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Conceptual Model of Subsurface Processes for Iodine at the Hanford Site

November 2018

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U.S. DEPARTMENT OF ENERGY

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Executive Summary

Currently, there are large dilute ^{129}I groundwater plumes at Hanford, including a groundwater plume in the 200-UP-1 operable unit (OU) located within the Central Plateau of the Hanford Site. The interim record of decision for the 200-UP-1 OU requires that the U.S. Department of Energy evaluate potential treatment options for ^{129}I through further technology evaluation. The approach to the evaluation was defined in the ^{129}I technology evaluation plan and includes an update to the conceptual model (CM) for the plume, as required by the 200-UP-1 remedial design/remedial action work plan. This report describes an updated CM of subsurface processes that affect ^{129}I behavior in the subsurface. This CM was developed to address identified data gaps and to provide input for fate and transport modeling needed to support the remedy evaluation. A significant advancement from previous the CM for the 200-UP-1 OU is recognition of the multiple iodine species in the subsurface and the biogeochemical processes that control their fate and transport.

The CM was developed to incorporate the current information from samples of 200 West Area groundwater (including samples within the 200-UP-1 OU) that show iodine is present as a mix of iodide, iodate, and organo-I species, with iodate being the predominant species. Confirmation of iodine species distribution in the plume is recommended to help validate this CM basis. Plume behavior is affected by differential transport of iodine species due to their different sorption characteristics. This CM describes behavior for radioiodine (^{129}I) and non-radioactive iodine (^{127}I) because both isotopes have the same geochemical behavior. Non-radioactive iodine (^{127}I) concentrations are estimated to be 1000 times higher than radioiodine (^{129}I) in Hanford Site Central Plateau groundwater. This ratio has important implications for remedial strategies because remedies cannot specifically treat ^{129}I without also targeting ^{127}I.

A network of biogeochemical processes controls the fate and transport behavior of iodine in the subsurface. A primary element of the effort to update the iodine CM was to quantify these processes and identify which are of importance at the Hanford Site, in particular for the 200-UP-1 OU. For future fate and transport or remedy evaluation efforts, this information can be used to identify the biogeochemical aspects of iodine behavior. Key elements of this biogeochemical network are described for the aqueous, solid, and gas phases and their interactions.

- Iodide, iodate, and organo-I are the prevalent stable aqueous species in the Hanford subsurface. While there are transformation processes that may occur between these species, iodate has been identified as the dominant species in the majority of groundwater samples that have been analyzed to date for the 200 West Area. Plume behavior is affected by differential transport of iodine species due to their different sorption characteristics. Therefore, fate and transport and remediation must consider the behavior of specific iodine species.
- Solid-phase interactions and species are also important for iodine in the subsurface and function to temporarily immobilize iodine from the aqueous phase. Sorption of iodide, iodate, and likely organo-I compounds to organic matter and minerals is a baseline process in the subsurface that retards iodine movement relative to water movement. This type of sorption has been quantified with distribution coefficient (K_d) values. Iodate, in particular, associates with iron oxides and carbonates. Studies with Hanford sediments have shown substantial iodate associated with these solid phases. These interactions are an attenuation mechanism slowing the flux of iodate toward the groundwater. Iodine can complex with organic compounds that are associated with the solid rather than aqueous phase. Initial studies with Hanford groundwater and sediment showed that soluble organic compounds are more suited to iodine complexation than are the solid-phase organic compounds. Microbial interactions with iodine are also important. Microbial reactions are associated with many of the iodine aqueous-phase reactions and microbes in biofilms associated with the sediments can be a zone of accumulation for iodine. Iodine would be cycled back to the aqueous phase through the cycle of cell

death and lysis. These solid-phase interactions are relevant with respect to attenuating iodine transport and need to be considered with respect to fate and transport and remediation.

- The gas phase is also relevant to the overall iodine cycle. In particular, microbial reactions that create methyl-iodine compounds are a mechanism of volatilization. This type of reaction can occur in Hanford sediments, so it should be considered as part of the potential fate for subsurface iodine. Current studies focused on groundwater conditions, but volatilization in the vadose zone during and after waste disposal is another potential ramification of these gas-phase iodine species. Volatilization is, therefore, another attenuation mechanism related to the fate and transport of iodine in the subsurface.

For iodate in the vadose zone or groundwater, transport is attenuated by sorption and co-precipitation with calcite (and other calcium carbonate polymorphs such as aragonite) and iron oxides (e.g., ferrihydrite). These solid-phase interactions are not a permanent sequestration and iodate may be released back into the aqueous phase via desorption and/or dissolution. The solubility of iodate bearing calcite is similar to that of pure calcite. Ferrihydrite has been previously shown to have a high affinity for iodate adsorption. Data showed that iodate transport was significantly retarded in ferrihydrite-amended sediment, whereas iodide and organo-I species showed little adsorption to ferrihydrite.

Organo-I complexes are present in the Hanford subsurface, predominantly in the aqueous phase. While the organo-I complexation structures in the 200-UP-1 site at Hanford could not be confidently identified, the results suggested that these compounds exist at Hanford. The differences in organic matter composition indicated that pore water samples have a higher abundance of aromatic compounds that are a better target for iodine complexation.

Volatilization of iodine occurred in Hanford sediments. Iodomethane was produced by all of the sediment samples examined and was positively correlated with ^{129}I concentrations in sediment cores. Moreover, its production rate was insensitive to nutrient supplements. This result reflects a nominal capacity of Hanford subsurface sediments to volatilize iodine without additional perturbation of the subsurface system. The fate of iodomethane in the aquifer or the extent to which this process may have impacted iodine in the vadose zone during and after waste disposal have not been quantified. However, this transformation mechanism should be considered when interpreting potential pathways for iodine in the subsurface.

Reduction of iodate to iodide has been observed in the laboratory. This reduction appears to occur via either abiotic and/or biotic pathways, though it is not determined how the observed rates in the laboratory translate to in situ field conditions. Continued reduction of iodate is not consistent with observations that iodate is the dominant iodine species in groundwater and, through its incorporation into carbonate and iron oxide solid phases, the majority of the iodine mass in the vadose zone samples examined to date. A most likely explanation for the continued prevalence of iodate in groundwater is that there is no or minimal reduction of iodate occurring in the aquifer, though this process (which may be either biological or abiotic) is readily induced in the laboratory. Additional investigation of the iodine species distribution in the plume is recommended to help evaluate potential in situ transformation processes during plume transport.

The subsurface processes observed during investigation of the iodine CM need to be considered in evaluating potential iodine remedies. In particular, the CM information has demonstrated that remedial actions may need to be evaluated relative to the effectiveness for each species. In addition, the coupled effects of natural attenuation pathways and induced changes from applying remediation technologies need to be considered.

Several subsurface processes may be relevant for development into remediation strategies. Calcite interactions have been shown important for removing iodate from the aqueous phase and could be designed as a remediation strategy. Interactions of iodate and ferrihydrite have also been shown to effectively remove iodate from the aqueous phase. For pump-and-treat (P&T) extraction of iodine from the groundwater, sorption will decrease extraction performance for iodate. Thus, mechanisms to reduce iodine retardation in the subsurface may improve P&T efficiency.

Acknowledgments

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Acronyms and Abbreviations

AGW	artificial groundwater
CAWSRP	Conducting Analytical Work in Support of Regulatory Programs
CM	conceptual model
DDI	double deionized
DOE	U.S. Department of Energy
DWS	drinking water standard
EDS	energy dispersive X-ray spectroscopy
ESL	Environmental Sciences Laboratory
FIB	focused ion beam
FY	fiscal year
GC	gas chromatography
HASQARD	Hanford Analytical Services Quality Assurance Requirements Document
HDI	PNNL's "How Do I…"
ICP-MS	inductively coupled plasma mass spectrometry
ICP-OES	inductively coupled plasma optical emission spectrometry
ID	identification (number or name)
K_d	linear equilibrium adsorption coefficient
LIMS	Laboratory Information Management System
MS	mass spectrometer
NanoSIMS	nanoscale secondary ion mass spectroscopy
NQA	Nuclear Quality Assurance
NQAP	Nuclear Quality Assurance Program
OC	organic carbon
organo-I	organo-iodine
OU	operable unit
pH	negative of the base 10 logarithm of the hydrogen ion activity in solution
P&T	pump and treat
PNNL	Pacific Northwest National Laboratory
PTFE	polytetrafluoroethylene
PVC	polyvinyl chloride
QA	quality assurance
ROD	record of decision
SAED	selected area electron diffraction
SEM	scanning electron microscopy
SD	standard deviation
SIM	selected ion monitoring
TEM	transmission electron microscopy

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1.0 Introduction

Currently, there are large, dilute ^{129}I groundwater plumes at Hanford, including a groundwater plume in the 200-UP-1 operable unit (OU) located within the Central Plateau of the Hanford Site. The feasibility study for the 200-UP-1 OU determined that there was no current treatment technology that can achieve the federal drinking water standard (DWS) of 1 pCi/L for the ^{129}I concentrations present in the OU (DOE/RL-2009-122, *Remedial Investigation/Feasibility Study for the 200-UP-1 Groundwater Operable Unit*). The interim record of decision (ROD) for the 200-UP-1 OU (DOE 2012, *Record of Decision for Interim Remedial Action, Hanford 200 Area Superfund Site, 200-UP-1 Operable Unit*) requires that the U.S. Department of Energy (DOE) evaluate potential treatment options for ^{129}I through further technology evaluation. The approach to the evaluation was defined in a ^{129}I remediation technology evaluation plan (DOE 2017) and includes an update to the conceptual model (CM) for the plume, as required by the 200-UP-1 remedial design/remedial action work plan. This report is the culmination of a four-year investigation to update the CM of subsurface processes that affect ^{129}I behavior in the subsurface. This CM was developed to address identified data gaps and to provide input for fate and transport modeling needed to support the remedy evaluation. A significant advancement from previous the CM for the 200-UP-1 OU is recognition of the multiple iodine species in the subsurface and the biogeochemical processes that control their fate and transport.

1.1 Sources of the Iodine Contamination at Hanford

A description of iodine sources and current distribution at Hanford is provided in previous reports (e.g., Truex et al., 2015, 2016, and 2017a). The following text summarizes pertinent information relevant to the evolving state of knowledge for the ^{129}I plumes.

Much of the contamination at the Hanford Site resulted from planned releases of process liquid wastes and wastewater to the soil via discharge to engineered structures (cribs, trenches, ditches, ponds, leach fields, or injection wells). Unplanned releases of the same or similar waste materials resulted in contaminant discharges from tanks, pipelines, or other waste storage or conveyance components to the subsurface.

A total of 49.4 Ci of ^{129}I was produced during reactor operations according to fuel activity estimates (Watrous et al. 2002). However, the distribution of that inventory to storage or environmental releases is very uncertain. The inventory has been distributed among the following mechanisms:

- Stored in single-shell and double-shell tanks
- Discharged to liquid disposal sites (e.g., cribs and trenches)
- Released to the atmosphere during fuel reprocessing operations
- Captured by off-gas absorbent devices (silver reactors) at chemical separations facilities (PUREX, B-Plant, T-Plant, and REDOX)

Once ^{129}I and other mobile contaminants reach the aquifer, they spread, producing large-scale plumes. Three ^{129}I plumes in groundwater originate in the Hanford Site Central Plateau and cover an area greater than 50 km^2. In general, the plume emanating from the 200 East Area is larger because of differences in subsurface geology. The water table beneath the 200 East Area and extending to the Columbia River is within more-permeable sediments, which results in faster groundwater flow and shorter travel times in the 200 East Area than in the 200 West Area (Freshley and Graham 1988). The largest ^{129}I plume extends toward the southeast from the 200 East Area. A smaller arm of the plume has moved toward the northwest between Gable Mountain and Gable Butte. The largest ^{129}I plume associated with the 200 West Area is in the 200-UP-1 OU.

The ^{129}I plumes in the Hanford Site Central Plateau are very large and dilute. The lengths of the leading edges of the plumes are on the scale of kilometers. The ^{129}I concentrations are all less than 50 pCi/L, with most less than 10 pCi/L, though above the DWS of 1 pCi/L. Furthermore, natural stable iodine (^{127}I) is also present in the aquifer at much greater concentrations than ^{129}I. The presence of ^{127}I is important because most remediation technologies are not specific for a particular iodine isotope (e.g., Kaplan et al. 2012). In addition, ^{127}I and ^{129}I have the same geochemical behavior in the subsurface so the presence of ^{127}I will influence the biogeochemical processes for ^{129}I.

1.2 Brief Description of the CM Elements

An overview of the system-level depiction of the CM elements affecting iodine fate and transport at the waste sites in the Hanford Central Plateau is presented in Figure 1. The CM elements are (1) inputs, (2) source flux to groundwater, and (3) plume behavior.

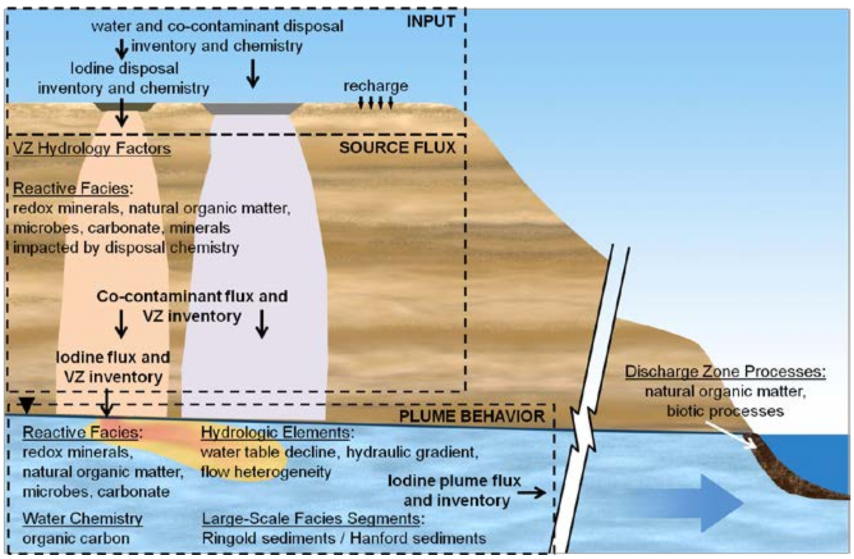


Figure 1. System-level depiction of elements affecting iodine fate and transport.

1.2.1 Inputs

Inputs to the system consist of waste disposal inventories, water disposal volumes, waste disposal chemistry, facility design, and recharge. An estimated amount of 4.7 Ci of ^{129}I was released to waste sites at Hanford (Corbin et al. 2005). The volume of liquid disposal is another important parameter that provides the primary driving force for initial distribution of contaminants in the subsurface, with large volumes generally leading to more extensive migration and in some cases, current breakthrough observed in the groundwater. The waste disposal chemistry (i.e., acidic, basic, elemental composition) is the third important factor controlling interactions of waste fluids and sediment minerals, ultimately affecting contaminant fate and transport in the vadose zone, and influencing the contaminant flux to groundwater (Truex et al. 2014). Additional information about this component of the iodine CM at Hanford has been included in the previously published CM reports (e.g., Truex et al. 2017a).

1.2.2 Source Flux to Groundwater

Source flux is considered in the CM development and remediation phase because the vadose zone contaminant fluxes to groundwater can continue to contribute to groundwater contamination for appreciable amount of time. Usually, contaminated sites have a time- and spatial-dependent long-term contaminant flux controlled by the recharge rate. In addition, iodine speciation affects the iodine source flux to the groundwater. The three primary aqueous iodine species at Hanford are iodate (IO_3^-), organo-I, and iodide (I^-), each exhibiting unique transport characteristics.

There are two major iodine isotopes present at the Hanford Site: ^{129}I (radioactive) and ^{127}I (stable). The source of ^{127}I at Hanford remains unknown but iodine commonly exists as a trace constituent of nitric acid, so ^{127}I plumes may differ from ^{129}I plumes. It is therefore likely that the enormous volumes of nitric acid used during operations are a contributing source for the groundwater ^{127}I. Both ^{129}I and ^{127}I concentrations should be considered when evaluating source flux, plume behavior, and solid phase interactions. ^{127}I and ^{129}I are found in Hanford Site groundwater at $^{127}IO_3^-/^{129}IO_3^-$ ratios ranging from 100 to 300, indicating much higher ^{127}I concentrations in the groundwater.

Other than the hydrologic features and processes, the controlling features for iodine transport in the vadose zone are the same as those in the groundwater. Additional information relevant to evaluating the source flux is provided by Truex and Carroll (2013), in the previously published iodine CM reports (Truex et al. 2015, 2016, and 2017a), and by Rockhold et al. (2018).

1.2.3 Plume Behavior: Controlling Factors, Reactions, and Processes

Hydrologic features are important with respect to water movement in the subsurface and, therefore, affect iodine transport and plume behavior. However, there are other factors that are as important in controlling iodine mobility and species transformation: for example, the presence of minerals that have high affinity for iodine (e.g., Fe oxides and phyllosilicates), minerals involved in electron transfer reactions (e.g., Fe and Mn oxides), as well as minerals that can accommodate iodine species inside their crystal structure, such as carbonates. In addition, the organic matter (either dissolved and/or associated with sediments) plays a crucial role not only because organo-I species comprise a significant portion of the total iodine speciation at Hanford, but also because its presence may promote microbial activities and changing subsurface redox conditions and reactivity of the minerals. Water chemistry components such as elemental composition, carbonate concentration, dissolved organic matter, and pH influence adsorption, transformation reactions, and transport. In addition, co-contaminants, such as nitrate, technetium, uranium, and chromium or other elements and/or organic compounds that participate in redox, sorption, or precipitation reactions may influence the extent and rate of iodine transformation and sorption reactions (e.g., U substitution into calcite may influence iodate incorporation into calcite).

Several observations from previous and ongoing field and laboratory studies of the iodine in groundwater at the Hanford Site provide context for evaluating processes controlling migration of the iodine plumes. Analysis of groundwater samples from the 200 West Area (Zhang et al. 2013) showed a mix of iodine species present with, on average, about 70% of the iodine present as IO_3^-, about 26% as organo-I, and a small amount (about 4%) as iodide (I^-). In addition, sequential extraction of Hanford sediment samples (Xu et al. 2015; Truex et al 2017b; Szecsody et al 2017) showed a significant fraction of iodine in sediment-associated phases in addition to aqueous and adsorbed phases. Collectively, this information and the additional information reported herein demonstrate iodine CM behavior.

1.3 Objectives

The objectives of this report are associated with synthesizing information from the previous iodine CM reports (Truex et al. 2015, 2016, and 2017a) and information from fiscal year 2018 efforts to provide a refined description of the iodine CM for the 200-UP-1 OU.

Specific laboratory objectives for the FY18 effort were as follows:

1. Determine the stability of calcite co-precipitated with iodate.

2. Quantify iodine desorption behavior in contaminated sediments and identify the role of Fe oxides (i.e., ferrihydrite) on adsorption and desorption of major iodine aqueous species (e.g., iodate, iodide, and organo-iodine).

3. Determine the importance and role of microbial-based and abiotic volatilization of iodine for Hanford sediments.

2.0 FY18 Laboratory Experiments

A series of batch and column experiments were conducted during FY18 to study the stability of iodate bearing calcite, measure the rate of microbial mediated iodine volatilization under different conditions, quantify adsorption and desorption behavior for iodate and ferrihydrite, and identify transport parameters for the three major iodine species that are present in the Hanford subsurface. These efforts were targeted at data gaps identified for the CM (Truex et al. 2015, 2016, 2017a).

2.1 Stability of Calcite Co-Precipitated with Iodate

2.1.1 Methodology

Because the incorporation of iodate into calcite is a potential sequestration mechanism, the stability of the co-precipitated calcite is needed to evaluate its role for natural attenuation and its potential use as a remediation mechanism. In previous years, a series of batch experiments was conducted to precipitate calcium carbonate minerals in the presence of iodate and follow iodine uptake as a function of time. The solubility of the calcite solid produced in the experiments was then tested to determine if inclusion of iodate (IO_3) in the calcite structure changed the solubility of the mineral. Stability testing of several calcite solids that were produced during FY16 and FY17 started during FY17. The solids include pure calcite (no iodate present), and calcite precipitated in the presence of 250 or 500 ppb iodate. These calcite solids contained 0, 4.75 and 9.15 µg/g iodine, respectively, as determined by alkaline fusion.

The experimental matrix of test conditions is shown in Table 1. An excess amount of calcium carbonate solid was added to a 50-mL polytetrafluoroethylene (PTFE) bottle, followed by calculated amounts of $NaHCO_3$ or Na_2CO_3 needed to reach pre-determined pH values ranging from 7.4 to 12.6, and then double deionized (DDI) water was added to a final initial volume of 30 mL. For the lower end of the target pH values, HCl was added to obtain the desired pH. For pH values above 9.8, NaOH was added to reach the desired pH. The poly bottles were fitted with an inlet and outlet tube to allow air to flow into the solution without pressurization (see Figure 2). The suspensions were then bubbled with humidified air for several days. Prior to entering the PTFE bottles, the air was passed through a gas washing bottle filled with DDI water to increase the humidity of the air.

Table 1. Calcite stability testing matrix.

Solid ID	Iodine Content (µg/g)	pH Values Tested	Calcite Production Information
Lab produced calcite	0	7.4, 7.8, 8.2, 8.6, 9.0, 9.4, 9.8, 10.2, 10.6, 11.0, 11.4, 11.8, 12.2, 12.6	Produced by combining 1M $CaCl_2$ and 1M $(NH_4)_2CO_3$
Test 7 Calcite	4.75		Produced by combining 1M $CaCl_2$ and 1M $(NH_4)_2CO_3$, spiked with 250 ppb I (added as $NaIO_3$)
Test 9 Calcite	9.15		Produced by combining 1M $CaCl_2$ and 1M $(NH_4)_2CO_3$, spiked with 500 ppb I (added as $NaIO_3$)

Figure 2. The batch reactors used in the calcite solubility studies and a closer look at the vented poly bottle (individual batch reactor).

The pH was measured in each reactor on a semi-regular basis (every 1-3 days) (if necessary, 1M or 2.5M NaOH was used to adjust the pH) until three subsequent pH measurements were ± 0.10 pH units, indicating that the pH had stabilized and therefore the solid and solution had reached equilibrium. Once the desired pH values were reached and remained stable (defined as the time 0), the PTFE bottles were removed from the gas and capped, and then the reactors were placed on a shaker and periodically sampled until Ca concentrations in the aqueous samples were consistent across three sampling points (±10%). Samples were taken several times at weekly or biweekly intervals until the equilibrium conditions were reached. The Ca and I concentrations were determined by inductively coupled plasma optical emission spectrometry (ICP-OES) and/or inductively coupled plasma mass spectrometry (ICP-MS). The determination of equilibrium was based on evaluation of two consecutive data points that showed a nearly identical solution concentration of Ca (±10%). The presence of a solid phase was monitored throughout the experiment as an indicator that the calcium carbonate was still in excess. The data was plotted and compared to modeled calcite dissolution data to determine if the iodate contents affect the stability of the calcite.

In addition to the solubility studies, solid phase (i.e., calcite) characterization studies were conducted. Scanning electron microscopy (SEM) combined with energy dispersive spectroscopy (EDS) and focused ion beam (FIB), and transmission electron microscopy (TEM) combined with selected area electron diffraction (SAED) was used to study the spatial surface and bulk distribution and the identity of phases interacting with iodine.

2.1.2 Results and Discussion

Data from a series of experiments conducted with 0.1 and 1 M calcite-forming solutions [i.e., $CaCl_2$ and $(NH_4)_2CO_3$)] are compiled in Figure 3 and show the starting conditions of the solids in term of iodine incorporation. The relationship between iodine in solution with that incorporated into calcite is linear (R^2 of 0.99 or higher). These data show that the incorporation of iodate into laboratory produced calcite is consistent and predicable, and indicate that the calculated µg/g values are consistent with those determined via alkaline fusion. The alkaline fusion samples (purple diamonds in Figure 3) represent the two solids tested for stability (Test 1 Calcite and Test 2 Calcite, Table 1). The alkaline fusion results are in good agreement with the µg/g calculations (10% to 15%). The comparison between the alkaline fusion data and the calculated µg/g confirms that the estimated calculations of the total mass of calcite produced in these experiments is accurate within margins of error, despite potential discrepancies in measuring the weight of the produced solids. This is clearly demonstrated in Figure 3 where the alkaline digestion results (Figure 3, diamonds) fall on the line of the calculated experimental results (Figure 3, squares).

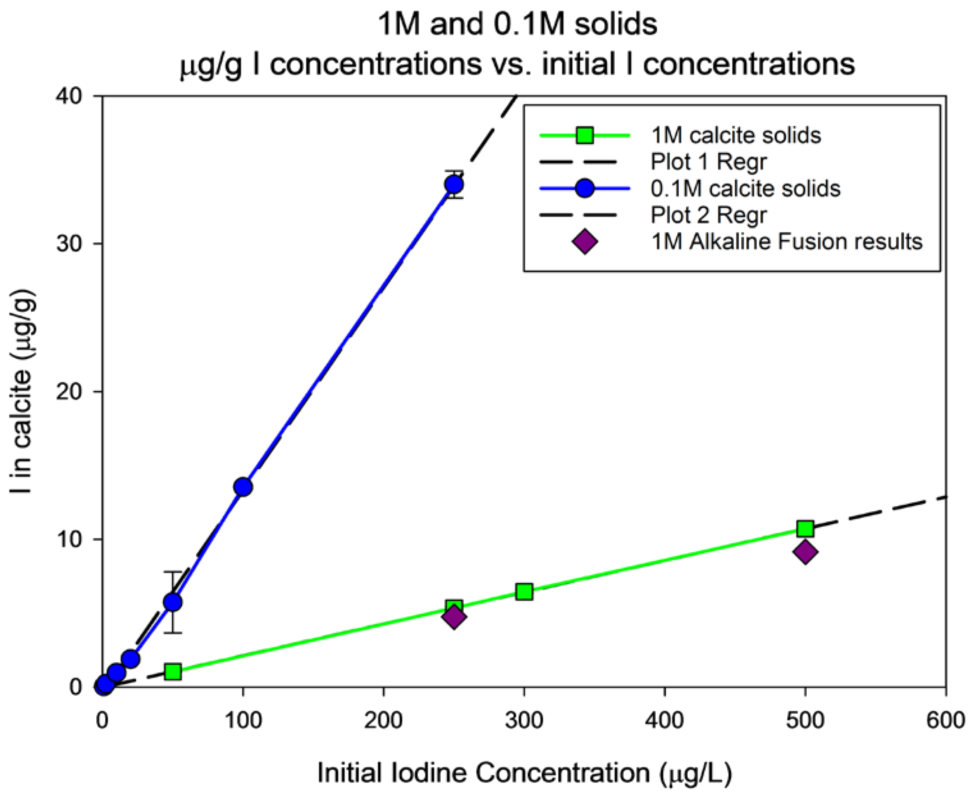


Figure 3. Iodate incorporated into calcite: A summary of data collected in different experiments using 0.1 and 1 M calcite-forming solutions (blue circles and green squares, respectively).

Figure 4 shows the data from the pure $CaCO_3$ and the two experiments with iodine, compared to published calculated solubility data for calcite. This data set shows that there is no significant difference in the solubility of calcite with and without iodate. In addition, aqueous iodine concentrations followed similar trends.

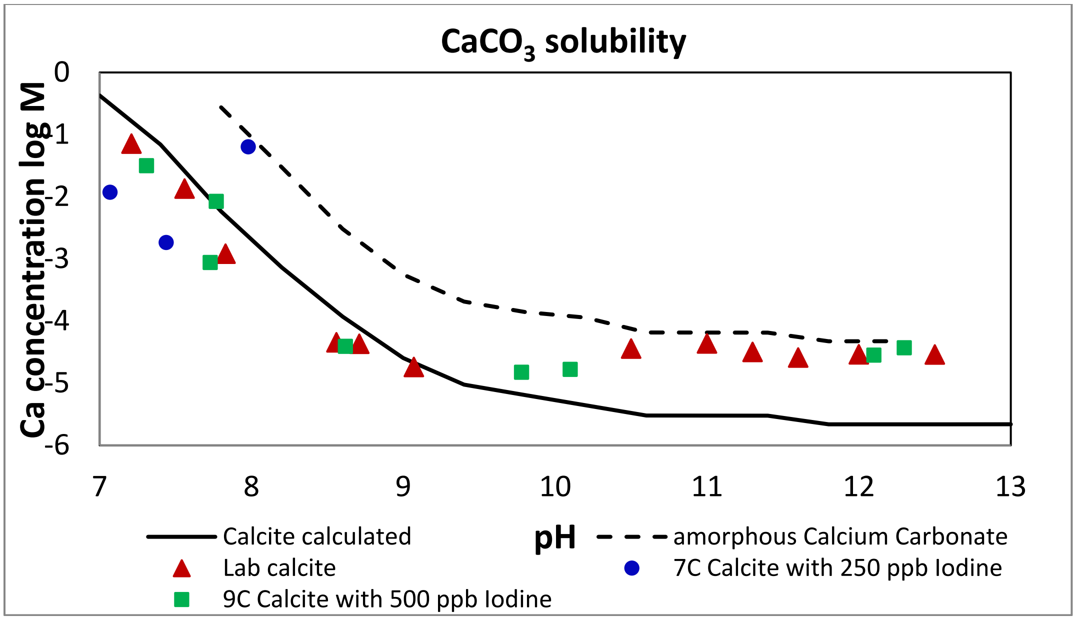


Figure 4. Calcite solubility as a function of pH for calcite produced without iodine spikes (1M; red triangles) and with 4.75 µg/g (Test 7, blue circles), or 9.15 µg/g (Test 9, green squares) iodine concentrations.

SEM images were evaluated with respect to the morphological features of calcite formed in the presence and absence of iodate. The example image shown in Figure 5 demonstrates that no differences were observed in the morphologies of calcite with iodate present.

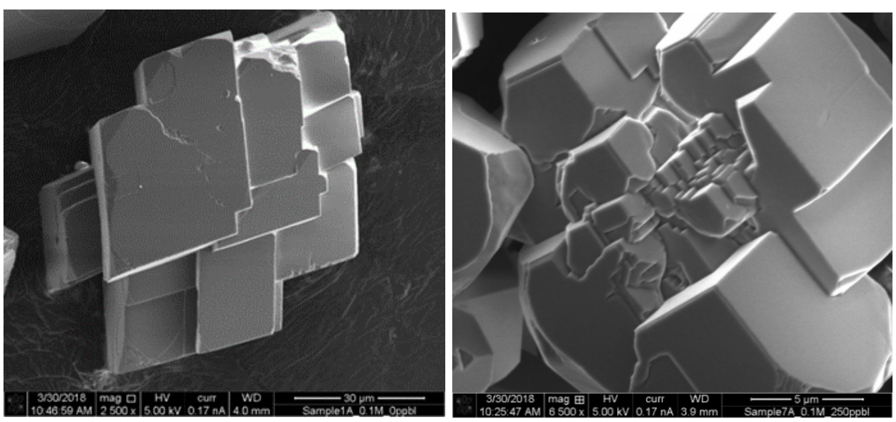


Figure 5. SEM images of calcite precipitated from 0.1M $CaCl_2$ and $(NH_4)_2CO_3$ and a 0 (left) and 250 µg/L iodate spike.

In another effort, SEM was combined with FIB and was used to collect a micron size sample of calcite (Figure 6), which was then inspected with TEM and SAED (Figure 7). The TEM image of the FIB-ed section of the calcite crystal showed a protrusion on the surface and small clusters of heavy metal accumulations in near-surface regions that may be iodine. The protrusion on the surface suggests that iodine is present. However, overlap of the calcium and iodine peaks in the analysis method complicates confirmation of iodine presence.

It is unlikely that the heavy metal observed in the TEM images was an element introduced as impurity in the sample during FIB sample preparation. The fact that the heavy metal was present only in the regions near (Figure 5, the top image) to the crystal surface and not in all other regions (Figure 5, bottom image) suggests that the observed heavy metal is not an artifact introduced during sample preparation efforts.

Other evidence collected from NanoSIMS analyses (see Truex et al. 2017a and McElroy et al. 2018) and molecular dynamic calculations (Kerisit et al. 2018) also strongly suggested that the heavy metal observed in the near-surface regions was indeed iodine (in the form of iodate incorporated into calcite). The SAED measurement included in the bottom image of Figure 7 (small inset in the bottom right corner) confirmed the crystallinity of calcite.

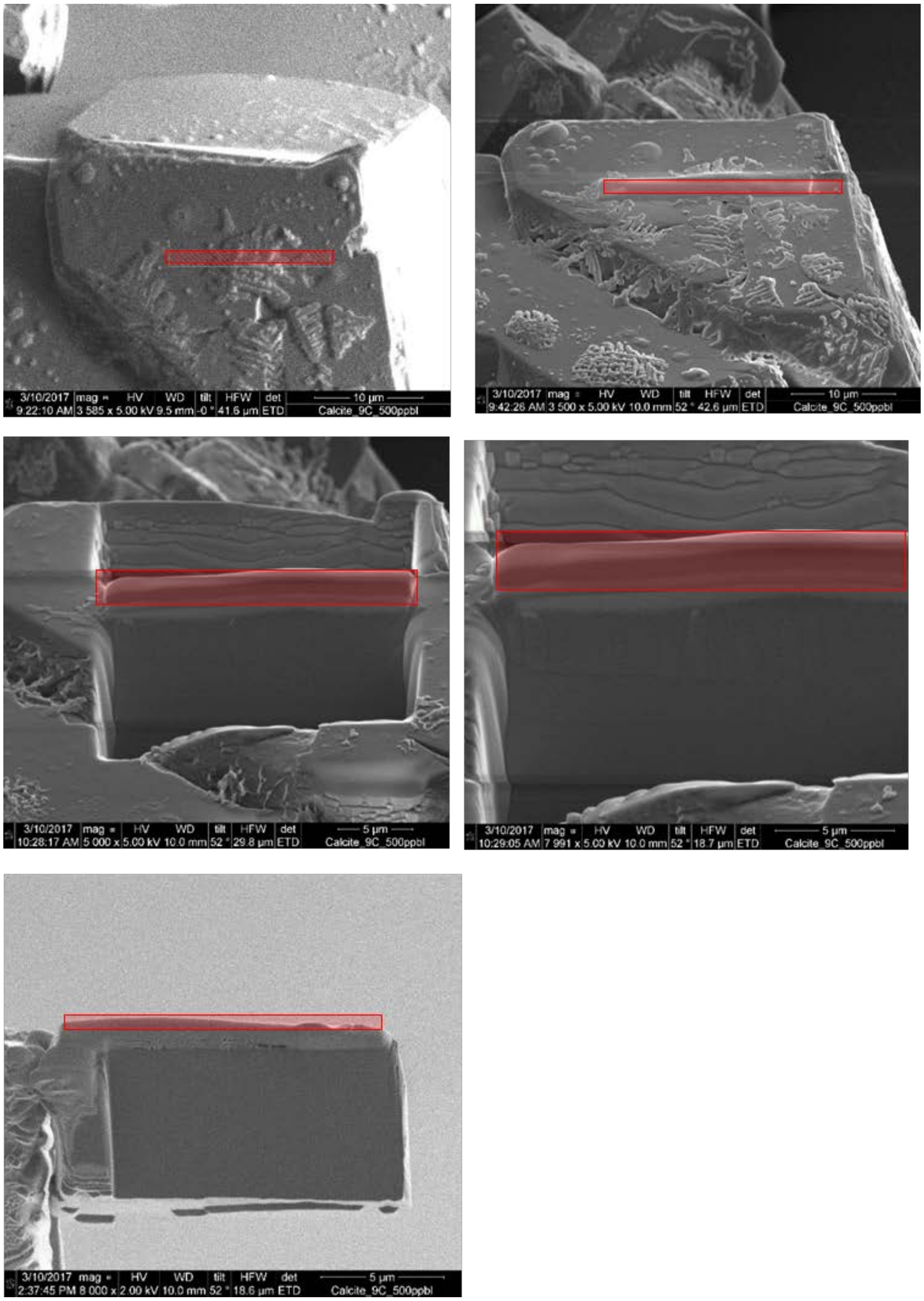
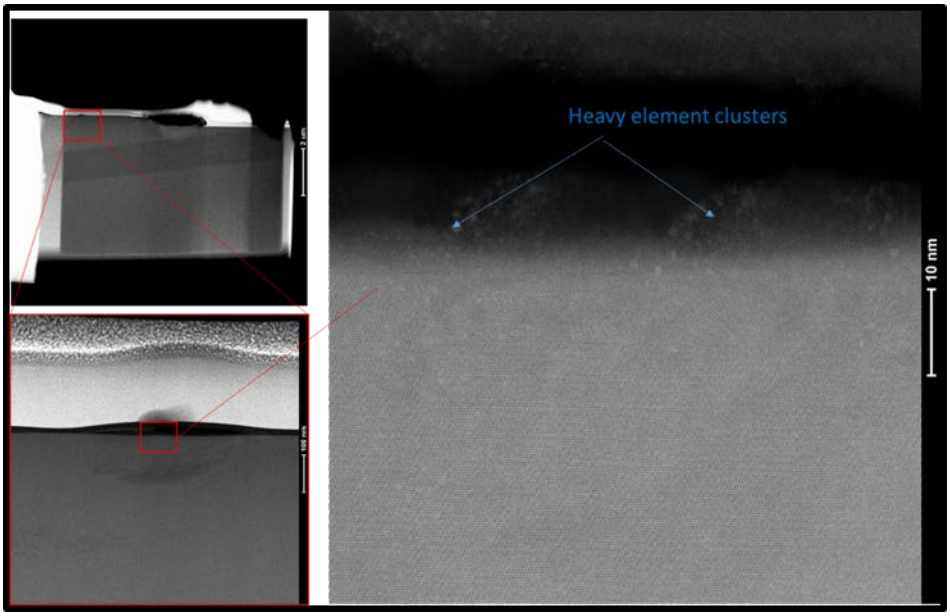


Figure 6. SEM micrograph depicting the location and the process of obtaining a micron size sample from the calcite microcrystal for subsequent TEM/SAED analyses.



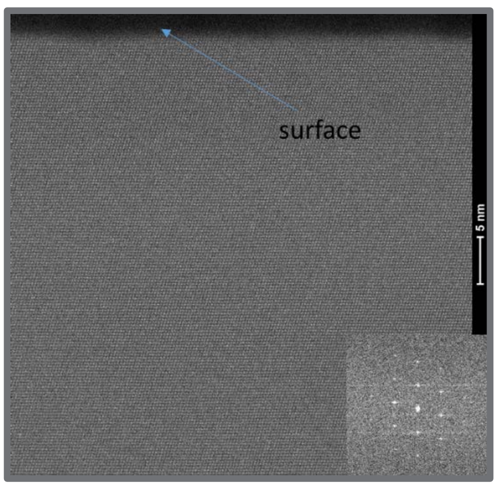


Figure 7. TEM images of a surface regions (top) and bulk region of the FIB-ed section of a calcite crystal, showing a protrusion on surface and small clusters of a heavy metal accumulations in near-surface regions. The clusters of heavy metal accumulations were absent in the TEM images of the bulk crystal (bottom image). The SAED measurement included in the bottom image (small inset in the bottom right corner) confirms the crystallinity of calcite.

In summary, these investigations indicate that the solubility of the iodate-bearing calcite and that of pure calcite are similar. This result means that co-precipitated iodate is not permanently sequestered, but co-precipitation is a process that will retard iodate transport through precipitations and dissolution reactions. These solubility results are consistent with analyses showing that the morphological features of iodate-bearing calcite and pure calcite are similar. In addition, analyses suggest that iodate was incorporated into calcite structure in the form of surface protrusions and clusters accumulations in near-surface regions.

2.2 Transport Studies

2.2.1 Methodology

Hydraulically saturated column experiments (a total of six columns) were conducted to initially study iodine desorption from a contaminated sediment collected in the 200-UP-1 OU (sample number B349R7, from borehole C9415, 315.79 to 316.29 feet below ground). A sediment characterization effort was conducted to determine the moisture content, reactive surface area, particle size distribution, and pH in the sediment that was used to pack the columns.

To study the role of iron (Fe) oxides in controlling iodine transport parameters such as distribution coefficient (K_d) and retardation coefficient (R), the sediment packed in three of the six columns (i.e., columns 2, 3, and 4) was amended with freshly made ferrihydrite. Ferrihydrite was added as a slurry (about 2.44 g of ferrihydrite), which was thoroughly mixed with 200 g of the < 2 mm size-fraction separated from the sediment (Figure 8).

Figure 8. The process of mixing the UP-1 sediment with the ferrihydrite.

The ferrihydrite (Figure 9 shows an SEM image of the ferrihydrite) was made in the laboratory following this method: Synthetic 2-line ferrihydrite was prepared by titrating 0.092M $FeCl_3$ solution with 2M NaOH to a neutral pH 7.0 in a plastic container that was acid washed with 2M HCl. The precipitate that rapidly formed was agitated in a shaker overnight followed by one last pH adjustment with 0.2M NaOH to the neutral pH. After three rinses with deionized water and centrifugations at 5000 g, ferrihydrite was re-suspended in deionized Milli-Q water and suspension density was calculated by dissolving a volume of ferrihydrite into 4M HCl, reducing it with 10% hydroxylamine hydrochloride at pH 7, and analyzing Fe^{2+} with ferrozine method (Stookey 1970).

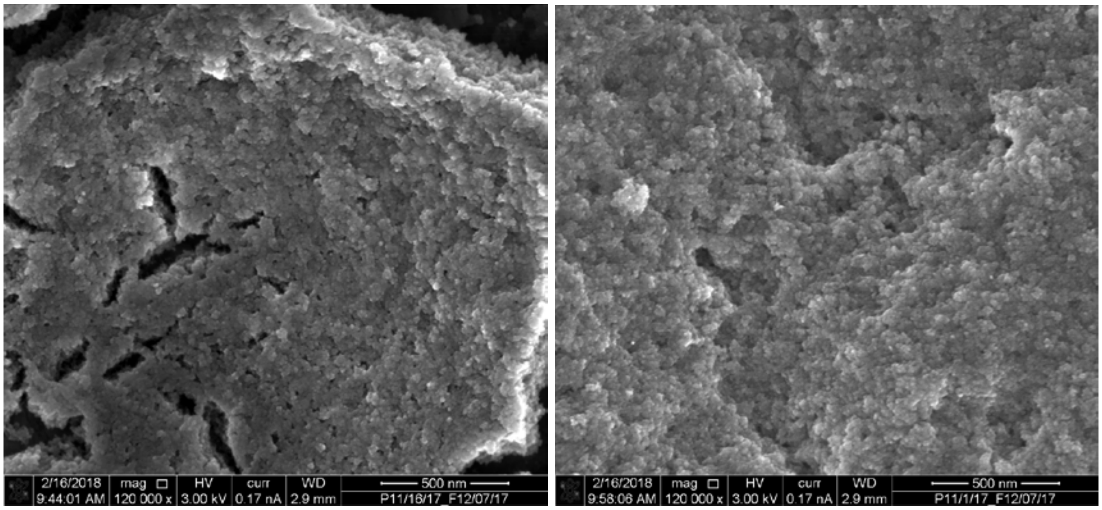


Figure 9. SEM images of the ferrihydrite used in the column experiments.

Six polyvinyl chloride (PVC) columns, each with inner diameter of 3.2 cm and length of 14.5 cm, were packed uniformly with the UP-1 sediment (about 2% water content) by pouring 10-g increments into the columns, then tamped with a plastic dowel (Qafoku et al. 2004, 2009). Before adding the next increment, the surface of the tamped portion was lightly scratched to minimize layering inside columns. Filter papers (0.25 cm thick and 10 µm pore diameter) were used at the top and bottom of each column to assist in uniform distribution of the leaching solution at the column inlet and to prevent sediments from being removed from or blocking the column outlet and tubing that connected the column outlet with the syringe pumps. A Klohen pump controlled flow through the columns that were oriented vertically. The flow rate during saturation of the columns was very slow (about 14.4 ml/min). [It took approximately 3 to 4 days to saturate the column by injecting artificial groundwater (AGW) from the bottom entry.] The flow rate during leaching was adjusted to 0.083 ml/min, which yielded an approximate fluid residence time of 8 hours (i.e., it took approximately 8 hours for 1 pore volume to go through the columns).

The columns were leached with AGW with a chemical composition presented in Table 2. The reagents were added to DDI water in the order identified in Table 1. Once the chemicals were dissolved, an excess of calcium carbonate ($CaCO_3$) was added to the solution and allowed to stir the AGW open to air for approximately 1 week until pH reached a value of ~7.5. After approximately 1 week, the solution and excess $CaCO_3$ were filtered out using a 0.45-µm filter.

Table 2. Hanford (artificial) groundwater (AGW)

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

Initially, an iodine-free solution was used to leach the columns (about 35 pore volumes, phase 1 of leaching) to study iodine desorption from the sediments until either steady low iodine concentrations or iodine concentrations below instrument detection limits were measured in the effluents. Phase 1 was followed by the injection of an iodine-spiked AGW with a concentration of 100 ppb (phase 2 of leaching) to study the adsorption extent of the iodine species, iodate (column 1 and 2), iodide (columns 3 and 5), and organo-I (the organo-I compound was 2-iodo-5-methyoxyphenol) (columns 4 and 6). The third phase of leaching was similar to the first one; during this phase, all columns were leached again with the iodine-free AGW to study desorption patterns and the extent of sorbed iodine (as iodate, iodide, and organo-I).

When physical and chemical steady-state conditions were established in the columns, the flow interruption method was used to test if non-equilibrium conditions were affecting solute transport in these experiments (Qafoku et al. 2004, 2009). Two stop-flow events of 137 and 74 hours of duration were applied during phase 1 of leaching. Additional stop-flow events were applied during phases 2 and 3 of leaching. The changes of iodine species concentrations during the stop-flow were used to calculate rates of iodine release from sediment.

In all column experiments described above, a bromide-rich AGW was then leached through the column to determine transport parameters of a non-conservative tracer. The AGW was spiked with a bromide concentration of 50 ppm and the bromide breakthrough curve generated was used to calculate the dispersion coefficient in each column, which is a parameter needed to calculate the retardation coefficient of iodine species.

Photos of the column setup apparatus are presented in Figure 10. The column effluent was collected in fraction collectors shown in Figure 10 in 8-ml vials that were capped after effluent collection (portions of about 5 ml). The column effluent was frequently analyzed for iodine, and periodically for iodide and iodate species. In addition, pH measurements in the effluent were taken frequently during leaching and the leachate was also periodically analyzed for other contaminants and chemical elements (i.e., Al, Ba, Br, Cd, Ca, Cs, Cl, Cr, Cu, F, Pb, Mg, Mn, Mo, NO_3, K, Se, Si, Ag, Na, Sr, S, SO_4, and Zn).

Figure 10. The column setup.

2.2.2 Results and Discussion

Results are presented for both native sediment and sediment amended with ferrihydrite. The ferrihydrite amendment tests the impact of zones in the aquifer where Fe oxides concentrations may be higher (and are also potentially relevant to a Fe oxide-based remedy). The results show the impact of ferrihydrite in promoting additional sorption capacity. However, the amendment of ferrihydrite also caused some geochemical changes that are not representative of natural conditions. These results are reported below for completeness, and are not necessarily part of an iodine CSM. The main element of the CSM related to ferrihydrite is its enhancement of sorptive capacity.

The results from the iodine desorption experiments conducted with six PVC columns packed with the 200-UP-1 sediment and leached with an iodine-free AGW are presented in Figure 11 and Figure 12 (note that columns 1, 5, and 6 serve as the no-ferrihydrite controls for columns 2, 3, and 4, respectively, and are therefore presented together as pairs in the figures).

Data showed that there was a pulse of iodine concentrations released from the sediments in the first 1 to 2 pore volumes. The initial concentration observed in the first pore volume was in the range of 45 to 65 μg/L. The amount of iodine released from the sediment in the column effluents was greater in the columns packed with the sediment amended with ferrihydrite (i.e., columns 2, 3, and 4). The effluent pH was slightly acidic (pH ~6.5) in these columns, as well. The slurry of ferrihydrite that was mixed with the sediment (shown in Figure 8) had a slightly acidic pH.

Because of the slightly acidic pH created in the mixture sediment-ferrihydrite, dissolution of sediment carbonates was promoted in this system. This was confirmed by the measurements of the Ca, Mg, and Ba effluent concentrations performed in the first pore volume, which were much greater in the columns amended with ferrihydrite (columns 2, 3, and 4) compared to the ones that did not have ferrihydrite (columns 1, 5, and 6) (e.g., Table 3; data for other columns are included in Appendix A). As a result, some iodine may have been released during carbonate mineral dissolution in the ferrihydrite columns. Iodine released from carbonate minerals is expected to be iodate. However, data from the iodine speciation analyses conducted in the effluent samples confirmed that the speciation of iodine in the experiment with no ferrihydrite was split between iodate and iodide, while iodine speciation was dominated by iodide in the effluents of columns with ferrihydrite in the first pore volume (Table 4 and Table 5).

Data from the speciation analyses conducted during iodine contaminant desorption phase showed that both iodate and iodide were present in the column aqueous phase. In the ferrihydrite columns, a higher percentage of the total iodine was present as iodide compared to iodate while the two iodine species were mostly present in equal amounts in the columns without ferrihydrite (Table 4 and Table 5). The data suggest that there is either an iodide-bearing source in the sediments and/or a potentially redox sensitive reactive phase coated with a carbonate mineral layer that reduces iodate to iodide as soon as the coating is removed via a pH-change-induced dissolution reaction. This is evidenced by the higher iodide concentrations in the ferrihydrite columns compared to the columns without ferrihydrite. Another possibility would be bacterial-induced reduction, but this process needs confirmation in separate batch experiments designed to study biotic effects on iodine species transformation in the presence of ferrihydrite.

Effluent iodine concentrations increased during the stop-flow events (Figure 11 and Figure 12). The increase during stop-flow events was substantial in the columns amended with ferrihydrite, varying in the range from 5 to almost 30 μg/L in these columns. These results indicate that desorption was time-dependent and that the processes such as dissolution and micro-scale diffusion may be occurring.

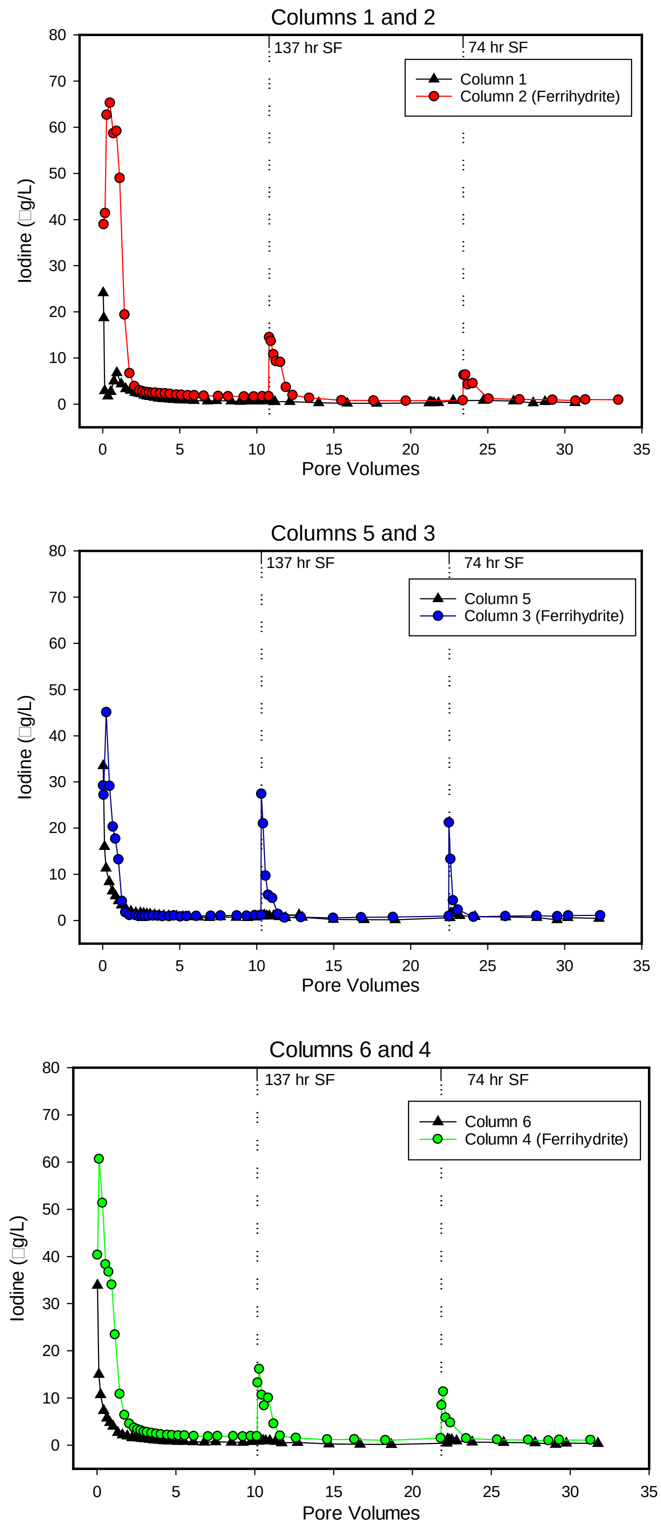


Figure 11. Changes in the total iodine concentration with time/pore volume during leaching with the iodine free artificial groundwater. The sediment packed in columns 2 (red), 3 (blue), and 4 (green) was amended with ferrihydrite. Two stop-flow (SF) events of different durations (i.e., 137 and 74 hours) were applied during leaching.

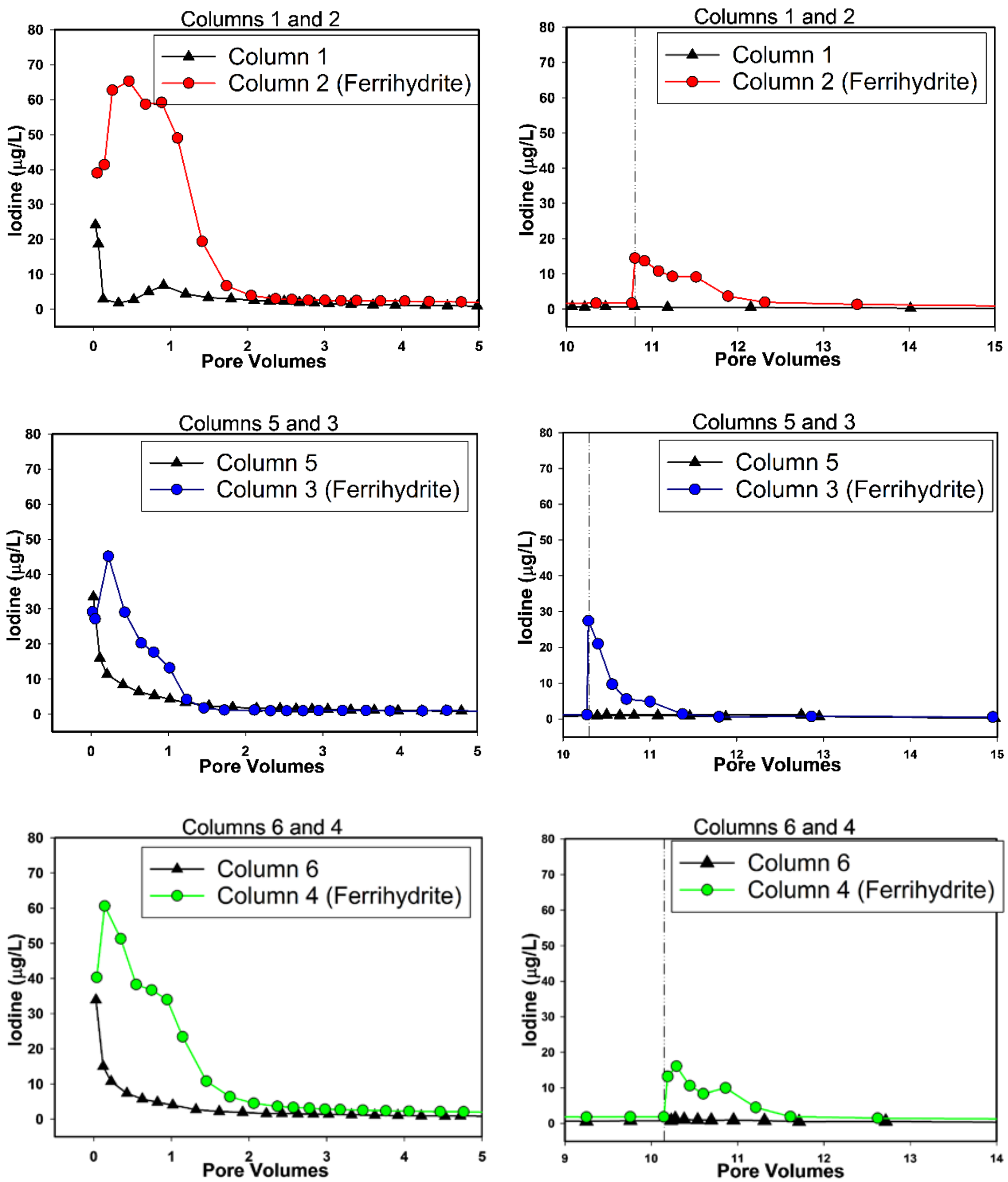


Figure 12. A closer look at the changes in total iodine concentration at the beginning of the leaching (1-5 pore volume) and during and immediately after the stop-flow events applied at different times/pore volumes during leaching with the iodine-free AGW. The sediment packed in columns 2, 3, and 4 was amended with ferrihydrite.

Table 3. Changes in Ca, Mg, and Ba concentrations during leaching in the presence (column 3) or absence (column 5) of ferrihydrite. (*) next to the pore volume indicates a stop flow.

Column 5 (no ferrihydrite)				Column 3 (ferrihydrite)			
Pore Volume	Ca (μg/L)	Mg (μg/L)	Ba (μg/L)	Pore Volume	Ca(μg/L)	Mg (μg/L)	Ba (μg/L)
0.01	177000	54400	207	0.00	401000	126000	560
0.07	105000	33100	124	0.04	354000	109000	491
0.12	72700	23000	97	0.06	425000	133000	598
0.31	35600	11200	47.7	0.33	229000	71000	323
2.35	12300	3870	ND	2.01	4490	1340	ND
3.26	13600	4270	17.6	3.05	4910	1510	ND
4.39	15500	4800	18.9	4.19	9340	2980	ND
4.69	17400	5000	24.6	4.50	11300	3340	ND
5.71	18000	5220	21	5.64	15700	4750	24.9
6.82	18200	5180	23.6	6.79	16400	4960	27.3
7.13	18900	5180	23.5	7.11	17200	5040	25.7
8.26	19700	5370	26.2	8.17	17800	5180	26.8
9.29	19300	5350	26.5	9.22	17600	5110	28.2
9.60	19400	5340	22.3	9.55	18800	5420	28.9
10.23	19600	5340	22.1	10.08	18700	5340	28.8
10.45*	18900	5510	21.7	10.34*	17600	5580	22.7
10.76	17300	5070	19.7	10.68	17300	5650	23.5
11.14	17700	5240	19.6	11.06	17100	5280	22.4
11.97	16200	4890	19.7	11.90	17400	5450	22
15.07	17100	5120	19	15.05	15900	5260	22.1
17.08	15800	5050	18	16.87	16700	5200	21.1
19.09	16800	5010	16.9	18.95	16700	5360	22
22.47	15000	4550	17.4	22.38	16100	5290	22.5
22.65	17200	4950	19.2	22.53	17800	5150	21.7
22.98	15200	4510	16.6	22.85	17200	5130	21.8
23.59	17400	5040	19.1	23.46	17900	5300	21.8
26.07	17200	5040	19.1	26.04	16600	4950	20.4
28.09	16600	4850	17.5	28.06	16900	5060	19.5
30.10	16700	4880	17.9	30.12	17300	5140	21.2
32.13	16200	4850	16.4	32.20	16300	4890	20.3

Table 4. Iodine speciation in the first effluent samples collected in each of the six columns (samples in grey font are below the instrument detection limit).

Column Experiment	Pore Volume	Iodate (μg/L)	Iodide (μg/L)	Ferrihydrite
Column 1	0.03	12.36	11.19	No
Column 1	0.15	2.128	1.19	No
Column 2	0.03	0.033	40.36	Yes
Column 2	0.27	0.111	68.7	Yes
Column 3	0.02	4.672	28.88	Yes
Column 3	0.20	0.201	48.65	Yes
Column 4	0.03	1.108	44.22	Yes
Column 4	0.33	0.499	59.63	Yes
Column 5	0.02	14.413	20.16	No
Column 5	0.22	8.535	4.5	No
Column 6	0.03	19.26	13.17	No
Column 6	0.22	9.822	2.95	No

Table 5. Iodine speciation in the effluent sample collected before the first stop-flow events (samples in grey font are below the instrument detection limit).

Column Experiment	Pore Volume	Iodate (μg/L)	Iodide (μg/L)	Ferrihydrite
Column 1	9.7	0.64	0.26	No
Column 2	10.7	0.14	1.38	Yes
Column 3	10.2	0.72	0.54	Yes
Column 4	10.1	0.33	1.43	Yes
Column 5	10.4	0.57	0.68	No
Column 6	10.2	0.58	0.56	No

After the initial phase of leaching with an iodine-free AGW for about 35 pore volumes (phase 1 of leaching), an iodine-spiked AGW with an iodine concentration of 100 ppb was injected into the columns (phase 2 of leaching) using the same flow rate as the one applied during phase 1 (i.e., 0.083 ml/min, which yielded an approximate fluid residence time of 8 hours).

The inlet AGW solution was spiked with different iodine species, e.g., iodate (columns 1 and 2), iodide (columns 3 and 5) and organo-I (the organo-I compound was 2-iodo-5-methoxyphenol) (columns 4 and 6) and the breakthrough of these species was followed in the column effluents. A sufficient amount of influent was injected in these columns until full breakthrough curve was observed (i.e., $C/C_0 = 1$) for each of the respective iodine species. Stop-flow events were applied to study the kinetic effects during adsorption.

The third phase of leaching was similar to the first one. During this phase, all columns were leached again with the iodine-free AGW to study desorption patterns and the extent of adsorbed iodine (as iodate, iodide, and organo-I) (phase 3 of leaching). Because of the high iodate sorption capacity demonstrated by the ferrihydrite-amended sediment, only the initial portion of the desorption data are reported for these columns.

Iodide adsorption was not significant (Figure 13) and full breakthrough was achieved after about 2 pore volumes of iodide AGW spiked solution were injected into the columns during contaminant loading and leaching phases. There were no significant differences observed in the presence and absence of ferrihydrite in terms of the transport (adsorption and desorption) of iodide. A similar behavior was observed in the columns leached with the organo-I species. However, the organo-I species concentration never reached the $C/C_0 = 1$ (i.e., full breakthrough). The upper section of the organo-I breakthrough curve during adsorption in both presence and absence of ferrihydrite showed an inconsistent pattern, likely indicating sorption and/or transformation reactions. In addition, desorption curve showed retardation in the initial phases during leaching indicating again interaction with the sediment matrix.

The transport of iodate was retarded significantly during contaminant loading and leaching phases of these columns. Very significant retardation was observed in the column packed with the ferrihydrite-amended sediment. Both adsorption and desorption proceeded slowly, confirming that ferrihydrite was a good sorbent and significant sink/source for iodate. The concentrations of the respective iodine species changed significantly during the stop-flow events (this was very well pronounced in the columns amended with ferrihydrite), indicating adsorption/desorption time dependency or that other reactions were occurring simultaneously, contributing to the aqueous iodine concentrations. Pictures of the sediment materials removed from columns 3, 4, 5, and 6 at the end of the experiments are shown in Appendix C.

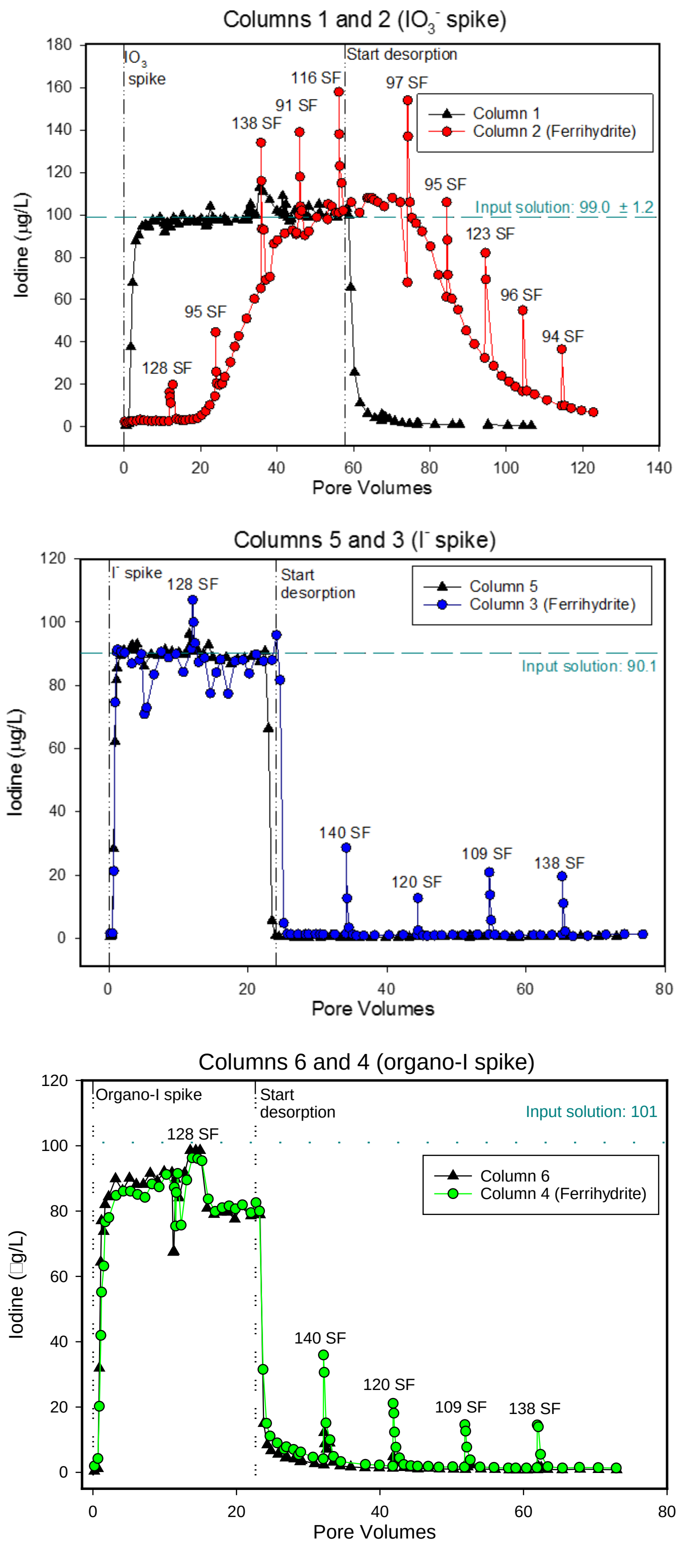


Figure 13. Changes in the iodine effluent concentrations in columns 1 and 2, 3 and 5, and 4 and 6 during leaching with the iodine (iodate, iodide, and organo-I) spiked solutions, respectively to identify adsorption, and desorption during leaching with the iodine-free solution. The input concentrations for the iodate, iodide, and organo-I were 100, 90.1, and 101 µg/L, respectively.

In summary, the results presented in this section demonstrate that, for the 200-UP-1 OU sediments, existing sorbed iodine is leaching occurs via slow-release mechanisms. Sorption is highest for iodate and very low for iodide and organo-I. When ferrihydrite is added it increases the iodate sorption capacity of the sediment. However, the added ferrihydrite also appears to have altered the existing geochemical conditions in the sediment (i.e., by lowering pH and promoting redox processes by exposing reduced materials), resulting in greater iodine leaching from the sediment, predominantly in the iodide form.

2.3 Microbial-Based and Abiotic Volatilization of Iodine

2.3.1 Methodology

Many bacteria and fungi have the capacity for volatilizing iodine as organo-I species, though relatively little information is available about iodine volatilization from terrestrial systems. Methylation and volatilization could be an important attenuation pathway for I contaminated sites at Hanford, however this activity has not been previously investigated. The potential capacity for I-contaminated Hanford subsurface sediments to volatilize iodine was measured, and the solubility of the organo-I species formed was evaluated under site relevant conditions.

Microcosms were prepared from two representative Hanford subsurface sediment cores [i.e., 200-UP-1 core 299-W21-3 (C9415) and 200-ZP-1 core 299-W18-42 (C9563)] that were stored at 4°C. UP-1 sediments were used from designated intervals R3 (275’ depth) and R4/R5 (317’ depth). 200-ZP-1 sediments were used from the T3 (198’ depth) designated interval. 200-UP-1 sediments from R4/R5 served as high radioiodine sediments (10 ppb ^{129}I), R3 sediments served as low radioiodine sediments (1.0 ppb ^{129}I), and 200-ZP-1 sediments from T3 provided the no radioiodine sediments.

Genomic DNA (0.25 g) was extracted (n = 6/interval) from 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).

Sediments (5 g) were aseptically weighted into sterile 160-mL serum bottles and combined with filter sterilized synthetic groundwater (20 mL; Truex et al. 2017a). To measure the effect of organic substrate amendment on iodine volatilization, glucose and yeast extract were added to microcosms at 1 mM (final concentration) and 20 g/L (final concentration), respectively. Baseline controls received no organic supplementation, only synthetic groundwater. Abiotic controls included sediments that were “heat killed” at 100°C for 60 min. Microcosms were spiked with a potassium iodide stock solution to achieve a final added I^- concentration of 0, 150, 200, and 250 µg/L. All experimental treatments were performed in triplicate (n=70). Resazurin was added to all bottles at 1 mg/L (final concentration) to monitor relative changes to the redox potential as a function of treatment conditions and incubation time. Bottles were fitted with a sterile butyl rubber stopper, crimp sealed, and incubated in the dark at 28°C for 40 days.

A GC-MS system (Agilent 7890A GC, SN# CN10934012; Agilent 5975C MS, SN#US93413356) was used for headspace sample analysis. Standards were prepared with analytical grade chemicals (

Table 6) at 200 ppb in synthetic groundwater. Standards and experimental microcosms were heated at 70°C for 30 min prior to headspace analysis. A GC-MS scan run was performed first to identify the iodine compounds on the mass spectrum, and to define their respective retention times. A GasPro 60m PORAPLOT column was used to separate the compounds. The temperature for the GC column was initially set at 40°C, held for 4 min, and then ramped up to 220°C at a rate of 20°C/min and held for 5 min. Only iodomethane, iodoethane, and 1-iodopropane could be detected by this GC-MS method. A selected ion monitoring (SIM) method was then developed in order to detect compounds at a lower concentration range (ppt). The ion numbers used in the SIM method were 57, 127, 141, 142, 156, 170, and 184. Headspace samples were collected using a gas tight syringe and analyzed using the GC-MS SIM method. The integrated areas of the MS spectrum peaks from the samples were compared to the peak area obtained from the pure standards to estimate the concentrations of compound produced.

An analytical scan method was developed on a GC-MS/MS (Agilent 7890B GC, SN# US15063008; Agilent 7000C triple quad MS/MS, SN#US1519T302) system. This method was used to detect the organic iodine compounds and to define their retention times. The HP-5MS 50m x 200 µm x 0.33 µm GC column was used at an initial temperature of 50°C, held for 3 min and then ramped up at a rate of 10°C/min to 250°C for 4 min. The column temperature was ramped again at a rate of 20°C/min to 300°C and held for 0.5 min. The mz range use for this analysis was from 120 to 260.

Iodomethane was the only compound that could not be detected by this method because it eluted during the solvent delay time for MS/MS. A SIM method was then developed to detect lower concentrations used to analyze all samples. In the SIM method, the same GC column and temperature program described above was used. The selected ions were 127, 156, 170, and 184 (these are signature ions for reference organo-I species and standard notation for mass spectra). The integrated areas of the MS spectrum peaks were compared to the peak areas obtained from pure standards to estimate the concentrations of the detected compounds. Post-incubation, synthetic groundwater was separated from ZP-1/UP-1 sediment by centrifugation (1000 g for 20 min) and transferred to a 40-mL glass vial. The synthetic groundwater was extracted with methylene chloride (2.0 mL) for 12 hours at room temperature by continuous gentle mixing. The methylene chloride phase was analyzed.

Batch experiments were conducted to determine the Henry’s law constant (K_H) for iodomethane (CH_3I; 100 µg/L) in Hanford simulated groundwater at 18°C. Three different water/headspace (v/v) ratios were measured in duplicate following 9 days of incubation in the dark. Gas phase concentrations of iodomethane were measured using the analytical method described above. Dimensionless K_H was calculated using the following equation:

$$K_H = C_g\,(\mathrm{mg/L})/C_l\,(\mathrm{mg/L}),$$

where C_g is the concentration in gas phase and C_l is concentration in liquid phase.

2.3.2 Results and Discussion

The resazurin in the synthetic groundwater was reduced from blue to pink in all of the biologically active experiments within 5 days of static incubation (28°C, dark), while the dye remained oxidized (blue) in the abiotic controls for the duration of the experiment (40 days). This rapid microbiological response to soil wetting confirmed the viability of the Hanford sediments used in these experiments, but also demonstrates the ability of the soil microbiome to quickly activate respiration when soil conditions change or become more favorable. Microbial cell densities were estimated by QPCR to be 2.24 x 10^7 [±0.1 standard deviation (SD)] 16S rRNA gene equivalents / gram for the no iodine 200-ZP-1 sediment, 1.27 x 10^6 (±0.05 SD) 16S rRNA gene equivalents / gram for the low iodine 200-UP-1 sediment, and 2.79 x 10^5 (±0.1 SD) 16S rRNA gene equivalents / gram for the high iodine 200-UP-1 sediment.

Iodomethane was produced by nearly all (52 out of 54) of the sediment microcosms constructed in this study, regardless of prior exposure to radioiodine contamination or the experimental treatments conducted in the laboratory. No other gaseous iodine compounds were detected. Only 2 microcosms, both derived from ZP-1 sediments but different treatments, failed to produce iodomethane by the end of the 40-day incubation period. Iodomethane was not detected from any of the heat-killed abiotic control sediments, implying that iodomethane was produced microbiologically. This unanimous result is consistent with numerous studies that have shown that iodine volatilizing bacteria are ubiquitous in soil environments (Amachi et al. 2001; Yeager et al. 2017). On average, iodomethane production was not significantly different (t-test, $p > 0.05$) between cores or experimental concentration of KI^- (Table 7). However, when iodomethane emissions were normalized by microbial cell densities (Table 8 and Table 9), iodine volatilization was positively correlated [$R^2 = 0.53$ (baseline, untreated microcosms) and 0.77 (carbon amended microcosms)]) with the relative radioiodine concentration in groundwater from the three sediment core intervals (ZP-1 No-I; UP-1, Low-I; UP-1, High-I). This result has been described previously in the literature for natural environments that span a range of iodine concentrations (e.g., marine to terrestrial), but this observation has not been extended to radioiodine-contaminated sites. It is unclear if iodine volatilization is occurring in the Hanford subsurface, but an averaged experimental conversion of >60% of the total iodine mass to organo-I species could be significant depending on the temporal and spatial scales of activity. These findings are particularly relevant to the Hanford site because iodine volatilization activity appears to be higher under oligotrophic conditions (i.e., resting cells) and would not require nutrient stimulation for growth.

Organic substrate amendment had an unexpected effect on iodomethane production (Figure 14). Iodomethane production was significantly higher in 200-ZP-1 (No ^{129}I) and UP-1 (High ^{129}I) microcosms that did not receive glucose and yeast extract supplementation compared to those that did (Table 8). Iodomethane production was statistically unaffected by nutrient supplementation in the 200-UP-1 (Low ^{129}I) microcosms, except for those that received 200 µg/L KI^-. This result is contrary to published studies on rice paddy soils where glucose and yeast extract were found to stimulate biological emission of iodomethane (Amachi et al. 2003). These experiments clearly indicate that iodide was being methylated and volatilized by soil bacteria, as no iodine emissions were detected from the abiotic controls; however, the decrease in activity in response to carbon and nutrient supplementation cannot be explained.

All of the organic iodine reference standards listed in Table 6, except iodomethane and I_2, could be detected and quantified from methylene chloride extractions and analysis by GC-MS/MS. None of these compounds were detected from methylene chloride extractions performed on the biotic or abiotic experimental microcosms.

Table 6. Organic iodine reference compounds.

Compound	Formula	MW	CAS #
Iodine	I_2	253.81	7553-56-2
Iodomethane	CH_3I	141.94	74-88-4
Iodoethane	C_2H_5I	155.97	75-03-6
1-Iodopropane	C_3H_7I	169.99	107-08-4
2-Iodopropane	C_3H_7I	169.99	75-30-9
2-Iodobutane	C_4H_9I	184.02	513-48-4
2-Iodo-2-methylpropane	C_4H_9I	184.02	558-17-8

To properly consider the flux of iodomethane from Hanford groundwater to the vadose zone, Henry's law constant was determined in synthetic groundwater medium at in situ groundwater temperature, 18°C. The dimensionless K_h for iodomethane was determined to be 1.8 x 10^{-1}, which is consistent with the averaged published value of 1.7 x 10^{-1} (SD ± 0.02; henrys-law.org/henry-3.0.pdf).

Table 7. Averaged (± standard deviation) iodomethane (nmol/L) production by sediment core and experimental iodide concentration. The total % iodine volatilized calculation was based only on the iodide added experimentally. Background iodine (^{129}I, ^{127}I) in the sample was not taken into consideration.

Core	KI^- (µg/L)	Iodomethane (nmol/L)	Range (nmol/L)	% Total
ZP-1, No ^{129}I		95.96 ± 73.21	187.06 – 1.42	43.46 ± 33.89
UP-1, 1 µg/L ^{129}I		193.33 ± 44.52	264.86 – 76.24	88.56 ± 31.81
UP-1, 10 µg/L ^{129}I		150.21 ± 82.04	264.51 – 51.31	67.99 ± 43.87
	150	160.31 ± 81.87	264.51 – 33.37	91.55 ± 46.76
	200	149.44 ± 77.39	240.36 – 1.42	64.01 ± 33.15
	250	129.74 ± 76.89	264.86 – 1.42	44.45 ± 26.35

Table 8. Averaged (± standard deviation) iodomethane (nmol/L) production by experimental treatment.

	ZP-1, No ^{129}I	UP-1, 1 µg/L ^{129}I	UP-1, 10 µg/L ^{129}I
Baseline (No additions)	164.28 ± 13.17*	199.49 ± 24.85	227.62 ± 24.68*
Glucose (1mM), YE (1 g/L)	27.63 ± 26.67	187.17 ± 59.24	72.80 ± 14.50
Heat-killed, Abiotic Controls	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

Student's t-test was used to test for statistical significance ($p < 0.05$), and is indicated by '*'.

Table 9. Averaged (± standard deviation) iodomethane (ug/L) production on a cellular basis by site and treatment. The total % iodine volatilized calculation was based on the amount of iodide added experimentally. Background iodine (^{129}I, ^{127}I) in the sample was not taken into consideration.

Core	KI^- (µg/L)	OC	% Total I Volatilized	fmol CH_3I / cell (± SD, n=3)
ZP-1, No ^{129}I				0.48 (± 0.37)
	150	+	23.65 ± 4.3	0.21 (± 0.04)
	200	+	15.68 ± 17.11	0.18 (± 0.2)
	250	+	1.67 ± 1.11	0.02 (± 0.02)
	150	-	94.55 ± 1.81	0.83 (± 0.02)
	200	-	65.27 ± 4.9	0.77 (± 0.06)
	250	-	59.93 ± 4.45	0.88(± 0.07)
UP-1, 1 µg/L ^{129}I				0.41 (± 0.09)
	150	+	127.06 ± 2.81	0.47 (± 0.01)
	200	+	80.5 ± 5.24	0.4 (± 0.03)
	250	+	51.76 ± 34.32	0.32 (± 0.2)
	150	-	120.28 ± 2.87	0.45 (± 0.01)
	200	-	94.4 ± 1.35	0.47 (± 0.0070.1)
	250	-	57.37 ± 2.49	0.36 (± 0.02)
UP-1, 10 µg/L ^{129}I				1.45 (± 0.8)
	150	+	39.15 ± 10.47	0.66 (± 0.2)
	200	+	29.27 ± 6.35	0.66 (± 0.14)
	250	+	27.92 ± 3.66	0.79 (± 0.1)
	150	-	144.61 ± 5.71	2.45 (± 0.1)
	200	-	98.92 ± 3.75	2.24 (± 0.1)
	250	-	68.07 ± 0.39	1.92 (± 0.01)

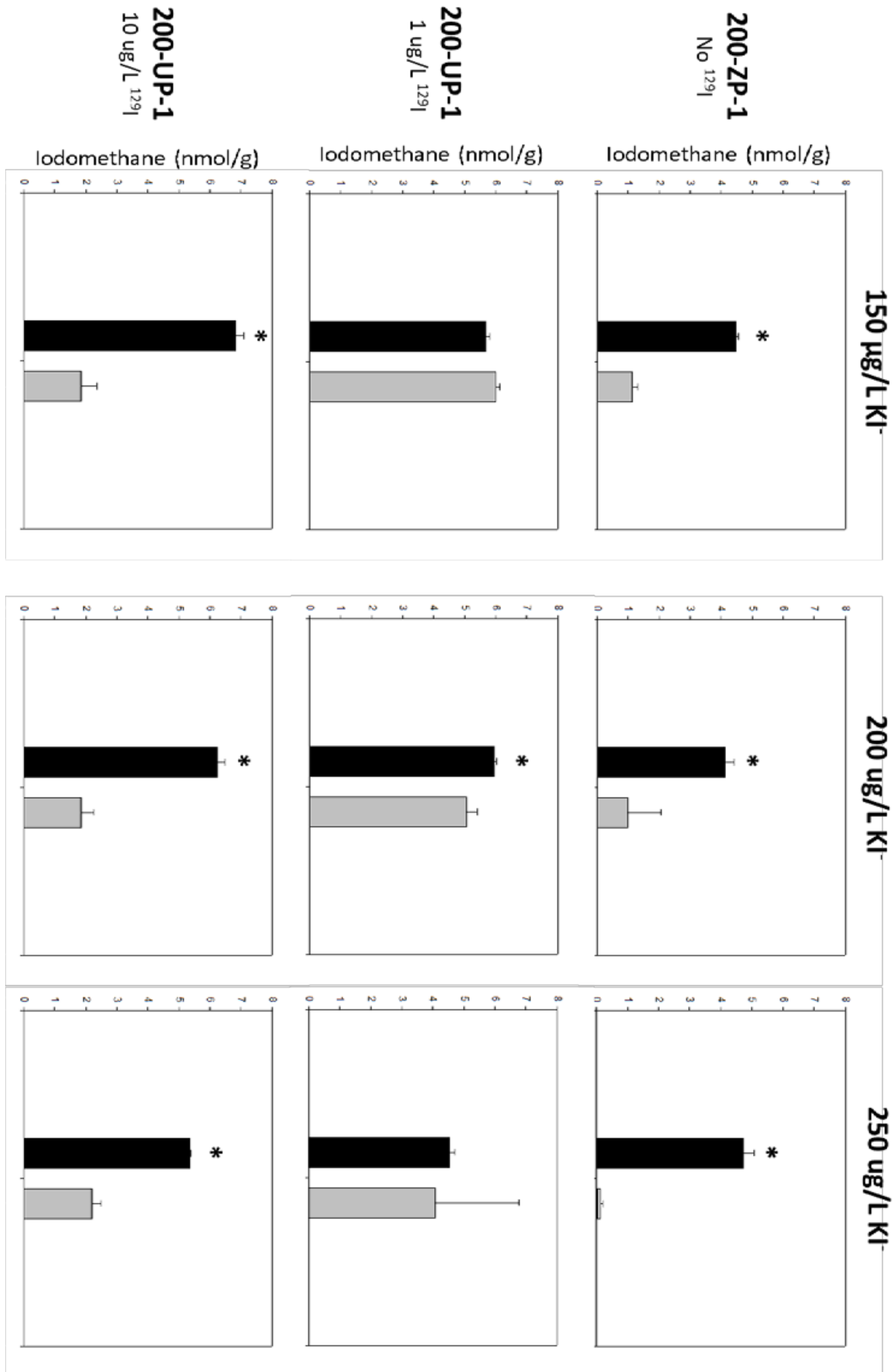


Figure 14. Iodomethane production from Hanford subsurface sediments. Bar graphs show averaged (± standard deviation) iodomethane production among experimental triplicates. Black bars indicate sediment microcosms that only received synthetic groundwater. Gray bars indicate sediment microcosms that received synthetic groundwater, glucose (1 mM), and yeast extract (20 g/L). Student t-tests were used to determine statistical significance ($p < 0.05$, indicated by '*') in iodomethane production between treatments.

In summary, experiments to evaluate microbially-induced iodine volatilization showed

1. Biotic volatilization of iodine by Hanford subsurface sediments was ubiquitous. Iodomethane was produced by all of the sediment samples examined and yield (or rate) was sensitive to nutrient supplementation. This result presumably reflects on the nominal capacity of Hanford subsurface sediments to volatilize iodine without more extensive manipulation of the system.

2. Iodomethane emissions were positively correlated with ^{129}I groundwater concentrations corresponding to the sediment cores (i.e., No, Low, High Iodine) used in these experiments. This association is consistent with other published studies (Amachi et al. 2001; Yeager et al. 2017), suggesting that environments having elevated concentrations of iodine (^{127}I, ^{129}I) will select for increased levels of iodide methylation activity or microbial populations to sustain increased levels of specific activity promoting iodine volatilization.

3. Microbial volatilization of iodine does indicates a mass loss term in the iodine cycle at the Hanford Site. Future work should be extended to the examination of unsaturated conditions.

4. Molecular iodine (I_2) could not be detected by the GC/MS methodology. Standards were tested. Laboratory enrichments of microbes from both UP-1 core intervals did produce yellow coloration to the spent medium, indicating I_2 accumulation. No color formation was evident from the 200-ZP-1 sediment enrichments. The 200-UP-1 sediments have prior exposure to radioiodine contamination, while 200-ZP-1 sediments have not. Nonetheless, efforts to assay the UP-1 enrichments and isolate bacteria catalyzing oxidation of $I^- \rightarrow I_2$ on starch plates were unsuccessful. Other than environments with inherently high iodine concentrations (brine waters, marine, etc.), it has been shown to be difficult to isolate iodide oxidizers using the plating assay without the addition of a chemical mediators to facilitate more rapid and ready detection (e.g., Nihei et al. 2018).

3.0 Discussion and Conclusions

3.1 Synthesis of Conceptual Model Information

This section synthesizes information from reports and manuscripts relevant to the iodine CM at Hanford. The synthesis focuses on biogeochemical processes controlling the fate of subsurface iodine. This information can then be applied to development of site-specific CM for ^{129}I at the Hanford Site. In particular, the process information can be used as input to fate and transport models used to integrate the biogeochemical processes with the disposal, hydrogeology, and flow information to simulate ^{129}I in the subsurface. A brief summary of recent related efforts that provide useful information for interpretation of iodine behavior in the subsurface is included in this section.

3.2 Synthesis of Biogeochemical Processes

A network of biogeochemical processes control the fate and transport behavior of iodine in the subsurface, as depicted in Figure 15. A primary element of the effort to update the iodine CM was to quantify these processes and identifying which are of importance at the Hanford Site, in particular for the 200-UP-1 OU. For future fate and transport or remedy evaluation efforts, the process diagram in Figure 15 can be used to identify the biogeochemical aspects of iodine behavior. The text in this section emphasizes those processes found to be most important under the conditions of the 200-UP-1 OU.

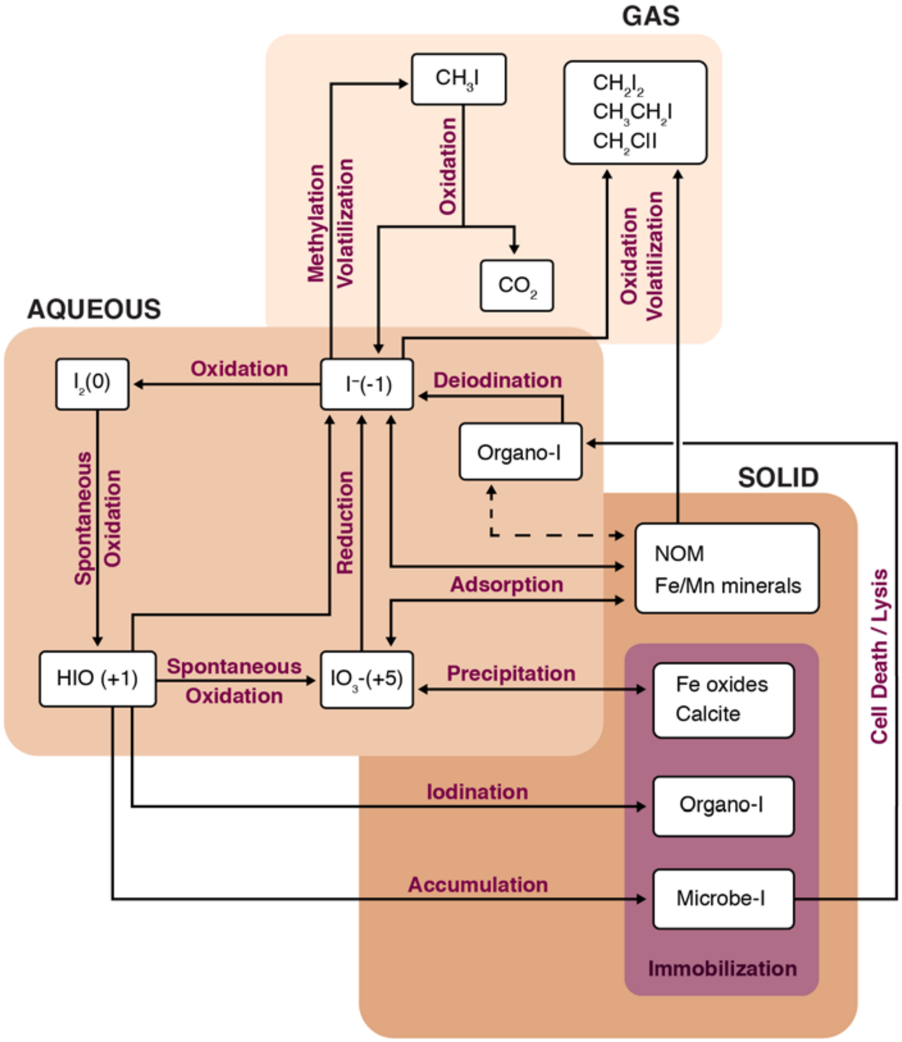


Figure 15. Iodine species transformation pathways and reaction network at Hanford

A core element of Figure 15 is recognition of the aqueous species (AQUEOUS block), where iodide, iodate, and organo-I are the prevalent stable species in the Hanford subsurface. As shown in the figure, there are transformation processes that result in cycling between these species. Only reduction of iodate to iodide has been identified as occurring in laboratory experiments with Hanford sediments (Truex et al. 2015, 2016; Szecsody et al. 2017; Truex et al. 2017a,b). However, iodate has been the dominant species in the majority of the groundwater samples that have been analyzed to date for the 200 West Area. A most likely explanation for the continued prevalence of iodate in groundwater is that there is no or minimal reduction of iodate occurring in the aquifer, though this process (which may be either biological or abiotic) is readily induced in the laboratory.

Solid-phase interactions and species (SOLID block shown in Figure 15) are also important for iodine in the subsurface and function to temporarily immobilize iodine from the aqueous phase. Sorption of iodide, iodate, and likely organo-I compounds to organic matter and minerals is a baseline process in the subsurface that retards iodine movement relative to water movement. This type of sorption has been quantified as K_d values as part of Hanford iodine CSM efforts (Truex et al. 2015,2016; Szecsody et al. 2017; Truex et al. 2017a,b). Iodate, in particular, associates with iron oxides and carbonates. Iodate in these solid phases exchanges with the aqueous phase through sorption and dissolution/precipitation interactions. Studies with Hanford sediments have shown substantial iodate associated with these solid phases (Truex et al. 2017b; Szecsody et al. 2017). The interactions with vadose zone sediments represent an attenuation mechanism slowing the flux of iodate toward the groundwater. Iodine can complex with organic compounds that are associated with the solid rather than aqueous phase. Initial studies with Hanford groundwater and sediment showed that soluble organic compounds are more suited to iodine complexation than are the solid-phase organic compounds. Microbial interactions with iodine are also important. Microbial reactions are associated with many of the iodine aqueous-phase reactions and microbes in biofilms associated with the sediments can be a zone of accumulation for iodine. Iodine would be cycled back to the aqueous phase through the cycle of cell death and lysis.

Figure 15 also depicts the gas phase (GAS block), which is relevant to the overall iodine cycle. In particular, microbial reactions that create methyl-iodine compounds are a mechanism of volatilization. As discussed herein, this type of reaction can occur in Hanford sediments, and so should be considered as part of the potential fate for subsurface iodine. Current studies focused on groundwater conditions, but volatilization in the vadose zone during and after waste disposal is another potential ramification of these gas-phase iodine species.

3.3 Related Efforts

Several recent studies have provided information relevant to interpreting iodine behavior in the Hanford subsurface. These efforts are briefly summarized below with discussion of how the information relates to the iodine CM. These findings should be considered in combination with the findings presented in the previous iodine CM reports (Truex et al. 2015, 2016, 2017a)

As part of characterization efforts for the 200-UP-1 OU, aquifer sediments and groundwater were evaluated for contaminant attenuation transport processes (Lee et al. 2017). In these tests, ^{129}I was above the DWS in the groundwater samples. Most iodine was present in the aqueous and adsorbed phase but slow increases in iodine over time indicate an additional source controlled by dissolution. Bacteria capable of heterotrophic nitrate, iron, and ^{129}I transformation were present, indicating potential for contaminant transformation using exogenous carbon when present.

The work conducted with sediments from the 200-DV-1 OU at Hanford showed that no ^{129}I was detectable in these sediments (Truex et al. 2017b; Szecsody et al. 2017). Most of the total iodine mass in vadose zone samples was associated with solid phases and exhibited slow leaching characteristics. Initial iodine released during soil column leaching tests was a mixture of iodide and iodate, with iodide more prevalent in some experiments. However, the iodine in the solid phase was likely iodate associated with carbonates and potentially iron oxides. For instance, in studies by Szecsody et al. (2017), 60% to 75% of total iodine was associated with carbonates and 25% to 40% was associated with Fe/Mn oxides. Adsorption studies were conducted with spiked samples and with native samples. These results showed a low K_d for iodide and a moderate K_d for iodate with highest adsorption related to high carbonate content. Desorption K_d values were generally higher than adsorption K_d values. Studies with vadose-zone sediment samples showed that abiotic (reduced Fe/Mn phases) or biotic reduction of iodate to iodide occurred in sediments, though it is not determined how the observed rates in the laboratory translate to in situ field conditions.

The role of co-contaminants in iodine sorption can also be important to consider. For instance, presence of uranium did not inhibit removal of iodine through calcite precipitation (Szecsody et al. 2017). Importantly, increases in iodine concentration increased uranium removal during calcite precipitation. Under high sediment/water conditions, the presence of nitrate did not increase the observable reduction rate of iodate. When microbial activity was reduced, a nine-fold decrease in the reduction rate of iodate was observed, indicating microbial contribution to the reduction of iodate. When Fe and Mn phases were reduced, and microbial activity was reduced, a 15-fold decrease in the reduction rate of iodate was observed. This indicates that there are significant contributions from both the abiotic and biotic processes in iodate reduction.

Another study investigated different iodine sorbents (Strickland et al. 2017) as part of evaluating potential remediation approaches. In this effort, experiments on iodate sorption to different types of iron oxides is useful to consider in relation to subsurface processes. Iodate adsorption capacity for iron oxide solids was determined in experiments conducted with AGW. Results showed that the relative capacities of these Fe oxides were HFO>goethite>magnetite>hematite. The specific surface areas followed the same order, suggesting that the iodate adsorption was controlled by surface area. Iodate adsorption increased significantly with decreasing pH, as expected. Higher adsorption was also observed when testing was conducted in DDI water instead of AGW. Very little iodide was adsorbed. When co-precipitated with HFO, both iodate and iodide were removed from the aqueous phase, with more removed in lower pH solutions and more iodate removed than iodide.

3.4 Recommended Subsurface Process Conceptual Model

Four alternative CMs were initially proposed, reflecting the evolving state of knowledge on iodine behavior at Hanford (Truex et al. 2015). Information from this report, previous iodine CM efforts (Truex et al. 2015, 2016, 2017a), and related efforts described in Section 3.2 were interpreted to generate a recommended CM for iodine in the 200-UP-1 OU. The CM is for the biogeochemical processes affecting fate and transport of the ^{129}I groundwater plume. This information will need to be integrated with other efforts to account for hydraulic and source-term aspects of plume behavior (i.e., modeling efforts). In addition, ramifications of this information for remedy evaluation are discussed.

3.4.1 Conceptual Model Description

The CM is based on the current information from samples of 200 West Area groundwater (including samples within the 200-UP-1 OU) that show iodine is present as a mix of iodide, iodate, and organo-I species, with iodate being the predominant species. Confirmation of iodine species distribution in the plume is recommended to help validate this CM basis. Plume behavior is affected by differential transport of iodine species due to their different sorption characteristics. In addition, the processes described in Section 3.1 and Figure 15 need to be considered, as discussed below.

For iodate in the vadose zone or groundwater, transport is retarded by sorption and co-precipitation with calcite (and other calcium carbonate polymorphs such as aragonite) and iron oxides (e.g., ferrihydrite). These solid-phase interactions are not a permanent sequestration because iodate may be released back in the aqueous phase via desorption and/or dissolution reactions. For example, with calcite co-precipitation, iodate appears to be accumulated in regions close to the surface and crystal boundaries rather than in the bulk calcite structure, and changes in aqueous phase chemistry (e.g., a pH decrease) may promote calcite dissolution and potential release of iodate. Surface area and pH significantly influence the extent of iodate incorporation into calcite. The solubility of co-precipitated iodate and calcite is the same as for pure calcite. Thus, iodate dissolution is not limited by the presence of calcite. Ferrihydrite has been previously shown to have a high affinity for iodate adsorption. Data showed that iodate transport was significantly retarded in ferrihydrite-amended sediment, whereas iodide and organo-I species showed little adsorption to ferrihydrite.

Organo-I complexes are present in the Hanford subsurface, predominantly in the aqueous phase. For organo-I complexes, (1) iodine speciation and the organic matter structures influence complexation, (2) iodate binds more readily than iodide, (3) cations present in Hanford AGW play a role in organo-I binding, and (4) the residence time influences binding kinetics. While the organo-I complexation structures in the 200-UP-1 site at Hanford could not be confidently identified, the results suggested that these compounds exist at Hanford. The differences in organic matter composition indicated that pore water samples have a higher abundance of aromatic compounds that are a better target for iodine complexation.

Volatilization of iodine occurred in Hanford sediments. Iodomethane was produced by all of the sediment samples examined and was positively correlated with ^{129}I concentrations in sediment cores. Moreover, its production rate was sensitive to nutrient supplements. This result reflects a nominal capacity of Hanford subsurface sediments to volatilize iodine without additional perturbation of the subsurface system. The fate of iodomethane in the aquifer or the extent to which this process may have impacted iodine in the vadose zone during and after waste disposal have not been quantified. However, this transformation mechanism should be considered when interpreting potential pathways for iodine in the subsurface.

Reduction of iodate to iodide has been observed in the laboratory. This reduction appears to occur by a either abiotic and/or biotic pathways, though it is not determined how the observed rates in the laboratory translate to in situ field conditions. Continued reduction of iodate is not consistent with observations that iodate is the dominant iodine species in groundwater and, through its incorporation into carbonate and iron oxide solid phases, the majority of the iodine mass in the vadose zone samples examined to date. A most likely explanation for the continued prevalence of iodate in groundwater is that there is no or minimal reduction of iodate occurring in the aquifer, though this process (which may be either biological or abiotic) is readily induced in the laboratory. If iodate reduction is occurring, then an oxidation mechanism is also likely occurring, though an oxidation process has not been specifically quantified. Additional investigation of the iodine species distribution in the plume is recommended to help evaluate potential in situ transformation processes during plume transport. The current CM recommendation is to consider that minimal or no aqueous species transformation is occurring and that the measured iodine species distribution (and associated species-specific interactions) can be used to assess fate and transport. However, iodine cycling at Hanford could occur over relatively short periods of time in response to system perturbation (e.g., changes in pH), and perturbations would be important to consider for these reasons.

This CM describes behavior for radioiodine (^{129}I) and non-radioactive iodine (^{127}I) because both isotopes have the same geochemical behavior. Non-radioactive iodine (^{127}I) concentrations are estimated to be 1000 times higher than radioiodine (^{129}I) in Hanford Site Central Plateau groundwater (Levitskaia et al. 2017). This ratio has important implications for remedial strategies because remedies cannot specifically treat ^{129}I without also targeting ^{127}I.

3.4.2 Ramifications for Remediation

The subsurface processes observed during investigation of the iodine CM need to be considered in evaluating potential iodine remedies. In particular, the CM information has demonstrated that remedial actions may need to be evaluated relative to the effectiveness for each species. In addition, the coupled effects of natural attenuation pathways and induced changes from applying remediation technologies need to be considered.

Several subsurface processes may be relevant for development into remediation strategies. Calcite interactions have been shown important for removing iodate from the aqueous phase and could be designed as a remediation strategy. Key factors in success for this type of remediation are the extent of incorporation and the potential need for additional sequestration by coating with another mineral phase because incorporation of iodate with calcite is not a permanent sequestration. Interactions of iodate and ferrihydrite have also been shown to effectively remove iodate from the aqueous phase. Again, evaluating the extent of removal and the stability of sequestered iodate with ferrihydrite or other iron oxides are important factors in evaluating the viability of ferrihydrite as a remediation approach. For pump-and-treat (P&T) extraction of iodine from the groundwater, sorption will decrease extraction performance for iodate. Thus, mechanisms to reduce iodine retardation in the subsurface may improve P&T efficiency.

4.0 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 DOE 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.

A portion of this work (e.g., the chemical analyses of the liquid samples from the batch and column experiments) used PNNL's Environmental Sciences Laboratory (ESL). The ESL operates under a dedicated QA plan that complies with the *Hanford Analytical Services Quality Assurance Requirements Document* (HASQARD; DOE/RL-96-68), Rev. 3. The ESL implements HASQARD through Conducting Analytical Work in Support of Regulatory Programs (CAWSRP). Data Quality Objectives established in CAWSRP were generated in accordance with HASQARD requirements.

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Appendix A

Summary of LIMS Data: Element Concentrations at Different Times during Leaching with an Iodine-Free Artificial Groundwater

Barium					
Sample Name	Results(µg/L)	EQL(µg/L)	Sample Name	Results(µg/L)	EQL(µg/L)
CM Column 1-1	146	16.4	CM Column 2-1	443	16.4
CM Column 1-3	114	16.4	CM Column 2-4	458	16.4
CM Column 1-5	93.9	32.8	CM Column 2-8	456	16.4
CM Column 1-7	24.8	16.4	CM Column 2-10	294	16.4
CM Column 1-27	17.1	16.4	CM Column 2-30	ND	16.4
CM Column 1-37	ND	16.4	CM Column 2-40	ND	16.4
CM Column 1-48	ND	16.4	CM Column 2-51	ND	16.4
CM Column 1-51	20.1	16.4	CM Column 2-54	18.7	16.4
CM Column 1-62	20.6	16.4	CM Column 2-65	24	16.4
CM Column 1-73	22.6	16.4	CM Column 2-76	26.5	16.4
CM Column 1-76	29.9	16.4	CM Column 2-79	27.3	16.4
CM Column 1-86	22.8	16.4	CM Column 2-89	28.1	16.4
CM Column 1-96	24	16.4	CM Column 2-99	28.7	16.4
CM Column 1-99	30.4	16.4	CM Column 2-102	32.1	16.4
CM Column 1-104	29.9	16.4	CM Column 2-107	36.2	16.4
CM Column 1-108	22.1	16.4	CM Column 2-111	22.7	16.4
CM Column 1-114	20.9	16.4	CM Column 2-117	23.8	16.4
CM Column 1-121	18.5	16.4	CM Column 2-124	21.4	16.4
CM Column 1-129	18.8	16.4	CM Column 2-132	21.5	16.4
CM Column 1-159	19.3	16.4	CM Column 2-162	20.4	16.4
CM Column 1-179	21	16.4	CM Column 2-182	21.9	16.4
CM Column 1-199	17.6	16.4	CM Column 2-202	21.8	16.4
CM Column 1-232	ND	16.4	CM Column 2-235	20.5	16.4
CM Column 1-236	18.6	16.4	CM Column 2-238	22.4	16.4
CM Column 1-241	18.5	16.4	CM Column 2-243	21.3	16.4
CM Column 1-247	19.9	16.4	CM Column 2-249	21.6	16.4
CM Column 1-272	19.8	16.4	CM Column 2-274	20.6	16.4
CM Column 1-292	18	16.4	CM Column 2-294	21	16.4
CM Column 1-313	18.2	16.4	CM Column 2-314	21	16.4
CM Column 1-333	18.2	16.4	CM Column 2-334	22.1	16.4

Barium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-1	207	16.4	0.01	CM Column 3-1	560	32.8	0.00
CM Column 5-4	124	16.4	0.07	CM Column 3-3	491	16.4	0.04
CM Column 5-8	97	65.7	0.12	CM Column 3-5	598	32.8	0.06
CM Column 5-10	47.7	16.4	0.31	CM Column 3-7	323	16.4	0.33
CM Column 5-30	ND	16.4	2.35	CM Column 3-28	ND	16.4	1.24
CM Column 5-39	17.6	16.4	3.26	CM Column 3-38	ND	16.4	2.01
CM Column 5-50	18.9	16.4	4.39	CM Column 3-49	ND	16.4	4.19
CM Column 5-53	24.6	16.4	4.69	CM Column 3-52	ND	16.4	4.50
CM Column 5-63	21	16.4	5.71	CM Column 3-63	24.9	16.4	5.64
CM Column 5-74	23.6	16.4	6.82	CM Column 3-74	27.3	16.4	6.79
CM Column 5-77	23.5	16.4	7.13	CM Column 3-77	25.7	16.4	7.11
CM Column 5-88	26.2	16.4	7.23	CM Column 3-87	26.8	16.4	8.17
CM Column 5-98	26.5	16.4	9.29	CM Column 3-97	28.2	16.4	9.22
CM Column 5-101	22.3	16.4	9.60	CM Column 3-100	28.9	16.4	9.55
CM Column 5-107	22.1	16.4	10.23	CM Column 3-105	28.8	16.4	10.08
CM Column 5-110b*	21.7	16.4	10.45	CM Column 3-109*	22.7	16.4	10.34
CM Column 5-116	19.7	16.4	10.76	CM Column 3-115	23.5	16.4	10.68
CM Column 5-123	19.6	16.4	11.14	CM Column 3-122	22.4	16.4	11.06
CM Column 5-131	19.7	16.4	11.97	CM Column 3-130	22	16.4	11.90
CM Column 5-162	19	16.4	15.07	CM Column 3-160	22.1	16.4	15.05
CM Column 5-182	18	16.4	17.08	CM Column 3-180	21.1	16.4	16.87
CM Column 5-202	16.9	16.4	19.09	CM Column 3-200	22	16.4	18.95
CM Column 5-235	17.4	16.4	22.47	CM Column 3-233	22.5	16.4	22.38
CM Column 5-238*	19.2	16.4	22.65	CM Column 3-236*	21.7	16.4	22.53
CM Column 5-243	16.6	16.4	22.98	CM Column 3-241	21.8	16.4	22.85
CM Column 5-249	19.1	16.4	23.59	CM Column 3-247	21.8	16.4	23.46
CM Column 5-274	19.1	16.4	26.07	CM Column 3-272	20.4	16.4	26.04
CM Column 5-294	17.5	16.4	28.09	CM Column 3-292	19.5	16.4	28.06
CM Column 5-314	17.9	16.4	30.10	CM Column 3-312	21.2	16.4	30.12
CM Column 5-334	16.4	16.4	32.13	CM Column 3-332	20.3	16.4	32.20

Barium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-1	200	16.4	0.01	CM Column 4-1	456	16.4	0.02
CM Column 6-4	124	16.4	0.07	CM Column 4-3	581	32.8	0.04
CM Column 6-8	53.2	16.4	0.14	CM Column 4-5	356	16.4	0.24
CM Column 6-10	43.5	16.4	0.33	CM Column 4-25	ND	16.4	2.26
CM Column 6-30	ND	16.4	2.32	CM Column 4-35	ND	16.4	3.27
CM Column 6-39	ND	16.4	3.22	CM Column 4-46	ND	16.4	4.36
CM Column 6-50	19.1	16.4	4.32	CM Column 4-49	ND	16.4	4.66
CM Column 6-53	26.2	16.4	4.62	CM Column 4-60	23.8	16.4	5.76
CM Column 6-63	26.3	16.4	5.62	CM Column 4-71	27.9	16.4	6.85
CM Column 6-74	21.4	16.4	6.70	CM Column 4-74	26.6	16.4	7.14
CM Column 6-77	24.6	16.4	7.01	CM Column 4-84	30.9	16.4	8.15
CM Column 6-88	24.5	16.4	8.12	CM Column 4-94	29.2	16.4	9.15
CM Column 6-98	27.2	16.4	9.15	CM Column 4-97	28.5	16.4	9.45
CM Column 6-101	28.4	16.4	9.45	CM Column 4-102	28.7	16.4	9.96
CM Column 6-107	26.4	16.4	10.07	CM Column 4-106*	22.8	16.4	10.24
CM Column 6-111*	24.8	16.4	10.33	CM Column 4-112	23.3	16.4	10.55
CM Column 6-117	19.8	16.4	10.64	CM Column 4-119	22.9	16.4	10.91
CM Column 6-124	19.1	16.4	11.00	CM Column 4-127	22.5	16.4	11.71
CM Column 6-132	16.7	16.4	11.81	CM Column 4-157	23.7	16.4	14.70
CM Column 6-163	18.5	16.4	14.90	CM Column 4-177	21.3	16.4	16.42
CM Column 6-183	19	16.4	16.87	CM Column 4-197	21.6	16.4	18.40
CM Column 6-203	18.4	16.4	18.87	CM Column 4-230	20	16.4	21.73
CM Column 6-235	16.8	16.4	22.11	CM Column 4-233*	21.8	16.4	21.91
CM Column 6-238*	19.6	16.4	22.28	CM Column 4-238	21.1	16.4	22.22
CM Column 6-243	18.1	16.4	22.60	CM Column 4-244	20.9	16.4	22.81
CM Column 6-249	17.7	16.4	23.20	CM Column 4-269	20.6	16.4	25.29
CM Column 6-274	17.2	16.4	25.68	CM Column 4-289	21.1	16.4	27.26
CM Column 6-294	17.8	16.4	27.68	CM Column 4-309	21.5	16.4	29.22
CM Column 6-314	17.6	16.4	29.66	CM Column 4-329	21.4	16.4	31.20
CM Column 6-334	17.7	16.4	31.66				

Calcium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-1	119000	168	0.01	CM Column 2-1	321000	168	0.02
CM Column 1-3	92800	168	0.05	CM Column 2-4	335000	168	0.09
CM Column 1-5	74700	336	0.07	CM Column 2-8	336000	168	0.17
CM Column 1-7	18800	168	0.23	CM Column 2-10	208000	168	0.35
CM Column 1-27	13600	168	2.18	CM Column 2-30	4550	168	2.47
CM Column 1-37	13400	168	3.15	CM Column 2-40	5580	168	3.52
CM Column 1-48	13200	168	4.21	CM Column 2-51	10100	168	4.67
CM Column 1-51	14100	168	4.50	CM Column 2-54	14100	168	4.99
CM Column 1-62	16100	168	5.55	CM Column 2-65	15400	168	6.13
CM Column 1-73	16600	168	6.60	CM Column 2-76	16500	168	7.28
CM Column 1-76	25400	168	6.89	CM Column 2-79	17300	168	7.60
CM Column 1-86	17800	168	7.85	CM Column 2-89	17700	168	8.64
CM Column 1-96	17800	168	8.82	CM Column 2-99	17700	168	9.69
CM Column 1-99	21500	168	9.11	CM Column 2-102	20300	168	10.02
CM Column 1-104	21300	168	9.59	CM Column 2-107	22900	168	10.56
CM Column 1-108*	18700	168	9.87	CM Column 2-111*	17900	168	10.85
CM Column 1-114	16700	168	10.16	CM Column 2-117	17700	168	11.18
CM Column 1-121	15700	168	10.50	CM Column 2-124	16800	168	11.57
CM Column 1-129	16300	168	11.27	CM Column 2-132	17600	168	12.42
CM Column 1-159	15300	168	14.11	CM Column 2-162	16200	168	15.60
CM Column 1-179	17000	168	15.96	CM Column 2-182	17000	168	17.68
CM Column 1-199	16100	168	17.89	CM Column 2-202	16400	168	19.78
CM Column 1-232	15500	168	21.09	CM Column 2-235	15700	168	23.29
CM Column 1-236*	17300	168	21.32	CM Column 2-238*	17600	168	23.48
CM Column 1-241	16900	168	21.61	CM Column 2-243	17800	168	23.80
CM Column 1-247	17500	168	22.18	CM Column 2-249	18100	168	24.41
CM Column 1-272	17100	168	24.62	CM Column 2-274	16600	168	26.95
CM Column 1-292	17300	168	26.58	CM Column 2-294	16900	168	29.08
CM Column 1-313	17900	168	28.62	CM Column 2-314	17600	168	31.22
CM Column 1-333	16500	168	30.56	CM Column 2-334	16300	168	33.36

Calcium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-1	177000	168	0.01	CM Column 3-1	401000	336	0.00
CM Column 5-4	105000	168	0.07	CM Column 3-3	354000	168	0.04
CM Column 5-8	72700	672	0.12	CM Column 3-5	425000	336	0.06
CM Column 5-10	35600	168	0.31	CM Column 3-7	229000	168	0.33
CM Column 5-30	12300	168	2.35	CM Column 3-28	4490	168	1.24
CM Column 5-39	13600	168	3.26	CM Column 3-38	4910	168	2.01
CM Column 5-50	15500	168	4.39	CM Column 3-49	9340	168	4.19
CM Column 5-53	17400	168	4.69	CM Column 3-52	11300	168	4.50
CM Column 5-63	18000	168	5.71	CM Column 3-63	15700	168	5.64
CM Column 5-74	18200	168	6.82	CM Column 3-74	16400	168	6.79
CM Column 5-77	18900	168	7.13	CM Column 3-77	17200	168	7.11
CM Column 5-88	19700	168	7.23	CM Column 3-87	17800	168	8.17
CM Column 5-98	19300	168	9.29	CM Column 3-97	17600	168	9.22
CM Column 5-101	19400	168	9.60	CM Column 3-100	18800	168	9.55
CM Column 5-107	19600	168	10.23	CM Column 3-105	18700	168	10.08
CM Column 5-110b*	18900	168	10.45	CM Column 3-109*	17600	168	10.34
CM Column 5-116	17300	168	10.76	CM Column 3-115	17300	168	10.68
CM Column 5-123	17700	168	11.14	CM Column 3-122	17100	168	11.06
CM Column 5-131	16200	168	11.97	CM Column 3-130	17400	168	11.90
CM Column 5-162	17100	168	15.07	CM Column 3-160	15900	168	15.05
CM Column 5-182	15800	168	17.08	CM Column 3-180	16700	168	16.87
CM Column 5-202	16800	168	19.09	CM Column 3-200	16700	168	18.95
CM Column 5-235	15000	168	22.47	CM Column 3-233	16100	168	22.38
CM Column 5-238*	17200	168	22.65	CM Column 3-236*	17800	168	22.53
CM Column 5-243	15200	168	22.98	CM Column 3-241	17200	168	22.85
CM Column 5-249	17400	168	23.59	CM Column 3-247	17900	168	23.46
CM Column 5-274	17200	168	26.07	CM Column 3-272	16600	168	26.04
CM Column 5-294	16600	168	28.09	CM Column 3-292	16900	168	28.06
CM Column 5-314	16700	168	30.10	CM Column 3-312	17300	168	30.12
CM Column 5-334	16200	168	32.13	CM Column 3-332	16300	168	32.20

Calcium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-1	181000	168	0.01	CM Column 4-1	323000	168	0.02
CM Column 6-4	108000	168	0.07	CM Column 4-3	413000	336	0.04
CM Column 6-8	42800	168	0.14	CM Column 4-5	262000	168	0.24
CM Column 6-10	34400	168	0.33	CM Column 4-25	5440	168	2.26
CM Column 6-30	12500	168	2.32	CM Column 4-35	5180	168	3.27
CM Column 6-39	13500	168	3.22	CM Column 4-46	7880	168	4.36
CM Column 6-50	15300	168	4.32	CM Column 4-49	9010	168	4.66
CM Column 6-53	25600	168	4.62	CM Column 4-60	13900	168	5.76
CM Column 6-63	17900	168	5.62	CM Column 4-71	16000	168	6.85
CM Column 6-74	18500	168	6.70	CM Column 4-74	17300	168	7.14
CM Column 6-77	19000	168	7.01	CM Column 4-84	18000	168	8.15
CM Column 6-88	19600	168	8.12	CM Column 4-94	18400	168	9.15
CM Column 6-98	19700	168	9.15	CM Column 4-97	18600	168	9.45
CM Column 6-101	20600	168	9.45	CM Column 4-102	18400	168	9.96
CM Column 6-107	21100	168	10.07	CM Column 4-106*	16800	168	10.24
CM Column 6-111*	18800	168	10.33	CM Column 4-112	17200	168	10.55
CM Column 6-117	16800	168	10.64	CM Column 4-119	16500	168	10.91
CM Column 6-124	17700	168	11.00	CM Column 4-127	17700	168	11.71
CM Column 6-132	16300	168	11.81	CM Column 4-157	16900	168	14.70
CM Column 6-163	15700	168	14.90	CM Column 4-177	16500	168	16.42
CM Column 6-183	16600	168	16.87	CM Column 4-197	16200	168	18.40
CM Column 6-203	16600	168	18.87	CM Column 4-230	16100	168	21.73
CM Column 6-235	15400	168	22.11	CM Column 4-233*	17700	168	21.91
CM Column 6-238*	17500	168	22.28	CM Column 4-238	17200	168	22.22
CM Column 6-243	16100	168	22.60	CM Column 4-244	17000	168	22.81
CM Column 6-249	17600	168	23.20	CM Column 4-269	16400	168	25.29
CM Column 6-274	16700	168	25.68	CM Column 4-289	16500	168	27.26
CM Column 6-294	16100	168	27.68	CM Column 4-309	16900	168	29.22
CM Column 6-314	16900	168	29.66	CM Column 4-329	15900	168	31.20
CM Column 6-334	16700	168	31.66				

Manganese							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-1	26.5	12	0.01	CM Column 2-1	276	12	0.02
CM Column 1-3	18.2	12	0.05	CM Column 2-4	285	12	0.09
CM Column 1-5	ND	23.9	0.07	CM Column 2-8	283	12	0.17
CM Column 1-7	13.2	12	0.23	CM Column 2-10	253	12	0.35
CM Column 1-51	ND	12	4.50	CM Column 2-54	14.3	12	4.99
CM Column 1-62	ND	12	5.55	CM Column 2-65	18.5	12	6.13
CM Column 1-73	ND	12	6.60	CM Column 2-76	19.1	12	7.28
CM Column 1-76	ND	12	6.89	CM Column 2-79	18.9	12	7.60
CM Column 1-86	ND	12	7.85	CM Column 2-89	19.3	12	8.64
CM Column 1-96	ND	12	8.82	CM Column 2-99	21.1	12	9.69
CM Column 1-99	ND	12	9.11	CM Column 2-102	20.4	12	10.02
CM Column 1-104	ND	12	9.59	CM Column 2-107	22.5	12	10.56
CM Column 1-108*	ND	12	9.87	CM Column 2-111*	25.8	12	10.85
CM Column 1-114	ND	12	10.16	CM Column 2-117	22.9	12	11.18
CM Column 1-121	ND	12	10.50	CM Column 2-124	21	12	11.57
CM Column 1-129	ND	12	11.27	CM Column 2-132	20.9	12	12.42
CM Column 1-159	ND	12	14.11	CM Column 2-162	18.3	12	15.60
CM Column 1-179	ND	12	15.96	CM Column 2-182	19.1	12	17.68
CM Column 1-199	ND	12	17.89	CM Column 2-202	18.7	12	19.78
CM Column 1-232	ND	12	21.09	CM Column 2-235	17.7	12	23.29
CM Column 1-236*	ND	12	21.32	CM Column 2-238*	19.4	12	23.48
CM Column 1-241	ND	12	21.61	CM Column 2-243	19.7	12	23.80
CM Column 1-247	ND	12	22.18	CM Column 2-249	18.9	12	24.41
CM Column 1-272	ND	12	24.62	CM Column 2-274	18.1	12	26.95
CM Column 1-292	ND	12	26.58	CM Column 2-294	18	12	29.08
CM Column 1-313	ND	12	28.62	CM Column 2-314	17.8	12	21.06
CM Column 1-333	ND	12	30.56	CM Column 2-334	16.7	12	23.18

Manganese							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-1	43.1	12	0.01	CM Column 3-1	369	23.9	0.00
CM Column 5-4	22.2	12	0.07	CM Column 3-3	318	12	0.04
CM Column 5-8	ND	47.9	0.12	CM Column 3-5	378	23.9	0.06
CM Column 5-10	ND	12	0.31	CM Column 3-7	265	12	0.33
CM Column 5-53	ND	12	4.69	CM Column 3-52	13.7	12	4.50
CM Column 5-63	ND	12	5.71	CM Column 3-63	17	12	5.64
CM Column 5-74	ND	12	6.82	CM Column 3-74	17.7	12	6.79
CM Column 5-77	ND	12	7.13	CM Column 3-77	17.7	12	7.11
CM Column 5-88	ND	12	7.23	CM Column 3-87	17.9	12	8.17
CM Column 5-98	ND	12	9.29	CM Column 3-97	17.1	12	9.22
CM Column 5-101	ND	12	9.60	CM Column 3-100	17.8	12	9.55
CM Column 5-107	ND	12	10.23	CM Column 3-105	18.1	12	10.08
CM Column 5-110b*	ND	12	10.45	CM Column 3-109*	20.3	12	10.34
CM Column 5-116	ND	12	10.76	CM Column 3-115	19.7	12	10.68
CM Column 5-123	ND	12	11.14	CM Column 3-122	18.6	12	11.06
CM Column 5-131	ND	12	11.97	CM Column 3-130	17.9	12	11.90
CM Column 5-162	ND	12	15.07	CM Column 3-160	16.7	12	15.05
CM Column 5-182	ND	12	17.08	CM Column 3-180	16.1	12	16.87
CM Column 5-202	ND	12	19.09	CM Column 3-200	17.4	12	18.95
CM Column 5-235	ND	12	22.47	CM Column 3-233	16.1	12	22.38
CM Column 5-238*	ND	12	22.65	CM Column 3-236*	16.7	12	22.53
CM Column 5-243	ND	12	22.98	CM Column 3-241	15.8	12	22.85
CM Column 5-249	ND	12	23.59	CM Column 3-247	15.6	12	23.46
CM Column 5-274	ND	12	26.07	CM Column 3-272	14.8	12	26.04
CM Column 5-294	ND	12	28.09	CM Column 3-292	14.4	12	28.06
CM Column 5-314	ND	12	30.10	CM Column 3-312	15.3	12	30.12
CM Column 5-334	ND	12	32.13	CM Column 3-332	13.7	12	32.20

Manganese							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-1	42.7	12	0.01	CM Column 4-1	270	12	0.02
CM Column 6-4	21	12	0.07	CM Column 4-3	330	23.9	0.04
CM Column 6-8	14.1	12	0.14	CM Column 4-5	264	12	0.24
CM Column 6-10	ND	12	0.33	CM Column 4-49	ND	12	4.66
CM Column 6-53	ND	12	4.62	CM Column 4-60	14.2	12	5.76
CM Column 6-63	ND	12	5.62	CM Column 4-71	16	12	6.85
CM Column 6-74	ND	12	6.70	CM Column 4-74	15.9	12	7.14
CM Column 6-77	ND	12	7.01	CM Column 4-84	16.8	12	8.15
CM Column 6-88	ND	12	8.12	CM Column 4-94	16.1	12	9.15
CM Column 6-98	ND	12	9.15	CM Column 4-97	16.2	12	9.45
CM Column 6-101	ND	12	9.45	CM Column 4-102	15.2	12	9.96
CM Column 6-107	ND	12	10.07	CM Column 4-106*	18.2	12	10.24
CM Column 6-111*	ND	12	10.33	CM Column 4-112	18.7	12	10.55
CM Column 6-117	ND	12	10.64	CM Column 4-119	16.5	12	10.91
CM Column 6-124	ND	12	11.00	CM Column 4-127	17.6	12	11.71
CM Column 6-132	ND	12	11.81	CM Column 4-157	16.2	12	14.70
CM Column 6-163	ND	12	14.90	CM Column 4-177	14.7	12	16.42
CM Column 6-183	ND	12	16.87	CM Column 4-197	15	12	18.40
CM Column 6-203	ND	12	18.87	CM Column 4-230	13.9	12	21.73
CM Column 6-235	ND	12	22.11	CM Column 4-233*	13.6	12	21.91
CM Column 6-238*	ND	12	22.28	CM Column 4-238	14.2	12	22.22
CM Column 6-243	ND	12	22.60	CM Column 4-244	14.1	12	22.81
CM Column 6-249	ND	12	23.20	CM Column 4-269	13.6	12	25.29
CM Column 6-274	ND	12	25.68	CM Column 4-289	12.6	12	27.26
CM Column 6-294	ND	12	27.68	CM Column 4-309	13.6	12	29.22
CM Column 6-314	ND	12	29.66	CM Column 4-329	12.5	12	31.20
CM Column 6-334	ND	12	31.66				

Magnesium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-1	37800	13.5	0.01	CM Column 2-1	99900	13.5	0.02
CM Column 1-3	29400	13.5	0.05	CM Column 2-4	104000	13.5	0.09
CM Column 1-5	23300	27	0.07	CM Column 2-8	104000	13.5	0.17
CM Column 1-7	5740	13.5	0.23	CM Column 2-10	65600	13.5	0.35
CM Column 1-27	4050	13.5	2.18	CM Column 2-30	1400	13.5	2.47
CM Column 1-37	3970	13.5	3.15	CM Column 2-40	1700	13.5	3.52
CM Column 1-48	4030	13.5	4.21	CM Column 2-51	3140	13.5	4.67
CM Column 1-51	3920	13.5	4.50	CM Column 2-54	3660	13.5	4.99
CM Column 1-62	4580	13.5	5.55	CM Column 2-65	4620	13.5	6.13
CM Column 1-73	4770	13.5	6.60	CM Column 2-76	4960	13.5	7.28
CM Column 1-76	7160	13.5	6.89	CM Column 2-79	5010	13.5	7.60
CM Column 1-86	5030	13.5	7.85	CM Column 2-89	5230	13.5	8.64
CM Column 1-96	4940	13.5	8.82	CM Column 2-99	5210	13.5	9.69
CM Column 1-99	5480	13.5	9.11	CM Column 2-102	5580	13.5	10.02
CM Column 1-104	5520	13.5	9.59	CM Column 2-107	5670	13.5	10.56
CM Column 1-108*	5530	13.5	9.87	CM Column 2-111*	5370	13.5	10.85
CM Column 1-114	5210	13.5	10.16	CM Column 2-117	5460	13.5	11.18
CM Column 1-121	4950	13.5	10.50	CM Column 2-124	5340	13.5	11.57
CM Column 1-129	4890	13.5	11.27	CM Column 2-132	5450	13.5	12.42
CM Column 1-159	4900	13.5	14.11	CM Column 2-162	5130	13.5	15.60
CM Column 1-179	5130	13.5	15.96	CM Column 2-182	5270	13.5	17.68
CM Column 1-199	4900	13.5	17.89	CM Column 2-202	5090	13.5	19.78
CM Column 1-232	4660	13.5	21.09	CM Column 2-235	4960	13.5	23.29
CM Column 1-236*	4930	13.5	21.32	CM Column 2-238*	5140	13.5	23.48
CM Column 1-241	4720	13.5	21.61	CM Column 2-243	5200	13.5	23.80
CM Column 1-247	4940	13.5	22.18	CM Column 2-249	5190	13.5	24.41
CM Column 1-272	4880	13.5	24.62	CM Column 2-274	4850	13.5	26.95
CM Column 1-292	4930	13.5	26.58	CM Column 2-294	4960	13.5	29.08
CM Column 1-313	5060	13.5	28.62	CM Column 2-314	5080	13.5	31.22
CM Column 1-333	4710	13.5	30.56	CM Column 2-334	4740	13.5	33.36

Magnesium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-1	54400	13.5	0.01	CM Column 3-1	126000	27	0.00
CM Column 5-4	33100	13.5	0.07	CM Column 3-3	109000	13.5	0.04
CM Column 5-8	23000	54	0.12	CM Column 3-5	133000	27	0.06
CM Column 5-10	11200	13.5	0.31	CM Column 3-7	71000	13.5	0.33
CM Column 5-30	3870	13.5	2.35	CM Column 3-28	1340	13.5	1.24
CM Column 5-39	4270	13.5	3.26	CM Column 3-38	1510	13.5	2.01
CM Column 5-50	4800	13.5	4.39	CM Column 3-49	2980	13.5	4.19
CM Column 5-53	5000	13.5	4.69	CM Column 3-52	3340	13.5	4.50
CM Column 5-63	5220	13.5	5.71	CM Column 3-63	4750	13.5	5.64
CM Column 5-74	5180	13.5	6.82	CM Column 3-74	4960	13.5	6.79
CM Column 5-77	5180	13.5	7.13	CM Column 3-77	5040	13.5	7.11
CM Column 5-88	5370	13.5	7.23	CM Column 3-87	5180	13.5	8.17
CM Column 5-98	5350	13.5	9.29	CM Column 3-97	5110	13.5	9.22
CM Column 5-101	5340	13.5	9.60	CM Column 3-100	5420	13.5	9.55
CM Column 5-107	5340	13.5	10.23	CM Column 3-105	5340	13.5	10.08
CM Column 5-110b*	5510	13.5	10.45	CM Column 3-109*	5580	13.5	10.34
CM Column 5-116	5070	13.5	10.76	CM Column 3-115	5650	13.5	10.68
CM Column 5-123	5240	13.5	11.14	CM Column 3-122	5280	13.5	11.06
CM Column 5-131	4890	13.5	11.97	CM Column 3-130	5450	13.5	11.90
CM Column 5-162	5120	13.5	15.07	CM Column 3-160	5260	13.5	15.05
CM Column 5-182	5050	13.5	17.08	CM Column 3-180	5200	13.5	16.87
CM Column 5-202	5010	13.5	19.09	CM Column 3-200	5360	13.5	18.95
CM Column 5-235	4550	13.5	22.47	CM Column 3-233	5290	13.5	22.38
CM Column 5-238*	4950	13.5	22.65	CM Column 3-236*	5150	13.5	22.53
CM Column 5-243	4510	13.5	22.98	CM Column 3-241	5130	13.5	22.85
CM Column 5-249	5040	13.5	23.59	CM Column 3-247	5300	13.5	23.46
CM Column 5-274	5040	13.5	26.07	CM Column 3-272	4950	13.5	26.04
CM Column 5-294	4850	13.5	28.09	CM Column 3-292	5060	13.5	28.06
CM Column 5-314	4880	13.5	30.10	CM Column 3-312	5140	13.5	30.12
CM Column 5-334	4850	13.5	32.13	CM Column 3-332	4890	13.5	32.20

Magnesium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-1	56400	13.5	0.01	CM Column 4-1	99700	13.5	0.02
CM Column 6-4	33700	13.5	0.07	CM Column 4-3	127000	27	0.04
CM Column 6-8	13100	13.5	0.14	CM Column 4-5	78300	13.5	0.24
CM Column 6-10	10600	13.5	0.33	CM Column 4-25	1690	13.5	2.26
CM Column 6-30	3900	13.5	2.32	CM Column 4-35	1660	13.5	3.27
CM Column 6-39	4300	13.5	3.22	CM Column 4-46	2480	13.5	4.36
CM Column 6-50	4870	13.5	4.32	CM Column 4-49	2690	13.5	4.66
CM Column 6-53	6340	13.5	4.62	CM Column 4-60	4010	13.5	5.76
CM Column 6-63	5220	13.5	5.62	CM Column 4-71	4770	13.5	6.85
CM Column 6-74	5190	13.5	6.70	CM Column 4-74	4770	13.5	7.14
CM Column 6-77	5240	13.5	7.01	CM Column 4-84	5130	13.5	8.15
CM Column 6-88	5400	13.5	8.12	CM Column 4-94	5140	13.5	9.15
CM Column 6-98	5340	13.5	9.15	CM Column 4-97	5310	13.5	9.45
CM Column 6-101	5710	13.5	9.45	CM Column 4-102	5240	13.5	9.96
CM Column 6-107	5550	13.5	10.07	CM Column 4-106*	5230	13.5	10.24
CM Column 6-111*	5550	13.5	10.33	CM Column 4-112	5290	13.5	10.55
CM Column 6-117	5210	13.5	10.64	CM Column 4-119	5170	13.5	10.91
CM Column 6-124	5330	13.5	11.00	CM Column 4-127	5510	13.5	11.71
CM Column 6-132	4930	13.5	11.81	CM Column 4-157	5350	13.5	14.70
CM Column 6-163	4980	13.5	14.90	CM Column 4-177	5140	13.5	16.42
CM Column 6-183	5000	13.5	16.87	CM Column 4-197	5190	13.5	18.40
CM Column 6-203	4980	13.5	18.87	CM Column 4-230	4920	13.5	21.73
CM Column 6-235	4470	13.5	22.11	CM Column 4-233*	4770	13.5	21.91
CM Column 6-238*	4820	13.5	22.28	CM Column 4-238	5110	13.5	22.22
CM Column 6-243	4600	13.5	22.60	CM Column 4-244	5320	13.5	22.81
CM Column 6-249	4950	13.5	23.20	CM Column 4-269	4900	13.5	25.29
CM Column 6-274	4850	13.5	25.68	CM Column 4-289	4880	13.5	27.26
CM Column 6-294	4710	13.5	27.68	CM Column 4-309	5100	13.5	29.22
CM Column 6-314	4910	13.5	29.66	CM Column 4-329	4840	13.5	31.20
CM Column 6-334	4860	13.5	31.66				

Potassium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-1	11900	806	0.01	CM Column 2-1	40600	806	0.02
CM Column 1-3	10200	806	0.05	CM Column 2-4	31900	806	0.09
CM Column 1-5	9460	1610	0.07	CM Column 2-8	39000	806	0.17
CM Column 1-7	4480	806	0.23	CM Column 2-10	14900	806	0.35
CM Column 1-27	5690	806	2.18	CM Column 2-30	3840	806	2.47
CM Column 1-37	3540	806	3.15	CM Column 2-40	2590	806	3.52
CM Column 1-48	5940	806	4.21	CM Column 2-51	6280	806	4.67
CM Column 1-51	6730	806	4.50	CM Column 2-54	6410	806	4.99
CM Column 1-62	4050	806	5.55	CM Column 2-65	4440	806	6.13
CM Column 1-73	4090	806	6.60	CM Column 2-76	4530	806	7.28
CM Column 1-76	4290	806	6.89	CM Column 2-79	4740	806	7.60
CM Column 1-86	4370	806	7.85	CM Column 2-89	4850	806	8.64
CM Column 1-96	4290	806	8.82	CM Column 2-99	4840	806	9.69
CM Column 1-99	6730	806	9.11	CM Column 2-102	5180	806	10.02
CM Column 1-104	4970	806	9.59	CM Column 2-107	5760	806	10.56
CM Column 1-108*	12900	806	9.87	CM Column 2-111*	10500	806	10.85
CM Column 1-114	3540	806	10.16	CM Column 2-117	4550	806	11.18
CM Column 1-121	6940	806	10.50	CM Column 2-124	8500	806	11.57
CM Column 1-129	5570	806	11.27	CM Column 2-132	6630	806	12.42
CM Column 1-159	2260	806	14.11	CM Column 2-162	3090	806	15.60
CM Column 1-179	3450	806	15.96	CM Column 2-182	3970	806	17.68
CM Column 1-199	2430	806	17.89	CM Column 2-202	3640	806	19.78
CM Column 1-232	3060	806	21.09	CM Column 2-235	3290	806	23.29
CM Column 1-236*	3690	806	21.32	CM Column 2-238*	3370	806	23.48
CM Column 1-241	3980	806	21.61	CM Column 2-243	3260	806	23.80
CM Column 1-247	3100	806	22.18	CM Column 2-249	2630	806	24.41
CM Column 1-272	2940	806	24.62	CM Column 2-274	2600	806	26.95
CM Column 1-292	3710	806	26.58	CM Column 2-294	2600	806	29.08
CM Column 1-313	3000	806	28.62	CM Column 2-314	3410	806	31.22
CM Column 1-333	3210	806	30.56	CM Column 2-334	2980	806	33.36

Potassium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-1	14300	806	0.01	CM Column 3-1	25500	1610	0.00
CM Column 5-4	10500	806	0.07	CM Column 3-3	20500	806	0.04
CM Column 5-8	9530	3220	0.12	CM Column 3-5	24700	1610	0.06
CM Column 5-10	6000	806	0.31	CM Column 3-7	17400	806	0.33
CM Column 5-30	6510	806	2.35	CM Column 3-28	4390	806	1.24
CM Column 5-39	7790	806	3.26	CM Column 3-38	2240	806	2.01
CM Column 5-50	6720	806	4.39	CM Column 3-49	5750	806	4.19
CM Column 5-53	7450	806	4.69	CM Column 3-52	7510	806	4.50
CM Column 5-63	4410	806	5.71	CM Column 3-63	7100	806	5.64
CM Column 5-74	7230	806	6.82	CM Column 3-74	4460	806	6.79
CM Column 5-77	4590	806	7.13	CM Column 3-77	4690	806	7.11
CM Column 5-88	4640	806	7.23	CM Column 3-87	9890	806	8.17
CM Column 5-98	4670	806	9.29	CM Column 3-97	4730	806	9.22
CM Column 5-101	4440	806	9.60	CM Column 3-100	5080	806	9.55
CM Column 5-107	4590	806	10.23	CM Column 3-105	8910	806	10.08
CM Column 5-110b*	5730	806	10.45	CM Column 3-109*	9050	806	10.34
CM Column 5-116	2490	806	10.76	CM Column 3-115	2840	806	10.68
CM Column 5-123	7760	806	11.14	CM Column 3-122	8250	806	11.06
CM Column 5-131	5870	806	11.97	CM Column 3-130	6700	806	11.90
CM Column 5-162	3720	806	15.07	CM Column 3-160	3240	806	15.05
CM Column 5-182	2460	806	17.08	CM Column 3-180	3650	806	16.87
CM Column 5-202	3000	806	19.09	CM Column 3-200	3180	806	18.95
CM Column 5-235	2830	806	22.47	CM Column 3-233	2550	806	22.38
CM Column 5-238*	2650	806	22.65	CM Column 3-236*	11100	806	22.53
CM Column 5-243	2700	806	22.98	CM Column 3-241	2900	806	22.85
CM Column 5-249	3070	806	23.59	CM Column 3-247	3420	806	23.46
CM Column 5-274	3000	806	26.07	CM Column 3-272	3150	806	26.04
CM Column 5-294	2580	806	28.09	CM Column 3-292	3340	806	28.06
CM Column 5-314	2930	806	30.10	CM Column 3-312	3520	806	30.12
CM Column 5-334	2710	806	32.13	CM Column 3-332	3400	806	32.20

Potassium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-1	14700	806	0.01	CM Column 4-1	32000	806	0.02
CM Column 6-4	10300	806	0.07	CM Column 4-3	24200	1610	0.04
CM Column 6-8	9140	806	0.14	CM Column 4-5	15900	806	0.24
CM Column 6-10	5980	806	0.33	CM Column 4-25	3560	806	2.26
CM Column 6-30	5920	806	2.32	CM Column 4-35	2190	806	3.27
CM Column 6-39	6320	806	3.22	CM Column 4-46	16100	806	4.36
CM Column 6-50	3270	806	4.32	CM Column 4-49	6750	806	4.66
CM Column 6-53	4600	806	4.62	CM Column 4-60	4150	806	5.76
CM Column 6-63	7400	806	5.62	CM Column 4-71	4640	806	6.85
CM Column 6-74	4350	806	6.70	CM Column 4-74	4750	806	7.14
CM Column 6-77	4570	806	7.01	CM Column 4-84	5060	806	8.15
CM Column 6-88	4630	806	8.12	CM Column 4-94	5170	806	9.15
CM Column 6-98	4720	806	9.15	CM Column 4-97	5060	806	9.45
CM Column 6-101	4980	806	9.45	CM Column 4-102	5020	806	9.96
CM Column 6-107	4940	806	10.07	CM Column 4-106*	9200	806	10.24
CM Column 6-111*	5390	806	10.33	CM Column 4-112	2600	806	10.55
CM Column 6-117	2170	806	10.64	CM Column 4-119	6350	806	10.91
CM Column 6-124	8100	806	11.00	CM Column 4-127	6270	806	11.71
CM Column 6-132	7820	806	11.81	CM Column 4-157	3400	806	14.70
CM Column 6-163	2520	806	14.90	CM Column 4-177	3760	806	16.42
CM Column 6-183	2830	806	16.87	CM Column 4-197	2600	806	18.40
CM Column 6-203	2770	806	18.87	CM Column 4-230	3480	806	21.73
CM Column 6-235	2510	806	22.11	CM Column 4-233*	3470	806	21.91
CM Column 6-238*	3910	806	22.28	CM Column 4-238	2830	806	22.22
CM Column 6-243	2420	806	22.60	CM Column 4-244	3310	806	22.81
CM Column 6-249	2750	806	23.20	CM Column 4-269	3080	806	25.29
CM Column 6-274	3060	806	25.68	CM Column 4-289	2780	806	27.26
CM Column 6-294	3360	806	27.68	CM Column 4-309	3880	806	29.22
CM Column 6-314	3670	806	29.66	CM Column 4-329	2840	806	31.20
CM Column 6-334	2440	806	31.66				

Silicon							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-1	22200	274	0.01	CM Column 2-1	1990	274	0.02
CM Column 1-3	20700	274	0.05	CM Column 2-4	2040	274	0.09
CM Column 1-5	9990	274	0.07	CM Column 2-8	2060	274	0.17
CM Column 1-7	15400	274	0.23	CM Column 2-10	1890	274	0.35
CM Column 1-27	17500	274	2.18	CM Column 2-30	1110	274	2.47
CM Column 1-37	17300	274	3.15	CM Column 2-40	1130	274	3.52
CM Column 1-48	15900	274	4.21	CM Column 2-51	1190	274	4.67
CM Column 1-51	14900	274	4.50	CM Column 2-54	1200	274	4.99
CM Column 1-62	14200	274	5.55	CM Column 2-65	1240	274	6.13
CM Column 1-73	12900	274	6.60	CM Column 2-76	1210	274	7.28
CM Column 1-76	11800	274	6.89	CM Column 2-79	1200	274	7.60
CM Column 1-86	11900	274	7.85	CM Column 2-89	1220	274	8.64
CM Column 1-96	11400	274	8.82	CM Column 2-99	1200	274	9.69
CM Column 1-99	10900	274	9.11	CM Column 2-102	1170	274	10.02
CM Column 1-104	10800	274	9.59	CM Column 2-107	1190	274	10.56
CM Column 1-108*	14900	274	9.87	CM Column 2-111*	1440	274	10.85
CM Column 1-114	13900	274	10.16	CM Column 2-117	1440	274	11.18
CM Column 1-121	13500	274	10.50	CM Column 2-124	1310	274	11.57
CM Column 1-129	13700	274	11.27	CM Column 2-132	1310	274	12.42
CM Column 1-159	11900	274	14.11	CM Column 2-162	1240	274	15.60
CM Column 1-179	11500	274	15.96	CM Column 2-182	1290	274	17.68
CM Column 1-199	10400	274	17.89	CM Column 2-202	1250	274	19.78
CM Column 1-232	9830	274	21.09	CM Column 2-235	1190	274	23.29
CM Column 1-236*	10900	274	21.32	CM Column 2-238*	1310	274	23.48
CM Column 1-241	10900	274	21.61	CM Column 2-243	1360	274	23.80
CM Column 1-247	10700	274	22.18	CM Column 2-249	1300	274	24.41
CM Column 1-272	9750	274	24.62	CM Column 2-274	1190	274	26.95
CM Column 1-292	9290	274	26.58	CM Column 2-294	1230	274	29.08
CM Column 1-313	8790	274	28.62	CM Column 2-314	1250	274	31.22
CM Column 1-333	7900	274	30.56	CM Column 2-334	1190	274	33.36

Silicon							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-1	23300	274	0.01	CM Column 3-1	981	274	0.00
CM Column 5-4	21500	274	0.07	CM Column 3-3	1650	274	0.04
CM Column 5-8	5750	274	0.12	CM Column 3-5	963	274	0.06
CM Column 5-10	18600	274	0.31	CM Column 3-7	1510	274	0.33
CM Column 5-30	17400	274	2.35	CM Column 3-28	1050	274	1.24
CM Column 5-39	16900	274	3.26	CM Column 3-38	1140	274	2.01
CM Column 5-50	15400	274	4.39	CM Column 3-49	1160	274	4.19
CM Column 5-53	15000	274	4.69	CM Column 3-52	1150	274	4.50
CM Column 5-63	14200	274	5.71	CM Column 3-63	1220	274	5.64
CM Column 5-74	13100	274	6.82	CM Column 3-74	1210	274	6.79
CM Column 5-77	12400	274	7.13	CM Column 3-77	1180	274	7.11
CM Column 5-88	11800	274	7.23	CM Column 3-87	1210	274	8.17
CM Column 5-98	11300	274	9.29	CM Column 3-97	1190	274	9.22
CM Column 5-101	11100	274	9.60	CM Column 3-100	1190	274	9.55
CM Column 5-107	11100	274	10.23	CM Column 3-105	1180	274	10.08
CM Column 5-110b*	13800	274	10.45	CM Column 3-109*	1390	274	10.34
CM Column 5-116	14500	274	10.76	CM Column 3-115	1470	274	10.68
CM Column 5-123	14300	274	11.14	CM Column 3-122	1330	274	11.06
CM Column 5-131	13500	274	11.97	CM Column 3-130	1330	274	11.90
CM Column 5-162	12300	274	15.07	CM Column 3-160	1380	274	15.05
CM Column 5-182	11300	274	17.08	CM Column 3-180	1330	274	16.87
CM Column 5-202	10500	274	19.09	CM Column 3-200	1380	274	18.95
CM Column 5-235	9540	274	22.47	CM Column 3-233	1400	274	22.38
CM Column 5-238*	10400	274	22.65	CM Column 3-236*	1320	274	22.53
CM Column 5-243	10200	274	22.98	CM Column 3-241	1280	274	22.85
CM Column 5-249	10700	274	23.59	CM Column 3-247	1320	274	23.46
CM Column 5-274	9720	274	26.07	CM Column 3-272	1270	274	26.04
CM Column 5-294	8380	274	28.09	CM Column 3-292	1310	274	28.06
CM Column 5-314	7910	274	30.10	CM Column 3-312	1330	274	30.12
CM Column 5-334	7550	274	32.13	CM Column 3-332	1240	274	32.20

Silicon							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-1	24000	274	0.01	CM Column 4-1	1780	274	0.02
CM Column 6-4	22300	274	0.07	CM Column 4-3	1080	274	0.04
CM Column 6-8	18600	274	0.14	CM Column 4-5	1610	274	0.24
CM Column 6-10	18600	274	0.33	CM Column 4-25	1180	274	2.26
CM Column 6-30	17900	274	2.32	CM Column 4-35	1220	274	3.27
CM Column 6-39	17800	274	3.22	CM Column 4-46	1280	274	4.36
CM Column 6-50	16300	274	4.32	CM Column 4-49	1200	274	4.66
CM Column 6-53	14900	274	4.62	CM Column 4-60	1300	274	5.76
CM Column 6-63	14400	274	5.62	CM Column 4-71	1330	274	6.85
CM Column 6-74	13400	274	6.70	CM Column 4-74	1330	274	7.14
CM Column 6-77	12400	274	7.01	CM Column 4-84	1330	274	8.15
CM Column 6-88	12000	274	8.12	CM Column 4-94	1310	274	9.15
CM Column 6-98	11500	274	9.15	CM Column 4-97	1280	274	9.45
CM Column 6-101	11600	274	9.45	CM Column 4-102	1260	274	9.96
CM Column 6-107	10900	274	10.07	CM Column 4-106*	1410	274	10.24
CM Column 6-111*	14000	274	10.33	CM Column 4-112	1460	274	10.55
CM Column 6-117	14100	274	10.64	CM Column 4-119	1350	274	10.91
CM Column 6-124	14100	274	11.00	CM Column 4-127	1480	274	11.71
CM Column 6-132	13900	274	11.81	CM Column 4-157	1500	274	14.70
CM Column 6-163	12300	274	14.90	CM Column 4-177	1360	274	16.42
CM Column 6-183	11200	274	16.87	CM Column 4-197	1430	274	18.40
CM Column 6-203	10500	274	18.87	CM Column 4-230	1370	274	21.73
CM Column 6-235	9630	274	22.11	CM Column 4-233*	1250	274	21.91
CM Column 6-238*	10700	274	22.28	CM Column 4-238	1350	274	22.22
CM Column 6-243	10300	274	22.60	CM Column 4-244	1390	274	22.81
CM Column 6-249	10800	274	23.20	CM Column 4-269	1280	274	25.29
CM Column 6-274	9560	274	25.68	CM Column 4-289	1330	274	27.26
CM Column 6-294	8550	274	27.68	CM Column 4-309	1350	274	29.22
CM Column 6-314	8200	274	29.66	CM Column 4-329	1250	274	31.20
CM Column 6-334	7650	274	31.66				

Sodium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-1	42700	223	0.01	CM Column 2-1	56200	223	0.02
CM Column 1-3	36300	223	0.05	CM Column 2-4	58800	223	0.09
CM Column 1-5	31900	447	0.07	CM Column 2-8	59600	223	0.17
CM Column 1-7	7490	223	0.23	CM Column 2-10	40400	223	0.35
CM Column 1-27	12500	223	2.18	CM Column 2-30	4130	223	2.47
CM Column 1-37	13300	223	3.15	CM Column 2-40	6320	223	3.52
CM Column 1-48	12200	223	4.21	CM Column 2-51	10400	223	4.67
CM Column 1-51	10800	223	4.50	CM Column 2-54	9300	223	4.99
CM Column 1-62	7780	223	5.55	CM Column 2-65	6720	223	6.13
CM Column 1-73	6300	223	6.60	CM Column 2-76	6080	223	7.28
CM Column 1-76	6040	223	6.89	CM Column 2-79	5610	223	7.60
CM Column 1-86	5740	223	7.85	CM Column 2-89	5700	223	8.64
CM Column 1-96	5580	223	8.82	CM Column 2-99	5500	223	9.69
CM Column 1-99	5450	223	9.11	CM Column 2-102	4470	223	10.02
CM Column 1-104	5320	223	9.59	CM Column 2-107	4870	223	10.56
CM Column 1-108*	6360	223	9.87	CM Column 2-111*	5970	223	10.85
CM Column 1-114	6010	223	10.16	CM Column 2-117	6090	223	11.18
CM Column 1-121	5530	223	10.50	CM Column 2-124	5800	223	11.57
CM Column 1-129	5880	223	11.27	CM Column 2-132	6070	223	12.42
CM Column 1-159	5310	223	14.11	CM Column 2-162	5510	223	15.60
CM Column 1-179	5820	223	15.96	CM Column 2-182	5790	223	17.68
CM Column 1-199	5560	223	17.89	CM Column 2-202	5580	223	19.78
CM Column 1-232	5380	223	21.09	CM Column 2-235	5410	223	23.29
CM Column 1-236*	5600	223	21.32	CM Column 2-238*	5660	223	23.48
CM Column 1-241	5720	223	21.61	CM Column 2-243	5740	223	23.80
CM Column 1-247	5880	223	22.18	CM Column 2-249	5780	223	24.41
CM Column 1-272	5790	223	24.62	CM Column 2-274	5510	223	26.95
CM Column 1-292	5810	223	26.58	CM Column 2-294	5630	223	29.08
CM Column 1-313	5900	223	28.62	CM Column 2-314	5830	223	31.22
CM Column 1-333	5600	223	30.56	CM Column 2-334	5470	223	33.36

Sodium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-1	53100	223	0.01	CM Column 3-1	82900	447	0.00
CM Column 5-4	40200	223	0.07	CM Column 3-3	62800	223	0.04
CM Column 5-8	34100	894	0.12	CM Column 3-5	72700	447	0.06
CM Column 5-10	22400	223	0.31	CM Column 3-7	42000	223	0.33
CM Column 5-30	12700	223	2.35	CM Column 3-28	4230	223	1.24
CM Column 5-39	11200	223	3.26	CM Column 3-38	5450	223	2.01
CM Column 5-50	7790	223	4.39	CM Column 3-49	10900	223	4.19
CM Column 5-53	7020	223	4.69	CM Column 3-52	9620	223	4.50
CM Column 5-63	6460	223	5.71	CM Column 3-63	6520	223	5.64
CM Column 5-74	5950	223	6.82	CM Column 3-74	5930	223	6.79
CM Column 5-77	5720	223	7.13	CM Column 3-77	5570	223	7.11
CM Column 5-88	5660	223	7.23	CM Column 3-87	5510	223	8.17
CM Column 5-98	5600	223	9.29	CM Column 3-97	5460	223	9.22
CM Column 5-101	5570	223	9.60	CM Column 3-100	5610	223	9.55
CM Column 5-107	5660	223	10.23	CM Column 3-105	5550	223	10.08
CM Column 5-110b*	6050	223	10.45	CM Column 3-109*	5990	223	10.34
CM Column 5-116	5820	223	10.76	CM Column 3-115	5990	223	10.68
CM Column 5-123	5900	223	11.14	CM Column 3-122	5880	223	11.06
CM Column 5-131	5760	223	11.97	CM Column 3-130	5930	223	11.90
CM Column 5-162	5800	223	15.07	CM Column 3-160	5330	223	15.05
CM Column 5-182	5320	223	17.08	CM Column 3-180	5760	223	16.87
CM Column 5-202	5560	223	19.09	CM Column 3-200	5690	223	18.95
CM Column 5-235	5250	223	22.47	CM Column 3-233	5430	223	22.38
CM Column 5-238*	5600	223	22.65	CM Column 3-236*	5910	223	22.53
CM Column 5-243	5340	223	22.98	CM Column 3-241	5620	223	22.85
CM Column 5-249	5940	223	23.59	CM Column 3-247	5870	223	23.46
CM Column 5-274	6120	223	26.07	CM Column 3-272	5610	223	26.04
CM Column 5-294	5750	223	28.09	CM Column 3-292	5870	223	28.06
CM Column 5-314	5620	223	30.10	CM Column 3-312	5850	223	30.12
CM Column 5-334	5570	223	32.13	CM Column 3-332	5550	223	32.20

Sodium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-1	60500	223	0.01	CM Column 4-1	59900	223	0.02
CM Column 6-4	40600	223	0.07	CM Column 4-3	68100	447	0.04
CM Column 6-8	25100	223	0.14	CM Column 4-5	44700	223	0.24
CM Column 6-10	22300	223	0.33	CM Column 4-25	4280	223	2.26
CM Column 6-30	13200	223	2.32	CM Column 4-35	5020	223	3.27
CM Column 6-39	12100	223	3.22	CM Column 4-46	8310	223	4.36
CM Column 6-50	8140	223	4.32	CM Column 4-49	8480	223	4.66
CM Column 6-53	7300	223	4.62	CM Column 4-60	7890	223	5.76
CM Column 6-63	6360	223	5.62	CM Column 4-71	6360	223	6.85
CM Column 6-74	5840	223	6.70	CM Column 4-74	5830	223	7.14
CM Column 6-77	5670	223	7.01	CM Column 4-84	5750	223	8.15
CM Column 6-88	5700	223	8.12	CM Column 4-94	5480	223	9.15
CM Column 6-98	5520	223	9.15	CM Column 4-97	5510	223	9.45
CM Column 6-101	5630	223	9.45	CM Column 4-102	5320	223	9.96
CM Column 6-107	5420	223	10.07	CM Column 4-106*	6090	223	10.24
CM Column 6-111*	5740	223	10.33	CM Column 4-112	5900	223	10.55
CM Column 6-117	5680	223	10.64	CM Column 4-119	5820	223	10.91
CM Column 6-124	6040	223	11.00	CM Column 4-127	5980	223	11.71
CM Column 6-132	5670	223	11.81	CM Column 4-157	5560	223	14.70
CM Column 6-163	5500	223	14.90	CM Column 4-177	5630	223	16.42
CM Column 6-183	5610	223	16.87	CM Column 4-197	5590	223	18.40
CM Column 6-203	5540	223	18.87	CM Column 4-230	5240	223	21.73
CM Column 6-235	5350	223	22.11	CM Column 4-233*	5860	223	21.91
CM Column 6-238*	6210	223	22.28	CM Column 4-238	5560	223	22.22
CM Column 6-243	5420	223	22.60	CM Column 4-244	5750	223	22.81
CM Column 6-249	5850	223	23.20	CM Column 4-269	5470	223	25.29
CM Column 6-274	5740	223	25.68	CM Column 4-289	5640	223	27.26
CM Column 6-294	5570	223	27.68	CM Column 4-309	5840	223	29.22
CM Column 6-314	5900	223	29.66	CM Column 4-329	5520	223	31.20
CM Column 6-334	5720	223	31.66				

Appendix B

Summary of LIMS Data: Element Concentrations at Different Times during Leaching with an Iodate, Iodide, or Organo-I Spiked Artificial Groundwater followed by an Iodine-Free Artificial Groundwater

Barium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-343	17.9	16.4	31.42	CM Column 2-344	21.0	16.4	34.32
CM Column 1-353	18.6	16.4	32.38	CM Column 2-354	21.6	16.4	35.39
CM Column 1-363	19.5	16.4	33.35	CM Column 2-364	21.3	16.4	36.46
CM Column 1-383	18.4	16.4	34.95	CM Column 2-384	22.5	16.4	38.36
CM Column 1-403	18.2	16.4	36.79	CM Column 2-404	23.7	16.4	40.45
CM Column 1-423	18.8	16.4	38.61	CM Column 2-424	22.4	16.4	42.54
CM Column 1-443	17.7	16.4	40.51	CM Column 2-444	21.9	16.4	44.64
CM Column 1-454	23.7	16.4	41.52	CM Column 2-456	29.0	16.4	45.89
CM Column 1-457*	18.4	16.4	41.64	CM Column 2-459*	19.9	16.4	46.04
CM Column 1-464	18.5	16.4	42.28	CM Column 2-466	20.7	16.4	46.74
CM Column 1-480	17.6	16.4	43.85	CM Column 2-482	19.8	16.4	48.46
CM Column 1-494	16.7	16.4	45.21	CM Column 2-496	19.6	16.4	49.96
CM Column 1-514	ND	16.4	47.15	CM Column 2-516	16.8	16.4	52.11
CM Column 1-534	16.9	16.4	49.12	CM Column 2-536	18.8	16.4	54.26
CM Column 1-567	ND	16.4	52.34	CM Column 2-569	17.0	16.4	57.78
CM Column 1-570*	18.2	16.4	52.58	CM Column 2-571*	19.1	16.4	57.96
CM Column 1-576	ND	16.4	53.05	CM Column 2-577	19.0	16.4	58.41
CM Column 1-584	17.1	16.4	54.11	CM Column 2-585	56.1	16.4	59.57
CM Column 1-599	ND	16.4	56.12	CM Column 2-600	18.0	16.4	61.75
CM Column 1-639	ND	16.4	60.14	CM Column 2-640	17.6	16.4	66.02
CM Column 1-673	ND	16.4	63.32	CM Column 2-680*	23.7	16.4	69.96
CM Column 1-677*	20.1	16.4	63.50	CM Column 2-684	19.5	16.4	70.22
CM Column 1-681	18.7	16.4	63.74	CM Column 2-702	19.6	16.4	72.13
CM Column 1-699	16.7	16.4	65.48	CM Column 2-742	20.6	16.4	76.03
CM Column 1-739	17.1	16.4	69.04	CM Column 2-771	19.1	16.4	78.99
CM Column 1-768	ND	16.4	71.75	CM Column 2-783	21.3	16.4	79.81
CM Column 1-780	18.6	16.4	72.49	CM Column 2-786*	22.9	16.4	80.06
CM Column 1-783*	20.5	16.4	72.66	CM Column 2-799	22.7	16.4	81.24
CM Column 1-788	19.2	16.4	72.99	CM Column 2-829	20.9	16.4	84.35
CM Column 1-796	19.2	16.4	73.73	CM Column 2-856	22.0	16.4	87.19
CM Column 1-806	17.8	16.4	74.68	CM Column 2-859	20.1	16.4	87.50
CM Column 1-826	18.7	16.4	76.55	CM Column 2-879	20.1	16.4	89.57
CM Column 1-853	18.4	16.4	79.11	CM Column 2-891*	19.4	16.4	90.58
CM Column 1-856	16.6	16.4	79.39	CM Column 2-957	18.6	16.4	97.63
CM Column 1-886*	18.4	16.4	82.05	CM Column 2-960	22.2	16.4	97.94
CM Column 1-889	16.7	16.4	82.29	CM Column 2-983	21.2	16.4	100.41
CM Column 1-955	17.2	16.4	88.66	CM Column 2-1056	22.0	16.4	108.20
CM Column 1-958*	18.2	16.4	88.94	CM Column 2-1061*	24.5	16.4	108.46
CM Column 1-981	18.9	16.4	91.20	CM Column 2-1094	23.9	16.4	111.98
CM Column 1-1054	18.2	16.4	98.33	CM Column 2-1154	23.1	16.4	118.37
CM Column 1-1059*	20.9	16.4	98.56	CM Column 2-1157*	25.1	16.4	118.54
CM Column 1-1092	18.8	16.4	101.79	CM Column 2-1250	22.4	16.4	128.30
CM Column 1-1152	18.8	16.4	107.56	CM Column 2-1351*	23.1	16.4	138.25
CM Column 1-1156*	21.2	16.4	107.76				
CM Column 1-1249	18.7	16.4	116.71				
CM Column 1-1347*	20.5	16.4	126.08				

Barium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-444	19.8	16.4	42.91	CM Column 3-342	20.1	16.4	33.03
CM Column 5-455	18.5	16.4	43.87	CM Column 3-352	21.4	16.4	34.07
CM Column 5-458*	18.2	16.4	44.02	CM Column 3-362	19.8	16.4	35.13
CM Column 5-465	19.0	16.4	44.68	CM Column 3-382	21.7	16.4	37.21
CM Column 5-481	17.1	16.4	46.23	CM Column 3-402	21.3	16.4	39.32
CM Column 5-495	16.5	16.4	47.59	CM Column 3-422	21.8	16.4	41.43
CM Column 5-515	ND	16.4	49.54	CM Column 3-442	21.5	16.4	43.55
CM Column 5-535	ND	16.4	51.15	CM Column 3-453	24.6	16.4	44.69
CM Column 5-580*	17.3	16.4	55.60	CM Column 3-456*	18.7	16.4	44.85
CM Column 5-595	ND	16.4	57.10	CM Column 3-463	20.4	16.4	45.54
CM Column 5-615	ND	16.4	59.04	CM Column 3-479	18.6	16.4	47.23
CM Column 5-655	ND	16.4	63.12	CM Column 3-493	20.2	16.4	48.72
CM Column 5-670	ND	16.4	64.66	CM Column 3-513	18.4	16.4	50.78
CM Column 5-673*	22.7	16.4	64.76	CM Column 3-533	19.8	16.4	52.83
CM Column 5-680	19.7	16.4	65.11	CM Column 3-578	19.1	16.4	57.25
CM Column 5-689	18.8	16.4	66.01	CM Column 3-593	17.3	16.4	58.82
CM Column 5-714	18.3	16.4	68.47	CM Column 3-613	17.4	16.4	60.92
CM Column 5-754	18.7	16.4	72.43	CM Column 3-653	17.2	16.4	65.15
CM Column 5-773	17.2	16.4	74.33	CM Column 3-668	16.9	16.4	66.76
CM Column 5-776*	22.4	16.4	74.50	CM Column 3-672*	21.9	16.4	66.94
CM Column 5-782	19.7	16.4	74.96	CM Column 3-679	19.8	16.4	67.30
CM Column 5-793	18.8	16.4	76.07	CM Column 3-688	20.3	16.4	68.24
CM Column 5-813	18.6	16.4	78.06	CM Column 3-713	18.6	16.4	70.86
CM Column 5-843	19.5	16.4	81.08	CM Column 3-753	20.3	16.4	75.00
CM Column 5-878	19.6	16.4	84.53	CM Column 3-772	19.5	16.4	76.99
CM Column 5-881*	17.6	16.4	84.67	CM Column 3-775*	24.0	16.4	77.23
CM Column 5-885	16.4	16.4	85.00	CM Column 3-778	21.0	16.4	77.54
CM Column 5-890	ND	16.4	85.48	CM Column 3-789	21.8	16.4	78.66
CM Column 5-924	ND	16.4	88.84	CM Column 3-809	21.9	16.4	80.73
CM Column 5-982	ND	16.4	94.63	CM Column 3-839	19.6	16.4	83.82
CM Column 5-985*	23.1	16.4	94.75	CM Column 3-874	20.9	16.4	87.40
				CM Column 3-877*	ND	16.4	87.52
				CM Column 3-881	18.6	16.4	87.84
				CM Column 3-886	17.5	16.4	88.35
				CM Column 3-920	18.5	16.4	91.85
				CM Column 3-978	19.9	16.4	97.90
				CM Column 3-981*	23.5	16.4	97.98

Barium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-344	17.3	16.4	32.55	CM Column 4-339	19.9	16.4	32.09
CM Column 6-354	18.1	16.4	33.55	CM Column 4-349	20.2	16.4	33.09
CM Column 6-364	18.6	16.4	34.53	CM Column 4-359	20.1	16.4	34.11
CM Column 6-384	18.7	16.4	36.47	CM Column 4-379	21.0	16.4	36.12
CM Column 6-404	18.2	16.4	38.40	CM Column 4-399	20.9	16.4	38.11
CM Column 6-424	20.5	16.4	40.33	CM Column 4-419	21.1	16.4	40.11
CM Column 6-444	17.7	16.4	42.28	CM Column 4-439	21.9	16.4	42.12
CM Column 6-455	17.9	16.4	43.35	CM Column 4-450	21.9	16.4	43.21
CM Column 6-458*	17.8	16.4	43.48	CM Column 4-453*	19.4	16.4	43.35
CM Column 6-465	18.1	16.4	44.15	CM Column 4-460	20.4	16.4	43.98
CM Column 6-481	18.4	16.4	45.71	CM Column 4-476	18.7	16.4	45.53
CM Column 6-495	16.7	16.4	47.08	CM Column 4-490	19.4	16.4	46.88
CM Column 6-515	ND	16.4	49.02	CM Column 4-510	18.2	16.4	48.71
CM Column 6-535	ND	16.4	50.94	CM Column 4-530	17.4	16.4	50.66
CM Column 6-569	18.4	16.4	54.16	CM Column 4-575	19.7	16.4	54.90
CM Column 6-582	ND	16.4	55.43	CM Column 4-590	18.4	16.4	56.37
CM Column 6-597	ND	16.4	56.95	CM Column 4-610	17.1	16.4	58.32
CM Column 6-617	ND	16.4	58.97	CM Column 4-650	17.9	16.4	62.35
CM Column 6-657	ND	16.4	63.04	CM Column 4-664	18.0	16.4	63.77
CM Column 6-670	16.6	16.4	64.32	CM Column 4-668*	22.3	16.4	63.96
CM Column 6-673*	20.0	16.4	64.50	CM Column 4-675	21.4	16.4	64.31
CM Column 6-680	19.7	16.4	64.83	CM Column 4-684	21.9	16.4	65.20
CM Column 6-689	18.7	16.4	65.61	CM Column 4-709	17.8	16.4	67.69
CM Column 6-714	18.1	16.4	68.08	CM Column 4-749	19.1	16.4	71.62
CM Column 6-754	18.0	16.4	72.05	CM Column 4-768	19.0	16.4	73.50
CM Column 6-773	ND	16.4	73.96	CM Column 4-771*	22.1	16.4	73.67
CM Column 6-776*	20.0	16.4	74.13	CM Column 4-777	20.6	16.4	74.11
CM Column 6-782	20.1	16.4	74.59	CM Column 4-788	21.0	16.4	75.20
CM Column 6-793	18.8	16.4	75.67	CM Column 4-808	20.8	16.4	77.13
CM Column 6-813	18.9	16.4	77.64	CM Column 4-838	21.5	16.4	80.09
CM Column 6-843	19.9	16.4	80.65	CM Column 4-873	19.9	16.4	83.49
CM Column 6-878	19.8	16.4	84.09	CM Column 4-876*	20.8	16.4	83.67
CM Column 6-881*	17.1	16.4	84.25	CM Column 4-880	18.3	16.4	83.98
CM Column 6-885	ND	16.4	84.56	CM Column 4-885	19.5	16.4	84.46
CM Column 6-890	ND	16.4	85.04	CM Column 4-919	17.4	16.4	87.77
CM Column 6-924	ND	16.4	88.38	CM Column 4-977	16.9	16.4	93.63
CM Column 6-982	ND	16.4	94.15	CM Column 4-980*	22.5	16.4	93.76
CM Column 6-985*	19.4	16.4	94.27				

Calcium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-343	17400	168	31.42	CM Column 2-344	16800	168	34.32
CM Column 1-353	18200	168	32.38	CM Column 2-354	16400	168	35.39
CM Column 1-363	17400	168	33.35	CM Column 2-364	16500	168	36.46
CM Column 1-383	18400	168	34.95	CM Column 2-384	17300	168	38.36
CM Column 1-403	18800	168	36.79	CM Column 2-404	18900	168	40.45
CM Column 1-423	18000	168	38.61	CM Column 2-424	17700	168	42.54
CM Column 1-443	18400	168	40.51	CM Column 2-444	17900	168	44.64
CM Column 1-454	21500	168	41.52	CM Column 2-456	22000	168	45.89
CM Column 1-457*	19400	168	41.64	CM Column 2-459*	18100	168	46.04
CM Column 1-464	18600	168	42.28	CM Column 2-466	18900	168	46.74
CM Column 1-480	18200	168	43.85	CM Column 2-482	18700	168	48.46
CM Column 1-494	16900	168	45.21	CM Column 2-496	17400	168	49.96
CM Column 1-514	17000	168	47.15	CM Column 2-516	17300	168	52.11
CM Column 1-534	17300	168	49.12	CM Column 2-536	17200	168	54.26
CM Column 1-567	16800	168	52.34	CM Column 2-569	16700	168	57.78
CM Column 1-570*	20400	168	52.58	CM Column 2-571*	18100	168	57.96
CM Column 1-576	17400	168	53.05	CM Column 2-577	17800	168	58.41
CM Column 1-584	17700	168	54.11	CM Column 2-585	26300	168	59.57
CM Column 1-599	16900	168	56.12	CM Column 2-600	16800	168	61.75
CM Column 1-639	16200	168	60.14	CM Column 2-640	16400	168	66.02
CM Column 1-673	16000	168	63.32	CM Column 2-680*	17600	168	69.96
CM Column 1-677*	17700	168	63.50	CM Column 2-684	16600	168	70.22
CM Column 1-681	15500	168	63.74	CM Column 2-702	15600	168	72.13
CM Column 1-699	15500	168	65.48	CM Column 2-742	15300	168	76.03
CM Column 1-739	16400	168	69.04	CM Column 2-771	15400	168	78.99
CM Column 1-768	15500	168	71.75	CM Column 2-783	16300	168	79.81
CM Column 1-780	16500	168	72.49	CM Column 2-786*	17100	168	80.06
CM Column 1-783*	20500	168	72.66	CM Column 2-799	16800	168	81.24
CM Column 1-788	17300	168	72.99	CM Column 2-829	16700	168	84.35
CM Column 1-796	16700	168	73.73	CM Column 2-856	16200	168	87.19
CM Column 1-806	16800	168	74.68	CM Column 2-859	16700	168	87.50
CM Column 1-826	16700	168	76.55	CM Column 2-879	16300	168	89.57
CM Column 1-853	20500	168	79.11	CM Column 2-891*	16400	168	90.58
CM Column 1-856	16600	168	79.39	CM Column 2-957	15600	168	97.63
CM Column 1-886*	16800	168	82.05	CM Column 2-960	16100	168	97.94
CM Column 1-889	17100	168	82.29	CM Column 2-983	15500	168	100.41
CM Column 1-955	16200	168	88.66	CM Column 2-1056	15300	168	108.20
CM Column 1-958*	16500	168	88.94	CM Column 2-1061*	16900	168	108.46
CM Column 1-981	16300	168	91.20	CM Column 2-1094	16200	168	111.98
CM Column 1-1054	16000	168	98.33	CM Column 2-1154	15600	168	118.37
CM Column 1-1059*	17500	168	98.56	CM Column 2-1157*	16600	168	118.54
CM Column 1-1092	16400	168	101.79	CM Column 2-1250	16100	168	128.30
CM Column 1-1152	16300	168	107.56	CM Column 2-1351*	16500	168	138.25
CM Column 1-1156*	17100	168	107.76				
CM Column 1-1249	15700	168	116.71				
CM Column 1-1347*	16300	168	126.08				

Calcium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-444	17700	168	42.91	CM Column 3-342	17200	168	33.03
CM Column 5-455	17700	168	43.87	CM Column 3-352	16600	168	34.07
CM Column 5-458*	19200	168	44.02	CM Column 3-362	16400	168	35.13
CM Column 5-465	19100	168	44.68	CM Column 3-382	17300	168	37.21
CM Column 5-481	18400	168	46.23	CM Column 3-402	17700	168	39.32
CM Column 5-495	17800	168	47.59	CM Column 3-422	18100	168	41.43
CM Column 5-515	16600	168	49.54	CM Column 3-442	17700	168	43.55
CM Column 5-535	17000	168	51.15	CM Column 3-453	19600	168	44.69
CM Column 5-580*	17200	168	55.60	CM Column 3-456*	18200	168	44.85
CM Column 5-595	16300	168	57.10	CM Column 3-463	18600	168	45.54
CM Column 5-615	15800	168	59.04	CM Column 3-479	18400	168	47.23
CM Column 5-655	15900	168	63.12	CM Column 3-493	17700	168	48.72
CM Column 5-670	15900	168	64.66	CM Column 3-513	15900	168	50.78
CM Column 5-673*	18400	168	64.76	CM Column 3-533	16300	168	52.83
CM Column 5-680	17000	168	65.11	CM Column 3-578	17500	168	57.25
CM Column 5-689	16200	168	66.01	CM Column 3-593	16300	168	58.82
CM Column 5-714	15900	168	68.47	CM Column 3-613	16400	168	60.92
CM Column 5-754	16100	168	72.43	CM Column 3-653	16300	168	65.15
CM Column 5-773	15400	168	74.33	CM Column 3-668	15600	168	66.76
CM Column 5-776*	19000	168	74.50	CM Column 3-672*	17500	168	66.94
CM Column 5-782	17000	168	74.96	CM Column 3-679	17600	168	67.30
CM Column 5-793	16200	168	76.07	CM Column 3-688	16600	168	68.24
CM Column 5-813	16600	168	78.06	CM Column 3-713	16100	168	70.86
CM Column 5-843	15900	168	81.08	CM Column 3-753	16100	168	75.00
CM Column 5-878	16800	168	84.53	CM Column 3-772	15200	168	76.99
CM Column 5-881*	18000	168	84.67	CM Column 3-775*	18100	168	77.23
CM Column 5-885	16000	168	85.00	CM Column 3-778	17300	168	77.54
CM Column 5-890	17100	168	85.48	CM Column 3-789	16400	168	78.66
CM Column 5-924	16200	168	88.84	CM Column 3-809	16500	168	80.73
CM Column 5-982	15900	168	94.63	CM Column 3-839	15900	168	83.82
CM Column 5-985*	18200	168	94.75	CM Column 3-874	16100	168	87.40
				CM Column 3-877*	14600	168	87.52
				CM Column 3-881	16900	168	87.84
				CM Column 3-886	16400	168	88.35
				CM Column 3-920	15700	168	91.85
				CM Column 3-978	15700	168	97.90
				CM Column 3-981*	17000	168	97.98

Calcium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-344	16800	168	32.55	CM Column 4-339	16600	168	32.09
CM Column 6-354	17800	168	33.55	CM Column 4-349	16400	168	33.09
CM Column 6-364	16900	168	34.53	CM Column 4-359	16500	168	34.11
CM Column 6-384	17300	168	36.47	CM Column 4-379	17300	168	36.12
CM Column 6-404	17300	168	38.40	CM Column 4-399	17000	168	38.11
CM Column 6-424	18600	168	40.33	CM Column 4-419	17700	168	40.11
CM Column 6-444	17500	168	42.28	CM Column 4-439	17300	168	42.12
CM Column 6-455	17500	168	43.35	CM Column 4-450	17100	168	43.21
CM Column 6-458*	18800	168	43.48	CM Column 4-453*	18800	168	43.35
CM Column 6-465	18400	168	44.15	CM Column 4-460	18900	168	43.98
CM Column 6-481	18300	168	45.71	CM Column 4-476	18100	168	45.53
CM Column 6-495	17800	168	47.08	CM Column 4-490	17700	168	46.88
CM Column 6-515	17400	168	49.02	CM Column 4-510	17500	168	48.71
CM Column 6-535	17200	168	50.94	CM Column 4-530	17400	168	50.66
CM Column 6-569	17000	168	54.16	CM Column 4-575	17800	168	54.90
CM Column 6-582	17400	168	55.43	CM Column 4-590	16400	168	56.37
CM Column 6-597	15600	168	56.95	CM Column 4-610	16500	168	58.32
CM Column 6-617	15800	168	58.97	CM Column 4-650	16000	168	62.35
CM Column 6-657	16100	168	63.04	CM Column 4-664	15600	168	63.77
CM Column 6-670	15400	168	64.32	CM Column 4-668*	16800	168	63.96
CM Column 6-673*	17300	168	64.50	CM Column 4-675	16900	168	64.31
CM Column 6-680	16800	168	64.83	CM Column 4-684	16800	168	65.20
CM Column 6-689	16000	168	65.61	CM Column 4-709	15600	168	67.69
CM Column 6-714	15800	168	68.08	CM Column 4-749	15700	168	71.62
CM Column 6-754	16800	168	72.05	CM Column 4-768	14900	168	73.50
CM Column 6-773	15900	168	73.96	CM Column 4-771*	17200	168	73.67
CM Column 6-776*	16800	168	74.13	CM Column 4-777	17100	168	74.11
CM Column 6-782	16600	168	74.59	CM Column 4-788	16300	168	75.20
CM Column 6-793	15700	168	75.67	CM Column 4-808	16200	168	77.13
CM Column 6-813	15900	168	77.64	CM Column 4-838	15900	168	80.09
CM Column 6-843	16500	168	80.65	CM Column 4-873	15800	168	83.49
CM Column 6-878	16400	168	84.09	CM Column 4-876*	16500	168	83.67
CM Column 6-881*	16300	168	84.25	CM Column 4-880	16500	168	83.98
CM Column 6-885	16500	168	84.56	CM Column 4-885	17200	168	84.46
CM Column 6-890	17000	168	85.04	CM Column 4-919	15700	168	87.77
CM Column 6-924	15900	168	88.38	CM Column 4-977	15500	168	93.63
CM Column 6-982	16500	168	94.15	CM Column 4-980*	16800	168	93.76
CM Column 6-985*	16700	168	94.27				

Manganese							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-343	ND	12.0	31.42	CM Column 2-344	17.2	12.0	34.32
CM Column 1-353	ND	12.0	32.38	CM Column 2-354	16.9	12.0	35.39
CM Column 1-363	ND	12.0	33.35	CM Column 2-364	17.0	12.0	36.46
CM Column 1-383	ND	12.0	34.95	CM Column 2-384	17.8	12.0	38.36
CM Column 1-403	ND	12.0	36.79	CM Column 2-404	18.4	12.0	40.45
CM Column 1-423	ND	12.0	38.61	CM Column 2-424	17.3	12.0	42.54
CM Column 1-443	ND	12.0	40.51	CM Column 2-444	17.6	12.0	44.64
CM Column 1-454	ND	12.0	41.52	CM Column 2-456	21.0	12.0	45.89
CM Column 1-457*	ND	12.0	41.64	CM Column 2-459*	17.8	12.0	46.04
CM Column 1-464	ND	12.0	42.28	CM Column 2-466	17.3	12.0	46.74
CM Column 1-480	ND	12.0	43.85	CM Column 2-482	16.3	12.0	48.46
CM Column 1-494	ND	12.0	45.21	CM Column 2-496	15.7	12.0	49.96
CM Column 1-514	ND	12.0	47.15	CM Column 2-516	17.7	12.0	52.11
CM Column 1-534	ND	12.0	49.12	CM Column 2-536	18.2	12.0	54.26
CM Column 1-567	ND	12.0	52.34	CM Column 2-569	18.6	12.0	57.78
CM Column 1-570*	ND	12.0	52.58	CM Column 2-571*	21.4	12.0	57.96
CM Column 1-576	ND	12.0	53.05	CM Column 2-577	19.4	12.0	58.41
CM Column 1-584	ND	12.0	54.11	CM Column 2-585	22.0	12.0	59.57
CM Column 1-599	ND	12.0	56.12	CM Column 2-600	17.8	12.0	61.75
CM Column 1-639	ND	12.0	60.14	CM Column 2-640	17.5	12.0	66.02
CM Column 1-673	ND	12.0	63.32	CM Column 2-680*	23.4	12.0	69.96
CM Column 1-677*	ND	12.0	63.50	CM Column 2-684	20.1	12.0	70.22
CM Column 1-681	ND	12.0	63.74	CM Column 2-702	19.5	12.0	72.13
CM Column 1-699	ND	12.0	65.48	CM Column 2-742	20.6	12.0	76.03
CM Column 1-739	ND	12.0	69.04	CM Column 2-771	18.5	12.0	78.99
CM Column 1-768	ND	12.0	71.75	CM Column 2-783	20.0	12.0	79.81
CM Column 1-780	ND	12.0	72.49	CM Column 2-786*	21.5	12.0	80.06
CM Column 1-783*	ND	12.0	72.66	CM Column 2-799	21.0	12.0	81.24
CM Column 1-788	ND	12.0	72.99	CM Column 2-829	21.2	12.0	84.35
CM Column 1-796	ND	12.0	73.73	CM Column 2-856	21.7	12.0	87.19
CM Column 1-806	ND	12.0	74.68	CM Column 2-859	21.4	12.0	87.50
CM Column 1-826	ND	12.0	76.55	CM Column 2-879	21.2	12.0	89.57
CM Column 1-853	ND	12.0	79.11	CM Column 2-891*	21.5	12.0	90.58
CM Column 1-856	ND	12.0	79.39	CM Column 2-957	21.3	12.0	97.63
CM Column 1-886*	ND	12.0	82.05	CM Column 2-960	23.1	12.0	97.94
CM Column 1-889	ND	12.0	82.29	CM Column 2-983	27.3	12.0	100.41
CM Column 1-955	ND	12.0	88.66	CM Column 2-1056	23.5	12.0	108.20
CM Column 1-958*	ND	12.0	88.94	CM Column 2-1061*	26.3	12.0	108.46
CM Column 1-981	ND	12.0	91.20	CM Column 2-1094	25.3	12.0	111.98
CM Column 1-1054	ND	12.0	98.33	CM Column 2-1154	25.1	12.0	118.37
CM Column 1-1059*	ND	12.0	98.56	CM Column 2-1157*	27.1	12.0	118.54
CM Column 1-1092	ND	12.0	101.79	CM Column 2-1250	26.3	12.0	128.30
CM Column 1-1152	ND	12.0	107.56	CM Column 2-1351*	26.2	12.0	138.25
CM Column 1-1156*	ND	12.0	107.76				
CM Column 1-1249	ND	12.0	116.71				
CM Column 1-1347*	ND	12.0	126.08				

Manganese							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-444	ND	12.0	42.91	CM Column 3-342	14.2	12.0	33.03
CM Column 5-455	ND	12.0	43.87	CM Column 3-352	14.1	12.0	34.07
CM Column 5-458*	ND	12.0	44.02	CM Column 3-362	13.4	12.0	35.13
CM Column 5-465	ND	12.0	44.68	CM Column 3-382	14.5	12.0	37.21
CM Column 5-481	ND	12.0	46.23	CM Column 3-402	15.3	12.0	39.32
CM Column 5-495	ND	12.0	47.59	CM Column 3-422	15.1	12.0	41.43
CM Column 5-515	ND	12.0	49.54	CM Column 3-442	14.5	12.0	43.55
CM Column 5-535	ND	12.0	51.15	CM Column 3-453	16.1	12.0	44.69
CM Column 5-580*	ND	12.0	55.60	CM Column 3-456*	13.8	12.0	44.85
CM Column 5-595	ND	12.0	57.10	CM Column 3-463	14.3	12.0	45.54
CM Column 5-615	ND	12.0	59.04	CM Column 3-479	13.9	12.0	47.23
CM Column 5-655	ND	12.0	63.12	CM Column 3-493	12.6	12.0	48.72
CM Column 5-670	ND	12.0	64.66	CM Column 3-513	15.5	12.0	50.78
CM Column 5-673*	ND	12.0	64.76	CM Column 3-533	15.9	12.0	52.83
CM Column 5-680	ND	12.0	65.11	CM Column 3-578	16.2	12.0	57.25
CM Column 5-689	ND	12.0	66.01	CM Column 3-593	14.5	12.0	58.82
CM Column 5-714	ND	12.0	68.47	CM Column 3-613	15.8	12.0	60.92
CM Column 5-754	ND	12.0	72.43	CM Column 3-653	15.6	12.0	65.15
CM Column 5-773	ND	12.0	74.33	CM Column 3-668	14.7	12.0	66.76
CM Column 5-776*	ND	12.0	74.50	CM Column 3-672*	19.2	12.0	66.94
CM Column 5-782	ND	12.0	74.96	CM Column 3-679	18.2	12.0	67.30
CM Column 5-793	ND	12.0	76.07	CM Column 3-688	18.3	12.0	68.24
CM Column 5-813	ND	12.0	78.06	CM Column 3-713	17.3	12.0	70.86
CM Column 5-843	ND	12.0	81.08	CM Column 3-753	17.0	12.0	75.00
CM Column 5-878	ND	12.0	84.53	CM Column 3-772	17.1	12.0	76.99
CM Column 5-881*	ND	12.0	84.67	CM Column 3-775*	20.1	12.0	77.23
CM Column 5-885	ND	12.0	85.00	CM Column 3-778	18.3	12.0	77.54
CM Column 5-890	ND	12.0	85.48	CM Column 3-789	17.8	12.0	78.66
CM Column 5-924	ND	12.0	88.84	CM Column 3-809	17.7	12.0	80.73
CM Column 5-982	ND	12.0	94.63	CM Column 3-839	17.9	12.0	83.82
CM Column 5-985*	ND	12.0	94.75	CM Column 3-874	13.8	12.0	87.40
				CM Column 3-877*	18.4	12.0	87.52
				CM Column 3-881	18.8	12.0	87.84
				CM Column 3-886	18.7	12.0	88.35
				CM Column 3-920	20.4	12.0	91.85
				CM Column 3-978	18.5	12.0	97.90
				CM Column 3-981*	22.8	12.0	97.98

Manganese							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-344	ND	12.0	32.55	CM Column 4-339	13.8	12.0	32.09
CM Column 6-354	ND	12.0	33.55	CM Column 4-349	12.9	12.0	33.09
CM Column 6-364	ND	12.0	34.53	CM Column 4-359	12.9	12.0	34.11
CM Column 6-384	ND	12.0	36.47	CM Column 4-379	13.5	12.0	36.12
CM Column 6-404	ND	12.0	38.40	CM Column 4-399	13.6	12.0	38.11
CM Column 6-424	ND	12.0	40.33	CM Column 4-419	14.0	12.0	40.11
CM Column 6-444	ND	12.0	42.28	CM Column 4-439	13.7	12.0	42.12
CM Column 6-455	ND	12.0	43.35	CM Column 4-450	14.1	12.0	43.21
CM Column 6-458*	ND	12.0	43.48	CM Column 4-453*	13.2	12.0	43.35
CM Column 6-465	ND	12.0	44.15	CM Column 4-460	14.0	12.0	43.98
CM Column 6-481	ND	12.0	45.71	CM Column 4-476	12.3	12.0	45.53
CM Column 6-495	ND	12.0	47.08	CM Column 4-490	ND	12.0	46.88
CM Column 6-515	ND	12.0	49.02	CM Column 4-510	14.4	12.0	48.71
CM Column 6-535	ND	12.0	50.94	CM Column 4-530	14.4	12.0	50.66
CM Column 6-569	ND	12.0	54.16	CM Column 4-575	ND	12.0	54.90
CM Column 6-582	ND	12.0	55.43	CM Column 4-590	12.9	12.0	56.37
CM Column 6-597	ND	12.0	56.95	CM Column 4-610	14.3	12.0	58.32
CM Column 6-617	ND	12.0	58.97	CM Column 4-650	15.0	12.0	62.35
CM Column 6-657	ND	12.0	63.04	CM Column 4-664	14.5	12.0	63.77
CM Column 6-670	ND	12.0	64.32	CM Column 4-668*	18.4	12.0	63.96
CM Column 6-673*	ND	12.0	64.50	CM Column 4-675	17.1	12.0	64.31
CM Column 6-680	ND	12.0	64.83	CM Column 4-684	17.0	12.0	65.20
CM Column 6-689	ND	12.0	65.61	CM Column 4-709	15.3	12.0	67.69
CM Column 6-714	ND	12.0	68.08	CM Column 4-749	15.9	12.0	71.62
CM Column 6-754	ND	12.0	72.05	CM Column 4-768	16.1	12.0	73.50
CM Column 6-773	ND	12.0	73.96	CM Column 4-771*	17.4	12.0	73.67
CM Column 6-776*	ND	12.0	74.13	CM Column 4-777	16.6	12.0	74.11
CM Column 6-782	ND	12.0	74.59	CM Column 4-788	16.1	12.0	75.20
CM Column 6-793	ND	12.0	75.67	CM Column 4-808	15.9	12.0	77.13
CM Column 6-813	ND	12.0	77.64	CM Column 4-838	16.3	12.0	80.09
CM Column 6-843	ND	12.0	80.65	CM Column 4-873	16.4	12.0	83.49
CM Column 6-878	ND	12.0	84.09	CM Column 4-876*	17.8	12.0	83.67
CM Column 6-881*	ND	12.0	84.25	CM Column 4-880	15.0	12.0	83.98
CM Column 6-885	ND	12.0	84.56	CM Column 4-885	16.7	12.0	84.46
CM Column 6-890	ND	12.0	85.04	CM Column 4-919	16.1	12.0	87.77
CM Column 6-924	ND	12.0	88.38	CM Column 4-977	16.4	12.0	93.63
CM Column 6-982	ND	12.0	94.15	CM Column 4-980*	19.2	12.0	93.76
CM Column 6-985*	ND	12.0	94.27				

Magnesium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-343	4860	13.5	31.42	CM Column 2-344	5000	13.5	34.32
CM Column 1-353	5110	13.5	32.38	CM Column 2-354	4970	13.5	35.39
CM Column 1-363	4930	13.5	33.35	CM Column 2-364	4820	13.5	36.46
CM Column 1-383	5220	13.5	34.95	CM Column 2-384	5040	13.5	38.36
CM Column 1-403	5290	13.5	36.79	CM Column 2-404	5660	13.5	40.45
CM Column 1-423	5150	13.5	38.61	CM Column 2-424	5200	13.5	42.54
CM Column 1-443	5240	13.5	40.51	CM Column 2-444	5300	13.5	44.64
CM Column 1-454	6070	13.5	41.52	CM Column 2-456	6050	13.5	45.89
CM Column 1-457*	5660	13.5	41.64	CM Column 2-459*	5350	13.5	46.04
CM Column 1-464	5300	13.5	42.28	CM Column 2-466	5590	13.5	46.74
CM Column 1-480	5230	13.5	43.85	CM Column 2-482	5510	13.5	48.46
CM Column 1-494	5130	13.5	45.21	CM Column 2-496	5180	13.5	49.96
CM Column 1-514	4800	13.5	47.15	CM Column 2-516	4900	13.5	52.11
CM Column 1-534	4930	13.5	49.12	CM Column 2-536	4980	13.5	54.26
CM Column 1-567	4800	13.5	52.34	CM Column 2-569	5020	13.5	57.78
CM Column 1-570*	5170	13.5	52.58	CM Column 2-571*	5260	13.5	57.96
CM Column 1-576	4970	13.5	53.05	CM Column 2-577	5100	13.5	58.41
CM Column 1-584	5120	13.5	54.11	CM Column 2-585	5470	13.5	59.57
CM Column 1-599	4700	13.5	56.12	CM Column 2-600	4940	13.5	61.75
CM Column 1-639	4630	13.5	60.14	CM Column 2-640	4750	13.5	66.02
CM Column 1-673	4560	13.5	63.32	CM Column 2-680*	5360	13.5	69.96
CM Column 1-677*	5450	13.5	63.50	CM Column 2-684	4940	13.5	70.22
CM Column 1-681	4930	13.5	63.74	CM Column 2-702	4900	13.5	72.13
CM Column 1-699	4730	13.5	65.48	CM Column 2-742	5150	13.5	76.03
CM Column 1-739	4980	13.5	69.04	CM Column 2-771	4700	13.5	78.99
CM Column 1-768	4660	13.5	71.75	CM Column 2-783	5040	13.5	79.81
CM Column 1-780	4970	13.5	72.49	CM Column 2-786*	5250	13.5	80.06
CM Column 1-783*	5330	13.5	72.66	CM Column 2-799	5220	13.5	81.24
CM Column 1-788	5200	13.5	72.99	CM Column 2-829	5090	13.5	84.35
CM Column 1-796	5080	13.5	73.73	CM Column 2-856	4820	13.5	87.19
CM Column 1-806	5090	13.5	74.68	CM Column 2-859	5040	13.5	87.50
CM Column 1-826	5100	13.5	76.55	CM Column 2-879	4970	13.5	89.57
CM Column 1-853	4970	13.5	79.11	CM Column 2-891*	5040	13.5	90.58
CM Column 1-856	4980	13.5	79.39	CM Column 2-957	4700	13.5	97.63
CM Column 1-886*	5040	13.5	82.05	CM Column 2-960	5150	13.5	97.94
CM Column 1-889	5010	13.5	82.29	CM Column 2-983	4850	13.5	100.41
CM Column 1-955	4800	13.5	88.66	CM Column 2-1056	4830	13.5	108.20
CM Column 1-958*	5070	13.5	88.94	CM Column 2-1061*	5320	13.5	108.46
CM Column 1-981	5120	13.5	91.20	CM Column 2-1094	5090	13.5	111.98
CM Column 1-1054	4950	13.5	98.33	CM Column 2-1154	4920	13.5	118.37
CM Column 1-1059*	5410	13.5	98.56	CM Column 2-1157*	5090	13.5	118.54
CM Column 1-1092	5110	13.5	101.79	CM Column 2-1250	4870	13.5	128.30
CM Column 1-1152	5000	13.5	107.56	CM Column 2-1351*	4760	13.5	138.25
CM Column 1-1156*	5290	13.5	107.76				
CM Column 1-1249	4950	13.5	116.71				
CM Column 1-1347*	5000	13.5	126.08				

Magnesium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-444	5100	13.5	42.91	CM Column 3-342	5000	13.5	33.03
CM Column 5-455	5130	13.5	43.87	CM Column 3-352	5020	13.5	34.07
CM Column 5-458*	5590	13.5	44.02	CM Column 3-362	4880	13.5	35.13
CM Column 5-465	5470	13.5	44.68	CM Column 3-382	5180	13.5	37.21
CM Column 5-481	5710	13.5	46.23	CM Column 3-402	5240	13.5	39.32
CM Column 5-495	5060	13.5	47.59	CM Column 3-422	5360	13.5	41.43
CM Column 5-515	4920	13.5	49.54	CM Column 3-442	5310	13.5	43.55
CM Column 5-535	4870	13.5	51.15	CM Column 3-453	5860	13.5	44.69
CM Column 5-580*	5030	13.5	55.60	CM Column 3-456*	5280	13.5	44.85
CM Column 5-595	4720	13.5	57.10	CM Column 3-463	5500	13.5	45.54
CM Column 5-615	4800	13.5	59.04	CM Column 3-479	5400	13.5	47.23
CM Column 5-655	4540	13.5	63.12	CM Column 3-493	5150	13.5	48.72
CM Column 5-670	4500	13.5	64.66	CM Column 3-513	4850	13.5	50.78
CM Column 5-673*	5740	13.5	64.76	CM Column 3-533	4960	13.5	52.83
CM Column 5-680	5130	13.5	65.11	CM Column 3-578	5170	13.5	57.25
CM Column 5-689	4890	13.5	66.01	CM Column 3-593	4760	13.5	58.82
CM Column 5-714	4750	13.5	68.47	CM Column 3-613	4790	13.5	60.92
CM Column 5-754	4810	13.5	72.43	CM Column 3-653	4790	13.5	65.15
CM Column 5-773	4640	13.5	74.33	CM Column 3-668	4530	13.5	66.76
CM Column 5-776*	5660	13.5	74.50	CM Column 3-672*	5330	13.5	66.94
CM Column 5-782	5080	13.5	74.96	CM Column 3-679	5340	13.5	67.30
CM Column 5-793	4880	13.5	76.07	CM Column 3-688	5200	13.5	68.24
CM Column 5-813	4860	13.5	78.06	CM Column 3-713	4870	13.5	70.86
CM Column 5-843	4870	13.5	81.08	CM Column 3-753	4880	13.5	75.00
CM Column 5-878	5040	13.5	84.53	CM Column 3-772	4640	13.5	76.99
CM Column 5-881*	5430	13.5	84.67	CM Column 3-775*	5510	13.5	77.23
CM Column 5-885	4780	13.5	85.00	CM Column 3-778	5240	13.5	77.54
CM Column 5-890	5270	13.5	85.48	CM Column 3-789	5000	13.5	78.66
CM Column 5-924	4870	13.5	88.84	CM Column 3-809	4990	13.5	80.73
CM Column 5-982	4780	13.5	94.63	CM Column 3-839	5130	13.5	83.82
CM Column 5-985*	5650	13.5	94.75	CM Column 3-874	4610	13.5	87.40
				CM Column 3-877*	4940	13.5	87.52
				CM Column 3-881	5010	13.5	87.84
				CM Column 3-886	4740	13.5	88.35
				CM Column 3-920	4830	13.5	91.85
				CM Column 3-978	4920	13.5	97.90
				CM Column 3-981*	5260	13.5	97.98

Magnesium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-344	4910	13.5	32.55	CM Column 4-339	5070	13.5	32.09
CM Column 6-354	5210	13.5	33.55	CM Column 4-349	4890	13.5	33.09
CM Column 6-364	4890	13.5	34.53	CM Column 4-359	4960	13.5	34.11
CM Column 6-384	5110	13.5	36.47	CM Column 4-379	5150	13.5	36.12
CM Column 6-404	5040	13.5	38.40	CM Column 4-399	5160	13.5	38.11
CM Column 6-424	5360	13.5	40.33	CM Column 4-419	5270	13.5	40.11
CM Column 6-444	5160	13.5	42.28	CM Column 4-439	5260	13.5	42.12
CM Column 6-455	5050	13.5	43.35	CM Column 4-450	5110	13.5	43.21
CM Column 6-458*	5280	13.5	43.48	CM Column 4-453*	5430	13.5	43.35
CM Column 6-465	5260	13.5	44.15	CM Column 4-460	5540	13.5	43.98
CM Column 6-481	5220	13.5	45.71	CM Column 4-476	5290	13.5	45.53
CM Column 6-495	5170	13.5	47.08	CM Column 4-490	5230	13.5	46.88
CM Column 6-515	4930	13.5	49.02	CM Column 4-510	5060	13.5	48.71
CM Column 6-535	4870	13.5	50.94	CM Column 4-530	4970	13.5	50.66
CM Column 6-569	4940	13.5	54.16	CM Column 4-575	5100	13.5	54.90
CM Column 6-582	4860	13.5	55.43	CM Column 4-590	4800	13.5	56.37
CM Column 6-597	4500	13.5	56.95	CM Column 4-610	4830	13.5	58.32
CM Column 6-617	4640	13.5	58.97	CM Column 4-650	4640	13.5	62.35
CM Column 6-657	4530	13.5	63.04	CM Column 4-664	4560	13.5	63.77
CM Column 6-670	4630	13.5	64.32	CM Column 4-668*	5210	13.5	63.96
CM Column 6-673*	5180	13.5	64.50	CM Column 4-675	5280	13.5	64.31
CM Column 6-680	5090	13.5	64.83	CM Column 4-684	5210	13.5	65.20
CM Column 6-689	4820	13.5	65.61	CM Column 4-709	4710	13.5	67.69
CM Column 6-714	4740	13.5	68.08	CM Column 4-749	4860	13.5	71.62
CM Column 6-754	4870	13.5	72.05	CM Column 4-768	4710	13.5	73.50
CM Column 6-773	4600	13.5	73.96	CM Column 4-771*	5250	13.5	73.67
CM Column 6-776*	5070	13.5	74.13	CM Column 4-777	5190	13.5	74.11
CM Column 6-782	5030	13.5	74.59	CM Column 4-788	5030	13.5	75.20
CM Column 6-793	4670	13.5	75.67	CM Column 4-808	4950	13.5	77.13
CM Column 6-813	4790	13.5	77.64	CM Column 4-838	4940	13.5	80.09
CM Column 6-843	4830	13.5	80.65	CM Column 4-873	4880	13.5	83.49
CM Column 6-878	5000	13.5	84.09	CM Column 4-876*	5110	13.5	83.67
CM Column 6-881*	4980	13.5	84.25	CM Column 4-880	4910	13.5	83.98
CM Column 6-885	5020	13.5	84.56	CM Column 4-885	5180	13.5	84.46
CM Column 6-890	5080	13.5	85.04	CM Column 4-919	4720	13.5	87.77
CM Column 6-924	4790	13.5	88.38	CM Column 4-977	4690	13.5	93.63
CM Column 6-982	4990	13.5	94.15	CM Column 4-980*	5200	13.5	93.76
CM Column 6-985*	5130	13.5	94.27				

Potassium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-343	2610	806	31.42	CM Column 2-344	3190	806	34.32
CM Column 1-353	3320	806	32.38	CM Column 2-354	3420	806	35.39
CM Column 1-363	2350	806	33.35	CM Column 2-364	3150	806	36.46
CM Column 1-383	2740	806	34.95	CM Column 2-384	2110	806	38.36
CM Column 1-403	2790	806	36.79	CM Column 2-404	3360	806	40.45
CM Column 1-423	3490	806	38.61	CM Column 2-424	3300	806	42.54
CM Column 1-443	3580	806	40.51	CM Column 2-444	4630	806	44.64
CM Column 1-454	3900	806	41.52	CM Column 2-456	4090	806	45.89
CM Column 1-457*	4170	806	41.64	CM Column 2-459*	2620	806	46.04
CM Column 1-464	2640	806	42.28	CM Column 2-466	3270	806	46.74
CM Column 1-480	3180	806	43.85	CM Column 2-482	2950	806	48.46
CM Column 1-494	2230	806	45.21	CM Column 2-496	2680	806	49.96
CM Column 1-514	4040	806	47.15	CM Column 2-516	4540	806	52.11
CM Column 1-534	4260	806	49.12	CM Column 2-536	4570	806	54.26
CM Column 1-567	3980	806	52.34	CM Column 2-569	4280	806	57.78
CM Column 1-570*	4350	806	52.58	CM Column 2-571*	5290	806	57.96
CM Column 1-576	4360	806	53.05	CM Column 2-577	4410	806	58.41
CM Column 1-584	4620	806	54.11	CM Column 2-585	4460	806	59.57
CM Column 1-599	4280	806	56.12	CM Column 2-600	4190	806	61.75
CM Column 1-639	4090	806	60.14	CM Column 2-640	4050	806	66.02
CM Column 1-673	4100	806	63.32	CM Column 2-680*	4110	806	69.96
CM Column 1-677*	5190	806	63.50	CM Column 2-684	4200	806	70.22
CM Column 1-681	3700	806	63.74	CM Column 2-702	6230	806	72.13
CM Column 1-699	5440	806	65.48	CM Column 2-742	3790	806	76.03
CM Column 1-739	4210	806	69.04	CM Column 2-771	6180	806	78.99
CM Column 1-768	4030	806	71.75	CM Column 2-783	4210	806	79.81
CM Column 1-780	4220	806	72.49	CM Column 2-786*	4400	806	80.06
CM Column 1-783*	4520	806	72.66	CM Column 2-799	6200	806	81.24
CM Column 1-788	4400	806	72.99	CM Column 2-829	6570	806	84.35
CM Column 1-796	6600	806	73.73	CM Column 2-856	4070	806	87.19
CM Column 1-806	5960	806	74.68	CM Column 2-859	10300	806	87.50
CM Column 1-826	7460	806	76.55	CM Column 2-879	4560	806	89.57
CM Column 1-853	4170	806	79.11	CM Column 2-891*	4270	806	90.58
CM Column 1-856	7890	806	79.39	CM Column 2-957	4860	806	97.63
CM Column 1-886*	6860	806	82.05	CM Column 2-960	4450	806	97.94
CM Column 1-889	4150	806	82.29	CM Column 2-983	4240	806	100.41
CM Column 1-955	4090	806	88.66	CM Column 2-1056	4210	806	108.20
CM Column 1-958*	4300	806	88.94	CM Column 2-1061*	4640	806	108.46
CM Column 1-981	4270	806	91.20	CM Column 2-1094	4550	806	111.98
CM Column 1-1054	4120	806	98.33	CM Column 2-1154	4320	806	118.37
CM Column 1-1059*	4570	806	98.56	CM Column 2-1157*	4380	806	118.54
CM Column 1-1092	4380	806	101.79	CM Column 2-1250	4310	806	128.30
CM Column 1-1152	4350	806	107.56	CM Column 2-1351*	4280	806	138.25
CM Column 1-1156*	4350	806	107.76				
CM Column 1-1249	4100	806	116.71				
CM Column 1-1347*	4200	806	126.08				

Potassium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-444	3220	806	42.91	CM Column 3-342	3690	806	33.03
CM Column 5-455	5180	806	43.87	CM Column 3-352	3420	806	34.07
CM Column 5-458*	2730	806	44.02	CM Column 3-362	3210	806	35.13
CM Column 5-465	3420	806	44.68	CM Column 3-382	4080	806	37.21
CM Column 5-481	3070	806	46.23	CM Column 3-402	3280	806	39.32
CM Column 5-495	3020	806	47.59	CM Column 3-422	3720	806	41.43
CM Column 5-515	4060	806	49.54	CM Column 3-442	3430	806	43.55
CM Column 5-535	3940	806	51.15	CM Column 3-453	3490	806	44.69
CM Column 5-580*	4710	806	55.60	CM Column 3-456*	2730	806	44.85
CM Column 5-595	3850	806	57.10	CM Column 3-463	2990	806	45.54
CM Column 5-615	3890	806	59.04	CM Column 3-479	2840	806	47.23
CM Column 5-655	4540	806	63.12	CM Column 3-493	2790	806	48.72
CM Column 5-670	4030	806	64.66	CM Column 3-513	3660	806	50.78
CM Column 5-673*	4630	806	64.76	CM Column 3-533	4160	806	52.83
CM Column 5-680	4270	806	65.11	CM Column 3-578	4810	806	57.25
CM Column 5-689	3870	806	66.01	CM Column 3-593	4050	806	58.82
CM Column 5-714	4260	806	68.47	CM Column 3-613	4130	806	60.92
CM Column 5-754	3970	806	72.43	CM Column 3-653	4000	806	65.15
CM Column 5-773	4130	806	74.33	CM Column 3-668	3820	806	66.76
CM Column 5-776*	4670	806	74.50	CM Column 3-672*	19100	806	66.94
CM Column 5-782	4390	806	74.96	CM Column 3-679	4540	806	67.30
CM Column 5-793	4150	806	76.07	CM Column 3-688	4310	806	68.24
CM Column 5-813	4260	806	78.06	CM Column 3-713	4420	806	70.86
CM Column 5-843	4060	806	81.08	CM Column 3-753	4690	806	75.00
CM Column 5-878	4330	806	84.53	CM Column 3-772	3960	806	76.99
CM Column 5-881*	6280	806	84.67	CM Column 3-775*	4570	806	77.23
CM Column 5-885	4910	806	85.00	CM Column 3-778	4330	806	77.54
CM Column 5-890	5230	806	85.48	CM Column 3-789	4350	806	78.66
CM Column 5-924	3380	806	88.84	CM Column 3-809	6720	806	80.73
CM Column 5-982	4590	806	94.63	CM Column 3-839	5960	806	83.82
CM Column 5-985*	4550	806	94.75	CM Column 3-874	23700	806	87.40
				CM Column 3-877*	4960	806	87.52
				CM Column 3-881	6290	806	87.84
				CM Column 3-886	4560	806	88.35
				CM Column 3-920	4190	806	91.85
				CM Column 3-978	4010	806	97.90
				CM Column 3-981*	4410	806	97.98

Potassium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-344	2830	806	32.55	CM Column 4-339	4100	806	32.09
CM Column 6-354	3290	806	33.55	CM Column 4-349	3250	806	33.09
CM Column 6-364	2710	806	34.53	CM Column 4-359	2490	806	34.11
CM Column 6-384	3230	806	36.47	CM Column 4-379	3590	806	36.12
CM Column 6-404	3030	806	38.40	CM Column 4-399	2780	806	38.11
CM Column 6-424	3030	806	40.33	CM Column 4-419	3500	806	40.11
CM Column 6-444	2720	806	42.28	CM Column 4-439	3670	806	42.12
CM Column 6-455	5970	806	43.35	CM Column 4-450	4830	806	43.21
CM Column 6-458*	2880	806	43.48	CM Column 4-453*	3100	806	43.35
CM Column 6-465	2610	806	44.15	CM Column 4-460	2700	806	43.98
CM Column 6-481	2660	806	45.71	CM Column 4-476	2930	806	45.53
CM Column 6-495	2520	806	47.08	CM Column 4-490	3010	806	46.88
CM Column 6-515	4520	806	49.02	CM Column 4-510	4300	806	48.71
CM Column 6-535	4600	806	50.94	CM Column 4-530	4350	806	50.66
CM Column 6-569	3580	806	54.16	CM Column 4-575	4590	806	54.90
CM Column 6-582	4360	806	55.43	CM Column 4-590	3860	806	56.37
CM Column 6-597	3890	806	56.95	CM Column 4-610	4650	806	58.32
CM Column 6-617	3780	806	58.97	CM Column 4-650	4060	806	62.35
CM Column 6-657	4130	806	63.04	CM Column 4-664	4000	806	63.77
CM Column 6-670	3770	806	64.32	CM Column 4-668*	4120	806	63.96
CM Column 6-673*	4540	806	64.50	CM Column 4-675	4450	806	64.31
CM Column 6-680	8190	806	64.83	CM Column 4-684	4390	806	65.20
CM Column 6-689	4360	806	65.61	CM Column 4-709	4470	806	67.69
CM Column 6-714	4360	806	68.08	CM Column 4-749	4240	806	71.62
CM Column 6-754	4000	806	72.05	CM Column 4-768	4170	806	73.50
CM Column 6-773	4040	806	73.96	CM Column 4-771*	4190	806	73.67
CM Column 6-776*	4310	806	74.13	CM Column 4-777	4220	806	74.11
CM Column 6-782	4250	806	74.59	CM Column 4-788	3980	806	75.20
CM Column 6-793	4050	806	75.67	CM Column 4-808	4220	806	77.13
CM Column 6-813	4170	806	77.64	CM Column 4-838	4040	806	80.09
CM Column 6-843	4070	806	80.65	CM Column 4-873	4070	806	83.49
CM Column 6-878	4180	806	84.09	CM Column 4-876*	4060	806	83.67
CM Column 6-881*	5120	806	84.25	CM Column 4-880	5850	806	83.98
CM Column 6-885	6100	806	84.56	CM Column 4-885	5150	806	84.46
CM Column 6-890	5310	806	85.04	CM Column 4-919	4090	806	87.77
CM Column 6-924	3780	806	88.38	CM Column 4-977	3990	806	93.63
CM Column 6-982	4540	806	94.15	CM Column 4-980*	4350	806	93.76
CM Column 6-985*	4140	806	94.27				

Silicon							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-343	8110	274	31.42	CM Column 2-344	1240	274	34.32
CM Column 1-353	7900	274	32.38	CM Column 2-354	1200	274	35.39
CM Column 1-363	7580	274	33.35	CM Column 2-364	1180	274	36.46
CM Column 1-383	8140	274	34.95	CM Column 2-384	1220	274	38.36
CM Column 1-403	7910	274	36.79	CM Column 2-404	1330	274	40.45
CM Column 1-423	7880	274	38.61	CM Column 2-424	1230	274	42.54
CM Column 1-443	8260	274	40.51	CM Column 2-444	1280	274	44.64
CM Column 1-454	9660	274	41.52	CM Column 2-456	1420	274	45.89
CM Column 1-457*	9410	274	41.64	CM Column 2-459*	1400	274	46.04
CM Column 1-464	9150	274	42.28	CM Column 2-466	1420	274	46.74
CM Column 1-480	9070	274	43.85	CM Column 2-482	1410	274	48.46
CM Column 1-494	8870	274	45.21	CM Column 2-496	1390	274	49.96
CM Column 1-514	8270	274	47.15	CM Column 2-516	1270	274	52.11
CM Column 1-534	8490	274	49.12	CM Column 2-536	1310	274	54.26
CM Column 1-567	8100	274	52.34	CM Column 2-569	1320	274	57.78
CM Column 1-570*	8970	274	52.58	CM Column 2-571*	1380	274	57.96
CM Column 1-576	8770	274	53.05	CM Column 2-577	1310	274	58.41
CM Column 1-584	9150	274	54.11	CM Column 2-585	1460	274	59.57
CM Column 1-599	8480	274	56.12	CM Column 2-600	1350	274	61.75
CM Column 1-639	8190	274	60.14	CM Column 2-640	1300	274	66.02
CM Column 1-673	8010	274	63.32	CM Column 2-680*	1640	274	69.96
CM Column 1-677*	9560	274	63.50	CM Column 2-684	1490	274	70.22
CM Column 1-681	8860	274	63.74	CM Column 2-702	1470	274	72.13
CM Column 1-699	8640	274	65.48	CM Column 2-742	1660	274	76.03
CM Column 1-739	8670	274	69.04	CM Column 2-771	1520	274	78.99
CM Column 1-768	7920	274	71.75	CM Column 2-783	1650	274	79.81
CM Column 1-780	7900	274	72.49	CM Column 2-786*	1670	274	80.06
CM Column 1-783*	8600	274	72.66	CM Column 2-799	1630	274	81.24
CM Column 1-788	8480	274	72.99	CM Column 2-829	1750	274	84.35
CM Column 1-796	8210	274	73.73	CM Column 2-856	1730	274	87.19
CM Column 1-806	8180	274	74.68	CM Column 2-859	1800	274	87.50
CM Column 1-826	8050	274	76.55	CM Column 2-879	1870	274	89.57
CM Column 1-853	7760	274	79.11	CM Column 2-891*	1730	274	90.58
CM Column 1-856	8200	274	79.39	CM Column 2-957	1870	274	97.63
CM Column 1-886*	8290	274	82.05	CM Column 2-960	1980	274	97.94
CM Column 1-889	8410	274	82.29	CM Column 2-983	1960	274	100.41
CM Column 1-955	7710	274	88.66	CM Column 2-1056	2190	274	108.20
CM Column 1-958*	7470	274	88.94	CM Column 2-1061*	2210	274	108.46
CM Column 1-981	7510	274	91.20	CM Column 2-1094	2340	274	111.98
CM Column 1-1054	7100	274	98.33	CM Column 2-1154	2480	274	118.37
CM Column 1-1059*	7910	274	98.56	CM Column 2-1157*	2400	274	118.54
CM Column 1-1092	7510	274	101.79	CM Column 2-1250	2740	274	128.30
CM Column 1-1152	7240	274	107.56	CM Column 2-1351*	2970	274	138.25
CM Column 1-1156*	7520	274	107.76				
CM Column 1-1249	7080	274	116.71				
CM Column 1-1347*	7060	274	126.08				

Silicon							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-444	7650	274	42.91	CM Column 3-342	1310	274	33.03
CM Column 5-455	7880	274	43.87	CM Column 3-352	1270	274	34.07
CM Column 5-458*	8960	274	44.02	CM Column 3-362	1210	274	35.13
CM Column 5-465	9200	274	44.68	CM Column 3-382	1300	274	37.21
CM Column 5-481	9710	274	46.23	CM Column 3-402	1320	274	39.32
CM Column 5-495	8580	274	47.59	CM Column 3-422	1380	274	41.43
CM Column 5-515	8500	274	49.54	CM Column 3-442	1380	274	43.55
CM Column 5-535	8280	274	51.15	CM Column 3-453	1510	274	44.69
CM Column 5-580*	8660	274	55.60	CM Column 3-456*	1470	274	44.85
CM Column 5-595	8640	274	57.10	CM Column 3-463	1500	274	45.54
CM Column 5-615	8670	274	59.04	CM Column 3-479	1500	274	47.23
CM Column 5-655	7700	274	63.12	CM Column 3-493	1500	274	48.72
CM Column 5-670	7510	274	64.66	CM Column 3-513	1380	274	50.78
CM Column 5-673*	9730	274	64.76	CM Column 3-533	1440	274	52.83
CM Column 5-680	9230	274	65.11	CM Column 3-578	1480	274	57.25
CM Column 5-689	8850	274	66.01	CM Column 3-593	1410	274	58.82
CM Column 5-714	8400	274	68.47	CM Column 3-613	1470	274	60.92
CM Column 5-754	8310	274	72.43	CM Column 3-653	1510	274	65.15
CM Column 5-773	7730	274	74.33	CM Column 3-668	1430	274	66.76
CM Column 5-776*	8760	274	74.50	CM Column 3-672*	1640	274	66.94
CM Column 5-782	8370	274	74.96	CM Column 3-679	1670	274	67.30
CM Column 5-793	8020	274	76.07	CM Column 3-688	1760	274	68.24
CM Column 5-813	8030	274	78.06	CM Column 3-713	1720	274	70.86
CM Column 5-843	7650	274	81.08	CM Column 3-753	1760	274	75.00
CM Column 5-878	7740	274	84.53	CM Column 3-772	1740	274	76.99
CM Column 5-881*	8450	274	84.67	CM Column 3-775*	1870	274	77.23
CM Column 5-885	7740	274	85.00	CM Column 3-778	1750	274	77.54
CM Column 5-890	8240	274	85.48	CM Column 3-789	1750	274	78.66
CM Column 5-924	7870	274	88.84	CM Column 3-809	1840	274	80.73
CM Column 5-982	7410	274	94.63	CM Column 3-839	1860	274	83.82
CM Column 5-985*	7770	274	94.75	CM Column 3-874	1750	274	87.40
				CM Column 3-877*	1760	274	87.52
				CM Column 3-881	1850	274	87.84
				CM Column 3-886	1880	274	88.35
				CM Column 3-920	1940	274	91.85
				CM Column 3-978	2130	274	97.90
				CM Column 3-981*	2010	274	97.98

Silicon							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-344	7780	274	32.55	CM Column 4-339	1300	274	32.09
CM Column 6-354	7610	274	33.55	CM Column 4-349	1250	274	33.09
CM Column 6-364	7000	274	34.53	CM Column 4-359	1250	274	34.11
CM Column 6-384	7050	274	36.47	CM Column 4-379	1290	274	36.12
CM Column 6-404	6960	274	38.40	CM Column 4-399	1290	274	38.11
CM Column 6-424	7720	274	40.33	CM Column 4-419	1320	274	40.11
CM Column 6-444	7740	274	42.28	CM Column 4-439	1320	274	42.12
CM Column 6-455	7580	274	43.35	CM Column 4-450	1300	274	43.21
CM Column 6-458*	8970	274	43.48	CM Column 4-453*	1480	274	43.35
CM Column 6-465	8920	274	44.15	CM Column 4-460	1560	274	43.98
CM Column 6-481	9000	274	45.71	CM Column 4-476	1500	274	45.53
CM Column 6-495	8820	274	47.08	CM Column 4-490	1500	274	46.88
CM Column 6-515	8410	274	49.02	CM Column 4-510	1400	274	48.71
CM Column 6-535	8220	274	50.94	CM Column 4-530	1380	274	50.66
CM Column 6-569	8430	274	54.16	CM Column 4-575	1420	274	54.90
CM Column 6-582	8260	274	55.43	CM Column 4-590	1390	274	56.37
CM Column 6-597	8300	274	56.95	CM Column 4-610	1440	274	58.32
CM Column 6-617	8330	274	58.97	CM Column 4-650	1490	274	62.35
CM Column 6-657	7700	274	63.04	CM Column 4-664	1450	274	63.77
CM Column 6-670	7880	274	64.32	CM Column 4-668*	1650	274	63.96
CM Column 6-673*	9390	274	64.50	CM Column 4-675	1660	274	64.31
CM Column 6-680	9190	274	64.83	CM Column 4-684	1660	274	65.20
CM Column 6-689	8960	274	65.61	CM Column 4-709	1610	274	67.69
CM Column 6-714	8260	274	68.08	CM Column 4-749	1740	274	71.62
CM Column 6-754	8420	274	72.05	CM Column 4-768	1740	274	73.50
CM Column 6-773	7670	274	73.96	CM Column 4-771*	1680	274	73.67
CM Column 6-776*	8210	274	74.13	CM Column 4-777	1650	274	74.11
CM Column 6-782	8150	274	74.59	CM Column 4-788	1650	274	75.20
CM Column 6-793	7560	274	75.67	CM Column 4-808	1740	274	77.13
CM Column 6-813	7940	274	77.64	CM Column 4-838	1820	274	80.09
CM Column 6-843	7520	274	80.65	CM Column 4-873	1880	274	83.49
CM Column 6-878	7630	274	84.09	CM Column 4-876*	1820	274	83.67
CM Column 6-881*	7990	274	84.25	CM Column 4-880	1700	274	83.98
CM Column 6-885	8110	274	84.56	CM Column 4-885	1830	274	84.46
CM Column 6-890	8140	274	85.04	CM Column 4-919	1890	274	87.77
CM Column 6-924	7610	274	88.38	CM Column 4-977	1960	274	93.63
CM Column 6-982	7790	274	94.15	CM Column 4-980*	1910	274	93.76
CM Column 6-985*	7450	274	94.27				

Sodium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 1-343	5610	223	31.42	CM Column 2-344	5640	223	34.32
CM Column 1-353	5800	223	32.38	CM Column 2-354	5400	223	35.39
CM Column 1-363	5510	223	33.35	CM Column 2-364	5540	223	36.46
CM Column 1-383	5710	223	34.95	CM Column 2-384	5610	223	38.36
CM Column 1-403	5880	223	36.79	CM Column 2-404	5530	223	40.45
CM Column 1-423	5620	223	38.61	CM Column 2-424	5540	223	42.54
CM Column 1-443	5730	223	40.51	CM Column 2-444	5720	223	44.64
CM Column 1-454	6660	223	41.52	CM Column 2-456	6520	223	45.89
CM Column 1-457*	5990	223	41.64	CM Column 2-459*	5620	223	46.04
CM Column 1-464	5700	223	42.28	CM Column 2-466	5790	223	46.74
CM Column 1-480	5660	223	43.85	CM Column 2-482	5840	223	48.46
CM Column 1-494	5220	223	45.21	CM Column 2-496	5420	223	49.96
CM Column 1-514	5610	223	47.15	CM Column 2-516	5660	223	52.11
CM Column 1-534	5590	223	49.12	CM Column 2-536	5560	223	54.26
CM Column 1-567	5480	223	52.34	CM Column 2-569	5750	223	57.78
CM Column 1-570*	5700	223	52.58	CM Column 2-571*	5830	223	57.96
CM Column 1-576	5500	223	53.05	CM Column 2-577	5650	223	58.41
CM Column 1-584	5810	223	54.11	CM Column 2-585	6610	223	59.57
CM Column 1-599	5640	223	56.12	CM Column 2-600	5630	223	61.75
CM Column 1-639	5460	223	60.14	CM Column 2-640	5400	223	66.02
CM Column 1-673	5370	223	63.32	CM Column 2-680*	5580	223	69.96
CM Column 1-677*	5640	223	63.50	CM Column 2-684	5490	223	70.22
CM Column 1-681	5120	223	63.74	CM Column 2-702	5200	223	72.13
CM Column 1-699	5230	223	65.48	CM Column 2-742	5130	223	76.03
CM Column 1-739	5560	223	69.04	CM Column 2-771	5250	223	78.99
CM Column 1-768	5230	223	71.75	CM Column 2-783	6010	223	79.81
CM Column 1-780	5990	223	72.49	CM Column 2-786*	6170	223	80.06
CM Column 1-783*	6240	223	72.66	CM Column 2-799	6100	223	81.24
CM Column 1-788	6260	223	72.99	CM Column 2-829	6180	223	84.35
CM Column 1-796	6020	223	73.73	CM Column 2-856	6060	223	87.19
CM Column 1-806	6140	223	74.68	CM Column 2-859	5890	223	87.50
CM Column 1-826	6090	223	76.55	CM Column 2-879	5790	223	89.57
CM Column 1-853	6040	223	79.11	CM Column 2-891*	5630	223	90.58
CM Column 1-856	5720	223	79.39	CM Column 2-957	5480	223	97.63
CM Column 1-886*	5600	223	82.05	CM Column 2-960	5910	223	97.94
CM Column 1-889	5740	223	82.29	CM Column 2-983	5670	223	100.41
CM Column 1-955	5520	223	88.66	CM Column 2-1056	5690	223	108.20
CM Column 1-958*	5930	223	88.94	CM Column 2-1061*	6160	223	108.46
CM Column 1-981	5880	223	91.20	CM Column 2-1094	6010	223	111.98
CM Column 1-1054	5780	223	98.33	CM Column 2-1154	5840	223	118.37
CM Column 1-1059*	6210	223	98.56	CM Column 2-1157*	6070	223	118.54
CM Column 1-1092	5920	223	101.79	CM Column 2-1250	5980	223	128.30
CM Column 1-1152	5890	223	107.56	CM Column 2-1351*	6070	223	138.25
CM Column 1-1156*	6030	223	107.76				
CM Column 1-1249	5700	223	116.71				
CM Column 1-1347*	5920	223	126.08				

Sodium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 5-444	5580	223	42.91	CM Column 3-342	5850	223	33.03
CM Column 5-455	5640	223	43.87	CM Column 3-352	5630	223	34.07
CM Column 5-458*	5680	223	44.02	CM Column 3-362	5510	223	35.13
CM Column 5-465	5760	223	44.68	CM Column 3-382	5810	223	37.21
CM Column 5-481	5730	223	46.23	CM Column 3-402	5630	223	39.32
CM Column 5-495	5480	223	47.59	CM Column 3-422	5890	223	41.43
CM Column 5-515	5300	223	49.54	CM Column 3-442	5790	223	43.55
CM Column 5-535	5510	223	51.15	CM Column 3-453	6400	223	44.69
CM Column 5-580*	5590	223	55.60	CM Column 3-456*	5650	223	44.85
CM Column 5-595	5480	223	57.10	CM Column 3-463	5670	223	45.54
CM Column 5-615	5500	223	59.04	CM Column 3-479	5620	223	47.23
CM Column 5-655	5570	223	63.12	CM Column 3-493	5410	223	48.72
CM Column 5-670	5530	223	64.66	CM Column 3-513	5270	223	50.78
CM Column 5-673*	5740	223	64.76	CM Column 3-533	5360	223	52.83
CM Column 5-680	5730	223	65.11	CM Column 3-578	5750	223	57.25
CM Column 5-689	5500	223	66.01	CM Column 3-593	5400	223	58.82
CM Column 5-714	5500	223	68.47	CM Column 3-613	5400	223	60.92
CM Column 5-754	5470	223	72.43	CM Column 3-653	5570	223	65.15
CM Column 5-773	5230	223	74.33	CM Column 3-668	5490	223	66.76
CM Column 5-776*	6520	223	74.50	CM Column 3-672*	5850	223	66.94
CM Column 5-782	6140	223	74.96	CM Column 3-679	5750	223	67.30
CM Column 5-793	5920	223	76.07	CM Column 3-688	5380	223	68.24
CM Column 5-813	6080	223	78.06	CM Column 3-713	5550	223	70.86
CM Column 5-843	5760	223	81.08	CM Column 3-753	5470	223	75.00
CM Column 5-878	6140	223	84.53	CM Column 3-772	5390	223	76.99
CM Column 5-881*	6050	223	84.67	CM Column 3-775*	6600	223	77.23
CM Column 5-885	5530	223	85.00	CM Column 3-778	6230	223	77.54
CM Column 5-890	5930	223	85.48	CM Column 3-789	5980	223	78.66
CM Column 5-924	5580	223	88.84	CM Column 3-809	6130	223	80.73
CM Column 5-982	5640	223	94.63	CM Column 3-839	5900	223	83.82
CM Column 5-985*	6120	223	94.75	CM Column 3-874	6310	223	87.40
				CM Column 3-877*	5950	223	87.52
				CM Column 3-881	5880	223	87.84
				CM Column 3-886	5550	223	88.35
				CM Column 3-920	6020	223	91.85
				CM Column 3-978	5750	223	97.90
				CM Column 3-981*	6000	223	97.98

Sodium							
Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume	Sample Name	Results(µg/L)	EQL(µg/L)	Pore Volume
CM Column 6-344	5670	223	32.55	CM Column 4-339	5780	223	32.09
CM Column 6-354	5820	223	33.55	CM Column 4-349	5600	223	33.09
CM Column 6-364	5450	223	34.53	CM Column 4-359	5590	223	34.11
CM Column 6-384	5580	223	36.47	CM Column 4-379	5700	223	36.12
CM Column 6-404	5460	223	38.40	CM Column 4-399	5550	223	38.11
CM Column 6-424	5850	223	40.33	CM Column 4-419	5800	223	40.11
CM Column 6-444	5680	223	42.28	CM Column 4-439	5660	223	42.12
CM Column 6-455	5500	223	43.35	CM Column 4-450	5550	223	43.21
CM Column 6-458*	5610	223	43.48	CM Column 4-453*	5740	223	43.35
CM Column 6-465	5630	223	44.15	CM Column 4-460	5770	223	43.98
CM Column 6-481	5650	223	45.71	CM Column 4-476	5590	223	45.53
CM Column 6-495	5390	223	47.08	CM Column 4-490	5470	223	46.88
CM Column 6-515	5610	223	49.02	CM Column 4-510	5750	223	48.71
CM Column 6-535	5560	223	50.94	CM Column 4-530	5680	223	50.66
CM Column 6-569	5540	223	54.16	CM Column 4-575	5800	223	54.90
CM Column 6-582	5610	223	55.43	CM Column 4-590	5400	223	56.37
CM Column 6-597	5210	223	56.95	CM Column 4-610	5470	223	58.32
CM Column 6-617	5370	223	58.97	CM Column 4-650	5500	223	62.35
CM Column 6-657	5510	223	63.04	CM Column 4-664	5380	223	63.77
CM Column 6-670	5210	223	64.32	CM Column 4-668*	5620	223	63.96
CM Column 6-673*	5830	223	64.50	CM Column 4-675	5590	223	64.31
CM Column 6-680	5760	223	64.83	CM Column 4-684	5530	223	65.20
CM Column 6-689	5860	223	65.61	CM Column 4-709	5300	223	67.69
CM Column 6-714	5330	223	68.08	CM Column 4-749	5340	223	71.62
CM Column 6-754	5570	223	72.05	CM Column 4-768	4980	223	73.50
CM Column 6-773	7060	223	73.96	CM Column 4-771*	6170	223	73.67
CM Column 6-776*	6110	223	74.13	CM Column 4-777	6160	223	74.11
CM Column 6-782	6020	223	74.59	CM Column 4-788	5890	223	75.20
CM Column 6-793	5760	223	75.67	CM Column 4-808	5970	223	77.13
CM Column 6-813	5800	223	77.64	CM Column 4-838	5910	223	80.09
CM Column 6-843	5830	223	80.65	CM Column 4-873	5820	223	83.49
CM Column 6-878	5940	223	84.09	CM Column 4-876*	5620	223	83.67
CM Column 6-881*	5780	223	84.25	CM Column 4-880	5860	223	83.98
CM Column 6-885	5890	223	84.56	CM Column 4-885	6020	223	84.46
CM Column 6-890	6070	223	85.04	CM Column 4-919	5500	223	87.77
CM Column 6-924	5610	223	88.38	CM Column 4-977	5490	223	93.63
CM Column 6-982	5810	223	94.15	CM Column 4-980*	5990	223	93.76
CM Column 6-985*	5810	223	94.27				

Appendix C

Additional Experiment Photographs

Appendix C

Additional Experiment Photographs

The sediment materials removed from the columns 3, 4, 5, and 6 at the end of the leaching experiments.

Column 3 and 4 (ferrihydrite amended sediment).

Column 5 and 6 (no ferrihydrite added in the sediment).

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