Table of Contents for Section 5

5. Contaminant Fate and Transport

This section primarily addresses contaminant fate and transport based on the Site condition as described in the 2004 RI/FS. The impacts of more recent RI activities are also addressed.

Prior to the demolition and removal of asphalt and concrete in late 2002, the Site was maintained in a manner such that transport of materials offsite was effectively mitigated. Except for small landscaped areas, floor penetrations (primarily drains), and cracked floor slabs and asphalt, there were no air or surface-water pathways to offsite areas (high groundwater levels potentially could have reached the deeper zones of the affected material). Efforts were made during the asphalt and concrete demolition operations to ensure the affected soil was left in the same area that it had been deposited during historical operations. However, demolition operations resulted in minor relocation of soil during excavation and the construction of haul roads. Special procedures (described in the project work plans) were in place during shipping operations to ensure that soil did not migrate onto access roads.

After demolition of the asphalt and concrete, the affected material was exposed to wind and water transport, but New Horizons installed erosion control measures to minimize offsite migration. These measures included installation of a silt fence along the southern edge of the Site, construction of several trenches to channel storm water into onsite depressions (former building foundations), and temporary seeding to control wind and water erosion. Solute and particle transport (groundwater pathway) and radon diffusion were not addressed. A natural clay layer limits solute transport over most of the Site, but some of the foundations of former Building 101 were completed in the silty/clayey sands and cobble zone.

During the 2006 RI activities completed by Stoller, contaminated soil above the tentative cleanup goals for metals and radionuclides was segregated from Site soils and placed in onsite, lined stockpiles. This action temporarily eliminated the water transport pathway, but the stockpile is subject to wind transport, which was temporarily mitigated through the application of a soil tackifier.

5.1 Potential Routes of Migration

The potential routes of migration associated with the Site prior to soil segregation activities and identified in the 2004 RI/FS included:

- Wind erosion, moving material primarily to the east (prevailing winds are from the west),
- Water erosion, transferring material offsite or into Clear Creek,
- Windborne diffusion, moving radon and radon decay products offsite (again driven by prevailing west winds),
- Plant material transport, moving material taken up by plants as wind or waterborne plant debris,
- Particle transfer, moving material via attachment to personnel and/or vehicle, and
- Solute and particle transport, transferring material into the underlying groundwater through percolation and preferential pathways.

Mitigation of these mechanisms, as described in the 2004 RI/FS, included the following. Wind and water erosion was controlled on the Site by storm-water best management practices. Minimal vegetation was growing on the Site, limiting the amount of material that could be transported in this manner. Particle transport was controlled by site-specific safety requirements. Radon diffusion and solute transport were not controlled at that time.

Soil segregation activities completed in 2006 eliminated many of the above-described transport mechanisms by placing the impacted soil in lined stockpiles. Following the soil segregation activities, only two transport mechanisms remain potentially active for the Site on a short-term, temporary basis. These mechanisms are wind erosion, moving material primarily to the east, and windborne diffusion, moving radon and radon decay products offsite. Mitigation of the wind erosion transport mechanism was addressed through the application of a soil tackifier to the soil stockpiles upon completion of segregation activities.

5.2 Contaminant Persistence

The primary COCs on the Site include metals and radionuclides. These materials are very persistent in the environment, and remedial techniques typically focus on stabilization, removal, or capping. Organic compounds discovered near the baseball field (see Section 4.1.7 in the 2004 RI/FS) included petroleum hydrocarbons and chlorinated solvents. The combination of these materials provided the proper environment for biodegradation of both materials. Current soil concentrations of the organic compounds are below current proposed CDPHE Soil Screening Levels.

The completion of RI activities in 2006 confirmed the presence of the metal and radionuclide compounds, but organics were not included as part of the characterization.

5.3 Contaminant Migration

The 2004 RI/FS evaluated affected material migration prior to the demolition of the asphalt and concrete and determined it was minimal, influenced only by minor soil exposure, plant uptake, and water infiltration. They estimated 90 percent of the Site was covered with asphalt or concrete prior to removal operations. Demolition and transportation activities resulted in some portion of the soil being displaced from its original location. Excavation of large foundation blocks and walls required soil to be moved and additional soil was moved to provide access roads for the trucks. Efforts were made to minimize the disturbed areas, but a small amount of material transfer did occur. None of the material left the Site.

As described in the 2004 RI/FS, demolition and transportation operations during the concrete and asphalt demolition generated some airborne particles, but operations were halted if wind speeds exceeded specified limits. Perimeter air monitoring was performed during the operations to ensure that offsite transport was minimal. During demolition, transportation, and sampling operations, all equipment was surveyed and cleaned as required. Personnel were required to survey footwear prior to leaving the Site. Erosion control measures were installed to minimize both wind- and water-affected surface erosion.

During the 2006 Site characterization activities, personnel and equipment were surveyed prior to exiting the Site, and no fixed or removable contamination was detected.

5.3.1 Material Migration to Groundwater

Prior to the 2006 RI activities, metals and radionuclides present in Site soils provided a continuing source of contaminants to the underlying groundwater. The 2004 RI/FS provided the following evaluation.

Factors including precipitation and ponding, material speciation and solubility, cation exchange capacity, and soil type, pH, and compaction can all affect the movement of the material to groundwater. Minor precipitation events can transport material deeper into the soil column where material concentrations increase until a major event transports the material to groundwater. Groundwater levels also can rise enough to interact with this material periodically. Sandy soil typically provides minimal resistance to transport of radionuclides and metals, while clays and organic materials can adsorb these materials, slowing the movement to groundwater. However, soil acidity and acid rain can reverse the adsorption process (hydrogen cations replace the metal/radionuclide cations), allowing continued material movement. The metal cations also compete with each other for available adsorption sites, continuing downward movement of material through the soil column.

Using arsenic as an example, speciation determines how arsenic compounds interact with the environment. In natural systems, arsenic may occur in four oxidation states: (-3), (0), (+3), and (+5). Movement in environmental matrices is a strong function of speciation and soil type. In a non-absorbing sandy loam, arsenite (As 3+) is 5 to 8 times more mobile than arsenate (As 5+).

Soil pH also influences arsenic mobility. At a pH of 5.8, arsenate is slightly more mobile than arsenite, but when pH changes from acidic to neutral to basic, arsenite increasingly tends to become the more mobile species. But the mobility of both arsenite and arsenate increases with increasing pH (preliminary data indicate primarily alkaline soils at the Site). In strongly adsorbing soils, transport rate and speciation are influenced by organic carbon content and microbial population. Both arsenite and arsenate are transported at a slower rate in strongly adsorbing soils than in sandy soils. Without speciation data, transport models can over or under predict material transport by several orders of magnitude.

The metal- and radionuclide-affected material identified during the RI were less mobile prior to the removal of the asphalt and concrete "cap". Without the cap, the affected material could migrate to groundwater more readily. The onsite groundwater is not a drinking water supply so there is no current threat to human health. But the groundwater flows into Clear Creek, which is a drinking-water supply for downstream communities. A boundary groundwater well (CSMRI-04) has historically had total uranium concentrations above the MCL as discussed in Section 4. This well is at the point of compliance. Dilution effects would significantly reduce concentrations in Clear Creek but the CDPHE, Water Quality Control Commission requires that uranium levels in surface water be maintained at the lowest practical level [5 CCR 1002-38, §38.5(3)(b)]. Precipitation events also moved additional material to groundwater.

The 2006 RI activities temporarily eliminated further migration of contaminants to groundwater by relocating contaminated materials to lined stockpiles on the Site. Once these stockpiles are dealt with (either onsite or offsite) the migration route to groundwater will be effectively eliminated.

5.3.2 Factors Affecting Migration

Factors assessed in the 2004 RI/FS that affect the migration of material from the Site included erosion, plant uptake, and material solubility. Wind and water erosion can be controlled using vegetation, cover material, engineered controls, or an impermeable barrier. Erosion controls included silt fencing, trenching, and temporary vegetation. Solubility is a function of precipitation, the parent material, and soil properties such as conductivity and pH. Solubility can be controlled primarily through limiting the movement of water through the material. Soil amendments and physically or chemically changing material properties also have been used to control solubility, but these methods are typically expensive and of varying success. No solubility controls are currently in place. Radon generated by the natural decay of the radionuclides diffuses through the soil and migrates to the atmosphere. Radon is typically a problem when a building foundation is in contact with the affected soil and the radon is trapped inside the building. No buildings are located on the Site at this time, although two valve pits are part of the baseball field irrigation system. Radon released to the atmosphere diffuses to the point that human health risk is negligible.

5.3.3 Modeling

Modeling of Site conditions was performed for the 2004 RI/FS and is reprinted herein.

The U.S. Department of Energy (DOE) and U.S. Nuclear Regulatory Commission (NRC) model for site-specific dose assessment of residual radioactivity, RESRAD 6.21 was used to model migration pathways such as wind and water erosion based on conditions in 2004. Because of the limited nature of the groundwater modeling package provided with RESRAD, Visual Modflow Pro in combination with Modflow SURFACT (Waterloo Hydrogeologic) was used in an attempt to model the movement of COCs to groundwater. Because only limited number of groundwater system parameters had been identified, the programs were primarily used to examine potential pathways for the contaminants.

Preliminary modeling efforts using Modflow did not converge because of the limited duration of the groundwater-sampling program and the complex nature of the Site hydrology. Accurate modeling of mixing zones is difficult with only a single year of sampling results. The drying and saturating of the soil column that is typical for semiarid regions increased the difficulty of producing an accurate representation of the Site hydrology. Unanswered questions about the multiple parameters associated with the transport portion of the model (e.g., metal species, variable pH, solubilities, and accurate representation of the sediment layers) also decreased the probability of an accurate model. Obvious particle pathways (material moves down to the Pierre Shale and then to Clear Creek) were predicted by the preliminary modeling efforts. Rough calculations show that saturating the soil column will move material to groundwater either through particle movement or solubility. The exact timing of the contaminant movement and the resulting concentrations are largely dependent on the precipitation amounts. A decision was made to focus resources on the control of the source area rather than expending additional resources to generate a model with a large degree of uncertainty.