DRAFT

ENGINEERING EVALUATION AND COST ANALYSIS
LA SAL CREEK WATERSHED PROJECT
SAN JUAN COUNTY, UTAH

Firefly/Pygmy Mine

Vanadium Queen Mine

Blue Cap Mine

Black Hat Mine

Prepared for

U.S. Bureau of Land Management

October 20, 2005

Au' Authum Ki, Inc.
2764 Compass Drive, Suite 200A
Grand Junction, Colorado 81506
(970) 241-8890

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1.0 INTRODUCTION

Au' Authum Ki, Inc. (AAK) has prepared this Engineering Evaluation and Cost Analysis (EE/CA) for the U.S. Bureau of Land Management (BLM). The report presents an engineering evaluation and cost analysis of alternatives for a removal action(s) for five abandoned uranium mines comprising the La Sal Creek Watershed Project. The project area is shown in Figure 1.1 and is located in southeastern Utah and southwestern Colorado, near the Town of La Sal, Utah and encompasses three abandoned uranium mine sites: (1) the Firefly/Pygmy Mine Site (also known as the Firefly/Pigmay Mine Site), (2) the Vanadium Queen Mine Site, and (3) the Black Hat/Blue Cap Mine Complex which includes the Black Hat Mine, Blue Cap Mine, and Saint Patrick Mine. The majority of the project area lies within San Juan County, Utah; however, the eastern portion of the area extends into Montrose County, Colorado. The area primarily consists of lands under the jurisdiction, custody, and control of BLM, with higher elevations lying on lands under the jurisdiction, custody, and control of the U.S. Forest Service (USFS) and portions of the La Sal Creek valley floor owned by the State of Utah and private residents.

The removal action(s) will address metals and radionuclide contamination in waste rock at each mine and in water draining from the mine adits. As proposed in this EE/CA, the removal action(s) are intended to be the final remedy to the extent practicable for reducing human-health and ecological risks at the mines and migration of contaminated media to downgradient areas.

1.1 Authority

The BLM is the lead agency responsible for the abandoned mine sites included in the La Sal Creek Watershed Project. Except for the Firefly/Pygmy Mine, the adit and waste-rock dump at each of the mines included in the La Sal Creek Watershed Project lie on BLM lands. A small portion of the waste-rock dump at the Firefly/Pygmy Mine (approximately 7 percent of the dump area) lies on USFS land. In accordance with a Memorandum of Understanding between BLM and the USFS, BLM will serve as lead agency for the entire Firefly/Pygmy Mine dump. Project support is provided through a multi-agency partnership among the BLM, USFS, and the U.S. Environmental Protection Agency (EPA). Pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act ("CERCLA"), the President is responsible for responding to releases of hazardous substances to protect public health or welfare or the environment. By Executive Order 12580, as amended by Executive Order 13016, the U.S. Department of the Interior (DOI) is delegated the President's CERCLA authority where either a release of

a hazardous substance is on, or the sole source of the release is from, land under the jurisdiction, custody, or control of DOI. DOI has re-delegated most of its authorities delegated pursuant to Executive Order 12580 to BLM with respect to land under the jurisdiction, custody, or control of BLM. The National Oil and Hazardous Substances Pollution Contingency Plan ("NCP") also recognizes BLM as the "lead agency" under CERCLA for remedial actions and removal actions other than emergencies where a release is on, or the sole source of a release is from, land under the jurisdiction, custody, or control of BLM. *See* 40 CFR § 300.5. Under this authority, the BLM may take action to protect public land resources and public land users from hazardous substances that pose a threat or potential threat to human health and the environment.

In accordance with the objective of the Clean Water Act (CWA), BLM initiates actions in watersheds affected by abandoned mine lands in an effort to “restore and maintain the chemical, physical and biological integrity of the Nation’s waters” (CWA § 101). The CWA establishes the basic structure for regulating discharges of pollutants into the water of the United States and the authority under which states have developed water quality standards for waters within their jurisdiction. Over the years, the approach of CWA programs has shifted from a program-by-program, source-by-source, pollutant-by-pollutant approach to a watershed approach. Using this approach, BLM seeks to satisfy water quality standards for the specific states and watersheds within those states.

1.2 Project Background and Regulatory Framework

The project was developed by the BLM using its delegated authority under CERCLA to assess impacts to human health and the environment posed by abandoned mine sites within the La Sal Creek Watershed and to evaluate potential alternatives for reducing or mitigating those impacts.

Existing information reported by previous investigators along with field observations and measurements during site reconnaissance were compiled, organized, interpreted, and ultimately used by the BLM to develop a conceptual understanding of contaminant sources, release mechanisms, pathways, exposure routes, and potential receptors associated with mines within the project area. The data used by the BLM were obtained from published reports regarding environmental conditions at mines in the area, analytical results for surface-water samples provided by BLM’s Moab Field Office, field observations and measurements recorded by AAK during site reconnaissance, and discussions with area residents. These data sources are summarized as follows:

- *Potential Hazardous Waste Site – Preliminary Assessment; Nine Inactive Uranium Mines, Manti-LaSal National Forest, San Juan County, Utah and Montrose County, Colorado* (USFS, 1990) – The preliminary assessment consists of a number of associated reports which are organized as follows:
    - *Preliminary Assessment Overview* (USFS, undated)
    - *Preliminary Assessment – Specific Mines* (USFS, undated)
    - *Data Report from Site Visits and Literature Search on Nine Inactive Uranium Mines, Manti-LaSal National Forest, Utah* (UNC Geotech, 1989)
    - *Ground Water and Surface Water Hydrology of Nine Inactive Uranium Mines, Manti-LaSal National Forest San Juan, County, Utah and Montrose County, Colorado* (USFS, undated)
- Utah Division of Water Quality, 1999. STORET Database (water quality data).
- Records contained in the reclamation file compiled by the USFS for the Gray Daun Mine
- *La Sal Creek Reconnaissance and Recommendations* (Korte, 2001)
- Recorded field observations, radiological monitoring data, water-quality field parameters, and photographs gathered during AAK site reconnaissance conducted on November 5-6, 2002, February 24-25, 2003, and April 2-3, 2003.
- Personal communications with area residents.
- *Conceptual Site Model – La Sal Creek Watershed Project, San Juan County, Utah* (AAK, 2003a).

BLM has elected to use its CERCLA authority for the mines comprising the La Sal Creek Watershed Project because the potential exists for a release or threat of a release of CERCLA hazardous substances. In accordance with Section 300.415(b)(2)(i-viii) of the NCP, a removal action is selected when one of the following criteria is satisfied:

- Actual or potential exposure to nearby populations, animals or the food chain from hazardous substances, pollutants or contaminants;
- Actual or potential contamination of drinking water supplies or sensitive ecosystems;
- Hazardous substances, pollutants, or contaminants in drums, barrels, tanks or other bulk storage containers, that may pose a threat of release;
- High levels of hazardous substances, pollutants, or contaminants in soils largely at or near the surface that may migrate;
- Weather conditions that may cause hazardous substances, pollutants, or contaminants to migrate or be released;

- Threat of fire or explosion;
- Availability of other appropriate Federal or State response mechanisms to respond to the release;
- Other situations or factors that may pose threats to public health, welfare or the environment.

A non-time-critical removal action is necessary for the mines comprising the La Sal Creek Project because waste rock present at the mines contains radionuclide and metals concentrations that pose a risk to human and ecological receptors and to the environment.

The project was designed using the watershed approach, BLM's general strategy for abandoned mine land assessments. The watershed approach is an interagency collaborative effort whereby assessments focus on the mine sites that are considered to most substantially impact water quality within a watershed. The project is being conducted through a multi-agency partnership among the BLM, USFS, and EPA. The mine sites considered to most likely impact water quality within the La Sal Creek Watershed were identified by reviewing the Federal Facilities Hazardous Waste Compliance Docket (Docket) and the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS), results of a Preliminary Assessment (PA) completed for specific mines within the Manti-LaSal National Forest (USFS, 1990.), and results of BLM reconnaissance of mine sites under BLM jurisdiction and located within the watershed. The sites identified for the project include the Firefly/Pygmy Mine, Vanadium Queen Mine, and the Blue Cap/Black Hat Mine Complex (consisting of the Black Hat Mine, the Blue Cap Mine, and the Saint Patrick Mine).

Two of the abandoned mine sites (the Firefly/Pygmy Mine and the Black Hat Mine) included in the La Sal Creek Watershed Project are listed on the Docket. The Docket, which was established and is maintained by the EPA as required under CERCLA Section 120(c), contains information about Federal facilities, and Federal lands in the case of abandoned mine sites, that manage hazardous waste or from which hazardous substances have been or may be released. CERCLA Section 120(d) specifies that for each Federal facility included on the Docket during an update, evaluation shall be completed in accordance with a reasonable schedule. The evaluation consists of a PA, and if warranted, a Site Inspection (SI). Such site evaluation activities provide EPA and the public with information about the facility which is used to help assess whether the facility should be included on the National Priorities List (NPL).

The Black Hat Mine and the Firefly/Pygmy Mine were added to the Docket in the early 1990s. The Black Hat Mine, identified as facility name "MANTI-LASAL NF: BLACK HAT MINE," was reported to the

Docket by the U.S. Department of Agriculture (USDA) on September 27, 1991. The Firefly/Pygmy Mine, identified as facility name "MANTI-LASAL NF: FIREFLY-PYGMY MINE," was reported to the Docket by the USDA on November 10, 1993. Information was submitted for both mines under CERCLA Section 103 and Section 3016 of the Solid Waste Disposal Act, 42 U.S.C.A. § 6937. Currently, the information listed on the Docket indicates that the "no further remedial action planned" status for both mines is "undetermined." The information further indicates that the NPL status for the MANTI-LASAL NF: FIREFLY-PYGMY MINE is "undetermined," and the NPL status for the MANTI-LASAL NF: BLACK HAT MINE is "not on NPL."

The USDA was the agency that reported the Black Hat and Firefly/Pygmy mines to the Docket because a portion of the surface disturbance associated with each mine lies on USFS lands. At the Black Hat Mine, a former production shaft extended to the underground workings on USFS lands. At the Firefly/Pygmy Mine, the northern portion of the waste-rock dump at the mine portal area lies on USFS lands. The USFS conducted a response action at the Black Hat Mine shaft area subsequent to the site being listed on the Docket. No actions have yet been taken at the Firefly/Pygmy Mine Site; however, a metal grate is in place at the mine portal.

Several other mine sites and claim groups located within the Manti-LaSal National Forest but outside of the project area were also reported by the USDA to the Docket on November 10, 1993. Those mine sites, along with the Firefly-Pygmy and Black Hat mines, were collectively added to CERCLIS under the site name "MANTI-LASAL NATIONAL FOREST MINES" (EPA ID No. UT1122307605). CERCLIS contains information on hazardous waste sites, potential hazardous waste sites, and remedial activities across the nation, including sites that are on the NPL or being considered for the NPL.

The Vanadium Queen Mine was included in the project because the mine presents a potentially significant contaminant source within the watershed and is located immediately upgradient of three nearby residences. Furthermore, results of previous investigations conducted by the BLM identified that the Vanadium Queen Mine had the potential for a release of CERCLA hazardous substances and that the waste rock piles had the potential for failure.

The Vanadium Queen, Blue Cap, and Saint Patrick mines were included in the La Sal Creek Watershed Project based on site reconnaissance conducted by the BLM and results of the PA for the Blue Cap and Saint Patrick mines. Although these sites were not listed on the Docket or CERCLIS, the BLM considers the sites potential contributors to water-quality impacts within the watershed.

The documents that have been prepared to date for the La Sal Creek Watershed Project include *Cultural Resource Inventory of Five Uranium Mines Along La Sal Creek – San Juan County, Utah and Montrose County, Colorado* (Alpine Archaeological Consultants, Inc., 2003), *Final Conceptual Site Model* (AAK, 2003), *Draft Community Relations Plan* (BLM, 2005, in preparation), and *Final Field Sampling Plan* (AAK, 2004). The Cultural Resource Inventory presents an archaeological inventory of the mines within the project, including site recordation and identification of any prehistoric or historic resources in the vicinity of the mines that might be impacted by removal actions. The Site Conceptual Model (CSM) provides a framework for identifying the likely contaminant source areas associated with the mines and assessing the relationship between site-derived contaminants, exposure pathways, and potential receptors. The Community Relations Plan (CRP) outlines the activities that will be implemented by the BLM to ensure that the community has input to decisions regarding cleanup actions and that the public is well-informed about the progress of those actions. The Field Sampling Plan (FSP) specifies the investigative activities performed to obtain the information needed to identify the substances present, determine whether hazardous substances are being released to the environment, and determine whether hazardous substances have impacted specific targets. Comments provided by the EPA on the draft FSP for this project indicated that EPA believes an SI or Expanded Site Inspection (ESI) is warranted for the mines being evaluated under the La Sal Creek Watershed Project. The BLM and EPA agreed that the information requested would be provided by the BLM in this EE/CA document.

Consistent with EPA guidance, *Improving Site Assessment: Integrating Removal and Remedial Site Evaluations* (EPA, 2000a), the BLM has elected to continue the site evaluation process in order to collect data that will meet the needs of both a removal assessment and provide EPA with the requested information. Evaluation results are reported in a single document, an EE/CA document, which is prepared as part of the site assessment process. It is the BLM's intention to provide the necessary documentation within the EE/CA to satisfy the requirements for a removal action and remedial site evaluations in an integrated process; thereby, meeting the requirement to perform a remedial site inspection on sites that are included within the Docket. Additionally, BLM has determined that a combined site assessment is preferred at this time for all three mine areas. BLM elected to increase the efficiency of the evaluation process by consolidating the data needs under one work plan and the reporting requirements under one document. Therefore, the investigation described in this EE/CA will provide EPA with the requested information and BLM with the information necessary to assess whether a non-time critical removal action is warranted at the mine sites, and if so, the removal action alternative(s) best suited for the sites based on effectiveness, implementability, and cost.

The field characterization effort was performed during two phases. The first phase was conducted in April 2004 and included collection of surface-water samples during the typical high-flow period, surface and subsurface waste-rock samples, and sediment samples along the primary ephemeral drainages downstream of the mines. Radiological surveys were also performed at each mine and along the ephemeral drainages during the first phase of the characterization effort. Alpha-track radon detectors were installed to monitor radon levels in a background area and within the portal at each mine and within each home of the nearby residents. The second phase was conducted in October 2004 and included collection of surface-water samples during the typical low-flow period, collocated sediment samples at the surface-water sampling sites, background soil and vegetation samples, vegetation samples at the mine sites, soil and produce samples from gardens at the nearby residences, and benthic macroinvertebrate samples for taxonomy analysis. Alpha-track radon detectors installed in April 2004 were retrieved and analyzed.

1.3 Purpose of this EE/CA

The purpose of this EE/CA is to complete the site assessment for the mine areas under consideration and to screen, develop, and evaluate potential removal action alternatives for reducing risks associated with waste rock and adit drainage at the five mine sites comprising the La Sal Creek Watershed Project. The EE/CA was developed in accordance with the procedures established by the EPA for non-time-critical removal actions under the CERCLA and the NCP. EPA guidance for non-time-critical removal actions is presented in *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993a).

The data used to prepare this EE/CA were collected during the site characterization effort conducted during the spring and fall of 2004. Characterization results were used to assess the risks posed by waste rock and adit drainage at the mines and to support evaluation of the potential effectiveness, implementability, and cost of removal actions alternatives for alleviating those risks. An Action Memorandum will be prepared by BLM to document the selected alternative following receipt of public comment on this EE/CA.

1.4 Project Organization

The La Sal Creek Watershed Project is being conducted by the BLM with technical assistance from AAK and guidance from the EPA Region 8. Project representatives are organized as follows:

BLM Project Inspector:	Ms. Terry Snyder, Utah State Office AML Coordinator (801) 539-4026
BLM QA Officer	Ms. Pamela Innis, National Science and Technology Center Environmental Engineer (303) 236-0020
BLM Technical Support	Mr. Karl Ford, National Science and Technology Center Toxicologist (303) 236-6622
	Mr. William Carey, National Science and Technology Center Water Quality Specialist
AAK Project Team	Mr. William Merrill, AAK Project Manager (970) 242-0170
	Mr. Bruce Smith, AAK Technical Leader/QA Officer (970) 242-0170
	Mr. Ken Baker, Environmental Restoration Group Radiation Specialist (505) 298-4224
EPA Site Assessment Manager	Mr. Stan Zawistowski, EPA Region 8 Environmental Scientist (303) 312-6255
EPA Technical Support	Mr. Robert Duraski, EPA Region 8 Radiation and Indoor Air Specialist (303) 312-6728
ACZ Analytical Laboratories	Ms. Susan Barkey Project Manager (970) 879-6590

1.5 Organization of this Document

The remainder of this EE/CA is organized as follows:

- Section 2.0 presents a description of each mine within the project area.
- Section 3.0 presents an evaluation of site characterization results
- Section 4.0 presents a streamlined risk evaluation

- Section 5.0 presents removal action scope, goals and objectives including statutory framework on removal actions, removal action scope and schedule and identification of preliminary Applicable or Relevant and Appropriate Requirements (ARARs).
- Section 6.0 presents the identification and analysis of removal action technologies and alternatives for waste rock.
- Section 7.0 presents the identification and analysis of removal action technologies and alternatives for mine drainage.
- Section 8.0 provides a comparative analysis of removal action alternatives.
- Section 9.0 presents the recommended removal action alternatives.
- Section 10.0 presents a list of acronyms.
- Section 11.0 presents a list references.

2.0 MINE DESCRIPTIONS

This section provides a general description of the project area and general site-specific descriptions of the Firefly/Pygmy, Vanadium Queen, Blue Cap, Black Hat, and Saint Patrick Mines. Photographs taken at each mine are provided in Appendix A. Detailed discussion of the regional setting and descriptions of the mines are found in the CSM (AAK, 2003a).

2.1 Project Area

The mines comprising the La Sal Creek Watershed Project are located in Sections 28, 29, 30, and 31 in Township 28 South, Range 26 East, Salt Lake Base and Meridian and Section 10, Township 47 North, Range 20 West, New Mexico Principal Meridian (Figure 2.1.) As shown, the mines are located along the northern rim of the canyon formed by La Sal Creek, a perennial stream that drains the southern flank of the La Sal Mountains and flows in an easterly direction south of the mines. The project area encompasses the mines and peripheral sampling stations established at upstream and downstream locations on the major perennial streams of La Sal Creek, Twomile Creek, and Hop Creek. In accordance with EPA CERCLA guidance, Figures 2.2 and 2.3 show the 4-mile radius and 15-mile surface water migration route extending from the project area. Figure 2.2 shows the 4-mile target distance limit for groundwater and air pathways for each mine in the study area, and the location of permitted wells within the radius distance. The 15-mile target distance limit for surface water is located on the Dolores River 15 miles downstream of the confluence of Lion Canyon Creek and La Sal Creek and is shown in Figure 2.3. There are no municipal wells within the 4-mile radius or the 15-mile surface water migration route.

Three residences are present within the project area. All three residences are situated on the valley floor, downgradient of the Vanadium Queen Mine (Figure 2.1). Residence 1 is located on a 5-acre parcel of private land in the southwest corner of Section 29. Residences 2 and 3 are located on 7- and 5-acre parcels of land, respectively, leased from the State of Utah in the northwest corner of Section 32.

Drilling programs conducted by the U.S. Geological Survey (USGS) in the 1950s as well as other exploration programs resulted in the discovery of uranium and vanadium mineralization in the area which has become known as the “La Sal Creek Mineral Belt.” The mines were constructed to intercept roll-front type uranium deposits occurring in paleochannels within the Salt Wash Sandstone Member of the Jurassic Morrison Formation. Such deposits occur along oxidation/reduction facies within the

paleochannels. To reach the deposits, drifts were extended through the host rock, resulting in accumulation of the waste materials which form the mine dumps present at each mine. The dump material predominantly consists of sandstone fragments from the host rock, with lesser amounts of siltstone and claystone which commonly occur above and below the sandstone paleochannels. Further discussion of the regional geologic and hydrologic setting may be found in the CSM (AAK, 2003a).

Mine water emanates from the adits at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines. In each case, the water flows onto the mine bench and infiltrates into the material covering the bench; there is no hydraulic connection by way of surface flow between the adits and receiving streams. A wetland area extending from the adit to the infiltration point is present at each of the three mines. Based on discussion with Mr. Nick Mezei (U.S. Army Corps of Engineers [USCOE] representative responsible for management of wetlands within the La Sal Creek Watershed Project area), the wetlands present at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines are not considered jurisdictional wetlands. The wetlands are non-jurisdictional because the wetlands form isolated features and water discharging from the features infiltrates into the ground a short distance from the features and is not conveyed as surface flow into any waters considered “navigable in fact.”

2.2 Firefly/Pygmy Mine

The Firefly/Pygmy Mine consists of an abandoned uranium mine situated on an east-facing slope in the upper portion of the canyon formed by La Sal Creek, about 800 feet east-northeast of Utah Highway 46 (Figure 2.3). The name “Firefly/Pygmy Mine” refers to a single mine, the Firefly Mine, which targets deposits under the Firefly group of claims and the Pygmy group of claims. The mine is located in the SE ¼ of the SW ¼ of Section 30 and NE ¼ of the NW ¼ of Section 31, Township 28 South, Range 26 East, Salt Lake Meridian. The mine portal is located at an elevation of approximately 6,600 feet above mean sea level (amsl), and the toe of the waste-rock dump lies at an elevation of approximately 6,450 feet amsl. Access is gained from Utah Highway 46 by following a 0.2 mile access road (passable to 4-wheel drive vehicles, all-terrain-vehicles [ATVs], and motorcycles) to the mine.

The disturbed area at the mine covers approximately 2.02 acres, with the waste-rock dump comprising approximately 50 percent of the disturbed area. The boundary between land under the jurisdiction, custody, and control of BLM and the USFS crosses the northern portion of the mine, with most of the portal area (adit, mine bench, waste rock dump, and associated structures) lying on BLM land, and the northern extent of the waste-rock dump (approximately 7 percent of the total dump area) and majority of

the mine workings lying on or beneath USFS land. La Sal Creek, which flows in a northeasterly direction near the mine, passes within approximately 600 feet of the toe of the waste-rock dump. Extensive evidence that cattle and wildlife frequent the mine was noted during site reconnaissance. In addition, the mine is accessible to the public since the mine is highly visible and located a short distance from Utah Highway 46.

Initial operations began at the mine in 1954, and the mine was evidently abandoned in 1992. It is estimated that the mine produced 80,000 tons of ore, averaging 0.22 percent U_3O_8 and 1.82 percent V_2O_5 during the life of the mine (UNC Geotech, 1989). It has been reported that the workings were extended to the Grey Daun Mine to facilitate ventilation (Robert Riley, personal communication).

2.2.1 Site Description

The mine was constructed to extract uranium and vanadium from paleochannels within the upper Salt Wash Sandstone Member of the Morrison Formation. The primary drift was driven westward into a 20-foot high sandstone outcrop. The site is generally bounded to the north and south by ephemeral drainages that extend to La Sal Creek which is located approximately 600 feet down the hill slope from the toe of the waste rock dump.

The primary features at the mine include the following:

- Mine adit
- Primary mine bench
- Two-tiered waste-rock dump separated by an intermediate bench
- Small waste-rock accumulation along the mine access road
- Two standing structures

The mine portal is a 10 by 10-foot opening at the base of a band of outcropping sandstone. The adit has been closed with a metal grate to discourage entrance into the mine workings. However, unauthorized access can be gained to the mine where the metal grate has been compromised by vandals. About 10-feet inside the portal, the adit narrows to about 8 feet wide by 8 feet tall. The portion of the main haulage drift visible from the mine entrance is generally free of trash/refuse or equipment debris. The floor of the adit is covered with 6 to 12 inches of water that freely flows from the adit at 1 to 2 gallons per minute (gpm). Outside of the portal, moist soil supports a heavy growth of willows, forbs, and grasses. Portions of the

mine workings that historically have been known to be flooded are the suspected source for the mine discharge (Robert Riley, personal communication). After exiting the portal, the mine drainage spreads across the mine bench, diverging into three separate shallow drainage channels. One channel conveys water to the north along the upslope margin of the bench. The water in this channel infiltrates into the ground surface before reaching the edge of the dump. The second channel conveys water toward the center of the bench where it also infiltrates before reaching the edge of the dump. The third channel conveys water across the southern portion of the bench. During an early field visit in 2003, water from this channel crested the upper waste-rock dump and flowed across the lower bench into a drainage channel that incises the southern portion of the lower dump and ultimately discharged to the natural drainage that forms the southern perimeter of the dump. During subsequent field visits, the mine drainage in this third channel seeps into the waste dump before reaching the crest of the upper dump. During the April and October 2004 site characterization visits, seepage was present at the toe of the upper mine dump on the lower bench. The seepage emanated from a discrete point in the loose sandstone fragments that make up the dump nearly directly downslope of the portal. This seepage water was interpreted to be mine drainage water that had infiltrated the upper dump. From the emanation point the seepage water flowed across the lower bench that separates the upper and lower dumps, forming a vegetated bog. Vegetation consisted mostly of grasses and sedges. Standing water in the bog was observed close to the crest of the lower dump but no flow was observed on the dump face. Flow from the emanation point was estimated at no more than 1 gpm.

The mine bench extends from the base of the outcrop and measures approximately 80 feet wide by 250 feet long. The bench area is littered with mine debris (miscellaneous equipment and metal pipes), one small concrete block/foundation at the southernmost former load-out structure, and the remnants of the mine tracks extending from the portal along three apparent alignments on the mine bench. One track leads to the suspected ore load-out area, and two tracks lead to separate lobes of the dump. A small, approximately 10-foot diameter depression or impoundment constructed adjacent to the outcrop and north of the mine portal was used to retain mine drainage during operations (Robert Riley, personal communication). The impoundment is lined with established grasses and ringed with willows. A buried, 2-inch diameter, metal pipe was installed during operations to convey water from the impoundment to the natural drainage that forms the northern boundary of the site. No water was present in the impoundment or the natural drainage during the AAK site visits. An aboveground, west-northwest trending power line crosses the site at the portal area. An electrical substation was constructed on the mine bench, approximately 60 feet from the mine portal. The remnants of the substation consist of an elevated wood platform capable of holding 3 or 4 transformers. No electrical components (transformers) remain onsite.

The waste-rock dump extending from the mine bench has been graded into two separate levels, with the upper level used for ore load-out. A small portion of the dump to the north (approximately 7 percent of the total dump area) lies on USFS-managed land; the remainder of the dump lies on land under the jurisdiction, custody, and control of BLM. Remnants of a suspected load-out structure are present in the southern portion of upper dump level. The surface area of the dump covers approximately 43,000 square feet based on aerial photographs (2003) of the mine area. According to the Preliminary Assessment (USFS, undated), the dump contains approximately 33,150 cubic yards of material, calculated as the average of 21,300 cubic yards of onsite waste (Bio West, Inc., 1988) and 45,000 cubic yards of waste generated (UNC Geotech, 1989). Both levels of the dump are littered with equipment refuse, metal and plastic piping, empty metal containers (5-gallon buckets and a few 50-gallon drums), mine timbers, and cables. Some of the discarded material likely represents dismantled structural elements of an ore bin. No cribbed areas are visible on the dump; however, it is suspected that some cribbing/structures may have once been associated with the suspected load-out areas. Large clasts of sandstone waste rock armor much of the surface of the dump. Loose sand derived from weathered waste rock underlies the armored surface. Several deep channels have formed across the face of the dump where the waste rock has been eroded by surface water runoff. Large waste-rock boulders have accumulated along the toe of the dump, waste rock debris is evident along the primary ephemeral drainage leading from the dump to La Sal Creek.

A small accumulation of waste rock is present along the mine access road, located approximately 250 feet southwest of the mine area. The waste-rock pile covers approximately 4,000 square feet based on aerial photography and is about 12 feet thick based on drilling records.

One of the two standing structures at the mine is a 14 by 16-foot, one story, wood frame structure located about 150 feet south of the adit. Both the exterior walls and roof have been covered with composition roll roofing. The building contains a partial wood floor which is littered with miscellaneous trash and debris. The area immediately south of the structure was apparently used for the disposal of general trash and debris.

The second standing structure is a 6.5 by 15-foot storage structure, dug into a steep, rocky slope and extending westward into sandstone bedrock. The excavation is timber-lined and access is gained through a double-door system at the exposed face. The floor of the doghole is littered with rodent droppings and some trash.

2.2.2 Geologic Setting

The portal at the Firefly/Pygmy Mine Site is constructed in the upper-most continuous sandstone ("ore-bearing sandstone") unit of the Salt Wash Sandstone Member of the Morrison Formation on a southeast-facing slope of a ridge that separates La Sal Creek to the south and Twomile Creek to the north. The sandstone unit consists of broad lenses of medium to fine-grained sandstone ranging in color from light gray, light brown, reddish brown and green. The sandstone unit ranges in thickness from 30 to 90 feet. Mudstone lenses are interbedded within the sandstone unit and range in thickness up to 3 feet and are generally red; some mottled green or green mudstone is present (Carter and Gualtieri, 1965). Observations by Carter and Gualtieri (1965) suggest the bedding contacts between the mudstone and sandstone lenses are from scour and fill and differential compaction.

Other geological formations exposed in the vicinity of the Firefly/Pygmy Mine Site include from oldest to youngest, the Entrada Sandstone (Dewey Bridge and Slick Rock Members), Summerville Formation, the Brushy Basin Shale Member of the Morrison Formation of Upper Jurassic age, and the Burro Canyon Formation and Dakota Sandstone of Lower Cretaceous age. The Summerville Formation underlies the Salt Wash Sandstone Member near the bottom of the slope of the northeast-trending ridge that separates Twomile Creek and La Sal Creek. This formation is generally poorly exposed in heavily forested/vegetated areas. The overlying Brushy Basin Shale Member of the Morrison Formation forms the broad sloped terrain above the mine. This area is forested with Ponderosa Pine, pinyon, and juniper and soils are relatively well-developed; rock exposure is generally poor. This area consists of undulating terrain with small poorly-drained grassy basins separated by small, rocky, hummocky areas. The "highlands" in the immediate area of the mine are comprised of the Burro Canyon and Dakota Sandstone. These formations form the prominent sandstone cliffs, approximately ¾ of a mile northwest of the mine portal.

2.2.3 Hydrologic Setting

Site-specific surface-water and groundwater characteristics were used to develop a conceptual hydrologic model of the site. Surface water, groundwater, and the resulting hydrologic model are discussed separately below.

2.2.3.1 Surface Water

Surface water features in the vicinity of the Firefly/Pygmy Mine Site include La Sal Creek and Twomile Creeks, several mapped springs and drainage from the mine portal. La Sal Creek is the closest perennial stream, located approximately 800 feet southeast and downslope of the portal. Twomile Creek lies approximately 0.6 miles to the northeast and is separated from the mine and dump by a prominent ridge. Reconnaissance of the mine and surrounding area showed water discharging from the portal and several seeps (characterized as diffuse moist areas) and springs (characterized as having defined flow and emanation point) on the hillslope at lower elevations. Drainages below the mine were dry during AAK site visits but may flow during periods of heavy snowmelt or intense thunderstorms.

Two small springs were located on the hill slope northeast of the waste-rock dump. The springs, identified as Firefly Spring No. 1 (6,511 ft amsl) and Firefly Spring No. 2 (6,474 ft amsl), are further discussed in Section 3.0 of this document. Willows (sp. *Salix*), Cottonwood trees (sp. *Populus*), common reed (sp. *phragmities*), and wetland-type grasses occur in association with the seeps and springs. The discharge rates of the two springs were generally in the range of 0.5 to 5 gpm. These springs occur in lower strata of the Salt Wash Sandstone Member, stratigraphically below the ore-bearing zone.

Mine drainage emanates from the adit in a shallow channel ranging from 1 to 2 feet wide. During visits in February and April 2003, flow was barely perceptible; however in February 2003, the slow-flowing water was not frozen at the mouth of the adit probably due to persistent flow and slightly elevated temperature of the groundwater. Flow from the main portal was estimated to be 1 to 2 gpm during AAK's site visits. UNC Geotech reported a flow rate of 6.5 gpm in 1989, and Korte (2001) reported a flow of 356 milliliter per second (ml/s) or 5.64 gpm in February of 2001. Mine drainage exits the portal and flows out onto the dump bench. Here the mine water disperses forming a vegetated wetland (non-jurisdictional) with willows, cattails (sp. Typhus), and marsh grasses. During visits in 2003, a portion of the water flowed over the brow and down the face of the upper dump. This water then dispersed on the top of the lower bench, again forming a thin bog or marsh-type feature. A shallow channel on the face of the lower dump appears to contain periodic flow from the lower bench; however, no such flow was occurring during AAK site visits. Surface water from the mine drainage is apparently lost by evapotranspiration and percolation into the dump and underlying bedrock strata.

Thick patches of grasses were observed in several places at the toe of the lower dump indicating that some seepage occurs in this area; however, no water was observed seeping from the dump toe during the

AAK site visits. Korte (2001) observed and sampled seepage from the toe of the dump; similar seepage was noted by UNC Geotech in 1989.

2.2.3.2 Groundwater

Carter and Gualtieri (1965) reported that groundwater conditions in the Firefly/Pygmy Mine prior to mining are indicated by ore type. The ore bodies of the lower level are not as oxidized and indicate that this zone was below the water table. The ore in the upper level, 20 to 30 feet above the lower level and above the main drift (portal at elevation of 6,600 ft amsl), was subjected to oxidation.

On the basis of the mine map published by Carter and Gaultieri (1953-1955) and a discussion with Mr. Robert Riley (the resident at Residence R1 and a former miner at the mine), the origin of the mine water is from lateral inflow from strata near the floor of the mine workings. Mr. Riley stated that the mine was generally dry on the back and ribs and that water was associated with lower decline workings in the mine. No water was heard dripping from the back while standing at the portal in February and April, 2003. It is therefore hypothesized that water discharges from the mine as flooded lower workings overflow into the main mine drift.

The map produced by Carter et. al. (1953-1955) showed several flooded declines that indicated the groundwater level to be at an elevation of approximately 6,615 feet. Mr. Riley further stated that present hydrologic conditions do not appear to differ greatly from when the mine was worked in the 1950's. Korte (2001) stated that observed adit flows and water quality data collected in April 2000 and February 2001 were very similar and suggested that adit discharge does not fluctuate greatly over time. Site observations by AAK in February and April 2003 support this premise. Observations support the impression that mine-water discharge from the Firefly/Pygmy Mine has been occurring for some time as evident from wetland (non-jurisdictional) development on the main mine bench and recorded by several investigators over a period of many years (UNC Geotech, 1989). The temperature of the water flowing from the Firefly/Pygmy Mine is consistently higher than the water draining from the Vanadium Queen Mine and Blue Cap Mine, indicating that the water source for the Firefly/Pygmy Mine is possibly of a different nature than the water source for the other mines.

2.2.3.3 Conceptual Hydrologic Model

The hydrologic model for the Firefly/Pygmy Mine Site assumes that the main water source to the workings discharges from strata near the mine floor. That is, water enters the mine where the workings have intercepted the isolated, saturated channel sandstone that hosts the ore body. It is hypothesized that a shale, siltstone, or other unit of low permeability may restrict water percolating downward from overlying strata and lateral flow from saturated and more deeply buried portions of the Salt Wash Sandstone Member. The apparent steady production and discharge of groundwater from the mine suggests that the main source of the groundwater is from strata that is not hydraulically well-connected to shallow permeable strata or fractures that may be influenced by recharge from precipitation events.

It is also probable that secondary sources of water discharge from water-bearing fractures in the upper part of the mine workings. The overlying Brushy Basin Shale Member, generally considered to be of lower permeability, would provide minimal recharge to the mine and regulate the flow of groundwater from surficial vertical recharge of precipitation. In the case that some groundwater does originate from the Brushy Basin Shale Member, low hydraulic pressure in the unit may not overcome atmospheric pressure in the open workings to the point that water drips freely from the back over broad areas. This suggests that groundwater flow in the Brushy Basin Shale and Salt Wash Sandstone Members occurs in a variably saturated state. Tensional forces may hold downward percolating groundwater within the upper sandstone of the Salt Wash Sandstone Member until a more impermeable layer is encountered near or below the elevation of the mine floor, where sufficient head can form to cause flow into the mine workings. Also, an alternate groundwater source to the mine has the potential to have originated from much greater distances than say, several hundred feet from the workings. The mine workings act as a discharge area and probably capture groundwater from a very broad area, similar to flow regimes for seeps and springs in the study area. Only during successive multiple years of climatic change, drought or above average precipitation, would the mine discharge rate fluctuate, and even then it may take months or years to see this fluctuation at the portal. Underground reconnaissance is necessary to refine the hydrogeologic model of the Firefly/Pygmy Mine.

2.3 Vanadium Queen Mine

The Vanadium Queen Mine consists of an abandoned uranium mine situated on a southwest-facing slope in the upper portion of the canyon formed by La Sal Creek, approximately 2,000 feet north of Utah Highway 46 (Figure 1.3). The mine is located in the NE ¼ of the SW ¼ of Section 29, Township 28 South, Range 26 East, Salt Lake Base and Meridian. The mine portal is located at an elevation of

approximately 6,550 feet amsl, and the toe of the waste-rock dump lies at an elevation of approximately 6,370 feet amsl. Access is gained from Utah Highway 46 by following the private road crossing State-leased property (Residence R2) and continuing up a 0.5 mile access road (passable to four-wheel drive vehicles, ATVs, and motorcycles) to the mine. The disturbed area at the mine covers approximately 4.21 acres, with the waste-rock dump comprising approximately 75 percent of the disturbed area. The mine portal area (adit, structures, and waste-rock dump) lies entirely on land under the jurisdiction, custody, and control of BLM. The USFS boundary lies approximately 1,000 feet north of the portal area; therefore, the northern portion of the mine workings underlies USFS land. To the south, La Sal Creek flows in an easterly direction passing within approximately 1,600 feet of the toe of the waste-rock dump. Extensive evidence that cattle and wildlife frequent the mine was noted during site reconnaissance. In addition, the mine is visible from Utah Highway 46 and reasonably accessible to the public; however, mine access is somewhat hindered by the private lands that must be crossed to reach the mine from the highway.

The Vanadium Queen Mine was initially located in 1931. Various owners and operators have been responsible for the mine since that time. Proof of Labor documents indicate that the mine was apparently last operated in 1992. No total mine production or grade estimates are provided in the existing site documentation.

2.3.1 Site Description

The underground mine workings extend to the northeast from the portal area which is located near the northern rim of the canyon formed by La Sal Creek. The mine site was constructed within an ephemeral drainage extending from the canyon rim to La Sal Creek; the mine bench and waste-rock dump largely fill the upper portion of the drainage. The primary features at the mine include the following:

- Primary production adit
- Auxiliary adit
- Mine bench
- Large waste-rock dump
- Small ore stockpile
- Compressor/workshop building

- Transformer platform
- Equipment storage area

The mine adit is a 7-foot-wide by 6-foot-tall wood framed portal entrance that extends east-northeast into the steep canyon hillside. At the mine entrance, approximately 12 feet of the drift has been stabilized with wooden timbers forming a canopy that is partially loaded by upslope colluvium. A metal gate was installed at the end of the timbered section (approximately 12 feet from the mine entrance) to prevent unauthorized access to the mine; the gate is currently unlocked and partially open allowing access to the mine workings. Much of the canopy framing at the portal has collapsed and the portion remaining is highly unstable. It is suspected that once the unstable framing fails, much of the adit opening will be covered with talus debris from the overlying hillside. Standing water covers the floor of the mine behind the gate. During the April 2004 characterization visit, the flow from the adit was blocked by debris and sediment and no direct surface flows were observed from the portal. However, water emanated from the ground surface approximately 30 feet outside of the mine portal. Water flowed from this spring at an estimated rate of 1 to 2 gpm. During the October 2004 characterization visit, the spring was less active and densely vegetated, and water from the adit was flowing around the debris and onto the mine bench. From the April emanation point and the portal area, the mine drainage spreads across the main mine bench with the majority of the flow crossing the eastern portion of the bench and into a drainage channel adjacent to the mine dump. A portion of the flow crosses the central portion of the bench and down the toe-drain along the mine access road. The mine drainage seeps into the ground along its course and no surface flow is visible in the natural drainage below the waste-rock dump.

A second adit, possibly used as an auxiliary portal, is located above and to the south of the main portal. No water was flowing from this adit during the site reconnaissance visit or subsequent visits. Approximately 50 percent of the mine drift is blocked by a thick deposit of sediment and debris. The deposit suggests that heavily sediment-laden water was present, and possibly retained by a small earthen berm at the mine entrance, in the mine workings.

The mine bench parallels the canyon rim and is approximately 70 feet wide by 200 feet long. The central portion of the bench is saturated where mine drainage spreads across the ground surface. Established willows, forbs, and grasses are present along the course of the mine drainage. Mine debris (miscellaneous equipment, old metal pipes, and several segments of metal irrigation pipe) litter the bench area. Ore car tracks lead from the mine portal along two track alignments. One alignment leads to the nose of the dump, and the second leads to the ore load-out area. Miscellaneous mine debris litter the bench area. An

aboveground power line, trending northwest-southeast, crosses the mine bench. A disposal area for general trash and debris, including one battery casing, is located on the slope below the southeast edge of the bench.

The waste-rock dump, sloping steeply to the southeast, has been partially graded into two separate levels, with the upper level used for ore load-out. Wood cribbing was used to secure the upper portion of the dump on the west side near the ore load-out. Much of the cribbing has recently failed and the remainder appears to be highly unstable. Two ore load-out areas were constructed on the west flank of the upper level where the mine access road passes next to the dump. The primary load-out area is supported with wood cribbing at the base, and wood planking was used to form the ore chute. The second ore load-out area is adjacent to the primary load-out. Based on recent aerial photographs of the mine area, it is estimated that the surface area of the dump is approximately 35,000 square feet. Large clasts of sandstone waste rock armor much of the surface of the dump. Loose sand derived from the weathered waste rock underlies the armored surface. Several deeply incised channels are evident across much of the dump, and waste-rock material is evident along the ephemeral drainage leading from the toe of the dump to La Sal Creek. It is suspected that the channels are largely the result of mass wasting and surface water runoff during heavy precipitation events. However, it is possible that portions of the dump were excavated for milling purposes following mine operation. Two blasting caps were encountered on the face of the mine dump during site reconnaissance. The blasting caps were disposed of through the proper authorities.

A small stockpile of suspected ore is located on the leveled area near the ore load-out. The stockpile was identified on the basis of radiological readings, which indicated gamma exposure rates of up to 3,000 microroentgen per hour (µR/hr). The stockpile is about 6 feet high and 12 feet in diameter.

The workshop/compressor structure is a 14 foot by 34 foot wood frame building. The walls and roof of the building are covered with corrugated galvanized sheet metal. The north end of the building is a 14 foot by 24 foot workshop, and the 14 foot by 10 foot room at the south end of the building houses an air compressor and electric engine. The workshop contains a work area and storage shelves partially filled with miscellaneous machine parts and supplies. Items observed in the area include one half-full 5-gallon container (closed lid with open bung hole) labeled Magnus Oil Grade 105 – Phillips Petroleum, one 12-volt battery casing, one-gallon cans and spray cans of paint, small machine parts, and miscellaneous hardware. The floor of the office/shop was littered with trash and cattle droppings. The compressor room houses a large Ingersol Rand compressor, electric motor (U.S. Electrical Motors, Inc.), and associated

piping and conduit. A plate on the electric motor specifies that the motor is “asbestos protected”, which indicates that asbestos was used as a component of the insulation system (personal communication with Mr. Howard Barr [Electrical Motors, Inc.], 2003). Three electrical boxes are mounted on the wall of the room; electrical components have been removed from the boxes. Small, isolated areas of stained soil were noted on the floor of the compressor room and in the general area surrounding the office/shop building.

The transformer platform is located adjacent to the north end of the workshop/compressor building. The condition of the platform is compromised and appears to be unstable. The platform is an elevated wooden structure that housed three transformers; the transformers have been removed from the platform and are currently located adjacent to the office/shop structure. Each transformer is labeled as “Spirakore Transformer – GE 50; the transformers are numbered 31695, 31696, and 31697. A “No-PCB” label dated May 14, 1985 is affixed to each transformer.

A flat area constructed about 50 feet northwest of the office/shop building was presumably used for material/equipment storage. The area contains general trash (including tires and household appliances), debris, and some equipment parts and timbers. A large, empty metal tank containing baffled internal chambers remains near the western edge of the area. The tank is approximately 10 feet long and 5 feet in diameter. The tank is the personal property of Mr. Riley and was released by BLM after a radiological survey was performed; however, the tank remains onsite at this time. An electrical switch box was discarded in the northern portion of the area. Electrical components remain in the box; it is not known whether the insulation materials contain asbestos. The western slope of the storage area was apparently used for trash disposal. A small, partially-collapsed building is located immediately west of the disposal area.

2.3.2 Geologic Setting

The portal of the Vanadium Queen Mine is constructed in the upper-most continuous sandstone (“ore-bearing sandstone”) unit of the Salt Wash Sandstone Member of the Morrison Formation on a southwest-facing slope of La Sal Creek Canyon. Strata show a shallow apparent dip to the north-northeast; Carter and Gualtieri (1965) state that is due to a local tilting and to a regional structure. The slope faces the confluence of Hop Creek and Twomile Creek, located one-third of a mile to the southwest. The sandstone unit consists of broad lenses of medium to fine-grained sandstone ranging in color from light gray to light brown. The sandstone unit ranges in thickness from 20 to 87 feet (Carter and Gualtieri,

1965). Mudstone lenses are interbedded in the sandstone unit at the portal, within the main drift, and at the east end of the workings. Observations by Carter and Gualtieri (1965) suggest the bedding contacts between the mudstone and sandstone lenses are from scour and fill and in some cases are complex, indicating several episodes of these stream processes. In general, however, significant mudstone units are not common, and are limited to thin seams and films (Carter and Gualtieri, 1965).

Other geological formations exposed in the vicinity of the Vanadium Queen Mine include, from oldest to youngest, the Entrada Sandstone (Dewey Bridge and Slick Rock Members), Summerville Formation, the Brushy Basin Shale Member of the Morrison Formation of Upper Jurassic age, and the Burro Canyon Formation and Dakota Sandstone of Lower Cretaceous age. The Summerville Formation and Entrada Sandstone (both of Jurassic age) underlie the Salt Wash Sandstone Member near the bottom of the slope to the south of the mine. A landslide deposit covers a large portion of the slope and valley floor between the Vanadium Queen Mine portal and Hop Creek. The deposit forms a gently-sloped floor and may have affected the course of Hop Creek, as the stream bends sharply to the west before joining Twomile Creek in this area. The Summerville Formation and lower Salt Wash Sandstone Member are covered by colluvium and landslide deposits immediately west (within several hundred feet) of the mine (Carter and Gualtieri, 1965). The Summerville Formation is generally poorly exposed in the area directly south of the mine due to colluvium, soil development and vegetation. The slope is forested and generally vegetated.

The overlying Brushy Basin Shale Member of the Morrison Formation forms the broad sloped terrain above the mine. This area is forested with mostly pinyon and juniper, and soils are relatively well-developed; outcrop is spotty. Ponderosa Pine occurs in the narrow and shaded portions of the canyons and at higher elevations. This area consists of undulating terrain with small poorly-drained grassy basins separated by small, rocky, hummocky areas. The area is also is dissected by numerous drill roads that are remnants of past mineral exploration activity.

The Burro Canyon and Dakota Sandstone form the “highlands” within one-half mile to the east and north of the mine. These formations form the prominent sandstone cliffs in the area including the upper elevations of Hop Creek Canyon.

Carter and Gualtieri (1965) showed that one joint set is prevalent at the mine, striking approximately N. 80º W. with mostly a vertical dip. Foreset beds dip mostly to the southwest and northeast.

2.3.3 Hydrologic Setting

Site-specific surface-water and groundwater characteristics were used to develop a conceptual hydrologic model of the site. Surface water, groundwater, and the resulting hydrologic model are discussed separately below.

2.3.3.1 Surface Water

The portals of the Vanadium Queen Mine are located in La Sal Creek Canyon, approximately one-third of a mile northeast of the confluence of La Sal and Twomile Creeks. Twomile and La Sal Creeks are perennial streams in this area. Hop Creek is located approximately one-quarter mile west of the mine and joins Twomile Creek approximately one-quarter mile above the confluence with La Sal Creek. The lower 1.5 miles of Hop Creek was mapped as perennial by Carter and Gualtieri (1953-1955). The USGS (Ray Mesa Quadrangle, 1986) shows the entire drainage as ephemeral. During years of normal precipitation, it is probable that lower Hop Creek flows as a result of discharge from the Burro Canyon and Dakota Sandstone as vertical groundwater flow is restricted by the underlying Brushy Basin Shale Member of the Morrison Formation.

A small north-northeast trending ridge and drainage separate the Vanadium Queen Mine dump from direct exposure to Hop Creek and Twomile Creek. This drainage originates immediately below the mine dump and is ephemeral. Erosional features in the drainage indicate that sporadic high flow events have occurred, probably associated with runoff from intense thunderstorms. Smaller flow events may occur as a result of snowmelt runoff and less intense storms. The occurrence of waste rock materials on small terraces and other deposits in this drainage indicate that past runoff events have been of significant magnitude. A broad and subtle drainage is present to the east of the main ephemeral drainage. This drainage is well vegetated and contains several small springs and seeps (discussed below). The south-facing flank of La Sal Creek Canyon between Hop Creek and Lion Canyon Creek does not contain any significant drainage features.

Three springs were located on the hillside south and east of the dump, between the toe of the dump and La Sal Creek. The springs, identified as VQ Spring No. 1, VQ Spring No. 2, and VQ Spring No. 3, are further discussed in Section 3.0 of this document. Similar to the Firefly Mine, springs were associated with more dense vegetation including cottonwood, willow, reed, and various grasses. Flows from the springs are small, generally less than or equal to one gpm.

Each of the residences located on the valley floor immediately below the Vanadium Queen Mine receives domestic water from springs near the homes. These springs are further discussed in Section 3.0 of this document.

At the Vanadium Queen Mine, adit drainage has been observed flowing directly from the portal and emanating from the ground approximately 30 feet away from the portal. It is possible that a buried pipe may be conveying water from inside the mine to this location. Alternatively, shallow groundwater flow may be conveying the water to this point from inside the adit. The drainage generally flows an estimated 1 to 2 gpm. Aluminum irrigation pipe was present on the dump in the area of the portal suggesting that the mine discharge water had previously been diverted and used for some purpose.

Flow from the portal and emanation point disperses on the upper mine dump bench, forming a small bog. Some flow trends northwest down the mine access road while other flow trends southeast, forming a wetlands-like marsh containing cattails, willows, and various unidentified grasses. Flow is somewhat concentrated to a channel closer to where the interface of the mine dump and upper hill slope, but this subtle channel is only saturated for 80 feet or so from the emanation point. Other portions of the drainage flow out on to the main upper dump. Here, some water flows into a open hole or sump-like structure near the southeast brow of the main dump. No seepage was observed elsewhere on the dump, including the toe area. Water from the mine drainage is apparently lost by evapotranspiration and percolation into the dump and underlying bedrock strata.

2.3.3.2 Groundwater

Information as to the hydrology of the Vanadium Queen Mine is noted in Carter and Gualtieri (1965). These authors noted that the ore in the outer workings is highly oxidized due to their location near the outcrop and above the water table, whereas the middle workings were wet and required pumping during mining operations. The middle workings make-up an area of 130 feet long and 125 feet wide and are located approximately 300 feet from the main portal. The approximate elevation of the floor of the middle workings is 6,572 feet amsl, thereby giving an approximate location of the water table during mining in the 1950s. The ore in the middle workings is unoxidized to partly oxidized suggesting that the ore lay partly beneath the water table. The ore occurs in a sandstone lens that was nearly encapsulated by mudstone and partly saturated prior to mining (Carter and Gualtieri, 1965). In 1954, shortly after the ore in the middle workings was exposed, the ore below the track level in the middle workings was completely water saturated. The ore in the inner workings, approximately 480 feet from the portal, was described as

wet and in places was mined below the level of the main drift and had to be pumped. The mine map published by Carter and others (1953-1955) also indicates the presence of groundwater in the mine as several sumps are identified in the area of the middle workings.

Based on information cited by Carter and Gualtieri (1965), the apparent water table was at an approximate elevation of 6,572 feet amsl and the elevation of Portal No. 1 was shown to be at 6,567 feet amsl. The inner workings did not significantly go below the 6,570 foot amsl elevation and flow currently observed from the mine is steady but generally of low volume. This information supports the concept that groundwater conditions in the mine currently are similar to conditions observed in the mid 1950s.

2.3.3.3 Conceptual Hydrologic Model

The conceptual hydrologic flow model for the Vanadium Queen Mine is similar to that described in Section 2.1.3.3 for the Firefly/Pygmy Mine Site. Information provided by Carter and Gualtieri, (1965) on the hydrologic conditions of the mine, support the theory that the workings were originally opened above but very near the water table, and inner workings eventually intercepted the water table. It is apparent that little water enters the mine directly from downward percolation through overlying strata or fractures. This is not to say that the water table does not receive recharge from overlying strata elsewhere. The Salt Wash Sandstone Member may be receiving recharge from infiltration of precipitation on outcrops, downward percolation of water from overlying strata, lateral recharge from distant sources within the formation, or from upward (vertical) recharge from underlying strata. Underground reconnaissance is necessary to refine the hydrogeologic model of the Vanadium Queen Mine.

2.4 Black Hat/Blue Cap Mine Complex

The Black Hat/Blue Cap Mine Complex consists of three abandoned uranium mines (Black Hat, Blue Cap, and Saint Patrick mines) situated immediately below the sandstone rim of Lion Canyon (Figure 1.3). The creek flowing down Lion Canyon (referred to herein as “Lion Canyon Creek”) is fed by water draining from the Blue Cap Mine which combines with flows from perennial seeps and springs below the sandstone rim of the canyon to form a perennial stream in the lower portion of the canyon. Above the mine complex, flow within Lion Canyon Creek is expected only in response to runoff and storm events. The Colorado-Utah state line passes through the mine complex with the Black Hat and Blue Cap mines lying in Utah and the Saint Patrick Mine lying in Colorado. The Black Hat and Blue Cap mines are located in the NE ¼ of the SW ¼ of Section 28, Township 28 South, Range 26 East, Salt Lake Base and

Meridian. The Saint Patrick Mine is located in the SE ¼ of the SE ¼ of Section 10, Township 47 North, Range 20 West, New Mexico Principal Meridian. Access to the mines is gained from Colorado Highway 90 by following a 1.5 mile, abandoned mine access road (currently only passable with ATVs or motorcycles). The portal area at each mine is on land under the jurisdiction, custody, and control of BLM; the mine workings at the Black Hat and Blue Cap mines extend beneath land under the jurisdiction, custody, and control of the USFS while the Saint Patrick workings lie beneath BLM-managed land, possibly extending below USFS land.

The deposit was discovered by the USGS in 1952 (USFS, undated). Production at the Black Hat Mine was initiated in 1954, and the year of last known operation was 1982. It is estimated that the Black Hat Mine produced 46,000 tons of ore, averaging 0.28 percent U_3O_8 and 1.42 percent V_2O_5 during the life of the mine (UNC Geotech, 1989). Production at the Blue Cap Mine was initiated in 1961, and the year of last known operation was 1984. It is estimated that the Blue Cap Mine produced 38,000 tons of ore, averaging 0.21 percent U_3O_8 and 1.48 percent V_2O_5 during the life of the mine (UNC Geotech, 1989). Production at the Saint Patrick Mine was initiated in 1953, and the year of last known production was 1984. It is estimated that the Saint Patrick Mine produced 30,000 tons of ore, averaging 0.22 percent U_3O_8 and 1.58 percent V_2O_5 during the life of the mine (UNC Geotech, 1989).

2.4.1 Site Description

General descriptions of the three mine sites comprising the Black Hat/Blue Cap Mine Complex are presented below.

2.4.1.1 Black Hat Mine

The Black Hat Mine workings extend to the north-northeast from the portal area which is located near the rim of the canyon. The site was constructed on the west bank of Lion Canyon Creek, within approximately 20 feet of the drainage channel. The disturbed area at the mine covers approximately 13,500 square feet (0.3 acre), with the waste-rock dump comprising approximately 60 percent of the disturbed area . The elevation of the mine adit is approximately 6,570 ft amsl, and the elevation of the toe of the waste-rock dump is approximately 6,490 ft amsl. No flow has been observed in Lion Canyon Creek along the reach adjacent to mine during AAK's site visits. Lion Canyon Creek enters La Sal Creek approximately 1.1 miles downstream of the Black Hat Mine. A vertical shaft located on the plateau north of the portal area was previously closed and the area reclaimed by the USFS. Three open vent holes

cased with 12-inch metal pipe remain in place north of the portal area. The primary features at the mine include the following:

- Primary production adit
- Metal building housing the production adit
- Mine bench
- Two-tiered waste-rock dump
- Metal-framed load-out structure
- Powder magazine

The production adit is approximately 6 feet wide by 7 feet high, opening on the east edge of the drainage at the head of Lion Canyon. The adit is covered by a metal building. A metal gate has been placed about 40 feet within the adit and is currently open. The floor at the mine entrance is dry, and no water drains from the mine. Air movement through the mine is noticeable at the portal.
The building that houses the mine portal is metal framed and sided, measuring about 20 feet wide and 24 feet long. The building was constructed on waste-rock fill outside of the adit. Waste rock beneath the southern portion of the building has eroded, leaving that portion of the structure unsupported. The building is empty, but some trash litters the floor.

The mine bench extends about 150 feet east-southeast from the portal to a large metal-framed load-out structure. Except for one metal pressure tank and miscellaneous trash, the bench is largely void of mine debris. The pressure tank is empty and measures 10 feet long by 3 feet in diameter. Remnants of a former electrical substation remain on the bench. The wooden substation structure was capable of housing 3 or 4 transformers; however, no transformers remain onsite.

The waste-rock dump is largely confined between the mine portal and the load-out structure. The dump slopes steeply from the mine bench, crossing the access road leading to the Blue Cap Mine and extending into the Lion Canyon Creek drainage. Based on aerial photographs (2003) of the mine area, it is estimated that the surface area of the dump covers approximately 8,000 square feet. Shallow rills and gullies incise the face of the dump. Ephemeral flows in Lion Canyon Creek have extensively eroded the dump near the mine portal and along the toe of the dump.

A large metal ore load-out structure extends down the hill side from the eastern end of the mine bench. The structure is approximately 24 feet long, 20 feet wide, and 25 feet high. The upper surface of the structure is covered with wooden floorboards, and a metal rail fence encircles the top of the structure. Ore was delivered to the structure from the mine bench and conveyed through vertical metal hoppers to ore trucks positioned below.

A suspected powder magazine is located up a steep section of road about 220 feet northeast of the ore load-out structure. The 6 by 8-foot structure has been dug into an exposed sandstone bedrock face and opens to the west. The opening has a 2-foot wide door; earth and rock have accumulated in front of the door, immobilizing it.

2.4.1.2 Blue Cap Mine

The Blue Cap Mine was constructed along the southwest rim of the canyon, immediately southwest of the Black Hat Mine. The disturbed area at the mine covers approximately 84,000 square feet (1.93 acres), with the waste-rock dump comprising approximately 80 percent of the disturbed area. The elevation of the mine adit is approximately 6,550 ft amsl, and the lowest elevation along the toe of the waste-rock dump is approximately 6,340 ft amsl. The primary features at the mine include the following:

- Primary production adit
- Secondary adit
- Office/storage room
- Small storage room
- Mine bench
- Large waste-rock dump

The primary production adit is constructed directly into the sandstone outcrop. The adit has a 20-foot wide flared opening that quickly narrows to 10-feet wide and 10 to 12-feet high. The adit is generally free of debris and appears to be relatively stable. Six to 8 inches of water covers the floor of the mine adit, and water flows from the portal at a rate of approximately 1 to 2 gpm. The mine drainage crosses the northern portion of the mine bench and is the most upstream source of water for Lion Canyon Creek. Moist soil along the mine drainage supports wetland-type vegetation of willows, forbs, and grasses. A

pipe and bar gate has been installed about 30 feet within the adit to prevent access. The gate is currently open.

A secondary adit is located about 25 feet south of the primary adit and joins the main haulage a short distance into the mine. The adit has a 13.5-feet wide by 11.5-feet high opening. The opening is covered by a fence incorporating a 6-foot high by 8-foot wide gate; the gate is currently open. Sediments on the floor of the adit are moist and heavily stained by suspected oil and grease in some areas. Water does not flow from the opening. The drift leading from the adit intersects the primary adit drift a short distance from the portal. It is suspected that the secondary adit was used as a compressor room and for storage of materials and equipment. The area immediately inside the adit is littered with miscellaneous debris, including cables, open buckets containing nuts and bolts, a 50-gallon drum partially full of a solid material, fuel/oil container with hand-pump, timbers, pipe, and general trash. Mine equipment (compressor) and several empty drums are located near the junction of this secondary adit and the main haulage; it is not known if the equipment contains fluids. Suspected oil staining is prevalent on the floor of the adit, and strong petroleum odors are evident at the entrance. The upper portion of a welded sheet steel and angle iron ore bin hopper has been placed upside down just outside of the adit.

A large office/storage room has been cut into the sandstone bedrock about 100 feet south of the secondary adit. The interior of the room is approximately 10 feet wide and 30 feet deep. The room contains some miscellaneous trash and debris along with a few tables and chairs, shelving, and a work bench. An abundance of rodent droppings was noted on the floor of the room, tables, and work bench. A horizontal metal pipe beneath the floor of the area daylights on the exterior sandstone face and extends several feet over the mine bench. It is suspected that the 2-inch pipe was used to drain the area around the office/shop. A small flow of water (less than one gallon per minute) drains from the pipe and falls directly on the mine bench. It appears that the drainage system was originally designed such that drainage from the pipe would enter a 6-inch metal pipe extending vertically into the bench and terminating on the face of the mine dump. Access to the room is currently open.

A small storage room has been cut into the sandstone outcrop approximately 110 feet south of the office/storage room. The storage room is 4 feet wide, 7 feet high, and 8 feet deep. Wood doors and high-pressure air hoses are stored in the room. Access to the room is currently open.

The mine bench forms a north-south elongated area between the face of the outcrop to the crest of the waste-rock dump. The bench was constructed on a narrow, natural soil terrace at the base of the outcrop.

A portion of the natural soil surface is visible near the center of the bench; elsewhere, the surface is covered with waste-rock material. The bench can be generally divided into two separate areas. The northern portion of the bench, measuring approximately 250 long by 50 feet wide, served as the primary area used for operations outside of the mine. Miscellaneous equipment debris are scattered across the area. Features on this portion of the bench include one power pole (labeled PacifiCorp No. 114-28-26#) containing three transformers, one small earthen ramp possibly used to load small quantities of ore, and an overhead power line extending from the power pole to the Black Hat Mine. The southern portion of the bench, measuring approximately 165 feet long by 15 wide was apparently formed by grading waste-rock along the natural soil bench. It is estimated that up to 8 feet of waste rock covers the natural soil bench in this area. The portion of the natural soil bench south of the mine bench was apparently used for refuse disposal. The refused area contains general trash and miscellaneous mine equipment parts and debris.

A large waste-rock dump extends down the steep hillside from the perimeter of the mine bench, terminating in the Lion Canyon Creek drainage. The dump slopes very steeply to the north-northeast and partially fills the Lion Canyon Creek drainage channel. Portions of the waste dump have been truncated by flows in Lion Canyon Creek. Recent flooding along Lion Canyon Creek (Summer 2004) resulted in erosional cuts into the waste rock that are up to 10 feet high. Perennial flows, fed by the mine drainage and springs on the opposite side of the canyon, occur within the reach of the channel adjacent to the dump. The face of the dump is deeply incised with rills and gullies. A small seep area can be seen in the southern portion of the dump where water appears to emanate from near a small outcrop of sandstone.

Based on aerial photographs of the site, the surface area of the waste-rock dump is estimated to be approximately 66,000 square feet. This large surface area is a result of the long, steep, natural slope that extends from the mine bench to the Lion Canyon Creek channel. Mine waste side-cast from the bench has formed a broad veneer of waste rock on the steep hillside and thick accumulations of material within the Lion Canyon Creek drainage which forms the toe of the slope. This appears to particularly be the case on the southern portion of the dump extending from the south bench area where the thickness of material covering the hillside may be one foot or less. A greater thickness of waste rock appears to be present along the slope forming the northern portion of the dump. The thickness of material in the northern part of the dump may range from 2 to 6 feet. Along the toe of the dump, the thickness of waste materials partially filling the drainage ranges from 5 to 10 feet.

2.4.1.3 Saint Patrick Mine

The Saint Patrick Mine is located on the northern rim of the canyon, across the drainage from the Blue Cap Mine. Existing site features include a partially-closed adit, small mine bench area, and waste-rock dump. According to previous studies regarding the site (UNC Geotech, 1989), other features were present at the mine at one time, including a metal storage shed, power pole with live transformers, and collapsed load-out and cribbing structures. These features have apparently been removed from the site.

The adit at the Saint Patrick Mine has been partially closed. A pile of large sandstone boulders has been placed in the adit, filling approximately 75 percent of the former opening. A metal gate can be seen across the drift behind the pile of boulders; however, it is uncertain whether the gate has been secured to the mine wall. According to personnel at the BLM's Montrose Field Office, the mine was closed with a bulkhead constructed 50 to 100 feet from the portal and then waste rock was pushed in place. The bulkhead cannot be seen from the existing adit opening. No flow has been observed emanating from the portal area during the AAK site visits. It is suspected that mine water may be retained by the closure, since previous investigators have noted flow from the mine. The small mine bench extending from the adit appears to have been re-graded, possibly at the time the adit closure was installed. No structures remain on the bench.

Five sticks of dynamite were discovered on a rock ledge near the mine adit during site reconnaissance. The dynamite was disposed of through the proper authorities.

The waste-rock dump covers the hillside below and east of the adit, essentially extending from the sandstone rim to near the access road leading to the Black Hat/Blue Cap Mine Complex. The dump slopes steeply to the southwest. Based on aerial photographs of the site (2003), the surface area of the dump is estimated to be about 43,340 square feet (1.0 acres).

2.4.2 Geologic Setting

The portals of the Blue Cap and Black Hat Mines are constructed in the upper-most continuous sandstone ("ore-bearing sandstone") unit of the Salt Wash Sandstone Member of the Morrison Formation in Lion Canyon. The portal of the Saint Patrick Mine appears to be constructed in yet a higher sandstone unit of the Salt Wash Sandstone Member, stratigraphically above the sandstone unit of the Black Hat and Blue Cap mines. The original Black Hat Mine was accessed from a shaft collared in the Brushy Basin Shale

Member on the slope above the Salt Wash Sandstone Member. The Salt Wash Sandstone Member forms the upper third of the walls or flanks in Lion Canyon.

Carter and Gualtieri (1965) briefly describe the geology of the Black Hat Mine but do not mention the Blue Cap or Saint Patrick mines in their report. The sandstone unit within the Black Hat Mine consists of broad lenses of medium to fine-grained sandstone ranging in color from light gray to light brown. The ore-bearing sandstone unit ranges in thickness from 40 to 70 feet in the vicinity of the deposit. The ore-bearing zone is within an interval 25 to 40 feet above the base of the sandstone unit and is underlain by a 0 to 4-foot thick lense of green mudstone (Carter and Gualtieri, 1965). The strata of the Salt Wash Sandstone Member exhibit attitudes consistent with the regional structure. At the portal, beds appear near horizontal, but may have a shallow dip to the southwest toward the axis of the La Sal Creek syncline near the mouth of Lion Canyon.

Other geological formations exposed in the vicinity of the Blue Cap and Black Hat Mine Complex include, from oldest to youngest, the Navajo Sandstone of Upper Triassic age, the Entrada Sandstone (Dewey Bridge and Slick Rock Members), Summerville Formation and Brushy Basin Shale Member of the Morrison Formation of Upper Jurassic age, and the Burro Canyon Formation and Dakota Sandstone of Lower Cretaceous age. The Summerville Formation forms a steep slope below the Salt Wash Sandstone whereas the Entrada Sandstone and Navajo Sandstone tend to form smooth-weathering massive sandstone ledges in lower part of Lion Canyon.

The overlying Brushy Basin Shale Member of the Morrison Formation forms the broad sloped terrain above the mine. This area is forested with Ponderosa Pine, Pinyon, and Juniper and soils are relatively well-developed. This area consists of undulating terrain with small poorly-drained grassy basins separated by small, rocky, hummocky areas. The area is also is dissected by numerous drill roads that are remnants of past mineral exploration activity.

The Burro Canyon and Dakota Sandstone form the small high mesas within one-half mile north and west of the mines. These formations form the prominent sandstone cliffs in the area including the Hideout Mesa to the northwest.

2.4.3 Hydrologic Setting

Site-specific surface-water and groundwater characteristics were used to develop a conceptual hydrologic model of the site. Surface water, groundwater, and the resulting hydrologic model are discussed separately below.

2.4.3.1 Surface Water

Surface water features in the vicinity of the Black Hat/Blue Cap Mine Complex include Lion Canyon Creek, La Sal Creek, springs, seeps, and mine drainage. Lion Canyon Creek is identified as an ephemeral stream on the geologic quadrangle published by Carter and Gualtieri (1965) and the USGS (1986) Ray Mesa 7.5-minute quadrangle. During AAK's site visits, the upper drainage was dry upstream of the Blue Cap Mine dump, but flow was always present below the dump and in the lower canyon. In contrast, flow was noted in upper Hop Creek, the next major drainage to the west, during the site visits. The geomorphology of the upper canyon is probably related to the lack of surface water in the area. The upper portion of Lion Canyon is much broader than the incised Hop Creek Canyon, and the Brushy Basin Shale and Quaternary deposits that form upper Lion Canyon do not constrict flow and may have more storage than a narrow canyon. A higher percentage of groundwater in the broad canyon may be discharged by way of evapotranspiration and not by seepage into an incised channel.

Flow in Lion Canyon Creek originates from mine drainage from the Blue Cap Mine portal. The creek's discharge rate increases significantly by the time the stream crosses the lower mine access road below the mine dump(s) at an elevation of approximately 6,340 feet amsl. This increase in discharge is due to numerous springs and seeps, most of which occur on the northeast side of the canyon across from the north east-facing mine dump. These springs include stations identified as Black Hat Spring and Alcove Spring. One apparent seep occurs on the southwest side of the canyon on the Blue Cap dump face where a small sandstone ledge outcrops with common reed vegetation at its base. This seep has been dry to slightly moist during the AAK site visits.

Two primary springs have been located within the drainage. The springs, identified as Black Hat Spring and Alcove Spring, occur along the hillside between the Black Hat and Saint Patrick Mines. Black Hat Spring discharges from fractures in a sandstone ledge in the road cut between the Black Hat Mine and the Saint Patrick Mine. This sandstone ledge appears to be an upper channel sandstone in the Salt Wash Sandstone Member, and therefore, possibly the same unit as the ore-bearing sandstone. Discharge at Black Hat Spring, as measured from a culvert that conveys the flow under the mine access road, is

approximately 5 gpm. Alcove Spring occurs on the southwest-facing side of the canyon approximately 40 feet below the elevation of the Blue Cap Mine portal. This spring has at least two emanation points from fractures at the base of an overhanging sandstone ledge. Remnants of metal pipe and drums at this spring suggest that this water source may have been used for mining operations, perhaps a drinking water source. Discharge at Alcove Spring (from one emanation point) was measured to be approximately 0.12 gpm. Several other springs were mapped down canyon from the mines and are apparently associated with the Summerville Formation, and the Entrada and Navajo Sandstones.

Lion Canyon Creek joins La Sal Creek approximately three-quarters of a mile below the Black Hat/Blue Cap Mine Complex. Deposits of apparent alluvial mine waste are evident in the lower Lion Canyon Creek streambed area. In April 2003, the discharge rate of Lion Canyon Creek just upstream of the confluence with La Sal Creek was approximately 0.5 cubic feet per second (cfs). La Sal Creek flow was estimated to be 3 cfs.

Mine drainage at the Black Hat, Blue Cap, and Saint Patrick Mines is limited to discharge from the Blue Cap Mine portal. Some minor discharge also occurs from a metal pipe originating from the mined out office/shop area just south of the Blue Cap Mine portal. Mine drainage from the Blue Cap Mine is similar to drainage at the Firefly and Vanadium Queen Mines. The discharged water forms a shallow marsh or bog on the northern portion of the mine dump. This non-jurisdictional wetland area is characterized by grasses, forbs, and some willows. The Blue Cap Mine discharge was measured at 1.3 to 2.0 gpm in April and October 2004, respectively.

2.4.3.2 Groundwater

Groundwater at the Blue Cap and Black Hat Mine Complex is not discussed by Carter and Gualtiere (1965), nor is a mine map included in their work. However, these authors do mention that the ore produced at the Black Hat Mine is of the unoxidized or slightly oxidized type, indicating that during initial mining, some of the ore zones may have been beneath the local water table. Although the Black Hat and Saint Patrick Mines do not discharge mine drainage, it is probable that water is present in the mines, but does not attain the head required to discharge at the elevation of the portals.

2.4.3.3 Conceptual Hydrologic Model

The conceptual hydrologic flow model for the Blue Cap Mine is similar to that described in Sections 2.2.3.3 and 2.3.3.3 for the Firefly/Pygmy and Vanadium Queen Mines, respectively. Similar to the Vanadium Queen Mine, it is postulated that the workings were originally opened above but very near the water table, and that little water enters the mine directly from downward percolation through overlying strata or fractures. This is not to say that the water table does not receive recharge from overlying strata elsewhere. The Salt Wash Sandstone Member may be receiving recharge from infiltration of precipitation on outcrops, downward percolation of water from overlying strata, lateral recharge from distant sources within the formation, or from upward (vertical) recharge from underlying strata.

The hydrologic model for the Black Hat and Saint Patrick Mines appears to differ from the other mines in the area, because these mines are not discharging water. There are three possible explanations for this: (1) the main drift and workings were driven above the local water table, (2) the main drift and workings collect and drain water from the local water table but the drainage discharges to underlying strata or laterally before reaching the portals (this includes water flow being obstructed by plugs or cave-ins), and (3) the portals decline such that the elevation of the local water table is sufficiently below the portal elevations.

3.0 SITE CHARACTERIZATION

A comprehensive site characterization program was implemented for the La Sal Creek Watershed Project to obtain the information needed to evaluate human-health and ecological risks resulting from mine operations and to evaluate removal action alternatives for the mines. The first element of the program was to perform a cultural resource inventory at each mine area. After the mines had been evaluated for cultural resources, a field investigation was performed to assess background conditions within three identified reference areas and the human-health and ecological risks resulting from mine operations (1) along the three primary perennial streams within the project area, (2) at the three residences located within the project area, and (3) at each of the designated mine areas.

Field investigation sampling/monitoring results are discussed in this section by locale (background, perennial streams, residences, and individual mines). In each discussion, tables are presented to show the sampling/monitoring results for the various media. Analytical results are compared to the screening specified in the FSP, which were derived based on state and federal human-health and ecological risk-based standards and risk management criteria established by the BLM. Results for synthetic precipitation leaching procedure (SPLP) analyses performed on the waste-rock samples were used to compute leaching RMC for comparison to total metals results in the waste rock. Screening levels and leaching RMC are further discussed in Section 4.0 (Streamlined Risk Evaluation) of this document.

3.1 Scope of Work

The field investigation was implemented in general accordance with the scope of work specified in the FSP (AAK, 2004) and the health and safety procedures and protocols specified in the *Site Safety and Health Plan – La Sal Creek Watershed Project* (AAK, 2003b). Some changes to the scope of work outlined in the FSP were necessary based on the actual conditions that were encountered in the field. The scope of work performed for the field investigation and the changes made in the field are summarized below.

3.1.1 Background Conditions

The following activities were performed to characterize conditions within each reference area:

- Collection of one surface-water sample during high-flow (spring) and one surface-water sample during low-flow (fall)

- Collection of one collocated composite sediment sample
- Collection of three composite surficial soil samples
- Collection of one benthic macroinvertebrate sample

The following changes to the scope of work outlined in the FSP were made on the basis of existing field conditions:

- Radiological surveys were not performed within the reference areas because background measurements were readily obtained at each mine area.
- The amount of benthic macroinvertebrates at the reference areas was not sufficient to allow collection of samples for chemical analysis. Benthic macroinvertebrate samples were collected within each reference area for taxonomy analysis.

3.1.2 Surface-Water

Surface-water sampling was conducted as follows:

- Adit-discharge samples were collected at the Firefly/Pygmy Mine, the Vanadium Queen Mine, and the Blue Cap Mine during high-flow (spring) and low-flow (fall).
- Samples were collected from the adit drainage channel at the Firefly/Pygmy Mine, the Vanadium Queen Mine, and the Blue Cap Mine during high-flow (spring) and low-flow (fall).
- Samples were collected at the designated sample locations along La Sal Creek, Twomile Creek, Hop Creek, and Lion Canyon Creek during high-flow (spring) and low-flow (fall).
- Samples were collected from three springs downgradient of the Vanadium Queen Mine during high-flow (spring) and low-flow (fall).

The following changes to the scope of work outlined in the FSP were made on the basis of existing field conditions:

- The second adit drainage channel samples were not collected at the Firefly/Pygmy and Vanadium Queen Mines during high-flow and low-flow events because the adit-discharge infiltrated into the ground upstream of the proposed sample locations.
- The proposed sample, VQ Seep 1, downgradient of the Vanadium Queen Mine did not produce sufficient flow for sampling.
- High-flow and low-flow samples were collected from a spring (VQ Spring 3) that had not previously been identified downgradient of the Vanadium Queen Mine.

3.1.3 Sediment

One co-located sediment sample was collected at each surface-water sampling location as specified in the FSP. No deviations to the proposed sediment sampling strategy were made in the field.

3.1.4 Waste Rock

Waste-rock sampling was conducted as follows:

- Sub-surface waste-rock samples were collected at 8 boreholes for chemical analysis and one borehole for geotechnical analysis at the Firefly/Pygmy Mine.
- Composite surface samples were collected from 9 segments on the waste-rock dump at the Firefly/Pygmy Mine.
- Sub-surface waste-rock samples were collected at 8 boreholes for chemical analysis and one borehole for geotechnical analysis at the Vanadium Queen Mine.
- Composite surface samples were collected from 6 of 7 segments on the waste-rock dump at the Vanadium Queen Mine.
- Sub-surface waste-rock samples were collected at 6 boreholes for chemical analysis and one borehole for geotechnical analysis at the Blue Cap Mine.
- Composite surface samples were collected from 6 segments on the waste-rock dump at the Blue Cap Mine.
- Sub-surface waste-rock samples were collected at 2 boreholes for chemical analysis at the Black Hat Mine.
- Composite surface samples were collected from 2 segments on the waste-rock dump at the Black Hat Mine.
- Composite surface samples were collected from 2 segments on the waste-rock dump at the Saint Patrick Mine.
- Ten samples were collected for radiological correlation at the Firefly/Pygmy Mine, Vanadium Queen Mine, and Blue Cap/Black Hat Mine Complex.

The following changes to the scope of work outlined in the FSP were made on the basis of existing field conditions:

- One of the 8 boreholes proposed at the Firefly/Pygmy Mine was relocated to assess waste-rock in a small dump identified near the mine access road below the mine area.

- Segregation of the waste-rock dumps was refined in the field, resulting in 9 verses 8 segments at the Firefly/Pygmy Mine, 7 verses 6 segments at the Vanadium Queen Mine, and 6 verses 4 segments at the Blue Cap Mine.

- Three of eight of the proposed boreholes at the Vanadium Queen Mine were not completed because either waste rock was not present or the drill rig could not safely access the location.

- A composite waste-rock sample could not be collected from Segment 2 at the Vanadium Queen Mine because of unsafe conditions.

- The four proposed boreholes at the Saint Patrick Mine could not be drilled because drill rig could not safely access the mine area.

3.1.5 Ephemeral Drainages

Three composite sediment samples were collected along the primary ephemeral drainage downstream of the Firefly/Pygmy and Vanadium Queen Mines as specified in the FSP. Sediment samples were not collected downstream of the Black Hat, Blue Cap, or Saint Patrick Mines because ephemeral drainage channels are not present downstream of these mines.

3.1.6 Vegetation

Vegetation sampling at the mines was conducted as follows:

- At the Firefly/Pygmy Mine, composite grass, forb, and shrub samples were collected along the adit discharge and around the perimeter of the dump.

- At the Vanadium Queen Mine, composite grass and forb, samples were collected along the adit discharge and composite grass, forb, and shrub samples were collected around the perimeter of the dump.

- At the Blue Cap Mine, composite grass, forb, and shrub samples were collected along the adit discharge and around the perimeter of the dump.

- At the Black Hat Mine, composite grass, forb, and shrub samples were collected around the perimeter of the dump.

- At the Saint Patrick Mine, composite grass, forb, and shrub samples were collected around the perimeter of the dump.

- Composite grass, forb, and shrub samples were collected at Reference Area 3.

The following changes to the scope of work outlined in the FSP were made on the basis of existing field conditions:

- One composite shrub sample was collected along the adit drainage at the Firefly/Pygmy Mine because willows and other shrubs were present along the drainage course.
- One composite shrub sample was collected along the adit drainage at the Blue Cap Mine because willows and other shrubs were present along the drainage course.
- Composite grass, forb, and shrub samples were collected in Reference Area 3 to allow comparison of analytical results for mine-site vegetation to background levels.
- Composite samples of Gambels Oak roots and stems were collected at the request of the on-site EPA representative at the Vanadium Queen Mine.

3.1.7 Residences

Surface-water, soil, vegetation, and produce sampling was conducted as follows:

- Residence 1
    - Surface-water samples were collected from one spring used for domestic purposes during high-flow (spring) and low-flow (fall).
    - One composite soil sample was collected from the garden
    - One composite soil sample was collected from the pasture.
    - One composite produce sample was collected from the garden.
    - One composite grass sample was collected from the pasture.
- Residence 2
    - Surface-water samples were collected from one spring used for domestic purposes during high-flow (spring) and low-flow (fall).
    - One composite soil sample was collected from the pasture.
    - One composite grass sample was collected from the pasture.
- Residence 3
    - Surface-water samples were collected from two springs used for domestic purposes during high-flow (spring) and low-flow (fall).
    - Surface-water samples were collected from one additional spring during high-flow (spring) and low-flow (fall).
    - One composite soil sample was collected from the garden.

- One composite produce sample was collected from fruit trees in the garden and yard.

The following changes to the scope of work outlined in the FSP were made on the basis of existing field conditions:

- The proposed irrigation spring samples at Residence 1 and Residence 2 were not collected because irrigation water is provided to both properties from adjacent perennial streams.
- A third spring was located and sampled at Residence 3. The spring is a flowing artesian well located near the entrance to the property. Water flowing from the well has not been used by the current resident.
- A garden was not present at Residence 2; therefore, no garden soil or garden produce samples were collected.
- A pasture was not present at Residence 3; therefore, no pasture soil or vegetation samples were collected.
- The garden at Residence 3 had not been planted; however, a composite produce sample was collected from fruit trees on the property in place of garden produce.

3.1.8 Radiological Survey

Radiological measurements were collected at the three mine areas as specified in the FSP. In situ gamma-ray surveys were performed by using a Ludlum™ Model 2221 digital ratemeter/scaler coupled to a Ludlum™ Model 44-10 2x2 NaI(T1) detector. The location of each count rate measurement was recorded using a Trimble™ digital Global Positioning System (GPS). In addition, a correlation study was performed to facilitate interpretation of the gamma-ray count data in terms of soil concentrations of Ra-226 and uranium. As discussed in Section 3.1.1, radiological measurements were not collected in the reference areas because background measurements were readily obtained at each mine area.

3.1.9 Radon Monitoring

Alpha-track detectors (radon cups) were placed in each of the five mine adits; background areas at the Firefly/Pygmy Mine, Vanadium Queen Mine, and Blue Cap/Black Hat Mine Complex; and in the bathroom at each residence as specified in the FSP. In addition, one additional detector was placed in a second home present at Residence 3. The detectors were placed in April and May 2004 and collected in October 2004. Except for the detector placed in the Firefly/Pygmy adit which was damaged, all devices were in good condition when collected.

3.1.10 Benthic Macroinvertebrates

Benthic macroinvertebrate samples were collected at each of the three reference areas, as discussed above, and at surface-water sampling sites La Sal Creek DN 1 and La Sal Creek DN 3. However, the amount of benthic macroinvertebrates at the sample sites was not sufficient to allow collection of samples for chemical analysis. Benthic macroinvertebrate samples were collected for taxonomy analysis only. No benthic macroinvertebrates were present at the La Sal Creek DN 5 sample site.

3.2 Cultural Resource Inventory

A cultural resource inventory of the five mines was conducted by Alpine Archaeological Consultants, Inc. (Alpine) on February 24 and May 29-30, 2003. The work was conducted under the provisions of Utah BLM Cultural Resource Use Permit No. 03UT62700 and Colorado BLM Cultural Resource Use Permit No. C-46920. The objective of the inventory was to record and evaluate each mine and identify any prehistoric and historic resources in the vicinity of the mine that might be impacted by remediation. The inventory, evaluation, and identification goals were achieved by conducting a site file search to identify previously recorded cultural resources and by performing intensive pedestrian surveys of the mines and their vicinities.

Each mine area was assessed against the National Register criteria for evaluation. These criteria specify that the quality of significance in American History, architecture, engineering, archeology, and culture is present in districts, sites, buildings, structures, and objects of State and local importance that possess integrity of location, design, setting, materials, workmanship, feeling, and association, and

a) that are associated with events that have made a significant contribution to the broad patterns of our history; or

b) that are associated with the lives of persons significant in our past; or

c) that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinctive; or
d) that have yielded, or may be likely to yield, information important in prehistory or history.

Results of the inventory are reported in *Cultural Resource Inventory of Five Uranium Mine Along La Sal Creek – San Juan County, Utah and Montrose County, Colorado* (Alpine, 2003). The study found that

the Firefly/Pygmy, Vanadium Queen, Blue Cap, and the Black Hat Mines have sufficient integrity for their operations to be readily understood and interpreted, highly visible from public roads, and important components of the uranium mining landscape of the La Sal Creek area. Because the sites were prominent mines during the Cold War Period and contribute to the mining landscape, the study recommends the sites as eligible for inclusion on the National Register of Historic Places under criteria a and c. The study further found that the artifacts at the four mines are unremarkable and would not provide important information if recovered archaeologically, and therefore, the mines are not considered important under criterion d. The Saint Patrick Mine is not recommended as National Register-eligible because the site has little physical integrity, its method of operation was either very simple or is no longer evident, and it is not very visible as a feature of the mining landscape.

Based on the findings of the inventory, the study recommends that alteration of the physical characteristics that identify the Firefly/Pygmy, Vanadium Queen, Blue Cap, and Black Hat Mines as former mine sites and thereby making the sites significant should be avoided if possible. If alteration is necessary, documentation packages to Athearn's (1990) Level II standards should be prepared.

3.3 Assessment of Background Conditions

Background conditions were assessed in three reference areas: (1) Reference Area 1 along La Sal Creek, (2) Reference Area 2 along Twomile Creek, and (3) Reference Area 3 along Hop Creek (Figure 3.1). The goal for establishing each reference area was to locate the station in a similar geologic area where no mining or other disturbance has occurred. Specifically, an attempt was made to locate stations near the base of the Salt Wash Member of the Morrison Formation, the main uranium-bearing strata in the region.

3.3.1 Surface Water and Stream Sediment

At Reference Area 1 on La Sal Creek, outcrop of the Salt Wash Member was not present and this station was approximated in the field. The station is located approximately 200 feet upstream of the old mine camp road that trends north off of Utah Highway 46 above the first switchback before the highway descends into "La Sal Creek Canyon."

The Reference Area 2 station was established on Twomile Creek upstream of the upper-most waste rock dump of the Gray Daun Mine (mine is now reclaimed). This station was established in an extremely inconvenient location amongst large boulders that choke the canyon and stream bed. The boulders consist of Cretaceous Dakota Sandstone and Burro Canyon Sandstone that is probably part of a landslide.

Outcrop of the Salt Wash Member is plainly visible on both sides of the canyon just downstream from the boulder area. The station was selected at this location to avoid being adjacent to the upper-most waste-rock dump from the mine and not totally above the original location of the Salt Wash outcrop.

The Reference Area 3 station was established on Hop Creek at the base of a 60-foot fall of the Salt Wash Member outcrop. Because of a divergent channel at the base of this fall, discharge and field parameter measurements were made at the top of the falls where the channel was restricted and an accurate flow measurement was possible. Sample collection was conducted at the base of the falls, below the Salt Wash Member.

It is suspected that several of the springs identified in the vicinity of the mines have not been impacted by mine operations. Water-quality results for these springs may be more representative of background conditions than of mine-impacted waters. However, the analytical results for samples collected from springs are addressed as part of the surface-water discussions for the individual mines.

3.3.1.1 Discharge

All Reference Area streams were flowing during the months of April and October. Discharge rates and water quality data are shown in Table 3.1. The discharge data indicate that all Reference Area stations exhibited high flows in the spring and significantly lower flows in the fall. April flows at Reference Areas 1 and 2 are 2 to 4 times flows in October, while April flow at Reference Area 3 was two orders of magnitude greater than flow in October. The high April flows are attributed to spring runoff from snowmelt. Lower flows in the fall reflect base flow conditions and the release of groundwater storage to the stream.

Discharge measured at the Reference Areas stations are summarized in the following table:

Station	April Discharge (cfs)	October Discharge (cfs)
Ref Area 1 (La Sal Creek)	1.0800	0.4657
Ref Area 2 (Twomile Creek)	3.7500	0.9421
Ref Area 3 (Hop Creek)	1.9000	0.0134

3.3.1.2 Water Quality

The reference areas were established to provide background conditions that could be used for comparison to stations in the study area. The water quality screening levels designated in the FSP were primarily determined through the use of federal or state standards or risk-based levels. Several water quality parameters analyzed did not have associated federal or state standards or risk-based levels and, as described in the FSP, are to be compared to background or reference area concentrations. The data tables and narrative text in this section discuss the results of these comparisons. In addition, this subsection summarizes the water quality at each reference area and compares the reference area data to federal or state standards or risk-based levels.

Table 3.1 presents the water quality data for the reference areas and also shows the average concentrations for the three areas. The following information summarizes the reference area water quality:

- All reference area waters are of the calcium bicarbonate type.
- The pH screening level of 6.5 to 8.5 standard units (s.u.) is exceeded by all reference areas for the April data, ranging from 8.76 to 9.11, but ranges from 8.35 to 8.47 s.u. for the October data.
- The total dissolved solids (TDS) concentrations are low to moderately low and was consistently low at Ref Area 2 with values ranging from 140 to 150 mg/L in April and October, respectively; and 300 to 270 mg/L at Ref Area 1 and 140 to 330 mg/L at Ref Area 3.
- Analytes exceeding designated screening levels occur in the April data and include:
    - The April total phosphorous concentration of 0.13 mg/L exceeds the screening level of 0.05 mg/L at Reference Area 3;
    - The April total recoverable iron concentrations of 370 µg/L and 2,910 µg/L at Reference Areas 1 and 2, respectively, exceeds the screening level of 300 µg/L;
    - The April total manganese concentrations of 68 µg/L and 218 µg/L at Reference Areas 1 and 3, respectively, exceeds the screening level of 50 µg/L .
- The April gross alpha concentration of 19 picocuries per liter (pCi/L) exceeds the screening level of 15 pCi/L at Reference Area 3.

The above summary indicates that background water quality in the study area generally does not exceed screening levels established in the FSP, but that local variances exist where natural background concentrations of select parameters slightly exceed these screening levels.

3.3.1.3 Stream Sediment

One stream sediment sample was collected at the surface-water station for each reference area in October 2004. Table 3.2 presents analytical results for the stream sediment samples collected at the reference areas. The analytical results indicate that analyte levels did not exceed human health screening levels or the risk management criteria (RMC) for elk. A general comparison of sediment and water quality data suggest that a positive correlation may exist for some analytes including total uranium and manganese. However, it should be noted that any inferred correlation may be coincidental as correlations between chemical compositions of water and sediment in higher gradient streams is expected to be transient and highly dependent on stream conditions including sediment load. Dynamic events such as flash flooding within La Sal Creek or from intermittent tributaries may greatly affect this chemical relationship.

3.3.2 Soil

Three composite soil samples were collected within each reference area. Analytical results for the composite soil samples are presented in Table 3.3. As shown, arsenic was the only analyte reported at concentrations exceeding the human-health criteria or elk RMC. Arsenic concentrations slightly exceeded the human-health criterion of 12 mg/Kg in four of the nine samples collected from the reference areas. The highest arsenic concentration, 25.7 mg/Kg reported for sample C of Reference Area 2, exceeded the human-health criterion by a factor of 2.1. In general, analyte levels were generally consistent among the three reference areas. However, the average uranium and vanadium concentrations and average gross alpha, gross beta, and radium 226 activities were higher in the Reference Area 2 samples than in the samples collected at Reference Areas 1 and 3.

3.3.3 Vegetation

One composite grass, one composite forb, and one composite shrub sample were collected at Reference Area 3. Analytical results for the reference area vegetation samples are presented in Table 3.4. Except for radium 226, analyte levels among the three types of vegetation were generally consistent and within the same order of magnitude. The radium 226 activity reported for the background grass sample was approximately 28 times the level reported for the forb sample.

3.3.4 Benthic Macroinvertebrates

Benthic macroinvertebrate (macroinvertebrates) samples were collected in October 2004 from each of the three reference areas for taxonomic analysis. Samples from all representative habitats—riffle, run, pool, and bank—at each area were combined into one composite sample; in Table 3.5 are the results of the taxonomic analysis of each of the three reference area composite samples (see Appendix B). The metrics used to assess the benthic macroinvertebrate community at each station are explained as follows:

- EPT Index – The EPT index is the total number of distinct taxa within the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies). EPT index values generally increase with increasing (better) water quality. EPT index value summarize taxa richness for these insect orders which are generally considered to be pollution sensitive (Barbour et al. 1999).

- HBI – The Hilsenhoff Biotic Index (HBI) measures macroinvertebrate community responses to organic pollution. HBI values may range from 0 to 10, with higher values (generally >6) indicating higher degrees of organic pollution. The tolerance values used for the HBI calculations were as provided by Barbour et al. (1999).

- ICI – The Invertebrate Community Index (ICI) was included in the evaluation of macroinvertebrate data to provide an additional objective measure of biological condition at study sites. ICI values were calculated according to methods outlined by DeShon (1995). The ICI analysis involves scoring ten different metrics with the sum of these metrics providing the final index score. The metrics used include: 1) total number of taxa, 2) number of mayfly taxa, 3) number of caddisfly taxa, 4) number of dipteran taxa, 5) percent mayflies, 6) percent caddisflies, 7) percent of tribe Tanytarsini midges, 8) percent other dipteran and non-insects, 9) percent tolerant organisms, and 10) number of qualitative ET (Ephemeroptera and Trichoptera) taxa. Each of these metrics is given a score of 6, 4, 2, or 0 depending on the value derived from macroinvertebrate data for each station. For tolerant species designations, any species with an HBI rating of 8 or higher was considered tolerant. Individual metric scores were determined by comparing derived values with species area plots for the reference data versus drainage area. A score of 6 for a given metric indicates the metric value is within the range exhibited by very good or exceptional aquatic communities, a score of 4 indicates that the value is characteristic of more typical or good communities, a score of 2 indicates the value is moderately deviating from the expected range of good to exceptional values, and a score of 0 indicates the value is strongly deviating from expected good or exceptional values. Final ICI scores were calculated for each site, and may range from 0 to 60. Corresponding benthic community condition ratings developed for the ICI are: *exceptional* (46-60), *good* (36-45), *fair* (13-35), and *poor* (0-12) (DeShon 1995).

- B-IBI – The Benthic Index of Biotic Integrity (B-IBI, Fore, 2001) is used to determine the overall health of macroinvertebrate communities, and was especially developed for assessing the effects of metals in high elevation montane streams in Colorado. Metrics incorporated in the B-IBI include: total taxa (excluding chironomids), total mayfly taxa, total stonefly taxa, total caddisfly taxa, number of metal intolerant taxa, number of clinger taxa, and the percent of heptageniid mayflies. The quality ratings developed for this index as defined as: *poor* (7-16), *fair* (17-25), and *good* (26-35). B-IBI results are most reliable when the total number of organisms collected is greater than 250 (Fore 2001).

Reference Areas 1 (La Sal Creek) and 3 (Hop Creek) revealed macroinvertebrate communities that appear to be quite stressed. Organism densities were low at both areas—92 organisms/m^2 at Ref Area 1, and only 13 organisms/m^2 at Ref Area 3. Taxa richness was poor at both sites, at 10. Species diversity was very low (0.66) at Ref Area 1 and moderate (2.56) at Ref Area 3. Various indices designed to measure community response to organic pollution, environmental (especially metals) stress, and overall community health showed the macroinvertebrate communities at both Ref Areas 1 and 3 to be impaired. Poor physical habitat conditions (e.g., an absence of riffles, unsuitable substrates) and low flows likely are major factors limiting macroinvertebrate production at both areas.

Reference Area 2 (Twomile Creek) harbored the healthiest macroinvertebrate community of the three reference areas. Organism density was somewhat higher at 125 organisms/m^2, taxa richness was 28, and species diversity was relatively high (4.02). The community of this reference area proved to be the least affected by organic pollution and the least environmentally stressed. Major contributing factors supporting a healthy community at this site likely are the presence of riffles, good physical habitat conditions, and a more stable flow.

3.4 Perennial streams

Four perennial streams are located within the project area: (1) La Sal Creek, (2) Twomile Creek, (3) Hop Creek, and (4) Lion Canyon Creek. Surface-water and sediment samples were collected to assess conditions along the streams from the network of sampling location shown in Figures 3.2 (Firefly/Pygmy and Vanadium Queen Mine areas) and Figure 3.3 (Black Hat/Blue Cap Mine Complex area). Surface-water samples were collected at each station during high-flow conditions (April 2004) and low-flow conditions (October 2004). One co-located sediment sample was collected at each stream-sample station during low-flow conditions (October 2004). In addition to the surface water and stream sediment samples, benthic macroinvertebrate samples were collected for taxonomy analysis at two of the La Sal Creek stations.

3.4.1 La Sal Creek

The headwaters of La Sal Creek originate approximately 11.5 miles northwest of the study area in the La Sal Mountains (South Mountain, Mount Peale, and Mount Tukuhnikivatz) at elevations exceeding 11,000 feet amsl. At lower elevations several miles west of the study area, the stream is diverted for irrigation use to a series of ditches that supply the town of La Sal area. It is suspected that a significant portion of

the stream's flow is diverted, the bypass water flows east through the prominent canyon that defines the study area.

Surface water monitoring stations established on La Sal Creek, include, from an upstream to downstream direction:

- Ref Area 1 (upstream of the old mine camp road, elevation ~6,680 feet amsl)
- La Sal Crk Up (upstream of Firefly/Pygmy Mine road, elevation ~ 6,480 feet amsl)
- La Sal Crk Dn1 (downstream of dry tributary from Firefly/Pygmy Mine, elevation ~ 6,290 feet amsl)
- La Sal Crk Dn2 (downstream of Twomile Creek confluence, elevation ~ 6,110 feet amsl)
- La Sal Crk Dn3 (downstream of dry tributary stemming from Vanadium Queen Mine, elevation ~6,080 feet amsl)
- La Sal Crk Dn4 (upstream of Lion Canyon Creek confluence, elevation ~ 5,930 feet amsl)
- La Sal Crk Dn5 (downstream of Lion Canyon Creek confluence, elevation ~ 5,880 feet amsl)

3.4.1.1 Discharge

The elevations at the Reference Area 1 station and the La Sal Crk Dn5 station are approximately 6,480 feet and 5,580 feet amsl, an elevation difference of 600 feet. The average stream gradient between these stations is 0.034 (rise/run).

Discharge measured at the La Sal Creek stations are summarized in the following table:

Station	April Discharge (cfs)	October Discharge (cfs)
REF AREA 1	1.08	0.4657
LA SAL CRK UP	1.43	0.5123
LA SAL CRK DN1	1.04	0.4476
LA SAL CRK DN2	6.79	1.7126
LA SAL CRK DN3	6.68	2.0064
LA SAL CRK DN4	7.08	2.3400
LA SAL CRK DN5	7.65	2.9091

Discharge data collected at the 7 stations established on La Sal Creek in the study area show the stream to gain considerable flow from its upstream-most station to the downstream-most station below the confluence with Lion Canyon Creek (Figure 3.4). A large part of the gain observed in the April data, from 1.08 cfs to 7.65 cfs, is inflow from its tributaries, mostly Twomile Creek, just upstream from station La Sal Crk Dn2. The flow in Twomile Creek at station "Twomile Creek," just upstream of the confluence with La Sal Creek, was 5.68 cfs in April 2004 and accounts for virtually all of increase in flow in La Sal Creek measured at the next downstream station, La Sal Crk Dn3. The gain in flow between Twomile Creek and Lion Canyon Creek, about 0.4 cfs, can be attributed to the inflow of springs observed along this reach including those sampled in the vicinity of the Vanadium Queen Mine and the residence springs in the project area. A significant portion of the 0.6 cfs gain between stations La Sal Crk Dn4 and La Sal Crk Dn5 is inflow from Lion Canyon Creek.

Figure 3.4 shows that the October discharge data for La Sal Creek exhibits subdued trends that mirror the April data and emphasizes the flow contribution from Twomile Creek during spring runoff. A portion of the overall gain in the discharge in La Sal Creek within the study area is likely attributed to groundwater influence, i.e. influent stream conditions.

Observations during the October 2004 sampling event indicated that a flood event had occurred on La Sal Creek. Watermarks and debris deposition indicated that the flood stage was 2 to 4 feet above bank levels. It is not known what date the flood occurred.

3.4.1.2 Water Quality

The water quality data for stations established on La Sal Creek are shown in Table 3.6. Some parameters were not assigned a screening level that was a promulgated standard or calculated risk level. These parameters are identified by footnote number 4 in Table 3.6, and were assigned a screening level based on reference area (background) concentrations. The screening level given for these parameters is the average concentration of results for Reference Area 1, 2, and 3. In general, the following information summarizes water quality conditions in La Sal Creek:

- Water is of the calcium bicarbonate type.
- TDS concentrations are generally low, ranging from 160 to 340 mg/L. In general, a slight increase in TDS was apparent in the October samples.

- pH is relatively high (basic conditions) and in the April samples consistently exceeds the most restrictive screening level of 8.5 s.u. Only the La Sal Crk Dn1 station exceeded the 8.5 s.u. level in October with a measurement of 8.52 s.u. All other stations in October had pH values near 8.3 s.u. It should be noted that pH values at or below 9.0 s.u. do not exceed levels for aquatic life, agriculture, or recreation in La Sal Creek.

- The total phosphorous screening level of 0.05 mg/L was equaled at 4 stations at or downstream of La Sal Crk Dn1 in the April samples, and exceeded at stations La Sal Crk Dn3 and La Sal Crk Dn4 in the October samples. The La Sal Crk Dn4 sample had a concentration over 100 times the screening level.

- The total suspended solids screening level of 35 mg/L was exceeded in the October sample at station La Sal Creek Dn4 with a concentration of 116 mg/L.

- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, calcium, magnesium, potassium, sodium, uranium, vanadium, and total vanadium, and combined thorium-230 and thorium-232. Concentrations of these parameters exceeded reference area concentrations at several stations by less than an order of magnitude:

    - The dissolved barium concentrations slightly exceeded the reference level concentration of 127 µg/L (April and October) at all stations (in April only for stations La Sal Crk Dn1 – Dn3) except La Sal Crk Up and had a consistent slight increasing trend in downstream stations.
    - The dissolved calcium concentrations exceeded the reference level concentrations of 45,667 (April) and 52,467 (October) µg/L at the upper stations of Ref Area 1, La Sal Crk Up and Dn1 with a maximum concentration of 67,000 µg/L.
    - The dissolved magnesium concentrations exceeded the reference level concentrations of 8,800 (April) and 10,233 (October) µg/L at all stations except La Sal Crk Dn2 and Dn3 with a maximum concentration of 19,400 µg/L.
    - The dissolved potassium concentrations exceeded the reference level April concentration of 2,300 µg/L at stations La Sal Crk Dn1 and Dn4 with a maximum concentration of 2,400 µg/L.
    - The dissolved sodium concentrations exceeded the reference level concentrations of 12,200 (April) and 21,000 (October) µg/L at the upper stations of Ref Area 1, La Sal Crk Up and Dn1 with a maximum concentration of 30,400 µg/L at the Dn1 station.
    - The dissolved uranium concentrations exceeded the reference level concentrations of 2.56 (April) and 3.69 (October) µg/L at all stations with concentrations ranging from 4.1 to 17 µg/L. No discernable trend was evident.
    - Dissolved vanadium concentrations exceeded the screening level concentration of 5 µg/L at the La Sal Crk Dn1 station with a concentration of 21 µg/L for the April sample.
    - Total vanadium slightly exceeded the screening level concentrations of 4.3 (April) and 2.5 (October) µg/L at stations La Sal Crk Dn4 (April only) and La Sal Crk Dn5 with concentrations of 5, 6 and 7 µg/L.
    - Combined thorium-230/thorium-232 concentrations exceeded the reference area concentrations of 0.06 (April) and 0.02 (October) pCi/L by an order of magnitude in all stations with exception of station Ref Area 1. April samples exceeded reference area concentrations at all stations except La Sal Crk Dn3. October samples exceeded concentrations at stations La Sal Crk Up, Dn2, Dn3, and Dn5. La Sal Crk Dn5 station had the greatest concentration at 2.39 pCi/L.

- Thorium 228 concentrations exceeded the October reference area concentration of 0 (zero) pCi/L at stations La Sal Crk Dn1-Dn4, with the greatest concentration being 0.18 at station La Sal Crk Dn2.

- Metals exceeding promulgated or risk-based screening levels include total recoverable iron, dissolved and total and manganese:

  - Total recoverable iron concentrations exceed the screening level of 300 µg/L at all stations except Ref Area 1; concentrations are 2 to almost 4 times the screening level with no obvious trend. With exception of stations La Sal Crk Up and Dn1, exceeding concentrations were in the April samples.
  - Total manganese concentrations exceed the screening level of 50 µg/L at all stations, ranging from 27 to 97 µg/L with no obvious trend. Similar to total recoverable iron, with exception of stations La Sal Crk Up and Dn1, exceeding concentrations were in the April samples.
  - Dissolved manganese concentrations exceed the 50 µg/L screening level at station La Sal Crk Dn 1 with a concentration of 88 µg/L in the April sample.

- The gross alpha screening level of 15 pCi/L was slightly exceeded at the La Sal Crk Dn1 station (15.8 pCi/L), just downstream of the Firefly-Pygmy Mine tributary in the April sample, and at was twice the screening level at station La Sal Crk Dn5 in the October sample with a concentration of 30.3 pCi/L. With exception of the La Sal Crk Dn1 station, the October concentrations were greater than April concentrations.

- An increase in concentrations of several other ions or parameters was evident at the La Sal Crk Dn1 station. Examples include total suspended solids and most radiological parameters.

- A dilution affect from the Twomile Creek inflow is evident at station La Sal Crk Dn2 where concentrations of common ions [e.g. chloride, sulfate, TDS] and some metals (calcium, iron, magnesium, manganese, sodium, uranium and vanadium) decrease from results in upstream stations.

In addition to surface-water and sediment samples, benthic macroinvertebrate samples were also collected at La Sal Creek DN1 and La Sal Creek DN2 sampling sites for taxonomy analysis. Numerous attempts were made to also collect samples at the La Sal Creek DN5 sampling site. However, no samples could be collected, and it was concluded that benthic macroinvertebrates were generally absent in this reach of La Sal Creek.

The general lack of benthic macroinvertebrates at the La Sal Creek DN5 site suggests that the health of the stream along this reach has been adversely impacted. Possible sources for such impacts could include mine-derived contamination, contamination resulting from non-mining activities (e.g., grazing and agricultural operations), and occasional overbank flood events. Numerous cattle tracks and droppings along the reach and on the private land immediately upstream of the sample site indicated that extensive cattle grazing had recently occurred in the area. It was also noted during the sampling event that an

overbank flood had recently occurred along the Lion Canyon Creek drainage which enters La Sal Creek just upstream of the sampled reach.

3.4.1.3 Stream Sediment

One sediment sample was collected at each surface water station established on La Sal Creek. Table 3.7 presents the analytical results for the stream sediment samples. The analytical results generally indicate that the radiological parameters of gross alpha, gross beta, radium-226, radium-228, thorium-228, thorium-230, and thorium-232, for some samples exceed human health screening levels or the RMC for elk. In addition, sediment from station La Sal Crk Dn1 exceeded the RMC lead concentration (127 mg/Kg) for elk with a concentration 141 mg/Kg.

The analytical results are summarized as follows:

- The gross alpha concentrations exceed the human health screening level concentration of 7.8 pCi/L at all stations except La Sal Crk Up and Dn2. Concentrations ranged from 9.24 pCi/L at station La Sal Crk Up to 89.8 pCi/L at station La Sal Crk Dn1.

- The gross beta concentrations exceed the human health screening level concentration of 10.2 pCi/L at all stations except La Sal Crk Dn2 and Dn3. Concentrations ranged from 10.4 pCi/L at station La Sal Crk Up to 45.4 pCi/L at station La Sal Crk Dn1.

- The radium-226 concentrations exceed the human health screening level concentration of 0.5 pCi/L at all stations except La Sal Crk Up. Concentrations ranged from 1.13 pCi/L at station La Sal Crk Dn3 (Dup) to 19.5 pCi/L at station La Sal Crk Dn1.
- The radium-228 concentrations exceed the human health screening level concentration of 1.1 pCi/L at all stations. Concentrations ranged from 1.2 pCi/L at station La Sal Crk Dn3 to 2.62 pCi/L at station La Sal Crk Dn5.

- The thorium-228 concentrations exceed the human health screening level concentration of 0.47 pCi/L at stations La Sal Crk Dn4 and Dn5. Concentrations ranged from 0.62 pCi/L at station La Sal Crk DN5 to 0.76 pCi/L at station La Sal Crk Dn4.

- The thorium-230 concentrations exceed the human health screening level concentration of 0.35 pCi/L at all stations except La Sal Crk Dn2. Concentrations ranged from 0.38 pCi/L at station La Sal Crk DN3(Dup) to 20.6 pCi/L at station La Sal Crk Dn1.

- The thorium-232 concentrations exceed the human health screening level concentration of 0.61 pCi/L at stations La Sal Crk Dn1 and Dn4. Concentrations ranged from 0.79 pCi/L at station La Sal Crk Dn4 to 0.81 pCi/L at station La Sal Crk Dn1.

- As indicated in the above summary, the station showing consistently high concentrations of radiological analytes is La Sal Crk Dn1. Stations La Sal Crk Dn4 and Dn5 have the second highest concentrations of radiological analytes.

- Relative to each other, the data results generally show moderate to high levels at the La Sal Crk Up and Dn1 stations, moderate to low concentrations at stations La Sal Crk Dn2 and Dn3, and moderate to high concentrations again at stations La Sal Crk Dn4 and Dn5.

A visual comparison of the sediment and water quality analytical results does not show a correlation for the sediment lead results as the water data was below detection for lead. A general comparison of sediment and water quality data suggest that a positive correlation may exist for stations with the higher concentrations of gross alpha and thorium-230 and thorium-232.

3.4.1.4 Benthic Macroinvertebrates

Benthic macroinvertebrate (macroinvertebrates) samples were collected in October 2004 from each of two sites—La Sal Ck Dn1, downstream of the abandoned Firefly/Pygmy Mine, and La Sal Dn3, downstream of the Vanadium Queen Mine—for taxonomic analysis. Samples from all representative habitats—riffle, run, pool, and bank—at each area were combined into one composite sample; Table 3.5 contains the results of the taxonomic analysis of each of the two sites' composite samples (see Appendix B).

Sites La Sal Ck Dn1 and La Sal Ck Dn3 revealed macroinvertebrate communities that appear to be moderately stressed. Organism densities were 108 organisms/m^2 at La Sal Ck Dn1, but only 37 organisms/m^2 at La Sal Ck Dn3. Taxa richness was moderate at both sites at 22 and 21, respectively, as was species diversity at 2.88 and 3.32, respectively. Various indices designed to measure community response to organic pollution, environmental (especially metals) stress, and overall community health showed the macroinvertebrate communities at both sites to be somewhat impaired—more productive than at Ref Areas 1 and 3, but less productive than Ref Area 2. Poor physical habitat conditions (e.g., channelization; high-energy, bottom-scouring flows) likely are major factors limiting macroinvertebrate production, particularly at La Sal Ck Dn3.

3.4.2 Twomile Creek

Twomile Creek originates 11 miles to the north-northwest at an elevation of approximately 9,500 feet amsl on the west flank of Mount Peale. USGS quadrangle maps indicate a portion of the flow of the stream is diverted at an elevation of 8,440 feet amsl to a ditch system that supplies the Old La Sal area.

Surface water monitoring stations established on Twomile Creek, include, from an upstream to downstream direction:

- Ref Area 2 (in boulder falls upstream of the Gray Daun Mine, elevation ~ 6,650 feet amsl)
- Twomile Creek (on Riley residence property upstream of confluence with La Sal Creek, elevation ~ 6,120 feet amsl)

3.4.2.1 Discharge

The elevations at station Ref Area 2 and station Twomile Creek are approximately 6,650 feet and 6,120 feet amsl, respectively, an elevation difference of 530 feet. The stations are approximately 0.9 miles apart, resulting in an average stream gradient between these stations of 0.11 (rise/run).

Discharge measured at the Twomile Creek stations are summarized in the following table:

Station	April Discharge (cfs)	October Discharge (cfs)
Ref Area 2	3.75	0.9421
Twomile Creek	5.68	0.79775

Twomile Creek consistently exhibited the highest flows of all perennial streams tributary to La Sal Creek in the study area (Table 3.8). Discharge measurement data collected on Twomile Creek at Reference Area 2, at an elevation of approximately 6,650 feet amsl, just upstream of the Gray Daun Mine, and at station Twomile Creek just upstream from its confluence with La Sal Creek, show a 2 cfs increase in April and a 0.14 decrease in the October over this reach. April flows were 4 to 7 times the volume of October flows.

The decrease in flow magnitude from April to October is mostly attributed to the lack of runoff associated with snow melt at higher elevations in the fall. October flows generally reflect base flow conditions; i.e. a higher percentage of flow is from influent groundwater. The April gain in flow from the Reference Area 2 station on Twomile Creek to the Twomile Creek station at the confluence of La Sal Creek is likely due to higher groundwater levels in the area at this time and augmented flow from area springs at higher elevations. The loss of flow from the Reference Area 2 station to the Twomile Creek station implies an effluent condition whereby groundwater storage is being recharged along the streams reach.

3.4.2.2 Water Quality

The water quality data for stations established on Twomile Creek are shown in Table 3.8. Some parameters were not assigned a screening level that was a promulgated standard or calculated risk level. These parameters are identified by footnote number 4 in Table 3.8, and were assigned a screening level based on reference area (background) concentrations. The screening level given for these parameters is the average concentration of results for Reference Area 1, 2, and 3. The following information summarizes water quality conditions in Twomile Creek:

- Water is of the calcium bicarbonate type.

- TDS concentrations are generally low, ranging from 140 at station Ref Area 2 to 300 mg/L at station Twomile Creek. With exception of the 300 mg/L analysis in April, all other results range between 140 and 160 mg/L for both the Ref Area 2 and Twomile Creek stations.

- pH values are basic from 8.35 and 9.0 s.u. at the Twomile Creek station and 8.9 and 8.42 s.u. at the Ref Area 2 station for the April and October samples, respectively. Both stations exceed the most restrictive screening level of 8.5 s.u. It should be noted that pH values at or below 9.0 s.u. do not exceed levels for aquatic life, agriculture, or recreation in La Sal Creek.

- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, combined thorium-230/thorium-232 and thorium-228.

    - The dissolved barium concentration slightly exceeded the reference level concentration of 127 µg/L in the April samples with concentrations of 146 and 145 µg/L at stations Ref Area 2 and Twomile Creek, respectively.
    - Combined thorium-230 and thorium-232 concentrations exceeded the April reference level concentration of 0.06 pCi/l at station Twomile Creek with a concentration of 0.24 pCi/L, and the October reference level concentration of 0.02 pCi/L with concentrations of 0.05 and 0.13 pCi/L at station Twomile Creek, respectively.
    - Thorium-228 concentrations exceeded the October reference level concentration of 0 (zero) pCi/l at station Twomile Creek with concentrations of 0.07 and 0.03 (duplicate sample) pCi/L.

- Metals exceeding promulgated or risk-based screening levels include total recoverable iron, total manganese.
    - Total recoverable iron concentrations exceeded the reference level concentration of 300 µg/L in the April samples with concentrations of 370 and 1,190 µg/L at stations Ref Area 2 and Twomile Creek, respectively.
    - Total manganese concentrations exceeded the reference level concentration of 50 µg/L in the April sample with a concentration of 87 µg/L at station Twomile Creek.

- Despite an increase in measured discharge, the overall water quality does not change significantly between the Ref Area 2 and Twomile Creek stations, with the exception of TDS which increases from 140 to 300 mg/L in April and total and dissolved uranium. The increase in TDS may be partially attributed to anions of sulfate and chloride. A potential reason for this is groundwater influx to Twomile Creek that is of moderate quality. The increase in uranium may be related to

natural sources or mining influences from the Gray Daun Mine in the Twomile Creek drainage. In addition, water quality is not significantly different in time (between April and October).

3.4.2.3 Stream Sediment

One sediment sample and a duplicate sample were collected at the surface water station established on Twomile Creek. Analytical results for the stream sediment samples are presented in Table 3.9. The analytical results show that the only parameter that exceeds the human health screening levels is radium-228. The concentration of radium-228 in the sediment samples were 2.35 and 1.42 pCi/L for the sample and duplicate sample, respectively, compared to a reference area average of 1.09 pCi/L.

3.4.3 Hop Creek

Hop Creek originates 10.5 miles to the north-northwest at an elevation of approximately 9,000 feet amsl on the west flank of Mount Peale. The stream has been mapped as intermittent on USGS quadrangle maps. During the site characterization study, some discharge was present at both stations established on this stream. The stream gradient between the two sampling stations on Hop Creek, Hop Crk Dn at an elevation of 6,180 feet amsl, and Ref Area 3 at an elevation of 6,440 feet amsl, is 0.18 (rise/run).

Surface water monitoring stations established on Hop Creek, include, from an upstream to downstream direction:

- Ref Area 3 (at base of 60 feet falls north of Vanadium Queen Mine, elevation ~ 6,560 feet amsl)
- Hop Crk Dn (upstream of confluence with Twomile Creek, elevation ~ 6,180 feet amsl)

3.4.3.1 Discharge

Hop Creek was flowing during both the April and October sampling events. Discharge rates are shown in Table 3.8. The data indicate that discharge in Hop Creek is dependent on seasonal runoff. Flows in April at both the Hop Crk Dn and Ref Area 3 stations are two orders of magnitude greater than flows in October. The high April flows are attributed to spring runoff from snowmelt. Lower flows in the fall reflect base flow conditions and the release of groundwater storage to the stream.
Discharge measured at the Hop Creek stations are summarized in the following table:

Station	April Discharge (cfs)	October Discharge (cfs)

Ref Area 3	1.90	0.0134
Hop Crk Dn	1.84	0.0263

The difference in flows between stations during a single sampling time are minimal, and probably within the margin of error inherent to the flow measurement methods. However, the minute amount of indicated loss between stations during high flow and gain between stations during low flow is consistent with the hypothesis that the high flow stream loses some flow to bank storage and the low flow stream gains some flow from groundwater storage along the reach. The significant difference in discharge magnitude between April and October measurements is attributed to runoff from snow melt during the spring months.

3.4.3.2 Water Quality

The water quality data for stations established on Hop Creek are shown in Table 3.8. Some parameters were not assigned a screening level that was a promulgated standard or calculated risk level. These parameters are identified by footnote number 4 in Table 3.8, and were assigned a screening level based on reference area (background) concentrations. The screening level given for these parameters is the average concentration of results from Reference Areas 1, 2, and 3. The following information summarizes water quality conditions in Hop Creek:

- Water is of the calcium bicarbonate type.
- pH values are basic from 8.76 s.u. at station Ref Area 3 to 8.98 s.u. at the Hop Crk Dn station. Both April values exceed the most restrictive screening level of 8.5 s.u. October pH is approximately 8.3 s.u. It should be noted that pH values at or below 9.0 s.u. do not exceed levels for aquatic life, agriculture, or recreation in La Sal Creek.
- TDS concentrations range from 140 to 330 mg/L at station Ref Area 3 for April and October samples, respectively; and 150 to 230 mg/L at station Hop Crk Dn for April and October samples, respectively.
- The total phosphorous screening level concentration of 0.05 mg/L was slightly exceeded (0.13 mg/L) at Ref Area 3 and Hop Crk Dn stations in the April samples.
- The total suspended solids screening level concentration of 35 mg/L was exceeded in April samples at both Ref Area 3 and Hop Crk Dn with concentrations of 326 mg/L and 138 mg/L, respectively. October concentrations were low, only 8 and 6 mg/L. The April suspended solids concentrations are among the highest in the study area. The results indicate that the cause for the

suspended solids concentration is upstream of the reference area sampling station and not an impact from mining activities in the area.

- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, calcium, magnesium, potassium, sodium, and uranium, total vanadium, combined thorium-230/thorium-232, and thorium-228.

    - The dissolved barium April and October screening level concentration of 127 mg/L was exceeded at both the Ref Area 3 and Hop Crk Dn stations for 3 of the 4 samples collected, ranging from 128 to 177µg/L, the higher concentrations being from the October samples.
    - The dissolved calcium October screening level concentration of 52,467 µg/L was exceeded at station Ref Area 3 with a concentration of 64,400 µg/L.
    - The dissolved magnesium October screening level concentration of 10,233 µg/L was exceeded at both stations Ref Area 3 and Hop Crk Dn with concentrations of 11,700 and 15,000 µg/L, respectively.
    - The dissolved potassium screening levels concentrations of 2,300 µg/L for April and 3,800 µg/L for October were exceeded at both stations Ref Area 3 and Hop Crk Dn with concentrations ranging from 3,100 to 7,600 µg/L.
    - The dissolved sodium October screening level concentration of 21,000 µg/L was exceeded at station Ref Area 3 with a concentration of 39,200 µg/L.
    - The dissolved uranium screening level concentrations of 2.56 µg/L for April and 3.69 µg/L for October were exceeded at station Hop Crk Dn with concentrations of 3.97 and 14.8 µg/L, respectively.
    - The total vanadium screening level concentration of 4.3 µg/L for April was exceeded at both stations Ref Area 3 and Hop Crk Dn with concentrations of 8 and 7 (both B qualified) µg/L. October samples were below detection.
    - The thorium-230/thorium-232 combined screening level concentrations of 0.06 pCi/L for April and 0.02 pCi/L for October, were exceeded at both stations Ref Area 3 and Hop Crk Dn in April with concentrations of 0.11 and 0.32 pCi/L, respectively; and 0.18 pCi/L in the October sample of station Hop Crk Dn.
    - The thorium-228 screening level concentration of 0.15 pCi/L for April was exceeded at the Ref Area 3 station with a concentration of 0.36 pCi/L.

- Metals exceeding promulgated or risk-based screening levels include total recoverable iron and total manganese:

    - The total recoverable iron screening level concentration of 300 µg/L was exceeded in 3 of the 4 samples collected with concentrations ranging from 420 to 3,170 µg/L in the October and April samples, respectively, at station Hop Crk Dn; and 2,910 µg/L in the April sample at Ref Area 3 station.
    - The total manganese screening level concentration of 50 µg/L was exceeded in 3 of the 4 samples collected with concentrations ranging from 147 to 253 µg/L in the October and April samples, respectively, at station Hop Crk Dn; and 218 µg/L in the April sample at Ref Area 3 station.

- The gross alpha concentration for the April sample at the Ref Area 3 station is 19 pCi/L and slightly exceeds the screening level of 15 pCi/L.

- Overall, there is slight indication that the October analyte concentrations are greater than April concentrations, but not a consistent difference in water quality between the Ref Area 3 station and the Hop Crk Dn station.

3.4.3.3 Stream Sediment

One sediment sample was collected at the surface water station established on Hop Creek. Analytical results for the stream sediment samples are presented in Table 3.9. The analytical results show that the only parameter that exceeds the human health screening levels is radium-228. The concentration of radium-228 in the sediment sample was 2.56 pCi/L, compared to a screening level (reference area average) of 1.09 pCi/L.

3.4.4 Lion Canyon Creek

The upper watershed for Lion Canyon Creek includes the three drainages of Dry Draw, Trinity Draw, and State Line Draw. These drainages have been mapped as intermittent on the U.S. Geological Survey (USGS) quadrangle and originate approximately 4 miles north of the Black Hat Mine on a prominent ridge that forms the north boundary of the upper watershed of Hop Creek.

Surface water monitoring stations established on Lion Canyon Creek, include, from an upstream to downstream direction:

- Lion Cyn Ck Up (upstream of confluence with Black Hat Spring drainage, elevation ~ 6,420 feet amsl)
- Lion Cyn Ck Dn1 (upstream of creek crossing of mine access road, elevation ~6,320 feet amsl)
- Lion Cyn Ck Dn2 (at BLM and private property boundary, elevation ~5,981 feet amsl)

3.4.4.1 Discharge

Lion Canyon Creek has exhibited perennial flow conditions throughout the life of the project. Numerous springs and seeps located throughout the canyon augment flow of the stream. Flow originates as mine drainage from the Blue Cap Mine portal at an elevation of approximately 6,510 feet amsl and gains considerably before the confluence with La Sal Creek at an elevation of approximately 5,950 feet amsl. The average gradient of the stream over this reach is 0.14. No natural flow in the drainage at elevations above the mine has been observed.

Discharge measured at the Lion Canyon Creek stations are summarized in the following table:

Station	April Discharge		October Discharge	
	cfs	gpm	cfs	gpm
Lion Cyn Ck Up	0.0013	0.58	0.002308	1.04
Lion Cyn Ck Dn1	0.01565	7.02	~ 0.014006	6.29
Lion Cyn Ck Dn2	0.201194	90.30	0.039321	17.65

Discharge measurements on Lion Canyon Creek were conducted with a bucket and stopwatch at suitable falls near each established sampling station. These measurements are accurate if all visible surficial flow can be captured. The results of measurements shown in Table 3.10, where the major portion but not all of the flow was captured during measurement, are indicated with a "~" symbol adjacent to the flow value.

The measured flow from the Blue Cap Mine is small, less than 2 gpm (0.0013 cfs) and becomes partially dispersed or infiltrates before reaching station Lion Cyn Ck Up, which is located in the Lion Canyon Creek drainage below the main Blue Cap Mine dump and upstream of the inflow from Black Hat Spring. On the basis of established stations, Lion Canyon Creek shows consistent gains in flow downstream for the April data; from 0.6 gpm at station Lion Cyn Ck Up to 90 gpm (0.2 cfs) at station Lion Cyn Ck Dn2, near the BLM/private property boundary. The opposite is apparent in the October data where flow drops from 1.04 gpm (0.002308 cfs) at station Lion Cyn Ck Up to 17.6 gpm (0.0393 cfs) at station Lion Cyn Ck-Dn2.

The April data gain in flow from the station Lion Cyn Ck Up to station Lion Cyn Ck Dn2 is likely due to higher groundwater levels in the area at this time and influent conditions, augmented by surface flow from area springs at higher elevations. In the spring months, it is probable that the stream gains additional flow in the lower canyon as several springs and seeps have been observed in the Mesozoic strata of this area. The loss of flow from the Lion Cyn Ck Up station to the Lion Cyn Ck Dn2 station implies an effluent condition whereby groundwater storage is being recharged along the stream's reach.

Observations during the October 2004 sampling event indicated that a flood event had occurred on Lion Canyon Creek. Watermarks and debris deposition indicated that the flood stage was 2 to 4 feet above bank levels. Erosion in upper Lion Canyon Creek included areas of waste rock from the toe of the Blue Cap Mine dump. It is not known what date the flood occurred.

3.4.4.2 Water Quality

The water quality data for stations established on Lion Canyon Creek are shown in Table 3.10. Some parameters were not assigned a screening level that was a promulgated standard or calculated risk level. These parameters are identified by footnote number 4 in Table 3.10, and were assigned a screening level based on reference area (background) concentrations. The screening level given for these parameters is the average concentration of Reference Areas 1, 2, and 3. The following information summarizes water quality conditions in Lion Canyon Creek:

- Water is of the sodium bicarbonate type for stations in the upper part of the canyon, whereas water analyzed at station Lion Cyn Ck Dn2 is of a calcium bicarbonate type.

- TDS concentrations are generally moderate, ranging from 170 mg/L at station Lion Cyn Ck Dn2 to 460 mg/L at station Lion Cyn Ck Up. TDS concentrations are consistent between sampling events. The upstream stations are significantly greater than TDS at the downstream-most station.

- pH values are moderately basic from 8.23 at station Lion Cyn Ck Up to 8.89 at the Lion Cyn Ck-Dn1 station. The pH for both the April and October measurements at station Lion Cyn Ck Dn1 exceed the most restrictive screening level of 8.5 s.u. It should be noted that pH values at or below 9.0 s.u. do not exceed levels for aquatic life, agriculture, or recreation in La Sal Creek.

- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, magnesium, molybdenum, potassium, sodium, uranium, dissolved and total vanadium and combined thorium 230/thorium-232. Some concentrations of these metals exceeded the reference area concentration by up to 3 orders of magnitude.

    - The dissolved barium screening level concentration of 127 µg/L was exceeded at stations Lion Cyn Ck Dn1 and Dn2 ranging from 131 to 214 µg/L in both April and October samples. Lion Cyn Ck Dn2 had barium concentrations almost twice that of the upper stations.
    - The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233 µg/L for October were exceeded at all stations for all sampling events, with concentrations ranging from 11,100 to 20,400 µg/L.
    - The dissolved molybdenum screening level concentration of 5 µg/L for April and October was exceeded at all stations for all sampling events, with concentrations ranging from 10 to 190 µg/L. Station Lion Cyn Ck Dn2 had the lowest concentrations of 10 and 20 µg/L, an order of magnitude less than the other station concentrations.
    - The dissolved potassium screening level concentrations of 2,300 µg/L for April and 3,800 µg/L for October were exceeded at stations Lion Cyn Ck Up and Dn1 for all sampling events, with concentrations ranging from 8,200 to 9,200 µg/L. Station Lion Cyn Ck Dn2 concentrations were at or below 2,300 µg/L.
    - The dissolved sodium screening level concentrations of 12,200 µg/L for April and 21,000 µg/L for October were exceeded at stations Lion Cyn Ck Up and Dn1. Concentrations ranged from 86,500 to132,000 µg/L, the highest sodium concentrations in the project area. Station Lion Cyn Ck Dn2 concentrations were 14,100 µg/L.

- The dissolved uranium screening level concentrations of 2.56 µg/L for April and 3.69 µg/L for October were exceeded at all stations for both sampling events, with concentrations ranging from 97.2 to 1,200 µg/L.
- The dissolved and total vanadium screening level concentrations of 2.5 µg/L (dissolved April and October) and 4.3 and 2.5 µg/L (total, April and October), were exceeded at all stations for both sampling events. Concentrations ranged from 53 to 630 µg/L, with the lower concentrations being associated with the downstream station of Lion Cyn Ck Dn2.
- The combined thorium 230/thorium-232 screening level concentrations of 0.06 pCi/L for April and 0.02 pCi/L for October were exceeded at stations Lion Cyn Ck Up in April and Lion Cyn Ck Dn1 in April and October with concentrations ranging from 0.55 to 1.17 pCi/L.

- Metals exceeding promulgated or risk-based screening levels include total recoverable arsenic and iron, total and dissolved manganese, total molybdenum, total and dissolved selenium, and total uranium.

  - The total recoverable arsenic screening level concentration of 10 µg/L is exceeded at stations Lion Cyn Ck Up and Dn1 in both the April and October samples with concentrations ranging from 28.3 to 44.7 µg/L. Station Lion Cyn Ck Dn2 had concentrations of the order of 5 µg/L. Concentrations do not vary significantly with sampling time.
  - The total recoverable iron screening level concentration of 300 was exceeded at all stations for one sampling event; the event time varied. Exceeding concentrations ranged from 340 to 610 µg/L.
  - The total and dissolved manganese screening level of 50 µg/L was exceeded in April and October in station Lion Cyn Ck Dn2 with concentrations ranging from 57 to 90 µg/L.
  - The total molybdenum screening level concentration of 100 µg/L was exceeded by up to 80 µg/L in the upstream stations of Lion Cyn Ck Up and Dn1 in both April and October. Concentrations decrease to undetectable concentrations at station Lion Cyn Ck Dn2.
  - The total and dissolved selenium screening level of 4.6 and 10 µg/L were exceeded at all stations at all times, with concentrations ranging from 9 to 330 µg/L. Concentrations decrease significantly in a downstream direction.
  - The total uranium screening level concentration of 30 µg/L was exceeded at all stations at all times, with concentrations ranging from 114 to 1240 µg/L. Concentrations decrease significantly in a downstream direction.

- The gross alpha screening level concentration of 15 pCi/L was exceeded at all stations for both sampling events, with concentrations ranging from 94.8 to 691 pCi/L.

- The gross beta screening level concentration of 50 pCi/L was exceeded at stations Lion Cyn Ck Up and Dn1 for both sampling events with concentrations ranging from 136 to 239 pCi/L.

- The combined radium-226/radium-228 screening level concentration of 5.0 pCi/L was exceeded at all stations and sampling times with exception of the April sample at station Lion Cyn Ck Dn2. Exceeding concentrations ranged from 7.15 to 14.48 pCi/L.

- In general, Lion Canyon Creek exhibits the poorest overall water quality in the study area but shows a pronounced increase in quality in the downstream direction. Most notably at the downstream-most station, Lion Cyn Ck Dn2.

- TDS, sulfate, potassium, sodium, gross alpha, gross beta, and combined radium-226/radium-228 concentrations are significantly less at this downstream station.
- Analytes that still exceed a reference area concentration at station Lion Cyn Ck Dn2 include dissolved barium, magnesium, molybdenum, uranium, vanadium, and total vanadium.
- Total recoverable iron, dissolved and total manganese and selenium, total uranium, gross alpha and combined radium-226 and radium-228 concentrations exceed promulgated or risk-based screening levels at station Lion Cyn Ck Dn2.

- There is no apparent trend in concentration versus sampling event.

3.4.4.3 Stream Sediment

One sediment sample was collected at each surface water station established on Lion Canyon Creek. Analytical results for the stream sediment samples are presented in Table 3.11; the negative values reported for thorium-228 and 230 are a function of the analytical procedure whereby the area of interest is subtracted from background for each detector. The analytical results show that the only metal exceeding the human health screening levels is arsenic with a concentration of 13.8 µg/L at station Lion Cyn Ck Up, slightly greater than the screening level of 12 µg/L. The results also show that several radiological parameters exceed the screening levels developed by averaging the concentration from the three reference areas sediment samples. These include the following:

- Gross alpha concentrations exceed the screening level concentration of 7.78 pCi/L at all three Lion Canyon Creek stations with concentrations ranging from 49.6 to 325 pCi/L.

- Gross beta concentrations exceed the screening level concentration of 10.16 pCi/L at all three Lion Canyon Creek stations with concentrations ranging from 24.6 to 157 pCi/L.

- Radium-226 concentrations exceed the screening level concentration of 0.79 pCi/L at all three Lion Canyon Creek stations with concentrations ranging from 0.84 to 45.2 pCi/L.

- Radium-228 concentrations exceed the screening level concentration of 1.09 pCi/L at all three Lion Canyon Creek stations with concentrations ranging from 1.12 to 2.33 pCi/L.

- Thorium-228 concentrations exceed the screening level concentration of 0.47 pCi/L at station Lion Cyn Ck Up with concentrations of 0.6 pCi/L.

- Thorium-230 concentrations exceed the screening level concentration of 0.35 pCi/L at all three Lion Canyon Creek stations with concentrations ranging from 7.96 to 45.8 pCi/L.

In all cases, the downstream station Lion Cyn Ck Dn2 had concentrations that were 1 to 2 orders of magnitude less than the upstream stations of Lion Cyn Ck Up and Lion Cyn Ck Dn1.

3.5 Residences

Site characterization at each the three residences located within the project area included collection of water samples from springs used for domestic purposes and soil and vegetation samples from garden areas and pastures (if present). In addition, alpha-track detectors were used to assess radon levels in each home. The locations of the residences are shown in Figure 3.5.

Water quality data for spring stations established for residences are shown in Table 3.12. The data in Table 3.12 indicate that the Residence stations have the best water quality within the project area. In general, the measured field parameters for April and October did not vary greatly at each station indicating relatively stable water quality.

3.5.1 Residence 1

Residence 1 is occupied on a year-round basis, and the current resident has lived there for many years. The domestic water is supplied to the residence by a spring located adjacent to the home, at an elevation of 6,201 feet amsl.

Water emanating from the domestic spring at Residence 1 was sampled in April and October. Measurement of spring discharge was not possible because flow apparently occurred by seepage into a perforated or gravel-bottomed concrete vault. Although discharge was not measured or estimated for the spring in April or October, field observations did not indicate that discharge conditions were significantly different during the two sampling events. Analytical results for water samples collected from the spring are presented in Table 3.12 and summarized as follows:

- Water emanating from the spring is calcium bicarbonate type water.
- The pH of the water is lower than that of surface water in the project area and other non-residential spring waters in the project area, ranging from 6.45 to 7.07 s.u. The value of 6.45 s.u. as measured in October is slightly less than the screening level of 6.5 s.u.
- Dissolved oxygen values at Residence 1 were some of the lowest measured in the project area, with concentrations of 1.14 mg/L in April and 0.75 mg/L in October. These concentrations of dissolved oxygen are less than the screening level of 5.0 mg/L. The low dissolved oxygen levels at Residence 1 may be related to the spring water collection method - by seepage into an open-bottomed or perforated collection tank sunk into the ground. The tank is also covered and sealed off from the atmosphere to prevent debris from collecting inside the structure.

- The TDS concentrations ranged from 100 to 150 mg/L, and were lower than the concentrations reported for surface water and other non-residential springs sampled in the project area.

- Parameters exceeding screening levels based on reference area concentrations include dissolved magnesium, combined thorium-230 and thorium-232, and thorium-228:
    - The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233µg/L for October, were exceeded by concentrations of 13,700 and 14,800 µg/L, respectively.
    - The combined thorium-230 and thorium-232 screening level concentration of 0.06 pCi/L for April was exceeded by the concentration of 0.28 pCi/L in the duplicate April sample.
    - The thorium-228 screening level concentrations of 0.15 pCi/L for April and 0.0 (zero) pCi/L for October, were exceeded by concentrations of 0.38 (duplicate sample) and 0.05 pCi/L, respectively.

- Metals exceeding promulgated or risk-based screening levels include dissolved and total selenium. Screening levels are 4.6 µg /L and 10 µg/L, respectively. Results ranged from 14 to 16.4 µg/L dissolved selenium in the October and April samples, respectively, and 12.4 µg/L total selenium in the April sample.
- No radiological parameter screening levels were exceeded.

Based on water quality results for the Residence 1 spring, there is no significant contamination by inorganic, metal, or radiological elements or parameters.

A garden is routinely planted at Residence 1, and an irrigated field of pasture grass is maintained at the property. Table 3.13 presents analytical results for the soil and vegetation samples collected at Residence 1.

Total metals and radionuclides in soil samples collected at Residence 1 exceeding screening levels included:

- Arsenic, which in garden soils (17.5 mg/Kg and 21.5 mg/Kg) and in pasture soils (12.4 mg/Kg) exceeded the screening level of 1 mg/Kg

- Gross alpha, which in garden soil (20.4 pCi/g) exceeded the screening level of 20.3 pCi/g

- Gross beta, which in garden soil (14.6 pCi/g) exceeded the screening level of 13.5 pCi/g

- Radium 226, which in garden soils (6.43 pCi/g and 6.75 pCi/g) and in pasture soil (4.84 pCi/g) exceeded the screening level of 0.06 pCi/g

- Radium 228, which in garden soil (0.87 pCi/g) and pasture soil (0.73 pCi/g) exceeded the screening level of 0.09 pCi/g

- Thorium 228, which in garden soil (0.41 pCi/g) exceeded the screening level of 0.40 pCi/g

- Thorium 230, which in garden soils (4.81 pCi/g and 4.27 pCi/g) and pasture soil (4.49 pCi/g) exceeded the screening level of 3.13 pCi/g

- Thorium 232, which in garden soils (0.48 pCi/g and 0.36 pCi/g) and pasture soil (0.58 pCi/g) exceeded the screening level of 0.35 pCi/g

Total metals and radionuclides in the pasture grass samples collected at Residence 1 exceeding the levels reported for the background grass sample included:

- Barium, which in pasture grass (55.4 mg/Kg) exceeded the background level of 41.5 mg/Kg

- Copper, which in pasture grass (10 mg/Kg) exceeded the background level of 2 mg/Kg

- Selenium, which in pasture grass (4 mg/Kg) exceeded the background level of 2.4 mg/Kg

- Uranium, which in pasture grass (0.16 mg/Kg) exceeded the background level of 0.03 mg/Kg

- Zinc, which in pasture grass (28 mg/Kg) exceeded the background level of 10 mg/Kg
- Gross alpha, which in pasture grass (2.02 pCi/g) exceeded the background level of 1.63 pCi/g

- Gross beta which in pasture grass (22.4 pCi/g) exceeded the background level of 7.15 pCi/g

- Radium-226, which in pasture grass (3.32 pCi/g) exceeded the background level of 1.65 pCi/g

- Thorium-228, which in pasture grass (0.05 pCi/g) exceeded the background level of -0.1 pCi/g

An alpha-track detector was placed in the bathroom at Residence 1 on April 27, 2004 and collected on October 12, 2004. The radon monitoring results for the detector placed in the bathroom at the residence show an overall exposure of 559.7 pCi/L for the 168-day monitoring period, or an average radon concentration of 3.3 pCi/L.

3.5.2 Residence 2

The former residents at Residence 2 recently passed away, and the home is now occupied by a relative of the former owners during a portion of the year. The domestic water is supplied to the residence by a spring that provides water to a cistern located adjacent to the home. The location of the spring could not be determined because the residents were not available during the characterization effort. The resident has indicated during subsequent conversations that the spring is located on the south side of La Sal Creek, upstream of his property.

Water emanating from the domestic spring at Residence 2 was sampled in April and October. The flow rate at the spring was not measured in April but was measured in October. The discharge was measured by diverting flow from the inflow pipe to a bypass valve; it is not certain that the flow measured is representative of the spring's full yield or all of the water used by the residence. The discharge rate in October was 3.53E-03 cfs (1.59 gpm). Analytical results for water samples collected from the spring are presented in Table 3.12 and summarized as follows:

- Water emanating from the spring is calcium bicarbonate type water.
- The pH of the water is lower than that of surface water and other non-residential spring waters in the project area, ranging from 6.79 to 7.52 s.u.
- Dissolved oxygen values were low (5.2 mg/L) to near the normal (≥7. 0 mg/L) concentrations expected for surface water.
- The TDS concentrations ranged from 150 to 180 mg/L and were lower than the concentrations reported for surface water and other non-residential springs sampled in the project area.
- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, magnesium, uranium, and thorium-228:
    - The dissolved barium screening level concentration of 127 µg/L for April and October, was exceeded by concentrations of 146 and 140 µg/L in the April and October samples, respectively.
    - The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233µg/L for October, were exceeded by concentrations of 20,100 and 19,100 µg/L, respectively.
    - The dissolved uranium screening level concentrations of 2.56 µg/L for April and 3.69 µg/L for October, were exceeded by concentrations of 18.1 and 19.3 µg/L, respectively.
    - The thorium-228 screening level concentration of 0 (zero) for October was exceeded with a concentration of 0.09 pCi/L.
- Metals exceeding promulgated or risk-based screening levels were limited to dissolved selenium which slightly exceeded the screening level of 4.6 µg/L with a concentration of 5.0 µg /L in the April sample.
- Note that the total uranium concentration of 19.2 µg/L was the highest concentration of this analyte for residence stations but did not exceed the screening level of 30 µg/L.
- The gross alpha screening level concentration of 15 pCi/L was exceeded in the October sample with a concentration of 16.5 pCi/L.

Based on water quality results for the Residence 2 spring water, contamination by common inorganic and metal ions is negligible. However, elevated dissolved uranium concentrations are present that are 15 to 50 times greater than other resident spring concentrations.

No evidence of a garden was found during the field characterization. One soil and one vegetation sample were collected from an irrigated field located north of the home and across La Sal Creek. Analytical results for the pasture samples (soil and vegetation) are presented in Table 3.14.

Total metals and radionuclides in the soil sample collected at Residence 2 exceeding screening levels included:

- Arsenic, which in pasture soil (7.1 mg/Kg) exceeded the screening level of 1 mg/kg
- Radium 226, which in pasture soil (1.59 pCi/g) exceeded the screening level of 0.06 pCi/g

Total metals and radionuclides in the pasture grass samples collected at Residence 2 exceeding the levels reported for the background grass sample included:

- Copper, which in pasture grass (10 mg/Kg) exceeded the background level of 2 mg/Kg
- Selenium, which in pasture grass (2.8 mg/Kg) exceeded the background level of 2.4 mg/Kg
- Uranium, which in pasture grass (0.08 mg/Kg) exceeded the background level of 0.03 mg/Kg
- Zinc, which in pasture grass (29 mg/Kg) exceeded the background level of 10 mg/Kg
- Gross beta, which in pasture grass (31.3 pCi/g) exceeded the screening level of 7.15 pCi/g

An alpha-track detector was placed in the bathroom at Residence 1 on April 27, 2004 and collected on October 18, 2004. The radon monitoring results for the detector placed in the bathroom at the residence show an overall exposure of 650.4 pCi/L for the 174-day monitoring period, or an average radon concentration of 3.7 pCi/L. It should be noted that the residence was not occupied during the monitoring period, and therefore, ventilation during the period was minimal.

3.5.3 Residence 3

One primary and one secondary home are located at Residence 3. Both homes have been occupied on a year-round basis for some time. However, the individual living the secondary home passed away in October 2004. The homes are supplied with domestic water by two separate springs on the property (RES 3U and RES 3L). Both springs are located on the hillside above the residence and downgradient of the Vanadium Queen Mine. Spring RES 3U is located at an elevation of 6,191 feet amsl, and Spring RES 3L is located at an elevation of 6,152 feet amsl. In addition to these two domestic springs, one additional spring (RES 3W) was identified on the property during the field investigation. This third spring is a

flowing artesian well located downgradient of the homes near the entrance to the property, at an elevation of 6,108 feet amsl. The source of the water emanating from the well is not known; however, the location of the well suggests that the well likely penetrates a confined aquifer within the Entrada Sandstone, which underlies the Morrison Formation. Water flowing from the well has not been used for domestic (drinking) water by the residents at Residence 3.

Water emanating from the two domestic springs and one flowing well at Residence 3 were sampled in April and October. The flow rate at the spring Residence 3 U was measured in April and October. The flow rates at springs Residence 3L and Residence 3W were not measured in April but were measured in October. Discharge at Residence 3U was measured directly from the end of the pipe conveying the spring water into a small steel tank (drum). The Residence 3L station consisted of a steel pipe connected to a cylindrical tank lying on its side. Overflow water spilled from a small opening in the top of the tank as well as at the pipe connection point. Discharge was partially measured using a container and stop watch but because of overflow spillage, not all of the water could be captured. Similarly, measurement of discharge of the flowing well at station Residence 3W was estimated as flow occurred vertically upward from well casing at the ground surface. The discharge rates at Residence 3U were 1.59E-02 cfs (7.13 gpm) in April and 1.77E-02 cfs (7.93 gpm) in October. The discharge rates at Residence 3L and Residence 3W in October were 5.77E-03 cfs (2.59 gpm) and 5.34E-02 cfs (23.95 gpm), respectively. Analytical results for water samples collected from the spring are presented in Table 3.12 and summarized as follows:

- Water emanating from springs Residence 3U, 3L, and 3W are calcium bicarbonate type waters.
- The pH values for the waters are lower than that of surface water and other non-residential spring waters in the project area, ranging from 7.36 s.u. at Residence 3W in April to 7.9 s.u. at Residence 3U in April.
- Dissolved oxygen values for the samples collected at Residence 3U and Residence 3L are near the normal value expected for surface water. Dissolved oxygen values at Residence 3W were some of the lowest measured in the project area, with concentrations of 2.12 mg/L in April and 0.62 mg/L in October. These concentrations of dissolved oxygen are less than the screening level of 5.0 mg/L, but are not unusual considering the groundwater source. The Oxidation-Reduction Potential (ORP) measurements at Residence 3W indicate reducing conditions.
- The TDS concentrations for the Residence 3U samples were the lowest in the project area with concentrations of 60 and 70 mg/L. Samples from Residence 3L and 3W were also generally low ranging from 90 mg/L to 160 mg/L, respectively. All TDS concentrations were lower than the concentrations reported for surface water and other non-residential springs sampled in the project area.

- Parameters exceeding screening levels based on reference area concentrations were limited to dissolved barium, beryllium, magnesium, potassium, combined thorium-230 and thorium-232, and thorium-228:

    - The dissolved barium screening level concentration of 127 µg/L was exceeded in both the April and October samples at the Residence 3W well with concentrations ranging from 164 to 167 µg/L. Concentrations in the 3U and 3L springs were of the order of 80 µg/L.
    - The dissolved beryllium screening level concentration of 0.05 µg/L for both April and October was exceeded in both the April and October samples at the Residence 3W well with concentrations of 0.10 (B qualifier) µg/L. Beryllium was not detected in the 3U and 3L springs.
    - The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233µg/L for October, were exceeded by concentrations of 9,200 and 10,200 in the April samples at Residence 3U and 3L, respectively; and concentrations of 15,900 and 16,700 µg/L at Residence 3W (including duplicate) for October and April, respectively.
    - The dissolved potassium screening level concentration of 2,300 µg/L for April was exceeded in the April sample at the Residence 3W well with a concentration of 2,400 µg/L. The October concentration was also 2,400 µg/L (screening level of 3,800 µg/L).
    - The combined thorium-230 and thorium-232 screening level concentration of 0.06 pCi/L for April, was exceeded at Residence 3W with a concentration of 0.07 pCi/L.
    - The thorium-228 screening level concentrations of 0.15 pCi/L for April and 0 (zero) pCi/L for October were exceeded with a concentrations ranging from 0.05 pCi/L (October sample) to 0.2 pCi/L (April sample).

- Metals exceeding promulgated or risk-based screening levels were limited to dissolved iron and total recoverable iron, and dissolved and total manganese:

    - The dissolved and total recoverable iron screening level concentration of 300 µg/L was exceeded at the Residence 3W well in both the April and October samples (and duplicate sample) with concentrations ranging from 560 to 600 µg/L.
    - The dissolved and total manganese screening level concentration of 50 µg/L was exceeded at the Residence 3W well in both the April and October samples (and duplicate sample) with concentrations ranging from 287 to 309 µg/L.

Based on water quality results for the Residence 3 springs and well, there is no significant contamination by inorganic, metal, or radiological elements or parameters. The Residence 3U and 3L water is the best quality water analyzed in the project area.

A garden has been planted at Residence 3 in the past but was not planted this year. Several fruit trees (apple and pear) are located adjacent to the garden area. There are no irrigated fields associated with the property. Analytical results for the soil sample collected from the garden area and produce sample collected from the fruit trees are presented in Table 3.15.

Total metals and radionuclides in the soil sample collected at Residence 3 exceeding screening levels included:

- Arsenic, which in garden soil (4.4 mg/Kg) exceeded the screening level of 1 mg/Kg
- Radium 226, which in garden soil (0.73 pCi/g) exceeded the screening level of 0.06 pCi/g
- Thorium 232, which in garden soil (0.55 pCi/g) exceeded the screening level of 0.35 pCi/g

Alpha-track detectors were placed in the bathroom of the primary home on April 27, 2004 and in the bathroom of the secondary home on May 27, 2004. Both detectors were collected on October 18, 2004. The radon monitoring results for the detectors placed in the bathroom at each of the two homes at Residence 3 are summarized as follows:

- Primary Home
  - Exposure: 121.6 pCi/L over 174-day monitoring period
  - Average: 0.7 pCi/L per day
- Secondary Home
  - Exposure: 154.3 pCi/L over 144-day monitoring period
  - Average: 1.1 pCi/L per day

3.6 Radiological Surveys

The radiological survey component of the characterization effort included the performance of radiological surveys at each of the three mine areas and a correlation study to assess relationships between *in situ* gamma-ray count rates and radium-226 and uranium concentrations in the soil.

3.6.1 In-Situ Gamma-Ray Surveys

The gamma-ray count rates over the three mine areas were collected using a Ludlum Model 2221 digital ratemeter/scaler coupled to a Ludlum model 44-10 2x2 NaI(Tl) detector. The detector threshold was set to detect gamma-rays of about 50 keV and above, and the scaler was operated in the gross mode. The count rate was recorded in one second intervals, and reported in units of counts per minute (cpm). The location of each count rate measurement was recorded using a Trimble digital global positioning system (gps). The count rate data and measurement location data was integrated and stored on a TSCE Trimble data logger.

Data was collected while traversing the mine bench, intermediate terraces, ore load-out areas, mine dump faces, along the ephemeral drainage areas, and the background areas for each mine site. The detector was held at a distance of approximately six (6) inches above the ground surface. The technician carrying the

equipment walked at an approximate speed of two feet per second. Therefore, cpm measurements were recorded approximately every two feet. Traverse line spacing varied depending on the slope of the terrain and the amount of boulders and brush which hindered measurements.

Results of these radiological surveys are presented Sections 3.6 (Firefly/Pygmy Mine), 3.7 (Vanadium Queen Mine, 3.8 (Blue Cap Mine), 3.9 (Black Hat Mine), and 3.10 (Saint Patrick Mine) of this document.

3.6.2 Correlation Study

While the *in situ* survey results depict the relative gamma-ray count rate over the reference areas and mine sites, it was also desired to interpret this data in terms of soil concentrations of Ra-226 and uranium. This was accomplished by a correlation study whereby 30 locations, ten from each mine site, were selected for further analysis. The locations were selected to represent the expected range of soil concentrations present at the sites, from near background to hundreds of picocuries per gram (pCi/g).

Each correlation point was first scanned with the 2x2 NaI(Tl) detector to determine if the area was homogeneous from the view of the gamma-ray count rate. If the correlation point appeared homogeneous, a one-minute static gamma-ray count was collected at 18 inches above the point using the 2x2 detector. A second *in situ* measurement of the gamma exposure rate at the same elevation was made using a Ludlum Model 19 microR meter. A five point composite soil sample of approximately 1 kg was then collected to a depth of approximately 6 inches. All organic material and rocks greater than 0.5 inch were discarded. Each sampling container was labeled with the location and date of the sample.

Each soil sample was transferred to a 1 liter Marinelli beaker and counted using an unshielded 2x2 NaI(Tl) detector for from 1 to 5 minutes, depending on the activity in the soil. The counting of this unprepared sample using this uncalibrated system was done to determine the relative activity in each sample before submitting it for laboratory analyses.

Each sample was then forwarded to an offsite analytical radiochemistry laboratory for isotopic analysis. Samples were dried, homogenized, and aliquots taken for Ra-226 analysis by a barium precipitation/gross alpha method, and for total uranium by ICP-MS.

Data from the correlation study are presented in Table 3.16. Column 1 lists the correlation point locations. Locations are identified by mine site, for example BC is Blue Cap, VQ is Vanadium Queen,

etc., followed by BKG if the location is the reference area, or COR- for all other correlation points. The *in situ* gamma-ray count rate in cpm and the exposure rate in microR/hour at each point are presented in columns 2 and 3. The fourth column presents the net gamma count rate in cpm from counting the unprepared sample in the Marinelli beaker. Columns five and six present the analytical laboratory results for total uranium in mg U per kg and pCi/g of dry soil. The sixth column presents analytical results for Ra-226 in pCi/g.

Review of these data allows some interpretation. In equilibrium, there are approximately (excluding the contribution from U-235) 2 pCi/g of total uranium per 1 pCi/g of Ra-226. Therefore, if in equilibrium, the ratio of total uranium to Ra-226 should be approximately 2. Of the 30 samples analyzed, 25 samples had U/Ra ratios ranging from 0.5 to 2.4. However, one ratio was 0.29, while four others were 3.7, 6.6, 575, and 704. The average U/Ra ratio of the 25 "best" correlation points was 1.6, with a standard deviation of the data of 0.4. It cannot be determined from the analytical results if there is enrichment in the Ra-226 concentration over what would be expected if it were in equilibrium with the total uranium, or if there is a bias in the analytical calibration. In any event, the five analytical results with the unusual U/Ra ratio, specifically SP-COR2, VQ-COR1, VQ-COR9, FF-COR8, and FF-COR9 were discarded from the correlation study.

The remaining soil sample analytical results indicate that the U/Ra ratio is fairly constant over the three mine sites. It is therefore expected that if the soil concentration is homogeneous, the *in situ* gamma measurement is an accurate representation of the average soil concentration. Another way of stating this is that many studies have shown that there is a strong linear relationship between soil sample analysis and *in situ* gamma measurements when the soil concentration within the field of view of the detector is homogeneous. Thus, the *in situ* measurement technique provides an accurate method of estimating the average soil concentration within the field of view of the detector. If the soil analysis and *in situ* gamma measurement do not fit a linear relationship, then the soil concentration is not homogeneous. In these cases, either a "hot spot" of radioactivity was elevating the *in situ* gamma measurement, but not picked up in the soil sample. Alternatively, a small "hot particle" was picked up in the soil sample, but was not of large enough volume to affect the *in situ* measurement. Both situations can be present. In an attempt to determine the best linear fit correlation for the La Sal sites, analytical data for the remaining 25 correlation points were evaluated to identify those which clearly appeared to be affected by soil non-homogeneity. This evaluation led to the exclusion from the correlation study the following five correlation points; BC-COR2, BH-COR2, SP-COR1, VQ-COR3, and VQ-COR4.

The average of the *in situ* gamma measurements for the three background areas was 12,741 cpm. The averages of the Ra-226 and total uranium soil concentrations in the three background areas were 1.8 pCi/g and 1.5 pCi/g, respectively. In the absence of gamma shine from contaminated areas, the linear relationship should intercept the Y axis at about 12,000cpm. Therefore, the correlation was forced to pass through this point.

The best fit of the correlation study data is presented in Figure 3.6 for Ra-226, and Figure 3.7 for total uranium. These figures depict strong linear correlations (R^2 of 0.95 and 0.93 respectively) between the *in situ* gamma count rate and either Ra-226 or uranium soil concentration, when the soil is homogeneous, and the *in situ* measurement is not affected by gamma shine from elevated areas of contamination.

3.7 Firefly/Pygmy Mine

Characterization activities at the Firefly/Pygmy Mine included a collection of surface-water and stream sediment, waste-rock, ephemeral drainage sediment, and vegetation samples for chemical analysis; collection of waste-rock samples for geotechnical analysis; radiological survey; and radon monitoring at the mine adit and a background area. Each component of the characterization effort is discussed below.

3.7.1 Surface Water and Stream Sediment

The water quality stations established at the Firefly-Pygmy (Firefly) Mine are shown in Figure 3.8 and include the following:

- Firefly Adit (discharge from the adit)
- Firefly Drainage (mine drainage at the toe of the upper dump)
- Firefly Spring 1 (small discharge northeast of the dump along slope)
- Firefly Spring 2 (small discharge northeast of the dump along slope)
- La Sal Crk Up (La Sal Creek just upstream of the Firefly access road)
- La Sal Crk Dn1 (La Sal Creek just downstream of confluence of gully below mine dump)

Table 3.17 shows field parameters and chemical analytical data for the stations listed above.

3.7.1.1 Mine Discharge

Discharge at the Firefly adit is small and not physically measurable at the portal or the at the drainage emanation point at the toe of the upper dump (Firefly Drainage). The Firefly Drainage station is seepage that is interpreted to be mine drainage water that has percolated through the upper dump waste rock. The Firefly Drainage station was established to assess potential leaching of waste rock material. No flow has been observed spilling off the upper bench. It is estimated that the flow at both the portal (Firefly Adit) and toe of the dump is approximately 1 gpm. Flow from the portal is barely perceptible and occurs in a 2 to 4 feet wide shallow channel that typically is less than 2-inches deep. Outside the gated portal, the channel is vegetated with various phreatophytes including grasses, rushes, and willows. Mine drainage flows from the portal onto the upper mine bench where it disperses forming a small wetland (non-jurisdictional) on the north portion of the bench. Discharge from the portal has appeared relatively constant during numerous mine visits extending from February 2003 to October 2004.

3.7.1.2 Spring Discharge

Two springs identified in the area of the mine were labeled Firefly Spring 1 and Firefly Spring 2. These springs are located several hundred feet to the northeast on the same slope as the mine (Figure 3.8). The purpose of sampling these spring sites was to assess impact from potential underground mine workings. There is no surface disturbance near the springs and since the springs are located some distance from the surface disturbance of the mine, it is not expected that waste rock at the mine would negatively impact the springs.

Both spring stations are characterized by small channel-like depressions in densely vegetated areas on the steep south-facing slope. Flow is not measurable due to extremely shallow conditions and lack of concentrated flow. Water is less than a half-inch deep and when sampling a small hole must be excavated in each channel to accommodate field parameter instruments. It is estimated that flow at both springs is less than or equal to 1 gpm. Discharge in La Sal Creek is discussed in Section 3.4.1.1.

3.7.1.3 Water Quality

Table 3.17 presents water quality data for stations at the Firefly/Pygmy Mine. Field parameter data do not indicate that the mine drainage water at the Firefly Adit station differ significantly from water at the Firefly Drainage station. Nor do the field parameter data at these stations indicate a significant difference from data collected at the nearby springs (Firefly Spring 1 and Firefly Spring 2). Field parameters at each

spring show very little variability between the April and October sampling events. Temperature data for the mine and spring stations indicate small 1 to 2 degree increases in the October sampling event. The temperature data support the hypothesis that the water emanating from these stations is relatively shallow and therefore influenced by seasonal ground temperature fluctuations. The following information summarizes water quality conditions for the mine water and spring water at the Firefly/Pygmy Mine:

- The mine and spring water is of the magnesium bicarbonate type but has nearly equivalent concentrations of magnesium, sodium, and calcium.
- The mine drainage water is basic with pH ranging from 7.99 to 8.61. Spring water pH ranges from 8.19 to 8.48 s.u. There is no apparent trend in pH with sampling time.
- Water at the adit is slightly more oxygen deficient and of a reducing condition than water at the drainage station. Specific conductance is moderately low, from 393 to 460 micro siemens per centimeter (µS/cm).
- TDS concentrations range from 220 to 300 mg/L and are considered moderate levels in the project area.
- Spring water has slightly greater concentrations of TDS, chloride, and sulfate, calcium, magnesium, sodium, and total recoverable iron, than the mine water samples.
- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, magnesium, potassium, sodium, uranium, and vanadium, total vanadium, combined thorium-230/thorium-232 and thorium-228.
    - Except for the October sample collected at Firefly Spring No. 2, the dissolved barium screening level concentration of 127 µg/L was exceeded at all Firefly stations in both April and October samples with concentrations ranging from 128 to 155 µg/L. Concentration varied at each sample site, with the spring stations having a slightly smaller average.
    - The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233 µg/L for October were exceeded at all stations for both sampling events, with concentrations ranging from 25,500 to 34,400 µg/L.
    - The dissolved molybdenum screening level concentration of 5 µg/L for April and October was exceeded at all stations for all sampling events, with concentrations ranging from 20 to 60 µg/L. Station Firefly Spring No. 2 had the lowest concentrations – both sample results of 20 µg/L. Station Firefly Spring No. 1 had the highest average concentration of 5 µg/L.
    - The dissolved potassium screening level concentrations of 2,300 µg/L for April and 3,800 µg/L for October were exceeded at all stations for both sampling events, with concentrations ranging from 4,700 to 6,000 µg/L. With exception of station Firefly Spring No. 2, which had an October concentration of 4,700 µg/L, most concentrations were between 5,500 and 6,000 µg/L.
    - The dissolved sodium screening level concentrations of 12,200 µg/L for April and 21,000 µg/L for October were exceeded at all Firefly stations at both sampling times. Concentrations ranged from 23,100 to 32,500 µg/L. Station Firefly Spring No. 1 had the greatest concentrations, and Spring No. 2 had the lowest concentrations.

- The dissolved uranium screening level concentrations of 2.56 µg/L for April and 3.69 µg/L for October were exceeded at all stations for both sampling events, with concentrations ranging from 55.5 to 144 µg/L. The lower concentrations were associated with Firefly Adit and Spring No. 2, the higher concentrations were associated with Firefly Drainage and Spring No. 1.
- The dissolved and total vanadium screening level concentrations of 2.5 µg/L (dissolved, April and October) and 4.3 and 2.5 µg/L (total, April and October), were exceeded at all stations for both sampling events. Concentrations ranged from 42 to 348 µg/L, with the higher concentrations being associated with station Firefly Drainage and the lower concentrations with Spring No. 1.
- The combined thorium 230/thorium-232 screening level concentration of 0.06 pCi/L for April was exceeded at each of the Firefly stations and adjacent La Sal Creek stations in April with concentrations ranging from 0.27 (La Sal Creek Up) to 0.65 pCi/L (La Sal Creek Down). The combined thorium-230/thorium-232 screening level of 0.02 pCi/L for October was not exceeded at any of the Firefly or adjacent La Sal Creek stations in October.

- Metals exceeding promulgated or risk-based screening levels were limited to total recoverable arsenic, total recoverable iron, dissolved and total selenium, and total uranium.

  - The total recoverable arsenic screening level concentration of 10 µg/L was exceeded at stations Firefly Adit, Drainage, and Spring No.1. Concentrations were exceeded in both the April and October samples at stations Firefly Adit and Drainage with levels ranging from 18 to 25.5 µg/L. The Adit and Drainage concentrations exhibit almost identical concentrations between sampling times. Firefly Spring No. 1 only slightly exceeds the screening level with a concentration of 10.4 µg/L in the April sample.
  - The total recoverable iron screening level concentration of 300 µg/L was exceeded at stations Firefly Spring No. 1 and Spring No. 2 in the October samples with concentrations of 420 and 460 µg/L, respectively. These results were significantly greater than April concentrations of 170 and 270 µg/L, respectively.
  - The total and dissolved selenium screening level of 4.6 µg/L for April and 10 µg/L for October were exceeded at all stations at all times, with concentrations ranging from 12.4 to 59.3 µg/L. Concentrations in Firefly Spring 2 are noticeably lower by approximately 2 to 3 times that of other sampling stations.
  - Total uranium concentrations exceed the screening level of 30 µg/L between 2 to 4 times at all sample stations and times, with concentrations ranging from 62 to 128 µg/L. Firefly Drainage and Spring No. 1 exhibit the higher concentrations. Firefly Spring 2 has the lowest concentration of 62 µg/L.

- The gross alpha screening level concentration of 15 pCi/L was exceeded for all mine water and spring water samples ranging from 31.5 to 105 pCi/L. Firefly Drainage has the highest concentrations followed by Spring No. 1, Firefly Adit, and Spring No. 2.

- The combined radium-226 and radium-228 screening concentration of 5 pCi/L was exceeded at Firefly Drainage in both the April and October samples with concentrations of 10.27 and 9.93 pCi/L, respectively; and 10.72 pCi/L for the October sample at Firefly Spring No. 1 All other station concentrations were one to two orders of magnitude smaller.

- The combined thorium-230 and thorium-232 screening concentration of 0.06 pCi/L for April and 0.02 pCi/L for October were exceeded at stations Firefly Drainage, Spring No. 1 and Spring No. 2 with concentrations of 0.61, 0.41, and 0.44 pCi/L, respectively.

- The thorium-228 screening level concentration of 0.15 pCi/L for April and 0 (zero) pCi/L for October were exceeded in the October sample event at stations Firefly Drainage and Adit with concentrations of 0.26 and 0.13 pCi/L.

- In general, parameters that exceed screening levels were observed at all mine and spring water sample stations. The highest concentration of analytes was usually associated with the Firefly Drainage station, whereas the most distant spring station, station Firefly Spring No. 2, frequently had the lowest concentrations of analytes.

3.7.1.4 Impact To La Sal Creek Water Quality

To assess the potential impact of the Firefly/Pygmy Mine on La Sal Creek water quality, an examination of water quality and sediment data was conducted of data collected on La Sal Creek upstream and downstream of the confluence with the dry tributary that extends from the toe of the Firefly/Pygmy Mine dump. The La Sal Creek water quality and sediment data evaluated was for stations La Sal Crk Up and La Sal Crk Dn1 as shown in Tables 3.7 and 3.17.

Table 3.17 indicates that parameters that exceed screening levels in surface water at both stations include dissolved barium, calcium, magnesium, potassium, uranium, and vanadium, and total recoverable iron, total manganese, gross alpha, combined thorium-230 and thorium-232, and thorium-228. The analytical results for stations La Sal Crk Up and La Sal Crk Dn1, show that the higher concentrations of these analytes consistently occurs in the downstream station of La Sal Crk Dn1. However, with the exception of a single sample result (April or October) for dissolved barium, total recoverable iron, and dissolved and total manganese, and dissolved uranium and vanadium, gross alpha, combined thorium-230/thorium-232, and thorium-228, results do not consistently differ greatly between these stations. Parameters that exceed the screening level in only the downstream station of La Sal Crk Dn1 include total phosphorous, dissolved manganese, dissolved vanadium, gross alpha, and thorium-228. The dissolved manganese concentration is 4 times greater in the downstream station of La Sal Crk Dn1. Dissolved vanadium was not detected in the upstream station of La Sal Crk Up, but had a concentration of 21 pCi/L in Station Dn1.

With the exception of thorium-228, the concentrations of radiological parameters are approximately 2 to 3 times greater at the downstream station La Sal Crk Dn1. There are no other significant differences observed for the other inorganic analytical data at the La Sal Creek stations. Based on the water quality data, the Firefly/Pygmy Mine may have a slight negative impact on water quality in La Sal Creek.

Table 3.7 shows the total metals and radionuclides concentration results for sediment samples collected in La Sal Creek. Section 3.4.1.3 summarizes the results of the sediment analyses at the La Sal Crk stations. Table 3.7 shows that concentrations of lead, gross alpha, gross beta, radium-226, radium-228, thorium-230 and thorium-232 all exceed the screening level in both stations La Sal Crk Up and Dn1 with the exception of lead in station La Sal Creek Up. In addition, in all cases the concentrations in the downstream station La Sal Crk Dn1 exceed the upstream concentrations in station La Sal Crk Up. This is particularly evident with lead, gross alpha, gross beta, and radium-226 where the downstream station La Sal Crk Dn1 had concentrations that are 12.8, 9.7, 4.3, and 15 times the concentrations, respectively, in the upstream station of La Sal Crk Up.

The analytical data from sediment samples at stations La Sal Crk Up and La Sal Crk Dn1 suggest that migration of contaminants from the Firefly mine has occurred and has caused elevated concentrations of contaminants in the stream sediments.

3.7.2 Waste Rock

Waste rock samples were collected at the mine from boreholes drilled into the mine dump and composite surface samples collected from the face of the dump.

3.7.2.1 Borehole Samples

Eight boreholes were drilled at the mine to obtain samples for chemical analysis and assess the depth to native material beneath the mine dump. Seven of the boreholes (FF 1 through FF 7) are located on the mine dump, and one borehole (FF 8) is located within the waste-rock accumulation area along the mine access road. One additional borehole (FF 9) was drilled on the dump to obtain samples for geotechnical analysis. Borehole locations are shown in Figures 3.8 and 3.9, and borehole logs and geotechnical analysis results are provided in Appendix C.

The thickness of waste rock encountered in each borehole is depicted in Figure 3.10. As shown, waste rock accumulations at the mine can be segregated into three separate zones (upper dump, lower dump, and ancillary dump) based on spatial orientation and thickness of waste rock: A conservative estimate of the volume of waste rock present in each zone was computed by measuring the total surface area of the zone based on recent aerial photography and assuming a uniform waste-rock thickness equal to the

average thickness encountered in the boreholes drilled within the zone. The resulting estimates do not account for thinning of waste rock along the perimeter of the zones; and therefore, the estimates are considered very conservative and to likely over-estimate the actual waste-rock volumes. The estimated volume of waste rock is 121,207 cubic feet (4,489 cubic yards) for the upper dump, 871,115 cubic feet (32,264 cubic yards) for the lower dump, 56,160 cubic feet (2,080 cubic yards) for the ancillary dump. Based on these estimates, 38,833 cubic yards of waste rock are present at the mine.

Analytical results are presented in Tables 3.18 (total metals and radionuclides) and 3.19 (SPLP metals). In comparison to the screening levels, arsenic is the only analyte reported at concentrations exceeding the human-health criteria; copper and lead are the only analytes reported at concentrations exceeding the RMC for elk; and each of the radionuclides exceeded background levels.

Total Metals

Except for the samples collected at FF 1 (8-9.5) and FF 4 (4-6), arsenic was reported at concentrations exceeding the human-health screening level of 12 milligrams per kilogram (mg/Kg) in all samples collected from the boreholes. It should be noted that the arsenic concentration exceeded the human-health screening level in sample FF 5 (21.5-23) which was collected from native soil material underlying the waste-rock dump. The arsenic concentrations exceeding the screening level ranged from 15.2 mg/Kg in sample FF 8 (10-12) to 140 mg/Kg in sample FF 4 (0-0.5). Arsenic concentrations exceeding the screening level in near-surface samples (0-0.5 foot depth interval) ranged from 29.7 mg/Kg at FF 8 to 140 mg/Kg at FF 4. Arsenic concentrations exceeding the screening level in sub-surface samples ranged from 15.2 in sample FF 8 (10-12) to 91.2 mg/Kg in sample FF 7 (18-22.5).

Copper concentrations exceeded the RMC for elk (131 mg/Kg) in near-surface samples (0-0.5 foot depth interval) collected at FF 4, FF 5, FF 6, and FF 7. Copper concentrations exceeding the screening level in near-surface samples (0-0.5 foot depth interval) ranged from 155 mg/Kg in sample FF 7 (0-0.5) to 383 mg/Kg in sample FF 4 (0-0.5). Copper concentrations exceeded the Elk RMC in sub-surface samples collected at FF 2, FF 3, FF 4, FF 5, FF 6, and FF 7. Copper concentrations exceeding the elk RMC in the sub-surface samples ranged from 155 /Kg in sample FF 7 (0-0.5) to 383 mg/Kg in sample FF 4 (0-0.5).

Lead concentrations exceeded the elk RMC (127 mg/Kg) in near-surface samples at FF 3, FF 4, FF 5, FF 6, FF 7, and FF 8. Lead concentrations exceeding the elk RMC in near-surface samples ranged from 187 mg/Kg at FF 8 to 452 mg/Kg at FF 7. Except for FF 1, lead concentrations exceeded the elk RMC in sub-

surface samples at each borehole. Lead concentrations exceeding the elk RMC in sub-surface samples ranged from 190 mg/Kg in sample FF 3 (4-6) to 665 mg/Kg in sample FF 7 (1-3).

SPLP Metals

As shown in Table 3.19, uranium and vanadium were reported at concentrations exceeding the method detection limits in each of the samples. Arsenic concentrations exceeded the method detection limit in all but one of the samples collected, with the highest arsenic concentration reported for the sample collected from native soil underlying the waste-rock dump (sample FF5: 21.5-23). Other analytes reported at concentrations above the method detection limit in one or more of the samples were antimony, barium, iron, manganese, molybdenum, and selenium. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Of the radionuclides included in the investigation, the activities of gross alpha, gross beta, radium-226 and thorium-230 were highest in comparison to background levels. Analytical results for these radionuclides in the waste-rock samples collected from boreholes are summarized as follows:

- Gross Alpha (pCi/g)
  - Minimum: 7 (FF 1: 8-9.5)
  - Maximum: 2,610 (FF 4: 0-0.5)
  - Mean: 572 (average background = 20.3 pCi/g)

- Gross Beta (pCi/g)
  - Minimum: 5 (FF 1: 8-9.5)
  - Maximum: 1,130 (FF 4: 0-0.5)
  - Mean: 260 (average background = 13.5 pCi/g)

- Radium-226 (pCi/g)
  - Minimum: 0.71 (FF 1: 8-9.5)
  - Maximum: 466 (FF 4: 0-0.5)
  - Mean: 104 (average background = 3.3 pCi/g)

- Thorium-230 (pCi/g)
  - Minimum: 1.23 (FF 1: 8-9.5)
  - Maximum: 424 (FF 4: 0-0.5)
  - Mean: 117 (average background = 3.1 pCi/g)

3.7.2.2 Composite Surface Samples

The waste-rock dump was segregated into nine segments as shown in Figures 3.8 and 3.9 for collection of composite surface samples. Analytical results for the composite sample collected in each segment are presented in Tables 3.20 (total metals and radionuclides) and 3.21 (SPLP metals). In comparison to the screening levels, arsenic is the only analyte reported at concentrations exceeding the human-health criteria; copper and lead are the only analytes reported at concentrations exceeding the RMC for elk; and except for radium-228, each of the radionuclides exceeded background levels (thorium-228 only slightly exceeded background in one sample).

Total Metals

As was found for the near-surface borehole samples, each composite sample contained arsenic at a concentration exceeding the human-health screening level. Arsenic concentrations ranged from 28 mg/Kg at Segment 1 to 124 mg/Kg at Segment 3. The elk RMC for copper was exceeded in samples collected in the northern portion of the dump (Segments 3, 4, 7, 8 (duplicate), and 9). Copper concentrations exceeding the RMC ranged from 149 mg/Kg in sample Segment 9 (duplicate) to 404 mg/Kg at Segment 3. Except for the Segment 1 sample, each sample contained lead at a concentration exceeding the elk RMC. Lead concentrations exceeding the RMC ranged from 190 mg/Kg at Segment 2 to 416 mg/Kg at Segment 7.

SPLP Metals

As shown in Table 3.21, arsenic, iron, uranium, and vanadium were reported at concentrations exceeding the method detection limits in each of the samples. Other analytes reported at concentrations above the method detection limit in one or more of the samples were antimony, barium, molybdenum, and selenium. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Of the radionuclides included in the investigation, the activities of gross alpha, gross beta, radium-226 and thorium-230 were highest in comparison to background levels. Analytical results for these radionuclides in the waste-rock samples collected from boreholes are summarized as follows:

- Gross Alpha (pCi/g)
    - Minimum: 20 (FF SEGMENT 1)
    - Maximum: 454 (FF SEGMENT 9)
    - Mean: 88 (average background = 20.3)

- Gross Beta (pCi/g)
  - Minimum: 12.4 (FF SEGMENT 1)
  - Maximum: 200 (FF SEGMENT 9)
  - Mean: 39.2 (average background = 13.5)

- Radium-226 (pCi/g)
  - Minimum: 3.67 (FF SEGMENT 1)
  - Maximum: 14.6 (FF SEGMENT 7)
  - Mean: 9.84 (average background = 3.3)

- Thorium-230 (pCi/g)
  - Minimum: 0.59 (FF SEGMENT 9 duplicate)
  - Maximum: 129 (FF SEGMENT 9)
  - Mean: 80 (average background = 3.1)

3.7.3 Ephemeral Drainage Sediment

Three composite sediment samples were collected along the ephemeral drainage extending from the toe of the waste-rock dump to La Sal Creek (Figure 3.8). Sample FF Sediment 1 was collected at near the toe of the mine dump, FF Sediment 2 was collected approximately half-way between the dump and La Sal Creek, and FF Sediment 3 was collected near the drainage confluence with La Sal Creek. Analytical results for the sediment samples are presented in Table 3.22. As shown, analyte concentrations are generally consistent (same order of magnitude) across the sampling sites. Exceptions to this general trend are noted for arsenic, chromium, uranium, vanadium, gross alpha, and radium-226 levels which are one order of magnitude higher in Segments 1 and 2 than in Segment 3. In addition, copper and gross beta levels are one order of magnitude higher in Segment 1 then in Segments 2 and 3, and radium-228 activities are three orders of magnitude higher in Segment 2 than Segment 1 and one order of magnitude higher in Segment 2 than in Segment 3.

Arsenic concentrations in samples FF Sediment 1 and FF Sediment 2 exceed the human-health screening level, and lead concentrations in samples FF Sediment 1 and FF Sediment 2 exceed the elk RMC. The activities reported for gross alpha, gross beta, radium-226, radium-228, and thorium-230 exceeded the levels reported for the background soil samples. Analytical results for these radionuclides are summarized as follows:

- Gross Alpha (pCi/g); average background = 20.3
  - FF Sed 1: 370
  - FF Sed 2: 187

  - FF Sed 3: 66.6

- Gross Beta (pCi/g); average background = 13.5
  - FF Sed 1: 136
  - FF Sed 2: 70.3
  - FF Sed 3: 29.8

- Radium-226 (pCi/g); average background = 3.3
  - FF Sed 1: 25
  - FF Sed 2: 35.2
  - FF Sed 3: 5.73

- Radium-228 (pCi/g); average background = 2.66
  - FF Sed 1: 0.08
  - FF Sed 2: 17.6
  - FF Sed 3: 4.39

- Thorium-230 (pCi/g); average background = 3.1
  - FF Sed 1: 57.4
  - FF Sed 2: 68.1
  - FF Sed 3: 11.3

3.7.4 Vegetation

Vegetation samples were collected along the adit drainage channel on the mine bench and around the perimeter of the waste-rock dump. One composite grass, one composite forb, and one composite shrub sample were collected along the adit drainage channel. One composite grass, one composite forb, and one composite shrub sample were collected around the perimeter of the mine dump. Analytical results for the vegetation samples are presented in Table 3.23.

Plant species were not formerly identified (keyed) at the Firefly mine however many species at the mine were identical to those identified at the Vanadium Queen Mine and the Blue Cap Mine area (see Sections 3.8.4 and 3.9.3.

Total metals and radionuclides in the grass samples collected from the adit drainage and the dump perimeter exceeding background values included:

- Antimony, which in grasses from the adit drainage (0.1B mg/Kg) and the dump perimeter (0.1B mg/Kg) exceeded the background value of <0.1 mg/Kg

- Arsenic, which in grasses from the adit drainage (1.6 mg/Kg) and the dump perimeter (2.7 mg/Kg) exceeded the background value of <0.3 mg/Kg

- Barium, which in grasses from the adit drainage (67 mg/Kg) exceeded the background value of 41.5 mg/Kg
- Cadmium, which in grasses from the adit drainage (0.18B mg/Kg) and the dump perimeter (0.12B mg/Kg) exceeded the background value of 0.07B mg/Kg
- Copper, which in grasses from the adit drainage (4B mg/Kg) and the dump perimeter (8 mg/Kg) exceeded the background value of 2B mg/Kg
- Lead, which in grasses from the dump perimeter(5B mg/Kg) exceeded the background value of <4 mg/Kg
- Manganese, which in grasses from the adit drainage (245 mg/Kg) exceeded the background value of 95 mg/Kg
- Molybdenum, which in grasses from the adit drainage (57 mg/Kg) and the dump perimeter (59 mg/Kg) exceeded the background value of 5 mg/Kg
- Selenium, which in grasses from the adit drainage (63.7 mg/Kg) and the dump perimeter (103 mg/Kg) exceeded the background value of 2.4 mg/Kg
- Uranium, which in grasses from the adit drainage (1.89 mg/Kg) and the dump perimeter (4.56 mg/Kg) exceeded the background value of 0.03B mg/Kg
- Vanadium, which in grasses from the adit drainage (5.9 mg/Kg) and the dump perimeter (33.9 mg/Kg) exceeded the background value of 0.7B mg/Kg
- Zinc, which in grasses from the adit drainage (34 mg/Kg) and the dump perimeter (33 mg/Kg) exceeded the background value of 10 mg/Kg
- Gross Alpha, which in grasses from the adit drainage (119 pCi/g) and the dump perimeter (15.9 pCi/g) exceeded the background value of 1.63 pCi/g
- Gross Beta, which in grasses from the adit drainage (220 pCi/g) and the dump perimeter (9.71 pCi/g) exceeded the background value of 7.15 pCi/g
- Radium 226, which in grasses from the adit drainage (6.31 pCi/g) and the dump perimeter (9.2 pCi/g) exceeded the background value of 1.98 pCi/g
- Thorium 228, which in grasses from the adit drainage (0.08 pCi/g) and the dump perimeter (0.09 pCi/g) exceeded the background value of –0.1 pCi/g
- Thorium 230, which in grasses from dump perimeter (1.59 pCi/g) exceeded the background value of –0.59 pCi/g

Total metals and radionuclides in the forbs samples collected from the adit drainage and the dump perimeter exceeding background values included:

- Arsenic, which in forbs from the adit drainage (1.1 mg/Kg) exceeded the background value of <0.3 mg/Kg; note arsenic value of <30 mg/Kg reported for the sample from the dump perimeter due to dilution effect
- Cadmium, which in forbs from the adit drainage (0.33 mg/Kg) exceeded the background value of 0.12B mg/Kg
- Copper, which in forbs from the dump perimeter (11 mg/Kg) exceeded the background value of 7 mg/Kg
- Molybdenum, which in forbs from the adit drainage (122 mg/Kg) and the dump perimeter (101 mg/Kg) exceeded the background value of 3B mg/Kg
- Selenium, which in forbs from the adit drainage (101 mg/Kg) and the dump perimeter (180B mg/Kg) exceeded the background value of 7.4 mg/Kg
- Uranium, which in forbs from the adit drainage (2.21 mg/Kg) exceeded the background value of 0.07B mg/Kg
- Vanadium, which in forbs from the adit drainage (1.9B mg/Kg) and the dump perimeter (14 mg/Kg) exceeded the background value of 0.8B mg/Kg
- Zinc, which in forbs from the dump perimeter (53 mg/Kg) exceeded the background value of 30 mg/Kg
- Gross alpha, which in forbs from the adit drainage (73.7 pCi/g) and the dump perimeter (39.4 pCi/g) exceeded the background value of 0.94 pCi/g
- Gross Beta, which in forbs from the adit drainage (71.8 pCi/g) and the dump perimeter (23.1 pCi/g) exceeded the background value of 13.6 pCi/g
- Radium-226, which in forbs from the adit drainage (9.16 pCi/g) and the dump perimeter (11.2 pCi/g) exceeded the background value of 0.07 pCi/g
- Thorium-230, which in forbs from the dump perimeter (0.08 pCi/g) exceeded the background value of -0.28 pCi/g

Total metals and radionuclides in the shrub sample collected from the adit drainage and the dump perimeter exceeding background values included:

- Antimony, which in the shrubs from the adit drainage (0.1B mg/Kg) exceeded the background value of <0.1 mg/Kg

- Arsenic, which in shrubs from the adit drainage (1.8 mg/Kg) and the dump perimeter (0.7B mg/Kg) exceeded the background value of <0.3 mg/Kg
- Cadmium, which in shrubs from the adit drainage (1.06 mg/Kg) and the dump perimeter (0.23B mg/Kg) exceeded the background value of 0.06B mg/Kg
- Manganese, which in shrubs from the adit drainage (82.6 mg/Kg) and the dump perimeter (93.1 mg/Kg) exceeded the background value of 42.4 mg/Kg
- Molybdenum, which in shrubs from the adit drainage (32 mg/Kg) and the dump perimeter (18 mg/Kg) exceeded the background value of <1 mg/Kg
- Selenium, which in shrubs from the adit drainage (87.1 mg/Kg) and the dump perimeter (60 mg/Kg) exceeded the background value of 1.3B mg/Kg
- Uranium, which in shrubs from the adit drainage (3.07 mg/Kg) and the dump perimeter (2.91 mg/Kg) exceeded the background value of <0.03 mg/Kg
- Vanadium, which in shrubs from the dump perimeter (6.3 mg/Kg) exceeded the background value of 0.6B mg/Kg
- Zinc, which in shrubs from the adit drainage (231 mg/Kg) and the dump perimeter (46 mg/Kg) exceeded the background value of 33 mg/Kg
- Gross Alpha, which in shrubs from the adit drainage (22.7 pCi/g) and the dump perimeter (18.9 pCi/g) exceeded the background value of 2.25 pCi/g
- Gross Beta, which in shrubs from the adit drainage (21.5 pCi/g) and the dump perimeter (14.2 pCi/g) exceeded the background value of 9.2 pCi/g
- Radium 226, which in shrubs from the adit drainage (4.59 pCi/g) and the dump perimeter (2.25 pCi/g) exceeded the background value of 0.45 pCi/g
- Radium 228, which in shrubs from the adit drainage (2.91 pCi/g) exceeded the background value of 2.31 pCi/g
- Thorium 228, which in shrubs from the adit drainage (0.15 pCi/g) and the dump perimeter (0.12 pCi/g) exceeded the background value of –0.13 pCi/g

3.7.5 Geotechnical Analysis

Samples of the materials comprising the waste-rock dump were collected for geotechnical analysis. In-situ samples were collected at borehole FF 9 from the 15 to 17 foot depth interval for natural-moisture (ASTM D2216), natural-density (liner atterberg-limits (ASTM D4318), and direct-shear (ASTM D3080) testing. In addition, a bulk sample was collected by compositing the material encountered from the top of each borehole to the bottom of the waste-rock material. The bulk sample was submitted to a geotechnical

laboratory for sieve analysis (ASTM D422), hydrometer (ASTM D422), atterberg limits (ASTM D4318), standard proctor (ASTM D698), and remolded direct shear (ASTM D3080). Geotechnical analysis results are provided in Appendix C and summarized in Tables 3.24 (geotechnical classification), 3.25 (moisture-density and shear strength), and 3.26 (in-situ properties).

Waste-rock material at the Firefly/Pygmy Mine is classified as low plasticity silty sands with gravel (SM) as shown on Table 3.24. Particle-size analysis results for the mine are nearly identical to the results for waste material at the Vanadium Queen, Blue Cap, and Black Hat Mines as shown by the standard error of average size fractions. All standard errors are less than 3% of the mean indicating striking similarity between samples.

Review of the standard penetration testing reveals that the waste rock is in a loose condition to an approximate depth of 20 feet and becomes medium dense from 20 to 36 feet. The loose condition indicates a susceptibility to settlement upon loading without geotechnical improvement.

Results of Standard Proctor testing are presented on Table 3.25. The maximum dry density of 121.5 pounds per cubic foot (pcf) and optimum moisture content of 11.5 percent fall within the normal range of 110 to 125 pcf at optimum moisture contents of 11 to 16 percent for SM soils (U.S. Navy, 1982). Shear strengths evaluated by direct shear testing for in-situ samples indicate an angle of internal friction (φ) of 45.8° and cohesion 243.7 pounds per square foot (psf). Soils remolded to 95 percent Standard Proctor maximum dry density exhibited an angle of internal friction of 43.4° and cohesion of 217.6 psf. Literature values for SM soils compacted to maximum Standard Proctor densities are 34° and 420 psf (U.S. Navy, 1982). The slightly higher strengths in the in-situ samples may be explained by capillary tensions developing in the unsaturated sample during testing.

3.7.6 Radiological Survey

Radiological measurements were collected at the mine over the period April 19-23, 2004. Radiological survey results are presented in Figure 3.11. The survey was performed across the mine bench, along a portion of the mine access road, intermediate bench, the lower waste-rock dump, and the ephemeral drainage from the toe of the dump to La Sal Creek. Much of the upper dump and portions of the lower dump could not be surveyed due to steep, unsafe conditions.

The radiological survey results show that the largest area of high gamma-ray counts (greater than 28,500 cpm) was measured on the intermediate bench in the vicinity of borehole FF 6, including the upper

portion of the lower dump near correlation samples FF-COR6 and FFCOR7. The area extends across the bench and down the waste-rock dump covering the upper portions of SEGMENT 6 and SEGMENT 7. The remainder of the lower dump exhibits gamma-ray count readings of 21,500 to 28,500 cpm. The gamma-ray counts measured on the mine bench predominantly range from 21,500 to 28,500, with some areas showing 18,500 to 21,500 cpm and isolated hot-spots along the crest of the bench showing greater than 28,500 cpm. Survey results along the access road, around the cabin, along the base of the outcrop, and east portion of the bench show values of less than 18,500 cpm. Measurements along the ephemeral drainage predominantly show values of less than 18,500 cpm, with slightly higher values (18,500 to 21,500 cpm) immediately downstream of the dump and at isolated areas along the drainage.

Correlation data for the mine are presented in Tables 3.16 and 3.27. Within the background area, the in-situ gamma count reading was 12,126 cpm (13 microroentgen per hour [μR/hr]), and the total uranium and radium-226 activities were 0.83 pCi/g (1.23 mg/Kg) and 1.67 pCi/g, respectively. The results reported for sample sites at the mine (FF-COR1 through FF-COR7) are summarized as follows:

- Highest gamma count, uranium, and radium-226 values: Site FF-COR4 located in south end of lower dump, near the ore load-out area.
    - In-situ gamma count: 279,718 cpm (320 μR/hr)
    - Total uranium: 355 pCi/g (524 mg/Kg)
    - Radium-226: 247 pCi/g

- Lowest gamma count, uranium, and radium-226 values: Site FF-COR1 located on the western perimeter of the mine bench, near the cabin.
    - In-situ gamma count: 35,369 cpm (33 μR/hr)
    - Total uranium: 18.7 pCi/g (27.6 mg/Kg)
    - Radium-226: 11.7 pCi/g

Sample sites were also established in sediment areas along La Sal Creek immediately downstream (FF-COR8) and upstream (FF-COR9) of the ephemeral drainage confluence. Downstream of the confluence, the in-situ gamma count reading was 9,477 cpm (11 μR/hr), and the total uranium and radium-226 activities were 155 pCi/g (229 mg/Kg) and 0.22 pCi/g, respectively. Upstream of the confluence, the in-situ gamma count reading was 61,817 cpm (80 μR/hr), and the total uranium and radium-226 activities were 69.1 pCi/g (102 mg/Kg) and 0.12 pCi/g, respectively.

3.7.7 Radon Monitoring

Alpha-track detectors were used to assess radon levels in the mine portal. One detector was placed inside the mine adit, and one detector was placed in the background area established for the radiological

correlation study. Both detectors were placed at the mine on April 27, 2004 and collected for analysis on October 11, 2004. The monitoring results reported for mine are as follows:

- Background Area
  - Exposure: 304.1 pCi/L over 167-day monitoring period
  - Average: 1.8 pCi/L per day

- Adit
  - Exposure: Greater than 140,000 pCi/L over 167-day monitoring period
  - Average: Greater than 838 pCi/L per day

These results suggest that high radon levels are associated with the mine.

3.8 Vanadium Queen Mine

Characterization activities at the Vanadium Queen Mine included a collection of surface-water and stream sediment, waste-rock, ephemeral drainage sediment, and vegetation samples for chemical analysis; collection of waste-rock samples for geotechnical analysis; radiological survey; radon monitoring at the mine adit and a background area; and one composite soil sample from the shop area. Each component of the characterization effort is discussed below.

3.8.1 Surface Water and Stream Sediment

The water quality stations established at the Vanadium Queen Mine are shown in Figures 3.12 and 3.13 and include the following:

- VQ Adit (discharge from the Vanadium Queen Mine adit)
- VQ Drainage 1(mine drainage on mine access road down slope of upper bench)
- VQ Spring No. 1 (small spring south and down slope of mine dump)
- VQ Spring No. 2 (small discharge northeast of the dump along slope)
- VQ Spring No. 3 (small discharge northeast of the dump along slope)
- La Sal Crk Dn2 (La Sal Creek downstream of the Twomile Creek confluence)
- La Sal Crk Dn3 (La Sal Creek just downstream of confluence of gully below mine dump)

Table 3.28 shows the field parameters and chemical analytical data for the stations listed above.

3.8.1.1 Mine Discharge

Discharge at the Vanadium Queen adit (station VQ Adit) is small and not physically measurable at the portal because of very shallow water within a broad 2 to 3 feet-wide channel. Pooled water within the mine portal slowly flows along one side of wooden cribbing and onto the mine bench area where it forms a bog wetland (non-jurisdictional) with various phreatophytes including grasses, rushes, and willows. Several small emanation points also occur under the shallow water surface near the portal by a metal pipe that may have once been used to convey mine water from the workings.

Discharge at the VQ Drainage 1 station was measured (some uncaptured flow was estimated) at approximately 0.5 gpm. VQ Drainage 1 is a portion of the flow that emanates from the mine portal that flows off the mine bench along the bench access road and into a toe-ditch adjacent to the road. Based on field observations, it is estimated that the total mine discharge from the Vanadium Queen Mine is 2 to 3 gpm.

3.8.1.2 Spring Discharge

Three springs were identified in the area down gradient of the mine and were labeled VQ Spring No.1, VQ Spring No.2, and VQ Spring No.3. A previously identified seep near VQ Spring No.1 was not discharging during the April sampling event. Therefore, a newly discovered spring, VQ Spring No.3 near La Sal Creek was designated as a new sampling station. The three springs are located in a progressive down gradient direction of the Vanadium Queen Mine along a subtle broad drainage just east of the main gully drainage below the mine dump (Figure 3.12).

The purpose of sampling the springs was to assess water quality impact from a potential hydraulic connection of underground mine workings to the springs. There is no mine-related surface disturbance near the springs nor is there the potential for direct upgradient runoff from the mine to impact the spring areas.

VQ Spring No.1 is located within the upper portion of a subtle drainage down slope of the mine and approximately 200 feet east of the mine access road at an approximate elevation of 6,330 feet amsl. The spring sampling area is on the down slope side of a dense thicket of willows. Flow occurs in a small shallow drainage. Because of the shallow depths flow is not measurable, but was estimated to be approximately 1 gpm in both April and October.

VQ Spring No.2 is located approximately 700 feet down slope of VQ Spring No.1 within the same drainage. The spring is located in a small grassy opening within a thicket of oak brush. This spring may qualify more as a seep as flow seemed to be enough to keep the ground wet. There is not good channel development at the spring. Before sampling in April 2004, a plastic perforated bucket was installed in the ground where the spring emanates to accommodate sampling instruments and collect enough water volume to pump during sampling. Because of these conditions, it is not possible to measure flow at the spring. Flow was estimated to be less than 1 gpm in both April and October.

VQ Spring No.3 is located at the toe of the small ridge that separates the dry gully stemming at the Vanadium Queen Mine dump and the more subtle drainage located to the east. The spring emanates into a sandy shallow pool containing dense aquatic plants (possibly watercress). Flow disperses onto the north bank (flood plain) of La Sal Creek, located 15 feet to the south. Again, because there is no relief to accommodate a bucket and stop watch measurement method, flow could not be measured. An estimated discharge at the spring is 5 gpm. Discharge in La Sal Creek is discussed in Section 3.4.1.1

3.8.1.3 Water Quality

Mine Discharge Water Quality

Field parameter data indicate that the water at the VQ Adit station differs slightly from water at the VQ Drainage 1 station. The VQ Drainage 1 water is a few degrees warmer in temperature but contains slightly less dissolved oxygen and is slightly more reducing than water emanating from the adit. These properties may be related to microbial reactions taking place in the bog area before water flows down the access road. The water at the portal, station VQ Adit, is significantly colder in temperature than the VQ Drainage 1 water and the spring samples. This may indicate that the water draining from the mine originates from a different source or is influenced by air temperatures in the mine. As postulated in the conceptual model, the mine drainage may originate from deeper strata intercepted by the mine workings. The following information summarizes water quality conditions for the mine water at the Vanadium Queen Mine:

- Mine water is of the sodium bicarbonate type.
- The pH of VQ Drainage 1 water ranged from 8.23 to 9.11; the April measurement exceeded the screening level pH of 8.5 and is also slightly greater that the pH level of 9.0 established for aquatic life and recreation on La Sal Creek. The April sample at the VQ Adit station had a pH of 8.64, also above the screening level of 8.5.

- The TDS concentrations for the VQ stations are of the low to moderate range with concentrations ranging from 160 to 300 mg/L, with an average concentration of approximately 244 mg/L.

- The total phosphorous screening level concentration of 0.05 was exceeded in one April sample at station VQ Adit, with a concentration of 0.24 µg/L.

- The total suspended solids screening level concentration of 35 µg/L was exceeded at station VQ Drainage with a concentration of 118 µg/L. This was an anomalous result compared to all other VQ data and is probably the result of sediment generated while sampling.

- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, magnesium, molybdenum, potassium, sodium, uranium, and vanadium, total vanadium, combined thorium-230 and thorium-232, and thorium-228.

    - The dissolved barium screening level concentration of 127 µg/L was exceeded at stations VQ Drainage and Adit in both the April and October samples. Concentrations ranged from 162 to 170 µg/L. Concentrations at VQ Spring No. 2 were higher.
    - The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233 µg/L for October were exceeded at all stations for both sampling events, with concentrations ranging from 26,800 to 27,500 µg/L.
    - The dissolved molybdenum screening level concentration of 5 µg/L for April and October was exceeded at stations VQ Drainage and Adit for both sampling events, with concentrations ranging from 150 to 170 µg/L. Total molybdenum concentrations were similar.
    - The dissolved potassium screening level concentrations of 2,300 µg/L for April and 3,800 µg/L for October were exceeded at all stations for both sampling events. Concentrations ranged from 8,400 to 9,600 µg/L.
    - The dissolved sodium screening level concentrations of 12,200 µg/L for April and 21,000 µg/L for October were exceeded at both VQ mine stations at both sampling times. Concentrations ranged from 48,100 to 52,100 µg/L.
    - The dissolved uranium screening level concentrations of 2.56 µg/L for April and 3.69 µg/L for October were exceeded at all stations for both sampling events. Concentrations ranged from 796 to 902 µg/L. The high concentrations associated with stations VQ Drainage and Adit were 17 to 160 times greater than results at the VQ Spring stations.
    - The dissolved and total vanadium screening level concentrations of 2.5 µg/L (dissolved, April and October) and 4.3 and 2.5 µg/L (total, April and October), were exceeded at all stations for both sampling events. Concentrations ranged from 1,020 to 1,460 µg/L, with the higher concentrations at stations VQ Drainage and Adit being over 100 times greater than concentrations at the VQ Spring stations (with the exception of a 506 µg/L result for VQ Spring No. 2 in October).
    - The combined thorium-230 and thorium-232 screening concentration of 0.06 pCi/L for April and 0.02 pCi/L for October were exceeded at all stations for all sampling events with exception of the original April sample at VQ Adit (the duplicate sample exceeded the screening level). Concentrations ranged from 0.21 to 4.97 pCi/L.
    - The thorium-228 screening level concentration of 0 (zero) pCi/L for October was exceeded at station VQ Drainage 1 with a concentration of 0.26 pCi/L.

- Metals exceeding promulgated or risk-based screening levels were limited to dissolved and total recoverable arsenic, total recoverable iron, total lead, manganese, molybdenum, dissolved and total selenium, and uranium.

    - The dissolved arsenic screening level concentration of 93 µg/L was exceeded at stations VQ Drainage and Adit for both sampling events with concentrations ranging from 123 to 143 µg/L. Dissolved arsenic was present at concentrations of 2 and 1.9 µg/L at VQ Spring No. 1, and undetected in Springs No. 2 and No. 3. VQ drainage concentrations were slightly greater.
    - The total recoverable arsenic screening level concentration of 10 µg/L was exceeded at stations VQ Drainage and Adit with concentrations ranging from 106 to 131 µg/L. The VQ Drainage concentrations were slightly greater.
    - The total recoverable iron screening level concentration of 300 µg/L was exceeded at stations VQ Drainage in the April and October samples, and at VQ Adit in the April sample (duplicate sample). Concentrations ranged from 460 to 2,370 µg/L. The greatest concentrations were at station VQ Drainage.
    - The total lead screening level concentration of 15 µg/L was exceeded in the October sample at station VQ Drainage with a concentration of 17.6 µg/L. All other lead results for the mine area were less than 2.7 µg/L including undetected results.
    - The total manganese screening level concentration of 50 µg/L was exceeded in the October sample at station VQ Drainage with a concentration of 89 µg/L, and in the April sample (duplicate) at station VQ Adit with a concentration of 67 µg/L.
    - The total molybdenum screening level concentration of 100 µg/L was exceeded for both sampling events at stations VQ Drainage and Adit with concentrations ranging from 150 to 170 µg/L.
    - The total and dissolved selenium screening level concentration of 4.6 µg/L for April and 10 µg/L for October were exceeded at stations VQ Drainage and Adit for both sampling events. Concentrations ranged from 284 to 371 µg/L, and were significantly less in the spring samples.
    - Total uranium concentrations exceed the screening level of 30 µg/L at sample stations VQ Drainage and Adit for both sample events, with concentrations ranging from 785 to 1,000 µg/L. VQ Drainage and Adit concentrations are 20 times the concentrations in Spring No. 1.

- The gross alpha screening level concentration of 15 pCi/L was exceeded for the April and October samples at stations VQ Drainage and Adit. Concentrations ranged from 520 to 792 pCi/L. The higher concentrations were associated with station VQ Adit followed by VQ Drainage. Spring No. 1 concentrations were of the order of 25 pCi/L.

- The gross beta screening level concentration of 50 pCi/L was exceeded in both sampling events at stations VQ Drainage and Adit, with concentrations ranging from 124 to 274 pCi/L. Other stations had concentrations one to two orders of magnitude less.

- The combined radium-226 and radium-228 screening level concentration of 5 pCi/L was exceeded in both sampling events at stations VQ Drainage and Adit, with concentrations ranging from 29.42 and 42.18 pCi/L. Results were of similar magnitude for these stations.

- The thorium-228 screening level concentration of 0.15 pCi/L for April was exceeded in the April sample event at stations VQ Drainage with a concentration of 0.26 pCi/L.

- The highest analyte concentrations were usually associated with the VQ Drainage station but these concentrations did not significantly exceed concentrations from samples of the VQ Adit station.

Spring Water Quality

Field parameters at each spring show some variability between the April and October sampling events. Temperature data for the VQ Spring No. 1 and VQ Spring No. 2 stations indicate 2 to 4 degree differences between the April and the October sampling events. This is probably due to seasonal fluctuations of ground and air temperature. The temperature decrease in VQ Spring No. 2 in October may be due to exposure of the standing water in the perforated bucket used to develop the spring to colder nighttime temperatures. Specific conductance and pH measurements are not significantly different between sampling events. The ORP measurements show significant variability between sampling events, but do not have a consistent trend among the spring stations sampled. The following information summarizes water quality conditions for the spring water at the Vanadium Queen Mine:

- Spring water is of the sodium bicarbonate type at spring VQ Spring No.1, and of the calcium bicarbonate type at springs VQ Spring No.2 and VQ Spring No.3.

- Spring water has slightly lower concentrations of TDS and slightly greater concentrations of chloride compared to mine water concentrations. Sulfate concentrations are similar.

- The total phosphorous screening level concentration of 0.05 was exceeded in the April sample at VQ Spring No.2 with a concentration 0.07 µg/L.

- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, calcium, magnesium, potassium, sodium, uranium, and vanadium, total vanadium, combined thorium-230 and thorium-232, and thorium-228.

    - The dissolved barium screening level concentration of 127 µg/L was exceeded at stations VQ Spring No. 1 and No. 2 in the April samples. Concentrations ranged from 129 µg/L (VQ Spring No. 1) to 195 µg/L (VQ Spring No. 2). Concentrations at VQ Drainage and Adit were similar.
    - The dissolved calcium screening level concentration of 45,667 µg/L for April was exceeded at station VQ Spring No. 3 with a concentration 45,900 µg/L.
    - The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233 µg/L for October were exceeded at all spring stations for both sampling events, with concentrations ranging from 16,000 to 24,100 µg/L.
    - The dissolved potassium screening level concentrations of 2,300 µg/L for April and 3,800 µg/L for October were exceeded at station VQ Spring No.1 for both sampling events, and at stations VQ Spring No. 2 and No.3 for the April event. Concentrations ranged from 2,500 to 4,800 µg/L.
    - The dissolved sodium screening level concentrations of 12,200 µg/L for April and 21,000 µg/L for October were exceeded at the VQ Spring No.1 at both sampling times, and in April at Springs No. 2 and No.3. Concentrations ranged from 15,000 to 37,100 µg/L.

The VQ Drainage and Adit samples exceeded 48,000 µg/L sodium while the VQ Spring samples were less than 17,000 µg/L sodium.

- The dissolved uranium screening level concentrations of 2.56 µg/L for April and 3.69 µg/L for October were exceeded for both sampling events at VQ Spring No.1 and No. 3, and in April at VQ Spring No. 2. Concentrations ranged from 4.89 to 46.4 µg/L. The high concentrations associated with stations VQ Drainage and Adit were 17 to 160 times greater than results at the VQ Spring stations.
- The dissolved and total vanadium screening level concentrations of 2.5 µg/L (dissolved, April and October) and 4.3 and 2.5 µg/L (total, April and October), were exceeded at station VQ Spring No.1 for both sampling events, and at Spring No. 2 for the April event. Total vanadium for the October event was also exceeded at Spring No.2. Concentrations ranged from 6 to 506 µg/L. Higher concentrations at stations VQ Drainage and Adit were over 100 times greater than concentrations at the VQ Spring stations (with the exception of a 506 µg/L result for VQ Spring No. 2 in October.
- The combined thorium-230 and thorium-232 screening concentrations of 0.06 pCi/L for April and 0.02 pCi/L for October were exceeded at station VQ Spring No. 1 in April and at Spring No. 3 in both April and October. Concentrations ranged from 0.16 to 0.36 pCi/L. Concentrations an order of magnitude greater were associated with stations VQ Drainage and Adit.

- Metals exceeding promulgated or risk-based screening levels were limited to dissolved and total recoverable iron, manganese, molybdenum, and uranium, and dissolved and total selenium.
  - The dissolved iron screening level concentration of 300 µg/L was exceeded at stations VQ Spring No.2 in April with a concentration of 1480 µg/L. This was an anomalous result as all other analyses for the mine did not detect dissolved iron.
  - The total recoverable iron screening level concentration of 300 µg/L was exceeded at station VQ Spring No. 2 in the April sample with a concentration of 1,230 µg/L. Overall concentrations ranged from 460 to 2,370 µg/L. The greatest concentrations were at station VQ Drainage.
  - The total manganese screening level concentration of 50 µg/L was exceeded in the October sample at station VQ Spring No. 2 with a concentration 500 µg/L. Concentrations in the VQ Drainage and Adit samples were 89 and 67 µg/L, respectively.
  - The total molybdenum screening level concentration of 100 µg/L was exceeded in the October sample at station VQ Spring No.2 with a concentration of 510 µg/L. Dissolved concentrations were not detected in the result for VQ Spring No.2. Molybdenum concentrations in the VQ Drainage and Adit samples were of the order of 160 µg/L.
  - The dissolved and total selenium screening level concentrations of 4.6 µg/L and 10 µg/L, respectively, were exceeded at all spring stations at all times with exception of the October sample at VQ Spring No. 2 where concentrations were conspicuously low (2 to 3 µg/L). Concentrations ranged from 42.3 to 159 µg/L, and consistently exceeded 300 µg/L at stations VQ Drainage and Adit.
  - The total uranium screening level concentration of 30 µg/L was exceeded at station VQ Spring No. 1 for the April and October sample events, with concentrations of 47.6 and 33.7 µg/L, respectively. VQ Drainage and Adit concentrations are 20 times the concentrations in Spring No. 1.

- The gross alpha screening level concentration of 15 pCi/L was exceeded for the April and October samples at the station VQ Spring No.1 with concentrations of 28.2 and 25.5 pCi/L, respectively. The mine area high concentration was at station VQ Adit with a value of 792 pCi/L.

- The thorium-228 screening level concentration of 0.15 pCi/L for April and 0 (zero) pCi/L for October were exceeded in the April sample event at VQ Spring No. 1 and No. 2 with concentrations of 0.34 pCi/L and 0.21 pCi/L, respectively. Concentrations were lower at the VQ Drainage and Adit stations.

- Of interest is the divergent concentrations in a number of metals in VQ Spring No.2 in the April and October samples. Concentrations of dissolved barium, total recoverable and dissolved iron, total and dissolved selenium, and total and dissolved uranium show high results in April and low results in October. Conversely, October concentrations of total manganese, molybdenum, and vanadium greatly exceed the April results. It is suspected that this is related to the change in conditions as a result of "developing" the spring sampling site. A perforated plastic bucket was installed in the ground at the spring to aid in collecting water because of insufficient flows. By October this collection bucket contained a fair amount of moss growth. It is suspected that this or other biological material affected dissolved and total metal concentrations by either adsorption, or by precipitation associated with oxidation/reduction reactions.

- In general, trace metals and radionuclide parameters that exceeded screening levels at the mine and spring water sample stations, showed a decreasing trend in concentration with increasing station distance from the mine. The highest concentration of analytes was usually associated with the VQ Drainage station or occasionally with the VQ Adit station.

3.8.1.4 Impact To La Sal Creek Water Quality

To assess the potential impact of the Vanadium Queen Mine on La Sal Creek water quality, an examination of water quality data was conducted of data collected on La Sal Creek upstream and downstream of the confluence with the dry tributary that extends from the toe of the Vanadium Queen Mine dump (Figure 3.12). The La Sal Creek data evaluated were for stations La Sal Crk Dn2 and La Sal Crk Dn3 as shown in Table 3.28.

Table 3.28 shows that the field parameter measurements and analytical concentrations of virtually all analytes are very similar between the two stations. Based on water quality data at stations La Sal Crk Dn2 and La Sal Crk Dn3 there is no indicated impact to the water quality of La Sal Creek by the Vanadium Queen Mine.

Table 3.7 shows the total metals and radionuclide concentration results for sediment samples collected in La Sal Creek. Section 3.4.1.3 summarizes the results of the sediment analyses at the La Sal Crk stations. Table 3.7 shows that radium-228 is the only analyte that exceeds screening level concentrations in both stations La Sal Crk Dn2 and Dn3 and that concentrations are similar (including the duplicate sample result). However, concentrations of total barium, uranium, vanadium, and gross alpha, radium-226, and

thorium-230 in the downstream station of La Sal Crk Dn3 exceed the concentrations in upstream station of La Sal Crk Dn2 by 2 to 8 times. Barium concentrations are approximately 8 times greater, and total uranium and radium-226 concentrations are approximately 4 times greater in the downstream station of La Sal Crk Dn3. Based on these analytical results, it is possible that migration of contaminants from the Vanadium Queen mine has occurred and has caused elevated concentrations of contaminants in the stream sediments.

3.8.2 Waste Rock

Waste rock samples were collected at the mine from boreholes drilled into the mine dump and composite surface samples collected from the face of the dump.

3.8.2.1 Borehole Samples

Eight boreholes (VQ 1 through VQ 8) were drilled at the mine to obtain samples for chemical analysis and assess the depth to native material beneath the mine dump. A near-surface sample (0 – 0.5 foot depth interval) was collected for chemical analysis at each borehole, and sub-surface samples were collected where possible based on the thickness of waste rock encountered in the borehole. One borehole (VQ 9) was drilled on the dump to obtain samples for geotechnical analysis. Borehole locations are shown in Figure 3.13, and borehole logs and geotechnical analysis results are provided in Appendix C.

The lithologic logs for the boreholes drilled on the mine bench (VQ 3 through VQ 8) show that the bench is constructed largely on native material and that little waste rock is present on the bench. Waste rock was encountered to a depth of 2.5 feet at borehole VQ 4, the depth to waste rock was 2 feet or less at the other boreholes on the bench. One borehole (VQ 6) was extended 28 feet below the suspected native soil contact to verify that waste rock had not been blended with native soil to form the existing bench feature. The thickness of waste rock was greater than 2.5 feet at only one borehole (VQ 2) drilled at the mine. As a result, sub-surface waste-rock samples could only be collected at boreholes VQ 2 and VQ 4.

The thickness of waste rock encountered in each borehole is depicted in Figure 3.14. Waste rock was encountered at depths ranging from 0 to 2.5 feet on the mine bench and from 2.5 feet on the western perimeter of the lower dump to 17 feet toward the center of the lower dump. To assess the volume of waste rock present at the mine, the dump was divided into an upper and a lower zone as shown in Figure 3.14. The surface area comprising each zone was measured on the basis of a recent aerial photograph of

the mine. It is suspected that waste rock forms a thin veneer (less than 5 feet thick) on the sideslope of the native soil bench. A conservative estimate of the volume of waste rock comprising the upper dump zone was calculated by assuming a uniform, average waste-rock thickness of 5 feet, two times the maximum thickness of waste rock encountered in boreholes on the bench. Based on this assumption, the volume of waste rock in the upper dump is estimated to be 50,465 cubic feet (1,869 cubic yards). A conservative estimate of the volume of waste rock comprising the lower dump zone was calculated by assuming a uniform, average waste-rock thickness of 17 feet, the thickness of waste rock encountered at VQ 2. Based on this assumption, the volume of waste rock in the lower dump is estimated to be 478,516 cubic feet (17,723 cubic yards).

Analytical results are presented in Tables 3.29 (total metals and radionuclides) and 3.30 (SPLP metals). In comparison to the screening levels, arsenic and vanadium are the only analytes reported at concentrations exceeding the human-health criteria; cadmium, copper, lead, and zinc are the only analytes reported at concentrations exceeding the RMC for elk; and gross alpha, gross beta, radium-226, radium-228, and thorium 230 exceeded background levels.

Total Metals

As shown in Table 3.29, arsenic was reported at concentrations exceeding the human-health screening level of 12 mg/Kg in all samples collected from the boreholes. Arsenic concentrations ranged from 14.2 mg/Kg in waste-rock sample VQ 6 (3-5) and native soil sample VQ 8 (0-0.5) to 141 mg/Kg in waste-rock sample VQ 1 (0-0.5 [duplicate]). Arsenic concentrations in near-surface samples (0-0.5 foot depth interval) ranged from 14.2 mg/Kg in the sample of predominantly native soil at VQ 8 to 141 mg/Kg in the duplicate waste-rock sample at VQ 1. Arsenic concentrations in sub-surface samples ranged from 14.2 mg/Kg in the native soil sample VQ 6 (3-5) to 91 mg/Kg in waste-rock sample VQ 2 (2-4).

Vanadium was reported at a concentration of 8,840 mg/Kg in sample VQ 6 (0-0.5), exceeding the human-health screening level of 7,154 mg/Kg. The vanadium concentrations in all the other samples were well below the screening level.

Cadmium concentrations slightly exceeded the RMC for elk (3 mg/Kg) in three samples. The cadmium concentrations in samples VQ 2 (0-0.5), VQ 3 (0-0.5), and VQ 6 (0-0.5) were 3.39 mg/Kg, 3.43 mg/Kg, and 3.6 mg/Kg, respectively.

Copper concentrations exceeded the RMC for elk (131 mg/Kg) in all near-surface samples (0-0.5 foot depth interval) except for the waste-rock sample collected at VQ 4 and the native soil sample collected at VQ 8. Copper concentrations exceeding the screening level in near-surface samples ranged from 166 mg/Kg in the waste-rock sample collected at VQ 3 to 368 mg/Kg in the duplicate waste-rock sample collected at VQ 5. Copper concentrations exceeded the Elk RMC only in sub-surface samples collected at VQ 2. Copper concentrations in the sub-surface samples collected at VQ 2 ranged from 160 mg/Kg in the 15-17 foot depth interval to 389 mg/Kg in the 10-12 foot depth interval.

Lead concentrations exceeded the elk RMC (127 mg/Kg) in near-surface samples at VQ 1, VQ 2, VQ 3, VQ 5, VQ 6, and VQ 7. Lead concentrations exceeding the elk RMC in near-surface samples ranged from 152 mg/Kg at VQ 6 to 832 mg/Kg at VQ 1. Lead concentrations exceeded the elk RMC in sub-surface samples at VQ 2 and VQ 6. Lead concentrations exceeding the elk RMC in sub-surface samples ranged from 129 mg/Kg in native soil sample VQ 6 (22-24) to 652 mg/Kg in waste-rock sample VQ 2 (2-4).

Zinc was reported at a concentration of 305 mg/Kg in sample VQ 2 (0-0.5) and 340 mg/Kg in sample VQ 3 (0-0.5), exceeding the RMC for elk of 275 mg/Kg. The zinc concentrations in all the other samples were below the RMC.

SPLP Metals

As shown in Table 3.30, arsenic and vanadium were reported at concentrations exceeding the method detection limits in each of the samples. Uranium was reported at a concentration exceeding the method detection limit in all but one of the samples. Other analytes reported at concentrations above the method detection limit in one or more of the samples were barium, iron, molybdenum, and selenium. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Gross alpha, gross beta, radium-226, radium-228, and thorium-230 activities reported for the waste-rock samples collected from boreholes exceeded the levels reported for background soil. The analytical results for these radionuclides are summarized as follows, with suspected native material encountered in samples VQ 6 (3-5), VQ 6 (8-10), VQ 6 (22-24), and VQ 8 (0-0.5):

- Gross Alpha (pCi/g)

  - Minimum: 9.89 (VQ 8: 0-0.5) – suspected native
  - Maximum: 126 (VQ 2: 0-0.5) – waste rock
  - Mean: 19.6 – suspected native
  - Mean: 68 – waste rock (average background = 20.3)

- Gross Beta (pCi/g)
  - Minimum: 7.2 (VQ 8: 0-0.5) – suspected native
  - Maximum: 75 (VQ 2: 0-0.5) – waste rock
  - Mean: 12.3 – suspected native
  - Mean: 45 – waste rock (average background = 13.5)

- Radium-226 (pCi/g)
  - Minimum: 3.5 (VQ 8: 0-0.5) – suspected native
  - Maximum: 31 (VQ 2: 0-0.5) – waste rock
  - Mean: 4.1 – suspected native
  - Mean: 17 – waste rock (average background = 3.3)

- Radium-228 (pCi/g)
  - Minimum: 1.02 (VQ 5: 0-0.5 [duplicate]) – waste rock
  - Maximum: 5.87 (VQ 1: 0-0.5) – waste rock
  - Mean: 2.53 – suspected native
  - Mean: 2.95 – waste rock (average background = 2.66)

- Thorium-230 (pCi/g)
  - Minimum: 3.26 (VQ 8: 0-0.5) – suspected native
  - Maximum: 30.8 (VQ 2: 0-0.5) – waste rock
  - Mean: 3.7 – suspected native
  - Mean: 16.4 – waste rock (average background = 3.1)

3.8.2.2 Composite Surface Samples

The waste-rock dump was segregated into seven segments as shown in Figure 3.13 for collection of composite surface samples; a sample could not be collected at for Segment 2 because unstable conditions. Analytical results for the composite sample collected in each segment are presented in Tables 3.31 (total metals and radionuclides) and 3.32 (SPLP metals). In comparison to the screening levels, arsenic is the only analyte reported at concentrations exceeding the human-health criteria; copper and lead are the only analytes reported at concentrations exceeding the RMC for elk; and except for thorium-228, each of the radionuclides exceeded background levels (radium-228 only slightly exceeded background in two samples and thorium-232 only slightly exceeded background in one sample).

Total Metals

As was found for the near-surface borehole samples, each composite sample contained arsenic at a concentration exceeding the human-health screening level. Arsenic concentrations ranged from 13.5 mg/Kg at Segment 1 to 71.1 mg/Kg at Segment 5. The elk RMC for copper was exceeded in samples

collected at Segments 3, 5, and 7. Copper concentrations exceeding the RMC ranged from 155 mg/Kg in at Segment 5 to 219 mg/Kg at Segment 7. The elk RMC for lead was exceeded in samples collected at Segments 3, 5, and 6. Lead concentrations exceeding the RMC ranged from 136 mg/Kg at Segment 6 to 758 mg/Kg at Segment 5.

SPLP Metals

As shown in Table 3.32, arsenic, barium, and vanadium were reported at concentrations exceeding the method detection limits in each of the samples. Uranium was reported at a concentration exceeding the method detection limit in all but one of the samples. Selenium was reported at concentrations above the method detection limit in two samples. Analyte concentrations for the remaining parameters were below method detection limits. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Gross alpha, gross beta, radium-226, and thorium-230 activities exceeded background levels in each of the segment samples; radium-228 only slightly exceeded background in two samples and thorium-232 only slightly exceeded background in one sample. Analytical results for gross alpha, gross beta, radium-226, and thorium-230 in the composite surficial waste-rock samples are summarized as follows:

- Gross Alpha (pCi/g)
  - Minimum: 27 (VQ SEGMENT 4)
  - Maximum: 965 (VQ SEGMENT 7)
  - Mean: 368 (average background = 20.3)

- Gross Beta (pCi/g)
  - Minimum: 12.5 (VQ SEGMENT 4)
  - Maximum: 411 (VQ SEGMENT 7)
  - Mean: 150 (average background = 13.5)

- Radium-226 (pCi/g)
  - Minimum: 3.35 (VQ SEGMENT 4)
  - Maximum: 141 (VQ SEGMENT 5)
  - Mean: 57 (average background = 3.3)

- Thorium-230 (pCi/g)
  - Minimum: 6.15 (VQ SEGMENT 1)
  - Maximum: 135 (VQ SEGMENT 5)
  - Mean: 56.5 (average background = 3.1)

3.8.3 Ephemeral Drainage Sediment

Three composite sediment samples were collected along the ephemeral drainage extending from the toe of the waste-rock dump to La Sal Creek (Figure 3.12). Sample VQ Sediment 1 was collected near the toe of the mine dump, VQ Sediment 2 was collected approximately half-way between the dump and La Sal Creek, and VQ Sediment 3 was collected near the drainage confluence with La Sal Creek. Analytical results for the sediment samples are presented in Table 3.33. As shown, analyte concentrations are generally consistent (same order of magnitude) across the sampling sites. Exceptions to this general trend are noted for copper, uranium, and radium-228 levels which are one order of magnitude higher in Segments 1 and 2 than in Segment 3, vanadium concentrations which are one order of magnitude higher in Segment 1 than in Segments 2 and 3, and radium-226 activities which are two orders of magnitude higher in Segments 1 than in Segment 3. None of the concentrations reported for the sediment samples exceed the human-health screening level or the RMC for elk.

Analytical results for uranium, gross alpha, gross beta, radium-226, and radium-228 in the ephemeral drainage samples are summarized as follows:

- Uranium (mg/Kg)
  - VQ Sed 1: 25.9
  - VQ Sed 1 (duplicate): 29.1
  - VQ Sed 2: 10.7
  - VQ Sed 3: 8.31

- Gross Alpha (pCi/g)
  - VQ Sed 1: 3.35
  - VQ Sed 1 (duplicate): 9.06
  - VQ Sed 2: 3.94
  - VQ Sed 3: 2.75

- Gross Beta (pCi/g)
  - VQ Sed 1: 1.36
  - VQ Sed 1 (duplicate): 3.87
  - VQ Sed 2: 1.52
  - VQ Sed 3: 1.39

- Radium-226 (pCi/g)
  - VQ Sed 1: 0
  - VQ Sed 1 (duplicate): 3.74
  - VQ Sed 2: 0
  - VQ Sed 3: 0.08

- Radium 228 (pCi/g
  - VQ Sed 1: 0.13

- VQ Sed 1 (duplicate): 0.07
- VQ Sed 2: 0.2
- VQ Sed 3: 0.08

3.8.4 Vegetation

Vegetation samples were collected along the adit drainage channel on the mine bench and around the perimeter of the waste-rock dump. One composite grass and one composite forb sample were collected along the adit drainage channel. One composite grass, one composite forb, and one composite shrub sample were collected around the perimeter of the mine dump.

Grasses collected from the adit drainage include *Oryzopsis hymenoides* (R&S) Ricker (Indian ricegrass), *Juncus arcticus* Willd. (wiregrass, or Baltic rush), and *Panicum virgatum* L. (switchgrass). Other grasses may have been collected that were not identified. Forbs collected from the adit drainage include *Chrysothamnus nauseosus* (rubber rabbitbrush), *Melilotus alba* Desr. ex. Lan. (white sweetclover), *Grindelia squarrosa* (Pursh) Dunal (curlycup gumweed), *Machaeranthera canescens* (Pursh) Gray (purple) aster, and [possibly] *Typha domingensis* Persoon (narrowleaf cattail).

From the perimeter of the mine dump, grasses collected included *Oryzopsis hymenoides* (R&S) Ricker (Indian ricegrass), *Hordeum jubatum* (foxtail barley), and *Calamagrostis* sp. (reedgrass). Forbs collected were *Chrysothamnus nauseosus* (rubber rabbitbrush), *Melilotus alba* (sweetclover), and possibly species of the genus *Baccharis*. Shrubs included *Quercus gambelii* Nutt. (gambel oak), *Rhus trilobata* Nutt. ex. T&G (skunkbush sumac) (syn. *Rhus aromatica* var. trilobata [Nutt.] Gray), *Melilotus officinalis* (or *alba*) (yellow or white sweetclover), *Cercocarpus montanus* (mountain mahogany), *Acer negundo* L. (boxelder), *and Amelanchier utahensis* Koehne (Utah serviceberry).

Analytical results for the vegetation samples are presented in Table 3.34. In general, analytical values for total metals and radionuclides in grasses collected from the adit drainage and the mine dump perimeter were consistent with respect to those exceeding background values. Analytes exceeding background values included:

- Antimony, which in grasses from the adit drainage (0.3 mg/Kg and 0.2 mg/Kg) and the dump perimeter (0.3 mg/Kg) exceeded the background value of <0.1 mg/Kg
- Arsenic, which in grasses from the adit drainage (1.5 mg/Kg and 1.4 mg/Kg) and the dump perimeter (4.5 mg/Kg) exceeded the background value of <0.3 mg/Kg

- Barium, which in grasses from the adit drainage (49.1 mg/Kg) exceeded the background value of 41.5 mg/Kg
- Cadmium, which in grasses from the adit drainage (0.21 mg/Kg and 0.54 mg/Kg) and the dump perimeter (1.06 mg/Kg) exceeded the background value of 0.07 mg/Kg
- Copper, which in grasses from the adit drainage (4 mg/Kg and 5 mg/Kg) and the dump perimeter (20 mg/Kg) exceeded the background value of 2 mg/Kg
- Lead, which in grasses from the dump perimeter(40 mg/Kg) exceeded the background value of <4 mg/Kg
- Manganese, which in grasses from the adit drainage (221 mg/Kg) exceeded the background value of 95 mg/Kg
- Molybdenum, which in grasses from the adit drainage (19 mg/Kg and 18 mg/Kg) and the dump perimeter (58 mg/Kg) exceeded the background value of 5 mg/Kg
- Selenium, which in grasses from the adit drainage (47 mg/Kg and 39.1 mg/Kg) and the dump perimeter (81.7 mg/Kg) exceeded the background value of 2.4 mg/Kg
- Uranium, which in grasses from the adit drainage (13.5 mg/Kg and 4.24 mg/Kg) and the dump perimeter (17.5 mg/Kg) exceeded the background value of 0.03 mg/Kg
- Vanadium, which in grasses from the adit drainage (15.9 mg/Kg and 11.6 mg/Kg) and the dump perimeter (53.4 mg/Kg) exceeded the background value of 0.7 mg/Kg
- Zinc, which in grasses from the adit drainage (23 mg/Kg and 55 mg/Kg) and the dump perimeter (47 mg/Kg) exceeded the background value of 10 mg/Kg
- Gross Alpha, which in grasses from the adit drainage (89.8 pCi/g and 100 pCi/g) and the dump perimeter (40.6 pCi/g) exceeded the background value of 1.63 pCi/g
- Gross Beta, which in grasses from the adit drainage (164 pCi/g and 256 pCi/g) and the dump perimeter (22.1 pCi/g) exceeded the background value of 7.15 pCi/g
- Radium 226, which in grasses from the adit drainage (10.1 pCi/g and 7.85 pCi/g) and the dump perimeter (9.75 pCi/g) exceeded the background value of 1.98 pCi/g
- Radium 228, which in grasses from the adit drainage (1.83 pCi/g) and the dump perimeter (2.22 pCi/g) exceeded the background value of 1.65 pCi/g
- Thorium 228, which in grasses from the adit drainage (0.11 pCi/g) exceeded the background value of –0.1 pCi/g
- Thorium 230, which in grasses from the adit drainage (1.03 pCi/g) and the dump perimeter (3.27 pCi/g) exceeded the background value of –0.59 pCi/g

- Thorium 232, which in grasses from the adit drainage (0.09 pCi/g) exceeded the background value of –0.17 pCi/g

Total metals and radionuclides in the forbs samples collected from the adit drainage and the dump perimeter exceeding background values included:

- Arsenic, which in forbs from the adit drainage (1.2 mg/Kg) and the dump perimeter (9.5 mg/Kg) exceeded the background value of <0.3 mg/Kg
- Cadmium, which in forbs from dump perimeter (0.43 mg/Kg) exceeded the background value of 0.12 mg/Kg
- Copper, which in forbs from the adit drainage (9 mg/Kg) and the dump perimeter (15 mg/Kg) exceeded the background value of 7 mg/Kg
- Manganese, which in forbs from the adit drainage (145 mg/Kg) exceeded the background value of 74.2 mg/Kg.
- Molybdenum, which in forbs from the adit drainage (41 mg/Kg) and the dump perimeter (115 mg/Kg) exceeded the background value of 3 mg/Kg
- Selenium, which in forbs from the adit drainage (67 mg/Kg) and the dump perimeter (519 mg/Kg) exceeded the background value of 7.4 mg/Kg
- Uranium, which in forbs from the adit drainage (1.47 mg/Kg) and the dump perimeter (5.35 mg/Kg) exceeded the background value of 0.07 mg/Kg
- Vanadium, which in forbs from the adit drainage (4.1 mg/Kg) and the dump perimeter (17.1 mg/Kg) exceeded the background value of 0.8 mg/Kg
- Zinc, which in forbs from the adit drainage (42 mg/Kg) and the dump perimeter (66 mg/Kg) exceeded the background value of 30 mg/Kg
- Gross Alpha, which in forbs from the adit drainage (14.5 pCi/g) and the dump perimeter (23.2 pCi/g) exceeded the background value of 0.94 pCi/g
- Gross Beta, which in forbs from the adit drainage (19.7 pCi/g) and the dump perimeter (27.8 pCi/g) exceeded the background value of 13.6 pCi/g
- Radium 226, which in forbs from the adit drainage (6.1 pCi/g) and the dump perimeter (6.84 pCi/g) exceeded the background value of 0.07 pCi/g
- Radium 228, which in forbs from the dump perimeter (3.7 pCi/g) exceeded the background value of 2.02 pCi/g
- Thorium 230, which in forbs from the dump perimeter (4.26 pCi/g) exceeded the background value of –0.28 pCi/g

- Thorium 232, which in forbs from the adit drainage (0.15 pCi/g) and the dump perimeter (0.14 pCi/g) exceeded the background value of 0.06 pCi/g

Total metals and radionuclides in the shrub sample collected from the dump perimeter exceeding background values included:

- Arsenic, which in shrubs from the dump perimeter (3 mg/Kg) exceeded the background value of <0.3 mg/Kg
- Cadmium, which in shrubs from the dump perimeter (0.35 mg/Kg) exceeded the background value of 0.06 mg/Kg
- Copper, which in shrubs from the dump perimeter (25 mg/Kg) exceeded the background value of 7 mg/Kg
- Lead, which in shrubs from the dump perimeter (6 mg/Kg) exceeded the background value of <4 mg/Kg
- Molybdenum, which in shrubs from the dump perimeter (21 mg/Kg) exceeded the background value of <1 mg/Kg
- Nickel, which in shrubs from the dump perimeter (1 mg/Kg) exceeded the background value of <1 mg/Kg
- Selenium, which in shrubs from the dump perimeter (152 mg/Kg) exceeded the background value of 1.3 mg/Kg
- Uranium, which in shrubs from the dump perimeter (2.62 mg/Kg) exceeded the background value of <0.03 mg/Kg
- Vanadium, which in shrubs from the dump perimeter (13.7 mg/Kg) exceeded the background value of 0.6 mg/Kg
- Gross Alpha, which in shrubs from the dump perimeter (14.1 pCi/g) exceeded the background value of 2.25 pCi/g
- Gross Beta, which in shrubs from the dump perimeter (17.4 pCi/g) exceeded the background value of 9.2 pCi/g
- Radium 226, which in shrubs from the dump perimeter (4.45 pCi/g) exceeded the background value of 0.45 pCi/g
- Thorium 230, which in shrubs from the dump perimeter (0.08 pCi/g) exceeded the background value of –0.44 pCi/g

Table 3.34 also compares analyte concentrations in stem and root samples from Gambles Oak at the perimeter of the waste-rock dump to analytical results for the shrub sample collected in the reference area.

These samples were collected at the request of the onsite EPA representative. As shown, analyte levels were generally higher in the root sample than the stem sample. For the stem sample, selenium and uranium were reported at the highest levels relative to background. The analytes reported at highest levels relative to background in the root sample included arsenic, cadmium, copper, selenium, uranium, vanadium, gross alpha, and radium 226. Of these analytes, uranium and vanadium concentrations in the root sample exceeded background levels by the greatest amount.

3.8.5 Geotechnical Analysis

Samples of the materials comprising the waste-rock dump were collected for geotechnical analysis. In-situ samples were collected at borehole VQ 9 from the 10 to 12 foot depth interval for natural-moisture (ASTM D2216), natural-density, liner atterberg-limits (ASTM D4318), and direct-shear (ASTM D3080) testing. In addition, a bulk sample was collected by compositing the material encountered from the top of each borehole to the bottom of the waste-rock material. The bulk samples was submitted to a geotechnical laboratory for sieve analysis (ASTM D422), hydrometer (ASTM D422), atterberg limits (ASTM D4318), standard proctor (ASTM D698), and remolded direct shear (ASTM D3080). Geotechnical analysis results are provided in Appendix C and summarized in Tables 3.24 (geotechnical classification), 3.25 (moisture-density and shear strength), and 3.26 (in-situ properties).

Waste-rock material at the Vanadium Queen Mine is classified as low plasticity silty sands with gravel (SM) as shown on Table 3.24. Particle-size analysis results for the mine are nearly identical to the results for waste material at the Firefly/Pygmy, Blue Cap, and Black Hat Mines as shown by the standard error of average size fractions. All standard errors are less than 3% of the mean indicating striking similarity between samples.

Review of the standard penetration testing reveals that the waste rock is in a loose condition to an approximate depth of 20 feet. The loose condition indicates a susceptibility to settlement upon loading without geotechnical improvement.

Results of Standard Proctor testing are presented on Table 3.25. The maximum dry density of 120.5 pcf and optimum moisture content of 12.0 percent fall within the normal range of 110 to 125 pcf at optimum moisture contents of 11 to 16 percent for SM soils (U.S. Navy, 1982).

Shear strengths evaluated by direct shear testing for in-situ samples indicate an angle of internal friction (φ) of 32.8° and cohesion 487.8 psf. Soils remolded to 95 percent Standard Proctor maximum dry density exhibited a higher angle of internal friction of 37.8° and lower cohesion of 258.0 psf. Literature values for SM soils compacted to maximum Standard Proctor densities are 34° and 420 psf (U.S. Navy, 1982).

3.8.6 Radiological Survey

Radiological measurements were collected at the mine over the period April 19-23, 2004. Radiological survey results are presented in Figure 3.15. The survey was performed across the mine bench, equipment storage/disposal area, along a portion of the mine access road, ore load-out area, the lower dump, and the ephemeral drainage from the toe of the dump to La Sal Creek. Much of the upper waste-rock dump and portions of the lower level dump could not be surveyed due to steep, unsafe conditions.

The gamma-ray counts across the mine bench predominantly range from 21,500 to 28,500 cpm, with local areas in the central and southeastern portions of the bench showing lower levels ranging from 18,500 to 21,500 cpm. Small isolated hot-spots (greater than 28,500 cpm) occur on the bench outside of the office/shop structure and southern end of the bench. The gamma-ray counts on the ore loadout terrace and the portions of the waste rock dump traversed predominantly range from 21,500 to 28,500 cpm. Several isolated areas showing higher gamma-ray counts (greater than 28,500 cpm) occur on the ore loadout terrace (e.g., the ore stockpile and along access road leading to mine bench) and in the southern portion of the dump. Along the ephemeral drainage extending from the toe of the dump, gamma-ray counts generally grade from 21,500 to 28,500 cpm immediately below the dump to 18,500 to 21,500 cpm through the central portion of the drainage to less than 18,500 cpm along the lower portion of the drainage. However, some area showing levels of 18,500 to 21,500 cpm occur near the drainage confluence with La Sal Creek. These results suggest the radioactive material has been transported along the drainage from the toe of the dump to La Sal Creek.

In addition to the measurements made at the mine, surveys were also performed at the equipment storage/disposal area and within a disturbed area along the access road leading to the mine. Gamma-ray counts are generally less than 18,500 cpm within the equipment storage/disposal area, with levels of 21,500 to 28,500 cpm occurring in the western portion of the area. Within the disturbed area surveyed along the mine access road, gamma-ray counts range from less than 18,500 cpm to greater than 28,500 cpm. It is suspected that ore may have been stockpiled in the disturbed area during mine operations.

Correlation data for the mine are presented in Table 3.35. Within the background area, the in-situ gamma count reading was 13,526 cpm (14.5 µR/hr), and the total uranium and radium-226 activities were 1.95 pCi/g (2.88 mg/Kg) and 1.44 pCi/g, respectively. The results reported for sample sites at the mine (VQ-COR1 through VQ-COR7) are summarized as follows:

- Highest gamma count: Site VQ-COR5 located on the ore loadout terrace.
  - In-situ gamma count: 247,672 cpm (260 µR/hr)
  - Total uranium: 191 pCi/g (282 mg/Kg)
  - Radium-226: 102 pCi/g

- Highest uranium, and radium-226 values: Site VQ-COR6 located between the ore loadout and small ore stockpile.
  - In-situ gamma count: 213,917 cpm (230 µR/hr)
  - Total uranium: 259 pCi/g (382 mg/Kg)
  - Radium-226: 144 pCi/g

- Lowest gamma count and uranium value: Site VQ-COR2 located near the electrical transformer station.
  - In-situ gamma count: 28,529 cpm (28 µR/hr)
  - Total uranium: 11.9 pCi/g (17.6 mg/Kg)
  - Radium-226: 10.5 pCi/g

- Lowest radium value: Site VQ-COR1 located on the southern end of the mine bench.
  - In-situ gamma count: 28,699 cpm (32 µR/hr)
  - Total uranium: 19.6 pCi/g (29 mg/Kg)
  - Radium-226: 2.98 pCi/g

Sample sites were also established in sediment areas along the ephemeral drainage (VQ-COR8) and along La Sal Creek immediately upstream of the ephemeral drainage confluence (VQ-COR9). At VQ-COR8, the in-situ gamma count reading was 42,995 cpm (46 µR/hr), and the total uranium and radium-226 activities were 26.7 pCi/g (39.5 mg/Kg) and 12.6 pCi/g, respectively. At VQ-COR9, the in-situ gamma count reading was 55,142 cpm (50 µR/hr), and the total uranium and radium-226 activities were 7.85 pCi/g (11.6 mg/Kg) and 27.1 pCi/g, respectively.

3.8.7 Radon Monitoring

Alpha-track detectors were used to assess radon levels in the mine portal. One detector was placed inside the mine adit, and one detector was placed in the background area established for the radiological correlation study. Both detectors were placed at the mine on April 27, 2004 and collected for analysis on October 14, 2004. The monitoring results reported for mine are as follows:

- Background Area
  - Exposure: 300.7 pCi/L over 167-day monitoring period
  - Average: 1.8 pCi/L per day

- Adit
  - Exposure: Greater than 140,000 pCi/L over 167-day monitoring period
  - Average: Greater than 838 pCi/L per day

These results suggest that high radon levels are associated with the mine.

3.8.8 Soil at Shop

One composite soil sample was collected from the floor of the equipment room attached to the office/shop. The sample consisted of five sub-samples collected from stained areas around the compressor. The sample was submitted for oil and grease and PCB analysis. Analytical results for the sample are presented in Table 3.36. As shown, PCBs were not detected in the sample and the reported oil and grease concentration was 59,000 mg/Kg.

3.9 Blue Cap Mine

Characterization activities at the Blue Cap Mine included a collection of surface-water and stream sediment, waste-rock, and vegetation samples for chemical analysis; collection of waste-rock samples for geotechnical analysis; radiological survey; radon monitoring at the mine adit and a background area; and one composite soil sample from the shop area. Each component of the characterization effort is discussed below.

3.9.1 Surface Water and Stream Sediment

Because the Blue Cap, Black Hat, and Saint Patrick Mines are located in close proximity at the head of Lion Canyon Creek, the discharge and water quality data collected in this area will be evaluated together to assess impact to Lion Canyon Creek and La Sal Creek. The water quality stations established at the Blue Cap, Black Hat, and Saint Patrick Mines are shown in Figures 3.16 and 3.17 and include the following:

- Blue Cap Adit (discharge from the Blue Cap Mine adit)
- Blue Cap Drainage 1(mine drainage at brow of main Blue Cap Mine dump)

- Alcove Spring (spring under sandstone alcove on southwest-facing slope opposite Blue Cap Mine dump)
- Black Hat Spring (spring emanating from rock face on mine access road approximately 400 feet southeast of Black Hat Mine)
- Lion Cyn Ck Up (Lion Canyon Creek upstream of confluence with Black Hat Spring drainage)
- Lion Cyn Ck Dn1 (Lion Canyon Creek upstream of the access road crossing)
- Lion Cyn Ck Dn2 (Lion Canyon Creek near BLM and private property boundary)

Table 3.37 shows the field parameters and chemical analytical data for the stations listed above.

3.9.1.1 Mine Discharge

Discharge at the Blue Cap Mine adit (station Blue Cap Adit) could not physically be measured at the portal because of very shallow water within a broad 2 to 3 foot wide channel. Pooled water within the mine portal flows out of the adit and onto the mine bench area where it forms a restricted wetland (non-jurisdictional) along a small channel lined with various phreatophytes including grasses, rushes, and willows. The channel trends north from the portal and spills off the north side of the mine dump. The mine drainage at the spill area is sampling location Blue Cap Drainage. Discharge measured at this location was 1.36 gpm in April and 2 gpm in October using a graduated container and stop watch.

3.9.1.2 Spring Discharge

Two spring sites were sampled in the vicinity of the Blue Cap and Black Hat Mines. The purpose of sampling the springs was to assess water quality impact from a potential hydraulic connection of underground mine workings to the springs. The springs sampled include Black Hat Spring and Alcove Spring which are located adjacent to and down slope of the mine access road, respectively, between Black Hat Mine and Saint Patrick Mine. Other than the road, there is no surface disturbance near the springs nor is there the potential for direct upgradient runoff from the mines to impact the spring areas.

Both springs are located on the southwest-facing slope opposite the Blue Cap Mine dump. Black Hat Spring emanates from fractures in a thick sandstone ledge exposed in the cut of the main mine access road, several hundred feet south of the Black Hat Mine dump (Figure 3.17). Flow from the spring follows a small channel along the road for a short distance before entering a galvanized culvert that conveys the

water under the road and spills it down the hill slope to the Lion Canyon Creek drainage. Discharge measured at the culvert was approximately 4.61 gpm in April and 5.1 gpm in October.

Alcove Spring is located at the base of a small alcove (overhang) in a sandstone ledge opposite the Blue Cap Mine dump. Willows partially shield the alcove and two old metal drums located inside the overhang. Discharge at Alcove Spring occurs in fractures at two discrete locations about 6 feet apart at the base of the sandstone wall forming the alcove. Sampling and discharge measurements were conducted at the northwest-most emanation point. Discharge measurements were 0.115 gpm in April and 0.145 gpm in October.

Discharge in Lion Canyon Creek is discussed in Section 3.4.4.1.

3.9.1.3 Water Quality

Mine Discharge Water Quality

The data presented in Table 3.37 indicate the mine drainage water is basic with pH ranging from 8.08 to 8.67. Field parameter data indicate that the water at the Blue Cap Adit station does not significantly differ from water at the Blue Cap Drainage station. Dissolved oxygen is not significantly different between stations and sampling times. The data indicate a slightly more reducing condition in the mine water in Adit water than the Drainage water, but not significantly different than the spring stations.

The difference in temperature of the adit water compared to spring water may indicate that the water draining from the mine originates from a different source or is influenced by air temperatures in the mine. As postulated in the conceptual model, the mine drainage may originate from deeper strata intercepted by the mine workings. The following information summarizes water quality conditions for the mine water at the Blue Cap Mine:

- Mine water is of the sodium bicarbonate type.
- The October samples at the Blue Cap Adit and Blue Cap Drainage slightly exceeded a pH of 8.5. As expected, adit water exhibited colder temperatures than drainage water outside of the mine.
- The inorganic chemistry of the Blue Cap Adit and Blue Cap Drainage water is similar with no significant differences. TDS concentrations are moderate; approximately 350 mg/L.
- Parameters exceeding screening levels based on reference area concentrations include, dissolved barium, magnesium, molybdenum, potassium, sodium, uranium, and vanadium, total vanadium, combined thorium-230 and thorium-232 and thorium-228.

- Dissolved barium concentrations exceed the screening level of 127 µg/L at both stations for both sampling times with concentrations ranging from 155 to 176 µg/L. Concentrations do not vary significantly between the Blue Cap Adit and Drainage stations.
- The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233 µg/L for October were exceeded at both mine stations for both sampling times, with concentrations ranging from 16,700 to 18,800 µg/L.
- Dissolved molybdenum concentrations exceeded the screening level of 5 µg/L (for both April and October) at both mine stations for both sampling times with concentrations ranging from 120 to130 µg/L in both mine water samples.
- The dissolved potassium screening level concentrations of 2,300 µg/L for April and 3,800 µg/L for October were exceeded at both mine stations for both sampling times with concentrations ranging from 7,100 to 8,200 µg/L.
- The dissolved sodium screening level concentrations of 12,200µg/L for April and 21,000 µg/L for October were exceeded at both mine stations for both sampling times, with concentrations ranging from 74,400 to 87,700 µg/L.
- The dissolved uranium screening level concentrations of 2.56 µg/L for April and 3.69 µg/L for October were exceeded at both mine stations for both sampling events with concentrations ranging from 518 to 548 µg/L.
- The dissolved and total vanadium screening level concentrations of 2.5 µg/L (dissolved, April and October) and 4.3 and 2.5 µg/L (total, April and October), were exceeded at both mine stations for both sampling times with concentrations ranging from 302 to 335 µg/L for dissolved vanadium and 288 to 308 µg/L for total vanadium.
- The combined thorium-230 and thorium-232 screening level concentrations of 0.06 pCi/L for April and 0.02 pCi/L for October were exceeded at both mine stations for both sampling events except October at station Blue Cap Adit, with concentrations ranging from 0.07 to 1.51 pCi/L.
- The thorium-228 screening level concentrations of 0.15 pCi/L for April and 0 (zero) for October, were slightly exceeded at station Blue Cap Drainage in the April and October samples with concentrations of 0.16 and 0.07 µg/L.

- Metals exceeding promulgated or risk-based screening levels were limited to total recoverable arsenic, total molybdenum, dissolved and total selenium, and total uranium:

  - Total recoverable arsenic concentrations exceeded the screening level of 10 µg/L by approximately 6 times at both mine water stations for both sampling times ranging from 55.3 to 59.1 µg/L concentrations do not vary significantly between the Blue Cap Adit and Drainage stations.

  - Total molybdenum concentrations slightly exceeded the screening level of 100µg/L with concentrations ranging from 110 to 120 µg/L in both mine water samples for both sampling times.

  - Dissolved and total selenium concentrations exceeded the screening levels of 4.6 and 10 µg/L, respectively, at both mine water stations for both sampling times with concentrations ranging from 173 to 251 µg/L.

  - The total uranium screening level concentration of 30 µg/L was exceeded at both mine water stations for both sampling times with concentrations ranging from 507 to 592 µg/L.

- The radiological parameters of gross alpha, gross beta, and combined radium-226 and radium-228 concentrations exceeded screening levels for mine water samples:
    - The gross alpha screening level concentration of 15 pCi/L was exceeded at both mine stations for both sampling times with concentrations ranging from 382 to 420 pCi/L.
    - The gross beta screening level concentration of 50 pCi/L was exceeded at both mine stations for both sampling times with concentrations ranging from 96 to 171 pCi/L.
    - The combined radium-226 and radium-228 screening level concentration of 5.0 pCi/L was exceeded for both mine stations for both sampling times, ranging from 12.46 to 28.2 pCi/L at station Blue Cap Adit, and 12.95 to 15.24 pCi/L at station Blue Cap Drainage.

Spring Water Quality

Field parameters at each spring show some variability between the April and October sampling events. Temperature data for the springs indicate slightly warmer (2 degree Celsius [ºC]) water during the October sampling event. This is probably due to seasonal fluctuations of ground and air temperatures. Specific conductance and pH measurements are not significantly different between sampling events but do differ between spring stations with Alcove Spring having a notably greater specific conductance of 579 µS/cm. The ORP measurements show significant variability between sampling events at each spring with more reducing conditions indicated in April. The following information summarizes water quality conditions for the spring water at Black Hat Spring and Alcove Spring in the Blue Cap, Black Hat, and Saint Patrick Mine area:

- Spring water is of the sodium bicarbonate type.
- One pH measurement of 8.58 s.u. exceeded the screening level of 8.5 s.u. at the October measurement at Alcove Spring.
- Spring water has a lower concentration of TDS at Black Hat Spring (270 to 240 mg/L) and a greater concentration of TDS at Alcove Spring (410 to350 mg/L). Mine water has TDS concentrations of 330 and 340 mg/L at the Blue Cap Adit and Blue Cap Drainage, respectively.
- Alcove Spring exhibits the highest concentration of sodium (137 mg/L) and chloride (16 mg/L) in the project area. Sulfate concentrations in spring water are similar to mine water.
- Parameters exceeding screening levels based on reference area concentrations include dissolved barium, magnesium, molybdenum, potassium, sodium, uranium, and vanadium, total vanadium, and combined thorium-230 and thorium-232:
    - Dissolved barium concentrations exceed the screening level of 127 µg/L in Black Hat Spring with a concentration of 163 µg/L in both sampling times. The Black Hat Spring

concentration is within the range of mine water samples. Alcove Spring concentrations are only 74 µg/L.

- The dissolved magnesium screening level concentrations of 8,800 µg/L for April and 10,233 µg/L for October were exceeded at Black Hat Spring for both sampling times, with concentrations ranging from 17,900 to 19,100 µg/L, similar to mine station concentrations.
- Dissolved molybdenum concentrations exceeded the screening level of 5 µg/L (for both April and October) at Alcove Spring for both April and October samples, and at Black Hat Spring for the April sample. Concentrations at Alcove Spring were 170 to 180 µg/L and only 10 µg/L at Black Hat Spring. Mine station concentrations were 120 to130 µg/L.
- The dissolved potassium screening level concentrations of 2,300 µg/L for April and 3,800 µg/L for October were exceeded at both spring stations for both sampling times with concentrations ranging from 5,900 to 7,500 µg/L.
- The dissolved sodium screening level concentrations of 12,200µg/L for April and 21,000 µg/L for October were exceeded both mine stations for both sampling times, with concentrations ranging from 50,100 to 137,000 µg/L.
- The dissolved uranium screening level concentrations of 2.56 µg/L for April and 3.69 µg/L for October were exceeded at both mine stations for both sampling events with concentrations ranging from 168 to 198 µg/L at Black Hat Spring and 1,170 to 1,210 µg/L at Alcove Spring.
- The dissolved and total vanadium screening level concentrations of 2.5 µg/L (dissolved, April and October) and 4.3 and 2.5 µg/L (total, April and October), were exceeded at both spring stations for both sampling times. Concentrations ranged from 337 to 448 µg/L. Mine station water had slightly smaller concentrations of dissolved and total vanadium.
- The combined thorium-230 and thorium-232 screening concentrations of 0.06 pCi/L for April was exceeded at Alcove Spring in April, with a concentration of 0.25 pCi/L. The October screening concentration of 0.02 pCi/L was not exceeded in either of the October samples.

- Metals exceeding promulgated or risk-based screening levels for the April sampling event were limited to total recoverable arsenic, total molybdenum, dissolved and total selenium, and total uranium:

  - The total recoverable arsenic screening level concentration of 10 µg/L was exceeded by approximately 4 times at Alcove Spring with a concentration of 40.8 µg/L. Concentrations in mine water are comparable at approximately 50 µg/L. Black Hat Spring had a significantly lower concentration of 7.3 µg/L.

  - Total molybdenum concentrations exceed the screening level of 100µg/L at Alcove Spring with concentrations ranging from 160 to 170 µg/L. Total molybdenum was not detected in the Black Hat Spring sample. Mine water samples had concentrations of 110 to 120 µg/L.

  - Dissolved and total selenium exceed the screening level concentrations of 4.6 and 10 µg/L in both spring water stations. Black Hat Spring dissolved and total selenium concentrations range from 30 to 44.5 µg/L. Whereas the Alcove Spring concentrations range from 318 to 395 µg/L and are higher than mine water concentrations (213 to 251 µg/L).

- The total uranium screening level concentration of 30 µg/L was exceeded at both mine stations for both sampling events with concentrations ranging from 160 to 195 µg/L at Black Hat Spring and 1,010 to 1,300 µg/L at Alcove Spring. These concentrations compare with mine water concentrations of 507 to 592 µg/L.

- The gross alpha screening level concentration of 15 pCi/L was exceeded at both springs for both sample times with concentrations of 111 and 107 pCi/L for April and October, respectively, at Black Hat Spring, and 1,130 and 1,020 pCi/L for April and October, respectively, at Alcove Spring. These concentrations compare with mine water concentrations of approximately 400 pCi/L.

- The gross beta screening level concentration 50 pCi/L was exceeded at Alcove Spring with concentrations of 255 and 523 pCi/L for April and October, respectively. These concentrations compare with mine water concentrations of almost 120 pCi/L.

- Combined radium-226 and radium-228 screening level concentrations of 5.0 pCi/L was exceeded at Black Hat Spring and Alcove Spring with concentrations of 8.16 pCi/L and 6.81 pCi/L, respectively, for the April sampling event. These concentrations compare with mine water concentrations of approximately 13 pCi/L.

- Overall, Alcove Spring water quality is of considerable poorer quality than Black Hat Spring, and has the highest concentrations of total uranium and gross alpha in the project area and is 2 to 3 times the concentrations found in mine station water. Other contaminants of concern include arsenic, molybdenum, and selenium. It is not known if the Alcove Spring water originates from a natural source or within mine workings.

3.9.1.4 Impact To Lion Canyon Creek and La Sal Creek Water Quality

Water quality data from stations established on Lion Canyon Creek and La Sal Creek were examined to assess the potential impact of the Blue Cap Mine, Black Hat Mine, and Saint Patrick Mine on Lion Canyon Creek and La Sal Creek water quality. These stations include Lion Cyn Ck Up, Lion Cyn Ck Dn1, and Lion Cyn Ck Dn2 on Lion Canyon Creek and stations La Sal Crk Dn4 and La Sal Crk Dn5 on La Sal Creek (Figures 3.16 and 3.17 and Table 3.37).

As discussed in Section 3.4.4.1, Lion Canyon Creek water quality generally increases in a downstream direction from the mine area. For example, TDS concentrations decrease from approximately 450 mg/L at station Lion Cyn Ck Up to 170 mg/L at station Lion Cyn Ck Dn2. The increase in quality is probably partially due to dilution as discharge at the downstream station is over 15 times greater than discharge at the upstream station. Water quality parameters that exceed reference area screening levels at the upstream-most station of Lion Cyn Ck Up and the downstream-most station of Lion Cyn Ck Dn2 are shown below.

Parameters Exceeding Screening Level Concentrations

Lion Cyn Ck Up	Lion Cyn Ck Dn2
Total recoverable arsenic	Dissolved barium
Total recoverable iron	Total recoverable iron
Dissolved lead	Dissolved molybdenum
Dissolved and total molybdenum	Dissolved and total manganese
Dissolved and total selenium	Dissolved and total selenium
Dissolved and total uranium	Dissolved and total uranium
Dissolved and total vanadium	Dissolved and total vanadium
Gross alpha	Gross alpha
Gross beta	
Combined radium-226 and radium-228	
Combined thorium-230 and thorium-232	

Magnesium, potassium, and sodium have not been included in the above lists. An examination of data in Table 3.37 show that the above listed analyte concentrations in station Lion Cyn Ck Dn2 are significantly lower than upstream concentrations with exception of dissolved barium, and dissolved and total manganese. These data support the reasonable conclusion that the Blue Cap Mine has a negative impact to water quality in Lion Canyon Creek. However, it should be reiterated that the discharge from the Blue Cap Mine is the source of Lion Canyon Creek at least at its highest point of observed flow, and that this flow is supplemented by flows from Alcove Spring and Black Hat Spring at elevations above or near station Lion Cyn Ck Up. The water quality data show that all of these sources contain numerous contaminants that exceed screening levels. Since there are no pre-mining water quality data and the origin of the springs is not known, it is not possible to say to what degree the spring sources affected water quality in Lion Canyon Creek in the past, and if mining has since affected spring water quality.

An examination of water quality data at stations La Sal Crk Dn4 and La Sal Crk Dn5 in Table 3.37 shows that field parameter measurements and concentrations of virtually all analytes are very similar between the two stations. A small increase in dissolved and total uranium concentrations is apparent between the stations for both sampling times. In addition, in the October sample, total vanadium, gross alpha, gross beta, combined radium-226 and radium-228, and combined thorium-230 and thorium-232 concentrations show increased concentrations in the downstream station (La Sal Crk Dn5) compared to the upstream station (La Sal Crk Dn4). Of these analytes, the increased concentration at station La Sal Crk Dn5 was great enough to exceed screening level concentrations for dissolved uranium, total vanadium, gross alpha,

and combined thorium-230 and thorium-232. Based on these data, there is an apparent negative impact to the water quality of La Sal Creek by the Blue Cap Mine, Black Hat Mine and Saint Patrick Mine areas.

Similar conclusions can be made in an examination of sediment analytical results. Table 3.7 shows the total metals and radionuclides concentration results for sediment samples collected in La Sal Creek. Section 3.4.1.3 summarizes the results of the sediment analyses at the La Sal Crk stations. Table 3.7 shows that total uranium, total vanadium, gross alpha, radium-228, and thorium-230 are analytes that increase in concentration at the downstream station of La Sal Crk Dn5 from the upstream station of La Sal Crk Dn4. Gross alpha, radium-228, and thorium-230 also exceed the screening level concentrations in addition to gross beta, radium-226, and thorium-228 in both stations. Concentrations at the downstream station of La Sal Crk Dn5 increase by a factor of less than 3.

Based on these analytical results, it is probable that migration of contaminants from the Blue Cap, Black Hat, and Saint Patrick Mine area has occurred and has caused elevated concentrations of contaminants in the stream sediments in La Sal Creek.

3.9.2 Waste Rock

Waste rock samples were collected at the mine from boreholes drilled into the mine dump and composite surface samples collected from the face of the dump.

3.9.2.1 Borehole Samples

Six boreholes (BC 1 through BC 6) were drilled at the mine to obtain samples for chemical analysis and assess the depth to native material beneath the mine dump. A near-surface sample (0 – 0.5 foot depth interval) was collected for chemical analysis at each borehole, and sub-surface samples were collected where possible based on the thickness of waste rock encountered in the borehole. Samples for geotechnical analysis were also collected from borehole BC 4. Borehole locations are shown in Figure 3.17, and borehole logs and geotechnical analysis results are provided in Appendix C.

The mine bench at the Blue Cap Mine consists of two separate areas. The northern area, overlying dump segments 1, 2, and 3 shown in Figure 3.17, contains the mine adit and forms the primary bench. The southern area, overlying dump segments 4 and 5 shown in Figure 3.17, forms an extension of the primary bench. The primary bench was originally constructed on native soil and broadened as waste rock was

dumped over the crest of the bench. It is suspected that the southern extension of the bench was later constructed to provide additional area for waste-rock disposal. The southern extension appears to have been constructed by laterally pushing waste rock along the base of the outcrop.

The thickness of waste rock encountered in each borehole is depicted in Figure 3.18. Along the crest of the primary bench, the waste-rock thickness ranges from 2 feet near the north end of the bench to 28.5 feet near the nose of the bench. Along the southern extension of the bench, the waste-rock thickness ranges from 4.5 feet near the center of the bench to 12 feet along the crest of the bench.

To assess the volume of waste rock present at the mine, the dump was segregated into five zones, each consisting of a relatively uniform thickness of waste rock (Figure 3.18). For zones I through IV, the waste-rock volume was calculated by multiplying the surface area of the zone measured from a recent aerial photograph by an estimated average thickness of waste rock within the zone. Zone V represents a wedge-shaped area forming the primary mine bench. The resulting volume of waste rock estimated for each zone is summarized as follows:

- Zone I
  - Estimated average thickness of waste rock: 2 feet (based on depth to native soil at boring BC 6 and visual observations on the face of the dump)
  - Surface area: 7,543 square feet
  - Volume: 15,086 cubic feet (559 cubic yards)

- Zone II
  - Estimated average thickness of waste rock: 10 feet (based on visual observations on the face of the dump)
  - Surface area: 21,047 square feet
  - Volume: 210,470 cubic feet (7,795 cubic yards)

- Zone III
  - Estimated average thickness of waste rock: 2 feet (based on visual observations on the face of the dump)
  - Surface area: 31,796 square feet
  - Volume: 63,592 cubic feet (2,355 cubic yards)

- Zone IV
  - Estimated average thickness of waste rock: 8.5 feet (based on average depth to native soil at borings BC 1, BC 2, and BC 3 and visual observations on the face of the dump)
  - Surface area: 10,760 square feet
  - Volume: 91,460 cubic feet (3,387 cubic yards)

- Zone V
  - Width of primary bench: 75 feet
  - Length of primary bench: 135 feet

- Estimated average thickness of waste rock at crest of bench: 24.5 feet (based on average depth to native soil at borings BC 4 and BC 5)
- Volume: 124,031 cubic feet (4,594 cubic yards)

Based on these volumes, the total volume of waste rock present at the Blue Cap Mine is estimated to be 18,690 cubic yards.

Analytical results for samples collected from boreholes at the Blue Cap Mine are presented in Tables 3.38 (total metals and radionuclides) and 3.39 (SPLP metals). In comparison to the screening levels, arsenic is the only analyte reported at concentrations exceeding the human-health criteria; copper, lead, and zinc (one sample) are the only analytes reported at concentrations exceeding the RMC for elk; and each radionuclide is reported at activities exceeding background levels in one or more of the samples.

Total Metals

Arsenic was reported at concentrations exceeding the human-health screening level of 12 mg/Kg in all of the samples, except BC 2 (0-0.5), BC 3 (10-12), and BC 4 (2-4). Arsenic concentrations exceeding the screening criterion in near-surface samples (0-0.5 foot depth interval) ranged from 14 mg/Kg in sample BC 5 (0-0.5 [duplicate]) to 74 mg/Kg in sample BC 3 (0-0.5). Arsenic concentrations exceeding the screening criterion in sub-surface samples ranged from 15.2 mg/Kg in sample BC 2 (2-4.5) to 70 mg/Kg in sample BC 1 (2-4).

Copper was reported at a concentration of 134 mg/Kg in sample BC 1 (2-4), slightly exceeding the RMC for elk of 131 mg/Kg. The copper concentrations in all the other samples were well below the screening level.

Lead concentrations exceeded the elk RMC (127 mg/Kg) in near-surface samples at BC 1, BC 3, BC 5, and BC 6. Lead concentrations exceeding the elk RMC in near-surface samples ranged from 129 mg/Kg at BC 5 to 699 mg/Kg at BC 3. Lead concentrations exceeded the elk RMC in sub-surface samples at BC 1, BC 4, and BC 5. Lead concentrations exceeding the elk RMC in sub-surface samples ranged from 130 mg/Kg in sample BC 4 (2-4) to 247 mg/Kg in sample BC 1 (2-4).

Zinc was reported at a concentration of 281 mg/Kg in sample BC 5 (18.5-20.5), slightly exceeding the RMC for elk of 275 mg/Kg. The zinc concentrations in all the other samples were below the RMC.

SPLP Metals

As shown in Table 3.39, arsenic, uranium, and vanadium were reported at concentrations exceeding the method detection limits in each of the samples. Other analytes reported at concentrations above the method detection limit in one or more of the samples were barium, iron, molybdenum, and selenium. Concentrations for the remaining analytes are below the method detection limit. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Gross alpha, gross beta, radium-226, and thorium-230 activities exceeded background levels in all of the waste-rock samples collected from boreholes. The radium-228 activity slightly exceeded background in only one sample, while thorium-228 and thorium-232 slightly exceeded background levels in seven and 12 of the 18 total samples, respectively. Analytical results for gross alpha, gross beta, radium-226, and thorium-230 in the waste-rock samples collected from boreholes are summarized as follows:

- Gross Alpha (pCi/g)
  - Minimum: 27.2 (BC 3: 10-12)
  - Maximum: 474 (BC 1: 0-0.5)
  - Mean: 251 (average background = 20.3)

- Gross Beta (pCi/g)
  - Minimum: 23.8 (BC 3: 10-12)
  - Maximum: 323 (BC 1: 0-0.5)
  - Mean: 171 (average background = 13.5)

- Radium-226 (pCi/g)
  - Minimum: 5.32 (BC 3: 10-12)
  - Maximum: 139 (BC 1: 0-0.5)
  - Mean: 72 (average background = 3.3)

- Thorium-230 (pCi/g)
  - Minimum: 3.58 (BC 3: 10-12)
  - Maximum: 290 (BC 5: 0-0.5)
  - Mean: 68 (average background = 3.1)

3.9.2.2 Composite Surface Samples

The waste-rock dump was segregated into five segments as shown in Figure 3.17 for collection of composite surface samples. Analytical results for the composite sample collected in each segment are presented in Tables 3.40 (total metals and radionuclides) and 3.41 (SPLP metals). In comparison to the screening levels, arsenic is the only analyte reported at concentrations exceeding the human-health criteria; lead is the only analyte reported at concentrations exceeding the RMC for elk; and gross alpha,

gross beta, radium-226, and thorium-230 activities exceed background levels in all of the samples while the radium-228 activity slightly exceeds background in two samples and thorium-228 and thorium-232 activities slightly exceed background in one sample.

Total Metals

Each composite sample contained arsenic at a concentration exceeding the human-health screening level. Arsenic concentrations ranged from 18.5 mg/Kg at Segment 3 to 57.2 mg/Kg at Segment 4. Except for Segment 3 sample, the elk RMC for lead was exceeded in each sample. Lead concentrations exceeding the RMC ranged from 176 mg/Kg at Segment 1 to 425 mg/Kg at Segment 4. The elk RMC for zinc was exceeded in one sample (Segment 4). The zinc concentration in the sample collected at Segment 4 was 324 mg/Kg.

SPLP Metals

As shown in Table 3.41, arsenic, uranium, and vanadium were reported at concentrations exceeding the method detection limits in each of the samples. Other analytes reported at concentrations above the method detection limit in one or more of the samples were barium and selenium. Concentrations for the remaining analytes are below the method detection limit. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Gross alpha, gross beta, radium-226, and thorium-230 activities exceed background levels in all of the samples while the radium-228 activity slightly exceeds background in two samples and thorium-228 and thorium-232 activities slightly exceed background in one sample. Analytical results for gross alpha, gross beta, radium-226, and thorium-230 in the composite surficial waste-rock samples are summarized as follows:

- Gross Alpha (pCi/g)
    - Minimum: 251 (BC SEGMENT 3)
    - Maximum: 685 (BC SEGMENT 6)
    - Mean: 485 (average background = 20.3)

- Gross Beta (pCi/g)
    - Minimum: 98.2 (BC SEGMENT 3)
    - Maximum: 254 (BC SEGMENT 6)
    - Mean: 198 (average background = 13.5)

- Radium-226 (pCi/g)

- Minimum: 35.8 (BC SEGMENT 3)
- Maximum: 96.9 (BC SEGMENT 1)
- Mean: 77.6 (average background = 3.3)

- Thorium-230 (pCi/g)
  - Minimum: 27.2 (BC SEGMENT 3)
  - Maximum: 86.9 (BC SEGMENT 1)
  - Mean: 60.4 (average background = 3.1)

3.9.3 Vegetation

Vegetation samples were collected along the adit drainage channel on the mine bench and around the perimeter of the waste-rock dump. One composite grass, one composite forb, and one composite shrub sample were collected along the adit drainage channel. One composite grass, one composite forb, and one composite shrub sample were collected around the perimeter of the mine dump.

From the adit drainage channel, grasses collected included *Oryzopsis hymenoides* (R&S) Ricker (Indian ricegrass), *Juncus arcticus* Willd. (wiregrass, or Baltic rush), *Panicum virgatum* L. (switchgrass), *Hordeum jubatum* (foxtail barley), *Elymus repens* L. Gould (syn. *Agropyron repens* L. Beauv.) (quackgrass), and [probably] *Juncus ensifolius* Wikstrom (swordleaf rush). Forbs collected included *Melilotus alba* (sweetclover), *Machaeranthera canescens* (Pursh) Gray (purple aster), and *Typha latifolia* (broadleaf cattail). Shrubs tentatively identified include *salix sp.* (willow).

Identified grasses collected from the perimeter of the mine dump include but are not limited to *Oryzopsis hymenoides* (R&S) Ricker (Indian ricegrass), *Panicum virgatum* L. (switchgrass), and *Hordeum jubatum* (foxtail barley). Identified forbs collected from the perimeter of the mine dump included *Chrysothamnus nauseosus* (rabbitbrush), *Melilotus alba* (sweetclover), and *Machaeranthera canescens* (Pursh) Gray (purple aster). *Phragmites australis* (common reed) was identified at the foot of an outcrop within the face of the main dump. Shrubs collected included *Ephedra torreyana* Wats. (Torrey's ephedra), *Cercocarpus montanus* (mountain mahogany), *Amelanchier alnefolia* (Nutt.) (Nutt. serviceberry), and *Rhus trilobata* (skunkbush sumac). Also tentatively identified was *Sarcobatus vermiculatus* (Hook.) Torr. (greasewood).

Analytical results for the vegetation samples are presented in Table 3.42. In general, analytical values for total metals and radionuclides in grasses collected from the adit drainage and the mine dump perimeter

were consistent with respect to those exceeding background values. Analytes exceeding background values included:

- Antimony, which in grasses from the adit drainage (0.2 mg/) and the dump perimeter (0.5 mg/Kg) exceeded the background value of <0.1 mg/Kg
- Arsenic, which in grasses from the adit drainage (1.2 mg/Kg) and the dump perimeter (4.5 mg/Kg) exceeded the background value of <0.3 mg/Kg
- Cadmium, which in grasses from the adit drainage (0.45 mg/Kg) and the dump perimeter (2.42 mg/Kg) exceeded the background value of 0.07 mg/Kg
- Chromium, which in grasses from the dump perimeter (4 mg/Kg) exceeded the background value of 1 mg/Kg
- Copper, which in grasses from the adit drainage (3 mg/Kg) and the dump perimeter (7 mg/Kg) exceeded the background value of 2 mg/Kg
- Iron, which in grasses from the adit drainage (371 mg/Kg) and the dump perimeter (526 mg/Kg) exceeded the background value of 322 mg/Kg
- Lead, which in grasses from the dump perimeter (15 mg/Kg) exceeded the background value of <4 mg/Kg
- Manganese, which in grasses from the adit drainage (171 mg/Kg) exceeded the background value of 95 mg/Kg
- Molybdenum, which in grasses from the adit drainage (16 mg/Kg) and the dump perimeter (69 mg/Kg) exceeded the background value of 5 mg/Kg
- Nickel, which in grasses from the dump perimeter (2 mg/Kg) exceeded the background value of <1 mg/Kg
- Selenium, which in grasses from the adit drainage (22.5 mg/Kg) and the dump perimeter (68.2 mg/Kg) exceeded the background value of 2.4 mg/Kg
- Uranium, which in grasses from the adit drainage (7.1 mg/Kg) and the dump perimeter (14.2 mg/Kg) exceeded the background value of 0.03 mg/Kg
- Vanadium, which in grasses from the adit drainage (7.3 mg/Kg) and the dump perimeter (65.7 mg/Kg) exceeded the background value of 0.7 mg/Kg
- Zinc, which in grasses from the adit drainage (36 mg/Kg) and the dump perimeter (53 mg/Kg) exceeded the background value of 10 mg/Kg
- Gross Alpha, which in grasses from the adit drainage (18.1 pCi/g) and the dump perimeter (39.8 pCi/g) exceeded the background value of 1.63 pCi/g

- Gross Beta, which in grasses from the adit drainage (19.3 pCi/g) and the dump perimeter (23 pCi/g) exceeded the background value of 7.15 pCi/g
- Radium 226, which in grasses from the adit drainage (4.9 pCi/g) and the dump perimeter (7.62 pCi/g) exceeded the background value of 1.98 pCi/g
- Radium 228, which in grasses from the dump perimeter (3.14 pCi/g) exceeded the background value of 1.65 pCi/g
- Thorium 230, which in grasses from the dump perimeter (4.43 pCi/g) exceeded the background value of –0.59 pCi/g

Total metals and radionuclides in the forbs samples collected from the adit drainage and the dump perimeter exceeding background values included:

- Arsenic, which in forbs from the adit drainage (0.8B mg/Kg) and the dump perimeter (11 mg/Kg) exceeded the background value of <0.3 mg/Kg
- Cadmium, which in forbs from the adit drainage (0.4 mg/Kg) and the dump perimeter (1.23 mg/Kg) exceeded the background value of 0.12 mg/Kg
- Copper, which in forbs from the adit drainage (8 mg/Kg) and the dump perimeter (10 mg/Kg) exceeded the background value of 7 mg/Kg
- Manganese, which in forbs from the adit drainage (80.3 mg/Kg) exceeded the background value of 74.2 mg/Kg
- Molybdenum, which in forbs from the adit drainage (22 mg/Kg) and the dump perimeter (183 mg/Kg) exceeded the background value of 3 mg/Kg
- Selenium, which in forbs from the adit drainage (15.9 mg/Kg) and the dump perimeter (467 mg/Kg) exceeded the background value of 7.4 mg/Kg
- Uranium, which in forbs from the adit drainage (1 mg/Kg) and the dump perimeter (2.23 mg/Kg) exceeded the background value of 0.07 mg/Kg
- Vanadium, which in forbs from the adit drainage (1.5B mg/Kg) and the dump perimeter (10.8 mg/Kg) exceeded the background value of 0.8 mg/Kg
- Zinc, which in forbs from the adit drainage (63 mg/Kg) and the dump perimeter (92 mg/Kg) exceeded the background value of 30 mg/Kg
- Gross Alpha, which in forbs from the adit drainage (18.8 pCi/g) and the dump perimeter (15.1 pCi/g) exceeded the background value of 0.94 pCi/g
- Gross Beta, which in forbs from the adit drainage (21.2 pCi/g) and the dump perimeter (21.3 pCi/g) exceeded the background value of 13.6 pCi/g

- Radium 226, which in forbs from the adit drainage (6.68 pCi/g) and the dump perimeter (5.28 pCi/g) exceeded the background value of 0.07 pCi/g
- Radium 228, which in forbs from the adit drainage (2.32 pCi/g) and the dump perimeter (2.62 pCi/g) exceeded the background value of 2.02 pCi/g
- Thorium 232, which in forbs from the dump perimeter (0.27 pCi/g) exceeded the background value of 0.06 pCi/g

Total metals and radionuclides in the shrubs samples collected from the adit drainage and the dump perimeter exceeding background values included:

- Arsenic, which in shrubs from the adit drainage (1 mg/Kg) and the dump perimeter (1.2 mg/Kg) exceeded the background value of <0.3 mg/Kg
- Cadmium, which in shrubs from the adit drainage (2.63 mg/Kg) and the dump perimeter (0.68 mg/Kg) exceeded the background value of 0.06 mg/Kg
- Copper, which in shrubs from the dump perimeter (10 mg/Kg) exceeded the background value of 7 mg/Kg
- Molybdenum, which in shrubs from the adit drainage (5B mg/Kg) and the dump perimeter (10 mg/Kg) exceeded the background value of <1 mg/Kg
- Nickel, which in shrubs from the dump perimeter (2 mg/Kg) exceeded the background value of <1 mg/Kg
- Selenium, which in shrubs from the adit drainage (19.1 mg/Kg) and the dump perimeter (107 mg/Kg) exceeded the background value of 1.3 mg/Kg
- Uranium, which in shrubs from the adit drainage (1.75 mg/Kg) and the dump perimeter (0.44 mg/Kg) exceeded the background value of <0.03 mg/Kg
- Vanadium, which in shrubs from the adit drainage (0.8B mg/Kg) and the dump perimeter (3.7 mg/Kg) exceeded the background value of 0.6 mg/Kg
- Zinc, which in shrubs from the adit drainage (251 mg/Kg) and the dump perimeter (70 mg/Kg) exceeded the background value of 33 mg/Kg
- Gross Alpha, which in shrubs from the adit drainage (9.51 pCi/g) and the dump perimeter (7.69 pCi/g) exceeded the background value of 2.25 pCi/g
- Gross Beta, which in shrubs from the dump perimeter (22.9 pCi/g) exceeded the background value of 9.2 pCi/g

- Radium 226, which in shrubs from the adit drainage (9.25 pCi/g) and the dump perimeter (5.32 pCi/g) exceeded the background value of 0.45 pCi/g
- Radium 228, which in shrubs from the adit drainage (4 pCi/g) and the dump perimeter (2.38 pCi/g) exceeded the background value of 2.31 pCi/g
- Thorium 228, which in shrubs from the adit drainage (0.37 pCi/g) and the dump perimeter (0.15 pCi/g) exceeded the background value of –0.13 pCi/g
- Thorium 230, which in shrubs from the dump perimeter (1.16 pCi/g) exceeded the background value of –0.44 pCi/g
- Thorium 232, which in shrubs from the dump perimeter (0.36 pCi/g) exceeded the background value of 0.05 pCi/g

3.9.4 Geotechnical Analysis

Samples of the materials comprising the waste-rock dump were collected for geotechnical analysis. In-situ samples were collected at borehole BC 4 from the 4 to 6 foot depth interval for natural-moisture (ASTM D2216), natural-density (liner atterberg-limits (ASTM D4318), and direct-shear (ASTM D3080) testing. In addition, a bulk sample was collected by compositing the material encountered from the top of each borehole to the bottom of the waste-rock material. The bulk samples was submitted to a geotechnical laboratory for sieve analysis (ASTM D422), hydrometer (ASTM D422), atterberg limits (ASTM D4318), standard proctor (ASTM D698), and remolded direct shear (ASTM D3080). Geotechnical analysis results are provided in Appendix C and summarized in Tables 3.24 (geotechnical classification), 3.25 (moisture-density and shear strength), and 3.26 (in-situ properties).

Waste-rock material at the Blue Cap Mine is classified as low plasticity silty sands with gravel (SM) or clayey sands with gravel (SC) as shown on Table 3.24. Particle-size analysis results for the mine are nearly identical to the results for waste material at the Firefly/Pygmy, Vanadium Queen, and Black Hat Mines as shown by the standard error of average size fractions. All standard errors are less than 3% of the mean indicating striking similarity between samples.

Review of the standard penetration testing reveals that the waste rock is in a loose condition to an approximate depth of 20 feet. The loose condition indicates a susceptibility to settlement upon loading without geotechnical improvement.

Results of Standard Proctor testing are presented on Table 3.25. The maximum dry density of 120.0 pcf and optimum moisture content of 12.5 percent fall within the normal range of 110 to 130 pcf at optimum moisture contents of 11 to 15 percent for SM/SC soils (U.S. Navy, 1982).
Shear strengths evaluated by direct shear testing for in-situ samples indicate an angle of internal friction (φ) of 44.2° and cohesion 382.5 psf. Soils remolded to 95 percent Standard Proctor maximum dry density exhibited a lower angle of internal friction of 41.1° and higher cohesion of 682.8 psf. Literature values for SM/SC soils compacted to maximum Standard Proctor densities range from 31° (SC) to 34° (SM) with cohesion ranging from 230 psf (SC) to 420 psf (SM) (U.S. Navy, 1982).

3.9.5 Radiological Survey

Radiological measurements were collected at the mine over the period April 19-23, 2004. Radiological survey results are presented in Figure 3.19. The survey was performed across the mine bench, disposal area, mine access road, central portion of the waste-rock dump, and along the mine drainage channel to the drainage crossing on the access road. Portions of the waste-rock dump could not be surveyed due to steep, unsafe conditions. The results show that the most of the surficial materials on the primary mine bench and the face of the waste-rock dump exhibit gamma-ray counts ranging from 21,500 to 28,500 cpm. Local hot-spots in the vicinity of the suspected ore-load ramp exhibit gamma-ray counts of greater than 28,500 cps. Gamma-ray counts on the southern extension of the mine bench range from 18,500 to 28,500 cpm, with a few isolated hot-spots showing counts greater than 28,500 cpm. The mine bench is bordered to the north and south by areas where gamma-ray counts are less the 18,500 cpm. Gamma-ray counts along the drainage channel that border the mine dump generally range from less than 18,500 to 21,500 cpm; isolated areas along the channel show levels of 21,500 to 28,500 cpm. Downstream of the waste-rock dump, gamma-ray measurements along the channel are generally less than 18,500 cpm, with slightly higher levels (18,500 to 21,500 cpm) near the access road crossing and along the road downgradient of the crossing. Gamma-ray counts along the access road leading to the mine complex range from less than 18,500 cpm to 21,500 cpm. Isolated areas along the road where count rates 21,500 to 28,500 cpm are most likely associated with spills from trucks transporting ore from the mines.

Correlation data for the mine are presented in Table 3.43. Within the background area, the in-situ gamma count reading was 12,571 cpm (13.3 μR/hr), and the total uranium and radium-226 activities were 1.58 pCi/g (2.33 mg/Kg) and 2.23 pCi/g, respectively. The results reported for sample sites at the mine (BC-COR1 through BC-COR4) are summarized as follows:

- Highest gamma count and uranium and radium-226 values: Site BC-COR2 located on the southern portion of the primary mine bench
  - In-situ gamma count: 364,623 cpm (390 µR/hr)
  - Total uranium: 634 pCi/g (937 mg/Kg)
  - Radium-226: 396 pCi/g

- Lowest gamma count and uranium and radium-226 values: Site BC-COR4 located on the northern portion of the primary mine bench
  - In-situ gamma count: 112,285 cpm (135 µR/hr)
  - Total uranium: 119 pCi/g (176 mg/Kg)
  - Radium-226: 49.3 pCi/g

3.9.6 Radon Monitoring

Alpha-track detectors were used to assess radon levels in the mine portal. One detector was placed inside the mine adit, and one detector was placed in the background area established for the radiological correlation study. Both detectors were placed at the mine on April 27, 2004 and collected for analysis on October 15, 2004. The monitoring results reported for mine are as follows:

- Background Area
  - Exposure: 214.6 pCi/L over 171-day monitoring period
  - Average: 1.3 pCi/L per day

- Adit
  - Exposure: Greater than 140,000 pCi/L over 171-day monitoring period
  - Average: Greater than 838 pCi/L per day

These results suggest that high radon levels are associated with the mine.

3.9.7 Soil at Shop

One composite soil sample was collected from the floor of the equipment/storage area within the mine adit. The sample consisted of five sub-samples collected from stained areas on the floor of the unit. The sample was submitted for oil and grease and PCB analysis. Analytical results for the sample are presented in Table 3.44. As shown, PCBs were not detected in the sample and the reported oil and grease concentration was 93,000 mg/Kg.

3.10 Black Hat Mine

Characterization activities at the Black Hat Mine included a collection of waste-rock and vegetation samples for chemical analysis; collection of waste-rock samples for geotechnical analysis; radiological survey; and radon monitoring at the mine adit and a background area. Each component of the characterization effort is discussed below.

3.10.1 Waste Rock

Waste rock samples were collected at the mine from boreholes drilled into the mine dump and composite surface samples collected from the face of the dump.

3.10.1.1 Borehole Samples

Two boreholes (BH 1 and BH 2) were drilled on the mine bench to obtain samples for chemical analysis and assess the depth to native material beneath the mine dump. A near-surface sample (0 – 0.5 foot depth interval) was collected for chemical analysis at each borehole, and sub-surface samples were collected where possible based on the thickness of waste rock encountered in the borehole. Borehole locations are shown in Figure 3.17, and borehole logs and geotechnical analysis results are provided in Appendix C.

The waste-rock dump at the Black Hat Mine consists of two separate levels. The upper level extends from the mine bench to the access road leading to the Blue Cap Mine. The mine bench was constructed on native soil and broadened as waste-rock was discarded over the crest of the bench. A metal-framed load-out structure borders the upper level dump to the east. The lower level extends from the access road to the Lion Canyon Creek drainage. The lower dump was likely created by periodically grading waste rock off the access road and side-casting the material down the steep hill slope into the Lion Canyon Creek drainage.

The thickness of waste rock encountered in each borehole is depicted in Figure 3.18. Along the crest of the mine bench, the waste-rock thickness ranges from 7.5 feet to 13 feet. To assess the volume of waste rock present at the mine, the dump was segregated into two zones, each consisting of a relatively uniform thickness of waste rock (Figure 3.18). Zone I corresponds to the upper level of the dump, and zone II covers the lower level of the dump and the access along the toe of the upper-level dump. For each zone, the waste-rock volume was calculated by multiplying the surface area of the zone measured from a recent

aerial photograph by an estimated average thickness of waste rock within the zone. The resulting volume of waste rock estimated for each zone is summarized as follows:

- Zone I
  - Estimated average thickness of waste rock: 10.25 feet (based on depth to native soil at borings BH 1 and BH 2 and visual observations on the face of the dump)
  - Surface area: 3,422 square feet
  - Volume: 35,076 cubic feet (1,300 cubic yards)

- Zone II
  - Estimated average thickness of waste rock: 2 feet (based on visual observations on the face of the dump)
  - Surface area: 4,487 square feet
  - Volume: 8,974 cubic feet (332 cubic yards)

Based on these volumes, the total volume of waste rock present at the Black Hat Mine is estimated to be 1,632 cubic yards.

Analytical results for samples collected from boreholes at the Black Hat Mine are presented in Tables 3.45 (total metals and radionuclides) and 3.46 (SPLP metals). In comparison to the screening levels, arsenic is the only analyte reported at concentrations exceeding the human-health criteria; lead is the only analyte reported at concentrations exceeding the RMC for elk; and each radionuclide was reported at an activity exceeding background in one or more of the samples.

Total Metals

Arsenic was reported at concentrations exceeding the human-health screening level of 12 mg/Kg in the two sub-surface samples collected at BH 2. The arsenic concentration in sample BH 2 (2-4) was 17 mg/Kg, and the arsenic concentration in sample BH 2 (5.5-7.5) was 30 mg/Kg. Arsenic concentrations in the near-surface sample (0-5 foot depth interval) at each borehole and sub-surface samples at BH 1 were below the screening criterion.

Lead concentrations exceeded the elk RMC (127 mg/Kg) in four of the sub-surface samples collected at BH 1 and BH 2. Lead concentrations exceeding the elk RMC in the sub-surface samples ranged from 141 mg/Kg at BH 1 (8-10) to 235 mg/Kg at BH 2 (2-4). Lead concentrations in the near-surface sample (0-5 foot depth interval) at each borehole were below the screening criterion.

SPLP Metals

As shown in Table 3.46, arsenic, uranium, and vanadium were reported at concentrations exceeding the method detection limits in each of the samples. Other analytes reported at concentrations above the method detection limit in one or more of the samples were barium, iron, and selenium. Concentrations for the remaining analytes are below the method detection limit. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Gross alpha, gross beta, radium-226, and thorium-230 were reported at the highest levels relative to background values. The radium-228 activity slightly exceeded background in one sample and thorium-228 and thorium-232 activities slightly exceeded background in three and five of the seven samples, respectively. Analytical results for gross alpha, gross beta, radium-226, and thorium-230 in the waste-rock samples collected from boreholes are summarized as follows:

- Gross Alpha (pCi/g)
  - Minimum: 8.16 (BH 1: 11-13)
  - Maximum: 383 (BC 2: 0-0.5)
  - Mean: 250 (average background = 20.3)

- Gross Beta (pCi/g)
  - Minimum: 8.3 (BH 1: 11-13)
  - Maximum: 262 (BH 2: 2-4)
  - Mean: 177 (average background = 13.5)

- Radium-226 (pCi/g)
  - Minimum: 1.45 (BH 1: 11-13)
  - Maximum: 184 (BH 2: 2-4)
  - Mean: 91 (average background = 3.3)

- Thorium-230 (pCi/g)
  - Minimum: 2.12 (BH 1: 11-13)
  - Maximum: 134 (BH 2: 0-0.5)
  - Mean: 62.4 (average background = 3.1)

3.10.1.2 Composite Surface Samples

The waste-rock dump was segregated into two segments as shown in Figure 3.17 for collection of composite surface samples. Analytical results for the composite sample collected in each segment are presented in Tables 3.47 (total metals and radionuclides) and 3.48 (SPLP metals). In comparison to the screening levels, arsenic is the only analyte reported at concentrations exceeding the human-health

criteria; lead is the only analyte reported at concentrations exceeding the RMC for elk; and gross alpha, gross beta, radium-226, and thorium-230 were reported at activities exceeding background values in both of the samples.

Total Metals

Each composite sample contained arsenic at a concentration exceeding the human-health screening level. Arsenic concentrations were 30.5 mg/Kg at Segment 1 and 16.9 mg/Kg at Segment 2. Each composite sample contained lead at a concentration exceeding the RMC for elk. Lead concentrations were 251 mg/Kg for Segment 1 and 190 mg/Kg for Segment 2.

SPLP Metals

As shown in Table 3.48, arsenic, selenium, uranium, and vanadium were reported at concentrations exceeding the method detection limits in both of the samples. Barium and iron were reported at concentrations exceeding the method detection limits in one of the two samples. Concentrations for the remaining analytes are below the method detection limit. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Gross alpha, gross beta, radium-226, and thorium-230 were reported at activities exceeding background values in both of the samples. Analytical results for gross alpha, gross beta, radium-226, and thorium-230 in the composite surficial waste-rock samples are summarized as follows:

- Gross Alpha (pCi/g)
  - Minimum: 563 (BH SEGMENT 2)
  - Maximum: 819 (BH SEGMENT 1)
  - Mean: 691 (average background = 20.3)

- Gross Beta (pCi/g)
  - Minimum: 233 (BH SEGMENT 2)
  - Maximum: 265 (BH SEGMENT 1)
  - Mean: 249 (average background = 13.5)

- Radium-226 (pCi/g)
  - Minimum: 78.7 (BH SEGMENT 1)
  - Maximum: 83.6 (BH SEGMENT 2)
  - Mean: 81.2 (average background = 3.3)

- Thorium-230 (pCi/g)
  - Minimum: 71.8 (BH SEGMENT 2)

- Maximum: 110 (BH SEGMENT 1)
- Mean: 90.9 (average background = 3.1)

3.10.2 Vegetation

Vegetation samples were collected around the perimeter of the waste-rock dump. One composite grass, one composite forb, and one composite shrub sample were collected around the perimeter of the mine dump. Analytical results for the vegetation samples are presented in Table 3.49.

Almost all of the total metals and radionuclides in grasses collected from the mine dump perimeter exceeded their respective background values, including:

- Antimony, which in grasses from the dump perimeter (0.4 mg/Kg) exceeded the background value of <0.1 mg/Kg
- Arsenic, which in grasses from the dump perimeter (3.4 mg/Kg) exceeded the background value of <0.3 mg/Kg
- Barium, which in grasses from the dump perimeter (50.3 mg/Kg) exceeded the background value of 41.5 mg/Kg
- Beryllium, which in grasses from the dump perimeter (0.13 mg/Kg) exceeded the background value of <0.05 mg/Kg
- Cadmium, which in grasses from the dump perimeter (0.73 mg/Kg) exceeded the background value of 0.07 mg/Kg
- Chromium, which in grasses from the dump perimeter (3 mg/Kg) exceeded the background value of 1 mg/Kg
- Copper, which in grasses from the dump perimeter (9 mg/Kg) exceeded the background value of 2 mg/Kg
- Iron, which in grasses from the dump perimeter (755 mg/Kg) exceeded the background value of 322 mg/Kg
- Lead, which in grasses from the dump perimeter (13 mg/Kg) exceeded the background value of <4 mg/Kg
- Molybdenum, which in grasses from the dump perimeter (42 mg/Kg) exceeded the background value of 5 mg/Kg
- Nickel, which in grasses from the dump perimeter (2 mg/Kg) exceeded the background value of <1 mg/Kg

- Selenium, which in grasses from the dump perimeter (66.6 mg/Kg) exceeded the background value of 2.4 mg/Kg

- Uranium, which in grasses from the dump perimeter (29 mg/Kg) exceeded the background value of 0.03 mg/Kg
- Vanadium, which in grasses from the dump perimeter (78.6 mg/Kg) exceeded the background value of 0.7 mg/Kg

- Zinc, which in grasses from the dump perimeter (77 mg/Kg) exceeded the background value of 10 mg/Kg

- Gross Alpha, which in grasses from the dump perimeter (47.6 pCi/g) exceeded the background value of 1.63 pCi/g

- Gross Beta, which in grasses from the dump perimeter (26.7 pCi/g) exceeded the background value of 7.15 pCi/g

- Radium 226, which in grasses from the dump perimeter (12.9 pCi/g) exceeded the background value of 1.98 pCi/g

- Radium 228, which in grasses from the dump perimeter (2.43 pCi/g) exceeded the background value of 1.65 pCi/g

- Thorium 230, which in grasses from the dump perimeter (3.33 pCi/g) exceeded the background value of –0.59 pCi/g

About half of the total metals and radionuclides in forbs collected from the mine dump perimeter exceeded their respective background values, including:

- Arsenic, which in forbs from the dump perimeter (14.7 mg/Kg) exceeded the background value of <0.3 mg/Kg

- Cadmium, which in forbs from the dump perimeter (0.58 mg/Kg) exceeded the background value of 0.12 mg/Kg

- Copper, which in forbs from the dump perimeter (12 mg/Kg) exceeded the background value of 7 mg/Kg

- Molybdenum, which in forbs from the dump perimeter (145 mg/Kg) exceeded the background value of 3 mg/Kg

- Selenium, which in forbs from the dump perimeter (660 mg/Kg) exceeded the background value of 7.4 mg/Kg

- Uranium, which in forbs from the dump perimeter (2.87 mg/Kg) exceeded the background value of 0.07 mg/Kg

- Vanadium, which in forbs from the dump perimeter (17.1 mg/Kg) exceeded the background value of 0.8 mg/Kg

- Zinc, which in forbs from the dump perimeter (43 mg/Kg) exceeded the background value of 30 mg/Kg
- Gross Alpha, which in forbs from the dump perimeter (48.4 pCi/g) exceeded the background value of 0.94 pCi/g

- Gross Beta, which in forbs from the dump perimeter (27.9 pCi/g) exceeded the background value of 13.6 pCi/g

- Radium 226, which in forbs from the dump perimeter (15.2 pCi/g) exceeded the background value of 0.07 pCi/g

- Thorium 230, which in forbs from the dump perimeter (0.6 pCi/g) exceeded the background value of –0.28 pCi/g

- Thorium 232, which in forbs from the dump perimeter (0.14 pCi/g) exceeded the background value of 0.06 pCi/g

About half of the total metals and radionuclides in shrubs collected from the mine dump perimeter exceeded their respective background values, including:

- Cadmium, which in shrubs from the dump perimeter (0.41 mg/Kg) exceeded the background value of 0.06 mg/Kg

- Copper, which in shrubs from the dump perimeter (17 mg/Kg) exceeded the background value of 7 mg/Kg

- Manganese, which in shrubs from the dump perimeter (46.4 mg/Kg) exceeded the background value of 42.4 mg/Kg

- Molybdenum, which in shrubs from the dump perimeter (9 mg/Kg) exceeded the background value of <1 mg/Kg

- Selenium, which in shrubs from the dump perimeter (50.9 mg/Kg) exceeded the background value of 1.3 mg/Kg

- Uranium, which in shrubs from the dump perimeter (0.56 mg/Kg) exceeded the background value of <0.03 mg/Kg

- Vanadium, which in shrubs from the dump perimeter (2 mg/Kg) exceeded the background value of 0.6 mg/Kg

- Zinc, which in shrubs from the dump perimeter (74 mg/Kg) exceeded the background value of 33 mg/Kg

- Gross Alpha, which in shrubs from the dump perimeter (3.27 mg/Kg) exceeded the background value of 2.25 mg/Kg
- Gross Beta, which in shrubs from the dump perimeter (15.9 mg/Kg) exceeded the background value of 9.2 mg/Kg
- Radium 226, which in shrubs from the dump perimeter (1.71 mg/Kg) exceeded the background value of 0.45 mg/Kg
- Radium 228 , which in shrubs from the dump perimeter (8.19 mg/Kg) exceeded the background value of 2.31 mg/Kg
- Thorium 232, which in shrubs from the dump perimeter (0.12 mg/Kg) exceeded the background value of 0.05 mg/Kg

3.10.3 Geotechnical Analysis

Samples of the materials comprising the waste-rock dump were collected for geotechnical analysis. One bulk sample was collected by compositing the material encountered from the top of each borehole to the bottom of the waste-rock material. The bulk samples was submitted to a geotechnical laboratory for sieve analysis (ASTM D422), hydrometer (ASTM D422), atterberg limits (ASTM D4318), standard proctor (ASTM D698), and remolded direct shear (ASTM D3080). Geotechnical analysis results are provided in Appendix C summarized in Tables 3.24 (geotechnical classification) and 3.25 (moisture/density and shear strength).

Waste-rock material at the Black Hat Mine is classified as low plasticity silty sands with gravel (SM) as shown on Table 3.24. Particle-size analysis results for the mine are nearly identical to the results for waste material at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines as shown by the standard error of average size fractions. All standard errors are less than 3% of the mean indicating striking similarity between samples.

Review of the standard penetration testing reveals that the waste rock is in a loose condition to an approximate depth of 20 feet. The loose condition indicates a susceptibility to settlement upon loading without geotechnical improvement.

Results of Standard Proctor testing are presented on Table 3.25. The maximum dry density of 119.5 pcf and optimum moisture content of 12.0 percent fall within the normal range of 110 to 125 pcf at optimum moisture contents of 11 to 16 percent for SM soils (U.S. Navy, 1982).

Shear strengths evaluated by direct shear testing for remolded samples indicate an angle of internal friction (φ) of 20.9° and cohesion 723.0 psf. Literature values for SM soils compacted to maximum Standard Proctor densities are 34° and 420 psf (U.S. Navy, 1982).

3.10.4 Radiological Survey

Radiological measurements were collected at the mine over the period April 19-23, 2004. Radiological survey results are presented in Figure 3.19. The survey was performed across the mine bench, access road leading to the mine portal and leading to the plateau above the portal, upper level of the waste-rock dump, mine access road between the upper and lower levels of the dump, and a small portion of the lower level of the dump. The lower level of the waste-rock dump could not be fully surveyed due to steep, unsafe conditions. The results show that the most of the surficial materials on the mine bench and along the access road exhibit gamma-ray counts ranging of less than 18,500 cpm. Gamma-ray levels ranging from 21,500 to 28,500 cpm were measured along the crest of the mine bench, near the portal structure, on the face of the upper level of the waste-rock dump, and the surveyed portion of the lower level of the dump. The highest gamma-ray levels were measured under the load-out structure and on the hillside immediately east of the structure.

Correlation data for the mine are presented in Table 3.43. Within the background area located south of the Blue Cap Mine, the in-situ gamma count reading was 12,571 cpm (13.3 μR/hr), and the total uranium and radium-226 activities were 1.58 pCi/g (2.33 mg/Kg) and 2.23 pCi/g, respectively. The results reported for sample sites at the mine (BHC-COR1 through BH-COR3) are summarized as follows:

- Highest gamma count and uranium and radium-226 values: Site BH-COR3 located on the mine bench near the portal structure
    - In-situ gamma count: 86,206 cpm (105 μR/hr)
    - Total uranium: 108 pCi/g (160 mg/Kg)
    - Radium-226: 59.6 pCi/g

- Lowest gamma count and uranium values: Site BH-COR1 located on the mine bench at the ore load-out structure
    - In-situ gamma count: 28,711 cpm (29.5 μR/hr)
    - Total uranium: 15.4 pCi/g (22.8 mg/Kg)
    - Radium-226: 14.9 pCi/g
- Lowest radium-226 activity: Site BH-COR2 located near the center of the mine bench
    - In-situ gamma count: 77,335 cpm (85 μR/hr)
    - Total uranium: 17.0 pCi/g (25.1 mg/Kg)
    - Radium-226: 12 pCi/g

3.10.5 Radon Monitoring

Alpha-track detectors were used to assess radon levels in the mine portal. One detector was placed inside the mine adit, and one detector was placed in the background area established for the radiological correlation study. Both detectors were placed at the mine on April 27, 2004 and collected for analysis on October 15, 2004. The monitoring results reported for mine are as follows:

- Background Area
  - Exposure: 214.6 pCi/L over 171-day monitoring period
  - Average: 1.3 pCi/L per day
- Adit
  - Exposure: 29,438.9 pCi/L over 171-day monitoring period
  - Average: 172.2 pCi/L per day

These results suggest that high radon levels are associated with the mine.

3.11 Saint Patrick Mine

Characterization activities at the Saint Patrick Mine included a collection of waste-rock and vegetation samples for chemical analysis; radiological survey; and radon monitoring at the mine adit and a background area. Each component of the characterization effort is discussed below.

3.11.1 Waste Rock

The waste-rock dump at the Saint Patrick Mine forms an elongated feature extending down the steep hillside from the former mine bench toward the primary access road leading to the mines comprising the Black Hat/Blue Cap Mine Complex. The waste-rock dump was segregated into two segments as shown in Figure 3.17 for collection of composite surface samples. Analytical results for the composite sample collected in each segment are presented in Tables 3.50 (total metals and radionuclides) and 3.51 (SPLP metals). In comparison to the screening levels, none of the analytes are reported at concentrations exceeding the human-health criteria; lead is the only analyte reported at concentrations exceeding the RMC for elk; and gross alpha, gross beta, radium-226, and thorium-230 were reported at activities exceeding background values in all three of the samples.

Total Metals

Metals concentrations in the composite samples did not exceed human-health screening criteria. However, both samples contained lead at concentrations exceeding the RMC for elk. Lead concentrations were 167 mg/Kg for Segment 1, 154 mg/Kg for Segment 1 (duplicate), and 173 mg/Kg for Segment 2.

SPLP Metals

As shown in Table 3.51, arsenic, iron, uranium, and vanadium were reported at concentrations exceeding the method detection limits in all of the samples. Concentrations for the remaining analytes are below the method detection limit. The SPLP results are further evaluated and used to derive leaching RMC for the risk evaluation presented in Section 4.0.

Radionuclides

Gross alpha, gross beta, radium-226, and thorium-230 were reported at activities exceeding background values in all three of the samples. Analytical results for gross alpha, gross beta, radium-226, and thorium-230 in the composite surficial waste-rock samples are summarized as follows:

- Gross Alpha (pCi/g)
  - Minimum: 35.2 (SP SEGMENT 2)
  - Maximum: 92.2 (SP SEGMENT 1)
  - Mean: 72.3 (average background = 20.3)

- Gross Beta (pCi/g)
  - Minimum: 13.6 (SP SEGMENT 2)
  - Maximum: 33.9 (SP SEGMENT 1)
  - Mean: 26.7 (average background = 13.5)

- Radium-226 (pCi/g)
  - Minimum: 5.25 (SP SEGMENT 1 [duplicate])
  - Maximum: 45.5 (SP SEGMENT 1)
  - Mean: 23.6 (average background = 3.3)

- Thorium-230 (pCi/g)
  - Minimum: 7.96 (SP SEGMENT 2)
  - Maximum: 16.2 (SP SEGMENT 1)
  - Mean: 13.2 (average background = 3.1)

3.11.2 Vegetation

Vegetation samples were collected around the perimeter of the waste-rock dump. One composite grass, one composite forb, and one composite shrub sample were collected at the mine. Analytical results for the vegetation samples are presented in Table 3.52.

Slightly more than half of the total metals and radionuclides in grasses collected from the mine dump perimeter exceeded their respective background values, including:

- Antimony, which in grasses from the dump perimeter (0.2 mg/Kg) exceeded the background value of <0.1 mg/Kg
- Arsenic, which in grasses from the dump perimeter (0.7 mg/Kg) exceeded the background value of <0.3 mg/Kg
- Cadmium, which in grasses from the dump perimeter (0.1 mg/Kg) exceeded the background value of 0.07 mg/Kg
- Copper, which in grasses from the dump perimeter (5 mg/Kg) exceeded the background value of 2 mg/Kg
- Molybdenum, which in grasses from the dump perimeter (8 mg/Kg) exceeded the background value of 5 mg/Kg
- Selenium, which in grasses from the dump perimeter (9.6 mg/Kg) exceeded the background value of 2.4 mg/Kg
- Uranium , which in grasses from the dump perimeter (1.42 mg/Kg) exceeded the background value of 0.03 mg/Kg
- Vanadium , which in grasses from the dump perimeter (8.1 mg/Kg) exceeded the background value of 0.7 mg/Kg
- Zinc, which in grasses from the dump perimeter (20 mg/Kg) exceeded the background value of 10 mg/Kg
- Gross Alpha, which in grasses from the dump perimeter (6.08 pCi/g) exceeded the background value of 1.63 pCi/g
- Gross Beta, which in grasses from the dump perimeter (12.1 pCi/g) exceeded the background value of 7.15pCi/g
- Radium 228, which in grasses from the dump perimeter (1.8 pCi/g) exceeded the background value of 1.65 pCi/g
- Thorium 230, which in grasses from the dump perimeter (0.38 pCi/g) exceeded the background value of –0.59 pCi/g
- Thorium 232, which in grasses from the dump perimeter (0.1 pCi/g) exceeded the background value of –0.17 pCi/g

Similarly, more than half of the total metals and radionuclides in forbs collected from the mine dump perimeter exceeded their respective background values, including:

- Antimony, which in forbs from the dump perimeter (0.2 mg/Kg) exceeded the background value of <0.1 mg/Kg
- Arsenic, which in forbs from the dump perimeter (1.5 mg/Kg) exceeded the background value of <0.3 mg/Kg
- Cadmium, which in forbs from the dump perimeter (0.34mg/Kg and 0.25 mg/Kg) exceeded the background value of 0.12 mg/Kg
- Copper, which in forbs from the dump perimeter (9 mg/Kg) exceeded the background value of 7 mg/Kg
- Molybdenum, which in forbs from the dump perimeter (20 mg/Kg and 29 mg/Kg) exceeded the background value of 3 mg/Kg
- Selenium, which in forbs from the dump perimeter (67.9 mg/Kg and 101 mg/Kg) exceeded the background value of 7.4 mg/Kg
- Uranium, which in forbs from the dump perimeter (1.33 mg/Kg and 1.93 mg/Kg) exceeded the background value of 0.07 mg/Kg
- Vanadium, which in forbs from the dump perimeter (14 mg/Kg and 15.5 mg/Kg) exceeded the background value of 0.8 mg/Kg
- Zinc, which in forbs from the dump perimeter (37 mg/Kg and 39 mg/Kg) exceeded the background value of 30 mg/Kg
- Gross Alpha, which in forbs from the dump perimeter (26.6 pCi/g and 32.2 pCi/g) exceeded the background value of 0.94 pCi/g
- Gross Beta, which in forbs from the dump perimeter (19.2 pCi/g and 22.7 pCi/g) exceeded the background value of 13.6 pCi/g
- Radium 226, which in forbs from the dump perimeter (8.5 pCi/g and 11.7 pCi/g) exceeded the background value of 0.07 pCi/g
- Radium 228, which in forbs from the dump perimeter (2.52 pCi/g) exceeded the background value of 2.02 pCi/g
- Thorium 230, which in forbs from the dump perimeter (3.33 pCi/g) exceeded the background value of –0.28 pCi/g
- Thorium 232, which in forbs from the dump perimeter (0.28 pCi/g and 1.4 pCi/g) exceeded the background value of 0.06 pCi/g

Slightly fewer than half of the total metals and radionuclides in shrubs collected from the mine dump perimeter exceeded their respective background values, including:

- Cadmium, which in shrubs from the dump perimeter (0.07 mg/Kg) exceeded the background value of 0.06 mg/Kg

- Copper, which in shrubs from the dump perimeter (8 mg/Kg) exceeded the background value of 7 mg/Kg
- Molybdenum, which in shrubs from the dump perimeter (2 mg/Kg) exceeded the background value of 1 mg/Kg
- Selenium, which in shrubs from the dump perimeter (13.2 mg/Kg) exceeded the background value of 1.3 mg/Kg
- Uranium, which in shrubs from the dump perimeter (0.95 mg/Kg) exceeded the background value of <0.03 mg/Kg
- Vanadium, which in shrubs from the dump perimeter (12.1 mg/Kg) exceeded the background value of 0.6 mg/Kg
- Zinc, which in shrubs from the dump perimeter (58 mg/Kg) exceeded the background value of 33 mg/Kg
- Gross Alpha, which in shrubs from the dump perimeter (6.06 pCi/g) exceeded the background value of 2.25 pCi/g
- Radium 226, which in shrubs from the dump perimeter (1.56 pCi/g) exceeded the background value of 0.45 pCi/g
- Thorium 228, which in shrubs from the dump perimeter (0.07 pCi/g) exceeded the background value of –0.13 pCi/g
- Thorium 230, which in shrubs from the dump perimeter (0.87 pCi/g) exceeded the background value of –0.44 pCi/g
- Thorium 232, which in shrubs from the dump perimeter (3.06 pCi/g) exceeded the background value of 0.05 pCi/g

3.11.3 Radiological Survey

Radiological measurements were collected at the mine over the period April 19-23, 2004. Radiological survey results are presented in Figure 3.19. The survey was performed across the mine bench and along the remnants of the access road leading to the adit. The waste-rock dump could not be surveyed due to steep, unsafe conditions. The results show that the surficial materials on the mine bench near the adit exhibit gamma-ray counts of less than 18,500 cpm. Northwest of the adit, in an area where the mine bench was regraded presumably during previous reclamation, gamma-ray counts generally range from less than 18,500 to 21,500 cpm, with isolated hot-spots ranging from 21,500 cpm to greater than 28,500 cpm. Measurements recorded along the primary access road immediately downgradient of the waste-rock dump generally show gamma-ray counts of 18,500 to 21,500 cpm, with readings of 21,500 to 28,500 cpm

in isolated areas. These readings suggest that radionuclide-contaminated sediment may have been transported from the mine dump to the access road as a result of erosion and mass wasting.

Correlation data for the mine are presented in Table 3.43. Within the background area located south of the Blue Cap Mine, the in-situ gamma count reading was 12,571 cpm (13.3 μR/hr), and the total uranium and radium-226 activities were 1.58 pCi/g (2.33 mg/Kg) and 2.23 pCi/g, respectively. Two samples were collected at the mine (SP-COR1 and SP-COR2). Both samples were collected on the mine bench in the area where the bench had been regraded. Gamma count, uranium values, and radium-226 activities for the two samples are summarized as follows:

- Gamma count:
  - SP-COR1: 182,464 cpm (190 μR/hr)
  - SP-COR2: 240,877 cpm (230 μR/hr)

- Uranium values:
  - SP-COR1: 387 pCi/g (571 mg/Kg)
  - SP-COR2: 217 pCi/g (321 mg/Kg)

- Radium-226 activity:
  - SP-COR1: 276 pCi/g
  - SP-COR2: 57.7 pCi/g

3.11.4 Radon Monitoring

Alpha-track detectors were used to assess radon levels in the mine portal. One detector was placed inside the mine adit, and one detector was placed in the background area established for the radiological correlation study. Both detectors were placed at the mine on April 27, 2004 and collected for analysis on October 15, 2004. The monitoring results reported for mine are as follows:

- Background Area
  - Exposure: 214.6 pCi/L over 171-day monitoring period
  - Average: 1.3 pCi/L per day

- Adit
  - Exposure: 6,118.6 pCi/L over 171-day monitoring period
  - Average: 35.8 pCi/L per day

These results suggest that high radon levels are associated with the mine.

4.0 STREAMLINED RISK EVALUATION

The streamlined risk evaluation process was used to assess the magnitude of human-health and ecological risk as a result of former operations at the mines comprising the La Sal Creek Watershed Project. The process was implemented in accordance with the streamlined risk evaluation guidance presented in *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (EPA, 1993) The evaluation was performed on the basis of the CSM (AAK, 2003a) and analytical results for surface water (during both high-flow and low-flow periods), waste-rock, soil, sediment, and vegetation samples collected in support of the characterization effort. A separate evaluation was performed for each mine area, focusing on the risks associated with adit drainage and the waste-rock dump. In addition, an evaluation was performed to assess the risks posed to residents at the three homes located within the project area.

Contaminants of concern (COCs) were selected for each mine area and residence by comparing the analytical results for each medium to background levels reported for samples collected within the reference areas. The results reported for the COCs were then compared to specific risk-based levels for the human-health and ecological receptors and exposure pathways identified in the CSM (AAK, 2003a). The risk-based levels used in the evaluation include federal and state standards and risk management criteria (RMC) from BLM Technical Note 390 (Ford, 2004). The inorganic parameters carbonate and bicarbonate were not considered COCs for this risk evaluation.

Comparison tables are presented for each mine area and residence showing the analytical results reported for COCs, background levels, and the standards/RMC used to evaluate risk. For the criteria based on regulatory standards or RMC, the ratio of the environmental media concentration to the screening level is analogous to a hazard quotient of 1.0, which is the concentration that should present negligible risk. Media concentrations exceeding screening levels for humans or wildlife by 1 to 10 times are flagged “+” in the comparison tables; these occurrences may pose a chronic threat. Media concentrations exceeding screening levels by more than 10- and 100-fold for humans or wildlife are flagged “++” and “+++”, respectively, in the tables. Similar notation is also used for comparison of media concentrations to background levels, where “+” indicates concentration is 1 to 10 times background, “++” indicates concentrations is 10 to 100 times background, and “+++” indicates concentration is more than 100 times background.

The risks posed by analyte concentrations exceeding risk-based levels (RMC and regulatory standards) are qualitatively described in this evaluation as follows:

- Low risk – Analyte level is less than risk-based level or exceeds risk-based level by a factor of 3 or less.
- Moderate risk – Analyte level exceeds risk-based level a factor of greater than 3 to 10.
- High risk – Analyte level exceeds risk-based level by a factor of greater than 10 to 100.
- Extremely high risk – Analyte level exceeds risk-based level by a factor greater than 100.

4.1 Primary Sources, Exposure Pathways, and Receptors

A detailed discussion of the primary sources, exposure pathways, and receptors for each of the three mine areas comprising the La Sal Creek Watershed Project is presented in the CSM (AAK, 2003a). Diagrams illustrating the general conceptual site models for human and ecological receptors at the mine areas are presented in Figures 4.1 and 4.2, respectively.

The primary sources associated with the Firefly/Pygmy Mine, Vanadium Queen Mine, and Black Hat/Blue Cap Mine Complex (including the Saint Patrick Mine) include the following:

- Surface water draining from the Firefly/Pygmy, Vanadium Queen, and Blue Cap mines
- Direct precipitation and runoff infiltrating the waste-rock dumps and discharging to creeks, seeps/springs, and possibly wells downgradient of the mine sites
- Soil/waste rock associated with each mine site
- Radon emanating from the mine portals
- Sediment deposited along drainages downstream of the mine sites

The primary human-health exposure pathways and receptors identified in the CSM (AAK, 2003a) are as follows:

- Ingestion of surface water emanating from the adit and crossing the waste-rock dump (site visitors)
- Ingestion of surface water from springs located downgradient of the mine sites (residents)
- Ingestion and inhalation of waste rock and sediment derived from the mine area (site visitors)

- Direct exposure to gamma radiation from site soil/waste rock (site visitors)
- Inhalation of radon near the mine portal (site visitors)
- Ingestion of homegrown vegetables and livestock (residents)
- Inhalation of radon in homes (Residences R1, R2, and R3) from water fixtures (residents)

The primary ecological exposure pathways and receptors of primary concern identified in the CSM (AAK, 2003a) are as follows:

- Ingestion of surface water and sediment by terrestrial wildlife/livestock
- Ingestion of grasses, forbs, and shrubs on the mine benches and immediately downgradient of the waste-rock dumps
- Direct exposure of aquatic life to metals and radionuclide constituents in surface water
- Direct exposure of wildlife/livestock to gamma radiation from site soil/waste rock
- Inhalation of radon near the mine portal (bats and birds nesting in the adit)
- Ingestion of aquatic organisms in the food chain

4.1.1 Human Health

Site visitors and area residents are the primary human receptors potentially affected by contaminants at the mines. Site visitor exposures occur at the mine area, while resident exposures primarily occur within the residential areas. The site visitors most likely expected at the mines include individuals using the mine areas for unsanctioned camping or ATV driving or individuals who work on the mine area. Of these site visitors, the risks associated with the mines pose the greatest threat to individuals using the mine areas for unsanctioned camping. Therefore, human-health risks at the mines are evaluated on the basis of the camper scenario. The principal exposure routes to the camper include ingestion, inhalation, dermal contact, and direct radiation.

The risks associated with metal COCs in adit drainages at the mines were evaluated by comparing metal concentrations reported for the adit drainages to camper RMC (swimming) and modified Maximum Contaminant Levels (MCLs) where a modifying exposure factor of 365/14 days (x26) was applied to EPA drinking water MCLs to better estimate the risk posed to campers who may ingest water from the drainage. MCLs established by the EPA for protection of public drinking water sources assume an

exposure duration of 365 days per year. Therefore, it is recognized that MCLs are not applicable under the camper scenario but are relevant and appropriate. The camper (swimming) scenario is used in the evaluation because shallow pools, immediately inside the currently open adits, are of sufficient size and depth to potentially be used by recreational visitors for wading and bathing. Table 4.1 presents the surface-water criteria (camper RMC and modified MCLs) used for the human-health risk evaluation.

The risks associated with metal COCs in waste rock and ephemeral drainage sediment at the mines were evaluated by comparing metal concentrations reported for the waste-rock samples to the camper RMC for metals in soil under the camper scenario; metal COCs in perennial drainage sediment were compared to camper RMC for sediment (Table 4.2). The risks associated with the metal COCs for which RMC under the camper scenario have not been established for soil were evaluated by comparing concentrations reported for the waste-rock samples to the industrial soil screening levels (SSLs) established by EPA Region 3 which are updated annually and contain SSLs for a comprehensive list of organic and inorganic constituents. EPA Region 3 SSLs are available at www.epa.gov/reg3hwmk/risk. It is recognized that the SSLs established for the industrial scenario are likely to be more restrictive than for the camper scenario; however, the levels allow identification of the analytes that may pose a threat to individuals using the mine areas for camping. Analyte concentrations found to exceed SSLs were then compared to background levels to assess the relative magnitude of the levels reported for the samples collected at the mines with respect to the levels reported for background soil.

Radionuclide COCs, for which specific risk benchmarks have not been established for the camper scenario, were evaluated by comparing analytical results reported for samples collected at the mines to the levels reported for the background soil samples collected in the reference areas. While these comparisons are not indicative or predictive of risk, the comparisons provide a descriptive means of evaluating radionuclide levels at the mines. In addition, radium-226 activities reported for near-surface samples are compared to the Uranium Mill Tailings Radiation Control Act (UMTRCA) standard of 5 pCi/g over background in the upper 6 inches of soil. This standard was established as a health-based standard for protection against exposure to gamma radiation and to limit the risk from inhalation of radon decay products in houses built on land contaminated with tailings. The standard was intended to signify when a Title I site had been cleaned up to a level suitable for unrestricted use. It is recognized that the UMTRCA standard is not applicable at the mine site as the mines are not Title I sites and will not be released for unrestricted use, e.g., construction of habitable structures. Nevertheless, the standard is relevant and appropriate and is used as a guide in this evaluation to identify the areas where exposure to gamma radiation may pose a human-health threat to campers at the mines. Radionuclide activities reported for

the waste rock samples are compared to the maximum levels reported for background samples, with exceedances of 1 to 10 times maximum background denoted with "+", greater than 10 to 100 times maximum background denoted with "++", and greater than 100 times maximum background denoted with "+++."

Radiation exposure at the mines was further evaluated by comparing gamma-exposure rates measured at the mines to gamma-exposure rates measured in background areas. In addition, gamma-exposure rates at the mine were used to calculate the radiation exposure in mRem that would be expected for an individual camping at the mine for a period of 14 days. The calculations were performed using the relationship of 1 milliroentgen per hour (mR/hr) is approximately equal to 1 milliroentgen equivalent man per hour (mRem/hr) which is considered appropriate given the accuracy of the field meters. The resulting gamma-exposure rates were compared to a ceiling level of 100 mRem/year exclusive of background radiation, based on the dose limit for individual members of the public for active licensees (10 CFR 20.1301-1302).

Radon exposures at the mines were evaluated on the basis of radon measurements taken within the portal of each mine and by comparing portal measurements to measurements taken within a background area adjacent to each mine area. Evaluation results were used to assess the amount of exposure at the mine portal relative to background areas.

Area residents are the other human receptors potentially impacted by contamination derived from the mine sites. The potential mechanisms for natural transport of mine-derived contaminants to the residences include migration of contaminants by way of the surface-water, groundwater, or air (windblown dust) pathways and deposition of material physically transported from the mines as a result of removal of material for personal use, erosion (fluvial and wind), or other mass wasting processes. The primary exposure routes within the residential area include ingestion of water from springs used for domestic purposes, ingestion of homegrown produce and livestock, and inhalation of radon from water fixtures within the homes.

The surface-water and soil ingestion pathways were evaluated on the basis of risk-based criteria (MCLs for surface water and the criteria listed in Table 4.3 for soils). The surface-water ingestion pathway at the residences was evaluated by comparing analytical results for samples collected from domestic springs to MCLs and secondary standards established by the EPA. The ingestion of soil pathway was evaluated by comparing the analytical results for soil samples collected at gardens and pastures to the BLM RMC

established for residences adjacent to BLM lands (Ford, 2004), EPA Region 3 SSLs for residential soil (EPA, 2004), and EPA generic SSL for radionuclides (EPA, 2000b).

The ingestion of homegrown produce pathway was directly evaluated by comparing radionuclide (radium-226 and radium-228) results for soil samples collected in the gardens, as well as in the pastures, to the generic SSLs for ingestion of homegrown produce specified in EPA generic SSL for radionuclides (EPA, 2000b). The ingestion of homegrown produce pathway was indirectly evaluated on the basis of soil ingestion pathway assessment coupled with examination of the analytical results reported for the produce samples collected at the residences.

The ingestion of livestock pathway was indirectly evaluated by comparing analytical results for the pasture grass samples to maximum tolerable levels of dietary minerals for domestic animals (National Research Council, 1980). In addition, analytical results for water samples collected from the water sources used to irrigate the pastures were compared to Utah stream standards for agricultural use and background levels.

The inhalation of radon pathway was evaluated by comparing results of radon monitoring conducted within the bathroom of each residence to EPA's recommended indoor air guideline of 4 pCi/L per day.

4.1.2 Ecological

The primary ecological receptors potentially affected by contaminants at the mine include terrestrial biota (wildlife and livestock) and aquatic biota. The principal exposure routes to ecological receptors include ingestion, inhalation, direct contact, and direct radiation.

The ecological risks associated with surface water at the mines were evaluated by comparing the analytical results for the adit drainages to Colorado and Utah aquatic-life (chronic) standards for La Sal Creek (Table 4.1). The risks associated with surface water to terrestrial biota were not directly assessed in this evaluation. It is recognized that any actions taken to protect aquatic life and humans (camper) would also provide protection for terrestrial biota.

Aquatic-life protection was further evaluated based on the results of benthic macroinvertebrate sampling along La Sal Creek. The density and diversity of benthic macroinvertebrates in La Sal Creek downstream of each mine area were compared to qualitatively assess potential impacts from the mines.

The ecological risks associated with metals in waste rock at the mines were evaluated by comparing the analytical results for waste rock to elk RMC for metals in soil (Table 4.2), including 2005 criterion for uranium and vanadium derived by the BLM and USEPA, respectively. The RMC for elk was used as the basis for evaluation of risk to terrestrial wildlife, because the elk RMC generally correspond with the median RMC for all receptors and are more protective than the RMC for cattle, which are known to frequent the mine areas. The elk RMC may be modified by the size of their home range. This modification, referred to as an "area use factor", is the quotient of the mine area divided by the home range (640 acres). The RMC is then modified by dividing the RMC by the area use factor. The resulting modified RMC provides a better estimate of the risk posed to elk at the mine. Where ecological RMC have not been established for a particular analyte, waste-rock results were compared to the levels reported for the soil samples collected within the reference areas. While these comparisons to background levels are not indicative or predictive of risk, the comparisons provide a descriptive means of evaluating the analytical results.

Because of the proximity of the waste-rock dumps to La Sal Creek, RMC were derived in this evaluation based on the leaching characteristics of the waste rock. The leaching RMC are intended to protect aquatic life from leaching of metals. The leaching RMC were derived by using the aquatic-life standards listed in Table 4.4 and the total metals and SPLP metals results reported for the waste-rock samples. The mean proportion leaching under the SPLP test was computed by dividing the total metal concentration by the SPLP concentration. A dilution-attenuation factor (DAF) of 20 was then applied using EPA's Soil Screening Level guidance (USEPA, 1996). Leaching RMC were calculated according to the following formula:

$$\text{Leaching RMC} = \text{Aquatic-Life Standard} \times \text{Total Metals} \times \text{DAF/SPLP}$$

The derived leaching RMC are compared to the total concentrations of the respective metals in the waste rock to assess whether the total metal concentrations pose a threat to aquatic life based on the leaching characteristics of the waste rock.

Ecological risk at the mine areas was further evaluated by comparing analytical results for vegetation samples collected at the mines to the levels reported for vegetation samples collected within the reference area and to maximum tolerable levels of dietary minerals for domestic animals from *Mineral Tolerance of Domestic Animals* (National Research Council, 1980).

4.2 BLM Risk Management Criteria

The RMC established by the BLM were developed to address the risks to human use and wildlife habitat at inactive/abandoned mines on or near BLM lands. The criteria are specific to the typical human and wildlife exposure scenarios at inactive/abandoned mines. The RMC designed to protect human receptors for the metals of concern were developed using available toxicity data and standard EPA exposure assumptions. The RMC designed to protect wildlife receptors for the metals of concern were developed using toxicity values and wildlife intake assumptions reported in the current ecotoxicological literature (Ford, 2004).

The RMC developed for the human receptors reflect generally recognized acceptable levels of health risk, corresponding to either a target excess cancer risk level of 1×10^{-5} or a target noncancer hazard index of 1.0 (Ford, 2004). An excess cancer risk of 1×10^{-5} means that an individual exposed at these RMC would have a 1 in 100,000 chance of developing any type of cancer in a lifetime as a result of contact with the COCs. A hazard index of less than 1.0 means that the dose of noncancer metals assumed to be received at the mine by any of the receptors in a medium is lower than the dose that may result in any noncancer health effects. The RMC are protective for exposure to multiple chemicals and media. Lead RMC for the child receptors were determined from EPA's Integrated Exposure Uptake Biokinetic Model (USEPA, 1993b) and other EPA regulations and guidance.

The process of calculating human health RMC, using a target hazard index and target excess life-time cancer risk has a number of inherent sources of uncertainty. The COCs may have synergistic (or antagonistic) effects on human or wildlife receptors. Cumulative effects were quantitatively dealt with for the human health assessment, although not all metals are elevated at the mine. Additionally, it is improbable that human receptors would be exposed concurrently via all possible exposure pathways, although this has been assumed for conservatism (Ford, 2004).

The BLM developed ecological RMCs for metals in soil and sediments. The RMC were developed using the best data available, including ecotoxicological effects data for the metals of concern, wildlife receptors representative of the southern Rocky Mountain ecosystem, body weights and food intake rates for each receptor, and soil ingestion rates for each receptor. The BLM surveyed literature for toxicity data relevant to either wildlife receptors at the mine or to closely related species. In the absence of available toxicity data for any receptor, data were selected on the basis of phylogenetic similarity between ecological receptors and the test species for which toxicity data were reported. Soil ingestion data for each receptor were obtained from a study on dietary soil content of wildlife from the U.S. Fish and

Wildlife Service (Beyer and others, 1994). Where no dietary soil content data were available for a particular receptor, the soil content was assumed to be equal to that of an animal with similar diets and habits. The amount of soil ingested by each receptor was estimated as a proportion of their daily food intake (Beyer and others, 1994). The food intake in grams for each receptor was calculated as a function of body weight (Nagy, 1987).

Ecological RMC were calculated for each COC in soil based upon assumed exposure factors for the selected receptors and species- and chemical-specific toxicity reference values (TRVs). The TRVs represent daily doses of the metals for each wildlife receptor that will not result in any adverse toxic effects. TRVs were computed by metal of concern for each wildlife receptor/metal combination for which toxicity data were available. Phylogenetic and intraspecies differences between test species and ecological receptors have been taken into account by the application of uncertainty factors in derivation of critical toxicity values. These uncertainty factors were applied to protect wildlife receptors which might be more sensitive to the toxic effects of a metal than the test species. The uncertainty factors were applied to the test species toxicity data in accordance with a method developed by the BLM. In accordance with this system, a divisor of two was applied to the toxicity reference dose for each level of phylogenetic difference between the test and wildlife species, i.e., individual, species, genus, and family (Ford, 2004).

There is uncertainty in deriving wildlife RMC due to the lack of toxicity data for these species. A standard uncertainty factor approach was used for interspecies extrapolation (Ford, 2004).

4.3 Firefly/Pygmy Mine

The Firefly/Pygmy Mine area is open to public access and currently used for recreation. Recreational uses in the area typically include camping, hiking, hunting, and ATV riding. Although a gate has been installed at the mine portal to discourage entry, the gate has been damaged and there is evidence that visitors have accessed the portal. Use of the area for recreation is expected to continue, and likely increase, in the future. A variety of wildlife also frequents the mine area.

The media of concern at the mine are surface water (mine drainage), waste rock, ephemeral drainage sediment derived from the waste-rock dump, and vegetation growing along the adit drainage channel and perimeter of the dump. Direct radiation exposure and radon are also potentially of concern at the mine.

4.3.1 Threats to La Sal Creek

La Sal Creek is the primary surface-water feature potentially impacted by contaminants at the mine. The potential threats to the creek as result of contaminant migration from the mine was evaluated by comparing analytical results for samples collected upstream and downstream of the mine to the aquatic-life chronic standards established for La Sal Creek (Table 4.4). The analytes reported at levels exceeding the standards are summarized as follows:

- Reported pH values were slightly above the risk range both upstream and downstream of the mine in April 2004.
- The total phosphorous as P concentration (0.06 mg/L) slightly exceeded the standard (0.05 mg/L) downstream of the mine in October 2004. The total phosphorous as P concentration in the upstream sample in October 2004 was 0.05 mg/L.
- The gross alpha activity (15.8 pCi/L) slightly exceeded the standard (15.0 pCi/L) downstream of the mine in April 2004. The gross alpha activity in the upstream sample in April 2004 was 7.13 pCi/L (4.75 pCi/L in the corresponding duplicate sample).

These findings suggest that during the spring when higher flows due to runoff are expected, gross alpha levels associated with the mine are contributing to the elevated levels of gross alpha in La Sal Creek, resulting in a potential threat to aquatic life downstream of the mine. For the other analytes in surface water, Table 4.4 shows that analyte levels were generally consistent between the two sampling stations, suggesting that mine-derived contaminants have an overall minimal impact on water-quality in La Sal Creek. Slight increases in analyte levels were noted in the downstream sample for some analytes. The analytes showing the greatest increases (more than 2 times the upstream level) were all reported for the samples collected in April 2004 and included dissolved and total recoverable iron, dissolved manganese, dissolved vanadium, gross alpha, gross beta, and thorium-230 and 232 (combined).

Comparison of analytical results for sediment samples collected at Reference Area 1, La Sal Creek upstream of the mine (La Sal Crk Up), and La Sal Creek downstream of the mine (La Sal Crk DN 1) to consensus-based probable effects concentrations (EPA, 2000c) is presented in Table 4.4 B. As shown, the lead concentration at the station downstream of the mine slightly exceeded the consensus-based probable effect concentration (by a factor of 1.1). Examination of analytical results for the sediment samples indicate that the analytes showing increases from the La Sal Crk Up station to the La Sal Crk DN 1 station were arsenic (2 times), chromium (2 times), copper (5 times), lead (13 times), selenium (9 times), uranium (10 times), vanadium (19 times), gross alpha (10 times), radium-226 (15 times), and thorium-230 (24 times). These results suggest contaminants have migrated from the mine by way of

sediment transport from the waste-rock dump. Mine-derived sediment is the most likely source for the elevated contaminant levels observed in both surface water and sediment in La Sal Creek. Sediment transport from the mine to the creek has likely been occurring for many years.

Based on taxonomic analysis results, the benthic macroinvertebrate community at station La Sal Creek Dn1 appears to be moderately stressed; however, the benthic macroinvertebrate community within La Sal Creek upstream of the mine (Reference Area 1) was found to be quite stressed. The sources of stress to the benthic macroinvertebrate community in the reference area are not known but may be attributed to upstream land uses along La Sal Creek and drought conditions experienced throughout the region the past several years. Based on upstream reconnaissance, such land uses include residential development, livestock grazing, and irrigated pasture lands. In addition, lands immediately upgradient of the reference area contain remnants (abandoned structures and miscellaneous trash and debris) of a former man-camp apparently constructed to support mining operations in the area. Various indices designed to measure community response to organic pollution, environmental (especially metals) stress, and overall community health showed that the benthic macroinvertebrate community at La Sal Creek Dn1 to be somewhat impaired but more productive than at Reference Area 1. These findings indicate that the ecosystem improves downstream of the reference area, possibly as a result of recharge from natural springs and groundwater inflow, and provide evidence that mine-derived contaminants may not be impacting the development of benthic macroinvertebrate communities in La Sal Creek downstream of the mine.

4.3.2 Surface Water

Water flowing from the mine adit is considered a potential contaminant source at the mine. However, water emanating from the mine forms an isolated surface-water feature, infiltrating into the waste-rock dump before reaching a perennial stream (i.e., La Sal Creek). The risks posed by surface water at the mine are evaluated below.

4.3.2.1 Contaminants of Concern

The COCs for surface water were selected by comparing analytical results for samples collected at the mine (stations Firefly Adit and Firefly Drainage) to the maximum levels reported for samples collected at Reference Areas 1, 2, and 3 (Table 4.5). The results reported for the following parameters exceeded background levels in one or both of the sampling events and were selected as COCs for this evaluation:

- Antimony, dissolved and total
- Arsenic, dissolved and total recoverable
- Barium, dissolved (slightly exceeds maximum value in one sample)
- Lead, dissolved and total
- Magnesium, dissolved
- Molybdenum, dissolved and total
- Potassium, dissolved
- Selenium, dissolved and total
- Sodium, dissolved
- Uranium, dissolved and total
- Vanadium, dissolved and total
- Gross Alpha
- Gross Beta
- Radium-226 and -228 (combined)
- Thorium-230 and 232 (combined)
- Thorium-228

4.3.2.2 Human-Health Risk Evaluation Results

Of the COCs identified for surface water at the mine, RMC under the camper scenario have been established for dissolved antimony (124 µg/L), dissolved arsenic (93 µg/L), dissolved lead (50 µg/L), and dissolved selenium (1,548 µg/L). As shown in Table 4.6, the concentrations of these analytes in samples Firefly Adit and Firefly Drainage did not exceed the RMC, and therefore, pose low risk under the camper scenario.

RMC for the camper scenario have not been established for the remaining COCs in surface water at the mine. As shown in Table 4.6, analyte concentrations for these remaining COCs do not exceed the modified MCLs, and therefore, are considered to pose low risk to campers at the mine.

Based on this evaluation, surface water at the Firefly/Pygmy Mine poses low risk to campers at the mine. However, it is suspected that adit water infiltrating the waste-rock dump is leaching contaminants from the waste materials as evidenced by the higher analyte levels for several parameters (primarily uranium, vanadium, and the radionuclides) in the sample collected from the spring emanating from the base of the upper dump than in the sample collected at the mine adit.

4.3.2.3 Ecological Risk Evaluation Results

Of the COCs identified for surface water at the mine, aquatic-life chronic standards have been established for dissolved arsenic, dissolved lead, dissolved selenium, gross alpha, and gross beta (Table 4.7). Although the standards apply to the quality of water in La Sal Creek downstream of the discharge point, comparing the standards directly to the mine discharge allows identification of the analytes in the mine water that may potentially pose a threat to aquatic life in the creek. The analytes reported at concentrations in the mine water exceeding the standards are summarized as follows:

- Dissolved selenium
  - Minimum: 9.8 times standard at Firefly Adit
  - Maximum: 12.9 times standard at Firefly Drainage

- Gross alpha
  - Minimum: 3.1 times standard at Firefly Adit
  - Maximum: 7.0 times standard at Firefly Drainage

Examination of the Table 4.4 shows that dissolved selenium concentrations in water samples collected from La Sal Creek downstream of the mine are below the aquatic-life standard and that the dissolved selenium concentrations upstream and downstream of the mine are generally consistent. The gross alpha activity in La Sal Creek downstream of the mine slightly exceeded the aquatic-life standard in April 2004 and was about 3 times greater than the levels reported for the upstream La Sal Creek sample in April 2004. Therefore, dissolved selenium levels in the adit drainage do not appear to be threatening aquatic life in La Sal Creek, but the gross alpha activities in the adit drainage may contribute to the elevated gross alpha levels, and potential aquatic-life threat, reported for La Sal Creek downstream of the mine. However, the potential contribution of gross alpha to La Sal Creek is expected to be small because of the low flow rates associated with the adit drainage and the uncertain hydraulic connection between the two water sources. As discussed in Section 4.3.1, the most likely source for the elevated levels of gross alpha observed in the creek is sediment which has been transported from the mine dump along the ephemeral drainage and deposited in the creek over many years.

The levels of dissolved selenium and gross alpha that exceed the standards are not considered to be of concern in the isolated reach of surface water discharging from the mine.

4.3.3 Waste Rock

Waste rock accumulations are considered potential contaminant sources at the mine. The risks posed by waste rock at the mine are evaluated below.

4.3.3.1 Contaminants of Concern

The COCs for waste rock were selected by comparing analyte concentrations in waste-rock samples collected at the mine to the maximum analyte concentrations reported for soil samples collected from the three reference areas. Examination of Table 4.8 (borehole samples) shows that barium, iron, and thorium-228 were not detected at concentrations greater than the maximum concentrations reported for the background samples. Examination of Table 4.9 (composite surface samples) shows that barium, beryllium, iron, manganese, radium-228, and thorium-228 were not detected at concentrations greater than the maximum concentrations reported for the background samples. Therefore, the analytes considered COCs for this evaluation include all of the analytes listed in Tables 4.8 and 4.9, excluding barium, iron, and thorium-228.

4.3.3.2 Human-Health Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for the camper scenario have been established for antimony, arsenic, cadmium, copper, lead, manganese, mercury, nickel, selenium, silver, and zinc. Arsenic was the only metal reported at concentrations exceeding the RMC (Tables 4.8 and 4.9). It should be noted that the maximum concentration of arsenic in background soil (25.7 mg/Kg) slightly exceeded the camper RMC (20 mg/Kg). Arsenic concentrations exceeded the RMC in all of the near-surface (0 to 6 inches) waste-rock samples and all but two of the subsurface waste-rock samples. The arsenic concentrations that exceeded the RMC in the near-surface samples collected from the 0 to 6-inch depth at boreholes and composite samples collected from the waste-rock dump are summarized as follows:

- Minimum arsenic value: 28 mg/Kg at FF Segment 1
- Maximum arsenic value: 140 mg/Kg at FF 4 (0 – 0.5)
- Mean arsenic value: 58.5 mg/Kg

- Median arsenic value: 50 mg/Kg

The mean and median concentration of arsenic in the near-surface waste-rock samples exceeded the RMC for the camper scenario by a factor of approximately 2. Therefore, arsenic levels in waste rock at the mine are generally considered to pose low risk to campers. The only areas in which arsenic levels pose moderate risk to campers include boreholes FF 3 (4 times RMC) and FF 4 (7 times RMC) on the mine bench near the former ore loadout, borehole FF 6 (3.5 times RMC) on the lower bench, borehole FF 7 (3.3 times RMC) below the former ore loadout, and dump segments 3 (6.2 times RMC) and 7 (3.2 times RMC) comprising the central portions of the upper and lower levels of the dump.

The camper risks associated with the metals for which RMC have not been established were evaluated by comparing analyte concentrations reported for the waste-rock samples to industrial SSLs. As shown in Tables 4.8 and 4.9, concentrations of the metals for which RMC have not been established do not exceed industrial SSLs, and therefore, are considered to pose low risk to campers at the mine.

Radionuclide activities reported for the waste-rock samples were compared to background levels. The sample sites where radionuclide activities in near-surface samples exceeded maximum background levels and the range of the exceedances for each radionuclide are summarized in Table 4.10. Above background radionuclide activities were much more prevalent in the near-surface samples collected from boreholes then in the composite surface samples collected from the face of the mine dump. The highest radionuclide activities of the near-surface samples were reported for the samples collected at boreholes FF 3 and FF 4. Borehole FF 3 is located on the nose of the upper dump near the mine adit, and FF 4 is located near the terminus of the mine tracks at the ore loadout. The highest radionuclide activities relative to maximum background levels in near-surface samples at boreholes were reported for gross alpha (2 to 30 times background), gross beta (2 to 30 times background), radium-226 (2 to 35 times background), and thorium-230 (2 to 19 times background). The activities of radium-228 and thorium-232 in near-surface samples were reported at activities generally at or below maximum background levels. Thorium-228 was not detected in any of the near-surface samples collected at the mine.

Radium-226 activities reported for near-surface samples collected at the mine (the 0-6 inches samples from boreholes and composite surface samples from the face of the dump) were compared to the UMTRCA standard of 5 pCi/g over background. As discussed in Section 4.1.1, the UMTRCA standard applies to unrestricted use (e.g., construction of habitable structures), and therefore, is not directly

applicable to the mine area and is only used to identify the areas where radium-226 levels could potentially pose a potential threat to campers at the mine. A factor of 26 (365 days/14 days) was applied to better assess the threats posed under the camper scenario, where radium-226 levels less than 26 times the UMTRCA standard are considered to not pose a threat to campers. The average background level reported for radium-226 in soil samples collected from the three reference areas was 3.3 pCi/g, resulting in a criterion of 8.3 pCi/g. The radium-226 activities reported for all of the near-surface samples collected from boreholes exceeded 8.3 pCi/g, with activities more than 26 times the criterion reported for near-surface samples collected near the former ore loadout at boreholes FF 4 (466 pCi/g) and FF 7 (286 pCi/g). Except for the composite surface sample collected from segment 1, the radium-226 activities reported for composite surface samples exceeded 8.3 pCi/g, with the highest radium-226 activity (14.6 pCi/g for segment 7) exceeding the standard by a factor of 1.8.

Gross alpha and gross beta, radium-226, and thorium-230 activities in sub-surface samples collected from boreholes exceeded maximum background levels by factors of up to 11, 15, and 16, respectively. Radium-228 and thorium-232 activities were up to 3 times greater than maximum background levels in the sub-surface borehole samples.

These results indicate that radionuclide levels in waste rock at the mine are elevated with respect to background areas with the highest activities relative to background reported for gross alpha, gross beta, radium-226, and thorium-230. Under current conditions, above background radionuclide levels are greater in the near-surface material covering the mine bench, lower bench, and ancillary dump along the access road than in the material covering the face of the dump. Radionuclides in the material covering the face of the waste-rock dump are generally consistent with the levels reported for the background areas. The above background levels of radionuclides in the waste rock likely contribute to the higher radionuclide levels in La Sal Creek surface water and sediment downstream of the mine as compared to the levels upstream. The potential threats posed by radionuclides at the Firefly/Pygmy Mine are further evaluated on the basis of radiation exposure in Section 4.3.6.

4.3.3.3 Ecological Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for elk have been established for arsenic, cadmium, copper, lead, mercury, uranium, vanadium, and zinc. Tables 4.11 (borehole samples) and 4.12 (composite surface samples) present comparisons of analytical results to the elk RMC, modified with an area use factor of 0.003 (2.02-acre mine area divided by 640-acre home range). As shown, analyte

concentrations did not exceed the modified RMC for elk, and therefore, the concentrations of these analytes in waste rock pose low risk to elk at the mine.

As found for the human-health risk evaluation, gross alpha, gross beta, radium-226, and thorium-230 activities in the waste-rock material covering the mine bench and lower bench exceed background levels. The above background levels of gross alpha, gross beta, and thorium-230 in waste rock may contribute to the higher levels of these analytes in La Sal Creek downstream of the mine as compared to upstream of the mine. Radionuclides in the material covering the surface of the mine dump are generally consistent with background levels, with thorium-230 activities slightly exceeding background levels (less than 10 times) in each segment and gross alpha, gross beta, radium-226, and thorium-232 activities slightly exceeding background levels (less than 10 times) in a few of the segments.

Analyte concentrations reported for waste rock samples were compared to leaching RMC to evaluate the leaching characteristics of the waste rock (Table 4.13 – borehole samples and Table 4.14 – composite surface samples). Because the criteria are based on aquatic life standards, the comparisons allow identification of the analytes in waste rock that may pose a threat to aquatic life. As shown, selenium was the only metal present in waste rock at concentrations exceeding the derived leaching RMC. Selenium concentrations exceeded the leaching RMC in borehole samples FF 2 (6-8), FF 5 (14.5-19.5), and FF 5 (21.5-23) and in composite surface sample FF Segment 4. In each case, the selenium concentration exceeded the leaching RMC by less than 3 times. Selenium in the waste rock is not considered to be of concern at the mine because (1) the concentration exceeded the leaching RMC in a limited number of samples, (2) concentrations exceeded the leaching RMC by less than 3 times (indicating low risk), and (3) selenium concentrations do not exceed aquatic life standards in La Sal Creek immediately downstream of the mine. Examination of the SPLP results shows that the metals most frequently reported at levels above method detection limits in leachate from the waste rock were arsenic, uranium, and vanadium.

4.3.4 Ephemeral Drainage

Sediment along the ephemeral drainage extending from the toe of the waste-rock dump to La Sal Creek is considered a potential contaminant source at the mine. The risks posed by sediment along the drainage are evaluated below.

4.3.4.1 Contaminants of Concern

The COCs for sediment were selected by comparing analyte concentrations in sediment samples collected along the ephemeral drainage to analyte concentrations in soil samples collected from the three reference areas. Examination of Table 4.15 shows that concentrations of the following analytes exceed maximum background levels in one or more of the sediment samples collected along the ephemeral drainage, and therefore, are considered COCs for this evaluation:

- Arsenic
- Chromium
- Copper
- Lead
- Molybdenum
- Selenium
- Silver
- Uranium
- Vanadium
- Gross alpha
- Gross beta
- Radium-226
- Radium-228
- Thorium-230

4.3.4.2 Risk Evaluation Results

Table 4.16 presents a comparison of metals concentrations in the ephemeral drainage sediment samples to the camper RMC, industrial SSLs, and the modified RMC for elk. As shown, metal concentrations do not exceed the camper RMC, industrial SSLs, or modified RMC for elk in any of the samples. Elk RMC were modified based on the area along the drainage channel of approximately 0.15 acre. Based on these comparisons, metal concentrations in sediment along the drainage pose low risk to human health and low risk to elk.

The above background levels of uranium, vanadium, gross alpha, gross beta, radium-226, radium-228, and thorium-230 in sediment samples collected along the drainage indicate that contaminants have migrated from the mine area, and are contributing to the higher metals and radionuclide levels in La Sal Creek surface water and sediment immediately downstream of the mine as compared to upstream of the mine.

4.3.5 Vegetation

Vegetation at the mine is considered both a receptor and dietary item for herbivores. Analyte levels in vegetation at the mine were evaluated by comparing analytical results for samples collected at the mine to the analytical results for samples collected within the reference area and maximum tolerable levels of dietary minerals for domestic animals (Table 4.17). In addition, the ecological risk evaluation results discussed in Sections 4.3.3.3 (waste rock) and 4.3.4.2 (ephemeral drainage sediment) were also considered in the evaluation because the ecological RMC developed by BLM for soil include consumption of vegetation by terrestrial herbivores.

The analytes reported at the highest levels relative to background (more than 10 times background levels) in vegetation along the adit drainage include cadmium (shrub), molybdenum, selenium, uranium, gross alpha, gross beta (grass), and radium-226 (forb and shrub). Of these analytes, radium-226 was reported at the highest concentration (131 times background) in the forb sample. The analytes reported at the highest levels relative to background (more than 10 times background levels) in vegetation along the perimeter of the mine dump include molybdenum, selenium, uranium (grass and shrub), vanadium, gross alpha (forb), and radium-226 (forb). Of these analytes, radium-226 was reported at the highest level (160 times background) in the forb sample.

The analytes reported at concentrations exceeding the maximum tolerable levels in vegetation along the adit drainage include barium, cadmium, molybdenum, and selenium. However, it should be noted that the concentrations of barium (grass, forb, and shrub) and selenium (grass and forb) in the background samples also exceeded the criteria. The analytes reported at the highest concentrations relative to the criteria were molybdenum (forb) and selenium (grass, forb, and shrub). The molybdenum concentration in the forb sample exceeded the criterion by factors 12. The selenium concentrations in the grass, forb, and shrub samples exceeded the criteria by factors of 32, 52, and 44, respectively. The concentrations of the other samples exceeding the criteria were less than 10 times the criteria.

The analytes reported at concentrations exceeding the maximum tolerable levels in vegetation along the perimeter of the mine dump include barium, molybdenum, selenium, and vanadium. However, it should be noted that the concentrations of barium (grass, forb, and shrub) and selenium (grass and forb) in the background samples also exceeded the criteria. The analytes reported at the highest concentrations relative to the criteria were molybdenum (forb) and selenium (grass, forb, and shrub). The molybdenum concentration in the forb sample exceeded the criterion by factors 10. The selenium concentrations in the grass, forb, and shrub samples exceeded the criteria by factors of 52, 90, and 30, respectively. The concentrations of the other samples exceeding the criteria were less than 10 times the criteria.

These results indicate that vegetation at the mine contains higher levels for several analytes than does vegetation in the background area. The analytes reported at the highest levels relative to background in vegetation along the mine drainage are cadmium, molybdenum, selenium, uranium, gross alpha, gross beta, and radium-226. The concentrations of barium, cadmium, molybdenum, and selenium in one or more of the vegetation samples collected along the adit drainage exceeded the maximum tolerable levels. The analytes reported at the highest levels relative to background in vegetation along the perimeter of the mine dump are molybdenum, selenium, uranium, vanadium, gross alpha, and radium-226. The concentrations of barium, molybdenum, selenium, and vanadium in one or more of the vegetation samples collected along the perimeter of the mine dump exceeded the maximum tolerable levels. The analytes reported at the highest levels relative to the criteria were molybdenum and selenium. Based on comparisons to the maximum tolerable levels, molybdenum and selenium likely pose the greatest threat to livestock and wildlife at the mine.

As discussed in Sections 4.3.3.3 and 4.3.4.2, waste rock and sediment at the mine are considered to pose a low risk to livestock and wildlife on the basis of the RMC established by BLM. Because the RMC account for the consumption of vegetation by herbivores, vegetation at the mine is considered to pose a low risk to herbivores with respect to the analytes for which ecological RMC for soil have been established.

4.3.6 Radiation Exposure

The risk associated with direct radiation exposure at the mine was evaluated on the basis of radiological surveys of the mine area, correlation study results, and uranium concentrations and radium-226 activities in waste rock. Gamma-count rates recorded across the mine area are shown in Figure 3.11, and gamma-count and gamma-exposure rate measurements taken at the mine are presented in Table 3.16. Based on

these measurements, a gamma-exposure rate of 1 µR/hr is approximately equal to a gamma-count rate of 932 cpm. Assuming this correlation, the cpm rates shown in Figure 3.15 of 18,500, 21,500, and 28,500 cpm represent approximately 20 µR/hr, 23 µR/hr, and 31 µR/hr, respectively. An individual camping at the mine for 14 days in an area where the gamma-exposure rate is 31 µR/hr (gamma-count rate of 28,500 cpm) would receive approximately 10 mRem, well below the 100 mRem per year ceiling level. The background gamma-exposure rate at the Firefly/Pygmy Mine was 13 µR/hr or approximately 0.013 mRem/hr (Table 3.16). Assuming a 14-day camper scenario, the 100 mRem per year ceiling exclusive of background would be exceeded by a camper spending the entire 14-day period in an area where the gamma-exposure rate was greater than 311 µR/hr (gamma-count rate greater than approximately 290,000 cpm).

Radiation survey results at the mine (Figure 3.11) show that gamma-count rates greater than 28,500 cpm primarily occur on the lower bench near the former ore loadout and within the upper portion of the lower dump. Based on these surveys, exposures rates greater than 100 mRem per year (exclusive of background) under the camper scenario could only occur in these areas. However, the gamma-scan survey is based on a walking average and provides only a relative assessment of gamma-count rates across the survey area. The static gamma-count rates and gamma-exposure rates recorded for the correlation samples provide a more accurate assessment of exposure than the gamma-scan results. As shown in Table 3.16, one of the seven discrete correlation samples collected at the mine exhibited gamma-exposure rates greater than 311 µR/hr. An in-situ gamma-exposure rate of 320 µR/hr (in-situ gamma-count rate of 279,718 cpm) was reported for correlation sample FF-COR4, located on the south end of the lower dump, near the former ore loadout. The average gamma-exposure rate for the four samples collected near the base of the former ore loadout (FF-COR4 through FF-COR7) was 223 µR/hr. Over a 14-day period, the gamma-exposure rate to a camper in this area would be approximately 75 mRem, or 71 mRem exclusive of background. The gamma-exposure rates measured at the two samples on the mine bench were 60 µR/hr (FF-COR 2 located 30 feet from the mine portal) and 120 µR/hr (FF-COR3 located on the top of the upper dump), resulting in a gamma-exposure rate to a camper on the mine bench of up to 40 mRem or 36 mRem exclusive of background. Based on the static readings, gamma-exposures to campers would exceed the 100 mRem per ceiling exclusive of background on the lower bench near the former ore loadout, and gamma-exposure rates on the mine bench are significantly lower than on the lower bench.

The correlations between gamma-count rate and radium-226 and uranium activities (Section 3.6.2 of this document) were also used to assess gamma exposure at the mine. Based on these correlations, a gamma-

count rate of 290,000 cpm (the count rate at which the 100 mRem per year ceiling exclusive of background would be exceeded for a 14-day camper) equates to a radium-226 activity of 226 pCi/g and a uranium activity of 382 pCi/g (570 mg/Kg, assuming an approximate correlation of 0.67 pCi/g to 1.0 mg/Kg). These radium-226 and/or uranium levels were exceeded in near-surface samples collected at boreholes FF-3 (676 mg/Kg uranium), FF-4 (466 pCi/g radium and 1510 mg/Kg uranium), FF-7 (286 pCi/g radium and 727 mg/Kg uranium), and FF-8 (585 mg/Kg uranium). Boreholes FF-3 and FF-4 are located on the crest of the mine bench in the vicinity of the former ore loadout, borehole FF-7 is located on the lower bench below the former ore loadout, and borehole FF-8 is located on the ancillary dump. The derived radium-226 level of 226 pCi/g was not exceeded in any of the subsurface samples, and the derived uranium level of 570 mg/Kg was only exceeded in samples FF-4: 1-2 (675 mg/Kg) and FF-7: 1-3 (618 mg/Kg). On the face of the mine dump, the derived radium-226 and uranium levels were not exceeded in any of the composite samples collected from the segments of the dump.

These results suggest that radiation exposures for individuals camping at the mine would likely exceed 100 mRem per year exclusive of background on the lower bench in the vicinity of the former ore loadout, on the mine bench in the vicinity of the former ore loadout, and on the ancillary waste-rock pile adjacent to the mine access road. Based on uranium concentrations reported for sediment within the ephemeral drainage at stations FF SED 1 (1560 mg/Kg uranium) and FF SED 2 (1240 mg/Kg uranium), gamma-exposure levels along the drainage could potentially exceed 100 mRem per year exclusive of background for campers.

Radiation exposure is not expected to be of ecological concern at the mine because gamma-exposures rates measured at the mine were well below the IAEA standard for wildlife of 0.1 Rad per day, or 4,167 µR/hr.

4.3.7 Radon

Radon poses a potential hazard at the mine. The relative risk posed by radon at the mine was evaluated by comparing radon levels inside the mine portal (approximately 50 feet from the mine entrance) to levels in an adjacent background area. The monitoring results reported for the mine are as follows:

- Background Area
    - Exposure: 304.1 pCi/L over 167-day monitoring period
    - Average: 1.8 pCi/L per day
- Adit

- Exposure: Greater than 140,000 pCi/L over 167-day monitoring period
- Average: Greater than 838 pCi/L per day

These results suggest that high radon levels are associated with the mine and that high exposures to radon occur within the mine portal.

4.3.8 Risk Evaluation Summary and Removal Action Criteria for Surface Water

The camper RMC and modified MCLs are proposed to be the removal criteria for metals and radionuclides in surface water at the mine adit. Because these criteria were not exceeded in any of the surface-water samples collected at the mine, surface water is considered to pose low risk to campers at the mine. However, surface-water results suggest that contaminants (primarily uranium, vanadium, and radionuclides) are leaching from the waste-rock dump as a result of the adit drainage infiltrating the dump materials. Therefore, actions should be taken to prevent adit drainage water from infiltrating the dump. To help ensure human-health protection in the future, actions should be considered to isolate the water from potential human contact (e.g., by piping the drainage) and inform the public that the water poses a potential hazard as a drinking water source.

Analyte levels in surface water at the mine do not appear to be threatening aquatic life in La Sal Creek. Surface water within the isolated reach of the drainage at the mine is not considered to be of concern with respect to ecological risk. However, any actions taken to reduce threats to human-health will provide protection for ecological receptors. It should be noted that actions taken to line or pipe the mine discharge water will likely eliminate the existing wetland (non-jurisdictional) ecosystem at the mine.

4.3.9 Risk Evaluation Summary and Removal Action Criteria for Waste Rock

The camper RMC are proposed to be the removal action criteria for metals in waste rock at the mine. Since these criteria are based on ingestion and inhalation, areas where surficial concentrations exceed these criteria will be removed or covered. Such actions will also provide protection for wildlife since the elk RMC modified with the 0.003 area use factor are greater than the camper RMC. Therefore, any actions taken to reduce the potential for direct contact with the waste would reduce the threats to both humans and wildlife.

Arsenic was the only metal found at concentrations exceeding the camper RMC of 20 mg/Kg. The mean and median concentrations of arsenic in near-surface waste-rock samples exceeded the camper RMC by a factor of approximately two. Therefore, the arsenic levels in the near-surface waste rock are generally considered to pose low risk to campers at the mine. The only areas where arsenic levels in near-surface waste rock pose moderate risk to camper are at boreholes FF-3 and FF-4 on the crest of the mine bench in the vicinity of the former ore loadout, boreholes FF-6 and FF-7 on the lower bench, and segments 3 and 7 comprising the central portions of the upper and lower dumps. Near-surface waste-rock samples in these areas were also found to contain the highest radionuclide activities (i.e., gross alpha, gross beta, radium-226, and thorium-230) relative to background levels.

Metals concentrations in sediment deposited along the ephemeral drainage extending from the toe of the dump did not exceed the camper RMC, and therefore, pose low risk to campers. However, above background levels of uranium, vanadium, and the radionuclides in the sediment samples indicate that contaminants are migrating from the mine area along the drainage.
The removal criteria for radionuclides in waste rock and sediment at the mine are proposed to be the gamma-exposure ceiling of 100 mRem per year exclusive of background plus as low as reasonably achievable (ALARA). The ALARA principle is defined by EPA as making reasonable efforts to maintain exposures as far below the applicable limits as practical. The ceiling plus ALARA will be applied to the 14-day camper scenario. Based on analytical results and radiological measurements, radiation exposures for individuals camping at the mine would likely exceed 100 mRem per year exclusive of background on the lower bench in the vicinity below the former ore loadout, the mine bench in the vicinity above the former ore loadout, and on the ancillary waste-rock pile adjacent to the mine access road. Uranium concentrations reported for sediment within the ephemeral drainage at stations FF SED 1 (1560 mg/Kg uranium) and FF SED 2 (1240 mg/Kg uranium) indicate that gamma-exposure levels along the drainage could potentially exceed 100 mRem per year exclusive of background for campers.

These findings indicate that removal actions should be implemented to reduce the risks to campers posed by above background arsenic concentrations, radionuclide activities, and gamma-exposure rates in areas potentially used for unsanctioned camping, specifically the mine bench, lower bench, and ancillary dump. Potential actions could include physical removal of waste rock or capping the areas with appropriate cover materials. Any potential camping areas created as a result of site grading during implementation of actions (e.g., stabilization terraces) should be covered with appropriate cover soil to ensure the 100 mRem per year ceiling plus ALARA is achieved. Such actions taken to reduce human-health risks at the mine would also provide protection for wildlife. Based on the contaminant levels reported for vegetation

samples collected at the mine, future livestock grazing should be discouraged in the mine area. Actions to reduce gamma exposures from sediment along the ephemeral drainage would be difficult to implement due to extremely rough terrain and not warranted because of the low probability that individuals would camp within the drainage.

Under existing conditions, the materials comprising the waste-rock dump are migrating from the mine area as a result of erosion (fluvial and wind) and mass wasting processes. The higher levels of metals and radionuclides in surface water and sediment downstream of the mine, as compared to upstream of the mine, are most likely attributed to the transport of contaminated sediment from the mine to the creek. Actions should be taken to stabilize the dump and reduce the potential for future migration of contaminants from the mine.

Actions should also be taken to properly close the Firefly/Pygmy Mine portal to prevent unauthorized access to the mine and reduce the threat of radon exposure in the portal, while maintaining adequate drainage of mine discharge.

4.4 Vanadium Queen Mine

The Vanadium Queen Mine area is open to public access and currently used for recreation. Recreational uses in the area typically include camping, hiking, hunting, and ATV riding. Use of the area for recreation is expected to continue, and likely increase, in the future. Several physical hazards are present at the mine including an open but highly unstable mine portal and a highly unstable, partially collapsed wooden crib wall on the face of the upper dump. A variety of wildlife also frequents the mine area.

The media of concern at the mine are surface water (mine drainage), waste rock, ephemeral drainage sediment derived from the waste-rock dump, and vegetation growing along the adit drainage channel and perimeter of the dump. Direct radiation exposure and radon are also of potential concern at the mine.

The area of stained soil around the compressor in the mine shop was investigated as part of the characterization effort. The analytical results showed that PCBs were not present in the soil and indicated that the staining was attributed to oil and grease. Because the area is of small, limited extent and PCBs were not detected, the stained soil is not considered to be of concern with respect to human health or wildlife.

4.4.1 Threats to La Sal Creek

La Sal Creek is the primary surface-water feature potentially impacted by contaminants at the mine. The potential threats to the creek as result of contaminant migration from the mine was evaluated by comparing analytical results for water samples collected upstream and downstream of the mine to the aquatic-life chronic standards established for La Sal Creek (Table 4.18). As shown, analyte levels were below aquatic-life standards in all samples collected upstream and downstream of the mine. In addition, analyte levels were consistent between the two monitoring stations, showing no marked increases from upstream to downstream. Therefore, contaminants associated with the mine do not appear to be impacting water quality in La Sal Creek.

Comparison of analytical results for sediment samples collected at Reference Area 1, La Sal Creek upstream of the mine (La Sal Crk DN 2), and La Sal Creek downstream of the mine (La Sal Crk DN 3) to consensus-based probable effects concentrations (EPA, 2000c) is presented in Table 4.18 B. As shown, analyte concentrations did not exceed the consensus-based probable effects concentrations at either station. Examination of analytical results for the sediment samples indicate that the analytes showing increases from the upstream station (La Sal Crk DN 2) to the downstream station (La Sal Crk DN 3) were barium (8 times), lead (2 times), uranium (4 times), vanadium (2 times), gross alpha (2 times), radium-226 (4 times), thorium-228 (5 times), and thorium-230 (7 times). These results suggest contaminants have migrated from the mine by way of sediment transport from the waste-rock dump. Mine-derived sediment is the most likely source for the higher contaminant levels observed in La Sal Creek sediment downstream of the mine as compared to upstream of the mine. Sediment transport from the mine to the creek has likely been occurring for many years.

Based on taxonomic analysis results, the benthic macroinvertebrate community at station La Sal Creek Dn3 appears to be moderately stressed; however, the benthic macroinvertebrate communities within La Sal Creek upstream of the mine (Reference Area 1 and La Sal Creek Dn1) were also found to be stressed. Various indices designed to measure community response to organic pollution, environmental (especially metals) stress, and overall community health showed that the benthic macroinvertebrate community at La Sal Creek Dn3 to be somewhat impaired but more productive than at Reference Area 1. These findings indicate that the ecosystem improves downstream of the reference area, possibly as a result of recharge from natural springs, groundwater inflow, and flows from Two Mile Creek and Hop Creek, and provide evidence that mine-derived contaminants may not be impacting the development of benthic macroinvertebrate communities in La Sal Creek downstream of the mine.

4.4.2 Surface Water

Water flowing from the mine adit is considered a potential contaminant source at the mine. However, water emanating from the mine forms an isolated surface-water feature, infiltrating into the ground before reaching a perennial stream (i.e., La Sal Creek). The risks posed by surface water at the mine are evaluated below.

4.4.2.1 Contaminants of Concern

The COCs for surface water were selected by comparing analytical results for samples collected at the mine to the maximum levels reported for samples collected in the reference areas (Table 4.19). The COCs selected for surface water are as follows:

- pH (one sample)
- Nitrate
- Sulfate
- Total phosphorous as P (one sample)
- Nitrate/nitrite as N, dissolved
- Antimony, dissolved and total
- Arsenic, dissolved and total recoverable
- Barium, dissolved
- Barium, total (one sample)
- Cadmium, dissolved and total
- Copper, dissolved (one sample at MDL)
- Copper, total
- Iron, total recoverable (one sample)
- Lead, dissolved and total (one sample)
- Magnesium, dissolved
- Manganese, total (one sample)

- Molybdenum, dissolved and total
- Potassium, dissolved
- Selenium, dissolved and total
- Silver, total (one sample)
- Sodium, dissolved
- Uranium, dissolved and total
- Vanadium, dissolved and total
- Gross alpha
- Gross beta
- Radium-226 and -228 (combined)
- Thorium-230 and 232 (combined)
- Thorium-228 (one sample)

4.4.2.2 Human-Health Risk Evaluation Results

Of the COCs identified for surface water at the mine, RMC under the camper scenario have been established for dissolved antimony (124 µg/L), dissolved arsenic (93 µg/L), dissolved cadmium (155 µg/L), dissolved copper (11,490 µg/L), dissolved lead (50 µg/L), and dissolved selenium (1,548 µg/L). Except for dissolved arsenic, the concentrations of these analytes in samples VQ Adit and VQ Drainage 1 do not exceed the RMC, and therefore, pose low risk under the camper scenario (Table 4.20). The concentration of dissolved arsenic slightly exceeds the RMC (by less than a factor of 2) in each of the samples. Therefore, dissolved arsenic in water at the mine is also considered to pose low risk under the camper scenario.

RMC for the camper scenario have not been established for the remaining COCs in surface water at the mine. As shown in Table 4.20, total uranium was the only analyte reported at concentrations exceeding the modified MCLs. The total uranium concentrations exceeded the modified MCL of 780 µg/L by less than a factor of 2 in each of the surface-water samples. Therefore, total uranium is considered to pose low risk to campers at the mine.

Based on this evaluation, surface water at the Vanadium Queen Mine poses low risk to camper at the mine. However, it is suspected that adit water infiltrating the waste-rock dump is leaching contaminants from the waste materials and potentially degrading water quality in the shallow groundwater system.

4.4.2.3 Ecological Risk Evaluation Results

Of the COCs identified for surface water at the mine, aquatic life chronic standards have been established for pH, nitrate, sulfate, total phosphorous as P, total recoverable arsenic, dissolved cadmium, dissolved copper, total recoverable iron, dissolved lead, dissolved selenium, gross alpha, and gross beta (Table 4.21). The analytes reported at concentrations exceeding these standards are summarized as follows:

- The pH value at VQ Drainage 1 in April 2004 (9.11 s.u.) was slightly higher than the upper limit of the standard.

- The concentration of total phosphorous as P in the duplicate sample collected at VQ Adit in April 2004 (0.24 mg/L) exceeded the Utah standard of 0.05 mg/L. The concentrations of total phosphorous as P in the corresponding sample and the sample collected in October 2004 were well below the standard.

- Total recoverable iron
  - Minimum: 1.1 times the standard at VQ Drainage 1
  - Maximum: 2.4 times the standard at VQ Drainage 1
  - Concentrations reported for VQ Adit did not exceed the standard.

- Dissolved selenium
  - Minimum: 70 times standard at VQ Adit
  - Maximum: 81 times standard at VQ Adit

- Gross alpha
  - Minimum: 35 times standard at VQ Drainage 1
  - Maximum: 53 times standard at VQ Adit

- Gross beta
  - Minimum: 2.5 times standard at VQ Adit
  - Maximum: 5.5 times standard at VQ Drainage 1

Examination of Table 4.18 shows that the levels of these analytes at station La Sal Creek Dn3 are below the standards. Station La Sal Creek Dn3 is located on La Sal Creek immediately downstream of the mine. Therefore, the levels reported for these analytes in the mine discharge do not appear to be threatening aquatic life in La Sal Creek. The levels reported for these analytes are not considered to be of concern in the isolated reach of surface water draining from the mine.

4.4.3 Waste Rock

Waste rock accumulations are considered potential contaminant sources at the mine. The risks posed by waste rock at the mine are evaluated below.

4.4.3.1 Contaminants of Concern

The COCs for waste rock were selected by comparing analyte concentrations in waste-rock samples collected at the mine to the maximum analyte concentrations reported for soil samples collected from the three reference areas. Examination of Table 4.22 (borehole samples) shows that beryllium, iron, manganese, thorium-228, and thorium-232 were not detected at concentrations greater than the maximum concentrations reported for the background samples. Examination of Table 4.23 (composite surface samples) shows that barium, beryllium, iron, manganese, nickel, radium-228, and thorium-228 were not detected at concentrations greater than the maximum concentrations reported for the background samples. Therefore, the analytes considered COCs for this evaluation include all of the analytes listed in Tables 4.22 and 4.23, excluding beryllium, iron, manganese, and thorium-228.

4.4.3.2 Human-Health Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for the camper scenario have been established for antimony, arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc. Arsenic was the only metal found at concentrations exceeding the RMC (Tables 4.22 and 4.23). It should be noted that the maximum concentration of arsenic in background soil (25.7 mg/Kg) slightly exceeded the camper RMC (20 mg/Kg). Arsenic concentrations exceeded the RMC of 20 mg/Kg in 13 of the 16 near-surface (0 to 6 inches) waste-rock borehole samples and 4 of the 7 subsurface waste-rock borehole samples. Arsenic concentrations exceeded the RMC in 4 of the 6 composite surface samples collected from the face of the dump. The arsenic concentrations that exceeded the RMC in the near-surface samples collected from the 0 to 6-inch depth at boreholes and composite samples collected from the waste-rock dump are summarized as follows:

- Minimum arsenic value: 26.7 mg/Kg at VQ 4 (0-0.5)
- Maximum arsenic value: 141 mg/Kg at VQ 1 (0-0.5)
- Mean arsenic value: 78.2 mg/Kg

- Median arsenic value: 71.1 mg/Kg

The mean and median concentration of arsenic in the near-surface waste-rock samples exceeded the RMC for the camper scenario by a factor of approximately 4. Therefore, above background arsenic concentrations in waste rock at the mine are considered to pose moderate risk to campers. The areas in which arsenic concentrations pose moderate risk to campers include boreholes VQ 1 (7.1 times RMC) and VQ 2 (4.4 times RMC) located on the ore loadout bench near the crest of the lower dump; boreholes VQ 3 (4.4 times RMC), VQ 5 (5.5 times RMC), and VQ 6 (3.2 times RMC) located on the mine bench near the crest of the upper dump; dump segment 3 near the former ore loadout; and dump segment 5 comprising the western portion of the lower dump.

The camper risks associated with the metals for which RMC have not been established were evaluated by comparing analyte concentrations reported for the waste-rock samples to industrial SSLs. As shown in Tables 4.22 and 4.23, vanadium was reported at a concentration exceeding the industrial SSL in one sample. The concentration of vanadium in sample VQ 6 (0-0.5) was 8,840 mg/Kg, slightly exceeding the industrial SSL of 7,154 mg/Kg by a factor of less than two. Borehole VQ 6 is located on the mine bench, near the nose of the waste-rock dump. In comparison to the maximum vanadium concentration reported in background soil, vanadium concentrations in most of the waste-rock samples were more than 10 times background levels. Although vanadium concentrations are higher in waste rock than in background soil, vanadium is not considered to be of concern in the waste rock because it was found to only slightly exceed the industrial SSL in one sample and vanadium concentrations in all other samples were well below the industrial SSL.

Radionuclide activities reported for the waste-rock samples were compared to background levels. The sample sites where radionuclide activities in near-surface samples exceeded maximum background levels and the range of the exceedances for each radionuclide are summarized in Table 4.24. Radionuclide activities in near-surface samples exceeded background levels at each borehole except VQ 3, located near the north end of the mine bench, and VQ 8, located on the central portion of the mine bench constructed largely on native soil. Radionuclide activities in the composite surface samples exceeded background levels within each segment of the dump except Segment 1, located at the north end of the upper dump, and Segment 4, located on central face of the upper dump. Radionuclide activities were generally higher in the material covering the face of the dump than in near-surface soil collected from boreholes on the mine bench and loadout bench areas. Gross alpha, gross beta, radium-226, and thorium-230 were the most commonly reported radionuclides above background levels, exceeding maximum background levels

by factors less than 2 on the benches and by factors up to 11 on the face of the dump. Radium-228 and thorium-232 were reported at levels slightly higher than background (less than a factor of 2 above background) in only one sample each. Thorium-228 was not detected in any of the near-surface samples collected at the mine.

Radium-226 activities reported for near-surface samples collected at the mine (the 0-0.5 samples from boreholes and composite surface samples from the face of the dump) were compared to the UMTRCA standard of 5 pCi/g over background. As discussed in Section 4.1.1, the UMTRCA standard applies to unrestricted use (e.g., construction of habitable structures), and therefore, is not directly applicable to the mine area and is only used to identify the areas where radium-226 levels could potentially pose a potential threats to campers at the mine. A factor of 26 (365 days/14 days) was applied to better assess the threats posed under the camper scenario, where radium-226 levels less than 26 times the UMTRCA standard are considered to not pose a threat to campers. The average background level reported for radium-226 in soil samples collected from the three reference areas was 3.3 pCi/g, resulting in a criterion of 8.3 pCi/g. Except for the near-surface samples collected at boreholes VQ 3 and VQ 8, the radium-226 activities reported for near-surface samples collected from boreholes exceeded 8.3 pCi/g, with the highest radium-226 activity (31.3 pCi/g at borehole VQ 2) exceeding the standard by a factor of 3.8. Except for the composite surface sample collected from segments 1 and 4, the radium-226 activities reported for composite surface samples exceeded 8.3 pCi/g, with the highest radium-226 activity (141 pCi/g for segment 5) exceeding the standard by a factor of 17. Because radium-226 activities in the waste-rock samples did not exceed the criterion by more the 26 times, it is suspected that the levels reported pose low risk to campers at the mine.

Radionuclide activities were also slightly higher in comparison to background levels in three of the seven sub-surface samples collected from boreholes. In the sub-surface samples, gross beta and radium-226 were the radionuclides most frequently reported at levels exceeding background levels.

These results indicate that radionuclide levels in waste rock at the mine are elevated with respect to background areas, with the highest activities relative to background reported for gross alpha, gross beta, radium-226, radium-228, thorium-230, and thorium-232. Under current conditions, above background radionuclide levels are greatest in the material covering the ore loadout bench near borehole VQ 2, the crest of the former ore loadout near borehole VQ 5, dump segment 3 adjacent to the former ore loadout, and dump segments 5, 6, and 7 comprising the lower dump. The potential threats posed by radionuclides are further evaluated on the basis of radiation exposure in Section 4.4.6.

4.4.3.3 Ecological Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for elk have been established for arsenic, cadmium, copper, lead, mercury, uranium, vanadium, and zinc. Tables 4.25 (borehole samples) and 4.26 (composite surface samples) present comparisons of analytical results to the elk RMC, modified with an area use factor of 0.007 (4.21-acre mine area divided by 640-acre home range). As shown, analyte concentrations did not exceed the modified RMC for elk, and therefore, the concentrations of these analytes in waste rock pose low risk to elk at the mine.

As found for the human-health risk evaluation, radionuclides levels in waste rock at the mine are elevated with respect to the background areas. The radionuclides most commonly reported at levels exceeding background were gross alpha, gross beta, radium-226, and thorium-230. The areas in which radionuclides most commonly reported at levels exceeding background were the ore loadout bench near borehole VQ 2, the crest of the former ore loadout near borehole VQ 5, dump segment 3 adjacent to the former ore loadout, and dump segments 5, 6, and 7 comprising the lower dump.

Analyte concentrations reported for waste rock samples were compared to leaching RMC to evaluate the leaching characteristics of the waste rock (Table 4.27 – borehole samples and Table 4.28 – composite surface samples). Because the criteria are based on aquatic life standards, the comparisons allow identification of the analytes in waste rock that may pose a threat to aquatic life. As shown, selenium was the only metal present in waste rock at concentrations exceeding the derived leaching RMC. Selenium concentrations exceeded the leaching RMC in borehole samples VQ 1 (0-0.5), VQ 2 (2-4), and VQ 6 (0-0.5) and in composite surface sample VQ Segment 5. In each case, the selenium concentration exceeded the leaching RMC by less than 3 times. Selenium in the waste rock is not considered to be of concern at the mine because (1) the concentration exceeded the leaching RMC in a limited number of samples, (2) concentrations exceeded the leaching RMC by less than 3 times (indicating low risk), and (3) selenium concentrations do not exceed aquatic life standards in La Sal Creek immediately downstream of the mine (station La Sal Creek Dn3). Examination of the SPLP results shows that the metals most frequently reported at levels above method detection limits in leachate from the waste rock were arsenic, barium, uranium, and vanadium.

4.4.4 Ephemeral Drainage

Sediment along the ephemeral drainage extending from the toe of the waste-rock dump to La Sal Creek is considered a potential contaminant source at the mine. The risks posed by sediment along the drainage are evaluated below.

4.4.4.1 Contaminants of Concern

The COCs for sediment were selected by comparing analyte concentrations in sediment samples collected along the ephemeral drainage to analyte concentrations in soil samples collected from the three reference areas. Examination of Table 4.29 shows that concentrations of the following analytes exceed maximum background levels in one or more of the sediment samples collected along the ephemeral drainage, and therefore, are considered COCs for this evaluation:

- Lead
- Selenium
- Uranium
- Vanadium

4.4.4.2 Risk Evaluation Results

Table 4.30 presents a comparison of COC concentrations in the ephemeral drainage sediment samples to the camper RMC, industrial SSLs, and the modified RMC for elk. The modified RMC for Elk is based on the area along drainage channel of approximately 1 acre. As shown, metals concentrations do not exceed the camper RMC, industrial SSLs, or modified RMC for elk in any of the samples. Based on these comparisons, metals concentrations in sediment along the drainage pose low risk to human health and low risk to elk.

The above background levels of COCs (i.e., uranium and vanadium) reported for the sediment samples indicate that contaminants have migrated from the mine area. Sediment transported from the mine along the ephemeral drainage has likely contributed to the higher levels of barium, radium-226, thorium-228, and thorium-230 in La Sal Creek sediment downstream of the mine as compared to upstream of the mine.

4.4.5 Vegetation

Vegetation at the mine is considered both a receptor and dietary item for herbivores. Analyte levels in vegetation at the mine were evaluated by comparing analytical results for samples collected at the mine to the analytical results for samples collected within the reference area and maximum tolerable levels of dietary minerals for domestic animals (Table 4.31). In addition, the ecological risk evaluation results discussed in Sections 4.4.3.3 (waste rock) and 4.4.4.2 (ephemeral drainage sediment) were also considered in the evaluation because the ecological RMC developed by BLM for soil include consumption of vegetation by terrestrial herbivores.

Analyte levels among the three varieties of vegetation were generally consistent; however, slightly higher levels were reported in the grass samples. The analytes reported at the highest levels relative to background (more than 10 times background levels) in vegetation along the adit drainage include molybdenum (forb), selenium (grass), uranium, vanadium (grass), gross alpha, gross beta (grass), and radium-226 (forb). Of these analytes, uranium was reported at the highest concentration (450 times background) in the grass sample. The analytes reported at the highest levels relative to background (more than 10 times background levels) in vegetation along the perimeter of the mine dump include arsenic (grass and forb), cadmium (grass), molybdenum, selenium, uranium, vanadium, gross alpha (grass and forb), and radium-226 (forb). Of these analytes, uranium was reported at the highest level (583 times background) in the grass sample.

The analytes reported at concentrations exceeding the maximum tolerable levels in vegetation along the adit drainage include barium, cadmium, molybdenum, selenium, and vanadium. However, it should be noted that the concentrations of barium (grass and forb) and selenium (grass and forb) in the background samples also exceeded the criteria. The analyte reported at the highest concentration relative to the criteria was selenium (grass and forb). The selenium concentrations in the grass and forb samples exceeded the criteria by factors of 24 and 20, respectively. The concentrations in the other samples exceeding the criteria were less than 10 times the criteria.

The analytes reported at concentrations exceeding the maximum tolerable levels in vegetation along the perimeter of the mine dump include barium, cadmium, lead, molybdenum, selenium, and vanadium. However, it should be noted that the concentrations of barium (grass, forb, and shrub) and selenium (grass and forb) in the background samples also exceeded the criteria. The analytes reported at the highest concentrations relative to the criteria were molybdenum (forb) and selenium (grass, forb, and shrub). The molybdenum concentration in the forb sample exceeded the criterion by a factor of 12. The selenium

concentrations in the grass, forb, and shrub samples exceeded the criteria by factors of 41, 260, and 76, respectively. The concentrations of the other samples exceeding the criteria were less than 10 times the criteria.

These results indicate that vegetation at the mine contains higher levels for several analytes than does vegetation in the background area. The analytes reported at the highest levels relative to background in vegetation along the mine drainage are molybdenum, selenium, uranium, vanadium, gross alpha, gross beta, and radium-226. The concentrations of barium, cadmium, molybdenum, selenium, and vanadium in one or more of the vegetation samples collected along the adit drainage exceeded the maximum tolerable levels. The analytes reported at the highest levels relative to background in vegetation along the perimeter of the mine dump are arsenic, cadmium, molybdenum, selenium, uranium, vanadium, gross alpha, and radium-226. The concentrations of barium, cadmium, lead, molybdenum, selenium, and vanadium in one or more of the vegetation samples collected along the perimeter of the mine dump exceeded the maximum tolerable levels. The analytes reported at the highest levels relative to the criteria were molybdenum and selenium. Based on comparisons to the maximum tolerable levels, molybdenum and selenium likely pose the greatest threat to livestock and wildlife at the mine.

As discussed in Sections 4.4.3.3 and 4.4.4.2, waste rock and sediment at the mine are considered to pose a low risk to livestock and wildlife on the basis of the RMC established by BLM. Because the RMC account for the consumption of vegetation by herbivores, vegetation at the mine is considered to pose a low risk to herbivores with respect to the analytes for which ecological RMC for soil have been established.

4.4.6 Radiation Exposure

The risk associated with direct radiation exposure at the mine was evaluated on the basis of radiological surveys of the mine area, correlation study results, and uranium concentrations and radium-226 activities in waste rock. Gamma-count rates recorded across the mine area are shown in Figure 3.15, and gamma-count and gamma-exposure rate measurements taken at the mine are presented in Table 3.16. Based on these measurements, a gamma-exposure rate of 1 µR/hr is approximately equal to a gamma-count rate of 932 cpm. Assuming this correlation, the cpm rates shown in Figure 3.15 of 18,500 cpm, 21,500, and 28,500 cpm represent approximately 20 µR/hr, 23 µR/hr, and 31 µR/hr, respectively. An individual camping at the mine for 14 days in an area where the gamma-exposure rate is 31 µR/hr (gamma-count rate of 28,500 cpm) would receive approximately 10 mRem, well below the 100 mRem per year ceiling

level. The background gamma-exposure rate at the Vanadium Queen Mine is 14.5 µR/hr or approximately 0.0145 mRem/hr (Table 3.16). Assuming a 14-day camper scenario, the 100 mRem per year ceiling exclusive of background would be exceeded by a camper spending the entire 14-day period in an area where the gamma-exposure rate was greater than 312.5 µR/hr (gamma-count rate greater than approximately 291,250 cpm).

Radiation survey results at the mine (Figure 3.15) show that gamma-count rates greater than 28,500 cpm occur within isolated areas at the mine, suggesting that exposures rates greater than 100 mRem per year (exclusive of background) under the camper scenario could only occur in these isolated areas. However, the gamma-scan survey is based on a walking average and provides only a relative assessment of gamma-count rates across the survey area. The static gamma-count rates and gamma-exposure rates recorded for the correlation samples provide a more accurate assessment of exposure than the gamma-scan results. As shown in Table 3.16, none of the seven discrete correlation samples collected at the mine exhibited gamma-exposure rates greater than 312.5 µR/hr. The highest gamma-exposure rates were measured at samples VQ-COR4 (150 µR/hr), VQ-COR5 (260 µR/hr) and VQ-COR6 (230 µR/hr) located on the ore loadout bench. Over a 14-day period, the average gamma-exposure rate to a camper on the ore loadout bench would be approximately 72 mRem or 67 mRem exclusive of background. The highest gamma-exposure rate measured on the mine bench was 110 µR/hr at sample VQ-COR3, indicating a gamma-exposure rate of up to 37 mRem or 32 mRem exclusive of background for a 14-day camper on the mine bench. Based on these static readings, gamma-exposure rates to campers at the mine would not exceed the 100 mRem per year ceiling exclusive of background; campers would experience higher gamma-exposure rates on the ore loadout bench than on the mine bench.

The correlations between gamma-count rate and radium-226 and uranium activities (Section 3.6.2 of this document) were also used to assess gamma exposure at the mine. Based on these correlations, a gamma-count rate of 291,250 cpm (the count rate at which the 100 mRem per year ceiling exclusive of background would be exceeded for a 14-day camper) equates to a radium-226 activity of 227 pCi/g and a uranium activity of 384 pCi/g (573 mg/Kg, assuming an approximate correlation of 0.67 pCi/g to 1.0 mg/Kg). The radium-226 activities reported in all of the near-surface and sub-surface borehole samples and all of the composite surface samples were well below 384 pCi/g. Uranium concentrations were greater than 573 mg/Kg in all samples collected at borehole VQ 2 located on the ore loadout bench near the crest of the lower dump and VQ 5 located on the mine bench near the crest of the ore loadout; uranium concentrations were well below 573 mg/Kg in samples collected at the other boreholes and from composite samples collected from the dump.

These results suggest that radiation exposures for individuals camping at the mine could potentially exceed 100 mRem per year exclusive of background on the ore loadout bench and on the mine bench near the crest of the ore loadout. Based on analytical results and radiological measurements along the ephemeral drainage, gamma exposure does not pose a threat to campers within the drainage.

Radiation exposure is not expected to be of ecological concern at the mine because gamma-exposure rates measured at the mine were well below the IAEA standard for wildlife of 0.1 Rad per day or 4,167 µR/hr.

4.4.7 Radon

Radon poses a potential hazard at the mine. The relative risk posed by radon at the mine was evaluated by comparing radon levels inside the mine portal (at the mine entrance) to levels in an adjacent background area. The monitoring results reported for the mine are as follows:

- Background Area
  - Exposure: 300.7 pCi/L over 167-day monitoring period
  - Average: 1.8 pCi/L per day
- Adit
  - Exposure: Greater than 140,000 pCi/L over 167-day monitoring period
  - Average: Greater than 838 pCi/L per day

These results suggest that high radon levels are associated with the mine and that high exposures to radon occur within the mine portal.

4.4.8 Risk Evaluation Summary and Removal Action Criteria for Surface Water

The camper RMC and modified MCLs are proposed to be the removal criteria for metals and radionuclides in surface water at the mine. The only analytes reported at concentrations exceeding the criteria were dissolved arsenic and total uranium. The dissolved arsenic concentrations in surface water at the mine exceeded the camper RMC of 93 µg/L, and total uranium concentrations exceeded the modified MCL of 780 µg/L. For both analytes, concentrations exceeded the criteria by less than a factor of two, and therefore, are considered to pose low risk to campers at the site. As a result, no surface-water actions are required for protection of human health. However, it is suspected that contaminants (primarily arsenic, barium, uranium, and vanadium based on SPLP results) are leaching from the waste rock dump as

a result of the adit drainage infiltrating the dump materials. Therefore, actions should be taken to prevent adit drainage water from infiltrating the dump. To help ensure human-health protection in the future, action should be taken to isolate the water from potential human contact (e.g., by piping the drainage) and inform the public that the water poses a potential hazard as a drinking water source.

The contaminants in surface water at the mine do not appear to be threatening aquatic life in La Sal Creek. Surface water within the isolated reach of the drainage at the mine is not considered to be of concern with respect to ecological risk. However, actions taken to reduce threats to human-health will provide protection for ecological receptors. It should be noted that actions taken to line or pipe the mine discharge water will likely eliminate the existing wetland (non-jurisdictional) ecosystem at the mine.

4.4.9 Risk Evaluation Summary and Removal Action Criteria for Waste Rock

The camper RMC are proposed to be the removal action criteria for metals in waste rock at the mine. Since these criteria are based on ingestion and inhalation, areas where surficial concentrations exceed these criteria will be removed or covered. Such actions will also provide protection for wildlife since the elk RMC modified with the 0.007 area use factor are greater than the camper RMC. Therefore, any actions taken to reduce the potential for direct contact with the waste would reduce the threats to both humans and wildlife.

Arsenic is the only analyte reported at concentrations posing moderate risk to campers at the mine. The areas in which arsenic concentrations pose a moderate threat to campers include the ore loadout bench, the mine bench near the crest of the upper dump, dump segment 3 near the former ore loadout; and dump segment 5 comprising the western portion of the lower dump. Radionuclide activities (i.e., gross alpha, gross beta, radium-226, and thorium-230) in near-surface soils in these areas slightly exceeded maximum background levels.

Metals concentrations in sediment deposited along the ephemeral drainage extending from the toe of the dump did not exceed the camper RMC, and therefore, pose low risk to campers. However, above background levels of COCs (i.e., uranium and vanadium) reported for the sediment samples indicate that contaminants are migrating from the mine area along the drainage.

The removal criteria for radionuclides in waste rock and sediment at the mine are proposed to be the gamma-exposure ceiling of 100 mRem per year exclusive of background plus ALARA. The ALARA

principle is defined by EPA as making reasonable efforts to maintain exposures as far below the applicable limits as practical. The ceiling plus ALARA will be applied to the 14-day camper scenario. Based on analytical results and radiological measurements, radiation exposures for individuals camping at the mine would potentially exceed the 100 mRem per year ceiling (exclusive of background) on the ore loadout bench and on the mine bench near the crest of the ore loadout. Gamma exposure does not pose a threat to campers within the drainage.

These findings indicate that removal actions should be implemented to reduce the risks to campers posed by above background arsenic, radionuclide activities, and gamma-exposure rates in areas potentially used for unsanctioned camping. These areas include the ore loadout bench and along the crest of the upper dump. Potential actions could include physical removal of waste rock or capping the areas with appropriate cover materials. Any potential camping areas created as a result of site grading during implementation of actions (e.g., stabilization terraces) should be covered with appropriate cover soil to ensure the 100 mRem per year ceiling plus ALARA is achieved. Although above background arsenic and gamma-exposure rates occur on the face of the upper dump near the ore loadout and the face of the lower dump, these areas are not considered potential camping areas and therefore do not pose a threat under the camper scenario. Based on the contaminant levels reported for vegetation samples collected at the mine, future livestock grazing should be discouraged in the mine area.

Under existing conditions, the materials comprising the waste-rock dump are migrating from the mine area as a result of erosion (fluvial and wind) and mass wasting processes. The higher levels of metals and radionuclides in sediment downstream of the mine, as compared to upstream of the mine, are most likely attributed to the transport of contaminated sediment from the mine to the creek. Actions should be taken to stabilize the dump and reduce the potential for future migration of contaminants from the mine.

Actions should also be taken to properly close the Vanadium Queen portal to prevent unauthorized access to the mine and reduce the potential for radon exposure in the portal, while maintaining adequate drainage of mine discharge. Currently, the portal area is highly unstable and is in danger of collapsing at any time. In addition, actions should be taken to mitigate the threat posed by the highly unstable crib wall along the crest of the upper dump. Much of the cribbing has collapsed and additional failure is expected.

4.5 Blue Cap Mine

The Blue Cap Mine area is open to public access and currently used for recreation. Recreational uses in the area typically include camping, hiking, hunting, and ATV riding. Use of the area for recreation is expected to continue, and likely increase, in the future. Although a gate has been installed within the mine portal to discourage entry, the gate is open and cannot be securely closed. Other openings associated with the mine (e.g., shop/office and storage areas) are also open. There is evidence that visitors have accessed the portal and other openings associated with the mine. A variety of wildlife also frequents the mine area.

The media of concern at the mine are surface water (mine drainage), waste rock, sediment within Lion Canyon Creek, and vegetation growing along the adit drainage channel and perimeter of the dump. Direct radiation exposure and radon are also potentially of concern at the mine.

Areas of stained soil within the portion of the mine portal apparently used for equipment and material storage were investigated as part of the characterization effort. The analytical results showed that PCBs were not present in the soil and indicated that the staining was attributed to oil and grease. Any potential human-health or ecological threats posed by contaminants within the soil will be mitigated upon proper closure of the mine openings.

4.5.1 Threats to La Sal Creek

La Sal Creek is the primary surface-water feature potentially impacted by contaminants at the Black Hat/Blue Cap Mine Complex. The potential threats to the creek as result of contaminant migration from the mine area was evaluated by comparing analytical results for water samples collected upstream and downstream of the confluence with Lion Canyon Creek, which drains the mine area, to the aquatic-life chronic standards established for La Sal Creek (Table 4.32). The stations evaluated on La Sal Creek were La Sal Creek Dn4 and La Sal Creek Dn5. The only parameters that were reported at levels exceeding the standards were total phosphorous as P and total suspended solids (upstream sample in October 2004 only) and gross alpha (downstream sample in October 2004 only). In general, analyte levels were consistent between the two monitoring stations, showing no marked increases from upstream to downstream. Analytes showing slight increases in the downstream sample compared to the upstream sample were dissolved and total uranium, gross alpha (October only), gross beta (October only), and radium-226 and -228 combined (April only). The elevated levels of these analytes may be attributed, at least in part, to contamination associated with the mines.

Comparison of analytical results for sediment samples collected at Reference Area 1, La Sal Creek upstream of its confluence with Lion Canyon Creek (La Sal Crk DN 4), and La Sal Creek downstream of its confluence with Lion Canyon Creek (La Sal Crk DN 5) to consensus-based probable effects concentrations (EPA, 2000c) is presented in Table 4.32 B. As shown, analyte concentrations did not exceed the consensus-based probable effects concentrations at either station. Examination of analytical results for the sediment samples indicate that the analytes showing increases from the upstream station (La Sal Crk DN 4) to downstream station (La Sal Crk DN 5) were selenium (4 times), uranium (2 times), vanadium (2 times), radium-228 (2 times), and thorium-230 (3 times). These results suggest contaminants have migrated from the mine area by way of sediment transport from the waste-rock dump. Mine-derived sediment is the most likely source for the higher contaminant levels observed in La Sal Creek surface water and sediment downstream of the mine as compared to upstream of the mine. Sediment transport from the mine area to the creek has likely been occurring for many years.

The fact that benthic macroinvertebrates were not present at station La Sal Creek Dn5, located downstream of the confluence with Lion Canyon Creek, indicates that the benthic macroinvertebrate community in this portion of La Sal Creek is severely stressed. Benthic macroinvertebrates were present at station La Sal Creek Dn3, located upstream of the confluence with Lion Canyon Creek and immediately downstream of the Vanadium Queen Mine. These findings could indicate that contaminants derived from mines within the Lion Canyon Creek drainage are limiting benthic macroinvertebrate production in La Sal Creek downstream of the confluence. However, the lack of organisms could also be attributed to other factors, such as reductions in flow caused by operation of a large irrigation diversion structure located immediately upstream of the sampling station, abrupt changes in flow as a result of periodic flooding, and impaired habitat as a result of heavy livestock grazing in the vicinity of the station.

4.5.2 Surface Water

Flow within Lion Canyon Creek originates as mine drainage from the Blue Cap Mine portal. Flow emanating from the portal crosses the mine bench and discharges into the Lion Canyon Creek channel. It is suspected that upstream of the mine, surface flow within the channel occurs only in response to runoff and storm events. After entering the Lion Canyon Creek channel, flow from the mine infiltrates and flows as interflow (flow immediately below the ground surface) along the channel. Surface flow reappears within the channel immediately upstream of station Lion Canyon Creek - Up which is located along the toe of the Blue Cap Mine dump. It is suspected that flow at the emanation point results from a

combination of adit drainage flowing as interflow along the channel, adit drainage which has infiltrated through the waste-rock dump at the Blue Cap Mine, and water emanating from Alcove Spring or other groundwater sources. The source of water flowing at Alcove Spring is not known, but the source is not likely connected to mine water at the Blue Cap Mine. Alcove Spring water is generally of poor quality, suggesting that the water has been impacted by mine workings or mineral deposits upgradient of the spring. During this study, perennial flow has been observed along Lion Canyon Creek from station Lion Canyon Creek - Up to its confluence with La Sal Creek.

It is recognized that any threats to human health and ecology associated with Lion Canyon Creek may be attributed in part to water draining from the Blue Cap Mine adit. The other primary sources for contamination within the creek include flow from Alcove Spring, sub-surface flow through the Blue Cap Mine Dump, and surface flow through the waste-rock material deposited within the channel along the toe of the Blue Cap mine dump. To fully evaluate the risks posed by surface water in the vicinity of the mine, the following discussion addresses the risks associated with surface water along the perennial reach of Lion Canyon Creek extending from station Lion Canyon Creek - Up to Lion Canyon Creek - Dn2, the reach of surface flow from the Blue Cap Mine adit to the point where the flow becomes sub-surface interflow, and flow emanating from Alcove Spring.

4.5.2.1 Perennial Reach of Lion Canyon Creek

The perennial reach of Lion Canyon Creek extends from station Lion Canyon Creek - Up to the creek's confluence with La Sal Creek. The human-health and ecological risks associated with surface water along this reach of the creek are evaluated below.

Contaminants of Concern

The COCs for surface water within the perennial reach of Lion Canyon Creek were selected by comparing analytical results for samples collected at stations Lion Canyon Creek - Up, Lion Canyon Creek - Dn1, Lion Canyon Creek - Dn2 to the maximum levels reported for samples collected in the reference areas (Table 4.33). The COCs selected for surface water along the perennial reach of Lion Canyon Creek are as follows:

- Nitrite
- Nitrate

- Sulfate
- Total phosphorous as P
- Nitrate/Nitrite
- Antimony, dissolved and total
- Arsenic, dissolved and total recoverable
- Barium, dissolved and total (Lion Cyn Creek Dn2 only)
- Cadmium, dissolved and total
- Iron, total recoverable
- Lead, dissolved and total
- Magnesium, dissolved
- Manganese, dissolved and total
- Molybdenum, dissolve and total
- Potassium, dissolved
- Selenium, dissolved and total
- Sodium, dissolved
- Uranium, dissolved and total
- Vanadium, dissolved and total
- Zinc, dissolved and total
- Gross alpha
- Gross beta
- Radium-226 and -228 (combined)
- Thorium-230 and 232 (combined)

Table 4.33 also shows a comparison of analytical results for samples collected from La Sal Creek downstream of its confluence with Lion Canyon Creek (station La Sal Creek Dn5) to the maximum values reported for samples from the reference area. The analytes reported at levels exceeding the

maximum background levels included dissolved antimony, total recoverable iron, dissolved lead, dissolved manganese, dissolved and total selenium, dissolved and total uranium, total vanadium, gross alpha, gross beta, radium-226 and -228 (combined), and thorium-230 and 232 (combined). Of these analytes, the parameters showing noticeable increases from La Sal Creek Dn4 (upstream of the Lion Canyon Creek confluence) to La Sal Creek Dn5 included dissolved and total uranium, gross alpha, gross beta, and radium-226 and -228 (combined).

Human-Health Risk Evaluation Results

Of the COCs identified for surface water in the perennial reach of Lion Canyon Creek, RMC under the camper scenario have been established for dissolved antimony (124 µg/L), dissolved arsenic (93 µg/L), dissolved cadmium (155 µg/L), dissolved lead (50 µg/L), dissolved manganese (1,548 µg/L), dissolved selenium (1,548 µg/L), and dissolved zinc (92,909 µg/L). The concentrations of these analytes in water along the perennial reach of Lion Canyon Creek do not exceed the RMC, and therefore, pose low risk under the camper scenario (Table 4.33).

RMC for the camper scenario have not been established for the remaining COCs in surface water along the perennial reach of Lion Canyon Creek. Of these remaining COCs, uranium was the only analyte reported at concentrations exceeding the modified MCL. Uranium concentrations exceeded the modified MCL of 780 µg/L in the samples collected at station Lion Canyon Creek-Up (1240 µg/L in April 2004 and 938 µg/L in October 2004). Because the uranium concentrations at station Lion Canyon Creek-Up were less than 2 times the modified MCL, uranium is considered to pose low risk to campers. Analyte levels were less than the modified MCL in all other samples collected from Lion Canyon Creek and from La Sal Creek downstream of the confluence.

Examination of Table 4.33 shows that the analytes reported at the highest levels relative to background (more than 100 times background) in the Lion Canyon Creek samples included selenium, uranium, vanadium, and gross alpha. For these parameters, analyte levels were highest in the samples collected at stations Lion Canyon Creek-Up and Lion Canyon Creek-Dn1; analyte levels were generally lower in the sample collected at Lion Canyon Creek-Dn2.

Based on this evaluation, surface water in Lion Canyon Creek poses low risk to campers. However, it is suspected that elevated levels of uranium and gross alpha in Lion Canyon Creek during low-flow

conditions (fall) likely contribute to the higher levels of these analytes in La Sal Creek downstream of the confluence as compared to upstream of the confluence.

Ecological Risk Evaluation Results

Examination of Table 4.34 shows that analyte concentrations in Lion Canyon Creek slightly exceed the aquatic-life standards for nitrite and dissolved lead, and greatly exceed the aquatic-life standards for dissolved selenium, gross alpha, and gross beta. The analytical results exceeding the standards for dissolved selenium, gross alpha, and gross beta are summarized as follows:

- Dissolved selenium
  - Maximum value: 72 times greater than standard at Lion Canyon Creek-Up
  - Minimum value: 2 times greater than standard at Lion Canyon Creek - Dn2
- Gross alpha
  - Maximum value: 46 times greater than standard at Lion Canyon Creek - Up
  - Minimum value: 6 times greater than standard at Lion Canyon Creek - Dn2
  - Value at La Sal Creek Dn5: 2 times greater than the standard
- Gross beta
  - Maximum value: 65 times greater than standard at Lion Canyon Creek - Up
  - Minimum value: 2.7 times greater than standard at Lion Canyon Creek - Dn1

These results suggest that levels of dissolved selenium, gross alpha, and gross beta in the perennial reach of Lion Canyon Creek pose a potential threat to aquatic life in the creek and elevated levels of gross alpha likely contribute to the threat posed by gross alpha to aquatic life in La Sal Creek downstream of the mine.

4.5.2.2 Blue Cap Mine Adit Drainage

Water flowing from the mine adit is considered a potential contaminant source at the mine. The risks posed by surface water at the mine and potential impacts to water quality in Lion Canyon Creek are evaluated below.

Contaminants of Concern

The COCs for surface water were selected by comparing analytical results for samples collected at the mine to the maximum levels reported for samples collected in the reference areas (Table 4.35). The COCs selected for surface water are as follows:

- Nitrate
- Sulfate
- Nitrate/nitrite as N, dissolved
- Antimony, dissolved and total
- Arsenic, dissolved and total recoverable
- Barium, dissolved
- Cadmium, dissolved and total
- Lead, dissolved (one sample)
- Lead, total
- Magnesium, dissolved
- Molybdenum, dissolved and total
- Potassium, dissolved
- Selenium, dissolved and total
- Sodium, dissolved
- Uranium, dissolved and total
- Vanadium, dissolved and total
- Gross alpha
- Gross beta
- Radium-226 and -228 (combined)
- Thorium-230 and 232 (combined)
- Thorium-228 (one sample)

Human-Health Risk Evaluation Results

Of the COCs identified for surface water at the mine, RMC under the camper scenario have been established for dissolved antimony (124 µg/L), dissolved arsenic (93 µg/L), dissolved cadmium (155

µg/L), dissolved lead (50 µg/L), and dissolved selenium (1,548 µg/L). The concentrations of these analytes in samples Blue Cap Adit and Blue Cap Drainage do not exceed the RMC, and therefore, pose low risk under the camper scenario (Table 4.36).

RMC for the camper scenario have not been established for the remaining COCs in surface water at the mine. As shown in Table 4.36, analyte levels for these remaining COCs do not exceed the modified MCLs, and therefore, are considered to pose low risk to campers at the mine.

Based on this evaluation, surface water at the Blue Cap Mine poses low risk to campers at the mine. However, it is suspected that adit water infiltrating the waste-rock dump is leaching contaminants from the waste materials and contributing to the higher contaminant levels observed in Lion Canyon Creek downstream of the mine as compared to upstream of the mine.

Ecological Risk Evaluation Results

Of the COCs identified for surface water at the mine, aquatic-life chronic standards have been established for pH, nitrate, sulfate, total recoverable arsenic, dissolved cadmium, dissolved lead, dissolved selenium, gross alpha, and gross beta (Table 4.37). The dissolved selenium, gross alpha, and gross beta levels in each sample exceeded the standards; the concentrations for the remaining COCs were below the standards in each sample. The analytical results exceeding the standards are summarized as follows:

- Dissolved selenium
  - Minimum: 46 times standard at Blue Cap Adit
  - Maximum: 55 times standard at Blue Cap Adit
- Gross alpha
  - Minimum: 25 times standard at Blue Cap Drainage
  - Maximum: 28 times standard at Blue Cap Adit
- Gross beta
  - Minimum: 1.9 times standard at Blue Cap Drainage
  - Maximum: 3.4 times standard at Blue Cap Adit

The reported levels of dissolved selenium, gross alpha, and gross beta in the adit drainage likely contribute to the aquatic-life threats posed by these analytes in the perennial reach of Lion Canyon Creek and the higher levels reported in La Sal Creek downstream of its confluence with Lion Canyon Creek as compared to upstream of the confluence. Gross alpha and gross beta activities in water are directly related to total and dissolved radionuclide (uranium and radium-226) concentrations in the water. A

simple mass loading calculation indicates that although Alcove Spring water contains greater concentrations of total uranium and radium-226, the greater discharge rate of water from Blue Cap Mine results in a mass loading of approximately 3 times more total uranium and 25 times more radium-226 to the upper drainage of Lion Canyon Creek in comparison to loading rates from Alcove Spring (Section 4.5.2.3). Other sources of these contaminants to Lion Canyon Creek include waste rock and mine-derived sediment within the creek's channel and potential leachate generated from infiltration of precipitation and mine drainage. On the basis of this evaluation, the Blue Cap Mine discharge water is a potentially significant source of the contaminants threatening aquatic life in Lion Canyon Creek and La Sal Creek.

4.5.2.3 Alcove Spring

Water flowing from Alcove Spring is considered a potential contaminant source in the vicinity of the Blue Cap Mine. The risks posed by surface water at the spring are evaluated below.

Contaminants of Concern

The COCs for surface water at Alcove Spring were selected by comparing analytical results for samples collected at the spring to the maximum levels reported for samples collected in the reference areas (Table 4.38). The COCs selected for surface water are as follows:

- Arsenic, total recoverable
- Lead, dissolved
- Molybdenum, dissolve and total
- Potassium, dissolved
- Selenium, dissolved and total
- Sodium, dissolved
- Uranium, dissolved and total
- Vanadium, dissolved and total
- Gross alpha
- Gross beta
- Radium-226 and -228 (combined)

- Thorium-230 and 232 (combined)
- Thorium-228 (one sample)

Human-Health Risk Evaluation Results

Of the COCs identified for surface water at Alcove Spring, RMC under the camper scenario have been established for dissolved lead (50 µg/L) and dissolved selenium (1,548 µg/L). The concentrations of these analytes in water at Alcove Spring do not exceed the RMC, and therefore, pose low risk under the camper scenario (Table 4.39).

RMC for the camper scenario have not been established for the remaining COCs in surface water at the spring. Of these remaining COCs, uranium is the only analyte reported at concentrations exceeding the modified MCL. The total uranium concentrations exceeded the modified MCL of 780 µg/L by less than a factor of 2 in each of the surface-water samples. Therefore, total uranium is considered to pose low risk to campers at the spring. However, elevated analyte levels in water emanating from the spring likely contribute to the higher analyte levels observed in the perennial reach of Lion Canyon Creek, particularly for selenium, uranium, and gross alpha.

Ecological Risk Evaluation Results

Of the COCs identified for surface water at the spring, aquatic life chronic standards have been established for pH, total recoverable arsenic, dissolved lead, dissolved selenium, gross alpha, and gross beta (Table 4.40). The concentrations of total recoverable arsenic in the samples do not exceed the standard. The dissolved lead concentration in the October 2004 sample slightly exceeded the standard. The dissolved selenium, gross alpha, and gross beta levels in both samples exceeded the standards. The analytical results exceeding the standards for dissolved selenium, gross alpha, and gross beta are summarized as follows:

- Dissolved selenium
    - 83 times standard in Spring 2004
    - 86 times standard in October 2004
- Gross alpha
    - 75 times standard in Spring 2004
    - 68 times standard in October 2004

- Gross beta
    - 5.1 times standard in Spring 2004
    - 10.5 times standard in October 2004

The elevated levels of dissolved selenium, gross alpha, and gross beta in water emanating from the spring likely contribute to the aquatic-life threats posed by these analytes in the perennial reach of Lion Canyon Creek and the higher levels reported in La Sal Creek downstream of its confluence with Lion Canyon Creek as compared to upstream of the confluence.

4.5.3 Waste Rock

Waste rock accumulations are considered potential contaminant sources at the mine. The risks posed by waste rock at the mine are evaluated below.

4.5.3.1 Contaminants of Concern

The COCs for waste rock were selected by comparing analyte concentrations in waste-rock samples collected at the mine to the maximum analyte concentrations reported for soil samples collected from the three reference areas. Examination of Table 4.41 (borehole samples) shows that barium, beryllium, iron, and, manganese were not detected at concentrations greater than the maximum concentrations reported for the background samples. Of the remaining analytes, antimony, mercury, and radium-228 were detected at concentrations exceeding maximum background values in only one sample. Examination of Table 4.42 (composite surface samples) shows that antimony, barium, beryllium, iron, manganese, mercury, nickel, and thorium-228 were not detected at concentrations greater than the maximum concentrations reported for the background samples. Of the remaining analytes, radium-228 and thorium-232 were detected at concentrations exceeding maximum background values in only one sample. Therefore, the analytes considered COCs for this evaluation include all of the analytes listed in Tables 4.41 and 4.42, excluding barium, beryllium, iron, and manganese.

4.5.3.2 Human-Health Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for the camper scenario have been established for antimony, arsenic, cadmium, copper, lead, mercury, nickel, selenium, silver, and zinc. Arsenic was the only metal found at concentrations exceeding the RMC (Tables 4.41 and 4.42). It should be noted that the maximum concentration of arsenic in background soil (25.7 mg/Kg) slightly exceeded the camper

RMC (20 mg/Kg). Arsenic concentrations exceeded the RMC of 20 mg/Kg in 3 of the 7 near-surface (0 to 6 inches) waste-rock samples and 4 of the 6 subsurface waste-rock samples. The arsenic concentrations that exceeded the RMC in the near-surface samples collected from the 0 to 6-inch depth at boreholes and composite samples collected from the waste-rock dump are summarized as follows:

- Minimum arsenic value: 33.3 mg/Kg at BC Segment 2
- Maximum arsenic value: 74 mg/Kg at BC 3 (0-0.5)
- Mean arsenic value: 50.9 mg/Kg
- Median arsenic value: 50.6 mg/Kg

The mean and median concentration of arsenic in the near-surface waste-rock samples exceeded the RMC for the camper scenario by a factor of approximately 2.5. Therefore, waste rock at the mine is generally considered to pose low risk to campers because of the above background arsenic levels. The only area in which arsenic in near-surface waste rock poses moderate risk to campers is in the vicinity of borehole BC 3, where the arsenic concentration is 3.7 times the RMC.

The camper risks associated with the metals for which RMC have not been established were evaluated by comparing analyte concentrations reported for the waste-rock samples to industrial SSLs. As shown in Tables 4.41 and 4.42, concentrations of the metals for which RMC have not been established do not exceed industrial SSL, and therefore, are considered to pose low risk to campers at the mine.

Radionuclide activities reported for the waste-rock samples were compared to background. The sample sites where radionuclide activities in near-surface samples exceeded maximum background levels and the range of the exceedances for each radionuclide are summarized in Table 4.43. Radionuclide activities in near-surface samples collected from boreholes on the mine bench were generally consistent with the activities reported for composite surface samples collected from the face of the mine dump. The highest radionuclide activities relative to maximum background levels in near-surface samples at boreholes were reported for gross alpha (2 to 5 times background), gross beta (2 to 8 times background), radium-226 (3 to 11 times background), and thorium-230 (2 to 13 times background). Radium-228 was reported at a level exceeding background in only one sample, collected from the face of the dump. Thorium-228 and thorium-232 were reported at levels slightly higher than background (on average, less than a factor of 2 above background) in 3 and 5 of the 12 near-surface samples, respectively.

Radium-226 activities reported for near-surface samples collected at the mine (the 0-0.5 samples from boreholes and composite surface samples from the face of the dump) were compared to the UMTRCA standard of 5 pCi/g over background. As discussed in Section 4.1.1, the UMTRCA standard applies to unrestricted use (e.g., construction of habitable structures), and therefore, is not directly applicable to the mine area and is only used to identify the areas where radium-226 levels could potentially pose a potential threats to campers at the mine. A factor of 26 (365 days/14 days) was applied to better assess the threats posed under the camper scenario, where radium-226 levels less than 26 times the UMTRCA standard are considered to not pose a threat to campers. The average background level reported for radium-226 in soil samples collected from the three reference areas was 3.3 pCi/g, resulting in a criterion of 8.3 pCi/g. The radium-226 activities reported for all of the near-surface samples collected from boreholes exceeded 8.3 pCi/g, with the highest radium-226 activity (139 pCi/g at borehole BC 1) exceeding the standard by a factor of 16.7. The radium-226 activities reported for all of the composite surface samples exceeded 8.3 pCi/g, with the highest radium-226 activity (96.9 pCi/g for segment 1) exceeding the standard by a factor of 11.7. Because radium-226 activities in the waste-rock samples did not exceed the criterion by more the 26 times, it is suspected that the levels reported pose low risk to campers at the mine.

Gross alpha, gross beta, radium-226, and thorium-230 activities in sub-surface samples collected from boreholes exceeded maximum background levels by factors of up to 5, 7, 8, and 5, respectively. The radium-228 activity was 3 times greater than maximum background levels in one sub-surface sample, and the thorium-228 activity did not exceed the background level in any of the sub-surface samples.

These results indicate that radionuclide levels in waste rock at the mine are elevated with respect to background areas, with the highest activities relative to background reported for gross alpha, gross beta, radium-226, and thorium-230. The potential threats posed by radionuclides are further evaluated on the basis of radiation exposure in Section 4.5.5.

4.5.3.3 Ecological Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for elk have been established for arsenic, cadmium, copper, lead, mercury, uranium, vanadium, and zinc. Tables 4.44 (borehole samples) and 4.45 (composite surface samples) present comparisons of analytical results to the elk RMC, modified with an area use factor of 0.003 (1.93-acre mine area divided by 640-acre home range). As shown, analyte concentrations did not exceed the modified RMC for elk, and therefore, the concentrations of these analytes in waste rock pose low risk to elk at the mine.

As found for the human-health risk evaluation, gross alpha, gross beta, radium-226, and thorium-230 activities in the waste-rock exceed background levels. The activities reported for these analytes were generally consistent for the material covering the mine bench and the material covering the face of the dump. However, the potential threats to elk are considered to be greater on the mine bench because elk are likely to spend more time on the bench than on the steep slope of the dump.

Analyte concentrations reported for waste rock samples were compared to leaching RMC to evaluate the leaching characteristics of the waste rock (Table 4.46 – borehole samples and Table 4.47 – composite surface samples). Because the criteria are based on aquatic life standards, the comparisons allow identification of the analytes in waste rock that may pose a threat to aquatic life. As shown, selenium was the only metal present in waste rock at concentrations exceeding the derived leaching RMC. Selenium concentrations slightly exceeded the leaching RMC (by less than 1.5 times) in four of the borehole samples (BC 1: 8-9, BC 2: 2-2.5, BC 3: 10-12, and BC: 0-0.5) but did not exceed the leaching RMC in any of the composite surface samples collected from the face of the dump. These results indicate that selenium concentrations are not considered to be of concern with respect to the criterion because the concentration exceeded the leaching RMC in a limited number of samples and concentrations exceeded the leaching RMC by less than 3 times (indicating low risk). Examination of the SPLP results shows that the metals most frequently reported at levels above method detection limits in leachate from the waste rock were arsenic, barium, uranium, and vanadium. The aquatic-life threats posed by selenium, gross alpha, and gross beta in the perennial reach of Lion Canyon Creek are likely attributed, in part, to leaching of selenium and uranium from the waste-rock dump as well as waste rock present within the Lion Canyon Creek channel along the toe of the dump.

4.5.4 Sediment Along Lion Canyon Creek

Sediment along Lion Canyon Creek extending from the toe of the waste-rock dump to La Sal Creek is considered a potential contaminant source attributed to the Blue Cap Mine. Sediment deposition of waste rock from the mine was evident from field observations of erosion and mass wasting processes within and adjacent to the drainage channel.

4.5.4.1 Contaminants of Concern

The COCs for sediment were selected by comparing analyte concentrations in sediment samples collected along the creek to analyte concentrations in sediment samples collected from the three reference areas. Examination of Table 4.48 shows that concentrations of the following analytes exceed maximum background levels in one or more of the sediment samples collected along the ephemeral drainage, and therefore, are considered COCs for this evaluation:

- Arsenic
- Cadmium
- Chromium (one sample)
- Copper
- Lead
- Molybdenum
- Selenium
- Uranium
- Vanadium
- Zinc
- Gross alpha
- Gross beta
- Radium-226
- Radium-228
- Thorium-228 (one sample)
- Thorium-230

Of the COCs listed above, uranium, vanadium, gross alpha, gross beta, and radium-226 were reported at levels 10 to 100 times the maximum background values at the two upstream stations (Lion Canyon Creek - Up and Lion Canyon Creek - Dn1). The activities of thorium-230 were 10 to 100 times the maximum background value at all three stations along the creek.

4.5.4.2 Risk Evaluation Results

Table 4.48 also presents a comparison of COC concentrations in the stream sediment samples to the camper RMC and the modified RMC for elk. It should be noted that the elk RMC listed in Table 4.48 are for soil; sediment RMC for livestock and wildlife have not been established. The modified Elk RMC is based on the area along the drainage channel, approximately 2.9 acres. As shown, metals concentrations in the sediment samples do not exceed the camper RMC for sediment or the modified RMC for elk in soil in any of the samples. Based on these comparisons, metals concentrations in sediment along the channel pose low risk to human health and low risk to elk.

Of the analytes for which RMC have not been established, gross alpha, gross beta, radium-226, and thorium-230 activities in sediment along the drainage exceed background levels. Furthermore, the analytical results for sediment indicate that contaminants have migrated from the mine area along the Lion Canyon Creek channel.

4.5.5 Vegetation

Vegetation is considered both a receptor and dietary item for herbivores. Analyte levels in vegetation at the mine were evaluated by comparing analytical results for samples collected at the mine to the analytical results for samples collected within the reference area and maximum tolerable levels of dietary minerals for domestic animals (Table 4.49). In addition, the ecological risk evaluation results discussed in Sections 4.5.3.3 (waste rock) and 4.5.4.2 (sediment along Lion Canyon Creek) were also considered in the evaluation because the ecological RMC developed by BLM for soil include consumption of vegetation by terrestrial herbivores.

Analyte levels among the three varieties of vegetation were generally consistent; however, slightly higher levels were reported in the grass samples. The analytes reported at the highest levels relative to background (more than 10 times background levels) in vegetation along the adit drainage include cadmium (shrub), selenium (shrub), uranium, vanadium (grass), gross alpha (grass and forb), and radium-226 (forb and shrub). Of these analytes, uranium was reported at the highest level (237 times background) in the grass sample. The analytes reported at the highest levels relative to background (more than 10 times background levels) in vegetation along the perimeter of the mine dump include arsenic (grass and forb), cadmium, molybdenum (grass and forb), selenium, uranium, vanadium (grass and forb), gross alpha (grass and forb), and radium-226 (forb and shrub). Of these analytes, uranium was reported at the highest level (473 times background) in the grass sample.

The analytes reported at concentrations exceeding the maximum tolerable levels in vegetation along the adit drainage include barium, cadmium, molybdenum, and selenium. However, it should be noted that the concentrations of barium (grass, forb, and shrub) and selenium (grass and forb) in the background samples also exceeded the criteria. The analyte reported at the highest concentrations relative to the criteria was selenium (grass). The selenium concentrations in the grass sample exceeded the criteria by a factor of 11. The concentrations in the other samples exceeding the criteria were less than 10 times the criteria.

The analytes reported at concentrations exceeding the maximum tolerable levels in vegetation along the perimeter of the mine dump include barium, cadmium, iron, molybdenum, selenium, and vanadium. However, it should be noted that the concentrations of barium (grass, forb, and shrub) and selenium (grass and forb) in the background samples also exceeded the criteria. The analytes reported at the highest concentrations relative to the criteria were molybdenum (forb) and selenium (grass, forb, and shrub). The molybdenum concentration in the forb sample exceeded the criterion by a factor of 18. The selenium concentrations in the grass, forb, and shrub samples exceeded the criteria by factors of 34, 234, and 54, respectively. The concentrations of the other samples exceeding the criteria were less than 10 times the criteria.

These results indicate that vegetation at the mine contains higher levels for several analytes than does vegetation in the background area. The analytes reported at the highest levels relative to background in vegetation along the mine drainage are cadmium, selenium, uranium, vanadium, gross alpha, and radium-226. The concentrations of barium, cadmium, molybdenum, and selenium in one or more of the vegetation samples collected along the adit drainage exceeded the maximum tolerable levels. The analytes reported at the highest levels relative to background in vegetation along the perimeter of the dump are arsenic, cadmium, molybdenum, selenium, uranium, vanadium, gross alpha, and radium-226. The concentrations of barium, cadmium, iron, molybdenum, selenium, and vanadium in one or more of the vegetation samples collected along the perimeter of the mine dump exceeded the maximum tolerable levels. The analytes reported at the highest levels relative to the criteria were molybdenum and selenium. Based on comparisons to the maximum tolerable levels, molybdenum and selenium likely pose the greatest threat to livestock and wildlife at the mine.

As discussed in Sections 4.5.3.3 and 4.5.4.2, waste rock and sediment at the mine are considered to pose a low risk to livestock and wildlife on the basis of the RMC established by BLM. Because the RMC

account for the consumption of vegetation by herbivores, vegetation at the mine is considered to pose a low risk to herbivores with respect to the analytes for which ecological RMC for soil have been established.

4.5.6 Radiation Exposure

The risk associated with direct radiation exposure at the mine was evaluated on the basis of radiological surveys of the mine area, correlation study results, and uranium concentrations and radium-226 activities in waste rock. Gamma-count rates recorded across the mine area are shown in Figure 3.19, and gamma-count and gamma-exposure rate measurements taken at the mine are presented in Table 3.16. Based on these measurements, a gamma-exposure rate of 1 µR/hr is approximately equal to a gamma-count rate of 932 cpm. Assuming this correlation, the cpm rates shown in Figure 3.15 of 18,500 cpm, 21,500, and 28,500 cpm represent approximately 20 µR/hr, 23 µR/hr, and 31 µR/hr, respectively. An individual camping at the mine for 14 days in an area where the gamma-exposure rate is 31 µR/hr (gamma-count rate of 28,500 cpm) would receive approximately 10 mRem, well below the 100 mRem per year ceiling level. The background gamma-exposure rate measured at the Blue Cap Mine was 13.3 µR/hr or approximately 0.0133 mRem/hr. Assuming a 14-day camper scenario, the 100 mRem per year ceiling exclusive of background would be exceeded by a camper spending the entire 14-day period in an area where the gamma-exposure rate was greater than 311 µR/hr (gamma-count rate greater than approximately 290,000 cpm).

Radiation survey results at the mine (Figure 3.19) show that gamma-count rates greater than 28,500 cpm occur within isolated areas at the mine, suggesting that exposures rates greater than 100 mRem per year (exclusive of background) under the camper scenario could only occur in these isolated areas. However, the gamma-scan survey is based on a walking average and provides only a relative assessment gamma-count rates across the survey area. The static gamma-count rates and gamma-exposure rates recorded for the correlation samples provide a more accurate assessment of exposure than the gamma-scan results. As shown in Table 3.16, one of the four discrete correlation samples collected at the mine bench exhibited a gamma-exposure rate greater than 311 µR/hr. An in-situ gamma-exposure rate of 390 µR/hr (in-situ gamma-count rate of 364,623 cpm) was reported for correlation sample BC-COR2, located in the central portion of the mine bench. The average gamma-exposure rate for the four samples collected on the mine bench (BC-COR1 through BC-COR4) was 244 µR/hr. Over a 14-day period, the gamma-exposure rate to a camper on the mine bench would be approximately 82 mRem or 77.5 mRem exclusive of background. Based on the static readings, gamma-exposures to campers would exceed the 100 mRem per ceiling

exclusive of background on portions of the mine bench, and on average, above background gamma-exposure rates are expected to campers on the mine bench.

The correlations between gamma-count rate and radium-226 and uranium activities (Section 3.6.2 of this document) were also used to assess gamma exposure at the mine. Based on these correlations, a gamma-count rate of 290,000 cpm (the count rate at which the 100 mRem per year ceiling exclusive of background would be exceeded for a 14-day camper) equates to a radium-226 activity of 226 pCi/g and a uranium activity of 382 pCi/g (570 mg/Kg, assuming an approximate correlation of 0.67 pCi/g to 1.0 mg/Kg). As shown in Tables 4.41 and 4.42, radium-226 activities were less than 226 pCi/g in all of the borehole and composite surface samples collected at the mine. Also, uranium concentrations were less than 570 mg/Kg in all of the borehole and composite surface samples collected at the mine. The highest radium-226 and uranium levels in near-surface samples on the mine bench were reported for the sample collected at borehole BC 1. The levels reported for this sample were 139 pCi/g (radium-226) and 351 mg/Kg (uranium). For these levels, the projected gamma-exposure rate to a 14-day camper would be up to 96 mRem or 83 mRem exclusive of background. The reported radium-226 and uranium levels reported for sediment samples collected along Lion Canyon Creek were well below 226 pCi/g and 570 mg/Kg, respectively.

These results suggest that the risk associated with radiation exposures to individuals camping at the mine is low but that the exposures approach, and may possibly exceed, the 100 mRem per year ceiling exclusive of background in isolated areas on the mine bench. Radiation exposure is not expected to be of ecological concern at the mine because gamma-exposure rates measured at the mine were well below the IAEA standard for wildlife of 0.1 Rad per day or 4,167 µR/hr.

4.5.7 Radon

Radon poses a potential hazard at the mine. The relative risk posed by radon at the mine was evaluated by comparing radon levels within the mine portal (approximately 75 feet inside the mine entrance) to levels in an adjacent background area. The monitoring results reported for the mine are as follows:

- Background Area
  - Exposure: 214.6 pCi/L over 171-day monitoring period
  - Average: 1.3 pCi/L per day
- Adit
  - Exposure: Greater than 140,000 pCi/L over 171-day monitoring period
  - Average: Greater than 838 pCi/L per day

These results suggest that high radon levels are associated with the mine and that high exposures to radon occur within the mine portal.

4.5.8 Risk Evaluation Summary and Removal Action Criteria for Surface Water

The camper RMC and modified MCLs are proposed to be the removal criteria for metals and radionuclides in surface water at the mine. Because these criteria were not exceeded in any of the surface-water samples collected at the mine, surface water is considered to pose low risk to campers at the Blue Cap Mine. However, it is suspected that contaminants (primarily arsenic, barium, uranium, and vanadium based on SPLP results) are leaching from the waste-rock dump as a result of the adit drainage infiltrating the dump materials. Therefore, actions should be taken to prevent adit drainage water from infiltrating the dump. To help ensure human-health protection in the future, actions should be considered to isolate the water from potential human contact (e.g., by piping the adit drainage) and inform the public that the water poses a potential hazard as a drinking water source.

Analyte levels in water draining from the mine adit are likely contributing to the elevated contaminant levels and threats to aquatic life in the perennial reach of Lion Canyon Creek. The analytes of primary concern in the adit drainage with respect to aquatic life are selenium, uranium, radium-226, gross alpha, and gross beta. It is recognized that other sources (Alcove Spring, leachate from the mine dumps, and mine-derived sediment and waste rock within the channel) also contribute to the aquatic-life threats in Lion Canyon Creek. Nevertheless, drainage from the Blue Cap adit is considered a significant source for the metals and radionuclide levels posing threats to aquatic life in Lion Canyon Creek. Therefore, actions should be taken to reduce the concentrations of selenium, uranium, radium-226, gross alpha, and gross beta in the adit discharge. Actions taken to prevent the adit drainage from infiltrating the dump will also help to reduce threats to aquatic life in Lion Canyon Creek.

4.5.9 Risk Evaluation Summary and Removal Action Criteria for Waste Rock

The camper RMC are proposed to be the removal action criteria for metals in waste rock at the mine. Since these criteria are based on ingestion and inhalation, areas where surficial concentrations exceed these criteria will be removed or covered. Such actions will also provide protection for wildlife since the elk RMC modified with the 0.003 area use factor are greater than the camper RMC. Therefore, any

actions taken to reduce the potential for direct contact with the waste would reduce the threats to both humans and wildlife.

Arsenic is the only analyte reported at concentrations exceeding the camper RMC at the mine. On average, the arsenic levels in near-surface soil and on the face of the mine dump only slightly exceed the RMC (by less than a factor of 3), and therefore, is generally considered to pose low risk to campers. Arsenic levels slightly more than 3 times the RMC were reported in only one of the near-surface samples, suggesting the arsenic in waste rock poses moderate risk to campers in isolated areas on the mine bench. Radionuclide activities (i.e., gross alpha, gross beta, radium-226, and thorium-230) in near-surface soil on the mine bench exceed maximum background levels by 2 to 13 times.

Metals concentrations in sediment deposited along the Lion Canyon Creek channel did not exceed the camper RMC, and therefore, pose low risk to campers. However, the above background levels of uranium, vanadium, gross alpha, gross beta, radium-226, and thorium-230 reported for the sediment samples indicate that contaminants are migrating from the mine area along the channel.

The removal action criteria for radionuclides in waste rock and sediment at the mine are proposed to be the gamma-exposure ceiling of 100 mRem per year exclusive of background plus ALARA. The ALARA principle is defined by EPA as making reasonable efforts to maintain exposures as far below the applicable limits as practical. The ceiling plus ALARA will be applied to the 14-day camper scenario. Based on analytical results and radiological measurements, radiation exposures for individuals camping at the mine would likely exceed the 100 mRem per year ceiling (exclusive of background) in isolated areas on the mine bench.

These findings indicate that removal actions should be implemented to reduce the risks to campers posed by arsenic, radionuclide activities, and gamma-exposure rates on the mine bench, the only area with camping potential at the mine. Potential actions could include physical removal of waste rock or capping the area with appropriate cover materials. Any potential camping areas created as a result of site grading during implementation of actions (i.e., stabilization terraces) should be covered with appropriate cover soil to ensure the 100 mRem per year ceiling plus ALARA is achieved. Based on the contaminant levels reported for vegetation samples collected at the mine, future livestock grazing should be discouraged in the mine area.

Under existing conditions, the materials comprising the waste-rock dump are migrating from the mine area as a result of erosion (fluvial and wind) and mass wasting processes. Much of the waste rock cast over the dump has accumulated within the Lion Canyon Creek channel at the toe of the dump. The material deposited in the channel is continually being transported downstream, particularly during flood events. The elevated levels of metals and radionuclides in surface water and sediment downstream of the mine along Lion Canyon Creek and La Sal Creek are most likely attributed to the transport of contaminated sediment from the mine. Removal actions should be taken to remove waste rock from the channel and stabilize the dump, thereby reducing the potential for future migration of contaminants from the mine.

Actions should also be taken to properly close the Blue Cap Mine portal and other openings associated with the mine to prevent unauthorized access to the mine and reduce the potential for radon exposure inside the portal, while maintaining adequate drainage of mine discharge.

4.6 Black Hat Mine

The Black Hat Mine area is open to public access and currently used for recreation. Recreational uses in the area typically include camping, hiking, hunting, and ATV riding. There is evidence that visitors have accessed the mine workings through the open portal. Use of the area for recreation is expected to continue, and likely increase, in the future. A variety of wildlife also frequents the mine area.

The media of potential concern at the mine are waste rock and vegetation growing along the perimeter of the mine dump. The mine portal is dry and no water flows from the adit. Direct radiation exposure and radon are also potentially of concern at the mine.

4.6.1 Waste Rock

Waste rock accumulations are considered potential contaminant sources at the mine. The risks posed by waste rock at the mine are evaluated below.

4.6.1.1 Contaminants of Concern

The COCs for waste rock were selected by comparing analyte concentrations in waste-rock samples collected at the mine to the maximum analyte concentrations reported for soil samples collected from the

three reference areas. Examination of Tables 4.50 (borehole samples) and 4.51(composite surface samples) shows that the following analytes were reported for the waste-rock samples at levels greater than the maximum levels reported for background soils and considered COCs for this evaluation:

- Arsenic
- Chromium
- Copper (one sample)
- Lead
- Manganese (one sample)
- Selenium
- Silver
- Uranium
- Vanadium
- Gross alpha
- Gross Beta
- Radium-226
- Thorium-230
- Thorium-232

4.6.1.2 Human-Health Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for the camper scenario have been established for arsenic, copper, lead, manganese, selenium, and silver. Arsenic was the only metal found at concentrations exceeding the RMC (Tables 4.50 and 4.51). It should be noted that the maximum concentration of arsenic in background soil (25.7 mg/Kg) slightly exceeded the camper RMC (20 mg/Kg). Analyte concentrations reported for the near-surface samples collected from boreholes located on the mine bench did not exceed any of the camper RMC. Arsenic was reported at concentrations slightly exceeding the RMC (by a factor 1.5) in one sub-surface sample collected from borehole BH 2 (5.5-7.5) and one of the composite surface samples (BH Segment 1) collected from the face of the dump. The arsenic levels in these areas are considered to pose low risk to campers.

The risks to campers associated metals for which RMC have not been established were evaluated by comparing analyte concentrations reported for the waste-rock samples to industrial SSLs. As shown in Tables 4.50 and 4.51, analyte concentrations for these metals did not exceed the SSLs in any of the waste-rock samples. Therefore, the metals for which RMC have not been established are considered to pose a low risk to campers at the mine.

Radionuclide activities reported for the waste-rock samples were compared to background levels. The sample sites where radionuclide activities in near-surface samples exceeded maximum background levels and the range of the exceedances for each radionuclide are summarized in Table 4.52. Radionuclide activities in near-surface samples collected from boreholes on the mine bench were generally consistent with the activities reported for composite surface samples collected from the face of the mine dump. The highest radionuclide activities relative to maximum background levels in near-surface samples at boreholes were reported for gross alpha (4 times background), gross beta (6 times background), radium-226 (7 and 11 times background), and thorium-230 (2 and 6 times background). Thorium-232 was reported at an activity slightly exceeding maximum background (by a factor of 1.1) in only one sample (BH 2: 0-0.5). Radium-228 and thorium-228 were reported at activities less than maximum background levels.

Radium-226 activities reported for near-surface samples collected at the mine (the 0-0.5 samples from boreholes and composite surface samples from the face of the dump) were compared to the UMTRCA standard of 5 pCi/g over background. As discussed in Section 4.1.1, the UMTRCA standard applies to unrestricted use (e.g., construction of habitable structures), and therefore, is not directly applicable to the mine area and is only used to identify the areas where radium-226 levels could potentially pose a potential threats to campers at the mine. A factor of 26 (365 days/14 days) was applied to better assess the threats posed under the camper scenario, where radium-226 levels less than 26 times the UMTRCA standard are considered to not pose a threat to campers. The average background level reported for radium-226 in soil samples collected from the three reference areas was 3.3 pCi/g, resulting in a criterion of 8.3 pCi/g. The radium-226 activities reported for both of the near-surface samples collected from boreholes exceeded 8.3 pCi/g, with the highest radium-226 activity (139 pCi/g at borehole BH 2) exceeding the standard by a factor of 16.7. The radium-226 activities reported for both composite surface samples exceeded 8.3 pCi/g, with the highest radium-226 activity (83.6 pCi/g for segment 2) exceeding the standard by a factor of 10. Because radium-226 activities in the waste-rock samples did not exceed the criterion by more the 26 times, it is suspected that the levels reported pose low risk to campers at the mine.

Gross alpha, gross beta, radium-226, and thorium-230 activities exceeded maximum background levels in each of the sub-surface samples collected from boreholes except sample BH 1 (11-13) , suggesting that the sample may reflect native soil underlying the waste-rock dump. Sample BH 2 (2-4) contained the highest radium-226 activity of the waste rock samples collected at the mine and was approximately 14 times the maximum background level.

These results indicate that radionuclide levels in waste rock at the mine are elevated with respect to background areas, with the highest activities relative to background reported for gross alpha, gross beta, radium-226, and thorium-230. The potential threats posed by radionuclides are further evaluated on the basis of radiation exposure in Section 4.6.3.

4.6.1.3 Ecological Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for elk have been established for arsenic, lead, uranium, and vanadium. Tables 4.53 (borehole samples) and 4.54 (composite surface samples) present comparisons of analytical results to the elk RMC, modified with an area use factor of 0.0005 (0.3-acre mine area divided by 640-acre home range). As shown, analyte concentrations did not exceed the modified RMC for elk, and therefore, the concentrations of these analytes in waste rock pose low risk to elk at the mine.

Selenium, uranium, vanadium, and radium-226 levels in near-surface samples exceeded maximum background levels by the greatest amounts. On the mine bench, uranium concentrations were up to 22 times greater than maximum background and radium-226 activities were up to 10.5 times greater than maximum background. On the face of the mine dump, selenium, uranium, and vanadium concentrations were up to 11, 23, and 12 times greater than maximum background values respectively.

As found for the human-health risk evaluation, gross alpha, gross beta, radium-226, and thorium-230 activities exceed the background levels. The activities reported for these analytes were generally consistent for the material covering the mine bench and the material covering the face of the dump. However, the potential threats to elk are considered to be greater on the mine bench because elk are likely to spend more time on the bench than on the steep slope of the dump.

Analyte concentration reported for waste rock samples were compared to leaching RMC to evaluate the leaching characteristics of the waste rock (Table 4.55 – borehole samples and Table 4.56 – composite surface samples). Because the criteria are based on aquatic life standards, the comparisons allow identification of the analytes in waste rock that may pose a threat to aquatic life. As shown, none of the metal concentrations in waste rock exceeded the derived leaching RMC. Examination of the SPLP results shows that the metals most frequently reported at levels above method detection limits in leachate from the waste rock were arsenic, uranium, and vanadium.

4.6.2 Vegetation

Vegetation is considered both a receptor and dietary item for herbivores. Analyte levels in vegetation at the mine were evaluated by comparing analytical results for samples collected at the mine to the analytical results for samples collected within the reference area and maximum tolerable levels of dietary minerals for domestic animals (Table 4.57). In addition, the ecological risk evaluation results discussed in Sections 4.6.1.3 (waste rock) and 4.5.4.2 (sediment along Lion Canyon Creek) were also considered in the evaluation because the ecological RMC developed by BLM for soil include consumption of vegetation by terrestrial herbivores.

In general, analyte levels were highest and most frequently exceeded background levels in the grass sample collected along dump perimeter. The analytes reported at the highest levels relative to background (more than 10 times background levels) in the grass sample included arsenic, cadmium, selenium, uranium, vanadium, and gross alpha. Of these analytes, uranium and vanadium were reported at the highest levels (967 and 112 times background, respectively). The analytes reported at the highest levels relative to background (more than 10 times background levels) in the forb sample included arsenic, molybdenum, selenium, uranium, vanadium, gross alpha, and radium-226. Of these analytes, radium-226 was reported at the highest level (217 times background). The shrub sample contained the fewest analytes at levels exceeding background. Selenium and uranium were the only analytes reported at levels exceeding background by more than 10 times.

The analytes reported at concentrations exceeding the maximum tolerable levels in vegetation along the perimeter of the mine dump include barium, cadmium, iron, molybdenum, selenium, and vanadium. However, it should be noted that the concentrations of barium (grass, forb, and shrub) and selenium (grass and forb) in the background samples also exceeded the criteria. The analytes reported at the highest concentrations relative to the criteria were molybdenum (forb) and selenium (grass, forb, and shrub). The

molybdenum concentration in the forb sample exceeded the criterion by a factor of 15. The selenium concentrations in the grass, forb, and shrub samples exceeded the criteria by factors of 33, 330, and 25, respectively. The concentrations of the other samples exceeding the criteria were less than 10 times the criteria.

These results indicate that vegetation at the mine contains higher levels for several analytes than does vegetation in the background area. The analytes reported at the highest levels relative to background in vegetation at the mine are uranium and vanadium in the grasses and radium-226 in the forbs. The concentrations of barium, cadmium, iron, molybdenum, selenium, and vanadium in one or more of the vegetation samples collected along the perimeter of the mine dump exceeded the maximum tolerable levels. The analytes reported at the highest levels relative to the criteria were molybdenum and selenium. Based on comparisons to the maximum tolerable levels, molybdenum and selenium likely pose the greatest threat to livestock and wildlife at the mine.

As discussed in Sections 4.6.1.3 and 4.5.4.2, waste rock and sediment at the mine are considered to pose a low risk to livestock and wildlife on the basis of the RMC established by BLM. Because the RMC account for the consumption of vegetation by herbivores, vegetation at the mine is considered to pose a low risk to herbivores with respect to the analytes for which ecological RMC for soil have been established.

4.6.3 Radiation Exposure

The risk associated with direct radiation exposure at the mine was evaluated on the basis of radiological surveys of the mine area, correlation study results, and uranium concentrations and radium-226 activities in waste rock. Gamma-count rates recorded across the mine area are shown in Figure 3.19, and gamma-count and gamma-exposure rate measurements taken at the mine are presented in Table 3.16. Based on these measurements, a gamma-exposure rate of 1 µR/hr is approximately equal to a gamma-count rate of 932 cpm. Assuming this correlation, the cpm rates shown in Figure 3.15 of 18,500 cpm, 21,500, and 28,500 cpm represent approximately 20 µR/hr, 23 µR/hr, and 31 µR/hr, respectively. An individual camping at the mine for 14 days in an area where the gamma-exposure rate is 31 µR/hr (gamma-count rate of 28,500 cpm) would receive approximately 10 mRem, well below the 100 mRem per year ceiling (exclusive of background). The background gamma-exposure rate measured at the Black Hat mine was 13.3 µR/hr or approximately 0.0133 mRem/hr. Assuming a 14-day camper scenario, the 100 mRem per year ceiling exclusive of background would be exceeded by a camper spending the entire 14-day period

in an area where the gamma-exposure rate was greater than 311 µR/hr (gamma-count rate greater than approximately 290,000 cpm).

Radiation survey results at the mine (Figure 3.19) show that gamma-count rates greater than 28,500 cpm occur only within isolated areas in the vicinity of the ore loadout structure, suggesting that exposures rates greater than 100 mRem per year (exclusive of background) under the camper scenario could only occur in these isolated areas. However, the gamma-scan survey is based on a walking average and provides only a relative assessment gamma-count rates across the survey area. The static gamma-count rates and gamma-exposure rates recorded for the correlation samples provide a more accurate assessment of exposure than the gamma-scan results. As shown in Table 3.16, none of the discrete correlation samples collected at the mine exhibited gamma-exposure rates greater than 311 µR/hr. The highest gamma-exposure rate measured at the mine was 105 µR/hr for correlation sample BH-COR3 located near the adit on the mine bench. The gamma-exposure rate for a 14-day camper in this area would be 35 mRem or 30.5 mRem exclusive of background. Based on the static readings, exposures to campers would be well below 100 mRem per year ceiling exclusive of background.

The correlations between gamma-count rate and radium-226 and uranium activities (Section 3.6.2 of this document) were also used to assess gamma exposure at the mine. Based on these correlations, a gamma-count rate of 290,000 cpm (the count rate at which the 100 mRem per year ceiling exclusive of background would be exceeded for a 14-day camper) equates to a radium-226 activity of 226 pCi/g and a uranium activity of 382 pCi/g (570 mg/Kg, assuming an approximate correlation of 0.67 pCi/g to 1.0 mg/Kg). As shown in Tables 4.50 and 4.51, radium-226 activities were less than 226 pCi/g and the uranium concentrations were less than 570 mg/Kg in both of the near-surface samples collected at boreholes on the mine bench and in both of the composite surface samples collected on the face of the waste-rock dump. These results suggest that radiation exposures for individuals camping at the mine would not likely exceed the 100 mRem per year ceiling exclusive of background.

Radiation exposure is not expected to be of ecological concern at the mine because gamma-exposure rates measured at the mine were well below the IAEA standard for wildlife of 0.1 Rad per day or 4,167 µR/hr.

4.6.4 Radon

Radon poses a potential hazard at the mine. The relative risk posed by radon at the mine was evaluated by comparing radon levels within the mine portal (approximately 75 feet inside the mine entrance) to levels in an adjacent background area. The monitoring results reported for mine are as follows:

- Background Area
  - Exposure: 214.6 pCi/L over 171-day monitoring period
  - Average: 1.3 pCi/L per day
- Adit
  - Exposure: 29,438.9 pCi/L over 171-day monitoring period
  - Average: 172.2 pCi/L per day

These results suggest that high radon levels are associated with the mine and that high exposures to radon occur within the mine portal.

4.6.5 Risk Evaluation Summary and Removal Action Criteria for Waste Rock

The camper RMC are proposed to be the removal criteria for metals in waste rock at the mine. Since these criteria are based on ingestion and inhalation, areas where surficial concentrations exceed these criteria will be removed or covered. Such actions will also provide protection for wildlife since the elk RMC modified with the 0.0005 area use factor are greater than the camper RMC. Therefore, any actions taken to reduce the potential for direct contact with the waste would reduce the threats to both humans and wildlife. Evaluation of the human-health threats associated with waste rock at the mine indicates that metals concentrations in waste rock pose low risk to campers.

The removal action criteria for radionuclides in waste rock at the mine are proposed to be the gamma-exposure ceiling of 100 mRem per year exclusive of background plus ALARA. The ALARA principle is defined by EPA as making reasonable efforts to maintain exposures as far below the applicable limits as practical. The ceiling plus ALARA will be applied to the 14-day camper scenario. Based on analytical results and radiological measurements, radiation exposures for individuals camping at the mine would be well less than the 100 mRem per year ceiling exclusive of background and likely less than 25 mRem per year exclusive of background.

These findings indicate that under existing conditions, waste rock at the mine poses low risk to campers, and therefore, removal actions for waste rock are not necessary at the mine for protection of human health. However, the materials comprising the waste-rock dump are migrating from the mine area as a

result of erosion (fluvial and wind) and mass wasting processes. Waste rock which has accumulated in the Lion Canyon Creek channel at the toe of the lower dump and along the western flank of the upper dump is continually being transported downstream, particularly during flood events. The elevated levels of metals and radionuclides in surface water and sediment downstream of the mine along Lion Canyon Creek and La Sal Creek are likely attributed, in part, to the transport of contaminated sediment from the mine. Removal actions should be taken to remove waste rock from the channel and stabilize the dump, thereby reducing the potential for future migration of contaminants from the mine. Based on the contaminant levels reported for vegetation samples collected at the mine, future livestock grazing should be discouraged in the mine area.

Actions should also be taken to properly close the Black Hat Mine portal to prevent unauthorized access to the mine and reduce the potential for radon exposure in the portal. The structure housing the adit (portal house) should be stabilized or removed to mitigate the physical hazards associated with the structure. The ore loadout structure at the mine appears to be stable but poses a fall hazard. Removal of the portal house and loadout structure would diminish the mining character of the site but mitigate physical hazards at the mine.

4.7 Saint Patrick Mine

The Saint Patrick Mine area is open to public access and currently used for recreation. Recreational uses in the area typically include camping, hiking, hunting, and ATV riding. The mine adit has been mostly backfilled and a metal gate (partially open) has been installed behind the backfill. Some reclamation has been performed at the mine, regrading in the vicinity of the mine bench, reclaimed access road, and revegetation of reclaimed areas. Use of the area for recreation is expected to continue, and likely increase, in the future. A variety of wildlife also frequents the mine area.

The media of potential concern at the mine are waste rock and vegetation growing along the perimeter of the waste-rock dump. The mine portal is dry and no water flows from the adit. Direct radiation and radon are also potentially of concern at the mine.

4.7.1 Waste Rock

Waste rock accumulations are considered potential contaminant sources at the mine. The risks posed by waste rock at the mine are evaluated below.

4.7.1.1 Contaminants of Concern

The COCs for waste rock were selected by comparing analyte concentrations in waste-rock samples collected at the mine to the maximum analyte concentrations reported for soil samples collected from the three reference areas. Examination of Table 4.58 shows that the following analytes were reported for the waste-rock samples at levels greater than the maximum levels reported for background soils and considered COCs for this evaluation:

- Chromium
- Lead
- Selenium
- Silver (one sample)
- Uranium
- Vanadium
- Gross alpha
- Radium-226

4.7.1.2 Human-Health Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for the camper scenario have been established for lead, selenium, and silver. The concentrations of these metals did not exceed the camper RMC, and therefore, a considered to pose low risk to campers at the site (Table 4.58).

The risks to campers associated with metals for which RMC have not been established were evaluated by comparing analyte concentrations reported for the waste-rock samples to industrial SSLs. As shown in Tables 4.58, the analyte concentrations for these metals did not exceed the SSLs in any of the waste-rock samples. Therefore, the metals for which RMC have not been established are considered to pose a low risk to campers at the mine.

Radionuclide activities reported for the waste-rock samples were compared to background. Gross alpha and radium-226 were the only radionuclides reported at activities exceeding maximum background

values. The gross alpha activity only slightly exceeded the maximum background value (by a factor of 1.05) in dump segment 1 and was below the maximum background value in dump segment 2. The radium-226 activity was 3.4 times background in dump segment 1 and 1.5 times background in dump segment 2.

Radium-226 activities reported for composite surface samples from the face of the dump were compared to the UMTRCA standard of 5 pCi/g over background. As discussed in Section 4.1.1, the UMTRCA standard applies to unrestricted use (e.g., construction of habitable structures), and therefore, is not directly applicable to the mine area and is only used to identify the areas where radium-226 levels could potentially pose a potential threats to campers at the mine. A factor of 26 (365 days/14 days) was applied to better assess the threats posed under the camper scenario, where radium-226 levels less than 26 times the UMTRCA standard are considered to not pose a threat to campers. The average background level reported for radium-226 in soil samples collected from the three reference areas was 3.3 pCi/g, resulting in a criterion of 8.3 pCi/g. The radium-226 activities reported for both composite surface samples exceeded 8.3 pCi/g, with the highest radium-226 activity (45.5 pCi/g for segment 1) exceeding the standard by a factor of 5.5. Because radium-226 activities in the waste-rock samples did not exceed the criterion by more the 26 times, it is suspected that the levels reported pose low risk to campers at the mine.

These findings indicate that radionuclide levels in waste rock at the mine are slightly elevated with respect to background areas, with the highest activities relative to background reported for gross alpha and radium-226. The potential threats posed by these analytes are further evaluated on the basis of radiation exposure in Section 4.7.3.

4.7.1.3 Ecological Risk Evaluation Results

Of the COCs identified for waste rock at the mine, RMC for elk have been established for lead, uranium, and vanadium. Table 4.59 presents a comparison of analytical results to the elk RMC, modified with an area use factor of 0.002 (1.0-acre mine area divided by 640-acre home range). As shown, lead concentrations did not exceed the modified RMC for elk, and therefore, the concentrations of lead in waste rock pose low risk to elk at the mine.

As discussed for the human-health risk evaluation, gross alpha and radium-226 in waste rock at the mine slightly exceed background levels.

Analyte concentrations reported for waste rock samples were compared to leaching RMC to evaluate the leaching characteristics of the waste rock (Table 4.60). Because the criteria are based on aquatic life standards, the comparisons allow identification of the analytes in waste rock that may pose a threat to aquatic life. As shown, none of the metal concentrations in waste rock exceeded the derived leaching RMC. Examination of the SPLP results shows that the metals most frequently reported at levels above method detection limits in leachate from the waste rock were arsenic, iron, uranium, and vanadium.

4.7.2 Vegetation

Vegetation is considered both a receptor and dietary item for herbivores. Analyte levels in vegetation at the mine were evaluated by comparing analytical results for samples collected at the mine to the analytical results for samples collected within the reference area and maximum tolerable levels of dietary minerals for domestic animals (Table 4.61). In addition, the ecological risk evaluation results discussed in Sections 4.7.1.3 (waste rock) and 4.5.4.2 (sediment along Lion Canyon Creek) were also considered in the evaluation because the ecological RMC developed by BLM for soil include consumption of vegetation by terrestrial herbivores.

The analytes reported at the highest levels relative to background (more than 10 times background levels) in the grass sample included uranium (47 times background) and vanadium (12 times background). The analytes reported at the highest levels relative to background (more than 10 time background levels) in the forb sample included selenium (14 times background), uranium (27 times background), vanadium (19 times background), gross alpha (34 times background), and radium-226 (167 times background). The analytes reported at the highest levels relative to background (more than 10 time background levels) in the shrub sample included selenium (10.1 times background), uranium (32 times background), vanadium (20 times background), and thorium-232 (61 times background).

The analytes reported at concentrations exceeding the maximum tolerable levels in vegetation along the perimeter of the mine dump include barium, molybdenum, selenium, and vanadium. However, it should be noted that the concentrations of barium (grass, forb, and shrub) and selenium (grass and forb) in the background samples also exceeded the criteria. The analyte reported at the highest concentration relative to the criteria was selenium (forb). The selenium concentration in the forb sample exceeded the criteria by a factor of 50. The concentrations of the other samples exceeding the criteria were less than 10 times the criteria.

These results indicate that vegetation at the mine contains higher levels for several analytes than does vegetation in the background area. The analytes reported at the highest levels relative to background in vegetation at the mine are selenium, uranium, and vanadium (each type of vegetation) and gross alpha, radium-226, and thorium-232 (forbs and shrubs). The concentrations of barium, molybdenum, selenium, and vanadium in one or more of the vegetation samples collected along the perimeter of the mine dump exceeded the maximum tolerable levels. The analyte reported at the highest level relative to the criteria was selenium. Based on comparisons to the maximum tolerable levels, selenium likely poses the greatest threat to livestock and wildlife at the mine.

As discussed in Sections 4.7.1.3 and 4.5.4.2, waste rock and sediment at the mine are considered to pose a low risk to livestock and wildlife on the basis of the RMC established by BLM. Because the RMC account for the consumption of vegetation by herbivores, vegetation at the mine is considered to pose a low risk to herbivores with respect to the analytes for which ecological RMC for soil have been established.

4.7.3 Radiation Exposure

The risk associated with direct radiation exposure at the mine was evaluated on the basis of radiological surveys of the mine area, correlation study results, and uranium concentrations and radium-226 activities in waste rock. Gamma-count rates recorded across the mine area are shown in Figure 3.19, and gamma-count and gamma-exposure rate measurements taken at the mine are presented in Table 3.16. Based on these measurements, a gamma-exposure rate of 1 µR/hr is approximately equal to a gamma-count rate of 932 cpm. Assuming this correlation, the cpm rates shown in Figure 3.15 of 18,500 cpm, 21,500, and 28,500 cpm represent approximately 20 µR/hr, 23 µR/hr, and 31 µR/hr, respectively. An individual camping at the mine for 14 days in an area where the gamma-exposure rate is 31 µR/hr (gamma-count rate of 28,500 cpm) would receive approximately 10 mRem, well below the 100 mRem per year ceiling exclusive of background. The background gamma-exposure rate measured at the mine was 13.3 µR/hr or approximately 0.0133 mRem/hr. Assuming a 14-day camper scenario, the 100 mRem per year ceiling exclusive of background would be exceeded by a camper spending the entire 14-day period in an area where the gamma-exposure rate was greater than 311 µR/hr (gamma-count rate greater than approximately 290,000 cpm).

Radiation survey results at the mine (Figure 3.19) show that gamma-count rates greater than 28,500 cpm occur only very isolated areas in the vicinity of the mine, suggesting that exposures rates greater than 100 mRem per year (exclusive of background) under the camper scenario could only occur in these isolated areas. However, the gamma-scan survey is based on a walking average and provides only a relative assessment gamma-count rates across the survey area. The static gamma-count rates and gamma-exposure rates recorded for the correlation samples provide a more accurate assessment of exposure than the gamma-scan results. As shown in Table 3.16, neither of the correlation samples collected on the waste-rock dump exhibited gamma-count rates greater than 311 µR/hr. The highest gamma-exposure rate of the two samples was 230 µR/hr, reported for correlation sample SP-COR2. Over a 14-day period, the gamma-exposure rate to a camper in the area of SP-COR2 would be approximately 77 mRem, or 72.5 mRem exclusive of background. Based on the static readings, exposures to campers would be below the 100 mRem per year ceiling exclusive of background.

The correlations between gamma-count rate and radium-226 and uranium activities (Section 3.6.2 of this document) were also used to assess gamma exposure at the mine. Based on these correlations, a gamma-count rate of 290,000 cpm (the count rate at which the 100 mRem per ceiling exclusive of background for a 14-day camper) equates to a radium-226 activity of 226 pCi/g and a uranium activity of 382 pCi/g (570 mg/Kg, assuming an approximate correlation of 0.67 pCi/g to 1.0 mg/Kg). As shown in Table 4.58, radium-226 activities were less than 226 pCi/g and the uranium concentrations were less than 570 mg/Kg in the composite surface samples collected on the face of the waste-rock dump. These results suggest that radiation exposures for individuals camping at the mine would not likely exceed the 100 mRem per year ceiling exclusive of background.

Radiation exposure is not expected to be of ecological concern at the mine because gamma-exposure rates measured at the mine were well below the IAEA standard for wildlife of 0.1 Rad per day or 4,167 µR/hr.

4.7.4 Radon

Radon poses a potential hazard at the mine. The relative risk posed by radon at the mine was evaluated by comparing radon levels within the mine portal (approximately 15 feet inside the mine entrance) to levels in an adjacent background area. The monitoring results reported for mine are as follows:

- Background Area
    - Exposure: 214.6 pCi/L over 171-day monitoring period
    - Average: 1.3 pCi/L per day
- Adit

- Exposure: 6,118.6 pCi/L over 171-day monitoring period
- Average: 35.8 pCi/L per day

These results suggest that high radon levels are associated with the mine and that high exposures to radon occur within the mine portal.

4.7.5 Risk Evaluation Summary and Removal Action Criteria for Waste Rock

The camper RMC are proposed to be the removal criteria for metals in waste rock at the mine. Since these criteria are based on ingestion and inhalation, areas where surficial concentrations exceed these criteria will be removed or covered. Such actions will also provide protection for wildlife since the elk RMC modified with the 0.002 area use factor are greater than the camper RMC. Therefore, any actions taken to reduce the potential for direct contact with the waste would reduce the threats to both humans and wildlife. Evaluation of the human-health threats associated with waste rock at the mine indicate that metals concentrations in waste rock pose low risk to campers.

The removal action criteria for radionuclides in waste rock at the mine are proposed to be the gamma-exposure ceiling of 100 mRem per year exclusive of background plus ALARA. The ceiling plus ALARA will be applied to the 14-day camper scenario. Based on analytical results and radiological measurements, radiation exposures for individuals camping at the mine would be less than the 100 mRem per year ceiling exclusive of background.

These findings indicate that under existing conditions, waste rock at the mine poses low risk to campers, and therefore, removal actions for waste rock are not necessary at the mine for protection of human health. Based on the contaminant levels reported for vegetation samples collected at the mine, future livestock grazing should be discouraged in the mine area.

Under existing conditions, the materials comprising the waste-rock dump are migrating from the mine area as a result of erosion (fluvial and wind) and mass wasting processes. Sediment derived from the waste-dump material does not migrate along a defined channel or drainage but generally migrates uniformly down the steep hillside. Established vegetation along the perimeter of the dump reduces migration of sediment from the dump. Because the material comprising the dump does not pose a threat to human health and established vegetation reduces the potential for sediment transport, actions to stabilize the dump are not warranted at this time.

Further actions should be considered to fully close the mine portal to prevent unauthorized access to the mine and reduce the potential for radon exposure in the portal. However, such efforts would result in significant disturbance to the areas that have been reclaimed at the site. Because of damage to reclaimed areas and the fact that the existing closure feature effectively discourages access to the mine, additional closure efforts are not warranted at this time.

4.8 Residential Areas

The primary human-health exposure pathways of concern at the three residences located within the project area are ingestion of surface water from residential springs, ingestion of homegrown vegetables and livestock, and inhalation of radon emanating from water fixtures in the homes. The risks associated with these pathways are evaluated on the basis of surface-water, soil, and vegetation samples collected at the residences during the site characterization.

The surface-water pathway was evaluated by comparing surface-water results to MCLs and secondary standards. MCLs are legally enforceable standards that apply to public water systems and are designed to protect public health by limiting the levels of contaminants in drinking water. Secondary standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

The ingestion of soil pathway was evaluated by comparing the analytical results for soil samples collected at gardens and pastures to the BLM RMC established for residences adjacent to BLM lands (Ford, 2004), EPA Region 3 SSLs for residential soil (EPA, 2004), and EPA generic SSL for radionuclides (EPA, 2000b). The ingestion of homegrown produce pathway was directly evaluated by comparing radionuclide (radium-226 and radium-228) results for soil samples collected in the gardens, as well as in the pastures, to the generic SSLs for ingestion of homegrown produce specified in EPA generic SSL for radionuclides (EPA, 2000b). The ingestion of homegrown produce pathway was indirectly evaluated on the basis of soil ingestion pathway assessment coupled with examination of the analytical results reported for the produce samples collected at the residences. The ingestion of livestock pathway was indirectly evaluated by comparing analytical results for the pasture grass samples to maximum tolerable levels of dietary minerals for domestic animals (National Research Council, 1980). In addition, analytical results for water samples collected from the water sources used to irrigate the pastures were compared to Utah stream standards for agricultural use and background levels.

The inhalation of radon pathway was evaluated by comparing results of radon monitoring conducted within the bathroom of each residence to EPA's recommended indoor air guideline of 4 pCi/L per day.

4.8.1 Residence 1

Residence 1 is located on a 5-acre parcel of private land (Figure 3.5). A comparison of analytical results reported for surface-water samples collected at Residence 1 to MCLs and secondary standards is presented in Table 4.62. As shown, analyte concentrations are well below MCLs in each of the surface-water samples collected from the spring used for domestic purposes. Except for pH and total manganese, sample results are also below the secondary standards. The pH value for the sample collected from the spring in October 2004 (6.45 s.u.) was slightly below the secondary standard of 6.5 s.u. Values of pH below the recommended range may cause bitter metallic taste and corrosion of pipes. The concentration of total manganese in the sample collected from the spring in October 2004 (123 µg/L) exceeded the secondary standard of 50 µg/L. Water containing manganese at concentrations exceeded the recommended standard may cause brown to black color, black staining, and bitter metallic taste. Based on these findings, the drinking water source does not appear to be impacted by upgradient mine operations and do not pose a threat to the residents.

A comparison of analytical results reported for soil samples collected from the garden and pasture to human-health criteria for residential soils, a summary of the results reported for produce samples, and comparison of vegetation (pasture grass) results to maximum tolerable levels of dietary minerals for domestic animals are presented in Table 4.63. The concentrations of arsenic in the soil samples (ranging from 12.4 to 21.5 mg/Kg) exceed the BLM RMC of 1 mg/Kg for residential soil. The activities of radium-226 (ranging from 4.8 to 6.8 pCi/g) exceed the generic soil screening levels established by EPA for ingestion of homegrown produce and ingestion of soil. The activities reported for radium-228 (ranging from 0.73 to 0.87 pCi/g) in the soil samples exceed the generic soil screening level established by EPA for ingestion of homegrown produce but are less than the generic soil screening level for ingestion of soil. These results suggest that the concentrations of these analytes in soil may pose an elevated risk at the residence. However, comparison to the background soil sample results shown in Table 4.63 shows that the reported concentrations for arsenic, radium-226, and radium-228 in the residential soil samples are within the range of background levels for arsenic (1.1 to 25.7 mg/Kg), radium-226 (0.49 to 13.2 pCi/g), and radium-228 (0.68 to 4.15 pCi/g). Analytical results for the garden produce samples collected at the residence show that arsenic was not detected in any of the samples and radium-226 and radium-228 were detected at relatively low levels. These findings suggest that the

magnitude of risk posed by arsenic, radium-226, and radium-228 in soil at the residence is considered similar to the magnitude of risk posed by native soil in the area.

Comparison of the analytical results reported for the pasture grass sample to maximum tolerable levels shows that the concentrations reported for barium and selenium slightly exceed the maximum tolerable levels for these analytes. However, it should be noted that the concentrations of barium and selenium in the pasture grass sample are consistent with the background concentrations which also exceed the maximum tolerable levels. Metals concentrations reported for the pasture grass sample were generally consistent with background levels, with barium, copper, selenium, uranium, and zinc only slightly exceeding (by a factor of 5.3 or less) background levels. Of the radionuclides reported for the pasture grass sample, the highest activity relative to background was reported for gross beta which exceeded background by a factor of 3.1. The activities of gross alpha and radium-228 in the pasture grass exceeded background levels by factors of 1.2 and 2.0, respectively. The radium-226, thorium-230, and thorium-232 activities in the pasture grass sample were less than the background levels, and the thorium-228 activity was similar to background.

Hop Creek is used as the irrigation source for the garden and pasture areas at the residence. A comparison of analytical results for the samples collected at Hop Creek Dn to background levels for the upstream samples at Reference Area 3 and Utah agriculture stream standards is presented in Table 4.64. As shown, analyte levels in both samples collected at station Hop Creek Dn did not exceed any of the agriculture standards. Except for dissolved manganese, analyte levels in the downstream samples were similar to the levels reported for the samples collected at the reference area. The dissolved manganese concentration in the downstream sample collected in October 2004 exceeded the background level by a factor of 10. The other analytes reported above background only slightly exceeded the background levels, generally by a factor of less than 2. Based on these findings, Hop Creek does not appear to be impacted by upstream mine operations, and surface water in Hop Creek is not expected to pose a threat as an irrigation source for the residence.

The radon monitoring results for the detector placed in the bathroom at the residence show an overall exposure of 559.7 pCi/L for the 168-day monitoring period, or an average radon concentration of 3.3 pCi/L per day. The 3.3 pCi/L per day value is below the EPA recommended indoor standard of 4 pCi/L per day; therefore, radon is not considered to be of concern at the residence on the basis of this radon test.

4.8.2 Residence 2

Residence 2 is located on a 7-acre parcel of land leased from the State of Utah (Figure 3.5). A comparison of analytical results reported for surface-water samples collected at Residence 2 to MCLs and secondary standards is presented in Table 4.65. Analyte levels are well below MCLs and secondary standards in each of the surface-water samples collected from the spring used for domestic purposes. Based on these findings, the drinking water source does not appear to be impacted by upgradient mine operations and do not pose a threat to the residents.

A comparison of analytical results reported for the soil sample collected from the pasture to human-health criteria for residential soils and comparison of vegetation (pasture grass) results to maximum tolerable levels of dietary minerals for domestic animals are presented in Table 4.66. The concentration of arsenic in the soil sample (7.1 mg/Kg) exceeded the BLM RMC of 1 mg/Kg for residential soil. The activity of radium-226 (1.59 pCi/g) in the soil sample exceeds the generic soil screening levels of 0.06 (ingestion of home grown vegetables) and 1.1 pCi/g (ingestion of soil) established by EPA. These results suggest that the concentrations of arsenic and radium-226 in soil may pose an elevated risk at the residence. However, comparison to the background soil sample results shown in Table 4.66 shows that arsenic and radium-226 levels reported for the pasture-soil sample are within the range of background levels for arsenic (1.1 to 25.7 mg/Kg) and radium-226 (0.49 to 13.2 pCi/g) and below the average arsenic (9.7 mg/Kg) and average radium-226 (3.3 pCi/g) for background soil. Analytical results for the pasture grass sample collected at the residence show that arsenic and radium-226 were not detected in the sample. These findings suggest that the magnitude of risk posed by arsenic and radium-226 in soil at the residence is considered similar to the magnitude of risk posed by native soil in the area.

Comparison of the analytical results reported for the pasture grass sample to maximum tolerable levels shows that the concentrations reported for barium and selenium slightly exceed the maximum tolerable levels for these analytes. However, it should be noted that the concentrations of barium and selenium in the pasture grass sample are consistent with the background concentrations which also exceed the maximum tolerable levels. Metals concentrations in the pasture grass sample were generally consistent with background levels, with copper, selenium, uranium, and zinc concentrations only slightly exceeding (by a factor of 5 or less) background levels. Of the radionuclides reported for the pasture grass sample, gross beta was the only analyte reported at a concentration higher than the level reported for the background sample. The gross beta activity in the pasture grass sample exceeded the background level be a factor of 4.3.

La Sal Creek is used as the irrigation source for the pasture at Residence 2. A comparison of analytical results for the samples collected at station La Sal Creek Dn2, located immediately upstream of the residence, to background levels for La Sal Creek at Reference Area 1 and Utah agriculture stream standards is presented in Table 4.64. As shown, analyte levels did not exceed the Utah agriculture standards in either sample collected at station La Sal Creek Dn2. The value of pH for the sample collected in April 2004 (9.02) slightly exceeded the pH range specified for the standard (6.5 – 9.0); however, the pH of surface water at the reference area also exceeded the pH range during the same period. Analyte levels reported for the La Sal Creek Dn2 samples were generally similar to the levels reported for the samples collected at the reference area. The analytes reported at levels above background only slightly exceeded the background values, generally by a factor of less than 2. Based on these findings, surface water in La Sal Creek at station La Sal Creek Dn2 does not appear to be impacted by upstream mine operations, and surface water in La Sal Creek is not expected to pose a threat as an irrigation source for the residence.

The radon monitoring results for the detector placed in the bathroom at the residence show an overall exposure of 650.4 pCi/L for the 174-day monitoring period, or an average radon concentration of 3.7 pCi/L per day. The 3.7 pCi/L per day value is below the EPA recommended indoor standard of 4 pCi/L per day; therefore, radon is not considered to be of concern at the residence on the basis of this radon test. It should be noted that the residence was not occupied during the monitoring period. Therefore, ventilation was minimal and monitoring results are expected to reflect maximum levels during the period.

4.8.3 Residence 3

Residence 3 is located on a 5-acre parcel of land leased from the State of Utah (Figure 3.5). Two springs at Residence 3 are used as drinking water sources, springs Residence 3U and Residence 3L. These springs are also used as an irrigation source for property. Station Residence 3W refers to a flowing well that has occasionally been used to provide irrigation water at times when flow from the other two springs is low.

A comparison of analytical results reported for surface-water samples collected at the two drinking water springs to MCLs and secondary standards is presented in Table 4.67. As shown, analyte concentrations in the two springs did not exceed any of the MCLs or secondary standards during the two sampling events. Based on these findings, the drinking water sources do not appear to be impacted by upgradient mine operations and do not pose a threat to the residents.

A comparison of analytical results reported for the soil sample collected from the garden area at the residence to human-health criteria for residential soils is presented in Table 4.68. The concentrations of arsenic in the soil sample (4.4 mg/Kg) exceed the BLM RMC of 1 mg/Kg for residential soil. The activity of radium-226 (0.73 pCi/g) in the soil sample exceeds the generic soil screening level of 0.06 (ingestion of home grown vegetables) but does not exceed the generic soil screening level of 1.1 pCi/g (ingestion of soil). These results suggest that the concentrations of arsenic and radium-226 in soil may pose an elevated risk at the residence. However, comparison to the background soil sample results shown in Table 4.68 shows that the arsenic and radium-226 levels in the residential soil sample are within the range of background levels for arsenic (1.1 to 25.7 mg/Kg) and radium-226 (0.49 to 13.2 pCi/g) and below the average arsenic (9.7 mg/Kg) and average radium-226 (3.3 pCi/g) for background soil. Analytical results for the fruit produce sample collected at the residence (Table 4.68) show that arsenic and radium-226 were not detected in the sample. These findings suggest that the magnitude of risk posed by arsenic and radium-226 in soil at the residence is considered similar to the magnitude of risk posed by native soil in the area.

A comparison of analytical results for the samples collected from irrigation water sources at Residence 3 to Utah agriculture stream standards is presented in Table 4.69. As shown, analyte levels did not exceed the Utah agriculture standards in any of the samples collected from irrigation sources at the residence. Based on these findings, the irrigation water sources do not appear to be impacted by mine operations upstream of the residence and are not expected to pose a threat as irrigation sources for the residence.

The radon monitoring results for the detectors placed in the bathroom at each of the two homes at Residence 3 are summarized as follows:

- Primary Home
  - Exposure: 121.6 pCi/L over 174-day monitoring period
  - Average: 0.7 pCi/L per day
- Secondary Home
  - Exposure: 154.3 pCi/L over 144-day monitoring period
  - Average: 1.1 pCi/L per day

The 0.7 and 1.1 pCi/L per day values are below the EPA recommended indoor standard of 4 pCi/L per day, and therefore, radon is not considered to be of concern at the residence.

4.9 Streamlined Risk Evaluation Summary

An overall summary of human-health risk evaluation results for the mines comprising the La Sal Creek Watershed Project is presented in Table 4.70. Water draining from the Firefly/Pygmy Mine, Vanadium Queen Mine, and Blue Cap Mine pose low risk to campers at the mines. However, it is suspected that contaminants are leaching from the waste rock dumps as a result of the adit drainage infiltrating the dump materials; thereby potentially degrading groundwater and surface-water quality downgradient of the mines. Waste rock poses a potential threat to campers at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines. Gamma exposure is the principal threat posed to campers at these mines. In addition, above background arsenic levels in waste rock comprising portions of the mine dumps at the Firefly/Pygmy Mine, Vanadium Queen, and Blue Cap Mines pose moderate risk to campers, and radionuclide activities are generally higher in waste rock than in background soil. Off-site migration of contaminants from the waste-rock dumps at the Firefly/Pygmy, Vanadium Queen, Blue Cap, and Black Hat mines as a result of erosion and mass wasting processes poses a threat to degradation of water resources (La Sal Creek and Lion Canyon Creek).

Table 4.71 presents an overall summary of ecological risk evaluation results for the mines. Although surface water draining from the Firefly/Pygmy and Vanadium Queen Mines potentially pose threats to aquatic life, the threats are not considered to be of concern because of water occurs only along isolated reaches at the mines. Adit discharge from the Blue Cap Mine represents an anthropogenic source for the headwaters of Lion Canyon Creek and is considered a significant source for the metals and radionuclide levels posing threats to aquatic life within the perennial reach of the creek. The analytes of primary concern in the adit discharge with respect to aquatic life are selenium, gross alpha, and gross beta; the elevated gross alpha and gross beta activities in the discharge are attributed to elevated concentrations of uranium and radium-226. Potential ecological threats posed by elevated levels of metals and radionuclides in waste rock (in comparison to background levels) at the mines are not considered to be of concern since the mine areas represent a small fraction of the home range for wildlife. However, future livestock grazing should be discouraged at the mines. In addition, actions taken to reduce the human-health risks associated with the mines would also reduce the ecological threats associated with these media.

5.0 REMOVAL ACTION SCOPE, GOALS, AND OBJECTIVES

This section provides the statutory framework for the removal action, removal action scope and schedule, potential ARARs, and objectives for performing removal actions at the mines comprising the La Sal Creek Watershed Project.

5.1 Statutory Framework on Removal Actions

CERCLA Section 104(c)(1), as amended by the Superfund Amendments and Reauthorization Act (SARA), and the NCP provide a framework for the removal action process. The process is a tool for accomplishing prompt risk reduction through implementation of an early action that is consistent with any final remedy that may be selected for site remediation. In some cases, the removal action itself becomes the final remedy. The removal action process is being applied to facilitate prompt risk reduction by reducing contaminant seepage and migration from the mine area.

The initial stage of the removal action process involves identifying the source and nature of a release or threatened release of hazardous substances to the environment and assessing the magnitude of the threat to public health and the environment. The primary contaminant sources at the mines comprising the La Sal Creek Watershed Project are waste-rock and, where present, water draining from the mine adits. Contaminant migration occurs as water draining from adits and runoff due to rainfall and snowmelt infiltrate and percolate through the waste-rock dumps, materials comprising the dumps are transported by way of erosion and other mass wasting processes, and as mine water discharges from the mine adits. The principal threats to public health and the environment resulting from contaminants at and released from the mines are (1) elevated metals and radionuclide levels in water draining from the mine adits, (2) elevated metals concentrations (arsenic) in waste rock, (3) elevated radionuclide activities (gross alpha, gross beta, radium-226, and thorium-230) in waste rock, and (4) elevated gamma-exposure rates.

5.2 Removal Action Scope and Schedule

The scope of this EE/CA is to evaluate appropriate removal actions to reduce threats to public health and the environment and reduce the potential for migration of contaminants from the mine areas. The EE/CA focuses on mitigation of (1) adit discharge as a contaminant source at the Blue Cap Mine and (2) the waste-rock dump as a contaminant source area at the Firefly/Pygmy Mine, Vanadium Queen Mine, Blue

Cap Mine, and Black Hat Mine. Water discharging from the Blue Cap Mine adit is a focus of the removal action because the adit discharge has been identified as a source posing threats to aquatic life and releasing contaminants to the environment. Waste rock is a focus of the removal action because waste-rock dumps have been identified as sources posing pubic-health and ecological threats and releasing contaminants to the environment. The actions for surface water at the Blue Cap Mine involve measures to reduce metals and radionuclide levels (primarily selenium, uranium, radium-226, gross alpha, and gross beta) in water discharging from the mine adit. The actions for waste rock at the Firefly/Pygmy, Vanadium Queen, Blue Cap mines involve measures to prevent or reduce adit drainage from contacting the materials comprising the waste-rock dumps; reduce threats posed by elevated metals, radionuclides, gamma-exposure rates in areas which could be potentially utilized for unsanctioned camping; and stabilize the waste-rock dumps to reduce the potential for off-site releases. The actions for waste rock at the Black Hat Mine involve measures to stabilize the waste-rock dump.

The scope of the removal action does not include directly addressing potentially contaminated groundwater beneath the mine area. Improvements in the quality of groundwater present beneath the mine area are expected to result from implementation of the actions taken to reduce the impact of the waste-rock dumps as contaminant sources.

The schedule for the removal action has not yet been determined by BLM. Implementation of the alternative selected under this EE/CA will occur upon formal issuance of an Action Memorandum.

5.3 Identification and Development of ARARs and Potential Preliminary Remediation Goals

This section presents a discussion of the framework for identifying ARARs, types of ARARs, and the identification of ARARs for removal actions implemented in support of the La Sal Creek Watershed Project.

5.3.1 Framework for Identifying Applicable or Relevant and Appropriate Requirements

Removal actions pursuant to CERCLA must attain, to the extent practicable considering the circumstances of the situation, ARARs under federal environmental or more stringent state environmental or

facility siting laws (Final NCP, 40 Code of Federal Regulations [CFR] Part 300.415(i); Preamble to Final NCP, 55 Federal Register 8695 [March 8, 1990]).

ARARs are derived from both federal and state laws. The definitions of "applicable" or "relevant and appropriate" requirements are found in the NCP, 40 CFR Part 300.5. "Applicable requirements" refer to cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental, state environmental, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site.

"Relevant and appropriate requirements" refer to cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal and state environmental, or facility siting laws that, while not “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site to attain goals protective of human health and the environment.

The analysis of requirements with respect to their relevance and appropriateness is somewhat flexible. Relevant statutes require that the types of removal or remedial actions being contemplated to treat the hazardous substances present, as well as the mine waste characteristics of the site, and other appropriate factors, be compared to determine relevant and appropriate requirements. As mentioned above, it is possible for only part of a requirement to be considered relevant and appropriate.

In addition to ARARs, this EE/CA identifies other Federal or State advisories, criteria, or guidance to be considered (TBC) for a particular release or removal action. TBCs are not required by the NCP but are meant to compliment the identified ARARs.

While the BLM may elect to obtain permits, it should be recognized that Congress limited the scope of a Federal agencies obligation to attain administrative ARAR through CERCLA Section 121(e), which states that no federal, state, or local permits requirements are required for on-site response actions. This includes procedural requirements. Only the substantive elements of other laws affect on-site responses. This permit exemption allows the response action to proceed in an expeditious manner, free from potentially lengthy delays associated with the permit process or an equivalent process. The lack of permitting authority does not impede implementation of an environmentally protective remedy, since

CERCLA and the NCP already provide a procedural blueprint for responding to the release or threatened release of a hazardous substance into the environment.

5.3.2 Types of Applicable or Relevant and Appropriate Requirements

Three different categories of ARARs exist. The first type of ARAR, chemical-specific requirements, sets health-, risk-, or technology-based concentration limits for various constituents that may be found in or discharged to an environmental media. An example of this type of ARAR could potentially include the MCLs established under the Safe Drinking Water Act (SDWA) and the National Ambient Air Quality Standards (NAAQS) established under the Clean Air Act (CAA).

A second type of ARAR, action-specific requirements, sets controls or restrictions on particular kinds of activities related to management of hazardous substances, pollutants, or contaminants. An example of an action-specific ARAR is the Clean Water Act (CWA) pretreatment standards for discharges to a publicly owned treatment works (POTW).

The third type of ARAR includes location-specific requirements, which restrict activities on the basis of site characteristics and the immediate site environment. These requirements may restrict the type of removal action that can be implemented and may impose restraints on removal or remedial actions. Limits on activities affecting floodplains are examples of location-specific ARARs.

5.3.3 Identification of Applicable or Relevant and Appropriate Requirements

Potential ARARs for the La Sal Creek Watershed Project removal actions generally include:

- Radiation control standards
- Water quality standards
- Waste disposal standards
- Archaeological/Cultural resource requirements
- Air quality standards
- Mined Land Reclamation Standards
- Threatened and endangered species

Potential ARARS for the removal actions are identified and summarized in Table 5.1. Key ARARs influencing actions at the mines comprising the La Sal Creek Watershed Project summarized as follows:

- Standards of Water Quality for Waters of the State of Utah (Rule R317-2) specifying the standards established for La Sal Creek within Utah.

- Stream Classifications and Numeric Standards for Gunnison and Dolores River Basins (5 CCR 1002-35) specifying the standards established for La Sal Creek within Colorado.

- Clean Water Act: The discharge from any passive treatment system implemented at the Site will be required to meet federal Clean Water Act requirements under the National Pollution Discharge Elimination System (NPDES) or State (Utah or Colorado) Water Quality Standards.

- National Primary Drinking Water Regulation (40 CFR Part 141): health-based standards (MCLs) established for public drinking water systems are considered relevant and appropriate for residential drinking water sources within the project area; standards modified for application to individuals using the mine sites for camping.

- Resource Conservation and Recovery Act (RCRA) Subtitle C Hazardous Waste: The waste rock and tailings generated during the operation of the mine are not considered as a "hazardous waste" as defined by RCRA 40 CFR § 261. Under 40 CFR § 261.4(b)(7), the Bevill Exclusion, solid waste from the extraction and beneficiation of ores and minerals are excluded from the definition of hazardous waste and therefore are not subject to RCRA Subtitle requirements.

- Utah Radiation Control Rule (Rule R313): Established requirements applied to the use of radiation, radiation machine, and radiation materials to ensure safety to all persons at or in the vicinity of the place of use, storage, or disposal. The rules specifies, consistent with 10 CFR Part 20.1301-1302, the total effective dose equivalent to individual members of the public from the licensed or registered operation does not exceed one mSv (0.1 rem) in a year, exclusive of the dose contributions from background radiation.

- National Historic Preservation Act: Section 106 of the National Historic Preservation Act (NHPA) of 1966, as amended (16USC 470f), requires that BLM consider the effects of actions on historic properties.

- Archaeological and Historic Preservation Act (16 USC § 469; 40 CFR 6.301(c)): Establishes procedures to provide preservation of historical and archaeological data which might be destroyed through alteration of terrain as a result of a federal construction project or a federally-licensed activity or program

The process of identifying additional ARARs or modifying this initial determination will continue in consultation with the states of Utah and Colorado as removal action alternatives are selected and further developed. The designations suggested should be used as guidance when working with Federal and State regulators involved in the final removal action.

5.4 Removal Action Objectives

Removal action objectives (RAOs) serve as a basis for selecting technologies and developing removal action alternatives. The goals of the removal actions are to reduce human-health and ecological threats associated with mine discharge and waste rock at the mines and migration of contaminants from waste-rock sources. Based on site characterization and streamlined risk evaluation results, the following specific objectives have been established for the mines comprising the La Sal Creek Watershed Project:

- Firefly/Pygmy Mine
    - Prevent or reduce the potential for water draining from the adit to contact and infiltrate the materials comprising the waste-rock dump and provide warning to visitors that the water poses potential hazard if used as a drinking-water source.
    - Prevent or reduce actual or potential exposure of nearby human or biotic populations from direct contact with the waste rock and gamma radiation emitting from waste rock in areas which could be potentially utilized for unsanctioned camping, including the mine bench, lower bench, ancillary dump, and any other potential camping areas that may be created during implementation of the action.
    - Reduce the potential for off-site migration of contaminants as a result of erosion and mass wasting processes.
    - Properly close the mine portal.
    - Discourage livestock grazing in the mine area.
    - Maintain the natural character of the mine area.
    - Satisfy state and federal ARARs.
- Vanadium Queen Mine
    - Prevent or reduce the potential for water draining from the adit to contact and infiltrate the materials comprising the waste-rock dump and provide warning to visitors that the water poses potential hazard if used as a drinking-water source.
    - Prevent or reduce actual or potential exposure of nearby human or biotic populations from direct contact with the waste rock and gamma radiation emitting from waste rock in areas which could be potentially utilized for unsanctioned camping, including the mine bench and lower bench, and any other potential camping areas that may be created during implementation of the action.
    - Reduce the potential for off-site migration of contaminants as a result of erosion and mass wasting processes.
    - Properly close the mine portal and mitigate the threat posed by the highly unstable crib wall along the crest of the upper dump.

- Discourage livestock grazing in the mine area.
- Maintain the natural character of the mine area.
- Satisfy state and federal ARARs.

- Blue Cap Mine
  - Reduce metals concentrations (selenium and uranium) and radionuclide activities (radium-226, gross alpha, and gross beta) in water discharging from the mine adit.
  - Prevent or reduce the potential for water draining from the adit to contact and infiltrate the materials comprising the waste-rock dump and provide warning to visitors that the water poses potential hazard if used as a drinking-water source.
  - Prevent or reduce actual or potential exposure of nearby human or biotic populations from direct contact with the waste rock and gamma radiation emitting from waste rock in areas which could be potentially utilized for unsanctioned camping, including the mine bench and lower bench, and any other potential camping areas that may be created during implementation of the action.
  - Remove waste rock material from the Lion Canyon Creek channel along the toe of the dump, and reduce the potential for off-site migration of contaminants as a result of erosion and mass wasting processes.
  - Properly close the mine portal and other openings in the face of the outcrop.
  - Discourage livestock grazing in the mine area.
  - Maintain the natural character of the mine area.
  - Satisfy state and federal ARARs.

- Black Hat Mine
  - Remove waste rock material from the Lion Canyon Creek channel along the toe of the lower dump and western flank of the upper dump, and reduce the potential for off-site migration of contaminants as a result of erosion and mass wasting processes.
  - Properly close the mine portal and stabilize or remove the highly unstable structure housing the mine portal.
  - Remove the ore loadout structure to mitigate potential fall hazard.
  - Discourage livestock grazing in the mine area.
  - Maintain the natural character of the mine area.
  - Satisfy state and federal ARARs.

Some reclamation actions have been completed at the Saint Patrick Mine. Based on results of the streamlined risk evaluation, no further actions are required at the mine to protect public health and the environment.

Utah and Colorado aquatic-life chronic standards are proposed to be the reclamation goals for selenium, gross alpha, and gross beta in water discharging from the Blue Cap Mine adit. The gross alpha and gross beta reclamation goals will be accomplished through reduction of uranium and radium-226 levels in the adit drainage. The surface-water reclamation goals for the Blue Cap Mine are as follows:

- Selenium, dissolved 4.6 ug/L (Colorado); 5 ug/L (Utah)
- Gross alpha 15 pCi/L (Utah)
- Gross beta 50 pCi/g (Utah)

BLM's RMC for the camper scenario are proposed to be the reclamation goals for metals in the waste-rock materials. Since these criteria are based on ingestion and inhalation, mean surficial concentrations of potential camping areas exceeding these criteria will be removed, covered, or otherwise controlled. Such actions would also reduce the threats posed to wildlife receptors at the mine. Waste-rock reclamation goals for metals at the mines are as follows:

- Antimony 50 mg/Kg
- Arsenic 20 mg/Kg
- Cadmium 70 mg/Kg
- Copper 5000 mg/Kg
- Lead 1000 mg/Kg
- Manganese 19000 mg/Kg
- Mercury 40 mg/Kg
- Nickel 2700 mg/Kg
- Selenium 700 mg/Kg
- Silver 700 mg/Kg

- Zinc 40000 mg/Kg

The removal action criteria for radionuclides in waste rock at the mines are proposed to be the gamma-exposure ceiling of 100 mRem per year exclusive of background plus ALARA. The ceiling plus ALARA will be applied to the 14-day camper scenario. ALARA will be applied to all potential camping areas where gamma-exposure rates pose a potential threat human health, including the potential camping areas where gamma-exposure rates exceed the 100 mRem per year ceiling exclusive of background. The surface materials in these areas will be removed, covered, or otherwise controlled. Such actions would also reduce the threats posed to wildlife receptors at the mine.

6.0 IDENTIFICATION AND ANALYSIS OF REMOVAL ACTION TECHNOLOGIES AND ALTERNATIVES FOR WASTE ROCK

The process for identifying and analyzing removal action alternatives presented in this section follows EPA guidance for non-time-critical removal actions (USEPA, 1993). The process entails first identifying potential response action technologies and process options, screening the technologies for applicability and feasibility in accordance with the scope of the removal action(s), and assembling the retained technologies into removal action alternatives for detailed analysis.

The scope of the removal actions for waste rock involves reduction of risks to public health and the environment associated with the materials comprising the waste-rock dumps. Technologies potentially appropriate for reducing threats posed by the waste-rock dumps were identified on the basis of literature research, vendor information, and experience in conducting other EE/CAs, feasibility studies, and mine reclamation actions.

Arsenic is the primary metal in the waste rock posing a human-health or ecological threat at the mines. Arsenic concentrations in waste rock are considered to pose moderate risk to campers in portions of the dumps at the Firefly, Vanadium Queen, and Blue Cap Mines. At these mines, gross alpha, gross beta, radium-226, and thorium-230 activities in waste rock pose greater threats to campers than do soils in the background areas, and gamma-exposure rates exceeds the human 100 mRem per annum level in portions of the dumps. Gamma-exposure rates from waste rock pose low risk to elk, the ecological receptor with near median RMCs for wildlife. The actions for mine waste rock will focus on reducing the exposure to arsenic-bearing and gamma radiation producing waste rock, particularly on the mine benches and other areas where campers would most-frequent the mine properties. Actions to prevent or reduce contaminant migration from the waste-rock dumps as a result of erosion (fluvial and wind) or other mass wasting processes will involve measures to promote physical stabilization of the dumps and retain waste-rock materials on-site.

6.1 Preliminary Screening of Removal Action Technologies for Waste Rock

This section addresses potential removal action technologies for waste rock at the mines on the basis of each technology's ability to meet the RAOs and reclamation goals identified in Section 5.4 of this report. Waste rock removal actions would be implemented to reduce the risk to human health and environment of

exposure to waste rock and potential for off-site migration of waste-rock materials. Reductions in contaminant concentrations in surface water, groundwater, and stream sediment will also likely occur as a result of the actions for waste rock at the mines.

6.1.1 Access Restrictions

Access restrictions would be implemented with the use of institutional controls. Potential process options include fencing and placement of signs to discourage direct access to controlled areas and warn of public hazards, as well as land use restrictions to limit the possible future uses of the mine area. In addition, physical modification of the ground surface may discourage long-term visitors. For example, regrading mine benches into uneven or boulder strewn surface may discourage some unsanctioned campers from camping in these areas. Although access and land use restrictions would limit and discourage direct exposure to waste-rock materials and limit future uses of the land, implementation of these process options alone would not mitigate threats to human health and the environment posed by the mines or migration of contaminated media from the waste-rock dumps. However, the controls are considered viable options when used in combination with other technologies.

Access restrictions ***are retained*** as potential technologies for mine removal action and will be combined with other process options.

6.1.2 Engineering Controls

Engineering controls are commonly used to reduce contaminant mobility by isolating the contaminated materials from direct exposure to the wind, surface water, and groundwater pathways. Engineering controls are generally not effective for the reduction of contaminant toxicity or volume. The potential engineering controls considered for the mines include surface controls, subsurface controls, containment, on-site disposal, and off-site disposal.

6.1.2.1 Surface Controls

Surface controls are used to reduce contaminant migration by minimizing water and wind erosion of the contaminated material and reducing the potential for infiltration of surface-water runoff. Used alone, surface controls do not reduce the risks of direct exposure to the contaminated materials. Surface controls are commonly combined with source control technologies where risks due to direct exposure are of

concern. The process options that are commonly used as surface controls include consolidation and erosion mitigation (run-on and run-off controls, revegetation, and grading).

Consolidation

Consolidation is used to group wastes of similar type in a common area for more efficient management or treatment. On-site wastes are excavated and transported to an identified on-site or off-site consolidation area. The technology is commonly used in mine land reclamation to consolidate similar mine wastes from small mine dumps, particularly dumps located in unstable or sensitive areas. The consolidated mine wastes can then be managed, treated, and/or disposed as a single unit.

Consolidation is considered a viable surface control process option for management of waste rock comprising the ancillary dump at the Firefly/Pygmy Mine, forming the bank of the ephemeral drainage along the northern boundary of the dump at the Firefly/Pygmy Mine, and deposited within Lion Canyon Creek channel along the toe of the mine dumps at the Blue Cap and Black Hat Mines. At the Firefly/Pygmy Mine, the materials comprising the ancillary dump would be excavated and transported to the mine area for consolidation with waste rock in the primary dump. Similarly, waste rock forming the bank of the adjacent drainage would be excavated and moved to the central portion of the dump for management. At the Blue Cap and Black Hat Mines, waste rock deposited within the Lion Canyon Creek channel along the toe of the dumps would be excavated and transported to the primary dump at each mine for management.

Consolidation ***is retained*** as a potential surface control process for the ancillary mine dump and bank of the ephemeral drainage adjacent to the dump at the Firefly/Pygmy Mine and for waste rock deposited within the Lion Canyon Creek channel along the toe of the dumps at the Blue Cap and Black Hat Mines.

Erosion Mitigation

Of concern at the La Sal Creek Mines is the transport of waste rock offsite by the fluvial processes associated with storm runoff, wind transport, and mass wasting processes. Erosion of waste-rock dumps at the Firefly/Pygmy, Vanadium Queen, Blue Cap, and Black Mines is evident by the development of gullies within the dumps, visible deposits of waste rock in ephemeral drainages below the dumps, and the results of radiological surveys and sediment sampling. In the case of the Blue Cap Mine, erosion is actively occurring at the toe of the dump within the Lion Canyon Creek drainage channel. Further erosion occurred during the summer of 2004, when a flood event eroded the toe of the dump and transported waste downstream.

Erosion mitigation includes but is not limited to run-on and run-off control, revegetation, and grading. Erosion mitigation can be accomplished by constructing diversions to channel surface water away from or around the contaminated area, regrading to lessen slopes and waste rock from fluvial channels, covering the contaminated material with erosion resistant materials such as natural or synthetic fabrics, and revegetating the surface of the contaminated area. Erosion protection is commonly a critical component of on-site reclamation efforts.

Erosion protection ***is retained*** as a potential surface control for the removal actions.

Run-On and Run-Off Control

Run-on and run-off controls are used to prevent run-off from upslope areas (run-on) from contacting the contaminated material and to control run-off derived from precipitation falling on contaminated or otherwise disturbed areas. Controls include the use of earthen berms, V-ditches, channel diversions, and gravel drains (French drains). Run-on and run-off controls are commonly a critical component of on-site reclamation efforts.

Run-on and run-off control ***is retained*** as a potential surface control process for the removal actions.

Revegetation

Revegetation is commonly used to stabilize surficial materials by reducing the potential for wind and surface-water erosion and minimize water infiltration through plant evapotranspiration processes. Revegetation is usually accompanied with ground preparation (grading or scarifying) and commonly requires application of soil amendments (nutrients and organic matter) as well as additives to improve pH conditions and water-storage capacity. Soil must be imported at sites where sufficient topsoil is not available on-site. Revegetation success is largely dependent on proper seed selection, site preparation, mulching, irrigation requirements, and fertilization. Proper seed mixes will consist of a diverse set of native species.

Revegetation ***is retained*** as a potential surface control process for the removal actions.

Grading

Grading is used to consolidate mine waste materials, control erosion by decreasing side slopes associated with contaminated areas, construct diversion structures and run-on/run-off controls, and improve site

aesthetics. Regrading work may include slope regrading and, in a broad sense, slope reinforcement (retaining walls). This improvement may include the construction of retaining walls to create terraces or benches, and armored or lined surfaces to protect against channel bank erosion. Armoring surfaces with gunite (shotcrete) or rip-rap, or establishing vegetation are common methods used to prevent erosion of diversion channels and structures. Grading may be conducted by the use of mechanized equipment, or in cases of remote, excessively steep, or restricted working space areas, manual labor is required.

Grading ***is retained*** as a potential surface control process for the mine removal action.

6.1.2.2 Subsurface Control

Subsurface controls are used to reduce the potential for interaction between contaminated materials and groundwater. The controls are generally designed to intercept upgradient groundwater and direct the flow away from or around the contaminated material. Potential passive control measures include the use of low-permeability liners, slurry walls, and intercept drains (e.g., French drains).

Site characterization efforts associated with this EE/CA did not focus on the characterization of groundwater in the waste rock materials or peripheral areas at the La Sal Creek Mines. However, characterization work conducted in April 2004 included the drilling of multiple borings in the waste rock on the benches of each mine. The borehole information indicated that (1) waste rock at the mines generally occurs as a veneer of variable thickness that overlies the natural steep slopes below the benches, (2) only one boring, boring FF 5, intercepted groundwater at a depth of 21.5 ft near the interface of waste rock and native materials at the Firefly Mine; all other borings also penetrated native materials, (3) groundwater within waste rock is expected to only occur in areas where adit discharge water infiltrates into the surface of the waste-rock, and (4) no significant seepage was delineated within or in the vicinity of the toes of the waste rock dumps. Based on these findings, subsurface controls are not warranted at the mines, and therefore subsurface control technologies ***are not retained*** for the removal actions

6.1.2.3 Containment

Containment is used as an on-site source control measure and involves capping the waste-rock material in place. By capping the material and implementing appropriate erosion controls, the technology can be used to eliminate direct exposure to the contaminated materials, reduce radiation exposure, reduce surface

water infiltration, and create a land surface that can support vegetation. Prior to cap construction, regrading to reduce side slopes is commonly required to mitigate the potential for erosion.

Cap design is dependent on site-specific conditions and the intended function of the system. Caps can range from a one-layer system of vegetated soil to a complex multi-layer system consisting of soil and geosynthetic materials of low permeability. The cap cover is commonly vegetated to reduce soil moisture through plant uptake and evapotranspiration, limit soil erosion, improve aesthetics, and support future natural and productive use of the mine area. In all cases, caps should be designed to ensure that cover materials are less permeable than natural subsoils beneath the contained mine waste to avoid retention of water within the unit.

Cover designs commonly considered at mines include natural-rock covers, soil covers, composite natural covers consisting of a low-permeability soil/clay layer overlain with native soil/rock, and geotextile covers with natural-rock or native soil cap. Low-permeability soil/clay or geotextile materials are incorporated in cover designs at mines where removal action objectives include preventing direct precipitation from infiltrating the waste-rock materials. Of these design options, natural-rock and/or soil covers are considered most applicable at the mines.

Containment with the use of a vegetated soil cover is considered a viable technology for the waste-rock materials at the mines. The technology could be used to satisfy the removal action objectives by effectively reducing direct contact with and gamma-exposure rates from the waste-rock materials in potential camping areas at the mines. In conjunction with revegetation and run-on controls, the technology would also reduce infiltration of direct precipitation and runoff into the waste rock in the covered areas.

The construction of structures/features to control off-site migration of materials is also considered a containment process option. The structures/features typically used at mines to control off-site migration of materials include those designed to capture sediment while allowing water to pass through the feature (e.g., structural silt fences), water retention features (e.g., sedimentation ponds) in combination with constructed channels to direct flow to the feature, and retaining structures (constructed walls or earthern berms) designed to capture materials transported from the slope of the dump as a result of mass wasting.

Containment with a vegetated soil cover to eliminate direct exposure to waste rock and constructed structures/features to mitigate off-site migration of materials ***is retained*** as a potential technology for the removal actions.

6.1.2.4 On-Site Disposal

On-site disposal is used as an on-site, surface source control measure. The technology is implemented by excavating the contaminated materials and placing the materials in an engineered, on-site repository. Prior to placement in the on-site repository, the contaminated material may be treated to stabilize or solidify the material, reduce mobility of contaminants, or remove contaminants through dissolution or leaching and precipitation processes. Repository design is a function of the characteristics of the mine waste and underlying hydrogeology. Potential designs range from an unlined repository with a vegetated soil cover to a fully lined and capped containment cell. Cover designs potentially applicable at the mines include a natural-rock cover, a soil cover, a composite natural cover consisting of a low-permeability soil/clay layer overlain with native soil/rock, and a geotextile cover with a natural-rock or native soil cap. A leachate collection system may be incorporated in the design to allow monitoring and proper management of any leachate within the repository.

Construction of an on-site repository is not a viable option for the mines, because of extremely limited suitable terrain. Construction of an on-site repository would require significant excavation work at each mine site to create a bench of the appropriate size to receive the waste rock. Such a disturbance of natural resources may be viewed as inconsistent with project goals and therefore unacceptable.

On-site disposal ***is not retained*** as a potential technology for the removal actions.

6.1.2.5 Mine Disposal

Mine disposal is a technology used to remove and isolate the source materials. This technology is implemented by excavating the mine waste and depositing it in the former mine workings. The technology is effective in that the source is moved to an isolated location where there is no direct exposure or contact with the mine waste materials. In addition, the mine waste is no longer subject to areal recharge and infiltration by precipitation and subsequent generation of contaminated leachate. The disadvantages to mine disposal include (1) the costs associated with mine rehabilitation, (2) the feasibility

of transporting the waste rock into the mine, and (3) the potential production of contaminated mine drainage after the waste rock has been placed in the mine.

The workings at the La Sal Creek mines may provide favorable locations for the waste rock provided the workings are of suitable condition and volume to receive the mine waste. However, mine disposal cannot be fully assessed until the mine workings have been properly inspected. If the BLM was to conduct mine inspections to assess the condition of the workings with respect to safety, integrity, and source of mine water and determine the volume available for disposal of the mine waste, mine disposal ***would be retained*** as a potentially viable technology for the mine removal action. Because no plans have been made by the BLM to conduct the necessary mine inspections at this time, mine disposal is not considered in the detailed analysis of alternatives in this document.

6.1.2.6 Off-Site Disposal

Off-site disposal is used as a source control measure. The technology involves excavating the contaminated materials and transporting the materials to an off-site area for disposal. The off-site area could be an area designated for consolidation of similar mine wastes (e.g., nearby waste rock material), an engineered disposal area or repository constructed for similar mine wastes, a permitted solid waste landfill, or a hazardous waste permitted facility. If the mine waste is to be transported off-site to a solid waste landfill, testing would be required to determine if the material has characteristics of a hazardous waste. Required analyses would include reactivity, corrosivity, and ignitability (RCI) testing and Toxicity Characteristic Leaching Procedure (TCLP) testing. If the material fails the RCI and/or TCLP criteria established for assessment of hazardous characteristics, the mine waste could not be placed in a solid waste landfill and would either need to be treated on-site and retested prior to disposal, or transported to a RCRA-permitted facility.

Off-site disposal in a repository designed specifically to receive the project waste rock would preferably require the use of nearby BLM or other federal land. It is conceivable that other abandoned mines, or mines on private land may serve as an effective disposal site. As described under “On-Site Disposal”, the technology is implemented by excavating the contaminated materials and placing the materials in an engineered repository. Prior to placement in the off-site repository, the contaminated material may be treated to stabilize or solidify the material, reduce mobility of contaminants, or remove contaminants through dissolution or leaching and precipitation processes. Repository design is a function of the characteristics of the mine waste and underlying hydrogeology. Potential designs range from an unlined

repository with a vegetated soil cover to a fully lined and capped containment cell. Potentially applicable cover designs include a natural-rock cover, a soil cover, a natural composite cover consisting of a low-permeability soil/clay layer overlain by rock/native soil, a geotextile cover with a natural-rock cap, and geotextile cover with soil cap. A leachate collection system may be incorporated in the design to allow monitoring and proper management of any leachate within the repository.

There are currently several disadvantages to the use of off-site disposal as a means to manage mine waste at the mine. These disadvantages are as follows:

- Disposal of the mine waste at a permitted solid waste or RCRA facility is not considered an option due to high transportation and disposal costs relative to the costs associated with viable on-site management options.
- The BLM would retain liability for the mine waste under any off-site disposal scenario.
- There currently are no mine-waste repositories or engineered disposal areas on BLM-managed lands in the vicinity of the mine.
- An investigation of potential off-site locations at existing privately held mine sites or disposal facilities has not been conducted.
- No suitable areas on nearby BLM-managed lands have been identified by the BLM to date for construction of an off-site repository; there are no suitable areas on BLM land in close proximity to the mines due to topography.
- Siting of a repository would require a thorough characterization study of at least one potential site followed by design and construction phases.
- Transport of waste rock would require significant road improvements and the possible construction of new roads which would increase overall disturbance associated with the mines.
- Significant transportation issues would be encountered regarding the transport of material on public roads, traffic requirements, and impacts to the roads themselves.
- The removal of waste rock would not be consistent with goals of maintaining historical mining character of the area.

Disposal at a repository constructed on nearby BLM-managed lands is the most probable option for off-site disposal of mine waste at the mine. Advantages of an off-site disposal repository include:

- Permanent placement of waste rock from all mines in a single controlled and stable site with negligible associated risk.
- Reduction in long-term monitoring costs that would otherwise involve multiple mine sites.
- Opportunity to use the site for disposal of other mine wastes.

If the BLM was to identify a suitable location, off-site disposal in a constructed repository ***would be retained*** as a potential technology for the mine removal action. Any identified location would need to be characterized to support repository design. At this time, the BLM has not conducted the studies necessary to assess potential repository locations and these studies are outside of the scope of work for this contract; therefore, off-site disposal in a constructed repository is not considered in the detailed analysis of alternatives in this document.

6.1.3 In-Situ Physical/Chemical Treatment

In-situ physical/chemical treatment allows the contaminated material to be treated without excavation and transportation. The treatment objective is to reduce the mobility and toxicity of contaminants while maintaining the mine waste essentially in place. Because treatment generally involves adding reagents to the contaminated media, in-situ treatment processes generally provide less control than ex-situ processes. The in-situ physical/chemical treatment technologies that are potentially applicable at the mines include soil washing, stabilization/solidification, and phytoremediation.

6.1.3.1 In-Situ Soil Washing

In-situ soil flushing involves flushing contaminants from the material with water or other suitable aqueous solutions. It is accomplished by passing the extraction fluids through the in-place media using an injection or infiltration process. The extraction fluids must then be recovered for additional treatment. Applicable target contaminant groups include inorganics (including radionuclides).

Several factors limit the applicability of the technology at the mines, including:

- Laboratory and field treatability studies would be required before soil washing could be selected as a remedy.
- Heterogeneity of the in-place materials (extraction fluids will tend to flow along preferential pathways within the material, reducing the overall effectiveness of the technology).
- As flushing progresses, reactions between the waste rock and fluids may reduce contaminant mobility.
- Full containment and capture of extraction fluids would be difficult to ensure and maintain over the duration of the treatment process.

- Treatment of the waste-stream would require study and implementation of waste treatment would likely be costly.
- Above-ground separation and treatment costs for recovered fluids would likely make the technology less cost-effective than other potential technologies.
- Metals present in the waste rock would require an aggressive acid leaching process with possible extended treatment times which would limit short-term effectiveness and elevate costs considerably.

In-situ soil washing ***is not retained*** as a potential technology for the removal actions.

6.1.3.2 In-Situ Stabilization/Solidification

In-situ stabilization/solidification is accomplished by inducing chemical reactions between the treatment media and contaminants to reduce contaminant mobility (stabilization) or enclosing the contaminants within an inert, stabilized mass (solidification). Stabilization processes used to treat mine waste of high metal sulfide content commonly involves combining reagents such as lime, limestone, calcium hydroxide, and fly ash with the mine waste to raise the pH and thereby reduce the mobility of metals.

Ore materials at the La Sal Creek Mines are not sulfide rich and the pH of the waste rock is expected to be basic ($\geq$ 8.0 s.u.). The results of the SPLP analyses indicate that the only contaminant exceeding a Leaching RMC at the mines was selenium. Contaminants that consistently exceeded soil background concentrations by 10 to 100 times at all mine sites included arsenic, uranium, and selenium. Reagents known to be effective in the stabilization of these metals include lime (selenium) and phosphate (arsenic). Such reagents bind with metals in the waste to form relatively insoluble compounds. For the treatment of selenium, the addition of an aggressive lime reagent (calcium hydroxide) may be necessary to achieve the desired result. However, the addition of lime to immobilize selenium may not be compatible with immobilization of uranium as the formation of mobile uranyl carbonate complexes may occur. Stabilization of uranium may be achieved by an iron reagent or organic matter to provide a reducing chemical environment. Solidification of mine wastes typically involves combining solidifying agents (e.g., cement) with the mine waste to encapsulate the material and immobilize contaminants.
General limitations for use of in-situ stabilization/solidification technology include the following:

- Most stabilization reagents render the metal contaminants insoluble, but do not remove them from the site. The risk associated with the newly formed compounds is not well studied.
- Metals stabilized with reagents would not be compatible with a combined removal effort using phytoremediation, i.e. reagent use would eliminate the need for phytoextraction methods.

- The addition and mixing of reagents are more difficult than for ex-situ treatment and the process would be extremely challenging for the steep dump faces.
- Depth of mine waste may limit mixing to only the upper portion of the waste-rock bench and dump. The treated waste rock would have to be furrowed in place or excavated for effective mixing and solidification.
- External effects of weather (e.g., freeze-thaw cycles and wind erosion) and physical disturbance (e.g., water erosion and other mass wasting processes) may significantly affect the integrity of the stabilized mass and contaminant mobility.
- Treatability testing may be required to support effective implementation of the technology.
- The use of stabilization or solidifying agents may be cost prohibitive, particularly in remote areas.
- Other technologies (i.e., containment) could be more easily implemented to mitigate threats to public health and the environment as a result of the elevated metal concentrations and gamma-exposure rates associated with the waste rock.

Recognizing that there are certain limitations associated with this technology, in-situ stabilization with the use of a metal-binding or solidifying agent to solidify the mine waste is considered cost-prohibitive if applied to the entire mine dumps at each mine and the latter would not support maintaining the natural character of the mine area.

In-situ stabilization/solidification ***is not retained*** as a potential technology for the removal actions.

6.1.3.3 Phytoremediation

Phytoremediation is the use of plants to reduce or stabilize metals toxicity in soils and water. The different categories of phytoremediation include phytoextraction, the use of plants to remove soil contaminants by uptake into plant tissue; phytotransformation, where plants transform soil contaminants into less toxic forms, e.g. the phytovolatilization of selenium; rhizofiltration, the use of plant roots to sorb, precipitate, and concentrate contaminants in flowing water; and phytostabilization, where plants are used to help contain contaminants in place (Schnoor 1997). More recent research on the phytoremediation of metals in soils and mine wastes has focused on the development and use of hyperaccumulators, or plants that have a high tolerance for accumulating high levels of metals, in particular zinc, cadmium, nickel, lead, chromium, and selenium (Chaney and others 1997).

The administrative decision to implement phytoremediation may require a commitment to a long-term project with a strict monitoring and maintenance schedule, especially if phytoextraction is used. The suitability of phytoremediation to each mine site is dependent on a number of physical factors including climate, contaminant concentration and mobility, soil properties, site aspect and topography and drainage to name a few. Literature research conducted for this EE/CA showed that a good number of plant species have been investigated for the removal of arsenic, selenium, and uranium and that very little to no information was found on phytoremediation of vanadium and radium. Although research has focused on plant species more common to temperate or wet climates, some plant species show promise in the semi-arid climate of the La Sal Creek area, including species native to the region. Some potential advantages of phytoremediation include:

- Generally, low capital and operative costs.
- Reduces leaching and off-site migration of contaminants.
- Aesthetically appealing – mining character of sites remains intact.
- May be limited to period of time to reduce contaminant in surface soils – not necessarily perpetual treatment.
- May be self-sustaining providing drought- and salt-tolerant plants are used.
- Metal-recycling is an option if plants hyperaccumulate and are harvested.

Some potential disadvantages of phytoremediation include:

- The phytoextraction method is not a passive technology; the plants would need to be harvested in order to remove the contaminant. Without harvesting, off-site migration of contaminants may still occur or increase, e.g. the transport of metal-containing dead vegetation by wind, gravity, or animals.
- Other phytoremediation methods will involve some degree of monitoring and maintenance.
- If plants are harvested, the biomass must be disposed of in a landfill or incinerator, composted, or undergo metal recovery treatment.
- The method may result in toxic plants or increase receptor exposure by bioaccumulation in certain animals and increase metal movement in the food chain.
- One-hundred percent removal will not be achieved.
- Some soils/waste require soil amendments to enhance plant accumulation. In high pH soils, the addition of acid may be required. A negative affect of acid amendments could be the mobilization of metals in the subsurface below the root zone.

It should be realized that implementation of phytoremediation may run counter to other remediation techniques that could be implemented at the mines. For example, the installation of a soil or rock composite earth cover on benches to mitigate the radiation exposure dose may not be compatible to planting phytoremediating plants in the same areas. However, while phytoremediation may not serve as the main remediation technique, it can be used in conjunction with other stabilization or in situ remediation technologies (phytostabilization). The plant species that have shown some promise for phytoremediation of metals occurring at the La Sal Creek Mines are summarized as follows:

- Arsenic:
    - Mouse ear cress (*Arabidopsis thaliana*) occurs in Utah and the species is a model plant used in microbiology research. Transgenic versions have been produced that are arsenic hyperaccumulators (Chaney and others 1997).
    - Vetivergrass. This grass species is reportedly tolerant to variations in climate and has been reported to accumulate arsenic, selenium, and other metals (Truong 2000). No field studies data was found on its application in the western United States.
    - Colonial bentgrass (*Agrostis castellana, Agrostis tenuis*). *Agrostis castellana* was noted in www.psat.wa.gov/Publications/ LID_tech_**manual**05/**lid**_index.htm and experiments with *Agrotis tenuis* was reported by Hartley-Whitaker and others (2001).
    - Common velvet grass (*Holcus lantus L.*). Reported by Hartley-Whitaker and others (2001) to accumulate moderate amounts of arsenic.
- Uranium:
    - Russian thistle (*Salsola tragus*). A noxious weed in Colorado and Utah, reported to be an effective accumulator of uranium (Ulmer-Scholle and others 2004).
    - Quinoa (*Chenopodium quinoa*). Reported to be an effective accumulator of uranium (Ulmer-Scholle and others 2004).
    - Purple amaranth (*Amaranthus blitum*). Reported to be an effective accumulator of uranium. Purple amaranth, along with Russian thistle and quinoa absorb most of the uranium before flowering and setting seeds (Ulmer-Scholle and others 2004).
    - Indian mustard (*Brassica juncea*). Listed in 43 states, not including Colorado and Utah, as a noxious weed. Occurs in Utah and is noted for ability to adapt to heat and drought. This plant is also a good base metal accumulator (Huang and others 1998).
- Selenium:
    - Indian mustard (*Brassica juncea*). Listed in 43 states, not including Colorado and Utah, as a noxious weed. Occurs in Utah and is noted for ability to adapt to heat and drought. This plant volatilizes selenium into dimethylselenide (Souza and others 2000) and is also a good base metal accumulator (Huang and others 1998).

- Milk Vetch (*Astragalus spp*). Numerous species are common to Colorado and Utah. Pickering and others (2003) reported that *A. bisulcatus* accumulated up to 0.65% (wt/wt) Se.
- Tall fescue *(Lolium arundinaceum)*. This common grass or similar varieties will accumulate and volatilize selenium (Banuelos and others 1997a).
- Birds-foot trefoil (*Lotus corniculatus or L utahensis*) (Banuelos and others 1997a)
- Rape (*Brassica napus*) (Banuelos and others 1997b)

In the search for plants that accumulate the contaminants of concern at the La Sal Creek mine sites, it is important to consider the characteristics of native plants that currently exist at the sites (in accordance with Executive Order 13112). Field characterization work did not reveal abundant vegetation on the waste rock slopes (dump faces), however a number of native plant species common to all mine site benches included white sweet clover (*Melilotus officinalis* or *alba*), gray or purple aster (*Machaeranthera canescens* (Pursh), and rubber rabbitbrush (*Chrysothamnus nauseous*). Curlycup gumweed (*Grindelia squarrosa* (Pursh) Dunal), another common native plant was identified on the Vanadium Queen Mine site. Sharmasarkar and Vance (2003) found that the plant species *Grindelia squarrosa* (Pursh) Dunal, and *Melilotus officinalis* (or *alba*), used for reclamation of a uranium mine accumulated up to 1,170 mg/kg and 95 mg/kg selenium, respectively in soils in the mine area. A species of vetch (Two-groove milk vetch [sp. *Astralgalus bisulcatus Hook. A. Gray*.]) also accumulated selenium exceeding 1,000 mg/kg. It is apparent that some native plants have the potential for metal accumulation. Further research and planning are required to develop a suite of native (or transgenic) plants suitable to accumulate metals in the soils and waste rock at the La Sal Creek Mines.

Although phytoremediation is considered a viable technology for application at the La Sal Creek Mines, the technology ***is not retained*** with respect to phytoextraction, phytotransformation, and phytovolatilization for the removal actions for the following reasons:

- The technology is not passive and would require long-term maintenance.
- Additional studies and testing would be required to develop an effective species list.
- Harvested plants would require disposal which could present liabilities issues for the government.
- Other less costly and more readily implementable options are available for mitigation of risks and contaminant migration at the mines.

Phytoremediation ***is retained*** as a potential technology with respect to phytostabilization, including the use of vegetation to promote consumption of water through evapotranspiration.

6.1.4 Ex-Situ Physical/Chemical Treatment

Ex-situ physical/chemical treatment assumes that the material is excavated and then treated to reduce mobility, toxicity, and/or volume prior to placement or disposal. The ex-situ process options potentially applicable at the mines include physical separation, soil washing, chemical extraction, chemical reduction/oxidation, soil washing, stabilization/solidification, and reprocessing.

6.1.4.1 Physical Separation

Physical separation is used to concentrate contaminated solids by separating more highly contaminated fractions of the material from less contaminated and/or uncontaminated fractions. Physical separation is commonly accomplished by passing the material through sieves and screens of varying sizes to concentrate contaminants into smaller volumes. This sieving separation process is based on the tendency of contaminants to bind, either chemically or physically, to the finer fraction of the material. Therefore, contaminants may be concentrated into smaller volumes by separating the finer fraction material from the coarser fraction. Mine-waste materials may also be physically separated on the basis of characterization data, with mine-waste materials having similar properties and contaminant concentration being segregated from less contaminated materials. This process would require labor-intensive efforts in visually segregating the waste rock types, the use of on-site x-ray fluorescence spectroscopy (XRF) equipment, and radiological equipment. The resulting contaminated fraction can then be managed, treated, or properly disposed.

Physical separation of the materials comprising the mine dumps on the basis of characterization data is considered an option at the mines. However, application of the technology at the mines would require that additional site characterization be performed to support segregation of the waste-dump materials into mine waste of different contaminant concentrations or categories, and natural soils and colluvium. Even though surface radiological surveys were conducted during the April 2004 site characterization work, additional measurements would be needed to characterize all of the waste rock and confirm initial field measurements. The additional characterization could be performed prior to treatment by collecting waste rock and soil samples for laboratory analysis or simultaneous with treatment using the observational approach coupled with on-site testing (e.g., gamma-exposure rate and gamma-count rate measurements

and XRF analysis). Excavation and detailed characterization of the entire volume of material comprising the mine dumps would be a significant task. Automation of the process (e.g. powered screen decks and conveyors) would be required.

The disadvantage of physical separation is the high costs expected to be incurred with a potentially intensive characterization effort and excavation and separation of waste rock. Although the areas to be excavated would primarily include the mine benches, data indicate that the separation of deeper horizons would be necessary. Once separation is complete, the more contaminated material would need further removal treatment. Because characterization has not been conducted to the degree necessary to support segregation of the material, it is not certain that physical separation presents a clear advantage.

Physical separation ***is not retained*** as a potential technology for the removal actions.

6.1.4.2 Ex-Situ Soil Washing

Soil washing is a water-based process for separating the finer fraction (including sorbed contaminants) from the bulk mass of the mine-waste material. The wash water may be augmented with a basic leaching reagent, surfactant, pH adjustment, or chelating agent to help remove contaminants. Contaminants are removed from the matrix materials by either (1) dissolving or suspending the contaminants in the wash solution or (2) concentrating the contaminants into a smaller volume of material through particle size separation. Other treatment process options must be used to treat the recovered wash solutions and concentrated volume of contaminated material.

Several factors limit the applicability of ex-situ soil washing at the mine, including:

- Lack of characterization data indicating that contaminant levels vary between the finer fraction and bulk mass of the waste rock dumps.
- Lack of a nearby source of clean water.
- Treatability testing would be required to support selection of the alternative.
- The method would generate wash solution waste that would require treatment (potentially including additional steps to remove any washing solvent in the treated residuals) or disposal.

Soil washing ***is not retained*** as a potential technology for the removal actions.

6.1.4.3 Ex-Situ Chemical Extraction

Chemical extraction is used to reduce the volume of contaminated material that must be treated. The process is similar to soil washing but uses a chemical extract rather than water to dissolve contaminants. The process consists of mixing the contaminated material with a chemical extractant that enhances contaminant dissolution. Physical separation processes are commonly used before chemical extraction to grade the material into coarse and fine fractions. Chemical extraction is commonly implemented by introducing hydrochloric acid into the fine fraction in a contained vessel. The acid is allowed to remain in contact with the material for a prescribed residence time, determined on the basis of the material properties, contaminants types, and contaminant concentrations. The resulting sludge (extractant and material being treated) is continuously removed from the vessel and the extractant is separated from the material. The solids are then rinsed with water to remove entrained acids and contaminants, dewatered, and mixed with lime and fertilizer to neutralize any residual acid. The extraction solution and rinse waters are regenerated using commercially available precipitants (e.g., sodium hydroxide or lime) along with a flocculent that removes the contaminants and reforms the acid.

Several factors limit the use of chemical extraction at the mine, including:

- Use and storage of hazardous chemicals in a remote, environmentally sensitive, and unsecured area.
- Residual acid in treated solids must be neutralized.
- Treatability testing would be required to assess the effectiveness of the technology for the mine wastes at the mines.
- The technology would likely not be cost effective given the high capital costs and the multiple mine locations in the study area.
- Potentially hazardous sludge generated during implementation would require additional treatment prior to disposal.

Chemical extraction ***is not retained*** as a potential technology for the removal actions.

6.1.4.4 Ex-Situ Chemical Reduction/Oxidation

Chemical reduction/oxidation technology is used to chemically convert hazardous constituents to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The process involves the transfer of electrons from one compound to another so that one reactant is oxidized and one

is reduced. The oxidizing agents most commonly used are ozone, hydrogen peroxide, hypochlorites, chlorine, and chlorine dioxide.

Several factors limit the applicability of chemical reduction/oxidation at the mines, including:

- Treatability testing required to support selection of the process and the type and amount of oxidizing agent.
- Use and storage of hazardous chemicals in remote, environmentally sensitive, and unsecured area.
- Potentially high cost relative to the other options given the multiple mine locations in the study area.
- Disposal of potentially hazardous waste.

Chemical reduction/oxidation ***is not retained*** as a potential technology for the removal actions.

6.1.4.5 Ex-Situ Stabilization/Solidification

As with in-situ stabilization/solidification, the technology is used to reduce the mobility of contaminants in the environment through both physical and chemical processes. The technology involves inducing chemical reactions between the treatment media and contaminants to reduce contaminant mobility (stabilization) or binding or enclosing the contaminants within a stabilized mass (solidification). Common stabilization processes used to treat mine waste involve combining reagents such as lime, limestone, and calcium hydroxide with the mine waste to raise the pH and thereby reduce the mobility of metals. The pH of the waste rock at the mines is expected to be moderately high (above 8.0 s.u.) so the addition of a more aggressive reagent (calcium hydroxide) may be necessary to achieve the desired reactions. Another potential stabilization technique for metal-contaminated soils and finely divided waste rock is the introduction of metal-binding reagents such as a phosphate compound. Such reagents bind with metals in the waste to form relatively insoluble compounds. Solidification of mine wastes typically involves combining solidifying agents (e.g., cement) with the mine waste to solidify the material and immobilize contaminants. The technology may be combined with physical separation processes to reduce the volume of material to be treated prior to placement or disposal.

General limitations for use of ex-situ stabilization/solidification technology include the following:

- Virtually all waste rock would have to be excavated for effective mixing and solidification.

- Long term external effects of weather (e.g., freeze-thaw cycles and wind erosion) and physical disturbance (e.g., avalanches, water erosion, and other mass wasting processes) may significantly affect the integrity of the stabilized mass and contaminant mobility.
- Treatability testing is usually required to support effective implementation of the technology.
- The use of stabilizing and solidifying agents may be cost prohibitive, particularly in remote areas.

Recognizing that there are certain limitations associated with this technology, ex-situ stabilization with the use of a metal-binding or solidifying agent to solidify the mine waste is considered cost-prohibitive if applied to the entire mine dumps at each mine and the latter would not support maintaining the natural character of the mine area. Alternatively, chemical stabilization may be implemented in the top 6-inches or 1 foot of waste rock on the mine benches. This option may be considered viable to mitigate existing areas of metals contamination, but does not effectively mitigate radiation exposure. Furthermore, if only the benches were treated with a stabilization reagent, it is likely the contribution of selenium and other metals from leachate generated on the dump face will continue to impact surface water quality in some areas, particularly at the Blue Cap Mine.

Solidification is considered a less viable process option because solidification and handling of the mine waste would likely be cost prohibitive as well as the potential that environmental conditions at the mine (e.g., freeze thaw cycles) could adversely impact the integrity of the solidified mass over time. In addition, solidification would not be consistent with the goal of maintaining the natural character of the mine.

Ex-situ stabilization with lime/limestone ***is not retained*** as a potential technology for the removal actions.

6.1.4.6 Reprocessing

Reprocessing is used as a source control measure. The technology is implemented by excavating the waste rock and transporting the material to an existing mill for processing and metals recovery. Use of the technology is limited to waste rock containing economically recoverable metals. Assuming all waste rock at the mine could be transported off-site for reprocessing, the technology would effectively mitigate the potential for future contaminant seepage and migration from the mine area as well as the potential for direct contact with the materials. This technology may be of initial interest considering the recent reopening of two uranium mines and uranium milling at Cotter Corporation's mill, located in Canyon

City, Colorado. However, the technology is not considered viable for the mine removal action because of the potential liability that would be retained by the BLM for mine wastes generated during reprocessing.

Reprocessing ***is not retained*** as a potential technology for the removal actions.

6.2 Response Alternative Development for Waste Rock

EPA guidance for non-time-critical removal actions recommends that only the most qualified technologies that apply to the media or source of contamination be evaluated in detail in the EE/CA. In accordance with this guidance, removal action alternatives for the mine were developed by combining the retained technologies to form alternative actions for meeting the RAOs and goals of the project. The most promising technologies that were identified and retained through the screening process are summarized in Table 6.1.

The technologies retained through the screening process have been combined to form a common set of removal action alternatives for waste rock at the mines (Table 6.2); a no-action alternative will be included in the analysis to serve as a baseline against which the potential alternatives can be compared. These common alternatives provide the basis for the detailed analysis of alternatives; however, the alternatives are further refined for application at each mine. In addition, a common set of technologies/process options will be incorporated in each alternative, including access restrictions (signage/fencing and land use), surface control (run-on and run-off control), and mitigation of physical hazards (portal closure and structure removal). Application of these common technologies is discussed in Section 6.4, and details regarding each potential alternative are provided in Section 6.5 of this document.

6.3 Basis for Analysis of Alternatives

The removal action alternatives listed in Table 6.2 are described and evaluated in Section 6.5 based on each alternative's effectiveness, implementability, and cost. The effectiveness, implementability, and cost evaluation criteria are discussed in further detail in the following subsections.

6.3.1 Effectiveness

The effectiveness of an alternative refers to its ability to meet the objectives within the scope of the removal action. Effectiveness focuses on the degree to which an alternative provides adequate overall protection of human health and the environment; complies with ARARs; affords long-term protection by minimizing residual risk; provides reduction of toxicity, mobility, or volume of hazardous material; and minimizes short-term effects.

Overall Protection of Human Health and the Environment

This evaluation criterion serves as a final check in assessing whether each alternative provides adequate protection of human health and the environment. Evaluations of long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs (discussed below) were used to assess the overall protection of human health and the environment. This criterion was also used to evaluate how risks would be eliminated, reduced, or controlled through treatment, engineering, or institutional controls.

Compliance with ARARs

Compliance with ARARs addresses the ability of each alternative to attain the requirements that are applicable or relevant and appropriate to the alternative. The summary table of potential ARARs listed in Table 5.1 and discussed in Section 5.3 provides the basis for the evaluation.

Long-term Effectiveness and Permanence

Long-term effectiveness and permanence addresses the risk remaining at the mines after remediation goals have been met.

Reduction of Toxicity, Mobility, or Volume

Reduction of toxicity, mobility, or volume addresses the statutory preference for selecting removal actions that permanently and significantly reduce toxicity, mobility, and/or volume of hazardous materials at the mine. This preference is satisfied when treatment is used to reduce principal risks through destruction or irreversible reductions of toxicity, mobility, and/or volume. This criterion focuses on the following:

- The degree of expected reduction in toxicity, mobility, or volume.
- The degree of irreversibility of the process.
- The type and quantity of residuals remaining following treatment.

- The statutory preference for treatment as a principal element.
- The relative amount of hazardous materials that will be destroyed or treated.

Short-term Effectiveness

Short-term effectiveness addresses the effects of each alternative in the protection of human health and the environment during the construction and implementation phase. The following factors were addressed during the evaluation process:

- Protection of the workers during removal actions - This factor assesses threats that may be posed to workers and the effectiveness and reliability of measures to be taken.
- Environmental impacts of the removal action - This factor addresses the potential adverse environmental impacts that may result from construction and implementation of a removal alternative, and evaluates the reliability of mitigation measures, if necessary, to prevent or reduce potential impacts.
- Time lapse before achievement of removal objectives - This factor includes an estimate of the time required to achieve protection for the mine.

6.3.2 Implementability

Implementability evaluates the technical feasibility of implementing each alternative, the availability of required services and materials during its implementation, and the administrative feasibility.

Technical Feasibility and Availability

Technical feasibility and availability addresses the ability of the alternative to implement the removal action, the reliability of the alternative, and the availability of services and materials. The following factors were addressed during the evaluation process:

- Ability to construct and operate the technology
- Reliability of the technology
- Ease of undertaking additional removal actions or remedial actions if necessary
- Ability to monitor effectiveness of removal action
- Availability of necessary equipment, materials, and personnel

Administrative Feasibility

The administrative feasibility criterion addresses the following factors:

- Likelihood of public acceptance of the alternative, including state and local concerns
- Activities needed to coordinate with other agencies
- Ability to obtain necessary approvals or permits

6.3.3 Cost

The cost of each alternative is evaluated based on estimates of projected capital cost (e.g., construction costs) and operation and maintenance costs over a 10-year period. It is assumed that periodic inspections of the mines will be performed by BLM personnel; therefore, no costs have been included for BLM inspections in these evaluations. Operation and maintenance costs are projected for the actions that will periodically required to ensure effectiveness of the alternatives. Cost estimates are based on vendor information, cost-estimating guides, and actual costs incurred during similar activities at other mines.

The net present value of each alternative was calculated as the sum of total capital cost plus the present worth of annual operation and maintenance cost (assuming an interest rate of 5 percent over a 10-year period). An interest rate of 5 percent was used on the basis of the EPA guidance (USEPA, 1988).

6.4 Commonalities of Alternatives

Certain technologies/process options and ancillary construction activities are common to the removal action alternatives for waste rock listed in Table 6.2. Common technologies/process options include access restrictions (signage/fencing and land use), surface control (run-on and run-off control), and mitigation of physical hazards (portal closure and structure removal). Common ancillary construction activities include access road improvement, site safety and health, and permitting and coordination.

6.4.1 Access Restrictions

Access restrictions will be implemented during implementation of the removal actions to prevent unauthorized access to active work areas and discourage access to reclaimed areas. The controls will include fencing and/or natural barriers and signage. Natural barriers will be used to prevent vehicle

access to the mine areas upon completion of the removal actions. Land use restrictions will be used to discourage livestock grazing at the mine areas.

6.4.2 Surface Controls

Surface controls are incorporated in each proposed alternative to manage surface water run-on and run-off. Erosion protection measures would be implemented to stabilize disturbed areas and protect the integrity of diversion control structures. Riprap (large boulders) will be installed as necessary to prevent erosion of constructed diversion channels and existing drainages within or adjacent to the mine area.

Run-on controls will be installed to prevent stormwater runoff from entering areas disturbed during implementation of the removal action. Run-off controls will be installed to reduce the sediment load carried by runoff originating within the disturbed areas. Run-on, run-off, and drainage controls may include earthen berms, riprap, V-ditches, hay bails, and temporary silt fencing. As a surface control , temporary silt fences, consisting of synthetic geotextile or equivalent material, are used to assist in control of sediment-laden runoff from disturbed areas. Temporary silt fences help contain overland flow and filter suspended soil particles from water, preventing environmental damage to areas adjacent to construction sites. Temporary silt fences and other temporary control features are maintained until permanent control measures have been installed at the site. The structural silt fence described in Section 6.5 is an example of a permanent control and stabilization measure constructed as part of the action.

6.4.3 Mitigation of Physical Hazards

Physical hazards at the mines will be mitigated during implementation of the removal actions. These hazards include open adits and other openings to underground areas, unstable structures, and unstable crib walls.

The adit at each mine is currently open and provides access to the underground workings. All primary and ancillary adits providing access to the workings will be closed in accordance with Utah Division of Oil, Gas, and Mining and Colorado Division of Minerals and Geology adit-closure guidelines. The adits will be closed during the time of year when bats are least likely to be visiting the mines. Because water currently discharges from the adits at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines, components of adit closures at these mines will include collection box or other structures to contain water within the adit and piping or other opening to allow water to freely drain from the mine. Some

excavation of the hillside surrounding adit and removal of existing portal structures will be required to properly close the adit at the Vanadium Queen Mine.

The structures to be removed as part of the actions include the crib wall at the Vanadium Queen Mine and the portal house and ore loadout at the Black Hat Mine. All trash and debris within the reclaimed area(s) at each mine will be removed for proper disposal. Proper disposal will be determined on the basis of radiological screening, and if required, analytical testing. Some such material may be incorporated into the regrading of the site. The electrical transformers present at the Vanadium Queen Mine and Blue Cap Mine will be removed by the electric utility company responsible for the transformers. Remnants of mine equipment removed to facilitate the actions will be replaced on the mine areas following implementation of the actions to preserve the mining character of the sites. The office/shop building at the Vanadium Queen Mine will remain in place; however, the compressor and electric motor housed in the structure will be removed for proper disposal. The electric motor is known to contain asbestos insulation, and therefore, will be removed such that the insulation is not disturbed.

6.4.4 Ancillary Construction Activities

Access road improvement will be conducted as an ancillary construction activity in addition to the primary reclamation actions associated with each alternative. Improvements will be limited to clearing fallen timber, boulders, and any vegetation restricting access along the road; minor grading to lessen slopes and broaden switchback turns where necessary; and some minor road widening. A V-ditch will be installed along the uphill side of the road alignments to prevent runoff originating in undisturbed areas from contacting the road surface.

The selected removal actions will be implemented in strict accordance with procedures and protocols specified in the site safety and health plan(s). The plans will address the procedures and protocols to be implemented to mitigate the physical, chemical, and radiation hazards associated with the actions. On-site monitoring will be conducted to ensure worker safety and prevent off-site releases of contamination.

In accordance with the ARARs discussed in Section 5.3, permits and coordination/consultation with various agencies and groups will be required prior to implementation of a removal action. These include federal, state, and county requirements. It is assumed that required permitting and coordination/consultation will be performed by the BLM, with contractor assistance.

While the BLM may elect to obtain permits, it should be recognized that Congress limited the scope of a Federal agencies obligation to attain administrative ARAR through CERCLA Section 121(e), which states that no federal, state, or local permits requirements are required for on-site response actions. This includes procedural requirements. Only the substantive elements of other laws affect on-site responses. This permit exemption allows the response action to proceed in an expeditious manner, free from potentially lengthy delays associated with the permit process or an equivalent process. The lack of permitting authority does not impede implementation of an environmentally protective remedy, since CERCLA and the NCP already provide a procedural blueprint for responding to the release or threatened release of a hazardous substance into the environment.

6.5 Detailed Analysis of Alternatives for Waste Rock

The potential alternatives listed in Table 6.2 have been developed for detailed analysis of effectiveness, implementability, and cost. Except for the no-action alternative, each alternative includes potential sub-alternatives as follows:

- Alternative 1: No action
- Alternative 2: Consolidation and Containment of Existing Benches
    - Sub-Alternative A: Containment of Dump Materials with Structural Silt Fence
    - Sub-Alternative B: Containment of Dump Materials with Earthen Berms
- Alternative 3: Consolidation, Regrading, and Containment
    - Sub-Alternative A: Containment of Dump Materials with Structural Silt Fence in Combination with Erosion Control and Revegetation in Graded Areas
    - Sub-Alternative B: Containment of Dump Materials with Structural Silt Fence in Combination with Revegetation Matting and/or Vegetated Terraces
    - Sub-Alternative C: Containment of Dump Materials with Earthen Berms in Combination with Erosion Control and Revegetation in Graded Areas
    - Sub-Alternative D: Containment of Dump Materials with Earthen Berms in Combination with Revegetation Matting and/or Vegetated Terraces

The structural silt fence would consist of a 3-foot high treated lumber crib wall anchored in place with vertical supports (e.g., 6-foot t-posts). The inside (uphill) face of the cribbing would be lined with permeable material (such as Mirafi® Fabric or equivalent) to provide sediment capture while allowing

water to percolate through the feature. This technology would also be used to construct vegetated terraces. The terraces would be constructed by installing 8- to 16-foot long crib walls lined with permeable material (such as Mirafi® Fabric or equivalent) at various locations on the face of the mine dump. The contained area behind the wall would be partially filled with waste rock from the surrounding slope to form a level bench. The surface of the bench would be amended with soil and essential nutrients and revegetated with native plants and grasses. Generalized maps and rough sketches showing locations for removal-action features at each mine along with typical cross-sections for the structural silt fence, earthen berm, and waste-rock containment structure are provided in Appendix D.

Earthen berms would be constructed by excavating a 3- to 5-foot deep by approximately 10-foot wide swale into waste rock and native soil along the toe of the dump. The surface of the berms would be revegetated to stabilize the features. The constructed berms would be covered with native soil, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. For cost estimating purposes, it is assumed that a sufficient amount of native soil to cover the berms and promote revegetation efforts could be obtained on-site or generated during implementation of the action.

The activities to be performed at each mine are further defined in the following analysis of each alternative.

6.5.1 Alternative No. 1: No Action

The no action alternative assumes that no steps are taken to promote reclamation of the mine. The waste rock comprising mine benches and mine dumps will continue to pose threats to public health and the environment and to be transported from the mine areas by way of wind and water erosion and mass wasting. No further investigation or monitoring would be required at the mine.

6.5.1.1 Effectiveness

The overall effectiveness of the no-action alternative is low. Metals and radionuclide contamination at the mines would continue to threaten human health and the environment, and no reductions in the human health and ecological risk associated with direct exposure to the mine waste would be expected in the future. Waste rock and sediment would continue to migrate from the mine areas by way of erosion and transport by water, wind, and mass wasting. Therefore, the toxicity, mobility, and volume of metals contaminants would not be reduced under the no-action alternative. The no-action alternative would not

lessen the BLM's existing liabilities associated with the mines or promote improvement of environmental conditions within the La Sal Creek Watershed.

6.5.1.2 Implementability

Implementation of the no-action alternative would be technically and administratively feasible. However, consideration would need to be given to public acceptance of the alternative. The no-action alternative may not be acceptable to the public, regulatory agencies, and the BLM.

6.5.1.3 Cost

No capital costs or indirect costs would be incurred under the no-action alternative. Other than periodic inspections by BLM personnel, no operation and maintenance costs would be incurred under the no-action alternative. However, the long-term costs associated with the no-action alternative are not known because there would be an ongoing risk associated with continued contaminant migration from the mines and direct exposure to humans and wildlife.

6.5.2 Alternative No. 2: Consolidation and Containment of Existing Benches

The general activities to be performed under Alternative 2 include (1) consolidation of off-site accumulation of waste rock to the waste-rock dump, (2) containment of the material covering the existing mine benches with a 6-inch-thick, vegetated soil cover, (3) erosion control measures to reduce erosion of the dump materials, and (4) containment (physical stabilization) of dump materials in accordance with Sub-Alternatives A or B.

At the Firefly/Pygmy Mine, Alternative 2 would be implemented as follows:

- The mine portal will be closed by constructing a cement seal, keyed into bedrock, at the portal opening. A galvanized metal grate or pipe will be incorporated into the base of the seal to allow mine water to freely discharge from the mine. A lockable, metal access door will also be incorporated into the seal to allow authorized access for inspection and maintenance of the mine-water drainage system and, if warranted, access to the workings in the future.

- Waste rock comprising the ancillary dump would be excavated, transported to the mine area, and placed on the upper and lower mine bench. Waste rock forming the bank of the ephemeral drainage along the north boundary of the waste-rock dump would be pulled away from the drainage and placed on the upper and/or lower mine bench. To discourage unsanctioned camping and promote revegetation efforts, a hummocky, uneven surface will be created as waste rock from

the ancillary dump and perimeter drainage is placed on the mine benches. Riprap consisting of native boulders from nearby colluvial debris would be placed on the exposed slope along the drainage to prevent future erosion of the dump and encroachment of the drainage.

- Erosion control measures such as installation of jute logs on the slope of the upper dump, construction of diversion channels along the base of the upper slope, and revegetation of the existing slope of the upper dump will be implemented to promote stabilization of the slope and reduce the potential for waste rock and sediment to migrate onto the lower bench. Erosion control measures such as jute logs in combination with revegetation will be implemented on the slope of the lower dump to promote stabilization of the lower dump.

- Remaining potential camping areas on the mine benches will be covered with a 6-inch thick layer of soil. Where possible, soil for the cover material will be obtained at or in the vicinity of the mine. However, onsite/nearby sources of soil are expected to be limited, and therefore, soil will likely need to be imported from an approved and permitted soil borrow area. For cost estimating purposes, it is assumed that a soil source will be identified within a 50-mile radius of the project area, encompassing the towns of Moab, Utah, Monticello, Utah, and Naturita, Colorado. The surface of the covered areas will be fertilized and seeded in accordance with BLM guidelines.
- Containment (physical stabilization) of the materials comprising the lower dump will be accomplished in accordance with one of the following sub-alternatives:

    - Sub-Alternative 2A: A structural silt fence will be installed along the perimeter of the dump to reduce the potential for sediment to migrate from the dump. The general location of the structural silt fence is shown on the generalized site map provided in Appendix D.

    - Sub-Alternative 2B: An earthen berm will be constructed by excavating a 3- to 5-foot deep by approximately 10-foot wide swale into waste rock and native soil along the toe of the dump. The surface of the berm will be revegetated to stabilize the features. The constructed berm will be covered with native soil, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. A sediment retention feature/pond will be constructed at the toe of the dump as shown on the generalized site map provided in Appendix D. The berm will provide a natural containment structure for capture of mass-wasting debris and will divert surface-water runoff from the dump to the constructed sediment retention feature/pond. Drop structures or jute logs will be installed across the alignment of the berm drainage to prevent erosion and promote sediment capture. The sediment retention feature/pond will consist of small depression or bermed area designed to detain surface water flows and promote sediment deposition before run-off waters are allowed to leave the site. The perimeter of the sediment retention feature/pond will be fenced per BLM guidelines to discourage livestock and wildlife from accessing ponded water. The size of the pond should be evaluated during design of the selected action on the basis of the possible maximum storm event.

At the Vanadium Queen Mine, Alternative 2 would be implemented as follows:

- The mine portal will be closed by seating a 3-foot diameter by 20-foot long culvert into the adit. A lockable metal grate will be installed with the culvert to allow authorized access for inspection and maintenance of the mine-water drainage system and, if warranted, access to the workings in

the future. The existing, unstable portal canopy structure will then be removed and colluvium from the overlying hillside will be collapsed around the culvert to form a permanent seal. The material comprising the portal canopy will be properly disposed. Proper disposal will be determined on the basis of radiological screening. If not radiologically contaminated, material will be disposed offsite, otherwise the material will be managed onsite.

- Cribbing formerly used to stabilize the upper dump at the ore loadout will be removed to mitigate physical hazard of the unstable wall as discussed in Section 6.4.3. The material comprising the crib wall will be properly disposed. Proper disposal will be determined on the basis of radiological screening. If not radiologically contaminated, material will be disposed offsite, otherwise the material will be managed onsite.

- Erosion control measures such as installation of jute logs on the slope of the upper dump, construction of diversion channels along the base of the upper slope, and revegetation of the existing slope of the upper dump will be implemented to promote stabilization of the slope and reduce the potential for waste rock and sediment to migrate onto the lower bench. Erosion control measures such as jute logs in combination with revegetation will be implemented on the slope of the lower dump to promote stabilization of the lower dump.

- Potential camping areas on the mine benches will be covered with a 6-inch thick layer of soil. Prior to placement of the soil cover, the surface of the mine benches will be hummocky or pock-marked to create an uneven surface to discourage unsanctioned camping and promote revegetation efforts. Where possible, soil for the cover material will be obtained at or in the vicinity of the mine. However, onsite/nearby sources of soil are expected to be limited, and therefore, soil will likely need to be imported from an approved and permitted soil borrow area. For cost estimating purposes, it is assumed that a soil source will be identified within a 50-mile radius of the project area, encompassing the towns of Moab, Utah, Monticello, Utah, and Naturita, Colorado. The surface of the covered areas will be fertilized and seeded in accordance with BLM guidelines.

- Containment (physical stabilization) of the materials comprising the lower dump will be accomplished in accordance with one of the following sub-alternatives:

    - Sub-Alternative 2A: A structural silt fence will be installed along the perimeter of the dump to reduce the potential for sediment to migrate from the dump. The general location of the structural silt fence is shown on the generalized site map provided in Appendix D.

    - Sub-Alternative 2B: An earthen berm will be constructed by excavating a 3- to 5-foot deep by approximately 10-foot wide swale into waste rock and native soil along the toe of the dump. The surface of the berm will be revegetated to stabilize the features. The constructed berm will be covered with native soil, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. A sediment retention feature/pond will be constructed at the toe of the dump as shown on the generalized site map provided in Appendix D. The berm, constructed using waste-rock materials from the lower portion of the dump, will provide a natural containment structure for capture of mass-wasting debris and will divert surface-water runoff from the dump to the constructed sediment retention feature/pond. Drop structures or jute logs will be installed across the alignment of the berm drainage to prevent erosion and promote sediment capture. The sediment retention feature/pond will consist of small

depression or bermed area designed to detain surface water flows and promote sediment deposition before run-off waters are allowed to leave the site. The perimeter of the sediment retention feature/pond will be fenced per BLM guidelines to discourage livestock and wildlife from accessing ponded water. The size of the pond should be evaluated during design of the selected action on the basis of the possible maximum storm event.

At the Blue Cap Mine, Alternative 2 would be implemented as follows:

- The primary mine portal will be closed by constructing a cement seal, keyed into bedrock, at the portal opening. A galvanized metal grate or pipe will be incorporated into the base of the seal to allow mine water to freely discharge from the mine. A lockable, metal access door will also be incorporated into the seal to allow authorized access for inspection and maintenance of the mine-water drainage system and, if warranted, access to the workings in the future. The secondary portal, adjacent to the primary portal, and the smaller (door-sized) openings leading to the office and shallow storage areas will be sealed with waste rock generated during grading of the mine dump.

- Waste rock within the Lion Canyon Creek channel along the toe of the mine dump will be excavated, transported to the mine area, and placed on the mine bench. To discourage unsanctioned camping and promote revegetation efforts, a hummocky, uneven surface will be created as waste rock from the channel is placed on the mine benches.

- Remaining potential camping areas on the mine bench will be covered with a 6-inch thick layer of soil. Where possible, soil for the cover material will be obtained at or in the vicinity of the mine. However, onsite/nearby sources of soil are expected to be limited, and therefore, soil will likely need to be imported from an approved and permitted soil borrow area. For cost estimating purposes, it is assumed that a soil source will be identified within a 50-mile radius of the project area, encompassing the towns of Moab, Utah, Monticello, Utah, and Naturita, Colorado. The surface of the covered areas will be fertilized and seeded in accordance with BLM guidelines.

- An engineered waste-rock containment structure will be installed along the perimeter of the mine dump in the areas where Lion Canyon Creek is undermining the toe of the dump and waste rock is actively migrating into the Lion Canyon Creek channel as a result of erosion and mass wasting. A V-ditch will be constructed along the uphill side of the structure to direct surface-water runoff along the alignment. Check dams (or equivalent) will be placed periodically across the V-ditch to slow flow rates and promote retention of sediment before the drainage exits the mine area. A rough design sketch of the waste-rock containment structure and map showing the general location of the feature are provided in Appendix D.

- A structural silt fence will be installed along the toe of the dump in area not protected by the engineered waste-rock containment structure. This area corresponds to the central portion of the toe where the existing terrain and vegetation reduce the potential for waste rock to directly migrate into the Lion Canyon Creek channel. The general location of the structural silt fence is shown on the generalized site map provided in Appendix D. Construction of an earthen berm (Sub-Alternative 2B) in place of the structural silt fence is not feasible at the Blue Cap Mine.

- Up to 15 vegetated islands will be constructed by hand on the face of the mine dump. Vegetated islands will be established by planting groups of native saplings on the dump face. Each island

will consist of approximately 25 saplings. Native species will include but may not be limited to *Quercus gambelii* (Gambel's Oak), *Cercocarpus montanus* (Mountain Mahogany), *Chrysothamnus Nauseosus* (Rubber Rabbitbrush), and *Amelanchier alnifolia* (Utah Serviceberry). Planting will be conducted by constructing a "v-pocket" for each plant in the face of the slope. A v-pocket will consist of a hand-excavated v-shaped cut and fill, approximately 2 to 4 feet long on each wing of the v-shaped feature, with the apex of the v pointing into the slope. The cut will be supported by the installation of staked silt fencing material (Marifi® fabric or equivalent). After the v-pocket is constructed, planting of quart to gallon sized saplings will consist of first hand-excavating an appropriate size hole, amending with organic-rich top soil or compost mix material, placement of the plant, backfilling with organic-rich soil, placing a time-release fertilizer pellet, and mulching with certified weed-free straw mulch. Protective polyethylene screen may be installed around each plant. Planting should be done in late fall.

At the Black Hat Mine, Alternative 2 would be implemented as follows:

- The portal house and ore loadout structure will be dismantled and materials removed from the area for proper disposal as discussed in Section 6.4.3. Proper disposal will be determined on the basis of radiological screening. If not radiologically contaminated, material will be disposed offsite, otherwise material will be disposed onsite within the adit.

- The mine portal will be closed by constructing a cement seal, keyed into bedrock, at the portal opening. A galvanized metal grate or pipe will be incorporated into the base of the seal to allow mine water to freely discharge from the mine. A lockable, metal access door will also be incorporated into the seal to allow authorized access to the workings in the future.

- Waste rock within the Lion Canyon Creek channel along the toe of the lower dump and waste rock forming the bank of the channel along the flank of the upper dump will be excavated, transported to the mine area, and placed on the mine bench. To discourage unsanctioned camping, an uneven surface will be created as waste rock is placed on the mine bench. Riprap consisting of native boulders from nearby colluvial debris would be placed on the exposed slope along the drainage to prevent future erosion of the dump and encroachment of the drainage.

- Erosion control measures such as jute logs in combination with revegetation will be implemented on the slope of the upper dump and, where feasible, on the lower dump to promote physical stabilization of the dump materials. The use of structural silt fences (Sub-Alternative 2A) or earthen berms (Sub-Alternative 2B) are not warranted at the mine because waste rock will be largely removed from the lower dump and containment of material from the upper dump is provided by the existing bench along the toe of the dump.

Operation and maintenance activities associated with Alternative 2 would include periodic inspections to monitor the integrity of the soil cover, erosion control measures, and revegetation success. Maintenance activities will include repair/replacement of site fencing, erosion-control features (jute logs or equivalent), and structural silt fences. In addition, sediment and debris will periodically be removed from the berm drainage channels and sediment-retention features/ponds at the Firefly/Pygmy and Vanadium Queen Mines and the waste-rock containment structure at the Blue Cap Mine. At each mine, accumulated waste rock and sediment will be moved to a suitable area on the former mine bench. The material will be placed

by first removing the soil cover in the disposal area. The material will then be placed on the exposed waste rock surface and soil cover replaced, and revegetated. Access routes (including the primary access road and construction access roads) will not be reclaimed upon completion of the action; however, natural barriers/boulders will be placed across the access routes to discourage vehicle (including ATVs) access. The natural barriers will be removed when necessary to allow access for maintenance activities.

6.5.2.1 Effectiveness

Overall, Alternative 2 would provide a moderately effective mechanism for protection of human health and the environment at the mines. Through the use of consolidation, the alternative would reduce the footprint of contaminated areas at the Firefly/Pygmy Mine and reduce the potential for surface water in the drainages adjacent to the dumps from contacting waste rock at the Firefly/Pygmy, Blue Cap and Black Hat Mines. The threats posed to public health and the environment as a result of direct contact with waste rock would be effectively mitigated by covering the mine benches with soil, rendering the surface of each bench less attractive for unsanctioned camping, and preventing vehicular access to the mines. However, the alternative would provide less effective mitigation of the threats resulting from direct contact with waste rock at the mines where lower, secondary benches are present (the Firefly/Pygmy and Vanadium Queen Mines). Although erosion protection measures would be implemented on the slopes of the upper dumps that overlie the lower benches, such measures alone would not provide long-term protection against erosion and mass wasting because of the steepness of the existing slopes. Future transport of material from the upper slopes onto the reclaimed lower benches would provide renewed opportunities for direct contact with waste rock by individuals and wildlife that may visit the mines and by potential unsanctioned camping on the lower benches.

Of the two sub-alternatives for erosion control and containment of dump materials, the use of an earthen berm in combination with a sediment retention feature/pond (Sub-Alternative 2B) would provide the greatest protection against off-site migration of contaminated sediment and waste rock. Sub-Alternative 2B would provide effective, long-term containment of sediment and waste rock at the mines. While the use of a structural silt fence (Sub-Alternative 2A) could effectively be used to reduce the potential for off-site migration of sediment and, to a lesser degree, waste rock, the effectiveness of the feature would likely decrease over time as sediment and debris begin to clog the permeable material used to construct the features. In addition, the silt-fence feature would be provide less volume for retention of sediment and waste rock than would earthen berms in combination with sediment retention features/ponds. Because structural silt fences would be more prone to damage than earthen berms, more frequent inspections and

maintenance would be required to ensure the long-term effectiveness of the silt fence sub-alternative. The use of vegetated islands has proven to be an effective means of promoting revegetation and stabilization of dump materials at other mines; however, the effectiveness of the technology would likely be limited at the Blue Cap Mine. The integrity of islands and vegetation success would likely be limited at the Blue Cap Mine because of the steepness and overall stability of the mine dump. The construction of an engineered waste-rock containment structure at the Blue Cap Mine would provide a highly effective mechanism of stabilizing the lower portion of the mine dump and preventing waste rock from entering the Lion Canyon Creek channel.

General compliance with ARARs would be achieved with implementation of Alternative 2. Greater compliance with ARARs would be expected with Sub-Alternative 2B than Sub-Alternative 2A since berms and sediment retention features/ponds would provide greater long-term effectiveness than would structural silt fences.

There would likely be some short-term ecological and environmental effects due to construction activities from dust generation, vegetation clearing, and general construction noise during implementation of Alternative 2. These short-term impacts would be minimal, with exposure pathways minimized through engineering controls and personal protective equipment.

6.5.2.2 Implementability

Implementation of Alternative 2 is technically feasible at the mines. The effectiveness of the alternative could be readily monitored by performing periodic gamma scans across sensitive areas (mine benches/unsanctioned camping areas and drainages or access routes for off-site migration of contaminated media). The necessary resources and materials for Alternative 2 are readily available from nearby sources; however, the BLM has not yet identified a soil borrow area in the vicinity of the project area. Sub-Alternative 2B would provide greater long-term reliability and require less frequent inspection and maintenance than Sub-Alternative 2A.

Alternative 2 is also administratively feasible at the mines; however, some public concerns (including local, state, and federal) would likely be encountered. These concerns would likely include the potential for recontamination of reclaimed areas (lower benches) due to continued erosion on the steep, overlying slope of the upper dumps at the Firefly/Pygmy and Vanadium Queen Mines and impacts to the natural character of the areas caused by the installation of unnatural features such as structural silt fences.

Applicable permit and agency coordination requirements, as identified in Section 5.3 of this document, would need to be met before commencing construction operations.

6.5.2.3 Cost

The estimated costs for Alternative No. 2 at the Firefly/Pygmy, Vanadium Queen, Blue Cap, and Black Hat Mines are presented in Table 6.3, and a detailed breakdown of the costs is provided in Appendix E. Direct capital costs include mobilization and the labor and materials required to complete the ancillary construction activities discussed in Section 6.4 and activities associated with the removal action alternative discussed in Section 6.5.2 above. The total capital costs for Alternative 2 at each mine are summarized as follows:

- Firefly/Pygmy Mine
  - Sub-Alternative 2A: $ 147,149
  - Sub-Alternative 2B: $ 159,859
- Vanadium Queen Mine
  - Sub-Alternative 2A: $ 105,367
  - Sub-Alternative 2B: $ 113,839
- Blue Cap Mine
  - Alternative 2: $ 293,610
- Black Hat Mine
  - Alternative 2: $ 36,691

Operation and maintenance costs correspond to the costs associated with post-reclamation inspection and maintenance (including vegetation-success, erosion-control monitoring, and adit closure integrity). It is assumed that post-reclamation inspections will be performed by BLM personnel on an annual basis for a 10-year period; no costs for BLM inspections are included in this analysis. Projected maintenance costs assume the following:

- Work performed by a contractor
- 10 percent of site fencing and 10 percent of erosion-control features (jute logs or equivalent) will require replacement every year
- 10 percent of the structural silt fences (Sub-Alternative 2A) will require replacement every two years
- Sediment and debris will be cleared from the earthen berms and sediment retention features/ponds at the Firefly/Pygmy and Vanadium Queen Mines (Sub-Alternative 2B) every 10 years

- At the Blue Cap Mine, waste rock and debris will be cleared from the waste-rock containment structure every five years

The total net present value of Alternative 2 at each mine over 10 years (total capital cost plus present worth of operation and maintenance cost) is summarized as follows:

- Firefly/Pygmy Mine
  - Sub-Alternative 2A: $ 171,535
  - Sub-Alternative 2B: $ 198,080
- Vanadium Queen Mine
  - Sub-Alternative 2A: $ 122,175
  - Sub-Alternative 2B: $ 139,762
- Blue Cap Mine
  - Alternative 2: $ 344,278
- Black Hat Mine
  - Alternative 2: $ 45,870

6.5.3 Alternative No. 3: Consolidation, Regrading, and Containment

The general activities to be performed under Alternative 3 include (1) consolidation of off-site accumulation of waste rock to the waste-rock dump, (2) regrading slopes forming the upper dumps, (3) regrading slopes of lower dumps where feasible, (4) containment of the material covering the remaining mine benches and regraded areas which could be potentially utilized for unsanctioned camping with a 6-inch-thick, vegetated soil cover, (5) erosion control measures to reduce erosion of the dump materials, and (6) containment (physical stabilization) of dump materials in accordance with Sub-Alternatives A, B, C, or D.

At the Firefly/Pygmy Mine, Alternative 3 would be implemented as follows:

- The mine portal will be closed by constructing a cement seal, keyed into bedrock, at the portal opening. A galvanized metal grate or pipe will be incorporated into the base of the seal to allow mine water to freely discharge from the mine. A lockable, metal access door will also be incorporated into the seal to allow authorized access for inspection and maintenance of the mine-water drainage system and, if warranted, access to the workings in the future.

- Waste rock comprising the ancillary dump would be excavated, transported to the mine area, and placed on the upper and lower mine bench. Waste rock forming the bank of the ephemeral drainage along the north boundary of the waste-rock dump would be pulled away from the drainage and placed on the upper and/or lower mine bench. To discourage unsanctioned camping

and promote revegetation efforts, a hummocky, uneven surface will be created as waste rock from the ancillary dump and perimeter drainage is placed on the mine benches. Riprap consisting of native boulders from nearby colluvial debris would be placed on the exposed slope along the drainage to prevent future erosion of the dump and encroachment of the drainage.

- The slope of the upper dump will be regraded to form a more stable configuration. Grading will involve consolidation of the material from the brows of the upper and lower dumps on the lower bench, resulting in a lower angle slope across the upper portion of the dump and a less abrupt break in slope between the upper and lower portions of the dump. A shallow berm or excavated channel will be installed along the perimeter of the graded area to direct stormwater runoff away from the face of the lower dump. The perimeter channel will terminate in an area where stormwater can be discharged away from waste rock.

- The lower portion of the dump will be regraded where feasible. Grading on this portion of the dump will focus on filling scours and drainage channels to reduce the potential for channeled, high-velocity flow of stormwater runoff.

- Remaining potential camping areas on the mine bench and regraded areas will be covered with a 6-inch thick layer of soil. Where possible, soil for the cover material will be obtained at or in the vicinity of the mine. However, onsite/nearby sources of soil are expected to be limited, and therefore, soil will likely need to be imported from an approved and permitted soil borrow area. For cost estimating purposes, it is assumed that a soil source will be identified within a 50-mile radius of the project area, encompassing the towns of Moab, Utah, Monticello, Utah, and Naturita, Colorado. The surface of the covered areas will be fertilized and seeded in accordance with BLM guidelines.

- Containment (physical stabilization) of the materials comprising the mine dump will be accomplished in accordance with one of the following sub-alternatives:

    - Sub-Alternative 3A: Erosion control measures such as installation of jute logs in combination with revegetation along the erosion control feature will be implemented on the regraded upper slope of the dump and across the lower slope of the dump. Waste rock in the areas to be vegetated will be amended with soil and appropriate nutrients to promote vegetation growth. A structural silt fence will be installed along the perimeter of the dump to reduce the potential for sediment to migrate from the dump. The general location of the structural silt fence is shown on the generalized site map provided in Appendix D.

    - Sub-Alternative 3B: The regraded surface of the upper dump will be amended with topsoil and nutrients required for vegetation growth, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. Up to five vegetated terraces will be installed on the lower dump. A structural silt fence will be installed along the perimeter of the dump to reduce the potential for sediment to migrate from the dump. The general location of the structural silt fence is shown on the generalized site map provided in Appendix D.

    - Sub-Alternative 3C: Erosion control measures such as installation of jute logs in combination with revegetation along the erosion control feature will be implemented on the regraded upper slope of the dump and across the lower slope of the dump. Waste rock in the areas to be vegetated will be amended with soil and appropriate nutrients to

promote vegetation growth. An earthen berm will be constructed by excavating a 3- to 5-foot deep by approximately 10-foot wide swale into waste rock and native soil along the toe of the dump. The surface of the berm will be revegetated to stabilize the features. The constructed berm will be covered with native soil, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. A sediment retention feature/pond will be constructed at the toe of the dump as on the generalized site map provided in Appendix D. The berm will provide a natural containment structure for capture of mass-wasting debris and will divert stormwater runoff from the dump to the constructed sediment retention feature/pond. Drop structures or jute logs will be installed across the alignment of the berm drainage to prevent erosion and promote sediment capture. The sediment retention feature/pond will consist of small depression or bermed area designed to detain surface water flows and promote sediment deposition before run-off waters are allowed to leave the site. The perimeter of the sediment retention feature/pond will be fenced per BLM guidelines to discourage livestock and wildlife from accessing ponded water. The size of the pond should be evaluated during design of the selected action on the basis of the possible maximum storm event.

- Sub-Alternative 3D: The regraded surface of the upper dump will be amended with topsoil and nutrients required for vegetation growth, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. Up to five vegetated terraces will be installed on the lower dump. An earthen berm will be constructed by excavating a 3- to 5-foot deep by approximately 10-foot wide swale into waste rock and native soil along the toe of the dump. The surface of the berm will be revegetated to stabilize the features. The constructed berm will be covered with native soil, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. A sediment retention feature/pond will be constructed at the toe of the dump as on the generalized site map provided in Appendix D. The berm will provide a natural containment structure for capture of mass-wasting debris and will divert stormwater runoff from the dump to the constructed sediment retention feature/pond. Drop structures or jute logs will be installed across the alignment of the berm drainage to prevent erosion and promote sediment capture. The sediment retention feature/pond will consist of small depression or bermed area designed to detain surface water flows and promote sediment deposition before run-off waters are allowed to leave the site. The perimeter of the sediment retention feature/pond will be fenced per BLM guidelines to discourage livestock and wildlife from accessing ponded water. The size of the pond should be evaluated during design of the selected action on the basis of the possible maximum storm event.

At the Vanadium Queen Mine, Alternative 3 would be implemented as follows:

- The mine portal will be closed by seating a 3-foot diameter by 20-foot long culvert into the adit. A lockable metal grate will be installed with the culvert to allow authorized access for inspection and maintenance of the mine-water drainage system and, if warranted, access to the workings in the future. The existing, unstable portal canopy structure will then be removed and colluvium from the overlying hillside will be collapsed around the culvert to form a permanent seal. The material comprising the portal canopy will be properly disposed. Proper disposal will be determined on the basis of radiological screening. If not radiologically contaminated, material will be disposed offsite, otherwise material will be disposed onsite within the adit.

- Cribbing formerly used to stabilize the upper dump at the ore loadout will be removed to mitigate physical hazard of the unstable wall as discussed in Section 6.4.3. The material comprising the crib wall will be properly disposed. Proper disposal will be determined on the basis of radiological screening. If not radiologically contaminated, material will be disposed offsite, otherwise material will be disposed onsite within the adit.

- The slope of the upper dump will be regraded to form a more stable configuration. Grading will involve consolidation of material from the brows of the upper and lower dumps on the loadout bench, resulting in a lower angle slope across the upper portion of the dump and a less abrupt break in slope between the upper and lower portions of the dump.

- The lower portion of the dump will be regraded where feasible. Grading on this portion of the dump will focus on filling scours and drainage channels to reduce the potential for channeled, high-velocity flow of stormwater runoff.

- Remaining potential camping areas on the mine bench and regraded areas will be covered with a 6-inch thick layer of soil. Where possible, soil for the cover material will be obtained at or in the vicinity of the mine. However, onsite/nearby sources of soil are expected to be limited, and therefore, soil will likely need to be imported from an approved and permitted soil borrow area. For cost estimating purposes, it is assumed that a soil source will be identified within a 50-mile radius of the project area, encompassing the towns of Moab, Utah, Monticello, Utah, and Naturita, Colorado. The surface of the covered areas will be fertilized and seeded in accordance with BLM guidelines.

- Containment (physical stabilization) of the materials comprising the mine dump will be accomplished in accordance with one of the following sub-alternatives:

    - Sub-Alternative 3A: Erosion control measures such as installation of jute logs in combination with revegetation will be implemented on the regraded upper slope of the dump and across the lower slope of the dump. Waste rock in the areas to be vegetated will be amended with appropriate nutrients to promote vegetation growth. A structural silt fence will be installed along the perimeter of the dump to reduce the potential for sediment to migrate from the dump. The general location of the structural silt fence is shown on the generalized site map provided in Appendix D.

    - Sub-Alternative 3B: The regraded surface of the upper dump will be amended with topsoil and nutrients required for vegetation growth, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. Up to five vegetated terraces will be installed on the lower dump. A structural silt fence will be installed along the perimeter of the dump to reduce the potential for sediment to migrate from the dump. The general location of the structural silt fence is shown on the generalized site map provided in Appendix D.

    - Sub-Alternative 3C: Erosion control measures such as installation of jute logs in combination with revegetation will be implemented on the regraded upper slope of the dump and across the lower slope of the dump. Waste rock in the areas to be vegetated will be amended with appropriate nutrients to promote vegetation growth. An earthen berm will be constructed by excavating a 3- to 5-foot deep by approximately 10-foot wide swale into waste rock and native soil along the toe of the dump. The surface of the berm will be revegetated to stabilize the features. The constructed berm will be

covered with native soil, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. A sediment retention feature/pond will be constructed at the toe of the dump as shown on the generalized site map provided in Appendix D. The berm, constructed using waste-rock materials from the lower portion of the dump, will provide a natural containment structure for capture of mass-wasting debris and will divert surface-water runoff from the dump to the constructed sediment retention feature/pond. Drop structures or jute logs will be installed across the alignment of the berm drainage to prevent erosion and promote sediment capture. The sediment retention feature/pond will consist of small depression or bermed area designed to detain surface water flows and promote sediment deposition before run-off waters are allowed to leave the site. The perimeter of the sediment retention feature/pond will be fenced per BLM guidelines to discourage livestock and wildlife from accessing ponded water. The size of the pond should be evaluated during design of the selected action on the basis of the possible maximum storm event.

- Sub-Alternative 3D: The regraded surface of the upper dump will be amended with topsoil and nutrients required for vegetation growth, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. Up to five vegetated terraces will be installed on the lower dump. An earthen berm will be constructed by excavating a 3- to 5-foot deep by approximately 10-foot wide swale into waste rock and native soil along the toe of the dump. The surface of the berm will be revegetated to stabilize the features. The constructed berm will be covered with native soil, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. A sediment retention feature/pond will be constructed at the toe of the dump as shown on the generalized site map provided in Appendix D. The berm, constructed using waste-rock materials from the lower portion of the dump, will provide a natural containment structure for capture of mass-wasting debris and will divert surface-water runoff from the dump to the constructed sediment retention feature/pond. Drop structures or jute logs will be installed across the alignment of the berm drainage to prevent erosion and promote sediment capture. The sediment retention feature/pond will consist of small depression or bermed area designed to detain surface water flows and promote sediment deposition before run-off waters are allowed to leave the site. The perimeter of the sediment retention feature/pond will be fenced per BLM guidelines to discourage livestock and wildlife from accessing ponded water. The size of the pond should be evaluated during design of the selected action on the basis of the possible maximum storm event.

At the Blue Cap Mine, Alternative 3 would be implemented as follows:

- The primary mine portal will be closed by constructing a cement seal, keyed into bedrock, at the portal opening. A galvanized metal grate or pipe will be incorporated into the base of the seal to allow mine water to freely discharge from the mine. A lockable, metal access door will also be incorporated into the seal to allow authorized access for inspection and maintenance of the mine-water drainage system and, if warranted, access to the workings in the future. The secondary portal adjacent to the primary portal, and the smaller (door-sized) openings leading to the office and shallow storage areas will be sealed with waste rock generated during grading of the mine dump.
- Waste rock will be removed from the Lion Canyon Creek channel along the toe of the mine dump and either used in construction of the waste-rock containment structure (described below) or

transported to the mine bench. Waste rock will be removed from the channel using equipment positioned on a construction access road to be constructed along the base of the waste-rock dump. To discourage unsanctioned camping and promote revegetation efforts, a hummocky, uneven surface will be created as waste rock from the channel is placed on the mine benches.

- Excavation equipment positioned on the mine bench will be used to pull waste rock from the upper portion of the dump onto the bench. This material will subsequently be graded to form a gently sloping, hummocky surface over the former mine bench; minimizing the actual size of the former bench area. A berm will be constructed along the crest of the regraded slope to divert stormwater runoff away from the face of the dump. The major scour incised into the northern portion of the dump will be filled by dumping waste rock into the scour from the mine bench and moving material from the adjacent interfluvial areas into the scour.

- Remaining potential camping areas on the mine bench will be covered with a 6-inch thick layer of soil. Where possible, soil for the cover material will be obtained at or in the vicinity of the mine. However, onsite/nearby sources of soil are expected to be limited, and therefore, soil will likely need to be imported from an approved and permitted soil borrow area. For cost estimating purposes, it is assumed that a soil source will be identified within a 50-mile radius of the project area, encompassing the towns of Moab, Utah, Monticello, Utah, and Naturita, Colorado. The surface of the covered areas will be fertilized and seeded in accordance with BLM guidelines.

- Areas of the regraded upper slope of the dump that are not potential camping areas will be stabilized in accordance with one of the following modified sub-alternatives:

    - Sub-Alternative 3A: Erosion control measures such as installation of jute logs in combination with revegetation will be implemented on the regraded upper slope of the dump. Waste rock in the areas to be vegetated will be amended with appropriate nutrients to promote vegetation growth.

    - Sub-Alternative 3B. The regraded surface of the upper dump will be amended with topsoil and nutrients required for vegetation growth, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting.

- Up to 10 vegetated terraces will be constructed by hand on the face of the dump. Due to the steepness of the slope, use of non-structural erosion controls such as jute logs in combination with revegetation (Sub-Alternatives 3A and 3C) and soil/nutrient amendment in combination with erosion-control matting (Sub-Alternatives 3B and 3D) are not practical at the mine.

- An engineered waste-rock containment structure will be installed along the perimeter of the mine dump in the areas where Lion Canyon Creek is undermining the toe of the dump and waste rock is actively migrating into the Lion Canyon Creek channel as a result of erosion and mass wasting. A V-ditch will be constructed along the uphill side of the structure to direct surface-water runoff along the alignment. Check dams (or equivalent) will be placed periodically across the V-ditch to slow flow rates and promote retention of sediment before the drainage exits the mine area. A rough design sketch of the waste-rock containment structure and map showing the general location of the feature are provided in Appendix D.

- A structural silt fence will be installed along the perimeter of the dump in the areas where the engineered waste-rock containment structure is not required because the existing terrain and vegetation currently inhibit migration of waste rock into the Lion Canyon Creek channel. The

general location of the structural silt fence is shown on the generalized site map provided in Appendix D. Construction of an earthen berm (Sub-Alternatives 3B and 3D) in place of the structural silt fence is not feasible at the Blue Cap Mine.

At the Black Hat Mine, Alternative 3 would be implemented as follows:

- The portal house and ore loadout structure will be dismantled and materials removed from the area for proper disposal as discussed in Section 6.4.3. Proper disposal will be determined on the basis of radiological screening. If not radiologically contaminated, material will be disposed offsite, otherwise material will be disposed onsite within the adit.

- The mine portal will be closed by constructing a cement seal, keyed into bedrock, at the portal opening. A galvanized metal grate or pipe will be incorporated into the base of the seal to allow mine water to freely discharge from the mine. A lockable, metal access door will also be incorporated into the seal to allow authorized access to the mine workings in the future.

- Waste rock within the Lion Canyon Creek channel along the toe of the lower dump and waste rock forming the bank of the channel along the flank of the upper dump will be excavated, transported to the mine area, and placed on the mine bench. Riprap consisting of native boulders from nearby colluvial debris would be placed on the exposed slope along the drainage adjacent to the upper dump to prevent future erosion of the dump and encroachment of the drainage.

- The upper dump will be regraded to form a more stable configuration. Grading will be accomplished by cutting the brow of the dump and spreading the excavated material across the mine bench and on a portion of the bench forming the access road leading to the Blue Cap Mine; an access to the Blue Cap Mine will remain. To discourage unsanctioned camping, a hummocky, uneven surface will be created as waste rock is graded across the former mine bench and mine access road bench. The existing culvert at the Lion Canyon Creek Crossing will be removed and a shallow-water crossing constructed across the channel to provide access to the Blue Cap Mine area for operation and maintenance purposes. Riprap will be used to protect the integrity of the crossing. A shallow drainage channel or small berm will be constructed along the toe of the regraded dump to direct stormwater runoff down the access road alignment and away from Lion Canyon Creek.

- Upon completion of grading, waste rock forming the lower dump will have been removed to the extent practicable and the material comprising the upper dump will be protected from migrating to the Lion Canyon Creek channel. Therefore, the use of a structural silt fence or containment berm will not be required at the mine. Physical stabilization of the dump will be accomplished in accordance with one of the following modified sub-alternatives:

    - Sub-Alternative 3A: Erosion control measures such as installation of jute logs in combination with revegetation will be implemented on the regraded slope of the dump. Waste rock in the areas to be vegetated will be amended with appropriate nutrients to promote vegetation growth. The use of structural silt fences is not warranted at the mine because waste rock will be largely removed from the lower dump and containment of material from the upper dump is provided by the existing bench along the toe of the dump.

- Sub-Alternative 3D: The regraded surface of the upper dump will be amended with topsoil and nutrients required for vegetation growth, fertilized and seeded in accordance with BLM guidelines, and covered with erosion protection matting. Because the upper dump was largely constructed on a native soil bench, it is anticipated that a sufficient amount of native soil for surface amendment will be generated during regrading of the upper dump. The use of earthen berms is not warranted at the mine because waste rock will be largely removed from the lower dump and containment of material from the upper dump is provided by the existing bench along the toe of the dump.

Operation and maintenance activities associated with Alternative 3 would include periodic inspections to monitor the integrity of the soil cover, erosion control measures, and revegetation success. Maintenance activities will include repair/replacement of site fencing, erosion-control features (jute logs or equivalent), and structural silt fences. In addition, sediment and debris will periodically be removed from the berm drainage channels and sediment-retention features/ponds at the Firefly/Pygmy and Vanadium Queen Mines and the waste-rock containment structure at the Blue Cap Mine. At each mine, accumulated waste rock and sediment will be moved to a suitable area on the former mine bench. The material will be placed by first removing the soil cover in the disposal area, the material will then be placed on the exposed waste rock surface and soil cover replaced, and revegetated. Access routes (including the primary access road and construction access roads) will not be reclaimed upon completion of the action; however, natural barriers/boulders will be placed across the access routes to discourage vehicle (including ATVs) access. The natural barriers will be removed when necessary to allow access for maintenance activities. Under Sub-Alternatives 3A and 3B at the Firefly/Pygmy and Vanadium Queen Mines and Alternative 3 at the Blue Cap Mine, it is suspected that the structural silt fence would likely require periodic maintenance and 50 percent of the fence would need to be replaced approximately every 10 years. Under Sub-Alternatives 3C and 3D at the Firefly/Pygmy and Vanadium Queen Mines, periodic cleaning (removal of sediment) would likely be required within the berm drainage channel and sediment retention feature/pond. Accumulations of waste rock and sediment would also need to be periodically removed at the Blue Cap Mine waste-rock containment structure; therefore, access routes established to construct the structure will remain to facilitate maintenance operations. Accumulated waste rock and sediment will be moved to a suitable area on the former mine bench. The material will be placed by first removing the soil cover in the disposal area, the material will then be placed on the exposed waste rock surface and soil cover replaced, and revegetated. Access routes (including the primary access road and construction access roads) will not be reclaimed upon completion of the action; however, barriers will be placed across the access routes to discourage vehicle (including ATVs) access. The barriers will be removed when necessary to allow access for maintenance activities.

6.5.3.1 Effectiveness

Overall, Alternative 3 would provide a highly effective mechanism for protection of human health and the environment at the mines. Through the use of consolidation, the alternative would reduce the footprint of contaminated areas at the Firefly/Pygmy Mine and reduce the potential for surface water in drainages adjacent to the mines from contacting waste rock at the Firefly/Pygmy, Blue Cap and Black Hat Mines. The potential for off-site migration of waste rock and sediment would be reduced by grading the mine dumps, where feasible, and implementing erosion control measures. The threats posed to public health and the environment as a result of direct contact with waste rock would be effectively mitigated by covering the regraded mine benches and other potential camping areas with soil, rendering the surface of each area less attractive for unsanctioned camping, and preventing vehicular access (including ATVs) to the mines by placing barriers across the road; the barriers will be removed when operation and maintenance access is required.

Of the two sub-alternatives for erosion control and containment of dump materials, the use of an earthen berm in combination with a sediment retention feature/pond would provide greater protection against off-site migration of contaminated sediment and waste rock than would the use of a structural silt fence. An earthen berm in combination with a sediment retention feature/pond would provide effective, long-term containment of sediment and waste rock at the mines. While the use of a structural silt fence could effectively be used to reduce the potential for off-site migration of sediment and, to a lesser degree, waste rock, the effectiveness of the feature would likely decrease over time as sediment and debris begin to clog the permeable material used to construct the features. In addition, the silt-fence feature would be provide less volume for retention of sediment and waste rock than would earthen berms in combination with sediment retention features/ponds. Because structural silt fences would be more prone to damage than earthen berms, more frequent inspections and maintenance would be required to ensure the long-term effectiveness of the silt fence sub-alternative. The construction of an engineered waste-rock containment structure at the Blue Cap Mine would provide a highly effective mechanism of stabilizing the lower portion of the mine dump and preventing waste rock from entering the Lion Canyon Creek channel.

With respect to the erosion control measures utilized for the sub-alternatives, revegetation of graded areas with soil/nutrient amendment and erosion-protection matting in combination with construction of vegetated terraces on the steeper portions of the dumps (Sub-Alternatives 3B and 3D) would provide the greatest protection against erosion. Highly effective erosion control would be provided by revegetating and matting the entire regraded area. The vegetated terraces would be moderately effective for control of erosion on the steeper portions of the dumps. The effectiveness of the terraces would improve as

vegetation becomes established and possibly spreads from the terrace to the surrounding areas. Revegetation along isolated erosion-control features such as jute logs on the graded areas and, where feasible, on steeper portions of the dumps (Sub-Alternatives 3A and 3C) would also provide effective erosion control and dump stabilization once vegetation establishes along the features. Routine inspections and maintenance would be required to ensure the features remain in place until vegetation becomes established. Periodic repair of the features would be required, particularly where used to stabilize steeper sections of the dumps. Because Sub-Alternative 3A and 3C measures would only be implemented on isolated, linear segments of the dumps, the measures would provide less effective erosion-control protection than would the measures described for Sub-Alternatives 3B and 3D.

General compliance with ARARs would be achieved with implementation of Alternative 3. Greater compliance with ARARs would generally be expected with implementation of Sub-Alternative 3D than Sub-Alternatives 3A, 3B, or 3C. Greater compliance with ARARs would be expected because Sub-Alternative 3D provides the most effective measures for erosion control and dump stabilization and therefore, the greatest level of protection for public health and the environment.

There would likely be some short-term ecological and environmental effects due to construction activities from dust generation, vegetation clearing, and general construction noise during implementation of Alternative 3. These short-term impacts would be minimal, with exposure pathways minimized through engineering controls and personal protective equipment.

6.5.3.2 Implementability

Implementation of Alternative 3 is technically feasible at the mines. The technology could be readily implemented at each of the mines, and the necessary resources and materials for the alternative are readily available from nearby sources; however, the BLM has not yet identified a soil borrow area in the vicinity of the project area. The effectiveness of the alternative could be readily monitored by performing periodic gamma scans across sensitive areas (mine benches/potential camping areas and drainages or access routes for off-site migration of contaminated media). At the Firefly/Pygmy and Vanadium Queen Mines, the use of earthen berms under Sub-Alternatives 3C and 3D would generally provide greater long-term reliability and require less frequent inspection and maintenance than would use of structural silt fences under Sub-Alternatives 3A and 3B; the use of earthen berms is not practical at the Blue Cap Mine. Greater long-term reliability with respect to dump stabilization and revegetation success would be

expected at each mine by fully revegetating and matting graded areas and installing vegetated terraces on steep sections of the dumps as described for Sub-Alternatives 3B and 3D.

Alternative 3 is also administratively feasible at the mines; however, some public concerns (including local, state, and federal) would likely be encountered. These concerns would likely include the reliability of erosion-control measures described for Sub-Alternatives 3A and 3C and visual impacts to the natural character of the areas caused by the installation of unnatural features such as silt fences and vegetated terraces. Concerns regarding the reliability of erosion-control measures could be addressed ensuring inspections and maintenance are conducted on a routine basis. Applicable permit and agency coordination requirements, as identified in Section 5.3 of this document, would need to be met before commencing construction operations.

6.5.3.3 Cost

The estimated costs for Alternative 3 at the Firefly/Pygmy, Vanadium Queen, Blue Cap, and Black Hat Mines are presented in Table 6.3, and a detailed breakdown of the costs is provided in Appendix E. Direct capital costs include mobilization and the labor and materials required to complete the ancillary construction activities discussed in Section 6.4 and activities associated with the removal action alternative discussed in Section 6.5.3 above. The total capital costs for Alternative 3 at each mine are summarized as follows:

- Firefly/Pygmy Mine
  - Sub-Alternative 3A: $ 243,012
  - Sub-Alternative 3B: $ 305,207
  - Sub-Alternative 3C: $ 255,722
  - Sub-Alternative 3D: $ 317,917
- Vanadium Queen Mine
  - Sub-Alternative 3A: $ 108,981
  - Sub-Alternative 3B: $ 152,754
  - Sub-Alternative 3C: $ 115,577
  - Sub-Alternative 3D: $ 159,350
- Blue Cap Mine
  - Sub-Alternative 3A: $ 359,225
  - Sub-Alternative 3B: $ 386,460
- Black Hat Mine
  - Sub-Alternative 3A: $ 58,912 (excludes structural silt fences)
  - Sub-Alternative 3D: $ 67,041 (excludes earthen berms)

Operation and maintenance costs correspond to the costs associated with post-reclamation inspection and maintenance (including vegetation-success, erosion-control monitoring, and adit closure integrity). It is assumed that post-reclamation inspections will be performed by BLM personnel on an annual basis for a 10-year period; no costs for BLM inspections are included in this analysis. Projected maintenance costs assume the following:

- Work performed by a contractor
- 10 percent of site fencing and 10 percent of erosion-control features (jute logs or equivalent) will require replacement every year
- 10 percent of the structural silt fences (Sub-Alternative 3A and 3B) will require replacement every two years
- Sediment and debris will be cleared from the earthen berms and sediment retention features/ponds at the Firefly/Pygmy and Vanadium Queen Mines (Sub-Alternative 3C and 3D) every 10 years
- Waste rock and debris will be cleared from the waste-rock containment structure at the Blue Cap Mine every five years

The total net present value of Alternative 3 at each mine over 10 years (total capital cost plus present worth of operation and maintenance cost) is summarized as follows:

- Firefly/Pygmy Mine
  - Sub-Alternative 3A: $ 267,661
  - Sub-Alternative 3B: $ 326,968
  - Sub-Alternative 3C: $ 291,267
  - Sub-Alternative 3D: $ 350,575
- Vanadium Queen Mine
  - Sub-Alternative 3A: $ 129,292
  - Sub-Alternative 3B: $ 169,562
  - Sub-Alternative 3C: $ 145,004
  - Sub-Alternative 3D: $ 185,273
- Blue Cap Mine
  - Sub-Alternative 3A: $ 410,170 (excludes structural silt fences)
  - Sub-Alternative 3B: $ 434,163 (excludes earthen berms)
- Black Hat Mine
  - Sub-Alternative 3A: $ 69,031 (excludes structural silt fences)
  - Sub-Alternative 3D: $ 76,731 (excludes earthen berms)

7.0 IDENTIFICATION AND ANALYSIS OF REMOVAL ACTION TECHNOLOGIES AND ALTERNATIVES FOR MINE DRAINAGE

7.1 Preliminary Screening of Removal Action Technologies for Mine Drainage

The Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines are characterized by mine water drainage from the open adits. The Streamlined Risk Evaluation (Section 4.0) concluded that mine discharge water from the Firefly/Pygmy and Vanadium Queen Mines do not pose a significant risk to human or ecological health. However, it was suggested that the potential generation of leachate by infiltration of mine drainage through waste rock could be mitigated by separating the drainage from the underlying waste rock. The potential for infiltration and generation of leachate also exists at the Blue Cap Mine, where the risk evaluation also found that the contaminants of selenium, gross alpha, and gross beta in the mine drainage were a threat to ecological receptors, particularly aquatic life in Lion Canyon Creek and La Sal Creek. The following sections address technologies applicable to mitigation of infiltration and the passive treatment of mine discharge water.

7.1.1 Access Restrictions

Access restrictions would be implemented with the use of institutional controls. Potential process options include fencing and placement of signs to discourage direct access to controlled areas and warn of public hazards, as well as land use restrictions to limit the possible future uses of the mine area. In addition, physical modification of the ground surface may discourage long-term visitors (see Section 6.0). Although access and land use restrictions would limit and discourage direct exposure to mine drainage and limit future uses of the land, implementation of these process options alone would not mitigate threats to human health and the environment posed by the mines or migration of contaminated mine drainage media from the mines. However, the controls are considered viable options when used in combination with other technologies.

Access restrictions ***are retained*** as potential technologies for mine removal action and will be combined with other process options.

7.1.2 Infiltration Mitigation

Engineering source controls will be implemented to reduce the potential for mine drainage to contact waste rock materials. The technologies available for reducing the infiltration of mine discharge into underlying waste rock are simple and readily achievable. They include lining the mine discharge channel, piping of the mine discharge from the adit to a point off the waste rock, and phytoremediation (water consumption by phreatophtyes). The alternative of stemming the flow from the mine by use of an adit plug is discussed in Section 7.1.5.

7.1.2.1 Channel Realignment

Channel realignment is a viable technology that may be applicable at the Firefly/Pygmy and Vanadium Queen Mines. Channel realignment at the mines would involve reconstruction of the mine discharge channel to focus discharge into a smaller, narrower channel, preferably in an area that limits contact with waste rock. Channel realignment can be used in conjunction with other technologies presented in this section.

The concentration of mine discharge into a narrow, realigned channel would significantly reduce the saturated surface area at the mines and therefore reduce that likelihood of infiltration into the subsurface. Realignment of the discharge channel near the toe of the outcrop or upper slope should also reduce or eliminate infiltration in waste rock that comprises the broader portion of the mine benches. To mitigate exposure of the mine water to potential receptors the channel would be filled with aggregate of appropriate size such that flow would occur within the pore spaces of the unconsolidated rock fill. A disadvantage to channel realignment is a probable reduction (but not elimination) of the wetland (non-jurisdictional) ecosystem at the mines.

Channel realignment ***is retained*** as a potential technology for the mine removal action.

7.1.2.2 Channel Lining

Lining the mine discharge channel is an effective means of reducing infiltration of the mine discharge water. This alternative would involve the excavation of a shallow, broad channel followed by liner installation. Lining materials may consist of synthetic products including polyvinylchloride (PVC), ethylene propylene diene monomer (EPDM), reinforced polypropylene (RPP) and high-density polyethylene (HDPE), or “natural” products such as concrete, clay, or aggregate. Of these products,

synthetic liners and milled clay (bentonite) are the most cost-effective materials to achieve separation of the water from underlying waste rock. Concrete is expensive and labor-intensive to install and aggregate does not provide a thorough seal to infiltration.

Synthetic Liner

Flexible synthetic liners designed to be resistant to ultra-violet light are easy to install and have a life span of several decades. The synthetic liners are virtually impermeable to water, unless punctured, and perform well under the natural range of temperatures. Liner materials exhibiting these characteristics include EPDM and RPP. The main advantage in using synthetic liner is the ease and speed of installation. Once the grade surface is properly prepared liner installation for an open channel can be performed in a small amount of time. The primary disadvantage to synthetic liners is that the performance of the liner is compromised if the fabric is punctured or torn. Care must be taken during installation to prevent such damage, which includes meticulous ground surface preparation. The visual impact of unnatural black plastic can also be a disadvantage; however, the visual impact can be reduced by covering the liner with rock aggregate or soil. Another disadvantage is that, in most cases, synthetic liners require a specific welding or bonding process which may involve a special technician, equipment or field conditions (temperatures).

Clay Liner

Milled clay or bentonite products have a natural appearance, are not sensitive to light, and maintain low permeabilities under most temperatures. However, in freezing or extremely dry conditions, bentonite may be susceptible to cracking. The life span of clay liners is comparable to synthetic liners. The disadvantages to clay liner products include:

- Installation can generate dust and therefore workers may be required to use proper personal protective equipment.
- Grade must be carefully prepared to ensure an even thickness of clay product.
- Because of the limitations of the clay properties, potential inherent heterogeneity in the product, and possible inconsistent installation methods, clay liner permeability may vary and not attain permeabilities as low as synthetic liners.

Synthetic and clay liners would be susceptible to damage from upslope rockfalls, wildlife, or vandalism; a monitoring and maintenance program would be required to assure optimum performance.

Lining mine discharge channels with synthetic or clay lining products ***are retained*** as potential technologies for the mine removal action.

7.1.2.3 Piped Drainage

Mitigation of infiltration from the mine discharge can be accomplished by directly piping mine discharge from the portal to a location away from the mine waste rock. The primary objective of piping the mine discharge is to minimize exposure of the water to potential receptors. This alternative involves the construction of an intake at the mine portal, the excavation of a trench, pipe installation, and trench backfilling. In addition, the construction of an outfall would involve covering the daylighted pipe with rock such that direct exposure of water to receptors is minimized. Costs to construct and backfill the trench and purchase pipe materials are not seen as significantly different as the liner alternatives.

The primary disadvantages of the piping alternative include the costs associated with construction of the pipe intake, and the potential for clogging of the intake or pipe. Secondary disadvantages include the probable destruction of the wetland (non-jurisdictional) ecosystems that exist at the Firefly/Pygmy and Vanadium Queen mines. The wetland ecosystems include a variety of plant life, macroinvertebrates, and in one case an unusual salamander was observed (a biological inventory was not in the scope of this study). Another disadvantage of piping is the potential for human receptors to mistake the outfall area for a spring. A rock-covered pipe would prevent immediate exposure to the mine water, but seepage is likely to surface at some point downgradient of the outfall. Human visitors may be less likely to drink from an exposed pipe outfall than an apparent natural spring-like emanation point. Signage at the outfall locations and potential downgradient emanation points could reduce human exposure.

Despite the potential negative impacts to wetland (non-jurisdictional) ecosystems associated with the discharges at the mines, the piping technology ***is retained*** as a potential technology for mine removal action.

7.1.2.4 Transpiration

Transpiration is evaporation of water from the leaves and stems of plants. Transpiration, through the use of phreatophytes, is a viable technology for the removal of mine discharge water at the mines. Phreatophytes are water-loving plants that thrive in saturated soils, inundated areas, or areas of shallow groundwater. Obligate wetland species of phreatophytes have been identified at the Firefly/Pygmy,

Vanadium Queen, and Blue Cap Mine sites associated with the mine discharge. These species include willow, cattail, and rushes. Phreatophytes consume water through the transpiration process. Water consumption varies by species, diurnally, and seasonally. Phytoremediation is sometimes used as a primary technology for the purpose of contaminant removal by plant uptake; plants are seldom used solely for the purpose of water consumption. Phytoremediation, for the purposes of reducing mine discharge at the mines, is proposed here as a complementary technology. Transpiration rates for some phreatophytes attain several feet per year. It has been reported that groves of cottonwood and willow vegetation consume up to 5 acre ft/acre/ year (Hinchman and others, 2005). It is possible that during the growing season willow plants will transpire almost 1 meter (3.5 feet) of water (Robinson 1970 in http://www.farwest.tamu.edu/rangemgt/Saltcedar/Brian_LitReview.pdf). It is anticipated that willow alone could consume and transpire between 5 and 10 percent of the mine discharge during the growing season at the Firefly/Pygmy Mine. Larger species such as cottonwood or willow trees could consume up to half the existing discharge at the mine during maximum transpiration periods. The use of plant transpiration offers an aesthetic alternative to managing infiltration of mine discharge into the waste rock areas, and could be used to complement a removal action where the mine discharge channel is realigned in such a way to reduce contact with waste rock.

A disadvantage of the transpiration technology is that it is seasonally dependent. During the dormant months, plants have very low transpiration rates, so consumption of mine water would be low. In addition, should phreatophytes be used to complement a clay-lined channel, water availability may not be adequate to fully take advantage of plant growth and the transpiration process. Also, the development of roots and shoots of some plants may provide higher permeability zones for infiltrating mine discharge water.

Transpiration ***is retained*** as a potential technology for the mine removal action.

7.1.3 Mine Drainage Treatment

The Streamlined Risk Evaluation (Section 4.0) concluded that mine discharge water at the Blue Cap Mine contained levels of selenium, gross alpha, and gross beta that were a threat to ecological receptors, particularly aquatic life in Lion Canyon Creek and La Sal Creek. Contaminants that directly contribute to gross alpha and gross beta activities are uranium and combined radium-226/radium-228 (radium). In-situ treatment technologies will be used to address treatment of these contaminants in the Blue Cap Mine drainage. Technologies potentially appropriate for reducing the concentrations of these metals in the

mine water discharge were identified on the basis of literature research, vendor information, and experience in conducting other EE/CAs and feasibility studies. Consideration was given to passive treatment technologies that utilize naturally-occurring physical, chemical, and biological processes to promote removal of metals from water, and source removal by adit plugging. Non-passive technologies, those that require energized or mechanized treatment systems, were not considered.

7.1.3.1 The Chemistry of Mine Water Treatment

As a precursor to discussing treatment technologies, a review of the important controlling chemical parameters, removal processes, and aqueous chemistry of contaminants of concern is worthy of discussion.

Chemical Processes

The chemistry of the mine water at the Blue Cap Mine is likely typical of uranium/vanadium deposits on the Colorado Plateau. An evaluation of mine drainage waters in the study area revealed relatively high pH and alkalinity (bicarbonate), and relatively low concentrations of base metals (including iron) and sulfate.

Dissolved metal concentrations in water are controlled in part by pH and oxidation-reduction potential (Eh) conditions. Characterization data show that the mine drainage waters that emanate from the Blue Cap Mine exceed a pH of 8.5 s.u.; pH neutralization of these net alkaline waters is therefore not of immediate concern. However, for some treatment methods, controlling pH may be required. The following general discussion reviews chemical processes that are inherent to the more promising passive treatment technologies.

Precipitation

Precipitation of insoluble metal oxides or hydroxides occurs over a broad pH range, depending on the metal ion of interest. For acidic mine drainage, pH neutralization is a vital part of the passive treatment method. For alkaline waters, oxidation-reduction potential (Eh) may influence metal precipitation. In general, with higher pH and oxidizing conditions, the oxidation of dissolved metals results in the precipitation of metal oxides and hydroxides. For example, a common oxidation reaction for iron is as follows:

$$4Fe^{+2} + O_2 + 10H_2O \rightarrow 4Fe(OH)_{3(s)} + 8H^+$$

This equation can be applied to any divalent metal ion, i.e. the symbol "M" is substituted for such cation. As indicated, this reaction can reduce the pH of the water.

Under reducing conditions in a sulfur system, metal sulfides will precipitate as sulfate is reduced to sulfide:

$$SO_4^{2-} + 2CH_2O + 2H^+ \rightarrow H_2S + 2CO_2 + 2H_2O$$

In the above reaction, CH_2O represents a generic organic carbon-hydrogen compound. Sulfate-reducing bacteria may metabolize this compound and in so doing use sulfur as an electron acceptor (i.e., sulfur is reduced from S^{6+} to S^{2-}). Similar reactions may result in the production of bicarbonate which can contribute to increasing pH. Dissolved metals may then react directly with sulfide or hydrogen sulfide gas to precipitate as a metal sulfide:

$$M^{2+} + H_2S \rightarrow MS_{(s)} + 2H^+$$

The production of hydrogen sulfide gas is optimal at neutral (7.0) pH levels. At pH levels of 8.0 or higher, the sulfide species is predominantly HS^-.

Adsorption

Adsorption of metals is commonly attained through direct adsorption on solid media such as granular activated carbon, organic matter, soils, or through an ion-exchange process using natural or man-made zeolite-type materials such as sodium and calcium alumina silicates. The following equation represents the adsorption of a metal ion with an ion-exchange media (Faust and Aly, 1999):

$$M^{2+} + NaR \rightarrow MR_2 + 2Na^+$$

In this cation-exchange reaction, sodium exchanges with the metal (M) at the adsorption site. Adsorption processes alone are normally not considered a long-term passive treatment technology solution because of the frequency of absorbate regeneration and/or replenishment. However, adsorption can be a significant component of the metal removal process in many passive systems and is therefore recognized in the preliminary screening process.

Bioremediation

Bioremediation involves the metabolism or stabilization of metal elements by living organisms. The sulfate-reducing bacteria mentioned above indirectly fall into this category, since sulfate reducing bacteria use sulfate to aid in the metabolism of organic carbon-hydrogen compounds. Microbial activity is believed to be related to the reduction of uranium in some systems.

Another bioremediation technology is phytoremediation, which uses living vegetation or plants to extract or stabilize the metal contaminant. Constructed treatment wetlands consist of several biological components affecting metal concentrations in water. Metals may be removed by adsorbtion on roots or rhizomes of certain plant species or by uptake into the upper portion of plants. A disadvantage of the use of phytoremediation for metals removal is the potential for metals to enter the food chain and bioaccumulate in certain organisms and animals. A treatment wetland would consist of organic soils, microbial fauna, algae and vascular plants such as sedges, cattail, reed, indian mustard, and barley.

7.1.3.2 The Chemistry of the COCs

Chemical conditions of mine water may present favorable or unfavorable conditions for passive treatment depending on the system of interest. For example, in the case of anaerobic treatment within a bioreactor or wetland, sulfate-reducing bacteria may not flourish without sufficient sulfate to reduce and in turn the precipitation of metal sulfides may be limited. Other microbes needed to reduce some metals may not flourish due to a variety of reasons, including water pH, salinity, temperature, or a lack of a common food source. Also, in a similar system, high alkalinity may promote the formation of metal complexes that may adsorb to organic media, but otherwise not react, again limiting the performance of the system. Alternatively, in an aerobic system the precipitation of iron oxides may facilitate co-precipitation of trace metals in solution. If dissolved iron and other base metals are in low concentrations, co-precipitation of other metals may be affected.

Selenium

Selenium may occur in oxygenated waters as the oxyanions selenite, SeO_3^{2-}, or selenate, SeO_4^{2-}. Ball and Brix (2005) report that selenate is the predominant of the two species. Passive treatment of selenium should focus on the reduction of selenate to selenite using chemical or biological processes. Selenite is effectively removed by sorbtion to soil, organic or cellular matter, and ferric iron. Selenium has been effectively treated through the use of anaerobic conditions where sulfate-reducing bacteria convert selenate to selenite or elemental selenium. The reduced selenium may co-precipitate as sulfides with

heavy metals present in the mine drainage. In addition, reduced selenium will adsorb to organic matter and soils or otherwise become entrapped in the treatment system (Ball and Brix 2005). A disadvantage of selenium by wetland treatment is the potential of uptake of selenium by aquatic invertebrates and wetland plants, which in turn may be consumed by fish and wildlife. Consumed organo-selenium compounds may be highly toxic and bioaccumulative (Ball and Brix 2005).

Morrison and others (2002) reported significant reduction in arsenic, manganese, molybdenum, selenium, uranium, vanadium, and zinc in groundwater using multiple forms of zero-valent iron (ZVI) in treatment cells. These researchers hypothesized that selenium was reduced and precipitated as the iron mineral $FeSe_2$.

Uranium

Uranium removal may occur by precipitation in the sexivalent [U^{6+}] state by oxidation forming oxide minerals such as carnotite or in the reduced U^{4+} state forming minerals such as uraninite or pitchblende. In a reducing or anaerobic condition, precipitation of U^{4+} as uraninite (UO_2) occurs after the reduction of U^{6+}, probably in the form of the uranyl ion (UO_2^{2+}), in which the latter acts as an electron acceptor. The reduced form of uranium tends to be less soluble than the oxidized form. A common reducing agent is organic matter, however the use of ZVI (FeO) has shown to be very effective in reducing U^{6+} (Farrell and others 1999, and Morrison and others 2001). The presence of reduced uranium in natural bogs or wetlands has been known for some time http://technology.infomine.com/enviromine/wetlands/ Welcome.htm).

The mine waters in the study area are alkaline and contain sufficient carbonate and bicarbonate. The presence of carbonate in combination with relatively high pH is expected to influence uranium solubility, and it is reasonable to assume that the likely dissolved uranium species are in the form of uranium carbonate complexes $UO_2(CO_3)_2^{2-}$ or $UO_2(CO_3)_3^{4-}$. Uranium carbonate complexes are stable at pH values greater than 7.6 and Eh lower than 0.2 Volts, and progressively lower Eh and higher pH conditions e.g. at pH of 9.0 and Eh of 0.0 Volts. A decrease in Eh would facilitate the precipitation of the uranium carbonate complexes possibly as uraninite.

The removal of uranium in water by organic media treatment systems such as natural or manmade wetlands or bioreactors involves reduction and precipitation and adsorption. Initial removal may occur primarily by adsorption with additional removal due to reducing conditions and the presence of sulfate-reducing bacteria. Critical conditions that are needed to successfully remove uranyl carbonates in an

organic media treatment system are prevalent reducing conditions and the presence of sulfate-reducing bacteria. Sulfate reducing bacteria are critical in removal process of some metals as they reduce sulfate to sulfide which becomes available for precipitation reactions with dissolved metals. In addition, sulfate-reducing bacteria consume oxygen produced in the sulfate reduction process and produce bicarbonate, which elevates or maintains pH.

Research investigations have shown that the chemical reduction of uranium in anaerobic reducing environments is effective and it has been implied that the presence of sulfate reducing bacteria or other microbial action is involved in the reaction. The exact mechanism involved is uncertain but may include direct enzymatic reduction by using U^{6+} as an electron acceptor, or the production of reduced compounds for abiological reduction of U^{6+}(Veselic and others 2002). In an organic reducing environment, the oxidized form of uranium, U^{6+}, becomes an electron acceptor forming the reduced form of uranium U^{4+}, which may precipitate as UO_2. The presence of the bacteria is therefore required to maintain a reducing condition.

In an iron (ZVI) environment, the dissolution of iron produces ferrous ions and electrons which are available to reduce U^{6+} to U^{4+} and precipitate uraninite (UO_2). Alternatively, the formation of ferric oxyhydroxides as Fe(0) is oxidized, may provide adsorption sites for dissolved U^{6+} ions.

The characterization data for the mines in the study area indicate that sulfate occurs in the mine drainage waters in relatively low concentrations (not exceeding 70 mg/L). This may be a factor in the performance of a constructed wetland or bioreactor.

Analytical data from the mine drainage waters, specifically that of the Vanadium Queen Mine and Blue Cap Mine, show that metal concentrations at the adit and at the outflow point of the small wetland (non-jurisdictional) are similar. This could be an indication that adsorption in the wetland media has reached capacity and that reduction reactions are not the primary controlling factor, perhaps due to limited exposure to the organic media.

Radium

The removal of radium in water with passive treatment technologies is not well documented in literature research. However, it is suggested here that the treatment of radium with a passive system used to remove arsenic and uranium may also reduce radium-226/radium-228 concentrations in the mine drainage. Radium removal in conventional water treatment plants is commonly achieved by way of lime

softening where radium is precipitated with calcium carbonate. Radium may also precipitate with barium sulfate, substituting for barium in the crystal lattice. Similar reactions may occur in passive treatment systems. Morrison (2005) has observed the reduction of radium in ZVI cells and has attributed this to co-precipitation with calcite ($CaCO_3$) and not necessarily a reaction associated with the iron corrosion process. Morrison has considered designing PRBs using $BaSO_4$ to control radium concentrations in mining-related waters. Guzek (2005) suggested that radium may be removed under low redox conditions (low Eh), but doesn't not know what the exact mechanism is responsible. The specifics of radium removal by passive techniques may need to be resolved by bench and field-scale testing, by first evaluating the removal effectiveness of systems designed for arsenic and uranium removal, and then adjusting these systems, if necessary.

7.1.4 Passive Treatment Technologies

Passive treatment technologies commonly involve aerobic or anaerobic processes that utilize the natural chemical reactions or mechanisms for precipitation, adsorption, and bioremediation (microbial reduction and phytoremediation) to remove dissolved metals from water. Aerobic technologies promote the oxidation process that may facilitate the precipitation of some metals. These technologies include aerobic wetlands, oxidation ponds, settling ponds, and open channels. Aerobic technologies were evaluated for this EE/CA but were not retained on the basis that reaction processes that favor the removal of uranium and selenium tend toward reduced (anaerobic) chemical reactions.

Treatment technologies are evaluated in this EE/CA on the basis of each technology's ability to promote metals removal using one or more of the chemical reaction processes described above. The process of metals removal may be accomplished by a single technology that utilizes one or more removal processes, or through the use of several technologies that are combined to enhance metals removal by using multiple processes (e.g., precipitation and adsorption). For example, a constructed wetland technology may remove metals by adjusting pH and Eh, enhancing oxidation and precipitation of metal oxides, hydroxides, and sulfides and providing organic matter for adsorption and an environment for sulfate-reducing bacteria.

It is recognized that the mine drainage emanating from the Blue Cap Mine is alkaline and that this condition has advantages and disadvantages in the application of passive treatment technologies. Based on literature research, the removal of most of the metal COCs by existing passive treatment techniques shows promise. It is important to realize that the implementation of a passive treatment system involves

preliminary bench-scale and field-scale testing to confirm and optimize contaminant removal. Each potential technology is discussed separately below.

7.1.4.1 Anaerobic Wetland

An anaerobic wetland consists of a saturated and partially inundated soil and plant ecosystem. The wetland promotes anaerobic reducing conditions that are favorable for metal contaminant removal by precipitation and adsorption. An anaerobic wetland consists of a pond with water depths sufficient to limit oxygen exchange. Depths may range from 1 to 2 feet or greater. To limit oxygen exchange with the atmosphere, water levels are usually kept below the surface of the organic media. The principal components of the system include organic matter, microbial fauna, algae, and vascular plants. Native or imported soils may be used and amended with other organic matter including peat, compost, leaves, straw, woodchips, etc. To assure more effective treatment and limit the potential of infiltration of mine water into the underlying waste rock, the wetland cell will be lined with a geosynthetic liner and then covered with soil substrate sufficient to support plant growth. An important component of an anaerobic wetland is the propagation of native wetland-type vegetation which can enhance metal removal by phytoremediation and will continually add organic media to the system. The addition of organic matter sustains a reducing condition and increases adsorption capacity. Living plants also add an aesthetic benefit to the treatment cell.

Of key importance is to minimize oxygen exchange with the atmosphere. This can be achieved by constructing the wetland such that the free water surface is within the substrate, i.e. pile the organic matter above the water surface. Metals in the influent water are removed through precipitation with geochemical and microbial oxidation and reduction, adsorption, and absorption. Microbial activity and sulfate-reducing bacteria are key components to the metal removal process. Reduction reactions catalyzed by bacteria occur in the wetland's anaerobic zones, leading to precipitation of metal oxides, hydroxides, and sulfides. Sulfate-reducing bacteria reduce the sulfur (sulfate becomes the electron acceptor) within the mine drainage water thereby producing sulfide and bicarbonate, the former of which can react and precipitate metal sulfides, and the latter of which maintains a high pH. The precipitated and adsorbed metals settle out in quiescent portions of the wetland or are adsorbed as the water percolates through the medium or the plants. Some metal adsorption uptake is expected to occur in wetland plants and ion exchange may occur as metals in the water contact humic or other organic substances in the wetland. The reducing conditions within an anaerobic wetland should be conducive to the reduction of the metal COCs. Uranium, for example, should trend toward the reduced state of U^{4+} and possible precipitate as uraninite

(UO_2). Selenium in its reduced state of selenite has been shown to adsorb readily to organic and other substrate media in anaerobic treatment systems.

Phytoremediation (rhizofiltration and phytoextraction) by living plants in the wetland immobilizes some metals by adsorption and uptake in the plant tissue. Common native wetland plants that are known for their ability to accumulate metals and are present in the study area include *typha latifolia* or other *typha* species (cattail), and *phragmites australis* (common reed) (Shardendu and others 2003), *Juncus spp*., and *Scirpus spp*. (Groudev and others 2001). With research, other plants could be introduced such as *Lemna gibba L.*(I. Duckweed) which was shown to remove selenium and other metals from contaminated water (Zayed and others 1998). Submergent plants such as algae water milfoil may also act as metal sorbents. Uranium removal by rhizofiltration has been shown to be effective in a number of studies (Dushenkov and others 1997).

Some disadvantages of an anaerobic system are similar to those of the aerobic system, particularly with regard to seasonal dependence (freezing conditions). However, the affects of freezing conditions can be mitigated somewhat by the depth of the wetland and thickness of organic "bedding" material. A constructed treatment wetland is not expected to be effective forever. Adsorption capacity is finite and precipitated metals in the wetland may eventually require removal. The success and longevity of an anaerobic wetland is partially dependent on vegetation growth and subsequent decomposition. It is estimated that a treatment wetland will perform in excess of 10 years before refurbishing actions are needed. The surface area for an anaerobic wetland is dependent on influent flow rates, contaminant concentrations, and condition of the reactive media. For costing purposes, it is assumed that a 2,500 ft^2 footprint would be needed to treat the Blue Cap Mine discharge.

An anaerobic wetland ***is retained*** as a potential treatment technology for this EE/CA.

7.1.4.2 Permeable Reactive Barrier

A permeable reactive barrier (PRB) is a sub-surface, passive, in-situ treatment zone of reactive material that degrades or immobilizes contaminants as water flows through it. Surface water and/or groundwater are forced to flow through a permeable barrier that is constructed downgradient of the contaminant source. The barrier consists of a thick wall of reactive material (iron filings, organic material, limestone or various other reactive agents). The wall is isolated from atmospheric conditions and thermal stresses with a cover of low permeability material. Permeable reactive barriers are cost effective to construct and an

excellent method to treat contaminated surface water or groundwater. However, sufficient residence time is required for the systems to be effective. The permeability of the reactive agent placed in the wall is generally on the order of 10^{-1} to 10^{-2} centimeters per second (cm/sec), depending on the ratio of permeability-enhancing material (aggregate) to reactive material. Long-term maintenance is required as the agent filling the wall must be replaced periodically over time as it loses its reactive properties or becomes plugged with precipitated contaminants. A PRB using ZVI was installed at Monticello, Utah to remove uranium, vanadium, arsenic, molybdenum, nitrate, and selenium from a groundwater plume at a former uranium and vanadium mill site. The treatment was successful in that arsenic, uranium, vanadium, and selenium were removed to nondetectable concentrations. Monitoring indicated that iron concentrations increased in the effluent and that clogging of the barrier was occurring.

Although a PRB is considered a viable option for treatment of mine discharge at the Blue Cap Mine, construction of a subsurface treatment system presents certain construction and operation and maintenance challenges that can be avoided with surface treatment methods. PRB systems eventually clog or show a reduction in reaction effectiveness, and replacement of such a system is expected to be more costly than a surface-oriented treatment system. It is anticipated that these costs would outweigh the benefit of mitigating surface exposure of the mine water.
A permeable reactive barrier ***is not retained*** as a potential technology for this EE/CA

7.1.4.3 Bioreactor

A bioreactor is similar to anaerobic wetland treatment in that both systems function under anaerobic reducing conditions. The main difference is that a bioreactor system does not necessarily focus on the propagation of wetland-type vegetation, or other designs that consider aesthetics and therefore may not utilized natural soils as part of the reactive media. A bioreactor consists of an excavation or cell containing a lower layer of organic substrate. The cell, which is sometimes lined, is designed to encourage flow through the substrate layer. The substrate layer typically is composed of organic matter (peat, manure, wood chips, sawdust, hay, compost, etc.) combined with limestone or other aggregate to enhance permeability. The bioreactor media creates a reducing environment where the organic substrate promotes chemical and microbial processes that generate alkalinity, increase the pH, and precipitate metals by reduction reactions. By removing or limiting oxygen in the system, the compost promotes a reducing environment and minimizes the oxidation of metals. At the Blue Cap Mine, the use of limestone as an aggregate is not initially recommended as it may add to the formation of mobile uranium-carbonate complexes.

Treatment systems incorporating bioreactor technology have proven to be very successful in reducing metals concentrations in water discharging from mine sites. The primary advantages of bioreactor systems in comparison to conventional limestone-based treatment systems include the capacity to elevate pH and maintain a reducing condition. However, the overall effectiveness of bioreactors is largely controlled by retention time. Therefore, the amount of area available for bioreactor installation is a critical design consideration. A retention time of at least 15 hours is generally considered the minimum retention time required for bioreactors. A retention time of 24 hours is commonly used as the standard for design.

A bioreactor is considered a potentially effective technology for reducing metals concentrations in water draining from the mines in the Blue Cap Mine. The low iron and sulfate concentrations of the mine drainage may be a factor that controls the precipitation of metals such as $FeSe_2$. The reduction of metals may occur by donation of electrons from the organic material and adsorption of metals may be a dominate removal process. Removal of uranium may occur by reduction of U^{6+} to U^{4+} and precipitation of U as uraninite (UO_2). As mentioned in the chemistry review above, however, the presence of uranium carbonate complexes may inhibit the removal process. Selenium in its reduced state of selenite has been shown to adsorb readily to organic and other substrate media in anaerobic treatment systems. In the presence of iron, reduced selenium may co-precipitate as $FeSe_2$. If necessary, iron (ZVI) could be added to the system to promote the formation of this mineral.

The technology would provide an effective mechanism for reduction of uranium and selenium through oxide and iron precipitation, respectively. The required size of a bioreactor for the Blue Cap Mine is controlled by discharge rates and desired retention time. Available construction space is also of concern. Preliminary calculations show that to provide a retention time of at least 15 hours and assuming a porosity of 0.25 (with no effects on porosity due to metal precipitation and biomass settling), and a flow rate of 2,500 gallons per day, a 50-foot sided square cell with a 1 to 2-foot depth should suffice. For costing purposes, it is assumed that a bioreactor with a 2,500 ft^2 footprint would be needed to treat the Blue Cap Mine discharge. It is anticipated that the equivalent volume of such a bioreactor cell could be constructed at the mine site.

A bioreactor ***is retained*** as a potential technology for this EE/CA.

7.1.4.4 ZVI Cell

The application of ZVI in passive water treatment systems has gained recognition in recent years as an effective metal removal technology, primarily in PRB applications. The use of ZVI in passive treatment cells constructed on or near the ground surface is not well documented but has gained interest in the treatment of mine drainage. ZVI treatment cells constructed at a former mill tailings site in Durango, Colorado effectively removed arsenic, manganese, molybdenum, selenium, uranium, vanadium, and zinc (Morrison et al 2002).

The chemical reactions resulting in uranium removal in ZVI systems is a topic of discussion amongst researchers. The primary suspected reactions are (1) reduction and precipitation and (2) oxidation and adsorption. In fact, both may occur in a ZVI system. In the adsorption process, uranium and other dissolved metals react with iron oxide (FeO) materials and their corrosion products to form uranium-iron oxide complexes. Alternatively, Morrison and others (2002) argue that a significant portion of the dissolved uranium is removed by the precipitation of reduced oxides (UO_2). In the presence of sulfur, selenium may be reduced and form selenium sulfide mineral(s). The work by Morrison and others (2002) successfully removed both selenium and uranium from the influent water without actively varying pH and Eh conditions in the treatment cells.
Research has shown that the use of ZVI treatment systems is characterized by an increase in pH, a decrease in Eh, a precipitation of carbonate minerals, and a redistribution of iron as U and other metals are removed (Morrison and others 2003). A problem with ZVI systems in the Colorado Plateau area is the presence of calcium and the formation of calcite which clogs the treatment media. Iron oxides also are problematic in reducing the media's permeability. Calcium concentrations in mine drainage waters in the study area are relatively small, indicating that the formation of calcite in a ZVI application may not present a significant problem in treatment performance.

Information on the removal of radium by ZVI is sparse. This is understandable as passive treatment of radium is difficult and mechanized treatment can be expensive. It is hypothesized that partial removal of radium-226 and radium-288 by ZVI is expected, probably from adsorption processes. Therefore, long-term effectiveness of radium treatment is not expected.

A ZVI cell can be constructed similar to other passive treatment systems, as a pond or channel. The pond or channel would be lined to contain and more completely treat the mine water discharge. Liner material can vary in composition ranging from a pliable plastic liner to a rigid concrete cell. The advantage of a rigid concrete structure is its ability to be readily reused when the reacting media is extracted and replaced

with new media. Plastic or geosynthetic liners are usually damaged and must be replaced during media replenishment. The size of the cell (basin or channel) would be determined through experimental testing, but it is anticipated that the mine sites have sufficient space to construct ZVI treatment cells as discharge rates are relatively small. Cell construction would include a cover to limit oxygen interaction with the ZVI which could cause the development of excessive iron oxide crust. The management of the ZVI waste would need to be considered in the final assessment of this technology. Replenishment is estimated to occur on a 5-year schedule. The surface area for a ZVI cell is dependent on influent flow rates, contaminant concentrations, and condition of the reactive media. For costing purposes, it is assumed that a ZVI cell with a 320 ft^3 volume would be needed to treat the Blue Cap Mine discharge.

ZVI cell treatment ***is retained*** as a potential technology for this EE/CA.

7.1.4.5 Underground In-Situ Treatment

Underground in-situ treatment involves passive treatment at the water source in the mine workings. This technology may be more favorable in cases where surface treatment is restricted by limited construction space, aesthetics, safety, or vandalism issues. If the mine workings are of sufficient volume and condition, the construction of an in situ passive treatment system may be feasible. Such systems may be as uncomplicated as loading mine water pools with biomass to create a bioreactor. Other systems may require the construction of channels and cells to convey and contain mine drainage. Underground in situ treatment systems are normally based on anaerobic removal processes (bioreactors or ZVI cells) because of the inherent lack of air flow in most abandoned mines. The disadvantages of underground in situ treatment include:

- Mine rehabilitation and maintenance costs and underground safety issues.
- The potential for remote (not readily accessible) monitoring stations.
- Special media extraction and replacement handling issues (i.e. underground training, specialized equipment and haul distances).

Because underground surveys of the mines have not been conducted, the significance of these disadvantages cannot be completely assessed. The mine workings may provide a favorable location for mine drainage treatment provided the workings are of suitable condition and volume to receive the treatment media. However, the high uncertainty associated with mine rehabilitation and feasibility of conveying the treatment media to the workings currently outweighs the underground treatment option.

If the BLM was to conduct the additional characterization needed to assess the condition of the workings with respect to safety, integrity, and source of mine water and determine the volume available for disposal of the mine waste, mine disposal ***would be retained*** as a potentially viable technology for the mine removal action. Because no plans have been made by the BLM to conduct the necessary mine characterization at this time and such characterization is outside of the scope of work for this contract, mine disposal is not considered in the detailed analysis of alternatives in this document.

7.1.5 Adit Plug

In addition to passive treatment technologies, consideration was also given to the technology used to stem flow from the open mine adits. The construction of hydraulic barriers for sealing mine water discharge has been used to successfully mitigate mine drainage problems. A hydraulically sealed adit ideally results in little or no discharge from the adit and by re-saturating mine workings may contribute to re-establishing chemically reducing conditions in the groundwater. Reducing conditions promote the precipitation of metals and reduces dissolved metal concentrations in the water.

Construction of an effective hydraulic barrier or adit plug typically involves installation of a concrete plug or bulkhead within the main tunnel and the use of pressure grouting techniques to seal surrounding rock fractures. The work can be performed using conventional or remote methods. The conventional method requires direct access to the plug location through an existing or reconstructed adit or a new adit. The remote method involves surface drilling techniques to access the adit plug location and inject grout material. The remote method is usually implemented when direct access to the workings is restricted due to geotechnical problems, excessive costs are required to re-open an existing adit or to drive a new adit, and/or health and safety issues. Using either method, one general procedure consists of the initial installation of upstream and downstream barriers (cement plugs). After the plugs have cured, the main adit plug is installed by pouring or injecting concrete into the area between the upstream and downstream barriers. This is followed by pressure grouting the peripheral areas upgradient, along, and downgradient of the adit plug. Grout for the peripheral areas may consist of polyurethane foam, bentonite slurry, or concrete mixes. The length of the adit plug is dependent on rock and cement strength as well as the hydraulic characteristics (i.e., hydraulic head) required to minimize leakage.

Much of the information needed to cost and support application of adit plug technology at the Blue Cap Mines is not currently available. Observations of the portal area generally indicate that the outer workings are competent. However, significant additional mine characterization would be required to

assess adit conditions (collapsed materials, void space sizes, and potential hydraulic head) and surrounding rock characteristics (strength and fracture densities). Although the hydraulic barrier technology could be an effective solution for mitigating mine drainage impacts at the mine, the costs associated with additional characterization efforts and implementation of the technology may greatly exceed the costs to implement other technologies.

If the BLM was to conduct the additional characterization needed to assess the condition of the workings with respect to safety, integrity, and source of mine water, adit plugging ***would be retained*** as a potentially viable technology for the mine removal action. Because no plans have been made by the BLM to conduct the necessary mine characterization at this time and such characterization is outside of the scope of work for this contract, adit plugging is not considered in the detailed analysis of alternatives in this document.

7.2 Response Alternative Development for Mine Water Discharge

EPA guidance for non-time-critical removal actions recommends that only the most qualified technologies that apply to the media or source of contamination be evaluated in detail in the EE/CA. In accordance with this guidance, removal action alternatives meeting the RAOs and goals of the project for the mine were developed from the retained technologies.

The most promising technologies that were identified and retained through the screening process for infiltration mitigation are shown in Table 7.1. The most promising technologies that were identified and retained through the screening process for mine water treatment at the Blue Cap Mine are shown in Table 7.2. The technologies for infiltration mitigation and mine drainage treatment also form a set of removal action alternatives that are summarized in Tables 7.3 and 7.4, respectively. A no-action alternative will be included in the analysis to serve as a baseline against which the potential alternatives can be compared. These common alternatives provide the basis for the detailed analysis of alternatives. In addition, a common set of technologies/process options will be incorporated in each alternative, including access restrictions (signage/fencing and land use), surface control (run-on and run-off control), and mitigation of physical hazards (portal closure and structure removal). Application of these common technologies is discussed in Section 6.4, and details regarding each potential alternative are provided in Section 6.5 of this document.

7.3 Basis for Analysis of Alternatives

The removal action alternatives listed in Tables 7.1 and 7.2 are described and evaluated in Sections 6.5 and 6.6 based on each alternative's effectiveness, implementability, and cost. For each alternative, an overall rating of "low", "moderate", or "high" is given for each evaluation criterion. To better describe the overall ratings given, a numerical scale ranging from 1 (low) to 3 (high) was used to refine the rating for each narrative category. For example a rating of low-1 indicates the low end of the low category, while a rating of high-3 indicates the high end of the high category. The effectiveness, implementability, and cost evaluation criteria are discussed in further detail in the following subsections.

7.3.1 Effectiveness

The effectiveness of an alternative refers to its ability to meet the objectives within the scope of the removal action. Effectiveness focuses on the degree to which an alternative provides adequate overall protection of human health and the environment; complies with ARARs; affords long-term protection by minimizing residual risk; provides reduction of toxicity, mobility, or volume of hazardous material; and minimizes short-term effects.

Overall Protection of Human Health and the Environment

This evaluation criterion serves as a final check in assessing whether each alternative provides adequate protection of human health and the environment. Evaluations of long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs (discussed below) were used to assess the overall protection of human health and the environment. This criterion was also used to evaluate how risks would be eliminated, reduced, or controlled through treatment, engineering, or institutional controls.

Compliance with ARARs

Compliance with ARARs was used to assess whether each alternative will attain the chemical-specific and action-specific ARARs identified in Section 5.3.

Long-term Effectiveness and Permanence

Long-term effectiveness and permanence addresses the risk remaining at the mines after remediation goals have been met.

Reduction of Toxicity, Mobility, or Volume

Reduction of toxicity, mobility, or volume addresses the statutory preference for selecting removal actions that permanently and significantly reduce toxicity, mobility, and/or volume of hazardous materials at the mine. This preference is satisfied when treatment is used to reduce principal risks through destruction or irreversible reductions of toxicity, mobility, and/or volume. This criterion focuses on the following:

- The degree of expected reduction in toxicity, mobility, or volume.
- The degree of irreversibility of the process.
- The type and quantity of residuals remaining following treatment.
- The statutory preference for treatment as a principal element.
- The relative amount of hazardous materials that will be destroyed or treated.

Short-term Effectiveness

Short-term effectiveness addresses the effects of each alternative in the protection of human health and the environment during the construction and implementation phase. The following factors were addressed during the evaluation process:

- Protection of the workers during removal actions - This factor assesses threats that may be posed to workers and the effectiveness and reliability of measures to be taken.
- Environmental impacts of the removal action - This factor addresses the potential adverse environmental impacts that may result from construction and implementation of a removal alternative, and evaluates the reliability of mitigation measures, if necessary, to prevent or reduce potential impacts.
- Time lapse before achievement of removal objectives - This factor includes an estimate of the time required to achieve protection for the mine.

7.3.2 Implementability

Implementability evaluates the technical feasibility of implementing each alternative, the availability of required services and materials during its implementation, and the administrative feasibility.

Technical Feasibility and Availability

Technical feasibility and availability addresses the ability of the alternative to implement the removal action, the reliability of the alternative, and the availability of services and materials. The following factors were addressed during the evaluation process:

- Ability to construct and operate the technology
- Reliability of the technology
- Ease of undertaking additional removal actions or remedial actions if necessary
- Ability to monitor effectiveness of removal action
- Availability of necessary equipment, materials, and personnel

Administrative Feasibility

The administrative feasibility criterion addresses the following factors:

- Likelihood of public acceptance of the alternative, including state and local concerns
- Activities needed to coordinate with other agencies
- Ability to obtain necessary approvals or permits

7.3.3 Cost

The cost of each alternative is evaluated based on estimates of projected capital cost (e.g., construction costs) and indirect cost (e.g., permitting and engineering oversight and support during construction). It is assumed that any operation and maintenance activities associated with the alternatives (e.g., periodic site inspections and performance monitoring) will be performed by BLM personnel; therefore, no operation and maintenance costs have been included the evaluations. Cost estimates are based on vendor information, cost-estimating guides, and actual costs incurred during similar activities at other mines.

The net present value of each alternative was calculated as the sum of total capital cost plus the present worth of annual operation and maintenance cost (assuming an interest rate of 5 percent over a 10-year period). An interest rate of 5 percent was used on the basis of the EPA guidance (USEPA, 1988).

7.4 Commonalities of Alternatives

Certain technologies/process options and ancillary construction activities are common to the removal action alternatives for waste rock also apply to removal action alternatives for mine water discharge. Common technologies/process options include access restrictions (signage/fencing and land use), and surface control (run-on and run-off control). Common ancillary construction activities include access road improvement, site safety and health, and permitting and coordination.

7.4.1 Access Restrictions

Access restrictions will be implemented during implementation of the removal actions to prevent unauthorized access to active work areas and discourage access to reclaimed areas. The controls will include fencing and/or natural barriers and signage. Natural barriers will be used to prevent vehicle access to the mine areas during implementation of the removal actions. Land use restrictions will be used to discourage livestock grazing at the mine areas. Signage will warn visitors of the presence of nonpotable water and of the presence and operation of passive treatment system that should not be disturbed.

7.4.2 Surface Controls

The construction of infiltration mitigation structures at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines and a passive treatment cell at the Blue Cap Mine, will occur on existing mine bench areas where surface control structures have already been proposed to protect waste rock media. Slight modifications to these structures may be necessary to accommodate mine water discharge. Surface controls are incorporated in each proposed alternative to manage surface water run-on and run-off. Erosion protection measures would be implemented to stabilize disturbed areas and protect the integrity of diversion control structures. Riprap (rock lining) will be installed as necessary to prevent erosion of constructed diversion channels and existing drainages within or adjacent to the mine area.

Run-on controls will be installed to prevent stormwater runoff from entering areas disturbed during implementation of the removal action. Run-off controls will be installed to reduce the sediment load carried by runoff originating within the disturbed areas. Run-on, run-off, and drainage controls may include earthen berms, riprap, V-ditches, hay bails, and silt fencing.

7.4.4 Ancillary Construction Activities

Access road improvement will be conducted as an ancillary construction activity in addition to the primary reclamation actions associated with each alternative. This construction activity is expected to also occur in association with waste rock removal actions and should not be an additional activity solely required to facilitate mine water management. Improvements will be limited to clearing fallen timber, boulders, and any vegetation restricting access along the road; minor grading to lessen slopes and broaden switchback turns where necessary; and some minor road widening. A V-ditch will be installed along the uphill side of the road alignments to prevent runoff originating in upslope areas from contacting the road surface.

The selected removal actions will be implemented in strict accordance with procedures and protocols specified in the site safety and health plan(s). The plans will address the procedures and protocols to be implemented to mitigate the physical, chemical, and radiation hazards associated with the actions. On-site monitoring will be conducted to ensure worker safety and prevent off-site releases of contamination.

In accordance with the ARARs discussed in Section 5.3, permits and coordination/consultation with various agencies and groups will be required prior to implementation of a removal action. These include federal, state, and county requirements. It is assumed that required permitting and coordination/consultation will be performed by the BLM, with contractor assistance.

While the BLM may elect to obtain permits, it should be recognized that Congress limited the scope of a Federal agencies obligation to attain administrative ARAR through CERCLA 121(e), which states that no federal, state, or local permits requirements are required for on-site response actions. This includes procedural requirements. Only the substantive elements of other laws affect on-site responses. This permit exemption allows the response action to proceed in an expeditious manner, free from potentially lengthy delays associated with the permit process or an equivalent process. The lack of permitting authority does not impede implementation of an environmentally protective remedy, since CERCLA and the NCP already provide a procedural blueprint for responding to the release or threatened release of a hazardous substance into the environment.

7.5 Detailed Analysis of Alternatives for Infiltration Mitigation of Mine Drainage

The potential alternatives listed in Table 7.4 have been developed for detailed analysis of effectiveness, implementability, and cost. Except for the no-action alternative, each alternative includes potential sub-alternatives as follows:

- Alternative 1: No action
- Alternative 2: Re-aligned Channel
- Alternative 3: Lined Channel
- Alternative 4: Piped Drainage
- Alternative 5: Transpiration

The activities to be performed at each mine are further defined in the following analysis of each alternative. Conceptual layout sketches of proposed structures are shown in Appendix D.

7.5.1 Alternative No. 1: No Action

The no action alternative assumes that no steps are taken to promote reclamation of the mine. The mine water discharge will continue to or have the potential to infiltrate the waste rock at the mine sites and produce leachate that may threaten subsurface and surface water sources. The non-jurisdictional wetlands that have developed on the mine benches would continue to exist and potentially improve mine drainage water quality. No further investigation or monitoring would be required at the mine.

7.5.1.1 Effectiveness

The overall effectiveness of the no-action alternative is low. The potential to generate leachate of worse water quality than the mine drainage will continue to exist with the potential to degrade water resources or otherwise threaten the environment. The toxicity, mobility, and volume of metal contaminants would not be reduced under the no-action alternative with the exception of some potential treatment benefits of wetlands that would continue to flourish on the mine benches where mine drainage disperses. The no-action alternative would not lessen the BLM's existing liabilities associated with the mines or promote improvement of environmental conditions within the La Sal Creek Watershed.

7.5.1.2 Implementability

Implementation of the no-action alternative would be technically and administratively feasible. However, consideration would need to be given to public acceptance of the alternative. The no-action alternative may not be acceptable to the public, regulatory agencies, and the BLM.

7.5.1.3 Cost

No capital costs or indirect costs would be incurred under the no-action alternative. Other than periodic inspections by BLM personnel, no operation and maintenance costs would be incurred under the no-action alternative. However, the long-term costs associated with the no-action alternative are not known because there would be an ongoing risk associated with continued contaminant migration from the mines and direct exposure to wildlife.

7.5.2 Alternative No. 2: Re-aligned Channel

Alternative 2 involves the construction of an unlined, aggregate filled channel.

At the Firefly/Pygmy Mine, Alternative 2 would be implemented as follows:

- The re-aligned channel would trend south to southwest from the portal near the base of the steep outcrop and upslope area that forms the portal escarpment. The channel would continue along the inside (upslope side) of the eroded access road to the upper bench to the junction with the road to the lower bench, where it would diverge across the access road to a small ephemeral drainage. The estimated distance of this alignment is 300 feet.

- Mine Drainage Collection Structure: Flow from the portal to the piped alignment will be facilitated by the construction of a 2-foot high concrete sack dam within the portal behind the final portal seal. A 4-inch ADS single-wall, corrugated, HDPE collection pipe will be sealed in place at the base of the dam to convey drainage from the mine. The pipe inlet will be screened to prevent large debris from entering the pipe. It is assumed that the base area in front and back of the dam will be appropriately sealed through the use of an impermeable geosynthetic liner material (e.g. EPDM or RPP) that is keyed into the portal floor. This seal will reduce leakage around the dam. If necessary, a temporary upstream dam will be constructed to divert mine drainage during construction of the concrete sack dam and pipe conveyance structure. The collection pipe will extend from the base of the dam and under the portal seal structure to the mine bench. In the portal area, the pipe will be laid and buried within a shallow trench (1- foot deep) such that gravity flow to the non-jurisdictional wetland is maintained. Native fill will be used to cover the pipe outside of the portal if trenching is not possible. The collection pipe will discharge outside the portal into an open lined channel.

- The drainage channel will consist of an open, small, v-shaped channel with dimensions of approximately 1-foot wide, 1.5 foot deep, and side slopes of 1-to 2-feet at a slope of approximately 2:1. Washed rock (non-limestone aggregate) of approximately 2-inches in

diameter will be placed in the channel to a depth of approximately 1 foot. The imported aggregate will consist of highly resistant rock. This material will reduce erosion in the channel and reduce direct surface exposure of the mine drainage to receptors by forcing flow to occur within the aggregate pore spaces. A small earth berm will separate the downslope side of the channel from the mine access road.

- A run-on channel will be constructed immediately upslope and parallel to the mine drainage channel to capture run-off and sediment from upslope areas and reduce clogging of the mine drainage channel. This run-on channel will also serve as the main run-on channel for mitigating erosion at the mine site (see Section 6.4). The two channels will be separated by an interstitial earth berm. The dimensions of the run-on channel will not be smaller in size than the open drainage channel portion of the drainage structure (if required the channel will be designed for a BLM-specified storm design).

    - Sub-Alternative 2A would involve the planting of phreatophytes along the re-aligned channel where some metal uptake by plants may occur and water consumption will reduce overall flows during the growing season. Species that may be effective in phytoextraction and transpiration include cattail, reed, willow, and cottonwood.

At the Vanadium Queen Mine, Alternative 2 would be implemented as follows:

- The re-aligned channel would trend northwest from the portal along the north side of the upper bench access road. The channel that already exists in this area would be cleaned of debris and modified where necessary. The channel would continue along the inside (upslope side) of the upper bench access road to the to the upper road switch back where an old road forks to the north toward an ephemeral drainage. The channel would be constructed on the inside (upslope side) of this old road to the intersection of the ephemeral drainage where the drainage water would potentially outfall into the ephemeral drainage. The estimated distance of this alignment is 420 feet.

- Mine drainage would exit and be collected from the mine by way of the 36-inch corrugated metal pipe (CMP) culvert that would be used as the portal seal described in Section 6.5.2. Mine water exiting the culvert will discharge directly into the open drainage channel.

- The drainage channel will consist of an open, small, v-shaped channel with dimensions of approximately 1-foot wide, 1.5 foot deep, and side slopes of 1-to 2-feet at a slope of approximately 2:1. Washed rock (non-limestone aggregate) of approximately 2-inches in diameter will be placed in the channel to a depth of approximately 1 foot. The imported aggregate will consist of highly resistant rock. This material will reduce erosion in the channel and reduce direct surface exposure of the mine drainage to receptors by forcing flow to occur within the aggregate pore spaces. A small earthen berm will separate the downslope side of the channel from the mine access road.

- A run-on channel will be constructed immediately upslope and parallel to the mine drainage channel to capture run-off and sediment from upslope areas and reduce clogging of the mine drainage channel. This run-on channel will also serve as the main run-on channel for mitigating erosion at the mine site (see Section 6.4). The two channels will be separated by an interstitial earth berm. The dimensions of the run-on channel will not be smaller in size than the open

drainage channel portion of the drainage structure (if required the channel will be designed for a BLM-specified storm design).

- Sub-Alternative 2A would involve the planting of phreatophytes along the re-aligned channel where some metal uptake by plants may occur and water consumption will reduce overall flows during the growing season. Species that may be effective in phytoextraction and transpiration include cattail, reed, willow, and cottonwood.

At the Blue Cap Mine, Alternative 2 would not be implemented because of the existing risk to aquatic life in Lion Canyon Creek. The construction of a passive treatment system is proposed for this mine drainage. The mine drainage will be conveyed to the treatment system by way of a small underground dam and collection pipe located behind the portal seal.

Operation and maintenance activities associated with Alternative 2 would include periodic inspections to monitor the integrity of the mine drainage channel and associated run-on channel. Maintenance may include repairs associated with large storm events where channel banks were eroded, or channels were clogged with sediment and other debris.

7.5.2.1 Effectiveness

Overall, Alternative 2 would provide a moderately effective mechanism for reducing the potential production of leachate from infiltration of mine drainage into the waste rock. Re-alignment of the mine drainage channel, as proposed, is expected to separate mine drainage from waste rock through a high percentage of the aligned channel. Mine drainage in the unlined channel will not be directly exposed to the atmosphere and terrestrial receptors because flow will occur in the pore spaces within the aggregate fill. Mine drainage will likely infiltrate the underlying native colluvium and soils over the reach of the channel alignment. This infiltration may be seen as attenuating the contaminants in the mine drainage water over terrain reasonably close to the mines in comparison to providing a potential point source of exposure in a lined channel or piped flow scenario. However, in the upper portion of the alignment, infiltration of mine drainage may be of concern because waste rock is located downgradient of the alignment.

General compliance with ARARs would be achieved with implementation of Alternative 2. Greater compliance with ARARs would be expected with Sub-Alternative 2A since overall consumption of mine water would be held in plants and not dispersed in the underlying subsurface.

Implementation of the alternative would remain effective in the long-term provided periodic inspection and maintenance of the re-aligned channel is performed over time. Inspections should be performed to monitor the integrity of the channel and the accumulation of contaminants within the channels and outfall areas. If the accumulation of contaminants becomes a concern in the future, passive treatment of the drainage waters can be considered.

There would likely be some short-term ecological and environmental effects due to construction activities from dust generation, vegetation clearing, and general construction noise during implementation of Alternative 2. These short-term impacts would be minimal, with exposure pathways minimized through engineering controls and personal protective equipment.

7.5.2.2 Implementability

Implementation of Alternative 2 is technically feasible at the mine. The necessary resources and materials for Alternative 2 are readily available from nearby sources. Sub-Alternative 2A would provide an additional means for removal of the mine drainage and add an aesthetic component (vegetation) to the action.

Alternative 2 is also administratively feasible at the mines; however, some public concerns (including local, state, and federal) would likely be encountered. These concerns would likely include the likely destruction of non-jurisdictional wetlands that exist on the upper mine benches, potential for contamination of off site areas (former access roads and ephemeral drainage) due to diversion of mine drainage to these areas, and the potential of underflow to waste rock downgradient of the alignment. Impacts to the natural character of the areas caused by the installation of the channel are minimal and would not impart a large visual impact. Applicable permit and agency coordination requirements, as identified in Section 5.3 of this document, would need to be met before commencing construction operations.

7.5.2.3 Cost

The estimated costs for Alternative No. 2 at the Firefly/Pygmy and Vanadium Queen Mines are presented in Table 7.5, and a detailed breakdown of the costs is provided in Appendix E. Direct capital costs for mobilization and labor and materials required to complete the ancillary construction activities such as site run-on and run-off erosion control are included in Section 6.4 (waste rock removal actions). Indirect

capital costs include permitting and engineering support and oversight during construction. No costs have been included for potential wetlands replacement. The total capital costs for Alternative 2 at Firefly/Pygmy and Vanadium Queen Mines are summarized as follows:

- Firefly/Pygmy Mine
  - Alternative 2: $ 17,691
  - Sub-Alternative 2A: $ 25,493

- Vanadium Queen Mine
  - Alternative 2: $ 18,436
  - Sub-Alternative 2A: $ 27,034

Operation and maintenance costs correspond to the costs associated with post-reclamation inspection and maintenance (including vegetation-success for Sub-Alternative 2A and erosion-control monitoring). It is assumed that post-reclamation inspections will be performed by BLM personnel on an annual basis for a 10-year period; no costs for BLM inspections are included in this analysis. Projected maintenance costs assume work performed by a contractor and 25 percent of the re-aligned channel and associated run-on ditch will require replacement every 5 years.

The total net present value of Alternative 2 at each mine over 10 years (total capital cost plus present worth of operation and maintenance cost) is summarized as follows:

- Firefly/Pygmy Mine
  - Alternative 2: $ 25,369
  - Sub-Alternative 2A: $ 35,464

- Vanadium Queen Mine
  - Alternative 2: $ 26,388
  - Sub-Alternative 2A: $ 37,538

7.5.3 Alternative No. 3: Lined Channel

Alternative 3 involves the construction of a lined, aggregate filled channel constructed along the proposed re-alignment.

At the Firefly/Pygmy Mine, Alternative 3 would be implemented as follows:

- The re-aligned channel would be constructed in the same alignment as proposed for Alternative 2. The estimated distance of this alignment is 300 feet. The alignment avoids excavation in the

waste rock where installation would require compliance with the regrading plan and would risk future pipe leakage into the waste rock materials.

- Mine Drainage Collection Structure: Flow from the portal to the piped alignment will be facilitated by the construction of a 2-foot high concrete sack dam within the portal behind the final portal seal. A 4-inch ADS single-wall, corrugated, HDPE collection pipe will be sealed in place at the base of the dam to convey drainage from the mine. The pipe inlet will be screened to prevent large debris from entering the pipe. It is assumed that the base area in front and back of the dam will be appropriately sealed through the use of an impermeable geosynthetic liner material (e.g. EPDM or RPP) that is keyed into the portal floor. This seal will reduce leakage around the dam. If necessary, a temporary upstream dam will be constructed to divert mine drainage during construction of the concrete sack dam and pipe conveyance structure. The collection pipe will extend from the base of the dam and under the portal seal structure to the mine bench. In the portal area, the pipe will be laid and buried within a shallow trench (1- foot deep) such that gravity flow to the non-jurisdictional wetland is maintained. Native fill will be used to cover the pipe outside of the portal if trenching is not possible. The collection pipe will discharge outside the portal into an open lined channel.

- The drainage channel will consist of an open small v-shaped channel with dimensions of approximately 1-foot wide, 1.5 foot deep, and side slopes of 1-to 2-feet at a slope of approximately 2:1. A geosynthetic liner material such as EPDM (ethylene propylene diene monomer) or RPP (reinforced polypropylene) will be installed in the channel and anchored to the channel side berms. Washed rock (non-limestone aggregate) of approximately 2-inches in diameter will be placed in the channel to a depth of approximately 1 foot. The imported aggregate will consist of highly resistant rock. This material will reduce erosion in the channel and reduce direct surface exposure of the mine drainage to receptors by forcing flow to occur within the aggregate pore spaces. A small earth berm will separate the downslope side of the channel from the mine access road. The lined channel will extend from the portal to ephemeral drainage mentioned in Alternative 2.

    - Sub-Alternative 3A – use of a clay (bentonite) liner. A bentonite liner will be installed in place of a geosynthetic liner. Bulk bentonite will be imported to the mine site and spread to a depth of 3 to 6-inches within the constructed channel before filling the channel with aggregate.

- A run-on channel will be constructed immediately upslope and parallel to the mine drainage channel to capture run-off and sediment from upslope areas and reduce clogging of the mine drainage channel. This run-on channel will also serve as the main run-on channel for mitigating erosion at the mine site (see Section 6.4). The two channels will be separated by an interstitial earth berm. The dimensions of the run-on channel will not be smaller in size than the open drainage channel portion of the drainage structure (if required the channel will be designed for a BLM-specified storm design).

At the Vanadium Queen Mine, Alternative 3 would be implemented as follows:

- The re-aligned channel would be constructed in the same alignment as proposed for Alternative 2. The estimated distance of this alignment is 420 feet. However, the upstream segment from the portal to the upper-most switchback of the mine access road, a distance of 245 feet, will be lined with an impermeable geosynthetic material. The remaining (lower) 175 feet from the switchback to the ephemeral drainage will be a constructed open channel. It is not necessary to line the entire

420 foot alignment because the upper 245-foot segment should sufficiently separate the drainage from the waste rock (modifications to the actual lined channel outfall location will be made in the field). This alignment is preferable because it keeps the outfall of the drainage at a relatively high elevation and distance from ephemeral drainages and perennial streams. The alignment avoids excavation in the waste rock where installation would require compliance with the regrading plan and would risk future pipe leakage into the waste rock materials.

- Mine drainage would exit and be collected from the mine by way of the 36-inch corrugated metal pipe (CMP) culvert that would be used as the portal seal described in Section 6.5.2. Mine water exiting the culvert will discharge directly into the open, lined, drainage channel.

- The drainage channel will consist of an open small v-shaped channel with dimensions of approximately 1-foot wide, 1.5 foot deep, and side slopes of 1-to 2-feet at a slope of approximately 2:1. A geosynthetic liner material such as EPDM or RPP will be installed in the channel and anchored to the channel side berms. Washed rock (non-limestone aggregate) of approximately 2-inches in diameter will be placed in the channel to a depth of approximately 1 foot in both the lined and unlined segments. The imported aggregate will consist of highly resistant rock. This material will reduce erosion in the channel and reduce direct surface exposure of the mine drainage to receptors by forcing flow to occur within the aggregate pore spaces. A small earth berm will separate the downslope side of the channel from the mine access road.

    - Sub-Alternative 3A – use of a clay (bentonite) liner. A bentonite liner will be installed in place of a geosynthetic liner. Bulk bentonite will be imported to the mine site and spread to a depth of 3 to 6-inches within the constructed channel before filling the channel with aggregate.

    - Sub-Alternative 3B – would involve the planting of phreatophytes along the open segment of the re-aligned channel where some metal uptake by plants may occur and water consumption will reduce overall flows during the growing season. Species that may be effective in phytoextraction and transpiration include cattail, reed, willow, and cottonwood.

- A run-on channel will be constructed immediately upslope and parallel to the mine drainage channel to capture run-off and sediment from upslope areas and reduce clogging of the mine drainage channel. This run-on channel will also serve as the main run-on channel for mitigating erosion at the mine site (see Section 6.4). The two channels will be separated by an interstitial earth berm. The dimensions of the run-on channel will not be smaller in size than the open drainage channel portion of the drainage structure (if required the channel will be designed for a BLM-specified storm design).

At the Blue Cap Mine, the construction of a passive treatment system is proposed because of the existing risk to aquatic life in Lion Canyon Creek. The mine drainage will be conveyed to the treatment system by way of a small underground dam and collection pipe located behind the portal seal.

Operation and maintenance activities associated with Alternative 3 would include periodic inspections to monitor the integrity of the mine drainage channel, liner, and associated run-on channel. Maintenance

may include repairs associated with large storm events where channel banks were eroded or channels were clogged with sediment and other debris, and liner repairs due to rock falls, vandalism, or wildlife.

7.5.3.1 Effectiveness

Overall, Alternative 3 would provide a moderately to highly effective mechanism for reducing the potential production of leachate from infiltration of mine drainage into the waste rock. Sub-Alternative 3A should also provide a moderately effective mechanism for reducing the potential production of leachate from infiltration of mine drainage into the waste rock. Re-alignment and lining of the channel, as proposed, is expected to effectively separate mine drainage from waste rock through a high percentage of the aligned channel. Mine drainage in the lined channel will not be directly exposed to the atmosphere and terrestrial receptors because flow will occur in the pore spaces within the aggregate fill. Although the contaminated mine drainage water was not seen as significant risk to human health and environment at the Firefly/Pygmy and Vanadium Queen Mines, the lined channel will convey the mine drainage to the outfall point where exposure to receptors may occur. Signage at the outfall point would be used to discourage potable use of the water.

At the Firefly/Pygmy Mine, the outfall of mine drainage will be at the small ephemeral drainage located below the junction of the upper and lower bench roads. Although the lined channel will transport mine drainage to an area that has not previously received mine drainage, it is anticipated that the drainage will infiltrate into the ground surface before reaching La Sal Creek.

At the Vanadium Queen Mine, the upper lined segment of the channel may prevent mine drainage from infiltrating underlying native colluvium and soils. This is seen as beneficial because this area is located hydraulically upgradient from existing waste rock areas. Furthermore, lining of the entire mine drainage channel would convey the mine discharge to an existing ephemeral drainage where mine drainage could potentially be transported to perennial streams during storm events. It is anticipated that mine drainage in the lower (unlined) portion of the channel will infiltrate and attenuate before reaching the ephemeral drainage. Monitoring of this surface flow will be necessary to assure that mine drainage does not directly flow into perennial streams.

General compliance with ARARs would be achieved with implementation of Alternative 3, assuming that the lined channel does not increase the likelihood of migration of contaminants directly to perennial streams in the study area. There would likely be some short-term ecological and environmental effects

due to construction activities from dust generation, vegetation clearing, and general construction noise during implementation of Alternative 3. These short-term impacts would be minimal, with exposure pathways minimized through engineering controls and personal protective equipment.

7.5.3.2 Implementability

Implementation of Alternative 3 is technically feasible at the mine. Lining of the channel would negate the need to monitor for waste rock (contaminated substrate) during channel construction as the channel lining would separate the mine water from underlying contamination. However, any waste rock identified during construction would be consolidated at the main waste rock dump areas. The necessary resources and materials for Alternative 3 are readily available from nearby sources. Sub-Alternative 3A is also technically feasible at the mine, but would inherently be more labor intensive and require more attention during installation.

Alternative 3 is also administratively feasible at the mines; however, some public concerns (including local, state, and federal) would likely be encountered. These concerns would likely include the likely destruction of non-jurisdictional wetland that exists on the upper mine benches, the potential for contamination of off site areas (former access roads and ephemeral drainage) due to diversion of mine drainage to these areas. Impacts to the natural character of the areas caused by the installation of the channel are minimal and would not impart a large visual impact. Applicable permit and agency coordination requirements, as identified in Section 5.3 of this document, would need to be met before commencing construction operations.

7.5.3.3 Cost

The estimated costs for Alternative No. 3 at the Firefly/Pygmy and Vanadium Queen Mines are presented in Table 7.5, and a detailed breakdown of the costs is provided in Appendix E. Direct capital costs for mobilization and labor and materials required to complete the ancillary construction activities such as site run-on and run-off erosion control are included in Section 6.4.4 (waste rock removal actions). Indirect capital costs include permitting and engineering support and oversight during construction. No costs have been included for potential wetland replacement. The total capital costs for Alternative 3 at Firefly/Pygmy and Vanadium Queen Mines are summarized as follows:

- Firefly/Pygmy Mine
  - Alternative 3: $ 25,338
  - Sub-Alternative 3A: $ 36,383

- Sub-Alternative 3B: NA

- Vanadium Queen Mine
  - Alternative 3: $ 23,778
  - Sub-Alternative 3A: $ 32,551
  - Sub-Alternative 3B: $ 29,676

Operation and maintenance costs correspond to the costs associated with post-reclamation inspection and maintenance and erosion-control monitoring. It is assumed that post-reclamation inspections will be performed by BLM personnel on an annual basis for a 10-year period; no costs for BLM inspections are included in this analysis. Projected maintenance costs assume work performed by a contractor and replacement of 25 percent of the lined, re-aligned channel and associated run-on ditch will be required every 5 years.

The total net present value of Alternative 3 at each mine over 10 years (total capital cost plus present worth of operation and maintenance cost) is summarized as follows:

- Firefly/Pygmy Mine
  - Alternative 3: $ 35,385
  - Sub-Alternative 3A: $ 49,782
  - Sub-Alternative 3B: NA

- Vanadium Queen Mine
  - Alternative 3: $ 33,665
  - Sub-Alternative 3A: $ 45,175
  - Sub-Alternative 3B: $ 41,234

7.5.4 Alternative No. 4: Piped Drainage

Alternative 4 involves the construction of a buried pipe that conveys mine drainage from the portal to a discharge location away from waste rock.

At the Firefly/Pygmy Mine, Alternative 4 would be implemented as follows:

- The alignment for the pipeline will be the same as proposed for Alternatives 2 and 3. The estimated distance of this alignment is 300 feet. This alignment is preferable because it keeps the outfall of the drainage at a relatively high elevation while limiting excavation within the waste rock materials. The alignment avoids excavation in the waste rock where installation would require compliance with the regrading plan and would risk future pipe leakage into the waste rock materials.

- Mine Drainage Collection Structure: Flow from the portal to the piped alignment will be facilitated by the construction of a 2-foot high concrete sack dam within the portal behind the final portal seal. A 4-inch ADS single-wall, corrugated, HDPE collection pipe will be sealed in place at the base of the dam to convey drainage from the mine. The pipe inlet will be screened to prevent large debris from entering the pipe. It is assumed that the base area in front and back of the dam will be appropriately sealed through the use of an impermeable geosynthetic liner material (e.g. EPDM or RPP) that is keyed into the portal floor. This seal will reduce leakage around the dam. If necessary, a temporary upstream dam will be constructed to divert mine drainage during construction of the concrete sack dam and pipe conveyance structure. The collection pipe will extend from the base of the dam and under the portal seal structure to the mine bench pipe alignment trench. In the portal area, the pipe will be laid and buried within a shallow trench (1- foot deep) such that gravity flow to the non-jurisdictional wetland is maintained. Native fill will be used to cover the pipe outside of the portal if trenching is not possible.

- The trench for the pipe outside of the portal will consist of a small box-shaped trench with dimensions of approximately 2-feet wide, 2 to 3 feet deep, and vertical walls. Four-inch ADS single-wall, corrugated, HDPE pipe will be laid in the trench to convey the mine drainage and connected to the collection pipe from the dammed portal. Pipe anchors consisting of poured concrete footers encasing the pipe will be installed every 100 feet. Cleanouts, consisting of a vertical clean-out fitting, will be constructed at each anchor point between the portal inlet and outlet. The pipe inlet will be constructed immediately outside of the existing portal.

- The outfall area will be armored with aggregate. The pipe will be buried with the excavated material and compacted with excavation machinery. Care will be taken not to backfill with large rock. Metal stakes will be installed at each clean out location for field identification purposes.

- A run-on channel will be constructed immediately upslope and parallel to the mine drainage pipeline to capture run-off and sediment from upslope areas and reduce clogging of the mine drainage channel. This run-on channel will also serve as the main run-on channel for mitigating erosion at the mine site (see Section 6.4). The dimensions of the run-on channel will not be smaller in size than the open drainage channel portion of the drainage structure (if required the channel will be designed for a BLM-specified storm design).

At the Vanadium Queen Mine, Alternative 4 would be implemented as follows:

- The alignment for the pipeline will be the same as proposed for Alternative 3. The upstream segment from the portal to the upper-most switchback of the mine access road, a distance of 245 feet, will be piped. The remaining (lower) 175 feet from the switchback to the ephemeral drainage will be a constructed open and unlined channel. It is not necessary to pipe the entire 420 foot alignment because the upper 245-foot segment should sufficiently separate the drainage from the waste rock (modifications to the actual pipe outfall location will be made in the field). This alignment is preferable because it keeps the outfall of the drainage at a relatively high elevation and distance from ephemeral drainages and perennial streams. The alignment avoids excavation in the waste rock where installation would require compliance with the regrading plan and would risk future pipe leakage into the waste rock materials.

- Mine drainage would exit and be collected from the mine by way of the 36-inch corrugated metal pipe (CMP) culvert that would be used as the portal seal described in Section 6.5.2. Mine water

exiting the culvert will discharge directly into a collection box fitting connected to the piped alignment.

- The trench for the pipe will consist of a small box-shaped trench with dimensions of approximately 2-feet wide, 2 to 3 feet deep, and vertical walls. Pipe bedding consisting of washed sand or pit run fines will be placed in the channel to a depth of approximately 3-inches. Four-inch ADS single-wall, corrugated, HDPE pipe will be laid in the trench to convey the mine drainage. Pipe anchors consisting of poured concrete footers encasing the pipe will be installed every 100 feet and at the inlet and outlet points. Cleanouts, consisting of a vertical pipe clean-out fitting will be constructed at each anchor point between the portal inlet and outlet. The pipe inlet will be constructed within the portal and incorporated into the portal seal structure as mentioned above. The inlet will be screened to prevent large debris from entering the pipe. The pipe will be buried with the excavated material and compacted with excavation machinery. Care will be taken not to backfill with large rock. Metal stakes will be installed at each clean out location.

- The lower (175 feet), open-channel portion of the alignment would be an unlined channel as described in Alternative 2. The drainage channel will consist of an open small v-shaped channel with dimensions of approximately 1-foot wide, 1.5 foot deep and side slopes of 1-to 2-feet at a slope of approximately 2:1. Washed rock (non-limestone aggregate) of approximately 2-inches in diameter will be placed in the channel to a depth of approximately 1 foot. The imported aggregate will consist of highly resistant rock. This material will reduce erosion in the channel and reduce direct surface exposure of the mine drainage to receptors by forcing flow to occur within the aggregate pore spaces. A small earth berm will separate the downslope side of the channel from the mine access road. The unlined, aggregate-filled channel will extend from the switchback area to the ephemeral drainage mentioned in Alternative 2.

    - Sub-Alternative 4A – would involve the planting of phreatophytes along the open segment of the re-aligned channel where some metal uptake by plants may occur and water consumption will reduce overall flows during the growing season. Species that may be effective in phytoextraction and transpiration include cattail, reed, willow, and cottonwood.

- A run-on channel will be constructed immediately upslope and parallel to the mine drainage pipeline and open channel to capture run-off and sediment from upslope areas and reduce clogging of the mine drainage channel. This run-on channel will also serve as the main run-on channel for mitigating erosion at the mine site (see Section 6.4). The dimensions of the run-on channel will not be smaller in size than the open drainage channel portion of the drainage structure (if required the channel will be designed for a BLM-specified storm design).

At the Blue Cap Mine, the construction of a passive treatment system is proposed because of the existing risk to aquatic life in Lion Canyon Creek. The mine drainage will be conveyed to the treatment system by way of a small underground dam and collection pipe located behind the portal seal.

Operation and maintenance activities associated with Alternative 4 would include periodic inspections to monitor flow conditions at the pipe inlet and outlet and within the pipeline (check cleanouts for clogging, etc.), and the integrity of the open mine drainage channel and associated run-on channel. Maintenance may include repairs associated with large storm events where channel banks were eroded or channels

were clogged with sediment and other debris, and other repairs related to rock falls, vandalism, or wildlife. Occasional maintenance to clean-out pipe clogging problems may be necessary.

7.5.4.1 Effectiveness

Overall, Alternative 4 and Sub-Alternative 4A would provide a highly effective mechanism for reducing the potential production of leachate from infiltration of mine drainage into the waste rock. Re-alignment and piping of the mine drainage, as proposed, will effectively separate mine drainage from waste rock throughout the piped reach at both the Firefly/Pygmy and Vanadium Queen Mines and within the open channel portion at the Vanadium Queen Mine. Mine drainage in the piped sections will not be directly exposed to the atmosphere and terrestrial receptors, and drainage in the open channel segment at the Vanadium Queen Mine will be filled with aggregate to prevent or reduce surface water exposure.

Although the contaminated mine drainage water was not seen as significant risk to human health and environment at the Firefly/Pygmy and Vanadium Queen Mines, exposure to receptors may occur at or downgradient of the pipe outfall. It is not known how far the mine discharge water will flow on the surface within the open channel segment of the alignment at the Vanadium Queen Mine or within the ephemeral drainage at the Firefly/Pygmy Mine.

At the Vanadium Queen Mine, the upper piped segment of the channel may prevent mine drainage from infiltrating underlying native colluvium and soils. This is seen as beneficial because this area is located hydraulically upgradient from existing waste rock areas. Furthermore, piping of the entire mine drainage alignment would convey the mine discharge to an existing ephemeral drainage where mine drainage could potentially be transported to perennial streams during storm events. Aggregate fill within the unlined channel segment will reduce surface exposure of the discharge and signage will be installed at the outfall point to discourage potable use of the water. It is anticipated that mine drainage in the lower open (unlined) portion of the channel at the Vanadium Queen Mine will infiltrate and attenuate before reaching the ephemeral drainage. Monitoring of this surface flow will be necessary to assure that mine drainage does not directly flow into perennial streams. Sub-Alternative 4A, the use of phreatophytes in the unlined channel below the pipe outlet, is expected to reduce the surface-water travel distance from the mine area, especially during the growing season.

At the Firefly/Pygmy Mine, the outfall of mine drainage will be the small ephemeral drainage located below the junction of the upper and lower bench roads. Although the piped drainage will transport mine

drainage to an area that has not previously received mine drainage, it is anticipated that the drainage will infiltrate into the ground surface before reaching La Sal Creek. Monitoring of this surface flow will be necessary to assure that mine drainage does not directly flow into perennial streams.

General compliance with ARARs would be achieved with implementation of Alternative 4, assuming that the piped drainage and channel do not increase the likelihood of migration of contaminants directly to perennial streams in the study area. There would likely be some short-term ecological and environmental effects due to construction activities from dust generation, vegetation clearing, and general construction noise during implementation of Alternative 4. These short-term impacts would be minimal, with exposure pathways minimized through engineering controls and personal protective equipment.

7.5.4.2 Implementability

Implementation of Alternative 4 is technically feasible at the mine. Piping of the drainage would negate the need to monitor for waste rock (contaminated substrate) during construction as the pipe would separate the mine water from underlying contamination. However, any waste rock identified during construction would be consolidated at the main waste rock dump areas. The necessary resources and materials for Alternative 4, and Sub-Alternative 4A are readily available from nearby sources.

Alternative 4 is also administratively feasible at the mines; however, some public concerns (including local, state, and federal) would likely be encountered. These concerns would likely include the likely destruction of the non-jurisdictional wetland that exists on the upper mine benches, the potential for contamination of off site areas (former access roads and ephemeral drainage) due to diversion of mine drainage to these areas and leakage from a damaged pipe. Impacts to the natural character of the areas caused by the installation of the pipeline and channel are minimal and would not impart a large visual impact. Applicable permit and agency coordination requirements, as identified in Section 5.3 of this document, would need to be met before commencing construction operations.

7.5.4.3 Cost

The estimated costs for Alternative No. 4 at the Firefly/Pygmy and Vanadium Queen Mines are presented in Table 7.5, and a detailed breakdown of the costs is provided in Appendix E. Direct capital costs for mobilization and labor and materials required to complete the ancillary construction activities such as site run-on and run-off erosion control are included in Section 6.4.4 (waste rock removal actions). Indirect

capital costs include permitting and engineering support and oversight during construction. No costs have been included for potential wetland replacement. The total capital costs for Alternative 4 at Firefly/Pygmy and Vanadium Queen Mines are summarized as follows:

- Firefly/Pygmy Mine
  - Alternative 4: $ 17,889
  - Sub-Alternative 4A: NA

- Vanadium Queen Mine
  - Alternative 4: $ 17,565
  - Sub-Alternative 4A: $ 23,463

Operation and maintenance costs correspond to the costs associated with post-reclamation inspection and maintenance and erosion-control monitoring. It is assumed that post-reclamation inspections will be performed by BLM personnel on an annual basis for a 10-year period; no costs for BLM inspections are included in this analysis. Projected maintenance costs assume that work performed by contractor and replacement of 25 percent of the piped, re-aligned drainage and associated run-on ditch will be required every 5 years.

The total net present value of Alternative 4 at each mine over 10 years (total capital cost plus present worth of operation and maintenance cost) is summarized as follows:

- Firefly/Pygmy Mine
  - Alternative 4: $ 25,632
  - Sub-Alternative 4A: NA

- Vanadium Queen Mine
  - Alternative 4: $ 25,487
  - Sub-Alternative 4A: $ 33,056

7.6 Detailed Analysis of Alternatives for Passive Treatment of Mine Water Drainage at the Blue Cap Mine

The potential alternatives listed in Table 7.4 have been developed for detailed analysis of effectiveness, implementability, and cost. Except for the no-action alternative, each alternative includes the potential for modifications or Sub-Alternatives. However, as reported earlier, the retained passive treatment technologies all have the potential for effectively treating the Blue Cap Mine discharge. It is common to implement bench-scale or field-scale treatment testing of potential treatment alternatives prior to constructing a final remedy. An example of a potential Sub-Alternative would be amending the media of

an anaerobic wetland with ZVI. No attempt will be made to discuss and cost the numerous possibilities for treatment "recipes"; only basic components of each treatment alternative will be addressed.

- Alternative 1: No action
- Alternative 2: Anaerobic Wetland
- Alternative 3: Bioreactor
- Alternative 4: ZVI Cell

The activities to be performed at each mine are further defined in the following analysis of each alternative. Conceptual layout sketches of proposed structures are shown in Appendix D.

7.6.1 Alternative No. 2: Anaerobic Wetland

The general activities to be performed under Alternative 2 include (1) bench or field-scale testing of anaerobic wetland media, and (2) wetland treatment cell construction. At the Blue Cap Mine, Alternative 2 would be implemented as follows:

- Mine Drainage Collection Structure: Flow from the portal to the anaerobic wetland will be facilitated by the construction of a 2-foot high concrete sack dam within the portal behind the final portal seal. A 4-inch ADS single-wall, corrugated, HDPE pipe will be sealed in place at the base of the dam to convey drainage from the mine to the wetland. It is assumed that the base area in front and back of the dam will be appropriately sealed through the use of an impermeable geosynthetic liner material (e.g. EPDM or RPP) that is keyed into the portal floor. This seal will reduce leakage around the dam. If necessary, a temporary upstream dam will be constructed to divert mine drainage during construction of the concrete sack dam and pipe conveyance structure. The collection pipe will extend from the base of the dam and under the portal seal structure to the mine bench. The pipe will be laid and buried within a shallow trench (1- foot deep) such that gravity flow to the wetland is maintained. Native fill will be used to cover the pipe outside of the portal if trenching is not possible.

- Ground Preparation. The bench area outside of the draining portal will be grubbed and regraded to a level condition. For costing purposes, it is assumed that a 50 foot by 50 foot square area will be sufficient to treat the average mine discharge (regrading will be sufficient to establish work space for cell construction).

- Cell Preparation: The cell area will be excavated to a depth of approximately 3 feet and contained by bounding berms of 2-foot height. Four internal berms, also of 3-foot height (sufficient height to act as a flow barrier – 1 foot above water line), will be constructed as parallel baffles, approximately 10 feet apart and opposing open ends. The berm baffles will enhance media contact and residence time. Excavated material identified as waste rock will be used to construct the basal portion of berms. Any material identified as native soil will be used as substrate in the cell or as exterior portion of berms. All rock fragments greater than 1-inch in size will be raked from the cell's interior ground surface. The cell bottom and all berms will be compacted. A spillway for the wetland cell will be installed on the north end of the cell at the appropriate elevation (such that the free water surface is at or below the estimated substrate surface). The spillway will be lined and partially filled with non-limestone aggregate; flow will be directed to

the ephemeral drainage portion of Lion Canyon Creek near the mine access road. The final water level in the cell will be at least one foot below the bounding berms and 6-inches below the wetland substrate. This will allow for potential fluctuations in discharge to the cell.

- Inlet: The mine drainage pipe will be connected to an appropriate fitting at the inlet end of the cell. The inlet will be in the upstream corner of the cell confined by the cell walls and an internal baffle.
- Liner Installation: An appropriate durable, non-woven, impermeable geosynthetic fabric such as EPDM (ethylene propylene diene monomer) or RPP (reinforced polypropylene), will be installed over the entire cell bottom, and internal and bounding berms. The liner will be flexible, UV resistant, and of at least 20 year lifespan rating. The liner will be anchored within the upper one foot of the bounding berms.
- Soil/substrate Installation: Two-feet of soil substrate, preferably of high organic content, will be laid down to cover the bottom of the cell. The soil will be lapped up the sides of all berms. The soil will be overlain by one foot of biomass materials, such as certified straw mulch, wood chips, composted leaves, grass, or manure, and peat. Soil along the berms should still be visible after placement of the biomass. The final surface should be slightly undulating.
- Outlet: The cell outlet will consist of a pipe fitting such that effluent will flow from the end of the last baffle section into a 4-inch ADS single-wall, corrugated, HDPE pipe. The pipe will be buried in a 1 to 2 foot trench. The outfall will be located in ephemeral portion of Lion Canyon Creek, near the existing access road culvert. The spillway will be protected with non-limestone aggregate, if needed.
- Security: An 8-foot high security fence will be constructed around the cell perimeter to protect the cell from vandalism, rock fall, and wildlife access.

- Establishing Plants: A seed mix consisting of a diverse suite of native phreatophytes will be added to the soil/biomass media. Seed may be sowed into to soil along the berm edges or directly onto the free water surface. Saplings of favorable native plants will be purchased and hand planted within the lined wetland. Once plants are established, additional biomass can be added to decrease the percentage of free water surface area.

- Run-on channels constructed as part of the overall erosion mitigation for the mine bench will be located in the vicinity of the treatment wetland to reduce potential erosion of the wetland berms.

Operation and maintenance activities associated with Alternative 2 would include periodic inspections to monitor the integrity of the wetland cell, including berm and liner integrity, flow and vegetation conditions, and conduct analytical sampling.. Under Alternative 2, it is anticipated that the treatment wetland would likely require periodic maintenance including berm repair, replenishment of biomass (if vegetation is not naturally replenishing this material), elimination of preferential flow paths, and liner repair (where visible near water line). It is estimated that approximately 30 percent of the wetland biomass would need to be replaced approximately every 10 years.

7.6.1.1 Effectiveness

Overall, Alternative 2 would provide a moderately effective mechanism for protection of ecologic health and the environment at the mine. Through the use of chemical and biochemical processes, the alternative would reduce level of contamination in the water emanating from the Blue Cap Mine adit. The threats posed to aquatic life as a result of mine drainage entering Lion Canyon Creek would be effectively mitigated by removal of selenium, gross alpha, and gross beta concentrations due to precipitation and adsorption of selenium, uranium and some radium (metals) within the wetland substrate and uptake by wetland plants. The overall effectiveness of the treatment wetland will depend on establishing reducing conditions to promote precipitation of metals and sufficient surface area to adsorb metals. Establishing plants within the wetland are important to propagating these conditions. However, it is likely that the alternative would likely have a finite life and replacement of media would be necessary.

General compliance with ARARs would be achieved with implementation of Alternative 2. There would likely be some short-term ecological and environmental effects due to construction activities from dust generation, vegetation clearing, and general construction noise during implementation of Alternative 2. These short-term impacts would be minimal, with exposure pathways minimized through engineering controls and personal protective equipment.

7.6.1.2 Implementability

Implementation of Alternative 2 is technically feasible at the mine. The effectiveness of the alternative would be monitored by performing periodic sampling and analysis of influent and effluent water at the treatment wetland cell. A comparison of analytical data for an initial influent sample and subsequent effluent samples will be used to judge the effectiveness of water treatment. Effluent sampling would be conducted on an annual basis and influent sampling on a bi-annual (every two years) basis. The necessary resources and materials for Alternative 2 are readily available.

Alternative 2 is also administratively feasible at the mines; however, some public concerns (including local, state, and federal) would likely be encountered. These concerns may include the overall effectiveness and longevity of the treatment wetland, the potential for greater exposure to wildlife receptors at the constructed wetland, impacts to the natural character of the mine site, the potential for media-introduced contaminants in the effluent, and disposal of wetland media during the replenishment work. The likely destruction of non-jurisdictional wetlands that exist on the mine bench is not expected to be of concern because the wetlands would be rebuilt as part of the alternative. Applicable permit and

agency coordination requirements, as identified in Section 5.3 of this document, would need to be met before commencing construction operations.

7.6.1.3 Cost

The estimated costs for Alternative No. 2 at the Blue Cap Mine are presented in Table 7.5, and a detailed breakdown of the costs is provided in Appendix E. Direct capital costs for mobilization and labor and materials required to complete the ancillary construction activities such as site run-on and run-off erosion control are included in Section 6.4.4 (waste rock removal actions). Indirect capital costs include permitting and engineering support and oversight during construction. The total capital costs (including construction and indirect costs) for Alternative No. 2 are estimated to be $105,957. In addition to the total capital costs, the estimated cost for pilot-scale testing of Alternative No. 2, in combination with Alternatives Nos. 3 and 4, is $25,052.

Operation and maintenance costs are costs associated with post-construction inspection, maintenance, and monitoring (including sampling and analysis of influent and effluent). It is assumed that post-reclamation inspections and monitoring will be performed by BLM personnel on an annual basis for a 10-year period; no costs for BLM labor is included in this analysis. It is assumed that 2 analytical samples will be collected per year of the wetland influent or effluent for comprehensive analysis at an estimated cost of $708 per sample. Projected maintenance costs assume work performed by a contractor and that 30 percent of the wetland media will require removal and replacement and berms will require repair every 10 years. It is assumed that replenishment of the anaerobic wetland will require disposal of spent media as a hazardous waste with an estimated disposal cost of $8,100 per 10 year period.

The total net present value of Alternative 2 over 10 years (pilot-scale testing and total capital cost plus present worth of operation and maintenance cost) is estimated to be $167,232.

7.6.2 Alternative No. 3: Bioreactor Cell

The general activities to be performed under Alternative 3 include (1) bench or field-scale testing of bioreactor media, and (2) bioreactor cell construction. At the Blue Cap Mine, Alternative 3 would be implemented as follows:

- Mine Drainage Collection Structure: Flow from the portal to the bioreactor cell will be facilitated by the construction of a 2-foot high concrete sack dam within the portal behind the final portal

seal. A 4-inch ADS single-wall, corrugated, HDPE collection pipe will be sealed in place at the base of the dam to convey drainage from the mine to the bioreactor cell. It is assumed that the base area in front and back of the dam will be appropriately sealed through the use of an impermeable geosynthetic liner material (e.g. EPDM or RPP) that is keyed into the portal floor. This seal will reduce leakage around the dam. If necessary, a temporary upstream dam will be constructed to divert mine drainage during construction of the concrete sack dam and pipe conveyance structure. The collection pipe will extend from the base of the dam and under the portal seal structure to the mine bench. The pipe will be trenched and buried to a shallow depth where possible such that gravity flow to the Bioreactor cell is maintained. Native fill will be used to cover the pipe outside of the portal if trenching is not possible.

- Ground Preparation. The bench area outside of the draining portal will be grubbed and regraded to a level condition. For costing purposes, it is assumed that a 50 foot by 50 foot square area will be sufficient to treat the average mine discharge (regrading will be sufficient to establish work space for cell construction).

- Cell Preparation: The bioreactor cell area will be excavated to a depth of approximately 3 feet and contained by bounding berms of 2-foot height. Four internal berms, also of 3-foot height (sufficient height to act as a flow barrier – 1 foot above water line), will be constructed as parallel baffles, approximately 10 feet apart and opposing open ends. The berm baffles will enhance media contact and residence time. Excavated material identified as waste rock will be used to construct the basal portion of berms. Any material identified as native soil will be used as substrate in the cell or as exterior portion of berms. All rock fragments greater than 1-inch in size will be raked from the cell's interior ground surface. The cell bottom and all berms will be compacted. A spillway for the wetland cell will be installed on the north end of the cell at the appropriate elevation (such that the free water surface is at or below the estimated substrate surface). The spillway will be lined and partially filled with non-limestone aggregate; flow will be directed to the ephemeral drainage portion of Lion Canyon Creek near the mine access road. The final grade of the cell will be such that water flows by gravity from the portal to the cell. Final water level in the cell will be at least one foot below the bounding berms and 6-inches below the biomass substrate. This will allow for potential fluctuations in discharge to the cell.

    - Inlet: The mine drainage pipe will be connected to an appropriate fitting at the inlet end of the cell. The inlet will be in the upstream corner of the cell confined by the cell walls and an internal baffle.
    - Liner installation: An appropriate durable, non-woven, impermeable geosynthetic fabric liner such as EPDM or RPP will be installed over the entire cell bottom, and internal and bounding berms. The liner will be flexible, UV resistant, and of at least 20 year lifespan rating. The liner will be anchored within the upper one foot of the bounding berms.
    - Biomass substrate installation: Three feet of biomass substrate of high organic content, will be placed in the cell. Biomass materials will consist of materials such as certified straw mulch, sawdust, wood chips, corn husks, composted leaves, grass, or manure, and peat.
    - Outlet: The cell outlet will consist of a pipe fitting such that effluent will flow from the end of the last baffle section into a 4-inch ADS single-wall, corrugated, HDPE pipe. The pipe will be buried in a 1 to 2 foot trench. The outfall will be located in ephemeral portion of Lion Canyon Creek, near the existing access road culvert. The spillway will be protected with non-limestone aggregate, if needed.

  - Security: An 8-foot high security fence will be constructed around the cell perimeter to protect the cell from vandalism, rock fall, and wildlife access.

- Run-on channels constructed as part of the overall erosion mitigation for the mine bench will be located in the vicinity of the treatment wetland to reduce potential erosion of the wetland berms.

Operation and maintenance activities associated with Alternative 3 would include periodic inspections to monitor the integrity of the bioreactor cell, including berm and liner integrity, flow conditions, and conduct analytical sampling. Under Alternative 3, it is anticipated that the bioreactor cell would likely require periodic maintenance including berm repair, elimination of preferential flow paths, liner repair (where visible near water line) and replenishment of biomass. It is estimated that approximately 50 percent of the biomass would need to be replaced every 10 years.

7.6.2.1 Effectiveness

Overall, Alternative 3 would provide a moderately effective mechanism for protection of ecologic health and the environment at the mine. Through the use of chemical and biochemical processes, the alternative would reduce level of contamination in the water emanating from the Blue Cap Mine adit. The threats posed to aquatic life as a result of mine drainage entering Lion Canyon Creek would be effectively mitigated by removal of selenium, gross alpha, and gross beta concentrations due to precipitation and adsorption of selenium, uranium and some radium (metals) within the biomass substrate. The overall effectiveness of the bioreactor will depend on establishing reducing conditions to promote precipitation of metals and sufficient surface area to adsorb metals. However, it is likely that the alternative would require periodic removal and replenishment of the biomass materials.

General compliance with ARARs would be achieved with implementation of Alternative 3. There would likely be some short-term ecological and environmental effects due to construction activities from dust generation, vegetation clearing, and general construction noise during implementation of Alternative 3. These short-term impacts would be minimal, with exposure pathways minimized through engineering controls and personal protective equipment.

7.6.2.2 Implementability

Implementation of Alternative 3 is technically feasible at the mine. The effectiveness of the alternative would be monitored by performing periodic sampling and analysis of influent and effluent water at the

bioreactor cell. A comparison of analytical data for an initial influent sample and subsequent effluent samples will be used to judge the effectiveness of water treatment. Effluent sampling would be conducted on an annual basis and influent sampling on a bi-annual (every two years) basis. The necessary resources and materials for Alternative 3 are readily available.

Alternative 3 is also administratively feasible at the mines; however, some public concerns (including local, state, and federal) would likely be encountered. These concerns may include the overall effectiveness and longevity of the bioreactor cell, the potential for greater exposure to wildlife receptors at the cell, impacts to the natural character of the mine site, the potential for media-introduced contaminants in the effluent, the likely destruction of non-jurisdictional wetlands that exist on the mine bench, and disposal of biomass media during replenishment work. Applicable permit and agency coordination requirements, as identified in Section 5.3 of this document, would need to be met before commencing construction operations.

7.6.2.3 Cost

The estimated costs for Alternative No. 3 at the Blue Cap Mine are presented in Table 7.5, and a detailed breakdown of the costs is provided in Appendix E. Direct capital costs for mobilization and labor and materials required to complete the ancillary construction activities such as site run-on and run-off erosion control are included in Section 6.4.4 (waste rock removal actions). Indirect capital costs include permitting and engineering support and oversight during construction. No costs have been included for potential wetlands replacement. The total capital costs (including construction and indirect costs) for Alternative No. 3 are estimated to be $103,172. In addition to the total capital costs, the estimated cost for pilot-scale testing of Alternative No. 3, in combination with Alternatives Nos. 2 and 4, is $25,052.

Operation and maintenance costs are costs associated with post-construction inspection, maintenance, and monitoring (including sampling and analysis of influent and effluent). It is assumed that post-reclamation inspections and monitoring will be performed by BLM personnel on an annual basis for a 10-year period; no costs for BLM labor is included in this analysis. It is assumed that 2 analytical samples will be collected per year of the bioreactor cell influent or effluent for comprehensive analysis at an estimated cost of $708 per sample. Projected maintenance costs assume work performed by contractor and that 50 percent of the wetland media will require removal and replacement and berms will require repair every 10 years. It is assumed that replenishment of the bioreactor cell will require disposal of spent media as a hazardous waste with an estimated disposal cost of $10,500 per 10 year period.

The total net present value of Alternative 3 over 10 years (pilot-scale testing and total capital cost plus present worth of operation and maintenance cost) is estimated to be $168,203.

7.6.3 Alternative No. 4: ZVI Cell

The general activities to be performed under Alternative 4 include (1) bench or field-scale testing of ZVI treatment media, and (2) ZVI treatment cell construction. At the Blue Cap Mine, Alternative 4 would be implemented as follows:

- Mine Drainage Collection Structure: Flow from the portal to the ZVI cell will be facilitated by the construction of a 2-foot high concrete sack dam within the portal behind the final portal seal. A 4-inch ADS single-wall, corrugated, HDPE collection pipe will be sealed in place at the base of the dam to convey drainage from the mine to the ZVI cell. It is assumed that the base area in front and back of the dam will be appropriately sealed through the use of an impermeable geosynthetic liner material (e.g. EPDM or RPP) that is keyed into the portal floor. This seal will reduce leakage around the dam. If necessary, a temporary upstream dam will be constructed to divert mine drainage during construction of the concrete sack dam and pipe conveyance structure. The collection pipe will extend from the base of the dam and under the portal seal structure to the mine bench. The pipe will be trenched and buried to a shallow depth where possible such that gravity flow to the ZVI cell is maintained. Native fill will be used to cover the pipe outside of the portal if trenching is not possible.

- Ground Preparation. The bench area outside of the draining portal will be grubbed and regraded to a level condition. For costing purposes, it is assumed that a 12 foot by 12 foot square area will be sufficient to treat the average mine discharge (regrading will be sufficient to establish work space for cell construction).

- Cell Preparation: The ZVI cell can be constructed as a lined excavation on the mine bench or as a prefabricated steel cell. This EE/CA assumes the use of a prefabricated ZVI cell. The advantages of a prefabricated steel cell include a design that can accommodate numerous vertical baffles within a minimum amount of space, therefore increasing residence time for the cell; baffles that may be removable during cell media replenishment; a durable container that will not be damaged during maintenance; modular design such that the cell size can be easily modified; and more adaptable valving for adjusting or bypassing flows within the cell. The cell area will be excavated to a depth of approximately 2 feet and contained by bounding berms of 2-foot height. The berms will act as containment system in the case of a spill. The 12-foot wide by 12-foot long by 2.5-foot deep steel ZVI cell will be set into the excavation such that approximately 0.5 foot is above grade. The cell will contain approximately 5 vertical baffles. The design can be such that the baffles are removable. A flow rate of 2 gallons per minute should result in a minimum residence time of 9.8 hours with a flow path of approximately 60 feet. Final water level in the cell will be at least 6-inches below the top cover of the cell. This will allow for potential fluctuations in discharge to the cell.

- Inlet: The mine drainage pipe will be connected to an appropriate fitting at the inlet end of the cell. The inlet will be in the upstream corner of the cell confined by the cell walls and an internal baffle.
- ZVI installation: Two-feet of granular ZVI material will be placed on the bottom of the cell. Cell loading can be conducted through closeable slots in the cover, from the side panels, or through the use of a dissolvable sheath containing the bulk ZVI prior to cover installation. An estimated 25 tons of ZVI product would be needed to fill the cell.
- Cover installation: The cover need not be welded to the base but will key into prefabricated slots. The berm baffles will enhance media contact and residence time. Air vents will be installed on the cover to allow the ZVI to degas. The cell cover will be covered with up to 1foot of soil (flow testing of the cell will be conducted before the soil cover is installed.
- Outlet: The cell outlet will consist of a pipe fitting such that effluent will flow from the end of the last baffle section into a 4-inch ADS single-wall, corrugated, HDPE pipe. The pipe will be buried in a 1 to 2 foot trench. The outfall will be located in ephemeral portion of Lion Canyon Creek, near the existing access road culvert. The spillway will be protected with non-limestone aggregate, if needed.
- Security: An 8-foot security fence will be constructed around the cell perimeter to protect the cell from vandalism, rock fall, and wildlife access.

- Run-on channels constructed as part of the overall erosion mitigation for the mine bench will be located in the vicinity of the treatment wetland to reduce potential erosion of the wetland berms.

Operation and maintenance activities associated with Alternative 4 would include periodic inspections to monitor the integrity of the ZVI cell, including inspections of the security fence, cell cover, indications of portal leakage and cell integrity (leakage), flow conditions, and conduct analytical sampling. Under Alternative 4, it is anticipated that the ZVI cell would likely require periodic maintenance and repair including the portal dam and collection pipe system, cell cover, the reduction of preferential flow paths, and replenishment of ZVI media. It is anticipated that the ZVI media would need to be replaced approximately every 5 years.

7.6.3.1 Effectiveness

Overall, Alternative 4 would provide a highly effective mechanism for protection of ecologic health and the environment at the mine. Through the use of chemical and biochemical processes, the alternative would reduce level of contamination in the water emanating from the Blue Cap Mine adit. The threats posed to aquatic life as a result of mine drainage entering Lion Canyon Creek would be effectively mitigated by removal of selenium, gross alpha, and gross beta concentrations due to precipitation and adsorption of selenium, uranium and some radium (metals) within the ZVI media. The overall effectiveness of the treatment wetland will depend on establishing reducing conditions to promote precipitation and of metals and sufficient surface area to adsorb metals. However, research has shown

that ZVI cells, although effective in metals removal, eventually clog with mineral precipitates and otherwise become less effective. Removal and replenishment of ZVI media is required.

General compliance with ARARs would be achieved with implementation of Alternative 4. There would likely be some short-term ecological and environmental effects due to construction activities from dust generation, vegetation clearing, and general construction noise during implementation of Alternative 4. These short-term impacts would be minimal, with exposure pathways minimized through engineering controls and personal protective equipment.

7.6.3.2 Implementability

Implementation of Alternative 4 is technically feasible at the mine. The effectiveness of the alternative would be monitored by performing periodic sampling and analysis of influent and effluent water at the ZVI cell. A comparison of analytical data for an initial influent sample and subsequent effluent samples will be used to judge the effectiveness of water treatment. Effluent sampling would be conducted on an annual basis and influent sampling on a bi-annual (every two years) basis. The necessary resources and materials for Alternative 4 are readily available.

Alternative 4 is also administratively feasible at the mines; however, some public concerns (including local, state, and federal) would likely be encountered. These concerns may include the overall effectiveness and longevity of the ZVI cell, impacts to the natural character of the mine site, the likely destruction of non-jurisdictional wetlands that exist on the mine bench, the potential for media-introduced contaminants in the effluent, and disposal of ZVI media during cell replenishment work. Applicable permit and agency coordination requirements, as identified in Section 5.3 of this document, would need to be met before commencing construction operations.

7.6.3.3 Cost

The estimated costs for Alternative No. 4 at the Blue Cap Mine are presented in Table 7.5, and a detailed breakdown of the costs is provided in Appendix E. Direct capital costs for mobilization and labor and materials required to complete the ancillary construction activities such as site run-on and run-off erosion control are included in Section 6.4.4 (waste rock removal actions). Indirect capital costs include permitting and engineering support and oversight during construction. No costs have been included for potential wetlands replacement. The total capital costs (including construction and indirect costs) for

Alternative No. 4 are estimated to be $136,450. In addition to the total capital costs, the estimated cost for pilot-scale testing of Alternative No. 4, in combination with Alternatives Nos. 2 and 3, is $25,052.

Operation and maintenance costs are costs associated with post-construction inspection, maintenance, and monitoring (including sampling and analysis of influent and effluent). It is assumed that post-reclamation inspections and monitoring will be performed by BLM personnel on an annual basis for a 10-year period; no costs for BLM labor is included in this analysis. It is assumed that 2 analytical samples will be collected per year of the wetland influent or effluent for comprehensive analysis at an estimated cost of $708 per sample. Projected maintenance costs assume work performed by a contractor and that 100 percent of the ZVI media will require replacement every 5 years. It is assumed that replenishment of the ZVI cell will require disposal of spent media as a hazardous waste with an estimated disposal cost of $6,600 per 5 year period.

The total net present value of Alternative 4 over 10 years (pilot-scale testing and total capital cost plus present worth of operation and maintenance cost) is estimated to be $307,738.

8.0 COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

In this section, the alternatives, including sub-alternatives, for waste rock and adit discharge evaluated in Sections 6.0 and 7.0 are compared against each other to evaluate the relative performance of each alternative in relation to each of the criteria. The criteria used in this comparison are the same as those evaluated in Sections 6.0 and 7.0, including effectiveness, implementability, and cost. The comparative analysis for waste rock and adit discharge are summarized in Tables 8.1 and 8.2, respectively. For each alternative listed in the tables, an overall rating of "low", "moderate", or "high" is given for each evaluation criterion. To better describe the overall ratings given, a numerical scale ranging from 1 (low) to 3 (high) is used to refine the rating for each narrative category. For example a rating of low-1 indicates the low end of the low category, while a rating of high-3 indicates the high end of the high category.

8.1 Removal Action Alternative for Waste Rock

A comparative analysis summary showing the rating of each waste-rock alternative relative to the other alternatives is provided in Table 8.1. The comparative analysis for each criterion is discussed below.

8.1.1 Effectiveness of Alternatives

The effectiveness of the alternatives was compared on the basis of six criteria: (1) compliance with RAOs, (2) overall protection of human health and the environment, (3) compliance with ARARs, (4) long-term effectiveness and permanence, (5) reduction of toxicity, mobility, or volume, and (6) short-term effectiveness. With respect to these factors, Alternative 3 (Consolidation, Regrading, and Containment) would provide the highest overall effectiveness for each mine. In addition to protecting human health and the environment from direct contact with the mine waste in sensitive areas (i.e., potential camping potential camping areas), Alternative 3 would provide the most effective mechanism for physical stabilization of the waste-rock dumps. By regrading the upper dump slopes and, where feasible, the lower dump slopes, the alternative would provide a more stable dump configuration and thereby facilitate revegetation efforts and reduce the potential for off-site migration of waste and sediment. Sub-Alternative 3B would be the most effective sub-alternative for further stabilization of the dumps. Application of Sub-Alternative 3D at the Firefly/Pygmy and Vanadium Queen Mines would involve installation of an earthen berm along the perimeter of each dump and amending regraded areas with soil and nutrients, fertilizing and seeding the amended areas, and covering the seeded areas with erosion-

control matting. At the Blue Cap and Black Hat Mines, Sub-Alternative 3D would be modified to exclude construction of earthen berms.

Alternative 2 would provide a moderate level of overall effectiveness. While the alternative would reduce the potential for direct contact with the waste rock in sensitive areas (i.e., potential camping areas), dumps would remain in their current configurations which would likely limit the success of erosion-control measures and increase the potential for recontamination of reclaimed areas (e.g., lower benches).

The overall effectiveness of Alternate 1 (No Action) would be low compared to the other alternatives.

8.1.1.1 Compliance with RAOs

The RAOs specified in Section 5.4 of this document would be achieved to varying degrees with implementation of Alternatives 2 or 3. By covering potential camping areas, both alternatives provide an effective means of isolating the mine waste and preventing actual or potential exposure to humans by direct contact with the waste rock in these sensitive areas at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines. However, regrading operations under Alternative 3 would result in fewer potential camping areas at the mines and reduce the potential for recontamination of reclaimed areas as a result of erosion and mass wasting from the overlying slopes. Both alternatives would also reduce the potential for off-site migration of contaminants as a result of erosion and mass wasting processes. Greater protection against erosion and mass wasting would be provided by Alternative 3 since the waste dumps would be regraded to form more stable configurations. Stabilization of the dump materials would be enhanced under Alternative 3 with implementation of the containment and physical stabilization measures specified in Sub-Alternatives 3A, 3B, 3C, and 3D. With proper inspection and maintenance, compliance with the RAOs regarding reduction of potential for direct contact, gamma exposure, and off-site migration of mine-derived materials could be effectively accomplished with each of these sub-alternatives. Of the containment options offered under the various sub-alternatives for Alternatives 2 and 3, the natural character of the mine areas would be better maintained with the use of earthen berms as opposed to structural silt fences.

8.1.1.2 Overall Protection of Human Health and the Environment

The greatest risks to human health and the environment are attributed to direct contact with waste rock in the potential camping areas and physical hazards posed by unstable structures and mine openings. In addition, off-site migration of waste rock and sediment poses threats to human health and the environment

in areas downgradient of the mines. Under the no-action alternative, there would be no reduction in the human health and ecological risks posed by the waste-rock contaminant sources or the physical hazards present at the mines. Exposures to elevated arsenic in the waste rock and gamma radiation at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines, physical hazards, and off-site migration of waste rock and sediment would be expected to continue in the future. Therefore, the no-action alternative would not promote protection of human health and the environment.

Alternatives 2 and 3 both provide protection of human health and the environment by eliminating the potential for direct exposure to the mine waste in potential camping areas, eliminating physical hazards present at the mines, and reducing the potential for off-site migration of waste rock and sediment. Animals burrowing into the mine waste would be the only remaining potential direct exposure pathway. Because the waste dumps would be regraded to form more stable configuration, Alternative 3 is expected to reduce the potential for contaminant migration from the waste-rock source areas to a greater degree than Alternative 2. With proper inspection and maintenance, each of these sub-alternatives under Alternative 3 would effectively contribute to physical stabilization of the dump materials. However, Sub-Alternatives 3B and 3D would enhance protection of human health and the environment since portions of the dumps would be amended with soil/nutrients, revegetated, and covered with erosion-protection matting.

Some short-term ecological and human health impacts would be anticipated during construction from dust generation, vegetation clearing, and general construction noise. These impacts would be minimized by use of engineering controls and personal protective equipment for on-site workers.

8.1.1.3 Compliance with ARARs

Under the no-action alternative, unsanctioned campers would continue to be exposed to elevated arsenic and gamma radiation levels at the mines. In addition, degradation of surface water quality in La Sal Creek and Lion Canyon Creek would continue as waste rock and sediment continue to migrate to these surface-water features. Contaminated sediment would also continue to migrate from the mines as a result of wind transport, impacting ambient air quality conditions in the vicinity of the mines.

Alternatives 2 and 3 both include provisions to place a soil cover over the potential camping areas where direct contact with the waste rock and elevated gamma-exposure rates pose threats to public health. Both alternatives also provide means of reducing the potential for off-site migration of waste rock and sediment

by (1) removing waste-rock debris from drainages adjacent to the dumps, (2) utilizing revegetation techniques and erosion controls, and (3) installing containment structures. However, the potential for off-site migration of waste rock and sediment would be less under Alternative 3 because portions of the dumps would be regraded to form more stable configurations. Containment and physical stabilization of the dumps would be less successful under Alternative 3 because the waste-rock dumps would remain in their existing, less stable configurations.

Of the two sub-alternatives for Alternative 2, both would generally provide the same level of compliance with ARARs. Of the four sub-alternatives for Alternative 3, the actions involving revegetation in combination with erosion-control matting (Sub-Alternatives 3B and 3D) would provide the greatest protection against off-site migration of waste materials.

Some improvement of air quality is expected after the waste-rock areas are partially covered under Alternative 2 or 3 in comparison to the existing exposed and unvegetated waste-rock dumps. However, greater compliance with ambient air-quality requirements would be expected where erosion-control matting is used to stabilize revegetated surfaces (Sub-Alternatives 3B and 3D).

Location-specific ARARs are expected to be met under either alternative. Historical surveys and reconnaissance conducted at the mines indicate that no features of historic or archaeological significance are present at the mines. Any threatened or endangered species that may be present in the project area would not be impacted in the long-term because the removal action will be completed in a relatively short period of time, all disturbed areas will be reclaimed, and operation and maintenance activities required to support the action will not require a level of activity that is greater than that existing under current conditions. In addition, removal activities associated with any mine waste in contact with surface water would be conducted such that any disturbance to the bed or banks of the drainage would be minimized. The bed and banks of any such affected drainage would be properly reclaimed and protected from flood erosion. In addition, proper controls will be implemented within each disturbed area to minimize erosion.

Action-specific ARARs are expected to be met by either alternative. Compliance with stormwater runoff requirements and emission of fugitive dust would be achieved through the use of best management practices. All activities performed in support of the actions will be conducted in compliance with procedures and protocols established by OSHA and MSHA.

8.1.1.4 Long-term Effectiveness and Permanence

Of the alternatives considered in the analysis, Alternative 3 would be the most effective in the long-term because the waste-rock dumps would be regraded to form more stable configurations, promoting effective erosion-control and physical stabilization of the dumps. The use of an earthen berms and sediment retention features/ponds would provide greater long-term effectiveness than structural silt fences because the effectiveness of structural silt fences would decrease over time as the permeable material clogs with sediment and debris. In addition, structural silt fences would provide less volume for retention of sediment than would earthen berms in combination with sediment retention features/ponds. Each of the Alternative 3 sub-alternatives would offer effective erosion-control and physical stabilization in the long term, provided the features are properly inspected and maintained over time. Inspection and monitoring requirements would be less for the measures involving revegetation in combination with matting.

Alternative 2 may not prove to be effective in the long term because waste-rock dumps would remain in the current, unstable configurations. As a result, reclaimed lower benches may become re-contaminated and erosion-control measures may fail over time reducing the ability of containment features (structural silt fences and earthen berms) to effectively contain waste materials onsite.

The no-action alternative would provide no long-term or permanent solution for the mine.

8.1.1.5 Reduction of Toxicity, Mobility, or Volume

None of the alternatives considered in the analysis involve treatment of the waste rock, and therefore, the volume, toxicity, or mobility of contaminants in the waste rock would not be reduced in any of the alternatives. The existing volume of waste materials will remain onsite, and waste materials will not be treated or otherwise stabilized to reduce toxicity or mobility. However, reduction of mobility with respect to off-site migration of contaminated materials would be reduced through implementation of the actions taken to physically stabilize the waste-rock materials.

8.1.1.6 Short-term Effectiveness

Some short-term ecological and human-health impacts would be anticipated during implementation of Alternative 2 or 3 from dust generation, vegetation clearing, and general construction noise. In addition, site workers will be subject to potential threats (e.g., direct contact, inhalation, ingestion, and radiation exposure) associated with the waste-rock materials during implementation of the action. Short-term

impacts to the public and workers during construction would be minimal, with exposure pathways minimized through engineering controls (e.g., restricting public access) and the use of personal protective equipment. Ecological impacts would be minimized by implementation of best management practices for control emissions of fugitive dust, off-site migration of sediment from disturbed areas, and protection of surface water channels. The duration of short-term impacts to human health and the environment would be limited because the actions could be completed within one construction season.

RAOs would be achieved in a shorter time frame under Alternative 3 than Alternative 2. The regrading operations included in Alternative 3 would improve the stability of the dumps and facilitate establishment of vegetation on the regraded areas.

Although there would be no construction-related impacts for the no-action alternative, the impacts from direct contact with the waste-rock materials and gamma-exposure rates would continue in both the short-term and long-term.

8.1.2 Implementation of Alternatives

Each of the alternatives is technically and administratively feasible. Essential project components including technical expertise, equipment, and materials are readily available in the eastern Utah and western Colorado region. Some specialized construction equipment and expertise would be required to properly construct and install the waste-rock containment structure at the Blue Cap Mine. Experienced personnel should also be used to ensure that proper quality assurance/quality control protocols are implemented during installation containment structures and erosion-control features. It is expected that such personnel are available in the regional area.

The amount of native soil available on-site and to be generated during implementation of the actions is not known. However, it is anticipated that the amount of soil available on-site will not be sufficient to support the actions, and therefore, some soil will likely need to be imported to the mines. Evaluation of the implementability of the various alternative and sub-alternatives must consider the amount of soil needed to support the actions. Because the BLM has not yet identified an approved and permitted soil borrow area for the mines, the alternatives and sub-alternatives requiring more soil are considered to be less implementable than those requiring less soil. Alternative 3 in combination with Sub-Alternative 3A or 3C would require the least amount of soil. Fewer potential camping areas will exist after the dumps

have been regraded (Alternative 3) and less soil amendment will be required to support revegetation efforts under Sub-Alternatives 3A and 3C).

Although technical feasibility is not an issue for the no-action alternative, some consideration would need to be given to the administrative feasibility of the alternative. The no-action alternative may not be acceptable to the public, regulatory agencies and the BLM because current threats to public health and the environment, as described in the streamlined risk evaluation, will remain at the mines and continue in the future.

8.1.3 Cost

No capital costs or indirect costs would be incurred under the no-action alternative. Other than periodic inspections by BLM personnel, no operation and maintenance costs would be incurred under the no-action alternative. However, the long-term costs associated with the no-action alternative are not known because there would be ongoing threats to public health and the environment from direct contact with the waste-rock and gamma exposure in potential camping areas. In addition, waste rock and sediment would continue to migrate off-site, potentially resulting in damage to other resources and requiring future action.

The estimated costs for Alternatives 2 and 3 are presented in Table 6.3. The total net present value of Alternatives 2 and 3 over 10 years (total capital cost plus present worth of operation and maintenance cost) is summarized for each mine as follows:

- Firefly/Pygmy Mine
  - Sub-Alternative 2A: $ 171,535
  - Sub-Alternative 2B: $ 198,080
  - Sub-Alternative 3A: $ 267,661
  - Sub-Alternative 3B: $ 326,968
  - Sub-Alternative 3C: $ 291,267
  - Sub-Alternative 3D: $ 350,575

- Vanadium Queen Mine
  - Sub-Alternative 2A: $ 122,175
  - Sub-Alternative 2B: $ 139,762
  - Sub-Alternative 3A: $ 129,292
  - Sub-Alternative 3B: $ 169,562
  - Sub-Alternative 3C: $ 145,004
  - Sub-Alternative 3D: $ 186,273

- Blue Cap Mine
  - Alternative 2: $ 344,278
  - Sub-Alternative 3A: $ 410,170 (excludes structural silt fences)

- Sub-Alternative 3B: $ 434,163 (excludes earthen berms)

- Black Hat Mine
  - Alternative 2: $ 45,870
  - Sub-Alternative 3A: $ 69,031 (excludes structural silt fences)
  - Sub-Alternative 3D: $ 76,731 (excludes earthen berms)

8.2 Removal Action Alternative for Mine Discharge

A comparative analysis summary showing the rating of each mine drainage alternative relative to the other alternatives is provided in Table 8.2. The comparative analysis for each criterion is discussed below.

8.2.1 Effectiveness of Alternatives

The effectiveness of the alternatives was compared on the basis of six criteria: (1) compliance with RAOs, (2) overall protection of human health and the environment, (3) compliance with ARARs, (4) long-term effectiveness and permanence, (5) reduction of toxicity, mobility, or volume, and (6) short-term effectiveness. With respect to these factors, Alternative 4, the re-aligned, piped drainage, would provide the highest overall effectiveness for the Firefly-Pygmy and Vanadium Queen Mines. Alternative 4 will effectively separate mine drainage at the mines from coming in contact with waste rock by containing flow within a pipe laid along the re-alignment route. This alternative will effectively stop infiltration of the mine drainage into the waste rock and thereby prevent the potential production of more highly contaminated leachate. Alternative 3, the re-aligned lined channel, would also provide a high degree of effectiveness at the Firefly-Pygmy Mine, and Vanadium Queen Mine, respectively. While the effectiveness for Alternatives 3 and 4 is similar, the advantage to the piped drainage is the potential for less maintenance, providing the pipe does not get blocked. Freezing conditions may have similar effects on both alternatives. At the Vanadium Queen Mine, Sub-Alternative 3B would provide a slightly improved effectiveness because of the benefit of water consumption and transpiration from plants along the unlined lower segment of the channel. Alternative 4A is considered having a high degree of effectiveness at the Vanadium Queen Mine because of the additional benefit of having plant water consumption (transpiration) employed in the open channel portion of the alternative.

Alternatives 2 and 2A would provide a moderate level of overall effectiveness with Alternative 2A providing a slightly greater level of effectives because of the added advantage of plant transpiration of mine water. Alternative 2 at the Vanadium Queen Mine is considered moderately effective because of a

small potential for mine drainage to infiltrate colluvium upgradient of peripheral waste rock. Even if Alternatives 2 and 2A were constructed entirely in native colluvium, a concern would remain that drainage might migrate into waste rock downgradient of the drainage channel.

For the Blue Cap Mine, Alternative 4, the ZVI Cell, provides the highest degree of effectiveness in removing the COCs from the mine drainage. This alternative was supported by quantitative research that demonstrated a high degree of effectiveness in removing selenium and uranium in mine drainage or milling-related contaminated waters. Alternative 2, the anaerobic wetland, and Alternative 3, the bioreactor cell, are both expected to provide a moderate degree of effectiveness. Research investigating reduction through the use of organic matter indicates that these alternatives commonly remove the COCs and that both precipitation by reduction and adsorption processes are probably involved. Seasonal fluctuations in temperatures are expected to have greater negative impact on the performance of these alternatives. Alternative 2, the anaerobic wetland, theoretically may have a longer life as wetland plants replenish organic matter vital to maintain reducing conditions and adsorption capacity.

The overall effectiveness of Alternate 1 (No Action) would be low compared to the other alternatives.

8.2.1.1 Compliance with RAOs

The RAOs specified in Section 5.4 of this document would be achieved to varying degrees with implementation of Alternatives 2, 3, or 4 for the Firefly-Pygmy and Vanadium Queen Mines. By capturing all mine discharge and conveying the water in a re-aligned channel or pipe, the potential contact and infiltration of waste rock by the discharge will be significantly reduced or prevented. Signage installed at the mines will warn visitors of the potential hazard associated with the mine discharge (the water is non-potable). Alternative 2 at both Mines, and to some degree Alternatives 3 and 4 at the Vanadium Queen Mine may have the advantage of reducing surface exposure and the potential surface flow to perennial streams because of the potential for infiltration of the discharge into colluvium along the channel reach. Alternative 2 therefore has the potential to reduce contact of the discharge with waste rock while limiting surface migration of mine drainage through infiltration in non-waste rock areas. Sub-Alternatives 2A and 3B may promote “containment” of mine discharge through consumption and transpiration of plants during the growing season. Conversely, infiltration occurring in the upper portions of the unlined channel of Alternative 2 may intercept waste rock located downgradient.

Alternatives 3 and 4 would provide a greater degree of effectiveness in separating mine drainage from waste rock, but would also promote the transport of contaminated mine drainage away from the mine sites.

At the Blue Cap Mine, Alternatives 2, 3, and 4 would meet the RAO of preventing or reducing the generation of leachate through the infiltration of mine drainage, as the proposed treatment systems would be lined and no infiltration would occur on the waste rock areas. In addition, the RAO of reducing the metal concentrations (selenium, uranium, and radium) and radionuclide activity levels of gross alpha and gross beta would be achieved at varying levels with all the proposed alternatives.

8.2.1.2 Overall Protection of Human Health and the Environment

Section 4.0, the Streamlined Risk Evaluation did not find that the mine drainage from the Firefly-Pygmy Mine or Vanadium Queen Mine were of significant risk to human health, as levels of contaminants in the mine drainage did not exceed RMCs or modified MCLs. However, because mine drainage emanates from the adits and disperses across the mine benches, a valid concern is the generation of leachate by infiltrating mine drainage in the waste rock and migration of the leachate into the surrounding environment. This concern was supported by analytical data that showed increased contaminants in a seep sample at the toe of the upper dump at the Firefly-Pygmy Mine compared to a sample of the adit discharge. The removal action alternatives for the mitigation of infiltration at Firefly-Pygmy and Vanadium Queen Mines were conceived to reduce or prevent the generation of contaminated leachate at the mines and are consistent with overall protection of human health and environment. Alternatives 2, 3, and 4 and associated sub-alternatives for the Firefly-Pygmy and Vanadium Queen Mine will not prevent exposure of receptors to the mine discharge, however, signage will be installed that warns human visitors of the non-potable water source at the mines.

The infiltration of mine drainage and generation of leachate is also of concern at the Blue Cap Mine where it was also found that the mine drainage contains levels of selenium, gross alpha, and gross beta that exceed aquatic life standards. The Blue Cap Mine drainage directly contributes to flows in Lion Canyon Creek which in turn, flows into La Sal Creek. The removal action alternatives at the Blue Cap Mine are designed to prevent infiltration of mine drainage and remove the COCs through passive treatment techniques. The implementation of a passive treatment alternative will provide protection of human health and the environment by reducing levels of COCs including those directly related to gross alpha and gross beta activities. Alternatives 2, 3, and 4, for the Blue Cap Mine should reduce COC levels to levels below aquatic life standards, however, it is recommended that bench-scale or field testing be

conducted to investigate the absolute and relative differences between these techniques. The alternatives will reduce or prevent exposure of receptors to the mine discharge upstream and within the treatment cell through the use of signage warning visitors of the non-potable water source at the mines, and the installation of a security fence around the treatment cell.

Some short-term ecological and human health impacts would be anticipated during construction from dust generation, vegetation clearing, and general construction noise. These impacts would be minimized by use of engineering controls and personal protective equipment for on-site workers.

In the short-term, under the no-action alternative, there would not be a reduction in the human health and ecological risks posed by the potential generation of leachate by infiltrating mine drainage at the three mines or effective metals removal at the Blue Cap Mine. The potential for generation of leachate by infiltrating mine drainage at all three mines and exposure of aquatic life to elevated levels of selenium, gross alpha, and gross beta at the Blue Cap Mine would be expected to continue in the future. However, the non-jurisdictional wetlands that have naturally established as a result of the mine drainage may continue to proliferate on the mine benches and potentially provide some water treatment benefits including mitigation of infiltration and metals removal.

8.2.1.3 Compliance with ARARs

Under the no-action alternative, the potential for the generation of metal-laden leachate due to infiltrating mine drainage at the Firefly-Pygmy, Vanadium Queen, and Blue Cap Mines would still exist and no protection of human health and the environment would occur. In addition, the degradation of surface water quality in Lion Canyon Creek and La Sal Creek would continue as a result of mine drainage from the Blue Cap Mine migrating to, and forming the head waters of Lion Canyon Creek.

Alternatives 2, 3, and 4 for infiltration mitigation at the Firefly-Pygmy Mine and Vanadium Queen Mine would generally provide the same level of compliance with ARARs. Alternatives 3 and 4 may be seen as better complying with ARARs specifying stream standards. Because the established wetlands at the mines are non-jurisdictional, activities impacting the features are not subject to the requirements set forth in Section 404 of the Clean Water Act (33USC §§ 1251 et seq.; 33 CFR Part 330). In accordance with the protection of wetlands order (40 CFR Part 6 and EO 11990), impacts to the non-jurisdictional wetlands under Alternatives 2, 3, and 4 will be minimized to the degree possible since there are no other practical alternatives for isolation of the waters from the waste-rock material. The concerns relative to wetland impacts result in an administrative implementability rating of "moderate" for these alternatives.

Discharge from abandoned mine facilities does not require compliance with the National Pollution Discharge Elimination System. Alternatives 2, 3, and 4 for treatment of mine drainage at Blue Cap Mine also provide approximately the same level of compliance with regard to stream standards. Alternatives 2 and 3 may comply more readily to effluent limitations compared to Alternative 4. Location-specific ARARs are expected to be met under either alternative. Historical surveys and reconnaissance conducted at the mines indicate that no features of historic or archaeological significance are present at the mines.

Any threatened or endangered (T and E) species that may be present in the project area, specifically those associated with the existing non-jurisdictional wetland areas may be impacted by Alternatives 2, 3, and 4 for the Firefly-Pygmy and Vanadium Queen Mines and Alternative 4 at the Blue Cap Mine. A biological survey would need to be conducted to evaluate if any T and E species are present. T and E species in the project area in general would not be impacted in the long-term because the removal action will be completed in a relatively short period of time, all disturbed areas will be reclaimed, and operation and maintenance activities required to support the action will not require a level of activity that is greater than that existing under current conditions. In addition, removal activities associated with mine drainage that involves contact with surface water or modification of a stream would be conducted such that any disturbance to the bed or banks of the drainage would be minimized and that sedimentation would be controlled. The bed and banks of any such affected drainage would be properly reclaimed and protected from flood erosion. In addition, proper controls will be implemented within each disturbed area to minimize erosion and sedimentation into perennial streams.

Action-specific ARARs are expected to be met by any alternative. Compliance with stormwater runoff requirements and emission of fugitive dust would be achieved through the use of best management practices. All activities performed in support of the actions will be conducted in compliance with procedures and protocols established by OSHA and MSHA.

8.2.1.4 Long-term Effectiveness and Permanence

Of the alternatives considered in the analysis for infiltration mitigation at the Firefly-Pygmy and Vanadium Queen Mines, Alternative 4, the piped alignment, would be the most effective in the long-term because the mine drainage would be confined to a pipe in the areas mostly likely containing or immediately upgradient of waste rock. With the exception of potential clogging of the pipe by an errant object, Alternative 4 offers an effective long-term solution to preventing infiltration of mine drainage into

waste rock. Overall maintenance for Alternative 4 for the piped segment is expected to be of a low to modest effort. Freezing conditions should be mitigated by the subsurface conveyance of mine drainage in the pipe.

Sub-Alternative 4A, the use of phreatophytes within the open, unlined portion of the channel at the Vanadium Queen Mine should provide the best long-term effectiveness and permanence at the mine. Planted cottonwoods, willows and other species will provide an additional means for reducing migration and infiltration of mine drainage along the channel. The consumption and transpiration of these plants will reduce surface and subsurface flow of this water and provide the added benefit of sequestering dissolved metals in the drainage water.

At the Blue Cap Mine, the collection of mine drainage within the mine and passive treatment of the drainage water with an anaerobic wetland, Alternative 2, is suspected to provide more long-term effectiveness and permanence. This is because of the self-perpetuating possibilities of this alternative. However, it is recommended that bench-scale or field testing be conducted during the design phase to investigate the absolute and relative differences between the passive treatment techniques
The no-action alternative would provide questionable long-term effectiveness or permanence for management of the mine drainage. The current impacts of the existing non-jurisdictional wetlands on the mine benches have not been fully assessed. The proliferation of these non-jurisdictional wetlands over time may have a more positive effect then current conditions imply.

8.2.1.5 Reduction of Toxicity, Mobility, or Volume

Alternatives 2, 3, and 4 and Sub-Alternatives 3A and 3B for the mitigation of infiltration at the Firefly-Pygmy and Vanadium Queen Mines will not reduce the toxicity, mobility, or volume of contaminants in the mine drainage at the mines. However, the toxicity of potentially generated leachate through infiltration of mine drainage will be reduced. Although the mobility of metals and radionuclides in the mine drainage would not be affected by the alternatives, a greater volume of water would actually be transported off-site through the use of these alternatives as the constructed channels focus flow and allow for more efficient transport of mine drainage to areas not previously receiving this water. Some reduction in the volume of metals and radionuclides released from the mine area in the mine drainage may be achieved through the use of Alternatives 2A and 4A, where consumption of some mine drainage water by plants will occur.

At the Blue Cap Mine, the mobility of metals and radionuclides in adit water discharging from the mine area would be reduced with implementation of Alternatives 2, 3, or 4 because treatment media will be used to capture the contaminants on-site. As a result, the toxicity of water discharging from the mine area would also be reduced; however, no reductions in the toxicity or volume of contaminants would be realized on-site. The use of ZVI treatment (Alternative 4) would likely provide the greatest reduction of contaminant mobility in the mine water, and therefore the greatest reduction of the toxicity of water downstream of the treatment unit, while the use of an anaerobic wetland (Alternative 2) would likely provide the lowest reduction of contaminant mobility, and therefore the lowest reduction of the toxicity of water downstream of the treatment unit. Contaminant removal from the site would occur during removal and replenishment of the treatment media.

8.2.1.6 Short-term Effectiveness

Of the alternatives considered in the analysis for infiltration mitigation at the Firefly-Pygmy and Vanadium Queen Mines, Alternative 2, the re-aligned, unlined channel, would be the most effective in the short-term because construction time would be slightly less than Alternatives 3 and 4. However, this difference in construction time is considered negligible.

Sub-Alternatives 2A and 4A, the use of phreatophytes within the open, unlined portion of the channel at the Vanadium Queen Mine and the entire channel at the Firefly-Pygmy Mine would not provide an effective short-term solution due to the time it takes for plants to mature.

At the Blue Cap Mine, the collection of mine drainage within the mine and passive treatment of the drainage water with a ZCI cell, Alternative 4, is expected to provide better short-term effectiveness. This is because of the reactivity of the media involved. It is anticipated that Alternatives 2 and 3 would be less effective in the short-term as the reaction kinetic are expected to be slower, especially those that depend on microbial reduction processes; incubation time for microbes must be considered. As mentioned, it is recommended that bench-scale or field testing be conducted to investigate the absolute and relative differences between the passive treatment techniques.

Implementation of infiltration mitigation alternatives at the Firefly-Pygmy and Vanadium Queen Mines and the treatment alternatives for the Blue Cap Mine are expected to have some short-term ecological and human-health impacts from dust generation, vegetation clearing, and general construction noise. Short-term impacts to the public and workers during construction would be minimal, with exposure pathways

minimized through engineering controls (e.g., restricting public access) and the use of personal protective equipment. Ecological impacts would be minimized by implementation of best management practices for control emissions of fugitive dust, off-site migration of sediment from disturbed areas, and protection of surface water channels. The duration of short-term impacts to human health and the environment would be limited because the actions could be completed within one construction season.

Although there would be no construction-related impacts for the no-action alternative, the impacts from the potential generation of leachate from the infiltration of mine drainage in the waste rock at all three mines, and the discharge of mine drainage that threatens aquatic life at the Blue Cap Mine would continue in both the short-term and long-term.

8.2.2 Implementation of Alternatives

Each of the alternatives is technically and administratively feasible. Essential project components including technical expertise, equipment, and materials are readily available in the eastern Utah and western Colorado region. Some specialized materials such as geosynthetic liner fabric and ZVI can be readily shipped to the project area. The installation of these materials can be conducted with local construction equipment and expertise in addition to information provided by the vendors. Experienced personnel should also be used to ensure that proper quality assurance/quality control protocols are implemented during installation of conveyance and containment structures and erosion control features. It is expected that such personnel are available in the regional area.

As mentioned in Section 8.2.1.3, implementation of Alternatives 2, 3, and 4 for infiltration mitigation at the Firefly-Pygmy Mine and Vanadium Queen Mine, as well as Alternatives 3 and 4 for passive treatment at the Blue Cap Mine, will result in adverse impacts to non-jurisdictional wetlands at the mines since there are no other practical alternatives for isolation of the adit waters from the waste-rock materials. Because the established wetlands are non-jurisdictional, activities impacting the features are not subject to the requirements set forth in Section 404 of the Clean Water Act (33USC §§ 1251 et seq.; 33 CFR Part 330). Nevertheless, the actions must be implemented in a manner consistent with the protection of wetlands order (40 CFR Part 6 and EO 11990) which specifies that long and short-tem adverse impacts associated with the destruction or modification of wetlands should be avoided to the extent possible when (1) acquiring, managing, and disposing of Federal lands and facilities; (2) providing Federally undertaken, financed, or assisted construction and improvements; and (3) conducting Federal activities

and programs affecting land use. As a result, the administrative implementability of the alternatives is considered to be moderate.

Alternative 2 for the Blue Cap mine will require the use of soil substrate. The amount of native soil available on-site and to be generated during implementation of the actions is not known. However, it is anticipated that the amount of soil available on-site will not be sufficient to support the actions, and therefore, some soil will likely need to be imported to the mine. Evaluation of the implementability of the various alternative and sub-alternatives must consider the amount of soil needed to support the actions. Because the BLM has not yet identified an approved and permitted soil borrow area for the mines, Alternative 2 is considered to be less implementable than those requiring no or less soil. Alternatives 3 and 4 at the Blue Cap Mine would require the less soil to implement.

Although technical feasibility is not an issue for the no-action alternative, some consideration would need to be given to the administrative feasibility of the alternative. The no-action alternative may not be acceptable to the public, regulatory agencies and the BLM because current threats to public health and the environment, as described in the streamlined risk evaluation, will remain at the mines and continue in the future.

8.2.3 Cost

No capital costs or indirect costs would be incurred under the no-action alternative. Other than periodic inspections by BLM personnel, no operation and maintenance costs would be incurred under the no-action alternative. However, the long-term costs associated with the no-action alternative are not known because there would be ongoing threats to public health and the environment from the potential generation of leachate that may migrate from the sites to water resources and discharge of Blue Cap Mine drainage that currently threatens aquatic life in Lion Canyon Creek.

The estimated costs for Alternatives 2 and 3 and 4 for the Firefly-Pygmy and Vanadium Queen Mine and the estimated costs for Alternatives 2, 3, and 4 for the Blue Cap Mine are presented in Table 7.5. The total net present value of Alternatives 2, 3, and 4 over 10 years (total capital cost plus present worth of operation and maintenance cost) is summarized for each mine as follows:

- Firefly/Pygmy Mine
  - Alternative 2: $ 25,369
  - Sub-Alternative 2A: $ 35,464

- Alternative 3: $ 35,385
- Sub-Alternative 3A: $ 49,782
- Sub-Alternative 3B: NA
- Alternative 4: $ 25,632
- Sub-Alternative 4A: NA

- Vanadium Queen Mine
  - Alternative 2: $ 26,388
  - Sub-Alternative 2A: $ 37,538
  - Alternative 3: $ 33,665
  - Sub-Alternative 3A: $ 45,175
  - Sub-Alternative 3B: $ 41,234
  - Alternative 4: $ 25,487
  - Sub-Alternative 4A: $ 33,056

- Blue Cap Mine
  - Alternative 2: $ 167,232 (includes pilot-scale testing)
  - Alternative 3: $ 168,203 (includes pilot-scale testing)
  - Alternative 4: $ 307,738 (includes pilot-scale testing)

9.0 RECOMMENDED REMOVAL ACTION ALTERNATIVES

This EE/CA was prepared in accordance with EPA guidance documents for non-time-critical removal actions under CERCLA (USEPA, 1993a). The purpose of the EE/CA is to identify and analyze alternative removal actions intended to address threats to public health and the environment associated with waste rock and adit discharge at the mines comprising the La Sal Creek Watershed Project. The threats associated with waste rock occur at the Firefly/Pygmy, Vanadium Queen, Blue Cap, and Black Hat Mines and are the result of direct contact with the waste-rock materials forming the mine dumps, elevated gamma radiation from the waste-rock dumps, and/or off-site migration of waste rock and sediment. The threats associated with adit discharge occur at the Blue Cap Mine and are the result of elevated metals and radionuclides in the mine water. Three removal action alternatives (including a no-action alternative) were identified and analyzed for the waste-rock contaminant source. Four removal action alternatives (including a no-action alternative) were identified and analyzed to reduce the potential for adit-drainage water to contact waste rock, and four removal action alternatives (including a no-action alternative) were identified and analyzed to reduce analyte levels in water discharging from the Blue Cap Mine adit.

9.1 Recommended Removal Action Alternative for Waste Rock

Waste rock at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines pose a threat to public health and the environment because of elevated arsenic concentrations and elevated gamma radiation. The primary threat is posed to unsanctioned campers at the mines. The concentrations of arsenic in the waste rock pose a moderate risk to human health based on the RMC established by the BLM for the camper scenario. Assuming a 14-day camper scenario, gamma-exposure rates on the waste-rock dumps exceed the 100 mRem per year ceiling. In addition to these threats, waste rock and mine-derived sediment is currently migrating from the waste-rock dumps at each of these mines, as well as from the Black Hat Mine dump, as a result of fluvial and wind erosion and mass wasting processes. The RAOs established for the removal actions are directed towards reducing the human health and ecological risks associated with the waste rock by minimizing the potential for direct exposure to the waste materials, reducing exposure to gamma radiation, and mitigating off-site migration of waste rock and mine-derived sediment.

As discussed in Section 6.0 of this document, off-site disposal and mine disposal were identified as potentially viable options for mine waste at the mines. However, the studies required to fully assess the

viability of the options for the removal action have not been conducted by the BLM at this time. Therefore, the options were not carried forward for detailed analysis in this EE/CA. If the studies are performed in the future, consideration should be given to these options for management of waste-rock materials comprising the mine dumps.

Based on the comparative analysis of the alternatives completed in Section 8.1, the most effective, implementable, and cost effective solutions for reduction of the public-health and ecological threats posed by waste rock at the Firefly/Pygmy, Vanadium Queen, Blue Cap, and Black Hat Mines are as follows:

- Firefly/Pygmy Mine: Alternative 3 in Combination with Sub-Alternative 3C which is summarized as follows:
    - Consolidate waste rock comprising ancillary dump and forming bank of adjacent ephemeral drainage on the mine bench.
    - Regrade the slope of upper dump and upper slope of lower dump to form more stable configuration.
    - Regrade the lower dump where feasible.
    - Install erosion-control features such as jute logs on the regraded surfaces and where feasible on lower dump.
    - Amend the waste rock along erosion-control feature alignments with soil and nutrients followed by seeding and fertilizing.
    - Cover remaining potential camping areas with 6-inch, vegetated soil cap.
    - Install an earthen berm in combination with sediment retention feature/pond along perimeter of lower dump.
- Vanadium Queen Mine: Alternative 3 in Combination with Sub-Alternative 3C which is summarized as follows:
    - Regrade the slope of upper dump and upper slope of lower dump to form more stable configuration.
    - Regrade the lower dump where feasible.
    - Install erosion-control features such as jute logs on the regraded surfaces and where feasible on lower dump.
    - Amend waste rock along erosion-control feature alignments with soil and nutrients followed by seeding and fertilizing.
    - Cover remaining areas suitable for camping with 6-inch, vegetated soil cap.

- Install an earthen berm in combination with sediment retention feature/pond along perimeter of lower dump.

- Blue Cap Mine: Alternative 3 in Combination with Sub-Alternative 3B which is summarized as follows:
  - Remove the waste rock from the Lion Canyon Creek channel along the toe of the dump and consolidate excavated waste on the mine bench.
  - Regrade the upper slope of the mine dump to form a stable slope extending from the bench to the new crest of the mine dump, and fill the large drainage channel that has incised into the northern portion of the mine dump.
  - Amend the regraded surface of upper dump with soil and nutrients followed by fertilizing and seeding and install erosion-protection matting on the reseeded surface.
  - Cover any remaining potential camping areas on the former mine bench with 6-inch, vegetated soil cap.
  - Install up to 10 vegetated terraces on the slope of the dump; terrace locations will be selected to optimize physical stabilization of the dumps after grading and filling operations have been completed.
  - An engineered waste-rock containment structure will be installed along the perimeter of the mine dump in the areas where Lion Canyon Creek is undermining the toe of the dump and waste rock is actively migrating into the Lion Canyon Creek channel.
  - A structural silt fence will be installed along the central portion of the toe of the dump where the existing terrain and vegetation currently inhibit migration of waste rock into the channel, and therefore, the engineered waste-rock containment structure is not required.

- Black Hat Mine: Alternative 3 in Combination with Sub-Alternative 3D which is summarized as follows:
  - Remove waste rock forming the bank of the Lion Canyon Creek channel adjacent to the upper dump and waste-rock in Lion Canyon Creek channel and, where feasible, forming the lower dump.
  - Regrade the slope of the upper dump to form a more stable configuration; protect access to Blue Cap Mine.
  - Amend regraded surface of upper dump with soil and nutrients followed by fertilizing and seeding and install erosion-protection matting on the reseeded surface.

The estimated net present value (over a ten-year period) for the recommended alternative at each mine is as follows:

- Firefly/Pygmy Mine (Alternative 3 with Sub-Alternative 3C): $ 291,267
- Vanadium Queen Mine (Alternative 3 with Sub-Alternative 3C): $ 145,004
- Blue Cap Mine (Alternative 3 with Sub-Alternative 3B): $ 434,163
- Black Hat Mine (Alternative 3 with Sub-Alternative 3D): $ 76,731

9.2 Recommended Removal Action Alternative for Adit Discharge

Water discharging from the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines contains elevated levels of metals and radionuclides. Metal concentrations and radionuclide activities did not exceed modified MCLs for the camper scenario. The levels of metals and radionuclides in mine discharge at all three mines exceed aquatic life standards for selenium and gross alpha. At the Vanadium Queen Mine, the levels of total phosphorous, total recoverable iron, and gross beta also exceed aquatic-life standards. At the Blue Cap Mine, gross beta also exceeds aquatic-life standards. Because mine discharge at the Firefly/Pygmy and Vanadium Queen Mines did not exceed Leaching RMCs and the water is not hydraulically contiguous on the surface with La Sal Creek, the mine discharge was seen as low risk to aquatic-life. Conversely, the mine discharge at the Blue Cap Mine directly contributes to and forms the headwaters of Lion Canyon Creek which is a perennial tributary to La Sal Creek. Water discharging from the Blue Cap Mine therefore poses a threat aquatic life because of elevated selenium concentrations and gross alpha and gross beta activities, which are attributed to elevated uranium and radium-226 levels in the water.

It was observed at the Firefly/Pygmy Mine that mine discharge water apparently infiltrates the upper bench, which is composed of waste rock, and reemerges as a spring at the toe of the upper dump on the lower bench. A sample of the reemerging mine discharge showed greater concentrations of metals and radionuclides, indicating that infiltrating mine discharge was leaching metals from the waste rock. This observation added support to the concern of the mine drainage water infiltrating waste rock and potentially generating leachate containing greater contaminant levels at all three mines. The potential generation of waste-rock leachate, although not fully characterized, was seen as a threat to human health and environment. Produced leachate would have the potential to migrate to underlying shallow groundwater which, in turn, could contribute to flows in La Sal Creek. Leachate may also appear as surface water (seeps or springs) downgradient of the mines.

The RAOs established for the removal actions are directed towards reducing the human health and ecological risks associated with the mine drainage by minimizing the potential for the generation and off-site migration of waste-rock leachate as a result of infiltration of mine drainage, and direct exposure to the mine drainage.

Based on the comparative analysis of the alternatives completed in Section 8.2, the most effective, implementable, and cost effective solutions for reduction of the public-health and ecological threats posed by mine drainage at the Firefly/Pygmy, Vanadium Queen, and Blue Cap Mines are as follows:

- Firefly/Pygmy Mine: Alternative 4 which is summarized as follows:
    - Construct a concrete sack dam and with a 4-inch flexible, HDPE collection pipe inside the portal behind the portal seal and construct a trench to bury the collection pipe within the mine to outside of the portal.
    - Construct a 1 to 2-foot deep trench for the mine water collection pipe from the portal along the inside of the upper bench access road to the confluence with and across the lower bench access road to a small ephemeral drainage. The trench is estimated to be 300 feet long.
    - The mine water discharge pipe will have clean out fittings every 100 feet with installed concrete anchors. The trench will be backfilled with the excavated native materials.
- Vanadium Queen Mine: Alternative 4 in Combination with Sub-Alternative 4A which is summarized as follows:
    - Construct a collection sump at the mouth of the corrugated metal pipe (CMP) that is proposed as a component of the portal closure for the Vanadium Queen Mine. The collection sump will consist of a grated metal cap on a CMP vault.
    - Construct a 1 to 2-foot deep trench for a mine water collection pipe from the base of the CMP collection sump along the inside of the upper bench access road to the confluence with the abandoned road located at the upper switchback on the mine access road.
    - From the intersection of the abandoned road, construct an open, unlined channel on the inside edge, to the ephemeral drainage that exists approximately 175 feet to the north. The channel will be filled with resistant stone aggregate to minimize erosion and direct exposure to mine drainage water (by porous flow).
    - Plant phreatophytes along the 175-foot open channel segment of the mine drainage alignment.
- Blue Cap Mine: Alternative 2 which is summarized as follows:
    - Construct a concrete sack dam and with a 4-inch flexible, HDPE collection pipe inside the portal behind the portal seal and construct a trench to bury the collection pipe within

the mine to outside of the portal (the pipe would be buried if bedrock prohibits trench construction).

- Construct a 1 to 2-foot deep trench for the mine water collection pipe from the portal along the inside of the upper bench to the site of a treatment wetland cell.

- Construct an anaerobic treatment wetland cell whose dimensions will maximize the contact time of the mine drainage water. An approximate size for the cell was estimated at 50 feet long by 50 feet wide by 3 feet deep. Five baffle berms will be constructed within the cell to increase contact time with the wetland media. An impermeable liner (geosynthetic) will be installed on the floor of the cell and anchored on 2-foot high bounding berms.

- The wetland cell will be backfilled with 2 feet of soil substrate, preferably of high organic content and approximately 1-foot of biomass materials consisting of certified straw, sawdust, wood chips, manure, and peat.

- Wetland plants such as willow, common reed, cattail, sedges, and rushes will be planted in the peripheral soil (along the internal baffle and bounding berms) and within developing shallow water areas.

- The wetland will be constructed such that the wetland water level will be maintained at or below the media surface.

- A spillway will be constructed on the north berm of the cell and extend from the cell along the inside of the mine bench to the ephemeral Lion Canyon Creek drainage.

The estimated net present value (over a ten-year period) for the recommended alternative at each mine is as follows:

- Firefly/Pygmy Mine (Alternative 4): $ 25,632
- Vanadium Queen Mine (Alternative 4 with Sub-Alternative 4A): $ 33,056
- Blue Cap Mine (Alternative 2): $ 167,232

9.3 Project Cost Summary

The estimated net present value (over a ten-year period) for the recommended alternatives for waste rock and adit drainage at each mine is as follows:

- Firefly/Pygmy Mine
  - Waste Rock (Alternative 3 with Sub-Alternative 3C): $ 291,267
  - Adit Drainage (Alternative 4): $ 25,632

Total:	$ 316,899

- Vanadium Queen Mine
  - Waste Rock (Alternative 3 with Sub-Alternative 3C): $ 145,004
  - Adit Drainage (Alternative 4 with Sub-Alternative 4A) $ 33,056

Total:	$ 178,060

- Blue Cap Mine
  - Waste Rock (Alternative 3 with Sub-Alternative 3B): $ 434,163
  - Adit Drainage (Alternative 2) $ 167,232

Total:	$ 601,395

- Black Hat Mine
  - Waste Rock (Alternative 3 with Sub-Alternative 3D): $ 76,731

The total net present value (over a ten-year period) for implementation of the recommended alternatives is $1,173,085.

10.0 ACRONYMS AND ABBREVIATIONS

AAK	Au' Authum Ki, Inc.
ALARA	As low as reasonably achievable
Alpine	Alpine Archaeological Consultants, Inc.
amsl	Above mean sea level
ARARs	Applicable or Relevant and Appropriate Requirements
ASTM	American Society for Testing and Materials
ATV	All Terrain Vehicle
BC	Blue Cap Mine
BH	Black Hat Mine
B-IBI	Benthic Index of Biotic Integrity
BLM	U.S. Dept. of the Interior Bureau of Land Management
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
cfs	Cubic feet per second
cm/sec	Centimeters per second
CMP	Corrugated metal pipe
COCs	Contaminants of concern
CRP	Community Relations Plan
CSM	Conceptual Site Model
cpm	Counts per minute
CWA	Clean Water Act
DAF	Dilution-attenuation factor

DO	Dissolved oxygen
Docket	Federal Facilities Hazardous Waste Compliance Docket
EE/CA	Engineering Evaluation/Cost Analysis
eH	Oxidation-reduction potential
EPA	U.S. Environmental Protection Agency
EPDM	Ethylene Propylene Diene Monomer
EPTI	Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) index
ESI	Expanded Site Inspection
FF	Firefly/Pygmy Mine
FSP	Field Sampling Plan
GIS	Geographic Information System
GPS	Global Positioning System
gpm	Gallons per minute
HBI	Hilsenhoff Biotic Index
HDPE	High-Density Polyethylene
IAEA	International Atomic Energy Agency
ICI	Invertebrate Community Index
MCL	Maximum Contaminant Level
mg/Kg	Milligrams per kilogram
mg/L	Milligrams per liter
ml/s	Milliliter per second
mRem	Milliroentgen equivalent man
mRem/hr	milliroentgen equivalent man per hour
mR/hr	milliroentgen per hour
µg/L	Microgram per liter
µR/hr	Microroentgen per hour

µS/cm	Microsiemens per centimeter
NAAQS	National Ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
ORP	Oxidation-Reduction Potential
PA	Preliminary Assessment
PCF	Per Cubic Foot
pCi/g	Picocuries per gram
pCi/L	Picocuries per liter
POTW	Publicly owned treatment works
PRB	Permeable reactive barrier
PSF	Per Square Foot
PVC	Polyvinylchloride, ethylene
QA/QC	Quality assurance/quality control
QC	Quality control
Rad	Radiation adsorbed dose
RPP	Reinforced Polypropylene
RMC	Risk Management Criteria
Rmv	Relative millivolts
SARA	Superfund Amendments and Reauthorization Act of 1986
SC	Clayey Sands – with or without gravel (Unified Soil Classification System designation)
SDWA	Safe Drinking Water Act
SI	Site Inspection
SM	Silty Sands with gravel (Unified Soil Classification System designation)
SP	Saint Patrick Mine
SPLP	Synthetic Precipitation Leaching Procedure

SSLs	Soil screening levels
s.u.	Standard Units
TDS	Total Dissolved Solids
TRVs	Toxicity reference values
TVS	Table Value Standard
UMTRCA	Uranium Mill Tailings Radiation Control Act
USCOE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USDI	U.S. Department of Interior
USGS	U.S. Geological Survey
USFS	U.S. Forest Service
VQ	Vanadium Queen Mine
ZVI	Zero-valent iron

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