Carbon equipment to treat hydro-test water. The first involved a turnkey service in which Calgon Carbon would own the equipment and provide carbon, equipment, major maintenance, operations support, carbon exchange, and reactivation for a cents-per-gallon fee which was several times more economical than off-site disposal.

The second option, the customer would purchase the model 7.5 outright. The amount of water (795,000 bbl) that would have to be treated at various sites on its system in the treatment time period led the customer to purchase the Model 7.5 and handle operations and major maintenance with its own personnel.

Calgon Carbon provided the company with carbon exchange services and technical support as needed. The high volume of water treated led to payback on the equipment purchase of less than 6 months, as compared to the cost of using an outside contractor for treatment, storage, and disposal.

The Model 7.5 adsorption system was used at seven different locations over a six-month time period to successfully treat more than 11.5 million gal of pipeline hydro-test water.

CalgonCarbon

Corporate Headquarters
Calgon Carbon Corporation
3000 GSK Drive Moon Twp,
PA 15108 USA
800.422.7266 • 412.787.6700
412.787.6713 Fax
www.calgoncarbon.com

Overview of Drinking Water Treatment Technologies

On this page:

Granular activated carbon

What is granular activated carbon?

Granular activated carbon (GAC) is a porous adsorption media with extremely high internal surface area. GACs are manufactured from a variety of raw materials with porous structures including:

- bituminous coal
- lignite coal
- peat
- wood
- coconut shells

Physical and/or chemical manufacturing processes are applied to these raw materials to create and/or enlarge pores. This results in a porous structure with a large surface area per unit mass.

Why is it useful?

GAC is useful for the removal of taste- and odor-producing compounds, natural organic matter, volatile organic compounds (VOCs), synthetic organic compounds and disinfection byproduct precursors. Organic compounds with high molecular weights are readily adsorbable.

Treatment capacities for different contaminants vary depending on the properties of the different GACs, which in turn vary widely depending on the raw materials and manufacturing processes used.

What are the advantages of using GAC?

GAC is a proven technology with high removal efficiencies (up to 99.9%) for many VOCs, including trichloroethylene (TCE) and tetrachloroethylene (PCE). In most cases, GAC can remove target contaminants to concentrations below 1 µg/l. Another advantage is that regenerative carbon beds allow for easy recovery of the adsorption media.

What are the disadvantages of using GAC?

The media has to be removed and replaced or regenerated when GAC capacity is exhausted. In some cases, disposal of the media may require a special hazardous waste handling permit. Other adsorbable contaminants in the water can reduce GAC capacity for a target contaminant.

How can the WBS model for GAC be used?

The work breakdown structure (WBS) model can estimate costs for two types of GAC systems where:

- the GAC bed is contained in pressure vessels in a treatment configuration similar to that used for other adsorption media (for example, activated alumina), referred to as pressure GAC
- the GAC bed is contained in open concrete basins in a treatment configuration similar to that used in the filtration step of conventional or direct filtration, referred to as gravity GAC

The WBS model for GAC includes standard designs to estimate costs for treatment of a number of different contaminants, including atrazine and various VOCs. The WBS model can also be used to estimate the cost of GAC treatment for removal of other contaminants.

To simulate the use of GAC for treatment of other contaminants, users will need to adjust default inputs (for example, bed volumes before breakthrough, bed depth) and, potentially, critical design assumptions (for example, minimum and maximum loading rates).

Where can I find more information on GAC?

The technical report Work Breakdown Structure-Based Cost Model for Granular Activated Carbon Drinking Water Treatment Technologies discusses GAC technology in detail.

Packed tower aeration

What is packed tower aeration?

Aeration processes, in general, transfer contaminants from water to air. Packed tower aeration (PTA) uses towers filled with a packing media designed to mechanically increase the area of water exposed to non-contaminated air. Water falls from the top of the tower through the packing media while a blower forces air upwards through the tower. In the process, volatile contaminants pass from the water into the air.

Why is it useful?

PTA is useful for removing volatile contaminants including:

- Volatile organic compounds (VOCs)
- Disinfection byproducts
- Hydrogen sulfide
- Carbon dioxide
- Other taste- and odor-producing compounds

The more volatile the contaminant, the more easily PTA will remove it. PTA readily removes the most volatile contaminants, such as vinyl chloride. With sufficient tower height and air flow, PTA can even remove somewhat less volatile contaminants, such as 1,2-dichloroethane.

What are the advantages of using PTA?

PTA is a proven technology and can achieve high removal efficiencies (99 percent or greater) for most VOCs. PTA removal efficiency is independent of starting concentration. Therefore, it can remove most volatile contaminants to concentrations below 1 µg/L. PTA generates no liquid or solid waste residuals for disposal.

What are the disadvantages of using PTA?

Depending on the location and conditions, air quality regulations might require the use of air pollution control devices with PTA, increasing the technology cost. PTA uses tall towers that could be considered unsightly in some communities. Under certain water quality conditions, scaling or fouling of the packing media can occur if precautions are not taken.

How can the WBS model for PTA be used?

The work breakdown structure (WBS) model for PTA includes standard designs to estimate costs for treatment of a number of different contaminants, including methyl tertiary-butyl ether (MTBE) and various VOCs. However, the WBS model can be used to estimate the cost of PTA treatment for removal of other contaminants as well.

To simulate the use of PTA for treatment of other contaminants, users will need to adjust default inputs (for example, Henry's coefficient, molecular weight) and, potentially, critical design assumptions (for example, minimum and maximum packing height).

Where can I find more information on PTA?

The technical report Work Breakdown Structure-Based Cost Model for Packed Tower Aeration Drinking Water Treatment Technologies discusses PTA technology in detail.

Multi-stage bubble aeration

What is multi-stage bubble aeration?

Aeration processes, in general, transfer contaminants from water to air. Multi-stage bubble aeration (MSBA) uses shallow basins that are divided into smaller compartments, or stages, using baffles.

Inside each stage, diffusers (consisting of perforated pipes or porous plates) release small air bubbles that rise through the water. The bubbles and their resulting turbulence cause volatile contaminants to pass from the water into the air.

Why is it useful?

MSBA is useful for removing volatile contaminants including:

- Volatile organic compounds (VOCs)
- Hydrogen sulfide
- Carbon dioxide
- Other taste- and odor-producing compounds

The more volatile the contaminant, the more easily MSBA will remove it. Vendors supply MSBA in skid-mounted, pre-packaged systems that can be particularly suitable for small systems.

What are the advantages of using MSBA?

MSBA is a proven technology. In recent EPA pilot tests, MSBA achieved high removal efficiencies (98 percent to greater than 99 percent) for most VOCs, removing them to concentrations below 1 µg/L. MSBA is a low-profile aeration technology that does not require tall, potentially unsightly towers. MSBA generates no liquid or solid waste residuals for disposal.

What are the disadvantages of using MSBA?

Depending on the location and conditions, air quality regulations might require the use of air pollution control devices with MSBA, increasing the technology cost.

MSBA is less efficient at removing contaminants than packed tower aeration, requiring high air flow rates to remove the most recalcitrant VOCs. Treating large water flows with MSBA can require a large number of basins. This might not be practical for large systems.

How can the WBS model for MSBA be used?

The work breakdown structure (WBS) model for MSBA includes standard designs for the treatment of a number of contaminants, including various VOCs. However, the WBS model can be used to estimate the cost of MSBA treatment for removal of other volatile contaminants as well.

To simulate the use of MSBA for treatment of other contaminants, users will need to adjust default inputs (for example, air-to-water ratio, number of stages) and, potentially, critical design assumptions (for example, maximum air surface intensity).

Where can I find more information on MSBA?

The technical report Work Breakdown Structure-Based Cost Model for Multi-stage Bubble Aeration Drinking Water Treatment Technologies discusses MSBA technology in detail.

Anion exchange

What is anion exchange?

In an anion exchange treatment process, water passes through a bed of synthetic resin. Negatively charged contaminants in the water are exchanged with more innocuous negatively charged ions, typically chloride, on the resin's surface.

Why is it useful?

Anion exchange is useful for the removal of negatively charged contaminants including arsenic, chromium-6, cyanide, nitrate, perchlorate, sulfate and uranium.

Treatment capacities for different contaminants vary depending on the properties of the resin used and characteristics of the influent water. A number of vendors manufacture different resins, including those designed to selectively remove specific contaminant ions.

What are the advantages of using anion exchange?

Anion exchange is a proven technology that can achieve high removal efficiencies (greater than 99 percent) for negatively charged contaminants. When the capacity of the resin is exhausted, it can be regenerated to restore it to its initial condition. The regeneration process uses a saturated solution, usually of sodium chloride (also known as brine). An alternative to regeneration is to dispose of the exhausted resin and replace it with fresh resin. This alternative is often employed in the case of perchlorate removal using perchlorate-selective resin.

What are the disadvantages of using anion exchange?

The spent regenerant brine is a concentrated solution of the removed contaminants and also will be high in dissolved solids and excess regenerant ions (e.g., sodium, chloride). This waste stream will require disposal or discharge. Anion exchange treatment also can lower the pH of the treated water and, therefore, may require post-treatment corrosion control. When replacement with fresh resin is used as an

alternative to regeneration, the spent resin, loaded with removed contaminants, will require disposal. In some cases, disposal of the resin may require a special hazardous waste handling permit.

How can the WBS model for anion exchange be used?

The primary work breakdown structure (WBS) model for anion exchange includes standard designs to estimate costs for treatment of arsenic and nitrate. EPA has developed a separate WBS model, also available on this page, to estimate costs for treatment of perchlorate. In addition, the WBS anion exchange models can be used to estimate the cost of anion exchange treatment for removal of other contaminants.

To simulate the use of anion exchange for treatment of other contaminants, users will need to adjust default inputs (for example, bed volumes before regeneration, bed depth) and, potentially, critical design assumptions (for example, minimum and maximum loading rates).

Where can I find more information on anion exchange?

The technical report Work Breakdown Structure-Based Cost Model for Anion Exchange Drinking Water Treatment discusses anion exchange technology in detail.

Cation exchange

What is cation exchange?

In a cation exchange treatment process, water passes through a bed of synthetic resin. Positively charged contaminants in the water are exchanged with more innocuous positively charged ions, typically sodium, on the resin’s surface.

Why is it useful?

Cation exchange is useful for water softening by removing hardness ions such as calcium and magnesium. It can also remove other positively charged contaminants including barium, radium and strontium.

Treatment capacities for different contaminants vary depending on the properties of the resin used and characteristics of the influent water. A number of vendors manufacture different resins, including those designed to selectively remove specific contaminant ions.

What are the advantages of using cation exchange?

Cation exchange is a proven technology for water softening and removal of positively charged contaminants. It can achieve high removal efficiencies (greater than 99 percent) for positively charged contaminants. When the capacity of the resin is exhausted, it can be regenerated to restore it to its initial condition. The regeneration process uses a saturated solution, usually of sodium chloride (also known as brine).

What are the disadvantages of using cation exchange?

The spent regenerant brine is a concentrated solution of the removed contaminants and also will be high in dissolved solids and excess regenerant ions (e.g., sodium, chloride). This waste stream will require disposal or discharge.

How can the WBS model for cation exchange be used?

The work breakdown structure (WBS) model for cation exchange includes standard designs for water softening. The same designs may also be appropriate for radium removal. The WBS model can also be used to estimate the cost of cation exchange treatment for removal of other contaminants.

To simulate the use of cation exchange for treatment of other contaminants, users will need to adjust default inputs (for example, bed volumes before regeneration, bed depth) and, potentially, critical design assumptions (for example, minimum and maximum loading rates).

Where can I find more information on cation exchange?

The technical report Work Breakdown Structure-Based Cost Model for Cation Exchange Drinking Water Treatment discusses cation exchange technology in detail.

Biological treatment

What is biological treatment?

Biological treatment of drinking water uses indigenous bacteria to remove contaminants. The process has a vessel or basin called a bioreactor that contains the bacteria in a media bed. As contaminated water flows through the bed, the bacteria, in combination with an electron donor and nutrients, react with contaminants to produce biomass and other non-toxic by-products. In this way, the biological treatment chemically “reduces” the contaminant in the water.

Why is it useful?

Biological treatment is useful for the removal of contaminants including nitrate and perchlorate. Following a startup period, the bacterial population in the water will adapt to consume the target contaminants as long as favorable conditions, such as water temperature and electron donor and nutrient concentrations, are maintained.

What are the advantages of using biological treatment?

Biological treatment can achieve high removals (greater than 90 percent) of nitrate and perchlorate. The process destroys contaminants, as opposed to removing them, and, therefore, does not produce contaminant-laden waste streams. Biological treatment remains effective even in the presence of certain co-occurring contaminants.

What are the disadvantages of using biological treatment?

An active bioreactor will have a continuous growth of biomass that needs to be periodically removed. Although the excess biomass will not be contaminant-laden, it still requires disposal. Also, biological treatment adds soluble microbial organic products and can deplete the oxygen in treated water. Post-treatment processes are needed to control these effects.

How can the WBS model for biological treatment be used?

The work breakdown structure (WBS) model can estimate costs for anoxic biological treatment using three types of bioreactors:

- pressure vessels with a fixed media bed
- open concrete basins with a fixed media bed
- pressure vessels with a fluidized media bed.

The WBS model for biological treatment includes standard designs for perchlorate and nitrate treatment. However, the model can also be used to estimate the cost of biological treatment for the removal of other contaminants.

To simulate the use of biological treatment for other contaminants, users will need to adjust default inputs (e.g., electron donor and nutrient doses) and critical design assumptions (e.g., minimum and maximum loading rates).

Where can I find more information on biological treatment?

The technical report Work Breakdown Structure-Based Cost Model for Biological Drinking Water Treatment discusses the technology in detail.

Reverse osmosis/nanofiltration

What are reverse osmosis and nanofiltration?

Reverse osmosis (RO) and nanofiltration (NF) are membrane separation processes that physically remove contaminants from water. These processes force water at high pressure through semi-permeable membranes that prevent the passage of various substances depending on their molecular weight. Treated water, also known as permeate or product water, is the portion of flow that passes through the membrane along with lower molecular weight substances. Water that does not pass through the membrane is known as concentrate or reject and retains the higher molecular weight substances, including many undesirable contaminants.

Why are they useful?

RO and NF are useful for the removal a wide range of contaminants. RO can remove contaminants including many inorganics, dissolved solids, radionuclides and synthetic organic chemicals. RO can also be used for removing salts from brackish water or sea water. NF is useful for removal of hardness, color and odor compounds, synthetic organic chemicals and some disinfection byproduct precursors.

What are the advantages of using RO and NF?

RO and NF are proven technologies that can achieve high removals of a broad range contaminants at once. They do not selectively target individual contaminants and remain effective for water that contains mixtures of contaminants. The processes do not usually require adjustment based on the specific trace contaminants present.

What are the disadvantages of using RO and NF?

RO and NF reject part of the feed water (15 to 30 percent) that enters the process. This "loss" of water as concentrate can present a problem when water is scarce. Furthermore, this large volume concentrate stream is laden with removed contaminants, salts and dissolved solids and will require discharge or disposal. Also, the high pressures used in these treatment processes can result in significant energy consumption. Pre-treatment processes are frequently required to prevent membrane fouling or plugging. Finally, RO can lower the pH of treated water and, therefore, may require post-treatment corrosion control.

How can the WBS model for RO and NF be used?

The work breakdown structure (WBS) model can estimate costs for either RO or NF. It includes standard designs for feed waters of various quality in terms of gross chemical composition (e.g., salt concentrations). The design parameters typically do not require adjustment to target a specific trace contaminant, other than selecting the appropriate type of membrane (e.g., RO or NF) given the contaminant's molecular weight and other characteristics.

Where can I find more information on RO and NF?

The technical report Work Breakdown Structure-Based Cost Model for Reverse Osmosis/Nanofiltration Drinking Water Treatment discusses these technologies in detail.

Nontreatment options

What are nontreatment options?

Instead of treating a contaminated water source, nontreatment options replace the source with water that meets applicable drinking water standards. Examples include interconnection with another system and drilling a new well to replace a contaminated one.

Why are they useful?

Nontreatment can provide a route to compliance with drinking water standards for various contaminants, as long as an alternate water source is available.

What are the advantages of using nontreatment options?

Small water utilities, particularly those that lack financial and/or technical capacity, might be able to use nontreatment approaches to avoid the cost and labor associated with installing and operating new treatment processes.

What are the disadvantages of using nontreatment options?

Interconnection requires a neighboring utility with excess capacity that is willing to sell water to the affected utility. Installation of a new well requires the existence and accessibility of an uncontaminated aquifer.

How can the WBS model for nontreatment options be used?

The work breakdown structure (WBS) model can estimate costs for either of two nontreatment options:

- interconnection with another system
- drilling a new well to replace a contaminated one

Where can I find more information on nontreatment options?

The technical report Work Breakdown Structure-Based Cost Model for Nontreatment Options for Drinking Water Compliance discusses these options in detail.

Contact Us <https://epa.gov/sdwa/forms/contact-us-about-safe-drinking-water-act> to ask a question, provide feedback, or report a problem.

LAST UPDATED ON JULY 8, 2022


UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY

Discover.

Accessibility Statement <https://epa.gov/accessibility/epa-accessibility-statement>

Budget & Performance <https://epa.gov/planandbudget>

Contracting <https://epa.gov/contracts>

EPA www Web Snapshot <https://epa.gov/utilities/wwwepagov-snapshots>

Grants <https://epa.gov/grants>

No FEAR Act Data <https://epa.gov/ocr/whistleblower-protections-epa-and-how-they-relate-non-disclosure-agreements-signed-epa>

Plain Writing <https://epa.gov/web-policies-and-procedures/plain-writing>

Privacy <https://epa.gov/privacy>

Privacy and Security Notice <https://epa.gov/privacy/privacy-and-security-notice>

Connect.

Data.gov <https://www.data.gov/>

Inspector General <https://epa.gov/office-inspector-general/about-epas-office-inspector-general>

Jobs <https://epa.gov/careers>

Newsroom <https://epa.gov/newsroom>

Open Government <https://epa.gov/data>

Regulations.gov <https://www.regulations.gov/>

Subscribe <https://epa.gov/newsroom/email-subscriptions-epa-news-releases>

USA.gov <https://www.usa.gov/>

White House <https://www.whitehouse.gov/>

Ask.

Contact EPA <https://epa.gov/home/forms/contact-epa>

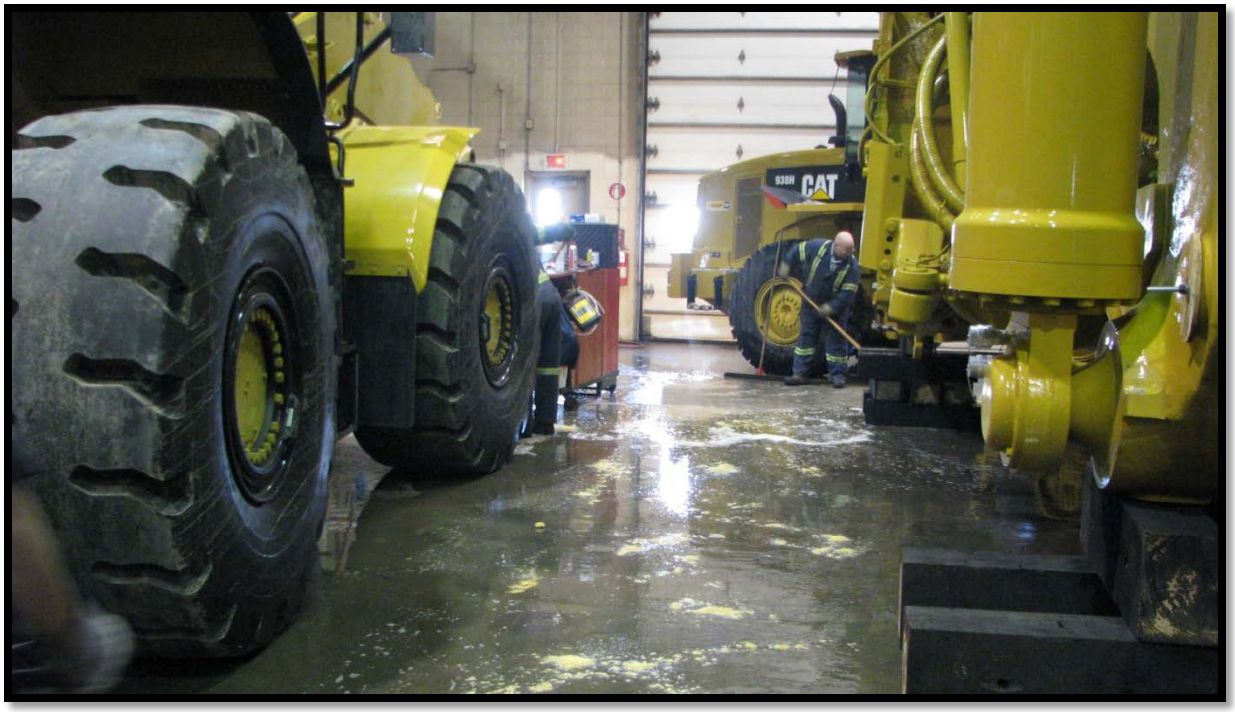
EPA Disclaimers <https://epa.gov/web-policies-and-procedures/epa-disclaimers>

Hotlines <https://epa.gov/aboutepa/epa-hotlines>

FOIA Requests <https://epa.gov/foia>

Frequent Questions <https://epa.gov/home/frequent-questions-specific-epa-programstopics>

Follow.



Oil-Water Separation System for Industrial Wastewater

McGill

SUMMIT TO:

BREE 495 ENGINEERING DESIGN III

FINAL REPORT

McGill University

SUBMIT BY:

HSIN-HUI HUANG

SEBASTIEN BOUFFARD

YUE SU

ACKNOWLEDGEMENTS

We would like to thanks Hewitt Equipment for allowing us to make a design project from their installation and for the financing of the water samples. Thanks to Hewitt staffs – the maintenance department, particularly Guy Teillet, Nicolas Lessard, Robert Benoit and the garage technician François for the achievement of the first stage of our design. We also thanks from Mr. Benoit Cloutier from Pompe-Atlantis for his advices about the chemical and the microbial treatment of industrial wastewater. Additionally, the assistance of the staff of Pompe-Atlantis has permitted to base our work on an existing design and improve it throughout this project. Lastly, but not the less, we would like to thanks Drs. Grant Clark and Ronald Gehr for their guidance during our project.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXCUTIVE SUMMARY

Petroleum and its derived products are harmful if they are released in the environment. At Hewitt in Pointe-Claire, oil spill occurs from the maintenance of machinery and it is released as wastewater from the cleaning of the garage floors. The wastewater system was installed 40 years ago when the regulation for industrial wastewater effluent were not as severe. Therefore, a new system is required for improving the quality of the wastewater.

The chemical property of the cleaning agent is one of the important parameter affecting the efficiency and the physical and chemical design of the separator. The current degreaser renders the cleaned oil to be in a state of emulsion, which cannot be efficiently treated by conventional gravity separator. In this report, specifications for the design of a new oil-water separator will be given to meet the stringent municipal regulation of a discharge wastewater concentration of 30 mg/L or less.

Based on the Stokes's Law, the new separator will have a dimension of 6m length by 1m width to meet the required minimum area of 5.29 sq. m. and it will be divided into three chambers. Physical additions to improve the overall operation include a coalescent media, an aeration/flotation device and a control system for bioremediation. Lastly, information for additional steps of design process of prototyping and testing will be overviewed.

1. INTRODUCTION

Oil can be classified into two different categories: biological and mineral. Biological oil has their origin from plants and animal, they are hydrophobic molecules such as cholesterol. Mineral oil is composed of plants that are buried underground during millions of years. Fossil fuel is necessary due to it is easily transported and highly energy dense, furthermore its byproducts have a wide range of application. The molecular constitutions of the hydrocarbon product derived from fossil fuel are not easily biodegradation by naturally occurring organisms found in the environment. Having a specific density that is lower than water, it is susceptible to form a thin layer on the surface. This layer can be harmful to the fish, birds, and plants. Therefore, the presence of oil in the ground, in water and on living organisms is considered as pollution.

In the past decades, many well-known accidental spills have occurred during petroleum extraction in sea or during its transportation by cargo, such as the Exxon Valdez and, the recent, Gulf of Mexico. However a more common source of oil spill occurs from the release from industrial, agricultural, and domestic sources. Often these sources are released by dumping untreated operational and cleaning wastewater into rivers and lakes. This process can account for a major portion of the annual 6 million gallons (Gary L. Gerdes, December 2000).

In this project, the focus will be put mineral oil used in the transportation industry, such as lubricant and fossil fuel. During the maintenance of the oil-dependent device, the release of contaminated and oil and grease is a common occurrence. However, the cleanup process usually consists of using detergent and water hose. This primitive process will result into the release of a huge amount of toxic oil that should be collected with the help of an oil and water separator.

For environmental purpose, municipal regulation exists as set a general guideline on a concentration of contaminants disposed by wastewater. In the case of oil, it is currently set a maximum concentration of 30ppm (Ontario Ministry of Transportation, February 2007).This strict new regulation can cause old separation unit to be in need of an overhaul. The article will explore various new method of improving existent system and the design of a new one.

2. DESIGNING A FEASIBLE SEPARATOR

It is important to note that the objective of this project is to design a cost-effective system that will respect the municipal regulation. Therefore, an evaluation of the performance of the current system is required. The resultant information will help identify potential improvements.

2.1 CURRENT SYSTEM

Initial experiment was conduct from the month of January to April of 2011. It had the purpose of identifying and confirming suspected problem of the existing system. The following parameters are the limiting factor of the current system:

- The utilization of emulsifying soap, which decrease the oil particles size beyond the operational capability of the current gravitation separator;
- The influent flow rate (17 gpm) which prevents an adequate hydraulic retention time;
- The small size of the current system, which does not meet the minimum required dimensions for an effective separation.

  Due to these constrains a barely noticeable decrease in oil concentration was found. An overview diagram of the current system is provided in the Appendix IV.

Table 1: oil concentration presented the wastewater before treating and after treating by the separator

	Separator Inlet (mg/L)	Separator Outlet (mg/L)
Middle of Cleaning	214	162
End of Cleaning	123	114

2.2 DESIGN CRITERIA

- The wastewater treatment system (WTS) needs to be embedded in the concrete floor;
- The separator dimension needs to optimize the physical separation by the buoyancy effect of the oil droplet. This criteria involves minimizing the depth for decrease the time of rise and maximizing the length for increasing the travelling the distance before the sewer inlet.
- The WTS is self-sufficient for receiving and treating efficiently the wastewater generated by the weekly event of the floor washing.

2.3 FEASIBLE SEPARATOR SIZE

As described before, the major component of current wastewater treatment system is a API gravity –based oil-water separator. The concept of this model is based on the difference of mass density between oil and water, based on Stokes's Law (WEF, 2008). This means that the separator, of a feasible size, must meet the minimum required resident time for an oil contained in a stream of wastewater to rise and float on the surface of water. Therefore, sizing the separator properly to ensure sufficient separation time is the key factor for a successful oil removal system.

This project conducts the feasible separator sizing calculation using Stokes' Law (WEF, 2008). This law is the major scientific theory behind API gravity separator. Many references (Kirby and Mohr.) mentions that this principal simplifies the overall process and often under-sizing might occur. Therefore incorporating enhanced components is recommended.

To calculate the size of an empty-vessel gravity separator, it is first necessary to calculate by the use of Stokes' Law the rising velocity of the oil droplets. The size of the separator is then calculated by considering the path of a droplet entering at the bottom of one end of the separator and exiting from the other end of the separator (Figure 1).

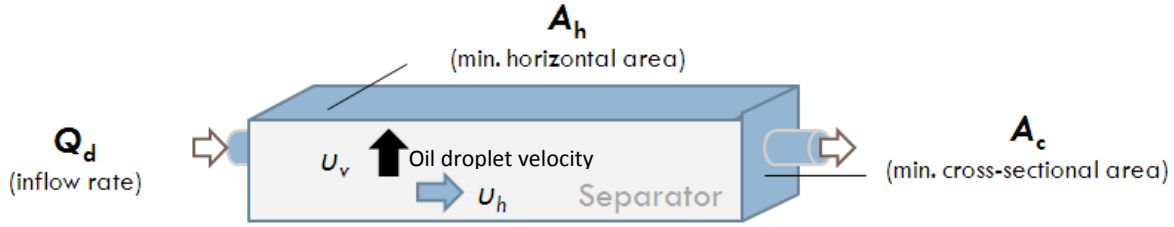


Figure 1: Illustration showing the relationship between inflow rates, minimum required area of a separator and oil droplet velocity

Defining oil rising velocity:

Stokes' Law (Equation 1) defines the rising velocity of oil droplet from the bottom of a separator to the surface of water. From this equation, the most important variables are the viscosity of the continuous liquid, specific gravity difference between the continuous liquid, and the oil droplet size. After these are known, the rising velocity and therefore the size of separator required may be calculated.

$$v_v = \frac{2}{9}\frac{(\rho_w - \rho_o)}{\mu} g R^2 \quad \text{Eq. 1}$$

$$v_h = 15\, v_v \text{ or } v_h = 0.015 \text{ (m/s)} \quad \text{Eq.2}$$

Where:

υ_v $[\frac{m}{s}]$: oil droplet rising velocity;
υ_h $[\frac{m}{s}]$: oil droplet rising velocity;
g $[\frac{m}{s^2}]$: gravitational acceleration
ρ_o $[\frac{kg}{m^3}]$: mass density of oil
ρ_w $[\frac{kg}{m^3}]$: mass density of water
μ $\left[N\frac{s}{m^2}\right]$: dynamic viscosity
R [m]: the radius of oil droplet

According to API, horizontal velocity υ_h is recommended to be 15 times of vertical velocity or 0.01524 (m/s) whichever the smallest one to maintain a laminar flow condition.

Determining a corresponded-feasible separator size

$$\upsilon_v = \frac{Q_d}{A_h} \quad \text{Eq.3}$$

$$\upsilon_h = \frac{Q_d}{A_c} \quad \text{Eq.4}$$

Where

Q_d $[\frac{m^3}{s}]$: designed flow rate
A_h $[m^2]$: Minimum separator horizontal area
A_c $[m^2]$: Minimum separator cross-sectional area

Equation 3 and 4 show that for a given flow rate, the calculated oil rising and horizontal velocity determine the minimum required horizontal and cross-sectional area of a separator. A list of parameters and values used in the design calculation are showed in Table 2.

Table 2: Parameters and values used in the design assumption

Wastewater	Value	Unit	Note	
Temperature	10	℃		
Gravitational acceleration, g	9.81	m/s^2		
Mass density of water, ρ_f	999	kg/m^3		
Mass density of oil, ρ_p	800	kg/m^3		
Dynamic viscosity, μ	0.00131	$N/m^2 \cdot s$		
Designed flow rate, Q_d	25	GPM	0.00158	m^3/s
Maximum allowable horizontal velocity, υ_h	0.01524	m/s		
Separator				
Length / Width (L/W >=5)	5			
Depth / Width (d/W = 0.3~ 0.5)	0.4			

The physical properties of water are obtained from literatures with the assumption that the designed wastewater has a temperature of 10°C (the estimated lowest temperature possible in the workshop during winter time). The value of oil density is the average of common transformer oil, hydraulic oil and engine oil. The length to width ratio is set to be 5 (a minimum value according to API) in the design; the ratio of depth to width is set to be 0.4 (must between 0.3 to 0.5 according to API). The capacity of this designed separator is assumed to treat 25 gallon per minute (GPM) or 5.7 m^3/h of wastewater.

By incorporating the values from previous table into equation 1 to 4, the minimum required separator size (eq. length, width, depth) allowing sufficient separation time can be obtained (Table 3). The design calculation considers oil droplet size between 20 microns and 150 micron because: 1) oil size smaller than 20 microns is generally produced under pressure which is not our case; 2) the case site of the project involves the use of detergent breaking down free oil (larger than 150 microns) into smaller droplets. In summary: for a wastewater flow rate of 25 GPM, a separator with a dimension of 5.14*1.03*0.41 (Length*Width*Depth) provides sufficient resident time for oil size larger than 60 micron to rise to the surface of water before reaching the separator outlet for wastewater.

Table 3: Minimum required separator sizes for the separation of oil droplet from 20 to 150 microns

	Dispersed Oil Droplet Size (diameter from 20-150 microns)					
Diameter of oil droplet, D [µm]	150	100	80	60	40	20
Radius of oil droplet, R[m]	0.000075	0.000050	0.000040	0.000030	0.000020	0.000010
Oil vertical rising velocity, υ_v[m/s]	0.001863	0.000828	0.000530	0.000298	0.000132	0.000033
Oil horizontal velocity, υ_h (max. 0.015)	0.027942	0.012419	0.007948	0.004471	0.001987	0.000497
Allowed υ_h	0.015	0.012419	0.007948	0.004471	0.001987	0.000497
Minimal separator horizontal area, A_h [m^2]	0.85	1.91	2.98	5.29	11.91	47.63
Minimal separator crossing area, A_v [m^2]	0.11	0.13	0.20	0.35	0.79	3.18
Separator Minimal Length, L [m]	2.06	3.09	3.86	5.14	7.72	15.43
Separator Minimal Width, W [m]	0.41	0.62	0.77	1.03	1.54	3.09
Separator Minimal Depth, d [m]	0.16	0.25	0.31	0.41	0.62	1.23
Separator Minimal Volume, V [m^3]	0.14	0.47	0.92	2.18	7.35	58.80

An extended calculation result showing required separator sizes to treat wastewater from 17 GPM to 50 GPM is also provided in Appendix II.

3. RESULT AND CONCLUSION

3.1 PHYSICAL MODIFICATION OF SEPARATOR

Based on the previously mentioned calculations, the design of the new system can be divided into two components: the physical and chemical enhancements. In the physical redesign, it will include a bigger separation tank to meet the requirement dimensions, a baffle to regulate the contaminants location, a flow valve to regulate the influent rate, coalescent media to help the coagulation of emulsified oil particles, aeration device to decrease the oil density, create turbulence, and to increase oxygen content for bacterial growth, and finally the addition of two oil skimmers. A detail diagram can be observed in Appendix Appendix V.

3.1.1 SIZE

As a safety measure, the design will incorporate for a higher capacity (eq. maximum wastewater inflow rate allowable) and more efficiency of oil removal (eq. separating smaller oil droplet) resulted in a larger separator size. The dimension of the separator, in this project, is designed to be 6*1*0.75 m^3 (for capacity ≤ 25 GPM; oil size ≥ 60 microns; temperature ≥ 10^oC) to minimize construction cost and required space in the workshop. The control of capacity and the removal of oil size smaller than 60 microns are discussed in following sections.

3.1.2 THREE STAGE COLLECTION PIT

$V_{generated\ wastewater\ with\ cleaning\ event} = V_{tank}$

For calculating the volume of the catchment, the average volume of water spread on the floor during the washing events. Based on an average flow rate of liters per minute for a period of 45 minutes, the total amount of wastewater is 2.89m^3. For the design purposes, a safety factor of 1.5 is added to the calculation and the total volume become is 4.34 m^3 (Appendice A1). Therefore a larger volume is required because the current volume of the catchment is 2.53m^3.

V_{tank} depends on stokes Law

Another way of calculating the volume required is by estimating an average droplet size based with calculation based on Stokes Law. In addition to the volume, these calculation would give estimated a required length for a basic catchment. The length required based on these calculations for a treatment

of oil particle of 60 µm is 6 meters. The dimension for the width and the depth are dependent on the volume of storage desired. In their optimization, the depth needs to be minimized and the width must be convenient for the purpose of maintenance. According to the previous consideration, the optimal geometry for having the required volume with a length of 6 meter is a width of 1 meter and a depth of 0.75 meter. The volume calculated from these dimensions is $4.5m^3$. Therefore, the volume requirement based on stoke law will be sufficient to store the volume of $4.3m^3$ of wastewater generated during the cleaning events.

3.1.3 DEVICES AND APPARATUS

Baffles

In addition to the different sizing of the catchment, chambers separated by baffles with a low porosity design for minimizing free oil migrating in the next chamber. The candidate material for the baffles can be recycled reinforced fiber carbon.

The baffle divides the collection pit in three distinct non hermetic chambers. The first chamber received the wastewater from the catchment; this chamber has the purpose of settling solid particles and is trapped by the first lower baffle. This extremely important, as it will prevent clogging of the coalescent media and the air diffuser, thus reducing its maintenance. Secondly, the middle chamber contains the coalescent type separator made of oleophilic material. The third tank contains the treated wastewater from the previous chamber will go into a clarification process, where the small residual contaminants will settle. The wastewater contains in the third chamber ideally should meet the criteria for Montreal effluent wastewater.

The coalescent media

The required area for the size of the coalescent block is 5 meters square of external surface area (Appendice A2). The dimension of the coalescent media to be fitted in the separator chamber has a length of 1.5 meter, a width of 1 meter and a width of 0.5 meter. Therefore, the middle chamber needs a length of 3.5 meter with the given depth of 0.5 meter and the given width of 1 meter. The design for a coalescent media has little to no straightforward calculation method. On occur small amount of information are provided by the supply, but they are often misleading (Gary L. Gerdes, December 2000).

One specific example on the calculation of the required volume from a Brentwood has yield an overall size of 2.33 cu. ft or 0.066 cu. m.. The obtained value seems a little too small to be accurate, thus as a safety factor, it has been increase to a volume of 0.6 cu. m., based on the above dimension. The exact calculation process will be shown in the appendix.

However one consistency has been the plate separation, with a fair majority recommending a 3/4". This is the ideal size to prevent clogging. In terms of efficiency, it is believe that the vertical mesh design is the most effective method based on the increase in contact surface of the design. The mesh design consists of crisscross plates that forms a mesh design, this will increase the flow path of the wastewater and, thus, the contact area.

The material of the media must be made from PVC, polypropylene, or recycled fibrous material such as kraft fibers, fibrillated lyocell fibers, glass microfibers or nanoceramic functionalized fibers (Stanfel and Cousard, 2011). According to Gerde et al (2000):"Some people in the industry believe that polypropylene is too oleophilic and does not allow oil to migrate to the water surface". The goal of a coalescent media is to get a non-laminar flow which will induce oil droplet growth on the media which promote a faster rise the particle (Gerdes et al. 2000). A series of parallel plates are juxtaposed to another series of parallel plates which form inverted V's with angles varying from 40^{o} to 60^{o} (Gerde et al., 2000). For wastewater with high loading in solid particles matter in suspension with Hewitt disposals, it is recommended using an angle of 60^{o}.

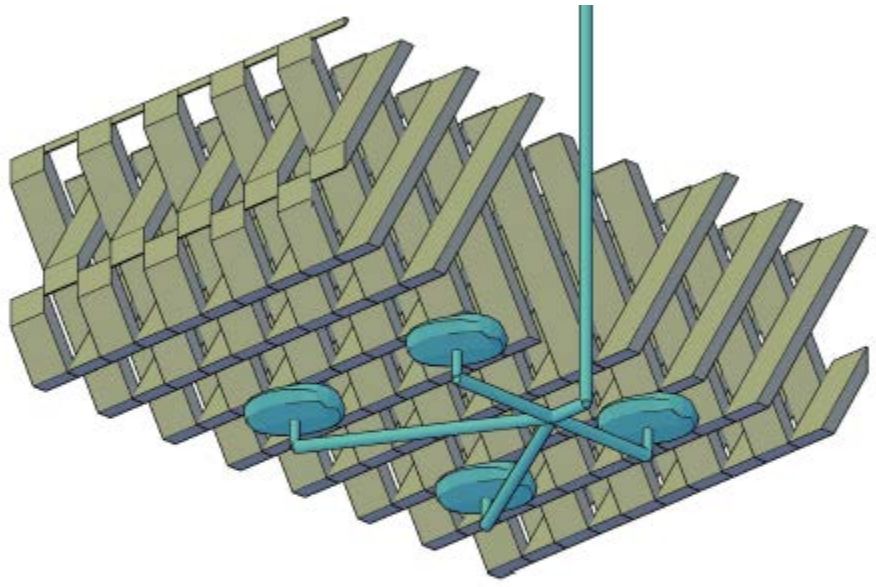


Figure 2: Coalescent media and aeration disc

Aeration system

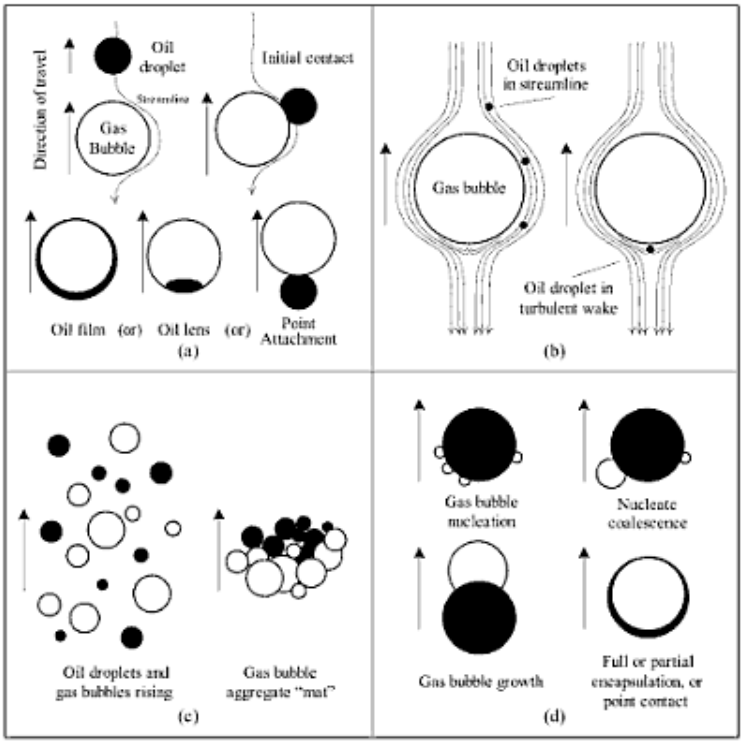


Figure 3: Principal behind the reduction of specific density (Malhotra, 2009)

An aeration unit will be added at the bottom of tank, right under the coalescent media. The addition of this devices have multiple implications. First of it is used as a tool to improve the vertical rising velocity of the oil particles by decreasing the specific weight of the molecules. This is does by the cohesive force of the oil particle and the air bubble, which reduces the overall density of the newly formed oil molecule. By injecting air bubbles into the system, the turbulence of the water flow will be increased. With an increase turbulence, a higher chance of surface contact between the oil particles and the coalescent media will occurs, thus improving the efficiency of the media. Studies has demonstrate the increase in removal rate of each of these method, where the combination of an aeration system and a coalescent media will result in a 95 percent removal rate and it will reduce a wastewater with an initial concentration of over 500ppm to under the desired amount of 30ppm.

Table 4: Reference removal efficiency

Type	Initial Concentration (ppm)	Processed Concentration (ppm)	Removal rate (%)
Conventional	550	110	80.7
With Coalescent Media	500	31	93.8
Aerated	725	70	90.6
Coalescent matrix and Aerated	500	24	95

Furthermore, the addition of an aeration system will increase the oxygen content of the wastewater. This will allow a better proliferation of the aerobic bacteria present that degrades oil. The overall design of the system will be based on the size of the coalescent media, as the increase in separation of oil the main as the purpose of this design. Thus based on FlexAir Threaded Disc, four disc shape differ with a dimension of 3 cm diameter will be installed. These will be connect to 3/4" pipes. (Hellotrade.com)

Skimmer

The skimmer is a rotating cylindrical device design to remove the surface oil layer. It consists of using cohesive force between the oil and the surface of the material to be move up. The metal part must be immerged in 1cm to 3cm of the free oil layer floating on the top of the water. The oil catches in the rotatory device drop in a conveyor which evacuates oil in a container for oil recovery.

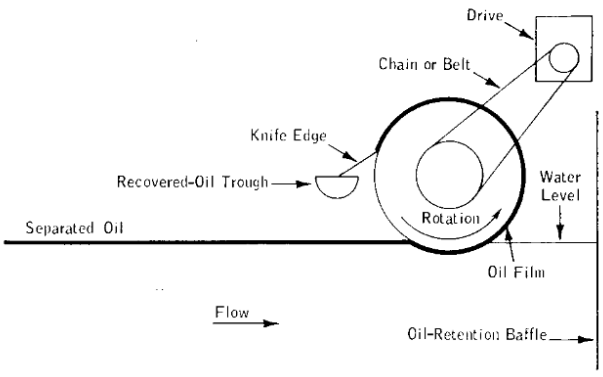


Figure 4: Oil Skimmer - American Petroleum Institute, 1969

Control Valves

The three chamber collection pit is designed to receive wastewater inflow limited to 25 gpm (5.7m^3/h). The control valve in the pipe linking the catchment to the catchment pit, will ensure a control of the maximum flow rate and a flow rate according to the level of water in the first chamber

Figure 5: Flow rate Valve - Alibaba Product, 2011

Centrifugal Pump

The wastewater exit the third chamber two ways: passively and by a centrifugal pump. A centrifugal pump is timed for pumping the wastewater out of the third chamber at determined period length depending upon the testing result. The active removal of the treated wastewater which meets effluent wastewater criteria is important because the outlet pipe is located at 60 cm from the floor. Therefore, the water below 60cm is retained in the three chambers. The pump will remove wastewater in chambers down to a depth of 10cm. The reason for not pumping all water is for avoiding pumping the free oil layer on the surface water. Once the content of the third chamber is pumped, the water from first and second chamber slowly flow through the porous baffles. After, a determined period of time, the pump is reactivated and the cycle start again. The currently described feature of the overall design is an essential component. It empties, by transient pumping, the three chamber collection pit design to receive the volume of generated wastewater on weekly wash prior the event. Without this system, the chambers will contains 60 cm of wastewater at any time, and the incoming inflow, although diluted wastewater contained in the chambers, will not ensure an effluent of 30 ppm of oil content. The passive effluent is designed only for emergency such as overflow occasioned by an extraordinary event.

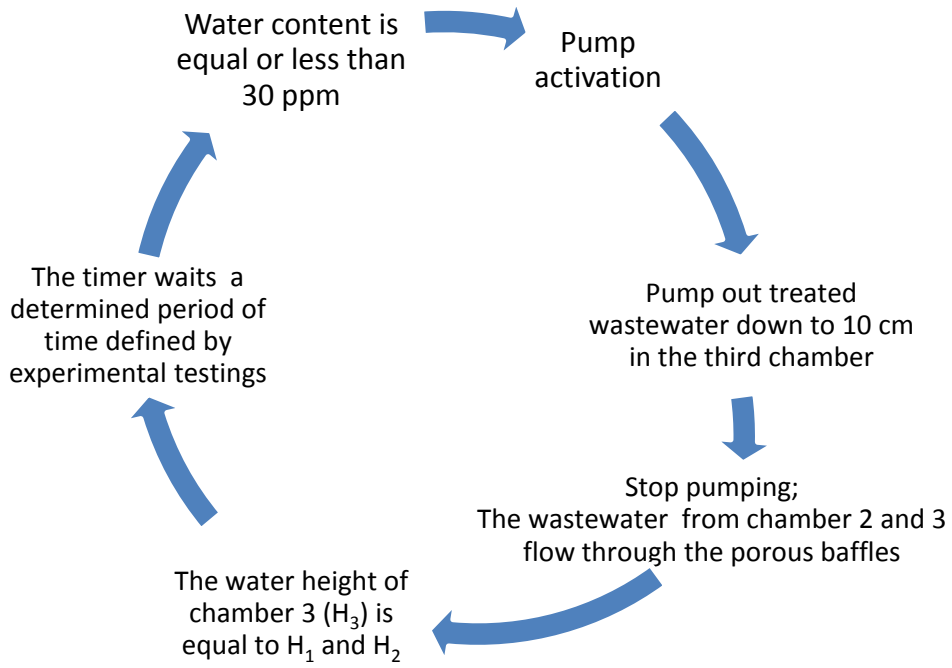


Figure 6: Wastewater Effluent Quality Control

Pipes

The pipe exit is centered horizontally and vertically on the side walls. The reason behind that design is to minimize the turbulent flow in the free oil layer on the surface and for minimizing the turbulence near the solid particles settled on the floor of the chamber. The pipe that conducts the wastewater in the sewage is centered horizontally and it is located at the 2/3 of the wall height in the third chamber. The reason that motivates the design is to increase the volume of water retained for the hydraulic retention time for the microbial degradation. Additionally, the outlet pipe has a 90 degree elbow with the outlet pointing toward the bottom for minimizing the release of the free oil layer.

3.2 BIOLOGICAL TREATMENT

In addition to physical changes to the system, an automated control panel will uses sensors to monitor the wastewater level and wastewater pH. This will also consists of measuring the microbial population, the nutrient level and other parameters described below.

Control system

The control system is performed by a program designed for injecting microbes when a low concentration of microbes is detected by a sensor in the third chamber. The same way, the sensors will adjusts the nutrient concentration, the pH level and the concentration of nutrients (Nitrogen and Phosphorus) and the dissolved oxygen. The volume of microbe injected (inoculum) is determined according to the volume of wastewater remaining in the tanks. The program includes a routine of for hourly data acquisition of the mentioned parameters. The program reports to the maintenance manager lacks of nutrients, microbial agent and enzymes contained in the containers located in the control panel. The level of wastewater and the thickness of free floating oil and/or floating debris should be recorded weekly in a data logger and reported weekly via transmission to the cell of the maintenance manager. If the wastewater level exceeds the allowance for freeboard an alarm is sent to the maintenance manager. Lastly, when the sensors detected an average concentration of 30 ppm or less of the oil content in the last chamber, the water is pumped out of the chambers.

Surface Active Agent

The surface active agents are microbes and detergents that inhibit the formation of hydrogen bond of water molecule and hydrocarbon chain. Since water is a polar molecule and hydrocarbon is a non-polar molecule. In the normal atmospheric and temperature conditions, the water, oil and concrete form three immiscible interfaces that are named the liquid-liquid-solid phase's mixture. The role of the surfactant is reducing the surface tension in the continuous phase for a homogenizing the immiscible liquid. For example, the mixture detergent-water allows the free oil to disperse in the continuous phase. In the maintenance operation, dispersion of oil in a continuous phase of water is desirable because water is a good carrying agent and its viscosity allows a good cleaning of impervious surface.

Microbes

In order to obtain maximize the microbes efficiency, parameters, such as the temperature, the pH, nutrients and the level of oxygen, should be controlled. The bacteria used in wastewater can be of type psychrophiles, mesophiles and thermophiles with stand in temperature ranges respectively from 0^0C to 15^0C, from 15^0C to 40^0C and from 40^0C to 60^0C. The supplied bacteria will grow in temperature between 0^oC and 15^0C because it is wastewater temperature. Typically, organisms better operate with a pH range from 6.0 to 9.0. However, detergents have a tendency to increase the pH beyond the desired

range. The control system, provided with sensors, will inject buffers to maintain optimal avoid excessive alkalinity and acidity. However, this process will occur only on occasion, as the metabolic waste produced from microbial activity, such as nitric acid, tends to lower the pH. The inoculum is the first colony of microbes injected in the first chambers. The inoculums is applied in the first chamber of the separator. With additional experiments, we may apply microbes diluted with the washing water with a mixture device of a sanitizing pressure gun (Buckeye International, 2011).

The microbial growth has four distinct phases as shown on the figure. The hydraulic residence time may vary from 0.5 hours to 34 hours depending on the wastewater characteristic and the type of cleaning agent (Rogers and Gibon, 2009). Shortening the time of microbial growth is achieved by avoiding the lag phase. The inoculums should be taken from colonies of microbes from the mid-end of the log phase on the graph.

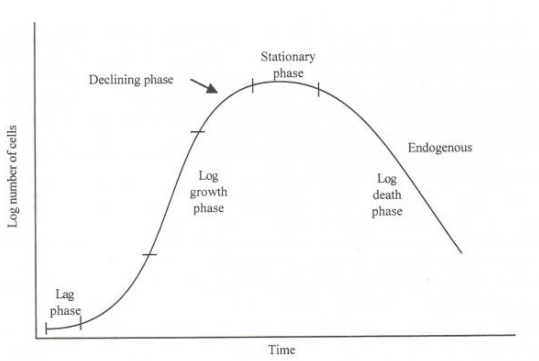


Figure 7: Microbial Growth - Rogers and Gibon (2009)

In the chambers of the collection pit, the homogenized interface of liquid-liquid which are characterized as oil in water emulsification, is an obstacle for the wastewater treatment. Quick-release detergents, which create an unstable emulsification, allow a better physical separation of the oil content. Nonetheless, conventional detergents will make a stable emulsion which will require cleaning other than by physical means.

pH Buffer

The detergent tends to increase the pH above the ideal pH range and in consequence, buffers are required for keeping an optimized alkalinity. Additionally, the metabolic waste produced from microbial activity such as nitric acid, tend to lower the pH.

3.3 OTHER PRACTICES TO BE CONSIDERED

3.3.1 REPLACING CLEANING DETERGENT

As previously mentioned, the current cleaning agent render the oil in a state of emulsion. This state will impede the efficiency of the system, thus other solutions should be look into. In the new design, the addition of the coalescent media and the bacteria degradation will help remove neutralizing these oil particles. Nevertheless, attempts should be made for using non-emulsifying soap. According to the Ontario Ministry of Transportation, three such soaps exist: Hotsy Blue Thunder, Indo 510, and Zep Split Vehicle Wash. In addition to their desired properties, they are product from Canadian companies. However the exact pricing of these soaps was determined. Thus some additional detergent will also be mentioned. (Ontario Ministry of Transportation, February 2007)

Brand	Supplier	Dilution Ratio (H_2O:soap)
Hotsy Blue Thunder	Metrovan Hotsy Equipment Ltd. Surrey, BC	110:1
Indo 510	Flexo Products Niagara Falls, ON	62.5:1
Zep Split Vehicle Wash	Zep Manufacturing Mississauga, ON	62.5:1

Note: Dilution ratio, for Hotsy Blue Thunder, means 110 parts water to 1 part of soap. (e.g. water must be added at a rate of 110 times the amount of soap). So 100 millilitres (mL) of soap requires 11,000 mL (or 11 Litres) of water.

Figure 8: Comparative product - Ministry on transportation of Ontario

In order to increase the efficiency of the coalescent media, detergent with a low phosphate content must be used. The expression “conventional detergent” designates soap without environmental virtue The expression “quick release” means that the detergent in aqueous state with the oil forms an unstable emulsification and after a short period of times the oil particle will separate from the wastewater (McLeod, 1999). The testing will allow determining the recurrent cost of the products and to select the best alternative.

3.3.2 REDUCING THE AMOUNT OF WASTEWATER

One of the major factors in determining the size of the separator is the flow rate. So in order to decrease the flow rate, pressurized water gun can be used. Furthermore, this device will allow the spread of microbial agent. A particular model called the Sockeye will produce a dilution factor from 4 up to 10 with a pressurized water gun including a mixer device. The rate of microbial mix is adjustable to 4 oz of microbe per gallon of water sprayed. The rate of microbial mix is adjustable from 4 to 10 ounces

of microbe per gallon of water sprayed. The mixing head is adjustable for different rate of dilution of the substance in the sprayed water.

However it is very important to note that since the amount of water has decreased, the concentration of the oil will increase. The overall effect should be tested once the prototype is built to ensure that the system can handle a higher concentration of oil. Nevertheless, the overall dimension could potentially be reduced.

3.3.3 Maintenance of the coalescent media

The media requires a routinely cleaning (weekly, monthly) for ensuring the plates keep their oleophilic property. Also, the top section of the coalescent media will have accumulated oil scum and solid debris because of the free oil layer. The media need pressurized water wash with a detergent outside the separator chamber. In order to facilitate the process, an access gate will be place right on top of the coalescent media. The exact routine should be adjusted with time, however initially a general check up should be done once a week and the cleaning process should occur once every three month.

4. COST ANALYSIS

One of the important considerations in the cost analysis is the recurrent operational cost of the cleaning agents. An initial fixed cost involves the modification of the tanks embedded in the concrete floor with the baffles, the coalescent media, the aeration system, and the monitoring system.

Components for physical modifications:

Excavation and Embedded Concrete-Casted walls and floors

The change of configuration of the tank by re-sizing its length, width and depth will involve some cost of material and labors. Hewitt Equipment may supply the heavy equipment and labor necessary for removing the concrete slab and digging the room for the new catchments.

Employees will cut a larger area of the concrete floor than required for the desired dimensions for the new tank. They will have to remove the concrete slab and the earth down up the desired depth including the depth required for the thickness of the concrete floor.

The cost of the concrete wall casted on site of the catchments tank will be 1000$ and can be delivered by Bozanto Inc. from Pointe-Claire.

Excavation Concrete walls and floors

The change of configuration of the tank by re-sizing its length, width and depth will involve some cost of material and labors. Hewitt Equipment may supply the heavy equipment and labor necessary for removing the concrete slab and digging the room for the new catchments.

Employees will cut a larger area of the concrete floor than required for the desired dimensions for the new tank. They will have to remove the concrete slab and the earth down up the desired depth including the depth required for the thickness of the concrete floor. The cost of the concrete wall casted on site of the catchments tank will be 1000$ and can be delivered by Bozanto Inc. from Pointe-Claire. Additionally, the four fiber-glass made baffles will cost 125$/unit and therefore the four unit will cost 500$.

Components for Biological Treatment:

Detergent and Enzyme

First, an experiment need to be performed for determining if the quick release detergent is sufficient for meeting regulation of industrial wastewater without microbe. Secondly, an analysis is required for comparing “the treatment from a conventional detergent and the microbe” with “the treatment with a quick release detergent only”. After, the cost analysis may be performed with the products from table 5.

This is a short comparison of prices of cleaning detergents available in Montreal. The choice of necessary products will be more defined after the testing step described above. The choice will be based on the cheapest recurrence cost that will have the highest efficiency.

Table 5: Operational cost

Product*	Quantity	Suggested water dilution ratio (water : product)	Price
Detergent , (Quick release degreaser)	55 gallons (207.9 liters)	--	555.46$
Enzyme X	55 gallons (207.9 liters)	--	826.86$
Bacteria Bio Puck Hydrocarbon	20 pucks	1000 gallons: 1 puck	--
Detergent Floor Kleen Conventional Floor Degreaser (not quick release)	55 gallons (207.9 liters)	15:1	420.00$
Detergent Konk (not quick release)	55 gallons (207.9 liters)	20:1	---

*The name of product and suppliers are kept confidential for marketing reasons

According the price comparison chart, quick-release soaps are more expensive than conventional floor degreasers. Perhaps, a quick-release detergent is required for having an efficient cleaning of the water. The use of a conventional soap would imply a longer hydraulic residence time because the distribution of droplet of smaller size not coalesced by the media in the second unit will be greater. Therefore, the quick-release soap, despite a higher price, may be essential for having an efficient treatment and a short residence time .

Control Panel

The bioremediation system which is a pit management system cost 3495.00$. The implementation of a program for the data acquisition and automated adjustments of the parameters in the wastewater will be evaluated for cost by the consulting firm. This automated system is optional since the parameter can be adjusted manually.

Alpha-Coalescent

The alpha coalescing parts grid which form the vertical coalescing media with the dimension of 20.5" x 32.5"x 1.0" (52.07cm X 82.55cm X 2.54cm) cost 47.84$ .The total cost will be times 144 plates

necessary for forming a coalescing block with the required dimension. Therefore, the total cost is 6900.00$.

pH Controller

The pH controller parts which includes a sensor cost 615.00$ additionally, the tubing of 1/4" ID x 7/16" OD (0.635cm x 1.11cm) will cost 5.66$ per foot. For eight foot, the cost of tubing is 45.00$.

Summary of the Cost:

Physical component:

Pre-Casted concrete walls and floors:	**1000$**
4 Baffles:	**500$**
Alpha Coalescent parts"	**6900$**
Butterfly Valve:	**50$ (optional automated control valve: 500$)**
Centrifugal Water Pump:	**100$**
4 Disc diffuser:	**60$**
Air diffuser Pipes:	**40$**
Biological treatment:	
Control Panel:	**3495$ (optional automated system: 25 000$)**
pH Controller part:	**615$**
Tubing for sensors:	**45$**
Recurrent cost (To be determined):	
Detergent	
Microbe	
Enzyme	
Nutrient	
Total of determined cost:	**12, 805$ (excluding optional choice and recurrent cost)**

4. PROTOTYPING, TESTING, OPTIMIZATION

4.1 PROTOTYPE

A scale model of the three stage collection pit can be built for testing its efficiency with the wastewater released in the garage of Hewitt Equipment. The minimum scale must be 1:40 because under this ratio, the surface tension or electro-chemical forces have an effect that impedes the inertial forces (pers. comm. Dr. Viaja Raghavan, 2011). For the testing of the dimension based on Stokes's Law , 1:10 is a reasonable scale for the testing purposes. The real dimensions are 6 meters x 1 meter x 0.75 meter, therefore the scale model will be 60cm x 10cm x 7.5cm.

The stoke number is the dimensionless measure useful for having a ratio of raising particles between the prototype and the real scale model.

$$S_k = \left(\frac{V * d_p^2 * \rho_p}{18 * l * \mu}\right) \quad \text{Eq. 5}$$

Where V = velocity (m/s)
d_p = diameter of the particle (m)
ρ_p = density of the particle (kg/m^3)
l = characteristic length (m)
μ = viscosity of the wastewater (m^2/s)

The Froude number characterize whether the state of the wastewater is sub-critical or super-critical. The first chamber is slightly turbulent induced by the inflow up to 25gpm (5.7m^3/s).The turbulence needs to be minimized for a proper settlement of the solid particles. The second chamber must have a turbulent flow in the coalescent media for optimizing the coalescing of the oil droplet. The state of fluid in the third chamber must remain as laminar as possible. The laminar state is required based on the assumption that the wastewater after the coalescent media may be treated further. The turbulence of wastewater would involve a greater mixing of the wastewater. The remaining oil droplet will raise by the difference the specific gravity of the continuous phase or degraded by the microbial activity that is accelerated with the addition of enzymes. The larger droplets may raise and the smaller droplets will be degraded. The dynamic of wastewater inside the chambers previously described, may be optimize by the height of the second and the fourth baffle which determine the entry of water respectively in the second and third compartment. The Froude number may be used for comparisons between the prototype and the real scale model.

$$Fr = \left(\frac{V}{\sqrt{g*l}}\right) \quad \text{Eq. 6}$$

Where V= velocity (m/s)
g = gravity (m/s^2)
l = characteristic length (m)

4.2 TESTING

The testing will involves a systematical approach for determining the timing and quantity of microbe input in the first chamber and for the addition of enzymes in the third chamber. The testing is primarily for simulating the extreme case such as the weekly wash event, when the separator is solicited for the given design criteria (25 gpm or 5.7m^3/h).

The testing will include comparison in wastewater effluents for different heights for the baffle 2 and 4 with constant collection pit dimensions and constant coalescent separator dimensions. The same approach may be repeated for testing different volume of the coalescent media with constant baffles height and constant collection pit dimensions.

The aerobic microbial activity transform the hydrocarbon substrate in water, carbon dioxide and waste such nitrate and sulfate. Nutrients are nitrogen and phosphorus which is already contained in wastewater and can be supplied by a maintenance operator if needed.

$$\text{Organic matter} + \text{Microbes} \xrightarrow{\text{yields}} \text{More microbes} + CO_2 + H_2O + \text{waste energy} \quad \text{Eq. 7}$$

(API- Biological Treatment, 1969)

Ex-situ testing is necessary for determining the microbe kinetic with the garage wastewater which contains a quick release detergent. The kinetic in microbiology is defined as the speed at which the reaction occurs.

$$A + E \rightleftharpoons_{k_{-1}}^{k_1} EA \overset{k_2}{\rightarrow} E + P \quad \text{Eq. 8}$$

The enzyme will reduce the activation energy for the product formation by the reactant

The Michaelis-Menten equation gives an approximation of the velocity at time t during the reaction:

$$V_t = \left(\frac{V_{max}[S]}{K_m[S]}\right) \quad \text{Eq. 9}$$

Where V = the velocity at any time (mol/s)

[S] = the substrate concentration at this time (mg/L)

V_{max} = the maximum speed (mol/s)

K_m = The Michaelis-Menten constant

The constant of association (K_m) evaluated the affinity at $V_{max/2}$ of the substrate and the enzyme for the formation of the complex substrate-enzyme. If K_m has low value, it means the association rate is greater than the dissociation rate and vice-versa. Therefore, K_m values will be used for the selection of best product from a comparative yield analysis of diverse products.

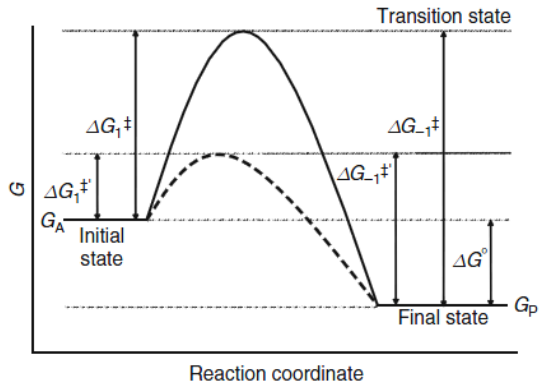


Figure 9: Constant of Dissociation (Km) - Rogers and Gibon, 2009

Conclusion

In conclusion, due to the unconventional physics behind the process, the design process was challenging. Many parameters have been overly design to ensure the compliance of the final 30 ppm oil concentration required by municipal regulations. Nevertheless, principals based on various literatures were followed. With simulation of a prototype, the overall design parameters can be improved.

REFERENCES

Alibaba. 2010. Ball float valve. Available at: http://www.alibaba.com/product-free/109389932/Ball_Float_Valve.html. Accessed on November 18th, 2011.

API. 1969. Manual of disposal of refinery wastes, Chapter 13: Biological treatment, Volume of liquid wastes

Brentwood Industries. S. 2001. Oil/water separators - Design & applications. Reading PA. Water Technology Group

Buckeye International. 2011. Operating instructions for Buckeye's Sani-Q sanitizing gun. Available at: http://www.buckeyeinternational.com/support/instructions/pdf/SaniQGunInstructions.pdf. Accessed at December 5th, 2011

Diffuser express. 2006. FlexAir TM. Threaded disc diffusers. Available at: http://www.diffuserexpress.com/catalog/flexair_threaded_disc_diffusers.html. Accessed on November 18th, 2011.

Gerdes, G. L., DeGuzman, A. and Grubich, J. 2000. Designing Coalescing Oil/Water Separators for Use at Army Wash racks. ERDC/CERL TR-00-40. Springfield VA. US army Corp of Engineers.

Kenneth, L. and Hudson, A. 1998. Decision tree for improving washrack oil/water separator operations, USAEC Report No. SFIM-AEC-ET-R-98003. Harford MD. U.S. Army Environmental Center.

McLeod, M. 1999. Effect of quick release detergent on oil/water separators. Public Works Technical Bulletins 420-49-28. Alexandria VA. US army Corp of Engineers.

Ontario Ministry of Transportation. F. 2007. Oil/water separtior - Field Guide for patrol yards. Ontario. Ministry of Transporation.

Rogers, A. Gibon, Y. 2009. Enzyme kinetics: theory & practice. (J Schwender Ed.) pp 71-103. Springer NY.

Stanfel, C. and Cousart, F. 2011. Coalescence media for separation of water-hydrocarbon emulsion. US patent No. 812190, PCT No PCT/FI09/50033.

Jordan, J.M. and Dexton, T.J., A. 1997. Method of removing dispersed oil from an oil in water emulsion employing aerated solutions within a coalescing media. US patent No. 5656173.

APPENDIX I

A1 Dimensions of the collection pit according to the volume of water generated on weekly wash.

Catchment tank: 72" * 58" * 37" = 1.83m * 1.47m * 0.94m = **2.53 m^3**
Tank that contain the O/W separator: 90" * 58" * 37" = 2.29m * 1.47m * 0.94m = 3.16 m^3
17 gallons per minute * 45 minutes = 765 gallons
765 gallons * 3.78 liters/gallons = 2895 liters
2895 liters * 1.5 of Safety Factor = 4344 liters or **4.34m^3**
Inflow wastewater >> retention tank capacity
4.34 m^3 >> 2.53m^3

A2 Determination of the size of the coalescent media (According to Brentwood Industries)

The surface loading rate of the coalescent medium:
Surface loading rate = $Q_m/A_H = 0.00386(S_w - S_o)/\mu$
Q_m = design flow (ft_3/min)
A_H = projected horizontal area (ft_2) for all coalescing surfaces (one side for each plate)
S_w = specific gravity of water
S_o = specific gravity of oil
μ = wastewater viscosity in poise

$Q_m/A_h = 0.00386(S_w - S_0)/\mu$
Qm = design flow (ft3/min) (25gpm or 3.34ft^2/s)
Ah = projected horizontal area for all coalescing surfaces (ft^2)
Sw = specific gravity of water (1)
So = specific gravity of oil (0.88 to 0.92)
μ= wastewater viscosity in poise (0.01)

The design is conceived for the worst case scenario and therefore the specific gravity of 0.92 is taken into account for the calculation. As discussed in the flow control section, the pipe is designed to have a maximum flow of 25 gpm (5.7 m^3/h).

$A_h = Q_m/ 0.00386(S_w - S_0)/\mu$
Ah = to determine
Qm = 3.34ft^2/s
Sw = 1
So = 0.92
μ= 0.01
A_h = 108.16 ft^2 or 10.05m^2

2[3x1]= 6m^2
2[1x0.5]= 1m^2

$\underline{2[3x0.5]= 3m^2}$
$10\ m^2$

A3 Characteristics of FlexAir Threaded Disc

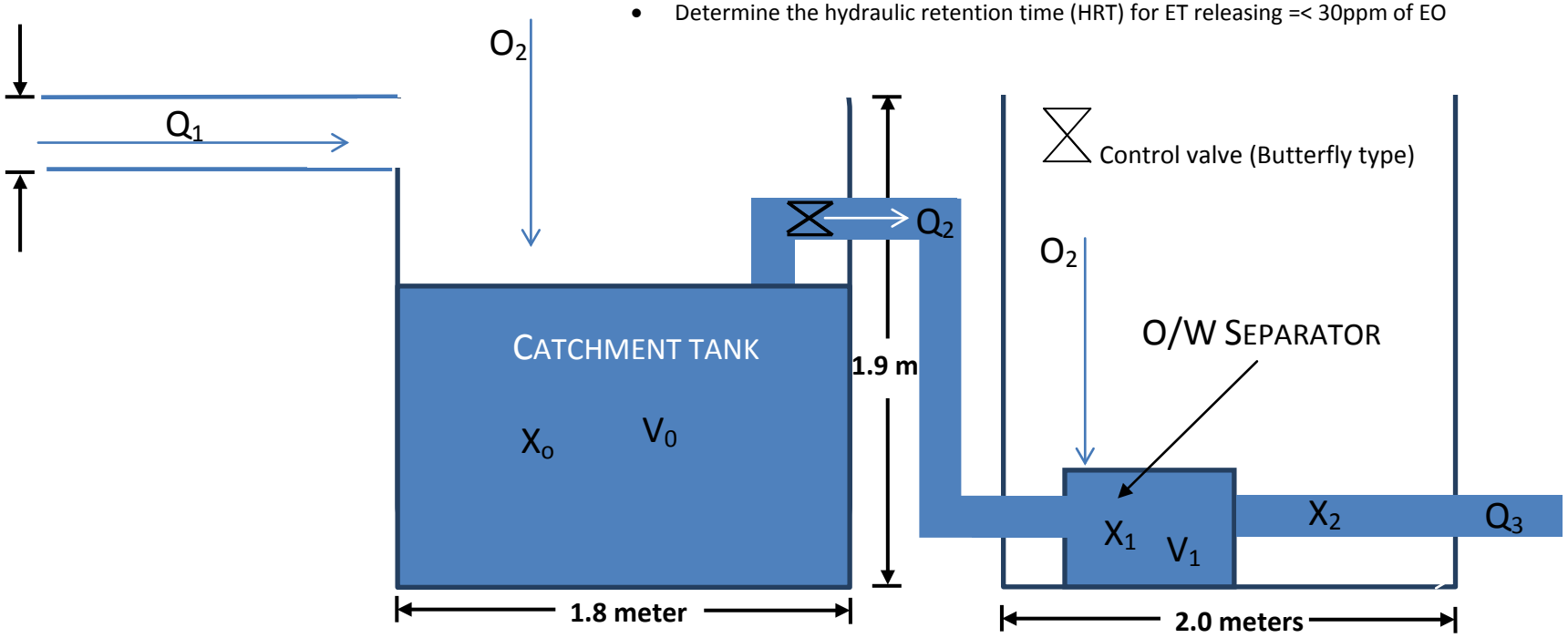
Part Number:	01691			
Model:	7" Standard			
Peak Airflow:	scfm	3.0	m^3_N/h	4.7
Design Airflow:	scfm	0.5-2.5	m^3_N/h	0.9-4.3
Diffuser Diameter:	in	9.0	mm	228.6
Active Surface Area:	ft^2	0.26	cm^2	221
Unit List Price:	$15.00			
Stocked:	No			

APPENDIX II: EXTENDED SIZING CALCULATION

	Diameter of oil droplet, D [µm]					
	150	100	80	60	40	20
Q_d =17						
Separator Minimal Length, L [m]	1.70	2.55	3.18	4.24	6.36	12.73
Separator Minimal Width, W [m]	0.34	0.51	0.64	0.85	1.27	2.55
Separator Minimal Depth, d [m]	0.14	0.20	0.25	0.34	0.51	1.02
Separator Minimal Volume, V [m3]	0.08	0.26	0.52	1.22	4.12	32.97
Q_d =25						
Separator Minimal Length, L [m]	2.06	3.09	3.86	5.14	7.72	15.43
Separator Minimal Width, W [m]	0.41	0.62	0.77	1.03	1.54	3.09
Separator Minimal Depth, d [m]	0.16	0.25	0.31	0.41	0.62	1.23
Separator Minimal Volume, V [m3]	0.14	0.47	0.92	2.18	7.35	58.80
Q_d =30						
Separator Minimal Length, L [m]	2.25	3.38	4.23	5.63	8.45	16.90
Separator Minimal Width, W [m]	0.45	0.68	0.85	1.13	1.69	3.38
Separator Minimal Depth, d [m]	0.18	0.27	0.34	0.45	0.68	1.35
Separator Minimal Volume, V [m3]	0.18	0.62	1.21	2.86	9.66	77.29
Q_d =50						
Separator Minimal Length, L [m]	2.91	4.36	5.46	7.27	10.91	21.82
Separator Minimal Width, W [m]	0.58	0.87	1.09	1.45	2.18	4.36
Separator Minimal Depth, d [m]	0.23	0.35	0.44	0.58	0.87	1.75
Separator Minimal Volume, V [m3]	0.39	1.33	2.60	6.16	20.79	166.31

APPENDIX III: SCHEMA OF ORGINAL SYSTEM

- Oil-Water Separator (O/WS): Device inefficient for treatment of wastewater containing emulsified-oil (EO)
- Change the sizing of the current O/WS + add a control valve+ enzymatic treatment (ET)
- Determine the hydraulic retention time (HRT) for ET releasing =< 30ppm of EO



Main parameters:

X_o = > X_1

X_1 = 6 to 200 ppm (mg/L)

X_2 = Required =>30 ppm (mg/L)

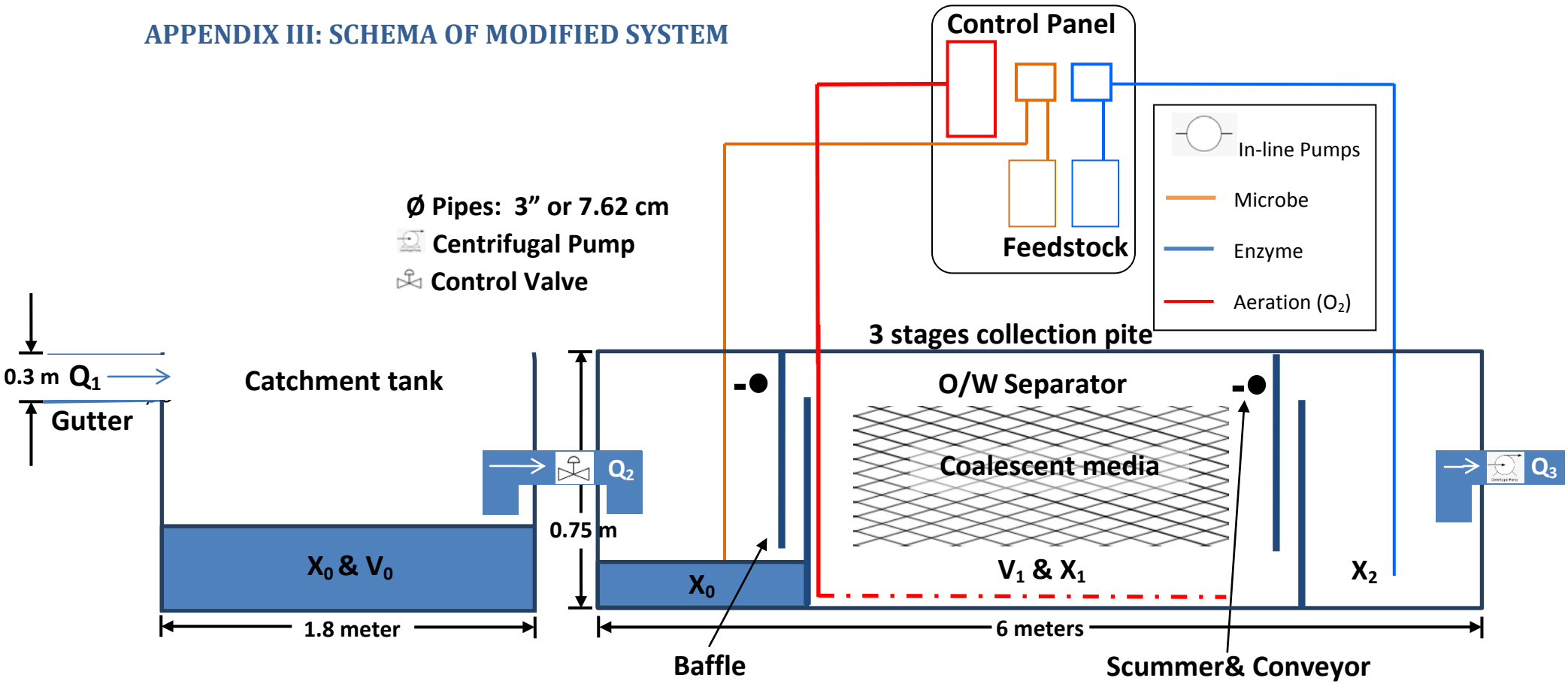
V_0 = 2180 L (2.78 m^3)

V_1 = 60 L (6.0 X 10^{-2} m^3)

Q_1 = 17 gpm (3.86 m^3/h)

Q_2 = To be determined according to HRT

APPENDIX III: SCHEMA OF MODIFIED SYSTEM



Main parameters:

X_o = > X_1

X_1 = 6 to 200 ppm (mg/L)

X_2 = required =>30 ppm (mg/L)

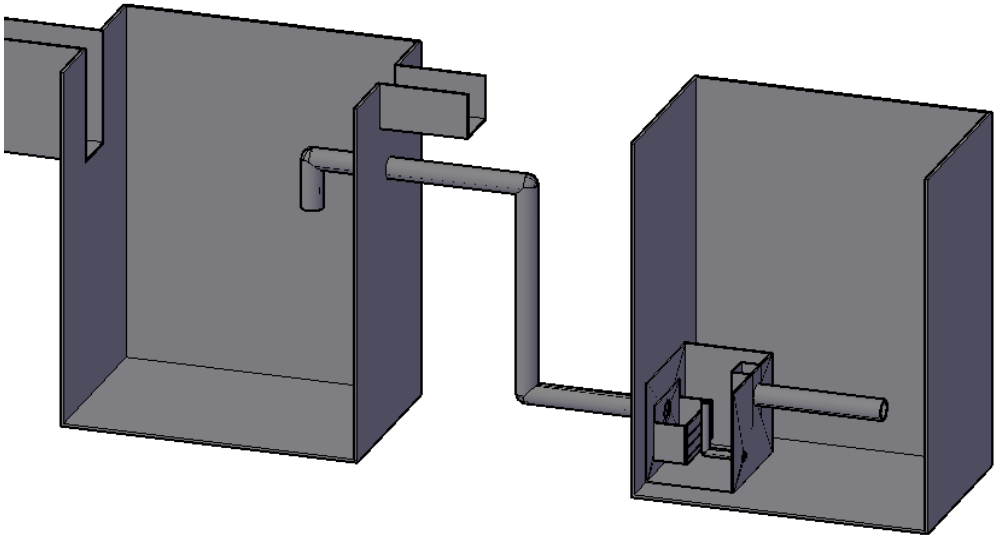
V_o = 1350 L (1.35 m^3)

V_1 = 5830 L (5.83 m^3)

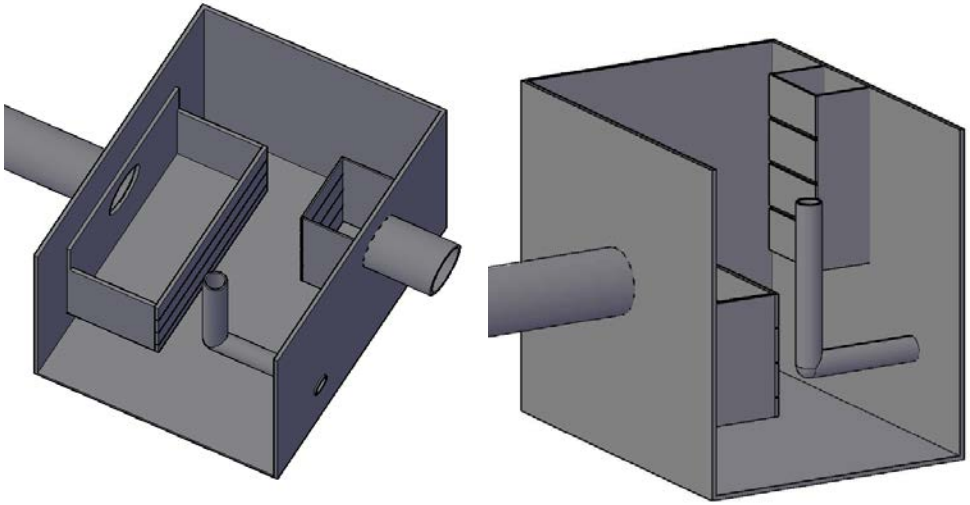
Q_1 = 17 gpm (3.86 m^3/h)

Q_2 = 25gpm (5.67m^3)

APPENDIX IV: OVERVIEW OF THE CURRENT SYSTEM

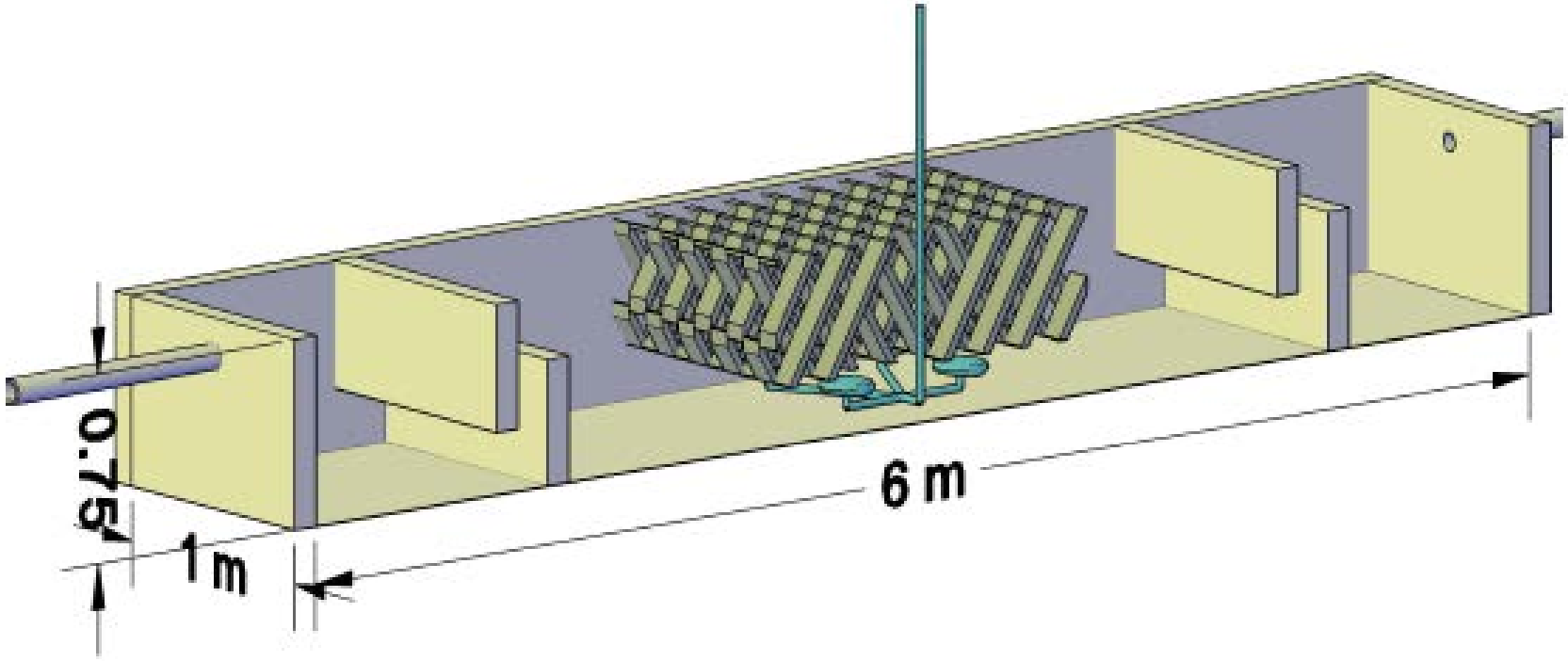


Overall representation of the existing system



Close up view of the existing separator

APPEEDIX V: NEWLY DEVELOPED SYSTEM



APPENDIX D

SOIL INFILTRATION TESTING SUMMARY FROM AKART REPORT

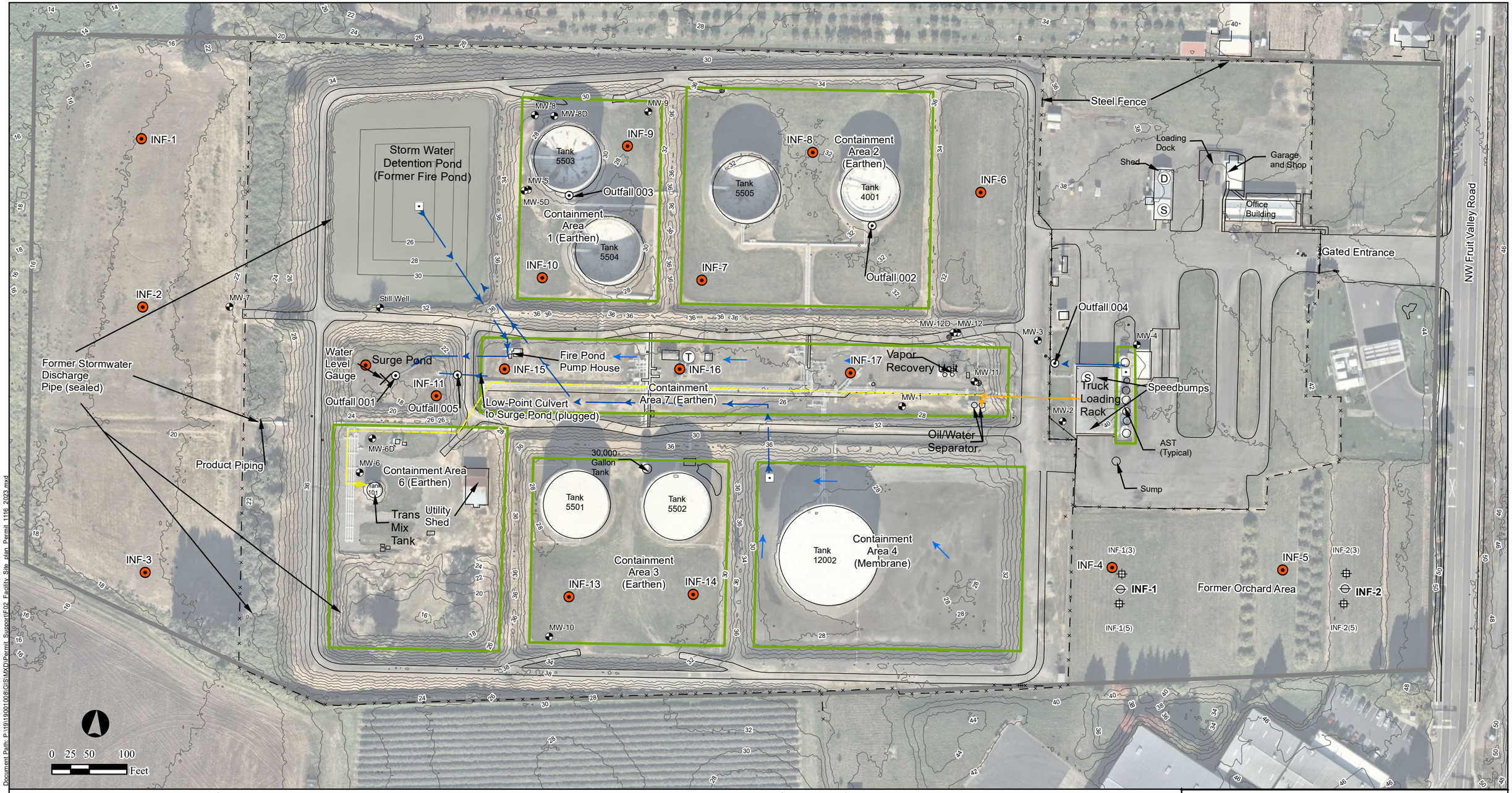
GeoEngineers

5820 S Kelly Ave, Suite B, Portland, Oregon 97239, Telephone: 503.624.9274 www.geoengineers.com

Memorandum

To:	Neil Alongi, Maul Foster & Alongi,Inc.
From:	Kurt Harrington, PE
Date:	November 16, 2023
File:	19001-008-04
Subject:	Summary of Soil Infiltration Testing

GeoEngineers, Inc. (GeoEngineers) has prepared this memorandum for Maul Foster & Alongi, Inc. (MFA) to summarize soil infiltration testing conducted within earthen secondary containment systems at the NuStar Vancouver Annex facility located at 5420 NW Fruit Valley Road in Vancouver, Washington (the Facility or Property). Soil infiltration rates were measured across the Facility in 2020 using a single ring falling head test method approved by the City of Vancouver. The results of the 2020 testing were presented in 2022 all known, available, and reasonable methods of prevention, control and treatment (AKART) report. A summary of the measured infiltration rates is provided in the attached Table 1. Test results inside the earthen containment areas are highlighted and averaged. The test locations are shown in Figure 1.



Document Path: P:\191\190100\GIS\MXD\Permit Support\FS02_Facility_Site_plan_Permit_1116_2023.mxd

Notes:
Base map completed from a number of sources including but not limited to; Figure VAN1-21-002 provided by NuStar (1/8/2007) and monitoring wells surveys by Statewide Land Surveying, Inc. (10/30/2007), bluedot group (12/06/2017), and MacKay Sposito (02/07/2022).

Locations of roads and containments are approximate.

Source:
Aerial from Mapbox.

- Groundwater Monitoring Well Location (MW-5D, MW-6D, MW-8D, and MW-12D are Deep Monitoring Well Locations)
- 2020 Infiltration Test Location
- 2022 Infiltration Test Pits
- Low Point Drain
- Stormwater Monitoring Point/Outfall
- (D) Drum Storage
- (S) Spill Kit
- (T) Transformer
- Piezometer
- Buried Stormwater Conveyance Piping and Flow Direction
- Direction of Process Water Drainage
- Direction of Stormwater Drainage
- Direction of Process Water Drainage in the Event of a Spill
- Steel Fence
- 2-Foot Contour (NAVD88)
- Facility Boundary
- Secondary Containment

11/16/2023		Drawn by: ES	Checked by: IM	

Facility Map

NuStar Terminals Operations Partnership, L.P. - Annex Terminal
Vancouver, Washington

GeoEngineers

Figure
1

Table 1
Soil Infiltration Testing
NuStar Energy, L.P. – Vancouver Annex Terminal
Vancouver, Washington

Test Location [1]	Date	Depth (feet)	Length of flow (*L*) (inches)	Time (*t*) (hour)	Initial head (h_1) (inches)	Final head (h_2) (inches)	Coefficient of Permeability (in/hr) [2]	Coefficient of Permeability (ft/day) [2]	Coefficient of Permeability (cm/sec) [2]	Design Infiltration Rate (ft/day) [3]			
West of Tank Farm Containment Areas													
INF-1	8/17/2020	2	3	1	15	14.75	0.05	0.10	3.56E-05	0.040			
INF-2	8/17/2020	3	2	1	15	15.00	0.00	0.00	0.00E+00	0.000			
INF-3	8/17/2020	2	3	1	15	14.50	0.10	0.20	7.18E-05	0.081	Ave =	0.10	ft/day
East of Tank Containment Areas (Orchard)													
INF-4	8/17/2020	3	2	1	15	12.50	0.36	0.73	2.57E-04	0.292			
INF-5	8/17/2020	2	3	1	15	13.50	0.32	0.63	2.23E-04	0.253	Ave =	0.68	ft/day
Unused Containment Area													
INF-6	8/17/2020	2	3	1	15	14.75	0.05	0.10	3.56E-05	0.040	Ave =	0.10	ft/day
Containment Area 2 (EFR Tanks 4001 and 5505)													
INF-7	8/18/2020	0.5	3	1	15	14.38	0.13	0.26	9.01E-05	0.102			
INF-8	8/18/2020	0.5	3	1	15	14.88	0.03	0.05	1.77E-05	0.020	Ave =	0.15	ft/day
Containment Area 1 (EFR Tanks 5503 and 5504)													
INF-9	8/18/2020	0.5	3	1	15	14.88	0.03	0.05	1.77E-05	0.020			
INF-10	8/18/2020	0.5	3	1	15	14.50	0.10	0.20	7.18E-05	0.081	Ave =	0.13	ft/day
Surge Pond													
INF-11	8/19/2020	0.5	4	1	15	14.00	0.28	0.55	1.95E-04	0.221			
INF-12	8/19/2020	0.5	4	1	15	14.75	0.07	0.13	4.75E-05	0.054	Ave =	0.34	ft/day
Containment Area 3 (Fixed Roof Tanks 5501 and 5502)													
INF-13	8/18/2020	0.5	3	1	15	14.63	0.08	0.15	5.36E-05	0.061			
INF-14	8/18/2020	0.7	3	1	15	14.88	0.03	0.05	1.77E-05	0.020	Ave =	0.10	ft/day
Containment Area 7 (Central Pipe Run)													
INF-15	8/19/2020	0.5	2	1	15	15.00	0.00	0.00	0.00E+00	0.000			
INF-16	8/19/2020	0.7	2	1	15	14.88	0.02	0.03	1.18E-05	0.013			
INF-17	8/19/2020	1	2	1	15	15.00	0.00	0.00	0.00E+00	0.000	Ave =	0.01	ft/day

Containment Area Average (coefficient of permeability) =	3.48E-05	cm/sec	or	0.10	ft/day

Notes:

[1] Refer to Figure 2 for test locations.

[2] Coefficient of Permeability (k) = L/t * ln (h_1/h_2)

[3] The design infiltration rate is determined by dividing the calculated coefficient of permeability by a correction factor of 2.5 (0.4) to account for layered soil conditions.

in/hr = inches per hour

ft/day = feet per day

cm/sec = centimeters per second

Cascadia Associates, LLC