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MEMORANDUM

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To: Shannon Harbour, PE
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Nevada Division of Environmental Protection

RE: Retention Basin Development and Design, Evaluation of Retention Basin Data for Risk Assessment, and Evaluation of Retention Basin Leaching Potential Issues, Tronox Henderson Remediation Project, Henderson, Nevada

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Northgate Environmental Management, Inc (Northgate) has prepared this memorandum to provide information requested by the Nevada Division of Environmental Protection (NDEP) on the proposed retention basins at the Tronox LLC facility (Tronox; the Site). The memorandum provides background information on the design and intended purposes of the proposed retention basins and addresses the action item noted in Comment 12h of the January 4, 2011 *WebEx Excavation Status Minutes* meeting notes regarding the sufficiency of the retention basin chemical data for risk assessment purposes. This memorandum also evaluates the retention basins' potential impacts on the leaching of contaminants to groundwater and on groundwater flow.

Background Information and Design of Retention Basins

The existing stormwater management design for the Site was developed in accordance with the *Removal Action Work Plan* (RAW, Northgate, June 22, 2010), the stormwater discharge permit issued by NDEP, and the grading permit issued by Clark County. The Stormwater Pollution Prevention Plan (SWPPP; included as Appendix B to the RAW) specified the use of three retention basins to contain stormwater runoff at the Tronox Site (see Figure 1). The SWPPP discussed the construction and long term use of the retention basins to retain stormwater. The current plan envisions three retention basins. All three of the proposed basin areas have historically been used to contain and infiltrate stormwater runoff at the Tronox facility. Two of the basins are located in the northern portion of Remediation Zone (RZ) -D, one at the west corner (Northwest Basin, Figure 2) and one at the east corner (Northeast Basin, Figure 3). A third retention basin (Central Basin) is proposed in the central portion of the Site. The Central Basin also includes a portion of the former Beta Ditch. The Central Basin consists of a western basin and an eastern basin connected by a narrow channel (see Figure 4).

The current stormwater management plan is consistent with Tronox's objective to retain all surface /stormwater on the facility. As noted above, the Beta Ditch, and the Northwest and Northeast Basin areas have historically been areas where surface/stormwater has been retained. The first water-retaining structures in these areas were the Trade Effluent Pond berms that were constructed in the 1940s. Portions of these berms remain on the Site and still serve as water retention features.

The western and eastern portions of the Beta Ditch will serve as conveyance channels to carry water from on-Site sheet flow and from off-Site sources to the Northwest and Northeast Retention Basins. New channels will connect to these portions of the Beta Ditch and convey the water northward to the retention basins (see Figures 4 and 5 of the Final Grading Plans submitted to NDEP on November 22, 2010).

The Central Basin was also identified as an opportunity to potentially utilize either stormwater or added water (from treatment system effluent or Lake Mead water) to enhance the flushing of perchlorate in vadose zone soils. Currently, Northgate is implementing a soil-flushing pilot study in the vicinity of the Central Basin as part of a remedial alternatives evaluation for perchlorate and other leachable chemicals in the unsaturated zone. The pilot study is being implemented based on the successful outcome of the bench-scale testing conducted in August and September 2010. Contingent on the outcome of the pilot study, the Central Basin may be utilized to assist in the flushing of a significant mass of perchlorate from soil. The Central Basin area was selected because of the relatively high perchlorate concentrations (see Figure 5) in soil as well as the fact that the Central Basin is upgradient of the groundwater barrier wall and on-Site interceptor well field (IWF; see Figure 4). It is anticipated that the perchlorate from this area, when flushed, can be captured using the existing extraction system and treated with the existing biological treatment system. A preliminary evaluation of the feasibility of this technology is presented below. Following implementation of the flushing pilot study, additional information will be available to further develop this evaluation. We anticipate that upon successful completion of the pilot study and remedial alternatives evaluation, flushing of the impacted area or other remedial technologies can be initiated and completed within a one-year period.

In the interim, before completion of the pilot study, water from the on-Site storm drain system will not be stored in the Central Basin area. Instead, this storm drain water will be diverted into the western portion of the Beta Ditch where it will be carried into the Northwest Basin for infiltration.

Human Health Risk Assessment

The three basin areas (Northeast, Northwest and Central Basins) will be evaluated separately in the human health risk assessment (HRA) as the conceptual model for the basins differs from other areas of the Site. As discussed above, the retention basins are designed to capture

surface water runoff, up to and including a theoretical hundred-year rainfall event, on the Site. Because the retention basins are essentially depressed pond-like areas and no below-ground utilities are located within their footprints, at no foreseeable time would contact with soils below the planned basin grade be expected to occur. Particularly, these areas do not support a default commercial worker scenario that would involve direct contact with surface soils (0-2 feet below ground surface; bgs) 250 days per year or a construction worker scenario involving contact with soils at depths 10 feet below the planned basin grades. Should the use of these areas change at some time in the future, it is possible that the basins would be filled to pre-remediation/pre-retention basin Site grades, depending on the remedial status of flushing activities in the area and residual concentrations. Regardless of this conceptual model issue, an assessment of available data was conducted and it was determined that sufficient data are available to evaluate any hypothetical scenario involving contact with soils below the planned grades within each of the basins.

As discussed above, Figures 2 through 4 present the soil borings available to represent soil concentrations in the basin areas. Table 1 lists the soil borings contained in the Northeast and Northwest Basins, along with the polygon excavation designation, excavation depth, soil boring depths, and analytes driving the excavations. Tables 2 and 3 contain the same information for the Central Basin. Cells containing an "x" indicate that soil concentrations exceed the comparison criteria and soil has been or will be excavated.[1] These data will not be retained in the post-remediation HRA. Blank cells indicate that, for any sampled constituent, the concentrations are below the comparison criteria. Yellow highlighted cells show the deeper (10 feet bgs and deeper) borings that are available to evaluate the planned basin grades. Any borings that will not be remediated as part of the basin grading are highlighted in purple. Data associated with each of these borings is provided in the RZ-B and RZ-D and RZ-C and RZ-E "Data Tables" previously submitted to NDEP.[2] Findings regarding the availability of data to evaluate exposure involving direct contact with soil beneath the planned basin grades are provided below:

- **Northeast Basin**

  This is an existing retention basin area and will be backfilled to within 2 feet of previously existing grades. As shown in Table 1, there are 17 soil borings within the Northeast Basin area. Four soil boring locations (SA 127, RSAJ5, RSAJ6 and RSAJ7) are along the toe of the WC pond berm and will not be excavated as they are part of the environmental covenant (EC) area (highlighted in purple). Rather, soil in the EC area will be capped with asphalt, limiting direct contact with soils. For the remaining

[1] Comparison criteria are NDEP commercial worker BCLs except for dioxin (site-specific), arsenic (BRC/TIMET 2007 background data), and asbestos (Parcel A/B).
[2] RZ-B and RZ-D Data Tables submitted to NDEP on December 29, 2010. RZ-C and RZ-E Data Tables to be submitted to NDEP on January 28, 2011.

Northeast Basin area, excavations range between one and 14 feet bgs. The shallow excavations (i.e., less than 2 feet bgs) will not be backfilled and a clean data point exists to represent the 0-2 feet bgs depth interval in these polygons. Deeper excavations will be backfilled to within 2 feet of existing grade and in those instances any hypothetical commercial worker scenario would involve direct contact with clean fill. Although a construction worker scenario is not relevant for the Northeast Basin, 10 feet bgs and deeper soils (yellow highlighted cells) are available to evaluate residual chemical concentrations in soil beneath the planned basin grade, and all sampled constituents are below comparison criteria.

- **Northwest Basin**

  As shown in Table 1, there are 14 soil borings within the Northwest Basin area. Excavations in this area range between one and approximately 30 feet bgs, with the majority of this area being excavated to 15 feet bgs due to the presence of the landfill. The shallow excavations (i.e., less than 2 feet bgs) will not be backfilled and a clean data point exists to represent the 0-2 feet bgs depth interval in these polygons. Deeper excavations will be backfilled to within 10 feet of the previously existing grades and in those instances any hypothetical commercial worker scenario would involve direct contact with clean fill. Although a construction worker scenario is not relevant for the Northwest Basin, 10 feet bgs and deeper soils (yellow highlighted cells) are available to evaluate residual chemical concentrations in soil beneath the planned basin grade, and all sampled constituents are below comparison criteria.

- **Central Basin**

  As shown in Tables 2 and 3, there are 42 soil borings within the Central Basin, which includes a portion of the Beta Ditch. Excavations in this area range between one and approximately 11 feet bgs, with the majority of these areas being excavated to 10 feet bgs. The intent of the grading is to level the grade at the bottom but not backfill this basin. Therefore, the approximate final grade of this basin will be between 6 and 10 feet below current Site grade, with the eastern portion of the Central Basin approximately 7 feet below current grade. The access to the bottom of the basin will be limited to a vehicular access ramp.

  Soil borings that are available to evaluate the 10 feet bgs depth are highlighted in yellow on Tables 2 and 3. Although a default commercial and construction worker scenario is not relevant for the Central Basin, 10 feet bgs and deeper soils (yellow highlighted cells) are available to evaluate residual chemical concentrations in soil beneath the planned basin grade and with the exception of perchlorate, all sampled constituents are below comparison criteria.

To further evaluate the perchlorate concentrations under a more realistic "basin worker" scenario, a retention basin-specific health-based level was determined to be 4,968 mg/kg (see Attachment 1 for calculation spreadsheet). The 4,968 mg/kg health-based concentration assumes access to the basin 3 times per month for 12 months per year for 25 years, along with other default commercial worker assumptions. The existing perchlorate concentrations (shown in purple) are all below the retention basin-specific health based levels. Therefore, the residual perchlorate soil concentrations will not pose a health risk to workers under a hypothetical scenario involving contact with basin soils.

Furthermore, even without considering a modified basin worker scenario, upon successful completion of the perchlorate pilot study, perchlorate soil concentrations will be reduced to below the NDEP commercial basic comparison level (BCL) through planned and natural flushing. The reduced perchlorate soil concentrations will be confirmed through soil confirmation sampling in the Central Basin area. Additionally, as an interim measure and until flushing occurs in this area, an option exists for placing clean fill on the areas with perchlorate concentrations above the NDEP commercial BCL.

Evaluation of Leaching Impacts on GWETS

Potential impacts to groundwater from leaching due to stormwater infiltration in the basins were evaluated by comparing analytical data from soil samples remaining in-place after excavation to Site-specific, leaching based screening levels (LSSLs; per *Revised Technical Memorandum: Calculation of Leaching-Based, Site-Specific Levels [LSSLs] for the Soil-to-Groundwater Pathway Using NDEP Guidance, Tronox LLC, Henderson,* Nevada, Northgate, November 18, 2010). The subsequent fate of the leached contaminants depends on the degree of attenuation during residence in the aquifer, whether the impacted groundwater is captured by the groundwater extraction and treatment system (GWETS), and to what extent the chemicals of concern (COCs) are treated and removed by the GWETS. The issue of attenuation in groundwater is not considered here. Below is a summary of the COCs for each basin based on a comparison to LSSLs and an evaluation of the expected and observed treatment of the COCs by the GWETS.

The soil boring locations used to evaluate soil beneath the retention basins for potential leaching concerns are listed in Table 4 and are shown on Figures 2, 3, and 4. Samples that have been removed by excavation were not included in the comparison. Analytical results for chemicals (except perchlorate) exceeding LSSLs for the Northeastern, Central, and Northwest basins are presented in Tables 5 through 8. These results indicate that, in addition to perchlorate, the following chemicals represent potential leaching concerns for the proposed retention basins:

- Northeast Basin: Alpha-BHC, beta-BHC, gamma-BHC, hexachlorobenzene (HCB), and magnesium
- Central Basin: Beta-BHC and chloroform
- Northwest Basin: Alpha-BHC, beta-BHC, and magnesium

Perchlorate is a potential leaching concern for all three basins. The hydraulic capacity of the GWETS is approximately 1,000 gallons per minute (gpm) and is limited by the effluent pipeline. The biological treatment process is capable of treating perchlorate concentrations at least as high as 350 to 400 mg/L, which the plant experienced in 2009. Stormwater infiltration and flushing through the retention basins, particularly flushing of the Central Basin, are expected to increase perchlorate concentrations in the GWETS influent from the current concentration of approximately 200 mg/L. The degree to which perchlorate concentrations might increase during soil flushing will be further evaluated during the planned pilot study, but based on preliminary calculations the concentrations are not expected to exceed 400 mg/L. Increases in concentration from the current levels will require a concomitant increase in the ethanol feed but will not impact treatment plant performance.

The primary organochlorine pesticides of concern for leaching are alpha- and beta-BHC, both of which are detected in several soil samples above LSSLs at a range of depths in the vadose zone. Gamma-BHC was not detected above LSSLs in any of the basins, although the detection limit for gamma-BHC exceeds the LSSL for a single soil sample in the Northeast Basin. The existing granular activated carbon (GAC) system should be capable of removing any organic compounds that may be mobilized by leaching from the retention basins. The GAC system consists of three 750-gallon canisters that filter water prior to biological treatment. The purpose of the GAC is to remove organic chemicals from the water that could potentially harm the perchlorate-degrading bacteria. A comparison of historical influent and effluent concentrations based on quarterly NPDES monitoring results between 2005 and 2009 indicates that the GWETS removed an average of 73.2% of alpha-BHC and 82% of beta-BHC over that time period. Average influent concentrations, effluent concentrations, and removal rates by the GWETS of the chemicals identified above as potential leaching concerns are provided in Table 9. As shown, effluent concentrations for alpha-BHC and beta-BHC, although significantly reduced from influent levels, exceed the BCLs. Groundwater discharge limits have not been established for these chemicals. However, Northgate recommends adjustments to the GAC system monitoring and change-outs to improve removal of these chemicals prior to discharge.

Chloroform is present above the LSSL in three samples associated with the Central Basin, all located at depths greater than 20 feet below original grade. Chloroform is currently present in groundwater beneath the Central Basin at concentrations several orders of magnitude over the BCL, and leaching from the Central Basin is not anticipated to create additional significant groundwater impacts. The GAC tanks in the treatment system are capable of removing chloroform. NPDES monitoring data between 2005 and 2009 indicate that the GWETS removed

an average of 88% of the chloroform present in the influent samples over that period of time. As shown on Table 9, effluent concentrations for chloroform, although significantly reduced from influent levels, exceed the BCL. Although groundwater discharge limits have not been established for this chemical, Northgate recommends adjustments to the GAC system monitoring and change-outs to improve removal of chloroform prior to discharge.

Hexachlorobenzene is present above LSSLs in the Northeast Basin. However, Tronox does not expect HCB to impact groundwater concentrations due to leaching. The remaining concentrations of HCB are confined to the top two feet of soil in areas that will be located beneath an asphalt cap and subject to ECs. In addition, despite widespread HCB in vadose zone soils prior to recent soil remediation efforts, it was not detected above the BCL in any Phase B groundwater samples, and was not detected in influent samples from quarterly NPDES monitoring results of the GWETS between 2005 and 2009. Based on historical groundwater data collected at the Site, HCB does not appear to represent a leaching concern despite its presence above the calculated LSSL.

Magnesium is present at concentrations slightly exceeding the LSSL in one sample from the Northwest Basin and two samples from the Northeast Basin, and leaching of magnesium may increase the hardness of the groundwater beneath and downgradient of the basins. Groundwater beneath the Northwest Basin is impacted with magnesium above the BCL (207 mg/L) due to sources located upgradient of the basin, and high concentrations of magnesium and total dissolved solids (TDS) are present on a regional scale in the shallow water-bearing zone. The results of laboratory column studies, presented in Northgate's *Revised Work Plan to Evaluate In Situ Soil Flushing of Perchlorate-Impacted* Soil, dated November 12, 2010, showed that magnesium concentrations in leachate samples declined rapidly over the span of two pore volumes of water flushed through several testing columns. The retention basins are therefore not expected to be a significant long-term source of magnesium in groundwater, although short-term pulses of groundwater with increased magnesium concentrations may be expected following initial major storm events. The additional contribution of magnesium is not expected to impact the operation of the GWETS, which currently treats very hard water: the average magnesium concentration was about 203 mg/L for influent samples between 2005 and 2009. Effluent concentrations over the same period indicate that the GWETS has little effect on magnesium concentrations, with an average effluent concentration of 202 mg/L.

Hexavalent chromium is not present above the LSSL in any soil samples from the retention basin areas. However, chromium was detected above the BCL in leachate samples during the laboratory column tests, and is being considered here for that reason. Chromium concentrations measured in the leachate samples were at or below the current influent concentrations of the GWETS. Additional contaminant mass due to stormwater infiltration or flushing will necessitate an increase in the ferrous sulfate feed used to treat the chromium, but will not impact treatment plant performance. However, the chromium treatment process at the on-Site IWF is currently

operating at approximately 75 gpm and has a capacity of 90 gpm. Additional volume related to stormwater infiltration or flushing from the Central Basin may require added treatment capacity at the IWF. This is discussed further below.

Evaluation of Groundwater Flow Impacts on GWETS

As discussed above, chemical analyses indicate that concentrations above LSSLs remain in the soil beneath the planned retention basins. Also as presented above, the Central Basin may be used to flush perchlorate and other leachable chemicals from the vadose zone into groundwater prior to using this area for stormwater retention. Under this scenario, stormwater that would normally accumulate in the Central Basin would be diverted to the Northwest Basin until soil flushing of the Central Basin is completed, which is expected to be within one year. With these considerations, the following three scenarios were identified as presenting potential concerns in terms of impacts to flow and capture of groundwater that may contain leached chemicals:

1. Controlled soil flushing of the entire Central Basin.
2. Infiltration of a ten-year rainfall event at the Northwest Basin, assuming runoff in the Central Basin drainage area is also diverted to the Northwest Basin.
3. Infiltration of a hundred-year rainfall event at the Northwest Basin and at the Central Basin before remediation of leachable chemicals is completed.

As presented in Attachment 2, preliminary evaluations of these three scenarios have been conducted. In summary, these analyses indicate that the impacts due to transient infiltration of stormwater or flushing water to the shallow water-bearing zone under each of these scenarios can be managed by the existing GWETS with appropriate modifications. A back-up lamella clarifier to be operated in parallel with the existing clarifier is recommended for the IWF to handle chromium treatment during potential periods of higher flow associated with soil flushing and/or high rainfall years. In addition, pumping rate increases to maintain current capture at the IWF and/or Athens Road well field (AWF) (following heavy rainfall events and/or soil flushing) may necessitate short-term pumping reductions at the seep well field (SWF) or other measures to maintain the total GWETS extraction rate below its 1,000 gpm capacity. Each of the three scenarios is discussed further below.

Central Basin Soil Flushing

This scenario assumes that the treatment system effluent or Lake Mead water is introduced into the basin at a controlled rate until sufficient water has been applied to flush the vadose zone. The feasibility of flushing the entire Central Basin will not be determined until after the planned pilot study; therefore only a preliminary evaluation of potential impacts to groundwater flow is presented here. A more comprehensive evaluation may be performed after initial results of the flushing pilot study become available. As described in Attachment 2, this preliminary evaluation

assumes that the western and eastern sub-basins of the Central Basin would be flushed sequentially. Because the western sub-basin is larger and extends beyond the western extent of the IWF/barrier wall, capture by the IWF during flushing of this sub-basin is more of a concern than capture during flushing of the eastern sub-basin. Therefore, for this preliminary evaluation, only flushing of the western sub-basin was modeled. As described in Attachment 2, this scenario assumes water is added to the western sub-basin at a rate of 70 gpm for four months to flush perchlorate and other leachable chemicals.

The results of this modeling indicate that the current capture could be maintained during flushing by increasing IWF pumping by approximately 70 gpm, bringing the total extraction rate to approximately 140 gpm (see Attachment 2). As mentioned above, treatment of this additional groundwater volume could be managed by the existing GWETS with the addition of a second lamella clarifier operated in parallel with the existing unit. A slight and short-term reduction in seep well field (SWF) pumping may also be needed to maintain total system flows below the 1,000 gpm capacity. Because this scenario was modeled with a steady-state recharge rate rather than for only a four-month period, these results likely overestimate the actual impact on IWF pumping.

Northwest Basin Infiltration of "Combined" Ten-Year Rainfall Event

This scenario assumes that a ten-year storm event occurs within the next year while runoff that would normally flow into the Central Basin is being diverted to the Northwest Basin via the Beta Ditch. To evaluate the potential effects of this retained rainfall on the underlying groundwater flow, we used the groundwater flow model with a steady-state recharge rate. The selected recharge rate was based on the total water volume expected to be captured in this basin; Site observations on surface infiltration rates; and, vadose zone calculations predicting wetting front velocity and transient recharge rates (Attachment 2).

As described in Attachment 2, the AWF capture under this steady-state simulation of rainwater discharge is similar to the baseline condition. Although somewhat more water is shown passing through the western half of the AWF under the rainwater discharge scenario, this assumes no increase to pumping rates in this area. Northgate plans to re-model this scenario with increased AWF pumping rates to confirm that current capture can be maintained within the constraints of the GWETS, but we do not anticipate this to be a concern assuming SWF flow rates can be reduced for a short period, if needed, to allow for higher extraction rates at the AWF and to assure that the total flow to the GWETS remains within the 1,000 gpm total system capacity. The modeling results also show greater groundwater bypass at the neighboring facility's (POSSM's) GWETS under the rainwater discharge scenario than under baseline conditions, however this may be an artifact of the coarser model discretization for this off-Site area.

Because this simulation is based on steady-state conditions and the rainfall infiltration is a transient event, this modeled simulation likely overestimates the impacts rainfall infiltration would have on groundwater flow. As described in Attachment 2, the recharge rate used in the model for this theoretical combined 10-year rainfall event was based on a three-month timeframe for all the rainwater to reach groundwater. Based on the nearly 1.5 mile distance from the basin to the AWF and the expected alluvial groundwater velocity, this added recharge would not be expected to reach the AWF for several years and would likely be significantly dispersed when it did. We also note that all rain falling on the Tronox facility is already captured on-Site and the proportion infiltrating into groundwater should not change significantly with the new retention pond system. The past five years of water level data for the facility in general, and specifically for monitoring wells near the Beta Ditch (which is unlined and captures/infiltrates significant rainwater), indicate only limited and localized increases in water levels in response to rainfall, and no clear evidence of changes in groundwater capture or extraction system flow rates.

Hundred-Year Rainfall Event

The "combined" ten-year rainfall volume described above slightly exceeds the hundred-year rainfall volume that is expected in the Northwest Basin, so no additional modeling analysis was conducted for this basin. For the Central Basin, the expected hundred-year rainwater event volume captured by the basin was calculated, and the potential impacts of this water on groundwater flow were qualitatively evaluated. As discussed in Attachment 2, this preliminary analysis indicates that the impact of the hundred-year rainfall event on groundwater flow is expected to be less than the impact from the flushing scenario described above, and therefore does not present a significant concern related to groundwater capture.

Conclusions

In conclusion, sufficient data are available within each of the basins to evaluate any hypothetical scenario involving contact with soils below the planned grades. With the exception of perchlorate in the Central Basin area, all soil concentrations that will remain under the basins are below commercial and construction worker screening levels. Because a default commercial and construction worker scenario is not relevant for these basins, a more appropriate perchlorate screening level for a modified basin worker scenario was calculated, and all soil concentrations in the Central Basin area are below this level. Regardless, it is anticipated that upon successful completion of the pilot scale flushing program, perchlorate soil concentrations beneath the basins will be reduced to well below the NDEP commercial BCL through planned and natural flushing.

Leaching of chemicals is likely from the retention basins during storm events or controlled flushing; however with minor modifications to the existing GWETS the impacts of leaching can

be mitigated. Northgate recommends adjustments to GAC monitoring and change-out to mitigate the potential impact of leached organic compounds. Northgate also recommends operation of an additional clarifier in parallel with the existing one at the IWF to increase treatment capacity of hexavalent chromium and handle increased flows due to flushing and/or infiltration from the Central Basin. Pumping rate increases to maintain current capture at the IWF and possibly at the AWF (following extreme rainfall events and/or soil flushing) may necessitate short-term pumping reductions at the SWF or other measures to maintain the total GWETS extraction rate below its 1,000 gpm capacity.

TABLES

FIGURES

4 Central Retention Basin

5 Perchlorate Remaining in Soil After Excavation

ATTACHMENTS

1 Exposure Parameters

2 Evaluation of Groundwater Flow Impacts on GWETS