Appendix A
Partially-Completed Supplemental Ground Water Study Report

WORK IN PROGRESS – SUBJECT TO REVISION

WORKING DRAFT
SUPPLEMENTAL GROUND WATER STUDY
CONTINENTAL MINE EXPANSION
GRANT COUNTY, NEW MEXICO

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TELESTO
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1.0 INTRODUCTION

At the request of Cobre Mining Company, Inc. (Cobre), Telesto Solutions Inc. (Telesto) has prepared this Supplemental Ground Water Study pursuant to Condition 84 of Discharge Permit DP-1403, approved by NMED on December 10, 2004. Condition 84 reads as follows:

> *Cobre shall perform a study to supplement existing ground water studies and evaluate the hydrologic conditions beneath the Continental Mine Facility. Within 240 days after the effective date of this Supplemental Discharge Permit, Cobre shall submit to NMED for approval a work plan, including an implementation schedule, for a study to evaluate the hydrologic conditions beneath the Continental Mine Facility. The study shall consider the data needs for the Pit Lake Formation study described in Condition 85 and the abatement plan required in Condition 32. The study shall be designed to determine whether the proposed closure alternatives will achieve the requirements of the WQA* [New Mexico 1987 Water Quality Act] *and the WQCC* [New Mexico Water Quality Control Commission] *regulations. As part of the study, Cobre may be required to install additional monitoring wells for the collection of temperature, flow direction, water quality and water level data beneath the Continental Mine Facility.*

This report consolidates available information on climate, geology, surface water, and ground water to develop a conceptual hydrogeologic model for the Continental Mine site and adjacent area. The conceptual model is then quantified by developing a three-dimensional numerical ground water flow model that incorporates all relevant aspects of the ground water system. To improve its predictive capabilities, the numerical model is calibrated to known hydraulic heads and ground water flows. The focus of this effort is to provide a defensible technical basis for assessing water-related impacts associated with operation and closure of the Continental Mine, and to provide a tool for guiding future investigations of the site (if required). The location of Continental Mine is shown on Figure 1-1 and the facility layout map is provided on Figure 1-2.

Mining has occurred in the Central Mining District since the sixteenth century. United States Smelting, Refining, and Mining Company owned and operated the Continental Mine area for most of the twentieth century. Subsequent owners included Sharon Steel, U.V. Industries, and Bayard Mining Corporation. Up to the late 1960s, ore production was generated solely from underground workings. Ore 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 with ore production from the underground Continental Mine and Continental Pit (Hillesland and others, 1995). In 1998, Phelps Dodge's Chino Mines Inc., acquired the Continental Mine. Mining operations at the site have been suspended since the spring of 1999. However, approval has been received to expand the Continental Mine and operations are planned to resume during 2009.

2.0 CLIMATE

2.1 Regional

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

- Mean annual precipitation of 15.66 inches/year (Fort Bayard)
- Mean annual temperature of 55.29 degrees F (Fort Bayard)
- Mean minimum temperature of 25.3 degrees F during the month of January and mean maximum temperature of 86.8 degrees F during the month of June (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 predicted from regional climate data and topography. 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 14 inches/year at lower elevations (Cron Ranch) to 24 inches/year at higher elevations (north of Hanover Mountain). The following estimated site-specific parameters were utilized for baseline evaluations of the site (SMI, 1999):

- Mean annual precipitation (MAP) of 18.3 inches/year. The monthly precipitation distribution (as percentage of MAP) is assumed similar to the distribution 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. The monthly distribution is assumed similar to the distribution measured at this station.

- Lake evaporation of 55.8 inches/year, estimated using a factor of 0.7 times the pan evaporation. The same factor is used to estimate monthly lake evaporation rates.

Mean monthly climate parameters are summarized in Table 2-1.

3.0 GEOLOGY

3.1 Regional Geology

The Continental Mine area is located within the Santa Rita Quadrangle, and lies in a broad transitional zone between the Colorado Plateau and the Basin and Range Province (Jones et al., 1967). South and southwest of the mine area are Paleozoic to Mesozoic sedimentary rocks and younger volcanic rocks that are exposed in north- to northwest-trending mountain 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).

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 Continental Mine are the Barringer Fault and the Hanover-Fierro Stock. A stratigraphic section of geologic units in the Cobre area is shown on Figure 3-1. A geologic map of the Continental Mine area is shown on Figure 3-2, and cross sections through the Continental Pit and Hanover Mountain areas are shown on Figures 3-3 and 3-4, respectively. A geologic map of the expanded Continental Pit is shown on Figure 3-5.

3.2 Local Geology

3.2.1 Sedimentary Rocks

The stratigraphic section in the Continental Mine area (Figure 3-1) 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 contain 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, which consist mainly of fine- to medium-grained clastic units that are overlain by up to several hundred feet of andesite flows and tuffs (Hillesland et al., 1995). The Continental Pit exposes mainly Paleozoic rocks, while Hanover Mountain contains mainly Mesozoic rocks.

3.2.2 Igneous Rocks

More than 30 distinct lithologies of intrusive rocks are found within the Santa Rita Quadrangle, with ages ranging from Late Cretaceous to Miocene. 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 Cretaceous andesite flows and Tertiary tuffs (Hillesland et al., 1995).

3.2.3 Structures

The Barringer Fault and associated extension fractures and conjugate shears are the most important structural features at the Continental Mine. The Barringer Fault is a normal fault that strikes approximately N40°E throughout most of the Central Mining District. Dips range from 55 to 75 degrees to the northwest. Vertical displacement along the Barringer Fault is estimated to range from 1,200 to 1,600 feet (Jones et al., 1967), with the northwest side down-thrown and the southeast side up-thrown. As exposed in the Continental Pit, the fault zone has a width of up to 200 feet wide. (Hillesland et al., 1995). Lobes of the Hanover-Fierro Stock terminate at the Barringer Fault. However, the fault does not offset the northwest contact of the stock, indicating that the Hanover-Fierro Stock post-dates most or all movement of the Barringer Fault (Jones et al., 1967).

As shown on Figure 3-2, the Dix, Super Cobre, and Gilchrist Faults belong to a set of north-northeast striking, steeply dipping normal faults associated with mineralization (Hillesland et al., 1995). The Dix Fault, which is now underneath the Main Tailings Impoundment, is a normal fault that dips north at about 50 degrees northwest and has about 600 feet of vertical displacement. There is a fracture zone adjacent to the Dix Fault that is about 100 feet wide. The Gap Fault, which is also underneath the Main Tailings Impoundment, is a normal fault that dips 60 to 65 degrees northwest and has approximately 300 feet of displacement.

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). Infiltration and 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 little 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

4.2.1 Creeks

The Site is located within the drainage area of Hanover Creek. 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 (Figure 1-2) 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 that may result from seepage associated with septic systems within the towns. It is also reported that historically there were other perennial reaches along the stream that are now ephemeral.

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 the Mine include the following (refer to Figure 1-2):

- Grape Gulch is an ephemeral drainage that flows through the Site adjacent to Mill #1.
- Poison Spring Drainage begins 3,400 feet upslope of Poison Spring and is intercepted by the Main Tailings Pond. Perennial flows of 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 Main Tailings Pond, Magnetite Tailings Pond, and northeast side of the South Waste Rock Facility (WRF).
- Buckhorn Gulch begins on-site near the West and South WRFs and discharges in Hanover Creek near the town of Hanover. A perennial reach occurs for a short distance downstream of Buckhorn Spring and at reaches where the channel consists of only bedrock.
- Ansones and Beartooth Creeks are ephemeral drainages located southwest of the mine site.

4.3 Springs and Seeps

4.3.1 Springs

Upslope of the mining area are perennial seeps and springs that originate at the base of a volcanic unit overlying the Colorado Formation. These springs likely result from distributed recharge that perches at the base of the volcanic unit due to the low hydraulic conductivity of the underlying Colorado Formation. The perched water migrates along the geologic contact between the volcanics and Colorado Formation and discharges as a spring line where the contact intercepts the ground surface.

Springs within the site area include the following (refer to Figure 1-2).

- Poison Spring is located northwest of the Main Tailings Pond. Flow from this spring is channeled through a small-diameter pipe to a stock water tank.

- Fierro Spring is located near the headwaters of Hanover Creek and flows at a rate of less than 1 gpm.

- Buckhorn Gulch Spring 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.

4.3.2 Pre-Mining Seeps

Prior to mining, there were several seeps in the vicinity of the site. These included:

- Seeps in Grape Gulch and Gap Canyon that had combined flows of less than 1 gpm.

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

4.3.3 Post-Mining Seeps

The following seeps are associated with past and current mine facilities:

- Tailings Ponds Seeps exist on the south and east sides of the Tailings Pond. At one time the combined flow rate of these seeps was about 500 gpm. Now that operations have been temporarily suspended, the flow rates have decreased significantly. These flows are intercepted by a combination of surface water containment facilities and a French drain, with the collected water being diverted to the Decant Pond #4 from where it is pumped back to the Main Tailings Pond. In the past, a portion of this water was used for mine process water. Seepage flow rates are estimated to be less than 110 gpm.

- West WRF seeps are located on the east side of the facility and flow intermittently during and after storm events. The water is collected by lined surface water containment facilities and pumped back to Decant Pond #4. In the past, this water was used for mine process water. The combined flow rates from these seeps on a yearly average are estimated to be less than 1 gpm.

- Buckhorn Containment Facility seep is located in a branch of Buckhorn Gulch, immediately downgradient of the West WRF seep. This seep emanates from the eastern toe of the Buckhorn WRF. The seep flow rate is estimated to average less than 1 gpm on a yearly average.

- East WRF seep is located on the north side of the facility and flows at an average rate of less than 1 gpm. The water is collected by a surface water containment facility ("Concrete Pond") and a French drain, and pumped to the Decant Pond #4. In the past, this water was used for dust suppression or allowed to evaporate.

- The Magnetite Dam seep exists downstream of the toe of the dam. The average flow rate of the seep is less than 1 gpm.

- Union Hill Adit seep is located on the east side of the Union Hill WRF. This seep is intermittent and has been dry for the past several years. Due to recently wet conditions, the water table has risen, resulting in flows from this seep. The seepage flow rate is estimated to be less than a few gpm. Historically, this seep was used as a domestic supply.

There are currently no direct flow rate measurements at these seeps. However, Cobre plans to install collection pumps with flow meters at some of these seeps to obtain flow information.

5.0 GROUND WATER

5.1 Regional

Ground water is the main source of water supply for municipal, domestic, agricultural, and industrial use within Grant County (Trauger, 1972). The viability of the ground water resource is dependent on characteristics of the geologic unit from which ground water is extracted. The following four main rock types are found within the county:

- Metamorphic and igneous rocks have relatively small well yields (1 and 15 gpm), except in highly weathered granitic rocks that can produce higher yields.
- Volcanic rocks do not produce significant yields, except for some porous pyroclastic deposits that can locally generate higher yields.
- Marine sedimentary rocks are generally poor aquifers. However, fractured carbonate rocks, which most commonly occur near major fault structures, can locally provide significant well yields.
- Consolidated and semi-consolidated clastic deposits are the most prolific ground water sources in Grant County. Well yields up to several hundred gpm can be developed from these formations.
- Unconsolidated stream alluvium along major stream channels range in thickness from 5 to 20 feet thick and can locally provide well yields up to several gpm (SMI, 1999).

5.2 Local

Local ground water flow is strongly controlled by the complex geology of the mine area. This includes sedimentary rock sequences that are displaced by faults and intruded by igneous rock bodies.

5.2.1 Bedrock Aquifers

Due to the presence of faulting and multiple igneous intrusions, the geometry of the bedrock aquifers is complex. The Barringer Fault separates the northern and southern portions of the Site. South of the fault, stratigraphically lower (older) units have been upthrown and younger strata have been eroded. After most fault displacement had occurred, intrusive igneous rock bodies were emplaced on both sides of the fault. The following three bedrock aquifers have been identified. They are renamed from previous documents (SMI, 1999, Telesto 2005a) for clarification purposes:

- The North Paleozoic Aquifer consists of Paleozoic clastic and carbonate sedimentary rocks north of the Barringer Fault. These rocks are stratigraphically below the Cretaceous Beartooth Quartzite. The North Paleozoic Aquifer is a deep aquifer north of the Barringer Fault. Based on mine inflows, the more important water producing geologic units within this aquifer are the Lake Valley and Oswaldo Formations

- The South Paleozoic Aquifer consists of the same Paleozoic rocks as the North Paleozoic Aquifer, but is located south of the Barringer Fault. Due to the fault, these rocks have been displaced upward and comprise a shallow bedrock aquifer. The Barringer Fault has been shown (SMI, 1999, Shomaker 1999) to be a low permeability structure, so there is little hydraulic communication between the North Paleozoic and South Paleozoic Aquifers even though they are geologically the same strata.

- The Cretaceous Aquifer consists of clastic sedimentary rocks of the Cretaceous Colorado Formation, which is stratigraphically above the Beartooth Quartzite. The Colorado Formation exists northwest of the Barringer Fault. Except at the tops of Humbolt Mountain, this unit is almost completely eroded southeast of the fault. Thus, the Cretaceous Aquifer south of the Barringer Fault is not significant.

The Createaceous Aquifer (shallow) and North Paleozoic Aquifer (deep) both exist north of the Barringer Fault. These aquifers are separated by an aquitard defined by shale units in the upper and lower portions of the Beartooth Quartzite. Additional confinement may be provided by a lower shale unit in the Colorado Formation and shales in the Abo Formation that underlie the Beartooth Quartzite (SMI, 1999). South of fault, the South Paleozoic Aquifer is present at a relatively shallow depth.

These three aquifers are intruded by igneous rock bodies that have relatively low hydraulic conductivity. Trauger (1972) and subsequent testing have shown these units to provide limited yields to wells. Emplacement of the igneous bodies appears to post-date movement of the Barringer Fault.

5.2.2 Alluvial Aquifers

There are four shallow, alluvial ground water flow systems in the mine area: (1) Upper Buckhorn Gulch, (2) Poison Spring Drainage, (3) Grape Gulch, and (4) Hanover Creek. These aquifers are recharged by storm water, snowmelt, spring water, and seepage from adjacent bedrock aquifers. Monitoring wells completed in the alluvial aquifers indicate saturated thicknesses of several feet or less, and sometimes the presence of perched water flowing in the downslope direction. The shallow alluvial systems may also include underlying weathered bedrock, especially in Hanover Creek. Current investigations have been completed to describe the extents of the alluvial aquifers and their interactions to the bedrock aquifers (Telesto 2005b, pending).

5.2.3 Ground Water Flow Systems

Because the site geology is very complex, aquifers and flow systems cannot be defined by lithologies alone. Geology must be combined with water level data to define ground water flow systems in this area. For purposes of this work, flow systems are defined using the aquifer designations discussed above, but they may contain many rock types including some with low hydraulic conductivities that would not be considered "aquifers" in the sense of providing flow to wells. The designated ground water systems are defined as follows (refer to Figure 5-1):

- North Paleozoic Flow System is a deep ground water flow system north of the Barringer Fault. This system is largely below the elevation of the Beartooth Quartzite and it contains intruded Cretaceous and Tertiary igneous rock bodies.

- South Paleozoic Flow System a shallow and deep ground water flow system south of the Barringer Fault. It is intruded by numerous Cretaceous and Tertiary igneous rock bodies.

- North Cretaceous Flow System is a shallow ground water flow system north of the Barringer fault composed mostly of the Colorado Formation, but which is extensively intruded by igneous rock bodies.

- Alluvium Flow Systems are composed of shallow stream alluviums adjacent to modern stream channels and may also include underlying weathered bedrock. These flow systems are narrow and follow the more prominent stream channels. They are named according their associated stream drainage (e.g., Hanover Creek Alluvium).

5.2.4 Ground Water Flow Patterns

Water levels have been measured in monitoring and production wells in the mine site area. Although there are variations in the distribution of measurements, a general picture of ground water flow patterns has been developed. Figure 5-1 shows water-level elevations for the ground water flow systems discussed above.

Ground water in the North Cretaceous Flow System generally flows to the south and appears to discharge into the Hanover Creek, Grape Gulch, and Poison Spring Alluviums, and also into the Continental Pit. Since large seeps are not observed in the pit walls, the ground water flow rates in the North Cretaceous Flow System are probably not large, indicating that the system is characterized by relatively low hydraulic conductivity.

Water level measurements in the North Paleozoic Flow System are limited, but suggest that ground water flow is to the north; that is, opposite to the direction of flow in the overlying North Cretaceous Flow System. This is likely the result of historical dewatering in the underground mine workings and the slow rate of water level recovery in the workings since the cessation of dewatering operations in August 2000.

The South Paleozoic Flow System generally flows to the southeast with discharge into the alluviums of Hanover Creek, the Poison Spring Drainage, and possibly into Buckhorn Gulch. The Continental Pit appears to have a moderate influence on this system.

5.2.5 Hydraulic Communication

The water level contours on Figure 5-1 can be used to interpret the relative degree of hydraulic communication between flow systems. Important features are summarized as follows:

- There are discontinuities in ground water levels on different sides of the Barringer Fault. In general, water levels in the South Paleozoic Flow System are significantly lower than levels in North Cretaceous Flow System, even though these systems are juxtaposed on opposite sides of the fault. This suggests that the fault zone operates as a low-permeability feature and inhibits lateral ground water flow. The low hydraulic conductivity in the fault zone could result from gouge formation, and subsequent weathering to produce low-permeability clays.

- North of the Barringer Fault, water levels in the North Paleozoic Flow System are hundreds of feet lower than those in the overlying North Cretaceous Flow System and the flow directions are opposite. This suggests that the aquitard separating the two systems is a laterally extensive low-permeability geologic unit that inhibits vertical flow. The aquitard is interpreted to contain upper and lower shales in the Beartooth Quartzite and may also be affected by a lower shale unit in the Colorado Formation and shales in the Abo Formation. The relatively low heads in the North Paleozoic System likely result from hydraulic communication with the dewatered underground mine workings.

- The North Cretaceous Flow System discharges mainly to alluvium flow systems and to the Continental Pit

- A small proportion of ground water in the North Cretaceous Flow System may flow to the underground mine workings which have been slowly refilling since the cessation of mine dewatering in 2000. Downward leakage from the North Cretaceous Flow System into the mine workings appears to be minimal because there wasn't significant drawdown in this system when the mine workings were completely dewatered. Also, it appears that dewatering in the deep underground workings did not significantly affect the flow directions in the North Cretaceous Flow System. These observations provide further evidence that there is an effective aquitard below the North Cretaceous Flow System, and Barringer Fault operates as a low-permeability structure.

- The North Cretaceous Flow System appears to be affected by the Continental Pit, as indicated by the head contours that wrap around the pit on its north and west sides (Figure 5-1).

- The South Paleozoic Flow System flows to the south to southeast. Ground water in this flow system discharges to the Hanover Creek, Poison Spring Drainage, and Buckhorn Alluviums.

5.2.6 General Conceptual Flow Model

For the Continental Mine area, a diagrammatic representation of the conceptual flow model is shown on Figure 5-2. The basic aquifer sequence consists of the North Cretaceous and North Paleozoic ground water flow systems separated by an aquitard. The Baringer Fault has offset the two ground water flow systems so that the Cretaceous and Paleozoic systems exist north of the fault, but only the Paleozoic system is present south of the fault. The Barringer Fault is a low permeabililty feature that restricts hydraulic communication from north to south. As a consequence, there are discontinuities in ground water levels on opposite sides of the fault.

The current and future Continental Pit is excavated through the fault zone and intersects the Cretaceous and Paleozoic flow systems north of the fault. Ground water in the North Cretaceous Flow System flows to the southeast and discharges into the pit wall. The flow rate in this system must be relatively small because active seeps are not visible in the upper portions of the pit walls. Ground water in the North Paleozoic system flows toward the dewatered underground workings that currently have a water-level elevation of about 5,760 ft (based on a December 21, 2004 measurement). The aquitard between the North Cretaceous and North Paleozoic Flow Systems appears to be effective in limiting vertical hydraulic communication between the two systems. The effectiveness of the aquitard is demonstrated by the fact that: (1) dewatered underground workings in the North Paleozoic Flow System has not resulted in dewatering of the overlying North Cretaceous Flow System, (2) water levels in the North Paleozoic Flow System can be hundreds of feet lower than those in the overlying North Cretaceous Flow System, and (3) flow directions in the two systems are opposite.

South of the Barringer Fault, flow in the South Paleozoic Flow System is to the south. The fault behaves as a low permeability boundary to this system so that its main source of ground water is from distributed recharge. As a consequence, the dewatered Continental Pit has relatively little impact to this flow system.

Shallow flow systems tend to discharge to the alluvium systems. North of the Barringer Fault, the North Cretaceous Flow System discharges to Hanover Creek, Grape Gulch, and Poison Spring Drainage Alluviums. South of the fault, the South Paleozoic Flow System discharges to the Hanover Creek, and Buckhorn Gulch Alluviums. North of the fault, discharge from North Paleozoic Flow System is primarily into the underground workings.

5.3 Facilities Influences on Ground Water

For discussion purposes, the Continental Mine is divided into the following facility areas shown on Figure 1-2:

- Main Tailings Impoundment
- Magnetite Tailings Impoundment
- Waste Rock Facilities (East, Union Hill, South, Buckhorn, and West), Ore Stockpiles and other stockpiles, Continental Pit, Underground Workings.

These facility areas have been selected based on the potential for impacts to ground water resulting from facilities operations. A description of each area and a discussion of the general ground water system are provided in this section.

5.3.1 Main Tailings Impoundment

The Main Tailings Impoundment was established in 1967 and is located directly north of the Continental Pit (Figure 1-2). The current footprint area is about 120 acres. The impoundment was constructed in the Poison Springs Drainage and contributes seepage to the underlying alluvium. It is estimated that current drainage from the impoundment into the underlying alluvium is about 110 gpm. It is further estimated that approximately 7 gpm flows from the alluvium into the underlying bedrock. The remaining 103 gpm flows in the alluvium and weathered bedrock towards the Fierro Area where it is captured and pumped to Decant Pond #4. After closure and reclamation, drainage from the impoundment is predicted to decrease over many years to approximately 5 gpm. This estimate assumes that long-term net infiltration through the reclamation cover is 4% of MAP.

5.3.2 Magnetite Tailings Impoundment

The Magnetite Tailings Impoundment (Figure 1-2) covers approximately 20 acres and served as a storage area for magnetite recovered during the milling process between approximately 1968 and 1980. The Magnetite Tailings Impoundment was also used to contain emergency process overflow during the 1990s. Cobre is currently reducing the volume of the impoundment by transporting magnetite tailings to offsite buyers by truck and rail. It is assumed that the Magnetite Tailings will be completely removed prior to closure.

5.3.3 Waste Rock Stockpiles

Waste rock from the Continental Pit was transported from the pit by haul truck and deposited on the East, Union Hill, South, Buckhorn, and West WRFs (Figure 1-2). Beginning in 1967, these areas were used for waste rock and overburden disposal as the Continental Pit was mined. The West WRF was developed first (before 1982), and the East, South, Union Hill and Buckhorn WRFs were developed after 1992 (DBS&A, 1999a). Water balance calculations performed by DBS&A (1999b) indicate that net infiltration into these facilities is approximately 11% of MAP.

5.3.4 Ore & Other Stockpiles

Low-grade ore used for mill feed was stockpiled along the eastern edge of the Continental Pit (Figure 1-2). The low-grade ore stockpiles were initially developed between 1967 and 1970 and have been raised and lowered at various times in the past, but have not been used since Cobre acquired the property in 1992. A high-grade ore stockpile is located at the northeast perimeter of the Continental Pit, above the Poison Springs Drainage. It is anticipated that the ore stockpiles will be consumed and/or reclaimed by the end of mine life.

5.3.5 Continental Pit

The Continental Pit (Figure 1-2) is situated on the lower slopes of the eastern side of Hermosa Mountain. Development of the Continental Pit began in 1967, and by early 1970 the pit encompassed approximately 50 acres (DBS&A, 1999a). In subsequent years, the Continental Pit was expanded to the south, and by 1978 the total area of the pit was approximately 82 acres, with an average depth of 310 feet below original ground surface. Between 1978 and 1981, the entire western crest of the Continental Pit was pushed back and the pit area increased to 100 acres. The mine closed in 1982 due to low copper prices, but operations resumed in 1993. The Continental Pit was further deepened by 1996 and the total area increased to 120 acres. When the mine suspended operations in 1999, the pit had been pushed back along the western side. The current pit area is 147 acres and the pit bottom is at an elevation of 6,725 feet.

At present, there are no visible springs or seeps in the Continental Pit, although temporary seeps may exist after storm events when water collects on the benches. After the end of mine dewatering, the deep bedrock aquifer water table will recover, and it is predicted that a terminal lake will form in the pit (SMI, 1999).

5.3.6 Underground Workings

Historic underground workings are located to the north (Continental Underground Mine), southwest (Pearson-Barnes) and east (Union Hill Mine) of the current Continental Pit. The Continental Underground Mine was excavated until 1999 and was dewatered until August of 2000. Prior to 1964, historic dewatering occurred in several shafts in the area of the Continental Mine. During 1964, the Number 3 Shaft of the current underground workings was excavated and became the main dewatering shaft at the site (SMI, 1997).

At the time dewatering activities were suspended in August, 2000, average extraction rate was about 132 gpm.

5.4 Pumping/Dewatering Influences on Ground Water

5.4.1 Underground Workings

In 2000, the Continental Underground Mine workings were dewatered at an average rate of 132 gpm with a seasonal variation of approximately plus or minus 10 percent (SMI, 1999). Approximately 92% of the water (121 gpm) was pumped from the upper sump, which is at an elevation of about 5,550 feet. The remaining water (11 gpm) was pumped from the lower sump, which is located north of the upper sump at an elevation of about 5,425 feet.

Most of the water comes from the Lake Valley and Oswaldo Formations, which are at the depth of the upper 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. These drill holes tended to produce significant flow rates when the Beartooth Quartzite was first penetrated, but the flows decreased rapidly to low values. In addition, approximately 1 gallon per hour (0.017 gpm) flows from the Gap Fault where it is intersected by the workings.

5.4.2 Local Water Supply

Water supplies in the vicinity of the Cobre mine include the Hanover Shaft, located north of the city of Hanover, the Princess Shaft, located north of the Santa Rita Pit, well PW-1, located south of the Continental Pit, and the new potable water supply well located north of Hanover Mountain. In addition, the town of Hanover has an existing supply well located to the southwest of PW-1, which has become inoperable in recent years, and three other domestic wells are reported in the area (SMI, 1999). PW-1 was never operated as a full production well, and therefore has had little impact on ground water elevations in the area. Since the mine suspended operations in 1999, the Princess and Hanover Shafts have not supplied water to the Continental Mine. The Princess Shaft is within the drawdown cone of the Santa Rita pit. It is presumed that halting the minimal pumping to the Continental Mine from the Princess Shaft likely had little effect on the ground water elevations near the Princess Shaft. The ground water system associated with the Hanover Shaft is likely experiencing a rebound since the end of active pumping from the shaft.

6.0 NUMERICAL MODEL

6.1 Objectives

The primary purpose of the Supplemental Ground Water Study is to provide the basis for evaluating past and future mining impacts on surface water and ground water resources. Specific objectives of the impacts evaluation include the following:

- Evaluate if water in the workings could discharge back into the regional ground water system.
- Evaluate if water in the Continental Pit lake could discharge back into the regional ground water system
- Evaluate pit inflow rates over time in support of the geochemical modeling effort
- Evaluate pit refill and estimate the time to reach a dynamic equilibrium where average inflow equals average evaporation
- Determine the extent of the ground water capture zone associated with ground water extraction via pit lake evaporation.

6.2 Software Selection

Modflow-Surfact (Hydrogeologic, Inc 1996) was used to develop the numerical ground water flow model at the site. Modflow-Surfact is an advanced version of the U.S. Geological Survey ground water flow code, MODFLOW (McDonald and Harbaugh, 1988). Modflow-Surfact offers several enhancements to the original MODFLOW model including the ability to reduce subsurface recharge if water levels exceed a specified elevation and the ability to represent seepage faces in areas where the water table intersects the land surface. These enhancements are particularly useful in developing the site model due to the shallow water table, moderate relief of the site area, and presence of a mine pit excavated below the pre-mining water table.

The recharge-seepage face boundary condition package allows recharge into the ground water system if the water table is below a user-prescribed ponding elevation. If the water table reaches this elevation, the simulation allows only as much recharge to occur to maintain the prescribed pool conditions. The remaining recharge is shed as surface runoff and removed from the ground water system.

The Modflow-Surfact package also can simulate a seepage face boundary condition by prescribing the elevation of a seepage-face boundary node. Prescribed recharge occurs at the boundary, if the water table is below the node. If the water table reaches the seepage face node elevation, the boundary condition changes to zero pressure head and allows ground water discharge at ground surface.

6.3 Model Extent

The model area completely encompasses the Continental Mine Site. Because the model is used to assess the capture zone associated with the Continental Pit, the model domain extends a significant distance away from the pit to ensure that the model boundary conditions do not artificially influence the model results.

6.3.1 Horizontal Extent

In areas of moderate to relatively steep terrain similar to those at the site, local ground water systems develop and ground water flow tends to generally follow topography. In these instances, the geometry of the ground water basin can be approximated by the surface water drainage geometry. As an initial approximation, the North and West model boundaries were configured to coincide with local surface water drainage divides. The east boundary of the model conforms to the Hanover Creek stream channel. The southern portion of the model domain does not have a similar surface water analogy; therefore, the south boundary was chosen to coincide with the northern portion of the

Chino Ground Water Model, near the town of Hanover. The horizontal extent of the model is shown on Figure 6-1.

6.3.2 Vertical Extent

The modeling objectives focus on ground water hydraulics in the North and South Paleozoic Flow Systems. North of the Barringer Fault, the model includes the North Paleozoic Flow System. This Hydrogeologic Unit (HGU) is assumed to receive distributed recharge (downward vertical leakage) from the overlying North Cretaceous Flow System that is controlled by properties of the Beartooth Quartzite aquitard. The South Paleozoic Flow System in the only bedrock HGU south of the Barringer Fault, and this unit receives distributed recharge from infiltration of meteoric water and enhanced recharge below saturated alluviums. Thus, in all areas, the top of the numerical model conforms to the top of the North or South Paleozoic Flow Systems. North of Barringer Fault the model generally extends upward to the top of the Abo Formation. South of the Barringer fault, the top of the model generally conforms to ground surface or the base of saturated alluviums.

The underground workings currently extend downward through the Oswaldo Formation and into the Lake Valley Formation, with a bottom elevation of approximately 5,425 feet. Because one model objective is to evaluate ground water flow through and below the underground workings, the model base is a flat horizontal surface at elevation 5,000 ft, which is 425 feet below the bottom of the underground workings.

6.4 Model Grid

The general finite difference cells have dimensions of 60 ft (E-W), 160 ft (N-S), and 100 ft (vertical). Due to issues associated with the hydraulic effects of the Continental Pit, it was necessary to use a finer model grid in the pit area; 20 ft by 20 ft horizontal and 25 feet vertical. Depending on the model stability and computation time, the grid may be further modified as necessary to produce accurate results. The horizontal and vertical model grid is shown on Figure 6-2.

6.5 Material Zones

Based on similarities in measured hydraulic conductivity and structure, the geologic units at the site have been separated into a series of model material zones. The zones are as follows:

- Zone-1 Barringer Fault Zone. Up to 200 feet wide; treated as a low-permeability feature.
- Zone-2 Hanover Fierro Stock (Thg)
- Zone-3 Syenodiorite Prophyry (Ksy)
- Zone-4 Colorado Formation (Kcs)
- Zone-5 Beartooth Quartzite including upper and lower shale units (Kb)
- Zone-6 Abo (Pa) / Syrena Formation (Ps)
- Zone-7 Oswaldo Formation (Po)
- Zone-8 Lake Valley Formation (Ml)
- Zone-9 Percha Shale (Dp)
- Zone-10 Fusselman and Montoya Dolomites (Sofm)
- Zone-11 Quaternary Alluvium (Qal)
- Zone-12 Underlying Precambrian Rock

Each of these zones represents materials that have been (initially) assigned uniform hydraulic properties. Because of its limited ability to transmit significant quantities of ground water, Zone-12 does not contribute materially to the ground water flow system at the site. Therefore, the top of this zone is specified as a no-flow boundary and it is not included as a material in the numerical model. [Figures 6-3a through 6-3x] depict the lateral extents of the material zones.

6.6 Hydraulic Properties

6.6.1 Hydraulic Conductivity

Hydraulic conductivity estimates are available based on short-term aquifer tests performed at 27 wells at the Continental Mine site. The results of 21 tests are presented in the Baseline Characterization (SMI, 1999) and are reproduced in Appendix B. Most of these tests were conducted in weathered bedrock units. The hydraulic conductivities of competent bedrock units are expected to be generally lower than the values reported in Appendix B. The remaining tests were conducted primarily at wells completed in alluvium (Telesto, 2005b), and these values are reported in Appendix B.

As an initial estimate, units are assigned hydraulic conductivity values based on the borehole tests and literature values. These initial values will be modified and refined through model calibration. Also, because most pumping tests were conducted in the relatively high permeability shallow alluvial deposits or weathered bedrock, it is likely that lower values will ultimately be assigned to more competent (deeper) geologic units. Initial (pre-calibration) hydraulic conductivity values assigned to the material zones are summarized in Table 6-1.

All sedimentary units are specified as having an anisotropy ration of 10, implying that horizontal hydraulic conductivity is 10 times greater than vertical hydraulic conductivity. The anisotrophy ratio for sedimentary units may be modified through model calibration. For competent portions of igneous intrusives (e.g., Zones 2 and 3), the anisotropy ratio is set to unity (horizontal hydraulic conductivity equal to vertical).

The void space of the underground workings is represented by assigning this portion of the model domain a hydraulic conductivity value several orders of magnitude higher than the surrounding bedrock.

6.6.2 Storage Parameters

Specific storage (Ss) of a saturated medium is defined as the volume of water released per unit volume of the medium per unit per unit decline hydraulic head. (Freeze & Cherry, 1979). Specific storage thus has units of reciprocal length (e.g., 1/ft). For a saturated confined aquifer, the aquifer storage coefficient (S) is equal to specific storage multiplied by the aquifer thickness, and is thus a dimensionless parameter. Typical values of specific storage for different geologic materials are provided in Table 6-2.

Specific yield is defined as the volume of water that an unconfined aquifer releases from storage per unit surface area per unit decline in the water table elevation (Freeze and Cherry, 1979). Typical values of specific yield for different geologic materials are provided in Table 6-2. For cells defining the open pit, the specific yield is set to unity which is appropriate for a pit lake. For cells defining the underground workings, the specific yield is assigned a weighted value that accounts for the fraction of the rock mass containing open voids.

Based on typical values reported in Table 6-2, preliminary input values of the storage parameters for each material zone are summarized in Table 6-1.

6.7 Recharge / Discharge

6.7.1 Areal Recharge

South of the Barringer Fault, recharge into the South Paleozoic Flow System is generally assumed to be 1.25 in/yr, which is equivalent to 6.8% of MAP and considered a reasonable value for natural infiltration in a semi-arid environment. Below alluvium, the recharge is increased to 2.0 in/yr (11% MAP) to account for the enhanced seepage that is likely to occur below stream channels and saturated alluviums. The enhanced recharge rate of 2.0 in/yr is also applied below WRFs prior to installation of soil/vegetation covers. After covers are installed, the recharge rate is assumed to decrease to the natural value (1.25 in/yr).

North of the Barringer Fault, the top of the North Paleozoic Flow System is bounded by an aquitard that controls downward leakage from the overlying North Cretaceous Flow System. In this portion of the model, the recharge into the North Paleozoic Flow System is set equal to the preliminary vertical hydraulic conductivity of the aquitard ($1 \text{ x } 10^{-7}$ cm/sec = 1.24 in/yr), which assumes that downward leakage is controlled by a unit hydraulic gradient. This initial recharge (leakage) flux will be modified during model calibration.

At the base of the Main Tailings Impoundment, long-term drainage will occur due to slow dewatering of the tailings. This water will be collected at the base of the facility and, after treatment (if required), will infiltrate into the Poison Spring Alluvium. A drainage function will be developed to estimate current and future drainage from the tailings. Predicted drainage from the facility will be applied to two areas: (1) alluvium south of the Barringer Fault which is treated as an enhanced recharge zone to the South Paleozoic Flow System and (2) the North Paleozoic Flow System at a rate equal to the vertical hydraulic conductivity of the aquitard. When and if the drainage from the Main Tailings Impoundment drops below the vertical hydraulic conductivity of the aquitard, all drainage will be provided to the North Paleozoic Flow System and no flow will be provided to the alluvium. Figure 6-4 provides a graphical representation of this process.

6.7.2 Evapotranspiration

Aerially distributed evapotranspiration is accounted for by the aerial recharge valve used in the model and is therefore not explicitly tracked by the ground water model. Direct evaporation from the pit lake is based on the monthly lake evaporation rates discussed in Section 2.1.

6.7.3 Pumping Stresses

6.7.3.1 Historic Mining

Prior to 1964, historic dewatering occurred in several shafts in the area of the Continental Mine. During 1964, the Number 3 Shaft of the current underground workings was excavated and became the main dewatering shaft at the site (SMI, 1999). Although ore production was temporarily suspended in 1982 due to depressed copper prices, mine dewatering continued.

6.7.3.2 Recent Mining

In 1993, the mine was reopened and operated until the spring of 1999 when operations were once again temporarily suspended. On August 9, 2000, dewatering from the underground workings was suspended and the workings began to refill.

During a site visit on May 30, 1997, it was observed that nearly all inflow into the current mine excavation occurred at a large sump ("upper" sump) located at an elevation of 5,550 ft. (SMI, 1999). A second sump ("lower" sump) was located near the upper sump, but approximately 125 ft lower (elevation 5,425 ft msl). At the time of observation, the total ground water inflow rate averaged approximately 132 gpm with approximately 92% (121 gpm) being pumped from the upper sump and the remainder (11 gpm) being pumped from the lower sump. Most of the inflow was from the Lake Valley and Oswaldo Formations. There are no significant underground 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. Additional ground water extraction occurs from the #3 Borehole Vent and the #4 Shaft. The combined extraction from these two shafts is approximately 23 gpm (SMI, 1999).

In the numerical model, all mine water extractions are assumed to occur from the upper sump. For recent dewatering conditions, the total extraction rate is assumed to be 155 gpm, which is the combined flow of all sumps and shafts. This extraction is assumed to terminate in August 2000, and from that time to the present, the workings are slowly refilling with ground water.

6.7.3.3 Expansion Mining

For future conditions, additional pumping from the aquifer will occur due to operational water supplies needs. Potential water supplies for mining operations include the Hanover Shaft (north of the city of Hanover), the Princess and Bull Frog Shafts (north and west of the Santa Rita Pit), water supply well PW-1 (south of the Continental Pit), and a domestic water supply well (north of Hanover Mountain).

Historically, pumping from the Hanover shaft has averaged 242 gpm (1993-1997). It is likely that the Hanover Shaft will continue to be pumped at this flow rate. The Princess and Bull Frog Shafts are located beyond the model domain and are therefore excluded from the numerical model. The domestic water supply well supplies potable water to the mine buildings and does extract a significant amount of water from the aquifer.

Ground water well PW-1 could be used to extract ground water during mining operations. PW-1 is located 1-mile southwest of the Continental Mine on the northwest flank of Humbolt Mountain. However, the well casing has been welded shut and water supplies from the Cron Ranch, Bull Frog, Princess and Hanover Shafts should supply more than enough water future mine expansion. Therefore, it is assumed in the numerical model that PW-1 will not be pumped.

6.7.3.4 Post Mining

No plans currently exist to resume mining the underground workings. Thus, the underground mine has been refilling since cessation of pumping in August of 2000.

Because there are no plans to resume underground mining, it is assumed that the underground workings will continue to refill in the future.

Depths to water in the Continental #3 Shaft taken on 21 December 2004 (4.4 years after pumping shutdown) showed a water level elevation in the underground workings of approximately 5,760 feet. Modification of the refilling analysis presented in SMI (1999), to match the actual proposed underground workings geometry, predicts that it would take between 4.4 and 5.2 years for the water level in the mine to reach the 5,760 foot elevation (Table 6-3). Thus, recent and current water level recovery in the underground mine is similar to analytical predictions.

6.8 Boundary Conditions

6.8.1 Lateral Boundaries

Because local ground water flow is expected to be topographically controlled, the numerical model boundary conditions generally conform to surface water divides and stream channels. The lateral boundaries are as follows (refer to Figure 6-1):

- **North Boundary:** The surface water divide of the Piños Altos Range is assumed to coincide with a ground water divide. This hydrologic feature is treated in the numerical model as a no-flow boundary.

- **West Boundary**: The surface water divide passing through Hermosa Mountain and Humbolt Mountain is assumed to constitute a no-flow ground water boundary.

- **East Boundary**: The Hanover Creek Alluvium is interpreted to be in hydraulic communication with adjacent and underlying bedrock flow systems. Although surface flow in Hanover Creek is not perennial, it is thought that ground water is always present in the alluvium and at an elevation at or just below the stream channel. Thus, the stream channel of Hanover Creek constitutes a prescribed head boundary in the numerical flow model. The prescribed head at each node along this boundary is set to the elevation at the base of the stream channel.

- **South Boundary:** Ground water exits the system as underflow across the south boundary. This boundary is treated as a prescribed head boundary with a hydraulic head distribution similar to that interpreted from water level measurements in bedrock wells and also predicted by the Golder (2005) flow model for the Chino Mine.

6.8.2 Flow Model Base

North of the Barringer Fault, the North Paleozoic Flow System is quite deep. Therefore, the bottom of the model is set at approximately 425 feet below the bottom of the underground workings (elevation 5,000 feet). This is assumed to be a depth at which ground water flow is minimally affected by dewatering of the underground workings. Thus, north of the Barringer Fault, the 5,000 foot elevation surface is treated as a no-flow boundary.

South of the Barringer Fault, the South Paleozoic Flow System is not thick. In this portion of the model, the top of Precambrian bedrock is treated as a no-flow boundary.

6.8.3 Internal Boundaries

One of the main objectives of the numerical model is to evaluate pit inflow rates. To accomplish this, nodes representing the walls of the Continental Pit are processed using the Modflow-Surfact recharge-seepage face boundary package that allows variable recharge and simulation of seepage face boundary conditions. This will allow a relationship between ground water inflow and pit lake elevation to be developed. This relationship will be used in a dynamic systems water and chemical mass balance model to determine the ultimate pit lake water level.

Seeps from the lower bedrock aquifer with surface expressions are represented using drain cells. This includes seeps south of the Barringer Fault including the West WRF Seep, Buckhorn WRF Seep, East WRF Seep, Main Tailings Dam Seep, and the Magnetite Tailings Dam Seep. Seeps north of the Barringer Fault emanate from the North Cretaceous Flow System, which is not included in the numerical model. These seeps are incorporated into the model via enhanced recharge below alluvium.

The sump in the underground workings will be modeled as pumping cells placed at 5,425 (lower sump) and 5,500 (upper sump) foot elevations. As stated previously, cells with large hydraulic conductivity will represent the open spaces in the underground workings.

REPORT SECTIONS TO BE COMPLETED

7.0 MODEL CALIBRATION

7.1 Pre-Mining Simulation

7.2 Active Mining Simulation

8.0 PREDICTIVE SIMULATIONS

8.1 Non-Backfilled Open Pit Scenario

8.2 Partially-Backfilled Pit Scenario

9.0 SENSITIVITY ANALYSIS

9.1 Introduction

9.2 Approach

9.3 Results

10.0 CONCLUSIONS

11.0 REFERENCES

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