BASELINE CHARACTERIZATION OF THE HYDROLOGY, GEOLOGY, AND GEOCHEMISTRY OF THE PROPOSED CONTINENTAL MINE EXPANSION PROJECT, COBRE MINING COMPANY, INC.

Prepared for:

Cobre Mining Company, Inc. c/o Chino Mines No. 14 Chino Boulevard Hanover, NM 88043

Prepared by:

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December 1999



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1.0 INTRODUCTION

At the request of Cobre Mining Company, Inc. (Cobre), this baseline characterization report has been prepared by Shepherd Miller, Inc. (SMI) to provide a description of data and analyses used to evaluate the geology, hydrology, geochemistry, and water quality at the Continental Mine Site, located in Grant County, New Mexico. This baseline report will form the basis of impact assessments to be presented in a future Environmental Assessment (EA) and Environmental Impact Statement (EIS) for expanded operations at the Continental Mine. This report provides a cursory summary of the results reported in the appendices. It retains analyses described in the February 1998 draft baseline report (SMI, 1998) for mining areas for which no current expansion plans are available (e.g., the Continental Pit and Tailings Pond expansions). Portions of the February 1998 draft baseline report were updated in this report to reflect modifications to the 1997 mine expansion plan and to include recently collected data (for example, Hanover Pit).

1.1 Recent Operations

The Continental Mine is located approximately 3 miles north of Hanover, New Mexico, within the Bureau of Land Management's (BLM's) Mimbres Resource Area (Figure 1-1). Cobre has historically engaged in copper mining using open pit and underground methods. Ore was crushed and processed via on-site milling, and the generated tailings material was discharged to an on-site tailings pond. Copper concentrate from the milling process was transported off-site for smelting. Waste rock was disposed into two waste rock disposal facilities (WRDFs) that exist within the site area. The existing Site facilities consist of the following:

- Continental Pit (an open mine pit approximately 300 feet deep)
- Continental Underground Mine (two underground excavations with depths up to 1,300 feet below ground surface)

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Tailings Pond and Magnetite Tailings Pond

- West Waste Rock Disposal Facility (WRDF) and South WRDF
- The Continental Mine is currently in standby status.

1.2 Proposed Expanded Operations

Cobre proposes to expand the Continental Mine to include the following:

- Excavating the new Hanover Pit, which will have a pit bottom elevation of approximately 6,560 feet (approximately 600 feet below the top of Hanover Mountain)
- Construction of the Fierro Leach Pad
- Expansion of the South WRDF
- Installation and operation of a pregnant leach solution (PLS) line from the leach pad to the Chino Mine.

No plans are currently available for the modification of the Continental Pit or further facility expansion.

1.3 Baseline Report Scope

This baseline report focuses on the following technical areas that will be relevant to the future EA and EIS:

- Geology, including stratigraphy, structure, and mineral alteration
- Climate
- Surface water hydrology
- Ground water hydrology including water resources
- Geochemistry of the waste rock, tailings, and future pit lake

• Water quality of surface and ground waters.

This report summarizes relevant data obtained from existing publications, Cobre Mining Company, Inc. records, and field activities. This report also summarizes analyses that were performed to evaluate the environmental impacts associated with the current and proposed (or previously proposed) mining activities. These impacts include the effects of:

- Mine dewatering
- Pumping of mine water supply wells
- Seepage through waste rock dumps and tailings impoundments
- Surface water diversions
- Development of pit lakes after mine closure.

The appendices to this report describe in detail the data and analyses used to support the discussions in this report. Appendix A describes the aquifer testing done at the site while Appendix B discusses impact issues associated with increased withdrawal rates from the Cron Ranch. Water quality associated with the mining district and the Continental Mine is discussed in Appendix C. Appendices D and E describe the geology, geochemistry, and hydrology associated with the current and expanded Continental Mine. Appendix F is a summary of the data collection-efforts by SMI at the Site in 1996. Appendix G presents preliminary calculations of potential, Continental Pit lake water quality. Appendix H presents geochemical modeling results of the future Hanover Pit lake water quality.

2.0 CLIMATE

2.1 Regional

The Site is located in a semi-arid region of New Mexico. The regional climate is described by data obtained from the Fort Bayard weather station and Chino Mine located 6 miles southwest and 4 miles south of the Site, respectively. The following statistics have been developed from these databases:

- Mean annual precipitation of 15.7 inches/year (Fort Bayard)
- Mean annual temperature of 54.9 degrees F (Fort Bayard)
- Mean minimum temperature of 25 degrees F during the month of January and mean maximum temperature of 86.7 degrees F during the months of June and July (Fort Bayard)
- Mean annual pan evaporation rate of 79.7 inches/year (Chino Mine)

Precipitation measurements from Fort Bayard show a distinct wet season during the months of July through September. Pan evaporation is greater than precipitation throughout the year, even during the cooler winter months.

2.2 Local

Site-specific weather data do not exist at the Site, but can be interpreted from regional climatic data and ecological observations. Based on the PRISM model for extrapolating climatic data (Daly et. al. 1994), the mean annual precipitation at the Site is estimated to range from 24 inches/year at higher elevations (north of Hanover Mountain) to 14 inches/year at lower elevations (Cron Ranch). The following estimated Site-specific parameters were utilized for baseline evaluations of the Site:

• Mean annual precipitation of 18.3 inches/year. Monthly precipitation percentages are assumed to equal those measured at the Fort Bayard weather station.

- Pan evaporation of 79.7 inches/year, assumed to equal that measured at the Chino Mine weather station.
- Lake evaporation of 55.8 inches/year, estimated to be equal to 0.7 times the pan evaporation.

-

3.0 GEOLOGY AND MINERALOGY

This section provides a brief summary of the geology and mineralogy of the Continental Mine area. More detailed information is provided in Appendix D.

3.1 Mining History

Mining has occurred in the Central Mining District since the sixteenth century. The United States Smelting, Refining, and Mining Company (USSR&M) owned and operated the Continental Mine area for most of the twentieth century. More recent owners include Sharon Steel, U.V. Industries, and Bayard Mining Corporation. Copper production from the Continental Open Pit first began in 1967. The mine closed in 1982 due to depressed copper prices. Metallic Ventures, Inc. purchased the Continental Mine in 1992 and formed Cobre Mining Company. The mine was reopened in 1993 (Hillesland and others, 1995). In 1998, Phelps Dodge's Chino Mines Inc., acquired the Continental Mine. The Site went into standby status in the spring of 1999.

3.2 Regional Geology

The Continental Mine area is located within the Santa Rita Quadrangle, which lies in a broad transitional zone between the Colorado Plateau and the Basin and Range Province (Jones et al., 1967). To the south and southwest of the quadrangle, Paleozoic to Mesozoic sedimentary rocks and younger volcanic rocks are exposed in north- to northwest-trending ranges. To the north, sedimentary formations thicken and form the broad highlands of the Colorado Plateau.

Within the Santa Rita Quadrangle, northwest-trending faults, such as the Mimbres and Silver City Faults, and northeast-trending faults, such as the Barringer, Nancy, and Groundhog Faults, define a broad area of uplift in the Central Mining District called the Santa Rita Horst. The Santa Rita Horst has a surface area of about 40 square miles (Hillesland et al., 1995; Jones et al., 1967).

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3.3 Local Geology

The geology of the northern part of the Central Mining District is complex. Jones et al. (1967) provides a comprehensive chronology of structural and igneous events of the district. The features most relevant to the ore at the Continental Mine are the Barringer Fault and the Hanover-Fierro Stock. Both played major roles in the mineral enrichment of the area.

A geologic map of the Continental Mine area is shown in Figure D-2, and cross sections in the Continental Pit and Hanover Mountain areas are shown in Figures D-3 and D-4. Geologic maps of the proposed Continental Pit and the future Hanover Pit are shown in Figures D-5 and D-6, respectively. Final pit wall compositions of the Continental Pit and the proposed Hanover Pit are presented in Appendix D.

3.3.1 Sedimentary Rocks

The stratigraphic section in the Continental Mine area includes about 2,400 feet of Paleozoic sedimentary rocks and 1,200 feet of Mesozoic sedimentary rocks above Precambrian gneiss and schist. Lower Paleozoic formations are dominated by limestone and dolomite and include the Bliss Formation, the El Paso Limestone, and the Montoya and Fusselman Dolomites. The Montoya and Fusselman Dolomites are indistinguishable in the Continental Mine area (Jones et al., 1967). Upper Paleozoic units contain significantly more limestone and include the Percha Shale, the Lake Valley Limestone, and the Oswaldo, Syrena, and Abo Formations. The Syrena and Abo Formations are often indistinguishable in the area. Mesozoic formations, including the Beartooth Quartzite and the Colorado Formation, consist largely of fine- to medium-grained clastic units and are overlain by up to a few hundred feet of andesitic breccia and tuff (Hillesland et al., 1995). The Continental Pit exposes mainly Paleozoic rocks, while Hanover Mountain contains mainly Mesozoic rocks (Cobre, 1997a).

3.3.2 Igneous Rocks

More than 30 distinct varieties of intrusive rocks are found within the Santa Rita Quadrangle, with ages between the Late Cretaceous Period and the Miocene Epoch. Intrusive rocks in the area include the Hanover-Fierro Stock, syenodiorite porphyry, granodiorite porphyry, quartz diorite porphyry, mafic porphyry dikes, and mafic stocks. Volcanic rocks include andesite breccia and tertiary volcanic units (Hillesland et al., 1995).

3.3.3 Structure

The Barringer Fault and associated extension fractures and conjugate shears are the most important structural features at the Continental Mine. The Barringer Fault trends approximately N40°E through most of the Central Mining District. Dips range from 55 to 75 degrees to the northwest. Vertical displacement along the Barringer Fault ranges from 1,200 to 1,600 feet (Jones et al., 1967). In the Continental Pit, the fault zone is up to 200 feet wide and is associated with strong iron-oxide staining (Hillesland et al., 1995). The Barringer Fault is stopped by northeast-trending lobes of the Hanover-Fierro Stock. The fault does not offset the northwest contact of the Stock, indicating that the Hanover-Fierro Stock postdates most movement of the Barringer Fault (Jones et al., 1967).

The Dix, Super Cobre, and Gilchrist Faults belong to a set of north northeast striking, steeply dipping faults associated with mineralization (Hillesland et al., 1995) (Figure D-2). The Dix Fault, which is now underneath the Tailings Pond, is a normal fault that dips north at about 50 degrees and has 600 feet of displacement. There is a fracture zone adjacent to the Dix Fault, which is about 100 feet wide. The Gap Fault, which is also underneath the Tailings Pond, dips northwest 60-65 degrees and has approximately 300 feet of displacement (Dahl, 1997, personal communication).

3.3.4 Alteration and Mineralogy

The Hanover-Fierro Stock is almost completely surrounded by a wide zone (up to 4,000 feet) of thermal metamorphism that decreases in intensity away from the contact. The

metamorphic effects vary according to the nature of the host rock and the distance from the contact. Observed contact metamorphic facies include hornfels within siltstone- and shale-dominated sections of the Colorado Formation; marble in the Fusselman, Montoya, Lake Valley, and Oswaldo Formations; and skarn in the lower Paleozoic, carbonate section. Hydrothermal alteration related to the Hanover-Fierro Stock and other late-stage porphyry intrusions is superimposed on early contact metamorphic facies (Hillesland et al., 1995).

Calcic skarn hosts the majority of copper ore recently mined in the Continental Pit and is found in the Syrena, Oswaldo, and Lake Valley Formations near the Hanover-Fierro contact (Hillesland et al., 1995). Copper minerals include chalcopyrite with lesser bornite and rare chalcocite. In the aforementioned formations, shale units acted as barriers to the upward migration of mineralizing fluids during prograde and retrograde events. Metals content increases significantly below such barriers as the Mountain Home Shale (at the base of the Syrena Formation), the Parting Shale (at the base of the Oswaldo Formation), and the Percha Shale (below the Lake Valley Limestone). The angle of contact between sedimentary bedding and the intrusion, and between pre-stock syenodiorite or diorite dikes, also affected fluid flow and thus skarn formation. Hillesland et al. (1995) suggests that the Barringer Fault Zone may have acted as a barrier to hydrothermal fluid migration from an intrusion located northwest of the Hanover-Fierro Stock.

Host rocks for the ore at Hanover Mountain include hornfels and silicified sandstone with minor dikes and sills of intermediate to felsic composition. Pre-metamorphic lithologies consist of intercalated siltstone, shale, and sandstone (Colorado Formation). Alteration associated with the development of the supergene deposits includes alteration of chlorite and biotite to sericite and bleaching of the host rock. Limestone beds or the metamorphic equivalent have not been encountered during mineral exploration at Hanover Mountain. The deposit is bounded on the eastern and southern edges by the Barringer Fault (Kilborn, 1997).

The thickness of the ore deposit at Hanover Mountain varies from 40 to 600 feet and averages about 280 feet. It mimics the present topographic profile and is centered under Hanover Mountain. A leached cap ("leach cap"), which varies from 80 to 150 feet thick, is present above the chalcocite zone. The underlying supergene chalcocite deposit was formed by oxidation of primary copper (chalcopyrite) mineralization, followed by leaching and enrichment of secondary chalcocite. Chalcocite also replaced some of the primary pyrite. Bornite and covellite have been observed along the margins of the deposit. Primary mineralization, as observed below the chalcocite blanket, consists of pyrite and chalcopyrite associated with alteration salvages of chlorite and, less commonly, actinolite. Mineralization is predominantly fracture-controlled and temporally distinct from the early metamorphism. Minor disseminated mineralization is associated with strongly silicified sandstone.

4.0 SURFACE WATER

4.1 Regional

The Site is located within the Mimbres River Basin, a closed basin that recharges an extensive valley-fill alluvial aquifer in Luna County, New Mexico. The Mimbres River drains a total area within Grant County of approximately 460 square miles. Perennial flow exists in the Mimbres River from the mouth of McKnight Canyon downstream to the town of San Lorenzo (Trauger, 1972). Irrigation diversions cause the stream channel to be dry at many locations downstream of San Lorenzo.

A major tributary of the Mimbres River is the San Vicente - Whitewater Creek Drainage system, which covers approximately 390 square miles within Grant County. The Site is located within this drainage system. Currently, there is no perennial flow within this system except possibly at its headwaters. Prior to drought conditions, which began in 1885, there was perennial flow in some streams within the drainage system.

4.2 Local

The Site is located within the Hanover Creek Drainage system. The elevation of the drainage ranges from approximately 6,000 feet, where Hanover Creek enters Whitewater Creek, to 7,820 feet north of Hanover Mountain in the Piños Altos Range. Hanover Creek is generally an ephemeral stream, except for a short perennial reach downstream of Fierro Spring. In addition, some perennial flow occurs adjacent to the towns of Hanover and Fierro.

The total drainage area of Hanover Creek is 10.9 square miles, of which about 70 percent are downstream of mining activities. Ephemeral tributaries within or adjacent to mining areas are the following:

• Grape Gulch, which flows through the Site near the Tailings Pond.

- Poison Spring Drainage, which begins 3,400 feet upslope of Poison Spring and is intercepted by the Tailings Pond. Perennial flows less than 1 gallon per minute (gpm) have been measured along certain reaches of the stream channel. These flows result from ground water discharge at Poison Spring and possible seepage from the Tailings Pond, Magnetite Tailings Pond, and northeast side of the South WRDF.
- Buckhorn Gulch, which begins on-site near the West and South WRDFs and discharges into Hanover Creek near the town of Hanover. A perennial reach occurs for a short distance downstream of Buckhorn Spring.
- Ansones and Beartooth Creeks, which are ephemeral drainages located southwest of the mine site.

Upslope of the mining area are perennial seeps and springs that originate at the base of a gravel unit overlying the Colorado Formation. These springs likely result from the discharge of perched ground water flowing along the top of the Colorado Formation due to a permeability contrast between the two formations. Springs within the site area include the following:

- Fierro Spring, which is located near the headwaters of Hanover Creek and flows at a rate of less than 1 gpm (estimated). In the past, the towns of Fierro and Hanover used this spring for drinking water. As the populations of Fierro and Hanover have decreased and a municipal supply has been provided to the town of Hanover, the importance of the spring as a drinking water source has diminished.
- Seeps in Grape Gulch and Gap Canyon, which have combined flows of less than 1 gpm.
- Poison Spring, which is located northwest of the Main Tailings Pond. Flow from this spring is channeled through a small-diameter pipe to a stock water tank.

Seeps and springs downstream of the mining area include the following:

• Buckhorn Gulch Spring, which issues from the base of a gravel unit overlying an intrusive syenodiorite sill within the Montoya Fusselman. Flow from this spring is generally less than 1 gpm.

• Seeps along Hanover Creek adjacent to the towns of Fierro and Hanover. It is suspected that these seeps are the result of seepage from septic leach fields in the towns.

The following seeps appear to be associated with past and current mine facilities:

- Tailings Ponds seeps, which exist on the north and east sides of the Tailings Pond. The combined flow rate of the seeps is about 500 gpm. These flows are intercepted by surface water containment facilities and are either pumped back to the Tailings Pond or used for mine process water. After deposition of tailings ceased (i.e., during standby), the flow from these seeps declined dramatically.
- West WRDF seeps, which are located on the east side of the facility, flow intermittently during and after storm events. The water is collected by surface water containment facilities and used for mine process water.
- Buckhorn Containment Facility (CF) seep, which is immediately downgradient of the northern most, West WRDF seep. This seep emanates from the southern toe of the South WRDF and has similar chemistry to that of the West WRDF seeps.
- South WRDF seep, which is located on the north side of the facility, flows at an average rate of less than 1 gpm. The water is collected by a surface water containment facility and used for dust suppression or allowed to evaporate.
- The Magnetite Dam seep, which exists downstream of the toe of the dam. The average flow rate of the seep is less than 1 gpm.

4.3 Facilities Impacts

4.3.1 Tailings Pond

Due to its location in the Poison Spring Drainage, the Tailings Pond captures all upgradient surface water runoff. Previously proposed expansion and closure of the Tailings Pond would not change upgradient runoff capture. Expansion would, however, increase the percentage of incident precipitation captured by a larger area. At the peak of production (at the end of mining), a larger Tailings Pond would allow more evaporative loss. Closure of Tailings Pond would include dewatering, re-grading, revegetation, and the construction of surface water collection channels. Diversion channels may be constructed to divert upgradient surface water around portions of the Tailings Pond. Closure activities would result in a less evaporative loss than would occur at the end of mining. Estimates of the magnitudes of surface water components associated with the Tailings Pond are provided in Appendix E.

4.3.2 Waste Rock Disposal Facilities

Changes to the surface water regime associated with the WRDFs are limited to incident precipitation falling directly on the facilities and the resulting runoff, evaporation, and deep percolation. All surface water runoff from upgradient areas will be diverted around the South and West WRDF facilities. The foot print of the South WRDF will not change significantly from that of the post 1999 standby facility. Thus, no significant change in surface water runoff is expected. No expansion is planned for the West WRDF; therefore, no additional loss of runoff to the watershed will be incurred. Appendix E quantifies the surface water components associated with the pre and post closure WRDFs.

4.3.3 Continental Pit

The main surface water effect associated with the Continental Pit would be the capture of precipitation falling on the pit walls. Previously, a portion this precipitation would have become surface water runoff. The pit would continue to act as a "funnel" to the underground workings for precipitation falling within the pit. Assuming the 1997-expansion plans were to proceed and the pit bottom was excavated to 6000 feet, SMI estimated the flow from precipitation falling within the pit. This and other components of the surface water regime associated with the Continental Pit can be found in Appendix E. Closure of the Continental Pit would be limited to final construction of open channels to divert storm runoff around the pit. Water quality impacts associated with the pit lake are discussed in Appendix G.

4.3.4 Hanover Pit

After mining is initiated on Hanover Mountain, best management practices would be implemented to reduce erosion and runoff from the mined area. A reduction in storm water runoff to the Hanover Creek Basin from Hanover Mountain would occur. From a rainfall-runoff analysis (Appendix E), this reduction in storm water runoff was estimated to be approximately 1.7 gpm. The contributing runoff area from Hanover Mountain is relatively small when compared to the entire area of the Hanover Creek Basin. For these reasons, the impact on the hydrologic regime from this loss of runoff should be minimal.

Erosion and flooding of the pit from upland area runoff and from Hanover Creek would be contained through the use of designed channels. Cobre would route upland stormwater runoff around Hanover Pit and provide erosion protection from the potential Hanover Creek 100-year flood event. Therefore, surface waters outside the immediate area of the pit should not be impacted. Precipitation within the pit area would result in some surface-water runoff to the eventual pit lake. Water quality impacts associated with the pit lake are discussed in Appendix H.

4.3.5 Fierro Leach Pad

Surface water contamination from erosion would be controlled through the use of best management practices. The PLS ponds would be constructed with leak detection and containment systems; therefore, potential impacts to the hydrologic system from a primary leak should be minimized. The ponds proposed in the 1997 expansion plan have been designed to contain the additional volume from a 100-year, 24-hour storm. The impacts associated with closure of the Fierro leach pad would be minimal. Underdrains installed beneath the leach facility to allow seep and spring flow to continue would continue after closure, thus reducing impacts from the covering of seeps and springs. Magnitudes of surface water components are described further in Appendix E.

5.0 GROUND WATER

5.1 Regional

Within Grant County, ground water is the main source of water for municipal, domestic, agricultural, and industrial uses (Trauger, 1972). The availability of ground water is dependent on rock type. The following four main rock types are found within the county:

- Metamorphic and igneous rocks, which have relatively low permeability and provide well yields ranging from less than 1 to about 15 gpm. Increased well yields can occur from wells completed in weathered granitic rocks.
- Volcanic rocks, which are generally poor aquifers except for porous pyroclastic deposits, which can locally provide higher well yields.
- Marine sedimentary rocks, including carbonates and fine-grained clastics, which are generally poor aquifers within the county. Fractured carbonate rocks, which most commonly occur near major fault structures, can locally provide higher well yields. Solution channeling of carbonate rocks is not common within Grant County.
- Consolidated and unconsolidated alluvial deposits, which are the most important ground water sources in Grant County. These deposits include: (1) the Gila Conglomerate, which is an extensive unit that underlies the north and central portions of the county, and (2) the Bolsom Deposit, which is a valley-fill alluvium several thousand feet thick in the southern part of the county. Water wells completed in these units may have yields ranging up to several hundred gpm. In addition, unconsolidated alluviums 5 to 20 feet thick are found in the channels of major streams such as the Gila and Mimbres Rivers. Where saturated, these stream alluviums may provide well yields up to several gpm.

Within igneous and consolidated sedimentary rocks, ground water flow tends to be controlled by fractures and geologic structures. For example, in the Colorado Formation, closely spaced wells can exhibit highly variable yields and hydraulic heads due to the presence of faults and intrusive dikes and sills.

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5.2 Local

Figure E-8 describes the conceptual hydrologic model for the Site. The conceptual model consists of three main hydrogeologic units:

- The Lower Bedrock Unit, which includes lower Paleozoic sedimentary rocks and the Cretaceous-Tertiary-age Hanover-Fierro intrusive stock.
- The Upper Bedrock Unit, which consists of upper Paleozoic sedimentary rocks including the Colorado and Beartooth Formations.
- The Shallow Alluvial Unit, which includes channel alluvium deposits and terrace gravels. Ground water in this unit may be perched above the water table in the underlying bedrock.

Figure E-9 shows the locations of monitoring wells completed in the above hydrogeologic units.

5.2.1 Bedrock Units

The Barringer Fault separates the northern and southern portion of the Site. Both the Lower and Upper Bedrock Units are present north of the fault. South of the fault, the Lower Bedrock Unit has been displaced upward and most of the Upper Bedrock Unit has been eroded or intruded.

Figure E-10 presents hydraulic head contours and inferred flow directions in the Lower and Upper Bedrock Units. In the northern portion of the site, the difference in hydraulic heads between the two units indicates that they are separated by an aquitard, which most likely consists of the basal shale unit of the Colorado Formation and the Abo shales. Flow in the Upper Bedrock Unit is generally to the south-southwest from the Piños Range. Some of this flow discharges to the: (1) Hanover-Fierro Stock, (2) underground workings where the Beartooth and Abo Formations are thin or eroded, and (3) deeper strata by downward leakage into deeper strata. Flow in the Lower Bedrock Unit is radially toward the underground workings. The flow in this unit is northward between the Barringer Fault and the underground workings (opposite to the flow direction in the Upper Bedrock Unit). The effectiveness of the aquitard is indicated by the fact that dewatering of the deep underground workings does not affect the flow direction in the Upper Bedrock Unit.

South of the Barringer Fault, ground water flow in the Lower Bedrock Unit is to the south, and a ground water divide appears to exist just south of the fault. North of the divide, flow in the Lower Bedrock Unit is toward the underground workings. South of the divide, ground water flows in the more regional southerly direction.

The Barringer Fault displaces several geologic units and, near Hanover Mountain, juxtaposes the Lower Bedrock Unit against the Upper Bedrock Unit. The fault is not interpreted to be a high permeability feature because: 1) significant ground water inflows have not been observed where underground workings intersect the fault zone, 2) at some locations, low-permeability intrusive rocks have been injected across the fault plane, 3) short-term aquifer testing results on monitoring well MW-5A imply that the fault is a low permeability feature, and 4) the results from a 24-hour pumping test conducted at water test hole TH-98-5 (August, 1999) that showed the well was surrounded by low permeability features..

Figure E-11 shows the distribution of measured hydraulic conductivity data from the formations comprising the basement rocks at the Continental Mine. The estimated values of hydraulic conductivity reported in Appendix A (Table A-9) for monitoring wells range from 1.60×10^{-7} centimeters per second (cm/sec) to 7.3×10^{-3} cm/sec with a geometric mean of 2.4 x 10^{-5} cm/sec. The estimated values of hydraulic conductivity reported in Appendix A (Table A-10) for specific capacity analysis on exploration borehole data range from 9.5 x 10^{-7} centimeters per second (cm/sec) to 2.8×10^{-4} cm/sec with a geometric mean of 2.1×10^{-5} cm/sec. Lower conductivity values tend to be measured in the intrusive stocks and shale units. Higher values are associated alluvial units and the Lake Valley Limestone.

5.2.2 Alluvial Unit

Shallow ground water flow systems exist in alluvial deposits and weathered bedrock. Three important alluvial systems include: 1) Upper Buckhorn Gulch, 2) the Poison Spring Drainage, and 3) Grape Gulch. These alluvial deposits receive recharge from infiltration of storm water, infiltration of spring water, and seepage from adjacent colluvium and weathered bedrock. Because streams within the site area are generally ephemeral, upward leakage of ground water from bedrock into alluvium is not considered to be a significant recharge mechanism. These alluvial deposits are generally constrained to the immediate channel areas of stream valleys, and ground water is in hydraulic communication with surface water. In many cases, stream channels flow for short distances from recharge sources (such as springs), and then the surface flow disappears due to infiltration into the channel alluvium.

The saturated thickness of water in the alluvial deposits is probably on the order of several feet or less, except during periods of storm flow. The ground water is normally perched and flows in the downslope (downstream) direction. Some amount of downward leakage probably occurs from the alluvial deposits into bedrock. It is probable that some alluvial deposits contain ground water near recharge sources but, due to downward leakage, become dry downstream of those sources.

5.3 Facilities Effects on Ground Water

The current and future impacts of mining facilities on ground water have been evaluated using analytical models, water balances, and interpretations of hydrogeology of the Site. Detailed descriptions of these evaluations are provided in Appendix E. Conclusions regarding the impacts of the mine facilities are summarized below.

5.3.1 Tailings Pond

The Tailings Pond is constructed in the Poison Springs Drainage over an alluvial deposit. It has been in operation since the late 1960s. Based on the current (circa 1997) water balance for the Tailings Pond, it is estimated that seepage from the tailings into the underlying alluvial deposit is about 112 gpm. Of this flow rate, about 7 gpm seeps downward into the underlying bedrock and 105 gpm flows down-valley within the alluvium towards the Fierro Area. Assuming the 1997 expansion plan were to proceed, it is estimated that at the end of mining the tailings seepage would be approximately 362 gpm, of which 17 gpm seeps into bedrock and 345 gpm flows down-valley within the alluvium. Following site closure, based on the 1997 expansion plan, it is estimated that tailings seepage would be approximately 24.7 gpm. Of this 24.7 gpm, approximately 1.3 gpm would seep into the bedrock and approximately 23.4 gpm would flow towards the Fierro Area. Appendix E contains more detail regarding these flow rates and their derivation.

5.3.2 Waste Rock Disposal Facilities

Based on modeling originally conducted by DBS&A, SMI estimated that current (circa 1997) uncovered South WRDF receives 163.8 gpm of precipitation. Of this 163.8 gpm, 103.9 gpm would evaporate and 59.9 gpm would infiltrate. For the end-of-mine scenario, assuming the 1997 expansion plan were to proceed, it was estimated that end-of-mining South WRDF would receive 312.8 gpm of precipitation of which: 199.8 gpm would evaporate and 115.0 gpm would infiltrate. For conservatism, it was assumed that none of the precipitation becomes runoff for either the current or the end-of-mine scenarios. Under the 1997 expansion plan it was estimated that after site closure the South WRDF would receive 312.8 gpm of precipitation. Of this 312.8 gpm, 0.6 gpm would become runoff, 280.5 gpm would evaporate and 34.4 gpm would infiltrate.

Based on modeling originally conducted by DBS&A, it was estimated that the current (circa 1997) uncovered West WRDF receives 53.6 gpm of precipitation. Of this 53.6 gpm, 34 gpm would evaporate and 19.6 gpm would infiltrate. For conservatism, it was assumed that none of the precipitation would runoff. Under the 1997 expansion plan, no changes are planned for the West WRDF, therefore, the water balance for the current West WRDF is the same as the water balance for the end-of-mine West WRDF. Under the 1997 expansion plan it was estimated that following site closure, the reclaimed West

WRDF would receive 53.6 gpm of direct precipitation. Of this 53.6 gpm, 0.12 gpm would run-off, 47.8 gpm would evaporate, and 5.7 gpm would infiltrate. Appendix E provides more detail on the hydrologic analysis of the South and West WRDFs.

5.3.3 Underground Workings

Currently, the underground workings are dewatered at an average rate of 132 gpm with a seasonal variation of approximately 20 percent. Approximately 92% of the water are pumped from the "upper" sump while approximately 8% are pumped from the "lower" sump. For the purposes of this report, all water was assumed to be extracted from the location of the upper sump. The depth of the upper sump is approximately 1,250 feet below ground surface (elevation of 5,550 feet).

It should be noted that the evaluation presented below is based on the 1997 planned expansion and the resulting analysis performed in 1997 and does not include water exiting the underground workings via ventilation shafts.

Most of the water comes from the Lake Valley and Oswaldo Formations, which are at the depth of the sump. There are no significant seeps at higher elevations in the underground workings or any indication of seepage where the workings intercept the Barringer Fault. Small amounts of water enter the workings from drill holes that penetrate the overlying Beartooth Quartzite. In addition, approximately 1 gallon per hour flows from the Gap Fault where it is intersected by the workings.

Expansion of the underground mine would result in a lateral extension of the underground workings and an increase in depth to 1,450 feet (elevation 5,350 feet). The expanded workings would not intersect any new geologic formations. Based on the analyses presented in Appendix E, the estimated inflow rate at the end of mining is predicted to be between 170 and 500 gpm.

At the end of mining, all dewatering activities would cease and ground water inflows would gradually fill the underground workings. The initial inflow rate is predicted to be about 302 gpm, and this rate would gradually decrease as the mine fills. Based on

calculations described in Appendix E, it is estimated that filling of the underground workings to the estimated pre-mining water table elevation of 6,665 feet could have taken 125 years.

5.3.4 Continental Pit

At present, there are no permanently flowing springs or seeps in the Continental Pit, although temporary seeps may occur after storm events. Precipitation and surface water runoff in the pit is channeled to underground sumps via adits. The lack of ground water inflow to the pit is consistent with drilling information, which indicates that the static ground water level is slightly below the current pit floor. The current water table is depressed due to dewatering of the underground workings.

At the end of mining, the water table would rise when dewatering activities are terminated. Regardless of whether or not the Continental Pit is expanded, the water table would rise above the pit floor and result in development of a pit lake.

If the complete 1997 proposed expansion of the Continental Pit were to take place, the calculations described in Appendix E predict that the ultimate pit lake would be terminal; that is, there would be no flow or recharge from the lake into the ground water system. As a consequence, the lake would not act as a chemical source to ground water. It is estimated that the filling time to a depth of 400 feet would be approximately 60 years. The elevation of the ultimate pit lake surface would be approximately 6,464 feet, the lake surface area would be about 56 acres, and the water depth would be about 464 feet. Evaporation from the ultimate pit lake would result in a net loss of 161 gpm.

If the 1997 proposed expansion to the Continental Pit does not occur, the calculations presented in Appendix E predict that the terminal pit lake would refill to a depth of 40 feet over a period of approximately 35 years after recovery of the underground working from dewatering. It is estimated that the elevation of the ultimate pit lake surface would be 6,523 feet, the lake surface area would be approximately 20 acres, and the water depth

would be approximately 43 feet. Evaporation from the ultimate pit lake would result in a net loss of approximately 58 gpm.

5.3.5 Hanover Pit

At the end of mining, the proposed Hanover Pit would be excavated to an elevation of 6,560 feet. The pit floor would be approximately 240 feet below the current maximum water level elevation below Hanover Mountain. Based on calculations in Appendix E, it is estimated that the steady-state ground water inflow rate at the end of mining is estimated to would be approximately 38 gpm.

After mining ceases and dewatering is discontinued, ground water and surface water inflows would cause a pit lake to form in the bottom of Hanover Pit. It is estimated that the lake would fill over a period of approximately 21 years. Calculation presented in Appendix E show that the ultimate pit lake would be terminal; that is, there would be no recharge from the lake into the ground water flow system. These calculations also estimate that the ultimate pit lake would have:

- A surface elevation of approximately 6,716 feet,
- A surface area of approximately 22.3 acres,
- A lake depth of approximately 156 feet
- Evaporative loss of about 64.2 gpm.

5.3.6 Fierro Leach Pad

Most of the ground water flow below the location of the proposed Fierro Leach Pad takes place in the Alluvial Unit. Below the Alluvial Unit is the Hanover-Fierro Stock, which is known to have very low hydraulic conductivity and hence relatively little ground water flow. Based on the calculations described in Appendix E, the estimated ground water flow rates in alluvium below the Fierro Pad area would be slightly more than 100 gpm.

At the end of mining, inflows to the Fierro Leach Pad would consist of seepage from the barren leach solution and direct infiltration of precipitation. Outflows would consist of evaporation and seepage from the pad, which would continue to be collected and processed. Appendix E presents estimates of the water balance components associated with the pre-reclamation leach pad for an average precipitation year:

- Approximately 65 gpm of seepage
- An average of approximately 5 gpm runoff
- An average of 76 gpm evaporation

Post-closure inflow to the Fierro Leach Pad would consist only of infiltration of precipitation. After pad reclamation and long-term steady-state conditions have been achieved, this would also be the rate of outflow from the Fierro Leach Pad (downward seepage). This flow would be passively treated (if it does not meet water quality standards) and allowed to recharge the underlying alluvium. Appendix E presents the estimation of post-closure water balance components associated with the leach pad for a average precipitation year:

- Less than 4 gpm of seepage
- Approximately 2.4 gpm of runoff
- Approximately 141.6 gpm of evapotranspiration

5.4 Water Supply Impacts

5.4.1 Cron Ranch Well Field

According to the 1997 expansion plan for the Continental Mine, Cobre would have to increase their water production rates beyond the current usage rate. Historically the majority of water used in mine processing has been derived from the Cron Ranch well field. The Cron Ranch well field is located approximately 10 miles southwest of the Site and approximately 3.4 miles southwest of the City of Santa Clara (formerly Central),

New Mexico. Currently, Cobre has ground water rights for 740 acre-feet/year beneath Cron Ranch. Transfer of certain irrigation rights would allow Cobre to extract a total of approximately 810 acre-feet/year (501 gpm) from the Cron Ranch well field.

At the Cron Ranch, Cobre operates two production wells: well 22-2 and 22-5. These are located between 450 and 2,700 feet south of the City of Santa Clara wells C-2, C-3, and C-4. Due to the aquifer heterogeneity in this area, only Cobre well 22-2 has the potential to be in hydraulic connection with City wells C-3 and C-4. City well C-2 does not appear to be in hydraulic connection to other wells; however, no geologic evidence has been presented to explain this phenomena. Pumping tests from well C-2 indicate a low permeability, which could be due to well failure. Cobre well 22-5 appears to have no hydraulic connection to either the city wells or Cobre well 22-2.

Increase pumping at the Cron Ranch well field (specifically from Cobre well 22-2) could result in increased drawdowns in the City wells. These drawdowns would not cause the City wells to dry up, nor would water production be hampered. However, increased pumping costs could be expected from the City wells. Cobre well 22-5 will not cause an impact to the City wells due to the structural control separating the wells. Assuming that the aquifers are infinite, the 10-foot drawdown isopleth due to maximum pumping at Cobre well 22-2 extends approximately 4 miles from the well. Appendix B discusses these results and the methodology used to derive them.

5.4.2 Other Water Supply Wells

Additional water supplies for Cobre mining operations are available from the Hanover Shaft (north of the city of Hanover), the Princess shaft (north of the Santa Rita Pit), water supply well PW-1 (south of the Continental Pit) and a newly constructed well (north of Hanover Mountain). No increased pumping was planned from the Hanover or Princess Shafts as a result of the 1997 expansion plan. The newly constructed well was created to supply a potable water supply to the mine buildings. Well PW-1 represents the largest change (in water supply pumping) to the ground water regime due to the proposed mining expansion. Ground water well PW-1 is located 1-mile southwest of the Continental Mine on the northwest flank of Humbolt Mountain. The well is 1,200 feet deep and screened from 500 to 1,200 feet below ground surface. The well produced at a constant rate of 242 gpm during a 72-hour constant rate discharge test in 1996. The estimated long-term pumping rate is 200 gpm.

Ignoring recharge and suspected geologic barriers, four wells in the vicinity of PW-1 would detect drawdown from pumping PW-1 at 200 gpm. At 10 years of continuous pumping, predictions indicate that drawdown could range between 57 and 75 feet in these wells. Three of the wells are private wells and the fourth is the water supply well for the City of Hanover. If PW-1 were pumping at a constant rate of 200 gpm, these wells have sufficient depths to ensure that they would be able to produce at their permitted rates without going dry. However, pumping costs at these wells would increase.

6.0 GEOCHEMISTRY

Geochemical data from the Continental Pit and Hanover Mountain were compiled and reviewed to characterize rocks associated with the proposed mine expansion at the Continental Mine site. The geochemical data were used for the following purposes: (1) to determine the potential for acid production from waste rock and pit walls, (2) to estimate the mobility of chemical constituents from weathering of the waste rock, and (3) for predictive pit lake modeling. This section is a summary of the Site geochemistry. A more detailed geochemistry report is provided in Appendix D, and pit lake modeling is discussed in Appendices G and H.

6.1 Geochemical Testing Methods

Samples from the Continental Pit, Hanover Mountain, the WRDFs, and the Tailings Pond were evaluated with Acid/Base Accounting, Whole Rock Analysis, and/or the Meteoric Water Mobility Procedure.

6.1.1 Acid/Base Accounting

Acid/Base Accounting (ABA) evaluates the balance between potentially acid-generating minerals and acid-neutralizing minerals in a rock or soil sample. The acid-generating potential (AGP) of a material is calculated from the amount of either: (1) total sulfur, (2) non-sulfate sulfur, (3) pyritic sulfur, or (4) peroxide-removable sulfur within the material. The acid neutralizing potential (ANP) is a measure of the amount of carbonate minerals. AGP and ANP are both reported in units of tons of equivalent CaCO₃ per kiloton of material (T CaCO₃/kT). ABA results are interpreted by computing the net neutralization potential (NNP) of the material (NNP = ANP - AGP) and the ratio of ANP to AGP of the sample. Samples with positive NNP values and with ANP to AGP ratios greater than 1 have more acid-neutralizing material available than acid-generating material. Bureau of Land Management (BLM) guidelines state that when NNP values are greater than +20 TCaCO₃/kT and the ANP to AGP ratio is greater than 3, the sample is not likely to be

acid generating. If ABA values do not meet these guidelines, kinetic testing may be required to determine if the sample is acid generating (BLM, 1996).

ABA analysis of samples from Cobre was performed by CORE Laboratories, Aurora, Colorado (CORE) and by SVL Analytical, Inc., Kellogg, Idaho (SVL). Samples were collected from the Continental Pit, the West WRDF, the South WRDF, and Hanover Mountain. A more detailed description of these samples is given in Appendix D.

6.1.2 Kinetic Testing

Kinetic testing (sometimes referred to as humidity cell testing [HCT]) is designed to simulate intense conditions of weathering so that acid production and release of constituents by a rock sample, if they are to occur, can be detected in a reasonable amount of time. Kinetic testing was conducted on eight of the Hanover Mountain samples that were analyzed with static testing (ABA). The kinetic tests were conducted by CORE following procedures detailed by Sobek et al. (1978), as modified by CORE (CDM, 1997). Details of kinetic-testing design, data, and weekly plots of pH, acidity, iron, and sulfate concentrations are given in Appendix D.

6.1.3 Whole Rock Analysis

Whole rock analysis is based on a strong-acid leach of a rock sample using concentrated acids and oxidants. Whole rock analysis is useful as an indicator of elements that exist in the samples at concentrations above their average abundance in rocks and is therefore a good screening tool. Whole rock analyses were conducted by CORE and Chemax Labs, Inc., Sparks, Nevada (Chemax) on samples from the Continental Pit and tailings, East and West WRDFs, Hanover Mountain, and magnetite tailings. CORE followed digestion methods given in EPA SW-846 (U.S. EPA, 1986), and Chemax used X-Ray Fluorescence.

6.1.4 Meteoric Water Mobility Procedure

The Meteoric Water Mobility Procedure (MWMP) is a leaching test designed by the Nevada Department of Environmental Protection (NDEP) for investigating the mobility of potentially toxic constituents in samples of mine soils and wastes (NDEP, 1996). Several samples of waste rock from the Continental Pit core, Hanover Mountain and the Tailings Pond were evaluated using MWMP by SVL. These are described further in Appendix D.

6.2 Geochemical Testing Summary

The majority of the rock in the Continental Pit is comprised of Paleozoic-age formations with high carbonate contents in the form of calcite and dolomite. Consequently, these rocks generally have high NNP values indicating that they are unlikely to produce acidic leachate due to weathering processes (oxidation and dissolution) with few exceptions. This conclusion is corroborated by the results of HCTs and MWMP tests on rocks from the Continental Pit that produced near neutral to slightly alkaline leachate with low metal concentrations. The potential exceptions include the Mesozoic and younger rocks of the Beartooth and Colorado Formations that generally have lower carbonate contents and lower NNP values than the older formations.

In contrast to the Continental Pit, nearly all of the rock tested from Hanover Mountain has negligible carbonate content and negative NNP values. Based on these data, there is a potential for the generation of acidic leachate in the waste rock and pit walls. HCTs and MWMP test results showed that a proportion of Hanover Mountain rock samples with negative NNP values produced acidic leachate corroborating this conclusion.

NAG pH analysis and peroxide sulfur determinations suggest that these methods are useful for rapidly estimating the acid production probability from waste rock. These testing procedures should provide reliable methods for determining waste rock handling and storage. Leaching tests conducted on tailings samples indicate that they are non-acid-generating but can release high concentrations of sulfate. These results are consistent with observations of neutral-pH water, containing sulfate concentrations from about 800 to 2,430 mg/L, in the Tailings Pond and Magnetite Tailings facilities.

6.3 Predicted Pit Lake Geochemistry

Planned expansion of the Continental Mine would involve enlargement of the Continental Pit (according to the 1997 proposed plan) and excavation of a new pit at Hanover Mountain. The results of preliminary hydrologic modeling (see Appendix E) indicate that lakes will begin to form in the pits soon (within a few tens of years) after mine closure. A preliminary prediction of the water quality of the pit lakes was made, based on available information on mine wall rock reactivity, predicted hydrologic inflow rates, and representations of equilibrium geochemical processes. A summary of the modeling is given here, and a more detailed report can be found in Appendices G and H.

6.3.1 Continental Pit

The Continental Pit lake is predicted to have a near-neutral pH and a chemical composition dominated by calcium and bicarbonate. Metal concentrations are predicted to be low as a result of the near-neutral pH.

The predictions of future water quality were based on a number of conservative assumptions, including:

• During filling of the pit lake, 50 percent of the groundwater inflow was specified as being derived from the Colorado Formation and 50 percent from the underlying calcareous units. In reality, most of the groundwater inflow will probably be derived from the calcareous units, which have high alkalinity, hence high acid-buffering capacities.

• The release of acid and sulfate from the calcareous rocks was represented by the average rate of sulfate release determined in four humidity cell tests conducted on samples from the Colorado Leach Cap Formation from the Hanover Pit. In contrast to the calcareous units of the Continental Pit, the Leach Cap rocks from Hanover have near-zero NNP values, hence their leachates provide a very conservative estimate of the alkalinity that would be derived from leaching of the calcareous rocks present in the Continental Pit.

These assumptions make it likely that the predictions for the Continental pit lake represent a reasonably conservative estimate of future water quality. The most important factors that control the predicted water quality are the high carbonate contents of the Continental Pit walls and high alkalinity of the ground water inflows. The influxes of alkalinity from these sources are sufficient to mitigate any acid generation by sulfide oxidation and maintain the predicted pH at near-neutral values.

6.3.2 Hanover Pit

In summary, the Hanover Pit Lake is predicted to have an initial pH between 4.8 and 5.9 and a composition dominated by sodium, calcium, magnesium, and sulfate. The pH is expected to increase or stay approximately constant over time, depending on the ground water flow system. Certain metals are also predicted to have elevated concentrations, namely aluminum, copper, and zinc because of releases to the pit lake by the processes of wallrock runoff and wallrock leaching.

The predictions of pit lake water quality were based on a number of conservative assumptions. The most important of these include:

- The ground water composition was specified as a 50:50 mix of waters characterized by compositions from MW-1A and MW-1. This approach reduced the amount of alkalinity flowing into the pit lake from the ground water system.
- The maximum rates of constituent release that were determined in humidity cell tests were used to represent the process of wallrock leaching. This approach maximized the rates of constituent flux to the pit lake.

• The pit walls were assumed to be exposed to weathering for a 10-year period before closure and filling of the pit with water. This approach resulted in a buildup of leachable constituents in the wallrock because of oxidation processes, which are then released to the pit lake in the model as the pit fills with water.

The assumptions listed above make it likely that the predictions for the Hanover Pit Lake represent a reasonably conservative depiction of future water quality.

Importantly, the pit chemistry is controlled by the balance of water that inflows from acidic sources, such as the pit walls, and alkaline sources, such as the ground water, predictions of the future chemical composition are highly dependent on the representation of the groundwater hydrologic system. However, the relative proportion of high alkalinity ground water flowing into the pit lake is predicted to increase over time. Consequently, the pH of the lake is also predicted to increase slowly. With increase in pH, the concentrations of many metals can be expected to decrease over time because of precipitation and adsorption reactions.

Additional calculations are being performed to assess the effects of parameter uncertainty on the final water quality predictions for the Hanover Pit. These results will be available in the early spring of 2000.

7.0 GROUND AND SURFACE WATER QUALITY

Ground and surface water quality data were obtained from both local and regional locations. Several companies and agencies collected these data various times between October 1929 and July 1997. The data were used to characterize and compare the water quality both locally and regionally for this study. Appendix C contains a detailed description of the data, analyses, and results that are summarized in this section.

Piper diagrams and statistical tests were used to describe and compare local and regional water quality. Median values instead of mean values were used for the analyses because there was no control over the location and frequency of sample collection. Thus, median values were considered a more representative descriptor of water quality. Five constituents were used for the comparison: sulfate, TDS, iron, copper, and zinc. In addition, the median values of constituents with applicable New Mexico Water Quality Control Commission (NMWQC) primary and secondary drinking water standards were compared to the standards in order to describe general water quality.

For several facilities, data were compared for samples taken upgradient and downgradient of the facility and at the facility itself to determine the effect of the facility on the surrounding water quality. All water quality constituents with applicable NMWQC drinking water standards for ground water were considered in evaluating a facility impact on water quality. Mean values were used for these analyses because there was more control over the collection of the local water samples.

7.1 Regional Water Quality

7.1.1 Surface Water

In Grant County, New Mexico, surface waters from storm runoff typically are elevated in TDS concentrations. Surface waters from baseflow are typically of higher quality (have lower TDS concentrations). Generally, surface water quality is highest at stream headwaters and decreases downstream (BLM, 1997).

The water from south of the mine site to just south of Hurley, New Mexico generally is classified as calcium-sulfate water. South of Hurley, the lack of a significant number of surface water samples prevents an accurate classification of the water type.

Overall, the regional surface water quality is good - The median values for regional surface water samples do not exceed NMWQC primary drinking water standards. However, the median values of sulfate and TDS for regional surface water samples exceeded secondary water quality standards.

7.1.2 Ground Water

The quality of ground water in nearly all of Grant County is suitable for livestock, irrigation, domestic use, and most industrial uses (Trauger, 1972); however, ground water of unsuitable quality for general use is found in localized areas. Ground water has moderate to high hardness nearly everywhere within the county. Hardness in water from carbonate aquifers generally arises from the dissolution of calcite and/or dolomite. The Colorado and Percha Shale Formations may also produce hard water due to naturally occurring high concentrations of calcium sulfate. Ground water from volcanic formations is typically of the best quality. It is usually soft (low concentrations of calcium and magnesium) and has low TDS concentrations (BLM, 1997).

As with surface water, ground water from south of the mine site to just south of Hurley, New Mexico is generally classified as calcium-sulfate water. Calcium-bicarbonate ground water is predominant in locations south of Hurley and south of the Peru Hill Mill (Luna County, New Mexico). Sodium-bicarbonate and sodium-chloride-sulfate ground waters occur south and east of the Florida Mountains (Luna County). The varying geologic formations in the region may cause the differing ground water types. For example, calcium-sulfate waters are typically found in limestone aquifers. The main aquifers near the mine site are limestone aquifers that may be heavily mineralized. Correspondingly, the water in this area is classified as calcium-sulfate water. The main aquifers south of Hurley are the Gila Conglomerate and the Bolson Fill (Trauger, 1972). The median values for the regional ground water meet the primary drinking water standards with the exception of cobalt and manganese. The regional data, which cause these parameters to exceed standards, are associated with wells that exhibit anthropogenic effects. If these data are ignored, the overall regional median values meet the standards. Secondary standards are exceeded for TDS and sulfate.

7.2 Local Water Quality

Local ground and surface water samples at the mine site are generally classified as calcium-sulfate water; however, calcium-bicarbonate water is prevalent on the northern portion of the site (particularly at Poison Spring, along Grape Gulch, and at Fierro Spring), which is upgradient of the mining area. The difference in water types could be due to the water flowing through the mining area, which has naturally occurring mineralized zones and historic disturbances. In most cases, the historically available water quality data are not sufficient to determine whether changes in water quality are caused by anthropogenic effects or by naturally occurring mineralization in host rocks.

For example, monitoring well MW-7 is hydraulically downgradient of Poison Spring (calcium-magnesium-bicarbonate water), and until recently, was upgradient of the Tailings Pond (calcium-sulfate water). The water from MW-7 is classified as calcium-sulfate water with a different chemical signature than water sampled from the Tailings Pond. Because MW-7 was upgradient of the Tailings Pond and no mining activities have occurred upgradient of MW-7 in the past, the difference in water type is likely due to flow through naturally mineralized zones.

Unlike MW-7, the water in MW-5 does not appear to be affected by the naturally occurring mineralization. MW-5 was probably downgradient of the mineralized zones of the Site prior to the dewatering of the underground mine. Thus, the water in this well may have shown the influence of mineralization; however, the water type of samples taken in MW-5 has always been calcium-bicarbonate, and it does not correspond to water types from the active mining area. Therefore, the water in this well may not have been impacted by naturally occurring mineralization.

7.2.1 Surface Water Quality

The quality of the local surface water is generally good. The median values for local surface water do not exceed NMWQC primary drinking water standards. However, the median values of sulfate and TDS exceed secondary water quality standards.

7.2.2 Ground Water Quality

As with the local surface water, the water quality of the local ground water is generally good. Median values do not exceed NMWQC primary drinking water standards except for manganese. Secondary water quality standards are exceeded by the median values for sulfate and TDS.

7.3 Comparison Between Regional and Local Water Quality

The statistical comparison between regional and local water quality (based on the 5 key parameters described in Section 7.0) can be summarized as follows. Generally, at least (and in some cases more) two distinct populations can be identified for each of the five constituents analyzed. Comparison of arithmetic mean values (from the constituent populations identified) to NMWQC drinking water standards indicates that the Upper Population (see Appendix C for a description), both locally and regionally, exceeds standards for sulfate and TDS.

7.4 Facilities Impacts on Water Quality

Where available, samples upgradient, downgradient, and at the facility were compared to determine the potential effect of the facility on the surrounding water quality. Mean values were used to compare the water quality. In addition, these values were compared with NMWQC drinking water standards.

7.4.1 Impacts from the Tailings Pond

Appendix C presents a description of the water quality upgradient and downgradient of the Tailings Pond. The water quality and material properties of the Tailings Pond could

explain increased concentrations from up to downgradient in a few water quality parameters (i.e., chloride, sulfate, and TDS). However, the Tailings Pond itself can not account for changes in other water quality parameters. Other processes and facilities must be contributing to the water quality downgradient of the Tailings Pond. Further studies are being conducted to investigate this phenomenon.

7.4.2 Waste Rock Disposal Facilities

As discussed in Appendix C, the seep on the northeast side of the South WRDF was assumed to characterize the water quality resulting from meteoric waters leaching through the WRDF. Downgradient water quality was assumed to be characterized by MW-12. Localized effects of historic mining on Union Hill best explain the difference in these two water qualities.

For the West WRDF, the upgradient sample is MW-21, the downgradient sample is MW-20, and the West WRDF disposal seep (WWRDF_SEEP) and sample location WWRDF are the samples considered at the facility. Only chloride appears to have increased between the upgradient area and the downgradient area, but the increase is not necessarily attributable to the West WRDF because the concentration downgradient is higher than at the facility itself. For almost all of the constituents considered (except chloride), the concentrations at the West WRDF are higher than the upgradient sample location, but do not appear to affect the water at the downgradient location. More hydrologic characterization is necessary to explain these results.

7.4.3 Underground Workings

The upgradient ground water is represented by the sample locations MW-2, MW-4, and MW-5. The downgradient ground water is represented by sample location UG_SUMP, which is water collected by the underground workings. The concentrations at UG_SUMP (downgradient) were higher than the average concentrations at upgradient locations for chloride, manganese, sulfate, TDS, and zinc. Increases in these constituents can be attributed to the mixing of meteoric waters entering the underground through the

Continental Pit and other zones were mineralized rocks have been allowed to oxidize. These effects may dissipate after the underground workings fill with water and oxidation halts.

7.4.4 Hanover Mountain (Pit)

Three samples are considered near Hanover Mountain to compare water quality: MW-1A, HSN-1, and HSN-2. Monitoring well, MW-1A, is approximately 1,000 feet upgradient of Hanover Mountain and is completed in a sandstone unit of the Colorado Formation (Figure C-3). HSN-1 is a surface water sample taken from a seep that issues from a sandstone unit on the north side of Hanover Mountain. HSN-2 is a surface water sample taken after the seep water traveled approximately 1,000 feet downstream from HSN-1 over other outcrops of the Colorado Formation. Concentrations in the HSN-1 sample were greater than those in the MW-1A sample for cobalt, copper, iron, manganese, nickel, sulfate, and zinc. In addition, the pH of the HSN-1 sample was lower than the pH of the MW-1A sample. Effects of mineralization associated with Hanover Mountain likely caused the differences between HSN-1 and MW-1A.

8.0 SUMMARY AND CONCLUSIONS

Generally, the data and analyses presented in this document provide a summary of the baseline (current) and possible future conditions at the Continental Mine. The most important results presented in this document are summarized below:

- The baseline water quality at the Continental Mine is generally not significantly different from the water quality of the surrounding area and generally meets drinking water quality standards.
- Not enough historical water quality data exist to determine if water passing through the mine site is impacted from either anthropogenic or natural processes. Most likely, it is affected by both.
- Surface and ground waters would have to be protected from disposal of waste rock from Hanover Mountain and reclamation of the West WRDF. Disposal of a majority of the waste rock from the Continental Pit would probably require little special handling.
- The expansion of the underground workings would cause more drawdown in the lower bedrock aquifer, and after mining ceases, it would take over 120 years for ground water to reach pre-mining elevations. The water quality associated with the workings is not likely to change due to the previously proposed expansion.
- Previously proposed Tailings Pond expansion would affect the hydrologic regime to the west of the current Tailings Pond; however, no additional offsite from the Tailings Pond would take place.
- Excavation of Hanover Mountain would ultimately result in a pit lake approximately 150 feet deep. The predicted water quality in the pit lake will likely be around pH of 5 and contain elevated levels of metals. A permanent loss about 60 gpm to evaporation from the local hydrologic regime would occur.
- Proposed expansion of the Continental Pit would result in a pit lake that would be deeper than if expansion does not occur. The ultimate lake depth would be over 450 feet, resulting in an evaporative loss to the local hydrologic regime greater than if expansion does not occur. The water quality of the Continental Pit would be relatively good with a near neutral pH and metals concentrations below drinking water standards.

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