northgate
environmental management, inc.

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To: Shannon Harbour, P.E.
Nevada Division of Environmental Protection

RE: Revised Engineering Evaluation of Slope Stability, WC and GW-11 Pond Embankments
Phase B Soil Remediation of RZ-D, Tronox LLC, Henderson, Nevada

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Introduction

Northgate Environmental Management, Inc. (Northgate) submits this revised memorandum on behalf of Tronox LLC, presenting the results of Northgate's engineering evaluation of the slope stability of the WC and GW-11 Pond embankments for the *Phase B Soil Remediation of RZ-D* (see Figure 1, Site Location Map). Northgate previously submitted the original Slope Stability Memorandum, dated August 23, 2010. Based on comments from NDEP, field exploration work was performed and the stability of the embankments was reanalyzed. The results of the analyses indicate that the factors of safety for static and seismic loading conditions are in the acceptable range without setbacks if the excavation slopes are constructed at 3 horizontal to 1 vertical.

Historical Geotechnical Data and Field Exploration

A significant number of laboratory classification data reports are available for the Site soils. Tests performed include grain size analyses, specific gravity, porosity, bulk density, hydraulic conductivity, and permeability. The grain size analyses indicate that the Site soils are primarily granular in nature and would generally be characterized as sand and gravel mixtures with traces of silt and clay. One sample of the soil was found to be fine sand and one sample was classified as silt.

Because no data was available for soil density, soil strength and documentation on construction, Northgate selected Cone Penetrometer Testing (CPT) as the method to supplement the classification data for use in assessing slope stability. Advantages of the CPT exploration method are:

- CPT testing is an in situ method that gives reliable data for the in-place soil;
- CPT eliminates the issues surrounding sample disturbance of sandy and gravelly soils which normally occurs during conventional sampling;
- CPT eliminates the need to establish in-place field densities for use in fabricating samples for laboratory testing;

- CPT eliminates the need for fabrication of laboratory samples and laboratory testing programs;
- CPT provides continuous data with depth which allows for assessment of soil layering and associated classification and engineering characteristics in the fill and native materials; and
- CPT provides timely results including classification, density, and strength.

CPT exploration work was performed on October 4, 2010 at three locations on the pond embankments. Location PSS-1 is located in the central portion of the southern WC Pond embankment, PSS-2 is located in the central eastern portion of the GW-11 Pond embankment, and PSS-3 is located in the northern portion of the western GW-11 Pond embankment. The exploratory locations are shown on Figure 2. CPT Locations PSS-2 and PSS-3 were pushed to depths of 28 and 26 feet, respectively. At these depths the embankment materials and the foundation materials were fully characterized. At location PSS-1, the CPT reached early refusal and only limited data was obtained. PSS-1 was also the location of the dilatometer testing which also reached early refusal. The data from the two successful CPT borings were used in the stability analysis for the PSS-1 location.

The CPT data are presented in Attachment 1 to this memorandum. As shown in the data, the soil strengths exceed normally expected strengths for sand and silty sand. Northgate consulted with Mr. Umesh Bachu, the president of U.S. operations and lead technical leader of Lankelma (the company that performed the CPT work). Mr. Bachu explained that the CPT correlations for strength are based on recently placed or “young” materials and often aged and /or partially cemented materials give very high results. He stated that in his work on assessing levee stability throughout the United States, he applies a reduction factor of 10 degrees on very high strengths. He also stated that he limits the maximum strength for granular soils to a phi angle of 35 degrees. The maximum strength obtained by the CPT at Tronox is 48 degrees. Based on the above recommendations from Lankelma, Northgate selected 38 degrees as the maximum strength and used similar reductions for the similarly high strengths less than 48 degrees.

Stability Analyses

Three locations were selected as representative of the steeper portions of the GW-11 Pond and WC Ponds (see Figure 2). Cross-sections were drawn through these locations and were used to model the Site surface and subsurface conditions in the slope stability analyses. STABL software was utilized for the analyses. STABL uses the PCSTABL slope stability analysis program from Purdue University. It allows calculations using Bishop’s Simplified Method, Spencer’s Method, as well as other methods. Both Bishop’s Modified Method and Spencer’s Method were utilized in these analyses.

Eight cases were selected for analysis. The cases are as follows:

1. WC pond configuration with slope of the existing embankment (2 horizontal on 1 vertical) extending to the design excavation depths of 14 feet without setback from the embankment;
2. WC pond configuration with slope of the existing embankment (2 horizontal on 1 vertical) extending to the design excavation depths of 14 feet without setback from the embankment including using a pseudo-static coefficient of 0.15g to account for seismic loading;
3. WC pond configuration with the subsurface cut slope at an inclination of 3 horizontal on 1 vertical extending to the design excavation depths of 14 feet without setback from the embankment;
4. WC pond configuration with the subsurface cut slope at an inclination of 3 horizontal on 1 vertical extending to the design excavation depths of 14 feet without setback from the embankment including using a pseudo-static coefficient of 0.15g to account for seismic loading;
5. GW-11 pond configuration of the eastern slope with the slope of the existing embankment (3 horizontal on 1 vertical) extending to the design depth of the excavation without setback from the embankment;
6. GW-11 pond configuration of the eastern slope with the slope of the existing embankment extending to the design depth of the excavation without setback from the embankment including using a pseudo-static coefficient of 0.15g to account for seismic loading;
7. GW-11 pond configuration of the western slope with the slope of the existing embankment (3 horizontal on 1 vertical) extending to the design depth of the excavation without setback from the embankment; and
8. GW-11 pond configuration of the western slope with the slope of the existing embankment extending to the design depth of the excavation without setback from the embankment including using a pseudo-static coefficient of 0.15g to account for seismic loading.

In all the analyses, Northgate assumed that the ponds contained water with a freeboard of 2 feet from the top of the embankments. The water was modeled to reflect its weight only. The soils were assumed to be moist but not saturated. These conditions would be typical for watertight lined ponds such as the GW-11 and WC ponds. The slope stability analyses are attached for NDEP review as Attachment 2. The results of the analyses are presented below:

Pond	Height of Cut Slope, Feet	Minimum Factor of Safety Static Case	Minimum Factor of Safety Seismic Case
WC (No Setback, Excavate Cut Slope at 2:1 Slope to Excavation Depth)	14	1.5	1.0

WC (No Setback, Excavate Cut Slope at 3:1 to Design Depth)	14	1.8	1.2
GW-11 Eastern Slope (No Setback, Excavate Cut Slope at 3:1 to Design Depth)	10	1.9	1.2
GW-11 Western Slope, (No Setback, Excavate Cut Slope at 3:1 to Design Depth)	10	2.2	1.3

All of the cases were analyzed using Bishop's Modified Method. Several of the exact same cases were also analyzed using Spencer's Method. The results of Spencer's Method were slightly lower but did not result in a significant change from Bishop's Modified Method; therefore, the analyses presented in Attachment 2 are Bishop's Modified Method.

Selection of acceptable factors of safety depends on the level of risk that Tronox is willing to accept and, in some cases, what the Nevada Division of Water Resources (NDWR), Engineering and Dam Safety program set as a minimum. The acceptable factors of safety are also selected based on the consequences of failure (potential for loss of life, property damage, and loss of facility use). Acceptable factors of safety for static conditions can range from 1.5 minimum to 3 or more. Acceptable factors of safety for seismic conditions can typically range from 1.1 to 1.5.

The factor of safety obtained for the WC Ponds for a cut slope inclination of 2:1 horizontal to vertical for static conditions is 1.5 and for seismic conditions is 1.0. These factors of safety are low and are not considered acceptable. If the cut slope is flattened to 3:1, the resulting factors of safety for static conditions of 1.8 and for seismic conditions of 1.2 are considered acceptable.

The static analysis for the GW-11 Pond embankments yields factors of safety of 1.9 to 2.2 for the 3:1 cut slope and are considered acceptable. The seismic factors of safety for the GW-11 Pond embankments with a 3:1 cut slope are 1.2 to 1.3 and are also considered acceptable.

Conclusion

Based on the above results, we conclude that the embankment slopes for the WC and GW-11 Ponds are stable under both static and seismic loading conditions with the proposed excavation slopes cut at 3:1 to the design depths. Northgate recommends that for differing excavation depths the 3:1 cut slope be utilized.

If you have any questions, please contact me at (510) 839-0688, ext. 204.

Sincerely,

Northgate Environmental Management, Inc.

Theodore Splitter, P.E., 020615

ENCLOSURES:

Figures

1 Site Location Map

2 Site Plan

Attachment

1 Laboratory Data

2 Slope Stability Analyses