Revised Work Plan to Evaluate In Situ Soil Flushing of Perchlorate-Impacted Soil
Tronox, LLC
Henderson, Nevada
NDEP Facility ID#000539

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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 the work to be performed to conduct a pilot scale test to evaluate the effectiveness of soil flushing to reduce the mass of perchlorate in Site soils.

A previous edition of this work plan was prepared and submitted to NDEP on May 27, 2010 (Northgate, 2010) and approved by NDEP on June 21, 2010 (NDEP, 2010). Since then, laboratory column studies have been conducted to test the effectiveness of soil flushing. Samples of soil were collected from the Site, loaded into laboratory test columns, and flushed with Stabilized Lake Mead water. These column studies showed that soil flushing was very effective in removing perchlorate from Site soils, and that the vast majority of the mass transfer of perchlorate from soil to the flushing water occurred within approximately the first pore volume of applied water (see Appendix A).

Based on the promising results from the column tests, Tronox will conduct a pilot scale study at the Site. The proposed pilot study consists of:

1. Installation of a system to uniformly deliver the required volumes of flushing water;
2. Installation of a monitoring system to track the progress of the soil flushing;
3. Conducting the soil flushing operation;
4. Post flushing sampling and analysis; and
5. Preparation of a report documenting the pilot test results.

While this work plan proposes and describes the pilot scale test of in situ soil flushing with water only, it is recognized that in-situ bioremediation of perchlorate in the vadose zone is an area of active investigation and technology development. Several different approaches for vadose zone in-situ bioremediation have been tested at other sites, and one or more of these approaches may be effective at the Site. There may also be other emerging technologies for remediating perchlorate in unsaturated zone soils that are potentially applicable. Therefore at the conclusion of the pilot test work an assessment of various in situ remediation technologies will be prepared in a feasibility study of remedial options to treat leachable chemicals in unsaturated zone soils. Tronox has initiated the technology screening phase of this feasibility study by conducting literature review and

discussions with technology vendors, and anticipates completing this assessment by the end of 2010. The results of this technology screening and of the pilot study will be used to develop unsaturated soil remedial alternatives for further evaluation. Based on the alternative evaluation, selected alternative(s) and an overall approach for unsaturated soil remediation will be developed and presented in the feasibility study report.

1.1 Objectives

The objective of the proposed pilot scale test is to examine the effectiveness of in situ soil flushing as an approach to decrease perchlorate mass in on-Site vadose zone soils. Data will be generated by flushing one closely monitored area of the Site, and collecting samples of soil, leachate, and groundwater before, during, and after a period of active flushing. The test will help demonstrate the amount of perchlorate that can be flushed from on-Site vadose zone soils. The specific objectives of the pilot scale test are as follows:

- Design and demonstrate the operation of a water delivery system for the application of flushing water over an approximately 4,400 square foot test area.
- Measure the amount of perchlorate that is leached from vadose zone soil into flushing water.
- Measure the mobilization of species including pesticides, anions, general minerals, and metals that may leached from the soil along with perchlorate (see Appendix A for column test data showing that leaching of metals was minor, and Tables 3 and 4 for a list of analytes to be measured in soil, leachate, and groundwater).
- Demonstrate the achievement of mass reduction.
- Evaluate the concentration of perchlorate remaining in vadose zone soils after the application of approximately 1.5 pore volumes of flushing water.
- Evaluate groundwater impact from the application of approximately 1.5 pore volumes of flushing water over an area of the Site that contains high concentrations of perchlorate in vadose zone soil.

2.0 DESCRIPTION OF PROPOSED PILOT SCALE FIELD TEST

The proposed pilot study consists of the installation of an underground system to uniformly deliver the required volumes of flushing water, installation of a monitoring system to track the progress of the soil flushing, application of about a million gallons of flushing water into the test area, post flush sampling and analysis, and the preparation of a report documenting the pilot test design, test conditions, and results.

2.1 Selected Pilot Test Area

The previous version of this work plan (Northgate, 2010a) selected a preliminary location for the pilot scale test. However, the maximum concentration of perchlorate measured in soil samples collected from four soil borings drilled in the proposed area was 110 mg/kg. This concentration is too low for a pilot test to adequately demonstrate whether soil flushing is adequate to reduce the mass of perchlorate in soil exceeding its Basic Comparison Level (BCL) of 795 mg/kg. Therefore, an alternate area on the Site has been selected for the pilot scale test. The area is south of the BT tank area, in an area identified as RZ-C-29. The location of RZ-C-29 and the revised pilot test area are shown in Figure 2.

This area was selected because:

1. It is upgradient of the interceptor well field, and therefore hydraulic control of the test area will be maintained to the degree afforded by the Interceptor Well Field;
2. Nearby soil sampling in RZ-C-28, RZ-C-29, and RZ-C-31, confirms that soil in this area contains in excess of 5000 milligrams per kilogram (mg/kg) of perchlorate;
3. The area is outside the boundaries of detention ponds that are being considered to be installed, and therefore the pilot test can be conducted in parallel with final grading of the Site; and
4. This area will not conflict with ongoing facility operations or existing subsurface improvements.

Conducting the pilot test in this area of the Site will allow us to simultaneously accomplish two major objectives. First, it will serve to demonstrate the effectiveness of soil flushing in an area of the Site that contains relatively high concentrations of perchlorate. Secondly, if successful, it will help demonstrate that soil flushing is a feasible interim measure to reduce the mass of perchlorate at the Site.

2.2 Selected Pilot Test Conditions

2.2.1 Discussion of Column Test Results

The conditions to be established during the pilot scale test are based upon the results of the laboratory column tests (Appendix A). In these tests, three samples of soil were collected from the Site and packed into six-inch diameter by six foot long test columns to approximate the bulk density of Site soils. Stabilized Lake Mead water was applied at a constant rate of 2 milliliters per minute (ml/min) to the top of each column until approximately 2 pore volumes of water had been applied to the top of the column. This water flowed through the test column by gravity, and the leachate was collected as it drained out of the soil column. Leachate was analyzed as sufficient volume of leachate was collected (approximately 0.2 pore volumes of the test column). At the conclusion of the test, soil was removed from the column, homogenized, and analyzed to compare with pre-test soil analysis.

These column tests demonstrated that perchlorate could be effectively leached from Site soil, and that perchlorate concentrations in soil were reduced by over 99%. In addition, the tests showed that over 98% of the perchlorate mass that was transferred to the leachate left the columns during application of the first 1.1 pore volume of water to the top of the column. The tests also showed that arsenic and chromium concentrations in the leachate were well below those currently measured in on-Site groundwater.

To identify other species that could impact groundwater as a result of soil flushing, column test results were compared with groundwater monitoring data from wells in the vicinity of the proposed pilot test area and NDEP residential groundwater BCLs (Table 1). This comparison determined that the maximum leachate concentrations measured in the column tests were higher than both local groundwater concentrations and the BCL for seven constiuents -- ammonia, nitrate, cobalt, magnesium, manganese, beta-BHC, and perchlorate. In addition, alpha-BHC and dieldrin were not detected in column test leachate, but their detection limits were higher than the respective BCLs.

This comparative analysis indicates which constituents have some potential to impact groundwater. However, this likely overestimates the issue, as some important mitigating factors have not been considered. For example, leachate concentrations above BCLs did not persist for most constituents as samples were taken throughout the column test, nor were leachate concentrations duplicated from column to column. For example,

manganese concentrations exceeded the local groundwater concentration and BCLs in the first two leachate samples collected from RSAM-5, but were almost an order of magnitude lower (and below the BCL) in subsequent samples taken from this column. As well, manganese concentrations were much lower in samples taken from SA-189 and RSAM-6, though the three columns showed similar manganese concentrations in the initial pre-test soil samples. Other mitigating factors not considered are mixing effects as leachate mixes with background groundwater, and as groundwater is extracted for treatment from a much larger region than will be flushed during this pilot test. The proposed water application rate in this soil flushing test is less than 2% of the volume extracted for treatment.

Potential groundwater impacts will be monitored during the pilot test. As described in detail in Sections 2.3 and 2.4, groundwater samples will be collected both upgradient and downgradient of the pilot study area before, during, and after the proposed pilot test. All constituents identified by this analysis will be monitored (as well as many others) to assess potential groundwater impacts. As well, leachate samples will be taken during and after the proposed pilot test and will be compared with leachate sample results from the column test.

As previously stated, the proposed pilot test area is upgradient of the interceptor well field. The interceptor well field has available hydraulic capacity to extract the additional volume of water that will be applied during the proposed soil flushing pilot test.

The current groundwater treatment system has available hydraulic capacity to treat the flow rate that will be applied during the soil flushing pilot test. The extracted water is treated through a series of processes, including a chemical reduction, precipitation, and filtration process to remove chromium, LGAC treatment to remove organics prior to biological treatment to reduce perchlorate. The existing groundwater treatment system has available treatment capacity to effectively reduce the mass of perchlorate and other species that may be flushed to groundwater during the pilot scale test. The system is anticipated to continue to operate within NPDES permit conditions.

Based on these column test results, it is proposed to flush the pilot test area with approximately 1.5 pore volumes of water. This equates to approximately 830,000 gallons of water over the 4,400 square-foot lateral area of the pilot test. The water will be introduced uniformly and continuously through an underground drip irrigation system over the entire lateral area of the pilot test at a total flow rate of 13 gallons per minute

(gpm). This flow rate equates to an infiltration rate of approximately 0.57 feet per day, which is within the typical infiltration rate for soil types at the Site and below that observed in the laboratory column tests. In addition, this added flow rate is within the available capacity of the existing groundwater extraction and treatment system. To apply a total of 1.5 pore volumes of water to the entire test area will require approximately 45 days of active flushing, assuming (and to be confirmed by pre-test sampling), a depth to groundwater of 32 feet and an average total soil porosity of 0.35.

2.3 Design of Pilot Test Monitoring System

Soil, groundwater, and leachate monitoring points will be installed in and around the selected pilot test area as shown in Figure 3. Each of these monitoring points will be sampled and analyzed prior to conducting the pilot scale flushing operation to establish the baseline condition.

Three downgradient and one upgradient groundwater monitoring wells will be installed and developed. The selected location of these monitoring wells is shown in Figure 3.

Three leachate collection well clusters will be installed in the percolation area. Each leachate collection well cluster will provide the ability to collect leachate samples from three discrete depth intervals, approximately 5, 15, and 25 feet bgs (Figure 3). A vacuum will be applied to these leachate collection points if needed to acquire leachate samples (see Section 2.4 for a more complete description of the leachate sampling schedule and procedure).

Soil borings will be advanced to groundwater at three locations within the pilot test area (Figure 3). Soil samples will be collected at three depths (5, 15, and 25 feet bgs) from each of these borings to characterize the conditions of the test area before and after the test.

2.4 Pilot Test Monitoring Schedule

Monitoring included as part of the pilot test will occur before, during, and after flushing water is introduced to the system. This section describes the sampling schedule that will be performed to monitor the condition of the soil, groundwater, and leachate throughout the pilot study. A summary of this monitoring program is included as Table 2.

The water to be applied during the flushing test (Stabilized Lake Mead water) will be sampled prior to the start of the pilot test at a location near the pilot test area and analyzed per Table 3.

Groundwater levels and samples will be taken at each of the three new groundwater monitoring wells in advance of the pilot scale test, and monthly during and after the active flushing period of the pilot test. Four monthly groundwater samples will be taken and analyzed after the conclusion of the active flushing period of the test. All groundwater samples will be analyzed in accordance with Table 3.

Leachate collection points will be monitored in advance of the pilot scale test, and if sufficient volume has accumulated, a sample will be collected and analyzed for the parameters listed in Table 3. Leachate collection points will be monitored and samples collected every other week during, and after the active flushing period of the test. Leachate monitoring will continue for up to four weeks after flushing water has been shut off. If insufficient volume has accumulated in the leachate wells to permit collection of a sample for analysis, a vacuum will be applied to the leachate collection point for up to 24 hours in an attempt to collect a sample. At this point, if insufficient volume has been collected to perform a complete analysis of the leachate, the sample will be analyzed in accordance with the priorities listed in Table 3.

Prior to the conduction of the pilot test, soil borings will be advanced at three separate locations within the pilot test area, and three soil samples (5, 15, and 25 feet bgs) will be collected from each boring and analyzed for the parameters listed in Table 4. At the conclusion of the active flushing period, the soil will be allowed to drain for at least one week. After this, soil borings will be advanced as close as possible to the pre-test locations, and soil samples will again be collected from 5, 15, and 25 feet bgs at each location.

2.5 Design of Water Delivery System

It is planned to install a subsurface water delivery system for the pilot test area. A sketch of the proposed water delivery system is shown in Figure 4. The system is designed as a buried drip line system. A PVC header line will feed drip line laterals to distribute water over the lateral area of the pilot test. The header will be connected to a nearby pressurized source of Stabilized Lake Mead water. Above ground, the header line will include a check valve, a shutoff valve, vents to allow air into the drip system when it is

shutdown, a pressure indicator, a pressure regulator, and a flow indicator/totalizer. The header line will feed each of the drip line laterals, which will be buried 2 to 3 inches below ground surface to minimize evaporation.

It is planned to run these drip line laterals in parallel rows at 2 foot spacing and each drip line will have internal emitters every 18 inches along its length. A brief field test with samples of drip line will confirm that this spacing will provide uniform water coverage near the soil surface. Modifications to this spacing will be made if indicated by the field test.

The drip line system that has been selected is a product suitable for heavy duty buried agricultural service, Rainbird A5PC. This 18 mm drip line has self-regulating internal emitters that deliver a constant flow of 0.53 gallons per hour (gph) at anywhere between 7 and 60 pounds per square inch (psi), maximizing the uniformity of distribution along each run of drip line. In addition, this product has reduced variability in flow rate from emitter to emitter as compared to similar landscape drip lines. If this specified drip line material is unavailable in time to install in the open excavation, another drip line material may be substituted.

2.6 Sampling Procedures

2.6.1 Soil Sampling Procedures

Soil samples will be collected using the sonic drill rig employed during the capture zone evaluation drilling activities. 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).

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.

2.6.2 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).

2.7 Permitting

Tronox requests use of the State general Underground Injection Control (UIC) permit for the soil flushing pilot test. If modification to the water delivery system, leachate collection wells, monitoring wells, or other test conditions is necessitated by factors

identified in the field during the test, Tronox will submit the revisions of this work plan for NDEP approval before making the proposed changes.

3.0 PROPOSED PILOT TEST SCHEDULE

Work will start upon the approval of this work plan by the NDEP with permitting, pre-test sampling, and installation of the monitoring points and the flushing system. Active soil flushing, and post test soil/leachate sampling and analysis will require approximately three months. Groundwater monitoring and analysis will continue for four months after completion of the active flushing. In parallel with the final groundwater monitoring, a report of the findings from this pilot study will be prepared and submitted for NDEP review. A detailed schedule of planned activities will be submitted upon the approval of this work plan by NDEP.

4.0 FUTURE WORK

If the results of the pilot test are favorable, Tronox intends to utilize soil flushing technology to reduce the mass of perchlorate in additional areas of the Site. These areas may include soil greater than 4 feet bgs in RZ-B-20 and RZ-B-21 where excavation is infeasible due to buried utilities; excavation areas in RZ-C and/or RZ-D where perchlorate is the only contaminant above BCLs; and other soils where it is determined that soil flushing can effectively and efficiently remove perchlorate to levels agreed upon by NDEP and Tronox.

To accommodate an expected increase in the volume of water that would flow towards and be captured by the Interceptor Well Field, Tronox will evaluate options for expansion or reallocation of the capacity of the groundwater treatment plant. Alternate sources of flushing water, such as facility process water or effluent from the treatment system, will also be considered for full-scale flushing activities. Alternate sources of soil flushing water will be analyzed for all Site Chemicals of Potential Concern.

After completion of the initial pilot test, soil samples collected from the treated area will be used to determine the effectiveness of the pilot study. The results will be evaluated and presented in a technical memorandum, as well as, a feasibility study of remedial options to treat leachable chemicals in unsaturated zone soils.

5.0 REFERENCES

Basic Remediation Company (BRC), 2009a, BRC Standard Operation Procedure (SOP) 05, Water Sampling, Revision 4, December.

Basic Remediation Company (BRC), 2009b, BRC Standard Operation Procedure (SOP) 06, Sample Management and Shipping, Revision 4, December.

Basic Remediation Company (BRC), 2009d, BRC Standard Operation Procedure (SOP) 14, Field Documentation, Revision 4, December.

Basic Remediation Company (BRC), 2009e, BRC Standard Operation Procedure (SOP) 17, Soil Logging, Revision 4, December.

Basic Remediation Company (BRC), 2009f, BRC Standard Operation Procedure (SOP) 19, Borehole Abandonment, Revision 4, December.

Basic Remediation Company (BRC), 2009g, BRC Standard Operation Procedure (SOP) 21, MW Destruction, Revision 4, December.

Basic Remediation Company (BRC), 2009h, BRC Standard Operation Procedure (SOP) 23, Split Spoon Sampling, Revision 4, December.

Basic Remediation Company (BRC), 2009i, BRC Standard Operation Procedure (SOP) 31, Equipment Drilling Decon, Revision 4, December.

Basic Remediation Company (BRC), 2009j, BRC Standard Operation Procedure (SOP) 34, Investigative Derived Waste (IDW) Management, Revision 4, December.

Nevada Division of Environmental Protection, 2010, Nevada Division of Environmental Protection (NDEP) Response to: REVISED Work Plan to Evaluation In Situ Soil Flushing of Perchlorate Impacted Soil, 21 June.

Northgate Environmental Management, 2010a, REVISED Work Plan to Evaluate In Situ Soil Flushing of Perchlorate-Impacted Soil and Response to April 16, 2010 NDEP Comments on original work plan, dated March 29, 2010, 27 May.

TABLES

FIGURES

APPENDIX A
Report on Results of Column Study Tests