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**To:** Shannon Harbour, PE  
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**RE:** Revised Technical Memorandum: Calculation of Leaching-Based, Site-Specific Levels (LSSLs) for the Soil-to-Groundwater Pathway Using NDEP Guidance, Tronox LLC, Henderson, Nevada

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## INTRODUCTION

This revised technical memorandum provides a screening evaluation of the potential for leaching of site-related chemicals (SRCs) from soil to groundwater at the Tronox facility in Henderson, Nevada (the Site). The evaluation uses the methods presented in the *Soil to Groundwater Leaching Guidance* from the Nevada Division of Environmental Protection (NDEP), dated January 16, 2010 (guidance). This screening evaluation of leaching from soil to groundwater was conducted as discussed in telephone conversations between representatives of Tronox, Northgate, and NDEP on February 12, 17, and 23, 2010. Additional discussions were held with NDEP and Paul Hackenberry of Paul Hackenberry & Associates on April 8 and July 16, 2010 regarding methods for estimation of infiltration rates for developed land. The purpose of this leaching evaluation is to identify chemicals of potential concern (COPCs) that have the potential to leach from unsaturated soil into shallow groundwater at the Site. Upon NDEP's review and concurrence with the evaluation, source control measures for leaching concerns will be addressed using remedial alternatives appropriate for the COPC.

On March 8, June 11, and August 23, 2010, Northgate submitted technical memoranda to NDEP presenting preliminary screening evaluations of the potential for SRCs to leach from soil to groundwater (Northgate, 2010a, 2010d, and 2010g). NDEP provided comments on these technical memoranda on March 29, 2010 and July 6, 2010 (NDEP, 2010b and 2010c; Attachment 1). On July 22, 2010, Northgate submitted a technical memorandum to NDEP presenting background comparisons for metals in Remediation Zones B through E (RZ-B through RZ-E), using Remediation Zone A (RZ-A) as the

background data set. NDEP provided comments on the July 22 background technical memorandum in a letter dated August 9, 2010, which was partially superseded by comments regarding background issues in a letter from NDEP dated August 17, 2010. A revised memorandum dated September 9, 2010 comprehensively addressed NDEP's comments on the March 8 and June 11 leaching evaluations, as well as NDEP's comments on the July 22 background evaluation. The September 9, 2010 memorandum was conditionally accepted with comments in a letter from NDEP dated October 12, 2010. This memorandum has been revised to address NDEP's October 12 comments. Tronox's responses to NDEP's comments are presented in Attachment 1.

## **SCREENING EVALUATION BASED ON NDEP GUIDANCE**

The guidance outlines the following progression of steps for evaluation of the soil-to-groundwater leaching pathway:

- 1 Comparison of Site soil concentration data with leaching-based, basic comparison levels (LBCLs), which are calculated using generic default values as input parameters for the soil-water partitioning (SWP) equation;
- 2 Comparison of Site soil concentration data with leaching-based, Site-specific levels (LSSLs), which are calculated using Site-specific chemical and soil properties in the SWP equation;
- 3 Unsaturated zone fate-and-transport modeling, employing Site-specific data; and
- 4 Synthetic precipitation leaching procedure (SPLP; U.S. EPA, 1994) testing, as required to support either the SWP equation or unsaturated zone fate-and-transport modeling.

This memorandum presents the results of the first two of these steps used to evaluate COPCs for the soil leaching to groundwater pathway. The methods for selection of organic and inorganic COPCs for the leaching evaluation are described in detail in Attachments 2 and 3.

## **METHODS USED TO SELECT CHEMICALS OF POTENTIAL CONCERN FOR THE LEACHING EVALUATION**

The data set evaluated for leaching in RZ-B through RZ-E includes Phase A and Phase B samples collected from the Quaternary alluvium (Qal) between the ground surface and the contact with the Upper Muddy Creek formation (UMCf).

As an initial step and in accordance with previous discussions and correspondence with NDEP, Site soil concentrations of metals were initially screened by comparison with the



background dataset (RZ-A) approved by NDEP to select chemicals for further evaluation. Methods and results of the background metal evaluation are provided in Attachment 2.

Metals retained for further evaluation, as well as organics, were then evaluated in accordance with NDEP guidance by comparing Site soil concentration data with LBCLs (NDEP, 2009). For chemicals without established LBCLs, generic LBCLs were calculated using default values as input parameters for the soil-water partitioning (SWP) equation (Attachment 3). Some LBCLs were adjusted based on the hierarchy of risk-based groundwater concentrations (RBGCs) approved by NDEP for this project.<sup>1</sup> Attachment 3 describes in detail the parameters and methods used to calculate generic and adjusted LBCLs. COPCs that did not exceed LBCLs using a dilution attenuation factor (DAF) of 20 were not carried forward for further analysis. However, the screening tables also include comparisons of Site soil concentration data with LBCLs for DAF=1, in accordance with the guidance.

The selection of COPCs for inorganic and organic chemicals is summarized below. Inorganic chemicals selected as COPCs are summarized by RZ area and depth, to be consistent with the background comparisons in Attachment 2. Organic COPCs are selected based on a Site-wide comparison of soil concentrations with LBCLs for RZ-A through RZ-E, and are summarized following the inorganic COPCs.

### **Inorganic Chemicals Selected as COPCs for Leaching Evaluation**

Inorganic COPCs for RZ-B through RZ-E were selected using the steps described in Attachment 2. The depth intervals for screening of inorganic COPCs are based on the statistical background comparisons presented in Attachment 2. The selection of COPCs for the leaching evaluation is summarized in Attachment 2, Tables 4A through 4D.

Perchlorate was selected as a COPC in all RZs for all depth intervals in the Qal, based on perchlorate's exceedance of the calculated generic LBCL for a dilution attenuation factor (DAF) of 20, as described in Attachment 3.

In addition to perchlorate, the inorganic COPCs for each RZ are the following:

- Antimony: RZ-C (0-10 feet below ground surface [fbgs]); RZ-E (0-10 fbgs)

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<sup>1</sup> In accordance with minutes of the meetings with NDEP on February 12 and 17, 2010, the following hierarchy was used for RBGCs: 1) primary Maximum Contaminant Levels (MCLs); 2) BCLs; and 3) secondary MCLs.



- Arsenic: RZ-B (0-2 fbgs, 2-10 fbgs); RZ-C (0-2 fbgs); RZ-E (0-2 fbgs)
- Barium: RZ-C (0-10 fbgs); RZ-D (0-10 fbgs)
- Boron: RZ-C (0-10 fbgs); RZ-D (0-10 fbgs)
- Chromium (total): RZ-C (0-2 fbgs); RZ-D (0-2 fbgs); RZ-E (0-2 fbgs)
- Chromium (VI): RZ-C (0-10 fbgs, 10 fbgs to UMCf)
- Cobalt: RZ-C (0-10 fbgs, 10 fbgs to UMCf); RZ-E (0-10 fbgs)
- Lead: RZ-C (0-10 fbgs); RZ-E (0-10 fbgs)
- Magnesium: RZ-B (10 fbgs to UMCf); RZ-C (0-2 fbgs); RZ-D (0-2 fbgs); RZ-E (0-2 fbgs)
- Manganese: RZ-B (0-10 fbgs); RZ-C (0-10 fbgs, 10 fbgs to UMCf); RZ-D (0-10 fbgs); RZ-E (0-10 fbgs)
- Molybdenum: RZ-C (0-2 fbgs)
- Thallium: RZ-C (0-10 fbgs)

#### **Organic Chemicals Selected as COPCs for Leaching Evaluation**

Organic COPCs were selected by screening Site-wide (RZ-A through RZ-E) soil concentrations against LBCLs for DAFs of 1 and 20 (Attachment 2, Table 3). The following organic COPCs exceeded LBCLs for DAF=20, and were retained for further evaluation of their leaching potential:

**Organochlorine Pesticides (OCPs):** 4,4'-DDE, 4,4'-DDT, Aldrin, alpha-, beta-, and gamma BHC (Lindane), and Dieldrin.

**Semivolatile Organic Compounds (SVOCs):** Benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, hexachlorobenzene, and indeno(1,2,3-cd)pyrene.

**Volatile Organic Compounds (VOCs):** 1,1-Dichloroethene (1,1-DCE), 1,2-dichloroethane (1,2-DCA), acetone, 1,2,3-trichloropropane, benzene, bromoform, carbon tetrachloride, chloroform, dibromochloromethane, hexachlorobutadiene, 1,2,4-trichlorobenzene, methylene chloride, tetrachloroethene (PCE), and trichloroethene (TCE).



## **CALCULATION OF LEACHING-BASED, SITE-SPECIFIC LEVELS AND SCREENING OF SITE SOIL DATA**

Attachment 3 describes in detail the parameters and methods used to calculate LSSLs. LSSLs for chemicals present above LBCLs were calculated using the SWP equation presented in the guidance, with Site-specific soil physical properties and chemical-specific DAFs. The DAFs, in turn, are based on hydrogeologic properties and the length of the chemical source ( $L$ ) in the unsaturated zone. To determine the source lengths, we used the LBCL for DAF=20 to define the extent of source areas for each COPC. As shown on Tables 4A and 4B of Attachment 3, with the exception of perchlorate, the DAFs for inorganics and organics ranged from approximately 30 to over 700 when calculated using this definition of source length. These DAFs were then used to calculate LSSLs in the SWP equation, as detailed in Attachment 3.

Tables 1A-D and 2A-E provide tabulated results of the comparison of Site soil concentrations with LBCLs and LSSLs for inorganic and organic COPCs, respectively, for each RZ area. These tables show the number of samples containing chemicals at concentrations exceeding the LBCLs and LSSLs. For the inorganic chemicals, the screening of chemicals is carried out for the same depth intervals that were determined for the statistical background comparison (Tables 1A-D and Attachment 2).

In addition to perchlorate, the following COPCs were detected in Site soils at concentrations above their respective LSSLs, as shown in Tables 1A-D and 2A-E:

### **COPCs Exceeding LSSLs in RZ-A**

- Inorganics: None
- Organics: Beta-BHC

### **COPCs Exceeding LSSLs in RZ-B**

- Inorganics (0-2 feet bgs): Arsenic
- Organics: Alpha- and beta-BHC<sup>2</sup>

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<sup>2</sup> Chloroform did not exceed the LBCL for DAF=20, but 2 soil samples in RZ-B and 7 soil samples in RZ-D contained chloroform at concentrations greater than the LSSL. The LSSL is less than the LBCL for chloroform because the target risk-based groundwater concentration (RBGC) used to calculate the LSSL (0.0016 milligrams per liter [mg/L]) is less than the RBGC used to calculate the LBCL (0.1 mg/L).



### **COPCs Exceeding LSSLs in RZ-C**

- Inorganics (0-2 feet bgs): arsenic and magnesium
- Inorganics (0-10 feet bgs): cobalt and manganese
- Inorganics (>10 feet bgs to UMCf): cobalt and manganese
- Organics: Alpha- and beta-BHC, hexachlorobenzene, and chloroform

### **COPCs Exceeding LSSLs in RZ-D**

- Inorganics (0-2 feet bgs): magnesium
- Inorganics (0-10 feet bgs): manganese
- Organics: Alpha-, beta-, and gamma-BHC (Lindane) and hexachlorobenzene

### **COPCs Exceeding LSSLs in RZ-E**

- Inorganics (0-2 feet bgs): arsenic
- Inorganics (0-10 feet bgs): manganese
- Organics: Alpha- and beta-BHC, Dieldrin, and chloroform

## **SUMMARY AND CONCLUSIONS**

Inorganic chemicals for the leaching evaluation for each RZ were identified by comparing Site soil concentration data to the RZ-A background dataset approved by NDEP in their August 17, 2010 letter. After the background comparison was completed, inorganic and organic COPCs were selected by comparison to LBCLs for DAF=1 and DAF=20. LSSLs were then calculated for each COPC using methods and procedures described in NDEP's January 16, 2010 guidance and in accordance with discussions and correspondence with NDEP. For each COPC and RZ, the number of Phase A and B soil samples that exceed the LSSLs are tabulated in Tables 1A-1D and 2A-2E. Upon NDEP's review and concurrence with the LSSLs, source control measures for leaching concerns will be addressed using remedial alternatives appropriate for the COPC (in addition to mass removal based on BCLs, technologies under consideration include soil flushing, in-situ bioremediation, and monitored natural attenuation).

## **REFERENCES**

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## **ENCLOSURES**

### **Tables**

- 1A Screening of Inorganic Chemicals in RZ-B Using LBCLs and LSSLs
- 1B Screening of Inorganic Chemicals in RZ-C Using LBCLs and LSSLs
- 1C Screening of Inorganic Chemicals in RZ-D Using LBCLs and LSSLs
- 1D Screening of Inorganic Chemicals in RZ-E Using LBCLs and LSSLs
- 2A Screening of Organic Chemicals in RZ-A Using LBCLs and LSSLs
- 2B Screening of Organic Chemicals in RZ-B Using LBCLs and LSSLs
- 2C Screening of Organic Chemicals in RZ-C Using LBCLs and LSSLs
- 2D Screening of Organic Chemicals in RZ-D Using LBCLs and LSSLs
- 2E Screening of Organic Chemicals in RZ-E Using LBCLs and LSSLs

### **Figures**

- 1 Remediation Zones

### **Attachments**

- 1 NDEP Correspondence and Responses to NDEP Comments
- 2 Background Comparison and Screening for Chemicals of Potential Concern (COPCs) for the Soil-to-Groundwater Leaching Pathway
- 3 Input Parameters

