Environmental Risk Management Plan

Tronox LLC
Henderson, Nevada

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Risk Management Plan

Tronox LLC
Henderson, Nevada

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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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ACRONYM LIST

Acronym	Meaning
ACM	asbestos-containing material
AOC	Administrative Order on Consent
AP	ammonium perchlorate
AP&CC	American Potash & Chemical Company
ASSD	active soil slab depressurization
BCL	basic comparison level
bgs	below ground surface
BMI	Black Mountain Industrial
BRC	Basic Remediation Company
COC	chemical of concern
CSM	Conceptual Site Model
DQO	data quality objective
ECA	environmental conditions assessment
ERMP	environmental risk management plan
GC	gas chromatograph
gpm	gallons per minute
HASP	health and safety plan
HCB	hexachlorobenzene
HCl	hydrochloric acid
HHRA	human health risk assessment
HI	hazard index
I/E Areas	Institutional/Engineering Control Areas
ITRC	Interstate Technology & Regulatory Council
LOU	Letter of Understanding
msl	mean sea level
NDEP	Nevada Division of Environmental Protection
OA	organic acid
OCP	organochlorine pesticide
OPP	organophosphate pesticide
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxins
PCDF	polychlorinated dibenzofurans
PPE	personal protective equipment
PPT	parts per trillion
PPV	positive-pressure ventilation
PSSV	passive sub-slab ventilation
RAW	removal action work plan
RBGCs	risk-based groundwater concentrations
RC	remediation concentration
RCRA	Resource Conservation and Recovery Act

RME	Reasonable Maximum Exposure
RZ	remediation zone
SF	slope factor
sf	square foot
SMD	sub-membrane depressurization
SOP	standard operating procedure
SRC	Site-related chemicals
SSD	sub-slab depressurization
SVOC	semi-volatile organic compound
TEQ	toxicity equivalent
TPH	total petroleum hydrocarbon
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank
VOC	volatile organic compound
WECCO	Western Electrochemical Company

EXECUTIVE SUMMARY

This Environmental Risk Management Plan (ERMP) provides a decision framework for the management of residual chemicals in soil vapor, soil, and groundwater at a 453-acre site in Henderson, Nevada (the Site), currently owned and operated by Tronox LLC (Tronox). This ERMP describes procedures to address the known remaining environmental conditions at the Site, as well as contingency actions to be taken if previously unknown environmental conditions are encountered.

This ERMP addresses the following:

- minimum design considerations for construction of new buildings;
- risk management measures to be implemented during construction activities; and
- procedures for long-term compliance with this ERMP.

This ERMP applies to the following areas of the Site:

- Areas of the Site that have been designated as Institutional Control/Engineering Control Areas (I/E Areas), where impacted soil has been left in place, as discussed in the *Environmental Covenants, Institutional and Engineering Controls Plan, Tronox LLC, Henderson Nevada* (Northgate, 2010a) which is Appendix A of this ERMP;
- Areas of the Site where soil gas concentrations exceed 10^{-6} risk levels, as discussed in the *Site-Wide Soil Gas Human Health Risk Assessment, Tronox LLC, Henderson Nevada* (Northgate, 2010b);
- Areas of the Site where concentrations of contaminants in groundwater exceed current regulatory standards; and
- Areas of the Site where unexpected environmental contamination is encountered during construction/demolition/excavation/investigation activities.

All owners, operators, tenants, project managers and other entities with responsibility for Site activities shall have the independent obligation to:

1. review available information concerning Site environmental conditions;
2. determine the adequacy of this ERMP with respect to the expected and actual Site conditions and the intended land use;
3. establish management procedures to ensure that risk management measures are properly implemented and maintained;

4. comply with applicable policies, environmental covenants, laws, and regulations; and
5. evaluate the current understanding of the health effects of identified chemicals of concern (COCs), to the extent the understanding of health effects assumed in this ERMP may change.

Existing Environmental Conditions

Numerous potential contaminant source areas have been investigated and remediated at the Site. Areas of the Site where soil gas concentrations are high enough to pose a potential health risk by exceeding the excess cancer risk level of 10^{-6} are subject to the provisions of this ERMP. When current soil remediation activities end, some areas of impacted soil will remain, and these areas are subject to the provisions of this ERMP. A regional groundwater plume containing perchlorate, hexavalent chromium, and other contaminants underlies most of the Site. The portions of the groundwater plume that are subject to the provisions of this ERMP are those areas where the plume exceeds regulatory levels. Additionally, any areas of the Site where unexpected contamination is encountered are also subject to the provisions of this ERMP.

Soil Basic Comparison Levels

Site-specific soil screening levels (including Basic Comparison Levels [BCLs] as well as asbestos and arsenic limits), have been developed for the Site (Table 1). These screening levels will be used to evaluate whether or not:

a. excavated soil can be reused as fill at the Site, and
b. additional soil removal should be considered at locations where soil contamination is observed during construction activities.

As explained in the *Removal Action Work Plan for Phase B Soil Remediation of Remedial Zones RZ-B through RZ-E, Tronox LLC, Henderson, Nevada, revised May 28, 2010 (RAW)* (Northgate 2010d), for purposes of designating potential remediation areas, “contaminated” soil is generally defined as concentrations exceeding Nevada Division of Environmental Protection (NDEP) worker BCLs, or modified risk-based goals as agreed upon by NDEP. For metals where background concentrations exceed NDEP BCLs (e.g., arsenic), “contaminated” soil is defined as concentrations greater than background. There are no NDEP BCLs for asbestos; therefore, “contaminated” soil is defined as one or more long amphibole fibers and greater than five long chrysotile fibers counted per sample. Based on the bioavailability study, NDEP has agreed the BCL for dioxins/furans (as 2,3,7,8-tetrachlorodibenzo-p-dioxin toxicity equivalents [2,3,7,8-TCDD TEQ]) is 2,700 parts per trillion (ppt).

Risk Goals for the Site

In general, risk goals for the Site are to achieve an estimated cumulative lifetime excess cancer risk of less than 1×10^{-6} and a hazard index (HI) of less than 1 for all potential receptors using NDEP default exposure parameters for a commercial and construction worker scenario. Potential exposure of receptors to contaminants in soil vapor, soil and groundwater will be considered. Measures for achieving these goals are discussed in Sections 3, 4, and 5 of this ERMP.

Soil Vapor Risk Management Considerations

Section 3 in this ERMP discusses the potential for vapor intrusion into existing and new buildings. Within the Site, the primary methods of vapor intrusion mitigation at individual buildings will likely include one or more of the following:

- Active sub-slab depressurization (ASSD),
- Passive sub-slab ventilation (PSSV),
- Interior positive-pressure ventilation (PPV),
- Interior mechanical ventilation with sufficient air exchange rates,
- Ground level open-air or mechanically-ventilated parking garages beneath all occupied spaces,
- Sub-membrane depressurization (SMD) for buildings constructed over a crawl space;
- Passive barriers, and,
- Sealing of cracks and conduits.

In each situation, an engineering analysis will be needed to select a control option appropriate to address Site-specific conditions and considerations.

Groundwater Risk Management Considerations

Due to the groundwater contamination in the aquifer underlying the Site, measures must be taken to prevent new construction from creating additional potential pathways for migration of COCs in groundwater. For example, if new construction requires deep pile foundations, mitigation measures must be included to reduce the potential for vertical cross-contamination or for creating conduits for downward contaminant migration. The project owner will prepare a design report for review by NDEP describing the measures that will be taken and demonstrating their effectiveness in preventing potential migration pathways of COCs caused by new construction.

Tronox currently operates a groundwater remediation system at the Site. This system is required to operate continuously. New construction must not interfere with operation of the remediation system. Procedures have been developed to coordinate construction activities to minimize disturbance to the remediation system, and if necessary, to allow the system to be modified in a way that does not adversely affect its operation.

Risk Management During Construction

This ERMP summarizes risk management measures and procedures to be implemented during construction to mitigate potential risks to human health and the environment from potential exposure to COCs, and to manage soil during construction activities. These measures and procedures include:

- Development and implementation of a Site-specific health and safety plan (HASP) that describes health and safety training requirements for on-Site workers, personal protective equipment to be used, and other precautions to be undertaken to minimize direct contact with soil, soil gas, and groundwater;
- Implementation of mitigation measures, such as dust and odor control, decontamination of construction and transportation equipment, and storm water pollution prevention controls;
- Sampling and analyzing groundwater generated during construction dewatering activities to determine appropriate storage and disposal practices;
- Management of abandoned underground storage tanks (USTs), sumps, pipes, and buried drums or containers that may be encountered during Site construction activities;
- Protection of the existing groundwater remediation systems during Site construction activities and implementation of NDEP-approved modifications to the existing systems; and
- Management of soil potentially impacted by COCs that is handled during construction activities. Soil management protocols include identifying COC-impacted soil that may be excavated during Site construction activities and contingencies if previously unknown soil contamination is encountered. Appropriate handling and disposition of contaminated soil that is excavated is described.

Long-Term Risk Management

This ERMP also describes measures that will be implemented over the long term to mitigate risks to human health and the environment related to potential exposure to any residual COCs during periods of normal non-construction activity. These measures include:

- Providing appropriate notification to future property managers and tenants of the known environmental conditions at the Site and the requirements of the ERMP;
- Ensuring that personnel use proper personal protective equipment (PPE) when they work on areas of the Site where they may encounter contaminated materials;
- Conducting additional risk analysis and modification of the ERMP, as appropriate, if there is any significant change in land use proposed for the Site, or if any significant change in toxicity values for COCs occurs;
- Ensuring that groundwater from the Site is not used for drinking water or any other purpose unless NDEP approves its use;
- Following site health and safety procedures (including use of appropriate PPE) for activities that disturb subsurface Site soil (e.g., utility repairs);
- Following appropriate procedures developed for construction activities (e.g., soil management);
- Conducting appropriate ongoing operation and maintenance to verify the continued adequacy of risk management measures, such as vapor intrusion mitigation, and evaluating ongoing environmental monitoring data (e.g., groundwater monitoring data) to determine if there are any significant changes in Site environmental conditions that require potential modification of this ERMP; and
- Monitoring changes in COC toxicity parameters to assess if additional or lesser mitigation may be needed based on an updated understanding of toxicity of the COCs at the Site.

It is anticipated that many of the measures outlined in this ERMP will be required on a parcel-specific basis, which will be memorialized through the use of environmental covenants.

1.0 INTRODUCTION

On behalf of Tronox LLC (Tronox), Northgate Environmental Management Inc. (Northgate) has prepared this Environmental Risk Management Plan (ERMP) for the Tronox facility, located in Henderson, Nevada (the Site). The Site is a 453-acre area that is part of the larger Black Mountain Industrial (BMI) complex. Tronox currently owns and operates the Site. The general location of the Site is shown on Figure 1, and the locations of site features are shown on Figure 2.

This ERMP was prepared following extensive environmental investigations and human health risk analyses that were performed at the Site with oversight from the Nevada Division of Environmental Protection (NDEP).

1.1 Scope of the Environmental Risk Management Plan

This ERMP applies to the following conditions at the Site:

- Areas of the Site where impacted soil has been left in place. These areas have been designated as Institutional Control/Engineering Control Areas (I/E areas) and are discussed in detail in the *Environmental Covenants, Institutional and Engineering Controls Plan* (Northgate 2010a), which is Appendix A of this ERMP;
- Areas of the Site where concentrations of contaminants in groundwater exceed current regulatory standards;
- Areas of the Site where soil gas concentrations exceed 10^{-6} risk levels, as discussed in the *Site-Wide Soil Gas Human Health Risk Assessment* (Northgate, 2010b); and
- Areas of the Site where unexpected environmental contamination is encountered during construction/demolition/excavation/demolition activities.

This ERMP provides a decision framework to manage residual chemicals in soil, groundwater, and soil gas at the Site in a manner that:

a. protects human health and the environment,

b. is consistent with current and planned future land uses, and

c. satisfies NDEP and other involved regulatory agencies with oversight authority.

1.2 Organization of the ERMP

This ERMP contains the following sections:

- Section 2 – a description of the Site background, including a brief history of Site usage, current and future planned land use, a brief summary of known remaining environmental conditions, and a summary of the *Human Health Risk Assessment Work Plan for the Tronox Facility* (Northgate 2010c) that was submitted March 7, 2010;
- Section 3 – A description of risk management measures for <u>soil</u> for new construction and existing buildings at the Site;
- Section 4 – A description of risk management measures for <u>groundwater</u> for new construction and existing buildings at the Site;
- Section 5 – A description of potential risk management measures for <u>soil vapor intrusion</u> for new construction and existing buildings at the Site; and
- Section 6 – A description of long-term risk management measures to mitigate potential long-term risks to human health and the environment, which includes procedures for long-term compliance with this ERMP.

1.3 Responsibilities

The property owner, future landowners, tenants, future contractors or developers, and other parties with responsibility for Site activities shall have an obligation to:

- Determine the adequacy of this ERMP in the light of the conditions actually encountered and the intended land use;
- Evaluate the current understanding of the health effects of identified chemicals of potential concern (COCs), to the extent information about health effects assumed in this ERMP may change;
- Comply with applicable policies, laws, and regulations;
- Comply with any Environmental Covenants that are recorded for the Site;
- Establish procedures for inspection, maintenance, and monitoring of the risk management measures that are implemented, and establish protocols for future sub-surface activities to ensure long-term compliance with the ERMP; and
- Assure that the ERMP is reviewed by qualified environmental professionals and updated, as necessary, to address significant changes in environmental conditions, land uses, and/or applicable laws and regulations.

1.4 Regulatory Oversight and Status

NDEP provides regulatory oversight for this project. Tronox and NDEP have signed several agreements that govern much of the activities performed at the Site, including the following:

- 1986: A Consent Order between Tronox (formerly Kerr-McGee Chemical Corporation [KMCC]) and NDEP requiring additional groundwater characterization and the implementation of remedial activities to address chromium in groundwater (NDEP, 1986).
- 1991: A Consent Agreement among six companies (including Tronox, formerly KMCC) and NDEP requiring environmental studies to assess Site-specific environmental conditions related to past and present industrial operations and waste disposal practices (NDEP, 1991).
- 1996: A Phase 2 Consent Agreement between Tronox (formerly KMCC) and NDEP covering Site Investigation/Remediation (NDEP, 1996).
- 1999: A Consent Agreement between Tronox (formerly KMCC) and NDEP defining remedial requirements and requiring a treatment process to remediate water that was impacted by perchlorate (i.e., in the seep area) (NDEP, 1999).
- 2001: An Administrative Order on Consent (AOC) between Tronox (formerly KMCC) and NDEP defining more permanent remedial requirements for perchlorate-impacted groundwater and surface water. This AOC supplemented the requirements of the 1999 Consent Agreement (NDEP, 2001).
- 2005: An AOC between Tronox (formerly KMCC) and NDEP addressing Bioplant Discharge Clarity and Decommissioning of the AP-5 Pond (Figure 2) (NDEP, 2005)

Tronox LLC is currently a debtor in possession in a Chapter 11 bankruptcy proceeding in the United States Bankruptcy Court for the Southern District of New York, Case No. 09-10167-ALG (Tronox, 2009). In conjunction with the settlement of Tronox's bankruptcy proceeding, an environmental restoration trust will own the Site and assume future responsibility for remediating existing contamination at the Site. Tronox will lease a portion of the Site back from the trust in order to continue manufacturing operations at this location.

1.5 Representations and Limitations

The risk management protocols specified in this ERMP are based on an understanding of current Site environmental conditions and current policies, laws, and regulations. No representation is made as to the applicability of this ERMP to future Site conditions, which may vary from current conditions, as conditions may change or new information may become available. This plan is not intended to conflict with or supplant any laws, or regulations regarding on-going operations at the Site.

In the event of changed site conditions or new information, further Site investigation and evaluation may be necessary to assess human health risks and to establish the specific procedures for remediation or containment of hazardous materials on the Site. Hazardous materials are deemed to include, but not be limited to: asbestos, asbestos-containing materials (ACMs), polychlorinated biphenyls (PCBs), lead, arsenic, dioxins/furans, perchlorate, volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and any other substances NDEP has identified as hazardous or toxic.

2.0 SITE BACKGROUND

This section provides an overview of the site, including site description, land use, site investigations, remediation, and risk assessment.

2.1 Site Description and Land Use

2.1.1 Physical Characteristics

The Site is a 453-acre property (Figure 2) that is generally rectangular in shape with the long side in the north-south direction. Elevations across the Site range from 1,677 to 1,873 feet above mean sea level (msl). The land surface slopes toward the north at a gradient of approximately 0.023 feet per foot (ft/ft). The developed portions of the Site have been modified by grading to accommodate plant facility buildings, surface impoundments, access roads, a former landfill, and other Site features.

2.1.2 General Site History

The BMI complex has been the site of industrial operations since 1942 and was originally sited and operated by the U.S. government as a magnesium production plant in support of the World War II effort. Following the war, Western Electrochemical Company (WECCO) leased a portion of the complex. By August 1952, WECCO had purchased several portions of the complex, including six of the large unit buildings (Units [Buildings] 1–6), and produced manganese dioxide, sodium chlorate, and various perchlorates. In addition, in the early 1950s, pursuant to a contract with the U.S. Navy, WECCO constructed and operated a plant to produce ammonium perchlorate (AP) on land purchased by the Navy.

In 1962, American Potash & Chemical Company (AP&CC) purchased the AP plant from the Navy, but continued to supply the Navy. AP&CC merged with Kerr-McGee Corporation (Kerr-McGee) in 1967. This merger included boron production processes in California, which were moved to Henderson and began operation in the early 1970s. These production processes included the production of elemental boron, boron trichloride, and boron tribromide. In 1994, the boron tribromide process was shut down and dismantled. In 1997, the sodium chlorate process was shut down; and, in 1998, production of commercial AP ended as well. The AP production equipment was used to reclaim perchlorate from on-Site materials until early 2002, when the equipment was permanently shut down.

In 2005, Kerr-McGee Chemical LLC’s name was changed to Tronox LLC. Tronox currently operates processes at the Henderson facility to produce manganese dioxide, boron trichloride, and elemental boron. Additional companies (collectively called the BMI companies) operate within the BMI complex, and details regarding ownership and leases within the BMI complex are described in the *Phase I Environmental Conditions Assessment* (ECA) report (Kleinfelder, 1993).

During the 1970s, the U. S. Environmental Protection Agency (USEPA), the State of Nevada, and Clark County investigated potential environmental impacts from the BMI companies' operations, including atmospheric emissions, groundwater and surface water discharges, and soil impacts (Ecology and Environment, 1982). From 1971 to 1976, Kerr-McGee modified their manufacturing process and constructed lined surface impoundments to recycle and evaporate industrial wastewater. In 1976, the Kerr-McGee facility achieved zero discharge status for industrial wastewater management.

As a result of current and historic business operations at the Kerr-McGee facility and from operations on nearby sites, soil and/or groundwater have been impacted with AP, hexavalent chromium, arsenic, asbestos, dioxin, VOCs, and other chemical compounds.

2.1.3 Current Land Use

Tronox currently operates processes at the Henderson facility to produce manganese dioxide, boron trichloride, and elemental boron. The BMI companies operate within the BMI complex.

The Site includes numerous buildings, sheds, labs, ponds, tanks, and pipelines related to the production of manganese dioxide, boron trichloride, and elemental boron. The current operating areas are shown on Figure 2.

The major buildings on the Site include Unit Buildings 1 through 6. These were the main buildings used during World War II for magnesium production. Tronox currently uses Unit Building 3 for offices and storage, Unit Building 5 also for storage, and Unit Buildings 5 and 6 for production of manganese dioxide. Unit Buildings 1 and 2 are not currently used except for support of utilities and electrical service and have been partially demolished. The Unit Building 4 is currently being refurbished for new processes.

Other buildings present on the Site include an administrative office building, a wash room building, Tronox production facilities, water treatment facilities operated by Veolia Water North America, the Laboratory Building, former perchlorate production facilities, and other ancillary buildings, including the Maintenance Building and Steam Plant (Figure 2). Included within the Site is a 600- by 750-foot area that the lime producer Lhoist North America (previously called both Chemstar and Chemical Lime) owns and operates. Three active ponds (GW-11, WC-West, WC-East) exist at the northern portion of the Site. WC-East and WC-West ponds and the Mn-1 pond will be leased by Tronox for process operations.

The Site is crossed by asphalt and concrete roads, dirt roads, active utility lines, a high-pressure chlorine line, and railroad spurs. Three of the rail spurs are still in service and are used by used by Lhoist, Olin Corporation, and Timet. An extensive network of active and inactive underground utility lines is present under the roads and open areas at the Site. A drainage ditch (Beta Ditch) crosses the Site from west to east. (During the main production era, the Beta Ditch was the main drainage for liquid wastes that flowed to the pond areas to the east.) Currently, the Beta Ditch is being remediated, and a gravel-filled bag barrier exists at the eastern end.

Within the boundaries of the Site, and as shown on Figure 3, are "Sale" Parcels A, B (a portion was sold to Nevada Pic-A-Part), C, D, E, F, G, H, I, and J (sold to Bobby Ellis). These parcels are at the edges of the Site at the north, west, and south. Most of the parcels are not currently in use and have had soil remediation completed (see Section 2.3). Impacted soil on the Sale Parcels has been excavated in accordance with a work plan submitted to and approved by NDEP (Basic Environmental Company, 2008). Excavation and removal of soil from the majority of the "Sale" Parcels began in March 2010 and was completed in April 2010 (Northgate, 2010d). (Parcels A and B were remediated in 2007).

2.1.4 Planned Future Land Use

Tronox plans to continue current manufacturing activities on a leased area of the Site. Several parcels within the Site may be sold in the future (Figure 3) or have been sold. The Site area is zoned for industrial use, and there are no plans to develop the Site for residential use.

2.2 Investigation History

The Site has been the focus of investigations and remedial activities for over 25 years. Documents listed in Section 7 (References) describe investigation and remedial activities. The reader is directed to those documents, many of which are available on the NDEP website (http://ndep.nv.gov/bmi/index.htm), for a comprehensive review of those activities.

As described in several investigation work plans, a least 70 potential contaminant source areas on the Site were identified. NDEP identified these source areas in their August 15, 1994 Letter of Understanding (LOU), and they are typically referred to as LOU areas or LOUs (NDEP, 1994). Potential source areas on the Site are diverse and include but are not limited to:

- settling, evaporation, and storage ponds,
- above and below-ground piping,
- above-ground ditches,
- leach plant and associated storage tanks and transfer lines,
- AP plant and associated buildings,
- agricultural division plant,
- disposal piles,
- landfills,
- storm sewers,
- maintenance shop, cooling tower, transformers, and former tailings areas, and
- conveyances associated with LOU areas that cross over into other sub-areas on the Site.

The source area investigations included a Phase A investigation (ENSR, 2006; ENSR, 2007a and 2007b) and a Phase B investigation that characterized soil and groundwater conditions across the Site (ENSR, 2008a–d). For the Phase B investigation activities, the Site was subdivided into four areas: Areas I, II, III, and IV (Figure 4). The Phase B investigation did not include Parcels A through D, F, G, and H (the "Sale" Parcels); the Basic Remediation Company (BRC) is independently investigating these (BRC, 2007). Parcel E is land that is jointly used by Montrose Chemical and others, and has not yet been investigated. The tenants of Parcels I and J are conducting investigations of these parcels independently from Tronox's Phase B activities. Phase B groundwater investigations are also ongoing; Northgate plans to complete an evaluation of the sources, distribution, and general fate-and-transport of these groundwater chemicals of interest during the first half of 2011.

Separate investigation work plans were prepared for each investigation area (I through IV), as were Site-wide groundwater and soil gas/vapor intrusion work plans (ENSR, 2008a–e). The four area-specific Phase B investigation work plans focused on the evaluation of potential source areas for the Site-related chemicals. Of the 70 potential source areas on the Site, 69 were identified in the NDEP LOU dated August 15, 1994 (NDEP, 1994). The 70th potential source area, identified as the former U.S. Vanadium site, has not been designated as a LOU. LOU areas are listed on Figure 4.

Based on groundwater depth measurements conducted over several years, the depth to groundwater across the Site varies from about 27 to 70 feet below ground surface (bgs) with depths generally increasing from north to south (Northgate, 2010e).

Primary chemical release mechanisms such as spills or leaks from above-ground chemical storage, effluent disposal in past decades, and handling activities, may have released chemicals of potential concern (COPCs) (e.g., VOCs, SVOCs, and inorganics) to surface soils, with subsequent migration into subsurface soils and groundwater. In addition, primary chemical release mechanisms from the subsurface, such as leaks or spills from below-ground piping or underground storage tanks, may have introduced COPCs to the subsurface, with subsequent migration to deeper soils and groundwater (Northgate, 2010c). Secondary release mechanisms may include re-suspension of COPCs from surface soils into ambient air in the form of dust particles or vapors, and transport of COPCs via surface water runoff and flow. These secondary release mechanisms may have caused COPCs to migrate away from primary source areas and be re-deposited to surface soils elsewhere. VOCs deposited in subsurface soil and groundwater potentially can vaporize into soil gas and migrate away from the primary source area, including upward to ambient outdoor air or into buildings (i.e., vapor intrusion), or downward to groundwater (March 2010 *Human Health Risk Assessment Work Plan* [HRA], Northgate, 2010c).

Individual area-specific work plans provide detailed descriptions of the individual LOUs and likely related COPCs based on known source areas. The work plans describe the potential impacts to surface and subsurface soils, groundwater, and soil gas; and identify the need for additional Phase B investigations.

During a meeting held in February 2010, NDEP recommended dividing the area for remediation into remediation zones, based upon geographic groupings of chemical detections and conceptual site model considerations. Based upon these discussions, Remediation Zones A through E (RZ-A through RZ-E) were defined for the Site. Figure 6 shows the boundaries of these remediation zones.

- Northgate, *Revised Excavation Plan for Phase B Soil Remediation of RZ-B, Addendum to the Removal Action Work Plan*, Tronox LLC, Henderson Nevada, August 20, 2010. (Northgate, 2010f)
- Northgate, *Revised Excavation Plan for Phase B Soil Remediation of RZ-C, Addendum to the Removal Action Work Plan*, Tronox LLC, Henderson Nevada, September 1, 2010. (Northgate, 2010g)
- Northgate, *Revised Excavation Plan for Phase B Soil Remediation of RZ-D, Addendum to the Removal Action Work Plan*, Tronox LLC, Henderson Nevada, August 31, 2010. (Northgate, 2010h)
- Northgate, *Excavation Plan for Phase B Soil Remediation of RZ-E, Addendum to the Removal Action Work Plan*, Tronox LLC, Henderson Nevada, July 13, 2010. (Northgate, 2010i)

2.3 Human Health Risk Assessment

Northgate submitted a *Human Health Risk Assessment (HRA) Work Plan* for the Site to NDEP on March 7, 2010 (Northgate, 2010c). Therein, Tronox proposed to perform an HRA for soil at the Site after remediation is completed, with the status of completion to be based upon confirmatory field observations and laboratory chemical analyses. Tronox elected to collect pre-conformation samples during the latest investigative event. By collecting pre-conformation sampling, preparation of the risk assessment could be initiated during the completion of the sampling and analysis event. The environmental conditions from pre-confirmation sampling represent a baseline for post-remediation exposures and risks

The objective of the HRA is to evaluate the potential for adverse human health impacts that may occur as a result of potential exposures to residual concentrations of COCs in soil, soil gas, and groundwater after remediation. Findings of the HRA are intended to support the site closure process.

In general, risk goals for the Site are to achieve an estimated cumulative lifetime excess cancer risk of $1x10^{-6}$ or less and a hazard index (HI) of less than 1 for all potential receptors using NDEP default exposure parameters for a commercial and construction worker. Potential exposure of receptors to contaminants in soil, groundwater, and soil gas have been considered, as shown on Figure 5, a conceptual site model for exposure risk (ENSR, 2005).

2.3.1 Conceptual Site Model

A Conceptual Site Model (CSM) is a tool used in risk assessment to describe relationships between chemicals and potentially exposed human receptor populations, thereby delineating the relationships between the suspected sources of chemicals identified at the Site, the mechanisms by which the chemicals might be released and transported in the environment, and the means by which the receptors could come in contact with the chemicals. The CSM provides a basis for defining data quality objectives (DQOs), guiding site characterization, and developing exposure scenarios. Figure 5, as mentioned previously, presents the CSM for the Site (ENSR, 2005).

2.3.2 Risk and Chemical-Specific Goals for Soil

Tronox's goal is to remediate Site soils such that it can be documented that, under a future commercial/industrial land use scenario, there is no significant risk to human health. It should be noted that although ½-acre areas are the target for exposure, sampling might not occur on some of these ½-acre exposure areas. Instead, assumptions of similar concentration distributions across areas larger than ½-acre, as supported by the data, might allow risk assessment to be applied to larger areas, which will be the “decision units” for the risk assessment. A risk-based decision might be made simultaneously for many ½-acre exposure areas where the data support aggregation of exposure areas.

This section provides a summary of the chemical-specific risk goals for the Site. In general, these chemical-specific goals follow NDEP’s BCLs, where they are available for specific chemicals.

1. Post-remediation chemical concentrations and radionuclide activities in Site soils will have a cumulative theoretical upper-bound incremental carcinogenic risk level point of departure of 10^{-6}. For cases where NDEP concurs that this goal is infeasible, Tronox understands that NDEP will re-evaluate the goal in accordance with USEPA guidance (USEPA 1991a, 1995). This point of departure risk goal will be evaluated separately for chemicals and asbestos.
2. Post-remediation chemical concentrations in Site soils are targeted to have an associated cumulative, non-carcinogenic screening HI of 1.0 or less. If the screening HI is determined to be greater than 1.0, target organ-specific HIs may be calculated for primary and secondary organs. The final risk goal will be to achieve target organ-specific non-carcinogenic HIs of 1.0 or less.
3. The risk-based target goal for lead in soil is 800 mg/kg for industrial/commercial land use. This is based on the USEPA’s Adult Lead Model using default input factors for an industrial/commercial worker (USEPA, 1996; NDEP, 2009a).
4. Where background levels exceed risk-based levels (e.g., as for arsenic), Site soils are targeted to have risks no greater than those associated with background conditions.
5. Asbestos cancer risks are based on the estimated additional deaths from lung cancer or mesothelioma due to constant lifetime exposure. The risk-based point of departure for asbestos is 10^{-6}. Risk from asbestos is evaluated separately from other chemicals.
6. Based on the bioavailability study, NDEP has agreed the BCLs for dioxin/furan are 2,700 ng/kg (parts per trillion [ppt]). Risks related to TEQs will only be quantified and presented if residual concentrations exceed the target goal. If risks are quantified, the uncertainty analysis will explain (at a minimum) the portion of the risks that are related to non-detected congeners, as well as the risks associated with the NDEP 2.7 ppb TEQ target goal.

To date, the HRA for remedial zone A (RZ-A) has been completed. NDEP has accepted the HRA for RZ-A, and has proposed using RZ-A to evaluate background concentrations for the other remediation zones. The findings from the RZ-A HRA indicate that direct contact with residual chemicals in the upper 10 feet of soil in RZ-A should not result in unacceptable risks for all future on-Site receptors (Northgate, 2010j).

2.3.3 Risk and Chemical-Specific Goals for Soil Vapor

Northgate submitted a *Site-Wide Soil Gas Human Health Risk Assessment* to NDEP on November 22, 2010 (Northgate, 2010b). The *Soil Gas HRA* concluded that chloroform contributed up to 99% of the overall excess cancer risk related to inhalation of vapors in indoor air at the majority of locations across the Site. The second largest contributor to risk of inhalation of vapors in indoor air was carbon tetrachloride. None of the other COCs had total excess cancer risk estimates that were greater than 10^{-6}, which is NDEP's point-of-departure risk goal.

2.4 Soil Investigations, COCs, and Remediation

Chemical analysis of soil samples collected during the Phase A and B site investigations showed that within the upper 10 feet of soil, selected areas of the Site contain dioxin, hexachlorobenzene (HCB), PAHs in terms of benzo(a)pyrene TEQs, PCBs, asbestos, metals, organochlorine pesticides (OCP) and/or perchlorate in soil at concentrations that exceed the Site-specific soil screening levels (Table 1). The soil screening levels were used to:

a. determine whether excavated soil could be reused as fill at the Site, and
b. define the boundaries of soil remediation areas

Tronox presented a soil remediation program in the RAW that was issued on June 22, 2010. As explained in the RAW, for purposes of designating potential remediation areas, "contaminated" soil is generally defined as soil with concentrations of COCs exceeding NDEP worker BCLs, or modified risk-based goals as agreed upon by NDEP. For metals where background concentrations exceed NDEP BCLs (e.g., arsenic), "contaminated" soil is defined as soil with arsenic concentrations greater than background concentrations. There are no NDEP BCLs for asbestos; therefore, "contaminated" soil is defined as one or more long fibers (amphibole) and/or five or more long fibers (chrysotile) per sample (collected according to BRC SOP-12 Surface Soil Sampling for Asbestos [BRC, ERM, MWH, 2008]). Based on the bioavailability study, NDEP has agreed the BCLs for dioxin/furan are 2,700 ng/kg (parts per trillion [ppt]).

The RAW proposed a program to remove the upper 10 feet of contaminated soils at numerous locations at the Site. This program is intended to remediate soils to meet the NDEP BCLs. After NDEP approved the RAW, Tronox developed remediation excavation plans for RZ-B through RZ-E. Each of these work plans is discussed below.

A total of approximately 560,000 cubic yards (including approximately 210,000 cubic yards of manganese tailings formerly located in RZ-C) will have been excavated and removed from the Site by the completion of the remediation program.

Impacted soil on the Sale Parcels (Figure 3) has been excavated in accordance with a work plan submitted to and approved by NDEP (Basic Environmental Company, 2008). Excavation and removal of soil from the majority of the "Sale" Parcels began in March 2010 and was completed in April 2010 (Parcels A and B were remediated in 2007).

An *Environmental Covenant, Institutional and Engineering Control Plan* (the *IC/EC Plan*) was prepared for the Site and submitted to NDEP on November 19, 2010 (Northgate, 2010a). The Plan identified areas of the Site where impacted soil cannot be excavated because it is present beneath existing, operational structures at the Site or is located under utilities or other Site features that preclude excavation. The *IC/EC Plan* also identified the specific institutional and/or engineering controls that will be implemented in each of these areas, and provided the rationale for the need for the institutional/engineering controls.

2.4.1 Remediation Zone A

Field investigation results indicated that RZ-A did not contain contaminants above the BCLs for on-site workers, and therefore no excavation or soil removal actions were completed for this area.

2.4.2 Remediation Zone B

RZ-B consists of approximately 42 acres of chemical manufacturing facility buildings (including Unit Buildings 1 through 6), manufacturing facility structures, ponds and vacant land (Figure 2). The areas undergoing soil remediation via excavation and off-Site disposal and the methodology for performing this work in RZ-B are presented in the *Revised Excavation Plan for Phase B Soil Remediation of RZ-B, Addendum to the Removal Action Work Plan, Tronox LLC, Henderson Nevada* (the *RZ-B Excavation Work Plan*), dated August 20, 2010 (Northgate 2010d). Chemical analysis of soil samples collected in RZ-B during the Phase A and B investigations showed that various chemicals in soil exceed the BCLs. These chemicals include the following:

- arsenic,
- dioxins/furans,
- SVOCs, including HCB and polycyclic aromatic compounds (PAHs),
- asbestos, and
- perchlorate.

Excavation boundaries and excavation depths for each of the RZ-B excavations are shown in the *RZ-B Excavation Work Plan*, which also lists each of the excavation areas, the approximate volume of soil to be excavated, and the chemicals driving the soil excavation.[1] Approximately 53,000 cubic yards of soil are being excavated and disposed of from RZ-B.

2.4.3 Remediation Zone C

RZ-C consists of approximately 64 acres that are sparsely occupied by existing buildings and ponds including the Laboratory Building, the Maintenance Building, the Steam Plant, and several other small buildings and sheds (Figure 2). The areas undergoing soil remediation via excavation and off-Site disposal and the methodology for performing this work in RZ-C are presented in the *Revised Excavation Plan for Phase C Soil Remediation of RZ-C, Addendum to the Removal Action Work Plan, Tronox LLC, Henderson Nevada* (the *RZ-C Excavation Work Plan*), dated September 1, 2010 (Northgate 2010e). Chemical analysis of soil samples collected in RZ-C during the Phase A and B investigations showed that various chemicals in soil exceed the BCLs. These chemicals include the following:

- dioxins/furans,
- SVOCs, including HCB and PAHs,
- metals, including arsenic, cobalt, lead, magnesium and manganese,
- asbestos, and
- perchlorate.

Excavation boundaries and excavation depths for each of the RZ-C excavations are shown in the *RZ-C Excavation Work Plan*, which also lists each of the excavation areas, the approximate volume of soil to be excavated, and the chemicals driving the soil excavation.[2] Approximately 120,500 cubic yards of soil are being excavated and disposed of from RZ-C.

2.4.4 Remediation Zone D

RZ-D consists of approximately 130 acres primarily occupied by active, existing groundwater and process water holding areas, including GW-11, WC-West, and WC-East (Figure 2). The areas proposed for soil remediation via excavation and off-Site disposal and the methodology for performing this work in RZ-D are presented in the *Revised Excavation Plan for Phase B Soil Remediation of RZ-D, Addendum to the Removal Action Work Plan, Tronox LLC, Henderson Nevada* (the *RZ-D Excavation Work Plan*), dated August 31, 2010 (Northgate, 2010f). Chemical analysis of soil samples collected in RZ-D during the Phase A and B investigations showed that various chemicals in soil exceed the BCLs. These chemicals include:

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[1] See Figure 1 and Table 1 of the *RZ-B Excavation Work Plan* for details.
[2] See Figures 2a, 2b, and 2c as well as Table 1 in the *RZ-C Excavation Work Plan* for details.

- arsenic,
- dioxins/furans,
- SVOCs, including HCB and PAHs,
- asbestos; and
- perchlorate.

Excavation boundaries and excavation depths for each of the RZ-D excavations are shown in the *RZ-D Excavation Work Plan*, which also lists the excavation areas, the approximate volume of soil to be excavated, and the chemicals driving the soil excavation.[3] Approximately 250,000 yards of soil are being excavated and disposed of from RZ-D.

2.4.5 Remediation Zone E

RZ-E consists of an unlined historic conveyance ditch referred to as the Beta Ditch, which extends roughly east-west across the entire Site (Figure 2). The Beta Ditch no longer serves as a conveyance ditch and is currently blocked near the eastern end by gravel-filled bags that were installed as part of the Storm Water Pollution Prevention Plan (SWPPP) for the removal of the manganese tailings pile. The areas proposed for soil remediation via excavation and off-Site disposal and the methodology for performing this work in RZ-E are presented in the *Excavation Plan for Phase B Soil Remediation of RZ-E, Addendum to the Removal Action Work Plan, Tronox LLC, Henderson Nevada* (the *RZ-E Excavation Work Plan*), dated July 13, 2010 (Northgate, 2010g). Chemical analysis of soil samples collected in RZ-E during the Phase A and B investigations showed that various chemicals in soil exceed the BCLs. These chemicals include:

- dioxins/furans,
- SVOCs including HCB and benzo(a)pyrene,
- pesticides (4,4-DDE, 4,4-DDT, dieldrin, and alpha-BHC),
- PCBs (aroclor 1260),
- metals, including arsenic, lead, magnesium, and manganese,
- asbestos, and
- perchlorate

Excavation boundaries and excavation depths for each of the RZ-E excavations are in the *RZ-E Excavation Work Plan*, which also lists each of the excavation areas, the approximate volume of soil being excavated, and the chemicals driving the soil excavation.[4] RZ-E differs from the other

[3] See Figure 1 and Table 1 of the *RZ-D Excavation Work Plan* for details.
[4] See Figure 1 and Table 1 of the *RZ-E Excavation Work Plan* for details.

remediation zones in that almost all of RZ-E will be excavated from 0 to 10 feet bgs. Approximately 45,000 cubic yards of soil are being excavated and disposed of from RZ-E.

2.5 Groundwater Investigations, COCs, and Remediation

Tronox currently operates a groundwater remediation system located on the Site, as well as in off-Site locations described below. The layout of major features of the existing groundwater treatment systems are shown on Figure 2. Components of the remediation systems include an on-Site bentonite-slurry barrier wall, three different areas of groundwater extraction wells, single and double-contained pipelines, air relief structures, electrical power and instrumentation conduits, fiber-optic instrument systems, electrical field control panels, leak detection systems, radio frequency communication links, settlement pin monuments, two groundwater treatment systems, a pond, and a network of groundwater monitoring wells. Existing groundwater monitoring and extraction wells are identified on Figure 7. A history of groundwater investigation, remediation, and related agreements is described below.

Groundwater investigations began in the 1970s, with USEPA, the State of Nevada, and Clark County investigating potential environmental impacts from the BMI companies' operations. KMCC initiated a groundwater investigation in July 1981 to comply with federal Resource Conservation and Recovery Act (RCRA) standards for monitoring existing on-site impoundments. In December 1983, NDEP requested that KMCC investigate the extent of hexavalent chromium impact to the groundwater at the Site. A Consent Order between KMCC and NDEP was issued in September 1986 (NDEP, 1986) that stipulated the requirement for additional characterization, and the implementation of remedial activities. Remediation of hexavalent chromium in groundwater began in September 1986, when four extraction wells (within the current Interceptor Well Field, Figure 7) and seven monitoring wells were installed. The treatment system (Figure 2) removed the hexavalent chromium, and the treated groundwater was re-injected via the recharge trenches (Figures 2 and 7).

In April 1991, KMCC was one of six past or present entities that conducted business within the BMI complex that entered into a Consent Agreement with the NDEP (NDEP, 1991) to conduct environmental studies. These studies assess Site-specific environmental conditions, which are the result of past and present industrial operations and waste disposal practices. In 1994, NDEP issued a LOU to KMCC identifying 69 specific areas or items of interest, and indicated the level of environmental investigation they wanted KMCC to conduct (NDEP, 1994). In late 1997, KMCC undertook a perchlorate characterization study to determine both the subsurface pathway(s) and the perchlorate concentrations in shallow groundwater downgradient from the

Site and extending to the Las Vegas Wash (KMCC, 1997), which is immediately north of the mapped area shown on Figure 1.

Remediation of perchlorate in groundwater began in September 1998, when a recovery well was installed at Athens Road (within the current Athens Road Well Field shown on Figure 7) to capture small volumes of perchlorate-bearing shallow groundwater. On-Site capture of perchlorate-bearing groundwater began in late 1998 via the installation of additional wells in the Interceptor Well Field (Figure 7). Extraction from this well field also continued to capture on-Site groundwater to remove hexavalent chromium; however, instead of re-injecting the treated groundwater to the shallow aquifer via the recharge trenches (Figures 2 and 7), it was impounded in an 11-acre lined pond (GW-11, constructed in late 1998, Figure 2) and held for additional treatment for perchlorate. Instead of the treated groundwater, untreated Lake Mead water was re-injected into the recharge trenches to replace the removed groundwater.

In 1999, a Consent Agreement between KMCC and NDEP defined remedial requirements and required a permanent treatment process to remediate water that was impacted by perchlorate. Groundwater collection for perchlorate reduction in the Seep area near Las Vegas Wash was initiated in late 1999.

In 2001, an Administrative Order on Consent between KMCC and NDEP defined more permanent remedial requirements for perchlorate-impacted groundwater and surface water. This AOC supplemented the requirements of the 1999 Consent Agreement.

During 2001 and 2002, the Seep Well Field (Figure 7) was constructed (ENSR, 2005), the Athens Road Well Field (Figure 7) was expanded, and a low-permeability barrier wall (Figure 7) was installed immediately downgradient of the Interceptor Well Field.

In 2004, the current perchlorate treatment plant (see Figure 2) was completed. Since then, several additional extraction wells have been added to the well fields shown on Figure 7. Both the perchlorate- and hexavalent chromium-remediation systems are currently operating.

In addition to perchlorate and hexavalent chromium, other groundwater chemicals of interest have been identified at the Site based on:

1. presence at concentrations greater than NDEP risk-based groundwater concentrations (RBGCs);
2. records of onsite use;
3. detections in offsite groundwater at elevated concentrations;

4. significant contributor to general water quality; and/or,
5. daughter product or chemical associated with other chemicals of interest.

Based on these criteria, the following chemicals have been identified as chemicals of interest:

- **Metals:** arsenic, boron, chromium, hexavalent chromium, magnesium, manganese, strontium, and uranium;
- **General Minerals:** ammonia, bicarbonate, calcium, chlorate, chloride, nitrate, phosphorous, potassium, sodium, sulfate, and total dissolved solids (TDSs);
- **Other:** perchlorate; and
- **Organics:** alpha-BHC, benzene, chlorobenzene, carbon tetrachloride, chloroform, 1,2-dichlorobenzene, 1,4-dichlorobenzene and 1,1-dichloroethene, and trichloroethene.

Northgate plans to complete an evaluation of the sources, distribution, and general fate-and-transport of these groundwater chemicals of interest during the first half of 2011.

2.6 Soil Vapor Investigations, COCs, and Remediation

AECOM performed a Site-wide evaluation of soil gas conditions beneath the Site in May 2008. The objectives of this soil gas survey were to:

- Gather sufficient soil gas data to assess the potential risk to human health via the indoor air vapor intrusion pathway for potential future commercial/industrial development and currently occupied buildings;
- Evaluate the nature and extent of VOCs in soil gas in areas where VOCs were reported in soil and groundwater samples from the Phase A investigation; and
- Evaluate LOUs where VOCs may have been used in past operations (AECOM, 2009).

Sample locations for this soil gas survey were based on the results of the *Phase A Source Area Investigation* (ENSR 2007a) and identification of LOU areas that may have been sources of VOCs to the subsurface. Results of this investigation indicated the following:

- Chloroform, TCE, chlorobenzene, carbon tetrachloride, and trichlorofluoromethane were detected at elevated concentrations in soil gas across the Site.
- Based upon the distribution of these VOCs, elevated concentrations of VOCs in soil gas at the Site appear to be localized within specific areas of the Site, including the following areas (Figures 2, 4, 8, 9):
    - The Western Area,
    - The Unit 4 Building,

    - LOU 8, the old P-3 Pond,
    - LOU 13, Pond S-1,
    - LOU 35, the former truck emptying/dumping site,
    - LOU 38, the AP Laboratory Building and former satellite accumulation point, and
    - LOU 62, the former State Industries catch basin.
- Chloroform is the main risk driver for the vapor intrusion pathway (Figures 8 and 9).

2.7 Hazards Associated with Existing Structures

2.7.1 Existing Subsurface Structures That May Require Future Removal

While some of the original ponds and pipelines within the Site area have been removed, a number of these structures still remain in place, supporting ongoing operations, and may need to be removed during future development of the Site area.

2.7.2 Hazardous Materials Associated with Existing Structures and Current Operations

Many of the existing buildings within the Site are either known or suspected to contain hazardous materials, such as asbestos-containing materials (ACM), lead-based paints, and equipment/materials containing PCBs and mercury. In addition, hazardous materials have been or are being stored, and hazardous waste has been or is being generated at existing buildings within the Site. Hazardous materials associated with existing structures or operations within the Site area are outlined below:

- Many of the existing buildings within the Site are known or suspected to contain ACM due to their age and construction (Converse Consultants, 2010).
- Given the age of buildings within the Site and the common use of lead-based paints before 1978, lead-based paints were most likely used on the majority of buildings/structures within the Site.
- Transformers or capacitors containing PCBs may be present within the Site. In addition, buildings with fluorescent lighting may contain PCB and mercury in the light ballasts, and caulking used in the buildings may contain PCBs.
- Tronox currently operates processes to produce manganese dioxide, boron trichloride, and elemental boron. These operations generate wastes that are managed in accordance with federal, state, and local laws and regulations.

Future Site demolition and/or redevelopment activities may need to incorporate measures to assess the presence of these hazardous materials and specify how they will be addressed within the planned action.

3.0 RISK MANAGEMENT FOR SOIL

This section addresses precautions that will be taken to mitigate potential risks to human health and the environment from COCs in soil during future Site development and maintenance activities. There are currently no development plans for the Site. Precautions to be taken during construction will include the following:

- Establishment of procedures to characterize and manage Site soil during construction excavation and trenching activities, and
- Implementation of best management practices (BMPs) for construction sites, including control of dust generation at the Site, decontamination of equipment, and prevention of sediment from leaving the Site in storm water runoff.
- Ensuring that proper health and safety precautions are taken, as discussed in Section 6.3.

3.1 Soil Management Protocols

Although there are currently no development plans for the Site, soil may be excavated or relocated within the Site during future demolition work, grading, foundation excavation, utility work, facility maintenance activities, and other construction-related activity.

Areas of known soil contamination that are being left in place are identified in the *Environmental Covenants, Institutional and Engineering Control Plan* (the *IC/EC Plan*) (Northgate 2010a). Also, there will be no excavation permitted within 10 feet of NV Energy transmission towers, per NV Energy rules.

Whenever soil in known or suspected contaminated areas is being excavated or exposed, the entity performing the work shall monitor the soil to determine if the soil is contaminated with COCs. Soil management protocols are also applicable when previously unknown soil contamination is encountered during construction/demolition/development activities.

3.2 Excavated Soil Screening Procedures

As described in Section 2.4, there are a number of areas within the Site where it is likely that soil containing COCs may be encountered during construction activities. This section describes the soil-handling procedures that will be implemented under the following scenarios:

- **Small Quantity IC/EC Soils.** A small quantity of soil (i.e., <10 cubic yards) excavated during limited subsurface activities (e.g., during routine maintenance or repair of underground structures or utilities) within areas that are identified as requiring institutional or engineering controls in the *IC/EC Plan*.

- **Large Quantity IC/EC Soils.** A significant quantity of soil (i.e., 10 cubic yards or more) excavated during subsurface activities within areas that are identified as requiring institutional or engineering controls in the *IC/EC Pla*n. If a majority of an IC/EC area is to be excavated, consideration will be given to the feasibility of complete removal of soils in that entire IC/EC area.
- **Building Perimeter Soils.** The top 3 inches of soil excavated from areas within 10 feet of the perimeter of Site buildings that is potentially impacted by lead or asbestos (i.e., adjacent to buildings known to have exterior lead paint or asbestos-containing siding).
- **Previously Unknown Contamination.** Previously unknown soil contamination that is encountered during construction activities.

3.2.1. Stockpile Management

Potentially contaminated soil that is excavated will be stockpiled for chemical analysis, as needed (if existing characterization data are sufficient for landfill disposal, then additional analyses will not be required). The contractor will place soil stockpiles on a plastic liner and will cover the stockpile with a plastic liner or tarp at all times except when material is being handled. The top covering will be adequately secured so that all surface areas are covered. Berms will be constructed around the stockpile area to control precipitation run-on and run-off.

3.2.2. Sampling and Analysis of Stockpiles

If sampling is required for disposal of excavated soil (e.g., where existing characterization data are insufficient), one composite sample will be collected from random locations from within every 250 cubic yards of stockpiled soil for the first 1,000 cubic yards and per every 1,000 cubic yards for each additional 1,000 cubic yards. Composite soil samples shall consist of at least four subsamples representative of the stockpiled soil. All samples will be submitted to a state-certified laboratory and analyzed for an appropriate suite of chemicals based upon the following criteria:

- Stockpile sampling and analysis will not be required for small quantities of soil (i.e., <10 cubic yards) from an institutional or engineering control area (IC/EC area). This soil may be reused to backfill the excavation, as it will still be within the IC/EC controlled area. If the area will not be capped with pavement, then the top three feet will be backfilled with clean soil to limit the potential for contact at the surface. This exemption is to allow for cost-effective repair and maintenance efforts which involve small quantities of soil.
- Significant quantities of soil (i.e., 10 cubic yards or more) from an institutional or engineering control area (IC/EC area) will be analyzed, if needed for disposal, for all of the chemical groups identified in the excavation plan for that area.

- Soil from areas surrounding the perimeter of Site buildings potentially impacted by lead or asbestos will be analyzed for lead using EPA Method 6010 and/or asbestos by the EPA elutriator method (USEPA, 1997).
- Soil from previously unknown contamination areas will be analyzed for selected chemicals based on field observations, historical operations in the area where the contamination is discovered, or other relevant information that is available (see Section 3.3).

3.2.3. Disposition of Sampled Stockpiles

Analytical results will be compared to soil screening levels (Table 1). If chemical concentrations in the soil stockpile samples do not exceed the soil screening levels, the soil can be reused at the Site for backfill, either within the project area from where it was excavated, or in other areas at the Site.

If chemical concentrations in the soil stockpile samples exceed the soil screening levels, the soil will be managed in accordance with all applicable laws and regulations. NDEP will be notified when the results of chemical testing indicates excavated soil contains COCs at concentrations that exceed the BCLs for the Site. In addition to the stockpile sampling, confirmation soil samples shall be collected from the excavation sidewalls and excavation floor. Laboratory analysis of the confirmation soil samples shall include the same analyses that were used for the soil stockpile. If the results of the confirmation soil samples indicate that all COC concentrations are below soil BCLs, no further action is required.

3.2.4. Confirmation Sampling for Excavations in Areas of Previously Unknown Contamination

For excavations in previously unknown contamination areas (but not for excavations in IC/EC areas), confirmation samples will be collected from in-place soils at the limits of the excavation as follows:

- Sidewall samples will be collected from freshly exposed soil at a depth equal to approximately one half of the excavation depth at a minimum frequency of every 50 linear feet of sidewall excavation face.
- Bottom confirmation samples will be collected from excavation bottoms at discrete locations on approximately 50-foot centers for areas greater than approximately 2,500 square feet. For excavations that are less than 2,500 square feet, one bottom confirmation sample will be collected.
- A minimum of one bottom sample and one sample per excavation sidewall face will be collected from each excavation.

If the results of the confirmation sample analyses indicate that COCs are present in soils at concentrations that exceed soil screening levels, then NDEP shall be notified. The project owner will manage soils remaining in place according to one of the following three tracks:

- Track 1 – Excavate and Remove, Collect Confirmation Samples
- Track 2 – Characterize In Situ
- Track 3 – Standard Agency Oversight

Details of these three tracks are provided below. The choice of the track will depend on the apparent extent of contamination, the construction schedule, and physical constraints. The first two tracks are designed to be implemented relatively quickly to completely address limited areas in locations that potentially affect the construction project. For example, during excavation for a building foundation, the contractor may encounter a potential COC-source area that extends underneath the footprint of the planned building. In this situation, it may be appropriate for the contractor to excavate impacted soils within the building footprint so that construction can proceed without delay. The third track is potentially appropriate for larger source areas for which excavation may not be practicable, or if the source area extends into areas that do not affect the construction project schedule.

- **Track 1 –** Excavate and Remove, Collect Confirmation Samples: Track 1 is considered a "fast track" remedial approach, and is designed to allow development work to proceed with minimal delay. Unsaturated zone soils that potentially contain chemicals above soil screening levels are excavated, stockpiled, and managed as described in the previous sections. Confirmation soil samples are then collected from remaining soil in the excavation sidewalls and floor to verify that impacted soils have been removed. Confirmation samples shall be collected at the same frequency as described earlier in this section. Excavation is considered complete if confirmation soil sample results are below soil screening levels, or until the bottom of the excavation has reached a depth of 10 feet relative to final surface grade. After soil excavation is considered complete, the excavation may be backfilled with clean soil, and development work may continue.
- **Track 2 –** In-Situ Characterization: Track 2 is considered the "middle track" remedial approach because in situ characterization requires significantly more time than the direct excavation approach. Track 2 may be more appropriate if:

  a. the construction schedule allows for *in situ* characterization, or
  b. the potentially impacted area is suspected to be large.

  Under Track 2, the extent of impacted soils is characterized in situ by collecting soil samples from soil borings prior to excavation (i.e., the extent is characterized in advance using samples collected from soil borings, rather than confirmation samples collected from excavation boundaries). Based on the nature and extent of contamination, the responsible party may proceed with the removal and disposal of impacted soils, or evaluate and implement remedial measures under Track 3 below.

- **Track 3 –** Standard Agency Oversight: Track 3, involving direct regulatory agency involvement in decision-making, may be more appropriate if:

    a. previously unknown contaminants of concern or uncharacterized contaminant sources are identified that warrant agency notification and involvement,

    b. complete excavation is not practicable at that time (e.g., the potentially impacted area is particularly large, or there are physical constraints such as a building),

    c. the construction schedule is not affected by the impacted area, or

    d. no further action is believed to be necessary due to the nature of the source, or because operation of the regional groundwater remediation system adequately addresses any potential impact due to the identified impacted soil.

3.3 Contingency Actions for Encountering Previously Unknown Soil Contamination

In addition to the known areas of soil contamination at the Site, previously unknown soil contamination may be observed during earthwork activities or building demolition, such as when existing building slabs are removed, during grading work, or within excavations for trenches or building foundations. If during any earthwork or building demolition activities at the Site, soil is encountered that is visibly stained, discolored, shiny, or oily, or that has a noticeable solvent- or hydrocarbon-like odor, actions will be taken as summarized below.

If previously unknown soil contamination is observed during construction activities at the Site, NDEP shall be immediately notified. A sample of the visibly contaminated or odorous soil will be collected for laboratory analysis and analyzed, at a minimum, for Site COCs by the following analytical methods:

- VOCs by EPA Method 8260;
- Perchlorate by EPA Method 314.0 or 6850;
- TPHg by EPA Method 8015m;
- TPHd by EPA Method 8015m;
- SVOCs by EPA Method 8270; and
- RCRA Metals by EPA Method 6020.

Additional analyses shall be performed if there is evidence that other chemicals may be present that could represent a potential health risk through direct contact by subsurface workers. Determination of whether other chemicals may be present would be based on field observation and professional judgment of a licensed or certified environmental professional, and take into consideration the location of the excavation in relation to known source areas that have been previously investigated. Additional analyses may include the following:

- PCBs/Pesticides by EPA Method 8080;
- Dioxins/Furans by EPA Method 8290.

If it is determined that no additional analyses beyond the initial analyses are required, soil excavation may proceed to the extent needed to continue construction activities. The excavated soil will be managed as described in this section. If the results of the evaluation sample indicate COCs are present in soil at concentrations above the soil screening levels, additional action may be necessary.

3.4 Documentation of Soil Screening and Management of Impacted Soils

The responsible party shall prepare a report documenting implementation of the excavated soil screening procedures. The report shall include, at a minimum, the following information:

- A summary of laboratory analytical results of soil stockpile sampling and a compilation of laboratory analytical data reports;
- An estimate of the volume—and approximate location—of excavated soil that exceeded Site soil screening levels; and
- A summary of excavated soil transported to an offsite disposal facility, including the dates the soil was transported and the estimated quantity of soil transported.

3.5 Construction Impact Mitigation Measures

This section outlines measures that will be implemented to mitigate potential impacts to human health and the environment during earthwork construction. Measures will be implemented to mitigate the potential impacts of the following activities:

- Dust generation associated with soil excavation and loading activities, construction or transportation equipment traveling over on-Site soil, and wind traversing COC-containing soil stockpiles;
- Tracking soil off the Site with construction or transportation equipment; and
- Transporting sediments from the Site in surface water run-off.

The mitigation measures for these potential activities will include, but are not limited to, the following:

- Implementing dust and odor control measures (Section 3.5.1);
- Decontaminating construction and transportation equipment (Section 3.5.2); and
- Implementing SWPPPs, BMPs, and applicable controls (Section 3.5.3).

These mitigation measures are discussed in more detail below. The responsible party shall prepare and submit to the appropriate authorities a plan describing mitigation measures that will be implemented during Site construction activities.

3.5.1 Dust Control Measures

Dust control measures will be implemented during construction activities at the project area to minimize dust generation. It is particularly important to minimize the exposure of on-Site construction workers to dust containing COCs, and to prevent nuisance dust and dust containing COCs from migrating off-Site. Dust generation may be associated with excavation activities, truck traffic, ambient wind traversing soil stockpiles, loading of transportation vehicles, and other earthwork.

Dust control measures may include the following:

- Mist or spray reclaimed water while performing excavation activities and loading transportation vehicles;
- Limit vehicle speeds on the property to 5 miles per hour;
- Control excavation activities to minimize dust generation; and
- Minimize drop heights while loading transportation vehicles.

Soil stockpiles generated as a result of excavating soil potentially impacted by COCs will be underlain with plastic sheeting and covered with plastic sheeting or tarps.

3.5.2 Decontaminating Vehicles and Construction Equipment

Construction equipment and transportation vehicles that contact soil that potentially contains COCs within the construction site will be decontaminated before they leave the construction site, to minimize the potential for their tracking COC-containing soil onto roadways.

Decontamination methods will include scraping, brushing, and/or vacuuming to remove dirt on vehicle exteriors and wheels. If these dry decontamination methods are not adequate, methods such as steam cleaning, high-pressure washing, and cleaning solutions will be used, as necessary, to remove soil. Wash water resulting from decontamination activities will be collected and managed in accordance with all applicable laws and regulations.

3.5.3 Storm Water Pollution Controls

The Site is subject to storm water regulations. To ensure that the Site complies with these regulations, all construction activities shall conform to NDEP requirements. It is anticipated that any contractor performing work at the Site that is subject to NDEP stormwater management requirements will implement specific BMPs appropriate to the construction plans and specifications.

3.6 Documentation of Contingency Actions Taken

The implementation of contingency actions shall be appropriately documented. After completion of a contingency action, the responsible party will prepare a report that describes the field activities, findings, actions taken, and analytical results. The report will include a figure depicting the location where the action was taken, laboratory analyses, and survey of the subject area.

4.0 RISK MANAGEMENT FOR GROUNDWATER

This section addresses risk management for groundwater, including limiting the potential for creating migration pathways during construction, dewatering considerations, and protection/removal/relocation of monitoring wells and remediation system components.

4.1 Reducing the Potential for Creating Conduits to Groundwater During Deep Construction Activities

Because subsurface material at the Site includes sands and gravels, most construction at the Site utilizes a slab on grade. However, it is possible that designs for new construction will include deep foundations. If deep foundations are required for new construction at the Site, they will be cast in place, eliminating the potential to create vertical conduits for migration of soil vapor from groundwater into overlying buildings.

It is unlikely that piles or deep excavations will be used in future construction, because of the nature of the subsurface material. However if piles or deep excavations are planned that would penetrate the first aquifer zone underlying the Site (i.e., 30 feet below ground surface), mitigation measures will be employed to minimize:

a. the potential to drive shallow, chemically-impacted soil into deeper soils,
b. the potential to create conduits for the migration of shallow, chemically-impacted groundwater to deeper groundwater, and
c. the potential to create conduits for the migration of soil vapor from groundwater into overlying buildings.

Mitigation measures may include pre-drilling through chemically-impacted soil or groundwater and using conductor casing to prevent downward or upward migration of COCs. Alternatively, if a geotechnical evaluation indicates that the aquitard sediments will seal around the installed piles to prevent formation of conduits, piles may be installed using a cone-shaped tip on the end of the pile to prevent soil from migrating to deeper zones. The builder will prepare a design report for submittal to NDEP for review and approval which describes the mitigation measures that will be implemented and which demonstrates their effectiveness in preventing downward or upward migration of COCs.

Other mitigation measures that can effectively reduce the potential for driving impacted soil deeper, or creating conduits for groundwater migration, may also be used, if their effectiveness can be demonstrated to the satisfaction of NDEP.

4.2 Dewatering

Groundwater is relatively deep at the site (typically 30 ft or more below grade), thus dewatering is unlikely to be required for future construction activities. However, if dewatering is to be performed as part of construction activities, then the groundwater will be sampled in planned work areas and analyzed to determine appropriate management practices. Depending on the analytical results, and with appropriate governmental agency approvals, extracted groundwater may be:

- Used for dust control on the Site;
- Discharged to the storm drain;
- Discharged to the sanitary sewer;
- Discharged to the Tronox Groundwater Treatment System; or
- Transported off-Site for disposal at an authorized facility.

4.3 Protection and Removal/Relocation of Existing Groundwater Monitoring Wells and Remediation System Components

Tronox currently operates a groundwater remediation system located on the Site, as well as in off-Site locations described in Section 2.5. The layout of major features of the existing groundwater treatment systems are shown on Figure 2. Components of the remediation systems include an on-Site bentonite-slurry barrier wall, three different areas of groundwater extraction wells, single and double-contained pipelines, air relief structures, electrical power and instrumentation conduits, fiber-optic instrument systems, electrical field control panels, leak detection systems, radio frequency communication links, settlement pin monuments, three groundwater treatment systems, ponds, and a network of groundwater monitoring wells. Existing groundwater monitoring and extraction wells are identified on Figure 7.

The groundwater remediation systems operate continuously, except when it is necessary to shut them off for required maintenance. Any parties planning construction work that could impact the groundwater remediation systems or monitoring wells must take appropriate measures to protect the integrity of these features. These measures should allow for the continued operation of these systems and wells while minimizing any shutdowns of system components. Issues that should be considered include:

- Procedures for planning and implementing remedial system modifications that may be necessary due to Site development activities; and

- Measures to be taken to protect remedial system components during construction.

4.3.1 Removal or Relocation of Remediation System Components and Monitoring Wells

If the location of existing remediation system wells and pipelines conflicts with any planned development, it may be possible to remove or relocate the affected well or pipeline. In identifying potential conflicts between existing remediation system components and planned development, the following criteria will be used:

- All existing wells located within 5 feet of the outer wall of a new building are considered in conflict with planned development and must be properly abandoned or relocated (if required) because they will be too difficult to access once the building is constructed. Wells located more than 5 feet from building walls may also be considered in conflict with planned development subject to a Site-specific evaluation.

- All pipelines located within 20 feet of the outer edge of the proposed footing or foundation of a new construction shall be protected, as necessary, from potential damage due to construction work. A qualified engineer shall determine the appropriate setback for any new construction as well as protective measures during construction .

- Wells, pipelines or other remediation system components that do not meet either criteria above, but are identified as potentially in conflict with the layout of the planned development or planned construction activities by the responsible party. For example, a monitoring well in the center of a planned roadway would be in conflict with the layout of the planned development, and would need to be removed or relocated.

Potential conflicts between future construction projects and the location of existing remediation system components should be identified and resolved during the design stage. Relocation or removal of any remediation system components may only occur with the prior approval of NDEP. In addition, NDEP must approve in advance any planned shutdown of the remediation system for more than 24 hours.

4.3.2 Protection of Existing Groundwater Wells and Remediation System Components

Before construction starts, the contractor shall confirm the location of all extraction and monitoring wells that are within or near the construction zone. Before commencing construction work, the contractor shall appropriately protect all groundwater monitoring and extraction wells. The contractor shall provide and place steel plate or equivalent protective measures over the existing pipelines and power and control conduits during construction activities.

4.3.3 Shutdown of Remediation Systems

If construction activities would require a planned shutdown of any portion of the remediation system, the contractor shall provide the property owner with written notice at least 5 working days before the proposed shutdown, and the property owner will coordinate obtaining NDEP approval. If the contractor's activities result in an unplanned shutdown of any components of the remediation system, they must immediately verbally notify the property owner. In addition, within 48 hours of the shutdown they must provide a written explanation of the reason for and the duration of the shutdown.

4.3.4 Remediation System Access

Site development must be performed in such a way that all groundwater wells, pull boxes, and the groundwater treatment system and associated components can be accessed for sampling, operation, and maintenance. If access to a well or other remediation system component is restricted during construction, the contractor must provide to the property owner written explanation of the reason for and the duration of the proposed restricted access 5 working days before creating the restriction.

4.3.5 Accidental Releases of Untreated Groundwater

Before starting construction in an area of the Site that contains any component of the groundwater monitoring, extraction, and treatment systems, the contractor shall prepare a contingency plan to outline actions that would be taken if the builder's contractors damage any remediation system component in a manner that causes the release of untreated groundwater. The plan shall identify any emergency equipment the contractor may need to retain on-Site during construction activities to control or contain potential releases of untreated groundwater. The contractor must submit the plan to the property owner for review and approval before starting construction activities in areas where remediation system components are located.

If construction activities result in the release of untreated groundwater, the contractor shall immediately notify the property owner, and the owner will then notify NDEP of the release and the status of remediation system operations. If the remediation system is shut down due to damage to the system or to control the release of untreated groundwater, the contractor will provide the property owner with a written explanation for the shutdown. The contractor will take immediate action to control the source of the spill, and contain untreated groundwater that has been released, in accordance with its approved contingency plan. Effort shall be made to avoid release of untreated groundwater into storm sewers.

Impacted groundwater produced during dewatering of excavated areas during Site development will either be discharged to the sanitary sewer system, if possible, or will be transported to the groundwater treatment system, depending on the COCs identified in the water through environmental sampling.

5.0 RISK MANAGEMENT FOR SOIL VAPOR INTRUSION

Northgate submitted a Site-Wide Soil Gas Human Health Risk Assessment (HRA) to NDEP on November 22, 2010 (Northgate, 2010h). The Soil Gas HRA concluded that chloroform contributed up to 99% of the overall potential excess cancer risk related to inhalation of vapors in indoor air at the majority of locations across the Site. The second largest contributor to risk of inhalation of vapors in indoor air was carbon tetrachloride. None of the other COCs had total excess cancer risk estimates that were greater than 10^{-6}, which is NDEP's point-of-departure risk level. A map showing the chloroform groundwater plume, which is an indicator of the presence of chloroform in the overlying soil gas, is presented on Figure 8.

In addition to the modeled indoor air concentrations presented in the *Soil Gas HRA*, indoor and outdoor ambient air sampling was conducted during the Spring 2010 season (Northgate, 2010k). Another round of sampling was completed in December 2010, and results are pending. The air sampling data will be used to provide context to the *Site-Wide Soil Gas HRA* findings.

The specific areas of the Site that may require risk management for potential soil vapor intrusion are the areas that exceed the 10^{-6} risk level (Figure 9), which are corroborated by indoor and ambient air sampling results. Risk management activities may apply both to existing buildings and to future construction. Currently no new development is planned for the Site; however, the measures described in this section may be applied to any new development that does occur in the future in the areas requiring risk management. Existing buildings can be retrofitted and new buildings and utilities can be constructed with mitigation measures that will limit potential exposure to chemicals in soil gas. Mitigation measures, design and regulatory approval processes, and monitoring that will be required for existing and new construction at the Site in areas with residual levels of volatile COCs in soil gas are described in Sections 5.1 through 5.3.

5.1 Prevention of Vapor Intrusion of VOCs into Occupied Buildings

The process of VOC migration in the vapor phase from the subsurface into overlying buildings with subsequent contamination of indoor air is termed "vapor intrusion." Figure 10 shows vapor intrusion pathways and mechanisms. Vapor intrusion may result in indoor workers being exposed to VOC vapors through inhalation of indoor air at concentrations that exceed the Site's risk goals. For future construction at the Site and for existing buildings, mitigation measures may be needed to reduce vapor intrusion to the extent needed to achieve the risk goals established for the Site.

The vapor intrusion process begins when VOCs in soil or groundwater volatilize into soil gas in the subsurface. The degree to which VOCs volatilize into soil gas depends on the chemical properties of the VOC. VOCs with higher vapor pressures, lower water solubilities, and less tendency to adsorb to soil particles tend to partition into soil gas more readily than other VOCs. Chlorinated solvents such as those found in groundwater at the Site readily partition into soil gas. The primary COCs detected in soil vapor at the Site are chloroform and carbon tetrachloride (Northgate 2010h).

Once in the soil gas, VOCs may migrate upwards or laterally by both diffusion and convection. In general, VOCs diffuse more readily in drier, granular soil than in wetter, clayey and silty soil. Diffusion is a relatively slow transport process as compared to convection, which occurs when soil gases containing the VOCs are drawn to the surface by pressure gradients. Pressure gradients can be caused by barometric pressure changes, as well as by the reduced pressure that occurs inside many buildings, as discussed below. After VOCs in soil gas migrate to the area directly beneath a building, vapor intrusion into the building can occur by diffusion through cracks in the floor. Soil gases may also be swept into the building through cracks in the floor by convective flow, driven by a lower pressure inside the building. Lower pressures inside of buildings are sometimes referred to as the “stack effect.” The stack effect can be caused by:

- Warmer air inside the building, which tends to rise and draw in air from the lower parts of the building;
- Wind, which tends to impart a lower pressure inside the building;
- Appliance exhausts, which tend to draw air into the building and lower the interior pressure; and
- Active ventilation systems that exhaust outside the building and induce a slight negative pressure inside the building.

Considering the mechanisms of vapor intrusion, vapor intrusion prevention or mitigation tends to be based on:

a. eliminating soil gas flow into the building by creating either a lower pressure (slight vacuum) beneath the floor of the building, or a higher pressure inside the building,
b. preventing VOCs from migrating to the area beneath the building floor, using barriers or source removal,
c. providing adequate air exchange inside a building to prevent the accumulation of vapors, and/or

d. sealing cracks and penetrations in the floor through which vapor intrusion might otherwise occur.

5.1.1 Design Guidance for Vapor Intrusion

In areas where vapor intrusion mitigation may be needed, vapor intrusion mitigation measures may be selected and designed based on consideration of the type of construction—and the degree to which vapor intrusion is a concern at the location of the new construction. Early guidance for vapor intrusion mitigation was developed by the radon control industry, to mitigate impacts from radon vapor intrusion. The intrusion of radon gas into buildings occurs by similar processes to the VOC vapor intrusion process, except that radon gas naturally occurs in soil gas at some properties. Subsequent guidance for vapor intrusion was expanded to incorporate impacts from VOC vapor intrusion. The following documents were consulted in the preparation of this section of the ERMP:

- *Radon-Resistant Construction Techniques for New Residential Construction, Technical Guidance*, U.S. EPA, Office of Research and Development, EPA/625/2-91/032, February 1991 (USEPA 1991);
- *Radon Reduction Techniques for Existing Detached Houses, Technical Guidance, (Third Edition) for Active Soil Depressurization Systems*, U.S. EPA, Office of Research and Development, EPA/625/R-93/011, October 1993 (USEPA 1993);
- *Radon Mitigation Standards*, U.S. EPA, Air and Radiation, EPA 402-R-93-078, October 1993 (Revised April 1994) (USEPA 1994a);
- *Radon Prevention in the Design and Construction of Schools and Other Large Buildings, Third Printing with Addendum*, U.S. EPA, Office of Research and Development, EPA/625/R-92/016, June 1994 (USEPA 1994b);
- *Guidance for the Design, Installation, and Operation of Sub-Slab Depressurization Systems*, Thomas DiPersio and John Fitzgerald, Massachusetts Department of Environmental Protection, Northeast Regional Office, December 1995 (MDEP 1995);
- *Technical and Regulatory Guidance, Vapor Intrusion Pathway: A Practical Guideline*, Interstate Technology & Regulatory Council (ITRC) Vapor Intrusion Team, January 2007 (USEPA 2007);
- *ASTM Standard E 2600-08: Standard Practice for Assessment of Vapor Intrusion into Structures on Property Involved in Real Estate Transactions,* March 2008 (ASTM 2008)
- *Engineering Issue: Indoor Air Vapor Intrusion Mitigation Approaches*, USEPA Contaminated Site Clean-up Information (CLU-IN), 2008 (USEPA 2008a);

- *Brownfields Technology Primer: Vapor Intrusion Considerations for Redevelopment*, USEPA Office of Solid Waste and Emergency Response, EPA 542-R-08-001, March 2008 (USEPA 2008b); and
- *Vapor Intrusion Mitigation Advisory*, Department of Toxic Substances Control, California Environmental Protection Agency, April 2009 (DTSC 2009).

5.1.2 Vapor Intrusion Mitigation Alternatives

Potential vapor intrusion mitigation alternatives are described below. Where needed, mitigation alternatives may be used individually or in combination, depending on the particular circumstance. Vapor intrusion mitigation technologies discussed in this ERMP include the following categories and specific mitigation technologies:

Physical barriers

- Vapor intrusion passive barrier
- Sealing cracks and utility penetrations in the floor

Sub-slab pressure controls

- Active Sub-Slab Depressurization (ASSD)
- Passive Sub-Slab Ventilation (PSSV)

Point-of-exposure measures

- Mechanical interior ventilation with adequate air exchange
- Interior Positive-Pressure Ventilation (PPV)
- Sub-Membrane Depressurization (SMD) for crawl spaces
- Ventilated parking garage construction

The following sections describe each of these potential control options. In cases where control measures are needed, an engineering analysis will be needed to select a control option or options appropriate to address Site-specific conditions and considerations. This is discussed further in Section 5.2.

5.1.2.1 *Vapor Intrusion Passive Barrier*

A vapor barrier may be installed beneath the floor slab of a building to reduce the advective flow of gases into the overlying building. However, the effectiveness of a barrier depends largely on the quality of the installation and long-term maintenance (i.e., prevention of punctures and tears).

Air leakage may be substantial if there are voids at seams with utility penetrations, or holes in the barrier. This technology is most appropriate for new building construction, and is often used in conjunction with PSSV.

5.1.2.2 *Sealing Cracks and Utility Penetrations in the Floor*

Vapor intrusion is believed to occur primarily through cracks and penetrations that occur in the floor that is in contact with the ground. Cracks in the floor should be minimized through proper design and installation of the floor. Cracks at control joints can be sealed with flexible sealants, such as polyurethane caulk. Cracks around utility penetrations in the floor can also be avenues for vapor intrusion. Such cracks can also be sealed with flexible sealants at the top of the concrete, and mechanical devices are available for placement around utility pipes to form a better seal with the floor. USEPA has indicated that sealing floor cracks and penetrations alone is not a reliable technology, but that sealing is a useful supplement to sub-slab passive controls (USEPA, 1993). This technology is most appropriate for existing buildings.

5.1.2.3 *Active Sub-Slab Depressurization (ASSD)*

An ASSD system typically consists of a blower and sub-slab air intake piping system. The ASSD system is operated continuously to create a slight vacuum beneath the concrete floor slab of the building. The induced vacuum beneath the building floor slab overcomes the lower pressure that is sometimes found inside buildings. Therefore, when the ASSD system is in operation, soil gases generally cannot flow from beneath the floor slab into the building. Rather, at the location of any cracks on the floor, indoor air will be drawn from inside the building into the lower pressure zone beneath the floor slab, thereby mitigating the vapor intrusion process.

An ASSD system requires installation of a vent intake pipe in one or more central or other appropriately selected location(s) in the layer beneath a concrete floor slab. As an alternative, a geo-composite drainage mat or other liner with lateral permeability can be installed beneath the building and used to withdraw air from beneath the entire floor area. The vent pipe or drainage mat is connected to a blower to continuously create ventilation and a slight vacuum beneath the floor slab. The vacuum level created beneath the floor must be at a level sufficient to overcome the anticipated vacuum level inside the building.

The air and soil gases withdrawn from beneath a building during ASSD operation are exhausted to the atmosphere. The emissions from the ASSD systems are treated to remove VOCs to the extent required by local regulation. This technology is most appropriate for new building construction, but it may be possible to retrofit existing buildings with an ASSD system.

5.1.2.4 *Passive Sub-Slab Ventilation (PSSV)*

Passive sub-slab ventilation involves the placement of a venting layer below the floor slab to allow soil gas to move laterally beyond the building under natural diffusion or pressure gradients. Passive venting layers must be permeable enough to allow gas to freely migrate laterally, and relies upon natural diffusion or pressure gradients to cause soil gas to migrate to collection pipes, and vent to the atmosphere (ITRC, 2007).

5.1.2.5 *Mechanical Interior Ventilation with Adequate Air Exchange*

Mechanical interior ventilation can be accomplished either by opening doors, windows, and vents in a building, or by modifying the heating, ventilation, and air conditioning (HVAC) system to ensure adequate air exchange. Vapor intrusion reductions from opening doors, windows, and vents are reversed when the doors, windows, and vents are closed, resulting in only temporary decreases in indoor air VOC concentrations. Mechanical interior ventilation can be designed and operated to reduce vapor intrusion effectively.

5.1.2.6 *Interior Positive-Pressure Ventilation (PPV)*

Vapor intrusion primarily occurs when there is a lower pressure inside the building as compared with atmospheric pressure outside the building, which causes soil gas to flow into a building through cracks in the floor due to a pressure gradient (USEPA, 2002). Vapor intrusion may be mitigated by creating a positive pressure inside the building, which would reverse the pressure gradient. When there is a positive pressure inside a building, air inside the building will flow outward through any cracks in the floor, i.e., toward the lower outdoor pressure. The USEPA recognizes this in its vapor intrusion guidance, indicating:

"A building may be positively pressurized as an inherent design of the heating, ventilation, and air conditioning system. It may be possible to show that the [vapor intrusion] pathway, in this case, is incomplete, at the current time, by demonstrating a significant pressure differential from the building to the atmosphere." (USEPA, 2002)

Positive-pressure ventilation is effectively the same as ASSD in that both methods use an air pressure gradient to mitigate vapor intrusion routes. However, PPV's effectiveness depends on operating and maintaining the building ventilation system properly so continuous positive pressure inside the building is maintained.

Positive-pressure ventilation involves designing the building's ventilation system to continuously impart a slight positive pressure inside the lowest floor of the building relative to the pressure below the floor slab. The mechanical ventilation systems in commercial buildings are often designed to operate this way. However, for energy efficiency, such systems are also commonly turned off during non-working hours, potentially allowing for some vapor intrusion when the system is not operating. At the Site, for buildings where vapor intrusion is mitigated by PPV, the PPV system must be continuously operated in the lowest level of the building, i.e., 24 hours a day, and 7 days per week, except for periodic shutdowns for normal maintenance. Heating and cooling conditions may be adjusted during non-working hours as long as the fan continues to impart positive pressure to the building's interior.

VOC vapors migrating from the subsurface may tend to accumulate in soil gas beneath a building that is operated using PPV. As such, it is recommended that passive ventilation be installed beneath buildings designed for PPV. The passive ventilation could be installed in the same manner as the sub-slab infrastructure for an ASSD system, i.e., perforated vent pipes in the sub-slab base rock, with a header vent pipe plumbed to outside the building, but without the ASSD blower. The passive ventilation system would provide a means for VOC vapors to migrate from the sub-slab area to outside the building to reduce potential vapor accumulation beneath the building. The passive ventilation system could also be converted to an active ASSD system (i.e., by the addition of the ASSD blower) if building use is changed in the future such that continuous PPV is rendered infeasible or impractical. This technology can be implemented in both existing buildings and in new building construction.

5.1.2.7 *Sub-Membrane Depressurization (SMD) for Crawl Spaces*

Sub-membrane depressurization (SMD) utilizes a membrane placed over the dirt at the base of a buildings' crawl space. The membrane may be a flexible liner, such as high-density polyethylene (HDPE), a layer of asphalt or concrete, or another durable membrane material. Air is withdrawn from beneath the membrane, similar to air being withdrawn from beneath the floor of a building that uses SSD to mitigate vapor intrusion.

5.1.2.8 *Ventilated Parking Garage Construction*

Vapor intrusion into buildings can be mitigated by using ventilated parking garage construction at or below ground level beneath the occupied space overlying the garage. Specific requirements for ventilation of parking garages are identified in Section 406 of the International Building Code (IBC), currently in use in Southern Nevada, and other comparable, local building codes. Under requirements such as these, above-ground parking garages can be ventilated using either openings to the atmosphere or mechanical systems to draw in fresh air and to exhaust fumes. The purpose of these systems is to adequately ventilate car exhausts that are generated within the garage. These systems can be used to mitigate vapor migration from chemically impacted soil gas into overlying indoor working spaces, as described below.

For parking garages that are constructed on or above ground level without mechanical ventilation, the primary driving force for vapor intrusion (i.e., the negative pressure that occurs inside of buildings) does not occur in open parking garages. In these cases, the air pressure inside the parking garage will be essentially the same as outside barometric pressure, and vapor intrusion of VOCs into the parking garage would occur primarily by diffusion through cracks in the floor. In addition, the natural ventilation in the parking garage would serve to reduce the concentrations of any VOCs that do migrate into the parking garage. Section 406.4.2.1 of the IBC describes alternative requirements for ventilating garages using mechanical ventilation systems:

- 0.75 cubic feet per minute (cfm) of fresh air ventilation per square foot (sf) of parking garage floor;
- 14,000 cfm of fresh air ventilation per operating vehicle; or
- Ventilation adequate to maintain an average carbon monoxide level of 50 parts per million (ppm) over an 8-hour period, not to exceed 200 ppm over any 1-hour period.

Consistent with these requirements, the ventilation system for each parking garage at the Site that will also serve as vapor intrusion mitigation should be designed with a capacity of at least 0.75 cfm/sf; however, the actual capacity and operational sequence should be designed according to the level of ventilation necessary for the particular condition at each parking garage.

Parking garages at the Site should also be designed to minimize the negative pressure that may be induced inside the parking garage by the ventilation systems. Maintaining the parking garages near atmospheric pressure will reduce the potential for advective flow of subsurface vapors into the parking garage, and will be accomplished by (a) maximizing open area at the perimeter of the garage, and (b) distributing the ventilation system intakes around the garage.

In summary, the potential for vapor intrusion into parking garages at the Site, and the magnitude of any vapor intrusion that may occur, will be mitigated in two ways:

- Air pressure in the parking garage will be at or very near ambient pressure due to the openings at the perimeter of the parking garage, thereby substantially reducing the pressure driving force for vapor intrusion, and
- Ventilation in the parking garage will provide substantial reductions in concentrations of any VOCs that may migrate into the parking garage.

While it is possible that air in a parking garage may enter occupied space above the garage, concentrations in those occupied space should be even lower than in the garage due to ventilation in the occupied space.

5.2 Design and Regulatory Approval of Vapor Intrusion Mitigation Measures

It is the responsibility of the owner to design and implement adequate measures to mitigate vapor intrusion into existing buildings, as necessary, or for future construction in locations where vapor intrusion has been identified as a potential concern, and to demonstrate that the system will effectively mitigate the vapor intrusion exposure pathway and meet the 10^{-6} excess cancer risk goal.

The owner shall submit a design report to NDEP for review and approval that describes the design of vapor intrusion mitigation measures that will be implemented and demonstrates how they will be effective in mitigating the potential vapor intrusion pathway. In addition, the report shall also describe any system operation, maintenance, and monitoring activities that will be implemented to demonstrate and maintain the long-term effectiveness of the implemented mitigation measures. Effectiveness may be demonstrated by:

a. monitoring for VOCs in indoor air,

b. monitoring for VOCs in sub-slab soil gas if a barrier or sub-slab ventilation system is designed to prevent VOC accumulation below the slab, or

c. some other means that can reliably demonstrate effectiveness.

5.3 Monitoring Vapor Intrusion Mitigation Effectiveness

After a vapor intrusion mitigation technology is implemented, it must be monitored during operation to ensure it achieves its objective, namely reducing contaminant concentrations in indoor air to acceptable risk levels. The specific type of monitoring to be performed will be dependent upon the mitigation measures implemented, and will need to be specified as part of the mitigation design submittals, and may be included as part of an Operations and Maintenance Plan. However, examples of monitoring data that should be collected to demonstrate the effectiveness of the vapor intrusion mitigation strategy include the following (USEPA 2008a and 2008b):

- **Indoor Air Sampling for COCs.** The most commonly used methods for indoor air sampling are EPA Methods TO-14a and TO-15, which both require the use of stainless steel canisters. Sample collection should be performed over a 24 hour period to obtain average air concentrations over the diurnal cycle.

- **Air Exchange Rate (AER) Measurements.** The air exchange rate can be measured using either tracer gases (ASTM Method E741) or by the blower door method (ASTM Methods E779 or E1827). AER measurements along with indoor air sampling measurements collected over time can be used to differentiate between soil gas and indoor sources of contaminants in indoor air.
- **Sub-slab Soil Gas Measurements.** These types of measurements are most appropriate for sub-slab depressurization or sub-slab ventilation mitigation systems. Sub-slab sampling probes can be installed as either temporary or permanent sampling points, and multiple rounds of sub-slab sampling are generally recommended to evaluate diurnal and seasonal variability in sub-slab soil gas concentrations.
- **Sub-slab Pressure Measurements.** This data is most appropriate for SSD systems, and can be used to demonstrate that negative pressure exists below the building foundation (DTSC, 2009).
- **Routine Monitoring Data for the System.** For example, if building pressurization is the mitigation technology, then the building HVAC system should monitored on a routine basis to ensure the system is maintaining a positive pressure in the building.

For vapor intrusion mitigation by a system not described in this ERMP but approved by NDEP, the method of demonstrating effectiveness must also be approved by NDEP.

6.0 LONG-TERM RISK MANAGEMENT

This section of the ERMP addresses actions that shall be implemented to mitigate long-term risks to human health and the environment related to potential exposure to COCs during periods of normal non-construction activity. Any construction that will disturb the soil, building foundations, or pavement shall be completed in a manner that is consistent with the ERMP, particularly Sections 3, 4, 5 and 6, with any Environmental Covenants in place for the Assessor's Parcel(s) where the construction is taking place, and all then-applicable environmental policies, laws, and regulations. Components of the ERMP for long-term risk management activities are as follows:

- Providing required notification to future property managers and tenants of the known environmental conditions at the Site, and also providing closure plans (if any), the completed HHRA, lead and asbestos surveys, results of available air monitoring data, and the requirements of the ERMP (Section 6.1);
- Ensuring that future land uses are consistent with the planned land-use assumed in this ERMP in terms of exposure risk assumptions (Section 6.2);
- Prohibiting the use of untreated groundwater at the Site (Section 6.3);
- Establishing a notification procedure and protocols for future subsurface activity to ensure long-term compliance with this ERMP (Section 6.4);
- Periodically reviewing and modifying this ERMP, as necessary, to address any new COCs encountered at the Site, any newly-developed toxicological data relating to COCs, and any significant changes in exposure assumptions because of an intended land use that is different from the planned land use upon which this ERMP is based (Section 6.5);
- Evaluating annual groundwater monitoring data collected to determine if there is any need to modify this ERM (Section 6.5.1); and
- Inspecting the Site as necessary to verify that risk management controls are being implemented and that they are effective in limiting potential exposure to COCs at the Site (Section 6.5.2).

6.1 Property Manager and Tenant Notification

The property owner shall be responsible for providing notification of the known environmental conditions at the Site and of the requirements of this ERMP to the property manager, tenants, and other entities leasing or otherwise exercising control over space at the Site.

6.2 Prohibiting Use of Site Groundwater

In the Site vicinity, the chemistry of the shallow groundwater is generally a sodium chloride-sulfate type and is classified as slightly to moderately saline. The shallow water aquifer in the Las Vegas Valley is of low quality (high total dissolved solids (TDS), nitrate, and phosphorus), primarily composed of secondary recharge from landscape irrigation and areas of sewage disposal (both municipal and septic tanks). The high levels of dissolved solids in the shallow aquifer (generally 3,000 to 10,000 milligrams per liter [mg/L]) are enriched through transpiration, as well as dissolution of naturally occurring evaporite deposits in the vadose zone. Additionally, perchlorate, hexavalent chromium, VOCs, and other chemicals are known to be present in groundwater at concentrations that exceed U.S. and Nevada maximum contaminant levels for drinking water. Therefore, groundwater beneath the site may not be used for drinking water or for any other purpose until such time that a risk assessment is performed that demonstrates the proposed use of groundwater does not represent a significant risk and the use of groundwater at the site is approved by NDEP. Notwithstanding, treated groundwater may be used for irrigation and/or industrial heating or cooling, or other processes, as approved by NDEP.

6.3 Health and Safety Plans for Future Subsurface Activities

Site landowners and tenants will require each contractor with workers that may contact groundwater or disturb soil at the site that is impacted by COCs to prepare its own site-specific health and safety plan (HASP). The requirement for preparation of a site-specific HASP also applies to activities involving work in utility vaults or other sub-grade areas (e.g., utility maintenance or modifications in subfloor areas of buildings) where potential exposure to accumulated VOC vapors may occur.

Every contractor has the responsibility to manage its operations in a safe manner and in compliance with all State and Federal occupational safety and health requirements. Each site-specific HASP must be consistent with State and Federal Occupational Safety and Health Administration standards for hazardous waste operations (29 Code of Federal Regulations 1910.120, respectively) and any other applicable health and safety standards. Each contractor will provide copies of its HASP to the current property owner for review. Among other things, a contractor's HASP will include a description of health and safety training requirements for on-Site personnel, a description of the level of personal protective equipment to be used, air monitoring requirements, confined space entry procedures, if applicable (e.g., work in utility vaults), and any other applicable precautions to be undertaken to minimize direct contact with contaminated soil and groundwater or exposure to COC vapors. Site workers will have the appropriate level of health and safety training and will use the appropriate level of personal protective equipment, as determined in the relevant HASP.

6.4 Long-Term Compliance; Periodic Review and Update of ERMP

The property owner shall maintain documentation of notification of the known environmental conditions at the Site and of the requirements of this ERMP to property buyers, and tenants and other entities leasing or otherwise exercising control over space at the Site. Property managers, tenants, or others exercising control over space at the Site will inform their construction contractors and maintenance workers about the ERMP, as needed, to ensure compliance. To the extent that subsurface work is performed, documentation shall be maintained to show that the protocols for the subsurface activities were followed as required by the ERMP.

For parcels where Environmental Covenants are in place, the Covenants will include specific guidelines regarding use of the land, long-term maintenance of engineering and/or institutional controls, and procedures for notifying NDEP of site activities.

This ERMP, and any addenda, will be periodically reviewed by NDEP as necessary to address new COCs encountered at the Site and not addressed in the existing ERMP, any newly available toxicological data relating to COCs, or any significant changes in land use from the planned land use on which this ERMP is based. The property owner will update the ERMP, as needed, based on annual review of site conditions.

6.4.1 Evaluation of Groundwater Monitoring Data

The property owner will review groundwater monitoring data in accordance with the schedule established by NDEP. For example, NDEP currently requires that groundwater data are reviewed on a semi-annual basis. These data will be compiled to determine if there has been any significant change in the nature, extent, or concentration of COCs in groundwater that would require potential modification of this ERMP.

6.4.2 Inspections/Maintenance/Monitoring

As described in Section 5, it is the responsibility of building owners and operators to periodically monitor and verify the adequacy of vapor intrusion mitigation measures that may be necessary depending on the specific measures implemented. In addition, regular inspections of system components, such as blowers in sub-floor ventilation systems, shall be conducted to ensure their proper operation.

In the event that work on utility lines or subfloor areas occurs in buildings that have implemented vapor mitigation measures as described in Section 5, cracks in the concrete floor and around utility penetrations shall be sealed. In addition, if a vapor intrusion barrier has been installed, work shall be completed in a manner that does not tear, penetrate, or otherwise compromise the vapor intrusion barrier. If penetration of the vapor barrier is unavoidable or occurs inadvertently, measures shall be taken to reseal the vapor barrier.

The property owner shall prepare an annual report summarizing and evaluating the results of the inspection/maintenance/monitoring activities and documenting the continued adequacy of the implemented risk management measures. This report shall include documentation that appropriate notifications have been made, as discussed in Section 6.1, and that appropriate protocols for subsurface activities have been implemented, as discussed in Section 6.4. This annual report shall be submitted to NDEP for review.

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