CAPTURE ZONE EVALUATION WORK PLAN

Tronox LLC

Henderson, Nevada

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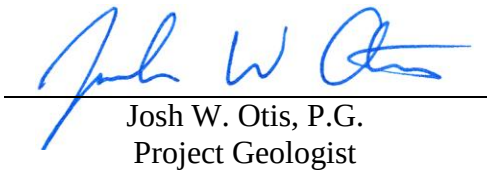

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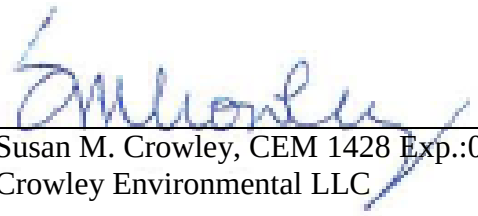
I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all 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 has been modified in response to the Nevada Division of Environmental Protection (NDEP) review comments provided in a March 8, 2010 letter. This document describes work to be performed in advance of a new stand-alone capture zone evaluation of the groundwater extraction and treatment system (GWETS) in accordance with the United States Environmental Protection Agency (USEPA) guidance document *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems* (USEPA, 2008). Although the Site has been well-characterized, Tronox recognizes that additional efforts need to be made to better evaluate the effectiveness of the GWETS and the capture zone(s) at the Site. The purpose of the scope of work proposed herein is three-fold:

- Update and improve the existing GWETS, including replacement or re-establishment of missing, damaged, and/or covered piezometers/monitoring wells, and connection of existing but unused recovery wells;
- Address remaining data gaps identified by Northgate in *Interim Groundwater Capture Evaluation and Vertical Delineation Report* dated December 23, 2009, and by NDEP in their January 26, 2010 comments on the Northgate report; and
- Evaluate and improve groundwater remediation by collecting additional data for use in the capture zone evaluation, re-evaluating capture incorporating the new data and using the USEPA 2008 guidance, and developing a three-dimensional groundwater flow model for use in evaluating capture and other remediation optimization activities.

Tasks proposed to address specific data gaps identified in the January 2010 NDEP comments are noted as such in this work plan. As required by NDEP, a revised version of *Interim Groundwater Capture Evaluation and Vertical Delineation Report* addressing NDEP comments, and formal responses to all comments was submitted on March 23, 2010. The stand-alone capture zone evaluation, incorporating the results of the scope of work outlined in this work plan, will be submitted by December 3, 2010.

1.1 Description of Groundwater Operations

Tronox operates three primary groundwater containment and extraction systems associated with its Henderson Facility in accordance with the Consent Order for remediation of chromium-impacted groundwater at the Henderson facility, finalized September 9, 1986, and the Administrative Order on Consent (AOC) for remediation of perchlorate-impacted groundwater in the Henderson area, finalized October 8, 2001. The locations of groundwater containment and extraction systems are

shown in Figure 1. In addition to chromium and perchlorate, the recent Phase B Investigation identified several other chemicals (i.e., metals, ammonia, cyanide, 4-chlorobenzenesulfonic acid, organochlorine pesticides, volatile and semi-volatile organic compounds) that impact groundwater quality at the Site. Northgate will consider these other chemicals as part of the assessment of groundwater capture and treatment. The three groundwater containment and extraction systems associated with the facility are:

On-Site Barrier Wall and Interceptor Well Field (IWF; Figure 2): A bentonite-slurry wall was constructed as a physical barrier across the higher concentration portion of the perchlorate/chromium plume on the Tronox site in 2001. The barrier wall is approximately 1,600 feet in length and 60 feet deep. The bottom of the barrier wall was constructed to tie into approximately 30 feet of Upper Muddy Creek formation (UMCf). There is a series of 23 groundwater extraction wells that are situated due south (upgradient) of the barrier wall. In December 2009, this upgradient well field pumped about 73 gallons per minute (gpm), dewatering the Quaternary alluvium (Qal) and the upper portion of the UMCf in the vicinity of the pumping wells. Most of the wells comprising the IWF are completed in both the Qal and unconfined portions of the upper fine-grained UMCf. North of the well field and barrier wall, the groundwater is artificially recharged with clean (less than 5 ppb perchlorate) Lake Mead water that is introduced into gravel-filled trenches to balance the loss of groundwater removed from the alluvium and Muddy Creek formations by the IWF.

Athens Road Well Field (ARWF; Figure 3): Located approximately 8,200 feet north (downgradient) of the barrier wall and the IWF, the ARWF includes a series of 14 groundwater extraction wells screened in the Qal at seven paired well locations. The pairs act as "buddy" wells with one pumping while the "buddy" well serves as a piezometer to monitor the impacts of pumping on the water levels adjacent to the well. The wells span roughly 1,200 feet of the Qal paleochannel. In December 2009, the ARWF pumped at a combined rate of about 256 gpm.

Seep Area Collection System (Figure 4): Located near the Las Vegas Wash, approximately 4,500 feet north (downgradient) of the Athens Road Well Field, the Seep area system includes a surface capture pump for the intermittent surface stream (Seep) flow and 10 groundwater extraction wells in the Seep well field to capture subsurface flow. The surface stream has not flowed since April 2007. The wells comprising the Seep Well Field (SWF) are completed in the Qal across the deepest portion of a buried paleochannel. In December 2009, the SWF pumped at a combined rate of about 580 gpm.

All groundwater from the hydraulic containment systems is routed for treatment to the Tronox facility and, following treatment, is discharged to the Las Vegas Wash under a National Pollution Discharge Elimination System (NPDES) permit.

2.0 SCOPE OF WORK

The scope of work for the capture zone evaluation and related activities is presented below. Proposed and existing well locations discussed for the Interceptor, Athens Road, and Seep Well Fields are shown in Figures 2, 3, and 4, respectively.

2.1 Maintenance and Improvement of GWETS

Several tasks are proposed to maintain and improve the current GWETS. As detailed below, these tasks include restoring 16 piezometers and monitoring wells that have become covered and/or damaged. Northgate plans to locate these wells using the surveyed location coordinates and GPS techniques, uncover them, and evaluate their condition. Wells that can be located and accessed will either be replaced, which includes proper abandonment of the existing well and replacement with a similarly constructed adjacent well, or re-established, which may include wellhead repairs. Wells that cannot be located and/or accessed will be replaced with new wells at nearby locations that are both readily accessible and that will provide useful data. Each well that is replaced or repaired will be surveyed for x-y coordinates and top-of-casing elevation. All new wells will be drilled using sonic methods. Well installation and destruction will be in accordance with the Nevada Division of Water Resources NAC 534 well regulations.

Northgate plans to perform the following field activities in the IWF:

- Install two new Shallow Zone recovery wells south of the barrier wall at the east Site property boundary (Figure 2). The purpose of these wells is to improve containment of that portion of the contaminant plume that may be susceptible to flow around the east end of the barrier wall in the Qal. The wells will extend to a total depth of approximately 40-45 feet below ground surface (bgs) and will terminate approximately 5 feet past the Qal/UMCf interface. These wells will be screened across the Qal, and the bottom 5 feet of the well will be completed with blank casing to serve as a sump;
- Replace damaged well M-61, a monitoring well located on the east end of the barrier wall;
- Install a new electrical cable and control panel to provide power to the additional recovery wells *(Addresses NDEP 1/26/10 comment 6.a.i)*;
- Connect recovery wells I-AA, I-AB, I-W, I-X, and I-Y to the extraction system to remove additional mass, and improve groundwater capture *(Addresses NDEP 1/26/10 comments 6.b.i, 6.b.ii, and 6.b.iii)*;
- Replace M-83, M-84, and M-85 recharge trench monitoring wells that were damaged as a result of the refurbishment of the groundwater recharge trenches; and

- Re-establish or replace damaged site-wide monitoring network wells M-48 and M-77. The locations of these wells are shown in Figure 1.

Northgate plans to perform the following field activities in the ARWF (Figure 3):

- Re-establish or replace piezometer/wells ARP-2A, ARP-3A, PC-134, PC-135, PC-136, and PC-137. Northgate is in the process of field-checking the physical locations and accessibility of these piezometers and wells, and locations of structures and other physical constraints. Piezometers and wells that cannot be re-established will be replaced. Replacement piezometers and wells will be placed at locations that are both accessible and optimal for plume monitoring. NDEP will be notified of the proposed location changes. The ARP wells are used to monitor ground water levels and downgradient contaminant concentrations. The PC wells provide data regarding vertical gradients and contaminant concentrations in the UMCf *(Addresses NDEP 1/26/10 comment 24)*;
- Replace recovery well ART-7 with a deeper well that extends to the Qal/UMCf interface. The modified recovery well (ART-7B) will be fully screened in the Qal, including the zone of caliche. Northgate estimates this will require drilling an additional 5-8 feet through the caliche zone to the top of UMCf. Existing well ART-7 will be converted to a monitoring well;
- Re-establish damaged and/or buried monitoring wells PC-12 and PC-17 and former recovery well ART-5 if possible, or replace with new wells at nearby locations to be determined based on accessibility; and
- Increase ARWF pumping rates to improve capture and achieve inward flow by extracting from the new deeper recovery well, ART-7B, and increasing pumping rates in existing wells as is feasible.

2.2 Remaining Data Gaps

Northgate plans to perform the following activities in the IWF and ARWF to address remaining data gaps:

- Evaluate Barrier Wall Effectiveness *(Addresses NDEP 1/26/10 comments 6.a.i, 6.a.ii, 6.a.iii, 6.a.iv, and 9)*: To confirm the effectiveness of the barrier wall, Northgate plans to install four new four-inch diameter wells in the "dead zone" between the barrier wall and the recharge trenches (Figure 5). Pumps will be installed in these new wells and they will be plumbed to the GWETS. It is planned that these wells will be pumped for three months while water quality and water levels are monitored in these wells and in nearby wells M-69 through M-72. Pumping may be extended for a longer period based on water quality and production rates. When pumping is stopped, water level recovery and water quality will be monitored and evaluated for evidence of barrier wall leakage.

In addition to pumping and monitoring these wells immediately downgradient of the barrier wall, Northgate proposes to pothole the area in the immediate vicinity of the barrier wall using a backhoe to expose the trench ends and barrier top at several locations along the length of the wall. The location of the wall will be mapped using GPS surveying techniques, and the barrier, where exposed by potholing, will be photographed. Physical markers will be installed at each end of the wall during this investigation.

Northgate also plans to collect samples of the barrier wall material, if possible, to be used for lab testing of its permeability. This testing will involve: 1) re-saturation of the material until it meets the original barrier wall slump test specifications; 2) re-molding of the re-saturated material; and, 3) laboratory permeability testing using ASTM Method D5084.

- Evaluate the IWF Upper Muddy Creek formation *(Addresses NDEP 1/26/10 comment 23)*: Install 15 additional monitoring wells screened only in the UMCf to further evaluate the lateral and vertical extent of contamination in the UMCf in the central, eastern and western portions at and upgradient of the IWF (Figures 2 and 5). These wells will also provide additional hydrogeologic and chemical data for capture zone evaluation.

  One of the new UMCf wells will be installed on the east side of the IWF adjacent to M-132 and M-133 to form a well triplet with these two existing wells. The existing wells are screened from 60 to 70 feet bgs (M-132) and 80 to 90 feet bgs (M-133). The new well will be approximately 110 feet deep and will be screened at the bottom 10 feet.

  Three of the new UMCf wells will form a new well triplet in the middle of the IWF (roughly equidistant from each end of barrier wall) (Figure 2). This new well triplet will have respective well depths of approximately 70 feet, 90 feet, and 110 feet. The bottom 10 feet of each well will be screened.

  One of the new UMCf wells will be installed adjacent to M-134 and M-136 on the west side of the IWF (Figure 2) to form a triplet for vertical gradient assessment and to further delineate the vertical extent of contamination. Well M-134 is screened from 60 to 70 feet bgs, and well M-136 is screened from 80 to 90 feet bgs. This additional well will be approximately 110 feet bgs and will be screened in the bottom 10 feet.

  Two of the new UMCf wells will be installed approximately 400 feet west of M-134 and M-136 to delineate the vertical extent of contamination on the western site boundary. These two wells will have total approximate depths of 50 feet and 70 feet, respectively (shallower than UMCf wells to east but still screened in only UMCf), and will be screened in the bottom 10 feet. The shallower planned depths of these two new wells are based on site lithologic data, which indicate that the Qal is thinner to the west of wells M-134 and M-136 and therefore the UMCf will be encountered much shallower.

  Six new UMCf wells will be installed to delineate the vertical distribution and extent of perchlorate along the eastern Site boundary. One cluster of two UMCf wells will be installed approximately 300 feet south of the more southern of the two proposed Shallow Zone extraction wells at the east end of the barrier wall (Figure 5), with approximate

screened intervals of 60 to 70 feet bgs, and 110 to 120 feet bgs. A second cluster of three wells will be located approximately 300 feet south of the first cluster (Figure 5), near TIMET well CLD4-R, and the wells will be screened from approximately 60 to 70 feet bgs, 110 to 120 feet bgs, and 160 to 170 feet bgs. The sixth well will be advanced adjacent to existing well M-148 (Figure 5), with an approximate screen depth of 110 to 120 feet bgs. These anticipated screened intervals are based on the observed distribution of perchlorate and of sandier intervals in the UMCf with depth at the Site and neighboring TIMET site, and may be modified in the field. Screened intervals will be selected to provide a depth profile and to incorporate any sandier layers at depths where significant perchlorate was detected on the neighboring TIMET site (TIMET, 2008).

A new pair of UMCf wells will also be installed to complete a west-to-east UMCf delineation transect upgradient of the IWF. Two new wells are proposed approximately 1,000 feet west of existing wells M-149 and M-153 (Figure 5), with anticipated screened intervals of 110 to 120 feet bgs for the shallower well and 160 to 170 feet bgs for the deeper well.

- Monitor ARWF UMCf High *(Addresses NDEP 1/26/10 comment 22)*: Install two monitoring wells within the UMCf high (Figure 3). Continuous core samples will be collected during the drilling of these two wells, and the core will be stored and saved in core boxes. The wells will be screened in the UMCf and will be used to measure the potentiometric surface and to monitor for the presence of contaminants within the UMCf high. These wells will be approximately 50 feet deep and will extend an expected 25 feet into the UMCf. A 20-foot screened interval will be placed 5 feet above the bottom of each of these wells, and the bottom 5 feet will be blank casing. Northgate will construct the wells with 6-inch diameter casing such that conversion to extraction wells in the future will be possible, if warranted.

2.3 Capture Zone Analysis and Groundwater Extraction Optimization

The primary objective of the work being performed is to evaluate the capture zones of the GWETS consistent with the EPA 2008 guidance document *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems.* An additional objective is to develop evaluation tools that can be used in the future for optimizing groundwater remediation and predicting transport pathways. Towards these objectives, Northgate plans to perform the additional field activities and additional evaluations and investigations presented in Sections 2.3.1 and 2.3.2, respectively.

2.3.1 Field Activities

Northgate plans to perform the following field activities in support of the capture zone and related evaluations:

- Install up to 22 new Shallow Zone piezometers adjacent to the IWF recovery wells (Figure 2) for potentiometric data that will be incorporated into the capture zone evaluation. Depending on location, these piezometers will be screened either in the bottom 15 feet of the Qal or across the Qal/UMCf contact with a maximum screen length of 20 feet;
- Install two additional monitoring wells east of, and two additional monitoring wells west of, the existing ARWF wells to further define the width of the contaminant plume in this area (Figure 3). Northgate is in the process of field-checking access for these wells. The two wells at the east end will be extended to the Qal/UMCf interface and screened over the bottom 15 feet of Qal. To evaluate potential perchlorate stratification in the thicker Qal channel at the west end, these two wells will be installed as a pair, with one well screened in the upper 10 feet of saturated alluvium and the other screened in the bottom 10 feet of alluvium;
- Install two additional monitoring wells between the ARWF and the ARP-series monitoring wells, north of ART-3 and ART-9 (Figure 3), and one new well between ART-4 and the UMCf high, to further define the potentiometric surface contours mapped around the well field;
- Install three additional monitoring wells in the SWF near recovery wells PC-117, PC-118, and PC-133 (Figure 4). The installation of these three additional wells was originally proposed in the *Revised Work Plan to Evaluate Effective Groundwater Capture* dated August 27, 2007; however, they were not installed because of access issues. These new wells will provide potentiometric data to improve the understanding of groundwater flow in this area. These wells will be installed to the Qal/UMCf interface (approximately 40 feet to 60 feet bgs) and will be screened in the Qal. Northgate will seek to obtain permission from BMI to access the SWF to perform remedial activities, including the installation of these piezometers. If Northgate encounters difficulties obtaining access, we will immediately notify NDEP and ask for assistance from NDEP; and,
- Perform slug testing using up to six wells screened only in the UMCf to develop current, site-specific horizontal hydraulic conductivity estimates for the UMCf. The wells to be tested will be selected from the well triplets described in Section 2.2 above. Slug tests will be conducted in triplicate for each well, and both "slug-in" and "slug-out" water level response will be monitored and evaluated. Selected soil core samples from the borings for the new triplet wells will also be analyzed for soil properties, including vertical hydraulic conductivity following the ASTM D5084 method for falling head. These data will be used in predicting flow paths and travel times from the UMCf into the Qal, as described in Section 2.3.2 below.

2.3.2 Additional Evaluations and Investigations

Northgate plans to use existing Site data and the new data collected, as described in this work plan, to revise the Site capture zone evaluation following the 2008 USEPA guidance. An early step in

this evaluation will be to clearly define the target capture zones based on geometry and concentrations, with input from NDEP.

Northgate will use the new water level and flow data generated from the work described in this work plan in conjunction with existing data to refine previous evaluations of groundwater flow directions and gradient magnitudes at the Site (Step 3 in the 2008 EPA guidance). To support the capture zone evaluation, Northgate plans to construct a three-dimensional hydrogeologic model (Step 4 in the 2008 EPA guidance) encompassing all three well fields. The model will use site-specific hydrogeologic data and nearby data from the BMI site, where significant data have recently been developed pertaining to vertical hydraulic connectivity, residence time, and flow velocity. The McGinley and Associates (2007) numerical groundwater model constructed for the ARWF may be used as a starting point for this new model. In developing the new model, Northgate will consider and address to the extent practical the limitations identified in the McGinley model, calibrate the model with Site data, and conduct thorough sensitivity analyses.

In addition to supporting the capture zone analysis, this new model will also be used for well-field operational optimization, predicting transport times, and other purposes. Two specific evaluations for which Northgate plans to use the three-dimensional model are: 1) pumping evaluation in the IWF to optimize capture and mass removal in this area; and, 2) calculation of expected travel times and paths for flow of perchlorate-impacted groundwater from the UMCf into the Qal.

3.0 SCHEDULE

The currently proposed schedule for the work described in this Work Plan is presented as Figure 6. In addition, Tronox will submit monthly status memoranda including an updated schedule to provide NDEP with preliminary maps and data for newly installed piezometers/wells as this information becomes available. Updates for the previous month will be submitted to NDEP by the 5th of the following month.

4.0 REFERENCES

NDEP 2010, *Comments on the Interim Groundwater Capture Evaluation and Vertical Delineation Report*, dated December 23, 2009: Nevada Division of Environmental Protection, Las Vegas, Nevada, January 26, 2010.

MCGINLEY 2007, *Athens Road Well Field Modeling Report – Near BMI Industrial Complex, Henderson, Nevada*: McGinley and Associates, Reno, Nevada, June 30, 2007.

NORTHGATE 2007, *Revised Work Plan to Evaluate Effective Groundwater Capture at Tronox Extraction Systems, Tronox LLC, Henderson, Nevada*: Northgate Environmental Management, Inc., Oakland, California, August 27, 2007.

NORTHGATE 2009, *Interim Groundwater Capture Evaluation and Vertical Delineation Report, Tronox LLC, Henderson, Nevada*: Northgate Environmental Management, Inc., Oakland, California, December 23, 2009. Titanium Metals Corporation (TIMET), 2008, Remedial Alternatives Study First Water Bearing Zone, Titanium Metals Corporation Facility, September 15, 2008.

USEPA 2008, *A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems*: U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-08/003, 2008.

FIGURES

APPENDIX A
RESPONSE TO COMMENTS