3.0 FINDINGS AND DISCUSSION

3.1 FIELD GAMMA RADIATION SURVEY DATA

The results of the field gamma radiation surveys presented herein were performed between August 15 and December 1, 2007 at the Site. The gamma radiation surveys consisted of static and scan gamma radiation surveys, as discussed in Section 2.2. The objective of the gamma radiation surveys was to characterize the nature and lateral extent of Ra-226 concentrations in surface soils at the Site. In addition to the surface soils at the Site impacted by past mining activities, impacts may have occurred to the northeast as a result of various transport mechanisms as discussed in the RSEWP. Due to these potential transport mechanisms, the objectives included characterization of radionuclides in surface soils outside the current survey area boundaries, along the Unnamed Arroyo and at the nine Home Sites.

As discussed in Section 2.2, static gamma radiation surveys were performed at on-site survey areas and the Home Site areas. The static gamma radiation level measurements obtained in CPM were recorded in the Static Gamma Radiation Survey Field Forms, which are included in Appendix B. The static gamma radiation reading counts were converted to surface soil Ra-226 concentrations using appropriate linear regression equations from the correlation study, as discussed in Section 2.2.3. All Ra-226 concentrations discussed in this section are the equivalent Ra-226 concentrations and not laboratory Ra-226 concentrations (laboratory Ra-226 concentrations are discussed in Section 3.2). The equivalent Ra-226 surface soil concentrations as determined from the gamma radiation surveys are presented graphically on Figure 3-1, *Results of Field Gamma Radiation Survey* and discussed in the following subsections.

3.1.1 NECR-1

The NECR-1 area was thought to contain non-economic materials and/or low-grade uranium ore, but was not expected to exceed the FSL, thus it was classified in the RSEWP as a potential Class 2 Area. Initially, one-minute static gamma radiation measurement was taken at a total of 156 grid nodes within and extending beyond the initial survey area boundary. The results of these static gamma survey measurements are summarized in Table 3.1, *NECR-1 Static Gamma Radiation Survey Results*. The results show that the surface soil Ra-226 concentrations within the initial survey boundary ranged from <0.6 to 218.8 pCi/g (averaged 29.8 pCi/g). The results show that the surface soil concentrations are above the FSL of 2.24 pCi/g at 153 of 156 locations (98% of the area). Gamma radiation readings exceeded the FSL of 4,600 CPM over 80% of the static survey points, therefore, no gamma radiation scan was performed to further identify hot spots within NECR-1.

The surface soil Ra-226 concentrations at grid points near the initial survey area boundary were above the FSL, as shown on Figure 3-1. A total of 149 step-out static gamma radiation survey measurements, as shown in Table 3.1 and Figure 3-1, were performed beyond the initial survey area boundary of NECR-1 to delineate the lateral extent of surface soil contamination. The levels measured during the step-out static gamma radiation survey for the NECR-1 were above the FSL at the outermost locations in three primary areas: to the east within the parking area and across Red Water Pond Road, to north towards and around the Home Sites, and in the IX Plant area. The area around the IX Plant consists of a near-vertical cliff that represents a natural, physiographic boundary, and does not warrant additional investigation. However, the areas to the north towards the Home Sites and to the east across Red Water Pond Road represent potential data gaps in definitively determining the FSL boundary, however results to the north are increasingly likely to represent disturbances or impacts associated with historical mining or exploration activities on the Quivera Mining Company lease, and results to the east appear to be related to the construction or historical use of the former Quivera mine haul road . The static gamma radiation survey was stopped for boundary delineation based on the criteria discussed in Section 2.2.4.1, and as follows:

- At the bank of the Unnamed Arroyo to the west and northwest.
- The Home Sites and wooded area with native soils to the north;
- The property fence, road and the Trailer Park area to the east and southeast.
- The boundary of Sandfill 1, Ponds 1 and 2, and Pond 3/3a to the southeast, south and southwest.

The gamma survey measurements and soil sample analytical results were then used to confirm or adjust the FSL boundary locations.

The gamma survey results at the 149 step-out locations from NECR-1 ranged from <0.6 to 85.8 pCi/g (averaged 8.9 pCi/g). The surface soil Ra-226 levels within the entire NECR-1 area including the step-out locations averaged 19.6 pCi/g.

3.1.2 NECR-2

The NECR-2 area, similar to NECR-1, was thought to contain non-economic materials and/or low grade uranium ore, but was not expected to exceed the FSL, therefore, it was also classified as a potential Class 2 survey area in the RSEWP. Initially, one-minute static gamma radiation measurements were obtained at a total of 75 grid nodes within, and extending beyond, the initial survey area boundary. The results of these static gamma survey measurements are summarized in Table 3.2, *NECR-2 Static Gamma Radiation Survey Results*. The results show that the surface soil Ra-226 concentrations ranged from <0.6 to 215.2 pCi/g (averaged 22.6 pCi/g); 64 out of the 75 (85%) exceeded the FSL. Gamma radiation readings exceeded the FSL of 4,600 CPM at over 80% of the static survey points; therefore, no scan gamma radiation survey was performed to delineate hot spots. Also, the surface soil Ra-226 concentrations at most of the grid points close to the initial survey area boundary were above the FSL, as shown on Figure 3-1.

Static gamma radiation measurements were made at 43 step-out locations around NECR-2 to delineate the lateral extent of Ra-226 in surface. The gamma radiation levels at the step-out locations were mostly above the FSL, except along the western boundary. Therefore, the static gamma radiation survey was stopped for boundary delineation based on the criteria discussed in Section 2.2.4.1, as follows:

- To the west until the readings were below the FSL.
- To the boundary of Sandfill 3 and Magazine area to the north.
- The wooded areas with native soils to the east.
- To the mesa cliff and Sandfill 2 to the southeast and south.

The gamma survey measurements and soil sample analytical results were then used to confirm or adjust the FSL boundary locations.

The gamma survey conducted at the 43 step-out locations indicated that Ra-226 ranged from <0.6 to 19.2 pCi/g (averaged at 3.4 pCi/g). The equivalent Ra-226 concentrations in surface soil within the entire NECR-2 area, including step-out locations and Magazine area averaged 15.6 pCi/g.

3.1.3 Sandfill 1

Sandfill 1 was previously remediated by UNC to remove mill tailings material (UNC, 1989). However, this area could contain residual ore material, and was expected to contain soils with Ra-226 in excess of the FSL. The area was therefore classified as a potential Class 1 Area in the RSEWP. A one-minute static gamma radiation survey was performed at 76 grid nodes within and just outside of the initial survey area boundary. The static gamma survey results are summarized in Table 3.3, *Sandfill 1 Static Gamma Radiation Survey Results.* The results show that the equivalent surface soil Ra-226 concentrations ranged from non-detect (<0.6) to 76.0 pCi/g (averaged 9.0 pCi/g); 45 of 76 (59%) exceeded the FSL of 2.24 pCi/g. The gamma radiation readings exceeded the FSL of 4,600 CPM at 62 of 73 (over 80%) static survey points; therefore, no scan gamma radiation survey was performed to delineate additional hot spots while in the field. Equivalent surface soil Ra-226 concentrations exceeded the FSL at some grid points around the area boundary, as shown on Figure 3-1. The Sandfill 1 survey was stopped for boundary delineation, based on the criteria discussed in Section 2.2.4.1, as follows:

- Pond 1 and 2 to the west.
- NECR-1 to the north.
- A road and cliff to the east.
- Concentrations below the FSL to the south.

The gamma survey measurements and soil sample analytical results were then used to confirm or adjust the FSL boundary locations.

Additional static and scan gamma radiation surveying was not performed for boundary delineation (i.e., step-outs) due to the physical limitations around the survey area. The survey did however provide sufficient data for establishing the area boundary. It is important to note that equivalent Ra-226 levels were below the FSL at 11 grid points (#16, 17, 20–22, 26-29, 35, and 36) within the interior of the area (see Figure 3-1).

3.1.4 Sandfill 2

Sandfill 2 was also remediated previously by UNC to remove mill tailings material (UNC, 1989). However, this area could contain residual ore material, and was expected to contain soils with Ra-226 in excess of the FSL. The area was therefore classified as a potential Class 1 Area in the RSEWP. A one-minute static gamma radiation survey was performed at 21 grid nodes. The static gamma survey results are summarized in Table 3.4, *Sandfill 2 Static Gamma Radiation Survey Results.* The results show that the surface soil Ra-226 levels ranged from non-detect (<0.6) to 26.0 pCi/g (averaged 5.6 pCi/g); 12 of 21 (57%) exceeded the FSL of 2.24 pCi/g. Gamma radiation measurements exceeded the FSL of 4600 CPM at over 80% of the static survey points; therefore, no scan gamma radiation survey was performed to delineate hot spots.

Equivalent Ra-226 levels around the area boundary were near or below the FSL along the west, south and east boundary, as shown on Figure 3-1. Sandfill 2 was therefore bounded based on the criteria discussed in Section 2.2.4.1, as follows:

- By NECR-2 to the north.
- By a mesa cliff and Ra-226 levels below the FSL to the east.
- By Ra-226 levels below the FSL to the west and south.

The gamma survey measurements and soil sample analytical results were then used to confirm or adjust the FSL boundary locations. No step-out gamma survey was necessary for boundary delineation. The revised boundary is shown on Figure 3-1.

3.1.5 Sandfill 3

Sandfill 3 was also remediated previously by UNC to remove mill tailings material (UNC, 1989). However, this area could contain residual ore material, and was expected to contain soils with Ra-226 in excess of the FSL. The area was therefore classified as a potential Class 1 Area in the RSEWP. A one-minute static gamma radiation survey was performed at the 28 grid nodes. The static gamma survey results are summarized in Table 3.5, *Sandfill 3 Static Gamma Radiation Survey Results.* The surface soil concentrations within the initial area boundary ranged from non-detect (<0.6) to 133.6 pCi/g (averaged 20.9 pCi/g); 25 of 28 (89%) exceeded the FSL. Gamma radiation readings exceeded the FSL of 4,600 CPM at over 80% of the static survey points; therefore, no scan gamma radiation survey was performed to delineate hot spots. A step-out static gamma survey was performed at 15 grid points for boundary delineation. The survey area boundary was confirmed based on the criteria discussed in Section 2.2.4.1, as follows:

- Gamma readings below the FSL and wooded hills with undisturbed, native soils to the west.
- The boundary of NECR-2 to the south and east.
- The boundary of the Sediment Pad to the north.

The gamma survey measurements and soil sample analytical results were then used to confirm or adjust the FSL boundary locations. As shown in Table 3.5, equivalent Ra-226 levels at the step-out locations ranged from non-detect to 14.9 pCi/g (averaged 3.1 pCi/g).

3.1.6 Ponds 1 and 2

Ponds 1 and 2 were considered as one area during the RSE due to their proximity and similarity in mining process and operations. The ponds could contain sediments from the historical mine water treatment that have Ra-226 concentrations in excess of the FSL, and the area was therefore classified as potential Class 1. Results of the static gamma radiation survey at 85 grid points within this area are shown in Table 3.6, *Pond 1 and Pond 2 Static Gamma Radiation Survey Results* and Figure 3-1. Ra-226 concentrations ranged from non-detect (<0.6) to 498.3 pCi/g (averaged 45.8 pCi/g); 76 of 85 (89%) locations exceeded the FSL. Gamma radiation readings exceeded the FSL of 4,600 CPM at over 80% of the static survey points; therefore, no scan gamma radiation survey was performed in this area to delineate hot spots. The survey area boundary was confirmed based on the criteria discussed in Section 2.2.4.1, as follows:

- By the steep pond bank and Pond 3/3a boundary to the north.
- Steep cliffs and Sandfill 1 to the east.
- Steep cliffs and wooded areas with undisturbed native soils to the south and west.

The gamma survey measurements and soil sample analytical results were then used to confirm or adjust the FSL boundary locations. No step-out gamma survey was necessary for boundary delineation.

3.1.7 Pond 3/3a

Ponds 3 and 3a were considered as one area (Pond 3/3a) during the RSE due to their proximity and similarity of mine water treatment operations. Both ponds contained radium sulfate precipitated mine discharge water during mine operations, and may contain residual radium sulfate in the pond

sediments. Due to the potential for exceedances of the FSL, the area was classified as a potential Class 1 Area in the RSEWP. Results of the static gamma radiation survey at the initial 69 grid nodes in the Pond 3/3a are summarized in Table 3.7, *Pond 3/3a Static Gamma Radiation Survey Results.* Four of the planned grid points were located under water and were therefore eliminated from the survey. The results show that the surface soil Ra-226 concentrations ranged from <0.6 to 293.6 pCi/g (averaged 25.5 pCi/g) within the initial area boundary. Ra-226 concentrations exceeded the FSL at 67 of 69 locations (97% of the area), as shown on Figure 3-1. Gamma radiation readings exceeded the FSL of 4,600 CPM at over 80% of the static survey points; therefore, no gamma survey was performed to delineate hot spots within Pond 3/3a.

Pond 3/3a was bounded based on the criteria discussed in Section 2.2.4.1, including the Sediment Pad to the west and NECR-1 to the east. A step-out static gamma radiation survey was performed at a total of 20 grid points along transects beyond the initial south boundary to the base of the Ponds 1 and Pond 2 embankments, and beyond the northern boundary to the base of the mesa cliff to adequately delineate the south and north portions of the area boundary. Results of this step-out static gamma radiation survey are included in Table 3.7; Ra-226 concentrations ranged from non-detect to 11.5 pCi/g (averaged 4.0 pCi/g). As shown on Figure 3-1, the northern boundary is bounded by concentrations below the FSL, while the southern boundary is bounded by a road as well as the Ponds 1 and 2 survey area.

3.1.8 Sediment Pad

The Sediment Pad was used to store sediments removed from the mine water radium precipitation treatment. Therefore, since it was known that the Sediment Pad could contain sediments with Ra-226 in excess of the FSL, the area was classified as a potential Class 1 Area. The one-minute static gamma radiation survey results at the initial 29 grid nodes are included in Table 3.8 *Sediment Pad Static Gamma Radiation Survey Results.* Surface soil Ra-226 concentrations within the initial area boundary ranged from 2.9 to 210.7 pCi/g (averaged 46.3 pCi/g); the FSL was exceeded at all of the initial 29 grid locations (see Figure 3-1). Gamma radiation readings exceeded the FSL of 4,600 CPM at over 80% of the static survey points; therefore no scan gamma radiation survey was performed to delineate hot spots. As shown on Figure 3-1, the Sediment Pad is bounded based on the criteria discussed in Section 2.2.4.1, as follows:

- By the Sandfill 3 to the west and southwest.
- A road and steep wooded hill to the south and southeast.
- By Pond 3/3a to the east.

The gamma survey measurements and soil sample analytical results were then used to confirm or adjust the FSL boundary locations. A step-out static gamma radiation survey for delineation of the northern boundary was performed at 11 points only beyond the northern boundary to the base of the mesa cliff. These results are included in Table 3.8 and summarized on Figure 3-1, and show that step-out surface soil Ra-226 concentration ranged from non-detect to 5.4 pCi/g (averaged 1.6 pCi/g). The northern boundary is therefore bounded by Ra-226 concentrations below the FSL.

3.1.9 Non-Economic Material Storage Area

An investigation by scan gamma radiation survey was specified in the RSEWP for characterization of the NEMSA. The NEMSA contains non-economic materials and/or low-grade ore with a clean soil cover. Ra-226 concentrations were expected to be below the FSL, thus it was classified as a potential Class 2 Area in the RSEWP. However, as a decision was made to suspend the scan survey and collect surface and subsurface soil samples for laboratory analysis instead. This decision was based on site reconnaissance that showed non-economic materials at or near the surface beneath thinner areas of

the cap and elevated gamma exposure rate measurements collected at various locations within the NEMSA and the Boneyard Area by EPA and UNC representatives.

3.1.10 Vent Holes 3 and 8

Characterization of the Vent Hole 3 and 8 area was not specified in the RSEWP. This area was included in the RSE because it was identified by the on-site EPA representatives during the field survey. This area consists of areas around Vent Holes 3 and 8, as shown on Figure 3-1. As discussed in Section 2.2, a scan gamma radiation survey was performed with the bare (uncollimated) 2x2 NaI detector #805522-33 within the overall area boundary shown on Figure 3-1 to identify any hot spots above the FSL. The area boundary was determined based on inspection of the ground surface conditions, suspect ore materials, and gamma exposure rate levels around the vent holes.

The scan gamma survey, which was conducted along transects spaced approximately 10 feet apart, identified three locations (small isolated areas of about two to five feet diameter) around Vent Hole 3, and 32 locations around the Vent Hole 8. A static gamma radiation survey was then performed with the bare 2x2 NaI detector at these elevated locations. The results of the static gamma radiation survey are included in Table 3.9, *Vent Hole No. 3 and No. 8 Static Gamma Radiation Survey Results,* and shown on Figure 3-1. Ra-226 surface soil concentrations at the three locations around Vent Hole 3 identified by the scan survey ranged from 4.3 to 15.0 pCi/g. Ra-226 concentrations at the 32 locations identified by the scan survey around Vent Hole 8 ranged from non-detect to 71.6 pCi/g (averaged 19.5 pCi/g); only two locations were below the FSL within the identified hotspots. The scan gamma radiation survey indicated that Ra-226 was below the FSL at all locations outside of the identified hot spots.

Eight or so of the isolated small areas northwest of the Vent Hole 3 and 8 structure are on a mound (see field sketch in Appendix B), where unidentified earthen material was observed; the elevated concentrations could be deeper than 0.5 feet bgs on this mounded area. An apparent sump was also observed in the southwest part of the Vent Hole 3 and 8 structure (see field sketches in Appendix B), where the surface soil concentrations were slightly above the FSL.

3.1.11 Trailer Park Area

The Trailer Park area was also not specified in the RSEWP, but was included in the survey after being identified as potentially impacted area during the field activities. As discussed in Section 2.2, a scan gamma radiation survey was performed in the Trailer Park Area within the area boundary, as shown on Figure 3-1, to identify hot spots above the FSL. The area boundary was determined based on an inspection of the ground surface, visible evidence of mine-related materials, features such as structure foundation pads and fills, and the base of wooded area and hills with undisturbed native soil. The scan survey identified a total of 39 locations (small isolated areas of about 2 to 50 square feet each) within the Trailer Park. Results of the one-minute static gamma radiation survey at these locations are included in Table 3.10, *Trailer Park Area Static Gamma Radiation Survey Results* and shown on Figure 3-1. The results show that surface soil Ra-226 concentrations ranged from 2.5 to 108.7 pCi/g (averaged 16.5 pCi/g). The static survey confirmed all 39 locations within the hotspots identified by the scan survey to be above the FSL. At locations #2, #7, #9, #13, #40, and #41, visible mine-related materials was observed, which could extend deeper than 0.5 feet bgs. The scan gamma radiation survey indicated that Ra-226 was below the FSL at all locations outside of the identified hot spots.

3.1.12 Home Sites

Due to potential wind or storm water, and to a lesser extent human and animal activity, transport of ore material still present at the Site, there was a concern about potential impacts to the nine Home Sites near the downstream end of the of the Unnamed Arroyo where it intersects with the unnamed

dirt road that runs east-west along the northern side of the Home Sites, as shown in Figure 2-3. . The Home Sites were classified as potential Class 3 Areas in the RSEWP, and a scan gamma radiation survey was specified to identify any locations above the FSL. As discussed in Section 2.2, a scan gamma radiation survey with a bare (uncollimated) 2x2 NaI detector was performed within a half-acre area around each of the nine Home Sites. The scan survey results showed the gamma radiation levels at or slightly above the background level, but below the FSL (16,600 CPM or 2.24 pCi/g Ra-226 in surface soil) at Home Sites 1 through 5, as shown in field forms in Appendix B. These low levels were confirmed by the results of the one-minute static gamma radiation survey, the results of which are included in Table 3.11, *Home Site Static Gamma Radiation Survey Results.*

At Home Sites 6 through 9, the scan survey results indicated gamma radiation levels from 13,000 CPM (background) to about 34,000 CPM. Results of the static gamma radiation survey, included in Table 3.11, at five elevated locations identified by the scan survey at each of the Home Sites, indicated surface soil Ra-226 concentrations above the FSL. Maximum equivalent Ra-226 concentrations were:

- 4.2 pCi/g at Home Site 6
- 11.0 pCi/g at Home Site 7
- 3.5 pCi/g at Home Site 8
- 3.2 pCi/g at Home Site 9

These results are shown on Figure 3-2, *Results of Gamma Survey and Soil Sampling at the Home Sites.* There are several potential mechanisms that could have contributed to the elevated levels detected at the Home Sites, including transport of windblown material from the NECR on-site areas and the Quivera Mine, historic disturbed areas from Quivera operations in the immediate vicinity of the Home Sites, and transport of eroded sediments from NECR-1 in storm water run off, and transport of windblown materials from the former Quivera haul road. During the NECR-1 step-out survey conducted north of NECR-1 (south of Home Sites #6 and #7), eroded sediment trails from the north slope of the NECR-1 pad were observed.

3.1.13 Unnamed Arroyo

A gamma radiation survey was specified in the RSEWP as a part of the characterization survey for the surface sediments within the Unnamed Arroyo bed. However, a scan gamma radiation survey was not performed, as discussed in Section 2.2, because the August 17, 2006 correlation gamma radiation level measurements and soil sampling data showed that gamma levels and Ra-226 concentrations are above the FSL (>80%) the entire length of the sediment bed from NECR-1 down to the Home Sites (the survey was extended to the unnamed dirt road that runs east-west on the northern side of the Home Sites, as shown on Figure 2-3). Therefore, in consultation with the on-site EPA representatives, a decision was made to eliminate the scan gamma radiation survey, and perform subsurface sediment sampling for laboratory analysis instead to evaluate the vertical extent of Ra-226.

As discussed in Section 2.2, a static gamma radiation static survey was performed at 33 transect locations along the north plus five transect locations on the south bank (downstream end) of the Unnamed Arroyo about two to three feet from the edge of the bank. The results, which are summarized in Table 3.12, *Arroyo Bank Static Gamma Radiation Survey Results,* and on Figure 3-2, indicated that surface soil Ra-226 concentrations ranged from <0.6 to 12.2 pCi/g (averaged 2.7 pCi/g). As can be seen on Figures 3-1 and 3-2, concentrations exceeded the FSL at most locations within 200 feet of NECR-1, but not farther to the northeast of NECR-1, except at two sample locations on the south side of the arroyo bank (3.2 and 12.2 pCi/g). The two farther samples are located approximately 1,100 feet northeast of NECR-1 along the south bank of the Unnamed Arroyo (see Figure 3-2).

The 33 samples collected along the north side of the Unnamed Arroyo included eleven samples collected from within the boundaries of the former IX Plant (see Figures 1-2 and 3-1). The results (see Table 3.12) indicated that equivalent surface soil Ra-226 concentrations in the area of the former IX Plant ranged from 1.3 to 9.5 pCi/g (averaged 4.3 pCi/g). Ra-226 concentrations were above the FSL at all but one of the locations within the boundaries of the former IX Plant. The FSL boundary in that area was based on the results of the static gamma survey and the presence of a near vertical cliff over 40 feet high on the north side of the IX Plant, as shown on Figures 1-2, 1-3 and 3-1.

3.1.14 Gamma Radiation Survey Results Summary

As discussed in the above subsections, the gamma radiation surveys indicated that surface soils within the initial boundaries of each of the on-site areas specified in the RSEWP, contain surface soils with Ra-226 concentrations above the 2.24 pCi/g FSL, as shown on Figure 3-1. A small fraction of the survey points within the initial boundaries areas are below the FSL. The locations of exceedances of Ra-226 (equivalent) are frequent and closely spaced such that delineation of any smaller, clean areas within the interior of the areas was not practical. About 11 survey grid points below the FSL are contiguous enough to isolate a potential, small clean area within Sandfill 1. The results of the static gamma radiation survey discussed above for all areas are further summarized in Table 3.13, *Gamma Radiation Results Summary*. The results show that the average surface soil Ra-226 concentrations, as determined by correlation with the gamma survey results (CPM), within the survey areas are significantly above the 2.24 pCi/g FSL, from approximately four to twenty times the FSL. As shown in Table 3.13, the surface soil Ra-226 concentration range is wide, with high standard deviations near or above the average concentrations indicating sporadic Ra-226 contamination in surface soil.

Based on the static survey level results (i.e., locations below the FSL), an outer boundary for each area was interpreted and is shown on Figure 3-1 as the "FSL Boundary". This boundary was drawn outside of most exceedances of the FSL. Where the results were inconclusive, the FSL Boundary was determined based on:

- Undisturbed ground, such as in wooded areas with native soils.
- Roads, structures, and fences.
- Topographic limitations such as precipices and steep hillsides.
- Boundaries of adjoining survey areas.

The RSEWP also specified one-point surface soil sampling for laboratory analysis at 20% of the 80-foot triangular grid nodes (sample locations), or at least 13 grid nodes within an area, and five from each of the nine Home Sites as discussed in Section 3.2. The FSL Boundary was confirmed and slightly revised based on the results of the surface soil sampling, as discussed in Section 3.2. Comparisons of surface soil Ra-226 concentrations by soil sampling and by static gamma radiation surveying at 218 points are shown in Table 3.14, *Gamma Radiation Survey and Surface Soil Ra-226 Results Comparison*. The results show that although there may be some variation between Ra-226 surface soil concentrations by soil sampling versus static gamma radiation survey at some locations, the averages are comparable. The average Ra-226 surface soil sampling results at 218 locations is 31.4 pCi/g with a standard deviation of 83.2 pCi/g whereas the static gamma radiation survey results at co-locations showed an average of 28.3 pCi/g with a standard deviation of 55.8 pCi/g. The static gamma radiation survey provided surface soil Ra-226 levels at over 750 additional on-site area locations and enhanced the completeness of surface soil Ra-226 characterization compared to soil sampling for laboratory analysis would have alone.

3.2 SURFACE SOILS METALS DATA

Surface soil samples (≤0.5 feet bgs) were collected from each of the survey areas, and analyzed for the preliminary COPCs (Ra-226, As, Mo, Se, U, and V), except those collected in August 2006 for the

initial gamma versus Ra-226 correlation, which were only analyzed for Ra-226. The locations of each of the surface soil sample locations are shown on Figures 2-2 and 2-3, and the analytical results are presented on Figure 3-2, and Figure 3-3, *Surface Soil Analytical Results.* The analytical results are tabulated in Table 3.15, *Summary of Surface Soil Analyical Results, Metals.* These results include the initial correlation samples, the primary surface soil samples, step-out and boundary confirmation samples, and any additional surface soil samples that were collected at subsurface sampling locations. The surface soil validated analytical data are presented in Appendix B, *Laboratory Analytical Data.*

The results show that Ra-226, arsenic, and uranium exceed the screening levels at some locations, while all results for molybedenum, selenium and vanadium were below their respective screening levels (see Table 3.15). Only the surface soil analytical results for Ra-226, total uranium and arsenic are discussed, by survey area, in the following sections. The surface soil analytical results were compared to the Ra-226 FSL and EPA Region 9 industrial PRGs for arsenic and uranium, except the Home Sites, which were compared to EPA Region 9 residential PRGs.

3.2.1 NECR-1

A total of 49 surface soil samples were collected from NECR-1 (see Table 3.15). Of these 49 samples, 31 were primary samples, 17 were step-out samples outside the original area boundary, and one sample was a correlation sample. On-site (within the NECR-1 boundary) concentrations of Ra-226 ranged from 7.0 to 93.3 pCi/g (averaged 39.3 pCi/g); all exceeded the FSL of 2.24 pCi/g. Most of the step-out samples were collected north, northeast, and southeast of NECR-1, as shown on Figure 3-3. To the north of NECR-1, concentrations of Ra-226 exceeded the FSL close to the boundary and then dropped off below the FSL within 100 to 300 feet from the boundary. To the northeast, there are Ra-226 concentrations above the FSL (e.g., locations NECR1-281, -293 and -307). The locations of these samples are shown on Figure 2-3, and the results are shown on Figure 3-3 (sheet 1) NECR1-307 is located adjacent to Red Water Pond Road, which was formerly used as the haul road for the nearby Quivera mine. The results of three samples collected between NECR-1 and Sandfill 1 ranged from 1.3 to 5.2 mg/kg. These results confirmed the gamma survey results, and it was not necessary to revise the FSL Boundary based on the gamma survey results (see Figure 3-3).

Only four out of 49 soil samples collected from NECR-1 exceeded the uranium screening level of 200 mg/kg (See Figure 3-3). Concentrations ranged between 209 and 758 mg/kg. All four of those samples were collected from on-site locations at disparate locations within the area.

On-site arsenic concentrations ranged from non-detect to 8.3 mg/kg (average 3.9 mg/kg), while step-out arsenic concentrations ranged from 2.7 to 14.9 mg/kg (average 6.0 mg/kg). These data indicate that there is no significant difference between on-site and step-out arsenic concentrations. There also does not appear to be a spatial pattern to the arsenic concentrations, or a correlation with Ra-226 concentrations.

3.2.2 NECR-2

Twenty-four surface soil samples were collected from NECR-2 (see Table 3.15). Of these 24 samples, 15 were primary samples, four were step-out samples, and five were correlation samples On-site concentrations of Ra-226 ranged from 1.2 to 160 pCi/g (averaged 27.7), and all but one of the step-out samples exceeded the FSL. The one step-out sample that exceeded the FSL was located northeast of NECR-2, within the Magazine Area. These results confirmed the gamma survey results, and it was not necessary to revise the FSL Boundary (see Figure 3-3).

Only one out of a total of 24 soil samples from NECR-2 exceeded the uranium screening level of 200 mg/kg. That one sample was collected from an on-site location (see Figure 3-3) and was reported to be 370 mg/kg.

On-site arsenic concentrations ranged from 1.3 to 6.4 mg/kg (averaged 3.5 mg/kg), while step-out arsenic concentrations ranged from 3.3 to 8.1 (averaged 5.7 mg/kg). These data indicate that there is no significant difference between on-site and step-out arsenic concentrations. Three of the highest arsenic concentrations were from the three step-out locations samples near the Magazine area. There is no apparent pattern to the spatial distribution of arsenic concentrations, no a correlation with Ra-226.

3.2.3 Sandfill 1

Eighteen surface soil samples were collected from Sandfill 1 (see Table 3.15), three of which were collected at boundary confirmation locations. On-site concentrations of Ra-226 ranged from 0.8 to 47.3 pCi/g (averaged 10.2 pCi/g); 72% exceeded the FSL. All three boundary samples were located to the east of Sandfill 1 and all three exceeded the FSL, but ranged from 3.8 and 5.4 pCi/g (averaged 4.5 pCi/g). These results were used to slightly modify the FSL Boundary (see Figure 3-3).

No results exceeded the uranium screening level of 200 mg/kg.

Arsenic concentrations at Sandfill 1 ranged from 2.0 to 6.7 (average 3.9 mg/kg); 60% exceeded the screening level. All three boundary confirmation samples exceeded the arsenic screening level.

3.2.4 Sandfill 2

Thirteen surface soil samples were collected from Sandfill 2; no step-out samples were required. Ra-226 concentrations ranged from 0.8 to 36.0 pCi/g (average 10.2 mg/kg); 77% exceeded the FSL. These results confirmed the gamma survey results, and it was not necessary to revise the FSL Boundary (see Figure 3-3).

No sample results exceeded the uranium screening level of 200 mg/kg.

Arsenic concentrations ranged from 3.2 to 9.0 mg/kg (average 5.2 mg/kg); 60% exceeded the screening level. The five highest concentrations (above 5.0 mg/kg) were located to the west of the original Sandfill 2 boundary (See Figure 3-3).

3.2.5 Sandfill 3

Sixteen surface soil samples were collected from Sandfill 3. Two were collected at boundary confirmation locations and one sample was collected at a correlation point. Ra-226 concentrations ranged from 1.0 to 123.0 pCi/g (averaged 28.7 mg/kg); all samples but the three on-site samples and the correlation sample exceeded the FSL. The boundary samples were below the FSL. These results confirmed the gamma survey results, and it was not necessary to revise the FSL Boundary (see Figure 3-3).

An additional 10 surface soil samples were collected 50 to 400 feet northwest of Sandfill 3 for the initial gamma versus Ra-226 correlation (see Table 3.15) and were analyzed for Ra-226 only. These samples were collected between the Unnamed Arroyo, the Sediment Pad, Sandfill 3 and the NEMSA, as shown on Figure 3-3. Ra-226 concentrations in these samples ranged from 1.1 to 6.6 pCi/g (average 3.1 pCi/g); 50% exceeded the FSL.

Only one out of 17 samples exceeded the uranium screening level of 200 mg/kg; this sample, at 396 mg/kg, was located in the middle of the survey area.

Arsenic concentrations ranged from 1.5 to 5.3 mg/kg (averaged 3.5 mg/kg); 35% exceeded the screening level.

3.2.6 Ponds 1 and 2

Twenty-five surface soil samples were collected from Ponds 1 and 2 (see Table 3.15). Four of the locations were boundary confirmation samples; three samples resulted from subsurface locations that were not paired with a primary surface sample; and one was a correlation sample. On-site concentrations of Ra-226 ranged from 1.0 to 655 pCi/g (averaged 105.9 pCi/g); 81% exceeded the FSL. Concentrations of Ra-226 were below the FSL at all four boundary confirmation locations. These results confirmed the gamma survey results, and it was not necessary to revise the FSL Boundary (see Figure 3-3).

Only three (on-site) out of 25 soil samples from Ponds 1 and 2 exceeded the uranium screening level of 200 mg/kg. The concentrations of these three samples ranged from 339 to 1,080 mg/kg. Two of these samples were located in the northeast corner of Pond 1, and the third in the northwest corner of Pond 1 (ore material was noted here). These samples coincided with the highest Ra-226 results.

On-site arsenic concentrations ranged from 2.5 to 8.8 mg/kg (average 4.5 mg/kg), while boundary confirmation arsenic concentrations ranged from 2.2 to 4.5 (average 3.0 mg/kg). There does not appear to be a distinct spatial pattern in arsenic concentrations, nor a clear correlation with Ra-226 concentrations.

3.2.7 Pond 3/3a

Sixteen surface soil samples were collected from Pond 3/3a (see Table 3.15); no step-out locations were required. Of the 16 samples, 13 were primary samples, two were from subsurface sample locations, and one was a correlation sample. Concentrations of Ra-226 ranged from 1.4 to 875 pCi/g (averaged 102.1 pCi/g) and all but one exceeded the FSL. These results confirmed the gamma survey results, and it was not necessary to revise the FSL Boundary (see Figure 3-3).

Three out of 16 soil samples from Pond 3/3a exceeded the uranium screening level of 200 mg/kg, corresponding to the three highest Ra-226 concentrations. These three exceedances ranged from 1,020 to 3,970 mg/kg). All three of these samples were collected within the original area boundary from the central and southwest portion of Pond 3.

Arsenic concentrations ranged from 2.7 to 8.1 mg/kg (averaged 5.3 mg/kg); all but two exceeded the screening level. There does not appear to be a spatial pattern in arsenic concentrations, nor a correlation with Ra-226 concentrations.

3.2.8 Sediment Pad

Thirteen primary surface soil samples and one additional sample paired with a subsurface location were collected from the Sediment Pad (see Table 3.15); no step-out locations were required. Concentrations of Ra-226 ranged from 1.5 to 236 pCi/g (averaged 60.5 pCi/g); all but one exceeded the FSL. These results confirmed the gamma survey results, and it was not necessary to revise the FSL Boundary (see Figure 3-3).

Three out of 14 soil samples collected from the Sediment Pad exceeded the uranium screening level of 200 mg/kg. The concentrations were reported to be 363 mg/kg, 366 mg/kg and 1,640 mg/kg. All three exceedances were located in the central portion of the area.

Arsenic concentrations ranged from non-detect to 11.6 mg/kg (average 2.9 mg/kg); only two exceeded the screening level. The two samples exceeding the screening level came from disparate locations.

3.2.9 Non-Economic Materials Storage Area

Five surface soil samples were collected from the NEMSA and were coincident with five judgmental test pit locations. Ra-226 concentrations ranged from 0.9 to 2.6 pCi/g (averaged 1.5 pCi/g) with only one sample slightly exceeding the FSL.

Uranium results were all below the screening level.

Arsenic concentrations ranged from 0.7 to 4.3 mg/kg (averaged 3.4 mg/kg) and three of the samples were just above the arsenic screening level.

3.2.10 Boneyard

Five surface soil samples were collected from the Boneyard and were coincident with five judgmental test pit locations. Ra-226 concentrations exceeded the FSL in only one sample (45.9 pCi/g), located at the southern end of the Boneyard.

Uranium concentrations were all below the screening level.

Arsenic concentrations ranged from 1.3 to 5.5 mg/kg (averaged 3.9 mg/kg). Three of the five samples were above the screening level and one sample was equal to the screening level.

3.2.11 Vent Holes 3 and 8

Five judgmental soil samples were collected from the Vent Hole 3/8 area. This area was not included in the RSEWP, but was added during the field investigation according to FCR#004 (see Appendix C). Ra-226 concentrations ranged from 1.4 to 137 pCi/g (averaged 31.5 pCi/g); all but one sample exceeded the FSL. Uranium concentrations exceeded the screening level at only one location, corresponding to the location with the highest Ra-226 concentration, located in the central portion of the Vent Hole 8 area near the Vent Hole 8 structure. Arsenic concentrations were above the screening level at only one location (5.1 mg/kg), located in the Vent Hole 8 area.

3.2.12 Trailer Park

Five judgmental soil samples were collected from the Trailer Park. This area was not included in the RSEWP, but was added during the field investigation according to FCR#004 (see Appendix C). Ra-226 concentrations ranged from 2.1 to 33.2 pCi/g (averaged 4.2 pCi/g); three of the samples exceeded the FSL. These three samples were all located at the northern end of the area (see Figure 3-3). Uranium concentrations were all less than the screening level. Arsenic concentrations ranged from non-detect (<0.5 mg/kg) to 6.1 mg/kg (averaged 4.2 mg/kg), with no apparent spatial pattern and no correlation with Ra-226..

3.2.13 Home Sites

Five surface soil samples were collected from each of the nine Home Sites in the areas where the highest readings were obtained from the gamma radiation scan survey. Overall, Ra-226 concentrations ranged from 0.9 to 29.6 pCi/g (averaged 16.6 mg/kg). All results were below the FSL for Home Sites 1, 2, 3 and 5 (see Figure 3-2). Ra-226 exceeded the FSL in 100% of the samples

collected around Home Sites 6, 7, 8 and 9 and in two of the five samples from around Home Site 4. A summary of the surface soil results for these five Home Sites is as follows:

- Home Site 4 – Ra-226 ranged from 1.3 to 3.6 pCi/g and two samples exceeded the FSL.
- Home Site 6 – Ra-226 ranged from 5.6 to 14.9 pCi/g and all five samples exceeded the FSL.
- Home Site 7 – Ra-226 ranged from 3.4 to 29.6 pCi/g. Removing the highest value in the range decreased to 3.4 to 9.4 pCi/g.
- Home Site 8 – Ra-226 ranged from 2.3 to 5.6 pCi/g. All five samples exceeded the FSL; however, two samples (2.3 and 2.5 pCi/g) were just above the FSL.
- Home Site 9 – Ra-226 ranged from 2.6 to 6.7 pCi/g and all five samples exceeded the FSL.

The results of the post-excavation soils removal confirmation sampling and analysis conducted by the EPA subsequent to the RSE investigation are included in Appendix D.

Uranium concentrations ranged from 0.7 to 20.5 mg/kg (averaged 4.5 mg/kg). The residential PRG of 16 mg/kg for uranium was exceeded at two sample locations; one from around Home Site 7 (20.5 mg/kg) and the other from around Home Site 9 (19.1 mg/kg).

Arsenic concentrations ranged from 2.8 to 5.5 mg/kg (averaged 4.2 mg/kg); 60% exceeded the screening level. There does not appear to be a correlation between arsenic concentrations and Ra-226 concentrations in surface soils collected around the Home Sites.

Molybdenum results were all non-detect (<5.0 mg/kg).

Selenium concentrations ranged from non-detect to 6.3 mg/kg and were all below the screening level of 5,100 mg/kg, as well as the residential PRG of 390 mg/kg.

Vanadium concentrations ranged from 21.5 to 49.7 mg/kg and were all below the screening level of 1,000 mg/kg, as well as the residential PRG of 78 mg/kg.

3.2.14 Unnamed Arroyo

Fifteen surface soil samples were collected from the Unnamed Arroyo during the correlation sampling in August 2006, and analyzed for Ra-226. Ra-226 ranged from 9.7 to 26.4 pCi/g (averaged 16.8 pCi/g); 100% exceeded the FSL. Because of these results, additional surface soil samples were not collected as planned in the RSEWP, and instead subsurface soil samples were collected according to FCR#001 (see Appendix C). The results of the subsurface soil sampling are discussed in Section 3.3.

3.2.15 Surface Soil Analytical Results Summary

Table 3.15 includes a statistical summary of the surface soils, which shows the following:

- Ra-226 values ranged from 0.8 to 875 pCi/g (averaged 30.6 pCi/g); 70% of the 263 surface soil samples analyzed for Ra-226 [includes stepouts] exceeded the FSL of 2.24 pCi/g.
- Toal uranium values ranged from 0.7 to 3,970 mg/kg (averaged 79.7 mg/kg); 7% of the 229 samples analyzed for total uranium exceeded the screening level of 200 mg/kg (industrial

PRG). Two samples from the forty-five samples collected from around the Home Sites exceeded the residential screening level of 16 mg/kg.

- Arsenic values ranged from non-detect (<0.5 mg/kg) to 14.9 mg/kg (averaged 4.2 mg/kg); 54% of the 229 samples analyzed for arsenic exceeded the screening level of 3.7 mg/kg. There did not appear to be a pattern to the spatial distribution of arsenic. The presence, absence or range of concentrations of arsenic do not consistently correlate with higher or lower Ra-226 or uranium concentrations.

- Molybdenuym values ranged from non-detect (<5.0 mg/kg) to 214.0 mg/kg (averaged 3.8 mg/kg); all results were below the screening level of 5,100 mg/kg (industrial PRG).

- Selenium values ranged from non-detect (<0.2 mg/kg) to 159 mg/kg (averaged 9.5 mg/kg); all results were below the screening level of 5,100 mg/kg (industrial PRG), and all samples from the Home Sites were below the residential PRG.

- Vanadium values ranged from 9.0 to 502 mg/kg (averaged 40.2 mg/kg); all results were below the screening level of 1,000 mg/kg (industrial PRG), and all samples from the Home Sites were below the residential PRG.

3.3 SUBSURFACE SOILS METALS DATA

Subsurface soil samples (>0.5 feet bgs) were collected from each of the original on-site survey areas, and the Unnamed Arroyo. Samples were collected from test pits, drill holes, and hand auger borings (Unnamed Arroyo). All subsurface soil samples were analyzed for the preliminary COPCs (Ra-226, As, Mo, Sc, U, and V). The locations of each of the test pits, soil borings and auger holes are shown on Figure 2-4, and the analytical results for Ra-226, uranium and arsenic are shown on Figure 3-4, *Subsurface Soil Analytical Results.* The results of these analyses are also tabulated in Table 3.16, *Summary of Subsurface Soil Analyical Results, Preliminary COPCs.* All validated subsurface data is located in Appendix B.

The subsurface data from the on-site survey areas were compared to the FSL for Ra-226 and the EPA Region 9 industrial PRGs for uranium and arsenic. The use of the FSL is not strictly valid in comparison to subsurface metals results, but was used as a rough comparison to surface soil concentrations. Subsurface soil concentrations were primarily used to evaluate the vertical extent of impacts from mining, and to determine the depths to native soils. Soils sample results to depths of 10 feet bgs were used in the HHRA, as discussed in Section 4.0. The analytical results of the subsurface soil samples show that Ra-226, uranium and arsenic exceed the screening levels at some locations, while all results for molybedenum, selenium and vanadium were below their respective screening levels (see Table 3.16).

3.3.1 NECR-1

Twenty-eight subsurface soil samples were collected from five soil borings and one test pit at NECR-1. Total depths of the soil borings ranged from 14 to 45 feet bgs, and were extended into native ground. Ra-226 concentrations ranged from 1.0 to 103.0 pCi/g (averaged 21.4 pCi/g). In all drill holes, Ra-226 exceeded the FSL in the top two samples (5 and 10 feet bgs), except SB-131 on the north edge of NECR-1 (less than the FSL at 10 feet bgs). Ra-226 concentrations exceeded the FSL at depths greater than 10 to 16.5 feet at only one location (SB-090), where it exceeded the FSL in all samples down to 25 feet bgs.

Based on a comparison of pre-mine topography with post-mine topography and observations made during drilling, the approximate depths of the NECR-1 survey area are known. Ra-226 did not

exceed the FSL in any samples deeper than the maximum depths of the NECR survey area, as summarized below.

Loc ID	Estimated Depth to Native	Observed Depth to Native	Max Depth of Screening Level Exceedance
SB-016	15-20	18	15
SB-046	25-30	25	10
SB-095	10-15	12	10
SB-090	35-40	28	25
SB-131	15-20	22	5

The estimated depths to native material shown above were based on a comparison of pre-mine to post-mine topography, and the observed depths were based on observations made during the drilling. The maximum depth of the screening level exceedances was based on the depth of the last sample with Ra-226 greater then the screening level; the next sample in each case was collected 5 feet deeper. Non-native material with a distinct petroleum odor was observed at approximately 22 feet bgs in SB-131.

In boring SB-016, native material was observed at 18 feet bgs and the Ra-226 data supported this observation. The first five sampling intervals (starting at 5 feet bgs) reported Ra-226 concentrations of 21.1, 64.6, and 63.1 feet bgs, respectively; Ra-226 decreased to 1.4 pCi/g at 20 feet.

This sharp decrease in Ra-226 concentrations was observed in all five the soil borings. In some instances the decrease coincided with the observed depth in native material such as in SB-016, SB-090 and SB-095. In borings SB-046 and SB-131, it appears that the decrease in Ra-226 concentrations was due to encountering either native soils or reworked native materials. In the impacted fill materials, Ra-226 concentrations ranged between 4.2 and 103 pCi/g, while in native or re-worked native materials, Ra-226 concentrations ranged between 1.0 and 1.9 pCi/g.

The one test pit advanced at NECR-1 was located at the eastern end of the area, outside the main entrance gate, where the NECR survey area is only about five feet thick. The test pit (TP-138) was excavated to 4 feet bgs (native bedrock encountered) and sampled from 3.5 to 4 feet bgs. The FSL for Ra-226 was exceeded (24.2 pCi/g) in this one sample.
Uranium concentrations exceeded the screening level in only five samples from two soil borings (SB-046 and SB-090). In SB-090, uranium concentration exceedances ranged from 218 to 331 mg/kg. The shallowest uranium exceedance was reported at 25 feet bgs and corresponded with a Ra-226 concentration of 48.9 pCi/g. The three subsequent (deeper) uranium exceedances were 313, 331, and 240 mg/kg at 30, 35, and 40 feet bgs, respectively, corresponding to Ra-226 concentrations between 1.2 and 1.7 pCi/g. At 45 feet bgs, the uranium concentration decreased to 165 mg/kg and the Ra-226 concentration at this depth was 1.3 pCi/g. The only exceedance of uranium in SB-046 (337 mg/kg) was reported at a depth of 15 feet bgs and the Ra-226 concentration in this sample was 1.3 mg/kg.

The concentrations of uranium and Ra-226 in the next sample (20 feet bgs) were 3.4 mg/kg and 1.0 pCi/g, respectively.

Arsenic concentrations ranged from non-detect (<0.5 mg/kg) to 7.9 mg/kg (averaged 6.9 mg/kg). In all five soil borings, arsenic exceeded the screening level. Many of the exceedances were within the native material, coincident with Ra-226 concentrations less than the FSL, but not in all cases (see Table 3.16).

These results indicate that impacted materials generally extend to 10 to 15 feet bgs, except for the area around SB-090, where it extends to approximately 25 feet bgs. Soil boring SB-090 is located near the

northwestern edge of NECR, and near an erosional gulley on the sideslope of the NECR-1 where the depth of NECR-1 is greatest.

3.3.2 NECR-2

Six subsurface soil samples were collected from five test pits at NECR-2. Ra-226 concentrations ranged from 1.2 to 12.6 mg/kg (averaged 5.9 pCi/g); all but one sample exceeded the FSL. The maximum depth of the test pits was from 1.0 to 5.0 feet bgs. Most areas of NECR-2 contain less than five feet of non-native or re-worked native materials. The eastern portion of the area appeared to have been cut, as the soils observed appeared to be primarily native. In the northwestern corner, around TP-052, the area appeared to have been filled in, possibly with the soil removed from the eastern portion of the area. Based on a comparison of pre-mine to post-mine topography, the northwestern corner of the area appears to be 15 to 20 feet deep, consisting primarily of native material.

At test pit location TP-015 in the southwestern corner of NECR-2, sandstone bedrock was observed at one foot bgs and excavating could not proceed any deeper. A sample was collected from 0.5 to 1.0 feet bgs and the Ra-226 concentration was 2.5 pCi/g, just above the FSL. Similarly, sandstone bedrock was observed at 1.5 feet bgs in TP-020 and excavating could not proceed any deeper. The Ra-226 concentration in the sample collected from 1.0 to 1.5 feet bgs was 1.2 pCi/g.

Native soils were logged in TP-035 (middle of area) from the ground surface to bedrock at 1.5 feet. The concentration of Ra-226 in the sample collected from 1.0 to 1.5 feet bgs was 10.4 pCi/g. This was also the case at TP-039 (eastern edge of area) where native soils were observed to bedrock at 1.5 bgs, and the sample collected from 1.0 to 1.5 ft bgs had a Ra-226 concentration of 5.5 pCi/g. Test pit TP-052 , located in the northwestern corner of NECR-2 contained non-native and reworked native materials to at least 4.0 feet bgs. The soil sampled collected from 1.5 to 2.0 bgs contained Ra-226 at 12.6 pCi/g, the highest in NECR-2. In what appeared to be native soils, the concentration of Ra-226 decreased to 2.9 pCi/g, just above the FSL.

Uranium and arsenic concentrations were all below the screening levels in the subsurface samples collected from NECR-2.

3.3.3 Sandfill 1

Nine subsurface soil samples were collected from five test pits in Sandfill 1. Ra-226 concentrations ranged from 0.6 to 113.0 pCi/g (averaged 39.4); all but one sample exceeded the FSL. Maximum sample depths ranged from 1.0 to 4.0 feet bgs. During test pitting, non-native material was observed to be as much as approximately 3.5 feet deep.

Native soils were observed starting at the surface of TP-043 to competent bedrock at 1.5 feet bgs. The one sample collected from this test pit from 1.0 to 1.5 feet bgs confirmed the presence of native soil. The concentration of Ra-226 in the sample was 0.6 pCi/g.

Non-native materials were observed to 3.5 feet bgs in TP-030. A shallow sample collected from 1.0 to 1.5 feet bgs reported a Ra-226 concentration of 113 pCi/g. A sample collected from observed native materials from 3.5 to 4.0 feet bgs showed a decrease in Ra-226 concentration to 4.8 pCi/g. Competent sandstone bedrock was encountered at 4.0 feet bgs.

Samples collected from test pits TP-049, TP-063, and TP-068, were similar to TP-030. Non-native materials were observed at depths ranging from 1.5 to 3.5 ft bgs. In all three test pits, sandstone bedrock was encountered at the bottom of the test pit. The samples collected above the bedrock reported a decrease in Ra-226 and usually uranium concentrations when compared to the samples

collected in the non-native materials. The concentration of Ra-226 in the non-native materials from these three test pits ranged from 57.4 to 75.8 pCi/g, whereas, the Ra-226 concentration above the bedrock ranged from 6.4 to 8.8 pCi/g.

Uranium concentrations were all below the screening level in the subsurface samples collected from Sandfill 1.

Arsenic concentrations ranged from 1.1 to 13.9 mg/kg (average 5.3 mg/kg); four of the samples that exceeded the arsenic background screening level were at locations coincident with Ra-226 FSL exceedances. However, the arsenic exceedances were all reported in the deeper sample collected above the sandstone bedrock. The shallow samples collected in the non-native materials did not report any exceedance of arsenic above background.

3.3.4 Sandfill 2

Five subsurface soil samples were collected from five test pits in Sandfill 2, which shares its northern boundary with NECR-2. Ra-226 concentrations ranged from 1.1 to 3.8 pCi/g (averaged 2.2 pCi/g); only two of the samples were slightly above the FSL (see Figure 3-4). Both of the samples with FSL exceedances were located in the southern portion of Sandfill 2 and the Ra-226 concentrations were 2.4 and 3.8 pCi/g in TP-008 and TP-012, respectively. Native materials were observed starting from the ground surface until bedrock was encountered at depths ranging from 1.0 to 3.0 feet bgs. Samples were collected approximately at the midpoint between the ground surface and sandstone bedrock.

Uranium concentrations were all below the screening level in the subsurface samples collected from Sandfill 2.

Arsenic concentrations ranged from 3.1 to 5.3 mg/kg (averaged 3.9 mg/kg). Except for one sample, the arsenic concentrations ranged from 3.1 to 3.8 mg/kg very close to the mean background concentration of 3.7 mg/kg.

3.3.5 Sandfill 3

Seven subsurface soil samples were collected from five test pits in Sandfill 3. Ra-226 concentrations ranged from 1.2 to 84.1 pCi/g (averaged 27.8 pCi/g); all but one sample exceeded the FSL. Maximum sample depths ranged from 1.0 to 2.0 feet bgs. During test pitting, non-native material was observed to approximately 1.5 feet deep. At test pit locations TP-006, TP-009, and TP-025, native soil was logged starting at the surface to sandstone bedrock at a depth of 1.0 foot. The concentrations of Ra-226 in the soil samples from 0.5 to 1.0 feet bgs above the bedrock ranged from 5.1 to 27.8 pCi/g.

Non-native fill materials were observed in TP-005 and TP-014 to a depth of approximately 1.0 to 1.5 feet bgs. The concentration of Ra-226 in TP-005 decreased from 40.8 to 28.1 pCi/g between the fill and native intervals. Sandstone bedrock was encountered at 2.0 feet bgs. The concentrations of Ra-226 in TP-014 were reported as 1.2 pCi/g and 84.1 pCi/g for the 0.5 to 1.0 feet bgs and the 1.0 to 1.5 feet bgs sample intervals, respectively. Since the log for this test pit reports the fill/native soil interface as 1.0 feet bgs, there is a possibility that the sample labels were inadvertently switched for this location.

Uranium concentrations ranged from 21.1 to 488 mg/kg (averaged 162.6 mg/kg). The two samples that exceeded the uranium screening level (227 and 488 mg/kg) were the two samples collected from TP-014.

Arsenic concentrations ranged from 0.8 to 6.9 mg/kg (averaged 3.9 mg/kg); all but two of the samples exceeded the screening level.

3.3.6 Ponds 1 and 2

Fourteen subsurface soil samples were collected from two soil borings and three test pits in Ponds 1 and 2. The soil borings extended to 15 and 20 feet bgs. The maximum sample depths collected from the test pits were between 5.0 and 9.5 feet bgs. Ra-226 concentrations ranged from 0.7 to 438 pCi/g (averaged 71.2 pCi/g). No exceedances of the FSL occurred in samples from SB-071, which was located in the Pond 1 berm along the road on the north side of the ponds (see Figures 2-3 and 3-4). The FSL was exceeded in the 5 and 10 foot samples only from SB-082, which was sampled to 20 feet bgs. Native material was observed at a depth of 15 feet bgs at SB-082. The concentration of Ra-226 decreased from 12.2 to 1.1 pCi/g between the 10 - and 15 -foot bgs samples in this boring.

The highest Ra-226 concentrations detected in Ponds 1 and 2 were 417 and 438 pCi/g. These two samples were collected in Pond 1 at 1.5 and 5.0 feet bgs from test pits TP-035 and TP-058, respectively. These two test pits are located on the western side of Pond 1 with TP-035 near the lowest point in the pond. The Ra-226 concentration decreased to 1.3 pCi/g in the 8.5 to 9.0-foot bgs sample interval in TP-058; however, bedrock sandstone was not reached in this test pit. A decreasing trend in Ra-226 concentrations was also observed in TP-035 with Ra-226 concentrations reported in the 2.0 to 2.5 feet bgs and 9.0 to 9.5 feet bgs sample intervals as 41.5 and 19.6 pCi/g, respectively. It did not appear that native soil was reached in TP-035 and the depth of impacted pond sediments appears to be greater than 10 feet bgs.

The only subsurface samples collected from Pond 2 were from TP-030 near the center of the pond. The lowest location in the pond was not accessible due to soft, muddy ground conditions. The Ra-226 concentration in non-native pond materials was reported as 41.3 pCi/g in the 2.0 - to 3.0-foot bgs sample interval. Native materials were observed starting at 4.0 feet bgs to the depth of the test pit at 7.0 feet bgs. The sample collected from 4.0 to 5.0 feet bgs in the logged native materials reported a decreased Ra-226 concentration of 6.2 pCi/g.

The maximum depths of non-native material within Pond 1 and Pond 2 are 5 and 15 feet, respectively, based on a comparison of pre-mine to post-mine topography. This assumes no excavation into native ground was conducted during pond construction. Pond 1, based on test pit observations, contains over three meters of construction debris and pond sediments.

Uranium concentrations ranged from 1.3 to 760 mg/kg (averaged 116.7 mg/kg). The screening level was exceeded in three samples (206 to 760 mg/kg), collected from test pits TP-035 and TP-058, where the two highest Ra-226 concentrations were detected.

Arsenic concentrations ranged from 1.4 to 6.8 mg/kg (averaged 4.9 mg/kg); all but two samples exceeded the screening level, including locations where Ra-226 was below the FSL.

3.3.7 Pond 3/3a

Fourteen subsurface soil samples were collected from one soil boring and four test pits in Pond 3/3a. The soil boring was sampled every five feet to 25 feet bgs. The maximum sample depths collected from the test pits were from 9.0 to 9.5 feet bgs. Ra-226 concentrations ranged from 0.7 to 15.7 pCi/g (averaged 3.4 pCi/g). There were no exceedances of the FSL from SB-061, which was located on the berm road between NECR-1 and Pond 3 on the east side of Pond 3 (see Figures 2-3 and 3-4). Ra-226 exceeded the FSL in only three of the test pit samples.

The concentration of Ra-226 in TP-007, located between Ponds 3 and 3a, was 4.5 pCi/g in the 5.0 to 5.5-foot bgs sample. The Ra-226 concentration at 9.0 to 9.5 feet bgs was 0.7 pCi/g and this sample appeared to be in native or re-worked native material. No exceedance of the FSL was reported in TP-014 and TP-037 at depths greater than 5.0 feet bgs. However, it was difficult to tell if the materials were pond sediments or native materials at these locations. No samples between 0.5 and 5.0 feet bgs were collected in these two locations; therefore, Ra-226 concentrations greater than the FSL could exist between the surface and 5.0 feet bgs. This observation is supported by the Ra-226 results from TP-029 located between TP-014 and TP-037. In TP-029, Ra-226 concentrations exceeded the FSL in the 3.0 to 3.5 foot bgs and 6.0 to 6.5 foot bgs sample intervals. The Ra-226 concentrations were reported to be 14.3 and 15.7 pCi/g, respectively. However, the Ra-226 concentration (2.1 pCi/g) decreased to below the FSL in the 9.0 to 9.5 foot bgs interval in the bottom of TP-029.

The maximum depth of non-native material within Pond 3/3a is 10 feet, based on a comparison of pre-mine to post-mine topography; this assumes no excavation into native ground was conducted during pond construction.

Uranium concentrations were all well below the screening level in the subsurface samples collected from Pond 3/3a.

Arsenic concentrations ranged from 2.9 to 6.7 mg/kg (average 4.7 mg/kg); all but three samples exceeded the screening level, at locations with Ra-226 both above and below the FSL.

3.3.8 Sediment Pad

Nine subsurface soil samples were collected from five test pits at the Sediment Pad. Ra-226 concentrations ranged from 2.8 to 165 pCi/g (averaged 70.0 pCi/g); all of the samples exceeded the FSL. Maximum sample depths ranged from 1.0 to 10.5 feet bgs.

Non-native fill materials were observed to a depth of 3.0 feet in TP-006, located on the west side of the Sediment Pad. The Ra-226 concentration reported from the fill sample (1.5 to 2.0 feet bgs) was 92.9 pCi/g. The sample collected from the observed native soil (3.0 to 3.5 feet bgs) showed a decrease in Ra-226 concentration to 2.8 pCi/g, just slightly above the FSL. This same trend was observed at TP-012 and TP-014. However, the depths of fill materials at these locations were between 1.0 and 1.5 feet bgs and the native soil Ra-226 concentrations were 2.9 and 9.8 pCi/g at TP-012 and TP-014, respectively.

The location investigated on the east side of the Sediment Pad, TP-021, appeared to be located over a historic pond. Both fill samples from this test pit exceeded the FSL (99.7 and 86.3 pCi/g) and the depth of fill materials exceeded the depth of the excavator (10.5 bgs).

Only one sample was collected from TP-026 where bedrock was encountered at 3.0 feet bgs. The test pit logs reported that the sample was collected in what appeared to native soils; however, the concentration of Ra-226 was 86.6 pCi/g, greater than the FSL.

The maximum depth of non-native material within the Sediment Pad is 10 feet, based on a comparison of pre-mine to post-mine topography. This assumes no excavation into native ground was conducted during pad construction.

Uranium concentrations ranged from 68.6 to 357 mg/kg (averaged 161 mg/kg). Three of the samples exceeded the screening level, at locations coincident with higher Ra-226 concentrations.

Arsenic concentrations ranged from non-detect to 5.5 mg/kg (averaged 2.7 mg/kg); four of the samples exceeded the screening level, generally at locations coincident with the lowest Ra-226 concentrations.

3.3.9 Non-Economic Materials Storage Area

Thirteen subsurface soil samples were collected from five test pits at the NEMSA. Ra-226 concentrations ranged from 0.8 to 140 pCi/g (averaged 45.4 pCi/g). Maximum sample depths ranged from 4.5 to 9.0 feet bgs. As specified in the RSEWP, one sample of the pre-cap material was to be collected at each test pit. In the case of TP-002, the pre-cap surface was located at 0.25 feet bgs. Therefore, this sample collected in non-economic material from 0.25 to 0.75 bgs is considered a subsurface sample. Based on test pit observations, the depths to native material ranged from around 2 feet along its southern boundary with the Boneyard, to greater than 10 feet at its northern end (based on visual observations). A comparison of pre-mine to post-mine topography suggested the maximum depth at the northern end is approximately 12 feet. Concentrations of Ra-226 in the non-economic materials ranged from 8.4 pCi/g to 140 pCi/g. The four Ra-226 concentrations below the FSL were all located in native materials and ranged between 0.8 and 1.3 pCi/g.

Uranium concentrations ranged from 1.4 to 390 mg/kg (averaged 124.9 mg/kg). Two of the exceedances (227 and 311 mg/kg) were coincident with native soil samples collected from TP-001 and TP-002. The uranium concentrations in the other two native sample from TP-003 and TP-005 were 49.3 and 1.4 mg/kg, respectively. Native soil was not reached in TP-004 as the depth to native soil exceeded the depth of the excavator. The third exceedance of uranium (390 mg/kg) was collected in non-economic material from TP-004.

Arsenic concentrations ranged from non-detect to 4.9 mg/kg (averaged 2.2 mg/kg); three of the samples exceeded the screening level, and two of these samples were collected in native soil.

3.3.10 Boneyard

Eleven subsurface soil samples were collected from five test pits in the Boneyard. Ra-226 concentrations ranged from 1.1 to 50.7 pCi/g (averaged 11 pCi/g). However, only three samples exceeded the FSL; all three of which were collected from test pit TP-004, which was located near northern boundary with the NEMSA. This test pit contained trash, scrap metals and gray fill materials. The Ra-226 concentrations in the three other test pits ranged from 1.1 to 1.9 pCi/g. This indicates that some mine materials were placed near TP-004 in addition to the scrap metal and other debris, but mine materials do not appear to be prevalent throughout the Boneyard

As specified in the RSEWP, one sample of the pre-cap material was to be collected at each test pit in the Boneyard. However, unlike NEMSA, there was not a visual distinction between the cap soil material and the re-worked native soil material mixed with debris. Therefore, no pre-cap samples were collected from the Boneyard; samples were collected approximately every five feet to native soil plus one sample of native soil.

Maximum sample depths ranged from 1.5 to 10.0 feet bgs. Based on test pit observations, the depths to native material ranged from at the surface at its southern end, to approximately 9 to 10 feet along the western lobe near TP-004 and TP-005. A comparison of pre-mine to post-mine topography suggested that depths were zero along its entire eastern lobe, 5 to 7 feet along its western lobe, and 8 feet or so in its northwestern corner.

No debris was noted in TP-001. Both TP-002 and TP-003 observed partially buried cables but no other debris. Both TP-004 and TP-005 contained large amounts of buried debris including scrap metal and plastic debris.

Uranium concentrations ranged from 0.8 to 240 mg/kg (average 46.2 mg/kg). Only two of the samples exceeded the FSL, both were from TP-004 and were coincident with two of the higher Ra-226 concentrations.

Arsenic concentrations ranged from 0.8 to 5.2 mg/kg (averaged 3.8 mg/kg). Seven of the samples exceeded the FSL; the four that did not were collected from test pit TP-004 in the northwestern corner.

3.3.11 Unnamed Arroyo

Ten hand auger holes were advanced each to 3 feet bgs from the edge of NECR-1 to near the confluence with the next arroyo (see Figure 3-4). Three composite subsurface soil samples were collected from each auger hole at 0-1 foot bgs, 1-2 feet bgs, and 2-3 feet bgs, for a total of 30 subsurface soil samples from the Unnamed Arroyo. Ra-226 concentrations ranged from 8.4 to 35.7 pCi/g (average 16.4 pCi/g); all 30 samples exceeded the FSL. The vertical distribution of concentrations does not suggest a downward decreasing trend from 0 to 3 feet bgs; in four of the holes, the highest concentrations were detected in the deepest samples. There also does not appear to be a spatial trend with the highest Ra-226 concentration located at SB-005 in between NECR-1 and the next arroyo.

Uranium concentrations were all below the screening level of 200 pCi/g.

Arsenic concentrations ranged from 1.2 to 8.2 mg/kg (averaged 3.4 mg/kg); the screening level was exceeded in only nine of the samples, seven from the deepest samples from each hole, and two from 1 to 2 feet bgs.

3.3.12 Subsurface Soil Analytical Results Summary

Table 3.16 includes a statistical summary of the analytical results, which shows the following, site wide:

- Ra-226 values ranged from 0.6 to 438 pCi/g (averaged 30.9 pCi/g); 66% of the 146 subsurface soil samples analyzed for Ra-226 exceeded the FSL of 2.24 mg/kg.
- Total uranium values ranged from 0.7 to 760 mg/kg (averaged 86.4 mg/kg); 12% of the 146 samples analyzed for uranium exceeded the screening level of 200 mg/kg.
- Arsenic values ranged from non-detect (<0.5) to 13.9 mg/kg (averaged 4.0 mg/kg); 52% of the 146 samples analyzed for arsenic exceeded the screening level of 3.7 mg/kg.
- Vanadium values ranged from 10.4 to 173 mg/kg (averaged 40.1 mg/kg); all results were below the screening level of 1,000 mg/kg.
- Selenium values ranged from non-detect (<0.2 mg/kg) to 227 mg/kg (averaged 16.0 mg/kg); all results were below the screening level of 5,100 mg/kg.
- Molybdenuym values were all non-detect (<5.0 mg/kg).

3.4 SOIL LEACHATE ANALYSES

3.4.1 Soils Synthetic Precipitation Leachate Procedure

A total of 16 surface and subsurface samples were collected for analysis by the SPLP method, as described in Section 2.3. Two samples were collected from each of the following areas.

- NECR-1
- NECR-2
- Ponds 1 and 2
- Pond 3/3a
- Sandfill 1, 2 and 3
- Sediment Pad

The leachate was analyzed for the preliminary COPCs (Ra-226, uranium, arsenic, selenium, and vanadium), the results of which are presented in Table 3.17, *Summary of Synthetic Precipitation Leaching Procedure Analytical Results.* Laboratory analytical reports are included in Appendix B. The results of the SPLP analyses indicated the following:

- Ra-226 ranged from non-detect to 27.1 pCi/L (averaged 5.6 pCi/L).
- Uranium concentrations ranged from 0.00096 to 4.4 mg/L.
- Arsenic concentrations ranged from 0.0013 to 0.0084 mg/L.
- Molybdenum results were all non-detect (<0.1 mg/L).
- Selenium concentrations ranged from non-detect (<0.0029 mg/L) to 0.94 mg/L.

Available analytical data for Site mine water are presented in the groundwater technical memorandum titled *Groundwater Quality in the Westwater Canyon Member at the Northeast Church Rock Mine* (MWH, 2004c). These data represent the ambient groundwater quality in the Westwater Canyon Member at the Site. These data indicated the following:

- Concentrations of Ra-226 ranged from 0.6 to 490 pCi/L (averaged 97.6 pCi/L), compared to the New Mexico Human Health Standard of 30 pCi/L (Ra-226 and Ra-228 combined).
- Concentrations of uranium ranged from 0.725 to 3.71 mg/kg (averaged 2.08 mg/kg), compared to the New Mexico Human Health Standard of 5.0 mg/kg.
- Concentrations of arsenic ranged from 0.0100 to 0.0118 mg/kg (averaged 0.0102 mg/kg), compared to the New Mexico Human Health Standard of 0.1 mg/kg.
- Concentrations of molybdenum ranged from 0.001 to 0.04 mg/kg (averaged 0.012 mg/kg), compared to the New Mexico Human Health Standard of 1.0 mg/kg.
- Concentrations of selenium ranged from 0.0.004 to 0.05 mg/kg (averaged 0.031 mg/kg), compared to the New Mexico Human Health Standard of 0.05 mg/kg.

The laboratory results from the SPLP leachate analyses suggested that if the materials within the areas listed in Table 3.17 were subjected to sufficient infiltration by rainwater or snowmelt, they could

generate a leachate that contains Ra-226, uranium, selenium and/or arsenic. While the SPLP leachate results were primarily below the New Mexico Human Health Standards for groundwater (NMAC 20.6.2.3103) or the Federal Maximum Contaminant Levels (MCLs), there were exceedances of one or the other of these standards for Ra-226, uranium and selenium, as shown in Table 3.17. Ra-226 exceeded the MCL of 5 pCi/L in five samples from Ponds 1/2, Pond 3 and Sandfill 1, but did not exceed the New Mexico standard of 30 pCi/L. Both selenium and uranium exceeded the MCL and New Mexico standard of 0.03 mg/L in two samples from Ponds 1/2 and one sample from Pond 3/3a. However, the concentrations of these constituents are all within the range of concentrations detected in the Westwater Canyon Member, with the exception of selenium. Selenium concentrations in the SPLP leachate exceeded the maximum concentrations detected in the Westwater Canyon Member in samples collected from Ponds 1 and 2 and Pond 3/3a. Additionally, it should be noted that as a practical matter, rainfall does not impact groundwater in the Westwater Canyon Member as a result of a combination of arid climate, depth to groundwater and the number and thickness of intervening confining layers.

3.4.2 Soils Toxicity Characteristic Leaching Procedure

Eleven subsurface soil samples were collected from the Boneyard and analyzed using the TCLP method, which is designed to determine the mobility of potential inorganic analytes, specifically the RCRA priority pollutant metals (arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). The results of these analyses are presented in Table 3.18, *Summary of Toxicity Characteristic Leaching Procedure Analytical Results.* Laboratory analytical reports are included in Appendix B. All results were non-detect, indicating that there are no materials in the Boneyard capable of generating a poor quality leachate of metals.

3.5 SOILS ORGANICS DATA

3.5.1 Boneyard

Eleven surface soil samples were collected between one and ten feet bgs from test pits in the Boneyard. The samples were analyzed for VOCs by EPA Method 8260B and for SVOCs by EPA Method 8270C. Laboratory analytical reports are included in Appendix B. The results of these analyses were non-detect for all VOC and SVOC parameters.

3.5.2 NECR-1

One subsurface soil sample was also collected from the north edge of NECR-1 for analysis of organic compounds. During drilling at soil boring SB-131 in NECR-1, which was located along the northeastern edge of NECR-1 (see Figure 3-4), a dark gray clayey material was encountered that had a distinct petroleum odor to it. Consequently, one soil sample was collected between 22.5 and 24 feet bgs and submitted for analysis of Total Petroleum Hydrocarbons (TPH) by EPA Method 8015B and VOCs by EPA Method 8260B. Laboratory analytical reports are include in Appendix B. All VOC parameters were non-detect, except for the parameters sec-Butylbenzene (0.24 mg/kg) and 1,2,3-trichlorobenzene (0.53 mg/kg). The results for these two compounds were both significantly below their respective EPA Region 9 PRGs. The results of the TPH analysis revealed the following:

- Diesel range organics at 1,400 mg/kg
- TPH C_8-C_{40} at 1,900 mg/kg
- Oil range organics at 460 mg/kg

These results suggest that the material sampled contained primarily diesel or fuel oil range organic compounds.

3.6 SOILS AGRONOMIC DATA

Fifteen surface soil samples and five subsurface soil samples (test pits) were collected from analysis of agronomic parameters, and other constituents that could have an impact on plant growth. The samples were analyzed for: pH, calcium, magnesium, potassium, sodium, Sodium Absorption Ratio (SAR), chlorine, arsenic, molybdenum, radium-226, selenium, uranium, and vanadium. The results of analyses for agronomic parameters are presented in Table 3.19, *Summary of Surface Soil Analytical Results, Agronomic Parameters.* The results of metals analyses in surface soils are shown in Table 3.15. The purpose of the analyses was to identify the potential risks to plant establishment based on the levels of constituents present. Results from the laboratory analysis were used to evaluate the impact of constituent levels on direct revegetation success at the Site and to determine if additional soil cover may be necessary in some areas to provide a suitable medium for root growth and plant establishment. Although toxicity thresholds of plants for each constituent will vary by individual species and life form (e.g. grasses, forbs, shrubs, trees), general toxicity guidelines and potential impacts on plant establishment at the Site are outlined below.

The level of arsenic that plants tolerate varies by plant species and life form. Although some species of grass are extremely tolerant of high levels of arsenic and maintain normal growth at very high levels, most plants will begin to exhibit symptoms of toxicity (reduction in plant biomass, decreased root growth, deceased germination) when arsenic levels in the soils reach 50 to 100 mg/kg. Studies evaluating the effect of arsenic toxicity on ryegrass, reported lowest observable effective concentration (LOEC) for arsenic in soils at 50 mg/kg, with substantial reductions in plant growth occurring at 250 mg/kg (Jiang and Singh, 1994). Concentrations of arsenic in surface soils ranged from non-detect (<0.5 mg/kg) to 13.9 mg/kg, well below the toxicity threshold of 50 mg/kg. Based on toxicity thresholds in the literature, arsenic concentrations in the soil would not negatively impact plant establishment at the Site.

Molybdenum is a microelement that is least soluble in an acid environment and more readily available in alkaline soils. When elevated levels of molybdenum occur in soils plant toxicity can occur. The level of molybdenum that plants tolerate varies by plant species and life form. Ducsay and Kovacik (2001) reported sensitive agronomic species displayed signs of molybdenum toxicity at 90 mg/kg, where native grasses and shrubs tend to have higher tolerances to molybdenum in soils, exhibiting toxic effects of molybdenum at much higher concentrations, around 150 mg/kg. As a general guide, molybdenum levels in soils are considered safe to native plants at levels below 150 mg/kg. Results from the laboratory analysis report molybdenum surface and sub-surface concentrations at all locations below laboratory detectable levels, with one exception, NECR-1. NECR-1 had four surface soil samples with detectable levels of molybdenum, with only one sample exceeding the molybdenum toxicity threshold of 150 mg/kg. Based on toxicity thresholds in the literature, the extent of molybdenum in NECR-1 would have negligible impact on vegetation establishment.

Radium-226 is the most abundant and stable radionuclide in the biosphere, with increased mobility and solubility in soils under extremely acidic conditions (Kabata-Pendias, 2000). Although results from the laboratory analysis report concentrations of Ra-226 at the Site ranged from non-detect (<0.6 mg/kg) to 438 mg/kg, the impact of these levels on vegetation establishment cannot be determined. No information was uncovered in the literature that would provide an adequate way to measure the phytotoxicity of Ra-226; therefore the impact of Ra-226 on plant establishment cannot be evaluated. However, due to the slightly basic pH of the soils at the Site and low mobility of Ra-226 in solution, it is probable that the amount of Ra-226 in solution available for plant uptake would be limited, lowering the potential for plant toxicity to occur.

Selenium is a naturally occurring element found in rocks, soil and water. Selenium enters the soil profile through the weathering of Selenium-rich rocks, moving through the soil until adsorbed on clay particles, iron hydroxides or organic particles. Selenite and selenates are produced in the soil by microorganisms from the less soluble forms of selenium. When selenium occurs in alkaline soils and becomes oxidized as selenate, the selenium becomes water-soluble. This form is highly toxic and easily leached from the soil, thus facilitating uptake of selenium by certain plants. Although some

studies have shown sensitive species of ryegrass exhibiting selenium toxicity in sandy soils with selenate concentrations as low as 2 mg/kg (Smith, 1984), symptoms of selenium toxicity for most plants occur when selenium levels in the soils range from 10 to 20 mg/kg. Results from the laboratory analysis at the site report selenium levels in NECR-1, Sediment Pad, NEMSA, Boneyard, Sandfill 1, Sandfill 3, and Ponds 1 and 2 exceeding the toxicity threshold of 10 to 20 mg/kg for plants. Based on information in the literature, direct revegetation at the site will be impaired in locations exhibiting elevated selenium concentrations in the soils, suggesting additional topsoil may be needed for successful plant establishment.

Uranium is a naturally occurring element found in low levels within all rock, soil, and water, existing in +4 and +6 oxidation states in most geologic environments (Kabata-Pendias, 2000). Through the process of weathering, uranium forms mainly organic complexes in the soil that are easily soluble and mobile, with the distribution of uranium highly controlled by the oxidation state and Eh-pH of the system. Although few studies have been done to evaluate the toxicity of uranium on plants, one study conducted in 1995 found no adverse effect of uranium on native plant species at uranium levels of 5,000 mg/kg in soil. All areas of the Site were well below the no observable effective concentration (NOEC) of 5,000 mg/kg, indicating uranium concentrations in the soil would not negatively impact plant establishment at the Site.

Vanadium is a natural element in the earth, forming compounds with other elements such as oxygen, sodium, sulfur, or chloride. Although small amounts of vanadium have been found to stimulate plant growth, present in large amounts vanadium is toxic to plants, with pentavalent vanadium being the most toxic form (Irwin, 1997). Vanadium toxicity to plants varies with soil type due to the differences in phytoavailablity associated with soil colloids and organic matter. For example, studies have shown vanadium toxicity occurring in sandy soils at 80 mg/kg, where vanadium concentrations of 100 mg/kg in loamy soils had no effect on plant growth (Kabata-Pendias, 2000). As a general guide, vanadium levels in soils are considered safe to plants at levels below 100 mg/kg. Although results from this RSE indicated a few samples with vanadium concentrations greater than 100 mg/kg, nearly all of the samples collected at the Site had vanadium concentrations below the phytotoxicity level of 100 mg/kg. Impacts to plant growth from vanadium concentrations in the soil will be limited to NECR-2 where elevated levels of selenium are already present, suggesting additional topsoil may be needed in this location to provide an adequate medium for plant growth.

Soluble salts, Sodium Absorption Ratio (SAR) and pH are important soil properties and can impact the success of plant growth and establishment. When high amounts of soluble salts (calcium, magnesium, potassium) are present, severe plant growth problems can occur. In addition, soils high in sodium or elevated SAR can present physical restrictions in the soil for plant growth. When high levels of sodium are present, exchange sites on the soil particles become saturated with sodium, creating dense layers, restricting root development and plant growth.

Soil pH controls the solubility of ions and impacts plant growth under extreme alkaline or acidic conditions. Under acidic conditions, many soil minerals dissolve, increasing the concentration of metal ions in solution to toxic levels, inhibiting plant growth. Under alkaline conditions, the solubility of minerals can decrease to the point that nutrient deficiencies can occur, reducing plant biomass.

Results from this RSE indicated consistently neutral or slightly basic pH at the Site, with low soluble salts and SAR, with one exception. Samples taken from the Sediment Pad had extremely high levels of salts and an elevated SAR at the surface (EC = 11.70 and SAR of 20.90). Although pH for the Sediment Pad is neutral and would not impact plant establishment at the Site, elevated salts and sodium levels will limit direct revegetation success on the Sediment Pad, indicating additional soil cover will be needed for plant establishment.

Overall, constituent concentrations at the site are relatively low and the quality of the soil high, suggesting some areas within the Site would be able to support plant communities without additional

soil cover. However, elevated selenium, vanadium or salts occurring in NECR-1, Sediment Pad, NEMSA, Boneyard, Sandfill 1, Sandfill 3, and Ponds 1 and 2 suggest that direct revegetation at these locations would be challenging in some areas and that additional soil cover would be advised to provide an adequate growth medium for vegetation establishment. The amount and total area of soil cover needed should be determined by the levels of constituents present at each location.