10. CONCEPTUAL SITE MODEL

This section presents a Conceptual Site Model (CSM) for the Site. The CSM summarizes:

- Site description and history;
- Geology and hydrology;
- Nature and sources of radiologically impacted material (RIM) and distribution in the landfill;
- Processes that effect the RIM;
- Pathways and receptors at the Site and off site; and
- Potential data gaps.

Per EPA's RI/FS guidance (EPA, 1988), the CSM should include known and suspected sources of contamination, types of contamination and affected media, known and potential routes of migration, and known or potential receptors.

Figure 7-1 depicts the sources of contamination, the potential release mechanisms and migration pathways, routes of exposure, exposure mechanisms, and potential current or future receptors. The evaluation of the potential exposure routes, receptors and potential current and future risks to on-site workers and the general public was performed as part of the update to the BRA, which was prepared and submitted concurrently with this RI Addendum.

10.1 Site Description and Setting

The West Lake Landfill Superfund Site is an approximately 200-acre parcel containing multiple solid waste disposal units and related facilities and adjacent properties where radionuclides have been detected (see Section 3.1 and Figure 3-7). The Site is within the western portion of the St. Louis metropolitan area on the east side of the Missouri River (Figures 3-1 and 3-2).

The Site consists of the landfill property and adjacent properties (Buffer Zone and Lot 2A2) where radionuclides have been identified (see Section 3.1). The landfill property contains several areas where solid wastes have been disposed, including: Areas 1 and 2, which contain RIM; an Inactive Sanitary Landfill; a Closed Demolition Landfill; and the North Quarry and South Quarry portions of the Bridgeton Landfill (Figure 3-6). Radionuclides were also previously detected in surficial soil on what is now the Buffer Zone, currently owned by Rock Road Industries, Inc., and Lot 2A2 of the Crossroads Industrial Park, currently owned by Crossroad Properties LLC and used by AAA Trailer for storage of tractor trailers (see Sections 3.4 and 6.7).

Land use near the Site is primarily industrial and commercial with limited retail operations and some residential areas. The closest part of the Site is located within approximately 8,450 ft of the

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end of Runway 11 of Lambert St. Louis International Airport and, therefore, the Site is within the takeoff and approach routes for the airport (Section 3.5).

The nearest residential areas are the Terrisan Reste mobile home park, which is to the southeast of the Site, approximately 0.7 mile from Area 1 and 1.1 miles from Area 2, and the Spanish Village subdivision, which is approximately 1 mile to the south of Area 1 and 1.25 miles south of Area 2 (see Section 5.2).

10.2 History of the Landfills

The West Lake Landfill contains multiple areas of differing past operations (see Section 3.3 for additional details). The landfill property was used agriculturally until a limestone quarrying and crushing operation began in 1939. The quarrying operation continued until 1988 and resulted in shallow excavation areas and two quarry pits, the North Quarry Pit and the South Quarry Pit (Figure 3-6).

Areas 1 and 2 plus the adjacent Buffer Zone and Lot 2A2 have been identified by EPA as Operable Unit-1 (OU-1) of the West Lake Landfill Site. All other portions of the landfill property are part of OU-2.

Area 1 encompasses approximately 17.6 acres. Area 2 encompasses approximately 41.8 acres. No contemporaneous reports, drawings or other records from the former site operators are currently known to exist regarding the construction of the disposal units or the overall types and amounts of wastes that were disposed in the Area 1 and Area 2 landfills during their operation. Based on inspection of the drilling cores and samples obtained as part of the RI/FS investigations for OU-1, the waste materials within Area 1 consist primarily of municipal solid waste (MSW) and within Area 2 consist of both construction and demolition waste/debris and MSW. See Sections 3.3.2, 5.5.2.1 and 6.1 for additional information regarding the history of the landfills and the waste materials disposed in Areas 1 and 2.

In approximately 2003-2004, the southwestern portion of Area 1 was covered by the above-grade portion of the North Quarry landfill (see Figure 3-9). In 2006-2008, inert fill was placed in low areas on the surface of Area 1, the adjacent North Quarry portion of the Bridgeton Landfill and on portions of the surface of Area 2 (see Sections 3.3.2.1, 3.3.2.2, 5.3.3 and 5.5.2.1). Pursuant to a Unilateral Administrative Order from EPA, in 2016, vegetation was cleared and road base material (non-combustible cover or NCC) was placed over approximately 2.6 acres of Area 1 and 17.2 acres of Area 2 where radionuclides were present at the ground surface (see Section 3.3.2).

10.3 Site Geology and Hydrogeology

10.3.1 Site Geology

The geology of the Site consists of Missouri River alluvial deposits overlying limestone and dolomite bedrock of the St. Louis and Salem Formations. The alluvial deposits typically consist of fine-grained (clay and silt) overbank deposits overlying poorly sorted, coarse-grained (sand and gravel) channel deposits associated with historic flooding and river meanders of the Missouri River. The presence of coarse-grained channel deposits could result in heterogeneities that could create preferential pathways for chemical migration through the alluvium. The observed depth of alluvial deposits range in thickness from 0 to 109 feet in the OU-1 soil borings (Appendix B). The depth to bedrock and the thickness of the alluvial deposits increases to the west of the Site where the thickness of alluvium (depth to bedrock) was reported to be 120 feet in other parts of the landfill (Herst & Associates, 2005).

10.3.2 Site Hydrology

The Site is on the eastern edge of the Missouri River floodplain in an area that is transitional between the floodplain immediately to the west and the bluffs approximately one-half mile to the east. The Missouri River is approximately 1.5 miles to the west of the Site and is oriented north to south near the Site. The river flows in a predominantly north-northeasterly direction in the vicinity of the Site at an elevation of approximately 425 feet above mean sea level (amsl). The river is separated from the surrounding areas by a levee system constructed to provide protection against flood levels associated with a 500-year recurrence interval flood. The landfill property is outside the flood plain while the Buffer Zone and Lot 2A2 are within the area of the 500-year flood plain protected by the levee system. The current (*i.e.*, 2016) surface water runoff patterns for Areas 1 and 2 are presented on Figure 4-15. Additional details of the surface water drainage features, including drainage during the OU-1 RI and the OU-2 RI, are summarized in Section 5.3.2.

The presence of alluvium beneath the northern two-thirds of the Site, including all of Areas 1 and 2, the Buffer Zone and Lot 2A2, indicates that the historic (geomorphic) floodplain extended beneath much of the Site. The only portions of the Site not located in the geomorphic floodplain are the North and South Quarry portions of the Bridgeton Landfill.

Groundwater is present in the unconsolidated alluvial deposits and the bedrock at the Site. Detailed discussions of the hydrogeology of the alluvial groundwater and bedrock groundwater are presented in Section 5.6 of this document and the OU-1 and OU-2 RI reports (EMSI, 2000 and Herst & Associates, 2005).

The regional direction of groundwater flow is generally northerly within the Missouri River alluvial valley, parallel or sub-parallel to the river alignment. The general direction of alluvial groundwater flow in the vicinity of the Site is to the northwest. There are localized variations to this general direction of groundwater flow. The horizontal hydraulic gradient in the alluvium is relatively flat and the flow, within the alluvium and bedrock is toward the river. Groundwater within the bedrock flows upward and discharges to the river.

There are no public water supply wells near the Site. The nearest private well is the well located at the Kirchner Block facility (No. 0432767), approximately one quarter mile to the east of the Site at 12901 St. Charles Rock Road (Figure 5-19). This well is a bedrock well drilled in 2010 and completed to a depth of 468 feet, with steel casing extending to a depth of 84 feet and an open hole from there to the total depth. It is reported in the MDNR database as a domestic well. The next closest well is a well (No. 0297268) owned by AMCI Corporate Woods BD Trustee (AMCI) located in Earth City. This well is an alluvial well drilled in 2002 and completed to a depth of 60 feet with steel casing extending to a depth of 40 feet. No information on the intended use of this well was included on the MDNR well record form. There are several wells located to the north and west of the Site (*i.e.*, regionally downgradient) that are used for industrial and commercial purposes such as irrigation, construction, and dewatering (levee system operations). Well No. 0038776 is an alluvial well owned by Banger Bros. Construction that was drilled in 1990 and completed to a depth of 80 feet with a steel casing extending to a depth of 72 feet. No information on the intended use of this well was included on the MDNR well record form. Well No. 0500354 is an alluvial well owned by Kienstra Enterprises that was drilled in 2009 and completed to a depth of 69 feet with steel casing reportedly present the full depth. This well is reported to be used for irrigation. Well No. 0470266 is an alluvial well owned by AMCI that was drilled in 2013 and completed to a depth of 65 feet with steel casing extending to a depth of 40 feet. This well is reportedly used for irrigation. Well No. 0360605 is an alluvial well owned by Gershenson Construction Company that was drilled in 2010 and completed to a depth of 70 feet with plastic casing extending to a depth of 45 feet. None of the wells are used to provide domestic or community (potable) water supplies.

10.4 Radiologically Impacted Material (RIM)

Radionuclides have been identified in soil within the solid waste materials within portions of the landfill deposits in Area 1 and Area 2. Radionuclides were also previously detected in soil on the Buffer Zone and Crossroads Lot 2A2. Together, Area 1, Area 2, the Buffer Zone and Lot 2A2 make up OU-1 of the West Lake Landfill Superfund Site.

The specific criteria approved by EPA to define RIM at the Site (as further described in Section 6.2.6) are:

- **7.9 pCi/g** of combined Radium-226 plus Radium-228;
- **7.9 pCi/g** of combined Thorium-230 plus Thorium-232; or
- **54.5 pCi/g** of combined uranium activity.

10.4.1 Potential Sources of RIM in Areas 1 and 2

Mallinckrodt Chemical Works (Mallinckrodt) processed uranium feed material for the production of uranium chemicals under contract with the Manhattan Engineering District (MED) and the AEC beginning in 1942. This work was performed at the Mallinckrodt Plant, on property known today as the St. Louis Downtown Site (SLDS). In 1947, the MED acquired the 21.7-acre tract of land now known as the St. Louis Airport Site (SLAPS) to store residuals from uranium processing at the Mallinckrodt Plant. See Section 6.1.

Among the materials generated by Mallinckrodt at SLDS was leached barium sulfate residue (LBSR). The LBSR originated from uranium ore processed at the Mallinckrodt facility in downtown St. Louis. Nearly all of the uranium and radium had been removed from the leached barium sulfate in previous precipitation steps (EPA, 2008a, NRC, 1988). See Section 6.1.

Leached barium sulfate residues and other uranium ore process residuals reportedly were moved from SLAPS to nearby 9200 Latty Avenue in Hazelwood, Missouri in 1966 (NRC, 1970, 1988). The different types of material brought to the Latty Avenue Site included C-slag, unleached barium sulfate, leached barium sulfate, Belgian Congo raffinates, and Colorado raffinates (NRC, 1970). An NRC investigation conducted in 1976 reported that approximately 8,700 tons of leached barium sulfate residues, together with approximately 39,000 tons of soil removed from the top 12 to 18 inches of the Latty Avenue site, were transported to the West Lake Landfill over a three-month period from July 16 through October 9, 1973 (EPA, 2008a and NRC, 1976 and 1988 and RMC, 1982). The other materials that had been brought to the Latty Avenue Site from SLAPS were shipped to Colorado for onward processing. See Section 6.1.1 and Appendix O-2.

10.4.2 Distribution of RIM in the Landfill

The West Lake Landfill has been investigated by the NRC, EPA, the OU-1 Respondents and others over the 40-plus-year period beginning in 1976. These investigations have all identified the presence of radionuclides in two areas of the landfill, Area 1 and Area 2. Investigations have also identified the presence of radionuclides in surface soil on the Buffer Zone and Lot 2A2, adjacent to Area 2, as a result of historic erosion and stormwater transport from the surface of Area 2 onto the adjacent property. No data or information have been located or developed that would indicate that radionuclides are present in other portions of the Site.

All of the investigations performed at the Site over the last 40-plus years have identified only two areas where radioactivity is present, Areas 1 and 2 (plus, more recently, the Buffer Zone and Lot 2A2). Most notably, the original flyover gamma survey performed in October 1977 by EG&G for DOE (EG&G, 1979) only identified two areas (Areas 1 and 2) with elevated levels of radioactivity. (See also NRC, 1982). This survey was performed four years after the LBSR mixed with soils from Latty Avenue was disposed at the Site, before most of the permits were issued by MDNR for placement of additional waste material at the Site. Other than Permit No. 118903 which allow for continued operation of the existing landfill disposal units in 1974, the only new permit that was issued prior to the 1977 EG&G flyover was Permit No. 218903 for the now Closed Demolition

Landfill. This permit was issued on January 27, 1976, approximately eight months prior to the EG&G survey. Therefore, the EG&G survey was performed not only within a few years of the placement of the soil mixed with LBSR, but also before much of the additional waste materials that are now present at the Site were placed. If LBSR containing soil were present in other parts of the Site, this survey should have been able to detect such material.

The long-term presence of physical boundaries around Area 1 support a conclusion that occurrences of radionuclides in Area 1 are contained within that area. For example, the northeast side of Area 1 is bounded by the landfill property boundary adjacent to St. Charles Rock Road. Based on review of historical aerial photography, the existence of St. Charles Rock Road extends back until at least 1941. Similarly, Area 1 is bounded on the northwest by the Site access road which is underlain by native (non-landfilled) ground and has existed in its present location since at least 1965. The southwest side of Area 1 is also bounded by native ground that underlies the area of the current transfer station and asphalt plant and the former cement plant at the Site. The presence of native materials (absence of waste) in this area was confirmed through review of the geologic logs for the borings associated with monitoring wells PZ-111-SD and PZ-111-KS located on the south side of the transfer station adjacent to Area 1, as these borings did not encounter waste material.

The southeast side of Area 1 is coincident with the outer boundary of the excavation associated with the former North Quarry as seen on the various aerial photographs obtained in the 1970s. The North Quarry was not permitted to accept waste and did not begin to accept waste until 1979. Review of aerial photography and comparison of topographic elevations of the bottom of the North Quarry confirms that quarry activity, including removal of substantial amounts of limestone rock, were still occurring in the North Quarry up through 1979. Therefore, waste material would not have been placed in the North Quarry prior to 1979 (or if any waste were placed there, it would have been removed as part of the ongoing quarrying activities). Waste materials were placed in the quarry portion of the North Quarry beginning in 1979 pursuant to a permit issued by MDNR. Additional waste material is first observed in the aerial photos being placed above the ground surface portion of the North Quarry, and extending over the southernmost portion of Area 1, in 1979. This is consistent with the permits issued by MDNR. Consequently, the above-grade portion of the North Quarry extends over the RIM located in the southern portion of Area 1. Because the above-grade portion of the North Quarry was not permitted to receive waste until Permit No. 118912 was issued in 1985, this filling occurred long after the placement of the LBSR-impacted soils. This conclusion is consistent with the results of the Phase 1 investigations (Feezor Engineering, Inc., 2014b and EMSI et al. 2016b).

The northeast side of Area 2 is bounded by the landfill property boundary adjacent to St. Charles Rock Road, which, as discussed above, has existed in its present location since at least 1941, prior to any landfilling or waste disposal activities at the Site. The northwestern and western boundaries of Area 2 are coincident with the landfill property boundary adjacent to the Crossroads Industrial Park. There are no data indicating that any waste disposal occurred on the industrial park. Other than the historic transport of eroded soil onto portions of the Buffer Zone and Lot 2A2, there are no indications that radionuclides are present on the industrial park. The southwest boundary of Area 2 is bounded by Old St. Charles Rock Road, which also has existed at least as far back as

1941, prior to any landfilling or waste disposal activities at the Site. The southern boundary of Area 2 is coincident with the northern boundary of the Inactive Sanitary Landfill. Review of historical aerial photographs indicates that activities associated with the quarry operations and landfill did occur contemporaneously across the boundary between these two areas; however, portions of the Inactive Sanitary Landfill located near to but not adjacent with Area 2 (e.g., MDNR Area 3 on Figure 3-8) were being used for waste disposal at the same time that Areas 1 and 2 were being used. Similarly, the southeast boundary of Area 2 is coincident with the northern boundary of the Closed Demolition Landfill. Review of historical aerial photographs indicates that activities associated with the quarry operations and landfill did occur contemporaneously across the boundary between these two areas; however, a portion of the area (e.g., MDNR Area 1) that later was encompassed by the Closed Demolition Landfill was being used for waste disposal at the same time that Areas 1 and 2 were being used. As discussed above, the 1977 EG&G survey did not detect elevated levels of radioactivity in either this area or that portion of the Inactive Sanitary Landfill that was in operation at the same time that wastes were being disposed in Areas 1 and 2.

Earlier interpretations of the RIM portrayed it as a relatively thin, continuous shallow layer within Areas 1 and 2 (see RMC, 1982 and NRC, 1988). The results of the multiple investigations conducted for the OU-1 RI that have been performed over the subsequent 35 years (described in Sections 2 and 4) have resulted in a more detailed understanding of the RIM in Areas 1 and 2. Specifically, 217 additional borings and GCPT soundings were drilled in Areas 1 and 2, providing more comprehensive information and data regarding the extent and distribution of RIM. Based on the hundreds of additional borings and other testing, we now know that the RIM is irregularly interspersed within the overall larger matrix of MSW, not in a thin, continuous layer as the NRC assumed. The distribution of the RIM within the landfilled areas has been impacted by both natural and anthropogenic processes, such as the initial placement and the subsequent 40-plus years of decomposition, consolidation and differential settlement of the MSW over time. Consequently, the RIM is interspersed within separate areas and intervals of MSW such that RIM cannot be easily distinguished from the surrounding MSW, landfill cover, and native soil matrix within which it is found.

RIM is present both at the ground surface and in the subsurface of Areas 1 and 2. RIM has been found to be present beneath approximately 8.4 acres in Area 1 and approximately 26.8 acres in Area 2 (Figures 6-12 and 6-13). RIM is present at depths up to 94 ft bgs in Area 1 and 49.5 ft bgs in Area 2 (Tables 6-4 and 6-5). Additional information regarding the nature and distribution of RIM can be found in Section 6.

10.4.3 Occurrence of Radionuclides in the Buffer Zone and Lot 2A2

The sampling performed during the 2000 OU-1 RI identified radionuclides in the surface soil (approximately 6 to at most 12 inches deep) beneath the Buffer Zone and Lot 2A2 (previously referred to as the former Ford property). The locations of the various soil borings and surface soil samples collected from the Buffer Zone and Lot 2A2 are shown on Figure 4-6. The analytical results are summarized on Table 6-7. Radionuclide occurrences on these properties were probably the result of erosional transport from the surface of Area 2. An investigation performed by ORAU in 1984 concluded that soil erosion was occurring and that radionuclides were present in the face and at the toe of the landfill slope extending out onto the adjacent property (Buffer Zone and Lot 2A2). Erosion of the landfill berm was also described by a former representative of the West Lake Quarry who reportedly observed the erosion of the landfill slope. Investigations consisting of overland gamma surveys and soil sampling have also confirmed the presence of radionuclides in soil at the top, on the face and at the toe of the landfill slope and extending out onto the adjacent properties (Buffer Zone and Lot 2A2). Based on the results of the soil samples, occurrences of radionuclides on the Buffer Zone and Lot 2A2 are limited to surface soil (i.e., the upper 3 to 6 inches).

10.5 Potential Migration Pathways

Potential migration pathways at the West Lake Landfill include:

- Airborne transport;
- Stormwater and sediment transport; and
- Leaching to groundwater and groundwater transport.

These pathways are identified in Figure 7-1 and are discussed in the following sections. Data obtained from sampling and monitoring of the environmental media associated with these pathways have provided information regarding the nature of site contaminants, and potential contaminant migration pathways, and have been used to support risk evaluations. Summaries of the monitoring results and site features/actions that mitigate the potential for migration along these pathways are discussed below.

10.5.1 Airborne Transport

Radionuclides can be transported to the atmosphere either as a gas (in the case of the various radon isotopes) or as particulate matter (in the case of the other radionuclides). Each is briefly discussed below.

10.5.1.1 Radon Emissions

Surface emissions of radon (radon flux) were measured in 1997 as part of the OU-1 RI field investigations and again in 2016 after substantial completion of the construction of the NCC in Areas 1 and 2 (see Section 7.1.1.1). The results of these two investigations indicate that radon flux, from both Areas 1 and 2, is below the standard of 20 pCi/m^2/sec established for uranium mill tailing piles under UMTRCA and NESHAP.

Based on prior reports and review of aerial photographs, a small building was present in Area 2 during the period from approximately 1975 through 1990. This building was identified as the "Shuman building" in the 1982 RMC and 1988 and 1989 NRC reports. No information has been located regarding the construction or use of this building. Ten-minute high-volume particulate air samples collected by RMC (1982) to determine both short-lived radon daughter concentrations and long-lived gross alpha activity detected gross alpha levels and radon daughter concentrations above the maximum permissible concentrations near and inside the Shuman building.

Perimeter monitoring of radon levels in the ambient air has been performed at 13 air monitoring stations around the perimeters of Areas 1 and 2 (see Section 7.1.1.3). Results indicate that current radon levels at the Site perimeter are less than the UMTRCA standard of 0.5 pCi/L above background concentrations. Evaluation of potential future (1,000 year) radon levels, based on projected ingrowth of radium-226 from thorium-230 decay, were developed for the BRA. Modeling of transport of future (1,000 year) radon emissions to areas adjacent to the landfill indicated that the projected future (1,000 year) radon level on Lot 2A2 would be 330 pCi/m^2 which is equivalent to 0.33 pCi/L, less than the UMTRCA standard of 0.5 pCi/L above background. Projected future radon concentrations for the off-site receptors were even lower (see BRA Table 25).

10.5.1.2 Volatile Organic Compounds

VOCs were only infrequently detected in waste samples and health and safety monitoring performed during the various field investigations did not detect VOCs in air in the work areas. Monitoring for VOCs has also been performed around the perimeter of Area 1 to evaluate potential VOC occurrences in air. Only background levels of VOCs have been detected. The presence of soil cover over the various landfill units also mitigates the potential for VOC emissions. Therefore, the BRA concluded that there is no complete pathway for VOC emissions and this pathway was eliminated from consideration in the BRA.

10.5.1.3 Particulate Matter

The collection of airborne particulate samples was conducted within Areas 1 and 2 in 1996, during the OU-1 RI field investigations, and again more recently in 2015 through the present, at the 13 perimeter air monitoring stations around Areas 1 and 2 (see section 7.1.2). Results obtained from the 1996 monitoring did not indicate a potential for airborne migration of radionuclides but due to the limited duration of the sample collection (8 hours) and the proximity of the upwind samples to areas that were later determined to contain RIM at the surface, this monitoring is not considered definitive with respect to potential migration. (Appendix H-2).

Results of the perimeter monitoring conducted in 2015-2017 indicated that levels of uranium, thorium and combined radium in the particulate samples were similar to, or less than, the baseline monitoring results obtained by EPA at its five off-site monitoring stations. The NCC now covers the majority of the areas where RIM was identified at the surface (two small, steeply sloped areas still remain to be covered), further reducing the potential for entrainment of particulates containing radionuclides.

10.5.2 Stormwater and Sediment Transport

Sampling for radionuclides and chemicals in Site stormwater runoff was conducted as part of the RI investigation and then again, more recently, in 2016-2017. Stormwater monitoring performed in 2016-2017 has not detected radium or uranium in stormwater onsite or where stormwater discharges from Areas 1 and 2 at levels above drinking water standards (see Table 7-12). There are no standards or other criteria for evaluation of thorium levels. Most of the thorium levels reported for OU-1 outfalls located along the perimeter of the Site (i.e., not including inspection points located within the interior of the Site) were approximately 1 pCi/L or less. The only exceptions were the May 12, 2016 result of 3.9 pCi/L from outfall NCC-004 (later renamed OU-1-004), and the February 21, 2017 result of 3.2 pCI/L for outfall OU-1-007. Therefore, although dissolved or suspended sediment transport in rainwater runoff is a potential pathway for radionuclide migration from Areas 1 and 2, construction of the NCC reduces the potential for stormwater transport of radionuclides from Area 1 and 2.

Some of the sediment samples collected during the OU-1 field investigations from on-site locations contained levels of radionuclides above background. The results of the 2016 sediment sampling detected Th-230 at SED-4 (in the perimeter drainage ditch northeast of Area 2) at a concentration (14.7 pCi/g) above the 7.9 pCi/g established by EPA for identification of RIM. The isolated nature of these occurrences suggests that current transport of radionuclides in sediment, while it could occur, is not a significant migration pathway.

10.5.3 Leaching to Groundwater and Groundwater Transport

Testing performed as part of the OU-1 RI indicated a potential for radionuclides to leach from the landfill mass under certain conditions. Any alternative implemented will address the potential for leaching, consistent with the RAOs. The extent of potential leaching of radionuclides, potential migration and transport from the landfill, and impacts to groundwater from the RIM in the landfill mass will be evaluated as part of the OU-3 investigation.

10.5.4 Occurrence of Radionuclides and Other Contaminants in Site Groundwater

As summarized in Section 7.5, groundwater samples have been analyzed for radionuclides as part of the various OU-1 investigations. Most recently (2012-2013), groundwater samples were collected at 85 monitoring wells.

Radionuclides in the groundwater are discussed in terms of the isotopes of three elements: radium, thorium, and uranium. A discussion of these constituents can be found in Section 7.5. Discussions of chemical occurrences in groundwater are presented in Section 8.7.

Radium has been detected in groundwater monitoring wells in most portions of the Site, in both the bedrock and the alluvium. The USGS (2014) identified four general hypotheses for the origin of dissolved combined radium above the MCL in the groundwater including:

- Leaching of radium from the RIM;
- Radium values are within the range found in natural groundwater;
- Leaching of radium from non-RIM wastes disposed at the Site; and
- Mobilization of naturally occurring radium from aquifer solids by some component of landfill leachate.

The USGS further stated that other than the radium in groundwater samples being from the natural variation in groundwater, no single hypothesis can be invoked to explain all of the occurrences of radium above the MCL. Furthermore, the available groundwater data are not adequate to provide definitive conclusions regarding the validity of any hypotheses.

Dissolved levels of thorium and uranium have never been detected at levels above the Gross Alpha MCL (relative to thorium) or the uranium MCL.

Volatile organic compounds (VOCs) and trace metals have also been detected in groundwater (see Section 8.7). Benzene has been detected in groundwater monitoring wells located near the South Quarry, the Inactive Sanitary Landfill and Area 1 (but not Area 2) at concentrations above its MCL of 5 ug/L (Figure 8-1). Chlorobenzene was detected in one well near the Inactive Sanitary Landfill and one well near Area 1 at concentrations above its MCL of 100 ug/L (Figure 8-2). Vinyl chloride has been detected during some, but not all sampling events in some wells near the Inactive Sanitary Landfill and Area 2 (Figure 8-3). Arsenic has been detected in most of the Site monitoring wells at concentrations above its MCL of 10 ug/L (Figures 8-4 and 8-5). Iron and manganese have been detected at concentrations above their respective secondary MCLs (300 and 50 ug/L, respectively) in most of the Site monitoring wells. Chloride has also been detected in most of the Site monitoring wells at concentrations above its MCL of 250 mg/L.

Additional evaluation of radionuclide and chemical occurrences in groundwater will be conducted as part of the OU-3 investigation. A preliminary evaluation of potential data gaps has been developed, which includes the following:

- Background groundwater quality
- Groundwater geochemistry
- Regional, Site and local hydraulic gradients
- Recharge and discharge points

- Leachate chemistry and occurrence
- Effect of leachate extraction system on groundwater levels and hydraulic gradients
- Nature and extent of off-site groundwater contamination
- Adequacy of the groundwater monitoring well network along the perimeters of Areas 1 and 2
- Hydraulic properties of the aquifer
- Effect of suspended sediment on groundwater quality
- Potential for vapor intrusion into onsite buildings
- Potential correlations between radium and geochemical indicators
- Evaluation of potential leaching of wastes

Further evaluation of these data gaps will be conducted during the groundwater (OU-3) RI/FS.

10.6 Potential Receptors and Exposure Routes

A baseline risk assessment was prepared to evaluate the potential receptors, exposure routes, and potential risks that the Site could pose to potential current and future workers at the Site and the general public, including off-site residential areas. Figure 9-1 depicts the potential migration pathways, routes of exposure, and potential receptors.

10.6.1 Potential Receptors

The landfill property is fenced and access to Areas 1 and 2, and the Buffer Zone is controlled. Access to Areas 1 and 2 and the Buffer Zone is currently further limited to qualified, trained remediation workers. Therefore, there currently are no receptors in Areas 1 and 2 and the Buffer Zone. Lot 2A2 is fenced and access to this property is monitored by AAA Trailer. It is only accessible to the general public via trespassing, but is regularly accessed by AAA Trailer workers. Potential current receptors therefore include workers at the landfill property and on Lot 2A2, off-site workers on adjacent properties, and off-site residents.

The primary future receptor of concern for these areas was identified as potential future workers (for 1,000 years in the future) on Areas 1 and 2. This group of receptors is assumed to spend a portion of their time employed on OU-1 (on-site) or adjacent to it (on-property or off-property). Examples of future workers (for 1,000 years in the future) include construction workers, grounds keepers, outdoor storage yard workers, and the commercial building users. Other potential future receptors that were evaluated in the risk assessment include residents, farmers, recreational users and trespassers. As discussed in the BRA, the potential exposures to these receptors and the potential risks were less than those for the future (for 1,000 years in the future) on-site workers.

10.6.2 Exposure Routes

Potential exposure routes include inhalation of air containing suspended particulates and gases, such as radon, originating in soil or waste. Receptors may also come into direct contact with contaminated soil, during which time they may be exposed through dermal contact with these contaminated media, or via inadvertent ingestion of a small amount of this material.

Direct exposures from radioactive material can occur when a receptor is near a radioactive source. The magnitude of exposure is inversely related to the distance of the receptor from the source. Exposures can be reduced when shielding, such as soil, is placed between the receptor and the source of radioactivity.

10.7 Summary of Potential Risks

The updated BRA (Auxier & Associates, Inc. 2017) calculated risks to current and future receptors and evaluated those risks in the context of the EPA's acceptable cancer risk range of 10^{-6} to 10^{-4} and the EPA's acceptable non-cancer hazard threshold (HI) of 1.

It is important to note that "future" as used in this BRA represents a point in time 1,000 years in the future, taking into account radionuclide decay and ingrowth and presuming no cover or remedial measures. Although BRA evaluations of future risks focused on 1,000 years, unacceptable risks to future on-site workers could occur before 1,000 years. However, "current" encompasses theoretical risks within the lifetime of most individuals based on conditions at the time this report was prepared. The results of the risk assessment are summarized below.

10.7.1 Current Receptors

Current on-property receptors are represented by the on-property grounds keeper and commercial building user. There are no complete pathways for exposure to chemical COPCs under current conditions and, hence, no unacceptable chemical risks or hazards to on-property receptors. Additionally, radionuclide COPCs do not pose an unacceptable cancer risk to current on-property receptors. Cumulative radionuclide cancer risks are within or below (more health protective than) the EPA's acceptable risk range (see Table 9-3).

Current off-property receptors are represented by the off-property resident and commercial building user. There are no complete pathways for exposure to chemical COPCs under current conditions and, hence, no unacceptable chemical risks or hazards to off-property receptors. Additionally, radionuclide COPCs do not pose an unacceptable cancer risk to current off-property receptors. Cumulative radionuclide risks are below the EPA's acceptable risk range. (see Table 9-3)

10.7.2 Future (1,000 year) Receptors

Landfill receptors 1,000 years in the future are evaluated based upon the maximally exposed Landfill grounds keeper and storage yard worker. Evaluation of the future risk for the Baseline Risk Assessment assumes that no cover is present on the Landfill and no remediation has occurred.

Chemical COPCs do not pose an unacceptable cancer risk to future Landfill receptors. Cumulative chemical risks are within or below the EPA's acceptable risk range (see Table 9-3). Chemical COPC HIs exceed EPA's acceptable threshold of 1 for some future Landfill receptors in OU1, indicating a potential for non-cancer health effects. Zirconium (Areas 1 and 2) and, to a lesser extent, cobalt (Area 2) are the primary contributors to HIs greater than 1 (see BRA Table 39). As discussed in the uncertainty assessment in the BRA, zirconium HQs are likely overestimated due to substantial uncertainties in the reference dose and due to contributions from naturally-occurring background soil. Exposure to lead in soil does not pose an unacceptable risk to future Landfill receptors.

Radionuclide COPCs do not pose an unacceptable cancer risk to future receptors (defined as 1,000 years in the future) that work at the Landfill and periodically access OU-1 (i.e., grounds keepers). Cumulative radionuclide risks are within the EPA's acceptable risk range for these potential future receptors (see Table 9-3). Radionuclide COPC cancer risks exceed the EPA's acceptable risk range for Landfill receptors that are assumed to spend a substantial portion (e.g., 4 hours) of each workday on OU-1 (i.e., Landfill storage yard workers). Where risks exceed 10^{-4}, direct contact with radium-226 in soil (gamma exposure and ingestion) and inhalation of radon-222 in air are the primary risk drivers.

Potential future risks to off-property receptors 1,000 years in the future, and assuming no cover is present on the Landfill, were calculated taking into account 1,000 years of ingrowth of Ra-226. Chemical COPCs do not pose an unacceptable cancer risk to future off-property receptors. Cumulative chemical risks are within or below the EPA's acceptable risk range (Table 9-3). Chemical COPCs do not pose an unacceptable non-cancer hazard to future off-property receptors. Calculated HIs are less than EPA's threshold HI of 1.

Radionuclide COPC cancer risks exceed EPA's acceptable risk range for future off-property farmers to the north and west, and future commercial building users to the north and at Lot 2A2. Radionuclide cancer risks to off-property farmers to the south and southeast, and off-property commercial building users to the west are within the EPA's acceptable risk range (Table 9-3). Where cumulative radionuclide risks exceed 10^{-4}, risk is driven by inhalation of radon-222 and its daughter products; as discussed in the uncertainty section of the BRA, modeled radon activity from OU-1 is similar to naturally-occurring activity. Exclusive of radon and its daughter products, radiological risks to off-property receptors are within the EPA's acceptable risk range of 10^{-6} to 10^{-4}.