



**Pacific Gas and
Electric Company®**

Yvonne J. Meeks
Site Remediation - Portfolio Manager
Environmental Affairs

6588 Ontario Road
San Luis Obispo, CA 93405

Mailing Address
4325 South Higuera Street
San Luis Obispo, CA 93401

805.546.5243
Internal: 664.5243
Fax: 805.546.5232
Internet: YJM1@pge.com

May 20, 2005

Mr. Norman Shopay
Project Manager/Senior Engineering Geologist
California Department of Toxic Substances Control
Permitting and Corrective Action Branch
700 Heinz Avenue, Suite 200
Berkeley, California 94710-2721

Subject: Aerobic Core Testing Results,
PG&E Topock Compressor Station, Needles, California

Dear Mr. Shopay:

This letter transmits the results of laboratory testing of anaerobic core sections collected at the PG&E Topock site. The aerobic testing was performed in conformance with the technical memorandum "Hexavalent Chromium (Aerobic) Zone Core Testing, PG&E Topock Compressor Station, Needles, California," dated June 7, 2004.

If you have any questions, please do not hesitate to call me.

Sincerely,

Enclosure

cc: Karen Baker/DTSC
Aaron Yue/DTSC
Alfredo Zanolio/DTSC
Kate Burger/DTSC

Summary of Results – Aerobic Zone Hexavalent Chromium Core Testing, PG&E Topock Compressor Station, Needles, California

DATE: May 20, 2005

Introduction and Purpose

This technical memorandum summarizes results of tests conducted on aerobic drill core sections collected from the Pacific Gas and Electric Company Topock Compressor Station (the Site), located near Needles, California. The aerobic core test program was implemented as described in the technical memorandum *Hexavalent Chromium (Aerobic) Zone Core Testing, PG&E Topock Compressor Station, Needles, California (Aerobic Core Testing Work Plan)*, submitted to the Department of Toxic Substances Control on June 7, 2004. The aerobic core test program evaluated interactions between hexavalent chromium [Cr(VI)] in groundwater and solids in the aerobic zones of the aquifer west of the Colorado River, northeast from the compressor station. The results provided herein include tabulated data from laboratory testing and preliminary interpretation of the data.

The purpose of the aerobic core test program was to investigate potential interactions between Cr(VI) in pore water and aquifer formation solids in shallow fluvial sediments. The primary interaction was expected to be adsorptive uptake of Cr(VI) onto the surfaces of the formation solids, with no indication of chemical (or biochemical) reduction and immobilization as trivalent chromium [Cr(III)]. The core testing program was designed to provide direct evidence to ascertain whether these interactions are occurring. Specific objectives for the aerobic core testing included the following:

1. Characterize the physical and functional (chemical) properties of the solids.
 - Grain size distribution
 - Moisture content (pore water)
 - Cr(VI) concentration in the pore water
 - Total organic carbon (TOC) content
 - Dithionite-citrate-bicarbonate (DCB) test for metal oxide content
2. Estimate the mass of Cr(VI) that is bound to the formation material per unit mass of formation solids at various depths below the water table
3. Estimate how strongly Cr(III) and Cr(VI) are bound to the formation material.

Selected Cores

During spring 2004, core sections were collected during drilling for monitoring well (MW) MW-39 located in the aquifer west of the Colorado River. The location of MW-39 is shown

on Figure 1. Core sections were collected at 10-foot intervals, and sections from below the water table were tested. The following core sections were selected for testing:

- A shallow core section, from 38 to 48 feet below ground surface (bgs);
- A core section at mid-depth between the water table surface and bedrock, from 58 to 68 feet bgs; and
- A core section just above bedrock, from 88 to 98 feet bgs.

Core sections were field-identified as aerobic from observations by the field geologist and preliminary characterization tests such as the oxidation-reduction potential (ORP) and dissolved oxygen concentration of groundwater samples from similar depths following well completion at the MW-39 cluster. Field parameters and preliminary laboratory tests used to identify aerobic core sections are summarized in Table 1. The MW-39@40' core, collected between 38 and 48 feet bgs, represents a depth interval in between two of the completed wells: MW-39-40 (30-40 feet) and MW-39-50 (47-52 feet). Samples from MW-39-50 showed aerobic conditions similar to deeper wells in the cluster (see Table 1), whereas MW-39-40 samples have demonstrated markedly more reducing conditions, with ORP in the -200 mV range with no detectable Cr(VI). The MW-39@40' core therefore represents a transitional interval with unknown redox conditions at the commencement of laboratory work.

Oxidation-reduction potential (ORP) measurements provide only rough indications of redox conditions in the groundwater sampling interval. Eh values, commonly cited in texts and journals, are approximately 220 mV greater than the ORP readings collected in the field with silver-silver chloride electrodes. An ORP value of -20 mV therefore corresponds to an Eh of +200 mV. In addition, ORP meter response varies with the redox characteristics of the groundwater system. At the Topock site, detectable Cr(VI) generally corresponds to ORP values greater (i.e. less negative) than about -150 mV. Consequently, only strongly negative ORP values correlate with conditions favoring the reduction of Cr(VI) to Cr(III). The ORP values listed in Table 1 are consistent with the persistence of Cr(VI) and are considered "aerobic" in this sense.

TABLE 1
Information used to Identify Core Sections for Aerobic Core Tests

Core Name	Core Depth Interval (feet BGS)	Well ID	MW Screen Interval (feet BGS)	ORP (mV)	pH	TDS (mg/L)	Conductivity (µS/cm)	Cr(VI) (µg/L)
MW-39@40'	38-48							
MW-39@60'	58-68	MW-39-70	60-70	230	7.2	5,670	8,440	5,900
MW-39@90'	88-98	MW-39-100	80-100	-2	7.9	9,810	16,200	10,300

Notes:

Groundwater sample data were collected in May 2004.

µS/cm = microSiemens per centimeter

bgs = below ground surface

ORP = Oxidation-Reduction Potential, in mV (millivolts) TDS = total dissolved solids, in mg/L (milligrams per liter)

TABLE 1
Information used to Identify Core Sections for Aerobic Core Tests

Core Name	Core Depth Interval (feet BGS)	Well ID	MW Screen Interval (feet BGS)	ORP (mV)	pH	TDS (mg/L)	Conductivity (µS/cm)	Cr(VI) (µg/L)
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No equivalent well screen interval was available for the MW-39@40' core.

Work Performed

The three core sections from MW-39 were sent to CH2M HILL's Applied Sciences Laboratory in Corvallis, Oregon, for characterization and testing consistent with the Aerobic Core Testing Work Plan. The selected cores were analyzed following the procedures described in Attachment A.

Four main testing programs were performed:

- Characterization of the physical and functional (chemical) properties of the cores, by testing for grain size distribution, moisture content (pore water), Cr(VI) concentration in the pore water, total organic carbon (TOC) content, and metal oxide content (dithionite-citrate-bicarbonate test).
- Four-step deionized water extraction through successive washing of formation solids with deionized water, followed by agitation and centrifugation, and analysis of rinses for Cr(VI), aluminum, iron, manganese, and total chromium.
- Sequential batch extraction testing to estimate how strongly chromium and other metals are bound to the aerobic formation solids. A six-step process was followed in which the core samples were subjected to a progressively more aggressive extraction solution. Following each extraction step, the liquid fraction was analyzed for total chromium, iron, manganese, and aluminum.
- Two-step phosphate extraction following the deionized water extraction testing to measure the quantity and binding strength of adsorbed Cr(VI) and to provide correlations between adsorbed Cr(VI) and extractable metals. This test was performed by adding extraction solution to a pre-weighed core sample, followed by agitation and centrifugation. Following extraction, the liquid fraction was analyzed for Cr(VI), total chromium, aluminum, iron, and manganese.

Summary of Results

Detailed results and interpretations, including answers to key questions from the Aerobic Core Testing Work Plan, are provided in Attachment B. This section consolidates the key findings.

Physical and Functional Properties

- The sample from 90 feet bgs was classified as silty gravel in the field, and the other two samples were described as sands. The grain size classification for this study only classified coarseness of sand in the samples, with the smallest sieve being 0.25 mm, a fine sand size. Half of the sample from 40 feet bgs passed through the 0.25 mm sieve, making this the least coarse-grained of the three.
- The moisture contents of the core sections ranged from 11.6 to 21.9 percent; the entrained moisture contained Cr(VI) in the intermediate and deep cores but not in the shallowest core. Moisture content and selected additional physical or functional properties of the core samples are summarized in Table 2. The absence of Cr(VI) in the shallow core section coincided with the highest total organic carbon content of the three sections that were tested. The presence of organic carbon would support microbial communities that produce a more reducing environment, resulting in the removal of Cr(VI) from solution. Subsequent to this testing, well MW-39-40 has never shown detectable Cr(VI) or nitrate, indicating that more reducing conditions prevail at this depth (32 to 42 feet bgs). Though the core depth interval was 38 to 48 feet, it appears that its characteristics are more similar to the more reducing conditions of well MW-39-40 than the more oxidizing conditions of well MW-34-50.

TABLE 2
Physical and Functional Properties of Core Samples

Sample ID	Moisture Content (% by mass)	Cr(VI) content ($\mu\text{g}/\text{kg}$ dry)	Total Organic Carbon (mg/kg dry)
MW-39@40'	21.9	<0.07	1,117.8
MW-39@60'	12.6	51.1	<114
MW-39@60' dup	12.6	57.1	<103
MW-39@90'	11.6	6.6	<102

Notes:

$\mu\text{g}/\text{kg}$ = micrograms per kilogram

mg/kg dry = milligrams per kilogram on a dry weight basis

dup = duplicate sample

< = less than; number shown is detection limit

- The highest observed pore water Cr(VI) concentration measured in the core samples was 455 $\mu\text{g}/\text{L}$, corresponding to 57 $\mu\text{g}/\text{kg}$ of solids, in core sample MW-39@60' (duplicate). In contrast, the concentration of Cr(VI) in the corresponding groundwater sample obtained at this depth was approximately 5,900 $\mu\text{g}/\text{L}$ (see Table 3). A potential explanation for these results is that the pore water represents micropore storage of stagnant groundwater while water collected during groundwater sampling is yielded from the larger macropores. Also, differences in Cr(VI) adsorptive capacity can exist locally at this small scale that may affect aqueous Cr(VI) concentrations. Another explanation is that the groundwater sample represents a much larger sample size than the core sample. Distribution of Cr(VI) is variable within the plume, and the core may represent a local concentration low.

TABLE 3
Cr(VI) Concentrations in Groundwater versus Pore Water from Core Samples

Core Sample ID	Cr(VI) Concentration in Groundwater Samples (µg/L)	Cr(VI) Concentration in Pore Water from Core Samples (µg/L)
MW-39@40'	N/A	<0.34
MW-39@60'	5,900	407
MW-39@60' dup	---	455
MW-39@90'	10,300	57

Notes:

µg/L = micrograms per liter

--- = not analyzed

dup = duplicate sample

< = less than; number shown is detection limit

Extraction Testing

- A four-step serial extraction of intermediate and deep core samples with deionized water removed incremental amounts of Cr(VI), with the largest removal rates occurring in the first step, and subsequent steps removing lower amounts of Cr(VI). After the fourth step, trace amounts of residual Cr(VI) remained in the extract samples (less than 2 µg/L in the extraction water). A subsequent extraction with phosphate buffer removed all the remaining Cr(VI) in a single step, indicating that a small amount of Cr(VI) had been adsorbed onto the surfaces of the core solids.
- The first step in the six-step sequential batch extraction tests, “exchangeable” metals, did not remove detectable concentrations of metals, except for low levels of aluminum and manganese in the shallowest core sample. The next four extraction steps removed substantial masses of manganese and iron, a smaller mass of aluminum, and between 1.5 and 2.3 percent of the total chromium in the core samples.
- Phosphate-extracted Cr(VI) correlated most strongly with manganese in the fourth sequential batch extraction step, and to a lesser extent with manganese in the third step.

Conclusions

Conclusions of the aerobic core testing were as follows:

- The entrained moisture in the intermediate and deep cores contained Cr(VI), but the shallow core did not. The absence of Cr(VI) in the shallow core section coincided with the highest total organic carbon content of the three sections that were tested. The presence of organic carbon is believed to support microbial activity which in turn enhances Cr(VI) removal from groundwater.
- Concentrations of Cr(VI) in entrained moisture of the core samples were one to two orders of magnitude smaller than Cr(VI) concentrations in groundwater samples from corresponding depth intervals. This discrepancy may reflect the difference between the

very localized core sample and a purged groundwater sample, which influences a much greater volume of aquifer material. The results may also reflect the difference between water in micropores (core sample) vs. water in macropores (groundwater sample)

- Results of the four-step serial extraction of Cr(VI) from the intermediate and deep core samples with deionized water and a phosphate buffer solution indicate that some Cr(VI) is adsorbed onto the surfaces of the core solids.
- The small but measurable quantity of exchangeable Cr(VI) in the soil matrix of the aerobic core samples indicates qualitatively that the matrix can adsorb Cr(VI). Variation between Cr(VI) concentrations measured in entrained moisture of the aerobic cores and in corresponding groundwater samples preclude quantitative estimation of soil-bound Cr(VI) based on existing data. Results suggest that partitioning of Cr(VI) between groundwater and aquifer matrix is a function of pore size, with smaller pores associated with greater adsorptive capacity. Results suggest a soil water partition coefficient of less than 0.1 L/g, which is considered very low and supports the common description of Cr(VI) as a weakly adsorbing solute.
- Total chromium [essentially Cr(III)] was not easily extracted during sequential batch extraction unless the extraction solution was acidic or alkaline phosphate buffer was used. This indicates that Cr(III) is essentially immobile in aerobic aquifer formation solids under natural geochemical conditions beneath the Topock site.
- Computed relative percent differences (RPDs) between replicated tests show that the tests are reproducible and can be treated as supportive of the reported conclusions.

Figure



LEGEND

- Core Sample Locations
- Groundwater Monitoring Well
- Groundwater Test, Extraction, Supply Well
- Surface Water Monitoring Location

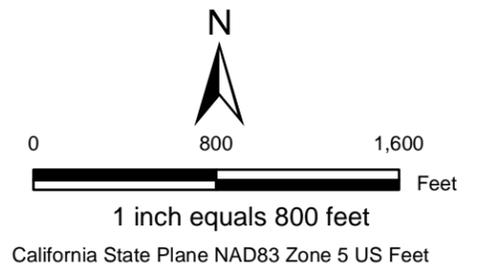


FIGURE 1
AEROBIC ZONE CORE TESTING
 AEROBIC ZONE CORE TESTING
 PG&E TOPOCK COMPRESSOR STATION
 NEEDLES, CALIFORNIA

Attachment A
Aerobic Core Task Descriptions

Aerobic Core Testing Procedures

This attachment presents the procedures used for the aerobic core testing of the selected cores.

Physical and Functional Properties

Initial Sample Preparation, Grain Size Analysis, Total Metals, and TOC

- Three composite 1,000-gram samples were formed from each zone by selecting representative materials from each core section (avoiding moisture loss to the extent possible).
- Each composite sample was homogenized and moisture content determined the by drying a small aliquot at 103 to 107° Celsius in a laboratory oven (including one duplicate moisture analysis). (See Question 5 in Attachment B).
- Total organic carbon (TOC) analyses were performed on dried, homogenized formation material from each zone (including one duplicate analysis). (See Question 3 in Attachment B).
- Performed lithium *metaborate* digestion; dissolved and analyzed for total aluminum, iron, manganese, and chromium. (Including one duplicate analysis). (See Questions 4 and 7 in Attachment B).
- Solids over ~0.25 millimeter (mm) were screened out in each dried aliquot, and each screened fraction weighed. Sieving the samples was difficult because the samples were cohesive and agglomerated during the initial efforts to measure size distribution. To perform the sieve analyses, particles that were obviously larger than the sieve openings were removed manually an weighted before the remaining material was sieved, and then the remaining material was dried and sieved in that form. Grain-size analysis was performed on small aliquot from each size range (≥ 0.25 mm and < 0.25 mm). (See Question 1 in Attachment B).
- Screened sufficient homogenized bulk formation material from each zone to produce 150 grams of the < 0.25 -mm fraction, to be used in tests outlined below. Both screened fractions were preserved in a cold, humid condition to prevent biological growth and dehydration.

After this point, tests were performed only with material with a grain size less than 0.25 mm, which has a high specific surface area.

Extraction Tests

Deionized Water Extraction

Hexavalent Chromium in Pore water

- Weighed out 150 grams (dry basis) (~97 cc) of formation material from each zone, added 30.0 milliliters (mL) of deionized water (assumes 2.2 theoretical mineral density and 30-percent pore volume), and gently mixed for 10 minutes. Centrifuged each sample, removed and measured the volume of the free liquid, and ran ion chromatography scans for Cr(VI). Back-calculated the concentration of Cr(VI) that was present in pore water. Pore water concentration was back-calculated by accounting for the added deionized water. It was assumed that the small amount of deionized water did not extract significant adsorbed Cr(VI). Performed one duplicate analysis. (See Question 2 in Attachment B).

First Deionized Water Extraction

- Working with formation material from the preceding step, added deionized water at a ratio of 3:1 (water weight-to-solids dry weight), and agitated for 10 minutes. Performed one duplicate test and carried it through the entire deionized water and phosphate extraction process.
- Centrifuged and decanted liquid for analysis of Cr(VI) at a target detection of 0.2 micrograms per liter ($\mu\text{g/L}$); aluminum, iron, and manganese each at a target detection of 10 $\mu\text{g/L}$; and total chromium at a target detection of 1 $\mu\text{g/L}$.
- Reanalyzed solids for water content.

Second Deionized Water Extraction

- Working with formation material from the preceding step, added deionized water at a ratio of 3:1 (water weight-to-solids dry weight), and agitated for 10 minutes.
- Centrifuged and decanted liquid for analysis of Cr(VI) to a target detection of 0.2 $\mu\text{g/L}$; aluminum, iron, and manganese each at a target detection of 10 $\mu\text{g/L}$; and total chromium at a target detection of 1 $\mu\text{g/L}$.
- Reanalyzed solids for water content.

Subsequent Deionized Water Extraction

- Working with formation solids from the preceding step, washed each sample three times with deionized water (2:1 weight ratio water-to-solids), centrifuging after each wash cycle, including the final wash; combined the first two rinses; measured the combined volume and analyzed for Cr(VI). Analyzed the third rinse separately to serve as a “zero” baseline for phosphate extractions.
- Split the sample into two approximately equal portions and weighed each. The largest portion was used for sequential extraction tests, and the smaller portion retained for use in DCB extractions and determinations of exchangeable Cr(VI).

- The core samples were washed one more time with deionized water (2:1 weight ratio water-to-solids) and again analyzed for Cr(VI). (See Questions 6 and 9 in Attachment B).

Dithionite/Citrate/Bicarbonate Extraction

- Weighed out 5 grams of each formation material, plus one duplicate (dry-weight basis) and performed DCB extraction.
- Followed the Walkley-Black Method for DCB-extractable iron, aluminum, chromium, and manganese, except used the 0.25 mm screened formation material; without grinding or sieving. The pre-weighed sample of core material was digested with measured volumes of citrate and bicarbonate buffer solutions, heated to ~80 degrees Celsius, dithionite added, and agitated for approximately 15 minutes.
- Following the digestion step, the free liquid was separated and analyzed the extract for aluminum, iron, chromium and manganese. Results are as DCB-extractable aluminum, iron, chromium, and manganese. (See Question 4 in Attachment A).

Sequential Batch Extractions

- Sequential batch extraction included the following extractions. The solids were washed before beginning each successive extraction step. Following extraction, the liquid fraction was analyzed for aluminum, iron, manganese, and chromium (target detection was 10, 10, 10, and 1 µg/L, respectively).
 - **Step 1 - Exchangeable** (sodium acetate at pH 8.2 for 1 hour to extract the exchangeable metals);
 - **Step 2 - Carbonate-bound** (sodium acetate at pH 5.0 for 1 hour to extract carbonate-bound metals);
 - **Step 3 - Amorphous** (0.05 molar [M] hydroxylamine hydrochloride and 0.01 M nitric acid for 1 hour to extract amorphous metal oxides);
 - **Step 4 - Organically-bound** (0.1 M sodium pyrophosphate at pH 10 for 1 hour to extract organically-bound metals);
 - **Step 5 - Crystalline** (0.25 M hydroxylamine hydrochloride and 0.25 M hydrochloric acid for 1 hour at 60° C to extract crystalline metal oxides); and
 - **Step 6 - Residual refractory** (lithium *metaborate* fusion, dissolution and analysis to measure residual refractory metals).
- Laboratory results from sequential batch extraction provide information about relative strength of formation-associated aluminum, iron, manganese, and chromium. (See Question 8 in Attachment B).

Exchangeable Hexavalent Chromium

First Phosphate Extraction

- Prepared 1.5 liters of buffer solution containing 0.871 g/L of K₂HPO₄ (5 milliMolar) and 0.68 g/L of KH₂PO₄ (5 milliMolar) (pH ~7.2).

- Weighed out 10 grams (dry-weight basis) of each deionized water-extracted formation material (plus duplicate) from deionized water extraction testing and added 100 ml of phosphate buffer solution.
- Gently shook or tumbled for 18 hours, then centrifuged the solids and analyzed aqueous phase for Cr(VI), total chromium, aluminum, iron, and manganese (target detection limits, 0.2, 1.0, 10, 10, and 10 $\mu\text{g/L}$, respectively).
- Recovered centrifuged solids, drained free water, and analyzed the moisture content of each sample.

Second Phosphate Extraction

- Weighed out 10 grams (dry-weight basis) of each first-step phosphate buffer-extracted formation material and added 100 ml of phosphate buffer solution.
- Gently shook or tumbled for 18 hours, then centrifuged the solids and analyzed aqueous phase for Cr(VI), total chromium, aluminum, iron, and manganese (target detection limits, 0.2, 1.0, 10, 10, and 10 $\mu\text{g/L}$, respectively).
- Recovered centrifuged solids, drained free water, and analyzed the moisture content of each sample. (See Question 7 in Attachment B).

Attachment B
Detailed Results and Work Plan Questions

Detailed Results and Work Plan Questions

This attachment presents detailed results and interpretations of the aerobic testing on the selected cores from the Topock site. The results are organized herein by the 13 specific questions developed during the planning phase of this testing program. The specific questions of the aerobic test program outline the general objectives of the aerobic testing program, and are documented in the Aerobic Test Work Plan. The aerobic testing methods used to answer the questions are provided in the task descriptions in Attachment A.

Question 1: What is the grain size distribution of formation materials from the three aerobic cores?

The grain size distribution provides an indirect indication of the surface area with which groundwater and its constituents, including Cr(VI), can interact. Sieve sizes between 2 mm (coarse sand/gravel) and 0.25 mm (fine/medium sand) were used to characterize the generally coarse-grained materials. Samples were initially oven dried to facilitate the sieving process. Particles that were obviously larger than the 2 mm sieve openings were manually removed and weighed before the remaining material was dried and sieved. .

Table B-1 shows that MW-39@40' contained the smallest grain size. This is one factor that may result in a greater potential for interaction between groundwater solute and formation solids based on specific surface area (surface per weight of material). Other factors can also affect solute-solid interactions, so Cr(VI) adsorption onto aquifer formation solids would not necessarily be controlled by specific surface area.

TABLE B-1
Grain Size Distribution of Aerobic Core Sections

Sieve Size (mm)	Grain Size Analysis – Oven Dried Aerobic Soil (dry weight basis)		
	MW-39 @40' (% retained)	MW-39 @60' (% retained)	MW-39 @90' (% retained)
2.00	6.66	32.6	37.5
1.40	3.96	6.43	6.91
1.00	3.89	5.13	6.33
0.750	4.76	5.85	8.30
0.500	7.28	5.38	7.63
0.250	22.1	7.63	9.70
Pan	51.4	37.0	24.3

Note:
mm = millimeter

In the ensuing tests, only as-received samples were tested after larger material was manually removed from the 5.66-mm sieve. None of the dried and sieved material described in Table B-1 was used for characterization testing. Table B-2 provides the weight-fractions of initial, as-received samples that passed through the sieve and were used for testing.

TABLE B-2
Weight-fraction of Core Samples Used for Testing

Gross Sieve Analysis – As-received Aerobic Soil (as-received basis)			
Sieve Size (mm)	MW-39 @40' (% pass)	MW-39 @60' (% pass)	MW-39 @90' (% pass)
5.66	96.9	71.3	66.2

Question 2: What is the as-received hexavalent chromium concentration in pore water in the three core segments?

Pore water in the two deeper core sections (58-68 and 88-98 feet bgs) from MW-39 contained detectable concentrations of Cr(VI), as shown in Table B-3. The Cr(VI) concentrations were much lower than those observed during drilling (compare with concentrations reported in Table 1). Pore water in the shallowest section (38-48 feet bgs) did not contain a detectable concentration of Cr(VI).

Absence of detectable Cr(VI) in the shallowest sample coincided with the highest observed total organic carbon concentration found in any of the soil samples. It is likely that the low Cr(VI) concentration in this sample is the result of ongoing biological activity in the organic-rich solids. This is supported by the consistent non-detectable Cr(VI) concentrations in well MW-39-40, screened between 32 and 42 feet bgs, which has shown detectable dissolved organic carbon.

Subsequent samples from the MW-39 well cluster show that Cr(VI) is below detection limits in MW-39-40, the shallowest well in the cluster, and between 2,000 and 14,000 µg/L in wells screened between 50 and 100 feet bgs.¹ The pore water Cr(VI) concentrations are in agreement with monitoring well samples at the 40-ft level, but are much lower for the 60- and 90-ft depths. A potential explanation for these results is that the pore water represents micropore storage of stagnant groundwater while water collected during groundwater sampling is derived from the larger macropores and differences in Cr(VI) adsorptive capacity can exist locally at this small scale. In addition, groundwater samples were derived from a larger volume of aquifer than the core, which may represent a lower Cr(VI) than average.

¹ See results of groundwater sampling in MW-39 in *Groundwater and Surface Water Monitoring Report, Fourth Quarter 2004, PG&E Topock Compressor Station, Needles, California*, dated March 24, 2005, prepared by CH2M HILL.

TABLE B-3
As-received Pore Water Cr(VI) Concentrations

Sample ID	Sample Characteristics				Pore Water Extraction Results		
	Solids (%)	Solids (g wet)	Solids (g dry)	Moisture (g)	Extracted Cr(VI) (µg/L)	Cr(VI) in Pore Groundwater (µg/L)	Total Cr(VI) in Core (µg/kg)
MW-39@40'	78.10	172.9	135.0	37.87	< 0.20	< 0.34	< 0.07
MW-39@60'	87.45	154.4	135.0	19.38	170	407	51.1
MW-39@60' dup	87.45	154.4	135.0	19.38	190	455	57.1
MW-39@90'	88.4	152.7	135.0	17.71	22.7	57	6.6

Notes:
µg/kg = micrograms per kilogram
g = grams

Question 3: What is the total organic carbon concentration of formation solids from each core sample?

The total organic carbon (TOC) concentration of the shallowest aerobic core section was higher than TOC concentrations in the other aerobic core sections. The TOC concentration in MW-39@40' was 1,118 milligrams per kilogram (mg/kg) (dry basis), whereas the TOC concentrations in the other two aerobic core sections were below detection limits, as shown in Table B-4. The TOC concentration in MW-39@40' was also higher than the TOC in core sections in the anaerobic investigation, that ranged from less than 92 to 202 mg/kg, dry basis. As in the aerobic study, the highest TOC values for anaerobic cores came from the shallowest sample in each boring.²

TABLE B-4
Total Organic Carbon Content of Aerobic Core Segments

Sample ID	Solids (%)	TOC (mg/kg as received)	TOC (mg/kg dry)
MW-39@40'	78.10	873	1,117.8
MW-39@60'	87.45	< 100	< 114
MW-39@60' dup	87.45	< 90.5	< 103
MW-39@90'	88.40	< 89.9	< 102

² See results for anaerobic core sections in *Summary of Results – Anaerobic Core Hexavalent Chromium Uptake Capacity at the PG&E Topock Compressor Station, Needles, California*, dated March 25, 2005, prepared by CH2M HILL.

Question 4: What are the water-rinsed, as-received dithionite-citrate-bicarbonate-extractable aluminum, iron, manganese, and chromium concentrations of the formation solids from the three zones? What percentage of the total concentration of each metal is removed with this extraction?

The dithionite-citrate-bicarbonate (DCB) test is a selective dissolution test designed to identify “free” iron oxide in soils. The extractive procedure provides an indication of the iron that might be available for various biological and geochemical reactions. The results of the DCB extractions of aerobic soils are reported in Table B-5.

TABLE B-5
Dithionite-Citrate-Bicarbonate Extraction Test Results

Sample ID	DCB Extraction Test Data Summary								
	Metals (mg/kg dry weight)				Solids (%)	Metals (mg/kg as-received weight)			
	Al (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Mn (mg/kg)		Al (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
MW-39@40'	< 350	< 16	2,539	53	78.10	< 320	< 13	1,983	41
MW-39@60'	< 350	< 16	3,340	96	87.45	< 320	< 13	2,921	84
MW-39@60' dup	< 350	< 16	3,176	92	87.45	< 320	< 13	2,777	80
MW-39@90'	< 350	< 16	3,611	614	88.40	< 320	< 13	3,192	543

As described in Attachment A, the test involves digestion of a pre-weighed sample of core material with measured volumes of citrate and bicarbonate buffer solutions, heating, adding dithionite, and agitating. Following this digestion step, the free liquid is separated and analyzed for dissolved iron, aluminum, chromium and manganese.

DCB extraction of aerobic core samples released a significant amount of iron and a smaller amount of manganese, but no detectable quantities of aluminum or chromium. More iron was extracted from the two deeper sections at 60 and 90 feet than was extracted from the shallower sample at 40 feet, which had high total organic carbon (Table B-4). Manganese was extracted at roughly comparable concentrations in core samples from 40 and 60 feet, but there was an order-of-magnitude increase in manganese concentration in the 90-foot core section. The extractable iron content ranged from 9.4 to 23.1 percent of the total iron concentration in the sample and the DCB-extractable manganese fell between 19 and 90 percent of the total manganese concentration in the fully digested solid.

Question 5: What is the as-received moisture content of formation solids from the three zones?

The moisture content of core sections ranged from 11.6 to almost 22 percent by weight. There was a decrease in moisture content with increasing depth. Moisture contents and solids concentrations are provided in Table B-6.

TABLE B-6
Moisture Content and Solids Concentrations

Sample ID	Solids (%)	Moisture (%)
MW-39@40'	78.10	21.9
MW-39@60'	87.45	12.6
MW-39@60' dup	87.45	12.6
MW-39@90'	88.40	11.6

Question 6: What mass of Cr(VI) is extractable by deionized water in each of four successive extractions? What percentage of the total chromium content does deionized-extractable Cr(VI) represent?

Pore water in core sections from MW-39 at 60- and 90-foot depths below ground surface contained measurable Cr(VI) (see Table B-3). Because Cr(VI) was present in some of the sections, samples of the cores were agitated with deionized water (3:1 water-to-solids by weight) in four successive extractions, and each successive extract was analyzed for Cr(VI).³ The results are summarized in Table B-7, and show that the first extract from the 60-foot core section and its duplicate contained the highest Cr(VI) concentration, at 39.7 and 46.8 µg Cr(VI)/kg solids. The first extraction from the deepest core section (from 90 feet bgs) contained only 5.7 µg Cr(VI)/kg dry solids, whereas the extraction from the shallowest core section (from 40 feet bgs) contained no detectable Cr(VI).

The second deionized water extract from the 60-foot core section contained an order of magnitude less Cr(VI) than was reported for the first extraction step. The second extract from the 90-foot core section contained about the same lower amount of Cr(VI) as was found in the first step (4.7 µg/kg). The extract from the shallowest core section contained no detectable Cr(VI).

Following the second deionized water extraction, the core samples were washed twice more with deionized water, then the two washes were combined and analyzed for Cr(VI). The results for this third extract (combined) are also shown in Table B-7, and indicate that Cr(VI) concentrations in the third extract were similar to those in the second extraction. The core samples were washed one more time and again analyzed for Cr(VI). These final rinses (fourth extract) contained about 1 µg Cr(VI)/kg solids. The total mass of Cr(VI) that was extracted in all four steps varied from <0.007 to 0.12 percent of the total chromium in the solid core samples.

³ Extract from the first two deionized water extractions was also analyzed for aluminum, total chromium, iron, and manganese

TABLE B-7
Results of Deionized Water Extraction – Aerobic Core Section

Sample ID	Metals (µg/kg dry weight)					As- received Solids (%)	Metals (µg/kg as-received weight)				
	Cr(VI) (µg/kg)	Al (µg/kg)	Cr (µg/kg)	Fe (µg/kg)	Mn (µg/kg)		Cr(VI) (µg/kg)	Al (µg/kg)	Cr (µg/kg)	Fe (µg/kg)	Mn (µg/kg)
First Deionized Water Extraction Summary											
MW-39@40'	< 0.50	1337	5.70	990	27.7	78.10	<0.4	1044	4	773	22
MW-39@60'	39.7	189	41.7	109	< 27.0	87.45	34.8	165	36	95	< 24
MW-39@60' dup	46.75	156	48.11	46	< 27.0	87.45	40.9	137	42	40	< 24
MW-39@90'	5.7	1317	6.5	656	52	88.40	5.1	1165	6	580	46
Second Deionized Water Extraction Summary											
MW-39@40'	< 1.0	3,079	8.7	3,415	59.3	78.10	<0.4	2405	6.8	2667	46
MW-39@60'	7.4	268	9.4	186	< 27.0	87.45	6.51	234	8.2	162	< 25
MW-39@60' dup	7.6	274	7.5	140	< 27.0	87.45	6.65	240	6.6	122	< 24
MW-39@90'	4.7	1,952	10.9	1,367	169	88.40	4.15	1725	9.7	1209	149
Third Deionized Water Extraction Summary											
MW-39@40'	< 0.90	--	--	--	--	78.10	<0.8	--	--	--	--
MW-39@60'	7.77	--	--	--	--	87.45	6.80	--	--	--	--
MW-39@60' dup	6.29	--	--	--	--	87.45	5.50	--	--	--	--
MW-39@90'	7.64	--	--	--	--	88.40	6.76	--	--	--	--
Fourth Deionized Water Extraction Summary											
MW-39@40'	< 0.50	--	--	--	--	78.10	<0.4	--	--	--	--
MW-39@60'	1.29	--	--	--	--	87.45	1.13	--	--	--	--
MW-39@60' dup	1.31	--	--	--	--	87.45	1.15	--	--	--	--
MW-39@90'	1.75	--	--	--	--	88.40	1.55	--	--	--	--

-- Not analyzed

Question 7: What mass of hexavalent chromium is extractable by phosphate buffer in each of two successive extractions, following the two deionized water extractions? What percentage of the total chromium does phosphate-extractable hexavalent chromium represent?

Aerobic core sections that had been extracted with deionized water through four cycles (see Table B-7) were then extracted twice in succession with pH 7.2, 5 milliMolar potassium phosphate buffer (see Table B-8). Cr(VI) concentrations in the first phosphate extraction step ranged from 5.1 to 6.5 $\mu\text{g Cr(VI)/kg}$ solids in the 60-foot and 90-foot core sections, but was not detected in the 40-foot (shallow) core section. This result suggests that residual Cr(VI) might have remained bound to the core solids by an ion exchange mechanism following the multiple deionized water extractions. However, this adsorbed Cr(VI) total is very low – between <0.005% and 0.013% of the total chromium in the solid cores. Given the pore water concentrations reported in Table B-3, the soil-water partition coefficient (K_d) ranges from zero to 0.09 L/kg. This K_d range is considered very low even for sandy soil, and is consistent with the widely reported characteristic that Cr(VI) is weakly adsorbed on mineral surfaces. If the groundwater Cr(VI) concentrations are used in the calculation instead of pore water concentrations, the K_d values would be over an order of magnitude lower.

No Cr(VI) was detected in the second phosphate extraction step.

Aluminum and iron were removed in both extraction steps, with more being removed in the second step than the first. Manganese was removed in comparable amounts in both extraction steps, as was total (trivalent) chromium.

TABLE B-8
Results of Phosphate Extraction - Aerobic Core Sections

Sample ID	Metals (µg/kg dry weight)					As- received Solids (%)	Metals (µg/kg as-Received weight)				
	Cr(VI) (µg/kg)	Al (µg/kg)	Cr (µg/kg)	Fe (µg/kg)	Mn (µg/kg)		Cr(VI) (µg/kg)	Al (µg/kg)	Cr (µg/kg)	Fe (µg/kg)	Mn (µg/kg)
First Phosphate Extraction Summary											
MW-39@40'	< 2.00	1,130	69.0	439	1,510	78.10	< 1.56	883	53.9	343	1,179
MW-39@60'	6.50	572	81.0	227	231	87.45	5.68	500	70.8	199	202
MW-39@60' dup	6.10	556	82.0	317	205	87.45	5.33	486	71.7	277	179
MW-39@90'	5.10	4,600	87.0	3,940	621	88.40	4.51	4,066	76.9	3,483	549
Second Phosphate Extraction Summary											
MW-39@40'	< 2.00	11,393	92.3	5,853	1,188	78.10	< 1.53	8,898	72.1	4,572	928
MW-39@60'	< 2.00	3,289	87.1	1,762	357	87.45	< 1.71	2,876	76.2	1,541	312
MW-39@60' dup	< 2.00	3,212	93	1,699	311	87.45	< 1.72	2,809	81.6	1,486	272
MW-39@90'	< 2.00	13,277	122.0	13,277	1,259	88.40	< 1.74	11,737	107.8	11,737	1,113

Question 8: How much aluminum, iron, manganese, and chromium are extracted in each step of sequential batch extraction tests? What is their relative binding strength to the formation materials? How are extractable metals distributed among the various sequentially extracted fractions?

Sequential batch extraction is a method for characterizing solids in which the sample is subjected to a progressively more aggressive extraction solution, and the dissolved metals in the extract are analyzed. A six-step sequential batch extraction protocol was used for aerobic core sections from the Topock site; extract solutions used are described in Attachment A.

The indicated mineral phases removed at each extraction step are generally accepted conventions and, therefore, not necessarily accurate descriptions of the true phases that are dissolving. The extract from each of these six steps was analyzed for aluminum, iron, chromium, and manganese. Results of the sequential batch extraction tests are provided in Table B-9. The results of the sequential extraction tests are summarized according to Steps 1 through 6.

Step 1 - Exchangeable (Sodium Acetate - pH 8.2 Extraction)

No detectable concentrations of chromium or iron were released in the first extraction step with sodium acetate at pH 8.2. However, small amounts of aluminum and manganese were detected in one of the core sections. The quantifiable aluminum concentration was 0.641 mg/kg (dry mass) and the manganese concentration was 0.288 mg/kg in the shallow (40-foot) core section, which also contained measurable total organic carbon.

Step 2 - Carbonate Bound (Sodium Acetate - pH 5.0 Extraction)

Significant concentrations of manganese and, to a lesser extent, aluminum and iron were extracted by the mildly acidic acetic acid solution. Very low levels of (total) chromium were also released in this extraction step. The highest manganese content was released from the shallow (40-foot) core section, which also contained the highest organic carbon content; a comparable manganese content was extracted from the deep (90-foot) core section.

Step 3 - Amorphous (hydroxylamine hydrochloride-nitric acid)

Extraction of "amorphous" metal-bearing minerals with dilute hydroxylamine hydrochloride yielded a significant amount of manganese from the deepest core section, but comparatively small amounts of iron, and essentially no aluminum or chromium.

Step 4 - Organically Bound (sodium pyrophosphate at pH 10)

The alkaline pyrophosphate solution (pH ~10) released relatively large amounts of aluminum and iron from the shallowest core section, with smaller quantities released from the deeper core sections. The largest amount of manganese was released from the deepest core section, with smaller amounts released from progressively shallower core sections. Measurable total chromium was released, again with largest quantities from the shallowest core section and decreasing quantities from progressively deeper cores.

Step 5 - Crystalline (hydroxylamine hydrochloride and hydrochloric acid)

Most of the “crystalline” metal oxides, more resistant to weathering than “amorphous” oxides, are liberated with a more strongly acidic solution of hydroxylamine hydrochloride than in Step 3. Iron and aluminum were detected at high concentrations in the core section extracts from Step 5, along with smaller amounts of manganese. Aluminum is not chemically reduced by this extraction solution; therefore, the co-extraction of aluminum with the iron probably occurred because of the acidity of the solution, unrelated to the presence of hydroxylamine hydrochloride. Total chromium concentrations were relatively low, about double the concentrations released with the pyrophosphate solution. The total chromium extracted as crystalline material from these core sections ranged from 0.303 to 0.494 mg/kg dry mass.

Step 6 - Residual Refractory (lithium *metaborate* fusion and dissolution)

Complete digestion by lithium borate fusion followed by acid dissolution and chemical analysis provides the concentration of metals of all (remaining) forms in the core sections. Concentrations from this step represent forms that are not expected to be released under any normal weathering process. Chromium concentrations in this extract were 40 to 50 mg/kg, lower than for any of the other metals. The aluminum concentration was highest, with values as high as 67,500 mg/kg. The iron concentration was second highest at about half the concentration of aluminum. Relatively small amounts of manganese and even smaller amounts of chromium were recovered from the fully digested sample.

TABLE B-9
Results of Sequential Batch Extraction – Aerobic Core Sections

Sample ID	Metals (mg/kg dry weight)				As- received Solids (%)	Metals (mg/kg as-received weight)			
	Al (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Mn (mg/kg)		Al (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
Step 1 - Exchangeable (Sodium Acetate – pH 8.2 Extraction)									
MW-39@40'	0.641	< 0.033	< 0.165	0.288	78.10	0.50	< 0.026	< 0.13	0.23
MW-39@60'	< 0.361	< 0.0289	< 0.144	< 0.144	87.45	< 0.32	< 0.025	< 0.13	< 0.13
MW-39@60' dup	< 0.336	< 0.0268	< 0.134	< 0.134	87.45	< 0.29	< 0.024	< 0.12	< 0.12
MW-39@90'	< 0.327	< 0.0262	< 0.131	< 0.131	88.40	< 0.29	< 0.023	< 0.12	< 0.12
Step 2 - Carbonate Bound (Sodium Acetate – pH 5.0 Extraction)									
MW-39@40'	0.471	0.104	3.661	38.679	78.10	0.37	0.081	2.86	30.2
MW-39@60'	1.799	0.0678	< 0.147	2.065	87.45	1.57	0.059	< 0.13	18.1
MW-39@60' dup	1.607	0.0554	< 0.135	1.863	87.45	1.41	0.048	< 0.12	16.3
MW-39@90'	5.648	0.0906	1.378	31.099	88.40	4.99	0.080	1.22	27.5
Step 3 - Amorphous (hydroxylamine hydrochloride-nitric acid)									
MW-39@40'	< 0.0410	< 0.0033	2.158	7.233	78.10	< 0.032	< 0.003	1.69	5.65
MW-39@60'	0.130	0.00896	1.023	19.502	87.45	0.11	0.008	0.89	17.1
MW-39@60' dup	0.128	0.010	0.948	19.310	87.45	0.11	0.009	0.83	16.9
MW-39@90'	< 0.161	< 0.0129	2.103	415.406	88.40	< 0.086	< 0.007	1.86	36.7
Step 4 - Organically Bound (sodium pyrophosphate at pH 10)									
MW-39@40'	25.539	0.336	75.792	4.333	78.10	19.9	0.26	59.2	3.38
MW-39@60'	9.173	0.264	7.728	31.203	87.45	8.02	0.23	6.76	27.3
MW-39@60' dup	8.663	0.265	7.076	31.345	87.45	7.58	0.23	6.19	27.4

TABLE B-9
 Results of Sequential Batch Extraction – Aerobic Core Sections

Sample ID	Metals (mg/kg dry weight)				As- received Solids (%)	Metals (mg/kg as-received weight)			
	Al (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Mn (mg/kg)		Al (mg/kg)	Cr (mg/kg)	Fe (mg/kg)	Mn (mg/kg)
MW-39@90'	4.825	0.209	4.773	51.345	88.40	4.27	0.18	4.22	45.4
Step 5 - Crystalline (hydroxylamine hydrochloride and hydrochloric acid)									
MW-39@40'	6.245	0.494	7.035	26.692	78.10	4.88	0.39	5.49	20.8
MW-39@60'	219.574	0.454	161.791	30.480	87.45	192	0.40	141	26.7
MW-39@60' dup	220.870	0.463	156.064	31.081	87.45	193	0.40	136.5	27.2
MW-39@90'	7.560	0.303	12.398	90.693	88.40	6.68	0.27	11.0	80.2
Step 6 - Residual Refractory (lithium metaborate fusion and dissolution)									
MW-39@40'	30,260	40	10,900	200	78.10	23,633	31	8,513	156
MW-39@60'	63,600	50	31,900	390	87.45	55,618	44	27,897	341
MW-39@60' dup	65,200	50	33,800	370	87.45	57,017	44	29,558	324
MW-39@90'	67,500	40	32,000	470	88.40	59,670	35	28,288	415

Question 9: Is deionized-water-extractable hexavalent chromium distinguishable from hexavalent chromium in pore water?

The purpose of this question is to verify that Cr(VI) extracted by the 4-step deionized water sequence (see Question 6) represents entrained pore water as reported in Question 2. To accomplish this, the total mass of Cr(VI) extracted by the four deionized washes was divided by the core sample water content to obtain a calculated pore water concentration for each sample. These calculated pore water concentration are compared to the values from Question 2. If a calculated concentration is greater than the measured pore water concentration, it is possible that some of the Cr(VI) derived from the deionized extractions was weakly adsorbed Cr(VI).

Masses of Cr(VI) collected from deionized extractions are summarized in Table B-10, along with comparisons of measured and calculated pore water Cr(VI) concentrations. No detectable Cr(VI) was obtained from MW-34@40', consistent with measured values. Calculated concentration from MW-34@60' extractions were somewhat less but generally consistent with measured values, and the duplicate sample results agreed well with each other. Only in MW-34@90' did the calculated concentration exceed the originally measured value. Review of the lithologic log indicates that 40% of the core section was comprised of silty deposits, compared to 0% in the 60 foot core. The relatively low Cr(VI) concentration in the measured sample suggests that micropores associated with the silty material are slow to yield the entrained water, as discussed previously. The steady release of Cr(VI) with each deionized extraction suggests this may be the case.

Also possible is that Cr(VI) obtained in extraction steps 2, 3, and 4 represents weakly adsorbed Cr(VI) from the fine-grained matrix. If this is the case, the combined mass of Cr(VI) from these steps (1.8 µg) would be added to the phosphate-extracted mass from this core (0.06 µg) to give a maximum adsorbed mass of 1.86 µg, or 169 µg/kg dry mass. This would raise the K_d value for this core from 0.09 to 3.0 L/kg, a substantial increase but still a relatively low K_d . This is not likely to be the case, since it would be in sharp disagreement with the K_d calculated for the 60 foot core (0.02 L/kg). Slow release from micropores as discussed above is considered a more likely explanation for the higher calculated pore water concentration.

TABLE B-10
Comparison of Hexavalent Chromium in Pore Water and Deionized Extraction

Sample ID	Deionized Extraction of Cr(VI) (µg)				Pore Water Cr(VI) Concentration (µg/L)	
	First	Second	Third	Fourth	Calculated from DI Extraction	Measured (Table B-3)
MW-39@40'	<0.07	<0.07	<0.12	<0.06	<8.5	< 0.34
MW-39@60'	5.37	0.98	0.98	0.16	386	407
MW-39@60' dup	6.31	0.99	0.79	0.17	426	455
MW-39@90'	0.77	0.61	0.97	0.22	146	57

Question 10: What is the phosphate-extractable hexavalent chromium loading per unit surface area (assuming spherical particle geometry) of formation solids from each zone?

The original purpose of relating solids-bound Cr(VI) to the solids surface area was based on the possibility that a relatively large amount of Cr(VI) might have been loosely bound. This would be especially relevant if a large fraction of the solids were in the silt and clay size range. Instead, most of the core material was larger than 0.25 mm (i.e. larger than fine sand size) in the two deeper core sections. This makes it unnecessary to demonstrate specific surface area effects, so Cr(VI) loading as a function of surface area was not calculated. For practical applications, Cr(VI) as a function of solids mass is more useful and has been reported throughout this document.

Question 11: Is there an apparent correlation between hexavalent chromium loading capacity and the TOC content of formation solids?

This question was intended to explore the possibility that significantly more Cr(VI) might have been bound to core solids than was found with the combination of the deionized water and phosphate buffer extraction tests in Tables B-7 and B-8, presuming the TOC concentrations would be above detection limits in all the core sections. The TOC concentrations were below detection except for the 40-foot core, and correlation conclusions are not drawn for these sections. In the 40-foot core section, the absence of Cr(VI) is probably the result of high total organic carbon in this shallow core. Cr(VI) concentrations occurred in the deeper core sections, which had much less total organic carbon, so it seems that there is a correlation between high TOC levels and absence of Cr(VI).

Question 12: Is there evidence of Cr(III) on formation solids based on DCB and/or hydroxylamine hydrochloride-extraction (amorphous metal oxides) results?

Dithionite-citrate-bicarbonate extraction did not release detectable amounts of total (trivalent) chromium and very little was released with the "amorphous" material during Step 3 of the sequential batch extraction. Total chromium was released in higher amounts during sequential batch extraction with the "carbonate" (Step 2) and "organic" (Step 4) fractions, which straddle the "amorphous" extraction step. The sequential extractions demonstrated that Cr(III) is present on the solids, but most appears to be in different forms from amorphous oxides. It is concluded that these methods only provide very general results and are not suited to quantify forms of trace metal concentrations in these samples.

Question 13: How reproducible are the deionized- and phosphate buffer-extraction tests, as indicated by a replicate test?

Duplicate pore water, deionized water, sequential batch extraction and phosphate extraction samples were analyzed for relative percent difference (RPD) between duplicate tests. These calculations provide a measure of data quality for these tests, and are reported in Table B-12.

TABLE B-11
Relative Percent Difference in Test Methods

Test Method	Duplicated Sample ID	Units	Cr(VI)	Al	Cr _T	Fe	Mn
Pore Water	MW-39@60'	µg/L	11.1				
First Deionized	MW-39@60'	µg/kg	16.20				
Second Deionized	MW-39@60'	µg/kg	2.1				
Third Deionized	MW-39@60'	µg/kg	21.0				
Fourth Deionized	MW-39@60'	µg/kg	1.66				
Sequential Batch Extraction							
Step 1	MW-39@60'	mg/kg					
Step 2	MW-39@60'	mg/kg		10.7	20.6		10.5
Step 3	MW-39@60'	mg/kg		1.8	11.8	7.1	1.0
Step 4	MW-39@60'	mg/kg		5.7	0.06	8.8	0.46
Step 5	MW-39@60'	mg/kg		0.59	2.0	3.6	2.0
Step 6	MW-39@60'	mg/kg		2.5	0.0	5.8	5.3
First Phosphate	MW-39@60'	µg/kg	6.3	2.8	1.2	33.1	11.9
Second Phosphate	MW-39@60'	µg/kg		2.4	6.9	3.6	13.7

Duplicate testing showed that 88 percent of the extractions were reproducible to within 20% RPD, and the largest deviation was 33 percent RPD. Sixteen (48.5 percent) of the test results had RPDs below 5 percent. This indicates that the tests described above give reliable indications of the Cr(VI) uptake capacity and metal release during extraction tests.