Work Plan to Evaluate In-Situ Soil Flushing of Perchlorate-Impacted Soil
Tronox, LLC
Henderson, Nevada

March 29, 2010

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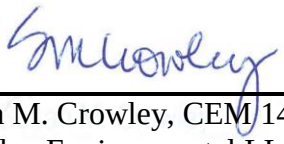
Tronox Project
Henderson, Nevada

Responsible CEM for this Project

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.



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1.0 INTRODUCTION

Northgate Environmental Management, Inc. (Northgate) has prepared this work plan on behalf of Tronox LLC, for the Tronox facility located in Henderson, Nevada (the Site; Figure 1). This document describes work to be performed to evaluate the technical feasibility and effectiveness of in-situ flushing to remediate perchlorate in Site soils.

Perchlorate has been detected in samples of vadose zone soil at the Site (Northgate, 2010a). These unsaturated soils may be a continuing source of perchlorate to groundwater. Reduction of perchlorate mass in these unsaturated soils may reduce an on-going source of perchlorate to groundwater.

Perchlorate is very soluble in water and is not readily adsorbed on the surface of unsaturated soils (Urbansky, 2003). In-situ flushing may be an effective remedial technology for sites with highly permeable sediments (e.g., sands and gravels) with relatively few heterogeneities (USEPA, 1991). Considering the high solubility of perchlorate and the presence of coarse-grained alluvial sediments over much of the vadose zone at the Site[1], in-situ soil flushing is a technique that has potential to reduce perchlorate mass in the soil.

In-situ soil flushing is essentially an acceleration of the natural process of precipitation and infiltration. The Site receives an average of approximately four inches of rainfall a year. A Site-specific infiltration rate has not yet been developed, though the USGS has estimated that 2 percent of this precipitation eventually reaches the groundwater in undeveloped land areas in the region (USGS, 2007).

The proposed evaluation consists of laboratory-scale column testing, as detailed below. Based on the results of the laboratory-scale testing, a pilot-scale demonstration will also be performed to further assess this technology for use at the Site.

[1] While the vadose-zone lithology at the Site consists primarily of sands and gravels, it should be noted that discontinuous caliche layers are present over much of the Site. They are most frequently encountered at depths greater than 10 feet below ground surface and usually within a few feet of the contact between alluvium (Qal) and Upper Muddy Creek formation (UMCf). They generally range from one to less than three feet in thickness. The presence of these caliche deposits may impact the feasibility and effectiveness of flushing perchlorate from soil to groundwater at the Site.

2.0 OBJECTIVES

The objective of the proposed program is to examine the feasibility of in-situ soil flushing as a remedial approach to decrease perchlorate mass in on-Site soils. Data will be generated in laboratory-scale column tests to measure percolation and leaching rates from soil samples and to help estimate the amount of perchlorate that can potentially be flushed from on-Site vadose zone soils. The specific objectives of the laboratory scale column tests are as follows:

- Simulate the percolation of 150% of annual rainfall through laboratory soil columns, for comparison with USGS estimates of groundwater recharge.
- Measure the amount of perchlorate that can be leached from soil columns as a function of flushing volume. Tests will be conducted on samples of alluvium gathered from the Site that contain a range of initial perchlorate concentrations.
- Measure the leaching rate of other materials (most notably arsenic and chromium) that may be flushed out of the soil along with perchlorate.

After the column studies are completed, the data will be used to design an on-Site pilot scale demonstration of in-situ soil flushing.

3.0 DESCRIPTION OF THE EVALUATION PROJECT

The proposed evaluation project will be conducted in two stages: laboratory scale column tests, followed by a pilot scale demonstration at the Site, as appropriate. Each of these stages is described below.

3.1 Laboratory Scale Column Tests

Tests will be conducted in laboratory-scale leaching column studies using soil samples obtained from the Site. Stabilized Lake Mead water will be used for the flushing tests. Three separate column tests will be conducted as detailed in Table 1.

Each of these tests will be run on homogenized samples of soil taken from the alluvium layer at the Site. Samples of soil run in these column tests will be collected in areas where previous sampling indicated that soil contains perchlorate in the desired range of concentrations.

The test columns will be approximately 6 feet long by 6 inches in diameter. The collection of soil and water required for these column tests will be coordinated with the upcoming drilling activities described in the Capture Zone Evaluation Work Plan (Northgate, 2010b).

Soils to be used for testing are expected to be classified as gravely sands or sandy gravels. Approximately 450 pounds of soil will be delivered to the laboratory – 150 pounds of soil anticipated to contain less than 100 mg/kg of perchlorate, 150 pounds anticipated to contain between 100 – 1,000 mg/kg of perchlorate, and 150 pounds anticipated to contain more than 1,000 mg/kg. Soil materials of each concentration range will be homogenized, sampled and analyzed by the laboratory prior to conducting the column studies. Table 2 lists the analytes and methods that will be used in the analysis of soil samples.

Approximately 100 liters of stabilized Lake Mead water will be provided to the laboratory along with the soil samples. Samples of Lake Mead water to be used in the column tests will be analyzed by the laboratory prior to conducting of the column studies. Table 3 lists the analytes and methods that will be used in the analysis of water samples. Results of these analyses will be reviewed by Northgate prior to conducting the column tests.

Three soil columns will be prepared by the laboratory for testing. Soil with varying perchlorate concentrations will be loaded in the test columns, and will be compacted to approximate the wet bulk density (1.856 g/cc) and moisture content (15.4 % by volume) of on-Site alluvium soils. A schematic of the laboratory scale column test apparatus is presented in Figure 2.

Two separate test conditions will be run in each of the three columns. In the first test condition, approximately 150% of the annual average rainfall at the Site will be applied to the top of the column and allowed to percolate as a batch into the soil column. In the second test condition, water will be continuously applied to the top of the column, and leachate samples will be collected from the bottom of the column until a total of approximately 2 pore volumes have been flushed through the soil column.

The first test condition will be established by applying approximately 2.8 liters[2] of water to the top of the columns, under atmospheric pressure, at a flow rate of approximately 2 ml/minute using a peristaltic pump or other suitable device. The water will be allowed to percolate through the soil column by gravity. The advancement of the percolation front will be monitored as a function of time until the water drains through the bottom of the column or stops migrating downward. If sufficient water drains through the column, it will be collected and sampled for the parameters specified in Table 3.

After the initial flushing volume (2.8 liters) has been applied to the columns and this water has either drained through the columns or stopped migrating downward, the second test condition will be initiated in each column. Additional water will be applied to the top of the columns as described above, until a total volume of 26.1 liters (approximately 2 pore volumes of water) has been introduced. At an addition rate of 2 mL/min, this will be approximately 8 days of continuous flushing. Water samples will be collected from the bottom of the column each day and analyzed for the parameters specified in Table 3.

Upon completion of the column tests, soil from the test columns will be re-homogenized, sampled, and analyzed for the parameters specified in Table 2.

Data from these column studies will be evaluated by Northgate. Plots will be prepared to evaluate the concentration of perchlorate in the leachate as a function of the volume of water infiltrated through the column. The mass of each analyte removed from the soil column will be estimated based on the mass recovered in the leachate, and this will be compared to the "before" and "after" soil mass of that analyte derived through analysis of soil samples.

A technical memorandum covering the column test results and pilot scale design will be prepared and reviewed with Tronox and NDEP in advance of conducting the pilot scale field demonstration. The following section describes the basic approach to this field test, which may be modified based on the column test results.

[2] This volume represents approximately 6 inches of rainfall (i.e., 150% of the annual average rainfall for the Site).

3.2 Conceptual Pilot Scale Field Test

Following the review of the laboratory column test results, a pilot scale field demonstration of perchlorate soil flushing may be conducted at the Site. The size, duration, and flushing volumes of the pilot scale demonstration will be established based on the results of the laboratory scale column tests.

The proposed pilot study demonstration area is shown in Figure 3. This area was selected because: (1) it is near the interceptor well field, and therefore hydraulic control of the demonstration area will be maintained; (2) nearby soil sampling results suggest that the vadose zone in this area contains perchlorate concentrations above 100 mg/kg; (3) this area is outside of the boundaries currently identified for shallow soil excavation, and therefore the excavation program and the soil flushing pilot test can be conducted in parallel if necessary; and (4) use of this area for pilot testing will not interfere with ongoing facility operations or subsurface improvements.

The final selection of the pilot study area will require additional soil sampling to confirm whether soil in this area contains perchlorate concentrations within the desired range and over the depth intervals needed for the pilot test. Soil samples will be taken and analyzed from the proposed pilot study area to confirm that this location is appropriate for the field test.

A percolation pond at the pilot study area will be constructed by installing berms. The interior area will be ripped to remove existing plant materials and break up compacted surface soils.

Monitoring points to be used during the pilot study demonstration will be installed. Four new leachate collection well clusters will be installed in and around the percolation area, as shown in Figure 4. Each leachate collection well cluster will provide the ability to collect water samples from three discrete depth intervals. Existing monitoring wells, also shown in Figure 4, will also be utilized as monitoring locations where possible, though the final selection of the pilot study location may necessitate adding new monitoring wells.

The bermed percolation pond will be flooded with stabilized Lake Mead water obtained from a metered connection located near the old Building D-1. Five days a week, water will be introduced to the percolation area. An inert and distinctive tracer material, such as sodium bromide, may be added to this water to provide a direct indication of subsurface flow. Water will be allowed to percolate into the ground, and the rate of infiltration will be observed by monitoring the depth of water in the pond. The evaporation rate will be estimated by monitoring the water level in an evaporation pan located near the pilot test area. This procedure will continue for up to six weeks.

Water levels will be measured and samples of the leachate/groundwater at all pilot study monitoring points will be collected on a bi-weekly basis. This monitoring program will continue throughout the active period of flushing (weeks 1-6) and for four weeks after the flushing of water has concluded. Water samples collected will be analyzed in accordance with Table 3.

At the conclusion of the pilot test, all analytical data collected during the demonstration will be evaluated. The amount of water flushed through the soil will be documented, and estimates of the mass of perchlorate flushed from the soil will be made. Estimates of flushing requirements for specific areas of the Site will be generated, and the conclusions of this pilot scale demonstration will be documented. Boring logs from the Site will be reviewed and lithologic cross-sections to show where caliche deposits have been observed will be prepared. A report on the test conditions and results will be prepared and submitted to NDEP.

After completion of the field work and evaluation of the data, the percolation area will be graded and all monitoring points installed specifically to conduct this test will be properly abandoned.

3.3 Sampling Procedures

3.3.1 Soil Sampling Procedures

Soil samples will be collected using the sonic drill rig employed during the capture zone evaluation drilling activities (Northgate, 2010b). Soil borings will be logged in the field using the procedures described in SOP-14 – Field Documentation (BRC, 2009d) and SOP-17 – Soil Logging (BRC, 2009e). Soil samples for laboratory analysis will be collected with a split-spoon sampler fitted with brass liners using the procedures described in BRC SOP-23 – Split Spoon Sampling (BRC, 2009h).

Equipment cleaning or decontamination procedures will be per the procedures described in SOP-31 – Drilling Equipment Decontamination (BRC, 2009i).

Sample containers will be sealed, labeled, and placed inside an ice chest under chain-of-custody protocol using the procedures described in SOP-06 – Sample Management and Shipping (BRC, 2009b).

Each sampling borehole will be abandoned once the target depth has been reached and the necessary samples are obtained. The boreholes will be abandoned by backfilling with a bentonite/neat cement grout using the procedures described in SOP-19 – Borehole Abandonment (BRC, 2009f). Soil cuttings (including unused soil cores) will be temporarily stored in U.S. Department of Transportation (DOT)-approved steel 55-gallon drums or debris boxes while

awaiting receipt of the final laboratory results. Containers will be managed according to the procedures described in SOP-34 – Investigative Derived Waste (IDW) Management (BRC, 2009j). At the end of each day, equipment decontamination water will be temporarily stored in DOT-approved 55-gallon drums. Each drum will be marked with water-proof labels and water-proof markers. Each drum will receive a unique identification number and will be catalogued for waste capture documentation purpose. Following characterization, each drum of material will be disposed of as appropriate per federal, state, and local requirements.

3.3.2 Water Sampling Procedures

Water samples will be collected in the field from monitoring wells and from temporary leachate collection wells. All water samples will be collected using the procedures described in SOP-05 – Water Sampling (BRC, 2009a). Field data will be recorded using the procedures described in SOP-14 – Field Documentation (BRC, 2009d).

Sample containers will be sealed, labeled, and placed on ice inside an ice chest provided to the laboratory under chain-of-custody protocol using the procedures described in SOP-06 – Sample Management and Shipping (BRC, 2009b).

Temporary leachate collection wells will be abandoned after completion of the pilot scale demonstration. The temporary wells will be abandoned using the procedures described in SOP-21 – MW Destruction (BRC, 2009g). Soil cuttings (including unused soil cores) will be temporarily stored in U.S. Department of Transportation (DOT)-approved steel 55-gallon drums while awaiting receipt of the final laboratory results.

Purge water and other materials associated with the installation, sampling, and abandonment of groundwater and leachate monitoring points will be managed according to the procedures described in SOP-34 – Investigative Derived Waste (IDW) Management (BRC, 2009j).

4.0 PROPOSED SOIL FLUSHING EVALUATION SCHEDULE

The proposed schedule for the work described in this work plan is presented in Figure 5.

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FIGURES

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