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Pacific Northwest
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Assessment of Pump-and-Treat System Impacts on 200 West Aquifer Conditions

Interim Status Report

September 2018

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U.S. DEPARTMENT OF
ENERGY

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Richland, Washington 99352

Executive Summary

The 200 West Area pump-and- treat (P&T) system is one of the key components of the final remedy selected for the 200-ZP-1 Operable Unit (OU), and the interim remedial action selected for 200-UP-1 OU at the Hanford Site. In addition, the facility has been receiving water from several other sources, such as 200-DV-1 OU perched water, groundwater from the 200-BP-5 OU, and leachate from the Environmental Restoration Disposal Facility. It is anticipated that the P&T system will continue to receive water from other sources, which may include Modular Storage Unit (purge) water, groundwater near the Waste Management Area C, and Gable Gap. Furthermore, maintaining the injection capacity of the system has been a significant issue since the facility startup in 2012. Fouling issues at the injection wells have necessitated frequent well redevelopment, resulting in decrease in injection capacity and the need to construct new injection wells—with significant effects on system performance and operational costs. Given the evolving nature of treatment plant effluent due to changes in influent, combined with issues observed at the injection wells, it is important to understand the impacts of the P&T operations on the 200 West aquifer where the treated water is injected. This study aims at determining these impacts and providing a quantitative evaluation of aquifer capacity for both current and future conditions. This information will provide a technical basis for decisions related to the P&T system operations that support remedy optimization efforts and short- and long-term remedy decisions related to multiple OUs in the Central Plateau.

As part of this effort, a baseline assessment of the 200-ZP-1 sediments was conducted for a series of samples received from three injection wells constructed in the 200-ZP-1 OU in 2016. There were 20 samples analyzed from the three locations. Future efforts could expand to include analysis of sediment samples from other locations within the 200- ZP-1 OU to enhance the understanding of geochemical and microbiological signatures. The baseline assessment included a physical, geochemical, mineralogical and microbiological characterization through a series of analyses which resulted in the measurements of important parameters such as particle size distribution, moisture content, mineral phase abundancies, pH, extractable elements and contaminants, carbon content, and bacterial types and abundance. A set of batch experiments was also conducted with the effluent samples received from the P&T effluents at Injection Transfer Buildings 1 and 2, and also with a representative Hanford artificial ground water (which provided a baseline control). These experiments provided initial results on potential geochemical reactions occurring in the aquifer with the injection of P&T effluent. Additional insight will be gained through planned column experiments to further evaluate changes in 200-ZP-1 OU aquifer sediment conditions as they are exposed to the P&T effluent to identify unintended consequences and effects of P&T effluent injection on the subsurface and injection well conditions. Reactive transport modeling is planned in conjunction with column studies to generate a model configuration that can be used to predict aquifer responses to P&T effluents. These modeling efforts will provide a quantitative assessment capability for assessing aquifer impacts and system performance under the current conditions and as part of the predictive evaluations of future conditions.

Acknowledgments

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Acronyms and Abbreviations

AGW	artificial groundwater
CCU	Cold Creek Unit
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminant of concern
DDI	double de-ionized
ERDF	Environmental Restoration Disposal Facility
FBR	fluidized bed reactor
ft bgs	feet below ground surface
GAC	granular activated carbon
gpm	gallons per minute
GWB	Geochemist's Workbench
HDPE	high-density polyethylene
HEIS	Hanford Environmental Information System
ICs	Institutional Controls
IC	ion chromatography
ICP-MS	inductively coupled plasma mass spectrometry
ICP-OES	inductively coupled plasma - optical emission spectrometry
ITB1/ITB2	Injection Transfer Building 1/2
LRB	Laboratory Record Book
MNA	monitored natural attenuation
OU	operable unit
P&T	pump-and-treat
PVDF	polyvinylidene fluoride
QXRD	quantitative X-ray diffraction
ROD	record of decision
rpm	rotations per minute
TOC	total organic carbon

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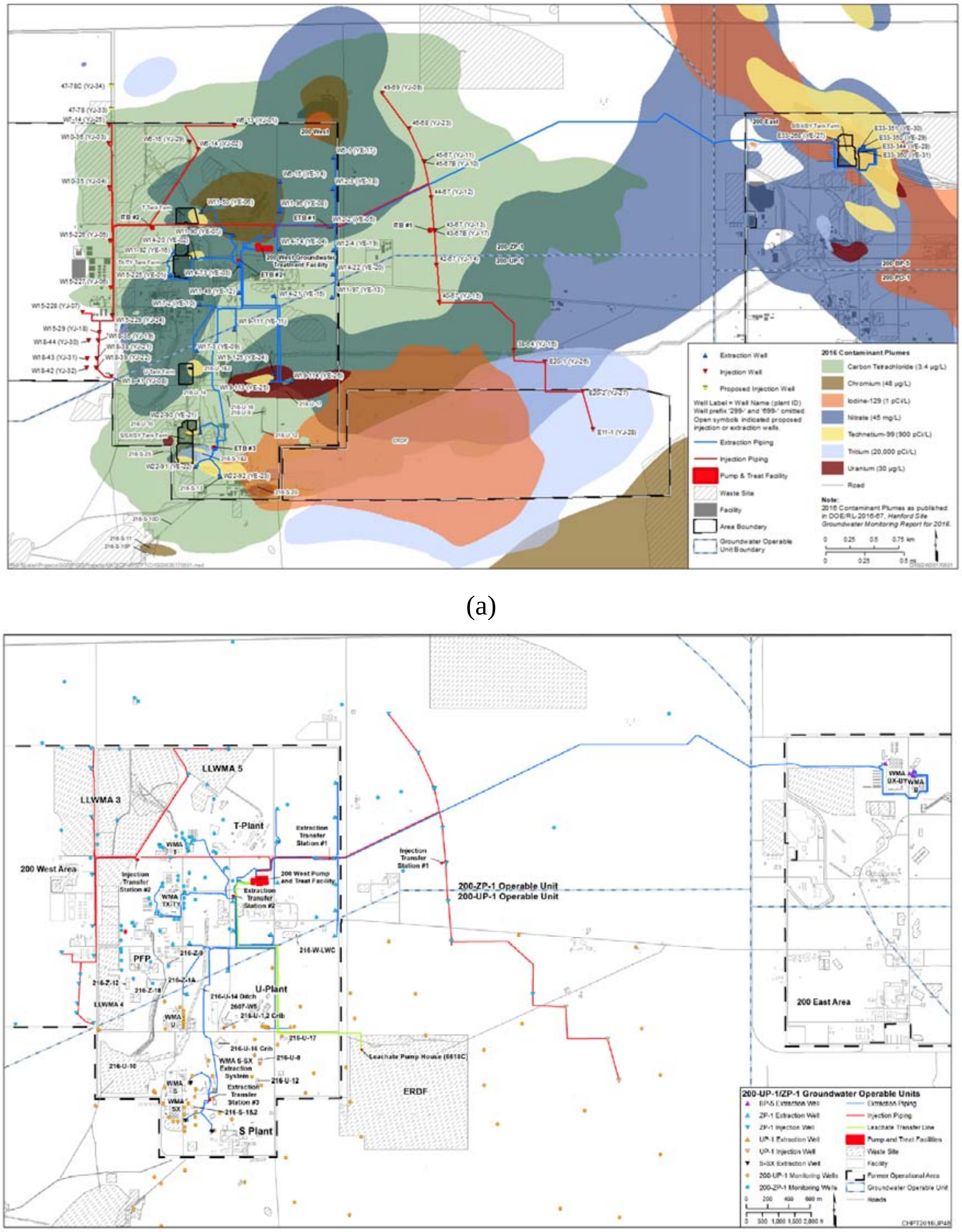
1.0 Introduction

The 200 West pump-and-treat (P&T) system is one of the key components of the final remedy selected for the 200-ZP-1 operable unit (OU) in the *Records of Decision, Hanford 200 Area 200-ZP-1 Superfund Site, Benton County, Washington* (EPA et al. 2008), referred to as 200-ZP-1 ROD, at the Hanford Site. It is also a major component of 200-UP-1 interim remedial action (EPA et al. 2012). The selected remedy for both the 200-ZP-1 and 200-UP-1 OUs is a combination of P&T, monitored natural attenuation (MNA), flow-path control, and institutional controls (ICs). This remedy is designed to meet the objective of achieving cleanup levels for all contaminants of concern (COCs) in 125 years (DOE 2016), except iodine-129 (I-129) in the 200-UP-1 OU. COCs that are addressed by the 200 West P&T system are shown in Table 1. Figure 1 shows the distribution of the contaminant plumes in the Central Plateau, and presents the location of the P&T system with respect to various waste sites. More detailed mapping of the P&T system well network is given in Figure 3.

Table 1. COCs that are addressed by the P&T system and the cleanup levels as established in 200-ZP-1 and 200-UP-1 RODs (DOE 2016).

COC	Units	Final Cleanup Level	Cleanup Level Basis
Carbon tetrachloride (CCl_4)	μg/L	3.4	WAC 173-340, Model Toxics Control Act—Cleanup Method B
Total chromium (Cr)	μg/L	100	Federal/State MCL
Hexavalent chromium (Cr(VI))	μg/L	48	WAC 173-340, Model Toxics Control Act—Cleanup Method B
Nitrate (NO_3^-)	μg/L	10,000	Federal/State MCL
Trichloroethene (TCE)	μg/L	1	Federal MCL
Iodine-129 (I-129)	pCi/L	1	Federal MCL
Technetium-99 (Tc-99)	pCi/L	900	Federal MCL
Tritium (H_3)	pCi/L	20,000	Federal MCL
Uranium (U)	μg/L	30	Federal MCL

After operations commenced in 2012, the use of P&T system has evolved to support remediation activities in other OUs. Currently, it is the selected alternative in the non-time critical removal action of the 200-DV-1 OU perched water (DOE 2014a) and for the treatment of contaminated water from the 200-BP-5 treatability testing (DOE 2015). Extracted perched water is treated to remove uranium (U), technetium-99 (Tc-99), nitrate (NO_3^-), total (Cr), hexavalent chromium (Cr(VI)), and tritium (H_3) and is injected into the aquifer below the 200 West Area. The purpose of the 200-BP-5 treatability test is to determine if pumping is an effective solution in providing hydraulic containments and reducing the mass of the Tc-99 and U plumes near the B Tank Farm Complex. Furthermore, the P&T system is also used to treat leachate from the Environmental Restoration Disposal Facility (ERDF) (EPA 2015). It is possible that the system may receive water from other potential sources as well, such as Modular Storage Unit (purge) water, groundwater near the Waste Management Area C, and Gable Gap. However, prior to any CERCLA-related contaminated water is sent to this facility, the appropriate evaluations must be made to ensure effective treatment to meet the cleanup levels identified in each applicable ROD (DOE 2016).



(a)

ERDF = Environmental Restoration Disposal Facility LLWMA = low-level waste management area PFP = Plutonium Finishing Plant

(b)

Figure 1. (a) Distribution of contaminant plumes in the central plateau as reported in the *Hanford Site* Groundwater *Monitoring Report for 2016* (DOE 2017b); (b) 200 West P&T extraction and injection wells for different OUs and associated waste sites (DOE 2017a).

In addition to the changes in contaminated groundwater signatures that the P&T system receives, there has also been reduction in injection capacity due to reoccurring biofouling issues at the injection wells (discussed in more detail in Section 1.1). These issues are expected to drive changes in standard operating procedures and equipment at the P&T facility.

Given the varying geochemical signatures from current and potential future sources, combined with the operational conditions and amendments considered for treatment processes, it is critical to understand the aquifer impacts with respect to P&T performance. This information provides a technical basis for decisions related to P&T system operations that support remedy optimization efforts, and short- and long-term remedy decisions related to multiple OUs. This will also ensure that the P&T system is able to support the intended objectives to achieve timelines established in 200-ZP-1 ROD and other decisions.

A data-driven methodology is needed to determine the P&T system impacts on the aquifer and support an assessment of system performance for both current and future conditions. Some key elements and data necessary for such an evaluation include: (1) developing an understanding of the effluent characteristics from the treatment plant, including any anticipated variations due to operational changes; (2) identification and collection of historical system performance data and an assessment of any correlations to the aquifer injection capacity; (3) identification of significant geochemical and microbiological mechanisms stimulated by the injection of P&T effluent at the wells and aquifer that impact system performance; and, finally, (4) developing a quantitative evaluation of the aquifer capacity for current and future conditions. This interim status report describes the tasks accomplished to date to address these elements and summarizes the preliminary results.

1.1 200 West Pump-and-Treat System Background

The 200 West P&T system is designed to capture and treat contaminated groundwater to reduce the mass of selected COCs (Table 1) by at least 95% in 25 years from the startup. It has the design capacity to treat 2,500 gallons per minute (gpm) of extracted groundwater using two parallel treatment trains—each unit with the capacity of 1,250 gpm. The design of the central facility included the ability to add a third treatment train (increasing the capacity to 3,750 gpm), depending on capacity needs (DOE 2016).

The facility operations and subsequent data collection efforts for monitoring the system performance started in 2012 (DOE 2017a). The treatment plant removes the key COCs from groundwater by combined chemical and physical processes, as well as biological treatment for removal of NO_3^- and carbon tetrachloride (CCl_4). Table 2 summarizes the unit processes that are used at the treatment facility and Figure 2 presents the process flow in the facility.

Table 2. 200 West P&T remedial system components (DOE 2016).

Unit Process	Process Description and Targeted COCs
Ion Exchange	Removal of Tc-99, I-129 and Uranium
Anoxic/anaerobic Biodegradation (Fluidized Bed Reactor, FBR)	Removal of NO_3^-, CCl_4, Cyanide (CN^-), TCE, and conversion of Cr(VI) to Cr(III)
Aerobic Biodegradation	Degradation/removal of residual organic carbon substrate
Membrane Filtration	Removal of particles, biomass, and precipitated Cr(III)
Air Stripping	Removal of volatile organic compounds, CCl_4, and TCE
Sludge Thickener and Dewatering	Thicken biological solids for dewatering process, and reduce water content to allow for landfill disposal
Treated Water Chemistry Adjustment	Provide treated water stability

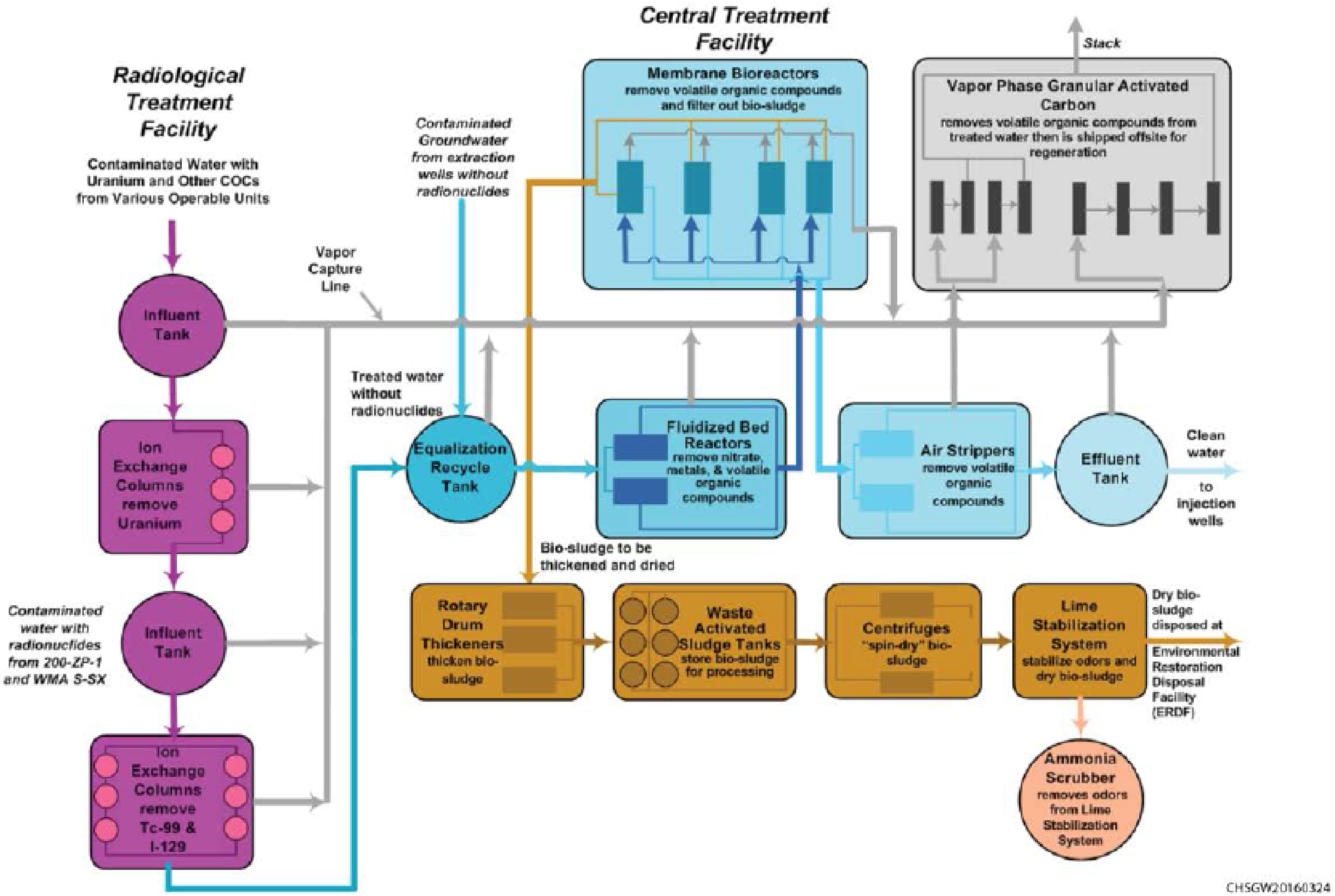


Figure 2. 200 West P&T treatment processes (DOE 2017).

In its current state, the P&T well network includes 31 extraction wells (see Figure 3); all extraction wells are operational and divided among the OUs as: 20 in 200-ZP-1; 3 in 200-UP-1; 3 in S-SX tank farm; 2 in 200-BP-5, and 3 in 200-DV-1. The majority of the treated water is injected into the 200-ZP-1 OU subsurface. Extraction wells are typically large diameter (20 cm) wells with long screens (>30 m) and pumps placed within 3 m of the bottom of each well. The extraction wells in the 200-ZP-1 OU are screened at intervals with CCl_4 concentrations greater than 100 μg/L, and for those in the 200-UP-1 and 200-BP-5 OUs, the target intervals are selected with U concentrations greater than 30 μg/L and Tc-99 concentrations greater than 900 pCi/L, respectively (DOE 2017).

Additionally, there are a total of 32 injection wells in the well network with only 29 currently in operation (CH2M 2018). Each injection well typically has an injection capacity of about 150 gpm. Location of injection wells are designed to provide flow-path control for the COC plumes by injecting treated water into the aquifer upgradient and downgradient of the groundwater contaminant plumes in 200-ZP-1 OU and downgradient of the 200-UP-1 I-129 plume. While this design allows hydraulic containment for the contaminant plumes, it also provides additional time for natural attenuation processes by redirecting the groundwater flow east (DOE 2016).

Decline in injection capacity and subsequent decline in flows through the P&T system were first observed in 2013 (after several months of operation) due to biofouling issues at the injection wells. It was concluded at the time that the biofouling material—slimy biomass produced by the microorganisms in the fluidized bed reactors (FBRs)— were caused by an imbalanced nutrient feed and went through the treatment facility reaching the effluent tank (Figure 2) and being distributed to the injection system (DOE 2014b). In the FBR, the granular activated carbon (GAC) bed media is suspended with the incoming water to grow and attach microorganisms to convert NO_3^- to nitrogen gas and degrade CCl_4. An organic carbon substrate and phosphorus are added in this unit to serve as the electron donor and provide nutrients for the microbial growth (DOE 2016). Although, proper nutrient balance was achieved in 2013 for FBR operations, biofouling issues persisted through 2016 (DOE 2017). An example of typical well performance data is given for the injection well YJ-2 in Figure 4 starting from 2012 until mid 2017.

The FBR effluent contains biological micronutrients, particularly manganese, and other precipitated particles, such as iron oxide, manganese oxides, micro-organisms, and extracellular material. Chemical dosing, or the amount of micronutrient and carbon substrate added, have been optimized to balance biological needs within the plant while minimizing the release of material that might cause fouling at the wells. Carbon and nutrient dosages are determined by a set of calculations that assume complete reduction of nitrate (Carlson et al. 2015). However, complete removal of these materials from the facility effluent is difficult, requiring drilling of new injection wells and multiple cleanings of each injection well to restore injection capacity, and as necessary (DOE 2017). These actions have affect the system performance and costs associated with operations. Suspended solids (colloids) and biological nutrients injected into the subsurface will contribute to injection well fouling and very likely decrease the permeability of the subsurface soils surrounding the injection wells.

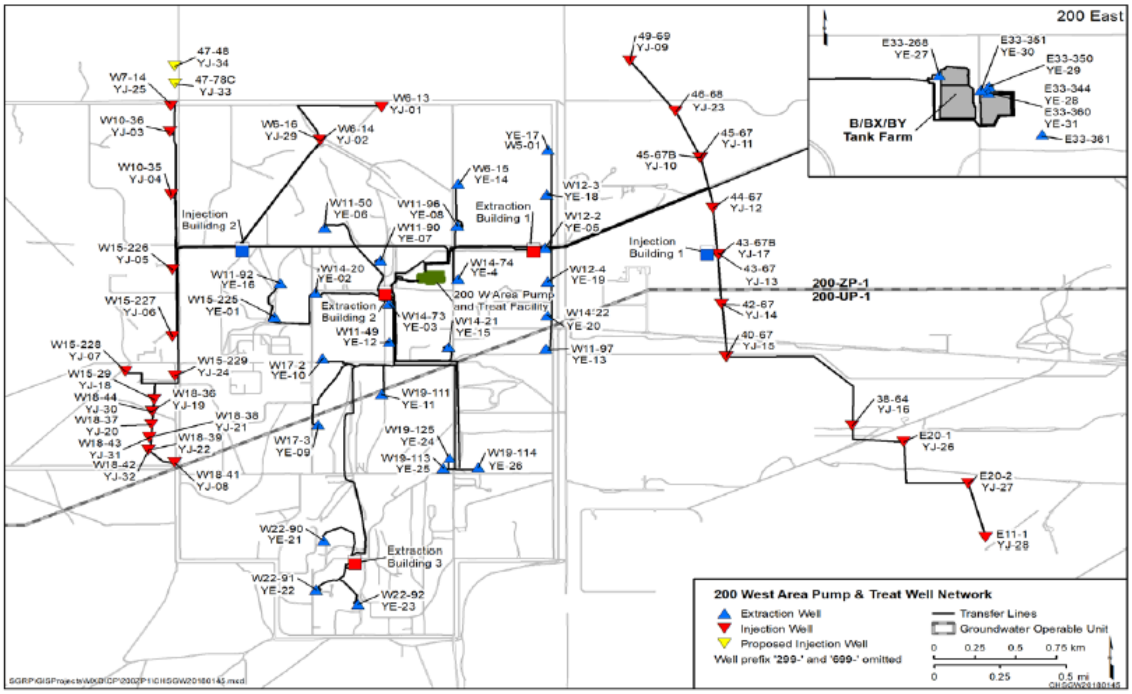


Figure 3. 200 West P&T well and conveyance piping network (CH2M 2018).

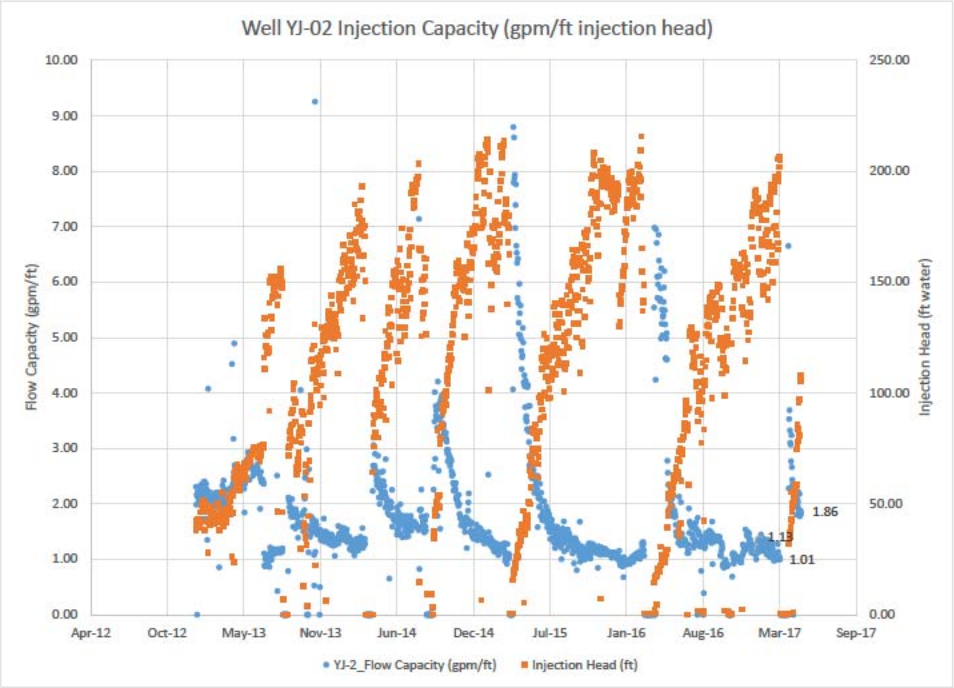


Figure 4. Typical performance data for well YJ-02 (Carlson et al. 2018).

1.2 Study Objectives and Methodology

As described above, the 200 West P&T system processes contaminated groundwater from multiple OUs with different water quality signatures. The majority of treated water is re-injected into the 200-ZP-1 OU. The aquifer in this region is affected by the mix of chemical signatures in the P&T effluent. Because large volumes of water will be processed over the approximate lifetime of the P&T system (~ 25 years), there is a potential for large mass loading of P&T effluent constituents in the aquifer, and subsequent reduction in aquifer capacity. These may have effects on the injectivity and/or flow through the aquifer and the aquifer biogeochemistry. An evaluation is needed to determine if P&T operations are having any unintended or lasting impacts on the aquifer that may interfere with continual P&T operations as planned.

Furthermore, reoccurring biofouling issues at the injection wells are expected to drive changes to the plant operations or equipment at the P&T facility. The potential impacts of these changes need to be carefully considered in the context of overall system performance, effluent characteristics, and aquifer impacts. A normalized baseline of P&T facility performance and aquifer conditions must first be established before future impacts can be assessed. Tasks accomplished to date focus on establishing this baseline characterization.

The objectives of the study and accomplishments to date are outlined below:

- **Objective 1**. Characterize effluent water chemistry from the treatment facility that is injected into the 200 West aquifer, including any anticipated changes due to operational changes. This is accomplished through laboratory analyses of samples from the Injection Transfer Buildings 1 and 2 (ITB1 and ITB2) (see Figure 1b for the location of these buildings). Speciation modeling is also used to fully characterize effluent samples. Sections 2.4 and 3.6 describe these efforts and the preliminary results. As a next step, potential changes in the P&T effluent characteristics will also be identified based on any changes to the treatment facility operations under consideration. Additional P&T effluent samples will be analyzed as needed to identify key characteristics and temporal variations. Speciation modeling will be expanded to include all results from the batch experiments described below.

- **Objective 2**. Identify and collect historical system performance data to conduct a correlation assessment of system performance to aquifer or injection conditions. This task is currently still ongoing and the results will be reported at a later date.

- **Objective 3**. Identify significant geochemical and microbiological reaction and processes occurring at the well(s) and/or in the aquifer due to the injection of P&T effluent that affect the system performance. Work accomplished to date includes characterization efforts for 200-ZP-1 sediments (as discussed in Sections 2 and 3) to establish a baseline that the future work can be compared against. These baseline characterization efforts and initial evaluations of the impacts include sediment characterization through physical, geochemical, and mineralogical assessments (Sections 2.2, 3.1, 3.3, and 3.4); and microbial assessment (Sections 2.3 and 3.2). Batch studies (Sections 2.5 and 3.5) were also conducted to provide initial information on the effects of P&T effluent on the aquifer conditions (including both pre water and sediments). Further assessments will be accomplished through a set of column studies.

- **Objective 4**. Develop a quantitative evaluation of the aquifer capacity for current and future conditions. This task will be accomplished by two modeling efforts. The first effort will focus on modeling the column studies to quantify the effects of significant geochemical and microbiological reactions with the 200-ZP-1 sediments at a small-scale. Later, this will be expanded into a larger-scale modeling domain (e.g., a single injection well radial model) to provide a numerical system representation of the aquifer conditions that can be used for assessing system performance/aquifer capacity for current conditions and/or in predictive evaluations of performance depending on P&T operational changes.

The remainder of this document describes the tasks accomplished to date. A discussion of future efforts is also provided in Section 4.

2.0 Approach

2.1 200-ZP-1 OU Sediment Samples

For the baseline and impact laboratory evaluations described in this report, sediments from three newly constructed injection wells in the 200-ZP-1 OU were analyzed. The sample inventory for this study is provided in Table 3 and the location of these samples within the 200-ZP-1 OU is shown in Figure 5. While two of the injection well locations are very close to each other on the eastern edge of the well network, the third well is located at the northern edge providing some variability in sediment characterization and impact evaluation.

Table 3. Samples included in this study and their geologic descriptions.

Well Location and Borehole ID	Sample ID	Depth Interval (ft bgs)	Geologic Unit	Geologic Description
299-W18-42 (C9563)	B398T1	77.85-78.35	Hanford	Sandy gravel
299-W18-42 (C9563)	B398T2	140-140.5	CCU	Silty clay
299-W18-42 (C9563)	B398T3	197.63-198.13	Ringold-Unit E	Sandy gravel
299-W18-42 (C9563)	B398T4	237.23-237.73	Ringold-Unit E	Sand
299-W18-42 (C9563)	B398T5	340.2-340.7	Ringold-Unit E	Mostly gravel
299-W18-42 (C9563)	B398T6	340.7-341.2	Ringold-Unit E	Sandy gravel
299-W18-42 (C9563)	B398T7	407.99-408.99	Ringold-Unit E	Sandy silt/gravel
299-W6-16 (C9561)	B398H3	78.0-80.59	Transition between CCU and Ringold-Unit E	Silty sand
299-W6-16 (C9561)	B398H4	132.6-138.1	Ringold-Unit E	Gravel
299-W6-16 (C9561)	B398H5	197.22-197.72	Ringold-Unit E	Sandy gravel
299-W6-16 (C9561)	B398H6	235.6-236.6	Ringold-Unit E	Muddy gravel
299-W6-16 (C9561)	B398H7	335.15-336.65	Ringold-Unit E	Sandy gravel
299-W6-16 (C9561)	B398H8	336.15-336.65	Ringold-Unit E	Sandy gravel
299-W6-16 (C9561)	B398H9	405.78-406.28	Ringold-Unit A	Sandy gravel
299-W18-44 (C9565)	B39927	78.79-80.79	Hanford	Fine sand
299-W18-44 (C9565)	B39928	138.6-139.1	Transition between Hanford and CCU	Sandy gravel
299-W18-44 (C9565)	B39929	198.02-198.52	Ringold-Unit E	Sandy gravel
299-W18-44 (C9565)	B39930	237.66-238.16	Ringold-Unit E	Sandy gravel
299-W18-44 (C9565)	B39931	338.13-338.63	Ringold-Unit E	Sandy gravel
299-W18-44 (C9565)	B39932	405.5-406	Ringold-Unit E	Sand
299-W18-44 (C9565)	B39933	406-406.5	Ringold-Unit E	Sand

CCU is Cold Creek Unit.

Static water level at 299-W6-16 (C9561) is about 252.8 ft bgs, at 299-W18-42 (C9563) is at 213.1 ft bgs, and at 299-W18-44 (C9565) is at 215.01 ft bgs.

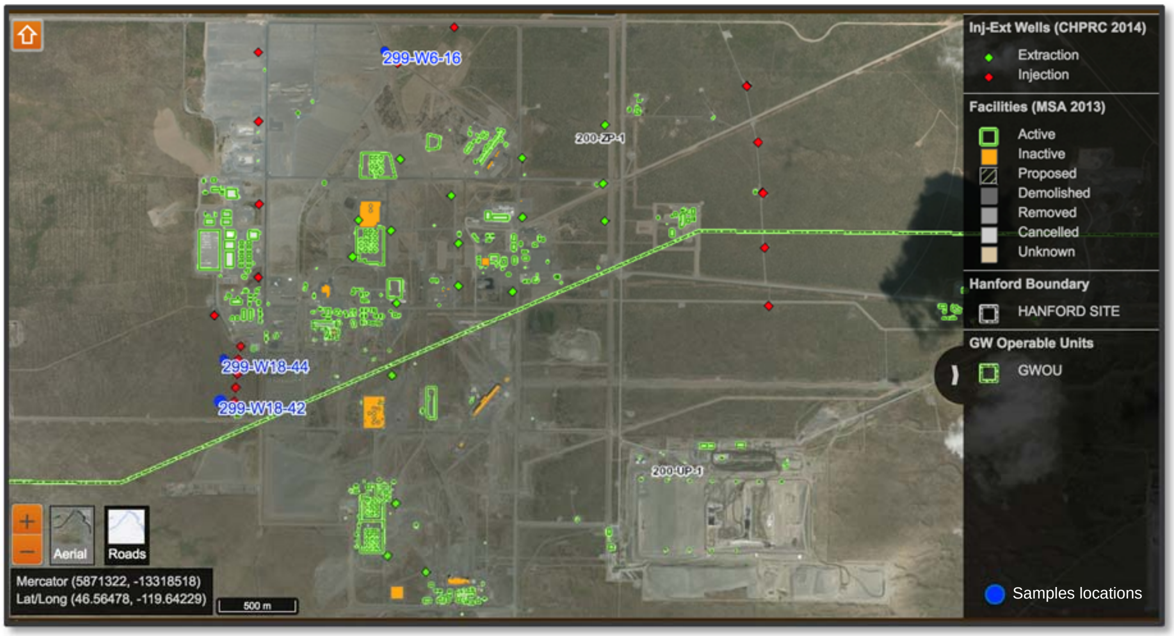


Figure 5. Location of the 200-ZP-1 samples used in the study as shown in the PNNL-Hanford Online Environmental Information Exchange (PHOENIX) application.

2.2 Sediment Characterization

The 20 sediment samples from 200-ZP-1 were received in 6 inch lexan core liners. The cores were weighed as received, opened, then emptied into Tupperware containers for photography and geologic description. The empty core liner was then weighed again to establish the amount of sediment received from each liner. While the dates the cores were opened and processed were recorded, several cores had already been previously sampled and the date and initial weight of the cores is unknown. After the cores were opened, a small amount (~50g) of each sediment was placed in a 60 mL PTFE bottle and stored at 4 ºC. The remaining sediment was sampled for moisture content determination. The sediment was then allowed to dry in the fume hood, then sieved to separate the <2mm size fraction. The <2mm size fraction was used in all of the work described in this report, unless otherwise indicated.

2.2.1 Physical Characterization

Physical characterization of 200-ZP-1 sediments were needed for providing a baseline understanding of lithology of the samples, their moisture contents, and particle size distribution. The methods used for this characterization are listed in Table 4. Borehole logs and the particle size distribution data are given in Appendix A.

Moisture content was determined by measuring the wet mass of sediment added to a container, then recording the mass again after drying in an oven at 105 ºC for more than 24 hours. The sediments were returned to the oven at 105 ºC for another 24 hours and then weighed again. The difference in weights between the first and second measurements did not change significantly, so the first dry weight was used to determine the % moisture in the samples. Moisture content was determined for the bulk, as-received samples as well as for the air dried <2mm sediments.

Table 4. Physical sediment analysis methods.

Required Data	Method Basis
Moisture content	ASTM D2216-10
Lithology, texture, petrologic composition (sand, gravel, basalt, quartz) and photos	Geologist inspection of borehole samples
Particle size by laser diffraction (< 2mm)	Operated according to the manual (Horiba Laser Particle Size Analyzer)

After the sediment samples were removed from the 6 inch lexan liners, they were emptied into Tupperware for photography and geologic descriptions. The Folk-Wentworth sediment classification scheme was used for the visual description of the samples. Visual observations of the samples include notes on grain-size, shape, color, moisture, consistency, compaction (if present), and reaction to hydrochloric acid (HCl) which are recorded on a Borehole Sample Log (Appendix A). A summary of the lithologic descriptions is included in Table 3.

Particle size distribution was determined using a Horiba laser particle size analyzer. The 20 sediments were analyzed by placing small amounts of air dried sediment into the particle size analyzer. The particle size analyzer measures the particle size three times per sediment, and then the three readings are averaged. Four of the sediments (B398H3, B398H4, B398T5, and B398T6) had a significant amount of large particles (> 63 µm), so for these sediments, the > 63 µm portion was removed by sieving prior to the laser analysis. The sand fraction was calculated for these sediments and the final particle size distribution percentages include this sand portion.

2.2.2 Chemical Characterization

Different extractions were used for evaluating contaminant distribution and geochemical constituents to characterize specific fractions of ions and contaminants from the pore water and sediments (adsorbed or as precipitates). All methods used for contaminant concentrations and geochemical conditions of the 200-ZP-1 sediments are listed in Table 5. The method basis is listed for each characterization technique and described here briefly. The characterization described in this section was all conducted on only the <2mm fraction of the sediments.

Water extractions were conducted on all 20 sediment samples at a 1:1 solid to solution ratio. Approximately 80-100 g of each sediment was added to a high-density polyethylene HDPE bottle. Then, taking moisture content of the sediment into consideration, double de-ionized (DDI) water was added to reach a 1:1 water to dry sediment ratio. The bottles were then placed on a shaker for 50 minutes of gentle mixing. After 50 minutes, the bottles were removed from the shaker and allowed to settle for 10 minutes prior to filtration using a 0.45 µm vacuum filter (Milipore). A duplicate, a blank containing only DDI water, and blank spikes containing analytes of interest were included in the water extraction batch. Water extraction solutions were analyzed for metals, Tc/U, iodine, and anions by ICP-OES, ICP-MS, and IC. The pH was measured on the solutions and specific conductivity was measured on select samples (not all extractions had enough solution volume to measure conductivity).

Acid extractions were conducted on all 20 sediments at a 1:3 sediment to acid ratio. For these extractions, 10 g of sediment was added to a centrifuge tube, and then 30 mL of 8M nitric acid was added to each tube. The tubes were covered with Teflon watch glasses and heated to 90-95°C for 3 hours using a heat block. After 3 hours, the tubes were removed from the heat block and allowed to cool, then filtered using a 0.45 µm vacuum filter (Milipore). A duplicate, a blank containing only 8M nitric acid, and blank spikes containing analytes of interest were included in the water extraction batch. Acid extraction solutions were analyzed for metals and Tc/U via ICP-OES and ICP-MS (respectively).

Table 5. Methods for contaminant and geochemical analysis.

Characterization Method	Method Basis
Water extraction (1:1 sediment:H_2O)	PNNL-ESL-WE (based on Rhoades 1996)
Acid extraction (1:3 sediment: 8M HNO_3)	PNNL-ESL-AE (based on ASTM D5198)
Sequential extraction	Gleyzes et al. 2002; Beckett 1989; Larner et al. 2006; Sutherland and Tack 2002; Massop and Davison 2003
Alkaline digestion for Cr(VI)	EPA 3060a
Total carbon (TC) and total inorganic carbon (TIC)	PNNL-ESL-TC
Metals by ICP-OES and/or ICP-MS (Al, Ba, Ca, Fe, K, Mg, Mn, Na, Si, Sr, Cr)	EPA 6010D
U, Tc-99 by ICP-MS	EPA 6020B
Anions by ion chromatography (Cl^-, F^-, Br^-, NO_3^-, NO_2^-, PO_4^{3-}, SO_4^{2-})	EPA 9056A
pH by electrode	EPA 9040C
Specific conductance (SpC) by electrode	EPA 9050A
Total iodine by ICP-MS	PNNL-ESL-ICPMS Rev4

Sequential extractions were conducted on all 20 sediment samples using six extraction solutions. These sequential extractions are conducted at a 1:2 sediment to liquid ratio. For these extractions, 3 g of sediment was added to a centrifuge tube, then 6 mL of the first extractant was added. After 50 minutes of gentle mixing on a shaker, the centrifuge tubes were centrifuged at 3000 rpm for 10 minutes, then the solution was decanted and 6 mL of the next extractant was added. Some extractants were mixed for more than 50 minutes; see Table 6 for more details. Between each extractant addition, the centrifuge tubes were weighed to determine the amount of remaining solution for µg/g conversions of the ICP data. One preparation blank and several blank spikes (to include analytes of interest) were prepared for each extraction solution. One duplicate was taken through the entire sequential extraction process. Sequential extraction solutions were analyzed for metals, Tc/U and iodine (on all extractions except the 8M HNO_3) by ICP-OES and ICP-MS.

Alkaline digestions were conducted on all 20 sediments to determine the Cr(VI) content of each sediment. The alkaline digestion method (EPA 3060a) was specifically designed to minimize the reduction of native Cr(VI) to Cr(III) and also to minimize dissolution of Cr(III) surface phases. Water-insoluble and water-soluble forms of Cr(VI) should be solubilized with this method, although the method specifies that barium carbonates that may contain Cr(VI) are only partially solubilized with this method (EPA 3060A). For this digestion, 2.0 g of sediment was added to a glass beaker and then 40 mL of digestion solution (0.28 mol/L Na_2CO_3 + 0.5 M NaOH) was added to each beaker. Approximately 0.32 g of $MgCl_2$ and 0.4 mL of phosphate buffer (87.09 g of K_2HPO_4 + 68.04 g of KH_2PO_4 in 1L of DDI water) was added to the beakers. The beakers were then covered with watch glasses and heated to 95ºC while being stirred via stir bars for 60 minutes. After allowing the beakers to cool and recording the final weight, the solution was filtered (0.45 µm vacuum filter, Milipore). The solutions were analyzed for Cr(VI) by ICP-MS.

Table 6. Sequential liquid extractions conducted for the 200-ZP-1 sediments.

Sequential extraction solutions	Solution chemistry (for 1L of solution in DDI water)	Target fractions	Extraction time/other details
Hanford Artificial Groundwater (AGW)	See Table X	Aqueous contaminants	50 minutes of mixing followed by 10 minutes of centrifugation
0.5M $Mg(NO_3)_2$	128.2 g $Mg(NO_3)_2$•$6H_2O$ + 30 µL 2 mol/L NaOH to reach pH 8.0	Adsorbed contaminants	50 minutes of mixing followed by 10 minutes of centrifugation
Acetate solution	68.05 g sodium acetate•$3H_2O$ + 15 mL glacial acetic acid (17.4 mol/L); pH = 5	Rind-carbonates	50 minutes of mixing followed by 10 minutes of centrifugation
Acetic acid solution	25.33 mL concentrated glacial acetic acid (17.4 mol/L) and 23.6 g $Ca(NO_3)_2$*$4H_2O$; pH = 2.3	Total carbonates	Mixed for 5 days followed by 10 minutes of centrifugation
Oxalate solution	9.03 g anhydrous oxalic acid and 14.2 g ammonium oxalate*H_2O	Fe-oxide	50 minutes of mixing followed by 10 minutes of centrifugation
8M HNO_3	Concentrated (~70%) nitric acid mixed with DDI water at a 1:1 ratio	Hard-to-extract	2 hours of mixing at 95ºC

Table 7. Hanford Artificial Groundwater (AGW) (Truex et al. 2017).

Constituent	Conc. (mg/L)	Mass for 1 L (g)
H_2SiO_3*nH_2O, silicic acid	15.3	0.0153
KCl, potassium chloride	8.20	0.0082
$MgCO_3$, magnesium carbonate	13.0	0.0130
NaCl, sodium chloride	15.0	0.0150
$CaSO_4$, calcium sulfate	67.0	0.0670
$CaCO_3$, calcium carbonate	150	0.1500

After adding the chemicals listed in above, an excess of CaCO3 is added. The solution needs to be stirred for approximately 1 week, and then filtered with a 0.45 µm filter to remove the remaining excess CaCO3.

2.2.3 Mineral Composition

The quantitative mineral composition of select 200-ZP-1 sediments was analyzed using X-ray diffraction (XRD) method (Table 8). QXRD was conducted on the five sediments chosen for the batch experiments (see Section 2.5). These sediments were ground and then delivered to EMSL, where QXRD analysis was conducted.

In addition, the five sediments (listed in Table 10) underwent clay separation. A modified decantation method developed by the U.S. Geological Survey (Poppe et al. 2001) was used, as described here. Approximately 100 grams of each sediment was placed into a 250 mL high-density polyethylene bottle (Fisher Scientific, USA), where 4 grams of sodium metaphosphate (Fisher Scientific, Laboratory Grade) was added and filled with DDI water. The bottles were sealed, placed on a shaker at 120 RPM for 4 h, and then transferred to a 1 L graduated cylinder. DDI water was then added to the graduated cylinder to just below 1 L. A rubber stopper was then secured on top and the mixture was inverted for 30 seconds. Any sediment remaining on the stopper and sides were rinsed back into the cylinder, filled to 1 L, and settling start time was recorded. The amount of settling time was based on Poppe et al. (2001), where for every 4 h the silt has settled 5 cm. Therefore, after 24 h, 30 cm of clay suspension remained and could be withdrawn using a modified J-tube from polypropylene tubing that was taped at the end in the shape of a “J”. The J-tube was connected to a rubber stopper that was placed on a 1 L Erlenmeyer flask, which was also connected to vacuum. Once the clay suspension was removed, the graduated cylinder was re-filled to just under 1 L, inverted, remaining sediment rinsed, and filled to 1 L as before. This was done multiple times until the clay suspension was clear. All clay suspensions were stored in 2 L bottles or 2 L buckets until time for separation. This procedure was done for each sediment; however, B398T2 clay did not settle completely and, therefore, all the clay was never fully removed.

Clay suspensions in 2 L bottles were mixed with ~ 30 g of magnesium chloride ($MgCl_2$; Fisher Scientific, A.C.S. Grade) and ~ 10 g in the buckets and left to settle until the clay settled to the bottom and the solution became clear. Once the clay suspension settled out, the solution was removed using the J-tube apparatus. Any remaining solution un-retrievable with the J-tube apparatus was decanted away using a 10 mL pipette. Additional $MgCl_2$ was added (2 mL of 1 M $MgCl_2$) until enough of the solution was removed so only clay and little water remained. Remaining clay was then transferred into 50 mL centrifuge tubes (Corning Incorporated) using a scoopula and centrifuged at 3000 RPM to further separate out clay and water. Solutions were decanted into waste containers and clay was stored wet at 4 °C.

Additional post-experiment samples were selected for QXRD after the 60 day batch experiment to determine any changes in mineralogy. Selected samples solids of one sediment from each of the treatment variables B398H9, B398T2, and B39927 post-experiment samples from the 23C and 50C tests with all three solutions were prepared for QXRD, for a total of 18 post-experiment samples. These sediments were chosen to represent a range of geologic units, depths, and boreholes (see Table 3). Only the clean sediment analyses are reported here. The analyses of the post-sediment samples are currently ongoing and will be reported at a later date.

Table 8. Method used for XRD analysis.

Required Data	Method Basis
Mineralogy by X-ray diffraction (XRD)	RGD106-SamplePrep Rev. 0

2.3 Sediment Microbiological Characterization

For microbial characterization of 200-ZP-1 sediments, bacterial enumeration technique by QPCR was used for the samples identified in Table 9. The majority of these samples were from the selected three newly constructed injection wells.

Genomic DNA (0.25 g) was extracted (n = 6/interval) from these selected Hanford sediments using the DNeasy PowerLyzer PowerSoil® DNA Isolation Kit (Qiagen; utilizes a combination of mechanical and chemical lysis) per the manufacturer's instructions. DNA extracts were pooled and concentrated by ethanol precipitation in high salt with GlycoBlue™ Coprecipitant (50 µg/mL; Ambion). DNA yields were quantified using the NanoDrop 1000 spectrophotometer (Thermo Scientific). QPCR assays were performed in triplicate on a Bio-Rad CFX96 Real-Time PCR Detection System using the SsoAdvanced™ Universal SYBR® Green Supermix (Bio-Rad) as instructed by the manufacturer and universal 16S rRNA primers F-316 and R-484. Amplification specificity was assessed by melt curve analysis. Cell equivalents were calculated from calibration curves using pure genomic DNA from *Desulfovibrio vulgaris* (DSM-644) and *Geobacter metallireducens* (DSM-7210) as described by He et al. (2003).

Table 9. Samples selected for microbial characterization.

Well Location	OU	Sample ID	~Depth (ft)
299-W18-42 (C9563)	200-ZP-1	B398T1	78
299-W18-42 (C9563)	200-ZP-1	B398T2	140
299-W18-42 (C9563)	200-ZP-1	B398T3	198
299-W18-42 (C9563)	200-ZP-1	B398T4	237
299-W18-42 (C9563)	200-ZP-1	B398T5	340
299-W18-42 (C9563)	200-ZP-1	B398T6	340
299-W18-42 (C9563)	200-ZP-1	B398T7	408
299-W6-16 (C9561)	200-ZP-1	B398H3	79
299-W6-16 (C9561)	200-ZP-1	B398H4	132
299-W6-16 (C9561)	200-ZP-1	B398H5	197
299-W6-16 (C9561)	200-ZP-1	B398H6	236
299-W6-16 (C9561)	200-ZP-1	B398H8	336
299-W6-16 (C9561)	200-ZP-1	B398H9	405
299-W18-44 (C9565)	200-ZP-1	B39927	79
299-W18-44 (C9565)	200-ZP-1	B39928	139
299-W18-44 (C9565)	200-ZP-1	B39929	198
299-W18-44 (C9565)	200-ZP-1	B39930	238
299-W18-44 (C9565)	200-ZP-1	B39931	338
299-W18-44 (C9565)	200-ZP-1	B39933	406

2.4 Pump and Treat Effluent Characterization

Effluent samples from the two transfer buildings (ITB1 and ITB2, Figure 1b) within the P&T system were collected and analyzed to determine element concentrations. These transfer buildings receive effluent from the treatment facility and distribute it to the certain injection wells within the well network. The characterization of these effluents were conducted as part of the batch experiments as described in Section 2.4. In these batch experiments, the effluent solutions were put in contact with the 200-ZP-1 sediments and blank samples with no sediments were also analyzed. The ITB solutions were analyzed via ICP-OES and ICP-MS for metals, ICP-MS for Tc, U, and I, IC for anions, and carbon analyzer for TC and TOC to determine the initial concentration of these elements in the solutions. The blank samples then provided the characterization information for ITB1 and ITB2 effluents along with the information for artificial ground water (AGW) also used during the course of the experiments.

In addition to laboratory evaluations, geochemical modeling of these effluents from ITB1 and ITB2 and also the AGW was conducted. Batch supernatants collected at 4h and 1day for the blank samples were computed using The Geochemist's Workbench®, GWB version 12.0.1 (Bethke et al. 2015). The Minteq thermodynamic database built within GWB was selected for all calculations. Geochemical modeling were performed at two temperatures, 23 °C and 50 °C. Analytical data was used in every simulation for calculating saturation indexes, i.e. log Q/K and for predicting aqueous ion speciation. In addition, since analytical data for CO_3 in AGW was not available, we performed several simulations where CO_3 was used as the counteranion for charge balance. This calculations allowed for evaluation of pCO_2 and saturation with carbonate solids. Experimental pH measured at 23 °C was used for calculation of AWG, ITB1, and ITB2 background solutions. The geochemical modeling of batch supernatants collected at 4 h and 24 h indicated some charge imbalance, varying from 3-18%.

2.5 Batch Experiments

Batch experiments were conducted to provide information on significant geochemical and microbiological processes that are occurring in the aquifer around the wells with the injection of P&T effluent. The results from these experiments will inform the design of the column studies that will be conducted next.

Sediments used for these experiments are from the 200-ZP-1 OU as described in Section 2.1. The samples for these experiments were selected based on their locations, depth, and the geologic units they represent. In addition, the < 2 mm material available for each sample had to be sufficient for characterization, batch experiments, and future column experiments. In addition, B398T4 was included for microbial testing. This sediment was not processed or characterized as the other five sediments were, and was not sampled at all time points due to the limited sample availability. Table 10 lists the samples selected for these experiments.

Table 10. Samples selected for the batch experiments.

Borehole Number	Sample Location	Sample ID (HEIS)	Depth (ft bgs)	Geologic Unit	Lithologic Description
C9561	299-W6-116	B398H3	78.09	Transition between CCU & Ringold unit E	Slightly muddy sand
C9561	299-W6-116	B398H9	405.78	Ringold- Unit A	Sandy gravel
C9563	299-W18-42	B398T2	140	CCU	Sandy mud
C9565	299-W18-44	B39927	78.79	Hanford Formation	Sand
C9565	299-W18-44	B39933	405.5	Ringold- Unit E	Sand
C9563	299-W18-42	B398T4	237	Ringold- Unit E	Sand

The experimental matrix for the batch experiments is given in Table 11. Three solutions (effluents from ITB1 and ITB2, and the AGW) were used with the five sediments samples from the 200-ZP-1 OU representing the four different geological units. Hanford AGW was used for the experiments as a control as the AGW groundwater should be chemically similar to the pre-treatment groundwater and provide a baseline for the geochemical and microbiological behavior in the sediments. To simulate the variable temperature found at the P&T facility, the batch experiments were conducted at room temperature and 50°C, with an additional, shortened test at 90°C to determine maximum leachability controlled by temperature. One sediment (B398T4) was used for microbial testing; this sediment had not been air dried or sieved prior to the batch experiments, and was not included in the initial characterization phase.

Table 11. Batch experiment matrix.

<table>
<tr><td colspan="6">200-ZP-1 Sediments</td></tr>
<tr><td colspan="2">Ringold-Unit E and A</td><td colspan="2">Cold Creek Unit (CCU)</td><td colspan="2">Hanford Unit</td></tr>
<tr><td colspan="6">Solutions</td></tr>
<tr><td colspan="2">ITB1</td><td colspan="2">ITB2</td><td colspan="2">Hanford AGW</td></tr>
<tr><td colspan="6">Microbial Activity</td></tr>
<tr><td colspan="3">Sterilized sediments (No microbial activity)</td><td colspan="3">Non-Sterilized sediments (Microbial activity)</td></tr>
<tr><td colspan="6">Temperature</td></tr>
<tr><td colspan="3">Ambient (23°C)</td><td colspan="3">50 °C (limited tests with 90°C)</td></tr>
</table>

The batch experiments were conducted at a 1:20 solid to solution ratio in duplicate. Sampling was done at 4 hours, 1, 3, 7 14, 21, 28, 42 and 60 days. During sampling, 2 mL was removed from each sample and filtered (except for the microbial sample) with a 0.22 µm PVDF syringe filter. Samples were then mixed by hand and returned to the oven, when applicable, until the next sampling. When solutions in the 50°C tests were noticeably low, solution was added back to return to the 1:20 ratio. The microbial set of experiments (using sediment B398T4 at 23°C) was sampled at 4 hours and 1, 3, 7, 14, and 60 days. These samples were not filtered and were stored at 4C for microbial analysis. This set was also sampled at 42 days, but the subsamples were filtered for ICP analysis instead of microbial analysis. Microbial analysis of these samples is currently ongoing and the results will be reported at a later date.

Table 12 below summarizes all the constituent and parameters measured during the batch experiments. Note that the microbiological assessments are not yet complete and will be reported at a later date.

Table 12. Measured constituents during the batch experiments.

Instrument	Analytes	Sampling Points analyzed (days)
ICP-OES	Al, Ba, Ca, Cr, Fe, Mg, Mn, K, Si, Na, Sr, S,	0.17, 1, 7, 14, 28, 42, 60
ICP-MS	Ba, Cr	0.17, 42, 60
	Tc, U	0.17, 7, 14, 28, 42, 60
	I	0.17, 14, 42, 60
pH (meter)	pH	0.17, 1, 3, 7, 14, 21, 28, 42, 60

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3.0 Results

3.1 200-ZP-1 OU Physical and Geochemical Baseline

The moisture content measured on both the bulk (as-received) sample and the < 2 mm sieved portion is shown in Table 13. Moisture content for the bulk samples varied from 8.43% to 15.8 % among the boreholes. Each borehole generally exhibited higher increasing moisture content with depth (in Ringold Unit sediments), except the borehole 299-W18-42 (C9563), where the highest moisture content (18.9%) was observed in the Cold Creek Unit. The moisture content of the <2mm fractions was used for all conversions to dry weights for the extractions (including water, acid, and sequential extractions). This information will support the geochemical and microbiological baseline analyses.

Table 13. Moisture content on the bulk, as-received sample ("Bulk") and the processed (sieved and air dried) < 2mm fraction ("< 2mm") for the 20 ZP-1 sediments.

Borehole Location and Sample ID	Moisture Content (% Moisture)		Depth Interval (ft bgs)	Geologic Unit
	Bulk	<2mm		
299-W6-16 (C9561) B398H3	5.89	2.70	78.0-80.59	Transition between CCU and Ringold-Unit E
299-W6-16 (C9561) B398H4	3.95	0.19	132.6-138.1	Ringold-Unit E
299-W6-16 (C9561) B398H5	7.62	4.82	197.22-197.72	Ringold-Unit E
299-W6-16 (C9561) B398H6	5.90	3.59	235.6-236.6	Ringold-Unit E
299-W6-16 (C9561) B398H7	5.75	5.78	335.15-336.65	Ringold-Unit E
299-W6-16 (C9561) B398H8	13.0	3.97	336.15-336.65	Ringold-Unit E
299-W6-16 (C9561) B398H9	16.9	11.1	405.78-406.28	Ringold-Unit A
299-W18-42 (C9563) B398T1	5.80	2.80	77.85-78.35	Hanford
299-W18-42 (C9563) B398T2	18.9	13.2	140-140.5	CCU
299-W18-42 (C9563) B398T3	11.6	4.81	197.63-198.13	Ringold-Unit E
299-W18-42 (C9563) B398T5	17.6	2.22	340.2-340.7	Ringold-Unit E
299-W18-42 (C9563) B398T6	4.82	5.71	340.7-341.2	Ringold-Unit E
299-W18-42 (C9563) B398T7	11.1	13.3	407.99-408.99	Ringold-Unit E
299-W18-44 (C9565) B39927	5.24	3.16	78.79-80.79	Hanford
299-W18-44 (C9565) B39928	8.54	5.63	138.6-139.1	Transition between Hanford and CCU
299-W18-44 (C9565) B39929	9.43	0.37	198.02-198.52	Ringold-Unit E
299-W18-44 (C9565) B39930	9.53	5.17	237.66-238.16	Ringold-Unit E
299-W18-44 (C9565) B39931	17.7	6.18	338.13-338.63	Ringold-Unit E
299-W18-44 (C9565) B39932	27.9	4.30	405.5-406	Ringold-Unit E
299-W18-44 (C9565) B39933	32.5	6.27	406-406.5	Ringold-Unit E

Different extractions were used for evaluating geochemical constituents to characterize specific fractions of ions from the pore water and sediments (adsorbed on surfaces or as precipitates). The water extraction was used to evaluate pore water geochemistry (i.e., pH, specific conductance), including COCs (as discussed in Section 3.4) and cations and anions present in pore water. Water extraction results indicate the aqueous and easily mobile constituents in the sediments. These results are presented in Table 14. Water extraction results were similar across most sediments, but each analyte had outliers. For example, Si and Na ranged from 2.3-6.4 µg/g and

1.0-6.3 µg/g in most sediments, respectively, but B398T2 was high in both elements (12.2 µg/g Si and 13.2 µg/g Na), while sediment B398T5 had a low Si content of 0.8 µg/g. The major aqueous constituents detected for these sediments include Ba, Al, Ca, Fe, Mg, K, Si, and Na.

Acid extractions provide a maximum extractable concentration from the sediments; the results of these extractions are given in Table 15 and Table 16. In the field, it is unlikely that sediments will encounter environments as harsh as provided in the acid extractions (using 8M nitric acid, heated to 95C for 2 hours). Relative to the water extraction results, several elements that were high in individual sediments in the water extractions, were not high in the acid extractions. For example, Fe was the highest in sediment B39930 in the water extractions, but only slightly higher than many of the other sediments (with 0.48 µg/g in B39930 compared to 0.2-0.4 in most of the other sediments). In the acid extractions, however, B398T2 was significantly higher in Fe compared to the other sediments, with 8810 µg/g Fe while most of the other sediments ranged from 3200-8000 µg/g Fe. This indicates that the Fe in sediment B398T2 was in a form that was more difficult to dissolve compared to the Fe available in B39930.

Both water- and acid-extractable elements and their concentrations observed for ZP-1 sediments are consistent with baseline characterization results conducted previously (for 200-UP-1 sediments) with only minor differences (Brady et al. 2017). For example, Ba, Fe, and Al concentrations were below detection limits in the 200-UP-1 sediments for water extractions while the results observed in this study indicate some presence of these elements in pore water in the aquifer. Also, some samples analyzed during this study showed much higher concentrations of Ca in acid extractions than the results observed from other samples and from the samples analyzed for 200-UP-1 OU. For example, sample B398H6 and B398H3 both showed Ca concentrations of 41,100 µg/g and 13,600 µg/g, respectively, whereas the highest concentration observed for UP-1 sediments was 10,400 µg/g. Overall, acid-extractable Al and Mn concentrations observed for ZP-1 sediments are slightly lower than those for UP-1 sediments, and Fe, Ba, Si, and Sr concentrations show similar ranges.

Table 17 summarizes the carbon content of the sediments. This data supported the microbiological evaluation described in the next section. Overall, the system has very low carbon content but this was not reflected in bacterial cell numbers – which were consistently high for a deep terrestrial system as discussed in Section 3.2.

Table 14. Water extraction results for the geochemical constituents, reported in µg/g dry or µg/kg dry.

Borehole Location and Sample ID (all <2mm)	NO_3 µg/g	Br µg/g	Cl µg/g	F µg/g	NO_2 µg/g	PO_4 µg/g	SO_4 µg/g	Ba µg/g	Al µg/g	Ca µg/g	Fe µg/g	Mg µg/g	K µg/g	Si µg/g	Na µg/g	Sr µg/g	S µg/g	pH pH units	EC ms/cm
299-W6-16 (C9561) B398H3	ND	ND	ND	ND	ND	ND	ND	4.62	0.07	4.69	0.08	1.32	0.58	2.43	1.03	0.03	1.23	8.22	0.09
299-W6-16 (C9561) B398H4	ND	ND	ND	ND	ND	ND	ND	4.31	0.11	4.84	0.09	1.27	1.52	2.30	2.45	0.04	1.98	7.65	0.11
299-W6-16 (C9561) B398H5	ND	ND	ND	ND	ND	ND	ND	5.33	0.16	4.77	0.39	1.59	1.35	4.46	3.22	0.03	1.75	7.43	-
299-W6-16 (C9561) B398H6	ND	ND	ND	ND	ND	ND	ND	4.77	0.13	6.32	0.21	2.43	2.09	4.40	5.52	0.03	1.37	7.64	-
299-W6-16 (C9561) B398H7	ND	ND	ND	ND	ND	ND	ND	4.88	0.18	4.55	0.44	1.50	1.64	5.36	3.41	ND	1.09	7.68	-
299-W6-16 (C9561) B398H8	ND	ND	ND	ND	ND	ND	ND	4.20	0.14	3.69	0.40	1.25	1.52	4.93	3.24	ND	0.99	7.35	-
299-W6-16 (C9561) B398H9	ND	ND	3.53	ND	ND	ND	ND	1.40	0.11	0.88	0.42	0.39	1.08	5.46	3.00	ND	1.02	6.88	-
299-W18-42 (C9563) B398T1	ND	ND	ND	ND	ND	ND	ND	4.62	0.28	4.15	0.37	1.06	2.16	3.43	6.31	ND	1.87	7.96	0.12
299-W18-42 (C9563) B398T2	29.2	ND	4.06	ND	ND	ND	8.37	9.50	0.28	9.77	0.28	2.96	2.66	12.2	13.2	0.05	3.27	7.59	-
299-W18-42 (C9563) B398T3	ND	ND	ND	ND	ND	ND	ND	3.26	0.17	1.33	0.47	0.49	1.19	5.16	3.51	ND	1.57	7.12	-
299-W18-42 (C9563) B398T5	ND	ND	ND	ND	ND	ND	ND	2.84	ND	1.20	0.05	0.43	0.88	0.84	2.09	ND	ND	6.98	0.05
299-W18-42 (C9563) B398T6	ND	ND	3.31	ND	ND	ND	ND	4.36	0.18	2.00	0.39	0.78	1.21	2.72	2.67	ND	1.62	6.90	0.08
299-W18-42 (C9563) B398T7	ND	ND	4.12	ND	ND	ND	ND	2.48	0.13	1.14	0.36	0.43	1.21	3.88	2.56	ND	1.14	6.71	-
299-W18-44 (C9565) B39927	ND	ND	ND	ND	ND	ND	ND	7.03	0.21	4.89	0.24	0.98	1.82	3.85	5.39	ND	1.1	7.77	-
299-W18-44 (C9565) B39928	ND	ND	ND	ND	ND	ND	ND	6.71	0.12	5.95	0.10	1.73	1.66	6.42	4.78	0.03	ND	8.04	0.14
299-W18-44 (C9565) B39929	ND	ND	ND	ND	ND	ND	ND	4.41	0.19	0.93	0.24	0.29	1.68	3.26	5.15	ND	0.974	7.47	0.08
299-W18-44 (C9565) B39930	ND	ND	6.59	ND	ND	ND	9.59	6.83	0.17	2.66	0.48	0.89	1.59	4.57	5.05	ND	3.64	6.45	-
299-W18-44 (C9565) B39931	ND	ND	4.52	ND	ND	ND	ND	5.77	0.14	2.63	0.30	0.96	1.55	5.79	3.42	ND	2.1	6.89	-
299-W18-44 (C9565) B39932	ND	ND	3.97	ND	ND	ND	ND	3.21	0.09	2.79	0.24	0.99	1.49	2.51	3.30	ND	1.99	6.92	-
299-W18-44 (C9565) B39933	ND	ND	4.59	ND	ND	ND	ND	3.96	0.10	2.72	0.30	0.98	1.45	3.16	3.58	ND	2.36	6.87	-
Detection Limits	5.0-5.1	5.0-5.1	2.5	1.0	5.0-5.1	7.5-7.6	7.5-7.6	<0.01	0.03	0.15	0.035	0.016	0.43	0.15	0.27	0.027	0.71	NA	

Table 15. Acid extraction results for the geochemical constituents, reported in µg/g dry or µg/kg dry.

Borehole Location and Sample ID (all <2mm)	As µg/g	Cd µg/g	Cs µg/g	Pb µg/g	Mo µg/g	Ag µg/g	Al µg/g	Ba µg/g	Ca µg/g	Cu µg/g	Fe µg/g	Mg µg/g
299-W6-16 (C9561) B398H3	0.89	0.07	0.56	2.00	0.14	0.03	3090	38.1	13600	7.49	6320	2850
299-W6-16 (C9561) B398H4	0.56	0.03	0.14	1.02	0.70	0.03	1990	28.2	2120	6.37	5630	1430
299-W6-16 (C9561) B398H5	0.52	ND	0.37	1.37	0.38	0.02	2700	30.9	5490	6.51	7960	2010
299-W6-16 (C9561) B398H6	0.49	0.06	0.30	1.21	0.96	0.02	3010	99.3	41100	7.57	5920	1900
299-W6-16 (C9561) B398H7	0.17	0.03	0.26	1.51	0.08	0.02	2430	25.6	6060	3.47	6740	1600
299-W6-16 (C9561) B398H8	0.15	ND	0.26	1.46	0.06	0.02	1800	15.5	3690	2.35	5520	1280
299-W6-16 (C9561) B398H9	0.33	ND	0.46	1.09	0.03	ND	2730	15.9	2310	3.92	8150	2130
299-W18-42 (C9563) B398T1	1.42	0.04	0.78	2.43	0.46	0.03	3150	42.5	6440	14.1	6810	2480
299-W18-42 (C9563) B398T2	0.92	0.05	0.67	3.31	0.06	0.05	6510	67.00	5760	11.1	8810	3380
299-W18-42 (C9563) B398T3	0.17	0.02	0.32	1.24	0.58	0.02	2890	29.6	2310	5.41	7710	1780
299-W18-42 (C9563) B398T5	0.28	0.04	0.33	2.81	2.09	0.02	2440	28.2	1490	43.5	6190	1450
299-W18-42 (C9563) B398T6	0.26	0.03	0.29	1.00	1.51	0.02	2160	28.00	1640	10.7	5550	1290
299-W18-42 (C9563) B398T7	0.60	0.05	0.63	2.95	0.60	0.02	2800	36.1	1900	10.2	5570	2040
299-W18-44 (C9565) B39927	1.44	0.04	0.97	2.29	0.07	0.02	2970	42.3	6350	4.47	5450	2360
299-W18-44 (C9565) B39928	0.66	0.03	0.30	1.65	0.03	0.03	4120	57.4	4270	4.91	6010	1670
299-W18-44 (C9565) B39929	0.26	ND	0.26	1.14	0.36	ND	1450	18.6	924	5.11	3200	1040
299-W18-44 (C9565) B39930	0.19	ND	0.36	1.34	0.09	0.01	1950	24.5	1860	4.37	4500	1490
299-W18-44 (C9565) B39931	0.26	ND	0.49	0.89	0.44	ND	2120	22.5	1670	3.94	4280	1500
299-W18-44 (C9565) B39932	0.27	ND	0.39	1.22	0.02	ND	1690	14.1	1060	2.33	3970	1380
299-W18-44 (C9565) B39933	0.32	ND	0.43	1.71	ND	ND	1870	17.2	1430	2.90	4310	1490

Table 16. Acid extraction results for the geochemical constituents, reported in µg/g dry or µg/kg dry (continued).

Borehole Location and Sample ID (all <2mm)	Mn µg/g	Ni µg/g	P µg/g	K µg/g	Si µg/g	Na µg/g	Sr µg/g	S µg/g	Sn µg/g	Ti µg/g	Zn µg/g	Zr µg/g
299-W6-16 (C9561) B398H3	149	6.68	387	641	ND	94.4	45.0	143	26.9	166	14.7	3.18
299-W6-16 (C9561) B398H4	86.6	4.19	342	312	ND	197	13.7	42.9	17.9	247	10.6	3.71
299-W6-16 (C9561) B398H5	198	5.41	325	452	ND	100	16.3	54.7	22.1	229	16.6	5.01
299-W6-16 (C9561) B398H6	750	4.42	264	360	41.1	207	20.0	352	19.8	22.3	8.12	3.20
299-W6-16 (C9561) B398H7	140	3.52	208	304	ND	67.5	9.93	55.0	19.0	219	10.8	6.00
299-W6-16 (C9561) B398H8	67.7	2.75	162	266	ND	49.0	7.82	33.7	16.9	192	8.87	5.27
299-W6-16 (C9561) B398H9	80.0	6.05	205	635	ND	39.9	10.5	21.2	24.3	42.7	10.2	1.70
299-W18-42 (C9563) B398T1	145	5.63	337	919	64.0	153	19.8	80.6	24.8	180	19.9	3.52
299-W18-42 (C9563) B398T2	215	7.72	415	1400	ND	212	25.3	70.2	31.4	88.4	18.4	8.56
299-W18-42 (C9563) B398T3	117	5.06	259	434	ND	99.5	10.4	23.3	21.5	148	13.6	3.87
299-W18-42 (C9563) B398T5	75.8	6.30	198	406	ND	114	7.47	ND	18.1	220	32.8	4.20
299-W18-42 (C9563) B398T6	66.2	4.74	214	372	ND	109	7.76	ND	16.5	243	16.2	4.41
299-W18-42 (C9563) B398T7	120	8.77	189	873	ND	43.8	11.2	ND	24.9	35.9	17.9	1.94
299-W18-44 (C9565) B39927	145	4.74	278	1050	ND	72.2	19.1	66.1	24.3	186	16.2	2.49
299-W18-44 (C9565) B39928	142	3.11	336	920	ND	165	19.5	45.7	20.0	106	11.4	9.05
299-W18-44 (C9565) B39929	70.1	3.79	167	380	ND	90.0	5.97	ND	14.5	139	10.4	2.00
299-W18-44 (C9565) B39930	83.1	4.94	212	343	30.4	50.1	8.81	20.2	19.0	115	10.5	3.24
299-W18-44 (C9565) B39931	92.4	3.70	137	550	ND	39.7	8.00	ND	19.8	103	12.1	3.08
299-W18-44 (C9565) B39932	47.6	3.47	151	475	ND	26.8	5.24	ND	18.8	101	11.6	1.62
299-W18-44 (C9565) B39933	52.3	3.62	223	527	ND	32.3	6.82	ND	19.5	110	13.5	1.99

Table 17. Carbon content for the sediments as-received (i.e., solid samples) and for the water extraction filtrates.

	Solid Samples			Water Extraction Samples	
Borehole Location and Sample ID (< 2mm)	Total Carbon (µg/g)	Total Inorganic Carbon (µg/g)	Total Organic Carbon (µg/g)	Total Carbon (µg/g)	Total Organic Carbon (µg/g)
299-W6-16 (C9561) B398H3	4860	4030	830	ND	ND
299-W6-16 (C9561) B398H4	656	386	270	ND	ND
299-W6-16 (C9561) B398H5	1090	1070	20	ND	ND
299-W6-16 (C9561) B398H6	13500	13400	100	ND	ND
299-W6-16 (C9561) B398H7	1280	1160	120	ND	ND
299-W6-16 (C9561) B398H8	857	696	161	ND	ND
299-W6-16 (C9561) B398H9	377	308	69	ND	ND
299-W18-42 (C9563) B398T1	2950	1650	1300	ND	ND
299-W18-42 (C9563) B398T2	1390	1010	380	ND	ND
299-W18-42 (C9563) B398T3	ND	ND	ND	ND	ND
299-W18-42 (C9563) B398T5	1530	304	1226	ND	ND
299-W18-42 (C9563) B398T6	ND	ND	ND	ND	ND
299-W18-42 (C9563) B398T7	ND	ND	ND	ND	ND
299-W18-44 (C9565) B39927	2160	1920	240	ND	ND
299-W18-44 (C9565) B39928	914	726	188	ND	ND
299-W18-44 (C9565) B39929	205	ND	ND	ND	ND
299-W18-44 (C9565) B39930	ND	ND	ND	ND	ND
299-W18-44 (C9565) B39931	ND	ND	ND	ND	ND
299-W18-44 (C9565) B39932	ND	ND	ND	ND	ND
299-W18-44 (C9565) B39933	ND	ND	ND	ND	ND
Detection Limit	200	294	N/A	100-200	100- 200

3.2 200-ZP-1 OU Microbial Baseline

Bacterial enumeration technique by QPCR was used to develop an understanding of the bacterial activity in the clean sediments of the 200-ZP-1 OU. This information provides the basis for the evaluation of the batch experiment results and the column studies that will be conducted as part of this effort.

It is generally assumed that bacterial cell densities will trend with TOC levels in terrestrial sediments, and that bacterial abundances were observed that remained consistently high (10^{5-7} cell equiv/g) over the ZP-1 sediment profiles (Table 18). The only exception was the wellbore 299-W18-44 (C9565); cell abundances were low at below 150 ft depth and increased by three orders of magnitude with increasing depth. Brockman et al. (2004) estimated from 200 West 216-Z-9 Trench cores that viable bacterial populations in the high moisture zone PPU are 10^6 g^{-1} and 10^4 g^{-1} in Ringold formation sediments. The results observed in this assessment generally show higher bacterial abundance in Ringold sediments.

These outcomes are important because they demonstrate from unimpacted, background sediments that bacterial abundances in the deep subsurface are high. Thus, any perturbation that stimulates the bacterial community, will likely have a significant effect on groundwater chemistry and subsurface hydrology around P&T injection wells.

Table 18. QPRC results for 200-ZP-1.

Well Location and Borehole ID	Sample ID	Depth Interval (ft bgs)	Geologic Unit	16S rRNA gene copies g^{-1} sediment (± SD)
299-W18-42 (C9563)	B398T1	77.85-78.35	Hanford	$8.25 \times 10^6 \pm 0.7$
299-W18-42 (C9563)	B398T2	140-140.5	CCU	$2.19 \times 10^3 \pm 0.3$
299-W18-42 (C9563)	B398T3	197.63-198.13	Ringold-Unit E	$5.37 \times 10^5 \pm 0.6$
299-W18-42 (C9563)	B398T4	237.23-237.73	Ringold-Unit E	$1.91 \times 10^5 \pm 0.3$
299-W18-42 (C9563)	B398T5	340.2-340.7	Ringold-Unit E	$1.04 \times 10^7 \pm 0.07$
299-W18-42 (C9563)	B398T6	340.7-341.2	Ringold-Unit E	$1.18 \times 10^7 \pm 0.1$
299-W18-42 (C9563)	B398T7	407.99-408.99	Ringold-Unit E	$3.42 \times 10^4 \pm 0.3$
299-W6-16 (C9561)	B398H3	78.0-80.59	Transition between CCU and Ringold-Unit E	$2.24 \times 10^7 \pm 0.1$
299-W6-16 (C9561)	B398H4	132.6-138.1	Ringold-Unit E	$3.81 \times 10^5 \pm 0.3$
299-W6-16 (C9561)	B398H5	197.22-197.72	Ringold-Unit E	$7.92 \times 10^6 \pm 0.5$
299-W6-16 (C9561)	B398H6	235.6-236.6	Ringold-Unit E	$6.99 \times 10^5 \pm 0.9$
299-W6-16 (C9561)	B398H8	336.15-336.65	Ringold-Unit E	$2.02 \times 10^7 \pm 0.1$
299-W6-16 (C9561)	B398H9	405.78-406.28	Ringold-Unit A	$6.06 \times 10^5 \pm 0.6$
299-W18-44 (C9565)	B39927	78.79-80.79	Hanford	$3.14 \times 10^3 \pm 0.1$
299-W18-44 (C9565)	B39928	138.6-139.1	Transition between Hanford and CCU	$1.37 \times 10^3 \pm 0.1$
299-W18-44 (C9565)	B39929	198.02-198.52	Ringold-Unit E	$4.18 \times 10^6 \pm 0.2$
299-W18-44 (C9565)	B39930	237.66-238.16	Ringold-Unit E	$1.40 \times 10^6 \pm 0.1$
299-W18-44 (C9565)	B39931	338.13-338.63	Ringold-Unit E	$5.27 \times 10^5 \pm 0.6$
299-W18-44 (C9565)	B39933	406-406.5	Ringold-Unit E	$2.87 \times 10^5 \pm 0.2$

3.3 200-ZP-1 OU Mineralogical Composition

QXRD analysis was conducted on the 200-ZP-1 clean sediments to provide baseline information on the solid phases. The clay fraction of the sediments chosen for the batch experiments as well as post-experiment batch sediments are currently being analyzed will be reported at a later date.

QXRD results (Table 19) showed similar concentrations of chlorite (0.7-2.8%) and mica (3.2-5.8%) in the five analyzed sediments from all three boreholes. These samples were selected to represent different geologic units, including CCU, Ringold-Unit A, Hanford, and Ringold-Unit E (see Table 3). None of the sediments had identifiable/detectable carbonates, but all of the sediments had high (18-52%) amorphous or unidentified constituents, which may have been at least partially amorphous carbonates. Quartz concentrations ranged from 14-38%, with the highest concentration in B39933 (borehole 299-W18-44, Ringold-Unit E) and the lowest concentration in B298T2 (borehole 299-W18-42, CCU); all other sediments ranged from 27-

29%. Feldspar concentrations ranged from 22-28% for three sediments, with higher concentrations (45%) in B398H3 and a low concentration (12%) in B398H9. Small amounts of smectite and amphibole were detected in some of the sediments.

Table 19. QXRD results for the 200-ZP-1 clean sediments.

Sample	Quartz	Feldspar	Mica	Chlorite	Smectite	Amphibole	Amorphous/Unidentified
B398H3	29%	45%	4.6%	2.8%		0.5%	18%
B398H9	27%	12%	3.2%	2.0%	4.3%		52%
B398T2	14%	28%	4.8%	1.6%	10%		41%
B39927	27%	22%	5.8%	0.7%		1.3%	43%
B39933	38%	22%	4.3%	0.9%	4.5%	0.4%	30%

3.4 Contaminant Content

Contaminant content in the ZP-1 sediments analyzed was measured through a series of extractions, including water, acid, and sequential extractions. Water extractions help determine the aqueous or easily mobile contaminants in pore water. It is important to note that the areas the sediments came from for this task (see Figure 5) are not known to be contaminated by Cr, U, or I. Also note that for the purposes of evaluating iodine distribution and content, this project used total iodine data in these extractions as a surrogate for I-129.

The COCs included in this section are to provide a baseline and do not necessarily represent Cr, U, or I from contamination; instead, these elements are likely natural. In ZP-1 sediments, chromium and nitrate were only detectable for samples B398H6 and B398T2, respectively. Iodine was detectable in all of the sediments in low concentrations (iodine reported here is total iodine, and may or may not be ^{129}I. This was not determined as part of these experiments). Iodine in the ZP-1 area is likely present as natural iodine, and is included here only has a baseline for future COC-relative studies. Tc and U are considered “non-reportable” due to a blank spike failure, but U data is included in Table 20 for information only (FIO). U was detected in the two most shallow sediments from each of the three boreholes (as well as a mid-range sediment from C9561) in low concentrations. This potentially indicates more mobile phases of U close to the surface. Tc was below detection limits for all sediments. Note that samples are from areas not known to be contaminated by Cr or U.

Table 20. Water extraction results for COCs (U, NO_3^-, and Cr) and total iodine, reported in µg/kg dry or µg/g dry.

Borehole Location and Sample ID (< 2mm)	Uranium µg/kg	Total Iodine* µg/kg	Chromium µg/kg	Nitrate µg/g
299-W6-16 (C9561) B398H3	0.09	1.16	ND	ND
299-W6-16 (C9561) B398H4	0.10	0.57	ND	ND
299-W6-16 (C9561) B398H5	ND	1.20	ND	ND
299-W6-16 (C9561) B398H6	0.11	4.75	0.78	ND
299-W6-16 (C9561) B398H7	ND	2.06	ND	ND
299-W6-16 (C9561) B398H8	ND	1.59	ND	ND
299-W6-16 (C9561) B398H9	ND	2.06	ND	ND
299-W18-42 (C9563) B398T1	0.18	1.11	ND	ND
299-W18-42 (C9563) B398T2	0.14	2.21	ND	29.2
299-W18-42 (C9563) B398T3	ND	1.15	ND	ND
299-W18-42 (C9563) B398T5	ND	1.04	ND	ND
299-W18-42 (C9563) B398T6	ND	3.43	ND	ND
299-W18-42 (C9563) B398T7	ND	5.18	ND	ND
299-W18-44 (C9565) B39927	0.10	0.76	ND	ND
299-W18-44 (C9565) B39928	0.19	1.01	ND	ND
299-W18-44 (C9565) B39929	ND	0.27	ND	ND
299-W18-44 (C9565) B39930	ND	2.07	ND	ND
299-W18-44 (C9565) B39931	ND	1.98	ND	ND
299-W18-44 (C9565) B39932	ND	2.30	ND	ND
299-W18-44 (C9565) B39933	ND	2.95	ND	ND

* For the purposes of evaluating iodine distribution and content, this project used total iodine data in these extractions as a surrogate for I-129.

Acid extraction yields a measure of the total contaminant present in pore water, adsorbed phases, and surface precipitates. During these experiments, an 8M nitric acid extraction was used to dissolve most (but not all) surface precipitates that may contain contaminants. As expected, acid extraction results showed higher concentrations of uranium and chromium. These concentrations can be attributed to natural uranium and chromium present in the sediment, though some portion of these elements may be COCs present in hard-to-extract (or less mobile) phases (Table 21). Note that samples are from areas not known to be contaminated by Cr or U. Tc was still below detection limits, but U was detected in all of the sediments, with high concentrations in B398H6 (0.31 µg/g) and B398T7 (0.53 µg/g) and less than 0.26 µg/g in the remaining sediments.

Chromium was also detected in all of the sediments, with the highest concentrations found in three of the C9563 borehole sediments. In these sediments, Cr decreased from 14.2 µg/g to 9.16 µg/g with increasing depth (Table 21); the highest concentration was found in B398T5, which is located below the static water level in this borehole (Table 3). The remaining sediments had Cr concentrations ranging from 2.52 to 7.43 µg/g. Alkaline digestions for Cr(VI) determination were also conducted, but all results were below the detection limit (detection limit = 138 µg/L; data not shown).

Iodine was not analyzed in the acid extractions because acidic samples cannot be analyzed on the ICP-MS for iodine. Iodine in the ZP-1 area is likely present as natural iodine, and is included here only has a baseline for future COC-relative studies.

Table 21. Acid extraction results for COC's, reported in µg/g dry.

Borehole Locations and Sample ID (<2mm)	Technetium (µg/g dry)	Uranium (µg/g dry)	Chromium (µg/g dry)
299-W6-16 (C9561) B398H3	ND	0.27	6.06
299-W6-16 (C9561) B398H4	ND	0.19	4.1
299-W6-16 (C9561) B398H5	ND	0.23	6.07
299-W6-16 (C9561) B398H6	ND	0.31	7.43
299-W6-16 (C9561) B398H7	ND	0.13	3.68
299-W6-16 (C9561) B398H8	ND	0.09	3.3
299-W6-16 (C9561) B398H9	ND	0.18	4.21
299-W18-42 (C9563) B398T1	ND	0.23	6.95
299-W18-42 (C9563) B398T2	ND	0.26	6.23
299-W18-42 (C9563) B398T3	ND	0.14	7.99
299-W18-42 (C9563) B398T5	ND	0.16	14.2
299-W18-42 (C9563) B398T6	ND	0.14	11.6
299-W18-42 (C9563) B398T7	ND	0.53	9.16
299-W18-44 (C9565) B39927	ND	0.24	4.99
299-W18-44 (C9565) B39928	ND	0.18	2.52
299-W18-44 (C9565) B39929	ND	0.14	5.05
299-W18-44 (C9565) B39930	ND	0.14	3.86
299-W18-44 (C9565) B39931	ND	0.13	6.57
299-W18-44 (C9565) B39932	ND	0.11	4.27
299-W18-44 (C9565) B39933	ND	0.17	4.51

In addition to water and acid extractions, the ZP-1 sediments were also exposed to a set of sequential extractions. In this process, a sediment sample is sequentially exposed to increasingly harsher extraction solutions and the contaminant concentration in each solution is measured. These data show how the contaminant mass in a sediment sample is distributed among different water- and sediment-associated phases.

As expected, based on previously reported results from Hanford Site sediments (Szecsody et al. 2017), iodine was associated with the carbonate phases (and potentially some Fe oxide phases) dissolved during the 3rd and 4th stage of the sequential extractions (using acetate solution and acetic acid solution, respectively; Table 6, Figure 6). While the iodine was associated with carbonate fractions, the highest iodine levels did not correlate with the sediments with the highest carbonate content (based on water extraction and acid extraction data) (see Tables 14-16). Several sediments also had relatively high concentrations of iodine in the Fe oxide fraction (extracted by oxalate solution). Due to the nature of the extraction solution, the 8M HNO_3 samples were not analyzed for iodine. Iodine in the ZP-1 area is likely present as natural iodine, and is included here only has a baseline for future COC-relative studies. The iodine reported here is total iodine (not I-129).

Chromium was also mostly associated with the hard-to-extract fraction, although some of the sediments from borehole C9563 (samples B398T3, B398T5, B398T6, and B398T7) also had relatively high amounts of Cr extracted from the Fe oxide and carbonate fractions (Figure 7).

This is in agreement with the relatively high Cr concentrations in these samples seen in the acid extraction results and may be indicative that the chromium is from background sources rather than from contamination. Acid extractions showed greater Cr content in sample B398T5, but sequential extractions show higher Cr concentrations in sample B398T6. Note that samples are from areas not known to be contaminated by Cr.

Uranium in all sediments was mostly associated with the hard-to-extract sediment fraction (Figure 8). These results may indicate that uranium is from background sources rather than from contamination. The AGW extractions were not reportable for U due to a blank spike failure, but the data showed less than 0.001 µg/g U in these samples. Tc was not detectable in any of the sequential extraction samples (detection limit ranged from 0.033 µg/L to 1.65 µg/L). Note that samples are from areas not known to be contaminated by U.

Data presented in this section will support the evaluations of effluent impact on contaminant geochemistry in the aquifer. Furthermore, the data will also be compared to the expected distributions of the contaminant plumes at these locations.

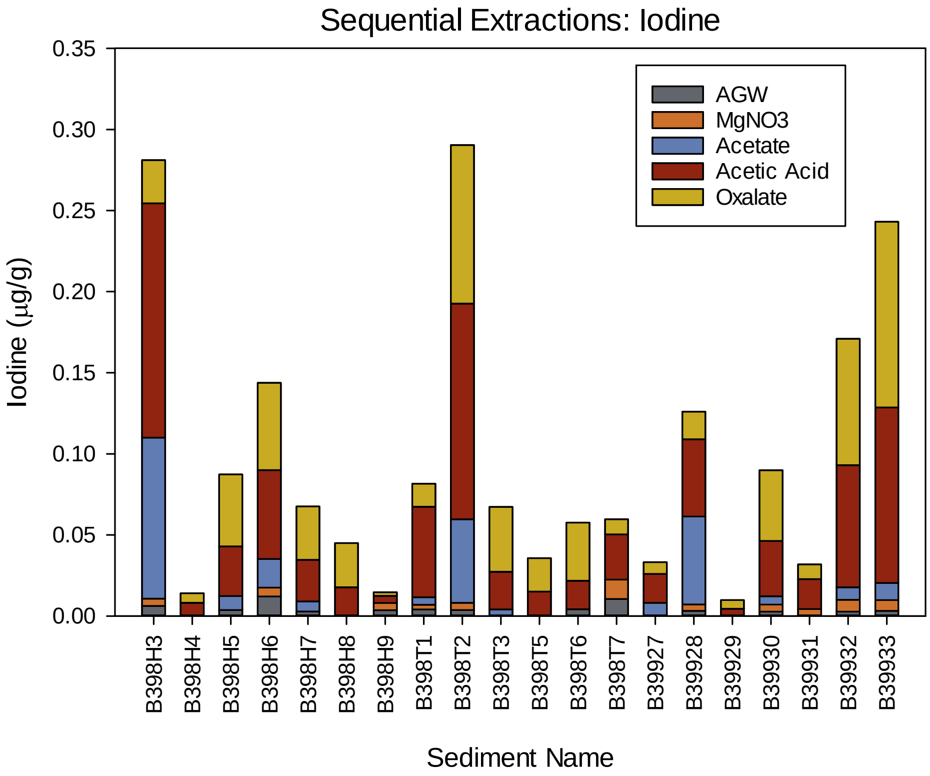
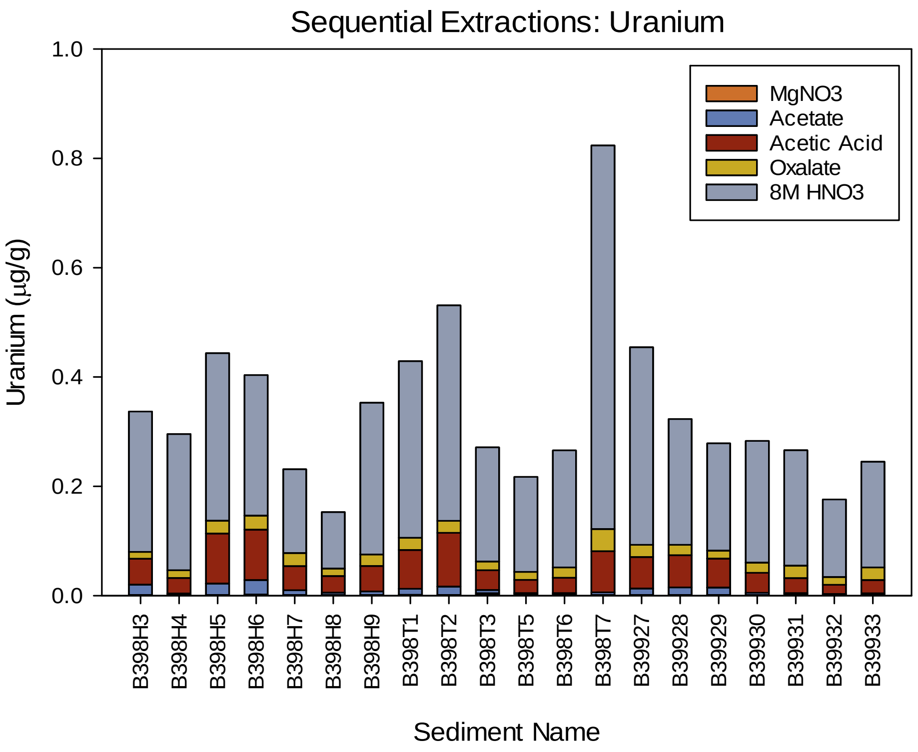


Figure 6. Sequential extraction results for iodine.



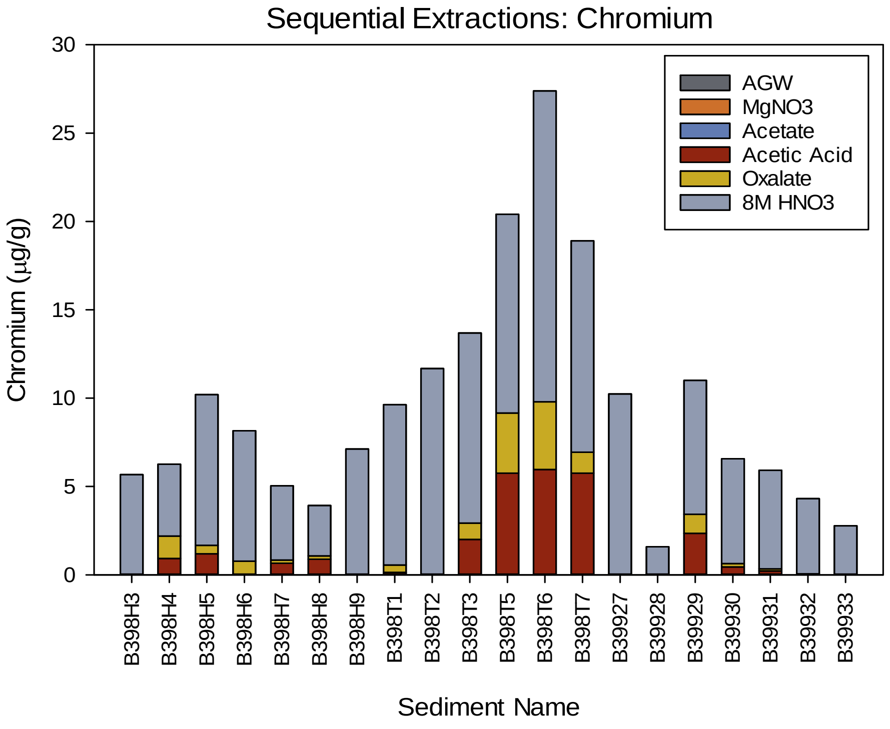


Figure 7. Sequential extraction results for chromium.

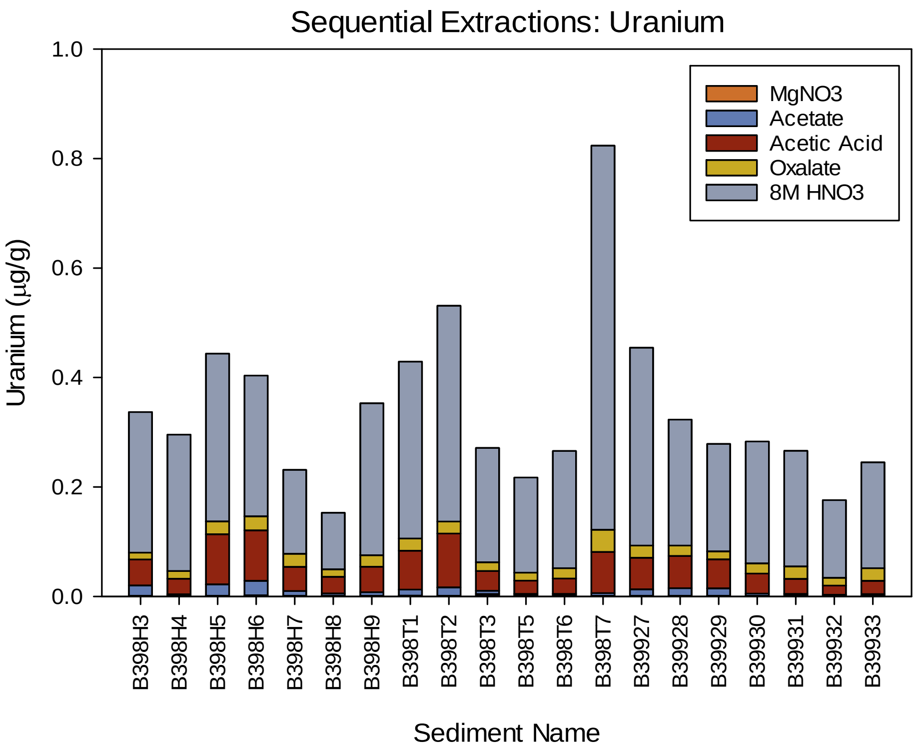


Figure 8. Sequential extraction results for uranium.

3.5 Batch Experiments

Batch experiments were conducted as described in Section 2.5 to provide a preliminary information on the significant geochemical and microbiological processes that may be occurring in the 200 West aquifer due to the injection of P&T effluent. The results from these experiments will inform the design of the column studies that will be conducted next.

Batch results showed several differences between the solutions used (AGW, ITB1, and ITB2) as well as differences in response to the experimental temperatures (23°C versus 50°C). Table 22 through 26 show selected data for each of the five sediments for the 23°C tests. Data for the 50°C tests and the results for the remaining analytes for the 23°C tests can be found in Appendix B. Starting solution results shown in Table 22 represent the solution composition for the ITB1 and ITB2 effluents. The starting solution chemistry and detailed analysis of the changes that occurred within the first 24 hours of the batch experiments can be found in Section 3.6, where geochemical modeling was also conducted for a selected batch experiment solution for the sample B398H3 at 4 and 24h.

Several analytes were below detection limits for most sampling points throughout the experiments, including Cr and Mn. Although Fe and Al also were below detection limits for the most sampling points, some increases in their concentration levels were observed for all solutions tested, especially during the earlier portion of the experiments (see Figure 9 and Figure 10). For example, the batch experiment with sample B398H3 and ITB1 solution showed the highest increase in Fe concentration at 4h with 630 µg/L (Figure 10 and Table 22).

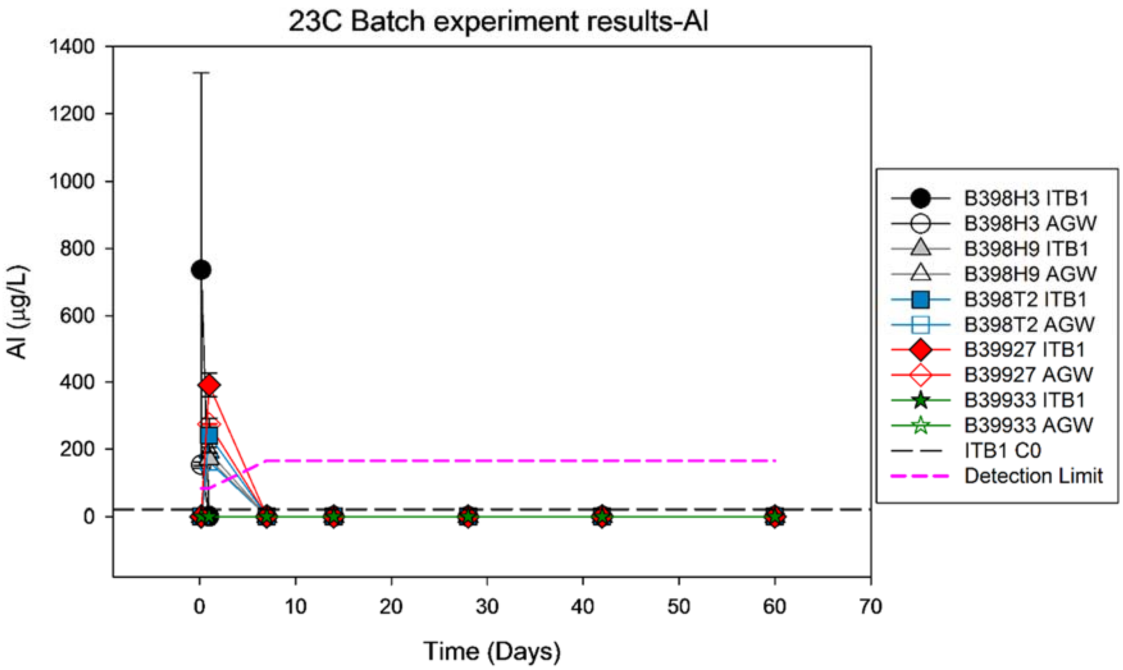


Figure 9. Results from the batch experiments with ITB1 effluent versus AGW at 23°C, showing Al concentrations. (ITB1 C0 indicates the initial solution concentration.)

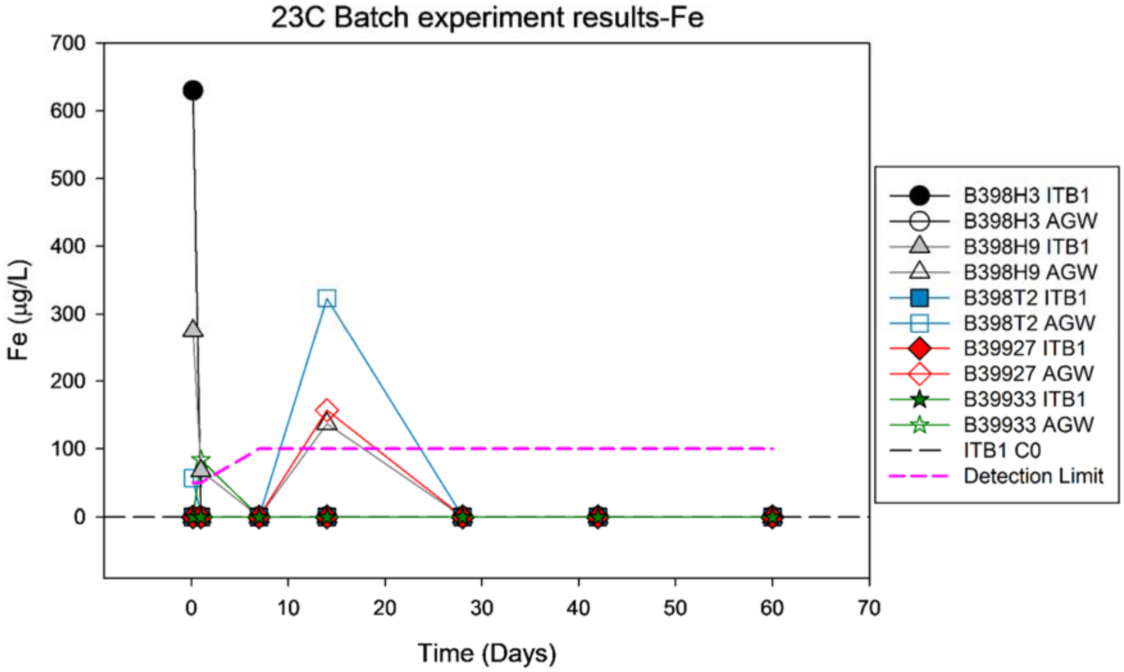


Figure 10. Results from the batch experiments with ITB1 effluent versus AGW at 23°C, showing Fe concentrations. (ITB1 C0 indicates the initial solution concentration.)

In general, the five sediments exhibited similar behaviors, with many elements remaining around the initial concentration in the ITB solutions, such as Ca, Mg, and Na. Mg and Ca in the 23°C tests showed concentration levels similar to their initial concentrations in ITB1 and ITB2 effluent solutions throughout the experiments (Figure 11 and Figure 12). However, as can be expected, Ca and Mg appeared to precipitate out of solution at the higher temperature (at 50°C) around the 7 day sampling, with Ca concentrations around 60 mg/L in the 23°C tests and 50 mg/L in the 50°C tests (see Appendix B). Similar behavior in concentration levels were also observed for the experiments with the AGW as well. However, the concentration levels were typically lower in the AGW treatments than those in the experiments with the ITB effluent solutions. Furthermore, the Ca and Mg concentrations in the AGW solution experiments remained equal in both the 23°C and 50°C tests.

Sr concentrations in the batch experiments with ITB1 effluent solution showed an initial increase followed by a slight decrease over time (Figure 13). Similar behavior was also observed for the treatments with ITB2 solution. In all five sediments, K decreased with time from 5-6 mg/L in the initial effluent solutions to 2-4 mg/L by the time of the last sampling (60 day)(excluding B398H9 at 50°C, which was still at 5.5 mg/L at 60 days). Most sediments had elevated Ba concentrations compared to the initial effluent solutions until the 28 day sampling, where the Ba concentration began to drop from 60-70 µg/L to 50-60 µg/L in samples B398H3, B398T2, and B39933 (Figure 14). In sample B39927, Ba concentrations remained elevated, whereas sample B398H9 experienced no increase from its initial measured concentration. A similar pattern for Sr concentration was observed in samples B398H3 and B39927, while samples B398H9 and B398T2 showed Sr concentrations remaining steady near the starting concentrations.

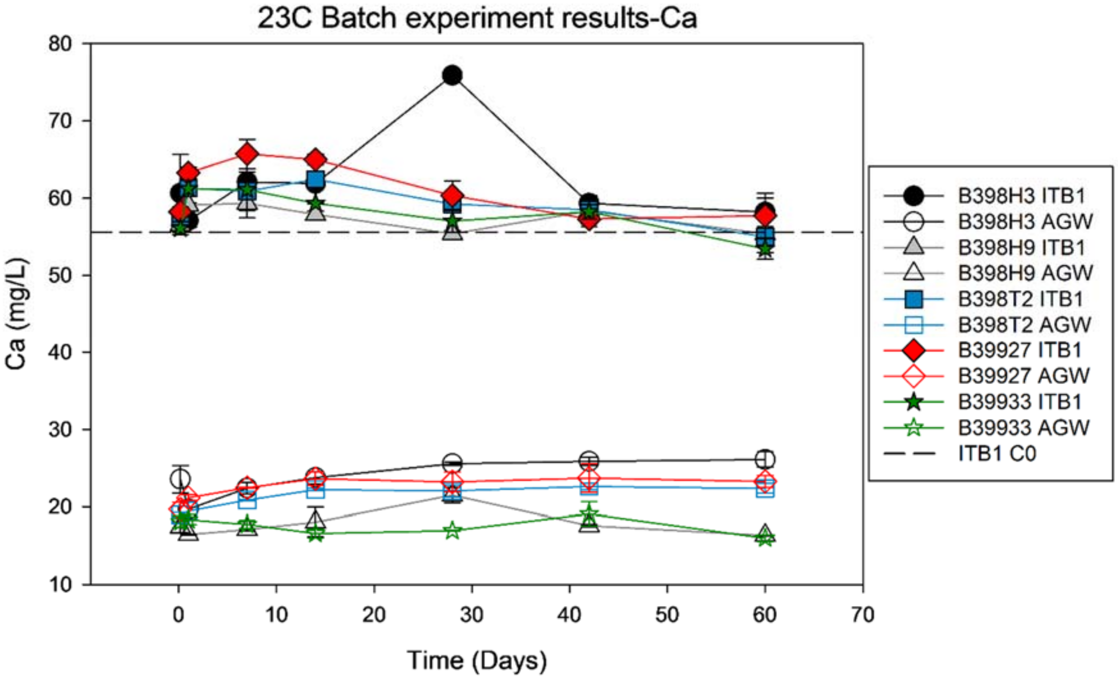


Figure 11. Results from the batch experiments with ITB1 effluent versus AGW at 23°C, showing Ca concentrations. (ITB1 C0 indicates the initial solution concentration.)

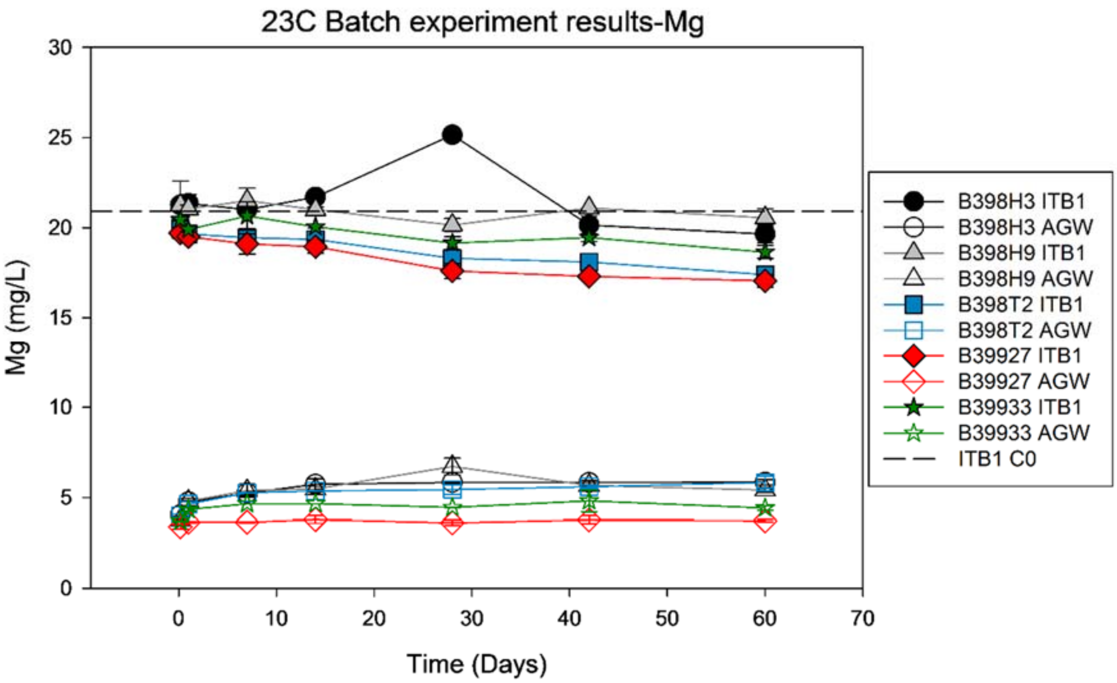


Figure 12. Results from the batch experiments with ITB1 effluent versus AGW at 23°C, showing Mg concentrations. (ITB1 C0 indicates the initial solution concentration.)

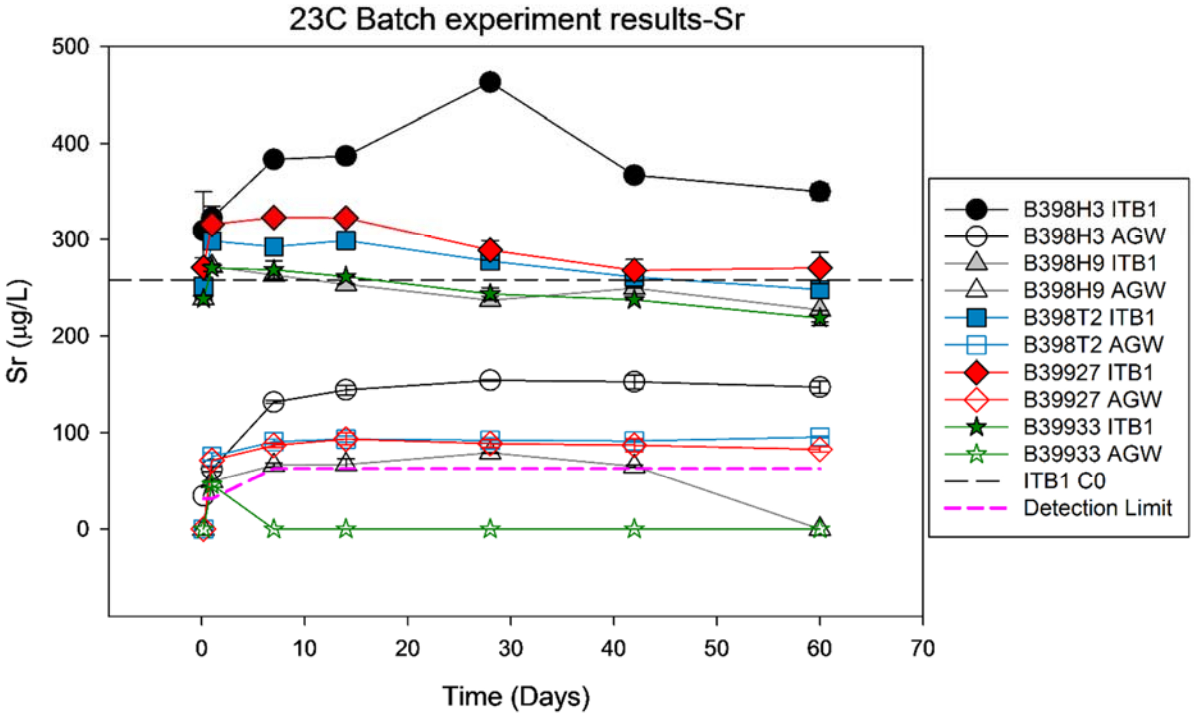


Figure 13. Results from the batch experiments with ITB1 effluent versus AGW at 23°C, showing Sr concentrations. (ITB1 C0 indicates the initial solution concentration.)

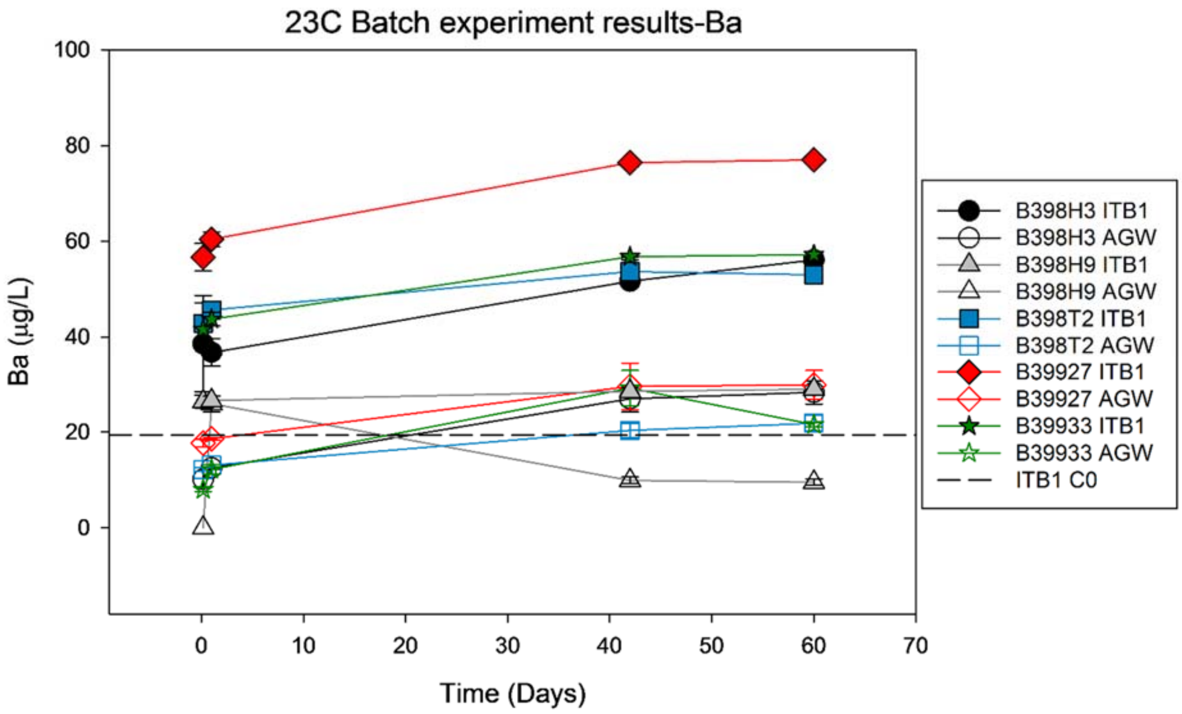


Figure 14. Results from the batch experiments with ITB1 effluent versus AGW at 23°C, showing Ba concentrations. (ITB1 C0 indicates the initial solution concentration.)

The two ITB solutions both started with ~1 µg/L uranium and ~14-18 µg/L total iodine. The sampling point at 4h showed ~ 1 µg/L I in the AGW solution tests (leached from the sediments) while the ITB1 and ITB2 solution tests were similar to the starting iodine concentrations (~20 p µg/L). By the 14th day of sampling, the ITB solution tests at 23°C had decreased to 10-15 ppb iodine, while the 50°C tests remained higher (Appendix B). The 50°C ITB tests consistently had higher iodine concentrations; iodine concentrations in the AGW tests did not vary with temperature. In the ITB solution tests, U behaved opposite with the varied temperature, with lower U concentrations in the 50°C tests compared to the 23°C tests. While the 23°C ITB solution tests remained around 1.3 µg/L U throughout the experiment, the 50°C ITB solution tests began to decrease in U concentration around day 14, and was near or below detection limits (<0.355 ppb U) by the 28 day sampling point. U is known to associate strongly with carbonates, and may have co-precipitated as the Ca and Mg were precipitating out of solution in the higher temperature tests. U was not detected in AGW tests.

While the pH values across the tests varied from 7.5-9, these tend to be higher in the 50°C tests compared to the 23°C tests across all of the sediments.

Furthermore, two sediments, B398H3 and B398T2, had increasing Si concentrations in the 50°C experiments compared to the 23°C experiments (~26 mg/L Si versus. ~22 mg/L Si). The Si concentrations in sample B39927 remained steady while it decreased in samples B398H9 and B39933 at 50°C tests (decreasing to ~13 mg/L).

These results will continue to be evaluated in light of other characterization results, particularly currently ongoing QXRD analysis of the sediments from these batch experiments. They will be used to inform the design of the column studies and support the additional modeling work.

Table 22. Batch experiment results for sediment H398H3 at 23°C. Additional results can be found in Appendix B. The starting solution concentrations found in this table apply to Table 23-Table 26 also.

Sample Time	B398H3, 23°C Solution	pH		Ba (µg/L)		Fe (µg/L)		Sr (µg/L)		Al (µg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
Starting Solution	ITB1	-	-	19.4	-	ND	-	258	-	ND	-	20.7	-	5.21	-	55.6	-	20.9	-	22.7	-
	ITB2	-	-	19.8	-	ND	-	255	-	ND	-	29.4	-	5.85	-	54.8	-	21	-	22.7	-
4 hour	AGW	7.86	0.09	10.2	1.63	ND	-	34.5	-	153	9.19	5.62	0.06	9.45	2.33	23.6	1.77	4.04	0.05	6.90	0.10
	ITB1	8.33	-	38.6	10.1	630	-	310	40.3	736	585	20.5	0.14	6.36	2.54	60.7	5.02	21.3	1.34	21.6	0.64
	ITB2	8.26	-	32.1	4.03	65.7	-	298	4.24	290	8.49	31.5	0.64	8.26	3.88	58.3	2.47	21.1	0.35	22.1	0.49
1 day	AGW	8.76	-	12.5	0.28	ND	-	62.3	2.47	ND	-	6.42	0.21	3.50	0.13	19.7	0.99	4.75	0.20	7.93	0.51
	ITB1	7.69	-	36.8	2.90	ND	-	323	12.0	ND	-	22.2	0.78	4.69	0.03	57.1	0.85	21.4	0.49	22.6	0.64
	ITB2	7.65	-	35.1	3.96	ND	-	323	0.71	ND	-	32.4	0.35	5.16	0.01	56.8	0.07	21.6	0.21	22.6	0.49
7 day	AGW	8.51	0.04	ND*	-	ND	-	132	1.41	ND	-	5.68	0.37	2.93	-	22.4	0.71	5.25	0.09	9.43	0.01
	ITB1	7.87	-	47.9	0.71	ND	-	384	4.95	ND	-	20.0	0.14	4.44	0.20	62.1	1.27	21.0	0.28	23.0	0.28
	ITB2	7.69	-	61.8	19.6	ND	-	402	14.8	ND	-	29.6	1.27	4.49	0.13	64.0	3.54	21.8	0.92	23.9	1.20
14 day	AGW	8.45	-	ND*	-	ND	-	145	4.95	ND	-	5.98	0.38	2.26	-	23.8	0.78	5.73	0.30	10.3	0.52
	ITB1	7.84	0.11	50.4	2.12	ND	-	387	4.24	ND	-	20.3	0.07	3.07	1.16	61.9	0.42	21.7	0.28	23.3	0.49
	ITB2	7.95	-	48.6	0.07	ND	-	377	7.78	205	-	27.3	0.78	6.14	0.52	59.2	1.48	20.1	0.57	23.1	0.28
28 day	AGW	8.31	-	ND*	-	ND	-	155	0.71	ND	-	5.68	0.13	3.92	0.37	25.6	0.21	5.84	0.05	11.2	0.35
	ITB1	7.81	-	61.5	2.97	ND	-	463	2.83	ND	-	23.3	0.14	7.47	0.79	75.9	0.14	25.2	0.07	28.1	0.21
	ITB2	7.91	-	63.3	3.61	ND	-	465	2.83	ND	-	33.6	0.07	7.65	0.53	74.6	1.34	25.4	0.42	27.9	0.21
42 day	AGW	8.32	-	27.0	2.76	ND	-	153	7.07	ND	-	5.62	0.14	4.06	1.10	25.9	0.49	5.83	0.13	10.8	0.07
	ITB1	7.82	-	51.7	0.64	ND	-	367	1.41	ND	-	18.8	0.07	5.39	0.39	59.4	0.07	20.2	0.49	22.2	0.35
	ITB2	8.07		51.8	2.55	ND	-	371	19.1	ND	-	27.1	1.41	5.21	0.88	59.3	2.97	20.4	0.99	22.4	1.13
60 day	AGW	8.02	0.23	28.3	2.40	ND	-	148	6.36	ND	-	5.52	0.22	2.25	-	26.1	0.99	5.85	0.16	11.1	0.14
	ITB1	7.85	-	56.1	1.27	ND	-	350	8.49	ND	-	18.7	0.64	2.99	0.59	58.2	1.84	19.7	0.49	22.9	0.71
	ITB2	8.00	-	50.9	0.57	ND	-	336	5.66	ND	-	25.6	0.14	2.30	0.16	55.1	0.28	19.1	0.14	22.3	0.07
Detection limits				3.09-7.87, 32.8*		50, 100		31.4, 62.8		82.4, 165		0.223, 0.447		0.8, 1.61*		0.17, 0.34		0.01, 0.03		0.274, 0.548	

Table 23. Batch experiment results for sediment H398H9 at 23°C. Additional results can be found in Appendix B. The starting solution concentrations for ITB1 and ITB2 can be found in Table 22.

Sample Time	B398H9, 23°C Solution	pH		Ba (µg/L)		Fe (µg/L)		Sr (µg/L)		Al (µg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
4 hour	AGW	7.86	-	ND	-	ND	-	ND	-	ND	-	5.96	0.24	4.97	1.30	17.40	0.71	3.77	0.04	6.92	0.21
	ITB1	8.16	-	26.35	1.34	275	-	238.5	2.12	ND	-	22.05	0.21	7.74	3.63	56.55	0.21	21.25	0.21	22.15	0.07
	ITB2	8.28	-	4.57	-	ND	-	230	5.66	ND	-	30.15	0.35	6.44	1.44	54.40	1.56	20.65	0.21	21.40	0.42
1 day	AGW	7.67	-	25.90	1.70	ND	-	49.45	0.78	191.5	13.44	6.71	0.13	3.95	0.14	16.45	0.07	4.80	0.04	7.68	0.01
	ITB1	7.41	-	26.6	0.85	67.3	-	272	2.83	171	15.56	22.75	0.21	5.82	0.08	59.10	0.28	21.05	0.21	22.10	0.28
	ITB2	7.58	0.06	23.9	1.56	ND	-	267	1.41	178.5	0.71	31.25	0.49	6.11	0.07	58.15	0.64	21.10	0.28	21.90	0.14
7 day	AGW	7.91	-	ND*	-	ND	-	66.35	2.33	ND	-	6.07	0.32	2.56	0.57	17.10	0.14	5.38	0.36	8.84	0.59
	ITB1	7.76	-	ND*	-	ND	-	263	5.66	ND	-	20.40	0.85	4.52	0.28	59.35	1.91	21.50	0.71	22.65	1.06
	ITB2	7.85	-	ND*	-	772	-	269	1.41	ND	-	29.30	0.00	4.97	1.00	60.60	0.28	21.95	0.35	22.95	0.49
14 day	AGW	7.82	-	ND*	-	137.00	-	67.20	6.08	ND	-	5.98	0.04	5.63	0.23	18.05	1.91	5.48	0.15	9.65	0.16
	ITB1	7.86	-	ND*	-	ND	-	253.5	0.71	ND	-	19.35	0.21	6.80	0.29	57.90	0.42	21.00	0.14	23.00	0.42
	ITB2	7.99	-	ND*	-	ND	-	256	12.73	ND	-	27.10	1.27	6.44	0.45	57.60	3.25	20.90	0.57	23.10	0.57
28 day	AGW	7.72	-	ND*	-	ND	-	79.30	0.42	ND	-	7.02	0.06	6.31	0.28	21.50	0.99	6.72	0.46	12.10	0.42
	ITB1	7.81	-	ND*	-	ND	-	237	4.24	ND	-	18.55	0.07	5.96	0.49	55.40	0.42	20.15	0.35	21.40	0.28
	ITB2	7.80	0.12	ND*	-	ND	-	237	5.66	ND	-	26.15	0.78	6.07	1.51	55.10	1.56	19.90	0.57	20.80	0.42
42 day	AGW	7.89	-	9.90	0.71	ND	-	65.30	1.27	ND	-	5.86	0.12	4.64	0.88	17.60	0.14	5.67	0.03	9.79	0.06
	ITB1	7.88	-	28.5	0.71	ND	-	249.5	4.95	ND	-	19.75	0.49	6.77	0.04	58.35	1.48	21.10	0.00	22.05	0.35
	ITB2	8.02	-	28.7	0.42	ND	-	245	7.07	ND	-	27.25	0.78	6.97	0.56	56.90	1.84	20.45	0.78	21.20	0.99
60 day	AGW	7.87	-	9.53	0.67	ND	-	ND	-	ND	-	5.46	0.23	1.95	0.39	16.35	0.07	5.41	0.13	9.83	0.25
	ITB1	7.84	-	28.95	0.07	ND	-	227	12.73	ND	-	18.95	1.48	3.60	0.93	55.40	2.40	20.55	0.49	22.80	0.85
	ITB2	7.90	-	29.05	0.21	ND	-	212	8.49	ND	-	24.40	1.13	3.01	0.44	51.05	1.77	18.75	0.64	20.65	0.92
Detection limits				3.09-7.87, 32.8*		50, 100		31.4, 62.8		82.4, 165		0.223, 0.447		0.8, 1.61*		0.17, 0.34		0.01, 0.03		0.274, 0.548	

Table 24. Batch experiment results for sediment H398T2 at 23°C. Additional results can be found in Appendix B. The starting solution concentrations for ITB1 and ITB2 can be found in Table 22.

Sample Time	B398T2 23°C Solution	pH		Ba (µg/L)		Fe (µg/L)		Sr (µg/L)		Al (µg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
4 hour	AGW	7.95	-	12.2	0.42	56.5	-	ND	-	ND	-	6.79	0.31	5.64	2.29	19.00	0.28	4.00	0.09	6.99	0.21
	ITB1	8.17	-	42.85	4.31	ND	-	251.5	9.19	ND	-	23.6	1.13	6.14	1.87	57.60	1.13	19.95	0.35	20.85	0.07
	ITB2	8.34	-	41.45	0.78	80.3	-	255	5.66	ND	-	32.55	0.78	6.24	1.11	57.30	1.98	20.35	0.35	22.00	0.57
1 day	AGW	8.34	-	13.10	0.00	ND	-	75.50	3.82	162.00	-	8.76	0.43	3.92	0.12	19.45	1.20	4.64	0.16	8.07	0.23
	ITB1	7.61	-	45.65	0.78	ND	-	298.5	2.12	240.5	51.62	24.45	0.35	5.76	0.11	61.30	0.71	19.65	0.35	22.25	0.07
	ITB2	7.54	-	48.5	1.13	ND	-	304.5	0.71	339	66.47	34.35	0.49	6.32	0.04	61.85	0.21	20.55	0.07	23.25	0.07
7 day	AGW	8.40	-	ND*	-	ND	-	90.90	2.55	ND	-	8.44	0.21	2.35	0.78	20.85	0.07	5.26	0.01	13.15	0.21
	ITB1	7.79	0.06	54.7	1.98	ND	-	292.5	2.12	ND	-	21.55	0.07	3.57	0.17	60.90	0.14	19.45	0.49	24.15	0.07
	ITB2	7.75	-	57.25	1.77	ND	-	299	5.66	ND	-	29.65	0.78	4.00	0.43	61.40	1.41	19.15	0.07	23.30	0.00
14 day	AGW	8.33	-	ND*	-	323	-	93.70	3.39	ND	-	8.10	0.21	4.29	0.95	22.20	0.14	5.36	0.03	14.80	0.28
	ITB1	7.81	-	55.5	2.26	ND	-	299	2.83	ND	-	21.20	0.14	5.95	1.64	62.45	0.07	19.35	0.07	24.90	0.00
	ITB2	7.84	-	58.2	1.84	ND	-	291	2.83	ND	-	28.30	0.28	7.25	0.95	60.45	0.49	19.10	0.14	24.90	0.14
28 day	AGW	8.31	-	ND*	-	ND	-	92.25	3.04	ND	-	7.75	0.03	4.30	0.18	22.05	0.78	5.44	0.27	14.75	0.35
	ITB1	8.26	-	51.35	0.35	ND	-	277.5	3.54	ND	-	20.65	0.21	5.20	0.05	59.25	0.49	18.30	0.14	22.85	0.07
	ITB2	7.91	-	52.45	0.92	ND	-	275	8.49	ND	-	27.85	0.64	6.59	0.48	58.55	1.77	18.60	0.42	23.00	0.28
42 day	AGW	8.35	0.03	20.35	1.48	ND	-	91.65	1.34	ND	-	9.08	0.11	2.38	0.67	22.60	0.42	5.59	0.10	15.70	0.00
	ITB1	7.82	-	53.65	2.47	ND	-	261	11.31	ND	-	21.05	0.92	4.68	1.15	58.50	1.84	18.10	0.42	23.75	0.64
	ITB2	8.26	-	62.6	9.05	ND	-	313.5	51.62	ND	-	33.55	5.44	5.92	1.39	68.35	11.53	21.60	3.68	28.10	5.09
60 day	AGW	8.26	-	21.85	1.63	ND	-	95.60	0.99	ND	-	7.32	0.89	2.12	0.51	22.35	0.64	5.84	0.35	16.15	0.49
	ITB1	7.85	-	53	1.13	ND	-	248	4.24	ND	-	19.90	0.28	2.49	0.84	55.00	0.71	17.40	0.14	23.05	0.07
	ITB2	8.00	-	59.2	5.37	ND	-	259	5.66	ND	-	27.60	0.57	3.33	1.11	56.15	1.48	17.95	0.21	23.55	0.21
Detection limits				3.09-7.87, 32.8*		50, 100		31.4, 62.8		82.4, 165		0.223, 0.447		0.8, 1.61*		0.17, 0.34		0.01, 0.03		0.274, 0.548	

Table 25. Batch experiment results for sediment H39927 at 23°C. Additional results can be found in Appendix B. The starting solution concentrations for ITB1 and ITB2 can be found in Table 22.

Sample Time	B39927 23°C Solution	pH		Ba (µg/L)		Fe (µg/L)		Sr (µg/L)		Al (µg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
4 hour	AGW	7.64	0.14	17.7	0.85	ND	-	ND	-	ND	-	6.845	0.43	10.70	5.37	19.70	0.85	3.40	0.13	7.09	0.30
	ITB1	8.12	-	56.65	2.90	ND	-	271	9.90	ND	-	22.85	0.64	5.76	0.57	58.25	0.64	19.70	0.28	21.95	0.49
	ITB2	8.26	-	57	5.66	ND	-	269.5	13.44	ND	-	31.9	0.57	6.43	1.02	57.80	1.27	19.75	0.49	21.45	0.64
1 day	AGW	8.47	-	18.60	0.28	ND	-	71.50	0.00	274.50	2.12	7.28	0.08	4.32	0.02	21.15	0.35	3.65	0.05	7.39	0.11
	ITB1	7.71	-	60.4	1.56	ND	-	316	5.66	391	35.36	23.50	0.71	5.84	0.08	63.30	0.71	19.50	0.28	22.00	0.00
	ITB2	7.75	-	62.95	3.04	ND	-	308	9.90	138.85	72.34	30.85	0.92	6.29	0.21	63.55	1.34	18.85	0.35	21.70	0.42
7 day	AGW	8.70	-	ND*	-	ND	-	87.05	2.33	ND	-	6.42	0.02	2.84	0.38	22.45	0.07	3.65	0.02	7.95	0.11
	ITB1	7.89	-	78.6	1.41	ND	-	323	4.24	ND	-	21.40	0.28	4.03	0.32	65.75	1.91	19.10	0.57	22.20	0.71
	ITB2	7.89	-	73.65	1.91	ND	-	313	2.83	ND	-	29.10	0.28	3.99	0.92	62.70	0.42	18.55	0.07	21.60	0.00
14 day	AGW	8.32	-	ND*	-	157.00	-	93.60	6.22	ND	-	6.13	0.31	5.34	0.77	23.60	0.85	3.79	0.20	8.89	0.30
	ITB1	7.83	-	79.85	1.06	ND	-	322.5	3.54	ND	-	20.60	0.42	6.34	0.91	65.00	0.71	18.95	0.35	23.70	0.57
	ITB2	7.80	-	79.5	1.27	ND	-	310	1.41	ND	-	27.95	0.35	5.47	0.93	62.25	0.07	18.65	0.07	22.95	0.35
28 day	AGW	8.16	-	ND*	-	ND	-	88.90	4.24	ND	-	6.13	0.11	4.72	0.23	23.20	1.27	3.61	0.14	7.90	0.05
	ITB1	7.77	-	69.3	0.42	ND	-	289	9.90	ND	-	19.15	0.64	4.93	0.97	60.35	1.91	17.60	0.42	20.55	0.49
	ITB2	7.73	-	72.35	0.21	ND	-	294	4.24	ND	-	27.20	0.28	6.17	0.50	60.60	1.41	17.95	0.07	21.25	0.07
42 day	AGW	8.38	-	29.55	4.88	ND	-	87.25	6.86	ND	-	6.52	0.33	2.25	0.33	23.70	1.84	3.78	0.21	8.43	0.30
	ITB1	7.87	-	76.4	0.85	ND	-	268	11.31	ND	-	18.00	0.99	3.01	-	57.30	0.99	17.30	0.14	21.20	0.57
	ITB2	7.90	-	78.25	0.78	ND	-	277.5	3.54	ND	-	26.00	0.42	3.08	0.09	60.20	0.99	17.20	0.14	21.45	0.07
60 day	AGW	7.57	-	29.85	3.04	ND	-	82.80	2.69	ND	-	5.59	0.12	2.45	0.48	23.25	0.78	3.73	0.06	8.39	0.12
	ITB1	7.73	-	77	0.57	ND	-	270.5	16.26	ND	-	18.85	1.34	4.08	0.01	57.75	2.90	17.05	0.35	20.80	0.28
	ITB2	7.92	-	76.8	1.13	ND	-	259	7.07	ND	-	25.10	0.42	3.15	0.42	55.05	1.20	16.55	0.49	20.10	0.85
Detection limits				3.09-7.87, 32.8*		50, 100		31.4, 62.8		82.4, 165		0.223, 0.447		0.8, 1.61*		0.17, 0.34		0.01, 0.03		0.274, 0.548	

Table 26. Batch experiment results for sediment H39933 at 23°C. Additional results can be found in Appendix B. The starting solution concentrations for ITB1 and ITB2 can be found in Table 22.

Sample Time	B39933 23°C Solution	pH		Ba (μg/L)		Fe (μg/L)		Sr (μg/L)		Al (μg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD	Ave	SD
4 hour	AGW	7.90	-	7.995	0.40	ND	-	ND	-	ND	-	6.20	0.11	4.72	1.04	18.10	0.71	3.71	0.03	6.82	0.06
	ITB1	8.16	-	41.6	-	ND	-	238.5	0.71	ND	-	22.0	0.14	6.29	1.75	56.10	0.85	20.45	0.07	21.65	0.07
	ITB2	8.31	-	42.35	5.16	ND	-	243	4.24	ND	-	32.4	0.35	6.82	1.52	56.20	0.99	21.05	0.21	21.95	0.35
1 day	AGW	7.75	-	12.20	0.99	83.80	-	46.20	2.55	ND	-	6.33	0.11	4.18	0.11	18.35	0.64	4.34	0.10	7.08	0.03
	ITB1	7.53	-	43.7	1.41	ND	-	270.5	3.54	ND	-	21.5	0.28	5.68	0.11	61.25	1.06	19.90	0.14	21.65	0.21
	ITB2	7.63	-	43.5	3.25	88.7	-	269.5	0.71	ND	-	30.5	0.49	5.93	0.08	60.70	0.42	20.15	0.07	21.70	0.00
7 day	AGW	7.70	-	ND*	-	ND	-	ND	-	ND	-	6.19	0.08	3.33	0.25	17.75	0.49	4.65	0.00	7.74	0.04
	ITB1	7.84	-	54.75	0.64	ND	-	268.5	9.19	ND	-	20.8	0.85	4.54	0.40	61.10	2.69	20.65	0.78	22.30	0.42
	ITB2	7.88	-	56.4	3.96	394	-	266	9.90	ND	-	29.2	1.06	5.08	0.60	59.75	1.91	20.40	1.13	22.05	1.34
14 day	AGW	7.54	0.00	ND*	-	ND	-	ND	-	ND	-	5.35	0.21	3.33	0.25	16.60	0.57	4.66	0.00	8.41	0.05
	ITB1	7.81	-	56.35	0.35	ND	-	261.5	0.71	ND	-	19.20	0.14	5.76	1.73	59.35	0.07	20.05	0.07	22.95	0.21
	ITB2	7.87	-	61.1	4.38	ND	-	275	4.24	ND	-	28.60	0.42	6.40	0.40	61.70	1.13	20.85	0.07	23.75	0.35
28 day	AGW	7.41	0.08	ND*	-	ND	-	ND	-	ND	-	5.86	0.48	5.15	0.56	16.95	0.07	4.46	0.01	7.65	0.03
	ITB1	7.78	-	51.5	1.27	ND	-	243.5	6.36	ND	-	18.50	0.28	5.64	0.59	57.05	1.48	19.15	0.35	20.85	0.35
	ITB2	7.89	-	55.1	0.85	ND	-	249	1.41	ND	-	26.75	0.07	5.78	0.96	57.75	0.21	19.35	0.21	21.05	0.35
42 day	AGW	8.31	-	29.20	3.68	ND	-	ND	-	ND	-	6.52	0.34	2.60	1.20	19.10	1.56	4.81	0.59	8.91	1.04
	ITB1	7.89	-	56.75	0.07	ND	-	237.5	0.71	ND	-	18.45	0.07	3.35	0.85	58.25	0.92	19.45	0.21	22.50	0.14
	ITB2	8.18	-	57.8	0.85	ND	-	228.5	2.12	ND	-	25.30	0.42	2.55	0.57	55.90	0.28	18.60	0.28	21.25	0.49
60 day	AGW	7.71	-	21.55	0.49	ND	-	ND	-	ND	-	5.18	0.57	3.22	-	16.00	0.42	4.42	0.13	8.10	0.19
	ITB1	7.95	-	57.2	0.28	ND	-	218.5	7.78	ND	-	17.30	0.99	3.03	1.10	53.45	1.34	18.65	0.35	21.00	0.28
	ITB2	8.05	0.10	57.8	0.42	ND	-	219	4.24	ND	-	24.50	0.85	3.22	-	52.80	0.99	18.10	0.28	20.35	0.21
Detection limits				3.09-7.87, 32.8*		50, 100		31.4, 62.8		82.4, 165		0.223, 0.447		0.8, 1.61*		0.17, 0.34		0.01, 0.03		0.274, 0.548	

3.6 Geochemical Modeling of Pump and Treat Effluent and Batch Solutions

ITB1 and ITB2 effluent characteristics were analyzed as part of the batch experiments through the inclusion of blank samples—samples with no sediments added. These evaluations and the evaluation of any changes in the batch solution geochemistry during the experiments are discussed in this section along with the geochemical modeling of these using Geochemist's Workbench (GWB).

This initial modeling evaluation was conducted with limited data (only 4 and 24 h responses) available from the batch studies at the time. It will be expanded with the newly analyzed data and modified to reflect some of the observations from the overall batch studies. Results of these efforts will inform the design of the column analyses.

3.6.1 Solution Compositions

The AGW, P&T effluents from ITB1 and ITB2, and the supernatants from batch experiments that were equilibrated for 4h and 24h with the 200-ZP-1 sediments (sample B398H3) were used (in Table 27 through Table 29) for preliminary geochemical modeling. The geochemical modeling will expanded to include other samples used in the batch experiments and data points gathered beyond 24h.

The major cations in each of the solutions were Ca, Mg, K, Al, and Na, while the major anions were Cl, SO_4, CO_3, and NO_3. Other important aqueous components were Si and also F for the P&T effluents (ITB1 and ITB2). In general, P&T effluent concentrations of these elements were higher than AGW concentrations, as expected. The pH was also higher, 8.4 for ITB1 and ITB2 compared to 7.5 for AGW. The increasing temperature from 23 °C to 50 °C did not cause a significant change in chemical composition of AGW or P&T effluents. Minor constituents that were present in the P&T effluents but not in AGW were Sr and Sn. Other significant minor constituents included some contaminants, such as Ba, I, Pb, Mo, and U. Redox active species were present in the P&T effluents, with Fe in ITB1 and Mn in both ITB1 and ITB2, as well as Cr.

Equilibration of AGW, ITB1, and ITB2 with the sediment B398H3 for 4h and 24h caused changes in pH that were significant at 24h equilibration. After equilibration at 23 °C and 50 °C, the concentrations of Ca, Mg, K, I were increased and components that were not initially present in the AGW, such as Al, Ba, Sr, and Zn, were detected. For ITB1 and ITB2 effluents, a significant increase in Fe concentration was observed for the 23 °C experiment while for 50 °C the increase was less significant. Some increase in Mn concentration was also observed for ITB1 effluent after the 4h equilibration with the sediment. Slight concentration changes were also observed for Ca, Mg, K (ITB1), Si, Na, S. Contaminant concentrations, such as Ba, Mo (ITB1), Sr, and U, showed some increase with the addition of sediments. Al and Cr were detected after equilibration with the sediment for ITB1 and ITB2 effluents. Lastly, the concentrations of I slightly decreased after ITB1 and ITB2 were reacted with sediment.

Table 27. AGW and batch supernatant (equilibrated for 4 and 24 hours) analysis results at 23 °C and 50 °C (average of 2 replicates).

Sediment	Solution	Reaction Time	Temp.	pH	Major components						Minor components					
					Ca	Mg	K	Si	Na	S	Al	^{138}Ba	^{127}I	Sr	Zn	Cl
		hours	°C		mg/L						µg/L					
Blank	AGW	4h	23	7.86	18.15	3.16	6.685	6.815	6.035	16.6	ND	ND	0.795	ND	ND	19.4
B398H3	AGW	4h	23	7.86	23.55	4.035	9.45	6.9	5.615	16.45	152.5	10.15	1.18	34.5	136	NA
B398H3	AGW	4h	50	7.89	21.45	4.185	5.785	7.435	5.735	16.55	184	12.45	1.29	40.4	ND	NA

Sediment	Solution	Reaction Time	Temp	pH	Major components						Minor components						
					Ca	Mg	K	Si	Na	S	Al	^{137}Ba	^{127}I	Sr	Zn	Sn	Cl
		hours	°C		mg/L						µg/L						
Blank	AGW	24h	23	7.79	19.05	3.075	4.495	6.73	6.075	16.25	ND	ND	NA	ND	ND	ND	19.4
B398H3	AGW	24h	23	8.76	19.7	4.75	3.495	7.93	6.42	17.15	ND	12.5	NA	62.25	136	ND	NA
B398H3	AGW	24h	50	8.36	20.8	5.015	3.865	10.75	6.365	16.8	ND	21.55	NA	90.65	ND	78.25	NA

Cl at 19.4 mg/L was used as counteranion in all the simulations.

Table 28. ITB1 effluent and batch supernatant (equilibrated for 4 and 24 hours) analysis results at 23 °C and 50 °C (average of 2 replicates).

Sediment	Solution	Reaction Time	Temp	pH	Major components						Minor components														
					Ca	Mg	K	Si	Na	S	Al	^{138}Ba	^{127}I	Sr	Zn	^{52}Cr	Fe	^{208}Pb	Mn	^{95}Mo	Sn	Ti	^{238}U	F	NO_3
		hours	°C		mg/L						µg/L														
Blank	ITB1	4h	23	8.18	57.85	21.55	6.165	22.85	23.05	32.05	ND	19.85	19.9	248.5	ND	ND	62.5	ND	ND	15.05	335.5	ND	0.90	0.495	25.8
B398H3	ITB1	4h	23	8.33	60.65	21.25	6.355	21.55	20.5	29.95	736	38.55	19.5	309.5	37.5	9.96	630	3.49	18.7	33.15	326	19.8	1.10	NA	NA
B398H3	ITB1	4h	50	8.42	58.75	20.85	6.05	22.25	21.4	30.9	412.5	27.2	19	292.5	ND	8.88	82.7	ND	17.6	14.05	314.5	ND	0.99	NA	NA

Sediment	Solution	Reaction time	Temp	pH	Major components						Minor components												
					Ca	Mg	K	Si	Na	S	Al	^{137}Ba	^{127}I	Sr	Zn	^{52}Cr	Fe	^{208}Pb	Mn	^{95}Mo	Sn	F	NO_3
		hours	°C		mg/L						µg/L												
Blank	ITB1	24h	23	7.69	61.25	20.35	5.405	22.2	22.45	30.95	ND	18.75	NA	276	ND	ND	ND	ND	ND	13.65	ND	0.495	25.8
B398H3	ITB1	24h	23	7.69	57.1	21.35	4.69	22.55	22.15	31.55	ND	36.75	NA	322.5	ND	ND	ND	2.49	ND	14.75	372	NA	NA
B398H3	ITB1	24h	50	7.97	56.7	21	5.355	24.8	22.75	32.1	ND	46.75	NA	357	ND	ND	ND	ND	12.4	14.85	366.5	NA	NA

Table 29. ITB2 effluent and batch supernatant (equilibrated for 4 and 24 hours) analysis results at 23 °C and 50 °C (average of 2 replicates).

Sediment	Solution	Reaction time	Temp	pH	Major components						Minor components												
					Ca	Mg	K	Si	Na	S	Al	^{138}Ba	^{127}I	Sr	^{52}Cr	Fe	^{208}Pb	Mn	^{95}Mo	Sn	^{238}U	F	NO_3
		hours	°C		mg/L						µg/L												
Blank	ITB2	4h	23	8.37	56.95	21.1	6.585	22.55	32.05	32.4	ND	21.95	15	244.5	ND	ND	11.8	52.3	15.6	355.5	0.983	0.51	18.7
B398H3	ITB2	4h	23	8.26	58.25	21.05	8.255	22.05	31.45	32.45	290	32.05	14.1	298	7.78	65.7	ND	ND	15.7	320.5	1.055	NA	NA
B398H3	ITB2	4h	50	8.36	57.45	20.5	6.46	22.1	30.5	31.6	201	25.75	14.4	285	7.09	ND	ND	46.1	14.5	302	1.075	NA	NA

Sediment	Solution	Reaction time	Temp	pH	Major components						Minor components											
					Ca	Mg	K	Si	Na	S	Al	^{137}Ba	^{127}I	Sr	^{52}Cr	Fe	^{208}Pb	Mn	^{95}Mo	Sn	F	NO_3
		hours	°C		mg/L						µg/L											
Blank	ITB2	24h	23	7.7	61.3	20.05	5.875	21.95	30.95	31.55	ND	21.3	NA	271.5	ND	ND	ND	135.5	15.1	ND	0.51	18.7
B398H3	ITB2	24h	23	7.65	56.75	21.55	5.16	22.55	32.35	32.45	ND	35.1	NA	322.5	ND	ND	ND	61.5	15.6	380	NA	NA
B398H3	ITB2	24h	50	8.46	56.05	21.3	5.92	25.1	33.05	32.85	ND	43.65	NA	353	ND	ND	ND	33.5	16.7	355.5	NA	NA

3.6.2 GWB Modeling

3.6.2.1 AGW

The geochemical modeling of the batch samples with AGW, as presented in Table 30, indicated that all solutions were oversaturated with quartz. At 4 hour reaction time with the sediment and both temperatures, solutions appeared to be oversaturated with Al silicate (kaolinite, imogolite, and halloysite) as well as with Al (oxy)hydroxides (diaspore, gibbsite, $Al(OH)_3$,boehmite, and Al_2O_3). However, after 24 hours reaction time, the modeling data indicated that the solution is no longer saturated with any of the Al phases. Instead the solution phase appeared to be in equilibrium with a Mg silicate (sepiolite) phase. The solutions also remained in equilibrium with SiO_2 solids (quartz and chrysotile). Other phases, such as Sn oxides and hydroxides were also shown to be in equilibrium with the AGW solution at 50 °C. Aqueous speciation of AGW shown in Table 20 revealed that, at experimental pH, the major anions were respectively SO_4^{2-} and Cl^-, while the neutral H_4SiO_4 is the dominant silicate species.

Table 30. Geochemical modeling AGW batch samples, showing solid saturation before and after equilibration with B398H3 sediment for 4h and 24h, at 23 °C and 50 °C.

Sediment	Solution	Reaction time	**Input Data**		**Output Data**									
			Fixed components		**pCO_2 log fugacity**	**Saturation Indexes log Q/K**								
						SiO_2	**Aluminum Silicates**			**Al (oxy)hydroxides**				
			Temp °C	pH		Quartz	Kaolinite	Imogolite	Halloysite	Diaspore	Gibbsite	$Al(OH)_3$ (Soil)	Boehmite	Al_2O_3
Blank	AGW	4h	23	7.9	N/A	0.40								
B398H3	AGW	4h	23	7.9		0.41	5.28	3.28	3.10	3.07	2.20	1.65	1.34	0.16
B398H3	AGW	4h	50	7.9		0.11	2.26	0.90	0.57	1.95	1.11	0.56	0.45	

Sediment	Solution	Reaction time	**Input Data**		**Output Data**					
			Fixed components		**pCO_2 log fugacity**	**Saturation Indexes log Q/K**				
						SiO_2		**MgSilicate**	**Sn-solids**	
			Temp °C	pH		Quartz	Chrysotile	Sepiolite	SnO_2	$H_2Sn(OH)_6$
Blank	AGW	24h	23	7.8	N/A	0.40				
B398H3	AGW	24h	23	8.8		0.44	1.45	0.72		
B398H3	AGW	24h	50	8.4		0.25	2.26	1.24	5.70	0.25

Table 31. Geochemical modeling of AGW batch samples, showing major aqueous species before and after equilibration with B398H3 sediment for 4h and 24h, at 23 °C and 50 °C.

Sediment	Solution	Reaction time	**Input Data**		**Output Data**										
			Fixed components		**Major Aqueous species mg/L**										
			Temp °C	pH	Ca^{2+}	Na^{+}	K^{+}	Mg^{2+}	$CaSO_4$ (aq)	$MgSO_4$ (aq)	SO_4^{2-}	Cl^{-}	H_4SiO_4	$H_3SiO_4^{-}$	$Al(OH)_4^{-}$
Blank	AGW	4h	23	7.86	16.964	6.019	6.664	2.990	3.951	0.809	46.188	19.367	23.129	0.186	
B398H3	AGW	4h	23	7.86	22.085	5.601	9.422	3.829	4.874	0.982	44.930	19.357	23.413	0.189	0.522
B398H3	AGW	4h	50	7.89	19.801	5.723	5.762	3.928	5.539	1.222	44.596	19.363	24.726	0.710	0.635

Sediment	Solution	Reaction time	**Input Data**		**Output Data**									
			Fixed components		**Major Aqueous species mg/L**									
			Temp °C	pH	Ca^{2+}	Na^{+}	K^{+}	Mg^{2+}	$CaSO_4$ (aq)	$MgSO_4$ (aq)	SO_4^{2-}	Cl^{-}	H_4SiO_4	$H_3SiO_4^{-}$
Blank	AGW	24h	23	7.79	17.826	6.060	4.482	2.913	4.060	0.771	45.113	19.367	22.866	0.157
B398H3	AGW	24h	23	8.76	18.404	6.403	3.484	4.491	4.317	1.224	47.252	19.367	25.472	1.634
B398H3	AGW	24h	50	8.36	19.174	6.351	3.850	4.697	5.421	1.477	45.233	19.363	33.870	2.871

3.6.2.2 ITB1 and ITB2 Effluents

Geochemical modeling of the ITB1 effluent, prior to reaction with the sediment (i.e., blank sample), revealed that this solution was oversaturated with several solid phases as shown in Table 32. As expected from analytical data and the measured pH, these solids include Fe(oxy)hydroxides (e.g., ferrihydrite), as well as Mg silicates, SiO_2 polymorphs, and Sn-solids. Although some of these phases are high temperature solids and will not precipitate at lower temperature (e.g., quartz, dolomite, hematite, etc.), a few others, in particular ferrihydrite, would precipitate at ambient conditions.

After 4h reaction time of the ITB1 effluent with the sediments from sample B398H3, the supernatants of the batch sample became saturated with Al (oxy)hydroxides and Al silicates at both temperatures. This behavior is similar to the observed results for the batch samples with the AGW (as discussed in the previous section), indicating high concentrations of Al in the 200-ZP-1 sediments. This is consistent with the QXRD results discussed in Section 3.3; the sample B398H3 showed 45% feldspar in that analysis. Similar to the results observed in the batch samples with the AGW, the supernatant at 24h reaction time no longer showed oversaturation with Fe(oxy)hydroxides or Al(oxy)hydroxides. This could be indicative that Al and Fe solids were already precipitated at this time. The supernatants, however, became oversaturated with carbonate solids at higher temperature as can be seen by saturation indexes in Table 32. This is due to carbonates being retroactive solids and precipitating as temperatures increase. The aqueous speciation of ITB1 effluent, as shown in Table 34 indicates that, at the experimental pH, Ca, Na, K, and Mg were the dominant cations and major anions were SO_4^{2-}, Cl^-, and NO_3^-. Ca and Mg bicarbonate and sulfate complexes were also observed in the results. The variation in pH only slightly increases the contributions of CO_3^{2-}, H_2CO_3 as well as $H_3SiO_4^-$ as aqueous species.

The modeling results shown in Table 35 and Table 37 for the batch samples with the ITB2 effluent are very similar to those described for ITB1 above with respect to solid saturation, type(s) of solid phases observed, and the dominant aqueous species in solution identified. We note that some of the data show a significant decrease in pH by approximately 1 unit. This decrease may have an effect on pCO_2 value and the solid saturations. As an example, the decrease in pH from 8.37 to 7.7 for the ITB2 effluent (data for the blanks sample at 4h versus 24 hours at 23 °C) resulted in solution becoming undersaturated with Mg silicates (sepiolite and chrysotile) at 23 °C.

These modeling results were computed using Fe(III) and Mn(II) as the oxidized Fe, and reduced Mn aqueous species, without considering redox reactions. Therefore, additional simulations were also computed with the corresponding species, Fe(II) and Mn(III), to observe whether at given experimental conditions, the solid saturations with respect to these species is reached if the redox reactions were allowed. The results indicate the potential for additional precipitation that may occur in the system, if these species exist. Additional precipitation may impact the injectivity around the wells.

If Fe(II) and Mn(II) are added as the reduced species then the solution becomes saturated with Fe(II)-silicate, Fe(II)-aluminate. This is the case for the sample with the highest Fe concentration, 630 µg/L (B398H3-ITB1-4h-23 °C, Table 17). If instead Fe(III) and Mn(III) are added as oxidized species in solution then (Mn, Fe)$_2$O$_3$ phase becomes highly oversaturated (i.e., bixbyite, which is a Mn/Fe oxide, saturation index of logQ/K=45.0). We note that saturation with respect to these new phases is in addition to saturated solids already shown in Table 21. The results from ITB2-blank at 24h were also used to recalculate saturation state, by selecting Fe(III) and Mn(III) as oxidized species. This sample was selected based on the highest Mn concentration. The result shows that bixbyite (Mn, Fe)$_2$O$_3$ is predicted to be oversaturated, in addition to SiO$_2$, and other carbonate solids. These results highlight the importance of determining the solution redox state at the time of collecting field samples either by measuring concentration of redox species or by measuring the Eh of solution. This will be considered for further laboratory analyses.

Table 32. Geochemical modeling ITB1 batch samples, showing solid saturation before and after equilibration with B398H3 sediment for 4h, at 23 °C and 50 °C.

Sediment	Solution	Reaction time	Input Data			Output Data										
			Fixed components		pCO$_2$ log fugacity	Saturation Indexes log Q/K										
						Carbonates				SiO_2			MgSilicates		Sulfates	
			Temp °C	pH		Dolomite ordered	Dolomite disordered	Calcite	Aragonite	Quartz	Chalcedony	Cristobalite	Sepiolite	Chrysotile	K-Jarosite	Cr(VI)-Jarosite
Blank	ITB1	4h	23	8.2	-3.76					0.9	0.5	0.3	1.0	0.7		
B398H3	ITB1	4h	23	8.3	-3.91			0.04		0.9	0.4	0.2	1.5	1.5	2.4	2.4
B398H3	ITB1	4h	50	8.4	-3.81	1.0	0.6	0.5	0.3	0.6	0.1		3.5	4.9		

Sediment	Solution	Reaction time	Input Data			4h reaction time Output Data Continues										
			Fixed components		pCO$_2$ log fugacity	Saturation Indexes log Q/K										
						Fe(oxyhydr)oxides and other Fe(III)-solids								SnO_2	$H_2Sn(OH)_6$	Rutile
			Temp °C	pH		Hematite	Magnesioferrite	Maghemite	$Fe(OH)_{2.7}Cl_{.3}$	Goethite	Lepidocrocite	Ferrihydrite aged	Ferrihydrite			
Blank	ITB1	4h	23	8.2	-3.76	17.0	11.7	9.4	7.6	7.3	6.5	5.2	4.6	6.6	1.2	
B398H3	ITB1	4h	23	8.3	-3.91	19.2	14.1	11.5	8.6	8.4	7.6	6.3	5.6	6.3	0.9	1.2
B398H3	ITB1	4h	50	8.4	-3.81	15.8	13.0	6.2	5.9	6.6	4.9	3.6	4.5	6.1	0.7	

Sediment	Solution	Reaction time	Input Data			4h reaction time Output Data Continues							
			Fixed components		pCO$_2$ log fugacity	Saturation Indexes log Q/K							
						Al(oxy)hydroxides					Aluminum Silicates		
			Temp °C	pH		Boehmite	Al_2O_3	Gibbsite (C)	$Al(OH)_3$ (soil)	Diaspore	Kaolinite	Halloysite	Imogolite
Blank	ITB1	4h	23	8.2	-3.76								
B398H3	ITB1	4h	23	8.3	-3.91	1.6	0.6	2.4	1.9	3.3	6.7	4.5	4.2
B398H3	ITB1	4h	50	8.4	-3.81	0.3		0.9	0.4	1.8	2.8	1.1	1.0

Table 33. Geochemical modeling ITB1 batch samples, showing solid saturation before and after equilibration with B398H3 sediment for 24h, at 23 °C and 50 °C.

Sediment	Solution	Reaction time	Input Data		Output Data										
			Fixed components		pCO_2 log fugacity	Saturation Indexes log Q/K									
						Carbonates		SiO_2			MgSilicates		SnO_2	$H_2Sn(OH)_6$	$Sn(OH)_4$
			Temp °C	pH		Dolomite ordered	Calcite	Quartz	Chalcedony	Cristobalite	Sepiolite	Chrysotile			
Blank	ITB1	24h	23	7.69	-3.28			0.9	0.5	0.3					
B398H3	ITB1	24h	23	7.69	-3.28			0.9	0.5	0.3			7.7	2.2	1.0
B398H3	ITB1	24h	50	7.97	-3.36	0.1	0.01	0.6	0.2	0.01	1.9	2.3	7.1	1.6	0.4

Table 34. Geochemical modeling of ITB1 batch samples, showing major aqueous species before and after equilibration with B398H3 sediment for 4h and 24h, at 23 °C and 50 °C

Sediment	Solution	Reaction time	Input Data		Output Data																		
			Fixed components		Major Aqueous species mg/L																		
			Temp °C	pH	Ca^{2+}	Na^+	K^+	Mg^{2+}	$CaSO_4$ (aq)	$MgSO_4$ (aq)	$CaHCO_3^+$	$MgHCO_3^+$	SO_4^{2-}	Cl^-	NO_3^-	HCO_3^-	CO_3^{2-}	H_2CO_3(aq)	H_4SiO_4	$H_3SiO_4^-$	F^-	$Al(OH)_4^-$
Blank	ITB1	4h	23	8.18	52.8	22.9	6.1	19.9	15.8	6.9	0.5	0.3	78.9	42.8	25.7	27.8	0.2	0.4	76.8	1.3	0.5	
B398H3	ITB1	4h	23	8.33	55.6	20.4	6.3	19.7	15.5	6.4	0.5	0.2	73.4	42.8	25.7	27.7	0.3	0.3	71.9	1.8	0.5	2.6
B398H3	ITB1	4h	50	8.42	52.7	21.3	6.0	19.0	18.4	7.4	0.6	0.3	73.4	42.8	25.7	27.1	0.6	0.2	69.0	7.0	0.5	1.4

Sediment	Solution	Reaction time	Input Data		Output Data																	
			Fixed components		Major Aqueous species mg/L																	
			Temp °C	pH	Ca^{2+}	Na^+	K^+	Mg^{2+}	$CaSO_4$ (aq)	$MgSO_4$ (aq)	$CaHCO_3^+$	$MgHCO_3^+$	SO_4^{2-}	Cl^-	NO_3^-	HCO_3^-	CO_3^{2-}	H_2CO_3(aq)	H_4SiO_4	$H_3SiO_4^-$	F^-
Blank	ITB1	24h	23	7.69	56.1	22.4	5.4	18.9	16.1	6.3	0.5	0.2	75.9	42.8	25.7	27.3	0.1	1.2	75.5	0.4	0.5
B398H3	ITB1	24h	23	7.69	52.2	22.1	4.7	19.8	15.4	6.8	0.5	0.2	77.8	42.8	25.7	27.3	0.1	1.2	76.7	0.4	0.5
B398H3	ITB1	24h	50	7.97	51.7	23.1	5.4	19.5	18.8	7.9	0.6	0.3	78.0	43.6	26.2	28.1	0.2	0.5	83.5	3.0	0.5

Table 35. Geochemical modeling ITB2 batch samples, showing solid saturation before and after equilibration with B398H3 sediment for 4h, at 23 °C and 50 °C.

Sediment	Solution	Reaction time	Input Data		Output Data									
			Fixed components		pCO_2 log fugacity	Saturation Indexes log Q/K								
						Carbonates				SiO_2			MgSilicates	
			Temp °C	pH		Dolomite ordered	Dolomite disordered	Calcite	Aragonite	Quartz	Chalcedony	Cristobalite	Sepiolite	Chrysotile
Blank	ITB2	4h	23	8.37	-3.92	0.1		0.1		0.9	0.5	0.3	1.7	1.8
B398H3	ITB2	4h	23	8.26	-3.81					0.9	0.5	0.3	1.3	1.1
B398H3	ITB2	4h	50	8.36	-3.72	0.9	0.5	0.4	0.3	0.6	0.1		3.3	4.5

Sediment	Solution	Reaction time	Input Data		4h reaction time Output Data Continues								
			Fixed components		pCO_2 log fugacity	Saturation Indexes log Q/K							
						Fe(oxyhydr)oxides							
			Temp °C	pH		Hematite	Magnesioferrite	Maghemite	$Fe(OH)_{2.7}Cl_{.3}$	Goethite	Lepidocrocite	Ferrihydrite aged	Ferrihydrite
Blank	ITB2	4h	23	8.37	-3.06								
B398H3	ITB2	4h	23	8.26	-2.94	17.2	12.0	9.5	7.7	7.4	6.6	5.3	4.6
B398H3	ITB2	4h	50	8.36	-2.88								

Sediment	Solution	Reaction time	Input Data		4h reaction time Output Data Continues									
			Fixed components		pCO_2 log fugacity	Saturation Indexes log Q/K								
						Al(oxy)hydroxides				Aluminum Silicates			SnO_2	$H_2Sn(OH)_6$
			Temp °C	pH		Boehmite	Gibbsite (C)	$Al(OH)_3$ (soil)	Diaspore	Kaolinite	Halloysite	Imogolite		
Blank	ITB2	4h	23	8.37	-3.06								6.3	0.8
B398H3	ITB2	4h	23	8.26	-2.94	1.2	2.1	1.5	2.9	6.0	3.8	3.5	6.4	1.0
B398H3	ITB2	4h	50	8.36	-2.88	0.01	0.7	0.1	1.5	2.3	0.6	0.5	6.2	0.8

Table 36. Geochemical modeling ITB2 batch samples, showing solid saturation before and after equilibration with B398H3 sediment for 24h, at 23 °C and 50 °C.

Sediment	Solution	Reaction time	**Input Data**		**Output Data**													
			Fixed components		**pCO_2 log fugacity**	**Saturation Indexes log Q/K**												
						Carbonates					SiO_2			MgSilicates		SnO_2	$H_2Sn(OH)_6$	$Sn(OH)_4$
			Temp °C	pH		Dolomite ordered	Dolomite disordered	Calcite	Aragonite	Vaterite	Quartz	Chalcedony	Cristobalite	Sepiolite	Chrysotile			
Blank	ITB2	24h	23	7.7	-3.26						0.9	0.5	0.3					
B398H3	ITB2	24h	23	7.7	-3.21						0.9	0.5	0.3			7.7	2.3	1.0
B398H3	ITB2	24h	50	8.5	-3.82	1.1	0.7	0.5	0.4	0.01	0.6	0.2		3.8	5.2	6.1	0.6	

Table 37. Geochemical modeling of ITB2 batch samples, showing major aqueous species before and after equilibration with B398H3 sediment for 4h and 24h, at 23 °C and 50 °C

Sediment	Solution	Reaction time	**Input Data**		**Output Data**																				
			Fixed components		**Major Aqueous species mg/L**																				
			Temp °C	pH	Ca^{2+}	Na^+	K^+	Mg^{2+}	$CaSO_4$ (aq)	$MgSO_4$ (aq)	$CaHCO_3^+$	$MgHCO_3^+$	SO_4^{2-}	Cl^-	NO_3^-	HCO_3^-	CO_3^{2-}	H_2CO_3(aq)	H_4SiO_4	$H_3SiO_4^-$	F^-	$Al(OH)_4^-$
Blank	ITB2	4h	23	8.2	51.9	31.9	6.6	19.5	15.6	6.8	0.5	0.3	80.1	54.3	18.6	29.9	0.4	0.3	75.1	2.0	0.5	
B398H3	ITB2	4h	23	8.3	53.1	31.3	8.2	19.4	15.9	6.8	0.6	0.3	80.1	54.3	18.6	29.9	0.3	0.4	73.8	1.6	0.5	1.0
B398H3	ITB2	4h	50	8.4	51.5	30.4	6.4	18.6	18.2	7.3	0.7	0.3	75.5	54.3	18.6	29.3	0.6	0.2	69.4	6.1	0.5	0.7

Sediment	Solution	Reaction time	**Input Data**		**Output Data**																	
			Fixed components		**Major Aqueous species mg/L**																
			Temp °C	pH	Ca^{2+}	Na^+	K^+	Mg^{2+}	$CaSO_4$ (aq)	$MgSO_4$ (aq)	$CaHCO_3^+$	$MgHCO_3^+$	SO_4^{2-}	Cl^-	NO_3^-	HCO_3^-	CO_3^{2-}	H_2CO_3(aq)	H_4SiO_4	$H_3SiO_4^-$	F^-
Blank	ITB2	24h	23	7.7	56.1	30.8	5.8	18.6	16.3	6.3	0.6	0.2	77.5	54.3	18.6	29.4	0.1	1.3	74.6	0.4	0.5
B398H3	ITB2	24h	23	7.7	51.8	32.2	5.1	19.9	15.5	7.0	0.5	0.3	80.2	54.3	18.6	29.3	0.1	1.4	76.7	0.4	0.5
B398H3	ITB2	24h	50	8.0	50.0	32.9	5.9	19.3	18.3	7.9	0.7	0.3	78.6	54.3	18.6	29.1	0.7	0.2	77.2	8.5	0.5

3.6.2.3 Aqueous Speciation of Contaminants

Modeling of the aqueous speciation of contaminants of interest was also conducted as part of this effort to support the evaluation of changes in contaminant distributions with respect to injection of P&T effluent injection. These results are reported here for I, Cr, and U, and are tabulated in Table 38. Note that speciation of total iodine is used as a surrogate to represent the type of speciation that would occur for I-129, if present.

As expected and in the absence of redox reactions, I^- is the major iodine aqueous species, accounting for 99.99 % of total I. The Cr speciation is distributed among two major species, CrO_4^{2-} that consist of 65 to 67% of total dissolved Cr and the neutral $CaCrO_4$ which accounts for 32-34 % of the total aqueous Cr. With respect to uranium, the neutral $Ca_2UO_2(CO_3)_3$ is the major species, consisting of 97-98% of total dissolved UO_2^{2+}.

Table 38. The aqueous speciation of the contaminants of interest for batch samples with AGW, ITB1 effluent, and ITB2 effluent before and after equilibration with the B398H3 sediment.

Sediment	Solution	Temp. °C	Reaction time	pH	Contaminants of interest, aqueous speciation						
					Iodine		Chromium				
					I^-	KI (aq)	CrO_4^{2-}	$CaCrO_4$ (aq)	$HCrO_4^-$	$NaCrO_4^-$	$KCrO_4^-$
					%		%				
Blank	AGW	23	4h	7.86	99.99	0.01	NA				
B398H3	AGW	23	4h	7.86	99.99	0.01					
B398H3	AGW	50	4h	7.89	99.99	0.01					
Blank	ITB1	23	4h	8.18	99.99	0.01	NA				
B398H3	ITB1	23	4h	8.33	99.99	0.01	64.92	34.06	0.75	0.24	0.04
B398H3	ITB1	50	4h	8.42	99.99	0.01	66.51	32.54	0.66	0.25	0.03
Blank	ITB2	23	4h	8.37	99.99	0.01					
B398H3	ITB2	23	4h	8.26	99.99	0.01	66.09	32.61	0.89	0.37	0.05
B398H3	ITB2	50	4h	8.36	99.99	0.01	67.16	31.68	0.76	0.36	0.04

Sediment	Solution	Temp. °C	Reaction time	pH	Contaminants of interest, aqueous speciation			
					Uranium			
					$Ca_2UO_2(CO_3)_3$ (aq)	$UO_2(CO_3)_3^{4-}$	$CaUO_2(CO3)_3^{2-}$	$UO_2(CO_3)_2^{2-}$
					%			
Blank	AGW	23	4h	7.86	NA			
B398H3	AGW	23	4h	7.86				
B398H3	AGW	50	4h	7.89				
Blank	ITB1	23	4h	8.18	96.84	0.93	1.01	1.22
B398H3	ITB1	23	4h	8.33	97.41	0.84	0.96	0.78
B398H3	ITB1	50	4h	8.42	97.81	0.27	1.04	0.89
Blank	ITB2	23	4h	8.37	97.18	1.00	1.04	0.77
B398H3	ITB2	23	4h	8.26	97.06	0.96	1.02	0.95
B398H3	ITB2	50	4h	8.36	97.63	0.29	1.07	1.01

4.0 Discussion

The 200 West P&T system is one of the key components of the final remedy selected for the 200-ZP-1 OU, and the interim remedial action selected for 200-UP-1 OU at the Hanford Site. In addition, the facility has been receiving water from several other sources, such as 200-DV-1 OU perched water, groundwater from the 200-BP-5 OU, and leachate from the ERDF. It is anticipated that the P&T system will continue to receive waters from other sources, which may include Modular Storage Unit (purge) water, groundwater near the Waste Management Area C, and Gable Gap. Furthermore, maintaining the injection capacity of the system has been a significant issue since the facility startup in 2012. Fouling issues at the injection wells have necessitated frequent well redevelopments and construction of new injection wells—with effects on the system performance and operational costs. Given the continuously changing nature of treatment plant effluent combined with issues observed at the injection wells, it is important to understand the impacts of the P&T operations on the 200 West aquifer, where the majority of the treated water is injected. This study aims at determining these impacts and providing a quantitative evaluation of aquifer capacity for the current conditions and potential future changes. This information would provide a technical basis for decisions related to the P&T system operations that support remedy optimization efforts and short- and long-term remedy decisions related to multiple OUs in the Central Plateau.

As part of this effort, a baseline assessment of the 200-ZP-1 sediments was conducted for a series of samples received from three injection wells constructed in the 200-ZP-1 OU (Table 3). There were 20 sediment samples analyzed from three locations. Future efforts could expand to include analysis of sediment samples from other locations within the 200- ZP-1 OU to enhance the understanding of the geochemical and microbiological signatures observed. The baseline assessment included a physical, geochemical, and microbiological characterization through a series of analyses (Tables 4-6) which resulted in measurement of: major geochemical constituents; physical parameters; soil carbon content; bacterial abundance; mineral phase(s); and contaminant distribution. A set of batch experiments was also conducted with the effluent samples received from the P&T effluents at ITB1 and ITB2, and also with AGW (to provide a baseline control). These experiments provided some preliminary results on potential geochemical reactions occurring in the aquifer with the injection of P&T effluent. Some of the analyses are ongoing and will be completed and reported at a later date. These results will provide the basis for designing a set of column experiments to further analyze the major reactions in the aquifer and will support additional characterization and modeling efforts.

Geochemical baseline characterization efforts, in general, showed that Ba, Al, Ca, Fe, Mg, K, Si, and Na are the major constituents in the samples analyzed. Differences between the water and acid extractions indicated various forms of Fe in the sediments. Overall, the elements observed in this study and their concentrations are in good agreement with the characterization data from the 200-UP-1 sediments (Brady et al. 2017) with only minor differences that indicate some Fe, Al, and Ba presence in pore water and occasional higher concentrations of Ca in the ZP-1 sediments. Further analyses of Fe and Mn—which are expected to be significant in the aquifer with respect to dissolution/precipitation reactions and the biofouling issues—will be conducted to understand the oxidation state of Mn and Fe in sediments sampled from the ZP-1 OU. For these analyses, X-ray absorption near edge structure (XANES) spectroscopy will be used. Taking advantage of access proposals at the Advanced Photon Source (APS) and the Stanford Synchrotron Radiation Lightsource (SSRL), select sediment sub-samples (50 – 100 mg) will be prepared in Teflon windows for bulk phase oxidation state analysis. Trends in oxidation state will be assessed as a function of sediment sample depth, geologic unit, and/or location.

Microbiological baseline evaluations indicated significant bacterial abundance in the sediments throughout the soil column. The carbon content of the sediments was also analyzed for the ZP-1 samples and compared to this microbiological baseline. While the carbon generally showed decreasing trends with and a low carbon content overall, the bacterial cell numbers were interestingly high. This indicates that any perturbation in the conditions of these sediments (e.g., increasing moisture content, or availability of substrate with the injection) may cause a significant effect in the geochemistry and the subsurface hydrology. Aqueous samples have been collected and preserved from the batch studies for microbiological analysis. The microbiological response will be quantified in these samples and compared among treatments to determine whether exposure to P&T effluent stimulated the growth of sediment associated bacteria—resulting in an increase of microbes present in the aqueous phase. Further, microbial viability and persistence in P&T effluent will be determined. Microbiology measurements will be coordinated with geochemistry for column experiments to quantitatively describe the temporal development (or evolution) of subsurface sediments in response to chronic exposure to effluent water and to quantify the distinct effects of effluent water chemistry. This effort will focus on quantifying the microbiological responses to effluent water chemistry over space and time.

The limited QXRD results provided a quantification of major solid phases in 200-ZP-1 sediments, which generally showed a significant amount of feldspar with some quartz, and some other minor minerals. These analyses along with the analyses of the clay fraction from the sediments are currently ongoing for the sediments used in the batch experiments which were exposed to the ITB1 and ITB2 effluents for a total of 60 days. The differences between the clean sediments and the sediments exposed to the P&T effluents will be analyzed to support the evaluation of major geochemical reactions occurring in the aquifer with the injection of P&T effluent. In addition, QXRD results from the clay fraction of these sediments will better identify the most reactive minerals within each sediment.

Batch experiment results have indicated that contact with effluent solutions caused changes in the aqueous concentrations of Si, K, Ba, Sr, and I, with inconsistent changes to other analytes as well. Overall, the batch experiments showed that the effluent samples tested had a minor effect on the aqueous concentration of elements. However, microbial analysis and post-experiment QXRD results may show changes that are not yet apparent in the batch experiment results reported here. In addition, with an established baseline, testing of potential P&T operational changes in the future through column experiments and modeling will allow for better understanding of potential effects of the effluent on the aquifer.

The P&T effluent characterization is an important component of evaluating the impact on the aquifer. In addition to the geochemical analysis of ITB1 and ITB2 effluents to provide information on solution components, a geochemical modeling (using GWB) of these effluents was also conducted. Both efforts indicated that major cations in the effluents were Ca, Mg, K, Al, and Na while the anions were found to be Cl, SO_4^{2-}, CO_3^-, and NO_3^-. The geochemical modeling was also expanded into analyzing some batch solution compositions limited to one sample and only 4 and 24h responses. This effort will continue to include all results from the batch experiments. It will also be further used to simulate reaction paths and model equilibration states (i.e., saturation state with respect to minerals, as well as compositional changes of solids and solutions) for assessing the sediment reactivity with groundwater and/or P&T effluents. These reactions will be constructed based on solution analytical data (from batch experiments) and the solid characterization results from QXRD.

Based on these results, a set of column experiments will be designed to further evaluate ZP-1 aquifer sediment conditions as they are exposed to the P&T effluent to further investigate unintended consequences and effects of P&T effluent injection on the subsurface and injection well conditions. In addition to solution characterization with the column studies, the solids will also be characterized using standard solid characterization techniques at the end. In addition, a reactive transport model of these column studies and a representative P&T injection well scenario will be developed using eSTOMP (Fang et al. 2018). These modeling efforts will provide a quantitative assessment of the aquifer impacts and system performance for the current conditions and as part of the predictive evaluations of future conditions.

5.0 Conclusions

Overall objective of this study is to determine the impacts of the 200 West P&T system effluent on the 200-ZP-1 aquifer and provide a quantitative evaluation of aquifer responses to the current system operation conditions and potential time dependent and spatial future changes. This information will provide a technical basis for decisions related to the short- and long-term P&T system operations that support remedy optimization efforts and remedy decisions related not only to the 200-ZP-1 OU but to multiple OUs in the Central Plateau.

Data collected to date establishes a baseline geochemical and microbiological characterization of the aquifer sediments in the 200-ZP-1 OU (for those not exposed to the P&T system effluent) that will be used for future evaluations and analyses. The results reported here indicate that the set of characterization data generated during this study are in good agreement with the data included in previous studies that investigated background properties of the 200-UP-1 sediments (Brady et al. 2017). In general, Ca, Mg, Fe, K, Si, Al, Ba, and Na were the major elements that were released into the aqueous phase from the ZP-1 sediments via desorption and/or dissolution reactions. These constituents were also identified in the batch experiments where the sediments were exposed to the P&T effluents. Importantly, some of the released elements, such as Fe, Al, Mg and Si underwent relatively rapid precipitation changing the liquid phase chemistry and the mineralogy of the sediment. Geochemical modeling indicated several solid phases that may be formed in these systems, including Fe(oxy)hydroxides (e.g., ferrihydrite), Al(oxy) hydroxides, Mg silicate, SiO_2 polymorphs, and Sn-solids. These solid phases, particularly ferrihydrite, may be important for evaluating the aquifer capacity and injectivity issues around the wells. Further efforts will use hydraulically saturated column experiments and will be directed to identification of the important reactions, completing the reaction network, determining the extent and rates of important reactions, and calculating relevant parameters that will be used in reactive transport modeling efforts to fit experimental data and predict aquifer responses to current and future changing conditions at the field scale.

Measuring microbiological activity and responses to changing conditions is important and this area requires further study. Microbiological baseline evaluations indicated significant bacterial abundance in the ZP-1 sediments throughout the soil column typically higher than the background levels determined elsewhere at the Hanford Site (Brockman et al. 2004). Microbial response to any perturbations in this system will be further evaluated because this response is usually coupled with and may cause significant changes in the geochemistry and the subsurface hydrology.

6.0 Quality Assurance

The results presented in this report originate from work governed by the Pacific Northwest National Laboratory (PNNL) Nuclear Quality Assurance Program (NQAP). The NQAP implements the requirements of the United States Department of Energy Order 414.1D, *Quality Assurance* and 10 CFR 830 Subpart A, *Quality Assurance Requirements*. The NQAP uses ASME NQA-1-2012, *Quality Assurance Requirements for Nuclear Facility Applications* as its consensus standard and NQA-1-2012 Subpart 4.2.1 as the basis for its graded approach to quality.

Two quality grading levels are defined by the NQAP:

Basic Research - The required degree of formality and level of work control is limited. However, sufficient documentation is retained to allow the research to be performed again without recourse to the original researcher(s). The documentation is also reviewed by a technically competent individual other than the originator.

Not Basic Research - The level of work control is greater than basic research. Approved plans and procedures govern the research, software is qualified, calculations are documented and reviewed, externally sourced data is evaluated, and measuring instrumentation is calibrated. Sufficient documentation is retained to allow the research to be performed again without recourse to the original researcher(s). The documentation is also reviewed by a technically competent individual other than the originator.

The work supporting the results presented in this report was performed in accordance with the *Basic Research* grading level controls.

7.0 References

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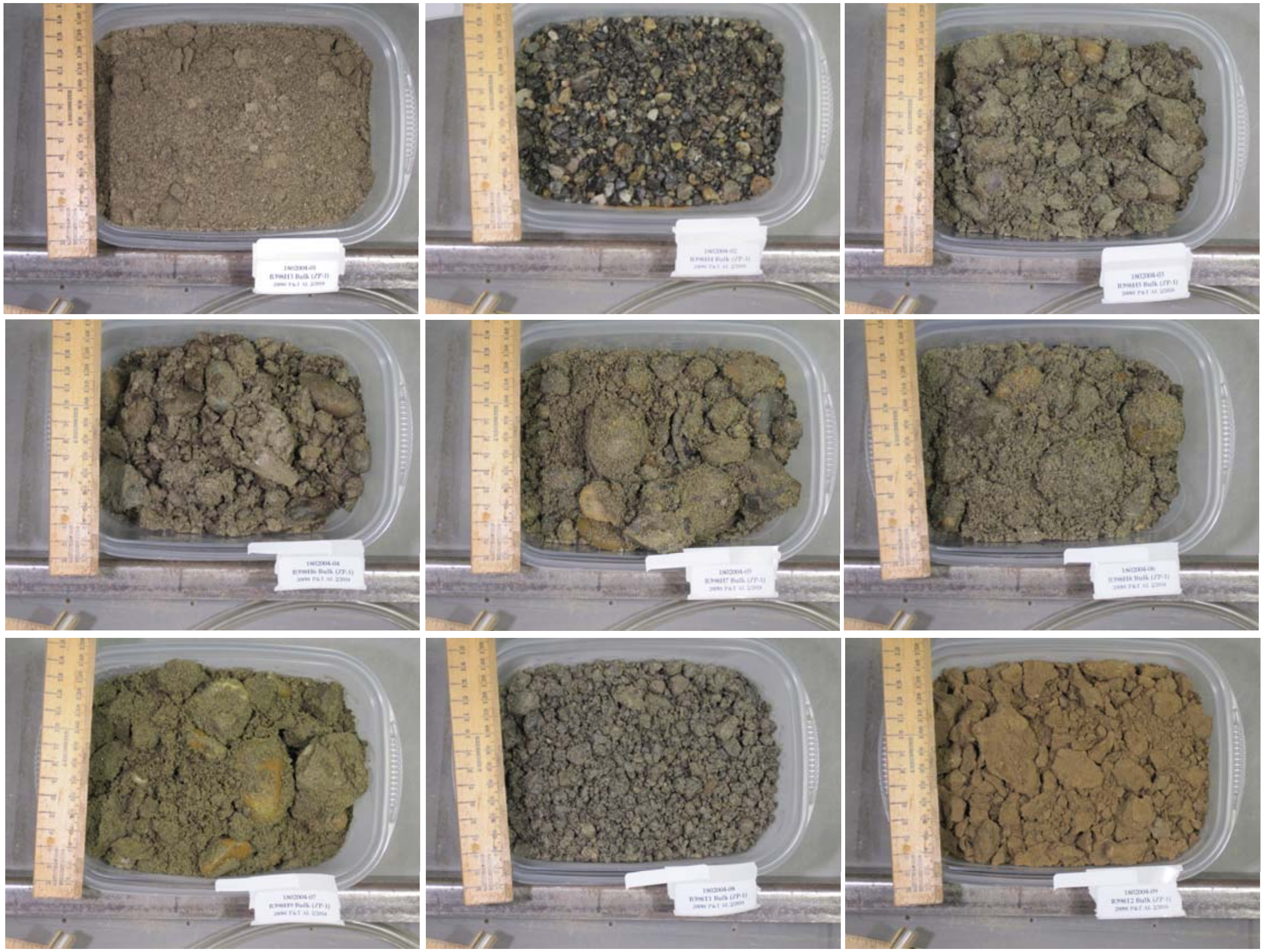
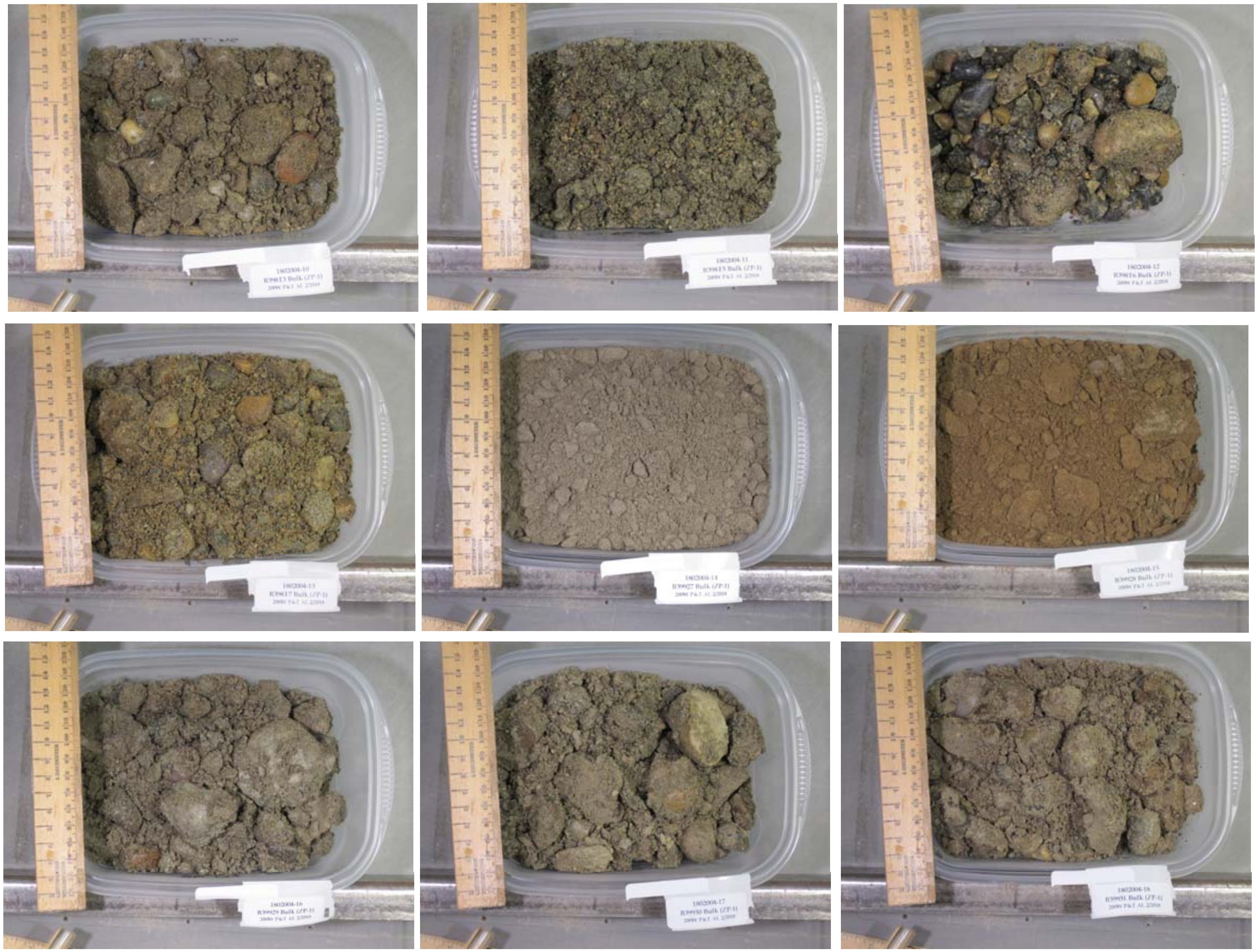
Appendix A

Sediment Physical Characterization

Photographs of cores, as received, after removing the materials from the lexan liners. First row, L to R: B398H3, B398H4, B398H5. Second row, L to R: B398H6, B398H7, B398H8. Third row, L to R: B398H9, B398T1, B398T2.

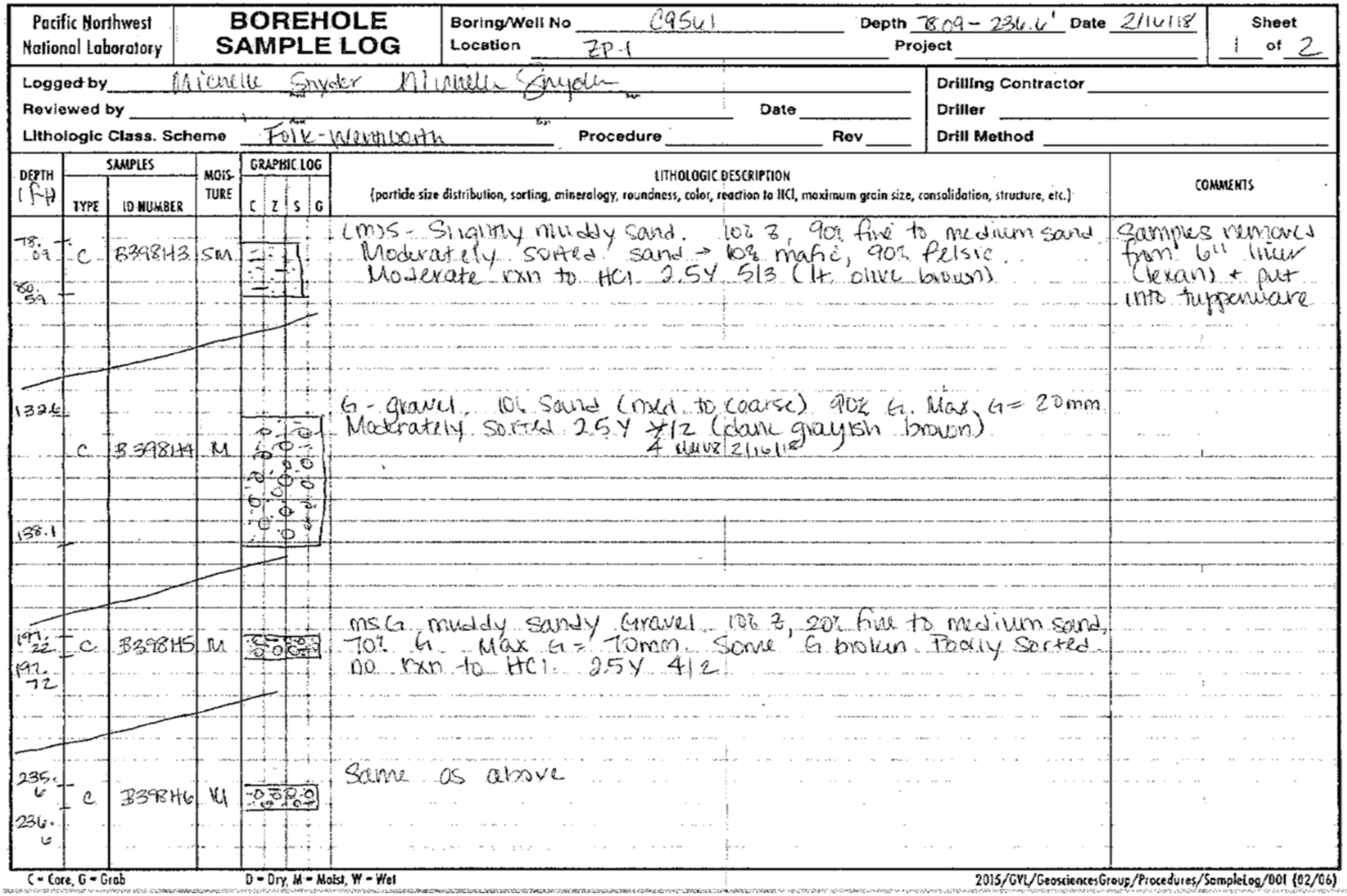


Photographs of cores, as received, after removing the materials from the lexan liners. First row, L to R: B398T3, B398T5, B398T6. Secone row, L to R: B398T7, B39927, B39928. Third row, L to R: B39929, B39930, B39931.



Photographs of cores, as received, after removing the materials from the lexan liners. L: B39932; R: B39933.

A.1 Geologic description logs for the 20 ZP-1 sediments included in this work



Pacific Northwest National Laboratory

BOREHOLE SAMPLE LOG

Boring/Well No C9561
Depth 78.09 – 236.6' Date 2/16/18
Sheet 1 of 2
Location ZP-1
Project
Logged by Michelle Snyder Michelle Snyder
Reviewed by
Date
Lithologic Class. Scheme Folk-Wentworth
Procedure
Rev
Drilling Contractor
Driller
Drill Method

DEPTH (ft)	SAMPLES TYPE	SAMPLES ID NUMBER	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, maximum grain size, consolidation, structure, etc.)	COMMENTS
78.09 80.59	C	B398H3	SM		(m)S - Slightly muddy sand. 10% Z, 90% fine to medium sand. Moderately sorted sand → 10% mafic, 90% felsic. Moderate rxn to HCl. 2.5Y 5/3 (lt. olive brown)	Samples removed from 6'' liner (lexan) + put into tupperware
132.6 138.1	C	B398H4	M		G - gravel. 10% Sand (med. to coarse) 90% G. Max G = 20mm. Moderately sorted 2.5Y ~~3~~/2 (dark grayish brown) 4 MVR 2/16/18	
197.22 197.72	C	B398H5	M		msG muddy sandy Gravel. 10% Z, 20% fine to medium sand, 70% G. Max G = 70mm. Some G broken. Poorly sorted. no rxn to HCl. 2.5Y 4/2	
235.6 236.6	C	B398H6	M		Same as above	

C = Core, G = Grab
D = Dry, M = Moist, W = Wet
2015/GVL/GeosciencesGroup/Procedures/SampleLog/001 (02/06)

Pacific Northwest National Laboratory	BOREHOLE SAMPLE LOG	Boring/Well No C9561	Depth ~~336.5~~ - 406.28'	Date 2/16/18	Sheet 2 of 2
		Location ZP-1	Project		

Logged by Michelle Snyder Michelle Snyder

Reviewed by

Date

Lithologic Class. Scheme Folk - Wentworth

Procedure

Rev

Drilling Contractor

Driller

Drill Method

DEPTH (ft)	SAMPLES TYPE	SAMPLES ID NUMBER	MOISTURE	GRAPHIC LOG C Z S G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, maximum grain size, consolidation, structure, etc.)	COMMENTS
336.5 – 336.65 –	C	B398H8	M		SG, sandy Gravel. 30% fine to medium sand, 70% G. Poorly Sorted. Max G = 60mm. 2.5Y 5/~~2~~ 3 ~~(grayish brown)~~ (lt. olive brown) no rxn to HCl. MMS 2/16/18	
					B398H7 - Duplicate of above (same geology)	
405.78 – 406.28 *	C	B398H9	M		mSG muddy sandy gravel. 5% Z, 25% fine to medium sand, 70% G. Max G = 55mm. Poorly Sorted. mica visible in sand. no rxn to HCl. 2.5Y 5/3	

C = Core, G = Grab

D = Dry, M = Moist, W = Wet

2015/GVL/GeosciencesGroup/Procedures/SampleLog/001 (02/06)

Pacific Northwest National Laboratory

BOREHOLE SAMPLE LOG

Boring/Well No C9563
Location ZP-1
Depth 77.85-408.99 Date 2/19/18
Project ZP-1
Sheet 1 of 1

Logged by Michelle Snyder Michelle Snyder
Reviewed by ______ Date ______
Lithologic Class. Scheme Folk-Wentworth Procedure ______ Rev ____
Drilling Contractor ______
Driller ______
Drill Method ______

DEPTH (ft)	SAMPLES TYPE	SAMPLES ID NUMBER	MOISTURE	GRAPHIC LOG (C Z S G)	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, maximum grain size, consolidation, structure, etc.)	COMMENTS
77.85 78.35	C	B398T1	M	▨	MG Muddy Gravel 15% Z, 5% sand, 80% G. Max G = 20mm Moderately sorted. 2.5Y 4/2 (dark grayish brown).	samples removed from 6" lexan liner + put into tupperware for geology + photo
140 140.5	C	B398T2	SM	▨	MMS 2/19/18 SM sandy mud 60% Z, 40% ~~Z~~ sand. Well sorted. Compacted. no rxn to HCl. 10YR 4/3 (brown)	
197.63 ~~198.~~ 13	C MMS 2/19/18	B398T3	M	▨	MMS 2/19/18 ~~MSG muddy~~, sandy gravel (SG) ~~G gravel~~. 5% Z, 20% sand, 75% G. poorly sorted. Max G = 68mm. no rxn to HCl. 2.5Y 6/3 (light olive brown)	
~~240~~ 340.2 340.7	C	B398T5	M	▨	MSG: muddy sandy gravel 10% Z, 50% sand, 40% G Poorly Sorted. Max G = 37mm 2.5Y 5/2 (grayish brown). B398T6 - Duplicate of above. More gravel: G = 5% Z, 10% sand, 85% G. Max G = 85mm	
407.99 408.99	C	B398T7	SM	▨	SG - sandy gravel. 30% sand, 70% Gravel. Max G = 53mm. Poorly sorted. no rxn to HCl. 2.5Y 5/4 (lt. olive brown)	

Pacific Northwest National Laboratory	**BOREHOLE SAMPLE LOG**	**Boring/Well No** C9565 **Depth** 78.79 - 338.63 **Date** 2/20/18 **Location** ZP-1 **Project**	**Sheet** 1 **of** 2

Logged by Michelle Snyder Michelle Snyder

Reviewed by **Date**

Lithologic Class. Scheme Folk-Wentworth **Procedure** **Rev**

Drilling Contractor

Driller

Drill Method

DEPTH (ft)	SAMPLES		MOISTURE	GRAPHIC LOG				LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, maximum grain size, consolidation, structure, etc.)	COMMENTS
	TYPE	ID NUMBER		C	Z	S	G		
78.79 80.79	C	B39927	SM					Sand: 5% Z, 95% fine to medium sand. 5% mafic, 95% felsic. Well-sorted. Weak rxn to HCl. 2.5Y 6/3 (lt. yellowish brown)	Samples removed from 6" lexan liner & put into tupperware
138.6 139.1	C	B39928	SM					(m)S Slightly muddy sand 20% Z, 79% fine to medium sand, 1% G. Trace G (one 10mm piece). no rxn to HCl. 7.5YR 4/4 MMS 2/20/18 (brown)	
198.02 198.52	C	B39929	M					mSG - Muddy sandy Gravel, 10% Z, 20% sand, 70% G. Poorly Sorted. Max G = 70mm. 2.5Y 5/2 (grayish brown).	
237.66 238.16	C	B39930	M					mSG: Same as above. Max G = 60mm. Some gravel broken from drilling	
338.13 338.63	C	B39931	M					mSG - Same as above. fine to medium sand - a lot of mica Visible. 2.5Y 5/3 (lt. olive brown).	

Pacific Northwest National Laboratory

BOREHOLE SAMPLE LOG

Boring/Well No C956~~8~~5 MMS 2/20/18 Depth 405.5-406.5' Date 2/20/18

Location ZP-1 200 West Project ZP-1

Sheet 2 of 2

Logged by Michelle Snyder Michelle Snyder

Reviewed by ______ Date ______

Lithologic Class. Scheme Folk-Wentworth Procedure ______ Rev ______

Drilling Contractor ______

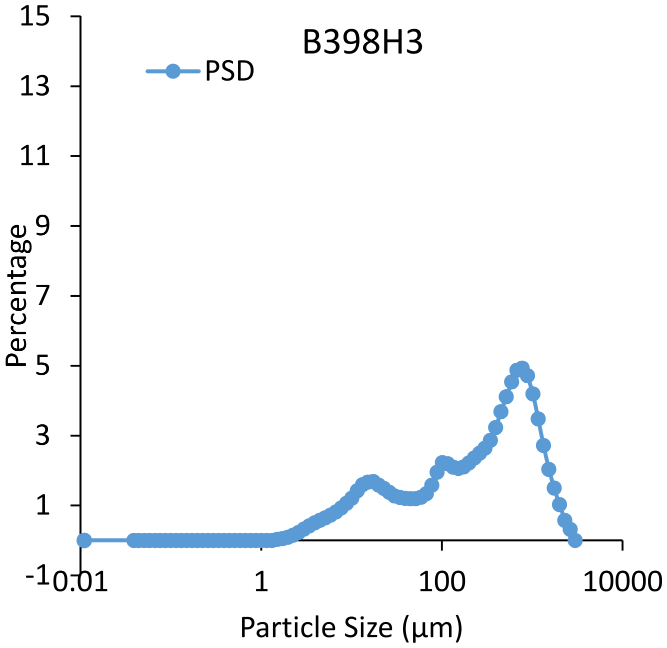
Driller ______

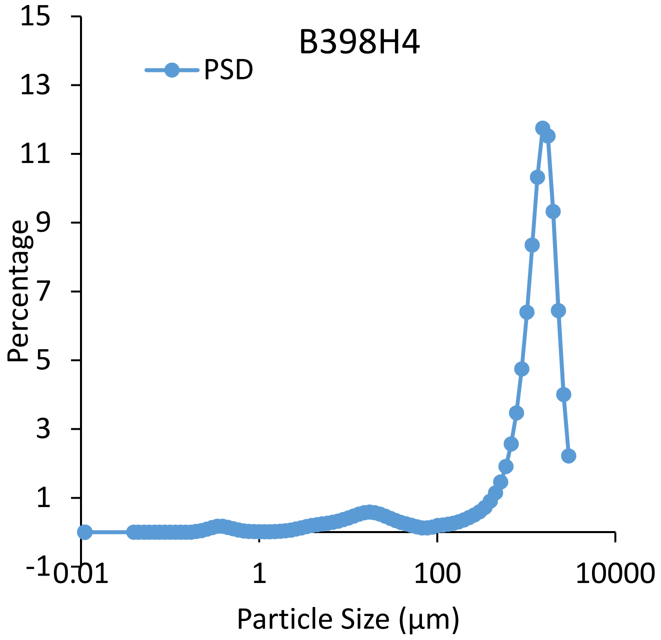
Drill Method ______

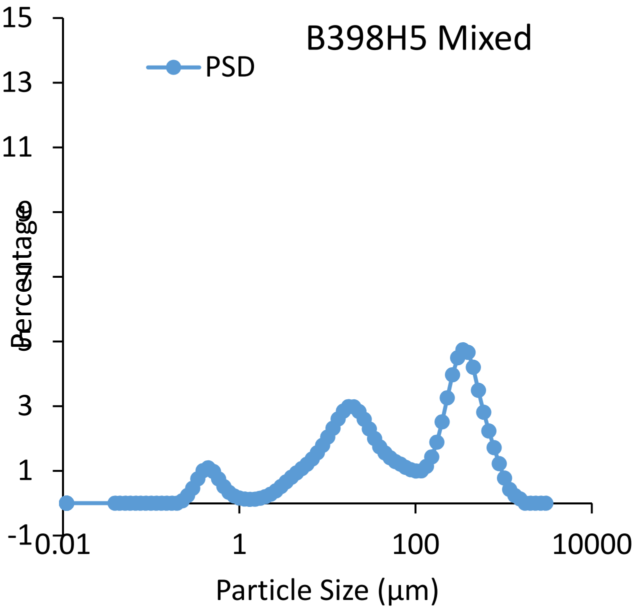
DEPTH (ft)	SAMPLES TYPE	SAMPLES ID NUMBER	MOISTURE	GRAPHIC LOG C	Z	S	G	LITHOLOGIC DESCRIPTION (particle size distribution, sorting, mineralogy, roundness, color, reaction to HCl, maximum grain size, consolidation, structure, etc.)	COMMENTS
MMS 2/20/18									
405.5			M					S- sand. fine to medium sand. Well sorted. Mica visible. 5% mafic, 95% felsic. r = rxn to HCl. 2.5Y 5/2 (grayish brown)	
406	C	B39933							
406.5	C	B39932	M						
								B39932 same as above	

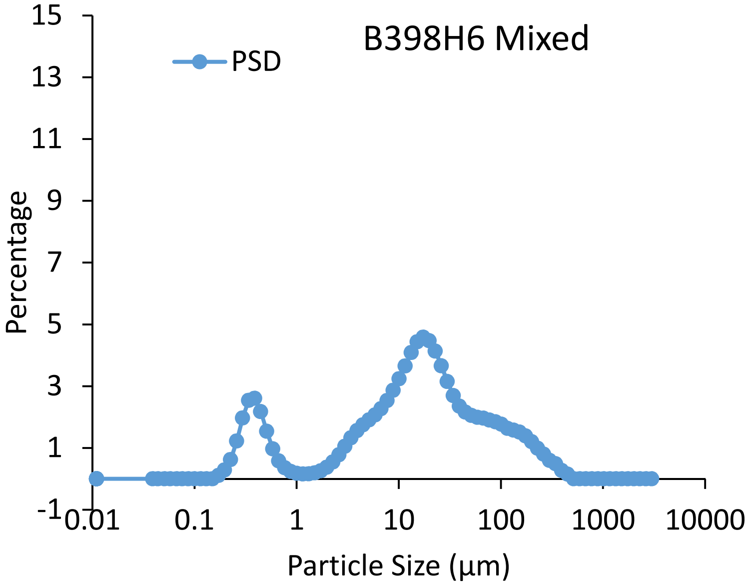
A.2 Particle Size Graphs

Sediment IDs are at the top center of each graph. IDs that do not include “mixed” are sediments that were visibly course and therefore the > 63 µm fraction was removed prior to laser analysis, but was used in calculating the PSD % and the cumulative percentages.






B398H5 Mixed
PSD
15
13
11
9
7
5
3
1
-1
0.01
1
100
10000
Percentage
Particle Size (µm)


B398H6 Mixed
PSD
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13
11
9
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3
1
-1
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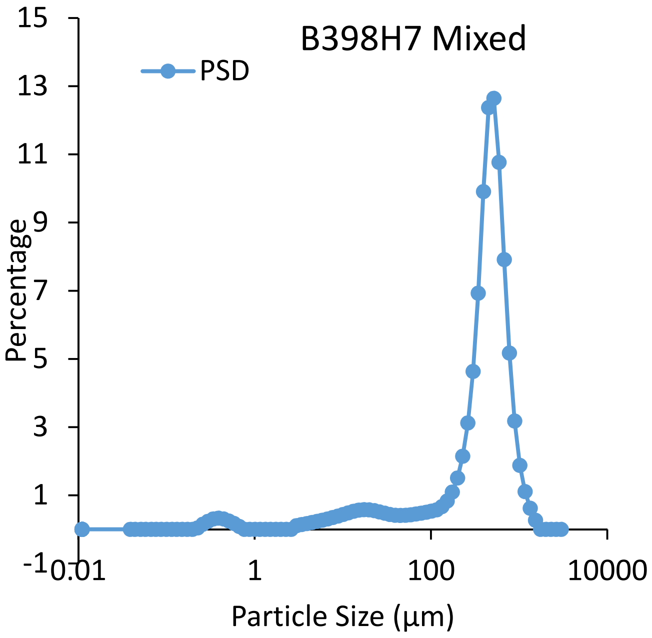
0.1
1
10
100
1000
10000
Percentage
Particle Size (µm)


B398H7 Mixed
PSD
Percentage
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9
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3
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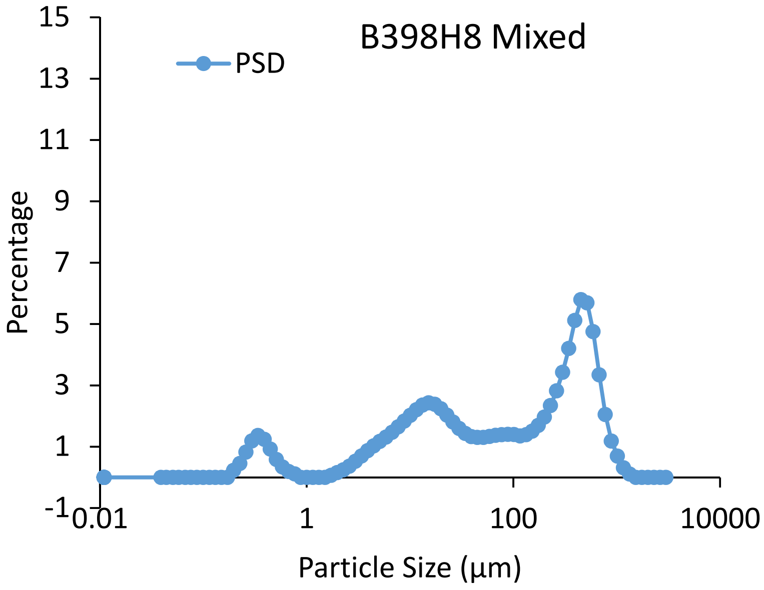
1
100
10000
Particle Size (µm)


B398H8 Mixed
PSD
Percentage
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11
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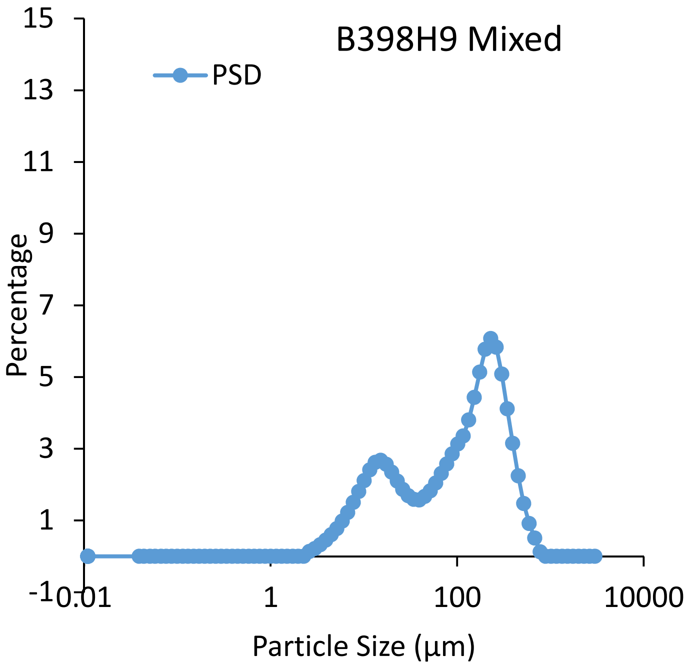
Particle Size (µm)


B398H9 Mixed
PSD
Percentage
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100
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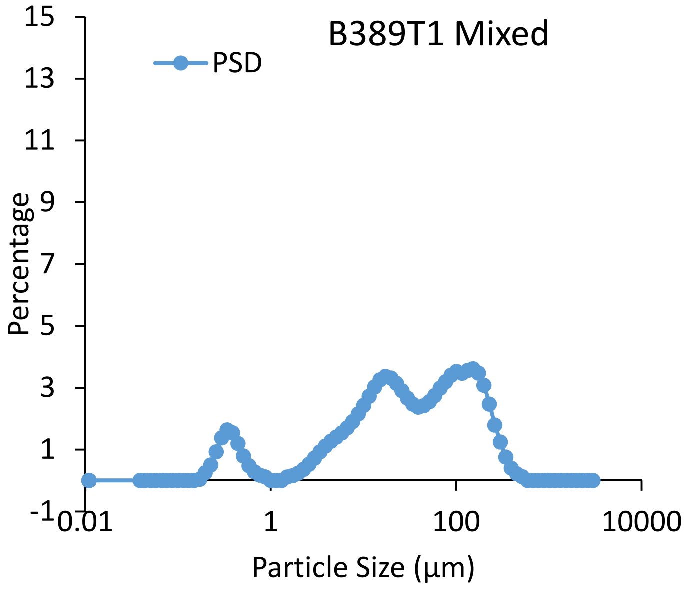
Particle Size (µm)


B389T1 Mixed
PSD
Percentage
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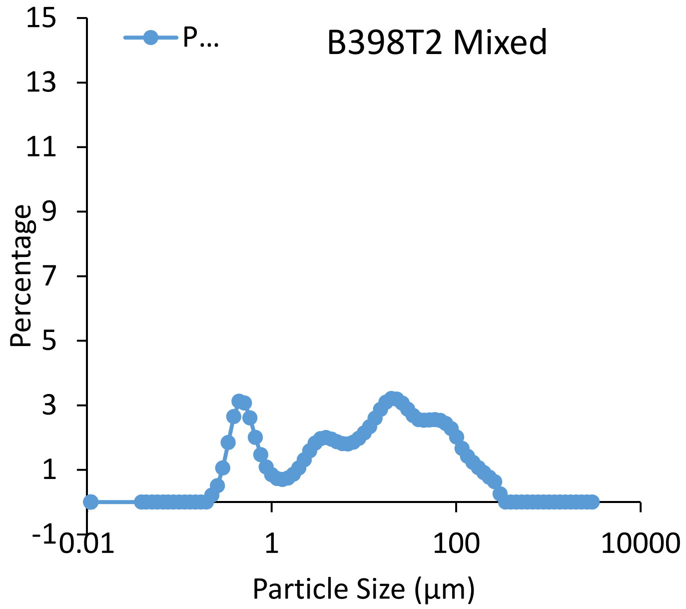
1
100
10000
Particle Size (µm)


B398T2 Mixed
P...
Percentage
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9
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3
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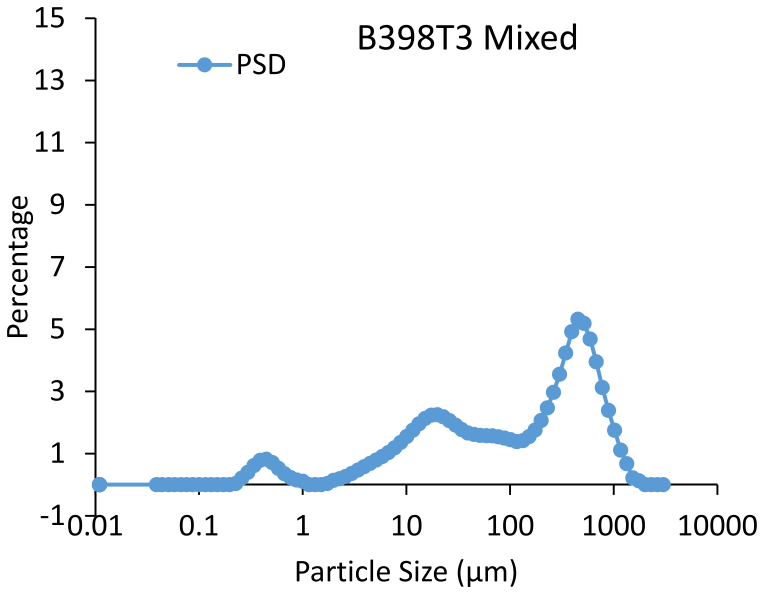
1
100
10000
Particle Size (µm)


B398T3 Mixed
PSD
Percentage
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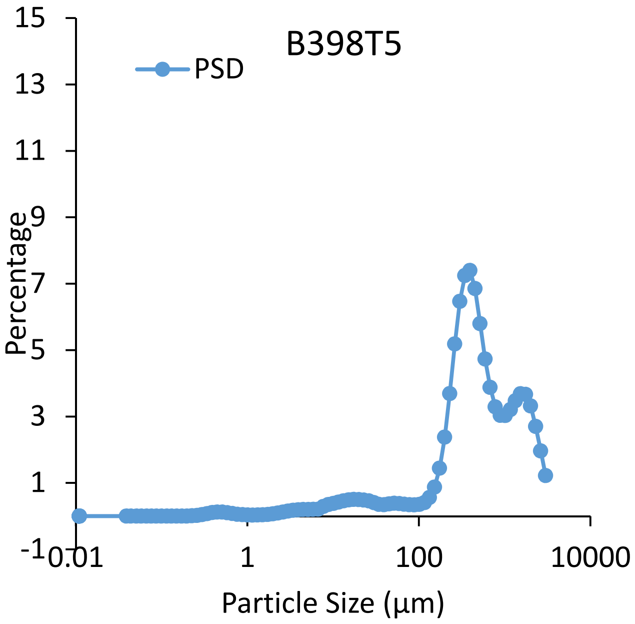
0.01
0.1
1
10
100
1000
10000
Particle Size (µm)


B398T5
PSD
Percentage
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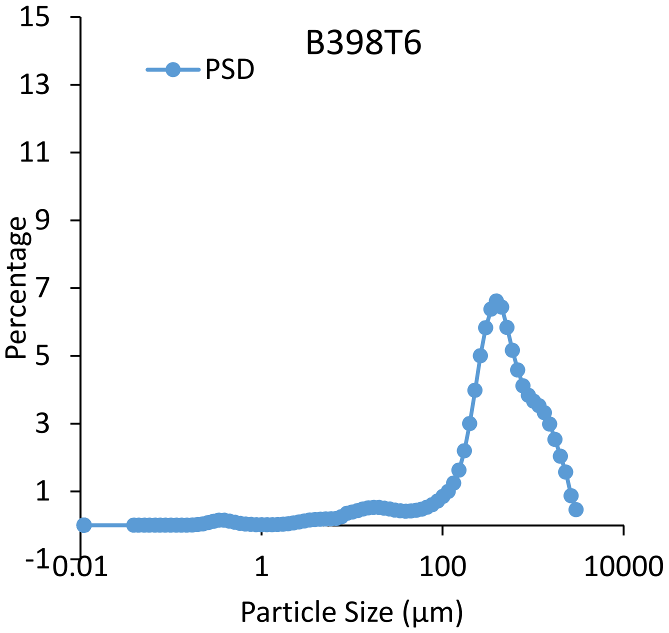
Particle Size (µm)


B398T6
PSD
Percentage
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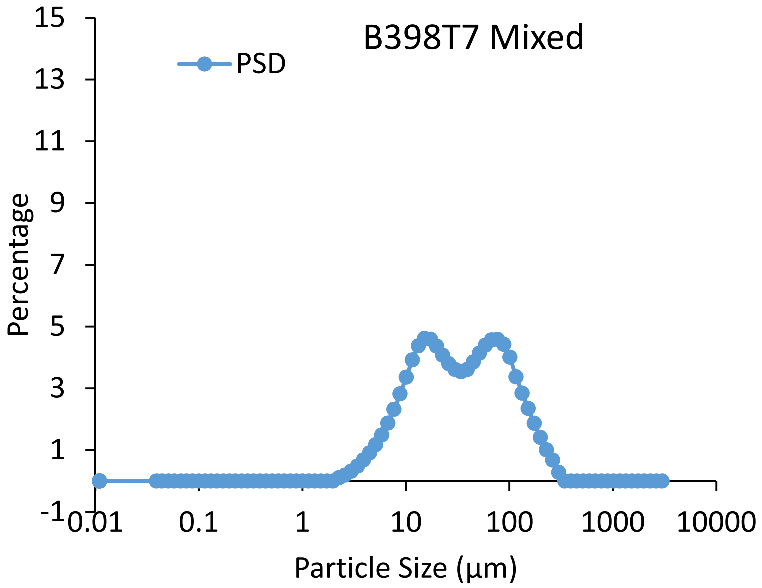
13
11
9
7
5
3
1
-1
0.01
1
100
10000
Particle Size (µm)


B398T7 Mixed
PSD
Percentage
15
13
11
9
7
5
3
1
-1
0.01
0.1
1
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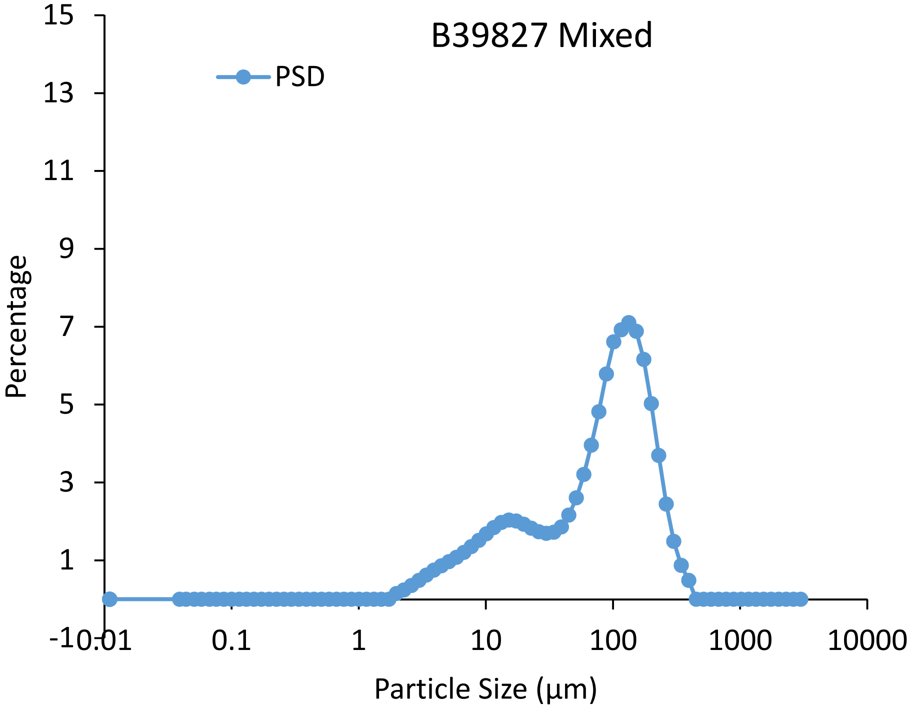
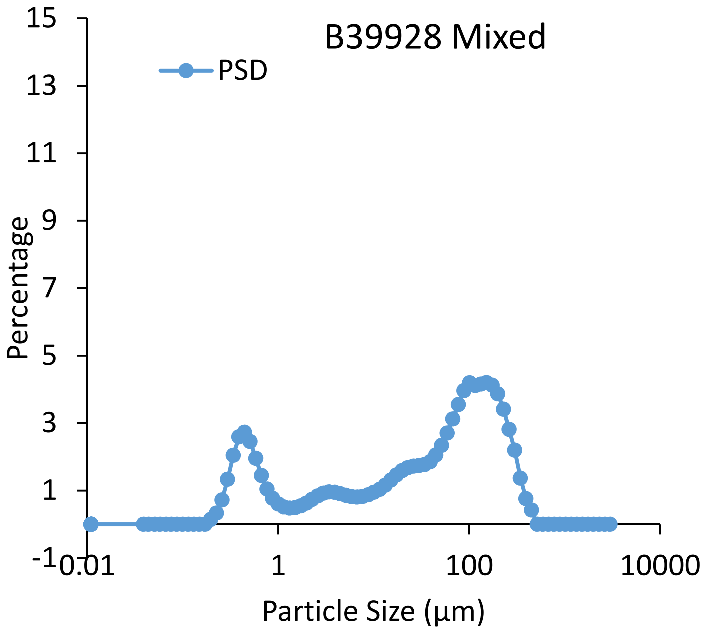
100
1000
10000
Particle Size (µm)


B39827 Mixed
PSD
Percentage
15
13
11
9
7
5
3
1
-1
0.01
0.1
1
10
100
1000
10000
Particle Size (µm)


B39928 Mixed
PSD
Percentage
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13
11
9
7
5
3
1
-1
0.01
1
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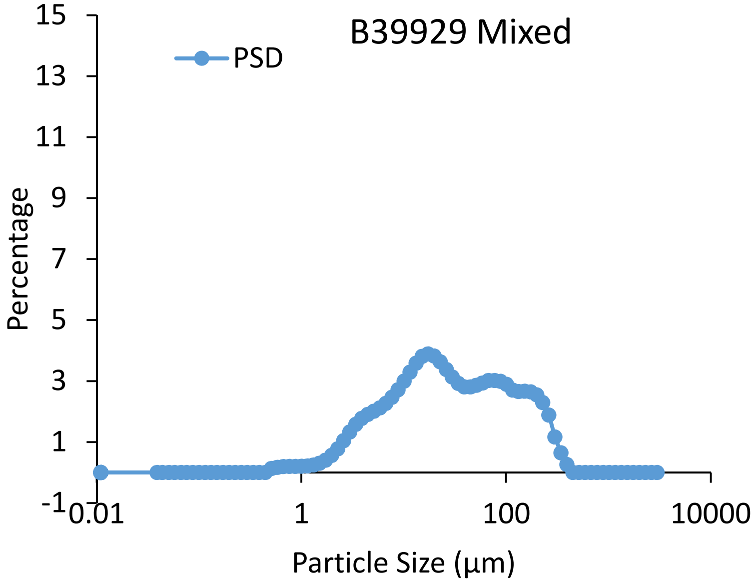
Particle Size (µm)


B39929 Mixed
PSD
Percentage
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13
11
9
7
5
3
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-1
0.01
1
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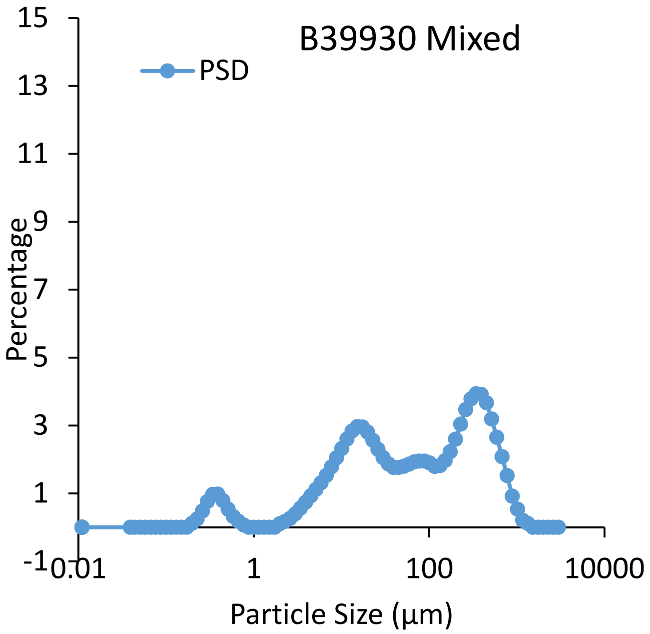
Particle Size (µm)


B39930 Mixed
PSD
Percentage
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13
11
9
7
5
3
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-1
0.01
1
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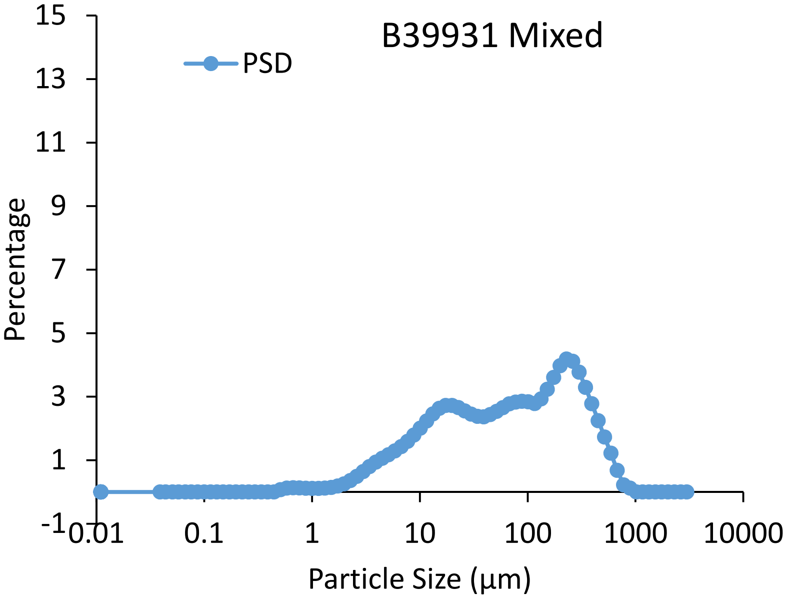
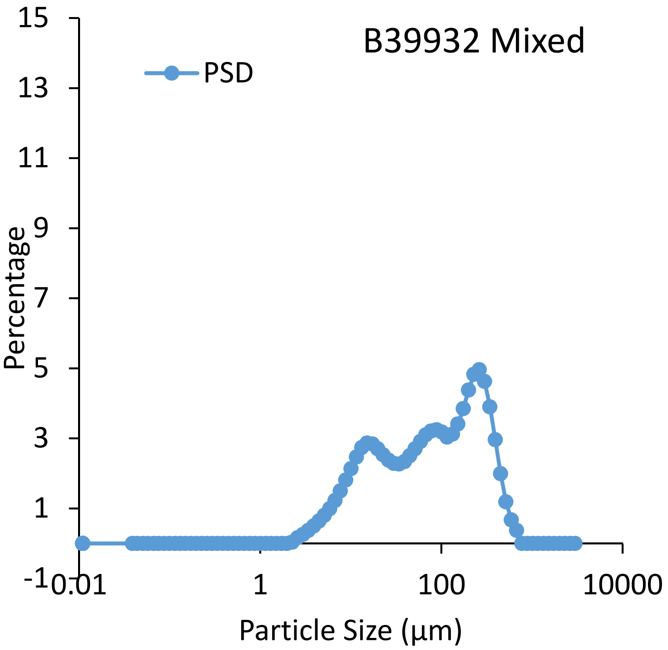
10000
Particle Size (µm)


B39931 Mixed
PSD
Percentage
15
13
11
9
7
5
3
1
-1
0.01
0.1
1
10
100
1000
10000
Particle Size (µm)


B39932 Mixed
PSD
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13
11
9
7
5
3
1
-1
Percentage
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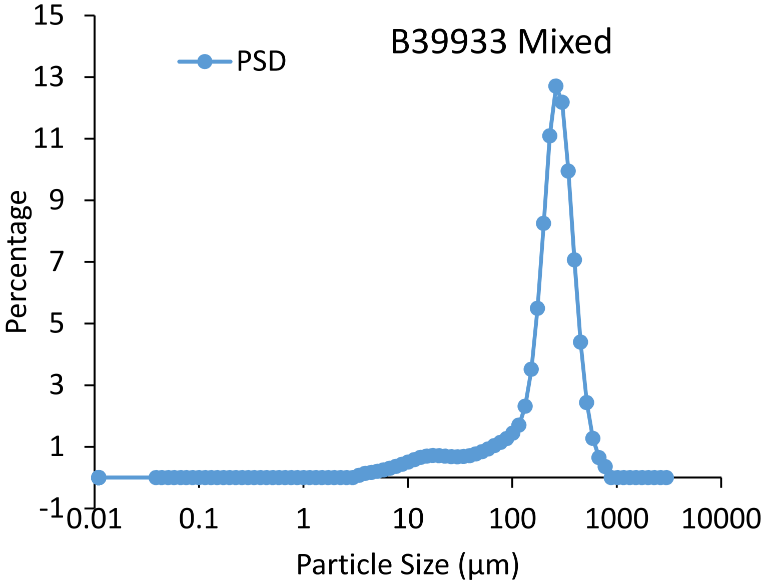
1
100
10000
Particle Size (µm)


B39933 Mixed
PSD
15
13
11
9
7
5
3
1
-1
Percentage
0.01
0.1
1
10
100
1000
10000
Particle Size (µm)

Appendix B

Additional Batch Experiment Results

B.1 Additional Batch Experiment Results

Sample Time	B398H3, 23C Solution	Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
Starting Solution	ITB1	5.51	-	0.94	-	18.5	-	ND	-	-	-
	ITB2	4.57	-	1.01	-	14.1	-	74	-	-	-
4 hour	AGW	ND	-	ND	-	1.18	0.00	ND	-	16.5	0.21
	ITB1	9.96	-	1.10	0.10	19.5	0.57	18.7	-	30.0	0.35
	ITB2	7.78	-	1.06	0.01	14.1	0.14	ND	-	32.5	0.64
1 day	AGW	ND	-					ND	-	17.2	0.78
	ITB1	ND	-					ND	-	31.6	0.92
	ITB2	ND	-					61.5	3.25	32.5	0.64
7 day	AGW	ND*	-	ND*	-			ND	-	16.1	0.07
	ITB1	ND*	-	1.17	0.03			ND	-	30.2	0.35
	ITB2	ND*	-	1.26	0.02			ND	-	31.8	1.34
14 day	AGW	ND*	-	ND*	-	1.55	0.00	ND	-	16.2	0.57
	ITB1	ND*	-	1.25	0.05	10.6	1.17	ND	-	29.4	0.57
	ITB2	ND*	-	1.2	0.06	10.6	0.07	ND	-	31.2	0.07
28 day	AGW	ND*	-	ND*	-			ND	-	17.2	0.35
	ITB1	25.8	-	1.19	0.00			ND	-	35.9	0.42
	ITB2	ND*	-	1.24	0.06			ND	-	36.5	0.07
42 day	AGW	ND	-	ND*	-	1.98	0.11	ND	-	15.8	0.07
	ITB1	4.90	0.14	1.24	0.06	9.5	0.46	ND	-	29.2	0.49
	ITB2	5.03	0.32	1.34	0.08	8.15	0.49	ND	-	30.4	1.63
60 day	AGW	ND	-	0.37	0.01	1.58	0.04	ND	-	17.1	0.21
	ITB1	4.65	0.42	1.36	0.01	7.5	0.11	ND	-	30.9	0.85
	ITB2	4.40	0.00	1.31	0.10	6.85	0.57	ND	-	30.8	0.21
Detection limits		3.46-6.92; 23.2*		0.071, 0.355*		0.126, 0.63		12, 23.9		0.239, 0.477	

		B398H9										B398T2									
Sample Time	23C Solution	Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)		Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	ND	-	ND	-	1.18	0.17	ND	-	16.25	0.21	ND	-	ND	-	1.31	0.23	ND	-	16.25	0.49
	ITB1	7	-	1.06	0.18	19.55	0.35	ND	-	31.20	0.28	ND	-	1.20	0.08	19.15	0.07	ND	-	30.20	0.57
	ITB2	ND	-	1.04	0.06	14.7	0.28	ND	-	30.85	0.35	ND	-	1.02	0.04	14.95	0.92	ND	-	31.90	0.42
1 day	AGW	ND	-					ND	-	16.25	0.21	ND	-					ND	-	16.65	0.21
	ITB1	ND	-					ND	-	30.85	0.21	ND	-					ND	-	31.00	0.00
	ITB2	ND	-					43.75	2.05	31.05	0.07	ND	-					33.5	4.10	32.35	0.07
7 day	AGW	ND*	-	ND*	-			ND	-	15.95	0.49	ND*	-	ND*	-			ND	-	16.80	0.14
	ITB1	ND*	-	1.13	0.04			ND	-	30.55	1.20	ND*	-	1.235	0.01			ND	-	31.25	0.35
	ITB2	ND*	-	1.2	0.08			ND	-	32.00	0.42	ND*	-	1.27	0.00			ND	-	31.05	0.21
14 day	AGW	ND*	-	ND*	-	1.13	0.04	ND	-	16.35	0.35	ND*	-	ND*	-	1.53	0.04	ND	-	17.05	0.07
	ITB1	ND*	-	1.145	0.02	13.85	2.47	ND	-	30.80	0.42	ND*	-	1.305	0.04	11.85	0.35	ND	-	31.55	0.07
	ITB2	ND*	-	1.155	0.05	10.2	0.00	ND	-	32.00	0.85	ND*	-	1.31	0.01	9.8	0.00	ND	-	32.30	0.14
28 day	AGW	ND*	-	ND*	-			ND	-	19.05	0.35	ND*	-	ND*	-			ND	-	16.00	0.42
	ITB1	ND*	-	1.125	0.05			ND	-	29.15	0.07	ND*	-	1.285	0.02			ND	-	29.40	0.14
	ITB2	ND*	-	1.215	0.06			ND	-	29.25	0.92	ND*	-	1.375	0.05			ND	-	30.35	0.07
42 day	AGW	ND	-	ND*	-	1.28	0.04	ND	-	15.50	0.14	ND	-	ND*	-	1.73	0.18	ND	-	16.75	0.07
	ITB1	5.3	0.00	1.19	0.01	10.8	0.00	ND	-	29.40	0.57	4.85	0.14	1.355	0.04	11.25	1.06	ND	-	30.45	0.78
	ITB2	4.6	0.07	1.275	0.01	9	0.21	ND	-	29.50	0.99	4.8	0.85	1.605	0.28	10.875	1.59	ND	-	36.20	6.65
60 day	AGW	ND	-	ND*	-	0.88	0.04	ND	-	16.30	0.14	ND	-	ND*	-	1.43	0.04	ND	-	16.85	0.35
	ITB1	5	0.49	1.225	0.02	9.325	0.88	ND	-	31.70	1.41	4.95	0.49	1.39	0.03	10.1	0.28	ND	-	29.75	0.07
	ITB2	5.1	0.71	1.285	0.01	8.325	0.11	ND	-	29.40	0.99	4.175	0.04	1.525	0.02	8.225	0.46	ND	-	30.45	0.21
Detection limits		3.46-6.92; 23.2*		0.071, 0.355*		0.126, 0.63		12, 23.9		0.239, 0.477		3.46-6.92; 23.2*		0.071, 0.355*		0.126, 0.63		12, 23.9		0.239, 0.477	

		B39927										B39933									
Sample Time	23C Solution	Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)		Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	ND	-	ND	-	1.035	0.12	ND	-	16.65	0.78	ND	-	ND	-	1.11	0.07	ND	-	16.35	0.07
	ITB1	ND	-	1.02	0.03	18.5	0.42	ND	-	31.05	0.35	ND	-	0.91	0.04	19.25	0.64	ND	-	30.65	0.07
	ITB2	ND	-	1.23	0.08	15.2	0.99	12.3	-	31.10	0.28	ND	-	1.02	0.06	14.55	0.07	ND	-	32.15	0.35
1 day	AGW	ND	-					ND	-	16.50	0.14	ND	-					ND	-	16.15	0.07
	ITB1	ND	-					ND	-	30.75	0.07	ND	-					53.05	2.62	30.20	0.28
	ITB2	ND	-					50.55	4.03	31.40	0.71	ND	-					99.35	0.78	31.30	0.00
7 day	AGW	ND*	-	ND*	-			ND	-	16.70	0.00	ND*	-	ND*	-			ND	-	16.15	0.21
	ITB1	ND*	-	1.27	0.01			ND	-	29.85	0.78	ND*	-	0.9935	0.02			ND	-	29.20	0.28
	ITB2	ND*	-	1.33	0.01			ND	-	29.95	0.07	ND*	-	1.0215	0.04			69.25	4.03	29.95	1.48
14 day	AGW	ND*	-	ND*	-	1.35	0.07	ND	-	17.05	0.49	ND*	-	ND*	-	1.23	0.04	ND	-	16.90	0.14
	ITB1	ND*	-	1.43	0.04	11.4	0.57	ND	-	32.10	0.85	ND*	-	1.035	0.19	12.6	0.57	ND	-	31.30	0.28
	ITB2	ND*	-	1.46	0.01	10.3	1.03	ND	-	32.10	0.57	ND*	-	1.1	0.06	10.2	0.00	ND	-	33.25	0.35
28 day	AGW	ND*	-	ND*	-			ND	-	15.40	0.28	ND*	-	ND*	-			ND	-	15.35	0.07
	ITB1	ND*	-	1.29	0.00			ND	-	28.80	0.85	ND*	-	0.9285	0.03			ND	-	29.00	0.57
	ITB2	ND*	-	1.43	0.03			ND	-	30.50	0.00	ND*	-	1.025	0.01			ND	-	30.10	0.85
42 day	AGW	ND	-	ND*	-	1.18	0.04	ND	-	17.00	0.57	9.70	-	ND*	-	1.53	0.04	ND	-	18.15	1.77
	ITB1	4.60	0.00	1.45	0.06	10.3	0.42	ND	-	30.10	0.71	5.025	0.18	0.9955	0.01	10.575	0.88	ND	-	31.80	0.42
	ITB2	4.10	0.07	1.51	0.07	9.10	0.00	ND	-	31.25	0.21	4.5	0.14	1.055	0.01	8.85	0.92	ND	-	30.70	0.42
60 day	AGW	ND	-	ND*	-	0.83	0.04	ND	-	16.30	0.00	ND	-	ND*	-	1.03	0.04	ND	-	16.20	0.42
	ITB1	4.45	0.14	1.46	0.01	8.525	0.25	ND	-	29.40	0.00	4.575	0.04	0.985	0.01	7.175	0.74	ND	-	29.10	0.57
	ITB2	4.23	0.11	1.50	0.04	7.875	0.46	ND	-	29.05	0.92	4.475	0.11	1.065	0.01	7.625	1.24	ND	-	29.35	0.35
	Detection limits	3.46-6.92; 23.2*		0.071, 0.355*		0.126, 0.63		12, 23.9		0.239, 0.477		3.46-6.92; 23.2*		0.071, 0.355*		0.126, 0.63		12, 23.9		0.239, 0.477	

Sample Time	B398H3, 50C Solution	pH		Ba (µg/L)		Fe (µg/L)		Sr (µg/L)		Al (µg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	7.89		12.5	0.92	ND	-	40.4	5.37	184	46.7	5.74	0.30	5.79	2.52	21.5	0.07	4.19	0.21	7.44	0.35
	AGW (90C)	8.56	0.04	19.9	0.14	ND	-	74.1	0.92	198	17.7	5.71	0.08	4.27	0.27	21.2	0.78	4.09	0.05	11.6	0.35
	ITB1	8.42	-	27.2	4.53	82.7	-	293	3.54	413	50.2	21.4	0.00	6.05	1.63	58.8	1.20	20.9	0.21	22.3	0.07
	ITB1 (90C)	8.42	-	40.1	6.15	ND	-	334	8.49	433	0.00	21.8	0.07	5.83	0.13	56.9	0.14	19.5	0.00	26.4	1.06
	ITB2	8.36	-	25.8	1.91	ND	-	285	1.41	201	-	30.5	0.57	6.46	1.15	57.5	1.20	20.5	0.14	22.1	0.28
	ITB2 (90C)	8.47	-	46.0	0.71	57.3	-	328	4.24	90.8	-	31.3	0.07	6.12	0.01	55.6	0.14	19.0	0.00	25.9	0.00
1 day	AGW	8.36	-	21.6	2.05	ND	-	90.7	4.31	-	-	6.37	0.05	3.87	0.04	20.8	0.57	5.02	0.09	10.8	0.21
	ITB1	7.97	-	46.8	4.17	ND	-	357	19.8	-	-	22.8	0.78	5.36	0.06	56.7	2.26	21.0	0.85	24.8	0.71
	ITB2	8.46	-	43.7	1.91	ND	-	353	5.66	-	-	33.1	0.78	5.92	0.01	56.1	0.92	21.3	0.00	25.1	0.00
7 day	AGW	8.45	-	ND*	-	ND	-	160	2.12	-	-	6.18	0.08	2.50	0.53	25.3	0.28	5.33	0.07	16.3	0.07
	ITB1	8.55	-	48.9	1.34	ND	-	340	7.78	-	-	20.0	0.28	3.92	0.31	44.4	0.85	17.2	0.21	26.5	0.49
	ITB2	8.56	-	50.7	1.20	ND	-	354	1.41	-	-	29.2	0.21	4.73	0.26	46.9	0.42	17.4	0.21	26.5	0.07
14 day	AGW	8.47	-	ND*	-	ND	-	166	4.24	-	-	6.45	0.34	3.66	1.20	26.2	1.27	5.23	0.27	17.3	0.35
	ITB1	8.52	-	49.4	0.71	ND	-	358	14.8	392	-	22.5	1.06	3.68	1.15	44.7	1.63	15.9	0.28	26.6	0.21
	ITB2	8.58	-	53.6	1.77	ND	-	338	0.00	-	-	28.5	0.07	6.27	0.18	42.3	0.14	15.2	0.14	26.9	0.42
28 day	AGW	8.41	-	ND*	-	ND	-	168	7.07	-	-	6.39	0.41	6.17	1.56	27.5	2.69	4.88	0.24	19.9	0.85
	ITB1	8.35	0.08	71.0	1.48	ND	-	434	10.6	-	-	26.1	0.99	8.03	0.53	56.5	1.70	18.3	0.49	33.0	1.20
	ITB2	8.32	-	71.1	1.98	ND	-	428	2.83	-	-	36.4	0.92	8.72	0.58	57.0	0.28	17.1	0.57	32.2	1.20
42 day	AGW	8.44	-	30.4	1.41	ND	-	164	4.24	-	-	6.26	0.16	3.58	1.44	26.5	0.57	4.58	0.08	19.9	0.07
	ITB1	8.38	0.04	57.5	1.34	ND	-	336	6.36	-	-	20.8	0.49	6.35	0.69	43.8	0.49	13.9	0.57	26.0	0.78
	ITB2	8.41		59.6	4.03	ND	-	337	8.49	-	-	29.0	0.28	6.00	1.32	43.6	1.06	13.4	0.21	25.7	0.00
60 day	AGW	8.45	-	29.7	0.64	ND	-	155	4.24	-	-	6.37	0.23	3.00	0.57	26.3	0.92	4.36	0.04	21.8	0.21
	ITB1	8.35	-	56.1	0.14	ND	-	314	3.54	-	-	20.7	0.07	3.55	1.36	42.1	0.14	12.6	0.07	26.4	0.14
	ITB2	8.26	-	58.6	5.44	ND	-	306	2.12	-	-	27.9	0.49	2.78	0.55	41.1	0.35	12.2	0.35	26.4	0.99

Sample Time	B398H9, 50C Solution	pH		Ba (µg/L)		Fe (µg/L)		Sr (µg/L)		Al (µg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	7.66	-	8.34	-	ND	-	ND	-	ND	-	6.015	0.16	5.05	1.24	16.00	0.71	4.11	0.11	7.34	0.10
	AGW (90C)	8.28	-	26.65	0.64	ND	-	ND	-	ND	-	6.45	0.08	4.95	0.01	15.45	1.20	4.79	0.04	10.55	0.64
	ITB1	8.46	-	26.15	0.49	ND	-	237.00	1.41	ND	-	21.85	0.07	10.41	6.78	55.20	0.57	20.95	0.07	22.20	0.14
	ITB1 (90C)	8.58	-	25.7	0.42	ND	-	231.5	2.12	ND	-	22.25	0.35	6.85	0.20	54.50	1.70	20.05	0.35	23.85	0.78
	ITB2	8.49	0.1061	5.47	0.01	ND	-	235	0.00	ND	-	30.85	0.35	11.00	1.13	54.65	0.64	20.80	0.28	22.25	0.21
	ITB2 (90C)	8.56	-	7.75	0.34	ND	-	229	2.83	ND	-	31.65	0.21	7.17	0.04	54.05	0.21	20.00	0.28	23.60	0.00
1 day	AGW	8.12	-	23.3	1	76.5	-	56.85	0	111	-	6.72	0.01	4.80	0.11	15.75	0.21	4.99	0.00	9.43	0.18
	ITB1	7.96	-	29.85	12	ND	-	267.5	1	197	18	22.55	0.21	6.68	0.06	57.85	0.49	20.80	0.14	23.25	0.07
	ITB2	8.63	-	26.55	0.92	ND	-	264.5	3.54	148	52.33	31.55	0.35	7.07	0.01	56.85	1.48	20.50	0.28	22.70	0.28
7 day	AGW	8.05	-	ND*	-	ND	-	66.45	0.7778	ND	-	6.30	0.13	4.35	0.21	17.05	0.78	5.38	0.11	13.05	0.07
	ITB1	8.52	-	ND*	-	ND	-	246.5	7.7782	ND	-	21.40	0.71	5.06	0.55	56.25	1.48	17.85	0.64	18.65	1.20
	ITB2	8.46	-	ND*	-	ND	-	237.5	6.36	ND	-	28.90	0.85	5.22	1.23	53.85	1.48	17.30	0.14	17.90	0.42
14 day	AGW	8.19	-	ND*	-	ND	-	73.7	3.8184	ND	-	6.47	0.35	5.62	0.36	19.45	1.63	5.89	0.29	15.10	0.71
	ITB1	8.63	-	ND*	-	ND	-	226	4.2426	ND	-	20.25	0.49	7.42	0.21	51.15	1.06	14.65	0.07	14.30	0.28
	ITB2	8.66	-	ND*	-	ND	-	227	1.41	ND	-	28.75	0.35	8.17	0.02	52.10	0.28	14.70	0.14	14.30	0.42
28 day	AGW	8.01	-	ND*	-	ND	-	82.5	0.5657	ND	-	7.65	0.16	7.45	0.29	21.85	0.21	6.55	0.14	17.20	0.28
	ITB1	8.29	-	ND*	-	ND	-	214.5	10.607	ND	-	20.35	0.78	6.54	0.28	49.85	2.33	12.80	0.57	12.50	0.71
	ITB2	8.34	-	ND*	-	ND	-	204.5	6.36	ND	-	28.00	0.42	7.10	0.51	48.05	1.06	12.35	0.21	11.75	0.07
42 day	AGW	8.06	-	10.05	0.21	ND	-	66.35	0.495	ND	-	6.23	0.13	6.47	0.25	18.45	0.35	5.52	0.18	14.25	0.35
	ITB1	8.33	-	23.9	1.56	ND	-	215.5	10.607	ND	-	21.20	0.99	8.50	1.42	50.40	2.83	13.00	0.42	13.40	0.28
	ITB2	8.33	-	23.8	0.85	ND	-	213	4.24	ND	-	29.30	0.57	7.59	0.13	49.15	0.92	12.40	0.14	12.75	0.07
60 day	AGW	8.13	-	9.225	0.53	ND	-	ND	-	ND	-	5.95	0.04	3.42	1.07	16.60	0.14	5.14	0.04	14.30	0.14
	ITB1	8.24	-	22.2	1.41	ND	-	186.5	6.364	ND	-	19.75	0.35	3.93	0.68	44.65	1.06	11.00	0.85	12.45	1.34
	ITB2	8.26	0.04	23.2	0.00	ND	-	183	4.24	ND	-	26.60	0.85	5.49	1.03	43.85	0.49	11.30	0.00	13.15	0.49

Sample Time	B398T2, 50C Solution	pH		Ba (μg/L)		Fe (μg/L)		Sr (μg/L)		Al (μg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	7.92	-	15.4	-	ND	-	38.75	2.76	ND	-	8.02	0.01	5.59	1.91	18.85	0.64	4.34	0.04	8.71	0.13
	AGW (90C)	8.52	-	21.35	1.34	ND	-	65.50	1.70	ND	-	9.33	0.38	5.64	0.27	19.40	0.14	4.57	0.09	20.00	1.27
	ITB1	8.36	-	41.85	0.49	ND	-	258.00	2.83	ND	-	23.90	0.28	6.99	1.65	57.10	0.71	20.35	0.21	22.75	0.07
	ITB1 (90C)	8.33	0.0283	54.35	2.90	ND	-	273	0.00	ND	-	29.7	6.51	7.68	0.06	56.95	0.64	17.70	0.28	30.90	1.13
	ITB2	8.34	-	43.95	0.35	ND	-	260	5.66	ND	-	33.2	0.71	7.20	1.12	56.90	0.85	20.30	0.42	23.45	0.35
	ITB2 (90C)	8.25	-	56.7	1.84	ND	-	276	1.41	ND	-	34.85	0.49	8.34	0.23	56.90	1.84	17.90	0.28	31.90	0.99
1 day	AGW	8.46	-	20.1	1	ND	-	91.9	2	123	-	9.37	0.07	5.48	0.09	20.20	0.00	4.91	0.01	16.35	0.35
	ITB1	8.65	-	54.25	0	ND	-	319.5	1	271.5	70	25.30	0.14	7.64	0.05	61.55	0.35	18.90	0.14	27.70	0.00
	ITB2	8.00	-	55.6	1.84	ND	-	315.5	3.54	387.5	65.76	34.85	0.21	8.26	0.25	60.20	0.71	18.80	0.14	28.05	0.35
7 day	AGW	8.48	-	33	-	ND	-	108	0	ND	-	8.77	0.01	4.41	0.49	23.25	0.07	5.46	0.07	26.75	1.20
	ITB1	8.61	-	51.25	0.78	ND	-	268	1.4142	185	-	22.85	0.49	5.16	0.63	53.20	0.42	14.75	0.21	31.45	0.49
	ITB2	8.51	-	53.7	3.11	ND	-	275.5	0.71	ND	-	31.05	0.07	5.85	1.57	54.65	0.49	15.10	0.00	31.15	0.35
14 day	AGW	8.45	-	ND*	-	163	-	108.5	0.7071	ND	-	8.71	0.40	5.87	1.15	23.65	0.21	5.06	0.13	28.10	0.85
	ITB1	8.44	-	49.35	1.20	ND	-	251.5	9.1924	ND	-	22.50	0.00	6.45	0.02	48.75	2.19	12.40	0.42	32.25	0.35
	ITB2	8.58	0.01	53.15	2.76	ND	-	250	1.41	ND	-	29.45	0.21	7.72	0.86	48.85	0.21	12.20	0.14	31.10	0.42
28 day	AGW	8.41	-	ND*	-	ND	-	104	4.2426	ND	-	8.46	0.21	5.30	1.18	22.75	0.35	4.56	0.08	26.70	0.14
	ITB1	8.26	-	46.3	1.13	ND	-	237	2.8284	ND	-	23.10	1.41	7.36	1.27	46.95	0.64	10.75	0.21	29.50	2.12
	ITB2	8.32	-	57.5	7.64	ND	-	234.5	3.54	ND	-	29.45	0.07	7.22	1.16	46.60	0.85	10.55	0.35	28.90	0.42
42 day	AGW	8.44	-	33.65	12.1	ND	-	102	0	ND	-	9.28	0.33	4.50	0.42	23.70	0.85	4.59	0.10	28.65	0.64
	ITB1	8.26	-	52.15	0.92	ND	-	226	8.4853	ND	-	23.30	0.14	5.61	1.47	46.20	1.70	10.55	0.07	31.45	0.49
	ITB2	8.26	-	60.3	9.19	ND	-	233	4.24	ND	-	30.40	0.99	6.74	0.04	46.70	1.56	10.50	0.57	31.10	0.85
60 day	AGW	8.45	-	34.7	14.3	ND	-	99.35	3.7477	ND	-	8.84	0.72	3.13	0.40	23.10	0.28	4.38	0.09	29.10	1.98
	ITB1	8.35	-	52.5	1.56	ND	-	215.5	3.5355	ND	-	22.25	0.64	4.20	0.24	44.10	0.99	9.93	0.53	31.05	0.92
	ITB2	8.26	-	58.75	9.40	ND	-	218	14.14	ND	-	29.30	0.85	5.36	0.14	44.10	0.99	9.58	0.08	30.50	0.00

Sample Time	B39927, 50C Solution	pH		Ba (µg/L)		Fe (µg/L)		Sr (µg/L)		Al (µg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	7.70	-	18.5	1.56	ND	-	ND	-	ND	-	6.85	0.07	5.86	1.97	20.55	0.49	3.41	0.04	7.30	0.02
	AGW (90C)	8.44	-	27.00	-	ND	-	52.15	3.46	ND	-	7.15	0.18	4.86	0.14	21.30	0.00	2.97	0.05	10.20	0.42
	ITB1	8.27	-	53.55	1.48	ND	-	266.50	0.71	ND	-	22.65	0.07	6.35	1.23	58.40	0.57	19.70	0.28	22.05	0.07
	ITB1 (90C)	8.44	-	70.8	2.55	ND	-	269	5.66	ND	-	23	0.57	6.57	0.17	57.70	1.41	17.55	0.21	23.75	0.49
	ITB2	8.39	-	51.55	0.64	ND	-	261.5	3.54	ND	-	32.1	0.42	7.01	1.11	57.75	0.64	19.95	0.35	22.10	0.28
	ITB2 (90C)	8.49	-	71.55	2.62	ND	-	277	4.24	ND	-	33.1	0.57	7.06	0.02	57.80	0.28	17.40	0.71	23.85	0.07
1 day	AGW	8.36	0.05	24.05	0	ND	-	84.4	1	269	16	7.64	0.14	5.06	0.07	22.25	0.64	3.65	0.04	9.44	0.01
	ITB1	8.36	-	71.65	1	ND	-	318	8	190.5	107	22.90	1.41	6.47	0.21	63.40	0.71	18.10	0.28	22.40	0.14
	ITB2	8.65	-	69.6	4.67	ND	-	310	2.83	ND	-	31.05	0.64	6.99	0.01	63.30	1.27	18.00	0.14	22.35	0.21
7 day	AGW	8.47	-	ND*	-	ND	-	102.5	0.7071	ND	-	6.78	0.13	3.68	0.94	25.90	0.28	3.42	0.01	11.20	0.14
	ITB1	8.68	-	62.4	4.24	ND	-	285.5	3.5355	ND	-	21.45	1.06	4.45	1.53	54.05	0.64	15.10	0.71	22.05	1.48
	ITB2	8.67	-	63.55	3.32	ND	-	287.5	3.54	ND	-	30.70	0.71	4.79	0.26	55.75	0.92	15.35	0.35	22.05	0.78
14 day	AGW	8.37	-	38.7	-	ND	-	103.5	3.5355	ND	-	6.74	0.08	5.76	0.15	26.55	0.64	3.15	0.07	12.65	0.35
	ITB1	8.55	-	64.05	1.48	ND	-	265.5	0.7071	ND	-	20.70	0.14	7.08	0.16	48.70	0.42	12.85	0.07	22.10	0.00
	ITB2	8.61	-	66.9	1.98	ND	-	274	1.41	ND	-	29.55	0.07	7.09	1.31	51.45	0.64	12.15	0.07	21.00	0.00
28 day	AGW	8.22	-	34.95	0.21	ND	-	96	0	ND	-	6.42	0.08	5.32	0.21	25.80	0.14	2.68	0.01	12.30	0.28
	ITB1	8.23	-	63.35	1.63	ND	-	256.5	0.7071	ND	-	20.70	0.00	6.85	0.51	47.95	0.21	10.75	0.07	19.55	0.35
	ITB2	8.49	-	64.25	1.34	ND	-	264	11.31	ND	-	30.10	1.41	6.85	0.28	51.00	2.55	10.03	0.25	18.60	0.57
42 day	AGW	8.33	-	40.7	2.97	ND	-	95.3	2.8284	ND	-	7.05	0.65	3.29	0.46	26.65	1.20	2.62	0.13	13.30	0.42
	ITB1	8.35	-	70.8	0.14	ND	-	251.5	4.9497	ND	-	21.45	0.21	5.80	1.05	48.10	0.99	10.11	0.56	20.50	0.14
	ITB2	8.42	-	73.15	0.78	ND	-	249.5	0.71	ND	-	28.70	0.28	4.96	0.13	50.25	0.49	9.09	0.30	19.40	0.42
60 day	AGW	8.33	-	39.6	1.98	ND	-	92.1	3.1113	ND	-	6.27	0.57	2.76	0.86	25.45	0.64	2.35	0.07	13.60	0.42
	ITB1	8.30	0.07	70.1	0.14	ND	-	233	5.6569	ND	-	20.00	0.71	4.48	0.01	45.15	2.19	8.71	0.50	19.10	0.85
	ITB2	8.41	-	72.15	0.07	ND	-	234	2.83	ND	-	28.15	0.07	4.02	0.26	46.50	0.57	7.99	0.03	18.40	0.42

Sample Time	B39933, 50C Solution	pH		Ba (µg/L)		Fe (µg/L)		Sr (µg/L)		Al (µg/L)		Na (mg/L)		K (mg/L)		Ca (mg/L)		Mg (mg/L)		Si (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	7.67	-	9.23	0.04	ND	-	ND	-	ND	-	6.18	0.04	4.90	0.84	17.70	0.85	3.85	0.12	7.01	0.20
	AGW (90C)	8.33	-	15.80	0.14	ND	-	ND	-	ND	-	6.60	0.51	4.60	0.16	16.10	0.28	4.24	0.01	8.87	0.03
	ITB1	8.19	-	35.15	0.64	ND	-	241.50	3.54	ND	-	22.6	0.42	6.39	1.50	55.65	0.07	20.90	0.00	22.20	0.14
	ITB1 (90C)	8.51	-	44.2	3.11	ND	-	244	4.24	ND	-	23.3	0.49	6.01	0.11	56.40	1.13	20.05	0.07	23.15	0.35
	ITB2	8.31	-	36.5	-	ND	-	245	0.00	86	-	32.4	0.14	6.94	1.10	56.90	0.42	21.20	0.00	22.35	0.07
	ITB2 (90C)	8.535	0.0071	46.65	0.64	ND	-	240	2.83	ND	-	32.4	0.35	6.68	0.04	55.70	0.99	19.80	0.14	23.00	0.28
1 day	AGW	8.11	-	16.5	1	ND	-	55.4	3	ND	-	6.44	0.01	4.90	0.04	18.05	0.35	4.47	0.04	8.31	0.03
	ITB1	8.4	-	47.5	1	ND	-	271	0	ND	-	21.9	0.07	6.22	0.10	60.90	0.00	19.75	0.07	22.10	0.14
	ITB2	8.75	-	48.9	0.99	ND	-	269.5	2.12	ND	-	30.8	0.35	6.56	0.12	60.65	0.07	19.55	0.07	21.80	0.14
7 day	AGW	7.94	-	ND*	-	ND	-	ND	-	ND	-	6.32	0.26	3.33	0.25	17.65	0.49	4.57	0.16	9.89	0.45
	ITB1	8.51	-	47.05	0.21	ND	-	248	5.6569	ND	-	20.7	0.21	3.83	0.12	56.65	1.34	16.90	0.00	18.40	0.00
	ITB2	8.535	0.04	49.45	0.78	ND	-	255	4.24	ND	-	29.4	0.28	5.62	0.08	58.45	0.78	16.90	0.71	18.55	0.78
14 day	AGW	8.01	-	ND*	-	ND	-	63.4	-	ND	-	6.12	0.35	4.78	0.16	17.95	1.34	4.61	0.30	11.20	0.85
	ITB1	8.58	-	49.05	3.89	ND	-	240	5.6569	ND	-	20.00	0.42	6.77	0.17	50.05	1.20	14.60	0.14	17.70	0.14
	ITB2	8.71	-	52.7	0.71	142	-	254	15.56	ND	-	28.40	1.41	7.54	0.05	56.95	3.46	14.25	1.20	16.15	1.20
28 day	AGW	7.71	-	ND*	-	ND	-	ND	-	ND	-	5.89	0.28	6.09	0.86	17.80	0.14	4.38	0.00	10.75	0.07
	ITB1	8.30	-	46.5	4.95	ND	-	223	4.2426	ND	-	19.95	0.35	6.11	0.92	47.40	1.70	12.75	0.21	15.40	0.14
	ITB2	8.37	-	47.8	0.28	ND	-	230.5	2.12	ND	-	28.15	0.21	6.75	0.12	51.80	0.71	11.75	0.21	13.90	0.28
42 day	AGW	7.89	-	23.5	1.84	ND	-	ND	-	ND	-	6.01	0.47	3.35	0.58	17.55	0.07	4.33	0.05	11.65	0.35
	ITB1	8.42	-	49.7	1.84	ND	-	220.5	9.1924	ND	-	20.65	0.49	4.50	2.09	48.10	1.84	12.40	0.99	16.00	1.56
	ITB2	8.3	-	54.15	0.49	ND	-	213.5	2.12	ND	-	26.45	0.64	4.04	0.35	50.95	0.35	11.15	0.21	14.45	0.35
60 day	AGW	8.03	-	22.2	0.57	ND	-	ND	-	ND	-	5.46	0.30	3.22	-	16.65	0.92	4.22	0.18	11.65	0.49
	ITB1	8.39	-	48.8	2.83	ND	-	196	9.8995	ND	-	18.55	1.20	3.15	0.95	42.90	1.41	10.85	0.35	14.65	0.35
	ITB2	8.27	-	53	1.41	ND	-	197.5	7.78	234	-	25.30	0.57	2.80	0.49	45.85	1.63	10.42	0.68	14.05	0.78

Sample Time	B398H3, 50C Solution	Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	ND	-	ND	-	1.29	0.08	ND	-	16.6	0.64
	AGW (90C)	ND	-	ND	-	1.88	0.11	ND	-	16.3	0.21
	ITB1	8.88	0.8	0.99	0.02	19.0	0.00	17.6	-	30.9	0.00
	ITB1 (90C)	7.56	-	0.93	0.00	18.8	0.21	ND	-	31.7	0.57
	ITB2	7.09	-	1.08	0.02	14.4	0.14	46.1	3.25	31.6	0.14
	ITB2 (90C)	7.73	-	1.00	0.07	14.1	0.14	ND	-	31.8	0.14
1 day	AGW	ND	-					ND	-	16.8	0.00
	ITB1	ND	-					12.4	-	32.1	1.13
	ITB2	ND	-					33.5	3.68	32.9	0.07
7 day	AGW	ND*	-	ND*	-			ND	-	17.3	0.21
	ITB1	ND*	-	0.83	0.04			ND	-	30.3	0.71
	ITB2	ND*	-	0.95	0.01			ND	-	31.6	0.07
14 day	AGW	ND*	-	ND*	-	2.00	0.00	ND	-	16.7	0.57
	ITB1	ND*	-	0.44	0.02	14.9	1.77	ND	-	30.3	0.14
	ITB2	ND*	-	0.54	0.02	12.4	0.28	ND	-	32.9	0.28
28 day	AGW	ND*	-	ND*	-			ND	-	19.5	1.06
	ITB1	ND*	-	ND*	-			ND	-	39.0	1.63
	ITB2	ND*	-	0.36	-			ND	-	39.7	1.06
42 day	AGW	ND	-	ND*	-	2.35	0.14	ND	-	17.8	0.28
	ITB1	5.00	0.07	ND*	-	14.7	0.49	ND	-	31.4	1.34
	ITB2	5.20	0.14	0.36	-	13.3	0.21	ND	-	32.2	0.14
60 day	AGW	ND	-	ND*	-	2.0	0.04	ND	-	19.3	0.35
	ITB1	4.88	0.11	ND*	-	15.3	0.21	ND	-	33.6	0.28
	ITB2	4.70	0.14	ND*	-	13.7	0.42	ND	-	33.4	1.27

		B398H9										B398T2									
Sample Time	50C Solution	Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)		Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	ND	-	ND	-	1.045	0.04	ND	-	16.35	0.35	ND	-	ND	-	1.525	0.25	ND	-	16.25	0.21
	AGW (90C)	ND	-	ND	-	1.16	0.02	ND	-	16.55	0.07	ND	-	ND	-	1.76	0.01	ND	-	16.60	0.28
	ITB1	ND	-	0.97	0.07	19.95	0.35	ND	-	30.75	0.21	ND	-	1.02	0.03	19.30	0.14	ND	-	30.70	0.14
	ITB1 (90C)	ND	-	0.70	0.06	55.9	53.60	ND	-	31.25	0.64	ND	-	0.85	0.03	18.35	0.35	ND	-	30.90	0.57
	ITB2	ND	-	0.97	0.04	14.95	0.07	50.05	0.64	31.25	0.35	ND	-	1.01	0.05	14.7	0.28	15.75	2.90	31.90	0.42
	ITB2 (90C)	ND	-	0.75	0.05	13.6	0.28	ND	-	32.00	0.14	ND	-	0.86	0.01	14.05	0.07	ND	-	32.30	0.42
1 day	AGW	ND	-					ND	-	16.10	0.14	ND	-					ND	-	16.40	0.14
	ITB1	ND	-					ND	-	30.65	0.21	ND	-					ND	-	31.45	0.07
	ITB2	ND	-					16.5	0.57	31.05	0.49	ND	-					ND	-	31.70	0.28
7 day	AGW	ND*	-	ND*	-			ND	-	16.95	0.07	ND*	-	ND*	-			ND	-	18.40	0.28
	ITB1	ND*	-	0.4785	0.01			ND	-	31.80	0.85	ND*	-	0.7135	0.065761			ND	-	31.95	0.92
	ITB2	ND*	-	0.528	0.00			ND	-	32.35	0.21	ND*	-	0.816	0.05			ND	-	31.70	0.00
14 day	AGW	ND*	-	ND*	-	1.325	0.035	ND	-	18.50	0.71	ND*	-	ND*	-	2.125	0.176777	ND	-	17.75	0.21
	ITB1	ND*	-	ND*	####	13.8	0	ND	-	32.25	0.49	ND*	-	ND*	-	13.8	0.565685	ND	-	33.70	0.57
	ITB2	ND*	-	ND*	####	11.75	0.07	ND	-	33.35	0.78	ND*	-	0.386	0.01	12.2	0.28	ND	-	32.75	0.49
28 day	AGW	ND*	-	ND*	-			ND	-	20.20	0.85	ND*	-	ND*	-			ND	-	17.15	0.07
	ITB1	ND*	-	ND*	-			ND	-	30.80	0.85	ND*	-	ND*	-			ND	-	32.10	2.12
	ITB2	ND*	-	ND*	-			ND	-	31.40	0.14	ND*	-	ND*	-			ND	-	31.65	0.07
42 day	AGW	ND	-	ND*	-	1.25	0	ND	-	16.35	0.78	ND	-	ND*	-	2.35	0.070711	ND	-	18.15	0.49
	ITB1	5.35	0.1414	ND*	-	13.8	0.566	ND	-	31.10	1.13	5.8	0.494975	ND*	-	14.7	1.272792	ND	-	33.80	0.14
	ITB2	4.825	0.18	ND*	-	12.85	0.49	ND	-	31.35	0.21	5.125	0.25	ND*	-	11.7	2.69	ND	-	32.95	0.78
60 day	AGW	ND	-	ND*	-	0.95	0.071	ND	-	17.25	0.07	ND	-	ND*	-	2.2	0	ND	-	18.20	0.99
	ITB1	5.05	0.0707	ND*	-	14.05	0.354	ND	-	31.55	0.07	5.275	0.388909	ND*	-	15.6	1.131371	ND	-	33.30	0.85
	ITB2	4.7	0.07	ND*	-	12.7	0.42	ND	-	32.30	1.13	4.8	0.21	ND*	-	13	0.57	ND	-	31.95	0.07

		B3927										B39933									
Sample Time	50C Solution	Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)		Cr (µg/L)		U (µg/L)		I (µg/L)		Mn (µg/L)		S (mg/L)	
		Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev	Ave	StDev
4 hour	AGW	ND	-	ND	-	1.095	0.15	ND	-	16.60	0.00	ND	-	ND	-	1.06	0.01	ND	-	16.50	0.28
	AGW (90C)	ND	-	ND	-	1.21	0.13	ND	-	16.65	0.07	ND	-	ND	-	1.44	0.02	ND	-	16.55	0.07
	ITB1	ND	-	1.00	0.03	19.5	0.07	ND	-	30.80	0.14	ND	-	0.93	0.06	19.60	0.14	ND	-	30.95	0.21
	ITB1 (90C)	ND	-	0.95	0.07	18.6	0.64	ND	-	30.25	0.35	ND	-	0.78	0.11	18.55	0.49	ND	-	31.95	0.49
	ITB2	ND	-	1.07	0.01	14.8	0.28	30.95	2.62	31.30	0.42	ND	-	0.94	0.02	15.2	0.14	53.05	2.62	32.10	0.14
	ITB2 (90C)	ND	-	1.01	0.03	13.7	0.14	ND	-	31.65	0.07	ND	-	0.89	-	14.1	0.28	24.25	1.48	32.65	0.21
1 day	AGW	ND	-					ND	-	16.55	0.07	ND	-					13.2	0	16.30	0.00
	ITB1	ND	-					ND	-	30.60	0.42	ND	-					22.05	1	30.50	0.00
	ITB2	ND	-					14.55	0.35	31.40	0.14	ND	-					58.55	9.97	31.40	0.57
7 day	AGW	ND*	-	ND*	-			ND	-	17.05	0.07	ND*	-	ND*	-			ND	-	16.50	0.42
	ITB1	ND*	-	1.09	0.01			ND	-	29.75	2.05	ND*	-	0.598	0.05			ND	-	29.25	0.92
	ITB2	ND*	-	1.14	0.07			ND	-	30.95	1.06	ND*	-	0.739	0.06			ND	-	29.65	0.21
14 day	AGW	ND*	-	ND*	-	1.28	0.11	ND	-	17.75	0.64	ND*	-	ND*	-	1.525	0.18	ND	-	17.65	1.34
	ITB1	ND*	-	0.50	0.02	12.9	0.42	ND	-	32.00	0.42	ND*	-	ND*	-	13.9	0.14	ND	-	32.25	0.92
	ITB2	ND*	-	0.646	0.01	11.4	0.07	ND	-	33.35	0.21	ND*	-	0.478	-	12.3	0.42	ND	-	33.00	1.41
28 day	AGW	ND*	-	ND*	-			ND	-	16.55	0.07	ND*	-	ND*	-			ND	-	16.80	0.00
	ITB1	ND*	-	ND*	-			ND	-	30.65	0.07	ND*	-	ND*	-			ND	-	30.20	0.99
	ITB2	ND*	-	0.38	-			ND	-	32.60	1.13	ND*	-	ND*	-			ND	-	31.50	0.14
42 day	AGW	ND	-	ND*	-	1.375	0.035	ND	-	17.70	0.85	ND	-	ND*	-	1.65	0	ND	-	18.15	0.35
	ITB1	4.88	0.25	ND*	-	14.25	0.071	ND	-	32.35	0.21	4.925	0.04	ND*	-	14.65	1.34	ND	-	34.05	0.49
	ITB2	4.70	0.07	0.368	-	12.85	0.07	ND	-	34.60	0.28	5.525	1.45	ND*	-	12.7	0.14	ND	-	33.15	0.49
60 day	AGW	ND	-	ND*	-	1.10	0.071	ND	-	17.40	0.14	ND	-	ND*	-	1.325	0.04	ND	-	17.25	0.92
	ITB1	4.93	0.18	ND*	-	14.75	0.354	ND	-	30.75	1.91	4.95	0.35	ND*	-	15.25	0.64	ND	-	31.40	1.98
	ITB2	4.75	0.07	ND*	-	12.55	0.07	ND	-	32.75	0.92	4.275	0.04	ND*	-	12.4	0.14	ND	-	30.95	0.21

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